# Kathir College of Engineering

Wisdom Tree, Avinashi Road, Neelambur, Coimbatore 641062

# Criteria-1

# Curricular Aspects

## Sub-Criteria 1.1

## Curricular Planning and Implementation

### 1.1.1

**The Institution ensures effective curriculum delivery through a well planned and documented process**

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Wisdom Tree, Neelambur, Avinashi Road, Coimbatore-62

## 1.1 Curricular Planning and Implementation

### 1.1.1 The Institution ensures effective curriculum delivery through a well-planned and documented process

# Kathir College of Engineering

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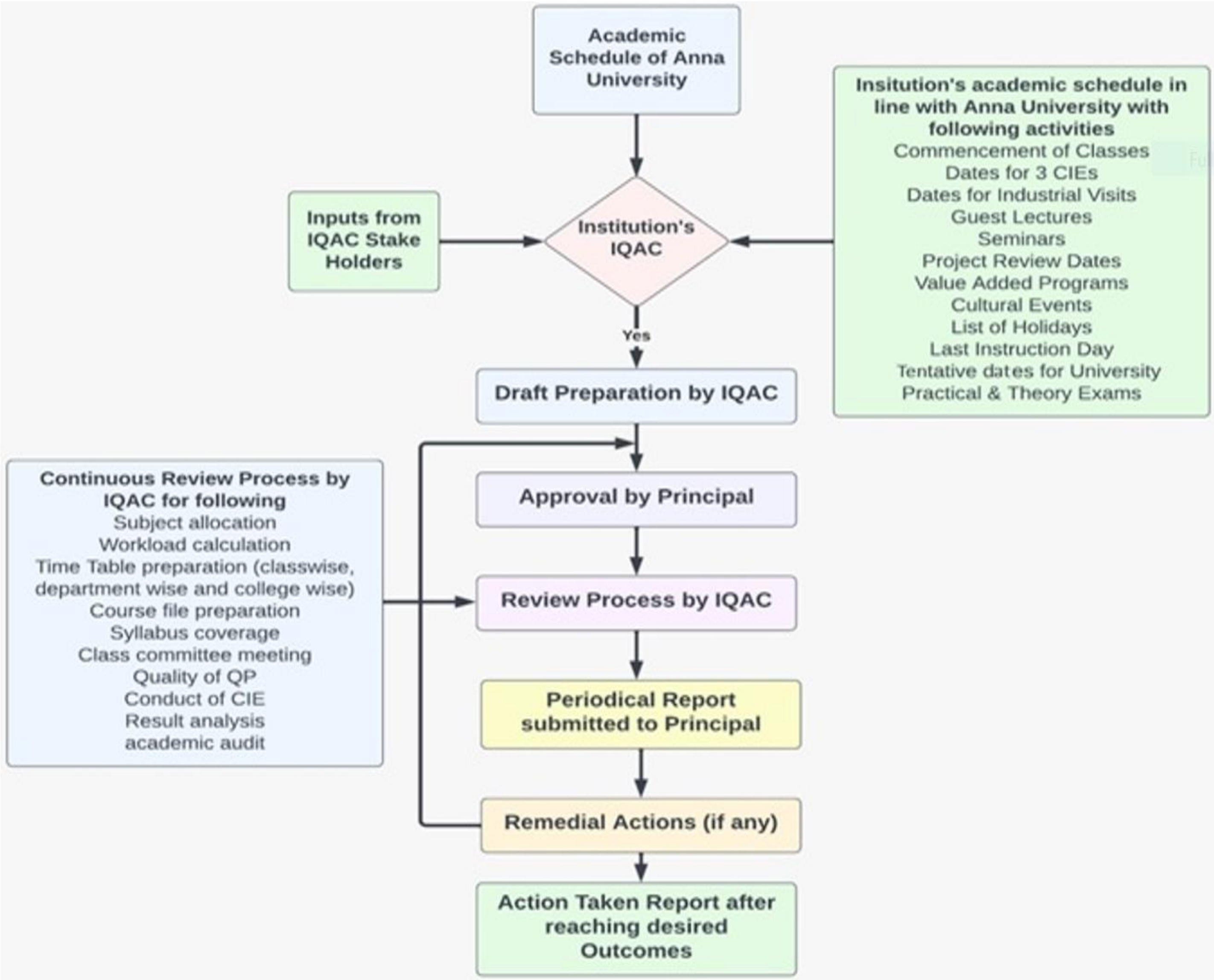
**Wisdom Tree, Neelambur, Avinashi Road, Coimbatore-62**

### 1.1 Curricular Planning and Implementation

## CURRICULUM PLANNING AND EFFECTIVE DELIVERY




PRINCIPAL
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COIMBATORE-62.

# Kathir College of Engineering

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Neelambur, Avinashi Road, Coimbatore-62

## ACADEMIC CALENDER (UG/PG) 2021-2022 (ODD SEMESTER)

| Date | Day | August 2021 | No. of Working Days | |
|---|---|---|---|---|
| | | | No. of days in Aug 2021 | Cumulative No. of Working Days |
| 1 | SUN | | Holiday | Holiday |
| 2 | MON | | | |
| 3 | TUE | | | |
| 4 | WED | | | |
| 5 | THU | | | |
| 6 | FRI | | | |
| 7 | SAT | | | |
| 8 | SUN | | Holiday | Holiday |
| 9 | MON | | | |
| 10 | TUE | | | |
| 11 | WED | | | |
| 12 | THU | | | |
| 13 | FRI | | | |
| 14 | SAT | | | |
| 15 | SUN | | Holiday | Holiday |
| 16 | MON | | | |
| 17 | TUE | | | |
| 18 | WED | Commencement of Classes (III/V/VII Semester) | 1 | 1 |
| 19 | THU | | 2 | 2 |
| 20 | FRI | Moharam | Holiday | Holiday |
| 21 | SAT | | 3 | 3 |
| 22 | SUN | | Holiday | Holiday |
| 23 | MON | | 4 | 4 |
| 24 | TUE | | 5 | 5 |
| 25 | WED | | 6 | 6 |
| 26 | THU | | 7 | 7 |
| 27 | FRI | | 8 | 8 |
| 28 | SAT | | 9 | 9 |
| 29 | SUN | | Holiday | Holiday |
| 30 | MON | Krishna Jayanthi | Holiday | Holiday |
| 31 | TUE | | 10 | 10 |
| No. of working days for this month | | | 10 | |
| Cumulative No. of working days as on 31.03.2021 | | | 10 | |

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| Date | Day | September 2021 | No. of Working Days | |
|---|---|---|---|---|
| | | | No. of days in Aug 2021 | Cumulative No. of Working Days |
| 1 | WED | | 1 | 11 |
| 2 | THU | | 2 | 12 |
| 3 | FRI | | 3 | 13 |
| 4 | SAT | | 4 | 14 |
| 5 | SUN | | Holiday | Holiday |
| 6 | MON | | 5 | 15 |
| 7 | TUE | | 6 | 16 |
| 8 | WED | | 7 | 17 |
| 9 | THU | | 8 | 18 |
| 10 | FRI | Vinayagar Charthurthi | Holiday | Holiday |
| 11 | SAT | | 9 | 19 |
| 12 | SUN | | Holiday | Holiday |
| 13 | MON | | 10 | 20 |
| 14 | TUE | | 11 | 21 |
| 15 | WED | | 12 | 22 |
| 16 | THU | | 13 | 23 |
| 17 | FRI | | 14 | 24 |
| 18 | SAT | | 15 | 25 |
| 19 | SUN | | Holiday | Holiday |
| 20 | MON | | 16 | 26 |
| 21 | TUE | | 17 | 27 |
| 22 | WED | | 18 | 28 |
| 23 | THU | | 19 | 29 |
| 24 | FRI | | 20 | 30 |
| 25 | SAT | | 21 | 31 |
| 26 | SUN | | Holiday | Holiday |
| 27 | MON | | 22 | 32 |
| 28 | TUE | | 23 | 33 |
| 29 | WED | | 24 | 34 |
| 30 | THU | Class Committee Meeting-1 (III/V/VII Semester) | 25 | 35 |
| No. of working days for this month | | | 25 | |
| Cumulative No. of working days as on 31.03.2021 | | | 35 | |

KATHIR COLLEGE OF ENGINEERING

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| Date | Day | October 2021 | No. of Working Days | |
|---|---|---|---|---|
| | | | No. of days in Oct 2021 | Cumulative No. of Working Days |
| 1 | FRI | CIA I QP Submission (III/V/VII Semester) | 1 | 36 |
| 2 | SAT | Gandhi Jayanthi | Holiday | Holiday |
| 3 | SUN | | Holiday | Holiday |
| 4 | MON | Continuous Internal Assessment I (III/V/VII Semester) | 2 | 37 |
| 5 | TUE | Continuous Internal Assessment I (III/V/VII Semester) | 3 | 38 |
| 6 | WED | Continuous Internal Assessment I (III/V/VII Semester) | 4 | 39 |
| 7 | THU | | 5 | 40 |
| 8 | FRI | Mark Display CIA I (III/V/VII Semester) | 6 | 41 |
| 9 | SAT | | 7 | 42 |
| 10 | SUN | | Holiday | Holiday |
| 11 | MON | Bridge Course for I Year Students | 8 | 43 |
| 12 | TUE | | 9 | 44 |
| 13 | WED | | 10 | 45 |
| 14 | THU | Aayutha Pooja | Holiday | Holiday |
| 15 | FRI | Vijaya Dasami | Holiday | Holiday |
| 16 | SAT | | 11 | 46 |
| 17 | SUN | | Holiday | Holiday |
| 18 | MON | | 12 | 47 |
| 19 | TUE | Miladi Nabi | Holiday | Holiday |
| 20 | WED | | 13 | 48 |
| 21 | THU | | 14 | 49 |
| 22 | FRI | | 15 | 50 |
| 23 | SAT | | 16 | 51 |
| 24 | SUN | | Holiday | Holiday |
| 25 | MON | | 17 | 52 |
| 26 | TUE | Class Committee Meeting-2 (III/V/VII Semester) | 18 | 53 |
| 27 | WED | CIA II QP Submission (III/V/VII Semester) | 19 | 54 |
| 28 | THU | | 20 | 55 |
| 29 | FRI | Continuous Internal Assessment II (III/V/VII Semester) | 21 | 56 |
| 30 | SAT | Continuous Internal Assessment II (III/V/VII Semester) | 22 | 57 |
| 31 | SUN | | Holiday | Holiday |
| No. of working days for this month | | | 22 | |
| Cumulative No. of working days as on 31.10.2021 | | | 57 | |

KATHIR COLLEGE OF ENGINEERING

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| Date | Day | November 2021 | No. of Working Days | |
|---|---|---|---|---|
| | | | No. of days in Nov 2021 | Cumulative No. of Working Days |
| 1 | MON | Continuous Internal Assessment II (III/V/VII Semester) | 1 | 58 |
| 2 | TUE | | 2 | 59 |
| 3 | WED | Special Holiday | Holiday | Holiday |
| 4 | THU | Diwali | Holiday | Holiday |
| 5 | FRI | Special Holiday | Holiday | Holiday |
| 6 | SAT | Mark Display CIA II (III/V/VII Semester) | 3 | 60 |
| 7 | SUN | | Holiday | Holiday |
| 8 | MON | Induction Programme Phase I | | |
| 9 | TUE | | 4 | 61 |
| 10 | WED | PG Continuous Internal Assessment-I (III Semester) | 5 | 62 |
| 11 | THU | PG Continuous Internal Assessment-I (III Semester) | 6 | 63 |
| 12 | FRI | | 7 | 64 |
| 13 | SAT | | 8 | 65 |
| 14 | SUN | | Holiday | Holiday |
| 15 | MON | M.B.A Commencent of Classes | 9 | 66 |
| 16 | TUE | | 10 | 67 |
| 17 | WED | Induction Programme Phase II | 11 | 68 |
| 18 | THU | | 12 | 69 |
| 19 | FRI | Class Committee Meeting-3 (III/V/VII Semester) | 13 | 70 |
| 20 | SAT | CIA III QP Submission (III/V/VII Semester) Orientation Program | 14 | 71 |
| 21 | SUN | | Holiday | Holiday |
| 22 | MON | Commencement of Classes for I Semester | 15 | 72 |
| 23 | TUE | Continuous Internal Assessment III (III/V/VII Semester) | 16 | 73 |
| 24 | WED | Continuous Internal Assessment III (III/V/VII Semester) | 17 | 74 |
| 25 | THU | Continuous Internal Assessment III (III/V/VII Semester) | 18 | 75 |
| 26 | FRI | | 19 | 76 |
| 27 | SAT | Mark Display CIA III (III/V/VII Semester) | Holiday | Holiday |
| 28 | SUN | | Holiday | Holiday |
| 29 | MON | | 20 | 77 |
| 30 | TUE | Last Working Day (III/V/VII Semester) | 21 | 78 |
| No. of working days for this month | | | 21 | |
| Cumulative No. of working days as on 30.11.2021 | | | 78 | |

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# Kathir College of Engineering

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Neelambur, Avinashi Road, Coimbatore-62

## Academic Calendar 2021-22(Even Semester)

[Prepared in line with academic schedule of Anna University]

| Date | Day | MARCH- 2022 | No. of Working Days | |
|---|---|---|---|---|
| | | | No. of days in March 22 | Cumulative no. of working days |
| 1 | TUE | | | |
| 2 | WED | | | |
| 3 | THUR | | | |
| 4 | FRI | | | |
| 5 | SAT | | | |
| 6 | SUN | | Holiday | Holiday |
| 7 | MON | | | |
| 8 | TUE | | | |
| 9 | WED | | | |
| 10 | THUR | Guest Lecturer on IPR-PR | | |
| 11 | FRI | | | |
| 12 | SAT | | | |
| 13 | SUN | | Holiday | Holiday |
| 14 | MON | | | |
| 15 | TUE | | | |
| 16 | WED | Re-opening for IV,VI,VIII Semester B.E/B.Tech | 1 | 1 |
| 17 | THUR | | 2 | 2 |
| 18 | FRI | | 3 | 3 |
| 19 | SAT | | 4 | 4 |
| 20 | SUN | | Holiday | Holiday |
| 21 | MON | Seminar on General Health Awareness | 5 | 5 |
| 22 | TUE | | 6 | 6 |
| 23 | WED | | 7 | 7 |
| 24 | THUR | | 8 | 8 |
| 25 | FRI | | 9 | 9 |
| 26 | SAT | | 10 | 10 |
| 27 | SUN | | Holiday | Holiday |
| 28 | MON | | 11 | 11 |
| 29 | TUE | | 12 | 12 |
| 30 | WED | | 13 | 13 |
| 31 | THUR | | 14 | 14 |
| | | No. of working days for this month | 14 | |
| | | Cumulative No. of working days as on 31.03.2022 | 14 | |

KATHIR COLLEGE OF ENGINEERING

Principal

KATHIR COLLEGE OF ENGINEERING, NEELAMBUR, COIMBATORE-62.

| Date | Day | APRIL – 2022 | No. of Working Days | |
|---|---|---|---|---|
| | | | No. of days in April 22 | Cumulative no. of working days |
| 1 | FRI | Unit-I completion | 1 | 15 |
| 2 | SAT | **Telugu New Year** | **Holiday** | **Holiday** |
| 3 | SUN | | **Holiday** | **Holiday** |
| 4 | MON | | 2 | 16 |
| 5 | TUE | | 3 | 17 |
| 6 | WED | | 4 | 18 |
| 7 | THUR | | 5 | 19 |
| 8 | FRI | | 6 | 20 |
| 9 | SAT | | 7 | 21 |
| 10 | SUN | | **Holiday** | **Holiday** |
| 11 | MON | | 8 | 22 |
| 12 | TUE | | 9 | 23 |
| 13 | WED | Cultural Events | 10 | 24 |
| 14 | THUR | **Tamil New Year** | **Holiday** | **Holiday** |
| 15 | FRI | **Good Friday** | **Holiday** | **Holiday** |
| 16 | SAT | | **Holiday** | **Holiday** |
| 17 | SUN | | **Holiday** | **Holiday** |
| 18 | MON | | 11 | 25 |
| 19 | TUE | | 12 | 26 |
| 20 | WED | Question paper submission for CIA I (II, III & IV year) | 13 | 27 |
| 21 | THUR | | 14 | 28 |
| 22 | FRI | Class Committee Meeting – I (II, III & IV year) | 15 | 29 |
| 23 | SAT | | 16 | 30 |
| 24 | SUN | | **Holiday** | **Holiday** |
| 25 | MON | Continuous Internal Assessment I (II, III & IV year) | 17 | 31 |
| 26 | TUE | Continuous Internal Assessment I (II, III & IV year) | 18 | 32 |
| 27 | WED | Continuous Internal Assessment I (II, III & IV year) | 19 | 33 |
| 28 | THUR | | 20 | 34 |
| 29 | FRI | | 21 | 35 |
| 30 | SAT | Display of Marks for CIA I (II, III & IV year) | 22 | 36 |
| | | **No. of working days for this month** | 22 | |
| | | **Cumulative No. of working days as on 30.04.2022** | 36 | |

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| Date | Day | MAY-2022 | No. of Working Days | |
|---|---|---|---|---|
| | | | No. of days in May 22 | Cumulative no. of working days |
| 1 | SUN | | Holiday | Holiday |
| 2 | MON | Unit-II completion | 1 | 37 |
| 3 | TUE | **Ramzan** | Holiday | Holiday |
| 4 | WED | | 2 | 38 |
| 5 | THUR | | 3 | 39 |
| 6 | FRI | | 4 | 40 |
| 7 | SAT | | 5 | 41 |
| 8 | SUN | | Holiday | Holiday |
| 9 | MON | | 6 | 42 |
| 10 | TUE | | 7 | 43 |
| 11 | WED | | 8 | 44 |
| 12 | THUR | | 9 | 45 |
| 13 | FRI | | 10 | 46 |
| 14 | SAT | Question paper submission for CIA II (II, III & IV year) | 11 | 47 |
| 15 | SUN | | Holiday | Holiday |
| 16 | MON | Class Committee Meeting – II (II, III & IV year) | 12 | 48 |
| 17 | TUE | Unit-III completion | 13 | 49 |
| 18 | WED | | 14 | 50 |
| 19 | THUR | Continuous Internal Assessment II (II, III & IV year) | 15 | 51 |
| 20 | FRI | Continuous Internal Assessment II (II, III & IV year) | 16 | 52 |
| 21 | SAT | Continuous Internal Assessment II (II, III & IV year) | 17 | 53 |
| 22 | SUN | | Holiday | Holiday |
| 23 | MON | | 18 | 54 |
| 24 | TUE | Display of Marks for CIA II (II, III & IV year) | 19 | 55 |
| 25 | WED | | 20 | 56 |
| 26 | THUR | | 21 | 57 |
| 27 | FRI | | 22 | 58 |
| 28 | SAT | | 23 | 59 |
| 29 | SUN | | Holiday | Holiday |
| 30 | MON | | 24 | 60 |
| 31 | TUE | Unit-IV completion | 25 | 61 |
| | | **No. of working days for this month** | 25 | |
| | | **Cumulative No. of working days as on 31.05.2022** | 61 | |
| | | | | |

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**Principal**

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| Date | Day | JUNE- 2022 | No. of Working Days | |
|---|---|---|---|---|
| | | | No. of days in June 22 | Cumulative no. of working days |
| 1 | WED | | 1 | 62 |
| 2 | THUR | | 2 | 63 |
| 3 | FRI | | 3 | 64 |
| 4 | SAT | | 4 | 65 |
| 5 | SUN | | Holiday | Holiday |
| 6 | MON | | 5 | 66 |
| 7 | TUE | | 6 | 67 |
| 8 | WED | Question paper submission for CIA III (II, III & IV year) | 7 | 68 |
| 9 | THUR | Unit-V completion | 8 | 69 |
| 10 | FRI | Class Committee Meeting – III (II, III & IV year) | 9 | 70 |
| 11 | SAT | Exit survey | 10 | 71 |
| 12 | SUN | | Holiday | Holiday |
| 13 | MON | Continuous Internal Assessment III (II, III & IV year) | 11 | 72 |
| 14 | TUE | Continuous Internal Assessment III (II, III & IV year) | 12 | 73 |
| 15 | WED | Continuous Internal Assessment III (II, III & IV year) | 13 | 74 |
| 16 | THUR | Last Working Day | 14 | 75 |
| 17 | FRI | Display of Marks for CIA III (II, III & IV year) | | |
| 18 | SAT | | | |
| 19 | SUN | | Holiday | Holiday |
| 20 | MON | | | |
| 21 | TUE | | | |
| 22 | WED | | | |
| 23 | THUR | Academic audit | | |
| 24 | FRI | | | |
| 25 | SAT | | | |
| 26 | SUN | | Holiday | Holiday |
| 27 | MON | | | |
| 28 | TUE | | | |
| 29 | WED | | | |
| 30 | THUR | | | |
| | | **No. of working days for this month** | 14 | |
| | | **Cumulative No. of working days as on 30.06.2022** | 75 | |

COLLEGE OF ENGINEERING

Principal

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# KATHIR COLLEGE OF ENGINEERING

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Wisdom Tree, Avinashi Road, Neelambur, Coimbatore 641062

Web: www.kathir.ac.in, Email: kathirce@kathir.ac.in


Ref: KCE/IQAC/2020-2021/10

22.1.2021

Internal Quality Assurance Cell (IQAC)

Circular

Sub: IQAC Meeting – Intimation to the members of the IQAC

Dear Member,

An IQAC Meeting is arranged on 28.01.2021 at MBA Seminar Hall. All the members of the IQAC are requested to attend the meeting at 3:30PM. The points to be discussed in the meeting are as follows:

AGENDA:

1. Governance at KCE
2. Online classes
3. Placement Record
4. System for slow learners
5. Conducting FDPs
6. Department association activities
7. Internal Academic Audit
8. AQAR 2020-2021

9. Content preparation
10. Students counselling
11. Funded research projects
12. Any other matter

Principal/Chairman of IQAC

PRINCIPAL
Kathir College Of Engineering
Neelambur,
Coimbatore - 641 062.

**Copy to**

1. All IQAC members
2. IQAC File for record
3. Management

# KATHIR COLLEGE OF ENGINEERING

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## Internal Quality Assurance Cell

**IQAC Meeting held on 28.01.2021**

**Attendance sheet**

| S.No | Name | Designation | Signature |
|---|---|---|---|
| 1. | Dr. R. Udaiyakumar | Principal, KCE | |
| 2. | Dr. G. Doraisamy | CEO, Kathir Institutions | |
| 3. | Shri. Malligarjunababu | Administrative Officer, KCE | |
| 4. | Smt. PreethaMoulishankar | Accounts Officer, KCE | |
| 5. | Dr. S J K Jagadeeshkumar | Professor &HoD, Department of Computing Sciences | |
| 6. | Dr. V L Mangesh | Professor &HoD, Department of Mechanical Engineering | |
| 7. | Dr. G. Manjula | Professor &HoDin Civil Engg. | |
| 8. | Dr. K.V.Kannan Nithin | Professor in Physics | |
| 9. | Shri.J.Hariharan<br>Reg.No:71161714010 | IV Year Mech | |
| 10. | Shri.T.Raja<br>Reg.No:711618105011 | III Year EEE | |
| 11. | Smt.V.Gayathiri<br>Reg.No:711619106008 | II Year ECE | |
| 12. | Shri. K.B.Aakaash<br>Reg.No:711620243001 | I year AI & DS | |
| 13. | Mr. Vigneshwaran | Chief Executive Officer<br>Virtual Frontier Robotics Private Limited. | |
| 14. | Dr. R. Pradeep Kumar | Chief Innovation Officer, Amphisoft Technologies. | |
| 15. | Mr. R. Rameshbabu | Manager- Training school, Fanuc India | |
| 16. | Dr. B. Prabakaran | Coordinator-IQAC | |

# KATHIR COLLEGE OF ENGINEERING

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| | |
|---|---|
| **Name of the Meeting: Internal Quality Assurance Cell (IQAC) meeting** | **Ref. No. :KCE/IQAC/2020-2021/11** |
| **Venue : MBA Seminar Hall** | **Date of the Meeting : 28.01.2021** |
| **Members Present : all IQAC members except Dr. G. Doraisamy, CEO/MR, KCE** | **Time : 3:30PM - 5PM** |

| SL. No. | Points taken up for Discussion | Remarks / Action to be taken | Responsibility | Target date |
|---|---|---|---|---|
| 1 | Governance at KCE | ▪ Principal welcomed all the members for the meeting.<br>▪ Strategic Planning for good governance at KCE was discussed | Principal and IQAC coordinator<br><br>All faculty members | 31.05.2021 |
| 2 | Online Classes | ▪ Online classes are conducted successfully by the faculty. | All faculty members | Continuous |
| 3 | Placement Record | ▪ Members were keen on knowing the steps taken to identify the career perspectives of final year students and suggested to improve the placement record further | Principal, Placement officer and all HoDs | Continuous |
| 4 | System for slow learners | ▪ Members were keen on understanding the system followed to take care of slow-learners and insisted to improve their knowledge for better academic performance | All the HODs | 31.05.2021 |

| | | | | |
|---|---|---|---|---|
| 5 | Conducting FDPs | ▪ The members insisted to take initiation for the conduction of FDPs in the emerging areas | All the Faculty | 31.05.2021 |
| 6 | Department association activities | ▪ The members insisted to improve all the department association activities | All the HODs | 31.05.2021 |
| 7 | Internal Academic Audit | ▪ The members insisted to conduct IQAC Internal Academic Audit | IQAC co-ordinator | 31.05.2021 |
| 8 | AQAR2020-2021 | ▪ The AQAR report of the academic year 2020-21 and accreditation process for the upcoming years | IQAC co-ordinator | 31.12.2021 |
| 9 | Content preparation | ▪ Principal insisted the content preparation for the upcoming semester | All the Faculty | 15.02.2021 |
| 10 | Students counselling | ▪ Principal insisted all the mentors for periodic counselling of the students to address their grievances | All the HODs | 31.05.2021 |
| 11 | Funded research projects | ▪ Principal insisted all the faculty members to apply and get the funds on research projects | All the faculty | 31.05.2021 |
| 12 | Concluding Remarks | ▪ The meeting was concluded with a vote of thanks from IQAC Coordinator | IQAC co-ordinator | |

B. [signature]

IQAC Coordinator

[Dr. B. Prabakaran]

[signature] 28/1/21

**PRINCIPAL**

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Coimbatore ...

**Copy to**

1. All IQAC members
2. IQAC File for record
3. Management

Kathir
College of Engineering
(An Institution run by Lamika Educational and Charitable Trust)
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Accredited by NAAC | ISO Certified College

"Wisdom Tree",
Avinashi Road, Neelambur,
Coimbatore - 641 062.

Phone : 0422 - 2203787, 2203778
Fax : 08030723600
E-mail : kathirce@gmail.com
Website : www.kathir.ac.in

12th September 2019

INTERNAL QUALITY ASSURANCE CELL (IQAC)
MINUTES OF MEETING

Meeting was held on 12th September 2019 at 11 AM in MBA seminar hall of the college. Following members were present for the meeting:

| S.No | Name | Designation/IQAC |
|---|---|---|
| 1. | Dr.G.Doraisamy | CEO/Management Representative |
| 2. | Dr. A.R.Suresh | Principal/ Chairman, HOD-Mech/Member |
| 3. | Dr.K.V. Kannan Nithin | HOD-S&H/Member |
| 4. | Dr. M. Varatharaj | HOD-ECE/Member |
| 5. | Dr. B. Vaikundaselvan | HOD-EEE/Coordinator |
| 6. | Mrs.T.Sakthisree | HOD-CSE/Member |
| 7. | Mr. S. Ganeshkumar | HOD-Civil/Member |
| 8. | Mr. D. Davidbaburaj | HOD-MBA/Member |
| 9. | Mr. M.Ramkumar | AP-EEE/Member |
| 10. | Mr.R.Rameshbabu | Manager-Training School, Fanuc India/Representative from Industry |

The chairperson Dr.A.R.Suresh welcomed the members. The following points were discussed in the meeting.

| S. No. | Details | Action to be taken |
|---|---|---|
| 1. | The HOD-EEE department proposed to set up centre of excellence in PLC lab, also requested to setup Incubation centre to enrich students' co-curricular and placement opportunities | HOD-EEE |
| 2. | The management insisted to organise the employability skill training programs to enhance the employability of the students | All the HODs |
| 3. | IQAC coordinator mentioned that Students counseling regarding academic and personal problems should be taken care by the respective mentors | All the HODs |
| 4. | The council members recommended conducting GATE coaching classes for UG students, Research Methodology lectures and talks from Industry experts for students. | All the HODs |
| 5. | The council members proposed making an action plan for improving the academic performance of the weak students | All the members |

12/9/19
Principal
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NEELAMBUR

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"Wisdom Tree",
Avinashi Road, Neelambur,
Coimbatore - 641 062.

Phone : 0422 - 2203787, 2203778
Fax : 08030723600
E-mail : kathirce@gmail.com
Website : www.kathir.ac.in

17th February 2020

INTERNAL QUALITY ASSURANCE CELL (IQAC)
MINUTES OF MEETING

Meeting was held on 17th February 2020 at 10 AM in the MBA seminar hall of the college. Following members were present for the meeting:

| S.No | Name | Designation/IQAC |
|---|---|---|
| 1. | Dr.G.Doraisamy | CEO/Management Representative |
| 2. | Dr. A.R.Suresh | Principal/ Chairman, HOD-Mech/Member |
| 3. | Dr.K.V. Kannan Nithin | HOD-S&H/Member |
| 4. | Dr. M. Varatharaj | HOD-ECE/Member |
| 5. | Dr. B. Vaikundaselvan | HOD-EEE/Coordinator |
| 6. | Mrs.T.Sakthisree | HOD-CSE/Member |
| 7. | Mr. S. Ganeshkumar | HOD-Civil/Member |
| 8. | Mr. D. Davidbaburaj | HOD-MBA/Member |
| 9. | Mr. M.Ramkumar | AP-EEE/Member |
| 10. | Mr.R.Rameshbabu | Manager-Training School, Fanuc India/Representative from Industry |

The chairperson Dr.A.R.Suresh welcomed the members. The following points were discussed in the meeting.

| S. No. | Details | Action to be taken |
|---|---|---|
| 1. | The AQAR report of the academic year 2019-20 and NBA accreditation process for the upcoming years | NAAC & NBA Co-ordinator |
| 2. | The management insisted that our Institute should follow a standard academic system in place to take care of the slow-learners, to improve their knowledge and to get good academic performance | All the HODs |
| 3. | The council members recommended to send proposals like Research Proposal Scheme and MODROB to various funding agencies especially to AICTE, DST and TNSCST | All the HODs |
| 4. | The council members reviewed the complete statement on teaching learning programs, action plan for high intensity training and other events | All the HODs |

The meeting came to an end with a vote of thanks by IQAC Coordinator Dr. B. Vaikundaselvan.

Principal 17/2/20

PRINCIPAL
KATHIR COLLEGE OF ENGINEERING,
NEELAMBUR.

# KATHIR COLLEGE OF ENGINEERING

[Approved by AICTE and affiliated to Anna University]

Wisdom Tree, Avinashi Road, Neelambur, Coimbatore 641062

Web: www.kathir.ac.in, Email: kathirce@kathir.ac.in


Ref: KCE/IQAC/2018-2019/1 07.09.2018

Internal Quality Assurance Cell (IQAC)

Circular

Sub: IQAC Meeting – Intimation to the members of the IQAC

Dear Member,

An IQAC Meeting is arranged on 14.09.2018 at ground floor conference room. All the members of the IQAC are requested to attend the meeting at 3PM. The points to be discussed in the meeting are as follows:

AGENDA:

1. Research Labs
2. NBA Accreditation
3. Any other matter

Principal/Chairman of IQAC

PRINCIPAL
Kathir College Of Engineering
Neelambur,
Coimbatore - 641 062.

**Copy to**

1. All IQAC members
2. IQAC File for record
3. Management

# KATHIR COLLEGE OF ENGINEERING

[Approved by AICTE and affiliated to Anna University]

Wisdom Tree, Avinashi Road, Neelambur, Coimbatore 641062

Web: www.kathir.ac.in, Email: kathirce@kathir.ac.in

## Internal Quality Assurance Cell

IQAC Meeting held on 14.09.2018

Attendance sheet

| S.No | Name | Designation/IQAC | Signature |
|---|---|---|---|
| 1. | Dr.G.Doraisamy | CEO/Management Representative | |
| 2. | Dr.P.Murthi | Principal/ Chairman | |
| 3. | Dr.K.V. Kannan Nithin | HOD-S&H/Member | |
| 4. | Dr. M. Kannan | HOD-ECE/Member | |
| 5. | Dr. B. Vaikundaselvan | HOD-EEE/Coordinator | |
| 6. | Mr. TKP. Rajagopal | HOD-CSE/Member | |
| 7. | Dr. A.R.Suresh | HOD-Mech/Member | |
| 8. | Ms. R. Priyanka | HOD-Civil/Member | |
| 9. | Mr. D. Davidbaburaj | HOD-MBA/Member | |
| 10. | Mr.R.Rameshbabu | Manager-Training School, Fanuc | |

# KATHIR COLLEGE OF ENGINEERING

(An Institution Run by Lamika Educational and Charitable Trust)
(Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai.)
"Wisdom Tree", Avinashi Road, Neelambur, Coimbatore - 641 062.
Phone : 0422 - 6554778, 2203737. Tele Fax : 08030723600.
E-mail : kathirce@gmail.com, www.kathir.ac.in

TÜVRheinland CERT ISO 9001

**Dr. P.Murthi**, B.E., MBA., M.Tech., Ph.D.,
Principal


14th September 2018

## INTERNAL QUALITY ASSURANCE CELL (IQAC)
## MINUTES OF MEETING

Meeting was held on 14th September at 3 PM in the ground floor conference hall of the college. Following members were present for the meeting:

| S.No | Name | Designation/IQAC |
|---|---|---|
| 1. | Dr.G.Doraisamy | CEO/Management Representative |
| 2. | Dr.P.Murthi | Principal/ Chairman |
| 3. | Dr.K.V. Kannan Nithin | HOD-S&H/Member |
| 4. | Dr. M. Kannan | HOD-ECE/Member |
| 5. | Dr. B. Vaikundaselvan | HOD-EEE/Coordinator |
| 6. | Mr. TKP. Rajagopal | HOD-CSE/Member |
| 7. | Dr. A.R.Suresh | HOD-Mech/Member |
| 8. | Ms. R. Priyanka | HOD-Civil/Member |
| 9. | Mr. D. Davidbaburaj | HOD-MBA/Member |
| 10. | Mr.R.Rameshbabu | Manager-Training School, Fanuc India/Representative from Industry |

The chairperson, Dr.P.Murthi welcomed Dr.G.Doraisamy, the management representative, Mr.R.Rameshbabu, Representative from Industry and other members. The following points were discussed in the meeting.

| S.No | Details | Action to be taken |
|---|---|---|
| 1. | The HOD, Mechanical department proposed to set up research labs in thrust areas like industry 4.0 and nano materials lab. He mentioned that the proposed labs would support research by both faculty and students. He added that it will enrich their knowledge and greatly improve student's placement opportunities. | HOD-Mechanical |
| 2. | The management insisted that the institution should prepare to work towards obtaining NBA accreditation which would help the institution in solicit support from various government programs as well as improve the operations from within the institute. | All the HOD's of ECE, Mechanical and Computer Science |
| 3. | IQAC Coordinator mentioned that the proforma for Student Satisfaction Survey mailed to the respective HODs, to be utilized for getting the feedback from students. | All the HODs |
| 4. | The Industry member, Mr R.Rameshbabu, appreciated installation of wi-fi in campus. He emphasized the importance of digitization. He further suggested having paperless office and resorting to emails over paper communication. | All the members |

PRINCIPAL
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# KATHIR COLLEGE OF ENGINEERING

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Wisdom Tree, Avinashi Road, Neelambur, Coimbatore 641062

Web: www.kathir.ac.in, Email: kathirce@kathir.ac.in


Ref: KCE/IQAC/2018-2019/2 13.02.2019

Internal Quality Assurance Cell (IQAC)

Circular

Sub: IQAC Meeting – Intimation to the members of the IQAC

Dear Member,

An IQAC Meeting is arranged on 20.02.2019 at MBA Conference Hall. All the members of the IQAC are requested to attend the meeting at 11AM. The points to be discussed in the meeting are as follows:

AGENDA:

1. Industry-Institute Interaction
2. Industrial Visits
3. Result Analysis
4. Any other matter

Principal/Chairman of IQAC

PRINCIPAL
Kathir College Of Engineering
Neelambur
Coimbatore - 641 062.

**Copy to**

1. All IQAC members
2. IQAC File for record
3. Management

# KATHIR COLLEGE OF ENGINEERING

[Approved by AICTE and affiliated to Anna University]

Wisdom Tree, Avinashi Road, Neelambur, Coimbatore 641062

Web: www.kathir.ac.in, Email: kathirce@kathir.ac.in

## Internal Quality Assurance Cell

IQAC Meeting held on 20.02.2019

Attendance sheet

| S.No | Name | Designation/IQAC | Signature |
|---|---|---|---|
| 1. | Dr.G.Doraisamy | CEO/Management Representative | [signature] |
| 2. | Dr.P.Murthi | Principal/ Chairman | [signature] |
| 3. | Dr.K.V. Kannan Nithin | HOD-S&H/Member | [signature] |
| 4. | Dr. M. Kannan | HOD-ECE/Member | [signature] |
| 5. | Dr. B. Vaikundaselvan | HOD-EEE/Coordinator | [signature] |
| 6. | Mr. TKP. Rajagopal | HOD-CSE/Member | [signature] |
| 7. | Dr. A.R.Suresh | HOD-Mech/Member | [signature] |
| 8. | Ms. R. Priyanka | HOD-Civil/Member | [signature] |
| 9. | Mr. D. Davidbaburaj | HOD-MBA/Member | [signature] |
| 10. | Mr.R.Rameshbabu | Manager-Training School, Fanuc | [signature] |

# KATHIR COLLEGE OF ENGINEERING

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Phone : 0422 - 6554778, 2203737. Tele Fax : 08030723600.
E-mail : kathirce@gmail.com, www.kathir.ac.in

TÜVRheinland CERT ISO 9001

**Dr. P.Murthi,** B.E., MBA., M.Tech., Ph.D.,
Principal

20th February 2019

INTERNAL QUALITY ASSURANCE CELL (IQAC)
MINUTES OF MEETING

Meeting was held on 20th February 2019 at 11 AM in the MBA conference hall of the college. Following members were present for the meeting:

| S.No | Name | Designation/IQAC |
|---|---|---|
| 1. | Dr.G.Doraisamy | CEO/Management Representative |
| 2. | Dr.P.Murthi | Principal/ Chairman |
| 3. | Dr.K.V. Kannan Nithin | HOD-S&H/Member |
| 4. | Dr. M. Kannan | HOD-ECE/Member |
| 5. | Dr. B. Vaikundaselvan | HOD-EEE/Coordinator |
| 6. | Mr. TKP. Rajagopal | HOD-CSE/Member |
| 7. | Dr. A.R.Suresh | HOD-Mech/Member |
| 8. | Ms. R. Priyanka | HOD-Civil/Member |
| 9. | Mr. D. Davidbaburaj | HOD-MBA/Member |
| 10. | Mr.M.Ramkumar | AP-EEE/Member |
| 11. | Mr.R.Rameshbabu | Manager-Training School, Fanuc India/Representative from Industry |

The chairperson, Dr.P.Murthi welcomed all the members. The following points were discussed in the meeting.

| S.No | Details | Action to be taken |
|---|---|---|
| 1. | The committee suggested to undergo the Industry-Institute Interaction through Membership & MOU's by conducting various activities through them. | All the HODs |
| 2. | The committee suggested all the members to arrange more numbers of industrial tours in the next semester. | All the Members |
| 3. | The results of B.E, M.E & MBA Examinations were reviewed | All the Members |
| 4. | The committee instructed all HODs to conduct at least one guest lecture and workshop in next semester. | All the HODs |
| 5. | The committee reviewed the placements of this academic year and instructed to communicate with more number of reputed companies to conduct placement drives in our campus. | Placement Officer |

The meeting ended with formal vote of thanks by IQAC Coordinator Dr. B. Vaikundaselvan.

Principal

PRINCIPAL
KATHIR COLLEGE OF ENGINEERING,
NEELAMBUR,
COIMBATORE-62.

# KATHIR COLLEGE OF ENGINEERING

[Approved by AICTE and affiliated to Anna University]

Wisdom Tree, Avinashi Road, Neelambur, Coimbatore 641062

Web: www.kathir.ac.in, Email: kathirce@kathir.ac.in


Ref: KCE/IQAC/2020-2021/2

26.8.2020

Internal Quality Assurance Cell (IQAC)

Circular

Sub: IQAC Meeting – Intimation to the members of the IQAC

Dear Member,

An IQAC Meeting is arranged on 02.09.2020 which will be conducted through online. All the members of the IQAC are requested to attend the meeting at 3:30PM. The points to be discussed in the meeting are as follows:

AGENDA:

1. Action taken on the previous meeting minutes
2. Mandatory disclosure submission
3. KCE website updation
4. Online classes
5. Alumni and Parent's meet
6. Webinars
7. Faculty performance appraisal
8. Faculty publications
9. Any other matter

26/8/20

Principal/Chairman of IQAC

PRINCIPAL
Kathir College of Engineering
Neelambur,
Coimbatore - 641 062.

**Copy to**

1. All IQAC members
2. IQAC File for record
3. Management

# KATHIR COLLEGE OF ENGINEERING

[Approved by AICTE and affiliated to Anna University]

Wisdom Tree, Avinashi Road, Neelambur, Coimbatore 641062

Web: www.kathir.ac.in, Email: kathirce@kathir.ac.in

| | |
|---|---|
| **Name of the Meeting: Internal Quality Assurance Cell (IQAC) meeting** | **Ref. No. :KCE/IQAC/2020-2021/3** |
| **Venue : online mode** | **Date of the Meeting : 02.09.2020** |
| **Members Present : all IQAC members except Dr. G. Doraisamy, CEO/MR, KCE** | **Time : 3:30PM - 5PM** |

| SL. No. | Points taken up for Discussion | Remarks / Action to be taken | Responsibility | Target date |
|---|---|---|---|---|
| 1 | Academic year plan | ▪ Principal welcomed all the members for the meeting.<br>▪ Follow up process is ongoing for the action taken for the academic year plan for even semester 2019-2020 and odd semester 2020-2021 | All the HODs | 31.12.2020 |
| 2 | Mandatory Disclosure submission | ▪ The IQAC coordinator told that the process of preparing mandatory disclosure for the Academic Year 2020-2021 is in process | IQAC Team | 31.12.2020 |
| 3 | Website updation | ▪ Principal insisted to update the KCE website in line with the current data | All the HODs | 15.01.2021 |
| 4 | Online classes | ▪ Principal briefed the process of handling academic classes in online mode through the EBox platform. | All Faculty | Continuous |
| 5 | Alumni and Parent's meet | ▪ IQAC proposes to organize Alumni and Parent's meet more frequently in order to acquire inputs from them regarding | All the HODs | 31.12.2020 |

| | | | | |
|---|---|---|---|---|
| | | academic matters | | |
| 6 | Webinars | ▪ Princ[illegible]l suggested that the faculty members may be encouraged to attend more webinars offered by various reputed organisations. | All faculty | Continuous |
| 7 | Faculty performance Appraisal | ▪ The Governing Council members insisted to design and implement standard format for Faculty Performance Appraisal for the forthcoming years | Principal | 31.12.2020 |
| 8 | Faculty publications | ▪ All department NAAC coordinators were requested to give the updated faculty list and their publication to IQAC cell | IQAC coordinator | 15.01.2021 |
| 9 | NSS Activities | ▪ The management insisted to conduct NSS activities for the upcoming semester | NSS coordinator | 31.12.2020 |
| 10 | Concluding Remarks | ▪ The meeting was concluded with a vote of thanks from IQAC Coordinator | IQAC co-ordinator | |

IQAC Coordinator
[Dr. B. Prabakaran]

21/9/20

**PRINCIPAL**

PRINCIPAL
Kathir College Of [illegible]
Neelambur,
Coimbatore - 641 062.

**Copy to**

1. All IQAC members
2. IQAC File for record
3. Management

# KATHIR COLLEGE OF ENGINEERING

WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062

Rev.0 | SUBJECT ALLOCATION- EVEN SEM - 2020 - 2021 | 05.04.21

| NAME OF THE DEPARTMENT | SCIENCE AND HUMANITIES |
|---|---|

| S.No | Name of the Faculty | Designation | Theory | Practical | Faculty Signature |
|---|---|---|---|---|---|
| 1 | Dr.K.V.Kannan Nithin | Professor | I CSE | | |
| 2 | Dr.V.S.Angulakshmi | Associate Professor | I - CSE/ EEE/ MECH | | |
| 3 | Dr.M.Prabhu | Associate Professor | I MECH | | |
| 4 | Mr.S.Saravanan S | Assistant Professor | II MECH/ II EEE | | |
| 5 | Mr.C.Vigneshwaran | Assistant Professor | | II MECH/II CSE/II CIVIL | |
| 6 | Mrs.A.Radhika | Assistant Professor | I - CSE/ EEE/ MECH | | |
| 7 | Ms.D.Meenakshi | Assistant Professor | I-AI&DS/CSE/ ECE/EEE/MECH | | |
| 8 | Ms.K.Kokilamani | Assistant Professor | I-AI&DS/CSE/ ECE/EEE/MECH | | |
| 9 | Mrs.G. Kalpana | Assistant Professor | I ECE/ I EEE | | |
| 10 | Ms.M.Nandhinipriya | Assistant Professor | | III MECH/III CIVIL | |
| 11 | Ms.K.Saranya | Assistant Professor | II CSE/ II ECE | | |
| 12 | Mr.S. David Selvaraj | Assistant Professor | I - CSE/ EEE/ MECH | | |
| 13 | Dr.S.R.Kannan | Assistant Professor | | III CSE/ III ECE | |
| 14 | Ms.K.Hemalatha | Assistant Professor | I AI&DS | | |

**I Year**

**THEORY**

1. MA8252 Linear Algebra (I –AI&DS)
2. MA8251 Engineering Mathematics-II (I CSE/ECE/EEE/MECH)
3. HS8251 Technical English (I AI&DS/CSE/ECE/EEE/MECH)
4. GE8291 Environmental Science and Engineering (I AI&DS/CSE/EEE/MECH)
5. AD8251 Data Structures Design (I AI&DS)
6. AD8252 Digital Principles and Computer Organization(I AI&DS)
7. PH8253 Physics for Electronics Engineering(I ECE/I EEE)
8. BE8255 Basic electrical Electronics and Measurements Engineering(I AI&DS/ I CSE)
9. PH8252 Physics for information Science(I CSE)
10. CS8251 Programming in C (I CSE)
11. BE8254 Basic Electrical and Instrumentation Engineering (I ECE)
12. EC8251 Circuits Analysis(I ECE)
13. EC8252 Electronic Devices(I ECE)
14. BE8252 Basic Civil and Mechanical Engineering(I EEE)
15. EE8251 Circuit Theory( I EEE)
16. PH8251 Material Science (I MECH)
17. BE8253 Basic Electrical Electronics and Instrumentation Engineering(I MECH)
18. GE8292 Engineering Mechanics(I MECH)

**PRACTICALS**

1. GE8261 Engineering Practice Lab (I AI&DS/CSE/ECE/EEE/MECH)
2. AD8261 Data Structures Design (I AI&DS)
3. CS8261 C Programming Lab (I CSE)
4. EC8261 Circuits and Devices Lab ( I ECE)
5. EE8261 Electric Circuit Lab( I EEE)
6. BE8261 Basic Electrical Electronics and Instrumentation Lab(I MECH)

**II /III Year / Service Papers**

**THEORY**

1. MA8402 Probability and Queuing Theory(II CSE)
2. MA8451 Probability and Random Process (II ECE)
3. MA8452 Statistics and Numerical Methods (II MECH)
4. MA8491 Numerical Methods(II EEE)

**PRACTICALS**

1. HS8461 Advanced Reading and Writing (II MECH/II CSE/ II CIVIL)
2. HS8581 Professional Communication (III CSE/III MECH/III ECE/III CIVIL)

**HOD** **PRINCIPAL**

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ATHIR COLLEGE OF ENGINEERING,
NEELAMBUR,
COIMBATORE-62.

| | | |
|---|---|---|
| | **KATHIR COLLEGE OF ENGINEERING**<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | CERT |
| Rev.0 | **CLASS TIME TABLE** | ACD 2.2 |

| | | | | | |
|---|---|---|---|---|---|
| Branch | *Artificial Intelligence and data science* | | | Academic Year | 2020-2021 |
| Semester | II | Section | - | Class Room No. | 311 |

| Days | 1<br>9.00 - 9.45 | 2<br>9.45 - 10.30 | -<br>10.30-10.45 | 3<br>10.45 – 11.30 | 4<br>11.30 - 12.15 | -<br>12.15-1.00 | 5<br>1.00 – 1.45 | 6<br>1.45 - 2.35 | -<br>2.35-2.50 | 7<br>2.50 – 3.40 | 8<br>3.40 – 4.30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mon | TE | DPCO | | EVS | MATH | | BEEM | | | ←DS LAB → | |
| Tue | EVS | MATH | | DS | TE | | DPCO | DS | | ←EP LAB→ | |
| Wed | DS | | Interval | EVS | MATH | Lunch | TE | DPCO | Interval | BEEM | |
| Thurs | EVS | DPCO | | TE | MATH | | ←DS LAB → | | | ←EP LAB→ | |
| Fri | DS | BEEM | | MATH | DPCO | | EVS | BEEM | | TE | BEEM |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MATH | MA 8252- Linear Algebra | 4 | 5 | Ms. K.Kokilamani.,AP/S&H |
| 2. | TE | HS8251 – Technical English | 4 | 5 | Ms .D.Meenakshi.,AP/ S&H |
| 3. | EVS | GE8291- Environmental Science and Engineering | 4 | 5 | Ms. K Hemalatha.,AP/ S&H |
| 4. | DS | AD8251- Data Structures Design | 3 | 5 | Ms .K Kavitha.,AP/ AI&DS |
| 5. | DPCO | AD8252- Digital Principles and Computer Organization | 4 | 5 | Ms .M.Swathi.,AP/ECE |
| 6. | BEEME | BE8255- Basic Electrical Electronics and Measurements Engineering | 3 | 6 | Mr. S. Haribabu.,AP/EEE |
| 7. | EPL | GE 8261- Engineering Practice Lab | 2 | 4 | Dr .Debayan Dasgupta.,AP Mech/ Mr S Haribabu.,AP/EEE |
| 8. | DSL | AD8261 – Data Structures Design | 2 | 4 | Ms K Kavitha.,AP/ AI&DS |

| | |
|---|---|
| Name of the Class Advisors | Dr.V.S.Angulakshmi.,AsP/S&H |
| Name of the Tutor | Ms.A.Radhika., AP/S&H |

Time table in-charge

HoD 05/4/21

Principal

PRINCIPAL
KATHIR COLLEGE OF ENGINEERING,
NEELAMBUR,
COIMBATORE-62.

# KATHIR COLLEGE OF ENGINEERING

WISDOM TREE, NEELAMBUR, COIMBATORE - 641 062

CERT ISO 9001

Rev.0 | CLASS TIME TABLE | ACD 2.2

| | | | | | |
|---|---|---|---|---|---|
| Branch | *Computer Science and Engineering* | | | Academic Year | 2020-2021 |
| Semester | II | Section | - | Class Room No. | 306 |

| Days | 1<br>9.00 - 9.45 | 2<br>9.45 - 10.30 | -<br>10.30-10.45 | 3<br>10.45 - 11.30 | 4<br>11.30 - 12.15 | -<br>12.15-1.00 | 5<br>1.00 - 1.45 | 6<br>1.45 - 2.35 | -<br>2.35-2.50 | 7<br>2.50 - 3.40 | 8<br>3.40 - 4.30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mon | TE | MATH | Interval | EVS | PIS | Lunch | BEEM | | Interval | ←PIC LAB→ | |
| Tue | EVS | PIC | | MATH | TE | | PIS | PIS | | ←EPLAB→ | |
| Wed | MATH | MATH | | EVS | PIS | | TE | PIC | | BEEM | |
| Thurs | EVS | PIS | | TE | PIC | | ←PIC LAB→ | | | ←EPLAB→ | |
| Fri | MATH | PIC | | PIC | MATH | | EVS | BEEM | | TE | EVS |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MATH | MA 8251- Engineering Mathematics II | 4 | 6 | Ms .K.Kokilamani .,AP/S&H |
| 2. | TE | HS8251 – Technical English | 4 | 5 | Ms .D.Meenakshi .,AP/S&H |
| 3. | EVS | GE8291- Environmental Science and Engineering | 4 | 6 | Mr.S.David Selvaraj.,AP/S&H |
| 4. | PIS | PH8252- Physics for information science | 3 | 5 | Dr .K .V .Kannan Nithin.,Prof/S&H |
| 5. | BEEM | BE8255- Basic Electrical Electronics and Measurements Engineering | 3 | 5 | Mr. S .Haribabu.,AP/EEE |
| | PIC | CS8251- Programming in C | 3 | 5 | Dr .S .Kalpana., AsP/CSE |
| 7. | EPL | GE 8261- Engineering Practice Lab | 2 | 4 | Dr .Debayan Dasgupta.,AP/Mech<br>Mr. S .Haribabu .,AP/EEE |
| 8. | PICL | CS8261- C Programming Lab | 2 | 4 | Dr. S. Kalpana .,AsP/CSE |

| | |
|---|---|
| Name of the Class Advisors | Ms.N.Nandhinipriya.,AP/S&H |
| Name of the Tutor | Dr.S.R.Kannan.,AP/S&H |

Time table in-charge　　　HoD 05/4/21　　　Principal

PRINCIPAL
KATHIR COLLEGE OF ENGINEERING
NEELAMBUR,
COIMBATORE-62.

| | | |
|---|---|---|
| KCE | **KATHIR COLLEGE OF ENGINEERING**<br>**WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062** | CERT ISO 9001 |
| Rev.0 | **CLASS TIME TABLE** | ACD 2.2 |

| | | | | | |
|---|---|---|---|---|---|
| Branch | *ELECTRONICS AND COMMUNICATIONS ENGINEERING* | | | Academic Year | 2020-2021 |
| Semester | II | Section | - | Class Room No. | 304 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 - 9.45 | 9.45 - 10.30 | 10.30- 10.45 | 10.45 – 11.30 | 11.30 - 12.15 | 12.15- 1.00 | 1.00 – 1.45 | 1.45 - 2.35 | 2.35 - 2.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | TE | MATH | Interval | BEI | PEE | Lunch | CA | ED | Interval | ED | CA |
| Tue | BEI | PEE | | MATH | TE | | ED | BEI | | ←EP LAB→ | |
| Wed | MATH | MATH | | BEI | CA | | TE | ED | | ←CD LAB-→ | |
| Thurs | BEI | CA | | TE | ED | | PEE | | | ←EP LAB→ | |
| Fri | MATH | ←CD | | LAB → | MATH | | BEI | PEE | | TE | CA |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MATH | MA 8251- Engineering Mathematics II | 4 | 6 | Ms. K.Kokilamani.,AP/S&H |
| 2. | TE | HS8251 – Technical English | 4 | 5 | Ms .D.Meenakshi.,AP/S&H |
| 3. | PEE | PH8253- Physics for Electronics Engineering | 3 | 5 | Ms. G. Kalpana.,AP/S&H |
| 4. | BEI | BE8254- Basic Electrical and Instrumentation Engineering | 3 | 6 | Ms.K.K.Hinduja.,AP/EEE |
| 5. | CA | EC8251- Circuit Analysis | 4 | 5 | Mr S.Lokesh.,AP/ECE |
| 6. | ED | EC8250- Electronic Devices | 3 | 5 | Mr.S.Nithiyasai.,AP/ECE |
| 7. | CDL | EC8261- Circuits and Devices Lab | 2 | 4 | Mr.S.Nithiyasai.,AP/ECE |
| 8. | EPL | GE 8261- Engineering Practice Lab | 2 | 4 | Dr .Debayan Dasgupta .,AP Mech/ Mr. S. Haribabu AP/EEE |

| | |
|---|---|
| Name of the Class Advisors | Dr.V.S.Angulakshmi.,AsP/S&H |
| Name of the Tutor | Ms.A.Radhika.,AP/S&H |

Time table in-charge

HoD 05/4/21

Principal

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COIMBATORE-62.

| | | |
|---|---|---|
| Rev.0 | **KATHIR COLLEGE OF ENGINEERING**<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | CERT |
| | **CLASS TIME TABLE** | ACD 2.2 |

| | | | | | |
|---|---|---|---|---|---|
| Branch | *ELECRTICAL AND ELECTRONICS ENGINEERING* | | | Academic Year | 2020-2021 |
| Semester | II | Section | - | Class Room No. | 307 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 - 9.45 | 9.45 - 10.30 | 10.30-10.45 | 10.45 - 11.30 | 11.30 - 12.15 | 12.15-1.00 | 1.00 – 1.45 | 1.45 - 2.35 | 2.35 - 2.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | TE | MATH | Interval | EVS | PEE | Lunch | BCM | | Interval | ←EC LAB-→ | |
| Tue | EVS | PEE | | MATH | TE | | BCM | | | ←EP LAB→ | |
| Wed | MATH | MATH | | EVS | CT | | TE | CT | | ←EC LAB-→ | |
| Thurs | EVS | CT | | TE | BCM | | PEE | | | ←EP LAB→ | |
| Fri | MATH | CT | | CT | MATH | | EVS | PEE | | TE | EVS |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MATH | MA 8251- Engineering Mathematics II | 4 | 6 | Ms. K.Kokilamani., AP/S&H |
| 2. | TE | HS8251 – Technical English | 4 | 5 | Ms. D.Meenakshi., AP/S&H |
| 3. | EVS | GE8291- Environmental Science and Engineering | 4 | 6 | Mr. David Selvaraj., AP/S&H |
| 4. | PEE | PH8253- Physics for Electronics Engineering | 3 | 5 | Ms .G .Kalpana.,AP/S&H |
| 5. | BCM | BE8252- Basic civil and Mechanical Engineering | 4 | 6 | Ms .Y. Subashini .,AP/CIVIL<br>Mr .A .Ashothaman .,AP/MECH |
| 6. | CT | EE8251- Circuit Theory | 3 | 5 | Mr.D.Mohanraj.,AP/ EEE |
| 7. | ECL | EE8261- Electric Circuit Lab | 2 | 4 | Mr.D.Mohanraj.,AP/ EEE |
| 8. | EPL | GE 8261- Engineering Practice Lab | 2 | 4 | Dr. Debayan Dasgupta .,AP Mech/<br>Mr. S .Haribabu.,AP/EEE |

| | |
|---|---|
| Name of the Class Advisors | Mr.C.Vigneshwaran,.AP/S&H |
| Name of the Tutor | Mr.S. David Selvaraj., AP/S&H |

Time table in-charge

05/4/21
HoD

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NEELAMBUR,
COIMBATORE-62.

| | | |
|---|---|---|
| Rev.0 | **KATHIR COLLEGE OF ENGINEERING**<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062<br>CLASS TIME TABLE | CERT ISO 9001<br>ACD 2.2 |

| | | | | | |
|---|---|---|---|---|---|
| Branch | *MECHANICAL ENGINEERING* | | | Academic Year | 2020-2021 |
| Semester | II | Section | - | Class Room No. | 308 |

| Days | 1<br>9.00 - 9.45 | 2<br>9.45 - 10.30 | -<br>10.30-10.45 | 3<br>10.45 – 11.30 | 4<br>11.30 - 12.15 | -<br>12.15-1.00 | 5<br>1.00 – 1.45 | 6<br>1.45 - 2.35 | -<br>2.35 - 2.50 | 7<br>2.50 – 3.40 | 8<br>3.40 – 4.30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mon | TE | MATH | Interval | EVS | MS | Lunch | EM | | Interval | ←BEE LAB → | |
| Tue | EVS | MS | | MATH | TE | | BEEI | | | ←EP LAB→ | |
| Wed | MATH | MATH | | EVS | MS | | TE | BEEI | | EM | |
| Thurs | EVS | EM | | TE | EM | | BEEI | | | ←EP LAB→ | |
| Fri | MATH | ←BEE | | LAB-→ | MATH | | EVS | MS | | TE | EVS |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MATH | MA 8251- Engineering Mathematics II | 4 | 6 | Ms. K.Kokilamani .,AP/S&H |
| 2. | TE | HS8251 – Technical English | 4 | 5 | Ms .D.Meenakshi.,AP/S&H |
| 3. | EVS | GE8291- Environmental Science and Engineering | 4 | 6 | Mr. S.David Selvaraj .,AP/S&H |
| 4. | MS | PH8251-Material Science | 3 | 4 | Dr .M. Probhu., AP/S&H |
| 5. | BEEI | BE8253-Basic Electrical Electronics and Instrumentation Engineering | 3 | 5 | Mr. S .Haribabu.,AP/EEE |
| 6. | EM | GE8292- Engineering Mechanics | 4 | 6 | Mr .Arun Prakash.,AP/MECH |
| 7. | BEEL | BE8261-Basic Electrical Electronics and Instrumentation Lab | 2 | 4 | Mr S Haribabu.,AP/EEE |
| 8. | EPL | GE 8261- Engineering Practice Lab | 2 | 4 | Dr .Debayan Dasgupta .,AP Mech/ Mr .S .Haribabu.,AP/EEE |

| | |
|---|---|
| Name of the Class Advisors | Dr .M. Probhu., AP/S&H |
| Name of the Tutor | Mr.S.David Selvaraj .,AP/S&H |

Time table in-charge

HoD

Principal

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NEELAMBUR,
COIMBATORE-62.

# KATHIR COLLEGE OF ENGINEERING

WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062

Rev.0

SUBJECT ALLOCATION- ODD SEM - 2020 - 2021 | 06.11.20

| NAME OF THE DEPARTMENT | SCIENCE AND HUMANITIES |
|---|---|

| S.No | Name of the Faculty | Designation | Theory | Practical | Faculty Signature |
|---|---|---|---|---|---|
| 1 | Dr.K.V.Kannan Nithin | Professor | | I-AI&DS/CSE/ECE/EEE/MECH | [signature] |
| 2 | Dr.V.S.Angulakshmi | Associate Professor | | I-AI&DS/CSE/ECE/EEE/MECH | [signature] |
| 3 | Dr.M.Prabhu | Associate Professor | | I-AI&DS/CSE/ECE/EEE/MECH | [signature] |
| 4 | Mr.S.Saravanan S | Assistant Professor | II-MECH/EEE | | [signature] |
| 5 | Mr.C.Vigneshwaran | Assistant Professor | | II-MECH/II CIVIL | [signature] |
| 6 | Mrs.A.Radhika | Assistant Professor | I-AI&DS/CSE/ECE/EEE/MECH | | [signature] |
| 7 | Ms.D.Meenakshi | Assistant Professor | | II ECE/ II CSE | [signature] |
| 8 | Ms.K.Kokilamani | Assistant Professor | I-AI&DS/CSE/ECE/EEE/MECH | | [signature] |
| 9 | Mrs.G. Kalpana | Assistant Professor | I-AI&DS/CSE/ECE/EEE/MECH | | [signature] |
| 10 | Ms.M.Nandhinipriya | Assistant Professor | | III-EEE | [signature] |
| 11 | Ms.K.Saranya | Assistant Professor | II-CSE/ECE<br>III-CSE | | [signature] |
| 12 | Mr.S. David Selvaraj | Assistant Professor | I-AI&DS/CSE/ECE/EEE/MECH | | [signature] |
| 13 | Dr.S.R.Kannan | Assistant Professor | I-AI&DS/CSE/ECE/EEE/MECH | | [signature] |
| 14 | Ms.K.Hemalatha | Assistant Professor | | | [signature] |

**I Year**

## THEORY

1. HS8151 Communicative English
2. MA8151 Engineering Mathematics-I
3. PH8151 Engineering Physics
4. CY8151 Engineering Chemistry
5. GE8151 Problem solving and python Programming
6. GE8152 Engineering Graphics

## PRACTICALS

7. GE8161 Problem Solving and Python Programming Laboratory
8. BS8161 Physics and Chemistry Laboratory

**II /III Year / Service Paper**

## THEORY

| | | |
|---|---|---|
| 1. | MA8351 | Discrete Mathematics (II CSE) |
| 2. | MA8352 | Linear Algebra and Partial Differential Equations (II ECE) |
| 3. | MA8551 | Algebra and Number Theory (III CSE) |
| 4. | MA8353 | Transforms and Partial Differential Equations (II MECH/II EEE) |

## PRACTICALS

| | | |
|---|---|---|
| 1. | HS8381 | Interpersonal Skills / Listening & Speaking (II MECH/II ECE/II CSE/II CIVIL) |
| 2. | HS8581 | Professional Communication (III EEE) |

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6/11/20

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| KATHIR COLLEGE OF ENGINEERING<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | | |
|---|---|---|
| Rev.0 | CLASS TIME TABLE | ACD 2.2 |

| Branch | *Artificial Intelligence and data science* | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | I | Section | | Class Room No. | 311 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 9.45 | 9.45 - 10.30 | 10.30- 10.45 | 10.45 – 11.30 | 11.30 - 12.15 | 12.15- 1.00 | 1.00 - 1.45 | 1.45 – 2.35 | 02.35 02.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | ENG | PHY | Interval | EG | EG | Lunch | MAT | ←PSPP | Interval | LAB --------→ | |
| Tue | PHY | PSPP | | MAT | CHE | | ENG | ←PHY& | | CHE LAB --→ | |
| Wed | CHE | ENG | | PSPP | MAT | | PSPP | EG | | EG | EG |
| Thurs | MAT | CHE | | ENG | PHY | | PHY | ←PSPP | | LAB --------→ | |
| Fri | PSPP | MAT | | EG | ENG | | CHE | ←PHY& | | CHE LAB --→ | |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MA8151 | ENGINEERING MATHEMATICS - I | 4 | 5 | Ms.K.KOKILAMANI.,AP/S&H |
| 2. | PH8151 | ENGINEERING PHYSICS - I | 3 | 4 | MS.G.KALAPANA.,AP/S&H |
| 3. | CY8151 | ENGINEERING CHEMISTRY - I | 3 | 4 | MR.S.DAVID SELVARAJ.,AP/S&H<br>MS.A.RADHIKA.,AP/S&H |
| 4. | HS8151 | COMMUNICATIVE ENGLISH | 4 | 5 | DR.S.R.KANNAN.,AP/S&H |
| 5. | GE8152 | PROBLEM SOLVING PYTHON PROGRAMMING | 3 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 6. | GE8151 | ENGINEERING GRAPHICS | 4 | 6 | Mr.T.GOKUL.,AP/MECH |
| 7. | BS8161 | PSPP LAB | 2 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 8. | GE8152 | PHY & CHE LAB | 2 | 4 | Dr.K.V.KANNANNITHIN.,PROF/S&H<br>Dr.M.PRABHU.,ASP/S&H &<br>Dr.V.S.ANGULAKSHMI.,AsP/S&H |

| Name of the Class Advisors | Ms.N.NANDINIPRIYA.,AP/S&H |
|---|---|
| Name of the Tutor | Ms.K.HEMALATHA.,AP/S&H |

21/11/2020

Time table in-charge

HoD

Principal

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KATHIR COLLEGE OF ENGINEERING
NEELAMBUR,
COIMBATORE-62.

| | | |
|---|---|---|
| | **KATHIR COLLEGE OF ENGINEERING**<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | CERT |
| Rev.0 | **CLASS TIME TABLE** | ACD 2.2 |

| Branch | *Computer Science and Engineering* | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | I | Section | | Class Room No. | 306 |

| Days | 1<br>9.00<br>9.45 | 2<br>9.45 -<br>10.30 | -<br>10.30-<br>10.45 | 3<br>10.45 –<br>11.30 | 4<br>11.30 -<br>12.15 | -<br>12.15-<br>1.00 | 5<br>1.00 -<br>1.45 | 6<br>1.45 –<br>2.35 | -<br>02.35<br>02.50 | 7<br>2.50 –<br>3.40 | 8<br>3.40 -<br>4.30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mon | ENG | PHY | Interval | EG | EG | Lunch | MAT | ←PSPP | Interval | LAB --------→ | |
| Tue | PHY | PSPP | | MAT | CHE | | ENG | ←PHY& | | CHE LAB --→ | |
| Wed | CHE | ENG | | PSPP | MAT | | PSPP | EG | | EG | EG |
| Thurs | MAT | CHE | | ENG | PHY | | PHY | ←PSPP | | LAB --------→ | |
| Fri | PSPP | MAT | | EG | ENG | | CHE | ←PHY& | | CHE LAB --→ | |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MA8151 | ENGINEERING MATHEMATICS - I | 4 | 5 | Ms.K.KOKILAMANI.,AP/S&H |
| 2. | PH8151 | ENGINEERING PHYSICS - I | 3 | 4 | MS.G.KALAPANA.,AP/S&H |
| 3. | CY8151 | ENGINEERING CHEMISTRY - I | 3 | 4 | MR.S.DAVID SELVARAJ.,AP/S&H<br>MS.A.RADHIKA.,AP/S&H |
| 4. | HS8151 | COMMUNICATIVE ENGLISH | 4 | 5 | DR.S.R.KANNAN.,AP/S&H |
| 5. | GE8152 | PROBLEM SOLVING PYTHON PROGRAMMING | 3 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 6. | GE8151 | ENGINEERING GRAPHICS | 4 | 6 | Mr.T.GOKUL.,AP/MECH |
| 7. | BS8161 | PSPP LAB | 2 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 8. | GE8152 | PHY & CHE LAB | 2 | 4 | Dr.K.V.KANNANNITHIN.,PROF/S&H<br>Dr.M.PRABHU.,ASP/S&H &<br>Dr.V.S.ANGULAKSHMI.,AsP/S&H |

| | |
|---|---|
| Name of the Class Advisors | Ms.N.NANDINIPRIYA.,AP/S&H |
| Name of the Tutor | Ms.K.HEMALATHA.,AP/S&H |

21/1/2020

Time table in-charge

HoD

Principal

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KATHIR COLLEGE ... ENG.
NEELA...
COIMBATORE-62.

# KATHIR COLLEGE OF ENGINEERING
WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062

| Rev.0 | CLASS TIME TABLE | ACD 2.2 |
|---|---|---|

| Branch | *ELECTRONICS AND COMMUNICATIONS ENGINEERING* | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | I | Section | | Class Room No. | 304 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 9.45 | 9.45 - 10.30 | 10.30-10.45 | 10.45 – 11.30 | 11.30 - 12.15 | 12.15-1.00 | 1.00 - 1.45 | 1.45 – 2.35 | 02.35 02.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | ENG | PHY | Interval | EG | EG | Lunch | MAT | ←PSPP | Interval | LAB --------→ | |
| Tue | PHY | PSPP | | MAT | CHE | | ENG | ←PHY& | | CHE LAB -- → | |
| Wed | CHE | ENG | | PSPP | MAT | | PSPP | EG | | EG | EG |
| Thurs | MAT | CHE | | ENG | PHY | | PHY | ←PSPP | | LAB --------→ | |
| Fri | PSPP | MAT | | EG | ENG | | CHE | ←PHY& | | CHE LAB -- → | |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MA8151 | ENGINEERING MATHEMATICS - I | 4 | 5 | Ms.K.KOKILAMANI.,AP/S&H |
| 2. | PH8151 | ENGINEERING PHYSICS - I | 3 | 4 | MS.G.KALAPANA.,AP/S&H |
| 3. | CY8151 | ENGINEERING CHEMISTRY - I | 3 | 4 | MR.S.DAVID SELVARAJ.,AP/S&H MS.A.RADHIKA.,AP/S&H |
| 4. | HS8151 | COMMUNICATIVE ENGLISH | 4 | 5 | DR.S.R.KANNAN.,AP/S&H |
| 5. | GE8152 | PROBLEM SOLVING PYTHON PROGRAMMING | 3 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 6. | GE8151 | ENGINEERING GRAPHICS | 4 | 6 | Mr.T.GOKUL.,AP/MECH |
| 7. | BS8161 | PSPP LAB | 2 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 8. | GE8152 | PHY & CHE LAB | 2 | 4 | Dr.K.V.KANNANNITHIN.,PROF/S&H Dr.M.PRABHU.,ASP/S&H & Dr.V.S.ANGULAKSHMI.,AsP/S&H |

| Name of the Class Advisors | Ms.N.NANDINIPRIYA.,AP/S&H |
|---|---|
| Name of the Tutor | Ms.K.HEMALATHA.,AP/S&H |

21/1/2020

Time table in-charge

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# KATHIR COLLEGE OF ENGINEERING

WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062

| Rev.0 | CLASS TIME TABLE | ACD 2.2 |
|---|---|---|

| Branch | ELECRTICAL AND ELECTRONICS ENGINEERING | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | I | Section | | Class Room No. | 307 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 9.45 | 9.45 - 10.30 | 10.30- 10.45 | 10.45 – 11.30 | 11.30 - 12.15 | 12.15- 1.00 | 1.00 - 1.45 | 1.45 – 2.35 | 02.35 02.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | ENG | PHY | Interval | EG | EG | Lunch | MAT | ←PSPP | Interval | LAB --------→ | |
| Tue | PHY | PSPP | | MAT | CHE | | ENG | ←PHY& | | CHE LAB --→ | |
| Wed | CHE | ENG | | PSPP | MAT | | PSPP | EG | | EG | EG |
| Thurs | MAT | CHE | | ENG | PHY | | PHY | ←PSPP | | LAB --------→ | |
| Fri | PSPP | MAT | | EG | ENG | | CHE | ←PHY& | | CHE LAB --→ | |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MA8151 | ENGINEERING MATHEMATICS - I | 4 | 5 | Ms.K.KOKILAMANI.,AP/S&H |
| 2. | PH8151 | ENGINEERING PHYSICS - I | 3 | 4 | MS.G.KALAPANA.,AP/S&H |
| 3. | CY8151 | ENGINEERING CHEMISTRY - I | 3 | 4 | MR.S.DAVID SELVARAJ.,AP/S&H MS.A.RADHIKA.,AP/S&H |
| 4. | HS8151 | COMMUNICATIVE ENGLISH | 4 | 5 | DR.S.R.KANNAN.,AP/S&H |
| 5. | GE8152 | PROBLEM SOLVING PYTHON PROGRAMMING | 3 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 6. | GE8151 | ENGINEERING GRAPHICS | 4 | 6 | Mr.T.GOKUL.,AP/MECH |
| 7. | BS8161 | PSPP LAB | 2 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 8. | GE8152 | PHY & CHE LAB | 2 | 4 | Dr.K.V.KANNANNITHIN.,PROF/S&H Dr.M.PRABHU.,ASP/S&H & Dr.V.S.ANGULAKSHMI.,AsP/S&H |

| Name of the Class Advisors | Ms.N.NANDINIPRIYA.,AP/S&H |
|---|---|
| Name of the Tutor | Ms.K.HEMALATHA.,AP/S&H |

21/1/2020

Time table in-charge | HoD | Principal

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KATHIR COLLEGE OF ENGINEERING,
NEELAMBUR,
COIMBATORE-62.

| | | |
|---|---|---|
| Rev.0 | **KATHIR COLLEGE OF ENGINEERING**<br>**WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062** | |
| | **CLASS TIME TABLE** | ACD 2.2 |

| Branch | *MECHANICAL ENGINEERING* | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | I | Section | | Class Room No. | 308 |

| Days | 1<br>9.00<br>9.45 | 2<br>9.45 -<br>10.30 | -<br>10.30-<br>10.45 | 3<br>10.45 –<br>11.30 | 4<br>11.30 -<br>12.15 | -<br>12.15-<br>1.00 | 5<br>1.00 -<br>1.45 | 6<br>1.45 –<br>2.35 | -<br>02.35<br>02.50 | 7<br>2.50 –<br>3.40 | 8<br>3.40 –<br>4.30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mon | ENG | PHY | Interval | EG | EG | Lunch | MAT | ←PSPP | Interval | LAB --------→ | |
| Tue | PHY | PSPP | | MAT | CHE | | ENG | ←PHY& | | CHE LAB --→ | |
| Wed | CHE | ENG | | PSPP | MAT | | PSPP | EG | | EG | EG |
| Thurs | MAT | CHE | | ENG | PHY | | PHY | ←PSPP | | LAB --------→ | |
| Fri | PSPP | MAT | | EG | ENG | | CHE | ←PHY& | | CHE LAB --→ | |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | MA8151 | ENGINEERING MATHEMATICS - I | 4 | 5 | Ms.K.KOKILAMANI.,AP/S&H |
| 2. | PH8151 | ENGINEERING PHYSICS - I | 3 | 4 | MS.G.KALAPANA.,AP/S&H |
| 3. | CY8151 | ENGINEERING CHEMISTRY - I | 3 | 4 | MR.S.DAVID SELVARAJ.,AP/S&H<br>MS.A.RADHIKA.,AP/S&H |
| 4. | HS8151 | COMMUNICATIVE ENGLISH | 4 | 5 | DR.S.R.KANNAN.,AP/S&H |
| 5. | GE8152 | PROBLEM SOLVING PYTHON PROGRAMMING | 3 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 6. | GE8151 | ENGINEERING GRAPHICS | 4 | 6 | Mr.T.GOKUL.,AP/MECH |
| 7. | BS8161 | PSPP LAB | 2 | 4 | Ms.S.SUGANYA.,AP/CSE |
| 8. | GE8152 | PHY & CHE LAB | 2 | 4 | Dr.K.V.KANNANNITHIN.,PROF/S&H<br>Dr.M.PRABHU.,ASP/S&H &<br>Dr.V.S.ANGULAKSHMI.,AsP/S&H |

| | |
|---|---|
| Name of the Class Advisors | Ms.N.NANDINIPRIYA.,AP/S&H |
| Name of the Tutor | Ms.K.HEMALATHA.,AP/S&H |

21/11/2020

Time table in-charge

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COIMBATORE-62.

| | KATHIR COLLEGE OF ENGINEERING<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | CERT ISO 9001 |
|---|---|---|
| **Rev.0** | **SUBJECT ALLOCATION** | |

| NAME OF THE DEPARTMENT | Computer Science and Engineering |
|---|---|

**Academic Year : 2020-2021**
**Semester : EVEN**

| S.No | Name of the Faculty | Designation | Theory | | Practical | Faculty Signature |
|---|---|---|---|---|---|---|
| | | | Subject-1 | Subject-2 | Subject-1 | |
| 1 | Dr.S.J.K.Jagadeesh Kumar | PROFESSOR & HEAD | MC (III CSE) | - | UG PROJECT (IV CSE) | [signature] |
| 2 | Dr.P.Banumathi | PROFESSOR | NDT (I M.E) | - | PG PROJECT (II M E) | [signature] |
| 3 | Mr.D.Ravi | ASSISTANT PROFESSOR | CA (II CSE) | - | MINI PROJECT (III CSE) | [signature] |
| 4 | Mrs.V.C.Nathiya | ASSISTANT PROFESSOR | DWDM (III CSE) | - | - | [signature] |
| 5 | Mrs.P.VidhyaPriya | ASSISTANT PROFESSOR | CD (III CSE) | SP (I M.E) | - | [signature] |
| 6 | Ms.R.PunithaGowri | ASSISTANT PROFESSOR | CF (IV CSE) | - | MAD LAB (III CSE) | [signature] |
| 7 | Mrs.S. Rajaambika | ASSISTANT PROFESSOR | DS (III CSE) | - | - | [signature] |
| 8 | Ms.V.V.Ramya Shree | ASSISTANT PROFESSOR | IoT (I M.E) | - | TP&S (I M.E) | [signature] |
| 9 | Mrs.S.DhivyaBharathi | ASSISTANT PROFESSOR | OS (II CSE) | - | OS LAB (II CSE) | [signature] |
| 10 | Mrs.J.Shivabhuvaneshwari | ASSISTANT PROFESSOR | IP (III CSE) | - | IP LAB (III CSE) | [signature] |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | Ms.S.Suganya | ASSISTANT PROFESSOR | AI (III CSE) | BDA (I M.E) | - | |
| 12 | Dr.N.MohanaSuganthi | ASSISTANT PROFESSOR | SE (II CSE) | MPC (I M.E) | - | |
| 13 | Mr.R.Eswaramoorthy | ASSISTANT PROFESSOR | GC (IV CSE) | - | - | |
| 14 | Mrs.M.Kavitha | ASSISTANT PROFESSOR | DSD (I AI&DS) | - | DSD LAB (I AI&DS) | |
| 15 | Dr.S.Kalpana | PROFESSOR | C (I CSE) | - | C LAB (I CSE) | |
| 16 | Dr.G.Prabhukanna | ASSOCIATE PROFESSOR | DAA (II CSE) | - | - | |
| 17 | Ms.R.S.Ramya | ASSISTANT PROFESSOR | DBMS (II CSE) | - | DBMS LAB (II CSE) | |
| 18 | MrsSwesti Patel | ASSISTANT PROFESSOR | AD (I M.E) | - | DA Lab (I M.E) | |

**HOD**

**Principal**

Dr. R. UDAIYAKUMAR, ME.,Ph.D.,
Principal
Kathir College of Engi...
"Wisdom Tree" Avi...
Neelam... Coimbat...

**II Year**

**Theory**

1. MA8402 - Probability and Queueing Theory**(PQT)**
2. CS8491 - Computer Architecture**(CA)**
3. CS8492 – Database Management Systems**(DBMS)**
4. CS8451 - Design and Analysis of Algorithms**(DAA)**
5. CS8493 - Operating Systems**(OS)**
6. CS8494 - Software Engineering**(SE)**

**LAB**

1. CS8481 – Database Management Systems Laboratory **(DBMS LAB)**
2. CS8461 - Operating SystemsLaboratory**(OS LAB)**
3. HS8461 – Advanced Reading and Writing**(AR&W LAB)**

**III Year**

**Theory**

1. CS8651 - Internet Programming**(IP)**
2. CS8691 - Artificial Intelligence**(AI)**
3. CS8601 – Mobile Computing**(MC)**
4. CS8602 – Compiler Design**(CD)**
5. CS8603 – Distributed Systems**(DS)**
6. CS8075 – Data Warehousing and Data Mining**(DWDM)**

**LAB**

1. CS8661 – Internet Programming Laboratory**(IP LAB)**
2. CS8662 - Mobile ApplicationDevelopment Laboratory**(MAD LAB)**
3. CS8661 – Mini Project**(PROJECT)**
4. HS8581 – Professional Communication**(PC LAB)**

**IV Year.**

**Theory**

1. CS8074 - Cyber Forensics**(CF)**
2. CS8078 - Green Computing**(GC)**

**LAB**

3. CS8811 - Project Work**(PROJECT)**

**I M.E**

**I Year**

**Theory**

1. CP5201 – Network Design and Technologies**(NDT)**
2. CP5291 – Security Practices**(SP)**
3. CP5292 – Internet of Things**(IoT)**
4. CP5293 – Big Data Analytics**(BDA)**
5. IF5191 - Advanced Databases**(AD)**
6. CP5093 - Mobile and Pervasive Computing**(MPC)**

**LAB**

1. CP5261 – Data Analytics Laboratory**(DA LAB)**
2. CP5281 – Term Paper Writing and Seminar**(TPWS)**

**II Year**

1. CP5411 - Project Work Phase – II**(PROJECT)**

**Service Paper**

**Theory**

Fundamentals of Data Structures in C (I CSE)

**LAB**

Fundamentals of Data Structures in C Laboratory (I CSE)

**HOD**

**Principal**

Dr. R. UDAIYAKUMAR, M.E.,Ph.D.,
Principal
Kathir College of E...
"Wisdom Tree" Av...
Neelambur,Coimbatore - ...

| | KATHIR COLLEGE OF ENGINEERING<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | CERT |
|---|---|---|
| Rev.0 | CLASS TIME TABLE | ACD 2.2 |

| Branch | Computer Science and Engineering | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | IV | Section | - | Class Room No. | 416 |

| Days | 1<br>9.00 - 9.45 | 2<br>9.45 - 10.30 | -<br>10.30- 10.45 | 3<br>10.45 – 11.30 | 4<br>11.30 - 12.15 | -<br>12.15- 1.00 | 5<br>1.00 – 1.45 | 6<br>1.45 - 2.35 | -<br>2.35- 2.50 | 7<br>2.50 – 3.40 | 8<br>3.40 – 4.30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mon | CA | OS | Interval | DBMS | PQT | Lunch | SE | DAA | Interval | OS LAB | |
| Tue | PQT | DBMS | | DAA | OS | | CA | PQT | | DBMS LAB | |
| Wed | DAA | CA | | PQT | SE | | OS | DBMS | | OS LAB | |
| Thurs | DBMS | SE | | PQT | CA | | DAA | OS | | DBMS LAB | |
| Fri | OS | SE | | DAA | DBMS | | PQT | CA | | AR&W | |

| S.No | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | PQT | MA8402 - Probability and Queueing Theory | 4 | 6 | Ms. K. Saranya, AP/S&H |
| 2. | CA | CS8491 - Computer Architecture | 3 | 5 | Mr.D.Ravi, AsP/CSE |
| 3. | DBMS | CS8492 – Database Management Systems | 3 | 5 | Ms.R.S.Ramya, AP/CSE |
| 4. | DAA | CS8451 - Design and Analysis of Algorithms | 3 | 5 | Dr.G.Prabhu kanna, AsP/CSE |
| 5. | OS | CS8493 - Operating Systems | 3 | 5 | Ms.S.Dhivya Bharathi, AP/CSE |
| 6. | SE | CS8494 - Software Engineering | 3 | 4 | Dr.N.Mohana Suganthi, Prof/CSE |
| 7. | DBMS LAB | CS8481 – Database Management Systems Laboratory | 2 | 4 | Ms.R.S.Ramya, AP/CSE |
| 8. | OS LAB | CS8461 - Operating Systems Laboratory | 2 | 4 | Ms.S.Dhivya Bharathi, AP/CSE |
| 9. | AR&W | HS8461 – Advanced Reading and Writing | 1 | 2 | Dr.S.R.Kannan, AsP/English |

| | | | |
|---|---|---|---|
| **Name of the Class Advisors** | Mr.D.Ravi, AsP/CSE | | |
| **Name of the Tutor** | Mr.D.Ravi, AsP/CSE | Mrs.P.VidhyaPriya, AP/CSE | Ms.R.Punitha Gowri, AP/CSE |

**Time table in-charge** **HoD** **Principal**

Dr. R. UDA[illegible] Ph.D.,
Kath[illegible]
"Wisd[illegible]
Neelam[illegible]Coimb[illegible]62.

| | KATHIR COLLEGE OF ENGINEERING<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | |
|---|---|---|
| Rev.0 | CLASS TIME TABLE | ACD 2.2 |

| Branch | Computer Science and Engineering | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | VI | Section | - | Class Room No. | 417 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 -9.45 | 9.45 - 10.30 | 10.30- 10.45 | 10.45 – 11.30 | 11.30 - 12.15 | 12.15- 1.00 | 1.00 – 1.45 | 1.45 -2.35 | 2.35 - 2.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | IP | DWDM | Interval | MC | AI | Lunch | DS | CD | Interval | MAD LAB | |
| Tue | MC | DS | | CD | MC | | PC LAB | | | IP LAB | |
| Wed | CD | AI | | IP | MC | | DWDM | DS | | MAD LAB | |
| Thurs | AI | MC | | DWDM | CD | | DS | IP | | IP LAB | |
| Fri | DS | IP | | DWDM | AI | | AI | CD | | PROJECT | |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | IP | CS8651 - Internet Programming | 3 | 4 | Ms.J.Shivabhuvaneshwari, AP/CSE |
| 2. | AI | CS8691 - Artificial Intelligence | 3 | 5 | Ms.S.Suganya, AP/CSE |
| 3. | MC | CS8601 – Mobile Computing | 3 | 5 | Dr.S.J.K.Jagadeesh Kumar, Prof&Head/CSE |
| 4. | CD | CS8602 – Compiler Design | 4 | 5 | Ms.S.P.VidhyaPriya, AP/CSE |
| 5. | DS | CS8603 – Distributed Systems | 3 | 5 | Ms.S.Rajaambika, AP/CSE |
| 6. | DWDM | CS8075 – Data Warehousing and Data Mining | 3 | 4 | Ms.V.C.Nathiya, AP/CSE |
| 7. | IP LAB | CS8661 – Internet Programming Laboratory | 2 | 4 | Ms.J.Shivabhuvaneshwari, AP/CSE |
| 8. | MAD LAB | CS8662 - Mobile Application Development Laboratory | 2 | 4 | Ms.R.Punitha Gowri, AP/CSE |
| 9. | PROJECT | CS8661 – Mini Project | 1 | 2 | Mr.D.Ravi, AsP/CSE |
| 10. | PC LAB | HS8581 – Professional Communication | 1 | 2 | Dr.S.R.Kannan, AsP/English |

| Name of the Class Advisors | Dr.N.Mohana Suganthi, Prof/CSE | | |
|---|---|---|---|
| Name of the Tutor | Ms.V.V.Ramya Shree, AP/CSE | Ms.S.Suganya, AP/CSE | Dr.N.Mohana Suganthi, Prof/CSE |

**Time table in-charge** **HoD** **Principal**

| | | |
|---|---|---|
| | **KATHIR COLLEGE OF ENGINEERING**<br>**WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062** | CERT ISO 9001 |
| Rev.0 | **CLASS TIME TABLE** | ACD 2.2 |

| | | | | | |
|---|---|---|---|---|---|
| Branch | Computer Science and Engineering | | | Academic Year | 2020-2021 |
| Semester | VIII | Section | - | Class Room No. | 418 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 - 9.45 | 9.45 - 10.30 | 10.30- 10.45 | 10.45 – 11.30 | 11.30 - 12.15 | 12.15- 1.00 | 1.00 – 1.45 | 1.45 - 2.35 | 2.35- 2.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | CF | | Interval | GC | | Lunch | PROJECT | | Interval | PROJECT | |
| Tue | GC | | | CF | | | PROJECT | | | PROJECT | |
| Wed | CF | | | GC | | | PROJECT | | | PROJECT | |
| Thurs | GC | | | CF | | | PROJECT | | | PROJECT | |
| Fri | PROJECT | | | PROJECT | | | PROJECT | | | PROJECT | |

| S.No | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | CF | CS8074 - Cyber Forensics | 3 | 6 | Ms.R.Punitha Gowri, AP/CSE |
| 2. | GC | CS8078 - Green Computing | 3 | 6 | Mr.R.Eswaramoorthy, AP/CSE |
| 3. | PROJECT | CS8811 - Project Work | 10 | 24 | Dr.S.J.K.Jagadeesh Kumar, Prof&Head/CSE |

| | | | | |
|---|---|---|---|---|
| Name of the Class Advisors | Dr.G.Prabhu kanna, AsP/CSE | | | |
| Name of the Tutor | Mrs.J.Shivabhuvaneshwari, AP/CSE | Mrs.V.C.Nathiya, AP/CSE | Mrs.S.Dhivya Bharathi, AP/CSE | Dr.G.Prabhu Kanna, AsP/CSE |

**Time table in-charge** **HoD** **Principal**

Dr. R. UDAIYAKUMAR, M.E., Ph.D.,

# KATHIR COLLEGE OF ENGINEERING

WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062

| Rev.0 | CLASS TIME TABLE | ACD 2.2 |
|---|---|---|

| Branch | M.E - Computer Science and Engineering | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | II | Section | - | Class Room No. | 407 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 - 9.45 | 9.45 - 10.30 | 10.30- 10.45 | 10.45 – 11.30 | 11.30 - 12.15 | 12.15- 1.00 | 1.00 – 1.45 | 1.45 - 2.35 | 2.35- 2.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | SP | BDA | | MPC | NDT | | AD | BDA | | IoT | SP |
| Tue | MPC | NDT | | AD | BDA | | SP | IoT | | DA LAB | |
| Wed | NDT | AD | Interval | SP | IoT | Lunch | MPC | BDA | Interval | AD | IoT |
| Thurs | IoT | SP | | BDA | MPC | | NDT | AD | | DA LAB | |
| Fri | BDA | AD | | NDT | SP | | IoT | MPC | | TPW&S | |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | NDT | CP5201 – Network Design and Technologies | 3 | 5 | Dr.P.Banumathi,Prof /CSE |
| 2. | SP | CP5291 – Security Practices | 3 | 6 | Ms.S.P.VidhyaPriya, AP/CSE |
| 3. | IoT | CP5292 – Internet of Things | 3 | 6 | Ms.V.V.RamyaShree, AP/CSE |
| 4. | BDA | CP5293 – Big Data Analytics | 3 | 6 | Ms.S.Suganya, AP/CSE |
| 5. | AD | Advanced Databases | 3 | 6 | Ms.Swesti Patel, AP/CSE |
| 6. | MPC | Mobile and Pervasive Computing | 3 | 5 | Dr.N.Mohana Suganthi, Prof/CSE |
| 7. | DA LAB | CP5261 – Data Analytics Laboratory | 2 | 4 | Ms.Swesti Patel, AP/CSE |
| 8. | TPW&S | CP5281 – Term Paper Writing and Seminar | 1 | 2 | Ms.V.V.RamyaShree, AP/CSE |

| | |
|---|---|
| Name of the Class Advisors | Dr.N.Mohana Suganthi, Prof/CSE |
| Name of the Tutor | Ms.R.S.Ramya, AP/CSE |

**Time table in-charge** **HoD** **Principal**

Dr. R. UDAIYAKUMAR, M.E., Ph.D.,
Principal
Kathir College of Eng
"Wisdom Tree" Avin
Neelam , Coimbatore

| KATHIR COLLEGE OF ENGINEERING<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | |
|---|---|
| Rev.0 | CLASS TIME TABLE | ACD 2.2 |

| Branch | M.E - Computer Science and Engineering | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | IV | Section | - | Class Room No. | 409 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 - 9.45 | 9.45 - 10.30 | 10.30- 10.45 | 10.45 - 11.30 | 11.30 - 12.15 | 12.15- 1.00 | 1.00 – 1.45 | 1.45 - 2.35 | 2.35- 2.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | ←--------- | | Interval | PROJECT | | Lunch | -------------- | | Interval | --------→ | |
| Tue | ←--------- | | | PROJECT | | | -------------- | | | --------→ | |
| Wed | ←--------- | | | PROJECT | | | -------------- | | | --------→ | |
| Thurs | ←--------- | | | PROJECT | | | -------------- | | | --------→ | |
| Fri | ←--------- | | | PROJECT | | | -------------- | | | --------→ | |

| S.No | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | PROJECT | CP5411 - Project Work Phase – II | 12 | 24 | Dr.P.Banumathi, Prof/CSE |

| | |
|---|---|
| Name of the Class Advisors | Mr.R.Eswaramoorthy.,AP/CSE |
| Name of the Tutor | Mrs .Swesti Patel, AP/CSE |

Time table in-charge HoD Principal

Dr. R. UDAIYAKUMAR. ME.,Ph.D.,
Principal
Kathir College of Engineering
"Wisdom Tree" ...
Neelambur ...

# KATHIR COLLEGE OF ENGINEERING

WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062

| Rev.0 | SUBJECT ALLOCATION |
|---|---|

| NAME OF THE DEPARTMENT | Computer Science and Engineering |
|---|---|

Academic Year : 2020-2021
Semester : ODD

| S.No | Name of the Faculty | Designation | Theory | | Practical | Faculty Signature |
|---|---|---|---|---|---|---|
| | | | Subject-1 | Subject-2 | Subject-1 | |
| 1 | Dr.S.J.K.Jagadeesh Kumar | Professor & Head | CC (IV CSE) | - | - | |
| 2 | Dr.P.Banumathi | Professor | SQAT (II M.E) | - | PG PROJECT (II M.E) | |
| 3 | Dr.N.Mohana Suganthi | Professor | POM (IV CSE) | - | NW LAB (IV CSE) | |
| 4 | Dr.S.Kalpana | Professor | OOP (II CSE) | - | OOP LAB (II CSE) | |
| 5 | Mr.D.Ravi | Associate Professor | DS (II CSE) | - | DS LAB (II CSE) | |
| 6 | Mrs.V.C.Nathiya | Assistant Professor | CNS (IV CSE) | ADS (I M.E) | - | |
| 7 | Mrs.S.P.VidhyaPriya | Assistant Professor | HCI (IV CSE) | ESD (II M.E) | - | |
| 8 | Ms.R.Punitha Gowri | Assistant Professor | OOAD (III CSE) | MLT (I M.E) | OOAD LAB (III CSE) | |
| 9 | Mrs.S. Rajaambika | Assistant Professor | OOP (III EEE) | ASE (I M.E) | OOP LAB (III EEE) | |
| 10 | Ms.V.V.Ramya Shree | Assistant Professor | ACA (I M.E) | IR (II M.E) | CC LAB (IV CSE) | |
| 11 | Mrs.S.Dhivya Bharathi | Assistant Professor | FDS (II ECE) | OSI (I M.E) | FDS LAB (II ECE) | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | Mrs.J.Shivabhuvaneshwari | Assistant Professor | CN (III CSE) | - | ADS LAB (I M.E) | |
| 14 | Ms.S.Suganya | Assistant Professor | PSPP (I Year) | - | PSPP LAB (I Year) | |
| 15 | Mr.R.Eswaramoorthy | Assistant Professor | BDA (IV CSE) | - | SEC LAB (IV CSE) | |
| 16 | Mrs.M.Kavitha | Assistant Professor | TOC (III CSE) | - | ADS LAB (I M.E) | |

**HOD**

**Principal**

Dr. R. UDAIYAKUMAR, ME.,Ph.D.,
Principal
Kathir College of Engineering
"Wisdom Tree"
Neelambur,Coimbatore

**II Year**

**Theory**

1. MA8351 Discrete Mathematics **(DM)**
2. CS8351 Digital Principles and System Design **(DPSD)**
3. CS8391 Data Structures (**DS**)
4. CS8392 Object Oriented Programming (**OOP**)
5. EC8395 Communication Engineering **(CE)**

**LAB**

1. CS8381 Data Structures **Laboratory (DS LAB)**
2. CS8383 Object Oriented Programming Laboratory **(OOP LAB)**
3. CS8382 Digital Systems Laboratory **(DIS LAB)**
4. HS8381 Interpersonal Skills/Listening & Speaking **(IS&LS LAB)**

**III Year**

**Theory**

1. MA8551 Algebra and Number Theory **(ANT)**
2. CS8591 Computer Networks **(CN)**
3. EC8691 Microprocessors and Microcontrollers **(MPMC)**
4. CS8501 Theory of Computation **(TOC)**
5. CS8592 Object Oriented Analysis and Design **(OOAD)**
6. OMF551 Product Design and Development **(PDD)**

**LAB**

1. EC8681 Microprocessors and Microcontrollers Laboratory **(MPMC LAB)**
2. CS8582 Object Oriented Analysis and Design Laboratory **(OOAD LAB)**
3. CS8581 Networks Laboratory **(NW LAB)**

**IV Year.**

**Theory**

1. MG8591 Principles of Management **(POM)**
2. CS8792 Cryptography and Network Security **(CNS)**
3. CS8791 Cloud Computing **(CC)**
4. OIE751 Robotics **(ROBO)**
5. CS8091 Big Data Analytics **(BDA)**
6. CS8079 Human Computer Interaction **(HCI)**

**LAB**

1. CS8711 Cloud Computing Laboratory **(CC LAB)**
2. IT8761 Security Laboratory **(SEC LAB)**

**I Year (M.E- CSE)**

**Theory**

1. MA5160 Applied Probability and Statistics **(APS)**
2. CP5151 Advanced Data Structures and Algorithms **(ADS)**
3. CP5152 Advanced Computer Architecture **(ACA)**
4. CP5153 Operating System Internals **(OSI)**
5. CP5154 Advanced Software Engineering **(ASE)**
6. CP5191 Machine Learning Techniques **(MLT)**

**LAB**

1. CP5161 Data Structures Laboratory **(DS LAB)**

**II Year**

**Theory**

1. CP5005 - Software Quality Assurance and Testing **(SQAT)**
2. CP5073 - Embedded Software Development **(ESD)**
3. CS8080 - Information Retrieval Techniques **(IRT)**

**LAB**

1. CP5311 - Project Work – Phase I **(PROJECT)**

**Service Paper**

**Theory**

1. Fundamentals of Data Structures in C (II ECE)
2. Object Oriented Programming (III EEE)
3. Problem Solving and Python Programming (I CIVIL. MECH, EEE,ECE)

**LAB**

1. Fundamentals of Data Structures in C  Laboratory (II ECE)
2. Problem Solving and Python Programming Laboratory (I CIVIL, MECH, EEE, ECE)
3. Object Oriented Programming Laboratory (III EEE)

**HOD**

**Principal**

Dr. R. UDAIYAKUMAR, M.E., Ph.D.,
Principal
Kathir College of E...
"Wisdom Tree" Avinas...
Neelambur, Coimbatore

| | KATHIR COLLEGE OF ENGINEERING<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | |
|---|---|---|
| Rev.0 | CLASS TIME TABLE | ACD 2.2 |

| Branch | Computer Science and Engineering | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | III | Section | - | Class Room No. | 416 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 - 9.45 | 9.45 - 10.30 | 10.30-10.45 | 10.45 – 11.30 | 11.30 - 12.15 | 12.15-1.00 | 1.00 – 1.45 | 1.45 - 2.35 | 2.35-2.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | DS | DPSD | Interval | DS | DM | Lunch | CE | OOP | Interval | DS LAB | |
| Tue | OOP | CE | | DM | DS | | OOP | DPSD | | DIS LAB | |
| Wed | DM | CE | | OOP | DPSD | | DS | DM | | OOP LAB | |
| Thurs | CE | DPSD | | DS | DM | | DS LAB | | | ISLS LAB | |
| Fri | DPSD | OOP | | DM | CE | | DIS LAB | | | OOP LAB | |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | DM | MA8351- Discrete Mathematics | 4 | 6 | Ms.K.Saranya, AP/S&H |
| 2. | DPSD | CS8351 - Digital Principles and System Design | 4 | 5 | Ms.R.Abirami, AP/ECE |
| 3. | DS | CS8391 - Data Structures | 3 | 5 | Mr.D.Ravi, AsP/CSE |
| 4. | OOP | CS8392 - Object Oriented Programming | 3 | 5 | Dr.S.Kalpana, AP/CSE |
| 5. | CE | EC8395 - Communication Engineering | 3 | 5 | Mr.R.Devendran, AP/ECE |
| 6. | DS LAB | CS8381- Data Structures Laboratory | 2 | 4 | Mr.D.Ravi, AsP/CSE |
| 7. | OOP LAB | CS8383 - Object Oriented Programming Laboratory | 2 | 4 | Dr.S.Kalpana, AP/CSE |
| 8. | DIS LAB | CS8382 - Digital Systems Laboratory | 2 | 4 | Ms.R.Abirami, AP/ECE |
| 9. | IS/LS LAB | HS8381 – Interpersonal Skills/Listening &Speaking | 1 | 2 | Ms.D.Meenakshi, AP/English |

| | | | |
|---|---|---|---|
| Name of the Class Advisors | Mr.D.Ravi, AsP/CSE | | |
| Name of the Tutor | Mr.D.Ravi, AsP/CSE | Mrs.P.VidhyaPriya, AP/CSE | Ms.R.Punitha Gowri, AP/CSE |

Time table in-charge

HoD

Principal

Dr. R. UDAIYAKUMAR,
Principal
Kathir College of
"Wisdom Tree"
Neelambur,Coimbatore

# KATHIR COLLEGE OF ENGINEERING

WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062

| Rev.0 | CLASS TIME TABLE | ACD 2.2 |
|---|---|---|

| Branch | Computer Science and Engineering | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | V | Section | - | Class Room No. | 417 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 - 9.45 | 9.45 - 10.30 | 10.30-10.45 | 10.45 – 11.30 | 11.30 - 12.15 | 12.15-1.00 | 1.00 – 1.45 | 1.45 - 2.35 | 2.35-2.50 | 2.50 – 3.40 | 3.40 – 4.30 |
| Mon | CN | MPMC | Interval | PDD | TOC | Lunch | PDD | OOAD | Interval | MPMC LAB | |
| Tue | ANT | OOAD | | TOC | CN | | MPMC | ANT | | OOAD LAB | |
| Wed | TOC | PDD | | MPMC | ANT | | OOAD | CN | | NW LAB | |
| Thurs | MPMC | CN | | ANT | TOC | | OOAD LAB | | | MPMC LAB | |
| Fri | OOAD | TOC | | CN | ANT | | MPMC | PDD | | NW LAB | |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | ANT | MA8551 - Algebra and Number Theory | 4 | 5 | Ms.K.Saranya, AP/S&H |
| 2. | CN | CS8591 - Computer Networks | 3 | 5 | Mrs.J.Shivabhuvaneshwari, AP/CSE |
| 3. | MPMC | EC8691 - Microprocessors and Microcontrollers | 3 | 5 | Ms.K.Meer Thahira, AP/ECE |
| 4. | TOC | CS8501 - Theory of Computation | 3 | 5 | Ms.M.Kavitha, AP/CSE |
| 5. | OOAD | CS8592 - Object Oriented Analysis and Design | 3 | 4 | Ms.R.Punitha Gowri, AP/CSE |
| 6. | PDD | OMF551 - Product Design and Development | 3 | 4 | Mr.M.Mareshwaran, AP/MECH |
| 7. | MPMC LAB | EC8681 - Microprocessors and Microcontrollers Laboratory | 2 | 4 | Ms.K.Meer Thahira, AP/ECE |
| 8. | OOAD LAB | CS8582 - Object Oriented Analysis and Design Laboratory | 2 | 4 | Ms.R.Punitha Gowri, AP/CSE |
| 9. | NW LAB | CS8581 - Networks Laboratory | 2 | 4 | Dr.N.Mohana Suganthi, Prof/CSE |

| | | | |
|---|---|---|---|
| Name of the Class Advisors | Dr.N.Mohana Suganthi, Prof/CSE | | |
| Name of the Tutor | Ms.V.V.Ramya Shree, AP/CSE | Ms.S.Suganya, AP/CSE | Dr.N.Mohana Suganthi, Prof/CSE |

**Time table in-charge** **HoD** **Principal**

Dr. R. UDAIYAKUMAR, M.E., Ph.D.,
Principal
Kathir College of Eng...
"Wisdom Tree" Av...
Neelambur, Coimbatore...

CBE-62

# KATHIR COLLEGE OF ENGINEERING

WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062

| Rev.0 | CLASS TIME TABLE | ACD 2.2 |
|---|---|---|

| Branch | Computer Science and Engineering | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | VII | Section | - | Class Room No. | 418 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 -9.45 | 9.45 - 10.30 | 10.30-10.45 | 10.45–11.30 | 11.30-12.15 | 12.15-1.00 | 1.00 – 1.45 | 1.45 - 2.35 | 2.35-2.50 | 2.50–3.40 | 3.40 – 4.30 |
| Mon | CNS | POM | Interval | ROBO | POM | Lunch | HCI | BDA | Interval | CC LAB | |
| Tue | HCI | CNS | | BDA | CC | | CNS | ROBO | | SEC LAB | |
| Wed | CC | ROBO | | POM | HCI | | CC | BDA | | CC LAB | |
| Thurs | BDA | CC | | HCI | CNS | | ROBO | POM | | SEC LAB | |
| Fri | POM | HCI | | CC | POM | | PDA | CC | | CNS | ROBO |

| S.No | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | POM | MG8591 - Principles of Management | 3 | 6 | Dr.N.Mohana Suganthi, Prof/CSE |
| 2. | CNS | CS8792 - Cryptography and Network Security | 3 | 5 | Mrs.V.C.Nathiya, AsP/CSE |
| 3. | CC | CS8791 - Cloud Computing | 3 | 6 | Dr.S.J.K. Jagadeesh Kumar, Prof&Head/CSE |
| 4. | ROBO | OIE751 – Robotics | 3 | 5 | Ms.V.V.RamyaShree, AP/CSE |
| 5. | BDA | CS8091 - Big Data Analytics | 3 | 4 | Mr.R.Eswaramoorthy, AP/CSE |
| 6. | HCI | CS8079 – Human Computer Interaction | 3 | 5 | Mrs.S.P.VidhyaPriya, AP/CSE |
| 7. | CC LAB | CS8711 - Cloud Computing Laboratory | 2 | 4 | Ms.V.V.RamyaShree, AP/CSE |
| 8. | SEC LAB | IT8761 - Security Laboratory | 2 | 4 | Mr.R.Eswaramoorthy, AP/CSE |

| Name of the Class Advisors | Dr.G.Prabhu Kanna, AsP/CSE | | | |
|---|---|---|---|---|
| Name of the Tutor | Mrs.J.Shivabhuvaneshwari AP/CSE | Mrs.V.C.Nathiya. AP/CSE | Mrs.S.Dhivya Bharathi, AP/CSE | Dr.G.Prabhu Kanna, AsP/CSE |

**Time table in-charge** **HoD** **Principal**

Dr. R. UDAIYAKUMAR, M.E., Ph.D.,
Principal
Kathir College of
"Wisdom Tree"
Neelambur

| | KATHIR COLLEGE OF ENGINEERING<br>WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062 | |
|---|---|---|
| Rev.0 | CLASS TIME TABLE | ACD 2.2 |

| Branch | M.E - Computer Science and Engineering | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | I | Section | - | Class Room No. | 409 |

| Days | 1<br>9.00 -9.45 | 2<br>9.45 - 10.30 | -<br>10.30-10.45 | 3<br>10.45–11.30 | 4<br>11.30-12.15 | -<br>12.15-1.00 | 5<br>1.00–1.45 | 6<br>1.45 - 2.35 | -<br>2.35-2.50 | 7<br>2.50–3.40 | 8<br>3.40–4.30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mon | APS | ADS | Interval | ASE | OSI | Lunch | ACA | ASE | Interval | APS | MLT |
| Tue | ACA | ASE | | MLT | OSI | | APS | ADS | | DS LAB | |
| Wed | ADS | MLT | | OSI | ACA | | APS | APS | | ASE | ACA |
| Thurs | ASE | OSI | | ADS | APS | | MLT | ACA | | DS LAB | |
| Fri | OSI | ADS | | ACA | ASE | | APS | OSI | | MLT | ADS |

| S.No. | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | APS | MA5160 - Applied Probability and Statistics | 4 | 7 | Ms.K.Kokilamani, AP/S&H |
| 2. | ADS | CP5151 - Advanced Data Structures and Algorithms | 4 | 6 | Mrs.V.C.Nathiya, AP/CSE |
| 3. | ACA | CP5152 - Advanced Computer Architecture | 3 | 6 | Mrs.V.V.RamyaShree, AP/CSE |
| 4. | OSI | CP5153 - Operating System Internals | 3 | 6 | Ms.S.DhivyaBharathi, AP/CSE |
| 5. | ASE | CP5154 - Advanced Software Engineering | 3 | 6 | Mrs.S. Rajaambika, AP/CSE |
| 6. | MLT | CP5191 - Machine Learning Techniques | 3 | 5 | Mrs.R.Punitha Gowri, AP/CSE |
| 7. | DS LAB | CP5161 - Data Structures Laboratory | 2 | 4 | Ms.J.Shivabhuvaneshwari, AP/CSE |

| | |
|---|---|
| Name of the Class Advisors | Dr.S.Kalpana, Prof/CSE |
| Name of the Tutor | Ms.R.S.Ramya, AP/CSE |

**Time table in-charge** **HoD** **Principal**

Dr. R. UDAIYAKUMAR, M.E.,Ph.D.,
Principal
Kathir College of Engineering
"Wisdom Tree" Avinashi Road,
Neelambur,Coimbatore - 641 062.

# KATHIR COLLEGE OF ENGINEERING

WISDOM TREE, NEELAMBUR, COIMBATORE – 641 062

| Rev.0 | CLASS TIME TABLE | ACD 2.2 |
|---|---|---|

| Branch | M.E Computer Science and Engineering | | | Academic Year | 2020-2021 |
|---|---|---|---|---|---|
| Semester | IV | Section | - | Class Room No. | 409 |

| Days | 1 | 2 | - | 3 | 4 | - | 5 | 6 | - | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9.00 - 9.45 | 9.45 - 10.30 | 10.30- 10.45 | 10.45– 11.30 | 11.30- 12.15 | 12.15- 1.00 | 1.00– 1.45 | 1.45 - 2.35 | 2.35- 2.50 | 2.50– 3.40 | 3.40– 4.30 |
| Mon | SQAT | ESD | Interval | IRT | ESD | Lunch | PROJECT | | Interval | PROJECT | |
| Tue | IRT | ESD | | SQAT | IRT | | PROJECT | | | PROJECT | |
| Wed | ESD | SQAT | | ESD | IRT | | PROJECT | | | PROJECT | |
| Thurs | SQAT | IRT | | SQAT | ESD | | PROJECT | | | PROJECT | |
| Fri | ESD | SQAT | | IRT | SQAT | | PROJECT | | | PROJECT | |

| S.No | Subject Abbreviation | Name of the Subject | Credit | Periods per week | Name of the Faculty |
|---|---|---|---|---|---|
| 1. | SQAT | CP5005 - Software Quality Assurance and Testing | 3 | 5 | Dr.P.Banumathi, Professor/CSE |
| 2. | ESD | CP5073 - Embedded Software Development | 3 | 3 | Ms.S.P.VidhyaPriya, AP/CSE |
| 3. | IRT | CS8080 - Information Retrieval Techniques | 3 | 3 | Ms.V.V.Ramya Shree, AP/CSE |
| 4. | PROJECT | CP5311 - Project Work – Phase I | 12 | 6 | Dr.P.Banumathi, Professor/CSE |

| Name of the Class Advisors | Ms.S.P.VidhyaPriya, AP/CSE |
|---|---|
| Name of the Tutor | Mrs.J.Shivabhuvaneshwari, AP/CSE |

Time table in-charge

HoD

Principal

Dr. R. UDAYAKUMAR, M.E., Ph.D.,
Principal
Kathir College of Engineering
"Wisdom Tree" Avinashi ...
Neelambur, Coimbatore - 641 062.

Date : 06.08.2020

# CENTRE FOR ACADEMIC COURSES

ANNA UNIVERSITY: : CHENNAI – 600 025

## ACADEMIC SCHEDULE FOR NON AUTONOMOUS AFFILIATED COLLEGES

## August 2020 – November 2020 (ODD SEMESTER – Except I Semester)

UG & PG Programmes

| Sl. No. | Programme | Commencement of Classes | Last working day | Commencement of Practical Examinations | Commencement of End Semester Examinations |
|---|---|---|---|---|---|
| 1. | All UG/PG Programmes (except I Semester) | 12.08.2020 | 26.10.2020** | 28.10.2020 | 09.11.2020 |
| 2. | B.E. / B. Tech.(Part-Time) – III, V , VII | | | | |

**RE - OPENING DAY FOR THE NEXT SEMESTER: 14.12.2020 (Monday)**

**NOTE:**

1. The Theory and Practical Examination schedules which will be published in due course by the Controller of Examinations, Anna University, Chennai should be followed. (Practical Examinations will be conducted before the theory examinations).
2. Assessment Schedule for the August 2020 – November 2020 should be followed strictly.
3. Saturdays included in the Assessment period shall be used for conducting the Assessment Tests.

**** In order to ensure minimum no. of working days, the following Saturdays are declared as working days.**

| Sl. No. | Working Days (Saturdays for UG & PG ) | Time Table of the Week Day to be Followed |
|---|---|---|
| 1. | 05.09.2020 | Tuesday |
| 2. | 12.09.2020 | Friday |
| 3. | 19.09.2020 | Monday |
| 4. | 26.09.2020 | Tuesday |

| Sl. No. | Working Days (Saturdays for UG & PG ) | Time Table of the Week Day to be Followed |
|---|---|---|
| 5. | 03.10.2020 | Wednesday |
| 6. | 10.10.2020 | Thursday |
| 7. | 17.10.2020 | Friday |
| 8. | 24.10.2020 | Monday |

06082020

DIRECTOR
ACADEMIC COURSES

6/8/2020

DAC - SB

Date: 21.11.2020

**REVISED**

# CENTRE FOR ACADEMIC COURSES

## ANNA UNIVERSITY: : CHENNAI – 600 025

## ACADEMIC SCHEDULE FOR NON AUTONOMOUS AFFILIATED COLLEGES

## November 2020 – March 2021 (ODD SEMESTER – I Semester)*

UG (FT) Degree Programmes

| Sl. No | Programme | Semester | Commencement of Induction Programme | Commencement of Classes | Last working day | Commencement of Practical Examinations | Commencement of End Semester Examinations |
|---|---|---|---|---|---|---|---|
| 1. | B.E. / B.Tech. (Full Time) | I | 09.11.2020 | 23.11.2020 | 24.02.2021** | 26.02.2021 | 08.03.2021 |
| 2. | B. Arch. (Full Time) | I | 23.11.2020 | 30.11.2020 | 03.03.2021*** | 05.03.2021 | 15.03.2021 |

* As per the directives of the Government of Tamil Nadu, the classes will be conducted in ONLINE mode

RE-OPENING DAY FOR THE NEXT SEMESTER: 05.04.2021 (Monday)

1. Theory and Practical Examination schedules will be published in due course. (Practical Examinations will be conducted before the theory examinations).
2. If necessary, loss of classes due to various curricular / co-curricular activities of the department / college may be compensated by conducting classes on Saturdays.

** In order to ensure minimum no. of working days, the following Saturdays are declared as working days.

| Sl. No. | Working Days (Saturdays for UG (FT)) | Time Table of the Week Day to be Followed |
|---|---|---|
| 1. | 28.11.2020 | Monday |
| 2. | 05.12.2020 | Tuesday |
| 3. | 12.12.2020 | Wednesday |
| 4. | 19.12.2020 | Thursday |
| 5. | 26.12.2020 | Friday |
| 6. | 02.01.2021 | Friday |

| Sl. No. | Working Days (Saturdays for UG (FT)) | Time Table of the Week Day to be Followed |
|---|---|---|
| 7. | 09.01.2021 | Thursday |
| 8. | 23.01.2021 | Friday |
| 9. | 30.01.2021 | Tuesday |
| 10. | 06.02.2021 | Monday |
| 11. | 13.02.2021 | Tuesday |
| 12. | 20.02.2021 | Wednesday |
| 13. | 27.02.2021*** | Thursday |

21.11.2020

DIRECTOR
ACADEMIC COURSES

DAC - SB

Date: 07.12.2020



# CENTRE FOR ACADEMIC COURSES

## ANNA UNIVERSITY: : CHENNAI – 600 025

## ACADEMIC SCHEDULE FOR NON AUTONOMOUS AFFILIATED COLLEGES

### December 2020 – April 2021 (ODD SEMESTER – I Semester)*

PG (FT) Degree Programmes

| Sl. No | Programme | Semester | Commencement of Classes | Last working day | Commencement of Practical Examinations | Commencement of End Semester Examinations |
|---|---|---|---|---|---|---|
| 1. | M.B.A./ M.C.A (FT) | I | 09.12.2020 | 13.03.2021** | 15.03.2021 | 24.03.2021 |
| 2. | M.B.A. (5 Yrs-Integrated) | I | | | | |
| 2. | M.E. / M. Tech. / M. Arch.(FT) | I | 30.12.2020 | 03.04.2021** | 05.04.2021 | 15.04.2021 |

* As per the directives of the Government of Tamil Nadu, the classes will be conducted in ONLINE mode

RE-OPENING DAY FOR THE NEXT SEMESTER: 03.05.2021 (Monday)

** In order to ensure minimum no. of working days, the following Saturdays are declared as working days.

| Sl. No. | Working Days (Saturdays) | Time Table of the Week Day to be Followed |
|---|---|---|
| 1. | 12.12.2020 | Friday |
| 2. | 19.12.2020 | Friday |
| 3. | 26.12.2020 | Thursday |
| 4. | 02.01.2021 | Friday |
| 5. | 09.01.2021 | Tuesday |
| 6. | 23.01.2021 | Thursday |
| 7. | 30.01.2021 | Monday |
| 8. | 06.02.2021 | Tuesday |

| Sl. No. | Working Days (Saturdays) | Time Table of the Week Day to be Followed |
|---|---|---|
| 9. | 13.02.2021 | Wednesday |
| 10. | 20.02.2021 | Thursday |
| 11. | 27.02.2021 | Friday |
| 12. | 06.03.2021 | Monday |
| 13. | 13.03.2021 | Tuesday |
| 14. | 20.03.2021*** | Wednesday |
| 15. | 27.03.2021*** | Thursday |
| 16. | 03.04.2021*** | Friday |

07.12.2020

DIRECTOR
ACADEMIC COURSES

DAC - SB

Off: 22357077 / 73
22357074
Fax / Dir : 22352272

# CENTRE FOR ACADEMIC COURSES

ANNA UNIVERSITY
CHENNAI – 600 025

**Dr. S. HOSIMIN THILAGAR**
**DIRECTOR**

Letter No.2407/AU/CAC/Ach Sch(Rev)/2020 16.10.2020

To
The Deans of Regional Campuses /
The Deans of Constituent Colleges /
The Principals of the Non-Autonomous Affiliated Colleges.

## NOTIFICATION

**Agenda Item: Extension of Academic Schedule (August – November 2020).**

Representations were received from various Principals of Affiliated colleges regarding the challenges / difficulties faced by both the students and faculty during the online teaching – learning process. The issues such as cramped academic schedule, poor network connectivity and insufficient time period between the conduct of three reviews for the project work were discussed.

After due deliberations, in order to address the above said issues and to facilitate the completion of syllabus and the conduct of the internal assessment, it was decided to extend the Academic schedule for the Affiliated Colleges for the current semester. The revised schedule for this session (August – November 2020) is tabulated as below:

## Affiliated Institutions

| Sl. No | Programme | Commencement of Classes | Last working day | | Commencement of Practical Examinations | | Commencement of End Semester Examinations | |
|---|---|---|---|---|---|---|---|---|
| | | | Existing | Revised | Existing | Revised | Existing | Revised |
| 1. | All UG / PG Programmes (except I Semester) | 12.08.2020 | 26.10.2020 | **13.11.2020** | 28.10.2020 | **17.11.2020** | 09.11.2020 | **26.11.2020** |
| 2. | B. E. / B. Tech. (Part-Time) – III, V, VII | | | | | | | |

**RE - OPENING DAY FOR THE NEXT SEMESTER: 28.12.2020 (Monday)**

** In order to ensure minimum no. of working days, the following Saturdays are declared as working days.**

| Sl. No. | Working Days (Saturdays for UG & PG ) | Time Table of the Week Day to be Followed |
|---|---|---|
| 1. | 05.09.2020 | Tuesday |
| 2. | 12.09.2020 | Friday |
| 3. | 19.09.2020 | Monday |
| 4. | 26.09.2020 | Tuesday |
| 5. | 03.10.2020 | Wednesday |

| Sl. No. | Working Days (Saturdays for UG & PG ) | Time Table of the Week Day to be Followed |
|---|---|---|
| 6. | 10.10.2020 | Thursday |
| 7. | 17.10.2020 | Friday |
| 8. | 24.10.2020 | Monday |
| 9. | 31.10.2020 | Friday |
| 10. | 07.11.2020 | Monday |

This decision is taken with the approval of the competent authority.

Thanking you,

Yours faithfully,

16/10/2020

**DIRECTOR**

**Copy to:**

1. PS to Vice Chancellor
2. PA to Registrar
3. The Chairpersons, Faculty of Civil / Mechanical / Electrical // ICE / Technology / Management Sciences / S&H / Architecture & Planning, AU, Ch – 25.
4. Office of the Controller of Examinations
5. Office of Additional Controller of Examinations (UDs)
6. The Stock File, CAC.

Date: 31.03.2021

DIRECTOR ACADEMIC COURSES ANNA UNIVERSITY CHENNAI-600 025

# CENTRE FOR ACADEMIC COURSES

## ANNA UNIVERSITY: : CHENNAI – 600 025

## ACADEMIC SCHEDULE FOR NON AUTONOMOUS AFFILIATED COLLEGES

## April 2021 – July 2021 (EVEN SEMESTER – II Semester)*

UG (FT/PT) Degree Programmes

| Sl. No. | Programme | Semester | Commencement of Classes | Last working day | Commencement of Practical Examinations | Commencement of End Semester Examinations |
|---|---|---|---|---|---|---|
| 1. | B.E. / B.Tech.(Full-Time) | II | 08.04.2021 | 08.07.2021** | 10.07.2021 | 22.07.2021 |
| 2. | B.Arch. (Full-Time) | II | | | | |
| 3. | B.E./ B.Tech. (Part Time) | II | | | | |

* As per the directives of the Government of Tamil Nadu, the classes will be conducted in ONLINE mode

RE-OPENING DAY FOR THE NEXT SEMESTER: 16.08.2021 (MONDAY)

1. Theory and Practical Examination schedules will be published in due course. (Practical Examinations will be conducted before the theory examinations).
2. If necessary, loss of classes due to various curricular / co-curricular activities of the department / college may be compensated by conducting classes on Saturdays.

** In order to ensure minimum no. of working days, the following Saturdays are declared as working days.

| Sl. No. | Working Days (Saturdays for UG (FT/PT)) | Time Table of the Week Day to be Followed |
|---|---|---|
| 1. | 10.04.2021 | Thursday |
| 2. | 17.04.2021 | Friday |
| 3. | 24.04.2021 | Monday |
| 4. | 08.05.2021 | Tuesday |
| 5. | 15.05.2021 | Wednesday |
| 6. | 22.05.2021 | Thursday |

| Sl. No. | Working Days (Saturdays for UG (FT/PT)) | Time Table of the Week Day to be Followed |
|---|---|---|
| 7. | 29.05.2021 | Friday |
| 8. | 05.06.2021 | Monday |
| 9. | 12.06.2021 | Tuesday |
| 10. | 19.06.2021 | Wednesday |
| 11. | 26.06.2021 | Thursday |
| 12. | 03.07.2021 | Friday |

31.3.2021

DIRECTOR
ACADEMIC COURSES

DAC - SB

# ANNA UNIVERSITY :: CHENNAI 600 025

## Internal Assessment Schedule for Non Autonomous Affiliated Institutions

**Period : December 2020 – May 2021 (Even Semester – Final Semester) Examinations**

**For all UG/PG Programmes**

| Report No | Report Period | Test Period | Report Entry Period |
|---|---|---|---|
| I | 14-12-2020 -- 07-01-2021 | No Test | 20-02-2021 -- 25-02-2021 |
| II | 08-01-2021 -- 30-01-2021 | 25-01-2021 -- 30-01-2021 | 26-02-2021 -- 05-03-2021 |
| III | 18-02-2021 -- 16-03-2021 | 10-03-2021 -- 16-03-2021 | 16-03-2021 -- 22-03-2021 |
| IV | 17-03-2021 -- 12-04-2021 | 05-04-2021 -- 12-04-2021 | 12-04-2021 -- 15-04-2021 |

**Period : February 2021 – June 2021 (Even Semester – Except II & Final Semester) Examinations**

**For all UG/PG Programmes**

| Report No | Report Period | Test Period | Report Entry Period |
|---|---|---|---|
| I | 18-02-2021 -- 06-03-2021 | No Test | 06-03-2021 -- 11-03-2021 |
| II | 08-03-2021 -- 30-03-2021 | 25-03-2021 -- 30-03-2021 | 30-03-2021 -- 08-04-2021 |
| III | 31-03-2021 -- 26-04-2021 | 20-04-2021 -- 26-04-2021 | 26-04-2021 -- 30-04-2021 |
| IV | 27-04-2021 -- 21-05-2021 | 17-05-2021 -- 21-05-2021 | 21-05-2021 -- 24-05-2021 |

Saturdays may be included as working days to make good the Shortages, if any.

19/02/2021

CONTROLLER OF EXAMINATIONS

## COMPLIANCE OF CURRICULUM AND GAP ANALYSIS

## B.E. – UG – 2017 – REGULATION – CBCS

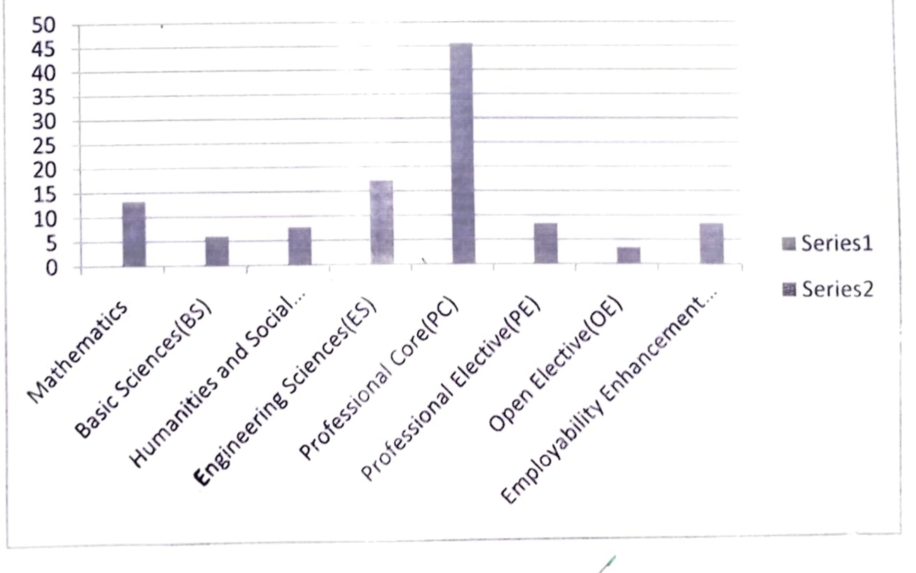
## DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

| Course Component | Course | Curriculum Content | Total Number of Contact Hours | Total Number of Credits |
|---|---|---|---|---|
| Mathematics (MA) | MA8151 Engineering mathematics | 24/180=13.3 | 360 | 180 |
| | MA8251 Engineering Mathematics II | | | |
| | MA8351 Discrete Mathematics | | | |
| | MA8402 Probability and Queuing Theory | | | |
| | MA8551 Algebra and Number Theory | | | |
| Basic Sciences(BS) | PH8151 Engineering Physics | 11/180=6.11 | 165 | 11 |
| | CY8151 Engineering Chemistry | | | |
| | BS8161 Physics Chemistry Laboratory | | | |
| | PH8252 Physics for Information Science | | | |
| Humanities and Social Sciences(HS) | HS8151 Communicative English | 14/180=7.7 | 210 | 14 |
| | HS8251 Technical English | | | |
| | MG8591 Principles of Management | | | |
| | GE8291 Environmental Science and Engineering | | | |
| | GE8151 Problem Solving and Python Programming | | | |
| Engineering | GE8152 Engineering | 23/180=17.22 | 490 | 23 |

| | | | | |
|---|---|---|---|---|
| Sciences(ES) | Graphics | | | |
| | GE8161 Problem Solving and Python Programming Laboratory | | | |
| | BE8255 Basic Electrical Electronics and Measurement Engineering | | | |
| | CS8351 Digital Principles and System Design | | | |
| | GE8261 Engineering Practice Laboratory | | | |
| | EC8395 Communication Engineering | | | |
| | CS8382 Digital Systems Laboratory | | | |
| Professional Core(PC) | CS8251 Programming in C | 82/180=45.55 | 1530 | 82 |
| | CS8261 Programming in C laboratory | | | |
| | CS8391 Object Oriented Programming | | | |
| | CS8381 Data Structures Laboratory | | | |
| | CS8383 Object Oriented Programming Laboratory | | | |
| | CS Data Structures | | | |
| | CS8491 Computer Architecture | | | |
| | CS8492 Database Management Systems | | | |
| | CS8451 Design and Analysis of Algorithm | | | |
| | CS8493 Operating Systems | | | |
| | CS8494 Software Engineering | | | |

| | | | | |
|---|---|---|---|---|
| | CS8481 Database management systems Laboratory | | | |
| | CS8461 Operating Systems Laboratory | | | |
| | CS8591 Computer Networks | | | |
| | EC8691 Microprocessor and Microcontroller | | | |
| | CS8501 Theory of Computation | | | |
| | CS8592 Object Oriented Analysis and Design | | | |
| | EC8681 Microprocessor and Microcontroller Laboratory | | | |
| | CS8592 Object Oriented Analysis and Design Laboratory | | | |
| | CS8591 Networks Laboratory | | | |
| | CS8601 Internet Programming | | | |
| | CS8691 Artificial Intelligence | | | |
| | CS8601 Mobile Computing | | | |
| | CS8602 Compiler Design | | | |
| | CS8603 Distributed Systems | | | |
| | CS8661 Internet Programming Laboratory | | | |
| | CS8662 Mobile Application Development Laboratory | | | |
| | CS8792 Cryptography and Network Security | | | |
| | CS8791 Cloud Computing | | | |

| | | | | |
|---|---|---|---|---|
| | CS8711 Cloud Computing Laboratory | | | |
| | IT8761 Security Laboratory | | | |
| Professional Elective(PE) | CS8075 Data warehousing and Data Mining | 15/180=8.33 | 225 | 15 |
| | CS8091 Big Data Analytics | | | |
| | CS8079 Human Computer Interaction | | | |
| | CS8074 Cyber Forensics | | | |
| | CS8078 Green Computing | | | |
| Open Elective(OE) | OMF551 Product Design and Development | 6/180=3.33 | 90 | 6 |
| | OIE751 Robotics | | | |



| | |
|---|---|
| Mathematics | 13.3 |
| Basic Sciences(BS) | 6.11 |
| Humanities and Social Sciences(HS) | 7.7 |
| Engineering Sciences(ES) | 17.22 |
| Professional Core(PC) | 45.55 |
| Professional Elective(PE) | 8.33 |
| Open Elective(OE) | 3.33 |
| Employability Enhancement Courses | 8.33 |

HoD/CSE

Principal

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B.E. – UG – 2017 – REGULATION – CBCS

DEPARTMENT OF MECHANICAL ENGINEERING

| Course Component | Course | Curriculum Content | Total Number of Contact Hours | Total Number of Credits |
|---|---|---|---|---|
| Basic Sciences(BS) | MA8151 Engineering mathematics | 27/184=14.67 | 435 | 27 |
| | PH8151 Engineering Physics | | | |
| | CY8151 Engineering Chemistry | | | |
| | BS8161 Physics Chemistry Laboratory | | | |
| | MA8251 Engineering Mathematics II | | | |
| | PH8251 Materials Science | | | |
| | MA8353 Transforms and Partial Differential Equations | | | |
| | MA8452 Statistics and Numerical Methods | | | |
| Humanities and Social Sciences(HS) | HS8151 Communicative English | 14/184=7.6 | 210 | 14 |
| | HS8251 Technical English | | | |
| | GE8291 Environmental Science and Engineering | | | |
| | MG8591 Principles of Management | | | |
| Engineering Sciences(ES) | GE8151 Problem Solving and Python Programming | 34/184=18.47 | 705 | 34 |
| | GE8152 Engineering Graphics | | | |
| | GE8161 Problem Solving and Python Programming Laboratory | | | |
| | BE8253 Basic Electrical, Electronics and Instrumentation Engineering | | | |

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| | | | | |
|---|---|---|---|---|
| | GE8292 Engineering Mechanics | | | |
| | GE8261 Engineering Practice Laboratory | | | |
| | BE8261 Basic Electrical, Electronics and Instrumentation Engineering Laboratory | | | |
| | CE8394 Fluid Mechanics and Machinery | | | |
| | EE8353 Electrical Drives and Controls | | | |
| | EE8361 Electrical Engineering Laboratory | | | |
| | CE8395 Strength of Materials for Mechanical Engineers | | | |
| | CE8381 Strength of Materials and Fluid Mechanics and Machinery Laboratory | | | |
| Professional Core(PC) | ME8391 Engineering Thermodynamics | 75/184=40.76 | 1410 | 75 |
| | ME8351 Manufacturing Technology - I | | | |
| | ME8361 Manufacturing Technology Laboratory - I | | | |
| | ME8381Computer Aided Machine Drawing | | | |
| | ME8492 Kinematics of Machinery | | | |
| | ME8451 Manufacturing Technology – II | | | |
| | ME8491 Engineering Metallurgy | | | |
| | ME8493 Thermal Engineering- I | | | |
| | ME8462 Manufacturing Technology Laboratory – II | | | |
| | ME8595 Thermal Engineering- II | | | |
| | ME8593 Design of | | | |

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| | | | | |
|---|---|---|---|---|
| | Machine Elements | | | |
| | ME8501 Metrology and Measurements | | | |
| | ME8594 Dynamics of Machines | | | |
| | ME8511 Kinematics and Dynamics Laboratory | | | |
| | ME8512 Thermal Engineering Laboratory | | | |
| | ME8513 Metrology and Measurements Laboratory | | | |
| | ME8651 Design of Transmission Systems | | | |
| | ME8691 Computer Aided Design and Manufacturing | | | |
| | ME8693 Heat and Mass Transfer | | | |
| | ME8692 Finite Element Analysis | | | |
| | ME8694 Hydraulics and Pneumatics | | | |
| | ME8681 CAD / CAM Laboratory | | | |
| | ME8792 Power Plant Engineering | | | |
| | ME8793 Process Planning and Cost Estimation | | | |
| | ME8791 Mechatronics | | | |
| | ME8711 Simulation and Analysis Laboratory | | | |
| | ME8781 Mechatronics Laboratory | | | |
| Professional Elective(PE) | Professional Elective – I | 12/184=6.52 | 180 | 12 |
| | Professional Elective – II | | | |
| | Professional Elective – III | | | |
| | Professional Elective– IV | | | |
| Open Elective(OE) | Open Elective I | 6/184=3.26 | 90 | 6 |
| | Open Elective - II | | | |
| Employability Enhancement Courses(EEC) | HS8381 Interpersonal Skills / Listening & Speaking | 16/184=8.70 | 480 | 16 |
| | HS8461 Advanced Reading and Writing | | | |
| | ME8682 Design and Fabrication Project | | | |

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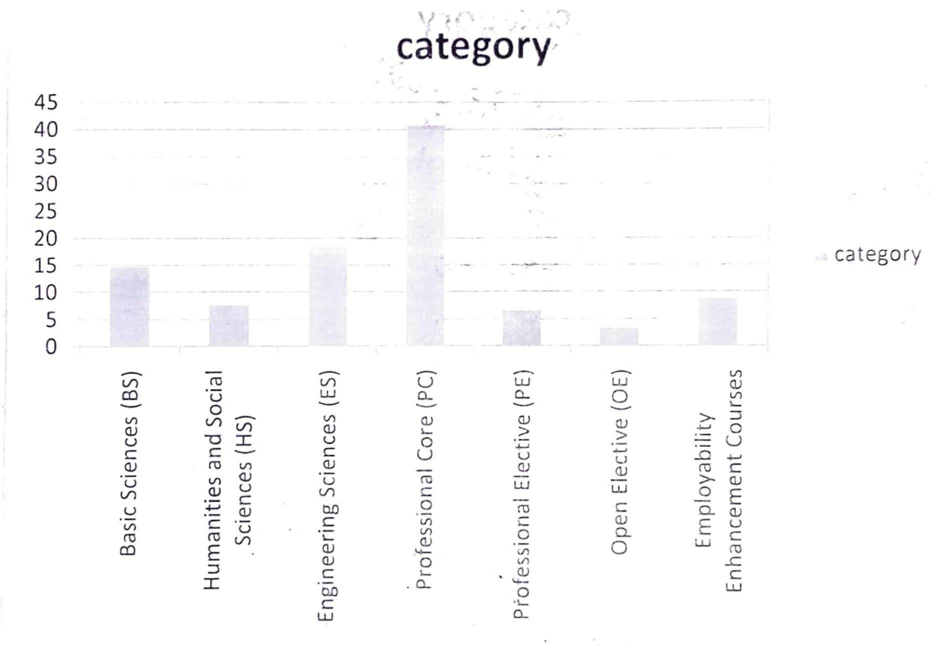
| | | | | |
|---|---|---|---|---|
| | HS8581 Professional Communication | | | |
| | ME8712Technical Seminar | | | |
| | ME8811 Project Work | | | |




| | | |
|---|---|---|
| Basic Sciences(BS) | | 14.67 |
| Humanities and Social Sciences(HS) | | 7.6 |
| Engineering Sciences(ES) | | 18.47 |
| Professional Core(PC) | | 40.76 |
| Professional Elective(PE) | | 6.52 |
| Open Elective(OE) | | 3.26 |
| Employability Enhancement Courses | | 8.70 |

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M.E. – PG – 2017 – REGULATION – CBCS

DEPARTMENT OF MECHANICAL ENGINEERING

M.E. MANUFACTURING ENGINEERING

| Course Component | Course | Curriculum Content | Total Number of Contact Hours | Total Number of Credits |
|---|---|---|---|---|
| Foundation Courses(FC) | MA5160 Applied Probability and Statistics | 4/72=5.55 | 60 | 4 |
| Professional Core(PC) | MF5101 Advanced in Manufacturing Technology | 31/72=43.06 | 540 | 31 |
| | MF5102 Computer Integrated Manufacturing Systems | | | |
| | MF5103 Advances in Casting and Welding | | | |
| | MF5104 Metal Cutting Theory and Practice | | | |
| | MF5111 CAD/CAM Laboratory | | | |
| | MF5201 Optimization Techniques in Manufacturing | | | |
| | CM5251 Advances in Metrology and Inspection | | | |
| | MF5202 Theory of Metal Forming | | | |
| | MF5203 Tooling for Manufacturing | | | |
| | MF5211 Automation and Metal Forming Laboratory | | | |
| Professional Elective(PE) | Professional Elective – I | 18/72=25 | 270 | 18 |
| | Professional Elective – II | | | |
| | Professional Elective – III | | | |
| | Professional Elective – IV | | | |

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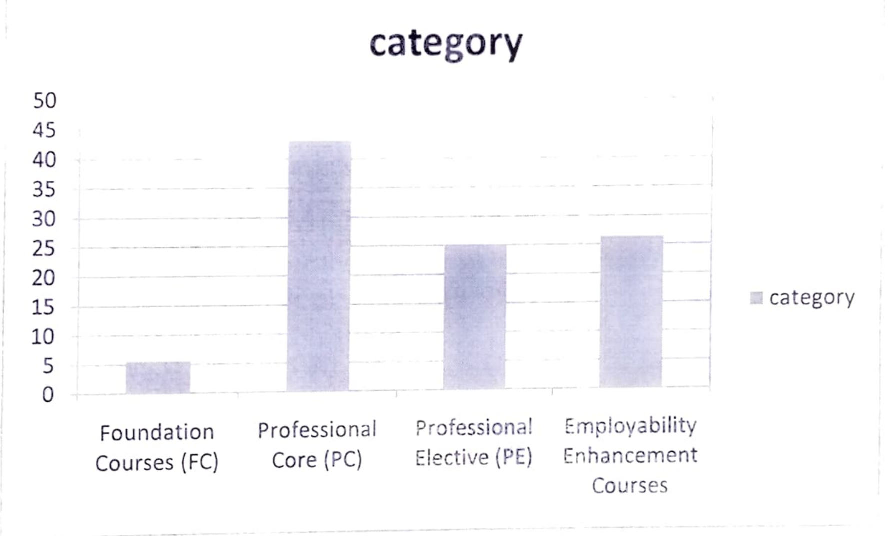
| | | | | |
|---|---|---|---|---|
| | Professional Elective– V<br>Professional Elective– VI | | | |
| Employability Enhancement Courses(EEC) | MF5212 Technical Seminar<br>MF5311 Project Work Phase I<br>MF5411 Project Work Phase II | 19/72=26.39 | 570 | 19 |




| | |
|---|---|
| Foundation Courses (FC) | 5.55 |
| Professional Core(PC) | 43.06 |
| Professional Elective(PE) | 25 |
| Employability Enhancement Courses | 26.39 |

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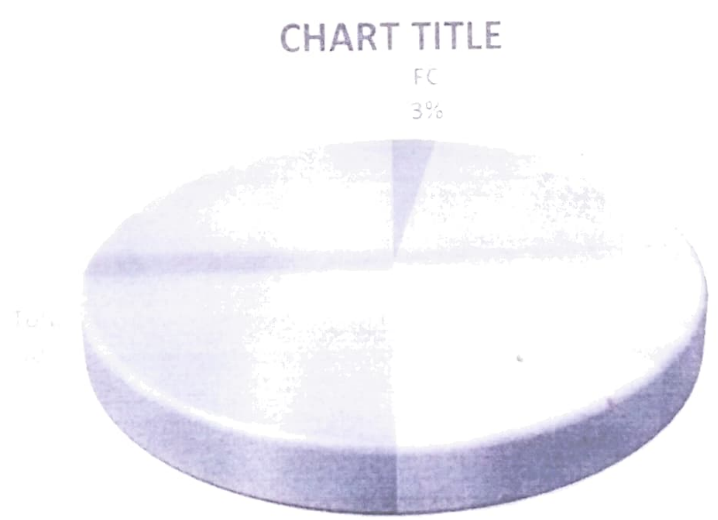
## COMPplANCE OF CURRICULUM AND GAP ANALYSIS

## M.E. – PG – 2017 – REGULATION – CBCS

## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

## SUMMARY

| SUBJECT AREA | CREDITS AS PER SEMESTER | | | | CREDITS TOTAL |
|---|---|---|---|---|---|
| | I | II | III | IV | |
| FC | 4 | - | - | - | 4 |
| PC | 15 | 15 | - | - | 30 |
| PE | 3 | 6 | 9 | - | 18 |
| EEC | - | 2 | 6 | 12 | 20 |
| Total | 22 | 23 | 15 | 12 | 72 |

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## COMPLIANCE OF CURRICULUM AND GAP ANALYSIS

## M.E. – PG – 2017 – REGULATION – CBCS

## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

| COURSE COMPONENT | COURSES | CURRUCULAM CONTENT (% OF TOTAL NUMBER OF CREDITS THE PROGRAM) | TOTAL NUMBER OF CONTACT HOURS | TOTAL NUMBER OF CREDITS |
|---|---|---|---|---|
| FOUNDATION COURSES(FC) | MA5155 Applied Mathematics for Electrical Engineers | 4/72 = 5.55 | 60 | 4 |
| PROFESSIONAL CORE(PC) | PX5101 Power Semiconductor Devices<br>PX5151 Analysis of Electrical Machines<br>PX5152 Analysis and Design of Power Converters<br>IN5152 System Theory (75)<br>PX5111 Power Electronics Circuits Lab<br>PX5201 Analysis and Design of Inverters<br>PX5202 Solid State Drives<br>PX5251 Special Electrical Machines<br>PX5252 Power Quality<br>PX5211 Electrical Drives Laboratory | 30/72 = 40 | 540 | 30 |
| PROFESSIONAL ELECTIVES (PE) | PX5001 "Electromagnetic Field Computation and Modelling"<br>PX5003 Flexible AC Transmission Systems<br>PS5071 Distributed Generation and Microgrid<br>PS5092 Solar and Energy Storage Systems<br>PX5071 Wind Energy Conversion Systems<br>PS5072 Energy Management and Auditing | 18/72 = 25 | 225 | 18 |
| EMPLOYABILITY ENHANCEMENT COURSES (EEC) | PX5212 Mini Project<br>PX5311 Project Work Phase I<br>PX5411 Project Work Phase II | 20/75 = 27.77 | 40 | 20 |

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## COMPLIANCE OF CURRICULUM AND GAP ANALYSIS

## B.E. – UG – 2017 – REGULATION – CBCS

## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

| COURSE COMPONENT | COURSES | CURRUCULAM CONTENT (% OF TOTAL NUMBER OF CREDITS THE PROGRAM) | TOTAL NUMBER OF CONTACT HOURS | TOTAL NUMBER OF CREDITS |
|---|---|---|---|---|
| BASIC SCIENCES (BS) | MA8151 Engineering Mathematics<br>MA8251 Engineering Mathematics II<br>MA8353 Transforms and Partial Differential Equations<br>MA8491 Numerical Methods<br>PH8151 Engineering Physics<br>CY8151 Engineering Chemistry<br>BS8161 Physics and Chemistry Laboratory<br>PH8253 Physics for Electronics Engineering | 27/180 = 15 | 405 | 27 |
| HUMANITIES AND SOCIAL SCIENCES (HS) | HS8151 Communicative English<br>HS8251 Technical English<br>GE8291 Environmental Science and Engineering | 11/180 = 6.11 | 165 | 11 |
| ENGINEERING SCIENCE (ES) | GE8151 Problem Solving and Python Programming<br>GE8152 Engineering Graphics<br>GE8161 Problem Solving and Python Programming Laboratory<br>BE8252 Basic Civil and Mechanical Engineering<br>GE8261 Engineering Practices Laboratory<br>EC8353 Electron Devices and Circuits<br>ME8792 Power Plant Engineering<br>EC8311 Electronics Laboratory<br>CS8392 Object Oriented Programming<br>CS8383 Object Oriented Programming Laboratory<br>EE8691 Embedded Systems | 31/180 = 17.22 | 615 | 31 |

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| COURSE COMPONENT | COURSES | CURRUCULAM CONTENT (% OF TOTAL NUMBER OF CREDITS THE PROGRAM) | TOTAL NUMBER OF CONTACT HOURS | TOTAL NUMBER OF CREDITS |
|---|---|---|---|---|
| PROFESSIONAL CORE (PC) | EE8251 Circuit Theory<br>EE8261 Electric Circuits Laboratory<br>EE8351 Digital Logic Circuits<br>EE8391 Electromagnetic Theory<br>EE8301 Electrical Machines - I<br>EE8311 Electrical Machines Laboratory – I<br>EE8401 Electrical Machines - II<br>EE8402 Transmission and Distribution<br>EE8403 Measurements and Instrumentation<br>EE8451 Linear Integrated Circuits and Applications<br>IC8451 Control Systems<br>EE8411 Electrical Machines Laboratory – II<br>EE8461 Linear and Digital Integrated Circuits Laboratory<br>EE8501 Power System Analysis<br>EE8551 Microprocessors and Microcontrollers<br>EE8552 Power Electronics<br>EE8591 Digital Signal Processing<br>EE8511 Control and Instrumentation Laboratory<br>EE8601 Solid State Drives<br>EE8602 Protection and Switchgear<br>EE8661 Power Electronics and Drives Laboratory<br>EE8681 Microprocessors and Microcontrollers Laboratory<br>EE8701 High Voltage Engineering<br>EE8702 Power System Operation and Control<br>EE8703 Renewable Energy Systems<br>EE8711 Power System Simulation Laboratory<br>EE8712 Renewable Energy Systems Laboratory | 73/180 = 40.55 | 1470 | 73 |

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| COURSE COMPONENT | COURSES | CURRUCULAM CONTENT (% OF TOTAL NUMBER OF CREDITS THE PROGRAM) | TOTAL NUMBER OF CONTACT HOURS | TOTAL NUMBE R OF CREDITS |
|---|---|---|---|---|
| OPEN ELECTIVE (OE) | OAN551 Sensors and Transducers | 6/180 = 0.33 | 90 | 6 |
| | OmI751 Testing of Materials | | | |
| PROFESSIONAL ELECTIVE (PE) | EE8002 Design of Electrical Apparatus | 18/180 = 10 | 270 | 18 |
| | EE8005 Special Electrical Machines | | | |
| | GE8071 Disaster Management | | | |
| | GE8077 Total Quality Management | | | |
| | MG8591 Principles of Management | | | |
| | EI8073 Biomedical Instrumentation | | | |
| EMPLOYABILITY ENHANCEMENT COURSES (EEC) | EE8412 Technical Seminar | 14/180 = 7.7 | 420 | 14 |
| | HS8581 Professional Communication | | | |
| | EE8611 Mini Project | | | |
| | EE8811 Project Work | | | |

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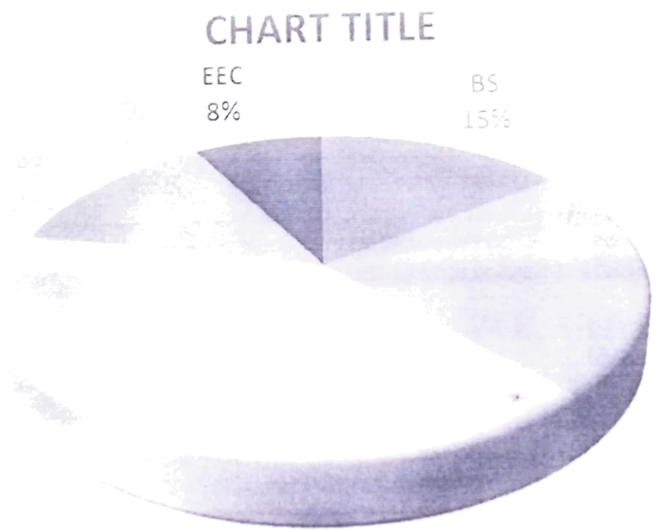
## COMPLIANCE OF CURRICULUM AND GAP ANALYSIS

## B.E. – UG – 2017 – REGULATION – CBCS

## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

### SUMMARY

| S.NO. | SUBJECT AREA | CREDITS AS PER SEMESTER | | | | | | | | CREDITS TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII | VIII | |
| 1. | BS | 12 | 7 | 4 | 4 | - | - | - | | 27 |
| 2. | HS | 4 | 7 | - | - | - | - | - | | 11 |
| 2. | ES | 9 | 6 | 8 | - | 5 | 3 | - | | 31 |
| 3. | PC | - | 5 | 11 | 20 | 14 | 10 | 13 | - | 73 |
| 4. | PE | | | | | | 6 | 6 | 6 | 18 |
| 5. | OE | | | | | 3 | - | 3 | | 6 |
| 6. | EEC | | | | 1 | 1 | 2 | | 10 | 14 |
| | Total | 25 | 25 | 23 | 25 | 23 | 21 | 22 | 16 | 180 |

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Wisdom Tree, Neelambur, Avinashi Road, Coimbatore-62

**COMPUTER SCIENCE AND ENGINEERING**

CIRCULAR

**Date: 17.3.2021**

This is to inform that the class committee meeting for II CSE will held on 19.03.2021 at 2.30pm to 3.15pm in CSE department. All the Student representatives are asked to attend the meeting without fail.

**HoD** 17/3/21

**Chairperson**

Dr. G.Manjula HoD/Civil

**Staff Members :**

Dr.S.J.K.Jagadeesh Kumar, Prof&Head/CSE

Ms. K. Saranya, AP/S&H

Mr.D.Ravi, AsP/CSE

Ms.R.S.Ramya, AP/CSE R.S.P

Dr.G.Prabhu kanna, AsP/CSE

Ms.S.Dhivya Bharathi, AP/CSE

Dr.N.Mohana Suganthi, Prof/CSE

Dr.S.R.Kannan, AsP/S&H

# KATHIR COLLEGE OF ENGINEERING

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Web: www.kathir.ac.in, Email: kathirce@kathir.ac.in


## DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

## Minutes of Class Committee Meeting

**Date** : 19.3.2021

**Chair Person** : Dr. Manjula HoD/Civil

**Class** :II CSE(IV sem)

**The discussion mainly covers**

1. PQT, CA,DBMS,OS,DAA,SE,DBMS Lab, OS Lab, AR&W Syllabus coverage for CIA1 Examination.
2. Discussed about completion of Lab Experiments.
3. Students were advised strictly to follow the Pandemic Rules and Regulations.
4. Students were asked to attend the certification programs Through Online

**Specific points regarding Teaching -Learning process:**

1. More problems and step by step Explanation needed in PQT
2. More SQL queries needed in DBMS.
3. Real time Example & Case Study needed for Software Engineering.

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Wisdom Tree, Neelambur, Avinashi Road, Coimbatore-62

COMPUTER SCIENCE AND ENGINEERING

MINUTES OF CLASS COMMITTEE MEETING DATE: 19.3.2021

| | |
|---|---|
| Year / Sem : II/IV | Venue: CSE DEPARTMENT |
| Time :2.30pm-3.15pm | Meeting No : 01 |

CHAIR PERSON : Dr.Manjula G HoD/Civil

| S.No | Name of the Member | Signature |
|---|---|---|
| 1 | Dr.S.J.K.Jagadeesh Kumar, Prof&Head/CSE | [signature] |
| 2 | Ms. K. Saranya, AP/S&H | [signature] |
| 3 | Mr.D.Ravi, AsP/CSE | [signature] |
| 4 | Dr.G.Prabhu kanna, AsP/CSE | [signature] |
| 5 | Ms.S.Dhivya Bharathi, AP/CSE | [signature] |
| 6 | Dr.N.Mohana Suganthi, Prof/CSE | [signature] |
| 7 | Dr.S.R.Kannan, AsP/S&H | [signature] |

| | | |
|---|---|---|
| 8 | Ms.R.S.Ramya, AP/CSE | |
| 9 | DAWOOD IBRAHIM H II/CSE | |
| 10 | ANSLINE LIDIYA D II/CSE | |
| 11 | GANGA GOWRI S II/CSE | |
| 12 | SUBBU KUTTY B II/CSE | |
| 13 | SUSMITHA SHREE K II/CSE | |
| 14. | KEERTHIVASAN S II/CSE | |

Faculty Advisor

HoD

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COMPUTER SCIENCE AND ENGINEERING

## ACTION TAKEN FOR CLASS COMMITTEE MEETING

1. More tutorial hours planned for PQT

2. Theory and lab topic coordination are planned to follow concurrently for both data structures and DBMS lab.

3. Real time examples to be discussed in class for SE

R.S. [signature] 22/3/21 [signature] 22/3/21 [signature]

Faculty Advisor HoD Principal

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**Wisdom Tree, Neelambur, Avinashi Road, Coimbatore-62**

## COURSE INFORMATION

**Course Code & Course Title** : MA8402 Probability & Queueing Theory

**Academic Year/Sem** : 2021-2022 (EVEN)

**Offering Semester** : IV

**Credits (L T P C)** : 4 0 0 4

**Course in-charge** : Mr. S Saravanan

### About the Course & Contents

This course is designed to provide necessary basic concepts in probability, standard distributions and random processes which are widely applied in random signals, linear systems in communication engineering and IT fields. The syllabus also covers the concepts of Markovian and advanced queueing models which are essential to design and analyze computer networks.

### Program Outcomes Addressed

| PO | Program Outcome |
|---|---|
| PO1 | **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems. |
| PO2 | **Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences. |
| PO3 | **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations. |
| PO9 | **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings. |
| PO10 | **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. |
| PO12 | **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change. |

Program Specific Outcomes addressed

| PSO | Program Specific Outcome |
|---|---|
| 1 | Design data structures and database management systems with a recurrent programming language to provide software solutions. |
| 2 | In the fields of artificial intelligence, big data, and cloud computing, use problem - solving techniques. |

**Course Outcomes**
**At the end of the course students will have the ability to**

| CO | Course Outcomes | POs | CL | Class Sessions (approx.) |
|---|---|---|---|---|
| CO1 | Understand the fundamental knowledge of the concepts of probability and have knowledge of standard distributions which can describe real life phenomenon. | PO1, PO2, PO12, PSO1, PSO2 | U | 12 |
| CO2 | Understand the basic concepts of one and two dimensional random variables and apply in engineering applications. | PO1, PO2, PO12, PSO1, PSO2 | U | 12 |
| CO3 | Apply the concept of random processes in engineering disciplines. | PO1, PO2, PO3, PO9, PO10, PO12, PSO1, PSO2 | AP | 12 |
| CO4 | Acquire skills in analyzing queueing models. | PO1, PO2, PO3, PO9, PO10, PO12, PSO1, PSO2 | AN | 12 |
| CO5 | Understand and characterize phenomenon which evolve with respect to time in a probabilistic manner | PO1, PO2, PO3, PO9, PO10, PO12, PSO1, PSO2 | U | 12 |
| | | **Total Hours of instruction** | | **60** |

Strength to which POs and PSO are addressed by COs

| No. of sessions devoted (Maximum 45 sessions) | % of classroom sessions are devoted | Program Outcome | Course Level PO1 Strength (3-strong, 2-moderate, 1-weak)* |
|---|---|---|---|
| 60 | 100 | PO1 | 3 |
| 60 | 100 | PO2 | 3 |
| 36 | 60 | PO3 | 3 |

| | | | |
|---|---|---|---|
| 36 | 60 | PO9 | 2 |
| 36 | 60 | PO10 | 1 |
| 60 | 100 | PO12 | 2 |
| 60 | 100 | PSO1 | 3 |
| 36 | 60 | PSO2 | 2 |

***Above 70% - Strong (3); 51% to 70% - Moderate (2); 5% to 60% - Weak (1); LT 5% - NIL (0)**

**Course – PO/PSO Mapping**

| Course | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | PSO1 | PSO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MA8402 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 2 | 3 | 2 |

**Competencies**

At the end of the course the student should be able to

| | Competency | CO | CL | Sessions (approx.) |
|---|---|---|---|---|
| C1 | Recalls the theory of probability and random variables and illustrate the use of CDFs, PDFs and PMFs of continuous as well as discrete nature | CO1 | U | 6 |
| C2 | Apply concepts of Probability to solve problems in Electronic Engineering. | CO1 | A | 6 |
| C3 | To make students understand Discrete and Continuous Random variables, Random Processes and their applications in Electronic Transmissions | CO2 | U | 6 |
| C4 | To Find functional relationship between random inputs and outputs with the use of Random Process Techniques | CO2 | AP | 6 |
| C5 | Understand the concept of random processes and determine covariance and spectral density of stationary random processes. | CO3 | U | 6 |
| C6 | Demonstrate the ability to formulate continuous-time Markov chain models for relevant practical systems | CO3 | U | 6 |
| C7 | To develop mathematical and modeling skills required for evaluating queueing systems performance | CO4 | U | 6 |
| C8 | Analysing networks of queuing systems | CO4 | AU | 6 |
| C9 | Apply and extend queueing models to analyze real world systems. | CO5 | AP | 6 |
| C10 | Understand and compute quantitative metrics of performance for queueing systems | CO5 | U | 6 |

| CO | Course Outcomes | Target (Class Average Marks) |
|---|---|---|
| CO1 | Understand the fundamental knowledge of the concepts of probability and have knowledge of standard distributions which can describe real life phenomenon. | 70 |
| CO2 | Understand the basic concepts of one and two dimensional random variables and apply in engineering applications. | 70 |
| CO3 | Apply the concept of random processes in engineering disciplines. | 70 |
| CO4 | Acquire skills in analyzing queueing models. | 70 |
| CO5 | Understand and characterize phenomenon which evolve with respect to time in a probabilistic manner | 70 |

**Assessment Pattern**

| Assessment Instrument | Percentage Weightage |
|---|---|
| Continuous Internal Assessment | 20% |
| Semester End examination | 80% |

**Continuous Internal Evaluation (20 marks)**

| Assessment Instrument | Weightage |
|---|---|
| CIE test-1 | 30% (6 marks) |
| CIE test-2 | 30% (6 marks) |
| CIE test-3 | 40% (8 marks) |

# Kathir College of Engineering

[Approved by AICTE | Affiliated to Anna University | Accredited by NAAC]
Wisdom Tree, Neelambur, Avinashi Road, Coimbatore-62

## LIST OF DOCUMENTS FOR COURSE FILE

| Sl.No | LIST OF DOCUMENTS |
|---|---|
| 1 | Syllabus ( signed by HoD, Principal) |
| 2 | University Question Bank ( 16marks & 2 marks with answers) |
| 3 | Programme Educational Objectives ( PEO's) and Programme outcomes ( PO's) |
| 4 | List of students ( signed by Class Advisor, HoD) |
| 5 | Individual Time table ( signed by HoD) |
| 6 | Course plan |
| 7 | Lecture notes |
| 8 | Record of class work(singed by HoD) |
| 9 | Internal test I Question papers (covering 1.5 units as per recommended pattern) |
| 10 | Sample answer scripts of Internal Test I |
| 11 | Mark list of Internal Test I ( signed by Faculty and HoD) |
| 12 | List of slow learners of Internal Test I |
| 13 | Corrective action taken report for slow learners ( Assignment, Improvement tests) |
| 14 | Mark statement for Anna university web portal entry |
| 15 | Internal test II Question papers (covering next 1.5 units as per recommended pattern) |
| 16 | Sample answer scripts of Internal Test II |
| 17 | Mark list of Internal Test II ( signed by Faculty and HoD) |
| 18 | List of slow learners of Internal Test II |
| 19 | Corrective action taken report ( Assignment, Improvement tests) |
| 20 | Mark statement for Anna university web portal entry |
| 21 | Internal test III Question papers (covering remaining 2 units as per the pattern) |
| 22 | Sample answer scripts of Internal Test III |
| 23 | Mark list of Internal Test III ( signed by Faculty and HoD) |
| 24 | List of slow learners of Internal Test III |
| 25 | Corrective action taken report ( Assignment, Improvement tests) |
| 26 | Mark statement for Anna university web portal entry |
| 27 | Consolidated Internal marks statement based on Continuous Assessment |
| 28 | Model test Question paper |
| 29 | Mark list of Model test |
| 30 | End semester exam question paper |
| 31 | Question paper Feedback form ( signed by HoD and Principal) |
| 32 | Course End Survey |
| 33 | CO-PO-PSO attainment sheet(After revaluation results) |

A. Lalithasaravanan
Faculty In-Charge

HoD/MECH

KATHIR COLLEGE OF ENGINEERING KCE COIMBATORE - 641 062

# Kathir College of Engineering

[Approved by AICTE | Affiliated to Anna University | Accredited by NAAC]
Wisdom Tree, Neelambur, Avinashi Road, Coimbatore-62

**ME8595** **THERMAL ENGINEERING – II** **L T P C**

**3 0 0 3**

**OBJECTIVES:**

- To apply the thermodynamic concepts for Nozzles, Boilers, Turbines, and Refrigeration & Air Conditioning Systems.
- To understand the concept of utilising residual heat in thermal systems.

**UNIT I** **STEAM NOZZLE** **9**

Types and Shapes of nozzles, Flow of steam through nozzles, Critical pressure ratio, Variation of mass flow rate with pressure ratio. Effect of friction. Metastable flow.

**UNIT II** **BOILERS** **9**

Types and comparison. Mountings and Accessories. Fuels - Solid, Liquid and Gas. Performance calculations, Boiler trial.

**UNIT III** **STEAM TURBINES** **9**

Types, Impulse and reaction principles, Velocity diagrams, Work done and efficiency – optimal operating conditions. Multi-staging, compounding and governing.

**UNIT IV** **COGENERATION AND RESIDUAL HEAT RECOVERY** **9**

Cogeneration Principles, Cycle Analysis, Applications, Source and utilisation of residual heat. Heat pipes, Heat pumps, Recuperative and Regenerative heat exchangers. Economic Aspects.

**UNIT V** **REFRIGERATION AND AIR – CONDITIONING** **9**

Vapour compression refrigeration cycle, Effect of Superheat and Sub-cooling, Performance calculations, Working principle of air cycle, vapour absorption system, and Thermoelectric refrigeration. Air conditioning systems, concept of RSHF, GSHF and ESHF, Cooling load calculations. Cooling towers – concept and types.

**OUTCOMES:**

**Upon the completion of this course the students will be able to**

CO1 Solve problems in Steam Nozzle

CO2 Explain the functioning and features of different types of Boilers and auxiliaries and calculate performance parameters.

CO3 Explain the flow in steam turbines, draw velocity diagrams for steam turbines and solve problems.

CO4 Summarize the concept of Cogeneration, Working features of Heat pumps and Heat exchangers

CO5 Solve problems using refrigerant table / charts and psychrometric charts

A. Sathishnarayanan 21/8/21
Faculty In-Charge

21/8/21
HoD/MECH

21/8/21
Principal

**KATHIR COLLEGE OF ENGINEERING**

**COIMBATORE - 641 062**

**DEPARTMENT OF MECHANICAL ENGINEERING**

**Class: III B.E. MECH** **Academic Year: 2021 - 22** **Total no. of students: 13**

| S.No. | Roll No. | Register Number | Student Name |
|---|---|---|---|
| 1 | 19ME01 | 711619114001 | ASWIN V |
| 2 | 19ME02 | 711619114002 | CHANDRU G |
| 3 | 19ME03 | 711619114003 | ILAKKIYA D |
| 4 | 19ME04 | 711619114004 | JEEVA P |
| 5 | 19ME07 | 711619114007 | SANTHAKUMAR P |
| 6 | 19ME08 | 711619114008 | SARAN R |
| 7 | 19ME09 | 711619114009 | UTHAYAKUMAR N |
| 8 | 19ME10 | 711619114010 | VASANTHA KUMAR M |
| 9 | 19ME11 | 711619114011 | VISHNUVARTHAN S |
| 10 | 19ME12 | 711619114301 | NIVEEN |
| 11 | 19ME13 | 711619114302 | SEENIVASAN |
| 12 | 19ME14 | 711619114701 | JAGATHESH |
| 13 | 19ME15 | 711619114501 | SARAN SK |

A. Saravanan 21/8/21
**STAFF INCHARGE**

21/8/21
**HOD**

| | | |
|---|---|---|
| | **Kathir College of Engineering**<br>**Coimbatore 62**<br>**Department of Mechanical Engineering** | DATE : 21-8-21 |

**COURSE PLAN**
**Academic Year : 2020-2021**
**Semester : V / ME 8595 / THERMAL ENGINEERING – II**

| | | |
|---|---|---|
| **BATCH : A** | **BRANCH : Mechanical Engineering** | **YEAR : III** |
| **Name of the Faculty : Dr. A. Lalitha Saravanan** | | **Designation: Associate Professor** |

**Course pre-requisites** : Thermal Engineering I

**Course learning objectives** :

1. To apply the thermodynamic concepts for Nozzles.
2. To apply the design concepts, basic principle for Boilers.
3. To apply the design concepts for Turbines.
4. To understand the concept of utilising residual heat in thermal systems.
5. To apply the thermodynamic concepts for Refrigeration & Air Conditioning Systems.

**Expected Level of Output** : Conceptual, Design and Analytical

**Department Offered** : Mechanical Engineering

**Nature of the Course** : Conceptual, Design and Analytical

**Continuous Internal Assessment (CIA)** : **20 Marks**
**Semester End Examination (SEE)** : **80 Marks**

6

| Sl.No. | Topics to be covered | Planned No. of Hours | Date and Period | Teaching aids (BB/ICT) | Course Outcomes | Bloom's Level | Resources (T1, T2, R1, R2,R3,R4,R5 W1) |
|---|---|---|---|---|---|---|---|
| **UNIT- I** | **TITLE : STEAM NOZZLE** | | | | | | **HOURS : 09** |
| 1 | Introduction to nozzles | 1 | 23-8-21 | ICT | CO1 | U | T1,R2 |
| 2 | Types and Shapes of nozzles | 1 | 23-8-21 | ICT | CO1 | U | T1,T2 |
| 3 | Flow of steam through nozzles | 1 | 26-8-21 | ICT | CO1 | U | T1,W1 |
| 4 | Critical pressure ratio | 1 | 26-8-21 | ICT | CO1 | AP | T1,T2 |
| 5 | Variation of mass flow rate with pressure ratio | 1 | 30-8-21 | ICT | CO1 | AN | T1,T2 |
| 6 | Effect of friction | 1 | 30-8-21 | ICT | CO1 | AP | T1 |
| 7 | Metastable flow | 1 | 02-9-21 | ICT | CO1 | AP | T1,T2 |
| 8 | Problem on nozzles | 1 | 02-9-21 | ICT | CO1 | AN | T1 |
| 9 | Problem on nozzles | 1 | 06-9-21 | ICT | CO1 | AN | T1,W1 |
| **UNIT- II** | **TITLE :BOILERS** | | | | | | **HOURS :09** |
| 1 | Introduction to Boiler | 1 | 06-9-21 | ICT | CO2 | U | T1,T2 |
| 2 | Types of Boilers | 1 | 09-9-21 | ICT | CO2 | U | T1,R2 |
| 3 | Types of Boilers | 1 | 09-9-21 | ICT | CO2 | U | T1,R2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | Comparison of Boilers | 1 | 13-9-21 | ICT | CO2 | AN | T1,R2 |
| 5 | Mountings and Accessories | 1 | 13-9-21 | ICT | CO2 | AP | T1,T2 |
| 6 | Fuels - Solid, Liquid and Gas | 1 | 16-9-21 | ICT | CO2 | U | T1,T2 |
| 7 | Performance calculations | 1 | 16-9-21 | ICT | CO2 | AN | T1,T2 |
| 8 | Boiler trial | 1 | 20-9-21 | ICT | CO2 | AN | T1,T2 |
| 9 | Problem on Boiler | 1 | 20-9-21 | ICT | CO2 | AN | T1,T2 |
| **UNIT- III TITLE : STEAM TURBINES** | | | | | | | **HOURS : 09** |
| 1 | Types of turbines | 1 | 23-9-21 | ICT | CO3 | U | T1,T2 |
| 2 | Impulse and reaction principles | 1 | 23-9-21 | ICT | CO3 | U | T1,T2 |
| 3 | Velocity diagrams | 1 | 27-9-21 | ICT | CO3 | AP | T1,T2 |
| 4 | Work done and efficiency | 1 | 27-9-21 | ICT | CO3 | AN | T1,T2 |
| 5 | optimal operating conditions | 1 | 30-9-21 | ICT | CO3 | AN | T1,T2 |
| 6 | Multi-staging | 1 | 30-9-21 | ICT | CO3 | AP | T1,T2 |
| 7 | compounding and governing | 1 | 04-10-21 | ICT | CO3 | AP | T1,T2 |
| 8 | Problems on Turbines | 1 | 04-10-21 | ICT | CO3 | AN | T1,T2 |
| 9 | Problems on Turbines | 1 | 07-10-21 | ICT | CO3 | AN | T1,T2 |
| **UNIT- IV TITLE : COGENERATION AND RESIDUAL HEAT RECOVERY** | | | | | | | **HOURS : 09** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Cogeneration Principles | 1 | 07-10-21 | ICT | CO4 | U | R3,R4 |
| 2 | Cycle Analysis | 1 | 11-10-21 | ICT | CO4 | AN | R3,R4 |
| 3 | Applications | 1 | 11-10-21 | ICT | CO4 | AP | R3,R4 |
| 4 | Source and utilisation of residual heat | 1 | 18-10-21 | ICT | CO4 | AP | R3,R4 |
| 5 | Heat pipes | 1 | 18-10-21 | ICT | CO4 | AP | R3,R4 |
| 6 | Heat pumps | 1 | 21-10-21 | ICT | CO4 | AP | R3,R4 |
| 7 | Recuperative and Regenerative heat exchangers | 1 | 21-10-21 | ICT | CO4 | AP | R4,R5 |
| 8 | Problems on heat exchangers | 1 | 25-10-21 | ICT | CO4 | AN | R4,R5 |
| 9 | Economic Aspects | 1 | 25-10-21 | ICT | CO4 | AN | R4,R5 |
| **UNIT- V TITLE : REFRIGERATION AND AIR – CONDITIONING** | | | | | | | **HOURS : 09** |
| 1 | Vapour compression refrigeration cycle. | 1 | 28-10-21 | ICT | CO5 | U | R1,R2 |
| 2 | Effect of Superheat and Sub-cooling | 1 | 28-10-21 | ICT | CO5 | AP | R1,R2 |
| 3 | Performance calculations | 1 | 01-11-21 | ICT | CO5 | AN | R1,R2 |
| 4 | Working principle of air cycle | 1 | 01-11-21 | ICT | CO5 | U | R1,R2 |
| 5 | vapour absorption system | 1 | 08-11-21 | ICT | CO5 | U | R1,R2 |
| 6 | Thermoelectric refrigeration | 1 | 08-11-21 | ICT | CO5 | U | R1,R2 |
| 7 | Air conditioning systems, concept of RSHF, GSHF and ESHF | 1 | 11-11-21 | ICT | CO5 | AN | R1,R2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | Cooling load calculations | 1 | 11-11-21 | ICT | CO5 | AN | R1,W1 |
| 9 | Cooling towers – concept and types | 1 | 15-11-21 | ICT | CO5 | U | R1,W1 |

**Text Book**

1. Kothandaraman, C.P., Domkundwar .S and Domkundwar A.V.,"A course in Thermal Engineering", Dhanpat Rai & Sons, 2016.
2. Mahesh. M. Rathore, "Thermal Engineering", 1st Edition, Tata Mc Graw Hill Publications, 2010.

**Reference Books**

1. Arora .C.P., "Refrigeration and Air Conditioning", Tata Mc Graw Hill, 2008
2. Ballaney. P.L ." Thermal Engineering", Khanna publishers, 24th Edition 2012
3. Charles H Butler : Cogeneration" McGraw Hill, 1984.
4. Donald Q. Kern, " Process Heat Transfer", Tata Mc Graw Hill, 2001.
5. Sydney Reiter "Industrial and Commercial Heat Recovery Systems" Van Nostrand Reinhols,1985.

**Web References**

1. https://nptel.ac.in/courses/112/103/112103277/

**Expected outcome of the course:**

**Upon the completion of this course the students will be able to**

CO1 Solve problems in Steam Nozzle

CO2 Explain the functioning and features of different types of Boilers and auxiliaries and calculate performance parameters.

CO3 Explain the flow in steam turbines, draw velocity diagrams for steam turbines and solve problems.

CO4 Summarize the concept of Cogeneration, Working features of Heat pumps and Heat exchangers

CO5 Solve problems using refrigerant table / charts and psychrometric charts

**Mapping course outcome with programme outcomes:**

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | - | 2 | - | 2 | 3 |
| CO2 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | - | 3 | - | 2 | 3 |
| CO3 | 3 | 3 | 3 | 2 | - | 2 | 2 | - | 2 | - | 2 | 3 |
| CO4 | 3 | 3 | 2 | 2 | - | 3 | 3 | - | 3 | - | 3 | 3 |
| CO5 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | - | 3 | - | 3 | 3 |

**Mapping Course Outcome with Programme Specific outcomes:**

| | PSO1 | PSO2 | PSO3 | PSO4 |
|---|---|---|---|---|
| CO1 | 2 | 2 | 1 | - |
| CO2 | 2 | 1 | 2 | - |
| CO3 | 2 | 2 | 1 | - |
| CO4 | 2 | 2 | 3 | - |
| CO5 | 2 | 1 | 2 | - |

**Mapping with Programme Educational Objectives:**

| | PEO1 | PEO2 | PEO3 |
|---|---|---|---|
| CO1 | 3 | 1 | 1 |
| CO2 | 2 | 1 | - |
| CO3 | 3 | 2 | 1 |
| CO4 | 2 | 2 | 1 |
| CO5 | 3 | 2 | 1 |

A. Sathiyasaravanan 21/8/21
**Faculty Signature**

21/8/21
**Head of the Department**

21/8/21
**Principal**

# KATHIR COLLEGE OF ENGINEERING

**COIMBATORE - 641 062**

**DEPARTMENT OF MECHANICAL ENGINEERING**

**Attendance Period: From 18.08.2021 to 13.09.2021**

**Branch : III-MECH Sem : 05** **Period No: 01**

**Subject Code & Name: ME8595 & THERMAL ENGINEERING – II**

| S. No. | Register Number | Student Name | Total Hours Taken | Total Hours Attended |
|---|---|---|---|---|
| 1 | 711619114001 | ASWIN V | 15 | 14 |
| 2 | 711619114002 | CHANDRU G | 15 | 14 |
| 3 | 711619114003 | ILAKKIYA D | 15 | 13 |
| 4 | 711619114004 | JEEVA P | 15 | 14 |
| 5 | 711619114007 | SANTHAKUMAR P | 15 | 15 |
| 6 | 711619114008 | SARAN R | 15 | 15 |
| 7 | 711619114009 | UTHAYAKUMAR N | 15 | 14 |
| 8 | 711619114010 | VASANTHA KUMAR M | 15 | 15 |
| 9 | 711619114011 | VISHNUVARTHAN S | 15 | 14 |
| 10 | 711619114301 | NIVEEN | 15 | 14 |
| 11 | 711619114302 | SEENIVASAN | 15 | 15 |
| 12 | 711619114701 | JAGATHESH | 15 | 11 |
| 13 | 711619114501 | SARAN SK | 15 | 12 |

A. [signature] 9/9/21
**Faculty In-Charge**

[signature] 9/9/21
**HoD**

[signature] 9/9/21
**Principal**

(9)

# Kathir College of Engineering

[Approved by AICTE | Affiliated to Anna University | Accredited by NAAC]

**Neelambur, Avinashi Road, Coimbatore-62**

## CONTINUOUS INTERNAL ASSESSMENT - I

| Branch | MECH | Sem. | V | Date | 04.10.21 | Duration | 90 min |
|---|---|---|---|---|---|---|---|
| Subject code & Name | | ME 8595- THERMAL ENGINEERING II | | | | Max. Marks | 50 |

| Course Outcomes: | | RBT |
|---|---|---|
| *CO1* | *To apply the thermodynamic concepts of nozzle and to learn its application.* | [CO] |
| *CO2* | *To utilize the boiler trial for effective performance calculation.* | [CO] |
| | *Understanding* | [U] |
| | *Applying* | [AP] |
| | *Analysis* | [AN] |

| | Part – A (07 x 02 = 14 Marks)<br>Answer All Questions | RBT | CO | Marks |
|---|---|---|---|---|
| 1 | Define coefficient of friction in nozzle. | U | 1 | 2 |
| 2 | Total enthalpy of stream at the inlet of a nozzle is 2800 kJ while static enthalpy at the exit is 2555 kJ. What is the steam velocity at the exit if expansion is isentropic? | AN | 1 | 2 |
| 3 | Define the term critical pressure ratio. | U | 1 | 2 |
| 4 | In a steam nozzle, inlet pressure of superheated steam is 10 bar. The exit pressure is decreased from 3 bar to 1 bar. The discharge rate will_______________ | AP | 1 | 2 |
| 5 | The subcritical steam generators operate between a pressure ranges of________ | U | 2 | 2 |
| 6 | What is the pressure range between which a marine steam generator works? | AP | 2 | 2 |
| 7 | What is supercritical boiler? | U | 2 | 2 |

| | Part – B (02 x 10 = 20 Marks)<br>Answer All Questions | RBT | CO | Marks |
|---|---|---|---|---|
| 8 (a) | Steam approaches a nozzle with velocity of 200 m/s, pressure of 4 bar and dryness fraction 0.98. If the isentropic expansion in the nozzle proceeds till the pressure of the exit is 1 bar, determine the change | AN | 1 | 10 |

| | | | | |
|---|---|---|---|---|
| | in enthalpy and dryness fraction of steam using mollier diagram. Also calculate the exit velocity of steam from nozzle and area of exit of the nozzle for flow of 0.8 kg/s. | | | |
| | **(OR)** | | | |
| 8 (b) | Dry air steam at 10 bar is expanded in a nozzle to 0.4 bar. The throat area is 7 cm2 and the inlet velocity negligible. Determine the mass flow and exit area. Assume isentropic flow and take the index n = 1.135 for dry saturated steam. | AN | 1 | 10 |
| 9 (a) | A coal fired boiler plant consumes 400 kg of coal per hour. The boiler evaporates 3,200 kg of water at 45°C into superheated steam at a pressure of 12 bar and 275°C. If the calorific value of fuel is 32,760 kJ/kg of coal, determine (i) equivalent evaporation from and at 100°C. (ii) Thermal efficiency of boiler. Specific heat of superheated steam is 2.1 kJ/kg.K. | AN | 2 | 10 |
| | **(OR)** | | | |
| 9 (b) | Describe the working of high pressure boiler with super heaters. | AP | 2 | 10 |

| | **Part – C (01 x 16 = 16 Marks)**<br>**(To be framed to test Higher Order Thinking skills)** | **RBT** | **CO** | **Marks** |
|---|---|---|---|---|
| 10 (a) | The inlet condition to a steam nozzle are 10 bar and 250°C, the exit pressure is 2 bar. Assuming isentropic expansion and negligible inlet velocity. Determine (i) throat area (ii) exit velocity and (iii) exit area of the nozzle. | AN | 1 | 16 |
| | **(OR)** | | | |
| 10 (b) | Dry saturated steam enters a steam nozzle at pressure of 12bar and is discharge to a pressure of 1.5bar. If the dryness fraction of a discharge steam is 0.95. What will be the final velocity of the steam? Neglecting initial velocity of steam. | AN | 1 | 16 |

**********************************************

A. S. S. 2/10/21
Faulty In-charge

2/10/21
HoD/mech

(11)

# KATHIR COLLEGE OF ENGINEERING

COIMBATORE - 641 062

DEPARTMENT OF MECHANICAL ENGINEERING

Attendance Period: From 14.09.2021 to 07.10.2021

**Branch** : III-MECH **Sem :** 05 **Period No:** 02

**Subject Code & Name:** ME8595 & THERMAL ENGINEERING – II

| S. No. | Register Number | Student Name | Total Hours Taken | Total Hours Attended | CIA - I Marks |
|---|---|---|---|---|---|
| 1 | 711619114001 | ASWIN V | 15 | 14 | 78 |
| 2 | 711619114002 | CHANDRU G | 15 | 15 | 88 |
| 3 | 711619114003 | ILAKKIYA D | 15 | 13 | 78 |
| 4 | 711619114004 | JEEVA P | 15 | 14 | 82 |
| 5 | 711619114007 | SANTHAKUMAR P | 15 | 14 | 88 |
| 6 | 711619114008 | SARAN R | 15 | 14 | 88 |
| 7 | 711619114009 | UTHAYAKUMAR N | 15 | 14 | 84 |
| 8 | 711619114010 | VASANTHA KUMAR M | 15 | 14 | 86 |
| 9 | 711619114011 | VISHNUVARTHAN S | 15 | 14 | 80 |
| 10 | 711619114301 | NIVEEN | 15 | 15 | 94 |
| 11 | 711619114302 | SEENIVASAN | 15 | 15 | 90 |
| 12 | 711619114701 | JAGATHESH | 15 | 13 | 80 |
| 13 | 711619114501 | SARAN SK | 15 | 13 | 78 |

A. Rathinasaravanan 8/10/21
Faculty In-Charge

8/10/21
HoD

8/10/21
Principal

# Kathir College of Engineering

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Neelambur, Avinashi Road, Coimbatore-62

## CONTINUOUS INTERNAL ASSESSMENT - II

| Branch | MECH | Sem. | V | Date | 29.10.21 | Duration | 90 min |
|---|---|---|---|---|---|---|---|
| Subject code & Name | | ME 8595- THERMAL ENGINEERING II | | | | Max. Marks | 50 |
| | | | | | | | |

| Course Outcomes: | | RBT |
|---|---|---|
| CO2 | *To utilize the boiler trial for effective performance calculation.* | [CO] |
| CO3 | *Explain the flow in steam turbines, draw velocity diagrams for steam turbines and solve problems.* | [CO] |
| | *Understanding* | [U] |
| | *Applying* | [AP] |
| | *Analysis* | [AN] |

| | Part – A (07 x 02 = 14 Marks)<br>Answer All Questions | RBT | CO | Marks |
|---|---|---|---|---|
| 1 | Define boiler efficiency | U | 2 | 2 |
| 2 | What is boiler inspection? | U | 2 | 2 |
| 3 | What is supercritical boiler? | U | 2 | 2 |
| 4 | Define the term compounding in turbines | U | 3 | 2 |
| 5 | What are the advantages and limitation of velocity compounded impulse turbine? | AP | 3 | 2 |
| 6 | What is the function of governor in steam turbine? | U | 3 | 2 |
| 7 | What is the principle of reaction turbine? | U | 3 | 2 |

| | Part – B (02 x 10 = 20 Marks)<br>Answer All Questions | RBT | CO | Marks |
|---|---|---|---|---|
| 8 (a) | A coal fired boiler plant consumes 400 kg of coal per hour. The boiler evaporates 3,200 kg of water at 45°C into superheated steam at a pressure of 12 bar and 275°C. If the calorific value of fuel is 32,760 kJ/kg of coal, determine (i) equivalent evaporation from and at 100oC (ii) Thermal efficiency of boiler. Specific heat of superheated steam is 2.1 kJ/kg.K. | AN | 2 | 10 |

| | | | | |
|---|---|---|---|---|
| (OR) | | | | |
| 8 (b) | Describe the working of high pressure boiler with super heaters. | AP | 2 | 10 |
| 9 (a) | The angles at inlet and discharge of the blading of a 50% reaction turbine are 20° and 35° respectively. The speed of rotation is 1600 rpm and at a particular stage, the mean ring diameter is 0.72 m and the steam condition is at 1.8 bar, 0.98 dry. Estimate the (a) required height of blading to pass 4.2 kg/s of steam and (b) power developed by the ring. | AN | 3 | 10 |
| (OR) | | | | |
| 9 (b) | Explain the pressure and velocity compounding diagram of an multi-stage turbines with sketch. | AP | 3 | 10 |

| Part – C (01 x 16 = 16 Marks) (To be framed to test Higher Order Thinking skills) | | RBT | CO | Marks |
|---|---|---|---|---|
| 10 (a) | The velocity of steam leaving the nozzle of an impulse turbine is 1000 m/s and the nozzle angle is 20°. The blade velocity is 350 m/s and the blade velocity of coefficient is 0.85. Assuming no losses due to shock at inlet calculate for a mass flow of 1.5 kg/s and symmetrical blading. Determine (i) Blade inlet angle Driving force on the wheel, (ii) Axial thrust in the wheel and (iii) Power developed by the turbine. | AN | 3 | 16 |
| (OR) | | | | |
| 10 (b) | In an impulse turbine, steam enters the wheel through a nozzle with a velocity of 350 m/s and an angle of 20° to the direction of motion of blade. The blade speed is 250 m/s and exit angle of moving blade is 35°. Find the inlet angle of moving blade, exit velocity of steam and its direction and work done per kg of steam. | AN | 3 | 16 |

************************************************

Prepared by,
A. Lalitha Saravanan 25/10/21
(Dr. A. LALITHA SARAVANAN)

Approved by,
25/10/21
(HOD-MECH)

(17)

# KATHIR COLLEGE OF ENGINEERING

COIMBATORE - 641 062

DEPARTMENT OF MECHANICAL ENGINEERING

Attendance Period: From 08.10.2021 to 05.11.2021

**Branch** : III-MECH **Sem : 05** **Period No: 03**

**Subject Code & Name: ME8595 & THERMAL ENGINEERING – II**

| S. No. | Register Number | Student Name | Total Hours Taken | Total Hours Attended | CIA - II Marks |
|---|---|---|---|---|---|
| 1 | 711619114001 | ASWIN V | 15 | 14 | 84 |
| 2 | 711619114002 | CHANDRU G | 15 | 14 | 86 |
| 3 | 711619114003 | ILAKKIYA D | 15 | 12 | 56 |
| 4 | 711619114004 | JEEVA P | 15 | 15 | 54 |
| 5 | 711619114007 | SANTHAKUMAR P | 15 | 14 | 60 |
| 6 | 711619114008 | SARAN R | 15 | 12 | 60 |
| 7 | 711619114009 | UTHAYAKUMAR N | 15 | 12 | 62 |
| 8 | 711619114010 | VASANTHA KUMAR M | 15 | 14 | 82 |
| 9 | 711619114011 | VISHNUVARTHAN S | 15 | 14 | 76 |
| 10 | 711619114301 | NIVEEN | 15 | 14 | 84 |
| 11 | 711619114302 | SEENIVASAN | 15 | 14 | 84 |
| 12 | 711619114701 | JAGATHESH | 15 | 12 | 60 |
| 13 | 711619114501 | SARAN SK | 15 | 12 | 62 |

A.N 6/11/21 Faculty In-Charge

6/11/21 HoD

Principal 6/11/21

21

# Kathir College of Engineering

[Approved by AICTE | Affiliated to Anna University | Accredited by NAAC]

Neelambur, Avinashi Road, Coimbatore-62

## CONTINUOUS INTERNAL ASSESSMENT - III

| Branch | MECH | Sem. | V | Date | 25.11.21&FN | Duration | 90 min |
|---|---|---|---|---|---|---|---|
| Subject code & Name | | ME 8595- THERMAL ENGINEERING II | | | | Max. Marks | 50 |
| | | | | | | | |

| Course Outcomes: | | RBT |
|---|---|---|
| CO4 | Summarize the concept of Cogeneration, Working features of Heat pumps and Heat exchangers | [CO] |
| CO5 | Solve problems using refrigerant table / charts and psychrometric charts | [CO] |
| | *Understanding* | [U] |
| | *Applying* | [AP] |
| | *Analysis* | [AN] |

| | Part – A (07 x 02 = 14 Marks)<br>Answer All Questions | RBT | CO | Marks |
|---|---|---|---|---|
| 1 | Define cogeneration. | U | 4 | 2 |
| 2 | Name the different methods to convert residual heat to power. | U | 4 | 2 |
| 3 | Define recuperator. | U | 4 | 2 |
| 4 | What is called regenerator? | U | 4 | 2 |
| 5 | Show the simple vapour compression cycle on pressure enthalpy diagram. | U | 5 | 2 |
| 6 | What is the effect of subcooling of the refrigerant on the performance of the vapour compression refrigeration system? | AP | 5 | 2 |
| 7 | List out the components in the vapour absorption refrigeration system. | U | 5 | 2 |

| | Part – B (02 x 10 = 20 Marks)<br>Answer All Questions | RBT | CO | Marks |
|---|---|---|---|---|
| 8 (a) | Explain working features of topping cycle cogeneration with its neat sketch. | AP | 4 | 10 |
| | **(OR)** | | | |

| | | | | |
|---|---|---|---|---|
| 8 (b) | Explain the working features of waste recovery boiler. | AP | 4 | 10 |
| 9 (a) | Draw a neat sketch of a simple vapour compression refrigeration system and explain its principle of operation. | AP | 5 | 10 |
| | **(OR)** | | | |
| 9 (b) | Explain with neat sketch practical Ammonia – water vapour absorbs refrigeration system. | AP | 5 | 10 |

| | **Part – C (01 x 16 = 16 Marks)** **(To be framed to test Higher Order Thinking skills)** | **RBT** | **CO** | **Marks** |
|---|---|---|---|---|
| 10 (a) | Describe bottoming cycle cogeneration with neat sketch. | AP | 4 | 16 |
| | **(OR)** | | | |
| 10 (b) | A vapour compression refrigerator uses methyl chloride (R-40) and operates between temperature limits of -10° C and 45° C. At entry to the compressor the refrigerant is dry saturated and after compression it acquires a temperature of 60° C. Find the C.O.P. of the refrigerator. The relevant properties of methyl chloride are as follows: | AN | 5 | 16 |

| *Saturation Temperature in °C* | *Enthalpy in kJ/kg* | | *Entropy in kJ/kg K* | |
|---|---|---|---|---|
| | *Liquid* | *Vapour* | *Liquid* | *Vapour* |
| *-10* | *45.4* | *460.7* | *0.183* | *1.637* |
| *45* | *133.0* | *483.6* | *0.485* | *1.587* |

Prepared by

A. Lalitha Saravanan 23/11/21

(Dr. A.Lalitha Saravanan)

Approved by

23/11/21

(HOD-MECH)

***********************************************

(23)

# KATHIR COLLEGE OF ENGINEERING

COIMBATORE - 641 062
DEPARTMENT OF MECHANICAL ENGINEERING

Attendance Period: From 06.11.2021 to 30.11.2021

**Branch** : III-MECH **Sem : 05** **Period No: 04**

**Subject Code & Name: ME8595 & THERMAL ENGINEERING – II**

| S. No. | Register Number | Student Name | Total Hours Taken | Total Hours Attended | CIA - III Marks |
|---|---|---|---|---|---|
| 1 | 711619114001 | ASWIN V | 15 | 15 | 90 |
| 2 | 711619114002 | CHANDRU G | 15 | 15 | 88 |
| 3 | 711619114003 | ILAKKIYA D | 15 | 14 | 80 |
| 4 | 711619114004 | JEEVA P | 15 | 15 | 80 |
| 5 | 711619114007 | SANTHAKUMAR P | 15 | 15 | 80 |
| 6 | 711619114008 | SARAN R | 15 | 14 | 80 |
| 7 | 711619114009 | UTHAYAKUMAR N | 15 | 15 | 80 |
| 8 | 711619114010 | VASANTHA KUMAR M | 15 | 15 | 88 |
| 9 | 711619114011 | VISHNUVARTHAN S | 15 | 14 | 80 |
| 10 | 711619114301 | NIVEEN | 15 | 15 | 84 |
| 11 | 711619114302 | SEENIVASAN | 15 | 15 | 90 |
| 12 | 711619114701 | JAGATHESH | 15 | 14 | 78 |
| 13 | 711619114501 | SARAN SK | 15 | 14 | 78 |

A. Parthasaravanan 1/12/21
Faculty In-Charge

1/12/21
HoD

Principal 1/12/21

(28)

# KATHIR COLLEGE OF ENGINEERING

COIMBATORE - 641 062

DEPARTMENT OF MECHANICAL ENGINEERING

Attendance Period: From 18.08.2021 to 30.11.2021

**Branch** : III-MECH **Sem** : 05

**Subject Code & Name:** ME8595 & THERMAL ENGINEERING – II

| S. No. | Register Number | Student Name | Total Hours Taken | Total Hours Attended | Attendance Percentage |
|---|---|---|---|---|---|
| 1 | 711619114001 | ASWIN V | 60 | 57 | 95.00% |
| 2 | 711619114002 | CHANDRU G | 60 | 58 | 96.67% |
| 3 | 711619114003 | ILAKKIYA D | 60 | 52 | 86.67% |
| 4 | 711619114004 | JEEVA P | 60 | 58 | 96.67% |
| 5 | 711619114007 | SANTHAKUMAR P | 60 | 58 | 96.67% |
| 6 | 711619114008 | SARAN R | 60 | 55 | 91.67% |
| 7 | 711619114009 | UTHAYAKUMAR N | 60 | 55 | 91.67% |
| 8 | 711619114010 | VASANTHA KUMAR M | 60 | 58 | 96.67% |
| 9 | 711619114011 | VISHNUVARTHAN S | 60 | 56 | 93.33% |
| 10 | 711619114301 | NIVEEN | 60 | 58 | 96.67% |
| 11 | 711619114302 | SEENIVASAN | 60 | 59 | 98.33% |
| 12 | 711619114701 | JAGATHESH | 60 | 50 | 83.33% |
| 13 | 711619114501 | SARAN SK | 60 | 51 | 85.00% |

A. Parthasarathy 1/12/21 Faculty In-Charge

1/12/21 HoD

Principal 1/12/21

| | Reg. No. | Name of the student | Month & Year | 8/21 | 8/21 | 8/21 | 8/21 | 8/21 | 8/21 | 8/21 | 8/21 | 9/21 | 9/21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Date | 23 | 23 | 26 | 26 | 28 | 28 | 30 | 30 | 2 | 2 |
| | | | Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 711619114001 | ASWIN V | | / | / | / | / | / | a | / | / | / | / |
| 2 | 711619114002 | CHANDRU. G | | / | / | / | a | / | / | / | / | / | / |
| 3 | 711619114003 | ILAKKIYA. D | | / | / | / | / | / | a | / | / | / | a |
| 4 | 711619114007 | JEEVA. P | | / | / | / | a | / | / | / | / | / | / |
| 5 | 711619114007 | SANTHAKUMAR. P | | / | / | / | / | / | / | / | / | / | / |
| 6 | 711619114008 | SARAN . R | | / | / | / | / | / | / | / | / | / | / |
| 7 | 711619114009 | UTHAYAKUMAR. N | | / | / | / | / | / | / | / | / | / | / |
| 8 | 711619114010 | VASANTHA KUMAR. M | | / | / | a | / | / | / | / | / | / | / |
| 9 | 711619114011 | VISHNUVARTHAN. S | | / | a | / | / | / | / | / | / | / | / |
| 10 | 711619114[illegible] | NIVEEN | | / | / | / | / | / | / | / | / | / | / |
| 11 | 711619114302 | SEENIVASAN | | / | / | / | / | / | / | / | / | / | / |
| 12 | 711619114701 | JAGATHESH | | a | a | / | / | / | / | / | / | a | / |
| 13 | 711619114501 | SARAN . S.K. | | a | a | / | / | / | / | / | / | / | / |
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| 36 | | | | | | | | | | | | | |
| | | Total No. of Students Present | | 11 | 10 | 12 | 11 | 13 | 11 | 13 | 13 | 12 | 12 |
| | | Number of Students Absent | | 2 | 3 | 1 | 2 | - | 2 | - | - | 1 | 1 |
| | | Signature of the Faculty | | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] |

| | 9/21 | 9/21 | 9/21 | 9/21 | 9/21 | 9/21 | 9/21 | 9/21 | 9/21 | 9/21 |
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| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
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| 11 | / | / | / | / | / | / | / | / | / | / |
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| 13 | a | / | / | / | / | / | a | / | / | / |
| Present | 12 | 13 | 12 | 13 | 12 | 13 | 12 | 12 | 11 | 13 |
| Absent | 1 | - | 1 | - | 1 | - | 1 | 1 | 2 | - |
| Signature | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] | [signature] |

[signature] 16/9/21

| | | CIA III | | Attendance (Total No. of Periods: ) | | CIA Marks | |
|---|---|---|---|---|---|---|---|
| | 00 | 50 | 100 | Period Attended | Percentage | 300 | 20 |
| | | | | 60 | % | | |
| 1 | 84 | 14 | 90 | 57 | 95 | 252 | 17 |
| 2 | 86 | 14 | 88 | 58 | 97 | 252 | 17 |
| 3 | 56 | 12 | 80 | 52 | 87 | 214 | 14 |
| 4 | 4 | 15 | 80 | 58 | 97 | 216 | 14 |
| 5 | 60 | 14 | 80 | 58 | 97 | 228 | 16 |
| 6 | 60 | 12 | 80 | 55 | 92 | 228 | 15 |
| 7 | 62 | 12 | 80 | 55 | 92 | 226 | 15 |
| 8 | 82 | 14 | 88 | 58 | 97 | 226 | 17 |
| 9 | 76 | 14 | 80 | 56 | 93 | 236 | 16 |
| 10 | 84 | 14 | 84 | 58 | 97 | 262 | 17 |
| 11 | 84 | 14 | 90 | 59 | 98 | 264 | 18 |
| 12 | 60 | 12 | 78 | 50 | 83 | 218 | 15 |
| 13 | 62 | 12 | 78 | 51 | 85 | 218 | 15 |

[signature] 1/12/21

| Assignment | CIA I | | CIA II | | CIA III | | Attendance (Total No. of Periods: ) | | CIA Marks | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ~~50~~ 15 | 100 | ~~50~~ 15 | 100 | ~~50~~ → | 100 | Period Attended | Percentage | 300 | 20 | |
| | | | | | | | 60 | % | | | |
| | 14 | 78 | 14 | 84 | 14 | 90 | 57 | 95 | 252 | 17 | 1 |
| | 14 | 88 | 15 | 86 | 14 | 88 | 58 | 97 | 252 | 17 | 2 |
| | 13 | 78 | 13 | 56 | 12 | 80 | 52 | 87 | 214 | 14 | 3 |
| | 14 | 82 | 14 | 54 | 15 | 80 | 58 | 97 | 216 | 14 | 4 |
| | 15 | 88 | 14 | 60 | 14 | 80 | 58 | 97 | 228 | 16 | 5 |
| | 15 | 88 | 14 | 60 | 12 | 80 | 55 | 92 | 228 | 15 | 6 |
| | 14 | 84 | 14 | 62 | 12 | 80 | 55 | 92 | 226 | 15 | 7 |
| | 15 | 86 | 14 | 82 | 14 | 88 | 58 | 97 | 226 | 17 | 8 |
| | 14 | 80 | 14 | 76 | 14 | 80 | 56 | 93 | 236 | 16 | 9 |
| | 14 | 94 | 15 | 84 | 14 | 84 | 58 | 97 | 262 | 17 | 10 |
| | 15 | 90 | 15 | 84 | 14 | 90 | 59 | 98 | 264 | 18 | 11 |
| | 11 | 80 | 13 | 60 | 12 | 78 | 50 | 83 | 218 | 15 | 12 |
| | 12 | 78 | 13 | 62 | 12 | 78 | 51 | 85 | 218 | 15 | 13 |
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1/12/21

## Lecture Plan

| S. No. | Proposed Date | Proposed Period | Topics Covered | Actual Date | Actual Period | COs | Teaching Aids | Book Referred | Initial |
|---|---|---|---|---|---|---|---|---|---|
| | | | Unit – I Steam nozzle | | | | | | |
| 1. | 23-8-21 | 3 | Introduction to nozzles | 23-8-21 | 3 | 1 | ICT | T1, R2 | [illegible] |
| 2. | 23-8-21 | 4 | Types and shapes of nozzles | 23-8-21 | 4 | 1 | ICT | T1, T2 | [illegible] |
| 3. | 26-8-21 | 3 | Flow of steam through nozzles | 26-8-21 | 3 | 1 | ICT | T1, W1 | [illegible] |
| 4 | 26-8-21 | 4 | Critical pressure ratio | 26-8-21 | 4 | 1 | ICT | T1, T2 | [illegible] |
| 5 | 30-8-21 | 3 | variation of mass flow rate with pressure ratio | 30-8-21 | 3 | 1 | ICT | T1, T2 | [illegible] |
| 6 | 30-8-21 | 4 | Effect of friction | 30-8-21 | 4 | 1 | ICT | T1 | [illegible] |
| 7 | 2-9-21 | 3 | Metastable flow | 2-9-21 | 3 | 1 | ICT | T1, T2 | [illegible] |
| 8 | 2-9-21 | 4 | Problem on nozzles | 2-9-21 | 4 | 1 | ICT | T1 | [illegible] |
| 9 | 6-9-21 | 3 | Problem on nozzles | 6-9-21 | 3 | 1 | ICT | T1, W1 | [illegible] |
| | | | [signature] 6/9/21 | | | | | | |

| S. No. | Proposed Date | Proposed Period | Topics Covered | Actual Date | Actual Period | COs | Teaching Aids | Book Referred | Initial |
|---|---|---|---|---|---|---|---|---|---|
| | | | Unit – II Boilers | 6-9-21 | 4 | 2 | ICT | T1, T2 | [illegible] |
| 1. | 6-9-21 | 4 | Introduction to Boiler | 9-9-21 | 3 | 2 | ICT | T1, R2 | [illegible] |
| 2 | 9-9-21 | 3 | Types of Boilers | 9-9-21 | 4 | 2 | ICT | T1, R2 | [illegible] |
| 3 | 9-9-21 | 4 | Types of Boilers | 13-9-21 | 3 | 2 | ICT | T1, R2 | [illegible] |
| 4 | 13-9-21 | 3 | Comparison of Boilers | 13-9-21 | 4 | 2 | ICT | T1, T2 | [illegible] |
| 5 | 13-9-21 | 4 | Mountings and Accessories | 16-9-21 | 3 | 2 | ICT | T1, T2 | [illegible] |
| 6 | 16-9-21 | 3 | Fuels – Solid, Liquid and Gas | 16-9-21 | 4 | 2 | ICT | T1, T2 | [illegible] |
| 7 | 16-9-21 | 4 | Performance calculations | 20-9-21 | 3 | 2 | ICT | T1, T2 | [illegible] |
| 8 | 20-9-21 | 3 | Boiler trial | 20-9-21 | 4 | 2 | ICT | T1, T2 | [illegible] |
| 9 | 20-9-21 | 4 | problem on Boiler. | | | | | | |
| 10 | | | [signature] 20/9/21 | | | | | | |

# Lecture Plan

| S. No. | Proposed Date | Proposed Period | Topics Covered | Actual Date | Actual Period | COs | Teaching Aids | Book Referred | Initial |
|---|---|---|---|---|---|---|---|---|---|
| | | | Unit-III: Steam turbines. | | | | | | |
| 1. | 23-9-21 | 3 | Types of turbines | 23-9-21 | 3 | 3 | ICT | $T_1, T_2$ | [illegible] |
| 2. | 23-9-21 | 4 | Impulse and reaction principles | 23-9-21 | 4 | 3 | ICT | $T_1, T_2$ | [illegible] |
| 3. | 27-9-21 | 3 | velocity diagrams | 27-9-21 | 3 | 3 | ICT | $T_1, T_2$ | [illegible] |
| 4. | 27-9-21 | 4 | work done and efficiency | 27-9-21 | 4 | 3 | ICT | $T_1, T_2$ | [illegible] |
| 5 | 30-9-21 | 3 | Optimal operating Conditions | 30-9-21 | 3 | 3 | ICT | $T_1, T_2$ | [illegible] |
| 6 | 30-9-21 | 4 | Multi staging | 30-9-21 | 4 | 3 | ICT | $T_1, T_2$ | [illegible] |
| 7 | 4-10-21 | 3 | compounding and governing | 4-10-21 | 3 | 3 | ICT | $T_1, T_2$ | [illegible] |
| 8 | 4-10-21 | 4 | problems on Turbines | 4-10-21 | 4 | 3 | ICT | $T_1, T_2$ | [illegible] |
| 9. | 7-10-21 | 3 | Problems on Turbines | 7-10-21 | 3 | 3 | ICT | $T_1, T_2$ | [illegible] |
| | | | [signature] 7/10/21 | | | | | | |

| S. No. | Proposed Date | Proposed Period | Topics Covered | Actual Date | Actual Period | COs | Teaching Aids | Book Referred | Initial |
|---|---|---|---|---|---|---|---|---|---|
| | | | Unit-IV: Cogeneration and Residual heat recovery | | | | | | |
| 1 | 7-10-21 | 4 | Cogeneration principles | 7-10-21 | 4 | 4 | ICT | $R_3, R_4$ | [illegible] |
| 2 | 11-10-21 | 3 | Cycle Analysis | 11-10-21 | 3 | 4 | ICT | $R_3, R_4$ | [illegible] |
| 3 | 11-10-21 | 4 | Applications | 11-10-21 | 4 | 4 | ICT | $R_3, R_4$ | [illegible] |
| 4 | 18-10-21 | 3 | Source and utilisation of Residual gases | 18-10-21 | 3 | 4 | ICT | $R_3, R_4$ | [illegible] |
| 5 | 18-10-21 | 4 | Heat pipes | 18-10-21 | 4 | 4 | ICT | $R_3, R_4$ | [illegible] |
| 6 | 21-10-21 | 3 | Heat pumps | 21-10-21 | 3 | 4 | ICT | $R_4, R_5$ | [illegible] |
| 7 | 21-10-21 | 4 | Recuperative and Regenerative heat exchangers | 21-10-21 | 4 | 4 | ICT | $R_4, R_5$ | [illegible] |
| 8 | 25-10-21 | 3 | Problems on heat exchangers | 25-10-21 | 3 | 4 | ICT | $R_4, R_5$ | [illegible] |
| 9 | 25-10-21 | 4 | Economic Aspects. | 25-10-21 | 4 | 4 | ICT | $R_4, R_5$ | |
| | | | [signature] 25/10/21 | | | | | | |

## Lecture Plan

| S. No. | Proposed Date | Proposed Period | Topics Covered | Actual Date | Actual Period | COs | Teaching Aids | Book Referred | Initial |
|---|---|---|---|---|---|---|---|---|---|
| | | | Unit - V Refrigeration & Air conditioning | | | | | | |
| 1 | 28-10-21 | 3 | Vapour Compression refrigeration cycle | 28-10-21 | 3 | 5 | ICT | R1, R2 | [illegible] |
| 2 | 28-10-21 | 4 | Effect of Superheat and Subcooling | 28-10-21 | 4 | 5 | ICT | R1, R2 | [illegible] |
| 3 | 1-11-21 | 3 | Performance Calculations | 1-11-21 | 3 | 5 | ICT | R1, R2 | [illegible] |
| 4 | 1-11-21 | 4 | Working principle of air cycle | 1-11-21 | 4 | 5 | ICT | R1, R2 | [illegible] |
| 5 | 8-11-21 | 3 | Vapour absorption system | 8-11-21 | 3 | 5 | ICT | R1, R2 | [illegible] |
| 6 | 8-11-21 | 4 | Thermoelectric refrigeration | 8-11-21 | 4 | 5 | ICT | R1, R2 | [illegible] |
| 7 | 11-11-21 | 3 | Air conditioning systems, concept of RSHF, GSHF and ESHF | 11-11-21 | 3 | 5 | ICT | R1, R2 | [illegible] |
| 8 | 11-11-21 | 4 | Cooling load calculations | 11-11-21 | 4 | 5 | ICT | R1, W1 | [illegible] |
| 9 | 15-11-21 | 3 | Cooling towers – concepts and Types | 15-11-21 | 3 | 5 | ICT | R1, W1 | [illegible] |

[signature] 15/11/21.

| S. No. | Proposed Date | Proposed Period | Topics Covered | Actual Date | Actual Period | COs | Teaching Aids | Book Referred | Initial |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

| C/A | | Portion Covered (Cumulative) | | Deviation (If any) | Period Taken (Cumulative) | | Deviation (If any) | Signature | |
|---|---|---|---|---|---|---|---|---|---|
| Test | Date | Planned | Actual | | Planned | Actual | | Faculty | HOD |
| 1 | 4/10/21 | 1.5 units | 1.7 units | Nil | 23/8/21 to 30/9/21 | 23/8/21 to 30/9/21 | NIL | [illegible] | [illegible] |
| 2 | 29/10/21 | 3 units | 3.5 units | Nil | 6/10/21 to 25/10/21 | 6/10/21 to 25/10/21 | NIL | [illegible] | [illegible] |
| 3 | 25/11/21 | 5 units | 5 units | Nil | 29/10/21 to 20/11/21 | 29/10/21 to 20/11/21 | NIL | [illegible] | [illegible] |

Reg. No. : [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ]

# Question Paper Code : 40836

B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2021.

Fifth/Seventh Semester

Mechanical Engineering

ME 8595 — THERMAL ENGINEERING — II

[Common to Mechanical Engineering (Sandwich)]

(Regulations 2017)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is the function of divergent nozzle?

2. What are the major effects of friction in nozzle?

3. What are the disadvantages of solid fuels?

4. What is the significance of factor of evaporation in boilers?

5. How does pressure and velocity change as the flow proceeds though the runner of the impulse turbine?

6. What is meant by diagram efficiency?

7. List the benefits of waste heat recovery.

8. Differentiate a recuperative heat exchanger from a regenerative heat exchanger.

9. What is the basic working principle of vapour compression refrigeration cycle?

10. What is GSHF?

PART B — (5 × 13 = 65 marks)

11. (a) (i) Explain various types of nozzles. (5)

(ii) Describe the flow of steam through nozzles and hence deduce the expression for a critical pressure ratio. (8)

Or

(b) (i) Explain the supersaturated flow in nozzles and their effects. (5)

(ii) A convergent-divergent nozzle is required to discharge 350 kg of steam per hour. The nozzle is supplied with steam at 8.5 bar and 90% dry and discharges against a back pressure of 0.4 bar. Neglecting the effect of friction, find the throat and exit diameters. (8)

12. (a) (i) Briefly explain the working of a water-tube boiler and list their merits and demerits. (5)

(ii) Compare the boiler mountings with accessories and give one examples for each. (4+4)

Or

(b) The following data was obtained in a steam boiler trial :

Feed water supplied per hour 690 kg at 28°C, steam produced 0.97 dry at 8 bar, coal fired per hour 91 kg of calorific value 27,200 kJ/kg, ash and unburnt coal collected from beneath the fire bars 75 kg/hour of calorific value 2760 kJ/kg, mass of flue gases per kg of coal burnt 173 kg, temperature of flue gases 325°C, room temperature 17°C, and the specific heat of the flue gases 1026 kJ/kg K.

Estimate the boiler efficiency, the percentage heat carried away by the flue gases, the percentage heat loss in ashes, and the percentage heat loss unaccounted for.

13. (a) (i) Mention the differences between Impulse and Reaction Turbines. (5)

(ii) Derive the value of blade speed ratio for maximum efficiency of impulse turbine. (8)

Or

(b) Describe the various methods of compounding with suitable diagrams. (13)

14. (a) (i) Explain the various sources of waste heat and their quality. (5)

(ii) Explain the advantages and disadvantages of various co-generation systems. (8)

Or

(b) (i) Explain the functioning of heat pipes. (5)

(ii) Describe the working of Fixed Bed Regenerators and Rotary Bed Regenerators. (8)

15. (a) A cold storage plant is required to store 20 tonnes of fish. The fish is supplied at a temperature of 30°C. The specific heat of fish above freezing point is 2.93 kJ/kg K. The specific heat of fish below freezing point is 1.26 kJ/kg K. The fish is stored in colds storage which is maintained at –8°C. The freezing point of fish is –4°C. The latent heat of fish is 235 kJ/kg. If the plant requires 75 kW to drive it.

Assume actual C.O.P. of the plant as 0.3 of the Carnot C.O.P.

(i) Find the capacity of the plant. (5)

(ii) Calculate the time taken to achieve cooling. (8)

Or

(b) (i) Explain the working of Thermoelectric cooling with its merits and demerits. (5)

(ii) List different parts of a cooling tower and their function and hence explain the working of natural and forced draught cooling towers. (8)

PART C — (1 × 15 = 15 marks)

16. (a) Consider a Parson's stage with a rotor (at mid-height of blades) diameter of 1.2 m, operating at a speed of 3000 rpm, with the steam entry angle of steam be 20°.

Steam enters the stator at 12 bar, 300°C and an isentropic enthalpy drop of 50 kJ/kg is chosen per row of blades. The isentropic efficiency of each row is assumed as 0.84.

(i) Plot the process of expansion in the turbine on the h-s diagram and find the pressure at the exit of stator and rotor. (8)

(ii) Draw the combined velocity triangles and label all the components of the velocity and find the specific work delivered. (7)

Or

(b) The following are the Cogeneration Gas turbine Parameters :

Capacity of gas turbine generator: 4000 kW

Plant operating hours per annum 8000 hrs.

Plant load factor : 90%

Heat rate as per standard given by gas.turbine supplier : 3049.77 kCal / kWh

Waste heat boiler parameters — unfired steam output: 10 TPH

Steam temperature :200°C

Steam pressure :8.5 kg /cm$^2$.

Steam enthalpy :676.44 kCal / kg.

Fuel used : Natural gas

Calorific value — LCV :9500 kCal/ 5m$^3$

Price of gas : Rs. 3000/1000 Sm$^3$

Capital investment for total co-generation plant : Rs. 1300 Lakhs

Plant Load Factor (PLF) : 90%

Estimate the cost of fuel per annum and cost of power per kWh.(15)

Take 1 kCal = 4.2 kJ.

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# Kathir College of Engineering

[Approved by AICTE | Affiliated to Anna University | Accredited by NAAC]
Wisdom Tree, Neelambur, Avinashi Road, Coimbatore-62

## QUESTION PAPER FEEDBACK FORM

1. Course Code & Name : ME 8595 & Thermal Engineering-II
2. Class/Semester : III Yr / V Sem
3. Date of Examination : 07-02-22 / AN
4. Name of the staff and Department : Dr. A. LALITHA SARAVANAN / Mechanical

| | | |
|---|---|---|
| 1. | Nature of Questions (Tick the appropriate one) | Easy ✓ / ~~Moderate~~ / ~~Difficult~~ |
| 2. | Does the question paper cover all 5 units? | Yes ✓ / ~~No~~ |
| 3. | Are all units given proper weightage of marks? | Yes ✓ / ~~No~~ |
| 4. | Is moderation required? | ~~Yes~~/No ✓ |
| 5. | Is there any missing data in the question paper? | ~~Yes~~/No ✓ |
| 6. | If yes mention the question number(s) | Nil |
| 7. | Expected pass percentage | 13/13 = 100%. |

Remarks:

Nil

A. Lalitha Saravanan 8/2/22
Signature of the faculty

Signature of the HoD

Principal

Survey Questionnaire- ME8595-Thermal Engineering-II

Name of the student : (optional)
Register Number : (optional)
Course Code & Name : ME8595-Thermal Engineering-II
Semester : 05
Name of the faculty handled : Dr. A.Lalitha saravanan

1. Can you able to understand the basic concept of Thermal Engineering –II?

☐ Yes, definitely ☐ Yes, doubtful ☐ No, doubtful ☐ No, definitely

2. Can you able to design nozzle and components?

☐ Exemplary ☐ Very Good ☐ Good ☐ Moderate

3. Can you able to understand the function of nozzle in power plant?

☐ Yes, definitely ☐ Yes, doubtful ☐ No, doubtful ☐ No, definitely

4.Can you able to understand and classify differentiate various types of boilers?

☐ Yes, definitely ☐ Yes, doubtful ☐ No, doubtful ☐ No, definitely

5. Rate your capability in designing and capacity of boiler

☐ Exemplary ☐ Very Good ☐ Good ☐ Moderate

6. Whether faculty uses Teaching aids like LCD, Animated videos, Models, etc?

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree

7. The evaluation method used in this course were fair and appropriate

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree

8. There was close agreement between the course outcome and what was actually covered

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree

9. The learning of the course has educated me to solve socio-economic issue related to mechanical engineering

☐ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree

10. What Changes can be made to improve the course content?

Survey Questionnaire- ME8595-Thermal Engineering-II

Name of the student : (optional)
Register Number : (optional)
Course Code & Name : ME8595-Thermal Engineering-II
Semester : 05
Name of the faculty handled : Dr. A.Lalitha saravanan

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☐ Strongly agree ☑ Agree ☐ Neutral ☐ Disagree

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9. The learning of the course has educated me to solve socio-economic issue related to mechanical engineering

☑ Strongly agree ☐ Agree ☐ Neutral ☐ Disagree

10. What Changes can be made to improve the course content?

More Practical video.

ME 8595 Thermal Engineering-II

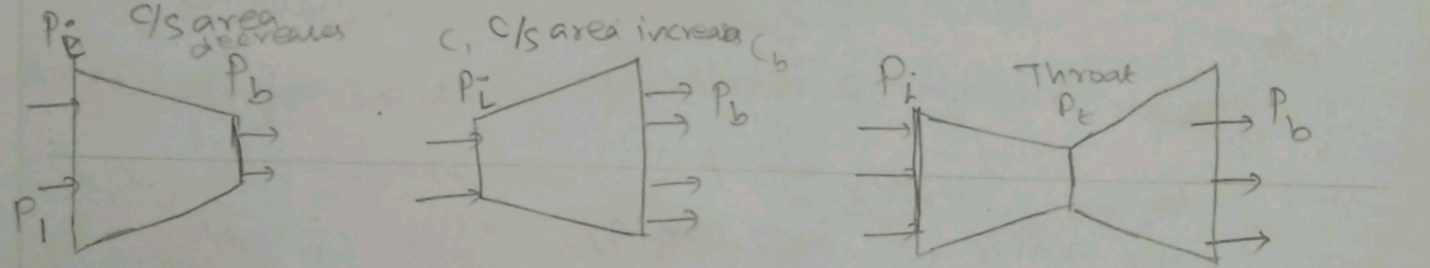
## Unit-I Steam Nozzle:-

Types and shapes of nozzles, Flow of steam through nozzles, critical pressure ratio, variation of mass flow rate with pressure ratio. Effect of friction. Metastable flow.

### Nozzle:-

Nozzle is a duct of varying cross sectional area in which the velocity increases with a drop of pressure. It main function is to produce a jet of steam with high velocity.

(e.g):- Nozzles are used in steam turbines, Jet engines etc.




$P_b < P_i$ ; $C_b > C_1$

$P_b$ - back pressure

Convergent nozzle.

Divergent nozzle

Convergent Divergent nozzle

$P_i < P_b$

Critical pressure : $P_c = \frac{P_i}{P_b}$ is only one value at which max discharge occurs.

### Types of nozzles:-

1. Convergent nozzle
2. Divergent nozzle.
3. Convergent - Divergent nozzle.

(2) Convergent nozzle:-

when the cross section of a nozzle decreases continously from entrance to exit, it is called a convergent nozzle.

Divergent nozzle:-

when the cross section of a nozzle increases continously from entrance to exit, It is called a divergent nozzle.

Convergent - Divergent nozzle:-

when the cross section of a nozzle first decreases from its entrance to throat, and then increases from its throat to exit, it is called a convergent-divergent nozzle.

This type widly used in steam turbines.

Continuity & Steady flow energy equations (SFEE)

Through a certain section of the nozzle,

$$m = \rho A C \quad \text{--- (1)} \qquad \frac{kg}{m^3} \times m^2 \times \frac{m}{s}$$

m - mass flow rate (Kg/s)

$\rho$ - Density (kg/m³)

A - Area (cross sectional) (m²)

C - velocity (m/s)

For nozzle, SFEE,

principle of conservation of energy states,

$$H_1 + V_1^2/2 + gz_1 + q = H_2 + \frac{V_2^2}{2} + gz_2 + W \quad \text{--- (2)}$$

For nozzle, change in P.E = 0 [$\because z_1 = z_2$]

$W = 0$; $q \simeq 0$.

$$\therefore (2) \Rightarrow \quad H_1 + \frac{V_1^2}{2} = H_2 + \frac{V_2^2}{2} \quad \text{--- (3)}$$

## Flow through nozzles:-

*) The steam enters the nozzle with a high pressure, but with a negligible velocity in the converging portion (i.e., from inlet to the throat), there is a drop in the steam pressure with a rise in its velocity.

*) There is also a drop in the enthalpy or total heat of the steam.

*) This drop of heat is not utlized in doing some external work, but is converted into kinetic energy.

*) In the divergent portion (i.e. from the throat to outlet), there is further drop of steam pressure with a further rise in its velocity.

*) Again, there is a drop in the enthalpy or total heat of steam, which is converted into kinetic energy.

*) It will be intresting to know that the steam enters the nozzle with a high pressure and negligible velocity.

*) But leaves the nozzle with a high velocity and small pressure.

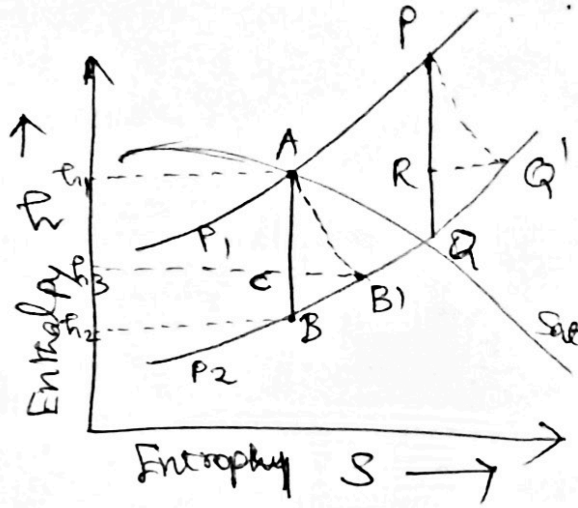
2mark (*) => *) The pressure, at which the steam leaves the nozzle, is known as Backpressure. ($P_b$).

*) moreover, no heat is supplied or rejected by the steam during flow through a nozzle.

*) Therefore, it is considered as isentropic flow, and the corresponding expansion is considered as an isentropic expansion.

## Friction in a nozzle:-

As a matter fact, when the steam flows through a nozzle, some loss in its enthalpy or total heat takes place due to friction between the nozzle surface and the flowing steam.




Mollier chart (h-s)

This can be easily understood with the help of h-s diagram or Mollier Chart

*) First of all, locate the point A for initial conditions of the steam, It is a point where the Saturation line meets the initial pressure ($P_1$) line.

*) Now draw vertical line through A to meet the final pressure ($P_2$) line. This is done as the flow through the nozzle is isentropic, which is expressed by a vertical line AB. The heat drop ($h_1 - h_2$) is known as Isentropic heat drop.

*) Due to friction in the nozzle the actual heat drop in the steam will be less than ($h_1 - h_2$). Let this heat drop be shown as AC instead of AB.

*) As the expansion of steam ends at the pressure P, therefore final condition of steam is obtained by drawing a horizontal line through C to meet the final pressure ($P_2$) line at B'.

* Now for actual expansion of steam in the nozzle is expressed by the curve AB' (adiabatic expansion) instead of ABC (Isentropic expansion). The actual heat drop ($h_1 - h_3$) is known as useful heat drop.

## Nozzle efficiency:

Now, the coefficient of nozzle or nozzle efficiency (usually denoted by K) is defined as the ratio of useful heat drop to the isentropic heat drop.

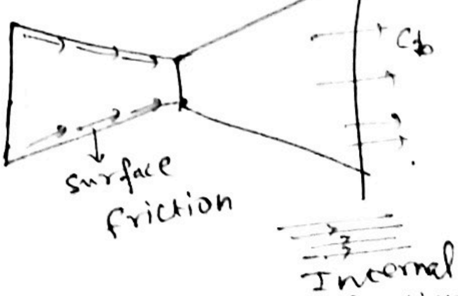
$$K = \frac{\text{useful heat drop}}{\text{Isentropic heat drop}} = \frac{AC}{AB} = \frac{h_1 - h_3}{h_1 - h_2}$$

## ~~Pressure~~ Various friction losses:

Various friction losses occur while steam flowing through nozzle.

When the steam flow through nozzle, the final velocity of steam for a given pressure is dropped due to:

1. To friction between the nozzle surface & steam.
2. to Internal fluid friction in the steam
3. To shock losses.

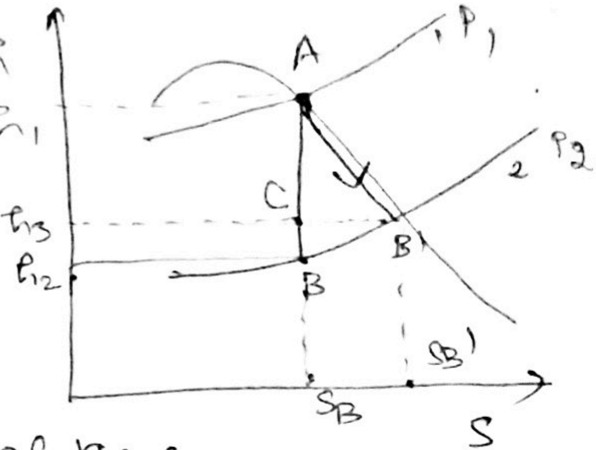



backpressure drop means shock will create.

(6) (8)

Effects of frictional Losses :-

1. The expansion is no more isentropic & enthalpy drop is reduced - so lesser the final velocity




2. The dryness fraction of the steam is ~~red~~ increased as the part of kinetic energy gets converted into heat due to friction & absorbed by steam with the increase in enthalpy.

3. The specific volume of steam increased due to frictional reheating.

4. It reduces efficiency of nozzle (if friction is 15%, then $\eta_{nozzle} \rightarrow 85\%$)

[∵ Irreversible processes, Entropy Increased]. $S_B' > S_B$, $h_3 > h_2$

5. Increases the enthalpy.

Super saturated flow or Metastable flow :-

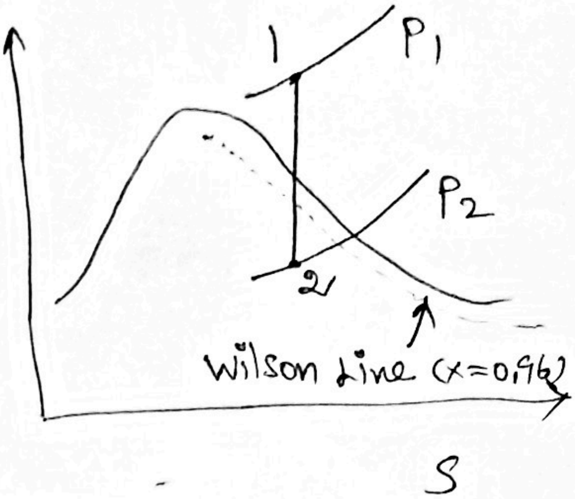
*) As steam expands in the nozzle, the pressure and temperature drop, and it is expected that the steam start condensing when it strikes the saturation line.

*) But this is not always the case owing to the high velocities, the residence time of the steam in the nozzle is small, and there may not sufficient time for the necessary heat transfer and the formation of liquid droplets.

*) Consequently, the condensation of steam is delayed for a little while, This phenomenon is known as supersaturation, and the steam that exists in the wet region without containing any liquid

is known as supersaturated steam.

*) The locus of points where condensation will take place regardless of the initial temperature and pressure at the nozzle entrance is called wilson line.




*) The wilson line lies between 4 and 5 percent moisture curves in the saturation region on the h-s diagram for steam, and is often approximately by the 4% moisture line.

*) The supersaturation phenomenon is shown on the h-s chart.

Effects of supersaturation:-

(i) The temperature at which the supersaturation occurs will be less than the saturation temperature corresponding to that pressure. Therefore, the density of supersaturated steam will be more than that of equilibrium condition which gives the increase in the mass of steam discharged.

(ii) Supersaturation increases the specific volume and entropy of the steam

(iii) Supersaturation reduces the heat drop. Thus the exit velocity of steam is reduced.

(iv) Supersaturation increases the dryness fraction of the steam.

## (8) Velocity of steam flowing through a nozzle

Consider a unit mass of steam flowing through a nozzle.

Let, $V_1$ – velocity of the steam at the entrance of the nozzle (m/s)

$V_2$ – velocity of the steam at any section (m/s)

$H_1$ – Enthalpy (or) total heat of steam entering nozzle (KJ/kg)

$H_2$ – Enthalpy (or) total heat of steam at the section considered in (KJ)

$$H_1 + \frac{V_1^2}{2} = H_2 + \frac{V_2^2}{2} \quad \text{—(1)}$$

$$\frac{V_2^2}{2} = \frac{V_1^2}{2} + (H_1 - H_2) \quad \text{—(2)}$$

$$V_2^2 = V_1^2 + 2000(H_1 - H_2) \quad \text{—(3)} \qquad [\times 1000 \text{ KJ into J in J}]$$

$$\therefore V_2 = \sqrt{2000(H_1 - H_2) + V_1^2} \quad \text{—(4)}$$

As the velocity of steam entering the nozzle is very small, $V_1$ can be neglected.

$$V_2 = \sqrt{2000(H_1 - H_2)} = 44.72\sqrt{(H_1 - H_2)} \text{ m/s}$$

If friction losses are taken into account then,

$$V_2 = 44.72\sqrt{(H_1 - H_2)\eta_n} \text{ m/s.}$$

Mass of the steam discharged through the nozzle

we have already discussed that the flow of steam through the nozzle is isentropic, which is approximately represented by general law:

$$pv^n = \text{constant}.$$

we know that gain in kinetic energy

$$= \frac{V_2^2}{2} \quad \ldots \text{(neglecting initial velocity of steam)}$$

Heat drop = work done during Rankine cycle

$$= \frac{n}{n-1}(p_1 v_1 - p_2 v_2)$$

Since gain in kinetic energy is equal to heat drop, therefore

$$\frac{V_2^2}{2} = \frac{n}{n-1}(p_1 v_1 - p_2 v_2) \quad \text{--- (1)}$$

$$= \frac{n}{n-1} p_1 v_1 \left(1 - \frac{p_2 v_2}{p_1 v_1}\right) \quad \text{--- (2)}$$

We know that $p_1 v_1^n = p_2 v_2^n$ --- (3)

$$\frac{v_2}{v_1} = \left(\frac{p_1}{p_2}\right)^{\frac{1}{n}} = \left(\frac{p_2}{p_1}\right)^{-1/n} \quad \text{--- (4)}$$

$$v_2 = v_1 \left(\frac{p_2}{p_1}\right)^{-1/n} \quad \text{--- (5)}$$

Substituting the value of $\frac{v_2}{v_1}$ in Eqn (2)

$\therefore$ (2) $\Rightarrow$

$$\frac{V_2^2}{2} = \frac{n}{n-1} p_1 v_1 \left[1 - \frac{p_2}{p_1}\left(\frac{p_2}{p_1}\right)^{-\frac{1}{n}}\right] \quad \text{--- (6)}$$

$$= \frac{n}{n-1} p_1 v_1 \left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right] \quad \text{--- (7)}$$

$$V_2 = \sqrt{2\frac{n}{n-1}p_1 v_1\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]} \quad \text{—(8)}$$

Now the volume of steam flowing per second

= cross sectional area of nozzle × velocity of steam

$= AV_2$

and volume of 1kg of steam i.e. specific volume of steam at pressure at $p_2$

$= v_2 \; m^3/kg$

∴ Mass of steam discharged through nozzle per second,

$$m = \frac{\text{volume of steam flowing per second}}{\text{volume of 1kg of steam at pressure } p_2}$$

∴ (8) ⇒

$$= \frac{AV_2}{v_2} = \frac{A}{v_2}\sqrt{2\frac{n}{n-1}p_1 v_1\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]} \quad \text{—(9)}$$

Substituting the value of $v_2$ from eqn (6),

$$m = \frac{A}{v_1}\left(\frac{p_1}{p_2}\right)^{-1/n}\sqrt{\frac{2n}{n-1}p_1 v_1\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]} \quad \text{—(10)}$$

$$= \frac{A}{v_1}\left(\frac{p_2}{p_1}\right)^{1/n}\sqrt{\frac{2n}{n-1}p_1 v_1\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]} \quad \text{—(11)}$$

$$= A\sqrt{\left(\frac{p_2}{p_1}\right)^{\frac{2}{n}} \times \frac{2n}{n-1}\frac{p_1}{v_1}\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]} \quad \text{—(12)}$$

$$= A\sqrt{\frac{2n}{n-1}\frac{p_1}{v_1}\left[\left(\frac{p_2}{p_1}\right)^{2/n} - \left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}}\right]} \quad \text{—(13)}$$

Condition for maximum discharge:-

A nozzle is normally designed for maximum discharge by designing a certain ~~amount~~ throat pressure which produces this condition.

$$m = A\sqrt{\frac{2n}{n-1}\frac{p_1}{v_1}\left[\left(\frac{p_2}{p_1}\right)^{2/n} - \left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}}\right]} \quad \text{—(14)}$$

$p_1$ – Inc pr $N/m^2$
$p_2$ – throat pr $N/m^2$
$v_1$ – volume of 1kg of steam
A – cross sec area

contd

## Condition for maximum discharge :-

There is only one value of the ratio $p_2/p_1$, which produces maximum discharge from the nozzle. This ratio $p_2/p_1$, is obtained by differentiating the right hand side of equation. We see from this equation that except $p_2/p_1$, all other values are constant. Therefore, only that portion of the equation which contains $p_2/p_1$, is differentiated and equated to zero for maximum discharge,

$$\therefore \frac{d}{d\left(\frac{p_2}{p_1}\right)}\left[\left(\frac{p_2}{p_1}\right)^{\frac{2}{n}} - \left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}}\right] = 0 \quad \text{— (15)}$$

$$\frac{2}{n}\left(\frac{p_2}{p_1}\right)^{\frac{2}{n}-1} - \frac{n+1}{n}\left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}-1} = 0 \quad \text{— (16)}$$

$$\frac{2}{n}\left(\frac{p_2}{p_1}\right)^{\frac{2-n}{n}} = \frac{n+1}{n}\left(\frac{p_2}{p_1}\right)^{\frac{1}{n}} \quad \text{— (17)}$$

$$\left(\frac{p_2}{p_1}\right)^{\frac{2-n}{n}} \times \left(\frac{p_2}{p_1}\right)^{-1/n} = \frac{n+1}{n} \times \frac{n}{2} \quad \text{— (18)}$$

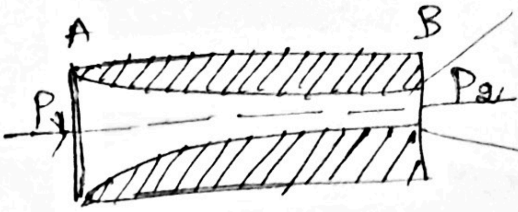
$$\left(\frac{p_2}{p_1}\right)^{\frac{1-n}{n}} = \frac{n+1}{2} \quad \text{— (19)}$$

$$\frac{p_2}{p_1} = \left(\frac{n+1}{2}\right)^{\frac{n}{1-n}} \quad \text{— (20)}$$

$$= \left(\frac{2}{n+1}\right)^{-\left(\frac{n}{1-n}\right)} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}} \quad \text{— (21)}$$

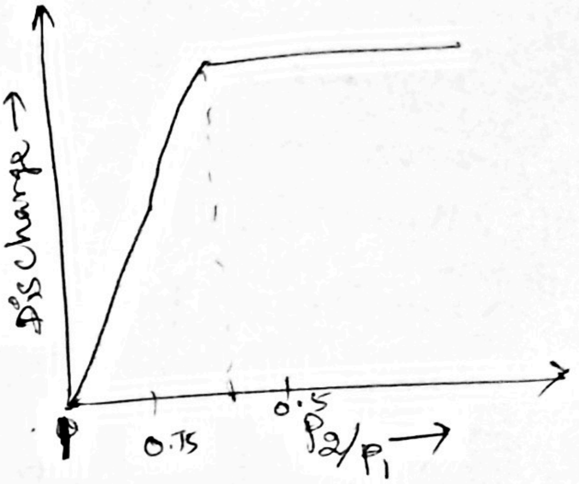
$$\boxed{\frac{p_2}{p_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}} \quad \text{— (21)}$$

## Critical pressure ratio & Critical pressure.




### Critical pressure ratio:

*) There is only one value of the ratio $\frac{P_2}{P_1}$, which produces the maximum discharge from the nozzle - that ratio is called critical pressure ratio.




*) When $\frac{P_2}{P_1}$ reached critical pressure ratio (i.e. reached maximum discharge) at $P_2$ - the velocity is sonic (at throat or at exit).

*) If the back pressure $P_2$ is furthur reduced below critical value, then mass flow remains at maximum value, but fluid expands violently outside the nozzle down to the back pressure

### Critical pressure ratio:

* The ratio of $P_2/P_1$ is known as critical pressure ratio, and the pressure $P_2$ at the throat is known as critical pressure.

* The maximum value of the discharge per second is obtained by substituting the value of ratio $P_2/P_1$ in equation ②

1. When the steam is initially saturated,

we know that for dry saturated steam, $n = 1.135$,

$$\frac{P_2}{P_1} = \left(\frac{2}{1.135+1}\right)^{\frac{1.135}{1.135-1}} = 0.577 \quad ; \quad P_2 = 0.577 P_1$$

2. When the Steam is initially superheated,

W.K.T. for superheated steam, $n = 1.3$.

$$\therefore \frac{p_2}{p_1} = \left(\frac{2}{1.3+1}\right)^{\frac{1.3}{1.3-1}} = 0.546 \quad \text{(or)} \quad p_2 = 0.546\, p_1$$

3. When the steam is initially wet,

It has been experimentally found that the critical pressure ratio for wet steam,

$$\frac{p_2}{p_1} = 0.582 \quad \text{(or)} \quad p_2 = 0.582\, p_1$$

4. For gases,

W.K.T, for gases $n = 1.4$.

$$\frac{p_2}{p_1} = \left(\frac{2}{1.4+1}\right)^{\frac{1.4}{1.4-1}} = 0.528 \quad \text{(or)} \quad p_2 = 0.528\, p_1$$

$\therefore$ Maximum discharge,

From (14) & (21)

$$m_{max} = A\sqrt{\frac{2n}{n-1}\frac{p_1}{v_1}\left[\left(\frac{2}{n+1}\right)^{\frac{2}{n-1}} - \left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}\right]} \quad \text{— (22)}$$

$$= A\sqrt{\frac{2n}{n-1}\frac{p_1}{v_1}\left(\frac{2}{n+1}\right)^{\frac{2}{n-1}}\left[1 - \left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}-\frac{2}{n-1}}\right]} \quad \text{— (23)}$$

$$= A\sqrt{\frac{2n}{n-1}\frac{p_1}{v_1}\left(\frac{2}{n+1}\right)^{\frac{2}{n-1}}\left[1 - \left(\frac{2}{n+1}\right)^{\frac{n-1}{n-1}}\right]} \quad \text{— (24)}$$

$$= A\sqrt{\frac{2n}{n-1}\frac{p_1}{v_1}\left(\frac{2}{n+1}\right)^{\frac{2}{n-1}}\left(\frac{n-1}{n+1}\right)} \quad \text{— (25)}$$

$$= A\sqrt{\frac{2n}{n+1}\frac{p_1}{v_1}\left(\frac{2}{n+1}\right)^{\frac{2}{n-1}}} \quad \text{— (26)}$$

## Values for maximum discharge:

1. When the steam is initially dry saturated,
W.K.T for dry saturated steam, $n = 1.135$. Therefore substituting the value of $n$ in the relation for maximum discharge, we have

$$m_{max} = 0.637 A \sqrt{\frac{p_1}{v_1}}$$

2. When the steam is initially superheated,
W.K.T for superheated steam, $n = 1.3$. Therefore substituting the value of $n$ in the relation for maximum discharge, we ~~know~~, have

$$m_{max} = 0.666 A \sqrt{\frac{p_1}{v_1}}$$

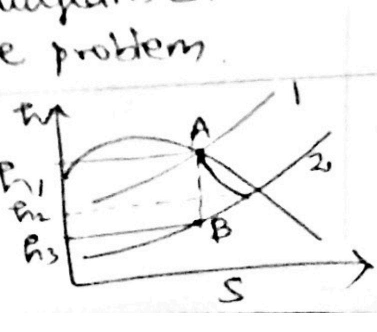
3. For gases.
W.K.T for gases, $n = 1.4$. Therefore substituting the value of $n$ in the relation for maximum discharge, we have

$$m_{max} = 0.685 A \sqrt{\frac{p_1}{v_1}}$$

## Difference between super ~~heated~~ saturated flow and isentropic flow

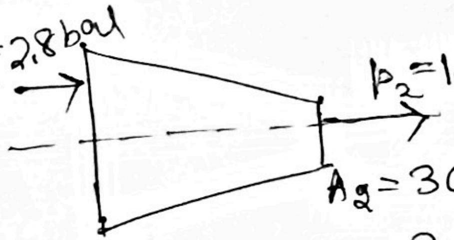
| | Super saturated flow | Isentropic flow |
|---|---|---|
| 1. | Entropy is not constant - AB' nearly ~~adiabatic~~ | Entropy is constant - AB Isentropic |
| 2. | It reduces enthalpy drop. $\Delta h = h_1 - h_2$ | There is no reduction in enthalpy drop $\Delta h = h_1 - h_3$ |
| 3. | Moiler diagram cannot be used to solve the problem. | Moiler diagram can be used to solve problem |

Enthalpy drop $h = h_1 - h_3 > h_1 - h_2$



P-(1) (1) Dry saturated steam at 2.8 bal is expanded through a convergent nozzle to 1.7 bal. The exit area is 3 cm². calculate the exit velocity and mass flow rate for (i) Isentropic expansion (ii) supersaturated flow.

**Given:**




$p_1 = 2.8$ bal

$p_2 = 1.7$ bal

$A_2 = 3 cm^2 = 3 \times 10^{-4} m^2$.

$A_2 = 3 cm^2$

$C_2 = ?$ m/s

$\dot{m} = ?$ kg/s

**To find:**

Case 1: Isentropic flow

(i) $C_2 = ?$ (m/s) (ii) $\dot{m}_2 = ?$ (kg/s)

Case 2: Supersaturated flow.

(i) $C_2 = ?$ (m/s) (ii) $\dot{m}_2 = ?$ (kg/s)

Formula to be used

$C_2 = \sqrt{2000(h_1 - h_2)}$ m/s

$C_2 = \sqrt{\frac{2n}{n-1} p_1 v_1 \left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]}$ m/s

$p_1 v_1^{\gamma} = p_2 v_2^{\gamma}$

$m = \frac{A C_2}{v}$ kg/s

**Solution:**

For 2.8 bal,

From steam table.

$h_1 = 2721.5$ KJ/kg

$v_1 = 0.646 m^3/kg$

$s_1 = 7.014$ KJ/kgK

For 1.7 bal, $s_1 = s_2$ ; $x_2 = ?$

$h_{f2} = 483.2$ KJ/kg

$h_{fg} = 2215.6$ KJ/kg

$s_{f2} = 1.475$ KJ/kgK

$s_{fg} = 5.706$ KJ/kgK

$v_{f2} = 0.001056 m^3/kg$ $v_{g2} = 1.0309 m^3/kg$

(16)

For Isentropic flow,

$$s_1 = s_2 = s_{f2} + x_2 s_{fg2}$$

$$7.017 = 1.475 + x_2 \times 5.706$$

$$\therefore \boxed{x_2 = 0.97}$$

$$h_2 = h_{f2} + x h_{fg2}$$

$$= 483.2 + (0.97 \times 2215.6)$$

$$\boxed{h_2 = 2632.33 \text{ kJ/kg}}$$

$$v_2 = x_2 v_{g2} = 0.97 \times 1.0369$$

$$v_2 = 1.00 \text{ m}^3/\text{kg}$$

$$C_2 = \sqrt{2000(h_1 - h_2)} = \sqrt{2000(2721.5 - 2632.33}$$

$$\boxed{C_2 = 422.3 \text{ m/s}}$$

$$\dot{m} = \frac{A_2 \times C_2}{v_2} = \frac{3 \times 10^{-4} \times 422.3}{1.00}$$

$$\boxed{\dot{m} = 0.13 \text{ kg/s}}$$

Case II :- Super saturated flow :-

$$C_2 = \frac{2n}{n-1} p_1 v_1 \left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]$$

$$= \frac{2 \times 1.3}{1.3 - 1} \times 2.8 \times 10^5 \times 0.646 \left[1 - \left(\frac{1.7}{2.8}\right)^{\frac{1.3-1}{1.3}}\right]$$

$$\boxed{C_2 = 412.93 \text{ m/s}}$$ Ans.

$$p_1 v_1^n = p_2 v_2^n$$

$$\therefore v_2 = \left[\frac{p_1}{p_2}\right]^{\frac{1}{n}} v_1 = 0.646 \cdot \left[\frac{2.8}{1.7}\right]^{\frac{1}{1.3}}$$

$$\boxed{v_2 = 0.948 \text{ m}^3/\text{kg}}$$

$$\dot{m} = \frac{A_2 \times C_2}{v_2} = \frac{3 \times 10^{-4} \times 412.93}{0.948}$$ $$\boxed{\dot{m} = 0.13 \text{ kg/s}}$$

P-2 ② Steam at 10.5 bal and 0.95 dryness is expanded through a convergent divergent nozzle. The pressure of steam leaving the nozzle is 0.85 bal. Find (i) velocity of steam at throat for maximum discharge (ii) the area at exit (iii) steam discharge if the throat area is 1.2 cm². Assume the flow as isentropic and there is no friction losses. Take n = 1.135.

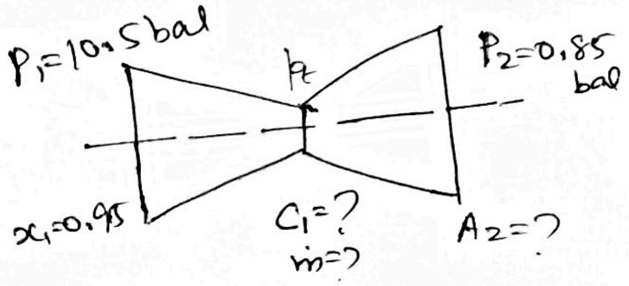
Given data:-

$p_1 = 10.5$ bal; $x_1 = 0.95$

$p_2 = 0.85$ bal.

$A_{nozzle} = 1.2\ cm^2$.

$n = 1.135$




To find:-

(1) velocity at throat $C_1$ (m/s)

(2) Mass flow rate $\dot{m}$ (kg/s)

(3) Exit area $A_2$ (m²)

Formula used,

$$C_t = \sqrt{2000(h_1 - h_2)}\ m/s$$

$$\dot{m} = \frac{A_t \times C_t}{v_t}\ kg/s$$

$$m_2 = \frac{A_2 \times C_2}{v_2}\ kg/s$$

$$\boxed{\frac{p_t}{p_1} = 0.577} \text{ for } n = 1.135$$

Solution:-

For maximum discharge

$$\frac{p_t}{p_1} = 0.577$$

$$p_t = 0.577 \times 10.5$$

$$\boxed{p_t = 6.06\ bal}$$

Inlet pressure 10.5 bal.

$h_{f1} = 772.0$ kJ/kg

$h_{fg1} = 2006.0$ kJ/kg

$s_{f1} = 2.159$ kJ/kgK

$s_{fg1} = 4.407$ kJ/kgK

Throat pressure 6.06 bal.

$h_{ft} = 672$ kJ/kg

$h_{fgt} = 2084$ kJ/kg

$s_{ft} = 1.935$ kJ/kgK

$s_{fgt} = 4.820$ kJ/kgK

$v_{f1} = 0.001101\ m^3/kg$ $v_g = 0.3126\ m^3/kg$

(18) Exit pressure 0.85 bar.

$h_{f2} = 398.6$ KJ/kg

$h_{fg2} = 2269.8$ KJ/kg

$S_{f2} = 1.252$ KJ/kgK

$S_{fg2} = 6.163$ KJ/kgK.

$v_{f2} = 0.001040\ m^3/kg$

$v_{fg2} = 1.9721\ m^3/kg$

$S_1 = S_{f1} + x_1 S_{fg1}$

$= 2.159 + (0.95 \times 4.405)$

$S_1 = 6.35$ KJ/kgK.

$h_1 = h_{f1} + x h_{fg1}$

$= 772.6 + (0.95 \times 2006)$

$h_1 = 2677.7$ KJ/kg

$S_1 = S_t = S_{ft} + x_2 S_{fgt}$

$6.35 = 1.935 + x_2 \times 4.82$

$x_2 = 0.92$

$h_t = h_{ft} + 0.92\, h_{fgt}$

$= 672 + 0.92 \times 2087$

$h_t = 2589.22$ KJ/kg

velocity at throat $C_t = \sqrt{2000(h_1 - h_t)}$

$= \sqrt{2000(2677.7 - 2589.22)}$

$C_t = 420.67$ m/s

$V_t = x_2 \times V_{fgt}$

$= 0.92 \times 0.3126$

$v_t = 0.288\ m^3/kg$

$\dot{m} = \frac{A_t \times C_t}{v_t} = \frac{1.2 \times 10^{-4} \times 420.67}{0.288}$

$\boxed{\dot{m} = 0.18 \text{ kg/s}}$

$S_1 = S_2 = S_{f2} + x_3 S_{fg2}$

$6.35 = 1.252 + x_3 \times 6.163$

$\boxed{x_3 = 0.83}$

$h_2 = h_{f2} + x_3 \cdot h_{fg3}$

$= 398.6 + 0.83 \times 2269.8$

$= 2282.53 \text{ kJ/kg}$

$v_2 = 0.83 \times v_{fg2} = 0.83 \times 1.9721$

$\boxed{v_2 = 1.637 \text{ m}^3/\text{kg}}$

$C_2 = \sqrt{2000(h_t - h_2)}$

$= \sqrt{2000(2677.7 - 2282.53)}$

$\boxed{C_2 = 889.01 \text{ m/s}}$ Exit velocity

$\dot{m} = \frac{A_2 \times C_2}{v_2}$

$\therefore A_2 = \frac{\dot{m} \times v_2}{C_2}$

$= \frac{0.18 \times 1.637}{889.01}$

$\therefore \boxed{A_2 = 3.31 \times 10^{-4} \text{ m}^2}$ Exit Area

x ——— x ——— x ——— x

# Unit - II BOILERS

(2) Types and Comparison. Mounting and Accessories. Fuels - Solid, Liquid, Gas. Performance calculations, Boiler trail.

## Boilers:

It is closed vessel in which steam is producing from water by combustion of fuel.

## Purpose:

*) For generating power in steam engine or turbines.

*) In textile Industries for sizing and bleaching etc and many other industries like sugar mills, chemical industries.

*) For heating the buildings in cold weather and for producing hot water for heating purpose.

## Primary Requirements of Steam Boilers:

*) The water must be contained safely.

*) The steam must be safely delivered in desired Conditions.

*) Also withstands very high pressure and temperature.

## Essential of A Good Steam Boiler:

A good boiler should possess the following features.

1. The boiler should produce the maximum weight of steam of the required quality at minimum expenses.
2. Steam production rate should be as per requirements
3. It should be absolutely reliable.
4. It should occupy minimum space.
5. It should be light in weight.
6. It should be Capable of quick starting.
7. There should be an easy access to the various parts of the boiler for repairs and Inspection.
8. The boiler components should be transportable

②

without difficulty.

9. The Installation of boiler should be simple.

10. The tubes of the boiler should not accumulate soot or water deposits and should be sufficiently strong to allow for wear and corrosion.

11. The water and gas circuits should be such as to allow minimum fluid velocity (for low frictional losses).

## Boiler terms.

* Shell: consists of one or more steel plates bent into a cylindrical form and riveted or welded together. The shell ends are closed with end plates.

* Setting: The primary function of setting is to confine heat to the boiler and form a passage for gases. It is made of brick work and may form the wall of the furnace and combustion chamber.

* Grate: It is a platform in the furnace upon which fuel is burnt.

* Furnace: It is the chamber formed by the space above the grate and below the boiler shell, in which combustion takes place.

* Water space and steam space: The volume of the shell that is occupied by the water is termed as water space while the entire shell volume less the water and tubes is called steam space.

* Mountings: The items which are used for safety of boiler are called mountings.

* Accessories: The items which are used for increasing the boiler efficiency are called accessories

* Water level: The level at which water stands in the boiler is called water level.

* Refractory:- Insulation material used for lining Combustion Chamber.
* Foaming:- Formation of steam bubbles on the surface of boiler water due to high surface tension of water.
* Scale: A deposit of medium due to extreme hardness occurring on the water heating surfaces of boiler because of an undesirable condition in the boiler water.
* Blowing off:- The removal of mud and other impurities of water from the lowest part of the boiler. Accomplished with the help of blow off cock or valve.
* Lagging:- Insulation wrapped on the outside of the boiler shell or steam piping.

## Selection of Boilers:

The following factors should be considered, while selecting a boiler,

1. The working pressure and quality of steam required (i.e, wheather wet or dry or superheated)
2. Steam generation rate.
3. Floor area available.
4. Accessibility for repair and inspection.
5. Comparitive Initial cost
6. Erection facilities.
7. The portable load factor.
8. The fuel and water avilable.
9. Operating and maintenance Costs.

# Classification of Boilers.

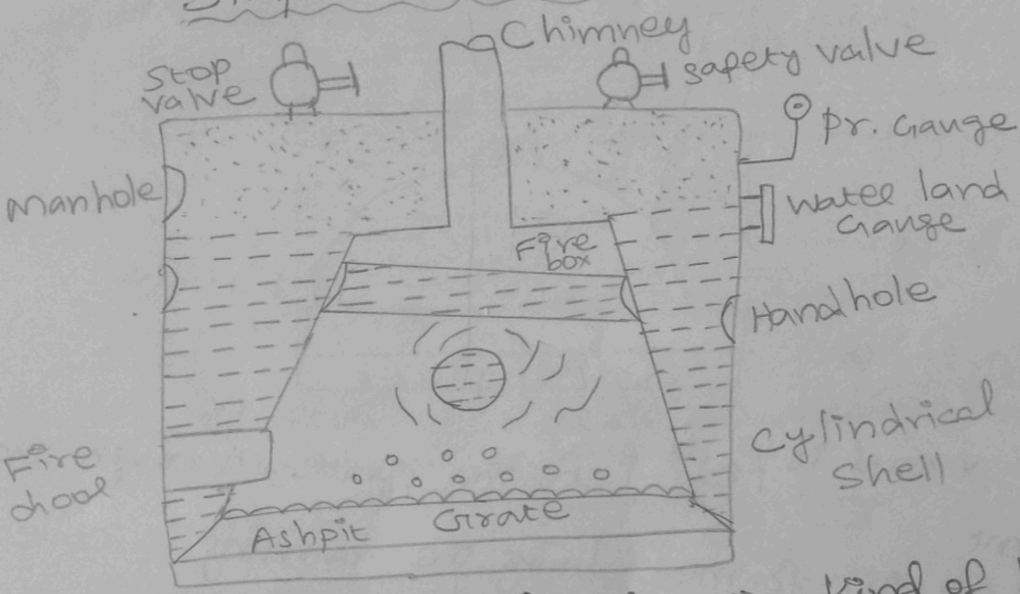
1. According to what flow in the tube.
   (i) Water tube (ii) Fire tube
2. According to steam pressure:
   (i) Low pressure (ii) Medium pressure (iii) High pressure
3. According to position of furnace:
   (i) Internally fired (ii) Externally fired
4. According to position of principle axis
   (i) vertical (ii) Horizontal (iii) Inclined.
5. According to application
   (i) Stationary (ii) Mobile (Marine, Locomotive)
6. According to the circulation water.
   (i) Natural circulation (ii) Forced circulation.

## Comparision of fire tube and water tube boilers.

| particulars | Fire tube boilers | water tube boilers |
|---|---|---|
| position of water and hot Gases | Hot Gases inside the tubes and water outside the tubes | Water inside the tubes and hot gases outside the tubes. |
| Mode of firing | Generally Internally fired | Externally fired |
| operation pressure | Limited to 16 bar | Can go upto 100 bar |
| Rate of steam production | Lower | Higher |
| Suitability | Not suitable for large power plants | Suitable for large power plants |
| Risk of bursting | Involves lesser risk of explosion due to Lower pressure | More risk on bursting due to high pressure |
| Floor area | For a given power it occupies more floor area | For a given power it occupies less floor area |
| Construction | Difficult | Simple |
| Transportation | Difficult | Simple |
| Shell diameter | Large for same power ~~pressure~~ | Small for same power ~~pressure~~ |

| | | |
|---|---|---|
| Chances of explosion | Less | More |
| Treatment of water | Not so necessary | More necessary |
| Accessibility of various parts | various parts not so easily accessible for cleaning, repair and Inspection | More accessible |
| Requirement of skill | Require less skill for efficient and economic working | Require more skill and careful attention. |

## Simple vertical Boiler.




*) The rate of production in this kind of boiler normally does not exceeds 2500kg/hr and pressure normally limited to 7.5 to 10 bar.

*) It is self contained and can be easily transported.

## Cochran Boiler.

*) It is well design of a vertical multi tubular fire tube boiler.

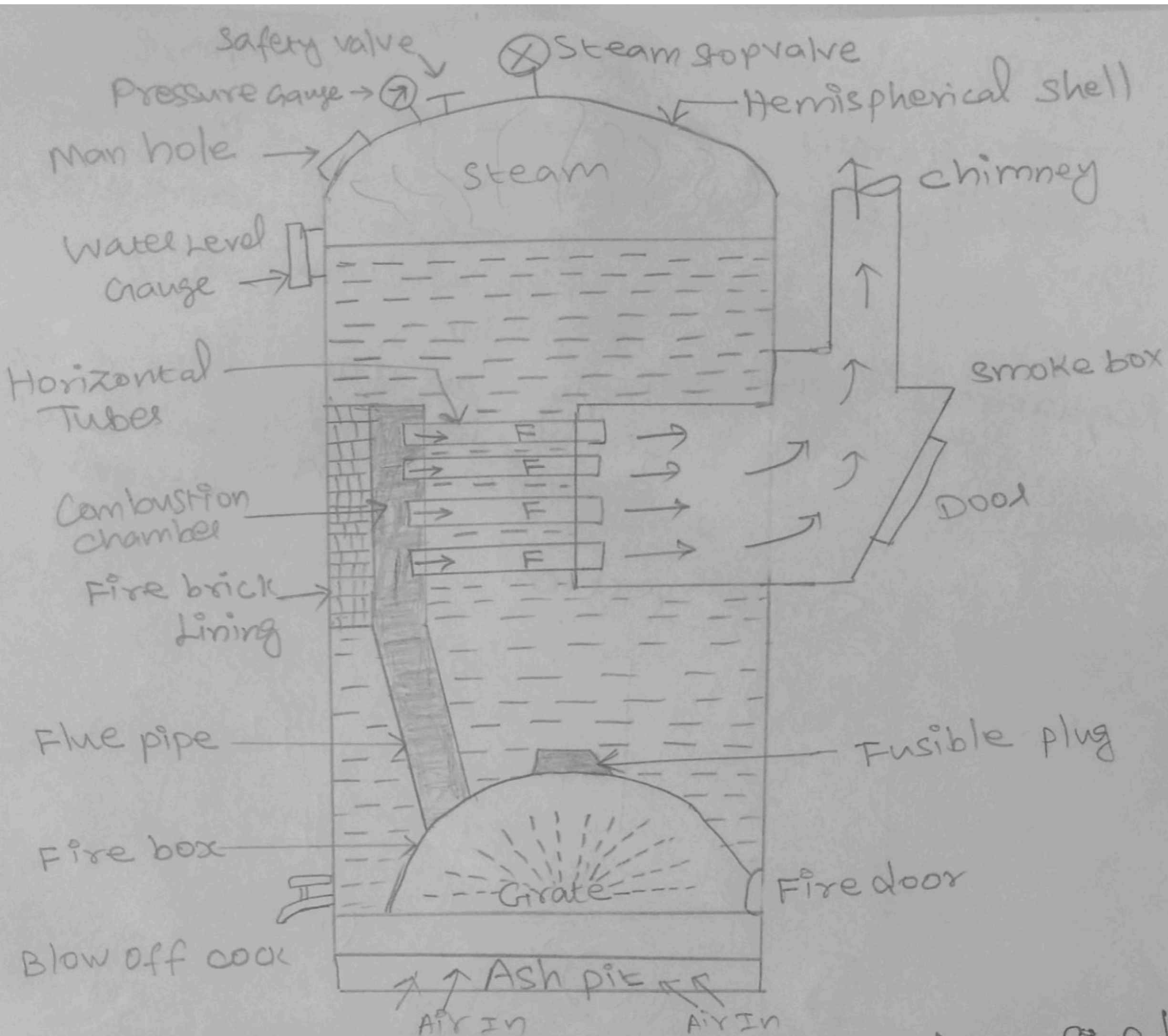
*) Improvement over the simple vertical boiler as it provides greater heating surface.

*) Total heating surface area is about 10-25 times the grate area.

*) Efficiency 70-75%.

*) Ranges from 1m dia x 2m high, evaporation 20kg/hr to 3m dia x 6m high, evaporation 3000kg/hr

(6)




* coal is fed into the grate through the fire hole and burnt

* Ash formed during the burning is collected in the ash pit provided just below the grate.

* The hot gases from the grate pass through the combustion chamber to the horizontal fire tubes and transfer the heat by convection.

*) The flue gases coming out of fire tube pass through the smoke box and escape to the atmosphere through the Chimney.

*) Smoke box is provided with a door for cleaning the fire tube and smoke box.

* The working pressure and steam capacity of cochran boiler are 6.5 bar and 3500 kg/hr respectively.

## Features:



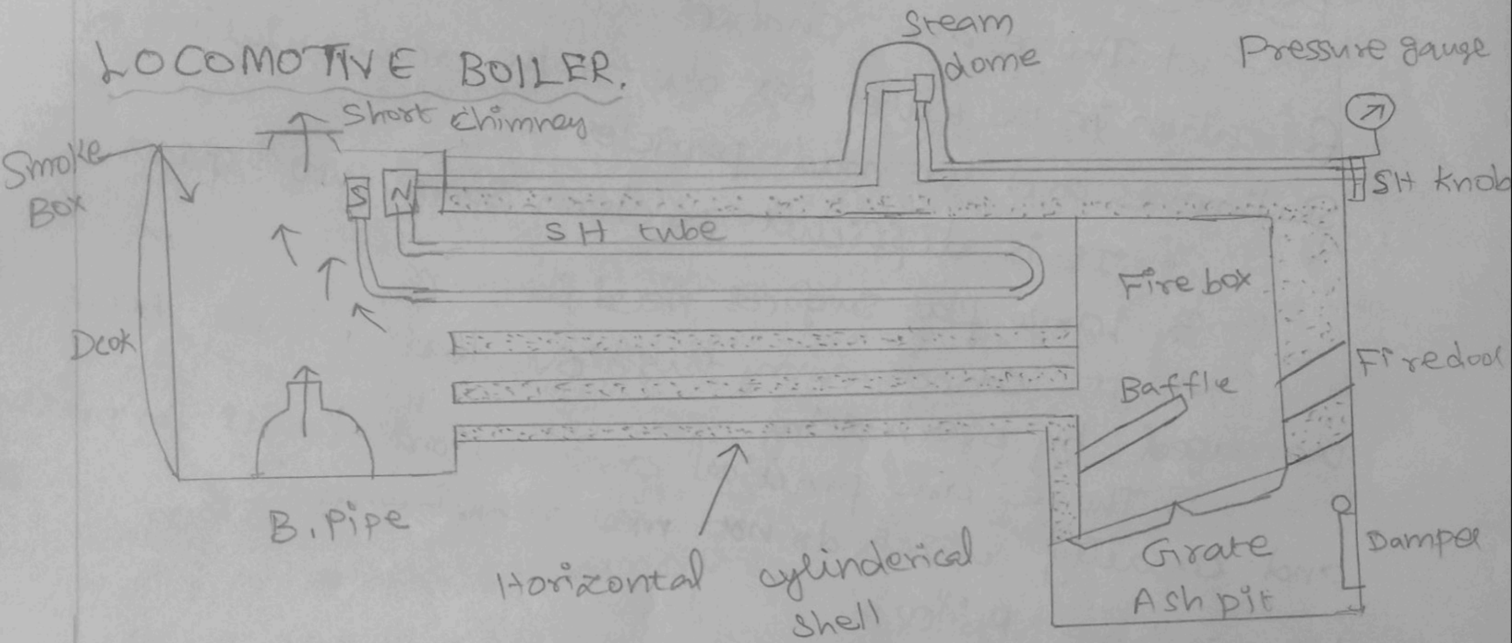
1) It is very compact and requires minimum floor area.

2) Any type of fuel can be used with this boiler

3) well suited for small capacity requirements.

4) It gives about 70% thermal efficiency with coal firing and about 75% with oil firing.

## LOCOMOTIVE BOILER.




Locomotive Boiler

*) It is mainly employed in locomotives though it may also used as a stationary boiler. It is compact and its capacity for steam production is quite high for its size as it can raise large quantity of steam rapidly.

*) In this type of boiler natural draft cannot be obtained because it requires a very high chimney which cannot be provided on a locomotive boiler since it has to run on rails.

*) Thus some artificial arrangements such as the draught here is produced by exhaust steam from the cylinder which is discharged through blast pipe to chimney. When locomotive is standing and no exhaust steam is avilable from engine fresh steam from the boiler is

(8) used for this purpose.

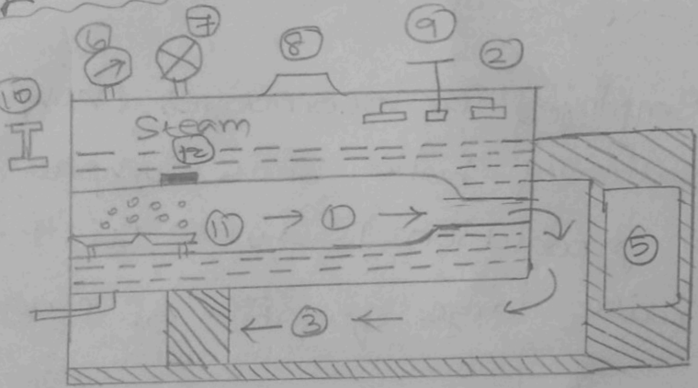
**Merits:**

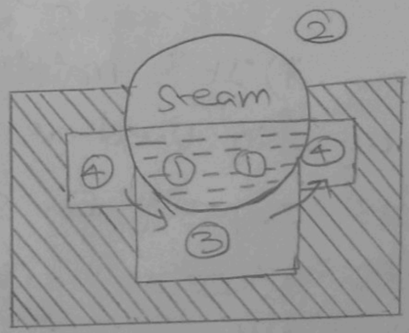
1. High steam capacity
2. Low cost of construction
3. portability
4. Low installation cost
5. compact

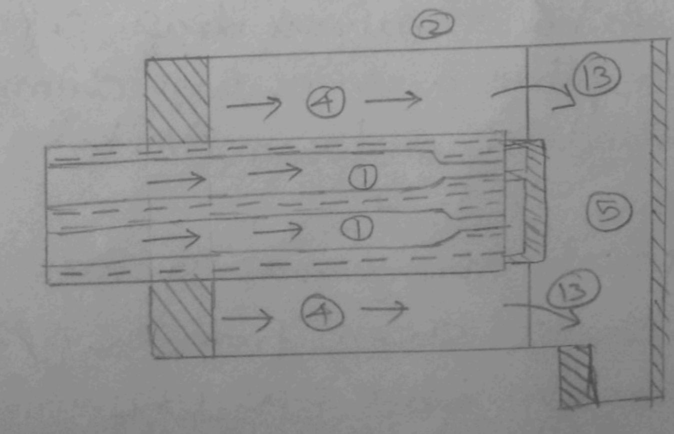
**Demerits:**

1. There are chances to corrosion and scale formation in the water legs due to the accumulation of sediments and the mud particles.
2. It is difficult to clean some water spaces.
3. Large flat surfaces need bracing.
4. It cannot carry high overloads without being damaged by overheating.
5. There are practical constructional limits for pressure and capacity which do not meet requirements.

**Lancashire Boiler:**



1. Flue tube
2. cylinderical Shell
3. Bottom flue
4. Side flue
5. Chimney flue
6. pressure gauge
7. Stop valve
8. Man hole
9. Safety valve
10. water level gauge
11. Grate
12. Fusible plug
13. Dampers.

This boiler is reliable has a simplicity of design, (9)
ease of operation and less operating and maintenance costs. It is commonly used in sugar mills and textiles industries where along with the power system and steam for the process work also needed. In addition this boiler is used where larger reserve of water and steam are needed.

In Cornish and Lancashire Boilers a conical shaped cross ~~section~~ tubes known as Galloway tubes inside the furnace to increase their heating surface and circulation of water. But those tubes have now obsolete for their considerable cost of fitting, they cool the furnace gases and ~~retard~~ retard combustion.

*) It is stationary fire tube, Internally fired, horizontal, natural circulation boiler.

*) It is commonly used in sugar mills and textile Industries.

*) This boiler is used where large reserve of water

*) Diameter of the shell is 2m to 3m, Length of the shell is 7m to 9m.

*) Maximum working pressure is 16 bar. and steam capacity is 9000 kg/hr.

*) This is widely used boiler because of its good steaming quality and its ability to burn coal of inferior quality.

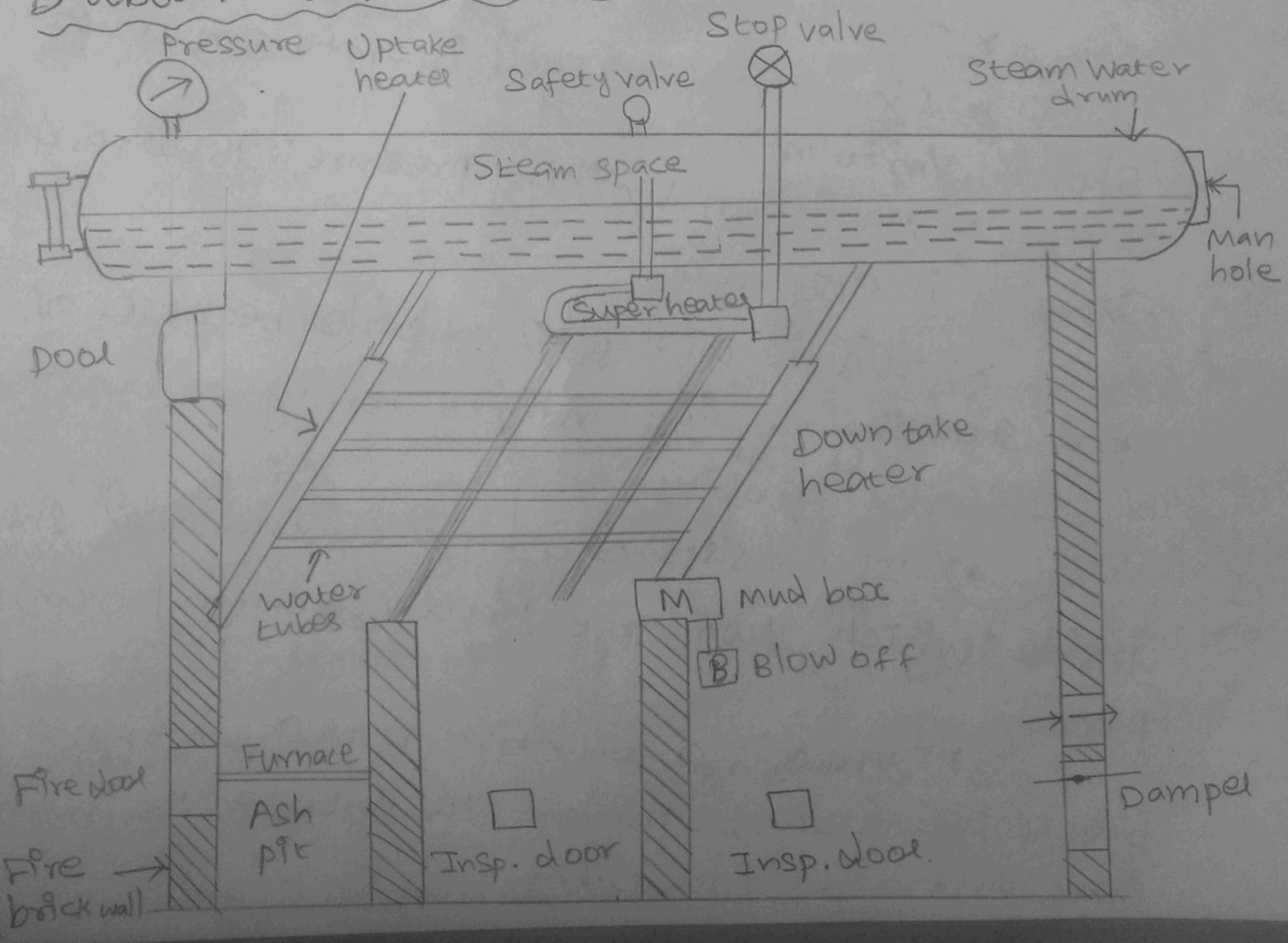
*) It consists of a large cylinderical shell inside which two large tubes (80 cm to 100 cm) are placed.

*) There is a low brick work fire bridge at the back of the grate to prevent the entry of the burning coal and ashes into tubes.

## Cornish boilee:-

*) cornish boiler is quite similar to the Lancashire boiler in every respect except that it has only one flue pipe at the centre of the cylinderical shell inside, instead of two flue pipes in the Lancashire boilee. The passage of the flue gases are similar to the Lancashire boilee. The diameter of Cornish boilee varies from 1 to 2m and the length varies from 5 to 7.5m. The inner furnace tube diameter varies from 60 cm to 120 cm. The steam generating capacity and the pressure of steam generated are comparatively low in the case of Cornish boilee.

## Babcock and wilcox Boilee:-



*) Babcock and wilcox water tube boiler is an example of horizontal straight tube boiler and may be designed for stationary and marine purposes.

*) Horizontal drum and cross drum type.

*) In horizontal drum restricts the no of tubes that can be connected to one drum circumferentially and limits capacity of the boiler. But in cross drum this problem are rectified.

*) The pressure of steam in case of cross drum boiler may be as high as 100 bar and steam capacity upto 2700kg/hr

## High pressure Boilers.

In application where steam is needed at pressure, 30 bar, and individual boilers are required to raise less than about 3000kg of steam per hour, shell boilers are considerably cheaper than the water tube boiler. Above these limits, shell boilers (generally factory built) are difficult to transport if not possible. There are no such limits to water tube boilers. These can be site erected from easily transportable parts, and moreover the pressure parts are of smaller diameter and therefore can be thinner. The geometry can be varied to suit a wide range of situations and furnace is not limited to cylinderical form. Therefore, water tube boilers are generally preferred for high pressure and high output whereas shell boilers for low pressure and low output.

The modern high pressure boilers employed for power generation are for steam capacities 30 to 650 tonnes/hr and above with a pressure upto 160 bar and maximum steam temperature of about 540°C

(12)

Unique features of the high pressure boilers:

1. Method of water circulation:- uses pumps to circulate water.

2. Types of tubing:- Reduce pressure drop in water tubes by arranging several sets of tubing

3. Improved method of heating:- The following methods are used to increase heat transfer,

(a) The saving of heat by evaporation of water above the critical pressure of steam.

(b) The heating of water can be made by mixing with super heated steam, this will improves HTC.

(c) Increasing the velocity of water inside the tube and also increase the sonic velocity of gas are increases the HTC.

Advantages:-

1. Pumps are used to maintain forced circulation of water.. This ensures positive circulation and increase evaporative capacity and less number of steam drums will be required.

2. The heat of combustion is utilised more efficiently by the use of small diameter tube in large number and in multiple circuits.

3. pressurised combustion is used in which increases rate of firing of fuel thus increasing the rate of heat release.

4. Due to compactness less floor area is required

5. The tendency of scale formation is eliminated due to high velocity of water through the tubes.

6. All the parts are uniformly heated, therefore the danger of overheating is reduced and thermal stress problem is simplified

7. The differential expansion is reduced due to uniform temperature and this reduce the possibility of gas and air leakages.

8. The components can be arranged horizontally as high head required for natural circulation is eliminated using forced circulation. There is a greater flexibility in the components arrangement

9. The steam can be raised quickly to meet the variable requirements without the use of complicated control devices.

10. The efficiency of plant increased upto 40 to 42 percent by using high pressure and high temperature steam.

11. A very rapid start from cold is possible if an external supply of power is available. Hence the boiler can be used for carrying peak loads or stand by purposes with hydraulic station.

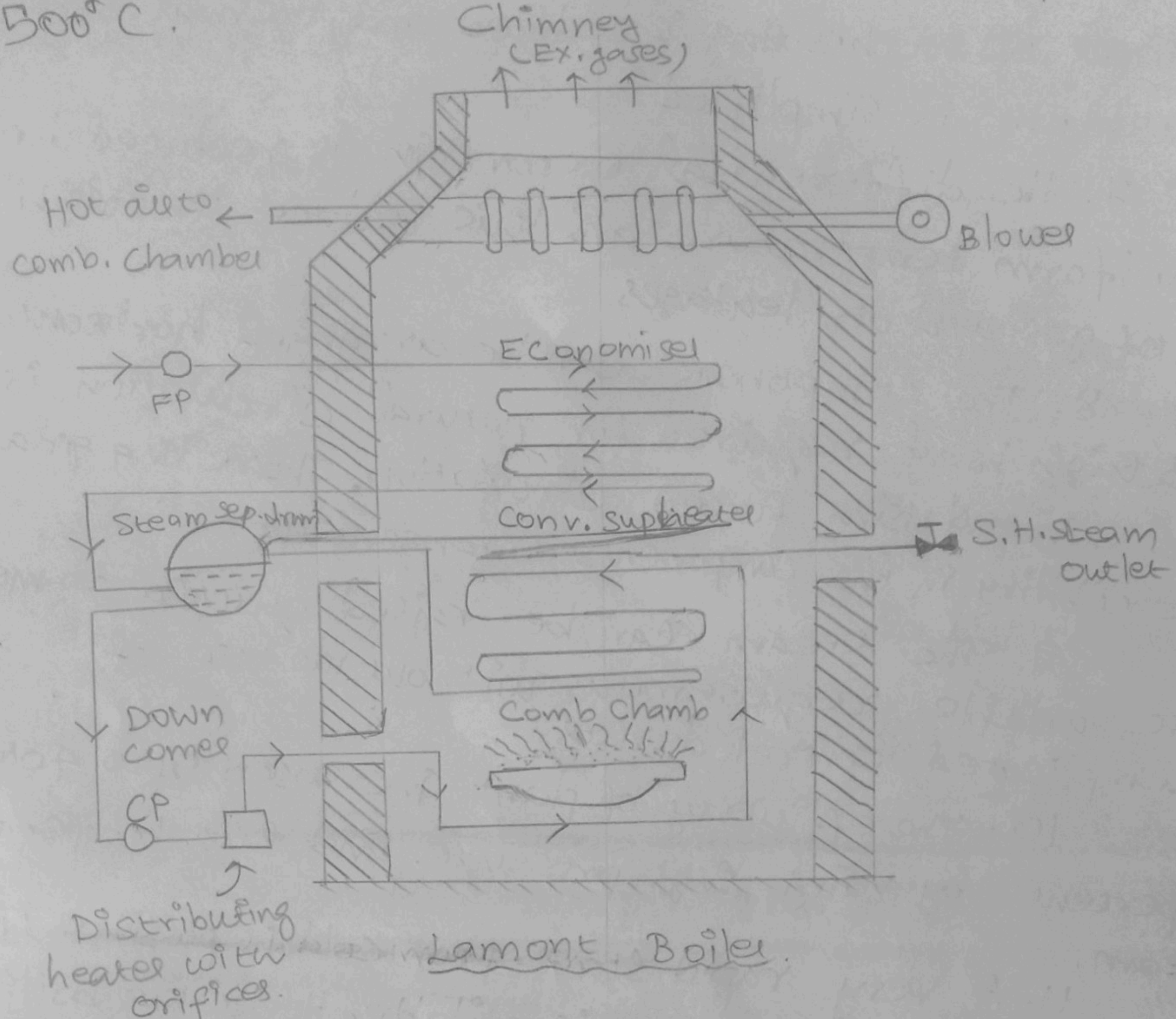
12. Use of high pressure and high temperature steam is economical.

## Lamont Boiler.

*) This boiler works on a forced circulation and the circulation is maintained by the centrifugal pump driven by the steam turbine using steam from the boiler. For emergency an electrically driven pump also fitted.

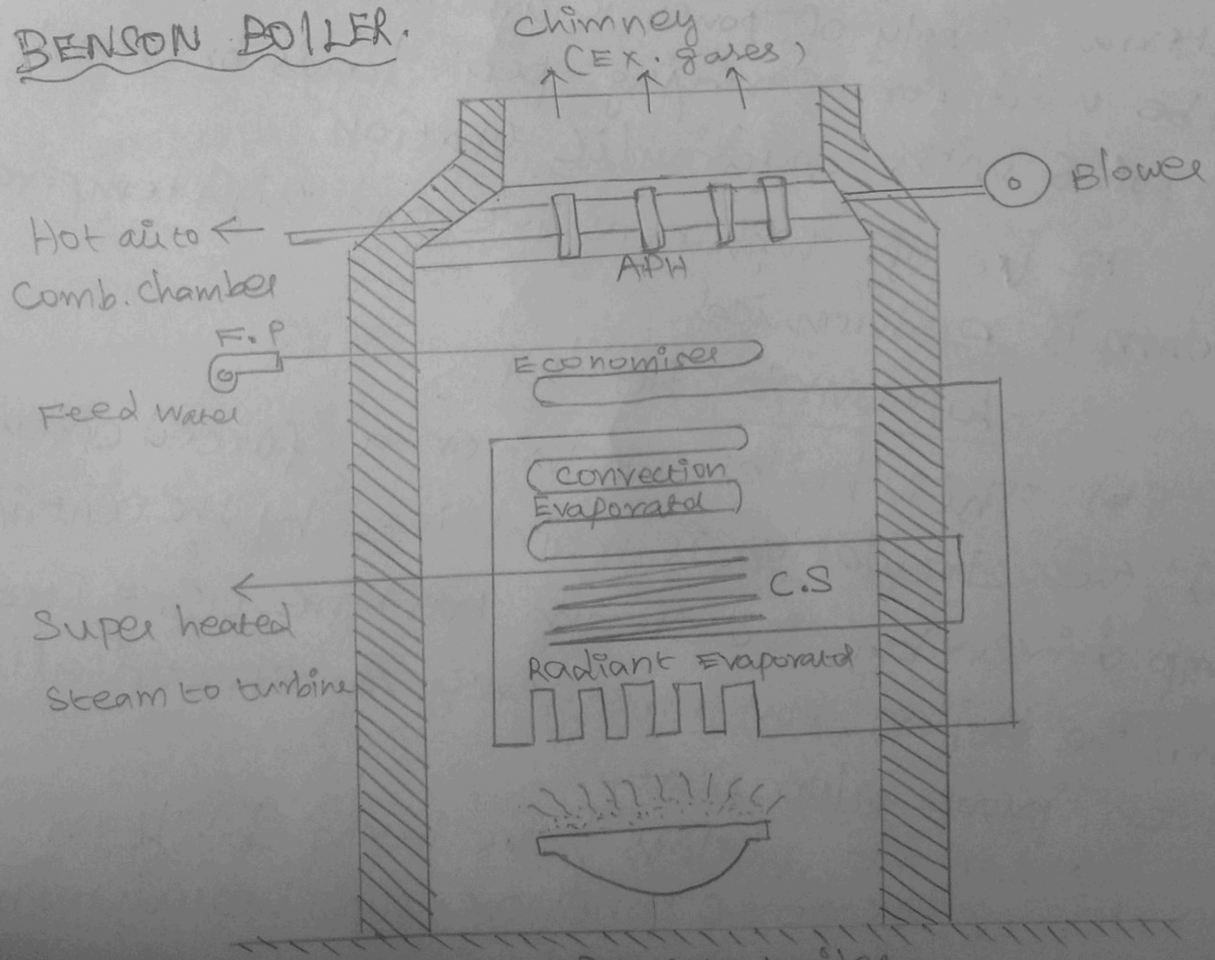
*) Lamont boilers have been built to generate of 45 to 60 tones of super heated steam at

(A) a pressure of 120 bar and at a temperature of 500°C.




Lamont Boiler.

**BENSON BOILER.**




Benson boiler.

*) In the lamont boiler, the main difficulty experienced is the formation and attachment of bubbles on inner surface of heating tubes. The attached bubbles to the inner surface reduce heat flow and steam generation as it offers high thermal resistance than the water film.

*) Benson in 1992 eliminates this problem by increasing the boiler pressure to critical pressure (225 atm), at this pressure steam and water having same density thus the bubbles formation can easily eliminated.

*) Its noral principle is that it eliminates the latent heat of water by compressing the feed to a pressure of 235 bar, it is above critical pressure and its latent heat is zero.

Advantages:-

1. It can be erected in a comparatively smaller floor area.

2. The total weight of a Benson boiler is 20% less than other boiler, since there are no drums. This also reduces the cost of the boiler.

3. It can be started very quickly because of welded joints.

4. Natural convection boilers require expansion joints but these are not required for Benson boiler as the pipes are welded.

5. The furnace wall of the boiler can be more efficiently producted by using smaller diameter and closed pitched tubes.

6. The transfer of parts of the boiler is easy as no drums

are required and majority of the parts are carried to the site without pre-assembly

7. It can be operated most economically by varying the temperature and pressure at partial loads and overloads. The desired temperature can also be maintained constant at any pressure.

8. The blow-down losses of the boiler are hardly 4% of natural circulation boiler of the same capacity.

9. Explosion hazards are not severe as it consists of only tubes of small diameter and has very little storage capacity.

10. The superheater in a Benson boiler is an integral part of forced circulation system, therefore no special starting arrangement for superheater is required.

## Boiler mountings and Accessories:

Boiler mountings are fittings that are mounted on the boiler for safe and efficient operation of the boiler. The following are some important mountings.

1) water level Indicator
2) pressure gauge
3) safety valve
4) Stop valve
5) Blow off cock
6) Feed check valve
7) Fusible plug
8) man hole

## Water level Indicator:

The function of water level Indicator is to indicate the level of water in the boiler constantly.

2. Pressure gauge:-

The function of pressure gauge is to measure the pressure exerted inside the vessel
1. Bourdon pressure gauge. 2. U tube syphon gauge.

3. Safety valve:-

* The function of safety valve is to release the excess steam when the pressure of the steam inside the vessel exceeds the rated pressure

* As per safety regulation every boiler must fitted with at least two safety valves.

Types:-

1. Dead weight safety valve
2. Lever safety valve
3. Spring loaded safety valve
4. Highsteam and low safety valve.

1. Dead safety valve:-

Mainly used for low pressure, low capacity, stationary boilers of Cornish and Lancashire types.

* Simple in design
* Satisfactory performance
* Not suitable for portable boilers.

2. Lever safety valve:-

Disadvantage of this valve is that it admits of being tempered with and the effects of small addition to the weight is magnified considerably in its action on the valve.

3. Spring loaded safety valve:-

Best suited for portable and high viberation boilers.

4. High steam and low safety valve:-

*) The steam automatically escapes out when the level of water falls below a certain level.

*) It automatically dischauges the excess steam when the pressure of the steam rises above a certain pressure

*) This is single device in which two valves are combined to serve the above mentioned function. Not used for mobile boilers, it is suited for Lancashire or Cornish boilers.

Fusible plug:-

The function of fusible plug is to protect the boiler against damage due to over heating for low water level. It is fitted on the fire plate or over the CC at its appropriate place.

Blow off cock:-

The blow off cock or valve performs the two functions. These are

* It may discharges a portion of water when the boiler is in operation to blow of mud, scale or sediments periodically

* It may empty the boiler when necessary for cleaning, inspection and repair.

It is fitted on the boiler shell directly or to a short pipe at the lowest part of the water space.

## Feed check valve:-

* The function of feed check valve is to control the supply of water to the boiler and to prevent the escaping of water from the boiler when the pump pressure is less or pump is stopped.

* The feed valve is fitted in the water space of the boiler slightly below the normal level of the water.

## Stop or Junction valve:-

A Junction valve is a valve which is placed directly over a boiler and connected to a steam pipe which carries steam to the engine. If a valve is placed in the steam pipe leading steam to the engine and placed near the engine, it is usually termed as stop valve.

## Boilers Accessories:-

* Feed pumps:- Rotary or Reciprocating pumps (Single and Double acting)
* Injectors
* Economiser
* Air pre-heater
* Super heater
* Steam seperator
* Steam trap.

## Fuels - solid, liquid and Gas.

## solid fuels:-

1. wood
   peat
2. Lignite
3. Lignite
4. Bituminous coal
5. Anthracite coal
6. wood charcoal

7) Coke
8. Briquetted coal
9. Pulverised coal.

1. Wood:-
The calorific value around 19,500 KJ/kg

2. Peat:-
Available can be found in foggy land; The calorific value around 23,000 KJ/kg. Since the moisture content of peat is 30% it has to be dried before use. It burns with a characteristics odour.

3. Lignite:-
It is also known as brown coal. It contains 40% moisture and 60% carbon. It has calorific value of 25,000 KJ/kg..

4. Bituminous Coal:-
The average Calorific value of this coal is 33500 KJ/kg. There are two varieties in this coal namely caking coal and non caking coal. Moisture around 5% and Carbon Content varies from 75% to 90%.

Caking bituminous coal:-
When it burns, it burns with a yellow long flame, and small particles of coal adheres together to form a lump. This coal is also known as soft coal having an average calorific value of 35,000 KJ/kg and its specific gravity ranges from 1.26 to 1.36. Highly suitable for manufacturing gas.

Non baking bituminous coal:-



The specific gravity of these type of coal ranges from 1.22 to 1.42. The Calorific value of this coal is around 33000 KJ/kg. These coals burn with small flame and produces either little smoke or no smoke. The carbon content of this coal is about 78 to 81%. If the carbon content increases, the caking property also increases.

5. Anthracite coal:-

Superior variety of coal in the coal family. having the greatest calorific value around 36,000 kJ/kg Contains 90% of carbon and a very little volatile matter. It burns without smoke, suitable for steam power stations.

6. wood charcoal:-

When wood is heated above 280°C under limited supply of air the wood char coal is formed. This charcoal finds lot of applications in metallurigical industries. It contains about 85 to 90% carbon and a C.V of 28,000 kJ/kg

7. Coke:-

The coke is formed by carbonization of coal. Carbonisation at low temperature (300 to 700°C) produces soft coke and at high temperature (900 to 1100°C) produces hard coke. soft coke can be used as a domestic fuel, whereas hard coke can be used as a fuel in industries particullarly in steel industries, where the carbonisation process is carried out for 42 to 48 hours in a clossed vessel in the absense of air.

8. Briquetted coal:

Briquetting is a process of mixing the finally ground coal with a suitable binder and making the mix into small briquettes. Naively ~~lignite~~ lignite corporation in Tamil Nadu, produced from waste fuel and sold in the brand name 'Leco'.

9. Pulverised coal:

Crushing of coal in pulveriser to get fine powder. Most of the cement industries and metallurgical industries used pulverised coal.

Advantages:

1. Easy to transport
2. Convenient to store without any risk of spontaneous combustion.
3. Cost less
4. Moderate ignition temperature.

Disadvantages:

1. Ash content is high
2. Large proportion of heat is wasted.
3. They form clinker while burning
4. Combustion cannot controlled easily
5. Handling cost is high.

Liquid fuels:

Most of the liquid fuels are derived from the natural petroleum or crude oil which is obtained from holes bored on the earth crust. Fractional disrillation of crude oil is carried out after it is brought to earth's surface to get petrol or gasoline, paraffin oil or kerosene, fuel oil and lubricating oils.

1. petrol or gasoline:-

Fuel in automobiles, aviation, generator sets etc. Lightest and most volatile liquid. fuel. The CV of 48000 KJ/kg. Its distillation temperature range is 65°C to 220°C.

2. Kerosine or paraffin oil:-

Heavier than petrol and less volatile also. Its distillation temperature ranges from 22°C to 345°C. It's calorific value is 35 000 KJ/kg

3. Heavy fuel oils:-

Distilled after petrol and kerosene. The distillation temperature of these oils are ranging from 345°C to 470°C. The CV is 41,200 KJ/kg.

Advantages:-

1. Higher efficiency
2. Higher calorific values.
3. No ash formation
4. Better cleanliness
5. Combustion effieiency more.
6. Better control of combustion
7. Less storage capacity needed
8. Economy in transportation.

9. No deterioration in storage.
10. No corrosion or erosion problems.

## Disadvantages:-

1. cost more
2. Greater risk in transportation and combustion
3. Storage facilities are costlier.

## Gaseous fuel:-

Natural has found in some places under the earth surface. It consist of methane, ethane, $CO_2$ and CO. available near petroleum field.

### 1. Coal Gas:-

It is obtained by carbonization of coal. Also known as 'town gas' as it is used in street light and domestic cooking purpose in towns. The C.V is 21000 to 25000 KJ/$m^3$.

### 2. Producer gas:-

It results from the partial oxidation of coal, coke or peat when they are burnt with an insufficient quantity of air. The heating value ranges from 3000 to 6700 KJ/$m^3$. This gas is used in glass melting industries and for power generation.

3. Watel gas:-

water gas is formed by passing steam over in candesent coke. Since it is burning with a blue flame it is known as 'blue watel gas'.
used in furnace and in welding

4. Blast furnace gas:-

product from the blast furnace used for the production of pig iron. The c.v of 3750 kJ/$m^3$
Used in steel Industries, power production in gas engines, for steam production in boilers, metallurgical Industries

5. Coke over gas:-

This gas is a product from the coke oven This is obtained by carbonisation of bituminous coal. The heating value from 14500 and 18500 kJ/$m^3$
Industrial heating and power generation

6. Mond Gas:-

CV of 5850 KJ/$m^3$. power generation and heating. obtained by large quantity of steam over waste coal at a temperature of 650°C.

7. Sewer Gas:-

Sewage is fermented from which the gas is produced.

Advantages:-

1. Excess air required minimized.
2. Easy maintenance
3. operation is clean
4. Efficiency is more
5. no problem in storage and supply
6. pipe line supply is possible
7. Better combustion control.

Dis Advantages:-

1. storage difficult
2. Inflammable, very careful operation is needed

Requirements:-

1. High Calorific value
2. Low Iginition temperature.
3. Freely burn with high Combustion efficiency
4. Minimum ash content
5. Not produce harmful gases
6. generate less smoke
7. Economical
8. not pose any problem in handling and transportation
9. Easily Iginitable

*) Evaporation Capacity
*) Equivalent Evaporation.
*) Factor of Evaporation
*) Boiler efficiency.
*) Heat Losses in a Boiler power plant.

## Evaporative Capacity:-

The evaporative Capacity of a boiler expressed in the following ways.

*) Kg of steam per hour
*) Kg of steam/hr/$m^2$ of heating surface.
*) Kg of steam/kg of fuel fired.

## Equivalent Evaporation:-

*) Equivalent Evaporation may be defined as the amount of water evaporated from water at 100°C to dry and saturated steam at 100°C

*) Equivalent Evaporation ($m_e$) from the definition is obtained as 100°C.

$$m_e = m_a(h - h_{f1})/h_{fg}$$

where,

$h$ - enthalpy of steam/kg under the generating condition.

$h_{f1}$ - Specific Enthalpy of water at given feed temperature.

$m_a$ - steam generation rate kg/hr.

## Factor of Evaporation:-

* It is defined as the ratio of heat received by 1kg of water under working conditions to that received by 1kg of water evaporated from and at 100°C.

$$F_e = h - h_{f1})/2257$$

(28) **Boiler efficiency:-**

Boiler efficiency is the ratio of heat actually utilized in generation of steam, to the heat supplied by the fuel in the same period.

$$\text{Boiler efficiency} = m_a (h - h_{f1}) / C$$

C - Calorific value of fuel (kJ/kg)

**Factors affecting the boiler efficiency:-**

**Fixed factors:-** Boiler Design, Heat recovery equipment, Built in losses and Rated rate of firing, the furnace Volume and heating surface.

**Variable factors:-**

*) Actual rate of firing
*) Fuel Condition as it is fired
*) conditions of heat absorbing surface
*) Excess air fluctuations
*) Humidity and temp of combustion air
*) Incomplete Combustion and combustible in the refuse
*) change in draft from the rated, due too atm Conditions.

**Heat Losses in a boiler plant:-**

*) Heat Lost to flue gases
*) Heat Lost due to Incomplete Combustion
*) Heat Lost due to un burnt fuel.
*) Convection and Radiation losses.

**1. Heat Lost to flue gases:-**

The flue gases contains dry products of Combustion as well as the steam generated due to the combustion.

Heat lost through the dry flue gases

$$Q_g = m_g C_{pg} (T_g - T_a)$$

$m_g$ – mass of gases formed/kg of coal

$C_{pg}$ – sp. heat of flue gases

$T_g$ – Temp of flue gases

$T_a$ – Temp of air entering the boiler.

Heat carried away by the steam in flue gases:

$$Q_s = m_{s_1} (h_{s_1} - h_{f_1})$$

$m_{s_1}$ – Mass of steam formed per kg of fuel due to combustion of $H_2$ of fuel.

$h_{f_1}$ – Enthalpy of water at boiler house temp.

$h_{s_1}$ – Enthalpy of steam at the gas temp and partial pressure of steam vapour.

2. Heat lost due to incomplete combustion:-

The combustion is said to be incomplete if the carbon burns to CO instead of $CO_2$. One kg of carbon releases 10120 KJ of heat if it burns CO whereas it can release 33800 KJ/kg if it burns $CO_2$.

Heat lost/kg = 33800 – 10120 = 23680 KJ

The presence of CO in the flue gases indicates the incomplete combustion.

Mass of carbon burnt to CO = $(CO \times C)/(CO_2 + CO)$

These values are in % by its volume in flue gases.

C – fraction of carbon in one kg of fuel.

Heat lost due to incomplete combustion of Carbon per kg of fuel,

$$= [CO \times C / (CO_2 + CO)] \times 23680 \text{ kJ/kg of fuel}$$

* This losses can be reduced by supplying excess amount of air and giving a turbulent motion to air before it enters the furnace in order to help the mixing process.

3. Heat lost due to unburnt fuel.

$$Q = m_{f1} \times C$$

$m_{f1}$ - mass of unburnt fuel / kg of fuel.

4. Convection and Radiation Losses:-

The total convection and radiation losses = heat released per kg of fuel - heat lost by flue gases - heat carried away by steam - heat lost due to incomplete combustion - heat lost due to unburnt fuel.

# Problems.

(1) Exa 14.1 An oil fuel with a lower calorific value of 44700 kJ is burnt in a boiler with air fuel ratio as 20:1. Neglecting ash, calculate the maximum temperature attained in the furnace of the boiler. Assume that whole of the heat of combustion is given to the products of combustion and their average specific heat is 1.08. Take boiler room temperature as 38°C

Given:

L.C.V. of fuel = 44,700 kJ

Air fuel ratio = 20 : 1

Average specific heat, $C_{pg} = 1.08$ kJ/kgK

boiler temperature $T_1 = 38 + 273 = 311$ K

Solution:

Maximum furnace temperature attained, $T_2$ :-

since the whole heat is taken by the gases, therefore

Heat of combustion = Heat of gases

$$1 \times 44{,}700 = m_g \times C_{pg} \times (T_2 - T_1)$$

$$= (20+1) \times 1.08 \; (T_2 - 311)$$

$$T_2 = \frac{1 \times 44{,}700}{21 \times 1.08} + 311$$

$$T_2 = 2282 \text{ K (or) } 2009°C$$

(2) Exa 14.2 The steam used by the turbine is 5.4 kg/kWh at a pressure of 50 bar and a temperature of 350°C. The efficiency of boiler is 82 per cent with feed water at 150°C.

(i) How many kg of 28100 kJ coal are required/kWh

(ii) If the cost of coal/tonne is Rs 500. what is fuel cost / kWh?

(32) Given:

Mass of steam used $m_s = 5.4$ kg/kWh

$p = 50$ bar

$t_{sup} = 350°C$

$\eta_{boiler} = 82\%$

Feed water $T_{feed} = 150°C$

$C = 28{,}100$ kJ.

Coal cost/tonne = Rs 500

Solution:

(i) Coal required, kg/kWh:

$$\eta_{boiler} = \frac{m_s (h - h_{f1})}{m_f \times C}$$

$$m_f = \frac{m_s (h - h_{f1})}{\eta_{boiler} \times C}$$

From steam table,

At 50 bar and 350°C,

$h = 3068.4$ kJ/kg

At 150°C $h_{f1} = 627$ kJ/kg (or) $C_p T = 4.18 \times 150 = 627$ kJ/kg

$$m_f = \frac{5.4 \times (3068.4 - 627)}{0.82 \times 28{,}100}$$

$m_f = 0.572$ kg/kWh //

(ii) Fuel cost/kWh

$$= \frac{0.572}{1000} \times 500 = 0.286 \text{ Rs/kWh}$$

(or)

= 28.6 paisa/kWh

(3) 

In a boiler test 1250 kg of coal are consumed in 24 hours. The mass of water evaporated is 13000 kg and the mean effective pressure is 7 bar. The feed water temperature was 40°C, heating value of coal is 30,000 KJ/kg. The enthalpy of 1 kg of steam at 7 bar is 2570.7 kJ. Determine:

(i) Equivalent evaporation per kg of coal.

(ii) Efficiency of the boiler.

Given:-

Coal consumed in 24 hr. $(m_f) = 1250 kg$

$m_s = 13000 kg$

$p_{mean} = 7 bar$

$T_{water} = 40°C$

$C = 30,000 \text{ kJ/kg}$

at 7 bar → $h = 2570.7$

(i) Equivalent evaporation per kg of coal, $m_e = ?$

$$m_e = \frac{m_s (h - h_{f1})}{m_f \, h_{fg}} \text{ (or) } \frac{m_a (h - h_{f1})}{h_{fg}} \quad \text{--- (1)}$$

Mass of water actually evaporated per kg of fuel

$$m_a = \frac{m_s}{m_f} = \frac{13000}{1250} = 10.4 \text{ kg}$$

Heat required to produce 1kg of steam,

$$= (h - h_f) = 2570.7 - 4.18 \times 40 = 2403.5 \text{ kJ}$$

$\therefore$ (1) ⇒

$$m_e = \frac{10.4 \times 2403.5}{2257} = 11.075 \text{ kg}$$

(ii) Efficiency of boiler.

$$\eta_{boiler} = \frac{m_s (h - h_{f1})}{m_f \times C} = \frac{10.4 \times (2403.5)}{30000} = 0.833$$

(or)

83.3%

(34) (4) A steam generator evaporates 18000 kg/h of steam at 12.5 bar and a quality of 0.97 from feed water at 105°C, when coal is fired at the rate of 2040 kg/h. If the higher calorific value of the coal is 27400 kJ/kg.

Find: (i) The heat rate of boiler in kJ/h;

(ii) The equivalent evaporation;

(iii) The thermal efficiency.

Given:-

$m_s = 18000$ kg/h

$p = 12.5$ bar

$x = 0.97$

$T_{feed\ wat} = 105°C$

$m_f = 2040$ kg/h

$C = 27400$ kJ/kg

Solution:-

(i) Heat rate of boiler:

= Heat supplied per hour

$= m_s(h - h_{f1})$ — ①

At 12.5 bar,

$h = h_f + x h_{fg} = 806.7 + 0.97 \times 1977.4 = 2724.78$ kJ/kg

$h_f @ 105°C \rightarrow h_{f1} = 438.9$ kJ/kg

∴ ① Heat rate $= 18000(2724.78 - 438.9)$

$= 4.1146 \times 10^7$ kJ/h

(ii) Equivalent evaporation:

$$m_e = \frac{m_s}{m_f} \frac{(h - h_f)}{h_{fg}}$$

$$m_a = \frac{m_s}{m_f} = \frac{18000}{2040} = 8.823 \text{ kg of steam/kg of fuel}$$

$$m_e = \frac{8.823 \times (2724.78 - 438.9)}{2257} = 8.936 \frac{\text{kg of steam}}{\text{kg of fuel}}$$

(iii) Thermal efficiency $\eta_{thermal}$:

$$\eta_{thermal} = \frac{m_s(h - h_{f1})}{m_f \times C} = \frac{8.823 \times (2724.78 - 438.9)}{27400} = 0.73$$

$= 73.61$

(5) The following data refer to a boiler plant consisting of an economiser, a boiler and a superheater 

Mass of water evaporated per hour = 5940 kg, mass of coal burnt per hour = 675 kg, L.C.V of coal = 31600 kJ/kg pressure of steam at boiler stop valve = 14 bar, temperature of feed water entering the economiser = 32°C, temperature of feed water leaving the economiser = 115°C, dryness fraction of steam leaving the boiler and entering superheater = 0.96, temperature of steam leaving the superheater = 260°C, specific heat of superheated steam = 2.33. Determine

(i) percentage of heat in coal utilized in economiser, boiler and superheater

(ii) overall efficiency of boiler plant.

Given:-

Mass of water evaporated $m_s = 5940$ kg/hr

$m_f = 675$ kg/h

$C = 31600$ kJ/kg

$P_1 = 14$ bar

In $t_{e1} = 32°C$

out $t_{e2} = 115°C$

$x = 0.96$

$t_{sup} = 260°C$

$C_p = 2.33$ kJ/kg K.

Solution:-

Heat utilised by 1 kg of feed water in economiser.

$$h_{f1} = C_p T = 4.18(t_{e2} - t_{e1}) = 4.18(115-32) = 346.9 \text{ kJ/kg}$$

Heat utilised in boiler per kg of feed water,

$$h_{boiler} = (h_f + x h_{fg}) - h_{f1}$$

At 14 bar, $h_f = 830.1$ kJ/kg ; $h_{fg} = 1957.7$ kJ/kg ; $t_s = 195°C$

$$\therefore h_{boiler} = (830.1 + 0.96 \times 1957.7) - 346.9 = 2362.6 \text{ kJ/kg}$$

(36) Heat utilised in superheater by 1 kg of feed water,

$$h_{supheat} = (1-x) h_{fg} + C_p (T_{sup} - T_s)$$

$$= (1-0.96)\ 1957.7 + 2.3 (260-195)$$

$$= 227.8 \text{ kJ/kg}$$

$$m_a = \frac{m_s}{m_f} = \frac{5940}{675} = 8.8 \text{ kg}$$

(i) percentage of heat utilised in economiser,

$$= \frac{346.9}{31600} \times 8.8 = 0.0966 = 9.66\%$$

percentage of heat utilised in boiler

$$= \frac{2362.6}{31600} \times 8.8 = 0.657 = 65.7\%$$

percentage of heat utilised in superheater

$$= \frac{227.8}{31600} \times 8.8 = 0.0634 = 6.34\%$$

(ii) $\eta_{overall}$ :-

Total heat absorbed in kg of water.

$$= h_{f_1} + h_{boiler} + h_{super\ heater}$$

$$= 346.9 + 2362.6 + 227.8$$

$$= 2937.3 \text{ kJ/kg}$$

$$\eta_{overall} = \frac{8.8 \times 2937.3}{31600} = 0.8179$$

$$= 81.79\%$$

# Unit-III Steam turbines

Types, Impulse and Reaction principles, velocity diagrams, work done and efficiency - optimal operating conditions Multi staging, compounding and governing

1. What is steam turbine? State the advantages of using steam turbine over steam engine.

*) Steam turbine is a device which is used to convert the kinetic energy of steam into mechanical energy

*) In this, enthalpy of steam is first converted into kinetic energy in nozzle or blade passages.

*) The high velocity steam impinges on the curved blades and its direction of flow is changed.

*) It causes a change of momentum and thus the force developed drives the turbine shaft.

*) Nowadays, a single steam turbine of 1000 MW capacity is built in many countries.

*) Large sizes are used for driving electric generators.

*) Small one are used to drive pumps, fans and compressors etc.

Advantages:-

1. High thermal efficiency

2. Torque developed is uniform and the rate of power generation is uniform.

3. Much high speed output is possible

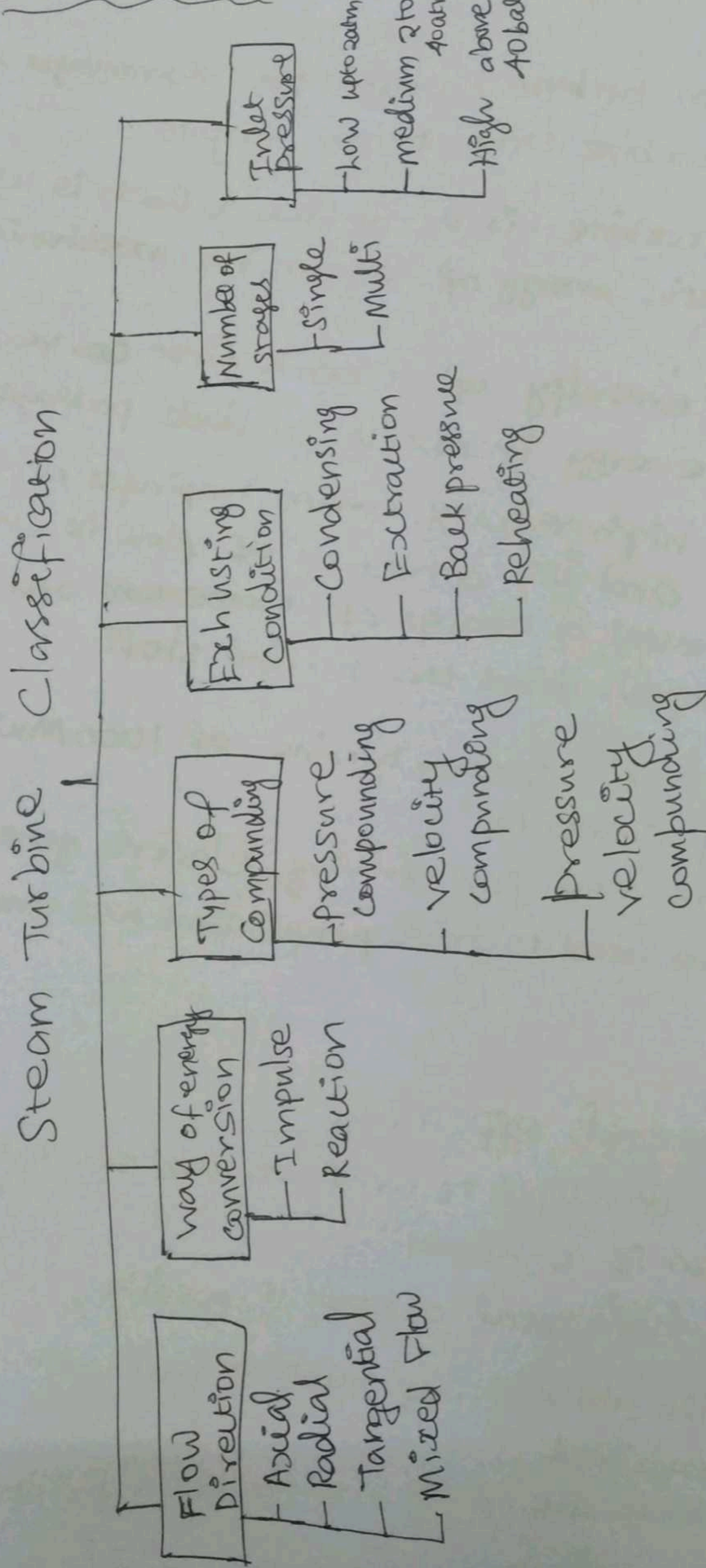
4. Since the absense of rubbing parts no internal lubrication is required.

5. Since there are fewer sliding parts, frictional loss is less

② 6. since the absense of reciprocating parts the balancing problem is less.

7. A single unit can be designed for 1000 MW output.

Classification:-



Explain the working principle of Impulse Turbine:- ③

*) The impulse turbine consists of one set of nozzle followed by one set of moving blades.

*) A rotor is mounted on a shaft

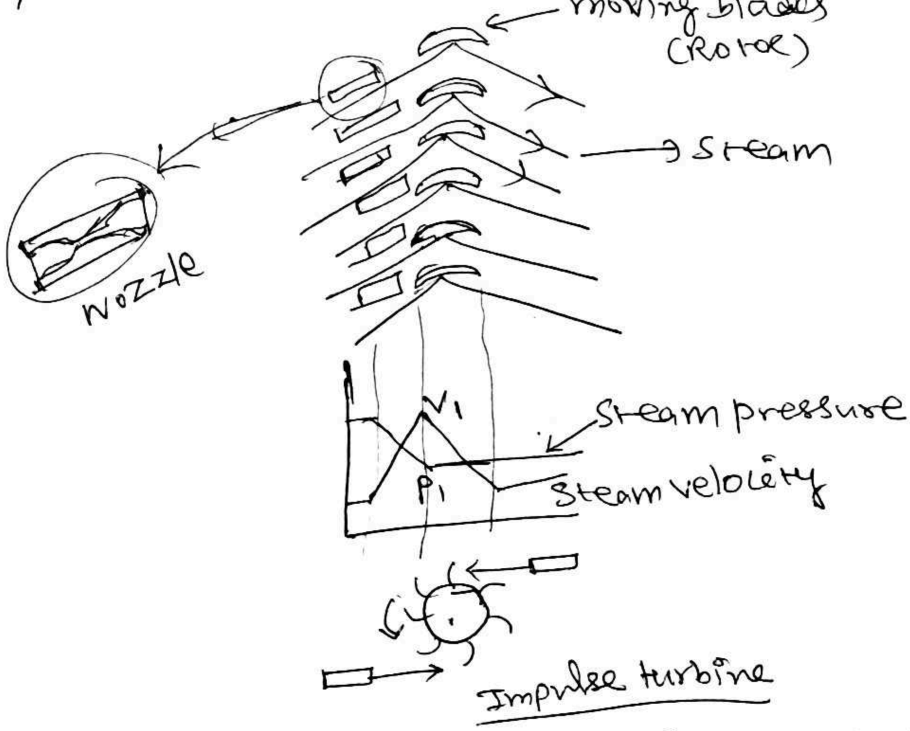
*) The moving blades are attached to the rotor.

*) The steam from the boiler at high pressure and low velocity enters the nozzle which is fitted in the casing

*) The steam expands in the nozzle where the pressure drops to $p_1$ and the velocity increases to $V_1$.

*) The high velocity steam jet impinges over the blades mounted on the rotor attached to the shaft.

*) It causes the rotation of the turbine shaft and thus, the useful work is obtained.




Impulse turbine

Explain the working principle of Reaction turbine.

* The reaction turbine consist of many sets of moving and fixed blades.

* The moving blades are mounted on a drum, the fixed blades are fixed to the casing

* In reaction turbine there is no sudden pressure drop. There is a gradual pressure drop and takes places continously over the fixed and moving blades.

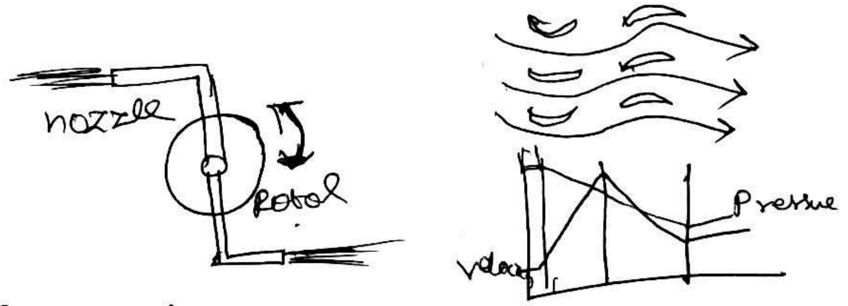
(4) *) Fixed guideways are provided in between a pair of rotating wheels as fixed blades.

*) The function of fixed blades is that they guide the steam as well as allow it to escpand in a larger velocity. It is similar to nozzle in impulse turbine

*) when the high pressure steam enters the reaction turbine, it first passes through a row of guide blades where it escpands slightly hence fall of pressure and increases in velocity.

*) Then this steam is passed over moving blades, where the steam further escpands results in a high relative velocity in a direction opposite to the movement of the blades, thus exerting a force due to reaction.

*) The reaction turbines work due to the energy transfer takes place through the rotor blades. Pressure reduction and rise in kinetic energy takes place when the fluid flows through the fixed blades.




Functions of Fixed blade and moving blades:

*) Fixed blades guide the steam as well as allow it to expand in a larger velocity. It is similar to nozzles as in the case of impulse turbine.

*) Moving blades converts the kinetic energy of the steam into useful mechanical energy

*) The steam escpands while flowing over moving blades and thus, it gives reaction to moving blades.

*) The velocity of the Steam decreases as the kinetic energy of steam is absorbed while steam passing through the moving blades.

Q) Difference between Impulse turbine and Reaction turbine.

| S. NO | Impulse Turbine | Reaction Turbine |
|---|---|---|
| 1. | It consists of nozzles and moving blades | It consists of fixed blades and moving blades. |
| 2. | pressure drop occurs only in nozzles not in moving blades | Pressure drop occurs in fixed as well as moving blades |
| 3. | Steam strikes the blade with Kinetic energy | Steam passes over the blades with pressure and Kinetic energy |
| 4. | It has constant blade channels area | It has varying blade channels area |
| 5. | Due to more pressure drop per blade, the number of stages required is less | Number of stages required is more due to more pressure drop |
| 6. | Less Floor space is required | More floor space is required |
| 7. | Efficiency is Less | Efficiency is high. |

Q) What is meant by compounding and what is the need for it?

*) Compounding is a method used to reduce the kinetic energy loss at the exit of turbine and to reduce the speed of rotor.

*) Compounding is a method of absorbing the jet velocity in more than one stage when steam flows over moving blades.

(6)

## The need of compounding :-

*) In Impulse turbine, the steam is expanded from the boilee pressure to the condense pressure in one stage only. Hence the speed of the rotor becomes very high (30,000 rpm) which is not suitable for pratical purposes.

*) Velocity of blade is limited to about 400 m/s. This gives rise to considerable loss of Kinetic energy (10% to 12%) and thus reducing the efficiency of the turbine.

*) To reduce the rotor speed and to make use of kinetic energy fully compounding is employed. Compounding is one such a method of reducing the rotor speed. The common methods of compoundings are employed are

1) velocity compounding
2) pressure compounding
3) pressure-velocity compounding

## Governing of steam Turbines:-

* All turbines are designed to run at a particular constant speed.

* Practically, load varies with respect to time. This results in a change in speed.

* In order to maintain the constant speed, the flow rate of steam may be varied.

* This is called governing of steam turbine.

* The main objective of governing is to maintain the turbine speed constant irrespective of load variation by varying the flow rate.

## Methods of Governing:-

1. Throttle governing
2. Nozzle control governing
3. By-pass governing
4. Combination of Throttle and nozzle governing
5. Combination of Throttle and By-pass governing

## Velocity compounding in Impulse Turbine:-

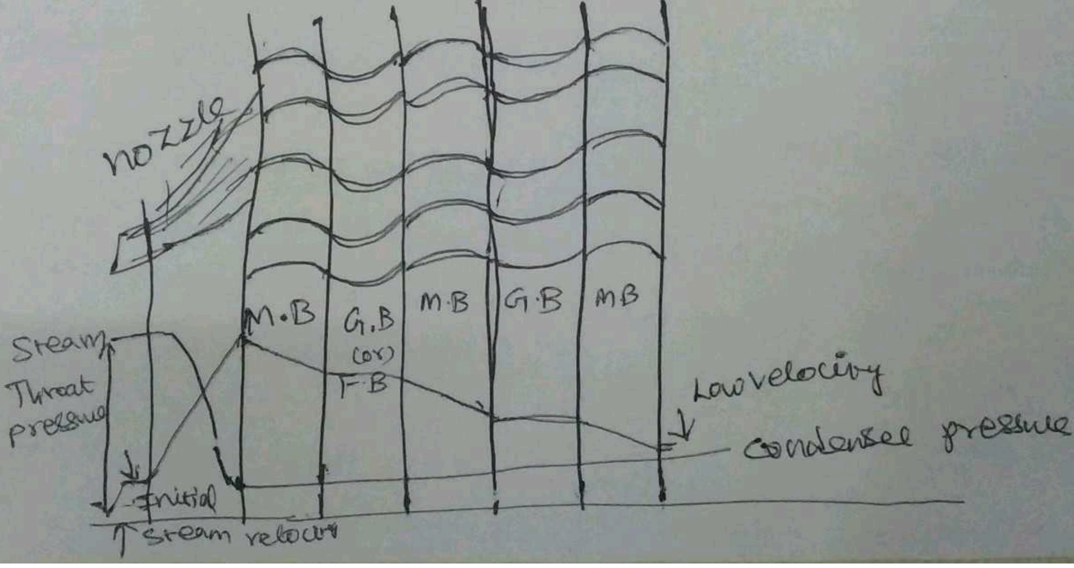
1. Construction.
2. Working
3. Advantages & Disadvantages.

### 1. Construction:-

*) In this method, there are a numbers of moving blades (MB) seperated by rings of fixed blades (FB) keyed in series on a common shaft.

*) It is composed of one stage of nozzle as in the single-stage turbine.

*) nozzle is followed by two rows of moving blades instead of one. These two rows are seperated by one row of fixed blades attached to the turbine stator, which has the function of redirecting the steam leaving the first row of moving blades to the second row of moving blades.



(8) Working of velocity compounding:-

*) The steam from the boiler is passed through the row of nozzles and there it attain high velocity *) The high velocity steam jet then passes over the rings of moving blades and fixed blades alternatively

*) A part of the kinetic energy is absorbed in each ring of moving blades.

*) The direction of steam is changed without altering much its velocity in the rings of fixed blades

*) Thus, the whole kinetic energy is utilized in moving blades

*) The pressure drops fully at the nozzle itself and pressure remains constant in moving blades and fixed blades *) The velocity of steam is constant while passing through fixed blades.

*) Hence, it is known as 'velocity compounding'.

Advantages:-

1. It initial cost is less because of few number of stages

2. Less space is required.

3. The system is reliable and easy to start

4. There is no need of strong casing due to low pressure

Disadvantages:-

1. Frictional losses are high due to high initial velocity Hence, the efficiency is low.

2. The ratio of blade velocity to steam velocity is not optimum for all wheels. It also reduces the efficiency.

3. The power developed in later rows is only a fraction of the power developed in the first row

Application:-

Since the efficiency of this type is low, three rows of wheels are used for driving small machines

# Pressure compounding in Turbine

## Construction:-

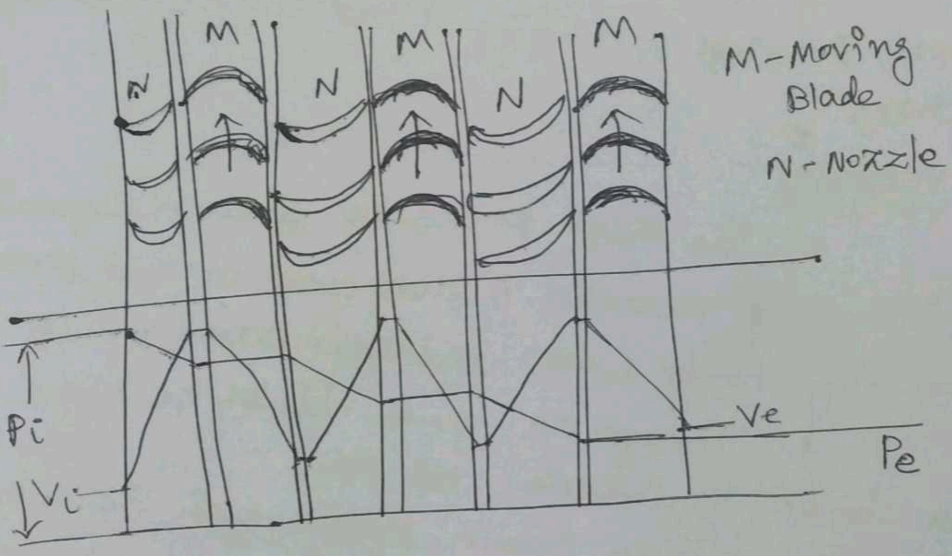
*) The arrangement consists of number of simple impulse turbines in series mounted on a common shaft

*) The exit steam from one turbine is made to enter the nozzle of the succeeding turbine.

*) Each of the simple impulse turbines would then be termed as "stage" of the turbine.

*) Each of these stage consists of one set of nozzle (FN) and one row of moving blades (MB).

*) The exhaust from each row of moving blades enters the succeeding set of nozzles




## Working:-

* The steam from boiler is passed through nozzles and moving blades

* The steam velocity increases when it passes through nozzles and the pressure gets dropped.

* The steam velocity decreases without much alteration in the pressure as it flows over the moving blades

* Finally, the pressure falls down to the condenser pressure

* Both the pressure and velocity vary while the steam flows through the fixed nozzle and moving blades.

* The pressure reduced in each stage of nozzle rings and hence, it is called "pressure compounding".

Advantages:

1. speed ratio remains constant
2. Most efficient method.

Disadvantage:

1. process is expensive

Pressure-velocity compounding:

Construction:

* This method is the combination of both pressure and velocity compounding.

* A nozzle rings is fixed at the begining of each stage.

* Each stage consists of rings of fixed and moving blades.

* If each stage there is one ring of fixed nozzles and 3-1 rings of moving blades with fixed blades between them.

Working:

*) The high pressure steam expands through the first ring nozzles, it does work on the first row of moving blades (MB) and then enters guide-blades.

*) Through the guide blades, the steam comes out with a change in direction of flow

*) Then the steam flows through the second row of moving blades where it does work.

*) The remaining reduction of pressure up to condensee pressure takes place in the second set of nozzle and the process of doing work is on the second set of moving and guide blade and is continued.

*) Thus, the total pressure drop is obtained in stages through nozzles sets and velocity changes take place through moving blades.

Advantages:

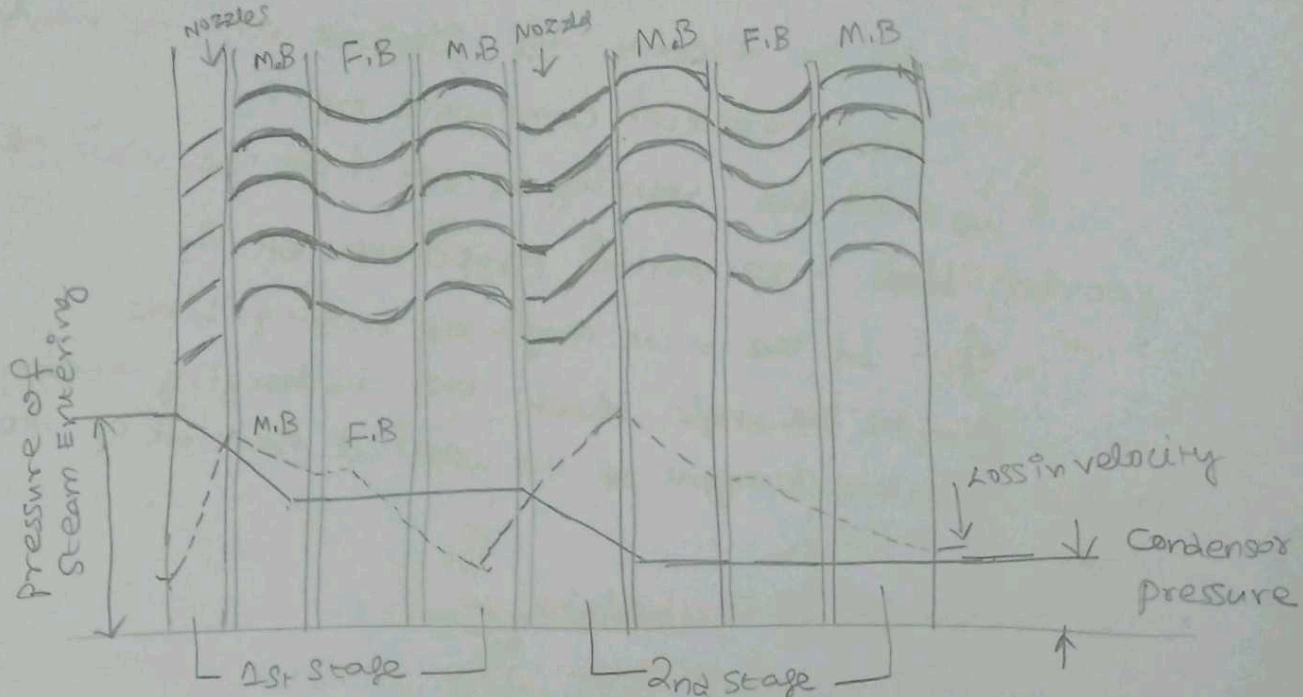
*) This method allows a bigger pressure drop in each stage and consequently less stages are necessary

* ∴ A Shorter or more compact turbine will be obtained for a given pressure drop.

* It is comparatively simple in construction and is more compact than the multi stage pressure compounded impulse turbine.

Disadvantages:-

* The efficiency is not so high

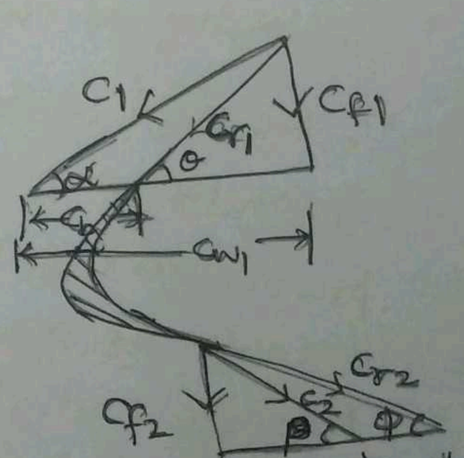



Q Describe the velocity diagram for Impulse turbine.

Let,

$C_1$ - be the absolute velocity of steam entering the moving blade

$C_{r1}$ - be the relative velocity of jet at entrance of moving blades.




$C_b$ - be the linear velocity of moving blades

$C_{f1}$ - be the velocity of flow at entrance of moving blade - axial component of $C_1$

$C_{w1}$ - be the velocity of whirl at the entrance of moving blade - tangential component of $C_1$

$\alpha$ - be the angle with the tangent of the wheel at which the steam with velocity $C_1$ enters. This is also called nozzle angle

(12) $\theta$ - be the entrance angle of moving blade.

Let,

$C_2$ - be the absolute velocity of steam leaving the moving blade.

$C_{r2}$ - be the relative velocity of jet at exit of moving blade.

$C_b$ - be the lineal velocity of moving blade

$C_{f2}$ - be the velocity of flow at exit of moving blade - axial component of $C_2$.

$C_{w2}$ - be the velocity of whirl at the exit of moving blade - tangential component of $C_2$.

$\phi$ - be the exit angle of moving blade

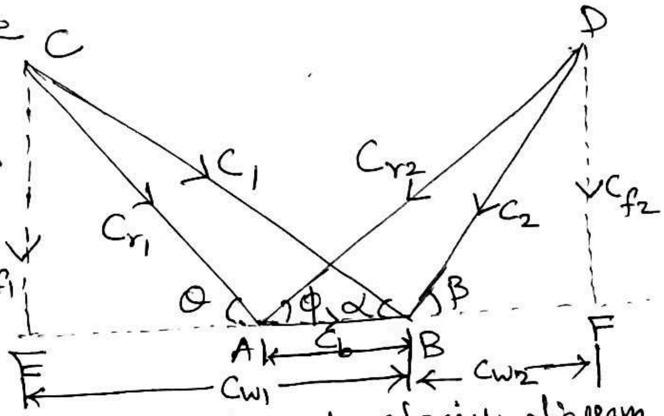
$\beta$ - be the angle which the discharging steam makes with the tangent of the wheel at the exit of moving blade.

*) The steam jet with absolute velocity $C_1$ impinges on the moving blade at angle of $\alpha$.

*) The tangential component of this jet ($C_{w1}$) performs work on the blade is called velocity of whirl ($C_{w1}$)

*) The axial component of velocity $C_{f1}$ of the jet $C_1$ - doesnot produce work on the blade, but it causes the steam to flow through the turbine. This component is known as velocity of flow ($C_{f1}$)

*) The velocity of flow $C_{f1}$ causes an axial thrust on rotor.




Combined velocity diagram

* when there is no friction

$C_{r1} = C_{r2}$ ; $\theta = \phi$ and $C_{f1} = C_{f2}$

Important formula used in Steam Turbines.

1. Workdone on blades (W):-

The work is done on blades by the velocity of whirl which produces tangential force on blades.

By newton's Second Law of motion,

Tangential force on the wheel } = Mass of Steam × Acceleration

= Mass of Steam/s × change of velocity

i.e., Driving force $F_x = m(C_{w1} + C_{w2})$

The value of $C_{w2}$ is negative as the steam is discharged in the opposite direction.

Work done on blades/s = Force × distance travelled.

$= m(C_{w1} + C_{w2}) C_b$

i.e, power developed per wheel $\boxed{P = m(C_{w1} + C_{w2}) C_b}$

The avilable energy of steam entering the blade ] $= \frac{mC_1^2}{2}$

2. Efficiency of the blade (or) Blade efficiency } $\eta_b = \frac{\text{work done on the blade}}{\text{Energy Supplied to the blade}}$

i.e, $\eta_b = \frac{m(C_{w1} + C_{w2})C_b}{\frac{mC_1^2}{2}} = \frac{2C_b(C_{w1} + C_{w2})}{C_1^2}$

This also known as 'Diagram efficiency'

3. Stage efficiency: $\eta_{stage}$

If $h_1$ & $h_2$ are the total enthalpy before & after expansion through the nozzle, then $(h_1 - h_2)$ is the heat drop in the nozzle ring.

$$\eta_{stage} = \frac{\text{Work done on the blade}}{\text{Total energy supplied per stage}} = \frac{C_b(C_{w1} + C_{w2})}{h_1 - h_2}$$

$\eta_{stage}$ can also given by $\boxed{\eta_{stage} = \text{Blade efficiency} \times \text{nozzle efficiency}}$

(14)

P-1 A simple impulse turbine has one ring of moving blades running at 150 m/s. The absolute velocity of steam at exit from the stage is 85 m/s at an angle of 80° from the tangential direction. Blade velocity coefficient is 0.82 and the rate of steam flowing through the stage is 2.5 kg/s. If the blades are equiangular, determine the (i) blade angles (ii) nozzle angle (iii) absolute velocity of steam issuing from the nozzle and (iv) axial thrust.

Given data:-

$C_b = 150\ m/s$

$C_2 = 85\ m/s$

$\beta = 80°$

$\frac{C_{r2}}{C_{r1}} = 0.82$

$\dot{m} = 2.5\ kg/s$

Blade angles $\phi = \theta$

To find:-

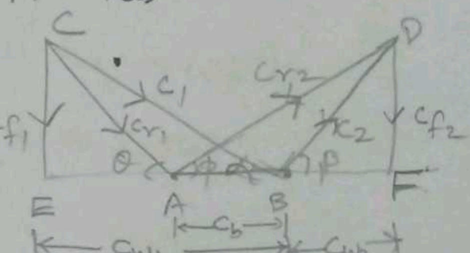
i) Blade angle $\phi = \theta = ?$

ii) nozzle angle $\alpha =$

iii) Absolute velocity at entry $C_1$

iv) Axial thrust $F_y$

$F_y = m(C_{f1} - C_{f2})\ \cdot N$




Scale:- 1 cm = 30 m/s.

$C_b = \frac{150 m/s}{30 m/s} = 5\ cm = AB$

$C_2 = \frac{85 m/s}{30 m/s} = 26.6 mm = BD$

$C_{r2} = 6.1\ cm$ measured $= 6.1 \times 30 = 183\ m/s.$

measured $\phi = \theta = 27°.$

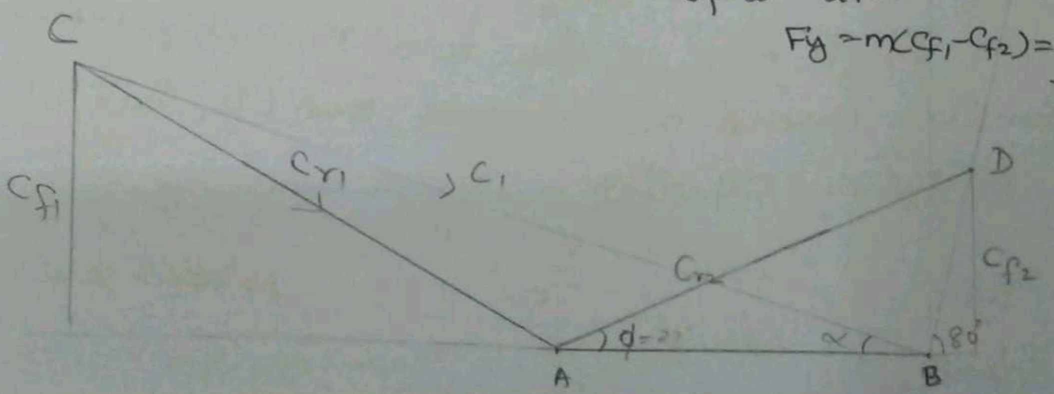
$\frac{C_{r2}}{C_{r1}} = 0.82;\ \therefore C_{r1} = \frac{183}{0.82} = 225.61\ m/s$

$C_{r1} = \frac{225.61}{30} = 7.53\ cm$

$C_{f1} = 3.4\ cm \times 30 = 102\ m/s$

$C_{f2} = 2.8 \times 30 = 84\ m/s$

$F_y = m(C_{f1} - C_{f2}) = 2.5(102 - 84) = 45\ N$



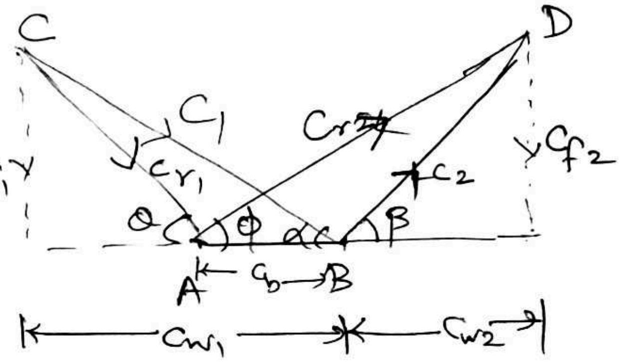

$\alpha = 19°$

$C_1 = 12.2 \times 30$

$C_1 = 366\ m/s$

P-2 In a De Laval turbine steam issues from the nozzle with a velocity of 1200 m/s. The nozzle angle is 20°, the mean blade velocity is 400 m/s and the inlet and outlet angles of blades are equal. The mass of steam flowing through the turbine per hour is 1000 kg. Calculate (i) blade angles (ii) relative velocity of steam entering the blades (iii) tangential force on the blades (iv) power developed (v) blade efficiency. Take blade velocity coefficient as 0.8. (15)

Given :-  Impulse turbine




$C_1 = 1200\ m/s$

$\alpha = 20^\circ$

$C_b = 400\ m/s$

$\theta = \phi$

$m = 1000\ kg/hr = 0.278\ kg/s$

$\frac{C_{r2}}{C_{r1}} = 0.8$

To find:-

(i) Blade angles $\phi = \theta = ?$

(ii) Entry relative velocity $C_{r1} =$

(iii) Tangential force $F_x = m(C_{w1} + C_{w2})$

(iv) power developed

(v) $\eta_{blade}$

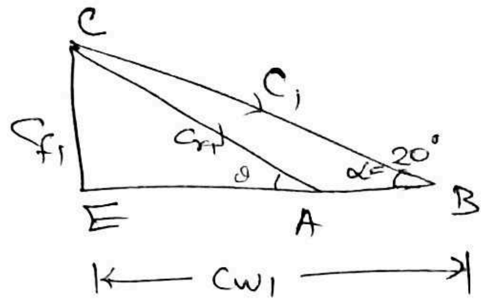
Formulas used:

(iv) $P = m\, C_b (C_{w1} + C_{w2})$

(v) $\eta_{blade} = \frac{2(C_{w1} + C_{w2})}{C_1^2} \times C_b$

(16)

Solution:-




$C_{w1} = C_1 \cos\alpha \quad [\because \cos\alpha = \frac{EB}{CB}]$

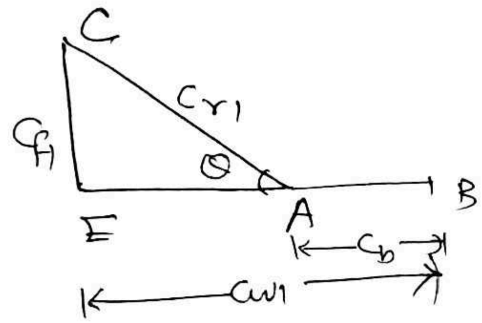
$= 1200 \times \cos 20°$

$C_{w1} = 1127.63 \ m/s$

$C_{f1} = C_1 \sin 20$

$= 1200 \times \sin 20°$

$C_{f1} = 410.42 \ m/s$




$\tan\theta = \frac{CE}{EA}$

$= \frac{C_{f1}}{C_{w1} - C_b}$

$= \frac{410.42}{1127.63 - 400}$

$\boxed{\theta = 29.425}$ //

$\cos\theta = \frac{EA}{CA} = \frac{C_{w1} - C_b}{C_{r1}}$

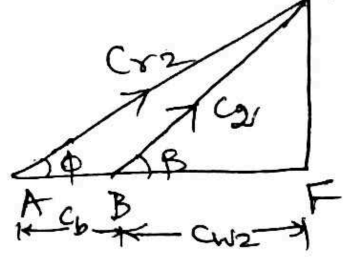
$\therefore C_{r1} = \frac{C_{w1} - C_b}{\cos\theta} = \frac{1127.63 - 400}{\cos 29.425}$

$\boxed{C_{r1} = 835.36 m/s}$ //

$\frac{C_{r2}}{C_{r1}} = 0.8$

$\therefore C_{r2} = 0.8 \times C_{r1} = 0.8 \times 835.36$

$C_{r2} = 668.29 \ m/s$




$\cos\phi = \frac{AF}{AD} = \frac{C_b + C_{w2}}{C_{r2}}$

$\cos 29.425 = \frac{400 + C_{w2}}{668.29}$

$\therefore C_{w2} = 182.08 \ m/s$

$F_x = m(C_{w1} + C_{w2})$

$= 0.278\,(1127.63 + 182.08)$

$\boxed{F_x = 364.09\,N}$ //

$P = mC_b(C_{w1} + C_{w2}) = C_b \times F_x$

$= 400 \times 364.09$

$\boxed{P = 145.64\,KW}$ //

$$\eta_b = \frac{2(C_{w1} + C_{w2}) \times C_b}{C_1^2}$$

$$= \frac{2(1127.63 + 182.08)\,400}{1200^2}$$

$\boxed{\eta_b = 72.76\%}$

P-3 The nozzle of a De Laval turbine deliver 1.5 kg/s of steam of 800m/s to a ring of moving blades having a speed of 200m/s. The exit angle of the nozzle is 18°. If the blade velocity coefficient is 0.75 and the exit angle of the moving blades is 20°. Calculate the (i) Inlet angle of moving and fixed blades (ii) diagram efficiency (iii) energy lost in blades per second (iv) power developed and (v) axial thrust on the turbine rotor.

Given Data:-

$\dot{m} = 1.5\,kg/s$

$C_1 = 800\,m/s$

$C_b = 200\,m/s$

$\alpha = 18°$

$\frac{C_2}{C_1} = 0.75$

$\phi = 20°$

Find:-

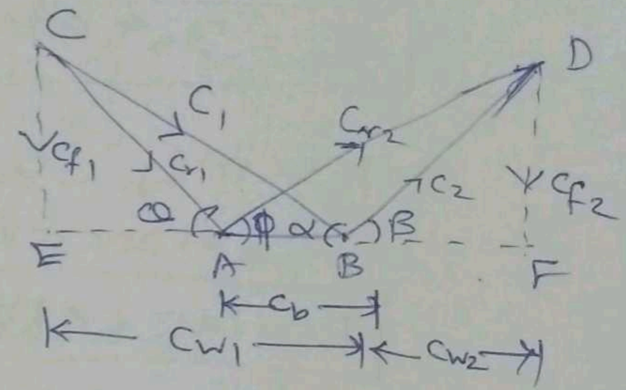
i) $\theta$

ii) $\eta_D$

iii) Energy lost in friction

iv) power developed

v) Axial thrust




Formula to be used:-

i) $\tan\theta = \dfrac{C_{f1}}{C_{w1} - C_b}$

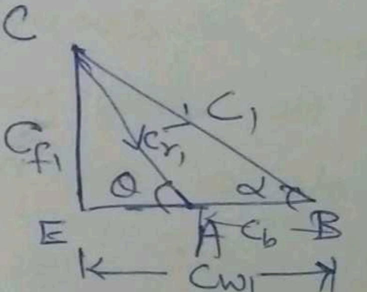
ii) $\eta_D = \dfrac{2(C_{w1} + C_{w2})\, C_b}{C_1^2}$

iii) Energy lost by friction $= \dfrac{m(C_{r1}^2 - C_{r2}^2)}{2}$

iv) power $P = m(C_{w1} + C_{w2}) \times C_b$

v) Axial thrust $F_y = m(C_{f1} - C_{f2})$

Solution:-




$\triangle$ CBE,

$\sin\alpha = \dfrac{C_{f1}}{C_1}$

$C_{f1} = C_1 \sin\alpha$

$= 800 \sin 18^\circ$

$\boxed{C_{f1} = 247.21\ m/s}$

$C_{w1} = C_1 \cos\alpha$

$= 800 \cos 18^\circ$

$\boxed{C_{w1} = 760.85\ m/s}$

$\triangle$ CEA,

$\tan\theta = \dfrac{C_{f1}}{C_{w1} - C_b}$

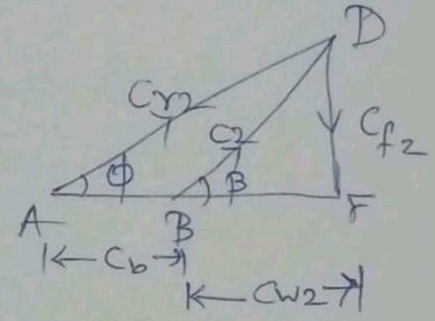
$\tan\theta = \dfrac{247.21}{760.85 - 200}$

$\boxed{\theta = 23.47^\circ}$ //

$$C_{r_1} = \sqrt{C_{f_1}^2 + (C_{w_1} - C_b)^2}$$

$$= \sqrt{247.21^2 + (760.85 - 200)^2}$$

$$\boxed{C_{r_1} = 612.92 \text{ m/s}}$$




$\triangle$ DAF,

$$\cos\phi = \frac{C_b + C_{w2}}{C_{r2}}$$

$$\frac{C_{r2}}{C_{r1}} = 0.75$$

$$C_{r2} = 0.75 \times 612.92$$

$$\boxed{C_{r2} = 459.69 \text{ m/s}}$$

$$\cos 23.47 = \frac{C_{w2} + 200}{459.69}$$

$$\therefore \boxed{C_{w2} = 231.97 \text{ m/s}}$$

$$\sin\phi = \frac{C_{f2}}{C_{r2}}$$

$$C_{f2} = \sin 23.47 \times 459.69$$

$$\boxed{C_{f2} = 157.22 \text{ m/s}}$$

$$\eta_D = \frac{2(C_{w1} + C_{w2}) \cdot C_b}{C_1^2}$$

$$= \frac{2(760.85 + 231.97)\,200}{800^2}$$

$$\boxed{\eta_D = 62.05\%}$$ //

$$\text{Energy lost by friction} = \frac{m(C_{r1}^2 - C_{r2}^2)}{2}$$

$$= \frac{1.5(612.92^2 - 459.69^2)}{2}$$

$$\boxed{\text{friction loss} = 123.27 \text{ kW}}$$

power $P = m(C_{w1} + C_{w2}) C_b$

$= 1.5(760.85 + 231.97)\,200$

$\boxed{P = 297.85\ kW}$ //

Axial thrust

$F_y = m(C_{f1} - C_{f2})$

$= 1.5(247.21 - 157.22)$

$\boxed{F_y = 134.99\ kW}$

P-4

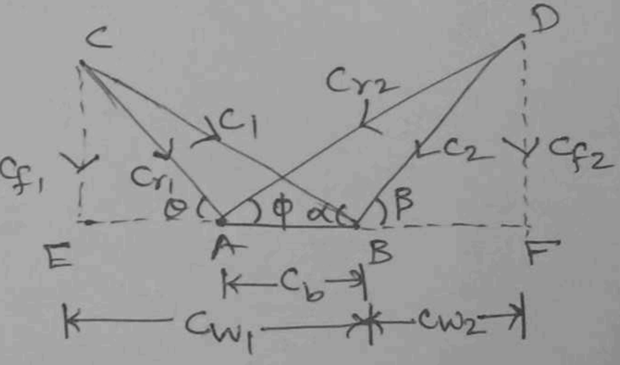
The angles at Inlet and discharge of the blading of a 50% reaction turbine are 20° and 35° respectively. The speed of rotation is 1600 rpm and at a particular stage, the mean ring diameter is 0.72 m and the steam condition is at 1.8 bar, 0.98 dry. Estimate (a) the required height of blading to pass 4.2 kg/s of steam and (b) the power developed by the ring.

Given data:-

50% Reaction Turbine

$\therefore \alpha = \phi$ & $\theta = \beta$;

$C_{f1} = C_{f2}$ & $C_{r1} = C_2$




$\alpha = \phi = 20°$

$\theta = \beta = 35°$.

$N = 1600\ rpm$

$D = 0.72\ m$

$P_1 = 1.8\ bar$

$x = 0.98$

$m = 4.2\ kg/s$

To find:-

i) Blade height h in m

ii) power developed P in kW.

Formula to be used:

$$C_b = \frac{\pi D N}{60} \text{ m/s}$$ ← Linear velocity formula. Emech.

Lamis theorem:

$$\frac{C_1}{\sin\theta_1} = \frac{C_b}{\sin\theta_2} = \frac{C_{r1}}{\sin\theta_3}$$

$$m = \frac{\pi d h C_f}{x v_g}$$

$\pi d h$ → volume, $C_f$ → velocity, $x v_g$ → density

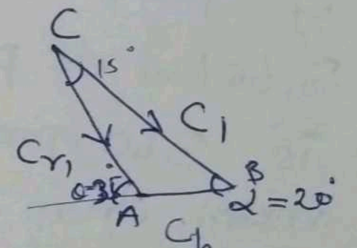
$$P = m(C_{w1}+C_{w2}) \cdot C_b$$

Solution:-

$$C_b = \frac{\pi D N}{60} = \frac{\pi \times 0.72 \times 1600}{60}$$

$$= 60.32 \text{ m/s}$$

$\Delta ABC$,




$$\frac{C_1}{\sin 145^\circ} = \frac{C_{r1}}{\sin 20^\circ} = \frac{C_b}{\sin 15^\circ}$$

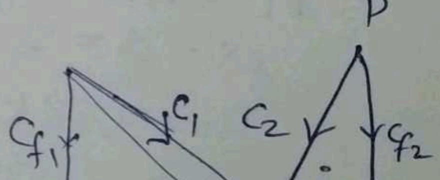
$$C_1 = \frac{C_b}{\sin 15^\circ} \times \sin 145^\circ$$

$$= 60.32 \times \frac{\sin 145}{\sin 15} = 133.68 \text{ m/s}$$

$$C_{r1} = \frac{60.32}{\sin 15^\circ} \times \sin 20^\circ = 79.71 \text{ m/s}$$

$$C_{r1} = C_2 = 79.71 \text{ m/s}$$

$\Delta DBF$,




$$C_{w2} = \cos 35^\circ \times C_2$$

$$= \cos 35^\circ \times 79.71$$

$$= 65.29$$

$$C_{w1} = C_1 \cos\alpha = 133.68 \cos 20^\circ$$

$$\therefore C_{w1} + C_{w2} = 133.68 \cos 20^\circ + 65.29 = 190.91 \text{ m/s}$$

$$C_{f1} = \sin\alpha\, C_1 = \sin 20^\circ \times 133.68 = 45.721 \text{ m/s}$$

From steam table, For 1.8 bar,

$$v_g = 0.977 \text{ m}^3/\text{kg}$$

(23)

$$4.2 = \dot{m} = \frac{\pi h d . C_{f_1}}{x . v_g} = \frac{\pi h \times 0.72 \times 45.72}{0.98 \times 0.977}$$

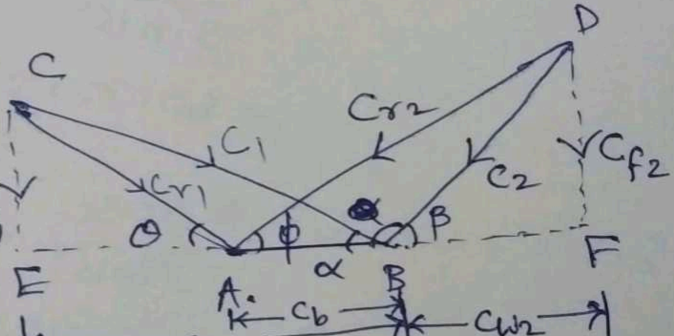
$$\therefore \boxed{h = 0.0388\,m = 38.8\,mm}$$

$$P = m(C_{w_1} + C_{w_2}) C_b$$

$$= 4.2 \times 190.91 \times 60.32$$

$$\boxed{P = 48.37\,kW}$$

P-5 300 kg/min of steam (2 bar, 0.[illegible]8 dry) flows through a given stage of a reaction turbine. The exit angles of fixed blades and moving blades are 20° and 3.68 kW of power is developed. If the rotol speed is 360 rpm and tip leakage is 5%, calculate the mean drum diameter and blade height. The axial flow velocity is 0.8 times the blade velocity.




Given data:-

$$\dot{m} = 300\,kg/min$$

$$= \frac{300}{60} = 5\,kg/s$$

$P_1 = 2$ bar & $x = 0.$[illegible]$8$

$\alpha = \phi = 20°$

$P = 3.68\,kW = 3680\,W$

$N = 360\,rpm$

Tip ~~clearance~~ Leakage $= 5\%$

$$\frac{C_{f1}}{C_b} = \frac{C_{f2}}{C_b} = 0.8$$

To find:-

Mean Drum Dia $D_M$

Height of blade $h$.

Formula to be use:

~~$\tan\phi = \frac{C_{f2}}{C_b + C_{w2}}$~~

$$P = \dot{m}(C_{w1} + C_{w2})C_b.$$

$$C_b = \frac{\pi D_m N}{60}$$

$$\dot{m} = \frac{\pi D_m h C_{f}}{x \cdot v_g}$$

Solution:-

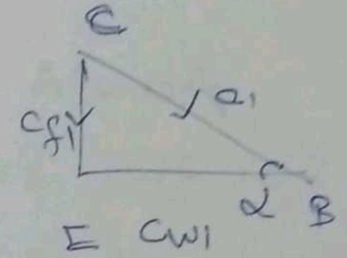
$\Delta CEB$,

$$C_{f1} = \sin\alpha \cdot C_1 = \sin 20\, C_1$$

$$C_{f1} = 0.34 C_1 = C_{f2}$$

$$C_{w1} = \cos\alpha\, C_1 = \cos 20^\circ\, C_1$$

$$C_{w1} = 0.94 C_1$$



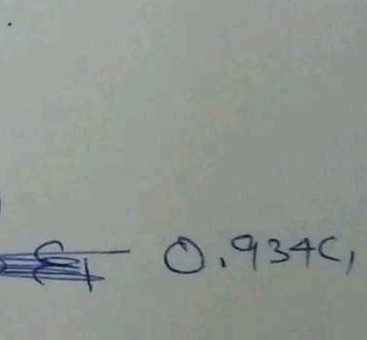

$$\frac{C_{f1}}{C_b} = 0.8 \quad \therefore C_b = \frac{C_{f1}}{0.8}$$

$$C_b = \frac{0.34 C_1}{0.8} = 0.43 C_1$$

In $\Delta DAF$,

$$\tan\phi = \frac{C_{f2}}{C_{w2} + C_b}$$

$$\tan 20^\circ = \frac{C_{f2}}{C_{w2} + C_b}$$




$$\therefore C_{w2} + C_b = \frac{C_{f2}}{\tan 20^\circ} = \frac{0.34 C_1}{\tan 20^\circ}$$

$$C_{w2} + C_b = 0.934 C_1$$

$$C_{w2} + 0.43 C_1 = 0.934 C_1$$

$$C_{w2} = 0.505 C_1.$$

$$P = \dot{m}(C_{w1} + C_{w2})C_b$$

(24)

$$3680 = 5[0.94C_1 + 0.505C_1]\,0.43C_1$$

$$3.106C_1^2 = 3680$$

$$C_1 = \sqrt{\frac{3680}{3.106}} = 34.42 \text{ m/s}$$

$$C_b = 0.43 \times C_1 = 0.43 \times 34.42 = 14.8 \text{ m/s}$$

$$C_{f2} = C_{f1} = 0.34C_1 = 0.34 \times 34.42 = 11.8 \text{ m/s}$$

$$C_b = \frac{\pi D_m N}{60} \; ; \; 14.8 = \frac{\pi D_m 360}{60}$$

$$\boxed{D_m = 0.79 \text{ m}}$$

$$\text{Actual } \dot{m} = 5 \times 0.95 = 4.75 \text{ kg/s}$$

For 2bar from sream table.

$$v_g = 0.8854 \text{ m}^3/\text{kg}$$

$$m = \frac{\pi D_m h C_{f4}}{x \cdot v_g}$$

$$4.75 = \frac{\pi \times 0.79 \times h \times 11.8}{0.8 \times 0.8854}$$

$$\therefore h = 0.1145 \text{ m}$$

$$\boxed{h = 114.5 \text{ mm}}$$

# ME 8595-THERMAL ENGINEERING II

## UNIT- IV COGENERATION AND WASTE HEAT RECOVERY

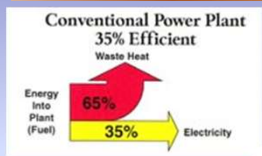
## CONTENTS

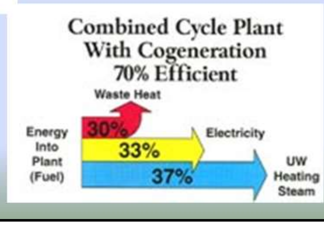
- Cogeneration Principles,
- Cycle Analysis, Applications,
- Source and utilization of waste heat Systems,
- Heat exchangers, Economic Analysis.

## COGENERATION

- A cogeneration system is the sequential or simultaneous generation of multiple forms of useful energy (usually mechanical and thermal) in a single, integrated system.
- Cogeneration systems are also called as **CHP- Combined Heat and Power Cycle. Also Tri-generation Cycle ( Combined Power, Heat and Cooling)**

## COGENERATION

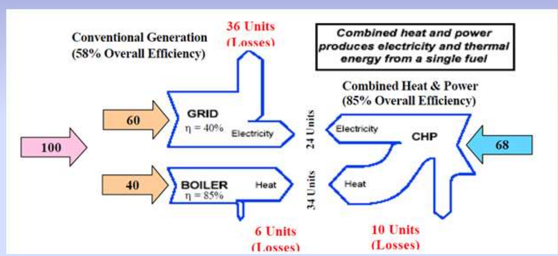



## COGENERATION

- CHP systems consist of a number of individual components – prime mover (heat engine), generator, heat recovery, and electrical interconnection – configured into an integrated whole.
- The type of equipment that drives the overall system (i.e. the prime mover) typically identifies the CHP system. Prime movers for CHP systems include reciprocating engines, combustion or gas turbines, steam turbines, micro-turbines, and fuel cells. These prime movers are capable of burning a variety of fuels, including natural gas, coal, oil, and alternative fuels to produce shaft power or mechanical energy.
- Although mechanical energy from the prime mover is most often used to drive a generator to produce electricity, it can also be used to drive rotating equipment such as compressors, pumps, and fans.
- Thermal energy from the system can be used in direct process applications or indirectly to produce steam, hot water, hot air for drying, or chilled water for process cooling.

## COGENERATION-ADVANTAGES



## BENEFITS OF COGENERATION

- Increased efficiency of energy conversion and use
- Lower emissions to the environment, in particular of CO2, the main greenhouse gas
- In some cases, biomass fuels and some waste materials such as refinery gases, process or agricultural waste are used. These substances which serve as fuels for cogeneration schemes, increases the cost-effectiveness and reduces the need for waste disposal
- Large cost savings, providing additional competitiveness for industrial and commercial users while offering affordable heat for domestic users also
- An opportunity to move towards more decentralized forms of electricity generation, where plants are designed to meet the needs of local consumers, providing high efficiency, avoiding transmission losses and increasing flexibility in system use. This will particularly be the case if natural gas is the energy carrier

## COGENERATION

- **Steam Turbine Co generation**

Combined cycle gas turbine with heat recovery
Steam backpressure turbine
Steam condensing extraction turbine

- **Gas turbine with heat recovery**
- **Internal combustion engine**

Micro turbines
Sterling engines
Steam engines

- **Hydro electric power cogener**

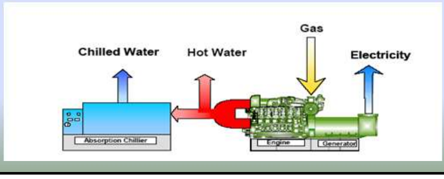
ORC
Fuel cells

- **Nuclear power cogeneration**




## COGENERATION

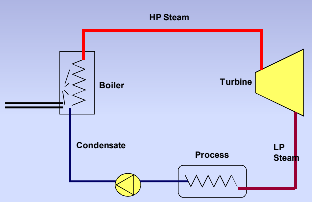
- Cogeneration units:
  - Micro-cogeneration means below 50 kWe;
  - Small-scale cogeneration means below 1 MWe.
- Power to heat ratio (P/H):
  - the ratio between electricity from cogeneration and useful heat when operating in full cogeneration mode




## STEAM TURBINE COGENERATION SYSTEM

- Steam turbines are one of the most versatile and oldest prime mover technologies still in general production. Power generation using steam turbines has been in use for about 100 years, when they replaced reciprocating steam engines due to their higher efficiencies and lower costs.
- The capacity of steam turbines can range from 50 kW to several hundred MWs for large utility power plants.
- Steam turbines are widely used for combined heat and power (CHP) applications.
- The two types of steam turbines most widely used are the back pressure and the extraction condensing types. The choice between back pressure turbine and extraction-condensing turbine depends mainly on the quantities of power and heat, quality of heat, and economic factors.

## BACK PRESSURE STEAM TURBINE




## BACK PRESSURE STEAM TURBINE

**Steam exits the turbine at a higher pressure that the atmospheric**

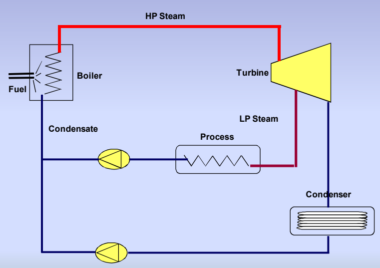
**Advantages:**

- Simple configuration
- Low capital cost
- Low need of cooling water
- High total efficiency

**Disadvantages:**

- Larger steam turbine
- Electrical load and output can not be matched

## EXTRACTION CONDENSING STEAM TURBINE




## EXTRACTION CONDENSING STEAM TURBINE

- Steam obtained by extraction from an intermediate stage.
- Remaining steam is exhausted.
- Relatively high capital cost, lower total efficiency.
- Control of electrical power independent of thermal load

## GAS TURBINE COGENERATION SYSTEM

- Operate on thermodynamic "Brayton cycle"
  - atmospheric air compressed, heated, expanded
  - excess power used to produce power
- Natural gas is most common fuel
- 1MW to 100 MW range
- Rapid developments in recent years
- Two types: open and closed cycle

## OPEN CYCLE GAS TURBINECOGENERATION

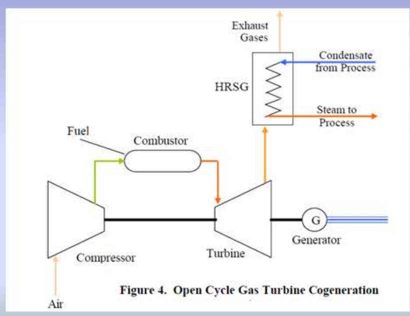
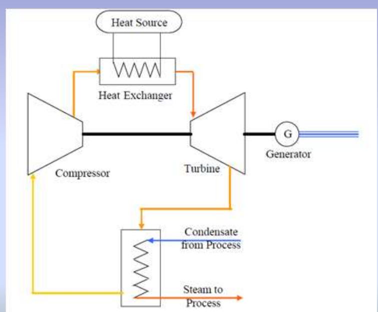


**Figure 4. Open Cycle Gas Turbine Cogeneration**

## OPEN CYCLE GAS TURBINE COGENERATION

- Open Brayton cycle: atmospheric air at increased pressure to combustor.
- Old/small units: 15:1 New/large units: 30:1
- Exhaust gas at 450-600 °C
- High pressure steam produced: can drive steam turbine

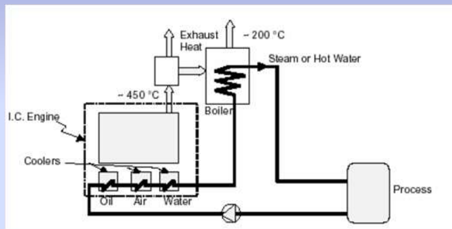
## CLOSED CYCLE GAS TURBINE COGENERATION



## CLOSED CYCLE GAS TURBINE COGENERATION

- Working fluid circulates in a closed circuit and does not cause corrosion or erosion
- Any fuel, nuclear or solar energy can be used

## INTERNAL COMBUSTION ENGINE COGENERATION




## INTERNAL COMBUSTION ENGINE COGENERATION

- Used as direct mechanical drives
- Many advantages: operation, efficiency, fuel costs
- Used as direct mechanical drives
- Four sources of usable waste heat

## TYPICAL COGENERATION PERFORMANCE

**Table 1. Typical cogeneration performance parameters** (adapted from: California Energy Commission, 1982)

| Prime Mover in Cogeneration Package | Nominal Range (Electrical) | Electrical Generation Heat Rate (kcal / kWh | Efficiencies, % | | |
|---|---|---|---|---|---|
| | | | Electrical Conversion | Thermal Recovery | Overall Cogeneration |
| Smaller Reciprocating Engines | 10 – 500 kW | 2650 - 6300 | 20-32 | 50 | 74-82 |
| Larger Reciprocating Engines | 500 – 3000 kW | 2400 - 3275 | 26-36 | 50 | 76-86 |
| Diesel Engines | 10-3000 kW | 2770 - 3775 | 23-38 | 50 | 73-88 |
| Smaller Gas Turbines | 800-10000 kW | 2770-3525 | 24-31 | 50 | 74-81 |
| Larger Gas Turbines | 10-20 MW | 2770-3275 | 26-31 | 50 | 78-81 |
| Steam Turbines | 10-100 MW | 2520-5040 | 17-34 | - | - |

## TOPPING AND BOTTOMING CYCLE

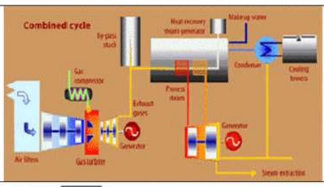
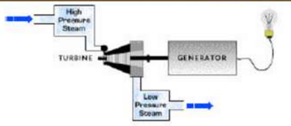
- Cogeneration systems are normally classified according to the sequence of energy use and the operating schemes adopted.
- On this basis cogeneration systems can be classified as either a topping or a bottoming cycle.

## Topping Cycle

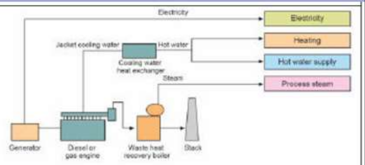
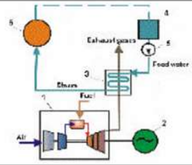
- In a topping cycle, the fuel supplied is used to first produce power and then thermal energy, which is the by-product of the cycle and is used to satisfy process heat or other thermal requirements.
- Topping cycle cogeneration is widely used and is the most popular method of cogeneration.

## TYPES OF TOPPING CYCLE COGENERATION

**Table 2. Four types of topping cycle cogeneration systems** (pictures from Department of Energy, Australia)

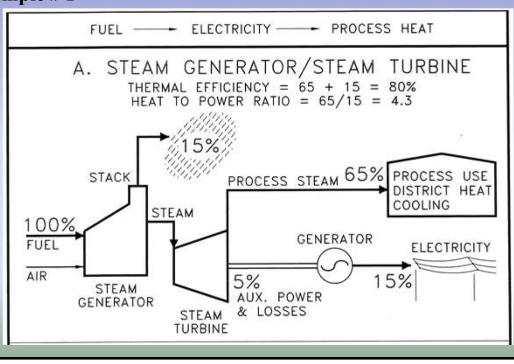
| | |
|---|---|
| **Combined-cycle topping system** A gas turbine or diesel engine producing electrical or mechanical power followed by a heat recovery boiler to create steam to drive a secondary steam turbine. |  |
| **Steam-turbine topping system** The second type of system burns fuel (any type) to produce high-pressure steam that then passes through a steam turbine to produce power with the exhaust provides low-pressure process steam. |  |

## TYPES OF TOPPING CYCLE COGENERATION

| | |
|---|---|
| **Heat recovery topping system** This type employs heat recovery from an engine exhaust and/or jacket cooling system flowing to a heat recovery boiler, where it is converted to process steam / hot water for further use. |  |
| **Gas turbine topping system** A natural gas turbine drives a generator. The exhaust gas goes to a heat recovery boiler that makes process steam and process heat. |  |

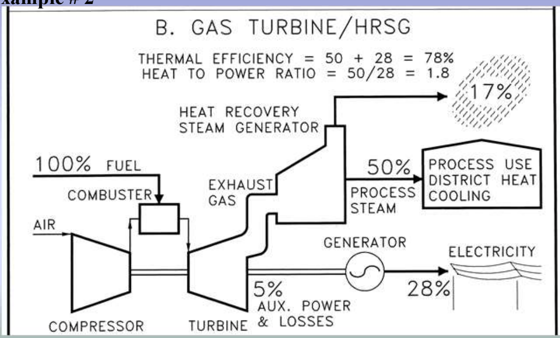
## TOPPING CYCLE COGENERATION - ANALYSIS

**Example # 1**




## TOPPING CYCLE COGENERATION - ANALYSIS

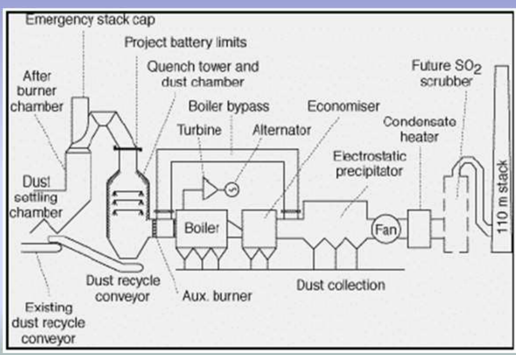
**Example # 2**




## BOTTOMING CYCLE COGENERATION

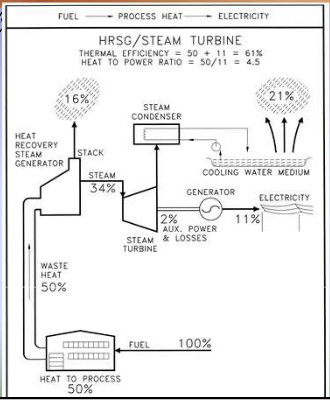
- In a bottoming cycle, the primary fuel produces high temperature thermal energy and the heat rejected from the process is used to generate power through a recovery boiler and a turbine generator.
- Bottoming cycles are suitable for manufacturing processes that require heat at high temperature in furnaces and kilns, and reject heat at significantly high temperatures.
- Typical areas of application include cement, steel, ceramic, gas and petrochemical industries. Bottoming cycle plants are much less common than topping cycle plants.

## BOTTOMING CYCLE COGENERATION



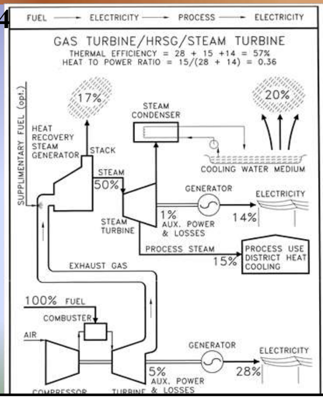
## BOTTOMING CYCLE COGENERATION - ANALYSIS

Example # 3




## COMBINED CYCLE COGENERATION - ANAlysis

Example # 4




## EFFICIENCY COEFFICIENT FOR HEAT GENERATION ONLY

| Fuel | type | Overall efficiency |
|---|---|---|
| Solid fuels | Hard coal/coke | 0.88 |
| | Peat | 0.86 |
| | Wood fuels | 0.86 |
| | Oil, LPG | 0.89 |
| | Biofuels | 0.89 |
| | Natural gas | 0.9 |
| | Biogas | 0.7 |

## EFFICIENCY COEFFICIENT FOR ELECTRICITY GENERATION ONLY

| Fuel | type | Overall efficiency |
|---|---|---|
| Solid fuels | Hard coal/coke | 0.442 |
| | Peat | 0.390 |
| | Wood fuels | 0.330 |
| | Oil, LPG | 0.442 |
| | Biofuels | 0.442 |
| | Natural gas | 0.525 |
| | Biogas | 0.420 |

## WHERE CAN CHP BE ECONOMICALLY ATTRACTIVE?

Data Centers
Colleges & Universities
Ethanol/ Bio - fuel Process Plants
Food Processing Plants
Hospitals
Hotels
Ice Arenas
Chemicals, Pulp & Paper,
Fabricated Metals, Plastics
Nursing Homes
Office Buildings
Large Multi-Family Apartments
Refrigerated Warehouses
Restaurants
Supermarkets
Theatres
Greenhouses
Wastewater Treatment Facilities

## BENEFITS OF COGENERATION

- Improved Reliability.(Avoiding business disruptions)
- 50% less $CO_2$ emissions.(Monetizing Environmental benefits)
- Up to 80% energy efficient.(Reducing Fuel use)
- Removes requirement for back-up diesels (Conserve Natural Resources)
- Can uplift Green Star ratings by 1-2 stars.
- Usually cost-effective.
- Support Grid Infrastructure
  - Fewer T&D Constraints
  - Defer Costly Grid Upgrades
  - Price Stability
- Facilitates Deployment of New Clean Energy Technologies

## ASSESSMENT OF COGENERATION

### Performance Terms & Definitions

- **Overall Plant Heat Rate (kCal/kWh):**

$$\frac{Ms\ x\ (hs - hw)}{Power\ Output\ (kW)}$$

**$M_s$ = Mass Flow Rate of Steam (kg/hr)**
**$h_s$ = Enthalpy of Steam (kCal/kg)**
**$h_w$ = Enthalpy of Feed Water (kCal/kg)**

- **Overall Plant Fuel Rate (kg/kWh)**

$$\frac{Fuel\ Consumption*(kg/hr)}{Power\ Output\ (kW)}$$

## ASSESSMENT OF COGENERATION

### Steam Turbine Performance

- **Steam turbine efficiency (%):**

$$\frac{Actual\ Enthalpy\ Drop\ across\ the\ Turbine\ (kCal/kg)}{Isentropic\ Enthalpy\ drop\ across\ the\ Turbine\ (kCal/kg)}\ x\ 100$$

### Gas Turbine Performance

- **Overall gas turbine efficiency (%) (turbine compressor):**

$$\frac{Power\ Output\ (kW)\ x\ 860}{Fuel\ Input\ for\ Gas\ Turbine\ (kg/hr)\ x\ GCV\ of\ Fuel\ (kCal/kg)}\ x\ 100$$

## ASSESSMENT OF COGENERATION

### Heat Recovery Steam Generator (HRSG) Performance

- **Heat recovery steam generator efficiency (%):**

$$\frac{M_s\ x\ (h_s - h_w)}{[M_f\ x\ Cp\ (t_{in} - t_{out})] + [M_{aux}\ x\ GCV\ of\ Fuel\ (kCal/kg)]}\ x\ 100$$

**Ms = Steam Generated (kg/hr)**
**hs = Enthalpy of Steam (kCal/kg)**
**hw = Enthalpy of Feed Water (kCal/kg)**
**Mf = Mass flow of Flue Gas (kg/hr)**
**t-in = Inlet Temperature of Flue Gas ($^0$C)**
**t-out = Outlet Temperature of Flue Gas ($^0$C)**
**Maux = Auxiliary Fuel Consumption (kg/hr)**

## ENERGY EFFICIENT OPPURTUNITIES

Steam Turbine Cogeneration System.

- Keep condenser vacuum at optimum value
- Keep steam temperature and pressure at optimum value
- Avoid part load operation and starting & stoppingGas Turbine Cogeneration System

Gas turbine – manage the following parameters

- Gas temperature and pressure
- Part load operation and starting & stopping
- Temperature of hot gas and exhaust gas
- Mass flow through gas turbine
- Air pressure

## WASTE HEAT RECOVERY SYSTEM

- Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved.
- Large quantity of hot flue gases is generated from Boilers, Kilns, Ovens and Furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered.

## WHR – Heat losses Quality

- Depending upon the type of process, waste heat can be rejected at virtually any temperature from that of chilled cooling water to high temperature waste gases from an industrial furnace or kiln. Usually higher the temperature, higher the quality and more cost effective is the heat recovery.
- In any study of waste heat recovery, it is absolutely necessary that there should be some use for the recovered heat. Typical examples of use would be preheating of combustion air, space heating, or pre-heating boiler feed water or process water.
- With high temperature heat recovery, a cascade system of waste heat recovery may be practiced to ensure that the maximum amount of heat is recovered at the highest potential.

## WHR – Heat losses Quality

In any heat recovery situation it is essential to know the amount of heat recoverable and also how it can be used. An example of the availability of waste heat is given below:

**Heat recovery from heat treatment furnace**

In a heat treatment furnace, the exhaust gases are leaving the furnace at 900°C at the rate of 2100 $m^3$/hour. The total heat recoverable at 180°C final exhaust can be calculated as

$Q = V \times \rho \times C_p \times \Delta T$

**Where,**

Q is the heat content in kCal
V is the flow rate of the substance in $m^3$/hr
ρ is density of the flue gas in kg/$m^3$
$C_p$ is the specific heat of the substance in kCal/kg °C
ΔT is the temperature difference in °C
$C_p$ (Specific heat of flue gas) = 0.24 kCal/kg/°C

## WHR – Heat losses Quality

Heat available (Q) = 2100 x 1.19 x 0.24 x (900-180) = 4,31,827 kCal/hr

By installing a recuperator, this heat can be recovered to pre-heat the combustion air. The fuel savings would be 33% (@ 1% fuel reduction for every 22°C reduction in temperature of flue gas.

## WHR – Classifications and Applications

TABLE 8.1 WASTE SOURCE AND QUALITY

| S.No. | Source | Quality |
|---|---|---|
| 1. | Heat in flue gases. | The higher the temperature, the greater the potential value for heat recovery |
| 2. | Heat in vapour streams. | As above but when condensed, latent heat also recoverable. |
| 3 | Convective and radiant heat lost from exterior of equipment | Low grade – if collected may be used for space heating or air preheats. |
| 4. | Heat losses in cooling water. | Low grade – useful gains if heat is exchanged with incoming fresh water. |
| 5. | Heat losses in providing chilled water or in the disposal of chilled water. | a) High grade if it can be utilized to reduce demand for refrigeration.<br>b) Low grade if refrigeration unit used as a form of heat pump. |
| 6. | Heat stored in products leaving the process | Quality depends upon temperature. |
| 7. | Heat in gaseous and liquid effluents leaving process. | Poor if heavily contaminated and thus requiring alloy heat exchanger. |

## WHR – Classified by Temperature

| Temperature Classification | Waste Heat Source | Characteristics | Commercial Waste Heat to Power Technologies |
|---|---|---|---|
| **High** (>1,200 °F) | • Furnaces<br>– Steel electric arc<br>– Steel heating<br>– Basic oxygen<br>– Aluminum reverberatory<br>– Copper reverberatory<br>– Nickel refining<br>– Copper refining<br>– Glass melting<br>• Iron cupolas<br>• Coke ovens<br>• Fume incinerators<br>• Hydrogen plants | • High quality heat<br>• High heat transfer<br>• High power-generation efficiencies<br>• Chemical and mechanical contaminants | • Waste heat boilers and steam turbines |

## WHR – Classified by Temperature

TABLE 8.2 TYPICAL WASTE HEAT TEMPERATURE AT HIGH TEMPERATURE RANGE FROM VARIOUS SOURCES

| Types of Device | Temperature, °C |
|---|---|
| Nickel refining furnace | 1370 –1650 |
| Aluminium refining furnace | 650-760 |
| Zinc refining furnace | 760-1100 |
| Copper refining furnace | 760- 815 |
| Steel heating furnaces | 925-1050 |
| Copper reverberatory furnace | 900-1100 |
| Open hearth furnace | 650-700 |
| Cement kiln (Dry process) | 620- 730 |
| Glass melting furnace | 1000-1550 |
| Hydrogen plants | 650-1000 |
| Solid waste incinerators | 650-1000 |
| Fume incinerators | 650-1450 |

## WHR – Classified by Temperature

| Temperature Classification | Waste Heat Source | Characteristics | Commercial Waste Heat to Power Technologies |
|---|---|---|---|
| **Medium** (500 –1,200 °F) | • Prime mover exhaust streams<br>– Gas turbine<br>– Reciprocating engine<br>• Heat-treating furnaces<br>• Ovens<br>– Drying<br>– Baking<br>– Curing<br>• Cement kilns | • Medium power-generation efficiencies<br>• Chemical and mechanical contaminants (some streams such as cement kilns) | • Waste heat boilers and steam turbines (>500 °F)<br>• Organic Rankine cycle (<800 °F)<br>• Kalina cycle (<1,000 °F) |

## WHR – Classified by Temperature

| TABLE 8.3 TYPICAL WASTE HEAT TEMPERATURE AT MEDIUM TEMPERATURE RANGE FROM VARIOUS SOURCES | |
|---|---|
| **Type of Device** | **Temperature, °C** |
| Steam boiler exhausts | 230-480 |
| Gas turbine exhausts | 370-540 |
| Reciprocating engine exhausts | 315-600 |
| Reciprocating engine exhausts (turbo charged) | 230- 370 |
| Heat treating furnaces | 425 - 650 |
| Drying and baking ovens | 230 - 600 |
| Catalytic crackers | 425 - 650 |
| Annealing furnace cooling systems | 425 - 650 |

## WHR – Classified by Temperature

| Temperature Classification | Waste Heat Source | Characteristics | Commercial Waste Heat to Power Technologies |
|---|---|---|---|
| Low (< 500 °F) | • Boilers<br>• Ethylene furnaces<br>• Steam condensate<br>• Cooling Water<br>– Furnace doors<br>– Annealing furnaces<br>– Air compressors<br>– IC engines<br>– Refrigeration condensers<br>• Low-temperature ovens<br>• Hot process liquids or solids | • Energy contained in numerous small sources<br>• Low power-generation efficiencies<br>• Recovery of combustion streams limited due to acid concentration if temperatures reduced below 250°F | • Organic Rankine cycle (>300°F gaseous streams, >175°F liquid streams)<br>• Kalina cycle (>200°F) |

## WHR – Classified by Temperature

| TABLE 8.4 TYPICAL WASTE HEAT TEMPERATURE AT LOW TEMPERATURE RANGE FROM VARIOUS SOURCES | |
|---|---|
| **Source** | **Temperature, °C** |
| Process steam condensate | 55-88 |
| **Cooling water from:** | |
| Furnace doors | 32-55 |
| Bearings | 32-88 |
| Welding machines | 32-88 |
| Injection molding machines | 32-88 |
| Annealing furnaces | 66-230 |
| Forming dies | 27-88 |
| Air compressors | 27-50 |
| Pumps | 27-88 |
| Internal combustion engines | 66-120 |
| Air conditioning and refrigeration condensers | 32–43 |
| Liquid still condensers | 32-88 |
| Drying, baking and curing ovens | 93-230 |
| Hot processed liquids | 32-232 |
| Hot processed solids | 93-232 |

## Benefits of WHR Systems

**Direct Benefits:**

Recovery of waste heat has a direct effect on the efficiency of the process. This is reflected by reduction in the utility consumption & costs, and process cost.

**Indirect Benefits:**

a) **Reduction in pollution**: A number of toxic combustible wastes such as carbon monoxide gas, sour gas, carbon black off gases, oil sludge, Acrylonitrile and other plastic chemicals etc, releasing to atmosphere if/when burnt in the incinerators serves dual purpose i.e. recovers heat and reduces the environmental pollution levels.

b) **Reduction in equipment sizes**: Waste heat recovery reduces the fuel consumption, which leads to reduction in the flue gas produced. This results in reduction in equipment sizes of all flue gas handling equipments such as fans, stacks, ducts, burners, etc.

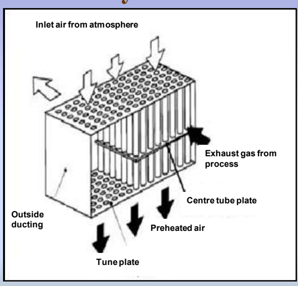
c) **Reduction in auxiliary energy consumption**: Reduction in equipment sizes gives additional benefits in the form of reduction in auxiliary energy consumption like electricity for fans, pumps etc..

## Types of WHR Systems

### Commercial Waste Heat Recovery

✓ **Recuperators**

- **The heat exchange takes place between the flue gases and the air through metallic or ceramic walls**
- **Duct or tubes carry the air for combustion to be preheated, the other side contains the waste heat stream**

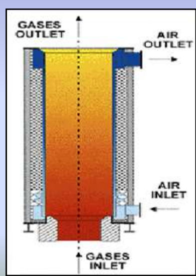





## Types of WHR Systems

✓ **Metallic radiation recuperators**

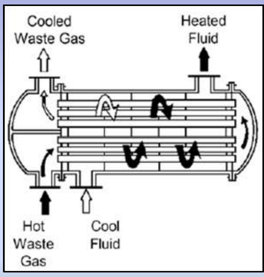
- **The simplest configuration of a recuperator and consists of two concentric lengths of metal tubing**
- **Less fuel is burned for a given furnace loading. reduced stack losses**
- **A substantial portion of the heat transfer takes place by radiative heat transfer**



## Types of WHR Systems

✓ **Convective recuperators**

- The hot gases are carried through a number of parallel small diameter tubes
- The tubes can be baffled to allow the gas to pass over them again
- Baffling increases the effectiveness of heat exchange, although the costs are higher for the exchanger

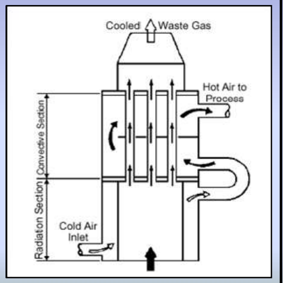





## Types of WHR Systems

✓ **Radiation/convective hybrid recuperators**

- For maximum effectiveness of heat transfer, combinations of radiation and convective designs are used
- These are more expensive than simple metallic radiation recuperators, but less bulky






## Types of WHR Systems

✓ **Ceramic recuperators**

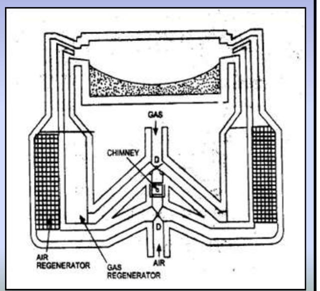
- Developed with materials that allow operation on the gas side to 1550 ◦C and on the preheated air side to 815 ◦C in order to overcome the temperature limitations of metal recuperators,
- New designs are reported to last two years with air preheat temperatures as high as 700◦ C, with lower leakage rates




## Types of WHR Systems

### Regenerator

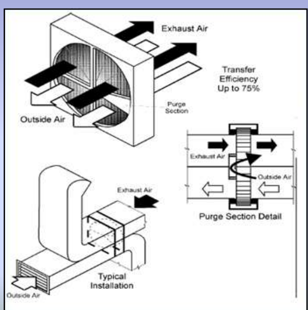
- Large capacities has been very widely used in glass and steel melting furnaces
- In a regenerator, the time between the reversals is an important aspect
- Heat transfer is reduced by the accumulation of dust and slagging on surfaces, heat losses from the walls etc




## Types of WHR Systems

### Heat Wheels

- A sizable porous disk that rotates between two side-by-side ducts
- Usually in low to medium temperature waste heat recovery systems
- The overall efficiency of sensible heat transfer can be as high as 85 %

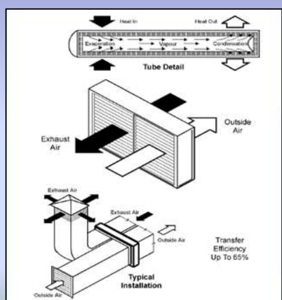





## Types of WHR Systems

### Heat Pipe

- Can transfer up to 100 times more thermal energy than copper
- Three elements:
- a sealed container
- a capillary wick structure
- a nanofluid
- Applied thermal energy to the external surface is in equilibrium with its own vapour



## Types of WHR Systems

### Heat Pipe

✓ Performance and advantage

- The heat pipe exchanger (HPHE) is a lightweight compact heat recovery system
- Virtually does not need mechanical maintenance, nor input power for its operation and is free from cooling water and lubrication systems
- It lowers the fan horsepower requirement and increases the overall thermal efficiency of the system
- Capable of operating at 315 °C with 60% to 80% heat recovery capability




## Types of WHR Systems

### Heat Pipe

✓ Typical application

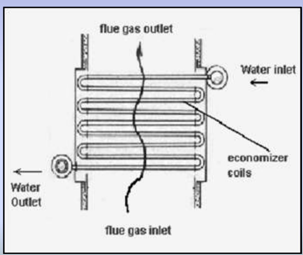
- Process to space heating
  - Transfers thermal energy from process exhaust for building heating
- Process to process
  - Transfer recovered waste thermal energy from the process to the incoming process air
- HVAC applications
  - Cooling and heating by recovering thermal energy



## Types of WHR Systems

### Economizer

- Economizers can be provided to utilize the flue gas heat for pre-heating the boiler feed water
- For every 60 °C rise in feed water temp. through an economizer, or 200 °C rise in combustion air temp. through an air pre-heater, there is 1% saving of fuel in the boiler



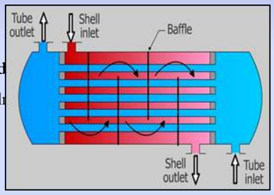



## Types of WHR Systems

### Economizer

✓ Shell and tube heat exchanger

- Used when the medium containing waste heat is a liquid or a vapor that heats another liquid
- The shell contains the tube bundle, and usually internal baffles to direct the fluid
- In this application, the vapor is al invariably contained within the shell

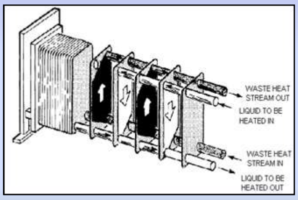





## Types of WHR Systems

### Plate Heat Exchanger

- Avoids the cost of heat exchange surfaces for lower temperature differences as it consists of a series of separate parallel plates forming thin flow pass
- To improve heat transfer the plates are corrugated
- When the directions of hot and cold fluids are opposite, the arrangement is counter current

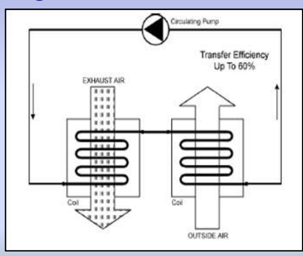



## Types of WHR Systems

### Plate Heat Exchanger

✓ **Run around coil exchanger**

- Heat from the hot fluid is transferred to the colder via an intermediate fluid known as the heat transfer fluid
- One coil is installed in the hot stream while the other is in the cold stream

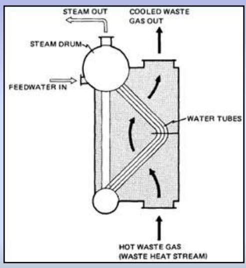


## Types of WHR Systems

### Plate Heat Exchanger

✓ **Waste heat boiler**

- A water tube boiler in which hot exhaust gases pass over parallel tubes with water
- Waste heat boilers are built in capacities from 25 m3 almost 30,000 m3 /min of exhaust gas

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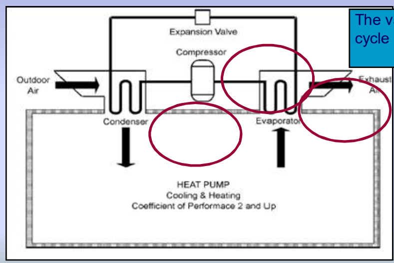
## Types of WHR Systems

### Heat Pump




The vapour compression cycle

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## Types of WHR Systems

### Heat Pump

✓ Was developed as a space heating system where low temperature energy is raised to heating system temperatures

✓ Have the ability to upgrade heat to a value more than twice that of the energy consumed by the device

✓ Heat pump applications are most promising when both the heating and cooling capabilities can be used in combination

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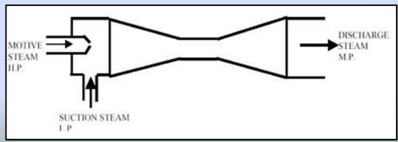
## Types of WHR Systems

### Heat Pump

✓ Thermo compressor

- Usually, it is feasible to compress low-pressure steam by very high-pressure steam and reuse it as a medium pressure steam
- Thermo compressor has a nozzle where HP steam is accelerated into a high velocity fluid.

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## PERFORMANCE EVALUATON

### Heat Saving Calculation Example

Saving money by recovering heat from hot waste water:

- Discharge of the waste water is 10000 kg/hr at 75°C
- Preheat 10000 kg/hr of cold inlet water of 20°C
- A heat recovery factor of 58%
- An operation of 5000 hours per year

The annual heat saving (Q) is:

**Q = m x Cp x ΔT x η**

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## PERFORMANCE EVALUATON

### Heat Saving Calculation Example

m = 1000 kg/hr = 10000 x 5000 kg/yr = 50000000 kg/year

Cp = 1 kCal/kg °C

ΔT = (75 – 20) °C = 55 °C

η = Heat Recovery Factor = 58% or 0.58

**⇒ Q = 50000000 x 1 x 55 x 0.58**
**= 1595000000 kCal/year**

GCV of Oil = 10,200 kCal/kg

Equivalent Oil Savings = 159500000 / 10200 = 156372 L

Cost of Oil = 0.35 USD/L

Monetary Savings = 54730 USD/Annum

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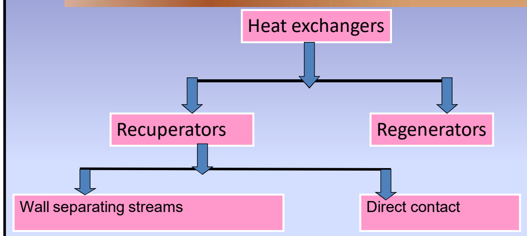
# HEAT EXCHANGERS

## HEAT EXCHANGERS

- Heat exchangers are practical devices used to transfer energy from one fluid to another
- To get fluid streams to the right temperature for the next process reactions often require feeds at high temp.
- To condense vapours
- To evaporate liquids
- To recover heat to use elsewhere
- To reject low-grade heat
- To drive a power cycle

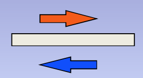
## HEAT EXCHANGERS




- Most heat exchangers have two streams, *hot* and *cold*, but some have more than two

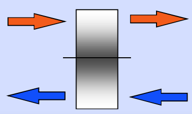
## HEAT EXCHANGERS

- Recuperative



Has separate flow paths for each fluid which flow simultaneously through the exchanger transferring heat between the streams

- Regenerative



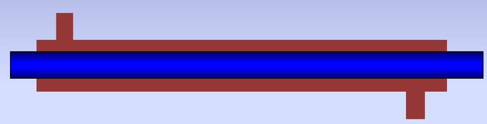
Has a single flow path which the hot and cold fluids alternately pass through.

## HEAT EXCHANGERS

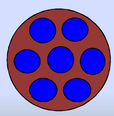
- Can be measured by the heat-transfer area per unit volume or by channel size
- Conventional exchangers (shell and tube) have channel size of 10 to 30 mm giving about 100m$^2$/m$^3$
- Plate-type exchangers have typically 5mm channel size with more than 200m$^2$/m$^3$
- More compact types available

## DOUBLE PIPE HEAT EXCHANGERS

- Simplest type has one tube inside another - inner tube may have longitudinal fins on the outside

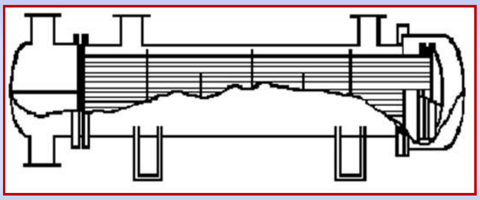


- However, most have a number of tubes in the outer tube - can have very many tubes thus becoming a shell-and-tube

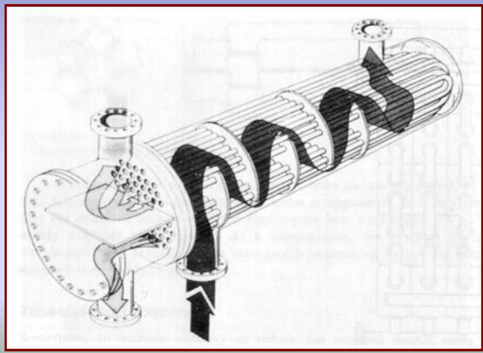


## SHELL AND TUBE HEAT EXCHANGERS

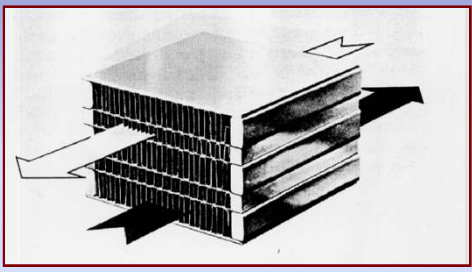
- Typical shell and tube exchanger as used in the process industry



## SHELL SIDE FLOW



## PLATE FIN HEAT EXCHANGERS



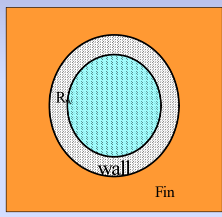
- Made up of flat plates (parting sheets) and corrugated sheets which form fins
- Brazed by heating in vacuum furnace

## HEAT TRANSFER CONSIDERATIONS

- Internal and external thermal resistances in series

$$\frac{1}{UA} = \frac{1}{(UA)_c} = \frac{1}{(UA)_h}$$

$$\frac{1}{UA} = \frac{1}{(h\eta_o A)_c} + \frac{R''_{f,c}}{(\eta_o A)_c} + R_w + \frac{1}{(h\eta_o A)_h} + \frac{R''_{f,h}}{(\eta_o A)_h}$$




- $A$ is wall total surface area on hot or cold side
- $R''_f$ is fouling factor ($m^2K/W$)
- $\eta_o$ is overall surface efficiency (if finned)

## HEAT TRANSFER CONSIDERATIONS

- Fouling factor

Material deposits on the surfaces of the heat exchanger tube may add further resistance to heat transfer in addition to those listed above. Such deposits are termed fouling and may significantly affect heat exchanger performance.

- Scaling is the most common form of fouling and is associated with inverse solubility salts. Examples of such salts are $CaCO_3$, $CaSO_4$, $Ca_3(PO_4)_2$, $CaSiO_3$, $Ca(OH)_2$, $Mg(OH)_2$, $MgSiO_3$, $Na_2SO_4$, $LiSO_4$, and $Li_2CO_3$.

- Corrosion fouling is classified as a chemical reaction which involves the heat exchanger tubes. Many metals, copper and aluminum being specific examples, form adherent oxide coatings which serve to passivity the surface and prevent further corrosion.

## HEAT TRANSFER CONSIDERATIONS

- Chemical reaction fouling involves chemical reactions in the process stream which results in deposition of material on the heat exchanger tubes. When food products are involved this may be termed scorching but a wide range of organic materials are subject to similar problems.

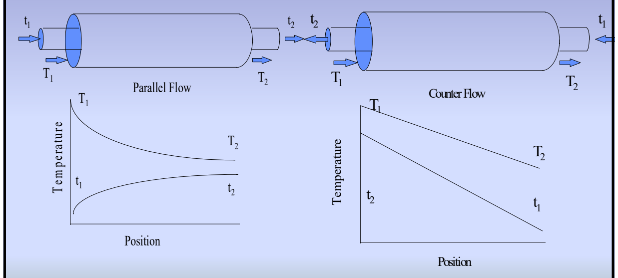
- Freezing fouling is said to occur when a portion of the hot stream is cooled to near the freezing point for one of its components. This is most notable in refineries where paraffin frequently solidifies from petroleum products at various stages in the refining process, obstructing both flow and heat transfer.

- Biological fouling is common where untreated water is used as a coolant stream. Problems range from algae or other microbes to barnacles.

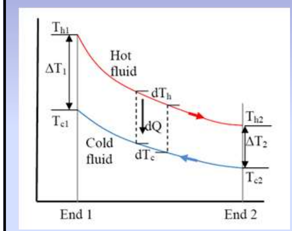
## HEAT TRANSFER CONSIDERATIONS

| Fluid | R”, $m^2K/Watt$ |
|---|---|
| Seawater and treated boiler feedwater (below 50°C) | 0.0001 |
| Seawater and treated boiler feedwater (above 50°C) | 0.0002 |
| River water (below 50°C) | 0.0002-0.001 |
| Fuel Oil | 0.0009 |
| Regrigerating liquids | 0.0002 |
| Steam (non-oil bearing) | 0.0001 |

## BASIC FLOW ARRANGEMENTS

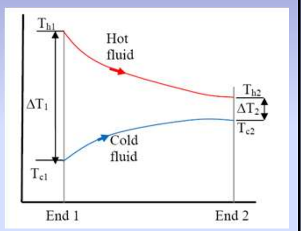



## HEAT EXCHANGER ANALYSIS




Counterflow

Note $T_{h,out}$ can be < $T_{c,out}$




Parallel flow

$T's$ cannot cross

## HEAT EXCHANGER ANALYSIS

Energy balance (counterflow) on element shown

$$d\dot{Q} = -\dot{m}_h c_h dT_h = -\dot{m}_c c_c dT_c \qquad (1)$$

$\dot{m}$ = mass flow rate of fluid

$c$ = specific heat

Rate Equation

$$d\dot{Q} = UdA\,(T_h - T_c) \qquad (2)$$

Now from (1) $dT_h = \frac{-d\dot{Q}}{\dot{m}_h c_h}$ $\qquad dT_c = \frac{-d\dot{Q}}{\dot{m}_c c_c}$

$$\therefore d(T_h - T_c) = d\dot{Q}\left(\frac{1}{\dot{m}_c c_c} - \frac{1}{\dot{m}_h c_h}\right)$$

## HEAT EXCHANGER ANALYSIS

Subtract $d\dot{Q}$ from (2),

$$\frac{d(T_h - T_c)}{T_h - T_c} = U\left(\frac{1}{\dot{m}_c c_c} - \frac{1}{\dot{m}_h c_h}\right)dA$$

Integrate $1 \rightarrow 2$

$$\ln\left(\frac{T_{h2} - T_{c2}}{T_{h1} - T_{c1}}\right) = UA\left(\frac{1}{\dot{m}_c c_c} - \frac{1}{\dot{m}_h c_h}\right)$$

Total heat transfer rate

$$\dot{Q} = \dot{m}_h c_h (T_{h1} - T_{h2}) \text{ and } \dot{Q} = \dot{m}_c c_c (T_{c1} - T_{c2})$$

## HEAT EXCHANGER ANALYSIS

Substitute for $\dot{m}_c$ and put

$\Delta T_1 = T_{h1} - T_{c1} \qquad END\,1$

$\Delta T_2 = T_{h2} - T_{c2} \qquad END\,2$

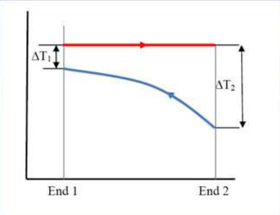
$$\dot{Q} = UA\left[\frac{\Delta T_2 - \Delta T_1}{\ln(\Delta T_2 / \Delta T_1)}\right]$$

$\dot{Q} = UA(\text{LMTD})$

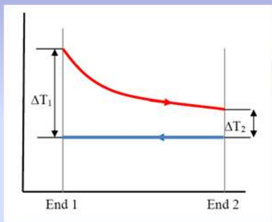
LMTD is Log Mean Temperature Difference

- Remember – 1 and 2 are ends, not fluids
- Same formula for parallel flow (but ΔT’s are different)
- Counterflow has highest LMTD, for given T’s therefore smallest area for Q.

## HEAT EXCHANGER ANALYSIS




Condenser

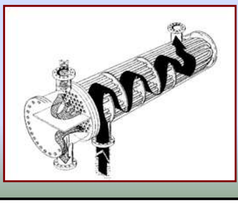



Evaporator

## MULTI PASS ARRANGEMENTS

❑ In order to increase the surface area for convection relative to the fluid volume, it is common to design for multiple tubes within a single heat exchanger.

❑ With multiple tubes it is possible to arrange to flow so that one region will be in parallel and another portion in counter flow.



1-2 pass heat exchanger, indicating that the shell side fluid passes through the unit once, the tube side twice. By convention the number of shell side passes is always listed first.

## MULTI PASS ARRANGEMENTS

❑ The LMTD formulas developed earlier are no longer adequate for multipass heat exchangers. Normal practice is to calculate the LMTD for counter flow, $LMTD_{cf}$, and to apply a correction factor, $F_T$, such that

$$\Delta\theta_{eff} = F_T \cdot LMTD_{CF}$$

❑ The correction factors, $F_T$, can be found theoretically and presented in analytical form. The equation given below has been shown to be accurate for any arrangement having 2, 4, 6, .....,2n tube passes per shell pass to within 2%.

## MULTI PASS ARRANGEMENTS

$$F_T = \frac{\sqrt{R^2+1}\,\ln\left[\frac{1-P}{1-R\cdot P}\right]}{(R-1)\ln\left[\frac{2-P\left(R+1-\sqrt{R^2+1}\right)}{2-P\left(R+1+\sqrt{R^2+1}\right)}\right]}$$

$$\text{Effectiveness}: \ P = \frac{1-X^{1/N_{shell}}}{R-X^{1/N_{shell}}}, \quad \text{for } R \neq 1$$

$$P = \frac{P_o}{N_{shell} - P_o\cdot(N_{shell}-1)}, \quad \text{for } R = 1$$

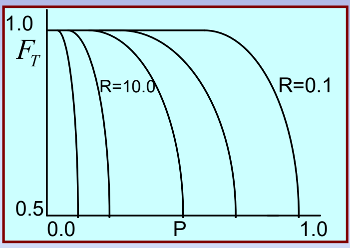
$$P_o = \frac{t_2 - t_1}{T_1 - t_1}$$

$$X = \frac{P_o \cdot R - 1}{P_o - 1}$$

$$\text{Capacity ratio } R = \frac{T_1 - T_2}{t_2 - t_1}$$

T,t = Shell / tube side; 1, 2 = inlet / outlet

## MULTI PASS ARRANGEMENTS




## EFFECTIVENESS – NTU METHOD

How will existing H.Ex. perform for given inlet conditions?

Define effectiveness: $\varepsilon = \frac{\dot{Q}_{actual}}{\dot{Q}_{\max}}$

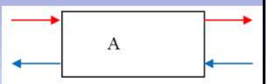
where $\dot{Q}_{\max}$ is for an infinitely long H.Ex.

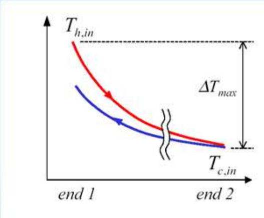
One fluid $\Delta T \rightarrow \Delta T_{\max} = T_{h,in} - T_{c,in}$

and since $\dot{Q} = (\dot{m}c_A)\Delta T_A = (\dot{m}c_B)\Delta T_B$

$= C_A \Delta T_A = C_B \Delta T_B$

then only the fluid with lesser of $C_A, C_B$ heat capacity rate can have $\Delta T_{\max}$



## EFFECTIVENESS – NTU METHOD

i.e. $\dot{Q}_{max} = C_{min}\Delta T_{max}$ and $\varepsilon = \dfrac{\dot{Q}}{C_{min}(T_{h.in} - T_{c.in})}$

or, $\dot{Q} = \varepsilon C_{min}(T_{h.in} - T_{c.in})$

Want expression for ε which does not contain outlet T's

Substitute back into $\dot{Q} = UA(LMTD)$ .........

$$\varepsilon = \frac{1 - \exp\left[\dfrac{-UA}{C_{min}}\left(1 - \dfrac{C_{min}}{C_{max}}\right)\right]}{1 - \dfrac{C_{min}}{C_{max}}\exp\left[\dfrac{-UA}{C_{min}}\left(1 - \dfrac{C_{min}}{C_{max}}\right)\right]}$$

$$\therefore \varepsilon = \varepsilon\left(NTU, \frac{C_{min}}{C_{max}}\right)$$

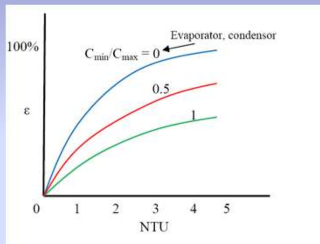
and No. of transfer units (size of HEx.) $NTU = \dfrac{UA}{C_{min}}$

## CHARTS FOR EACH CONFIGURATION

<u>Procedure</u>:

Determine $C_{max}$, $C_{min}/C_{max}$

Get $UA/C_{min}$, → ε from chart




$$\dot{Q} = \varepsilon C_{min}(T_{h.in} - T_{c.in})$$

## EFFECTIVENESS – NTU METHOD

$$NTU_{max} = \frac{UA}{C_{min}} \quad \Rightarrow \quad A = \frac{NTU_{max} C_{min}}{U}$$

- $NTU_{max}$ can be obtained from figures in textbooks/handbooks

First, however, we must determine which fluid has $C_{min}$

## PROBLEMS – LMTD METHOD

## PROBLEMS

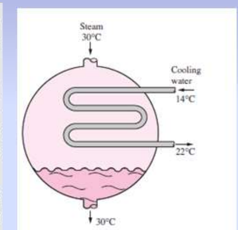
1. Steam in the condenser of a power plant is to be condensed at a temperature of 30°C with cooling water from a nearby lake, which enters the tubes of the condenser at 14°C and leaves at 22°C. The surface area of the tubes is 45 m$^2$, and the overall heat transfer coefficient is 2100 W/m$^2$ · °C. Determine the mass flow rate of the cooling water needed and the rate of condensation of the steam in the condenser.

## PROBLEMS

**SOLUTION** Steam is condensed by cooling water in the condenser of a power plant. The mass flow rate of the cooling water and the rate of condensation are to be determined.

***Assumptions*** 1 Steady operating conditions exist. 2 The heat exchanger is well insulated so that heat loss to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. 3 Changes in the kinetic and potential energies of fluid streams are negligible. 4 There is no fouling. 5 Fluid properties are constant.

***Properties*** The heat of vaporization of water at 30°C is $h_{fg}$ = 2431 kJ/kg and the specific heat of cold water at the average temperature of 18°C is $C_p$ = 4184 J/kg · °C (Table A–9).



## PROBLEMS

***Analysis*** The schematic of the condenser is given in Figure 13–19. The condenser can be treated as a counter-flow heat exchanger since the temperature of one of the fluids (the steam) remains constant.

The temperature difference between the steam and the cooling water at the two ends of the condenser is

$$\Delta T_1 = T_{h,\,in} - T_{c,\,out} = (30 - 22)°C = 8°C$$
$$\Delta T_2 = T_{h,\,out} - T_{c,\,in} = (30 - 14)°C = 16°C$$

That is, the temperature difference between the two fluids varies from 8°C at one end to 16°C at the other. The proper average temperature difference between the two fluids is the *logarithmic mean temperature difference* (not the arithmetic), which is determined from

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} = \frac{8 - 16}{\ln(8/16)} = 11.5°C$$

This is a little less than the arithmetic mean temperature difference of $\frac{1}{2}(8 + 16) = 12°C$. Then the heat transfer rate in the condenser is determined from

$$\dot{Q} = UA_s \Delta T_{lm} = (2100\ W/m^2 \cdot °C)(45\ m^2)(11.5°C) = \mathbf{1.087 \times 10^6\ W = 1087\ kW}$$

## PROBLEMS

This is a little less than the arithmetic mean temperature difference of $\frac{1}{2}(8 + 16) = 12°C$. Then the heat transfer rate in the condenser is determined from

$$\dot{Q} = UA_s \Delta T_{lm} = (2100\ W/m^2 \cdot °C)(45\ m^2)(11.5°C) = \mathbf{1.087 \times 10^6\ W = 1087\ kW}$$

Therefore, the steam will lose heat at a rate of 1,087 kW as it flows through the condenser, and the cooling water will gain practically all of it, since the condenser is well insulated.

The mass flow rate of the cooling water and the rate of the condensation of the steam are determined from $\dot{Q} = [\dot{m}C_p(T_{out} - T_{in})]_{cooling\ water} = (\dot{m}h_{fg})_{steam}$ to be

$$\dot{m}_{cooling\ water} = \frac{\dot{Q}}{C_p(T_{out} - T_{in})} = \frac{1{,}087\ kJ/s}{(4.184\ kJ/kg \cdot °C)(22 - 14)°C} = \mathbf{32.5\ kg/s}$$

and

$$\dot{m}_{steam} = \frac{\dot{Q}}{h_{fg}} = \frac{1{,}087\ kJ/s}{2431\ kJ/kg} = \mathbf{0.45\ kg/s}$$

Therefore, we need to circulate about 72 kg of cooling water for each 1 kg of steam condensing to remove the heat released during the condensation process.

## PROBLEMS

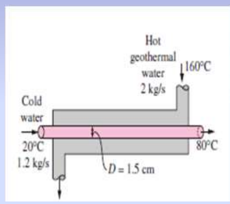
2.A counter-flow double-pipe heat exchanger is to heat water from 20°C to 80°C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160°C at a mass flow rate of 2 kg/s. The inner tube is thin-walled and has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640 W/m² · °C, determine the length of the heat exchanger required to achieve the desired heating.

## PROBLEMS

**SOLUTION** Water is heated in a counter-flow double-pipe heat exchanger by geothermal water. The required length of the heat exchanger is to be determined.

***Assumptions*** **1** Steady operating conditions exist. **2** The heat exchanger is well insulated so that heat loss to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. **3** Changes in the kinetic and potential energies of fluid streams are negligible. **4** There is no fouling. **5** Fluid properties are constant.

***Properties*** We take the specific heats of water and geothermal fluid to be 4.18 and 4.31 kJ/kg · °C, respectively.




## PROBLEMS

***Analysis*** The schematic of the heat exchanger is given in Figure 13–20. The rate of heat transfer in the heat exchanger can be determined from

$$\dot{Q} = [\dot{m}C_p(T_{out} - T_{in})]_{water} = (1.2\ kg/s)(4.18\ kJ/kg \cdot °C)(80 - 20)°C = 301\ kW$$

Noting that all of this heat is supplied by the geothermal water, the outlet temperature of the geothermal water is determined to be

$$\dot{Q} = [\dot{m}C_p(T_{in} - T_{out})]_{geothermal} \longrightarrow T_{out} = T_{in} - \frac{\dot{Q}}{\dot{m}C_p} = 160°C - \frac{301\ kW}{(2\ kg/s)(4.31\ kJ/kg \cdot °C)} = 125°C$$

Knowing the inlet and outlet temperatures of both fluids, the logarithmic mean temperature difference for this counter-flow heat exchanger becomes

$$\Delta T_1 = T_{h,\,in} - T_{c,\,out} = (160 - 80)°C = 80°C$$
$$\Delta T_2 = T_{h,\,out} - T_{c,\,in} = (125 - 20)°C = 105°C$$

and

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} = \frac{80 - 105}{\ln(80/105)} = 92.0°C$$

Then the surface area of the heat exchanger is determined to be

$$\dot{Q} = UA_s \Delta T_{lm} \longrightarrow A_s = \frac{\dot{Q}}{U \Delta T_{lm}} = \frac{301{,}000\ W}{(640\ W/m^2 \cdot °C)(92.0°C)} = 5.11\ m^2$$

## PROBLEMS

To provide this much heat transfer surface area, the length of the tube must be

$$A_s = \pi DL \longrightarrow L = \frac{A_s}{\pi D} = \frac{5.11\ m^2}{\pi(0.015\ m)} = \mathbf{108\ m}$$

***Discussion*** The inner tube of this counter-flow heat exchanger (and thus the heat exchanger itself) needs to be over 100 m long to achieve the desired heat transfer, which is impractical. In cases like this, we need to use a plate heat exchanger or a multipass shell-and-tube heat exchanger with multiple passes of tube bundles.

## PROBLEMS

3.A 2-shell passes and 4-tube passes heat exchanger is used to heat glycerin from 20°C to 50°C by hot water, which enters the thin-walled 2-cm-diameter tubes at 80°C and leaves at 40°C. The total length of the tubes in the heat exchanger is 60 m. The convection heat transfer coefficient is 25 W/m2°C on the glycerin (shell) side and 160 W/m2 · °C on the water (tube) side. Determine the rate of heat transfer in the heat exchanger *(a) before any fouling occurs* and *(b) after fouling with a fouling factor of 0.0006 m2 · °C/ W occurs on* the outer surfaces of the tubes.

## PROBLEMS


## PROBLEMS

**SOLUTION** Glycerin is heated in a 2-shell passes and 4-tube passes heat exchanger by hot water. The rate of heat transfer for the cases of fouling and no fouling are to be determined.

***Assumptions*** **1** Steady operating conditions exist. **2** The heat exchanger is well insulated so that heat loss to the surroundings is negligible and thus heat transfer from the hot fluid is equal to heat transfer to the cold fluid. **3** Changes in the kinetic and potential energies of fluid streams are negligible. **4** Heat transfer coefficients and fouling factors are constant and uniform. **5** The thermal resistance of the inner tube is negligible since the tube is thin-walled and highly conductive.

***Analysis*** The tubes are said to be thin-walled, and thus it is reasonable to assume the inner and outer surface areas of the tubes to be equal. Then the heat transfer surface area becomes

$$A_s = \pi DL = \pi(0.02\text{ m})(60\text{ m}) = 3.77\text{ m}^2$$

The rate of heat transfer in this heat exchanger can be determined from

$$\dot{Q} = UA_sF\,\Delta T_{lm,CF}$$

where $F$ is the correction factor and $\Delta T_{lm,CF}$ is the log mean temperature difference for the counter-flow arrangement. These two quantities are determined from

$$\Delta T_1 = T_{h,in} - T_{c,out} = (80 - 50)°\text{C} = 30°\text{C}$$
$$\Delta T_2 = T_{h,out} - T_{c,in} = (40 - 20)°\text{C} = 20°\text{C}$$
$$\Delta T_{lm,CF} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} = \frac{30 - 20}{\ln(30/20)} = 24.7°\text{C}$$

## PROBLEMS

and

$$\left.\begin{aligned} P &= \frac{t_2 - t_1}{T_1 - t_1} = \frac{40 - 80}{20 - 80} = 0.67 \\ R &= \frac{T_1 - T_2}{t_2 - t_1} = \frac{20 - 50}{40 - 80} = 0.75 \end{aligned}\right\} F = 0.91 \qquad \text{(Fig. 13–18}b\text{)}$$

(*a*) In the case of no fouling, the overall heat transfer coefficient $U$ is determined from

$$U = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}} = \frac{1}{\frac{1}{160\text{ W/m}^2\cdot°\text{C}} + \frac{1}{25\text{ W/m}^2\cdot°\text{C}}} = 21.6\text{ W/m}^2\cdot°\text{C}$$

Then the rate of heat transfer becomes

$$\dot{Q} = UA_sF\,\Delta T_{lm,CF} = (21.6\text{ W/m}^2\cdot°\text{C})(3.77\text{m}^2)(0.91)(24.7°\text{C}) = \mathbf{1830\text{ W}}$$

(*b*) When there is fouling on one of the surfaces, the overall heat transfer coefficient $U$ is

$$U = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o} + R_f} = \frac{1}{\frac{1}{160\text{ W/m}^2\cdot°\text{C}} + \frac{1}{25\text{ W/m}^2\cdot°\text{C}} + 0.0006\text{ m}^2\cdot°\text{C/W}}$$
$$= 21.3\text{ W/m}^2\cdot°\text{C}$$

The rate of heat transfer in this case becomes

$$\dot{Q} = UA_sF\,\Delta T_{lm,CF} = (21.3\text{ W/m}^2\cdot°\text{C})(3.77\text{ m}^2)(0.91)(24.7°\text{C}) = \mathbf{1805\text{ W}}$$

***Discussion*** Note that the rate of heat transfer decreases as a result of fouling, as expected. The decrease is not dramatic, however, because of the relatively low convection heat transfer coefficients involved.

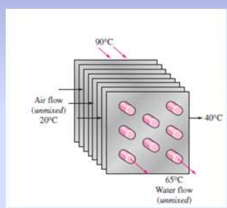
## PROBLEMS

4. A test is conducted to determine the overall heat transfer coefficient in an automotive radiator that is a compact cross-flow water-to-air heat exchanger with both fluids (air and water) unmixed. The radiator has 40 tubes of internal diameter 0.5 cm and length 65 cm in a closely spaced plate-finned matrix. Hot water enters the tubes at 90°C at a rate of 0.6 kg/s and leaves at 65°C. Air flows across the radiator through the interfin spaces and is heated from 20°C to 40°C. Determine the overall heat transfer coefficient *Ui of this radiator* based on the inner surface area of the tubes.

## PROBLEMS

**SOLUTION** During an experiment involving an automotive radiator, the inlet and exit temperatures of water and air and the mass flow rate of water are measured. The overall heat transfer coefficient based on the inner surface area is to be determined.

***Assumptions*** **1** Steady operating conditions exist. **2** Changes in the kinetic and potential energies of fluid streams are negligible. **3** Fluid properties are constant.



## PROBLEMS

**Properties** The specific heat of water at the average temperature of (90 + 65)/2 = 77.5°C is 4.195 kJ/kg · °C.

**Analysis** The rate of heat transfer in this radiator from the hot water to the air is determined from an energy balance on water flow,

$$\dot{Q} = [\dot{m}C_p(T_{in} - T_{out})]_{water} = (0.6\ \text{kg/s})(4.195\ \text{kJ/kg}\cdot°\text{C})(90 - 65)°\text{C} = 62.93\ \text{kW}$$

The tube-side heat transfer area is the total surface area of the tubes, and is determined from

$$A_i = n\pi D_i L = (40)\pi(0.005\ \text{m})(0.65\ \text{m}) = 0.408\ \text{m}^2$$

Knowing the rate of heat transfer and the surface area, the overall heat transfer coefficient can be determined from

$$\dot{Q} = U_i A_i F \Delta T_{lm,CF} \longrightarrow U_i = \frac{\dot{Q}}{A_i F \Delta T_{lm,CF}}$$

where $F$ is the correction factor and $\Delta T_{lm,CF}$ is the log mean temperature difference for the counter-flow arrangement. These two quantities are found to be

$$\Delta T_1 = T_{h,in} - T_{c,out} = (90 - 40)°\text{C} = 50°\text{C}$$
$$\Delta T_2 = T_{h,out} - T_{c,in} = (65 - 20)°\text{C} = 45°\text{C}$$
$$\Delta T_{lm,CF} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} = \frac{50 - 45}{\ln(50/45)} = 47.6°\text{C}$$

## PROBLEMS

and

$$\left.\begin{aligned} P &= \frac{t_2 - t_1}{T_1 - t_1} = \frac{65 - 90}{20 - 90} = 0.36 \\ R &= \frac{T_1 - T_2}{t_2 - t_1} = \frac{20 - 40}{65 - 90} = 0.80 \end{aligned}\right\} F = 0.97 \qquad \text{(Fig. 13–18c)}$$

Substituting, the overall heat transfer coefficient $U_i$ is determined to be

$$U_i = \frac{\dot{Q}}{A_i F \Delta T_{lm,CF}} = \frac{62{,}930\ \text{W}}{(0.408\ \text{m}^2)(0.97)(47.6°\text{C})} = 3341\ \text{W/m}^2\cdot°\text{C}$$

Note that the overall heat transfer coefficient on the air side will be much lower because of the large surface area involved on that side.

## PROBLEMS – NTU METHOD

## PROBLEMS

5. Cold water enters a counter-flow heat exchanger at 10°C at a rate of 8 kg/s, where it is heated by a hot water stream that enters the heat exchanger at 70°C at a rate of 2 kg/s. Assuming the specific heat of water to remain constant at Cp =4.18 kJ/kg°C, determine the maximum heat transfer rate and the outlet temperatures of the cold and the hot water streams for this limiting case.

## PROBLEMS

**SOLUTION** Cold and hot water streams enter a heat exchanger at specified temperatures and flow rates. The maximum rate of heat transfer in the heat exchanger is to be determined.

**Assumptions** **1** Steady operating conditions exist. **2** The heat exchanger is well insulated so that heat loss to the surroundings is negligible and thus heat transfer from the hot fluid is equal to heat transfer to the cold fluid. **3** Changes in the kinetic and potential energies of fluid streams are negligible. **4** Heat transfer coefficients and fouling factors are constant and uniform. **5** The thermal resistance of the inner tube is negligible since the tube is thin-walled and highly conductive.

**Properties** The specific heat of water is given to be $C_p$ = 4.18 kJ/kg · °C.

**Analysis** A schematic of the heat exchanger is given in Figure 13–24. The heat capacity rates of the hot and cold fluids are determined from

$$C_h = \dot{m}_h C_{ph} = (2\ \text{kg/s})(4.18\ \text{kJ/kg}\cdot°\text{C}) = 8.36\ \text{kW/°C}$$

and

$$C_c = \dot{m}_c C_{pc} = (8\ \text{kg/s})(4.18\ \text{kJ/kg}\cdot°\text{C}) = 33.4\ \text{kW/°C}$$

## PROBLEMS

Therefore

$$C_{min} = C_h = 8.36\ \text{kW/°C}$$

which is the smaller of the two heat capacity rates. Then the maximum heat transfer rate is determined from Eq. 13-32 to be

$$\begin{aligned} \dot{Q}_{max} &= C_{min}(T_{h,in} - T_{c,in}) \\ &= (8.36\ \text{kW/°C})(70 - 10)°\text{C} \\ &= 502\ \text{kW} \end{aligned}$$

That is, the maximum possible heat transfer rate in this heat exchanger is 502 kW. This value would be approached in a counter-flow heat exchanger with a *very large* heat transfer surface area.

The maximum temperature difference in this heat exchanger is $\Delta T_{max} = T_{h,in} - T_{c,in}$ = (70 − 10)°C = 60°C. Therefore, the hot water cannot be cooled by more than 60°C (to 10°C) in this heat exchanger, and the cold water cannot be heated by more than 60°C (to 70°C), no matter what we do. The outlet temperatures of the cold and the hot streams in this limiting case are determined to be

$$\dot{Q} = C_c(T_{c,out} - T_{c,in}) \longrightarrow T_{c,out} = T_{c,in} + \frac{\dot{Q}}{C_c} = 10°\text{C} + \frac{502\ \text{kW}}{33.4\ \text{kW/°C}} = 25°\text{C}$$

$$\dot{Q} = C_h(T_{h,in} - T_{h,out}) \longrightarrow T_{h,out} = T_{h,in} - \frac{\dot{Q}}{C_h} = 70°\text{C} - \frac{502\ \text{kW}}{8.38\ \text{kW/°C}} = 10°\text{C}$$

## PROBLEMS

6. A counter-flow double-pipe heat exchanger is to heat water from 20°C to 80°C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160°C at a mass flow rate of 2 kg/s. The inner tube is thin-walled and has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640 W/m$^2$ · °C, determine the length of the heat exchanger required to achieve the desired heating using NTU method.

## PROBLEMS

*Analysis* In the effectiveness–NTU method, we first determine the heat capacity rates of the hot and cold fluids and identify the smaller one:

$$C_h = \dot{m}_h C_{ph} = (2\ \text{kg/s})(4.31\ \text{kJ/kg}\cdot{}^\circ\text{C}) = 8.62\ \text{kW/}^\circ\text{C}$$
$$C_c = \dot{m}_c C_{pc} = (1.2\ \text{kg/s})(4.18\ \text{kJ/kg}\cdot{}^\circ\text{C}) = 5.02\ \text{kW/}^\circ\text{C}$$

Therefore,

$$C_{min} = C_c = 5.02\ \text{kW/}^\circ\text{C}$$

and

$$c = C_{min}/C_{max} = 5.02/8.62 = 0.583$$

Then the maximum heat transfer rate is determined from Eq. 13-32 to be

$$\dot{Q}_{max} = C_{min}(T_{h,\,in} - T_{c,\,in}) = (5.02\ \text{kW/}^\circ\text{C})(160 - 20)^\circ\text{C} = 702.8\ \text{kW}$$

## PROBLEMS

That is, the maximum possible heat transfer rate in this heat exchanger is 702.8 kW. The actual rate of heat transfer in the heat exchanger is

$$\dot{Q} = [\dot{m}C_p(T_{out} - T_{in})]_{water} = (1.2\ \text{kg/s})(4.18\ \text{kJ/kg}\cdot{}^\circ\text{C})(80 - 20)^\circ\text{C} = 301.0\ \text{kW}$$

Thus, the effectiveness of the heat exchanger is

$$\varepsilon = \frac{\dot{Q}}{\dot{Q}_{max}} = \frac{301.0\ \text{kW}}{702.8\ \text{kW}} = 0.428$$

Knowing the effectiveness, the NTU of this counter-flow heat exchanger can be determined from Figure 13–26*b* or the appropriate relation from Table 13–5. We choose the latter approach for greater accuracy:

$$\text{NTU} = \frac{1}{c-1}\ln\left(\frac{\varepsilon - 1}{\varepsilon c - 1}\right) = \frac{1}{0.583 - 1}\ln\left(\frac{0.428 - 1}{0.428 \times 0.583 - 1}\right) = 0.651$$

Then the heat transfer surface area becomes

$$\text{NTU} = \frac{UA_s}{C_{min}} \longrightarrow A_s = \frac{\text{NTU}\ C_{min}}{U} = \frac{(0.651)(5020\ \text{W/}^\circ\text{C})}{640\ \text{W/m}^2\cdot{}^\circ\text{C}} = 5.11\ \text{m}^2$$

To provide this much heat transfer surface area, the length of the tube must be

$$A_s = \pi DL \longrightarrow L = \frac{A_s}{\pi D} = \frac{5.11\ \text{m}^2}{\pi(0.015\ \text{m})} = \mathbf{108\ m}$$

## PROBLEMS

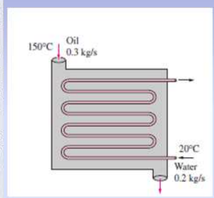
7. Hot oil is to be cooled by water in a 1-shell-pass and 8-tube-passes heat exchanger. The tubes are thin-walled and are made of copper with an internal diameter of 1.4 cm. The length of each tube pass in the heat exchanger is 5 m, and the overall heat transfer coefficient is 310 W/m2 °C. Water flows through the tubes at a rate of 0.2 kg/s, and the oil through the shell at a rate of 0.3 kg/s. The water and the oil enter at temperatures of 20°C and 150°C, respectively. Determine the rate of heat transfer in the heat exchanger and the outlet temperatures of the water and the oil.

## PROBLEMS

**SOLUTION** Hot oil is to be cooled by water in a heat exchanger. The mass flow rates and the inlet temperatures are given. The rate of heat transfer and the outlet temperatures are to be determined.

*Assumptions* **1** Steady operating conditions exist. **2** The heat exchanger is well insulated so that heat loss to the surroundings is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid. **3** The thickness of the tube is negligible since it is thin-walled. **4** Changes in the kinetic and potential energies of fluid streams are negligible. **5** The overall heat transfer coefficient is constant and uniform.

*Analysis* The schematic of the heat exchanger is given in Figure 13–30. The outlet temperatures are not specified, and they cannot be determined from an energy balance. The use of the LMTD method in this case will involve tedious iterations, and thus the ε–NTU method is indicated. The first step in the ε–NTU method is to determine the heat capacity rates of the hot and cold fluids and identify the smaller one:




## PROBLEMS

$$C_h = \dot{m}_h C_{ph} = (0.3\ \text{kg/s})(2.13\ \text{kJ/kg}\cdot{}^\circ\text{C}) = 0.639\ \text{kW/}^\circ\text{C}$$
$$C_c = \dot{m}_c C_{pc} = (0.2\ \text{kg/s})(4.18\ \text{kJ/kg}\cdot{}^\circ\text{C}) = 0.836\ \text{kW/}^\circ\text{C}$$

Therefore,

$$C_{min} = C_h = 0.639\ \text{kW/}^\circ\text{C}$$

and

$$c = \frac{C_{min}}{C_{max}} = \frac{0.639}{0.836} = 0.764$$

Then the maximum heat transfer rate is determined from Eq. 13-32 to be

$$\dot{Q}_{max} = C_{min}(T_{h,\,in} - T_{c,\,in}) = (0.639\ \text{kW/}^\circ\text{C})(150 - 20)^\circ\text{C} = 83.1\ \text{kW}$$

That is, the maximum possible heat transfer rate in this heat exchanger is 83.1 kW. The heat transfer surface area is

$$A_s = n(\pi DL) = 8\pi(0.014\ \text{m})(5\ \text{m}) = 1.76\ \text{m}^2$$

Then the NTU of this heat exchanger becomes

$$\text{NTU} = \frac{UA_s}{C_{min}} = \frac{(310\ \text{W/m}^2\cdot{}^\circ\text{C})(1.76\ \text{m}^2)}{639\ \text{W/}^\circ\text{C}} = 0.853$$

# PROBLEMS

The effectiveness of this heat exchanger corresponding to $c = 0.764$ and NTU $= 0.853$ is determined from Figure 13–26c to be

$$\varepsilon = 0.47$$

We could also determine the effectiveness from the third relation in Table 13–4 more accurately but with more labor. Then the actual rate of heat transfer becomes

$$\dot{Q} = \varepsilon \dot{Q}_{max} = (0.47)(83.1\ \text{kW}) = \mathbf{39.1\ kW}$$

Finally, the outlet temperatures of the cold and the hot fluid streams are determined to be

$$\dot{Q} = C_c(T_{c,\,out} - T_{c,\,in}) \longrightarrow T_{c,\,out} = T_{c,\,in} + \frac{\dot{Q}}{C_c}$$
$$= 20°\text{C} + \frac{39.1\ \text{kW}}{0.836\ \text{kW/°C}} = \mathbf{66.8°C}$$

$$\dot{Q} = C_h(T_{h,\,in} - T_{h,\,out}) \longrightarrow T_{h,\,out} = T_{h,\,in} - \frac{\dot{Q}}{C_h}$$
$$= 150°\text{C} - \frac{39.1\ \text{kW}}{0.639\ \text{kW/°C}} = \mathbf{88.8°C}$$

Therefore, the temperature of the cooling water will rise from 20°C to 66.8°C as it cools the hot oil from 150°C to 88.8°C in this heat exchanger.

# THANK YOU

# ME 8595-THERMAL ENGINEERING II

## UNIT- V REFRIGERATION AND AIR CONDITIONING

## REFRIGERATION AND AIR CONDITIONING

- Vapour compression Refrigeration cycle :Superheat, Sub cooling, Performance calculations,
- Working of vapour absorption system, Air cycle refrigeration, Thermo electric refrigeration,
- Psychrometry and Psychrometric properties, Psychrometric chart, Instrumentation,
- Cooling load calculations and circulating systems,
- Concept of RSHF, GSHF and ESHF,
- Air conditioning systems.

## Introduction

- The term refrigeration may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings.
- In other words, the refrigeration means a continued extraction of heat from a body whose temperature is already below temperature of its surroundings.

## Introduction

Ways of producing of refrigeration effect:

- By Melting of Solid
- By Sublimation of Solid
- By Evaporation of a Liquid

Most of the commercial refrigeration is produced by the evaporation of liquid called refrigerant.

## Refrigeration – Air Conditioning Differences

- Both refrigerator and air conditioning are the names varied depends on applications.
- In refrigeration's : The temperature of the conditioned space is only parameter is to be considered.
- In Air Conditioning: There are totally three parameters are controlled .
  - Temperature
  - Humidity
  - Air Velocity

## APPLICATIONS OF REFRIGERATION AND AIR CONDITIONING

The major applications of refrigeration can be grouped into following four major equally important areas.

1. Food processing, preservation and distribution
2. Chemical and process industries
3. Special Applications
4. Comfort air-conditioning

## Application of refrigeration in food processing, preservation and distribution

- Storage of Raw Fruits and Vegetables
- Meat and poultry
- Dairy Products ( Milk and Ice creams)
- Beverages ( Production of Beer, Wine etc)
- Processing and distribution of frozen food

## Applications of refrigeration in chemical and process industries

- Separation of gases
- Condensation of Gases
- Dehumidification of Air
- Solidification of Solute
- Storage as liquid at low pressure
- Removal of Heat of Reaction

## Special applications of refrigeration

- Cold Treatment of Metals
- Medical
- Ice Skating Rinks ( Ice Skating Hockey Game)
- Desalination of Water ( Sea water into Drinking Water)
- Ice Manufacture

## Applications of Air Conditioning

**Industrial air conditioning**:

Laboratories, Printing,

Manufacture of Precision Parts, Textile Industry,

Pharmaceutical Industries, Computer Rooms, Power

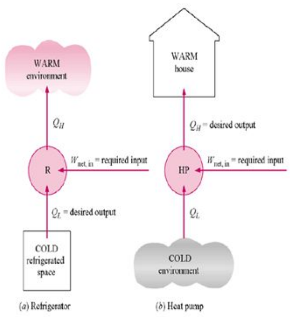
Plants, Vehicle .Air-conditioning.

**Comfort Air-Conditioning**

## Types of Refrigeration Systems

- Ice refrigeration
- Air Refrigeration
- Vapour Compression Refrigeration (VCR) System
- Vapour Absorption Refrigeration (VAR) System
- Adsorption Refrigeration System
- Cascade Refrigeration System
- Steam Jet Refrigeration System
- Thermoelectric Refrigeration System
- Vortex tube Refrigeration System
- Magnetic Refrigeration System and Etc

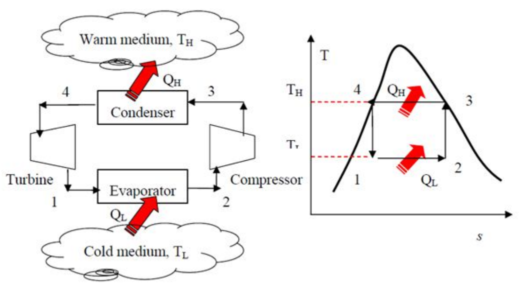
## Heat Pump and Refrigerator




$$COP_R = \frac{Q_L}{W_{net,in}}$$

$$COP_{HP} = \frac{Q_H}{W_{net,in}}$$

## Reversed Carnot Refrigeration Cycle




## Reversed Carnot Refrigeration Cycle

- Reversing the Carnot cycle does reverse the directions of heat and work interactions. A refrigerator or heat pump that operates on the reversed Carnot cycle is called a Carnot refrigerator or a Carnot heat pump.
- The reversed Carnot cycle is the most efficient refrigeration cycle operating between two specified temperature levels. It sets the highest theoretical COP. The coefficient of performance for Carnot refrigerators and heat pumps are:

$$COP_{Ref,Carnot} = \frac{1}{T_H/T_L - 1} \qquad COP_{HP,Carnot} = \frac{1}{1 - T_L/T_H}$$

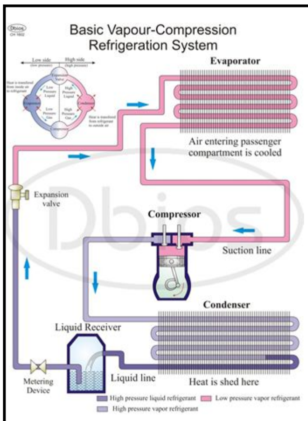
$$COP_{Hp} = COP_R + 1$$

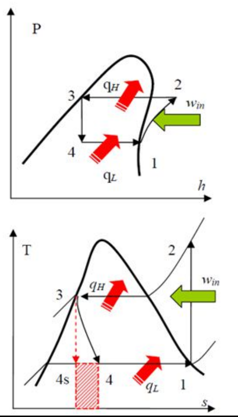
## Standard rating of Refrigeration Machine: Ton of Refrigeration (TR)

- <u>Ton of Refrigeration (TR)</u>: Ton of Refrigeration (abbreviated as TR) is an important historical unit of refrigeration capacity. Originally 1 TR was defined as the rate of heat transfer required to make 1 short ton (2000 lbs) of ice per day from water at $0^oC$. American Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE) defines 1 TR as equivalent to a refrigeration capacity of 3516.85 W or 3023.95 kcal/h. Tons of Refrigeration or simply Tons is often used as a general term to indicate the capacity or size of the refrigeration plant. Thus 1 TR air conditioner has a refrigeration capacity of 3516.85 W at the prescribed temperatures.

## Vapour Compression Refrigeration (VCR) System

- Vapour compression refrigeration systems are the most commonly used among all refrigeration systems.
- Vapour compression cycle is an improved type of air refrigeration cycle in which a suitable working substance, termed as refrigerant, is used. The refrigerant used, does not leave the system, but is circulated throughout the system alternately condensing and evaporating. In evaporating, the refrigerant absorbs its latent heat from the solution which is used for circulating it around the cold chamber and in condensing; it gives out its latent heat to the circulating water of the cooler.




## Vapour Compression Refrigeration (VCR) System : Components

**Compressor**
The low pressure and temperature vapour refrigerant from evaporator is drawn into the compressor through the inlet or suction valve, where it is compressed to a high pressure and temperature. This high pressure and temperature vapour refrigerant is discharged into the condenser through the delivery or discharge valve .

**Condenser**
The condenser or cooler consists of coils of pipe in which the high pressure and temperature vapour refrigerant is cooled and condensed.
The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water.

**Receiver**
The condensed liquid refrigerant from the condenser is stored in a vessel known as receiver from where it is supplied to the evaporator through the expansion valve or refrigerant control valve.

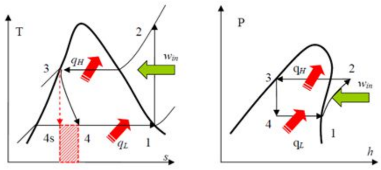
## Vapour Compression Refrigeration (VCR) System : Components

**Expansion Valve**

- It is also called throttle valve or refrigerant control valve. The function of the expansion valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporized in the evaporator at the low pressure and temperature.

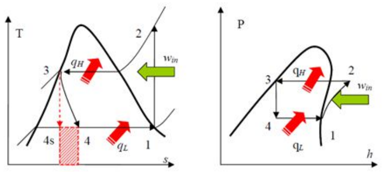
**Evaporator**

- An evaporator consists of coils of pipe in which the liquid-vapour. refrigerant at low pressure and temperature is evaporated and changed into vapour refrigerant at low pressure and temperature. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.




1-2: A reversible, adiabatic (isentropic) compression of the refrigerant. The saturated vapor at state 1 is superheated to state 2. ***Wc =h2 − h1***

2-3: An internally, reversible, constant pressure heat rejection in which the working substance is de-superheated and then condensed to a saturated liquid at 3. During this process, the working substance rejects most of its energy to the condenser cooling water. ***Qc = h2 − h3***



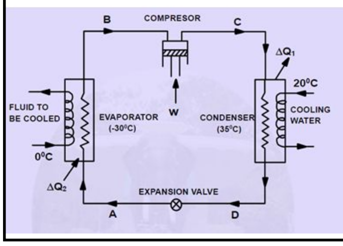

3-4: An irreversible throttling process in which the temperature and pressure decrease at constant enthalpy. The refrigerant enters the evaporator at state 4 as a low-quality saturated mixture. **h3 = h4**

4-1: An internally, reversible, constant pressure heat interaction in which the refrigerant (two-phase mixture) is evaporated to a saturated vapor at state point 1. The latent enthalpy necessary for evaporation is supplied by the refrigerated space surrounding the evaporator. The amount of heat transferred to the working fluid in the evaporator is called the refrigeration load. **Qe = h1 − h4**

## COP of VCR System

$$COP = \frac{\text{Heat extracted at low tempreature}}{\text{Work supplied}}$$

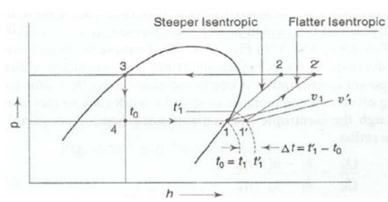
$$COP = \frac{h_1 - h_4}{h_2 - h_1} = \frac{h_1 - h_{f3}}{h_2 - h_1}$$




## Factors Affecting the Performance of Vapor Compression Refrigeration System:

1. **Super Heating**
2. **Sub Cooling**
3. **Suction Pressure**
4. **Discharge Pressure**

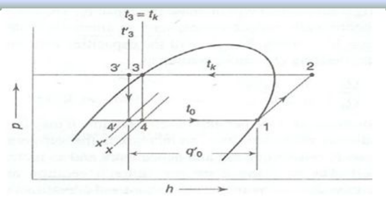
## Effects of Suction Vapour Super Heating




**COP of the system gets reduced**

**It can be seen from Figure ,that the effect of superheating of the vapour from t1= t1 to t1' is as follows :**
**(a) Increase in specific volume of suction vapour from v1 to v1'**
**(b) Increase in refrigerating effect from (h1 – h4) to (h1' – h4)**
**(c) Increase in specific work from (h2 – h1) to (h2'– h1')**

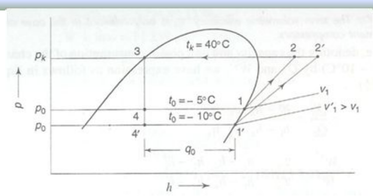
## Effects of Sub Cooling




COP of the system should increased

- The effect of sub-cooling of the liquid from t3 to t3' is shown in Figure. It will be seen that sub-cooling reduces flashing of the liquid during expansion and increases the refrigerating effect. Consequently, the piston displacement and horsepower per ton are reduced for all refrigerants.

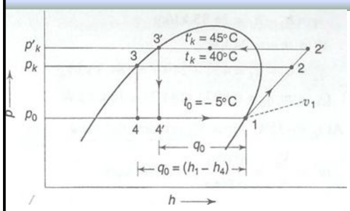
## Effects of Suction (Evaporation) Pressure




It is observed that a decrease in evaporator pressure results in :

- Decrease in refrigerating effect from (h1 – h4) to (h1' – h4')
- Increase in the specific volume of suction vapour from v1 to v1'
- Decrease in volumetric efficiency, due to increase in the pressure ratio, from $\eta_v$ to $\eta_{v'}$.
- Increase in compressor work from (h2 – h1) to (h2' – h1') due to increase in the pressure ratio

## Effects of Discharge (Condensation) Pressure




- An increase in condenser pressure, similarly results in a decrease in the refrigerating capacity and an increase in power consumption, as seen from the changed cycle *in Figure.*

The decrease in refrigerating capacity is due to a decrease in the refrigerating effect and volumetric efficiency. The increase in power consumption is due to increased mass flow (due to decreased refrigerating effect) and an increase in specific work (due to increased pressure ratio), although the isentropic line remains unchanged.

## PERFORMANCE CALCULATIONS

## PERFORMANCE CALCULATIONS

1. The temperature limits of an ammonia refrigerating system are 25°C and -100°C. If the gas is dry at the end of compression, calculate the coefficient of performance of, the cycle assuming no undercooling of the liquid ammonia. Use the following table for properties of ammonia:

| Temperature (°C) | Liquid heat (kJ/kg) | Latent heat (kJ/kg) | Liquid entropy (kJ/kg K; |
|---|---|---|---|
| 25 | 298.9 | 1166.94 | 1.1242 |
| – 10 | 135.37 | 1297.68 | 0.5443 |

## PERFORMANCE CALCULATIONS

**Solution.** Given : $T_2 = T_3 = 25°C = 298$ K ; $T_1 = T_4 = -10°C = 263$ K ; $h_{f3} = h_{f2} = 298.9$ kJ/kg ; $h_{fg2} = 1166.94$ kJ/kg ; $s_{f2} = 1.1242$ kJ/kg K ; $h_{f1} = 135.37$ kJ/kg ; $h_{fg1} = 1297.68$ kJ/kg ; $s_{f1} = 0.5443$ kJ/kg K

The *T-s* and *p-h* diagrams are shown in Fig. 36.4 (*a*) and (*b*) respectively.

Let $x_1$ = Dryness fraction at point 1.

We know that entropy at point 1,

$$s_1 = s_{f1} + \frac{x_1 h_{fg1}}{T_1} = 0.5443 + \frac{x_1 \times 1297.68}{263}$$

$$= 0.5443 + 4.934\, x_1 \qquad \ldots (i)$$

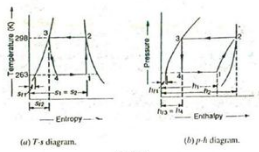
Similarly, entropy at point 2,

$$s_2 = s_{f2} + \frac{h_{fg2}}{T_2} = 1.1242 + \frac{1166.94}{298} = 5.04 \qquad \ldots (ii)$$

## PERFORMANCE CALCULATIONS

Since the entropy at point 1 is equal to entropy at point 2, therefore equating equations (*i*) and (*ii*),

$$0.5443 + 4.934\,x_1 = 5.04 \quad \text{or} \quad x_1 = 0.91$$




(*a*) *T-s* diagram. (*b*) *p-h* diagram.

Fig. 36.4

We know that enthalpy at point 1,

$$h_1 = h_{f1} + x_1\,h_{fg1} = 135.37 + 0.91 \times 1297.68 = 1316.26 \text{ kJ/kg}$$

and enthalpy at point 2, $h_2 = h_{f2} + h_{fg2} = 298.9 + 1166.94 = 1465.84$ kJ/kg

∴ Coefficient of performance of the cycle

$$= \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{1316.26 - 298.9}{1465.84 - 1316.26} = 6.8 \text{ Ans.}$$

## PERFORMANCE CALCULATIONS

2.A vapour compression refrigerator works between the pressure limits of 60 bar and 25 bar. The working fluid is just dry at the end of compression and there is no under cooling of the liquid before the expansion valve. Determine: 1.C.O.P. of the cycle; and 2. Capacity of the refrigerator if the fluid flow is at the rate of 5 kg/min.

| Pressure, bar | Saturation temperature, K | Enthalpy, kJ/kg | | Entropy, kJ/kg K | |
|---|---|---|---|---|---|
| | | Liquid | Vapour | Liquid | Vapour |
| 60 | 295 | 61.9 | 208.1 | 0.197 | 0.703 |
| 25 | 261 | −18.4 | 234.5 | −0.075 | 0.896 |

## PERFORMANCE CALCULATIONS

**Solution.** Given : $p_2 = p_3 = 60$ bar ; $p_1 = p_4 = 25$ bar ; $T_2 = T_3 = 295$ K ; $T_1 = T_4 = 261$ K ; $h_{f3} = h_4 = 61.9$ kJ/kg ; $h_{f1} = -18.4$ kJ/kg ; $h_{g2} = h_2 = 208.1$ kJ/kg ; $h_{g1} = 234.5$ kJ/kg ; $*s_{f2} = 0.197$ kJ/kg K ; $s_{f1} = -0.075$ kJ/kg K ; $s_{g1} = 0.896$ kJ/kg K ; $s_{g2} = s_2 = 0.703$ kJ/kg K

1. *C.O.P. of the cycle*

The *T-s* and *p-h* diagrams are shown in Fig. 36.5 (*a*) and (*b*) respectively.

Let $x_1$ = Dryness fraction of the vapour refrigerant entering the compressor at point 1.

We know that entropy at point 1 ($s_1$)

= Entropy at point 2 ($s_2$)

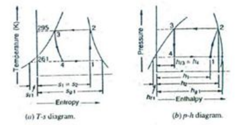
$$s_{f1} + x_1\,s_{fg1} = s_2$$

$$s_{f1} + x_1\,(s_{g1} - s_{f1}) = s_{g2} \qquad \ldots(\because s_{g1} = s_{f1} + s_{fg1} \text{ and } s_{g2} = s_2)$$

$$-0.075 + x_1\,[0.896 - (-0.075)] = 0.703$$

∴ $0.971\,x_1 = 0.778$ or $x_1 = 0.8$

## PERFORMANCE CALCULATIONS




(*a*) *T-s* diagram. (*b*) *p-h* diagram.

Fig. 36.5

We know that enthalpy at point 1,

$$h_1 = h_{f1} + x_1\,h_{fg1} = h_{f1} + x_1\,(h_{g1} - h_{f1}) \quad \ldots(h_{g1} = h_{f1} + h_{fg1})$$

$$= -18.4 + 0.8\,[234.5 - (-18.4)] = 183.9 \text{ kJ/kg}$$

∴ C.O.P. of the cycle $= \dfrac{h_1 - h_{f3}}{h_2 - h_1} = \dfrac{183.9 - 61.9}{208.1 - 183.9} = 5.04$ Ans.

2. *Capacity of the refrigerator*

We know that the heat extracted or refrigerating effect produced per kg of refrigerant

$$= h_1 - h_{f3} = 183.9 - 61.9 = 122 \text{ kJ/kg}$$

Since the fluid flow is at the rate of 5 kg/min, therefore total heat extracted

$$= 5 \times 122 = 610 \text{ kJ/min}$$

∴ Capacity of the refrigerator $= \dfrac{610}{210} = 2.9$ TR Ans. ...($\because$ 1 TR = 210 kJ/min)

## PERFORMANCE CALCULATIONS

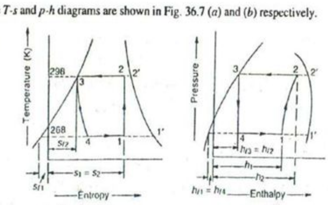
3.Find the theoretical C.O.P. for a $CO_2$ ,machine working between the temperature range of $25^0$C and $-5^0$C. The dryness fraction of $CO_2$, gas during the Suction stroke is 0.6. Following properties of $CO_2$ are given

| Temperature °C | Liquid | | Vapour | | Latent heat kJ/kg |
|---|---|---|---|---|---|
| | Enthalpy kJ/kg | Entropy kJ/kg K | Enthalpy kJ/kg | Entropy kJ/kg K | |
| 25 | 81.3 | 0.251 | 202.6 | 0.63 | 121.4 |
| −5 | −7.54 | −0.042 | 237 | 0.84 | 245.3 |

## PERFORMANCE CALCULATIONS

**Solution.** Given : $T_2 = T_3 = 25°$ C = 298 K ; $T_1 = T_4 = -5°$C = 268 K ; $x_1 = 0.6$ ; $h_{f3} = h_{f2} = 81.3$ kJ/kg ; $h_{f1} = h_{f4} = -7.54$ kJ/kg ; $s_{f2} = 0.251$ kJ/kg K ; $s_{f1} = -0.042$ kJ/kg K ; $h_2' = 202.6$ kJ/kg ; $*h_1' = 237$ kJ/kg ; $*s_2' = 0.63$ kJ/kg K ; $*s_1' = 0.84$ kJ/kg K ; $h_{fg2} = 121.4$ kJ/kg ; $h_{fg1} = 245.3$ kJ/kg

The *T-s* and *p-h* diagrams are shown in Fig. 36.7 (*a*) and (*b*) respectively.




(*a*) *T-s* diagram. (*b*) *p-h* diagram.

## PERFORMANCE CALCULATIONS

$$s_1 = s_{f1} + \frac{x_1 h_{fg1}}{T_1} = -0.042 + \frac{0.6 \times 245.3}{268} = 0.507 \quad \ldots (i)$$

Similarly, entropy at point 2,

$$s_2 = s_{f2} + \frac{x_2 h_{fg2}}{T_2} = 0.251 + \frac{x_2 \times 121.4}{298} = 0.251 + 0.407\, x_2 \quad \ldots (ii)$$

Since the entropy at point 1 ($s_1$) is equal to entropy at point 2 ($s_2$), therefore equating equations (*i*) and (*ii*),

$$0.507 = 0.251 + 0.407\, x_2 \quad \text{or} \quad x_2 = 0.629$$

$\therefore$ Enthalpy at point 1, $h_1 = h_{f1} + x_1 h_{fg1} = -7.54 + 0.6 \times 245.3 = 139.64$ kJ/kg

and enthalpy at point 2, $h_2 = h_{f2} + x_2 h_{fg2} = 81.3 + 0.629 \times 121.4 = 157.66$ kJ/kg

$$\therefore \text{Theoretical C.O.P.} = \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{139.64 - 81.3}{157.66 - 139.64} = 3.24 \text{ Ans.}$$

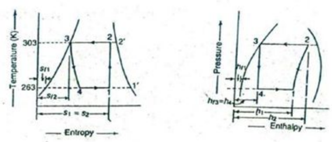
## PERFORMANCE CALCULATIONS

4. An ammonia refrigerating machine fitted with an expansion valve works between the temperature limits of -10°C and 30°C. The vapour is 95% dry at the end of isentropic compression and the fluid leaving the condenser is at 30°C. Assuming actual C.O.P. as 60% of the theoretical, calculate the kilograms of ice produced per kW hour at 0°C from water at 10° C. Latent heat of ice is 335 kJ/kg. Ammonia has the following properties:

## PERFORMANCE CALCULATIONS

| Temperature °C | Liquid heat kJ/kg | Latent heat kJ/kg | Liquid entropy | Total entropy of dry saturated vapour |
|---|---|---|---|---|
| 30 | 323.08 | 1145.80 | 1.2037 | 4.9842 |
| −10 | 135.37 | 1297.68 | 0.5443 | 5.4770 |

**Solution.** Given : $T_1 = T_4 = -10°C = 263$ K ; $T_2 = T_3 = 30°C = 303°$ K ; $x_2 = 0.95$
$h_{f3} = h_{f2} = 323.08$ kJ/kg ; $h_{f1} = h_{f4} = 135.37$ kJ/kg ; $h_{fg2} = 1145.8$ kJ/kg ; $h_{fg1} = 1297.68$ kJ/kg ;
$s_{f2} = 1.2037$ ; $s_{f1} = 0.5443$ ; $*s_2' = 4.9842$ ; $*s_1' = 5.4770$




(*a*) *T-s* diagram. (*b*) *p-h* diagram.

## PERFORMANCE CALCULATIONS

Let $x_1$ = Dryness fraction at point 1.

We know that entropy at point 1,

$$s_1 = s_{f1} + \frac{x_1 h_{fg1}}{T_1} = 0.5443 + \frac{x_1 \times 1297.68}{263} = 0.5443 + 4.934\, x_1 \quad \ldots (i)$$

Similarly, entropy at point 2,

$$s_2 = s_{f2} + \frac{x_2 h_{fg2}}{T_2} = 1.2037 + \frac{0.95 \times 1145.8}{303} = 4.796 \quad \ldots (ii)$$

Since the entropy at point 1 ($s_1$) is equal to entropy at point 2 ($s_2$), therefore equating equations (*i*) and (*ii*),

$$0.5443 + 4.934\, x_1 = 4.796 \quad \text{or} \quad x_1 = 0.86$$

$\therefore$ Enthalpy at point 1, $h_1 = h_{f1} + x_1 h_{fg1} = 135.37 + 0.86 \times 1297.68 = 1251.4$ kJ/kg

and enthalpy at point 2, $h_2 = h_{f2} + x_2 h_{fg2} = 323.08 + 0.95 \times 1145.8 = 1411.6$ kJ/kg

## PERFORMANCE CALCULATIONS

We know that theoretical C.O.P.

$$= \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{1251.4 - 323.08}{1411.6 - 1251.4} = 5.8$$

$\therefore$ Actual C.O.P. $= 0.6 \times 5.8 = 3.48$

Work to be spent corresponding to 1 kW hour,

$$W = 3600 \text{ kJ}$$

$\therefore$ Actual heat extracted or refrigeration effect produced per kW hour

$$= W \times \text{Actual C.O.P.} = 3600 \times 3.48 = 12\,528 \text{ kJ}$$

We know that heat extracted from 1 kg of water at 10°C for the formation of 1 kg of ice at 0°C

$$= 1 \times 4.187 \times 10 + 335 = 376.87 \text{ kJ}$$

$$\therefore \text{Amount of ice produced} = \frac{12\,528}{376.87} = 33.2 \text{ kg/kW hour Ans.}$$

## PERFORMANCE CALCULATIONS

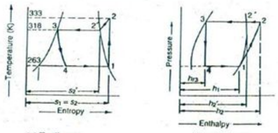
3. A vapour compression refrigerator uses methyl chloride (R-40) and operates between temperature limits of -10° C and 45° C. At entry to the compressor the refrigerant is dry saturated and after compression it acquires a temperature of 60° C. Find the C.O.P. of the refrigerator. The relevant properties of methyl chloride are as follows:

| Saturation Temperature in °C | Enthalpy in kJ/kg | | Entropy in kJ/kg K | |
|---|---|---|---|---|
| | Liquid | Vapour | Liquid | Vapour |
| −10 | 45.4 | 460.7 | 0.183 | 1.637 |
| 45 | 133.0 | 483.6 | 0.485 | 1.587 |

## PERFORMANCE CALCULATIONS

**Solution.** Given : $T_1 = T_4 = -10°\text{C} = 263\text{ K}$ ; $T_2' = T_3 = 45°\text{C} = 318\text{ K}$ ; $T_2 = 60°\text{C} = 333\text{ K}$ ; $*h_{f1} = 45.4$ kJ/kg ; $h_{f3} = 133$ kJ/kg ; $h_1 = 460.7$ kJ/kg ; $h_2' = 483.6$ kJ/kg ; $*s_{f1} = 0.183$ kJ/kg K ; $*s_{f3} = 0.485$ kJ/kg K ; $s_2 = 1.637$ kJ/kg K ; $s_2' = 1.587$ kJ/kg

The *T-s* and *p-h* diagrams are shown in Fig. 36.10 (*a*) and (*b*) respectively.




(*a*) *T-s* diagram. (*b*) *p-h* diagram.

Fig. 36.10

Let $c_p$ = Specific heat at constant pressure for superheated vapour.

We know that entropy at point 2,

$$s_2 = s_2' + 2.3\, c_p \log\left(\frac{T_2}{T_2'}\right)$$

## PERFORMANCE CALCULATIONS

$$1.637 = 1.587 + 2.3\, c_p \log\left(\frac{333}{318}\right)$$

$$= 1.587 + 2.3\, c_p \times 0.02 = 1.587 + 0.046\, c_p$$

$\therefore \quad c_p = 1.09$

and enthalpy at point 2, $\quad h_2 = h_2' + c_p \times \text{Degree of superheat} = h_2' + c_p(T_2 - T_2')$

$$= 483.6 + 1.09\,(333 - 318) = 500 \text{ kJ/kg}$$

$\therefore$ C.O.P. of the refrigerator $= \dfrac{h_1 - h_{f3}}{h_2 - h_1} = \dfrac{460.7 - 133}{500 - 460.7} = 8.34$ **Ans.**

## PERFORMANCE CALCULATIONS

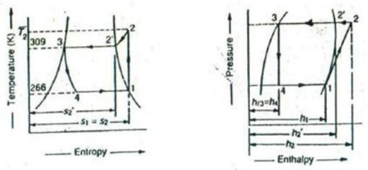
6. A refrigeration machine using R-12 as refrigerant operates between the pressures 2.5 bar and 9 bar. The compression is isentropic and there is no undercooling in the condenser. The vapour is in dry saturated condition at the beginning of the compression. Estimate the theoretical coefficient of performance. If the actual coefficient of performance is 0.65 of theoretical value, calculate the net cooling produced per hour. The refrigerant flow is 5 kg per minute. Properties of refrigerant are

| *Pressure, bar* | *Saturation temperature, °C* | *Enthalpy, kJ/kg* | | *Entropy of saturated vapour, kJ/kg K* |
|---|---|---|---|---|
| | | *Liquid* | *Vapour* | |
| *9.0* | *36* | *456.4* | *585.3* | *4.74* |
| *2.5* | *–7* | *412.4* | *570.3* | *4.76* |

*Take $c_p$ for superheated vapour at 9 bar as 0.67 kJ/kg K.*

## PERFORMANCE CALCULATIONS

**Solution.** Given : $T_2' = T_3 = 36°\text{C} = 309\text{ K}$ ; $T_1 = T_4 = -7°\text{C} = 266\text{ K}$ ; $(\text{C.O.P.})_{actual} = 0.65\,(\text{C.O.P.})_{th}$ ; $m = 5$ kg/min $= 300$ kg/h ; $h_{f3} = h_4 = 456.4$ kJ/kg ; $*h_{f1} = h_{f4} = 412.4$ kJ/kg ; $h_2' = 585.3$ kJ/kg ; $h_1 = 570.3$ kJ/kg ; $s_2' = 4.74$ kJ/kg K ; $s_1 = s_2 = 4.76$ kJ/kg K ; $c_p = 0.67$ kJ/kg K




(*a*) *T-s* diagram. (*b*) *p-h* diagram.

## PERFORMANCE CALCULATIONS

First of all, let us find the temperature at point 2 ($T_2$).

We know that entropy at point 2,

$$s_2 = s_2' + 2.3\, c_p \log\left(\frac{T_2}{T_2'}\right)$$

$$4.76 = 4.74 + 2.3 \times 0.67 \log\left(\frac{T_2}{309}\right)$$

$$\therefore \quad \log\left(\frac{T_2}{309}\right) = \frac{4.76 - 4.74}{2.3 \times 0.67} = 0.013$$

$$\frac{T_2}{309} = 1.03 \qquad \text{...(Taking antilog of 0.013)}$$

$$\therefore \quad T_2 = 309 \times 1.03 = 318.3\text{ K}$$

We know that enthalpy of superheated vapour at point 2,

$$h_2 = h_2' + c_p(T_2 - T_2')$$

$$= 585.3 + 0.67\,(318.3 - 309) = 591.5 \text{ kJ/kg}$$

## PERFORMANCE CALCULATIONS

$\therefore$ Theoretical coefficient of performance,

$$(\text{C.O.P.})_{th} = \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{570.3 - 456.4}{591.5 - 570.3} = 5.37 \textbf{ Ans.}$$

*Net cooling produced per hour*

We also know that actual C.O.P. of the machine,

$$(\text{C.O.P.})_{actual} = 0.65 \times (\text{C.O.P.})_{th} = 0.65 \times 5.37 = 3.49$$

and actual work done,

$$W_{actual} = h_2 - h_1 = 591.5 - 570.3 = 21.2 \text{ kJ/kg}$$

We know that net cooling (or refrigerating effect) produced per kg of refrigerant

$$= W_{actual} \times (\text{C.O.P.})_{actual} = 21.2 \times 3.49 = 74 \text{ kJ/kg}$$

$\therefore$ Net cooling produced per hour

$$= m \times 74 = 300 \times 74 = 22\,200 \text{ kJ/h}$$

$$= \frac{22\,200}{210 \times 60} = 1.76 \text{ TR} \textbf{ Ans.} \qquad \text{...}(\because 1\text{ TR} = 210 \text{ kJ/min})$$

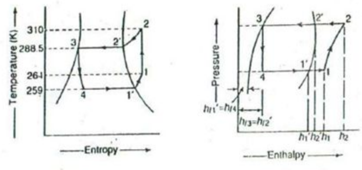
## PERFORMANCE CALCULATIONS

7.A vapour compression refrigeration plant works between pressure limits of 5.3 bar and 2.1 bar. The vapour is superheated at the end of compression, its temperature being 37°C. The vapour is superheated by 5° C before entering the compressor. If the specific heat of superheated vapour is 0.63 kJ/kg K, find the coefficient of performance of the plant. Use the data given below:

| Pressure, bar | Saturation temperature, °C | Liquid heat, kJ/kg | Latent heat, kJ/kg |
|---|---|---|---|
| 5.3 | 15.5 | 56.15 | 144.9 |
| 2.1 | – 14.0 | 25.12 | 158.7 |

## PERFORMANCE CALCULATIONS

**Solution.** Given : $p_2 = 5.3$ bar ; $p_1 = 2.1$ bar ; $T_2 = 37° C = 310$ K ; $T_1 - T_1' = 5°$ C ; $c_{pv} =$ 0.63 kJ/kg K ; $T_2' = 15.5° C = 288.5$ K ; $T_1' = -14° C = 259$ K ; $h_{f3} = h_{f2}' = 56.15$ kJ/kg ; $h_{f1}' = 25.12$ kJ/kg ; $h_{fg2}' = 144.9$ kJ/kg ; $h_{fg1}' = 158.7$ kJ/kg




(a) T-s diagram. (b) p-h diagram.

## PERFORMANCE CALCULATIONS

We know that enthalpy of vapour at point 1,

$$h_1 = h_1' + c_{pv}(T_1 - T_1') = (h_{f1}' + h_{fg1}') + c_{pv}(T_1 - T_1')$$

$$= (25.12 + 158.7) + 0.63 \times 5 = 186.97 \text{ kJ/kg}$$

Similarly, enthalpy of vapour at point 2,

$$h_2 = h_2' + c_{pv}(T_2 - T_2') = (h_{f2}' + h_{fg2}') + c_{pv}(T_2 - T_2')$$

$$= (56.15 + 144.9) + 0.63\,(310 - 288.5) = 214.6 \text{ kJ/kg}$$

∴ Coefficient of performance of the plant,

$$\text{C.O.P.} = \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{186.97 - 56.15}{214.6 - 186.97} = \frac{130.82}{27.63} = 4.735 \text{ Ans.}$$

## PERFORMANCE CALCULATIONS

8.A vapour compression refrigerator uses R-12 as refrigerant and the liquid evaporates in the evaporator at -15°C. The temperature of this refrigerant at the delivery from the compressor is 15° C when the vapour is condensed at 10°C. Find the coefficient of performance if 1. there is no undercooling, and 2. the liquid is cooled by 5°C before expansion by throttling. Take specific heat at constant pressure for the superheated vapour as 0.64 kJ/kg K and that for liquid as 0.94 kJ/kg K. The other properties of refrigerant are as follows:

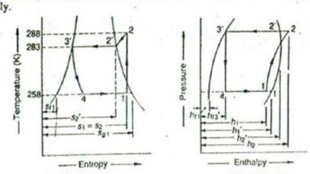
| Temperature in °C | Enthalpy in kJ/kg | | Entropy in kJ/kg K | |
|---|---|---|---|---|
| | Liquid | Vapour | Liquid | Vapour |
| –15 | 22.3 | 180.88 | 0.0904 | 0.7051 |
| +10 | 45.4 | 191.76 | 0.1750 | 0.6921 |

## PERFORMANCE CALCULATIONS

**Solution.** Given : $T_1 = T_4 = -15° C = 258$ K ; $T_2 = 15° C = 288$ K ; $T_2' = 10° C = 283$ K ; $c_{pv} = 0.64$ kJ/kg K ; $c_{pl} = 0.94$ kJ/kg K ; $h_{f1} = 22.3$ kJ/kg ; $h_{f3}' = 45.4$ kJ/kg ; $h_1' = 180.88$ kJ/kg ; $h_2' = 191.76$ kJ/kg ; $s_{f1} = 0.0904$ kJ/kg K ; $*s_{f2} = 0.1750$ kJ/kg K ; $s_{g1} = 0.7051$ kJ/kg K ; $s_2' = 0.6921$ kJ/kg K

1. *Coefficient of performance if there is no undercooling*

The T-s and p-h diagrams, when there is no undercooling, are shown in Fig. 36.15 (a) and (b) respectively.




(a) T-s diagram. (b) p-h diagram.

## PERFORMANCE CALCULATIONS

Let $x_1$ = Dryness fraction of the refrigerant at point 1.

We know that entropy at point 1,

$$s_1 = s_{f1} + x_1 s_{fg1} = s_{f1} + x_1(s_{g1} - s_{f1}) = 0.0904 + x_1(0.7051 - 0.0904)$$

$$= 0.0904 + 0.6147\,x_1 \qquad \ldots (i)$$

and entropy at point 2,

$$s_2 = s_2' + 2.3\,c_{pv}\log\left(\frac{T_2}{T_2'}\right) = 0.6921 + 2.3 \times 0.64 \log\left(\frac{288}{283}\right)$$

$$= 0.6921 + 2.3 \times 0.64 \times 0.0077 = 0.7034 \qquad \ldots (ii)$$

## PERFORMANCE CALCULATIONS

Since the entropy at point 1 is equal to entropy at point 2, therefore equating equations (*i*) and (*ii*),

$$0.0904 + 0.6147\, x_1 = 0.7034 \quad \text{or} \quad x_1 = 0.997$$

We know that the enthalpy at point 1,

$$h_1 = h_{f1} + x_1\, h_{fg1} = h_{f1} + x_1\, (h_1' - h_{f1}) \qquad \ldots (\because h_{fg1} = h_1' - h_{f1})$$

$$= 22.3 + 0.997\,(180.88 - 22.3) = 180.4 \text{ kJ/kg}$$

and enthalpy at point 2, $h_2 = h_2' + c_{pv}\,(T_2 - T_2')$

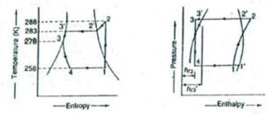
$$= 191.76 + 0.64\,(288 - 283) = 194.96 \text{ kJ/kg}$$

$$\therefore \qquad \text{C.O.P.} = \frac{h_1 - h_{f3}'}{h_2 - h_1} = \frac{180.4 - 45.4}{194.96 - 180.4} = 9.27 \text{ Ans.}$$

## PERFORMANCE CALCULATIONS

2. *Coefficient of performance when there is an undercooling of 5° C*

The *T-s* and *p-h* diagrams, when there is an undercooling of 5° C, are shown in Fig. 36.16 (*a*) and (*b*) respectively.




(*a*) *T-s* diagram. (*b*) *p-h* diagram.

Fig. 36.16

We know that enthalpy of liquid refrigerant at point 3,

$$h_{f3} = h_{f3}' - c_{pl} \times \text{Degree of undercooling}$$

$$= 45.4 - 0.94 \times 5 = 40.7 \text{ kJ/kg}$$

$$\therefore \qquad \text{C.O.P.} = \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{180.4 - 40.7}{194.96 - 180.4} = 9.59 \text{ Ans.}$$

## PERFORMANCE CALCULATIONS

9. A food storage locker requires a refrigeration capacity of 12 TR and works between the evaporating temperature of -8 ° C and condensing temperature of 30° C. The refrigerant R-12 is subcooled by 5°C before entry to expansion valve and the vapour is superheated to -2° C before leaving the evaporator coils. Determine: I. coefficient of performance and 2. theoretical power per tonne of refrigeration. Use the following data for R-12

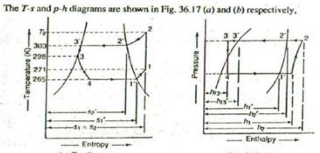
## PERFORMANCE CALCULATIONS

| *Saturation temperature, °C* | *Pressure, bar* | *Enthalpy, kJ/kg* | | *Entropy, kJ/kg K* | |
|---|---|---|---|---|---|
| | | *Liquid* | *Vapour* | *Liquid* | *Vapour* |
| –8 | 2.354 | 28.72 | 184.07 | 0.1149 | 0.7007 |
| 30 | 7.451 | 64.59 | 199.62 | 0.2400 | 0.6853 |

*The specific heat of liquid R-12 is 1.235 kJ/kg K, and of vapour R-12 is 0.733 kJ/kg K.*

**Solution.** Given : $Q = 12$ TR ; $T_1' = -8°C = 265$ K; $T_2' = 30°C = 303$ K; $T_3' - T_3 = 5°C$ ; $T_1 = -2°C = 271$ K ; $h_{f1} = 28.72$ kJ/kg ; $h_{f3}' = 64.59$ kJ/kg ; $h_1' = 184.07$ kJ/kg ; $h_2' = 199.62$ kJ/kg ; $*s_{f1} = 0.1149$ kJ/kg K ; $*s_{f3} = 0.2400$ kJ/kg K ; $s_1' = 0.7007$ kJ/kg K ; $s_2' = 0.6853$ kJ/kg K ; $c_{pl} = 1.235$ kJ/kg K ; $c_{pv} = 0.733$ kJ/kg K

The *T-s* and *p-h* diagrams are shown in Fig. 36.17 (*a*) and (*b*) respectively.




(*a*) *T-s* diagram. (*b*) *p-h* diagram.

## PERFORMANCE CALCULATIONS

1. *Coefficient of performance*

First of all, let us find the temperature of superheated vapour at point 2 ($T_2$).

We know that entropy at point 1,

$$s_1 = s_1' + 2.3\, c_{pv} \log\left(\frac{T_1}{T_1'}\right)$$

$$= 0.7007 + 2.3 \times 0.733 \log\left(\frac{271}{265}\right) = 0.7171 \qquad \ldots (i)$$

and entropy at point 2, $s_2 = s_2' + 2.3\, c_{pv} \log\left(\frac{T_2}{T_2'}\right)$

$$= 0.6853 + 2.3 \times 0.733 \log\left(\frac{T_2}{303}\right)$$

$$= 0.6853 + 1.686 \log\left(\frac{T_2}{303}\right) \qquad \ldots (ii)$$

## PERFORMANCE CALCULATIONS

Since the entropy at point 1 is equal to entropy at point 2, therefore equating equations (*i*) and (*ii*),

$$0.7171 = 0.6853 + 1.686 \log\left(\frac{T_2}{303}\right)$$

or

$$\log\left(\frac{T_2}{303}\right) = \frac{0.7171 - 0.6853}{1.686} = 0.0188$$

$$\frac{T_2}{303} = 1.0444 \qquad \ldots \text{(Taking antilog of 0.0188)}$$

$$\therefore \qquad T_2 = 316.4 \text{ K or } 43.4\,°\text{C}$$

We know that enthalpy at point 1,

$$h_1 = h_1' + c_{pv}\,(T_1 - T_1')$$

$$= 184.07 + 0.733\,(271 - 265) = 188.47 \text{ kJ/kg}$$

Enthalpy at point 2, $h_2 = h_2' + c_{pv}\,(T_2 - T_2')$

$$= 199.62 + 0.733\,(316.4 - 303) = 209.44 \text{ kJ/kg}$$

and enthalpy of liquid refrigerant at point 3,

$$h_{f3} = h_{f3}' - c_{pl}\,(T_3' - T_3)$$

$$= 64.59 - 1.235 \times 5 = 58.42 \text{ kJ/kg}$$

$$\therefore \qquad \text{C.O.P.} = \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{188.47 - 58.42}{209.44 - 188.47} = \frac{130.05}{20.97} = 6.2 \text{ Ans.}$$

## PERFORMANCE CALCULATIONS

2. *Theoretical power per tonne of refrigeration*

We know that the heat extracted or refrigerating effect per kg of the refrigerant,

$$R_E = h_1 - h_{f3} = 188.47 - 58.42 = 130.05 \text{ kJ/kg}$$

and the refrigerating capacity of the system,

$$Q = 12 \text{ TR} = 12 \times 210 = 2520 \text{ kJ/min} \quad \text{. . .(Given)}$$

∴ Mass flow of the refrigerant,

$$m_R = \frac{Q}{R_E} = \frac{2520}{130.05} = 19.4 \text{ kg/min}$$

Work done during compression of the refrigerant

$$= m_R (h_2 - h_1) = 19.4 (209.44 - 188.47) = 406.82 \text{ kJ/min}$$

∴ Theoretical power per tonne of refrigeration

$$= \frac{406.82}{60 \times 12} = 0.565 \text{ kW/TR Ans.}$$

## VAPOUR ABSORPTION REFRIGERATION (VAR) SYSTEM

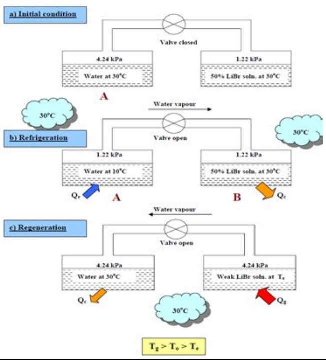
## Vapour Absorption Refrigeration (VAR) System

- Vapour Absorption Refrigeration Systems (VARS) belong to the class of vapour cycles similar to vapour compression refrigeration systems. However, unlike vapour compression refrigeration systems, the required input to absorption systems is in the form of heat. Hence these systems are also called as heat operated or thermal energy driven systems. Since conventional absorption systems use liquids for absorption of refrigerant, these are also sometimes called as wet absorption systems. Similar to vapour compression refrigeration systems, vapour absorption refrigeration systems have also been commercialized and are widely used in various refrigeration and air conditioning applications. Since these systems run on low-grade thermal energy, they are preferred when low-grade energy such as waste heat or solar energy is available. Since conventional absorption systems use natural refrigerants such as water or ammonia they are environment friendly.

## Basic Principle of VAR System

- When a solute such as lithium bromide salt is dissolved in a solvent such as water, the boiling point of the solvent (water) is elevated. On the other hand, if the temperature of the solution (solvent + solute) is held constant, then the effect of dissolving the solute is to reduce the vapour pressure of the solvent below that of the saturation pressure of pure solvent at that temperature. If the solute itself has some vapour pressure (i.e., volatile solute) then the total pressure exerted over the solution is the sum total of the partial pressures of solute and solvent. If the solute is non-volatile (e.g. lithium bromide salt) or if the boiling point difference between the solution and solvent is large (≥ 300°C), then the total pressure exerted over the solution will be almost equal to the vapour pressure of the solvent only.

## Basic Principle of VAR System




**In the simplest absorption refrigeration system, refrigeration is obtained by connecting two vessels, with one vessel containing pure solvent and the other containing a solution. Since the pressure is almost equal in both the vessels at equilibrium, the temperature of the solution will be higher than that of the pure solvent. This means that if the solution is at ambient temperature, then the pure solvent will be at a temperature lower than the ambient. Hence refrigeration effect is produced at the vessel containing pure solvent due to this temperature difference.**

## Refrigerant-absorbent combinations for VARS

The desirable properties of refrigerant-absorbent mixtures for VARS are:

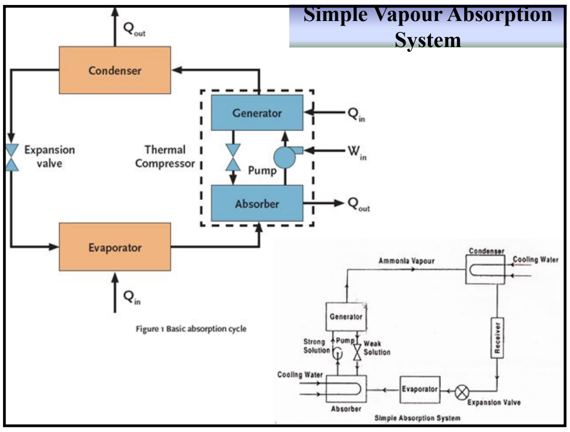
- The refrigerant should exhibit high solubility with solution in the absorber.
- There should be large difference in the boiling points of refrigerant and absorbent (greater than 200°C), so that only refrigerant is boiled-off in the generator. This ensures that only pure refrigerant circulates through refrigerant circuit (condenser-expansion valve-evaporator) leading to isothermal heat transfer in evaporator and condenser.
- It should exhibit small heat of mixing so that a high COP can be achieved.
- The refrigerant-absorbent mixture should have high thermal conductivity and low viscosity for high performance.
- It should not undergo crystallization or solidification inside the system.
- The mixture should be safe, chemically stable, non-corrosive, inexpensive and should be available easily.

## Types of VARS ( Depends on refrigerant – absorbent pair)

The most commonly used refrigerant-absorbent pairs in commercial systems are:

- **Water-Lithium Bromide ($H_2O$-LiBr)** system for above 0°C applications such as air conditioning. Here water is the refrigerant and lithium bromide is the absorbent.
- **Ammonia-Water ($NH_3$-$H_2O$) system** for refrigeration applications with ammonia as refrigerant and water as absorbent.

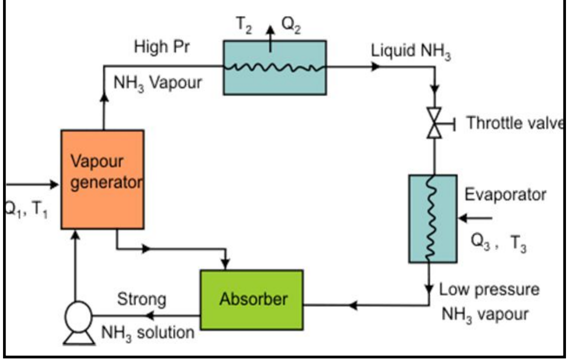
## Simple Vapour Absorption System



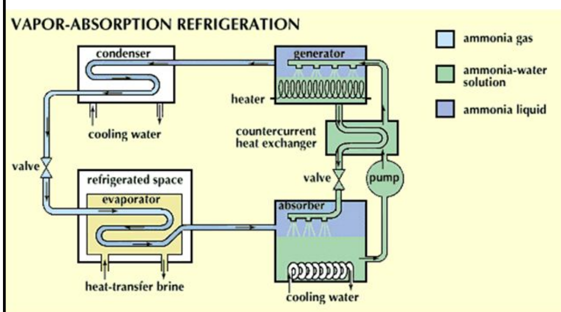

## Simple Vapour Absorption System

- Some liquids like water have great affinity for absorbing large quantities of certain vapors (NH3) and reduce the total volume greatly.
- The absorption refrigeration system differs fundamentally from vapor compression system only in the method of compressing the refrigerant.
- **An absorber, generator and pump in the absorption refrigerating system replace the compressor of a vapor compression system**.

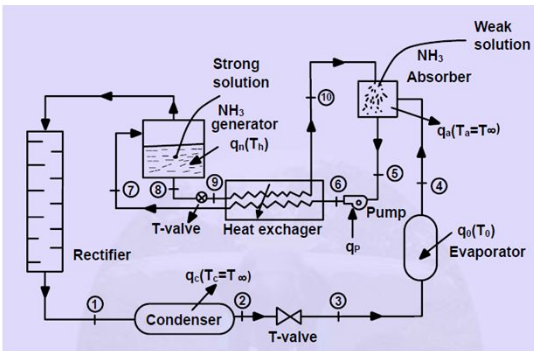
## Simple Vapour Absorption System




## Practical Ammonia Vapour Absorption System




## Practical Ammonia Vapour Absorption System



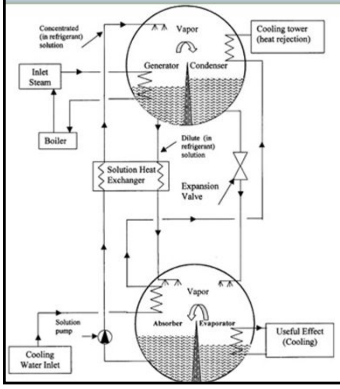
## Practical Ammonia Vapour Absorption System

- Figure shows the schematic diagram of a vapor absorption system. Ammonia vapor is produced in the generator at high pressure from the strong solution of NH3 by an external heating source. The water vapor carried with ammonia is removed in the rectifier and only the dehydrated ammonia gas enters into the condenser.
- High pressure NH3 vapor is condensed in the condenser. The cooled NH3 solution is passed through a throttle valve and the pressure and temperature of the refrigerant are reduced below the temperature to be maintained in the evaporator.
- The low temperature refrigerant enters the evaporator and absorbs the required heat from the evaporator and leaves the evaporator as saturated vapor. Slightly superheated, low pressure NH3 vapor is absorbed by the weak solution of NH3 which is sprayed in the absorber as shown in Fig.
- Weak NH3 solution (aqua–ammonia) entering the absorber becomes strong solution after absorbing NH3 vapor and then it is pumped to the generator through the heat exchanger.

## Practical Ammonia Vapour Absorption System

- The pump increases the pressure of the strong solution to generator pressure. The strong NH3 solution coming from the absorber absorbs heat form high temperature weak NH3 solution in the heat exchanger.
- The solution in the generator becomes weak as NH3 vapor comes out of it. The weak high temperature ammonia solution from the generator is passed to the heat exchanger through the throttle valve. The pressure of the liquid is reduced to the absorber pressure by the throttle valve.

## $H_20$ – LiBr Vapour Absorption System



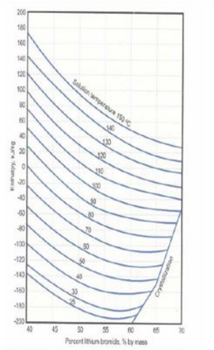
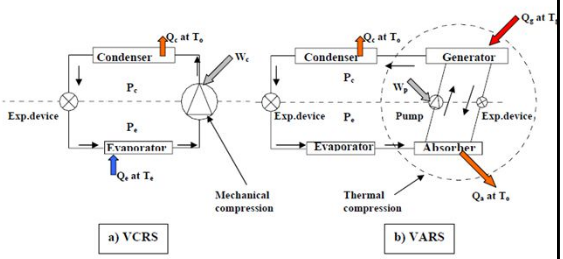




Fig.15.4: Enthalpy –Temperature - Concentration diagram for H2O-LiBr solution

## VAR System VS VCR System




## VAR System VS VCR System

| Sl.No | Vapour Absorption Refrigeration (VAR) System | Vapour Compression refrigeration (VCR) System |
|---|---|---|
| 1 | Uses low grade energy like heat. Therefore, may be worked on exhaust systems from I.C engines, etc. | Using high-grade energy like mechanical work. |
| 2 | Moving parts are only in the pump, which is a small element of the system. Hence operation is smooth. | Moving parts are in the compressor. Therefore, more wear, tear and noise. |
| 3 | The system can work on lower evaporator pressures also without affecting the COP. | The COP decreases considerably with decrease in evaporator pressure. |
| 4 | No effect of reducing the load on performance. | Performance is adversely affected at partial loads. |
| 5 | Liquid traces of refrigerant present in piping at the exit of evaporator constitute no danger. | Liquid traces in suction line may damage the compressor. |
| 6 | Automatic operation for controlling the capacity is easy. | It is difficult. |

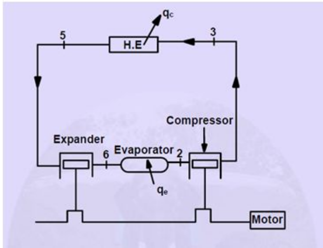
## VAR System VS VCR System

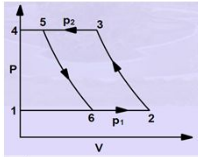
| Sl.No | Vapour Absorption Refrigeration (VAR) System | Vapour Compression refrigeration (VCR) System |
|---|---|---|
| 7 | Small Capacity system designs are very difficult | Easy to design small capacity systems |
| 8. | There is crystallization problems in $H_20$-LiBr system | No Crystallization Problems |
| 9 | Ozen Friendly refrigerants | There is problem in Ozone Depletion and Global Warming. |
| 10 | In $NH_3$ – $H_20$, Ammonia is Toxic Gas. So need some prevention. Cant used in direct cooling system. Needs secondary systems | - |

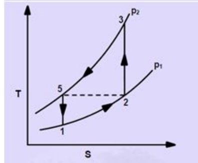
## Air Cycle Refrigeration Systems

- Air cycle refrigeration systems belong to the general class of gas cycle refrigeration systems, in which a gas (Air) is used as the working fluid. The gas does not undergo any phase change during the cycle, consequently, all the internal heat transfer processes are sensible heat transfer processes.
- Gas cycle refrigeration systems find applications in air craft cabin cooling and also in the liquefaction of various gases.
- Air Refrigeration System is also called as Bell-Coleman Cycle Or Reversed Brayton Cycle.

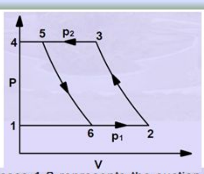
## Air Cycle Refrigeration Systems

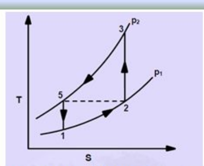



## Air Cycle Refrigeration Systems




Process 1-2 represents the suction of air into the compressor. Process 2-3 represents the isentropic compression of air by the compressor. Process 3-5 represents the discharge of high pressure air from the compressor into the heat exchanger. The reduction in volume of air from $v_3$ to $v_5$ is due to the cooling of air in the heat exchanger. Process 5-6 represents the isentropic expansion of air in the expander. Process 6-2 represents the absorption of heat from the evaporator at constant pressure.

## Air Cycle Refrigeration Systems - Analysis

**Assumptions:**

1) *The compression and expansion processes are reversible adiabatic processes.*
2) *There is a perfect inter-cooling in the heat exchanger.*
3) *There are no pressure losses in the system.*

$$COP = \frac{\text{Net refrigeration effect}}{\text{Net work supplied}}$$

Work done per kg of air for the isentropic compression process 2-3 is given by,

$$W_C = C_p(T_3 - T_2)$$

Work developed per kg of air for the isentropic expansion process 5-6 is given by,

$$W_E = C_p(T_5 - T_6)$$

$$\text{Net work required} = W_{net} = (W_C - W_E) = C_p(T_3 - T_2) - C_p(T_5 - T_6)$$

## Air Cycle Refrigeration Systems - Analysis

Net refrigerating effect per kg of air is given by,

$$R_{net} = C_p(T_2 - T_6)$$

$$COP = \frac{R_{net}}{W_{net}} = \frac{C_p(T_2 - T_6)}{C_p\{(T_3 - T_2) - (T_5 - T_6)\}}$$

For perfect inter-cooling, the required condition is $T_5 = T_2$

$$COP = \frac{(T_2 - T_6)}{(T_3 - T_2) - (T_2 - T_6)}$$

$$= \frac{1}{\frac{(T_3 - T_2)}{(T_2 - T_6)} - 1} \quad \text{(for isentropic process)}$$

$$= \frac{1}{\frac{T_3(1 - T_2/T_3)}{T_2(1 - T_6/T_2)} - 1}$$

## Air Cycle Refrigeration Systems - Analysis

For isentropic compression process 2-3 and for expansion process 5-6, we have,

$$\frac{T_3}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} \text{ and } \frac{T_5}{T_6} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$= \frac{1}{\frac{(T_3 - T_2)}{(T_2 - T_6)} - 1} \quad \text{(for isentropic process)}$$

Therefore, $\frac{T_3}{T_2} = \frac{T_5}{T_6}$ or $\frac{T_6}{T_5} = \frac{T_2}{T_3}$ $\because (T_5 = T_2)$

$$= \frac{1}{\frac{T_3(1 - T_2/T_3)}{T_2(1 - T_6/T_2)} - 1}$$

$$COP = \frac{T_2}{T_3 - T_2}$$

## Air Cycle Refrigeration Systems - Analysis

**Advantages:**

a) *Air is a cheaper refrigerant and available easily compared to other refrigerants.*
b) *There is no danger of fire or toxic effects due to leakage.*
c) *The total weight of the system per ton of refrigerating capacity is less.*

**Disadvantages:**

(a) *The quantity of air required per ton refrigerating capacity is far greater than other systems.*
(b) *The COP is low and hence maintenance cost is high.*
(c) *The danger of frosting at the expander valves is more as the air taken into the system always contains moisture.*

## THERMO ELECTRIC REFRIGERATION SYSTEM

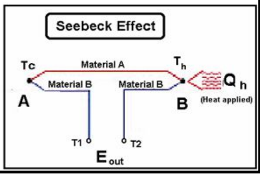
- Thermoelectric are based on the Peltier Effect, The Peltier Effect is one of the three thermoelectric effects; the other two are known as the Seebeck Effect and Thomson Effect. Whereas the last two effects act on a single conductor, the Peltier Effect is a typical junction phenomenon.
- Thermoelectric coolers are solid state heat pumps used in applications where temperature stabilization, temperature cycling, or cooling below ambient are required. There are many products using thermoelectric coolers, including CCD cameras, laser diodes, microprocessors, blood analyzers and portable picnic coolers.

## SEEBECK EFFECT

- **The conductors are two dissimilar metals denoted as material A and material B. The junction temperature at A is used as a reference and is maintained at a relatively cool temperature ($T_C$). The junction temperature at B is used as temperature higher than temperature $T_C$. With heat applied to junction B, a voltage ($E_{out}$) will appear across terminals $T_1$ and $T_2$ and hence an electric current would flow continuously in this closed circuit.**

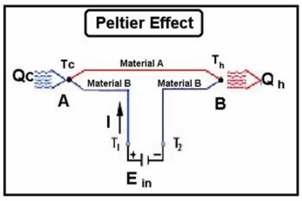
$$E_{out} = \alpha\,(T_H - T_C)$$

**α - Seeback coefficient**
**$E_{out}$ – Voltage output**




## PELTIER SEEBECK EFFECT

- Peltier found there was an opposite phenomenon to the Seebeck Effect, whereby thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flowed within the closed circuit.




## PELTIER SEEBECK EFFECT

- If a voltage ($E_{in}$) is applied to terminals $T_1$ and $T_2$, an electrical current (I) will flow in the circuit. As a result of the current flow, a slight cooling effect ($Q_C$) will occur at thermocouple junction A (where heat is absorbed), and a heating effect ($Q_H$) will occur at junction B (where heat is expelled).
- Note that this effect may be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow.

## PELTIER SEEBECK EFFECT

- This Joule heating effect acts in opposition to the Peltier Effect and causes a net reduction of the available cooling. The Peltier effect can be expressed mathematically as

$$Q_C \text{ or } Q_H = \beta \times I = (\alpha T) \times I$$

Where:

- β is the differential Peltier coefficient between the two materials A and B in volts.
- I is the electric current flow in amperes.
- $Q_C$ and $Q_H$ are the rates of cooling and heating, respectively, in watts.

## IMPORTANT EFFECT OF β ON THERMOELECTRIC COOLING

Peltier coefficient β has important effect on Thermoelectric cooling as following:

a) β <0 ; Negative Peltier coefficient

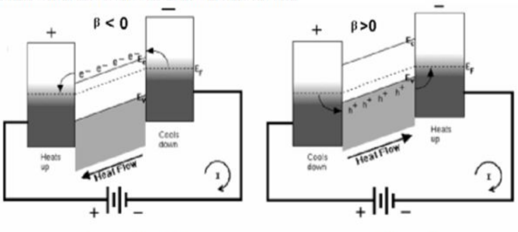
High energy electrons move from right to left.

Thermal current and electric current flow in opposite directions

b) β >0 ; Positive Peltier coefficient

High energy holes move from left to right.

Thermal current and electric current flow in same direction



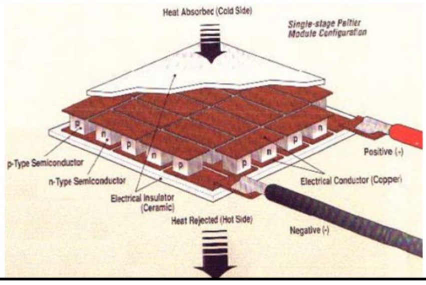

a) -ve Peltier coefficient     b)+ve Peltier coefficient

## THOMSON EFFECT

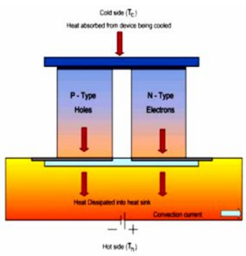
- William Thomson, who described the relationship between the two phenomena, later issued a more comprehensive explanation of the Seebeck and Peltier effects. When an electric current is passed through a conductor having a temperature gradient over its length, heat will be either absorbed by or expelled from the conductor. Whether heat is absorbed or expelled depends on the direction of both the electric current and temperature gradient. This phenomenon is known as the **Thomson Effect**.

## THERMOELECTRIC PRINCIPLE OF OPERATION

- The typical thermoelectric module is manufactured using two thin ceramic wafers with a series of P and N doped bismuth-telluride semiconductor material sandwiched between them as shown in Figure.

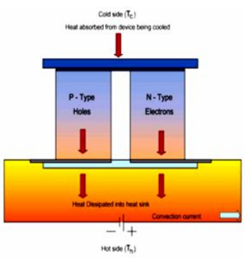



## THERMOELECTRIC PRINCIPLE OF OPERATION




- The N type material has an excess of electrons, while the P type material has a deficit of electrons. One P and one N make up a couple, as shown in Figure. The thermoelectric couples are electrically in series and thermally in parallel. A thermoelectric module can contain one to several hundred couples.

## THERMOELECTRIC PRINCIPLE OF OPERATION

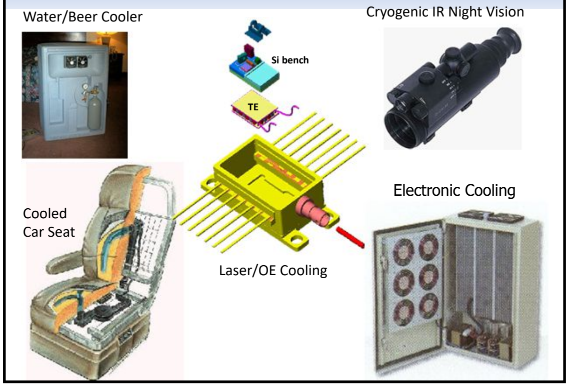



- As the electrons move from the P type material to the N type material through an electrical connector, the electrons jump to a higher energy state absorbing thermal energy (cold side). Continuing through the lattice of material; the electrons flow from the N type material to the P type material through an electrical connector dropping to a lower energy state and releasing energy as heat to the heat sink (hot side).

## THERMOELECTRIC PRINCIPLE OF OPERATION

- A thermoelectric refrigerator :At the cold junction, energy is absorbed by electrons as they pass from a low energy level in the p-type semiconductor element, to a higher energy level in the n-type semiconductor element. The power supply provides the energy to move the electrons through the system. At the hot junction, energy is expelled to a heat sink as electrons move from a high energy level element (n-type) to a lower energy level element (p-type). As the electrons move from the p-type material to the n-type material through an electrical connector, the electrons jump to a higher energy state absorbing thermal energy (cold side). Continuing through the lattice of material, the electrons flow from the n-type material to the p-type material through an electrical connector, dropping to a lower energy state and releasing energy as heat to the heat sink (hot side). A TE module thus uses a pair of fixed junctions into which electrical energy is applied causing one junction to become cold while the other becomes hot.

## THERMOELECTRIC REFRIGERATION - APPLICATIONS




## THERMOELECTRIC REFRIGERATION - DISADVANTAGES

•Able to dissipate limited amount of heat flux.

•Lower coefficient of performance than vapor-compression systems.

•Relegated to low heat flux applications.

## PSYCHROMETRY

## PSYCHROMETRY

- **Air:**
  - **It is mechanical mixture of dry air and super heated water vapour.**
- **Psychrometry:**
  - **It is the study of the properties of mixtures of air and water vapour.**

## PSYCHROMETRY

**Moist Air:**

Atmospheric air is a mixture of many gases plus water Vapour and a number of pollutants. The amount of water vapour and pollutants vary from place to place. The concentration of water vapour and pollutants decrease with altitude, and above an altitude of about 10 km, atmospheric air consists of only dry air. The pollutants have to be filtered out before processing the air. Hence, what we process is essentially **a mixture of various gases that constitute air and water vapour**. This mixture is known as **moist air.**

## METHODS FOR ESTIMATING PROPERTIES OF MOIST AIR

- In order to perform air conditioning calculations, it is essential first to estimate various properties of air.
- It is difficult to estimate the exact property values of moist air as it is a mixture of several permanent gases and water vapour.
- However, moist air up to 3 atm. pressure is found to obey perfect gas law with accuracy sufficient for engineering calculations.

## BASIC GAS LAWS FOR MOIST AIR

- According to the Gibbs-Dalton law for a mixture of perfect gases, the total pressure exerted by the mixture is equal to the sum of partial pressures of the constituent gases.

$$p = p_t = p_a + p_v$$

where $p = p_t$ = total barometric pressure
$p_a$ = partial pressure of dry air
$p_v$ = partial pressure of water vapour

## IMPORTANT PSYCHROMETRIC PROPERTIES

- **Dry bulb temperature (DBT)** is the temperature of the moist air as measured by a standard thermometer or other temperature measuring instruments.
- **Saturated vapour pressure ($p_{sat}$)** is the saturated partial pressure of water vapour at the dry bulb temperature. This is readily available in thermodynamic tables and charts.
- **Dew-point temperature:** If unsaturated moist air is cooled at constant pressure, then the temperature at which the moisture in the air begins to condense is known as **dew-point temperature (DPT) of air.**

## IMPORTANT PSYCHROMETRIC PROPERTIES

- **Degree of saturation μ**: The degree of saturation is the ratio of the humidity ratio W to the humidity ratio of a saturated mixture $W_s$ at the same temperature and pressure.

$$\mu = \left| \frac{W}{W_s} \right|_{t,P}$$

$$DPT = \frac{4030(DBT + 235)}{4030 - (DBT + 235)\ln\phi} - 235$$

## IMPORTANT PSYCHROMETRIC PROPERTIES

- **Enthalpy:** The enthalpy of moist air is the sum of the enthalpy of the dry air and the enthalpy of the water vapour. Enthalpy values are always based on some reference value. For moist air, the enthalpy of dry air is given a zero value at 0°C, and for water vapour the enthalpy of saturated water is taken as zero at 0°C.
- The enthalpy of moist air is given by:

$$h = h_a + Wh_g = c_p t + W(h_{fg} + c_{pw} t)$$

$$h = 1.005\,t + W(2501 + 1.88t)$$

## IMPORTANT PSYCHROMETRIC PROPERTIES

- **Relative humidity (Φ)** is defined as the ratio of the mole fraction of water vapour in moist air to mole fraction of water vapour in saturated air at the same temperature and pressure. Using perfect gas equation we can show that:

$$\phi = \frac{\text{partial pressure of water vapour}}{\text{saturation pressure of pure water vapour at same temperature}} = \frac{p_v}{p_{sat}}$$

## IMPORTANT PSYCHROMETRIC PROPERTIES

- **Humidity ratio (W):** The humidity ratio (or specific humidity) W is the mass of water associated with each kilogram of dry air. Assuming both water vapour and dry air to be perfect gases, the humidity ratio is given by:

$$W = \frac{\text{kg of water vapour}}{\text{kg of dry air}} = \frac{p_v V / R_v T}{p_a V / R_a T} = \frac{p_v / R_v}{(p_t - p_v)/R_a}$$

$W = \omega = 0.622\ [P_v/P_a]$

Where

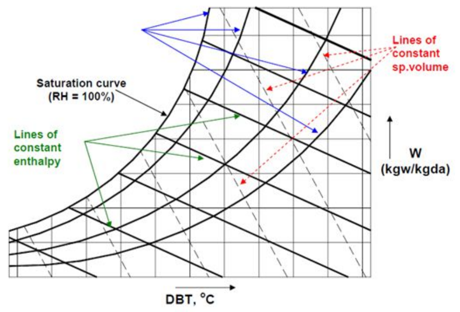
$P_t = P_a + P_v$

$$W = 0.622 \frac{p_v}{p_t - p_v}$$

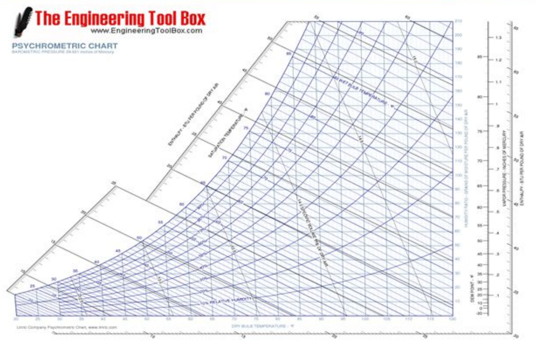
## PSYCHROMETRIC CHART

- A Psychrometric chart graphically represents the thermodynamic properties of moist air.
- Psychrometric charts are readily available for standard barometric pressure of 101.325 kPa at sea level and for normal temperatures (0-50°C). ASHRAE has also developed Psychrometric charts for other temperatures and barometric pressures (for low temperatures: -40 to 10°C, high temperatures 10 to 120°C and very high temperatures 100 to 120°C)

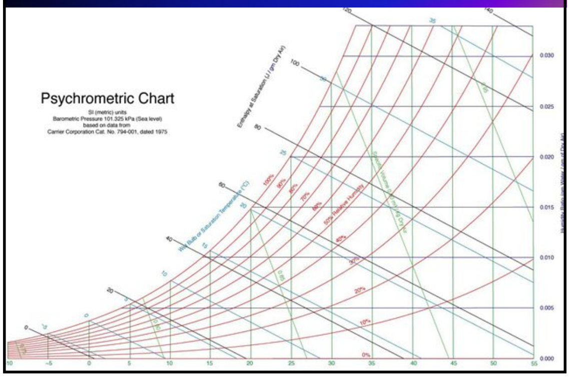
## PSYCHROMETRIC CHART




## PSYCHROMETRIC CHART

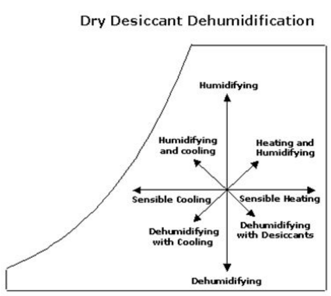



## PSYCHROMETRIC CHART

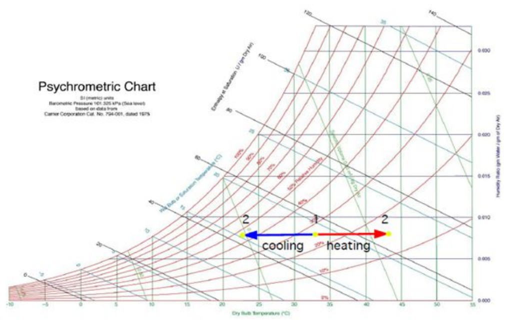



## PSYCHROMETRIC PROCESSES

- Sensible Heating(OA)
- Sensible Cooling (OB)
- Humidifying (OC)
- Dehumidifying (OD)
- Heating and Humidifying (OE)
- Heating and Dehumidifying(OH)
- Cooling and Humidifying (OG)
- Cooling and Dehumidifying (OF)



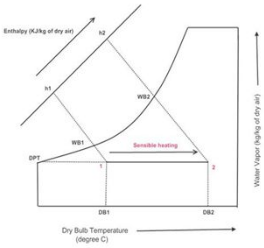

## SENSIBLE HEATING / COOLING



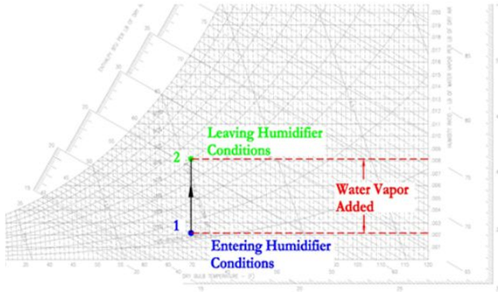
## SENSIBLE HEATING / COOLING

**Qs = ma (h2 – h1)**
**= ma Cp (t2 – t1)**
**= ma Cpa (t2 – t1) + ma. φ Cpv (t2 – t1)**
**= ma (1.005 + 1.88φ) (t2 – t1)**
**Where,**
**ma = Qv.ρ = cmm.ρ/ 60**
**Therefore**
**Qs = [cmm x 1.2 x 1.0216 / 60] Δt**

**Qs = 0.0204cmmΔt in kW**




## LATENT HEAT PROCESS – Humidification / Dehumidifying




## LATENT HEAT PROCESS – Humidification / Dehumidifying

- $Q_L = m_a (h_2 – h_1)$
  $= m_a (C_p t_2 + h_{fgo} \omega_2) – (C_p t_1 + h_{fgo} \omega_1)$
  $= m_a h_{fgo} (\omega_2 - \omega_1)$
  $= 2500 m_a (\omega_2 - \omega_1)$
  $Q_L = [cmm \times 1.2 \times 2500/ 60] (\omega_2 - \omega_1)$

  $$\mathbf{Q_L = 50 \times cmm \times (\omega_2 - \omega_1)}$$

## ROOM SENSIBLE HEAT FACTOR (RSHF)

- **The ratio of the sensible heat transfer to the total heat transfer is termed as the sensible heat factor.**

**General Design Values**
Auditoriums, Theaters - SHR : 0.65 - 0.75, Apartments - SHR : 0.80 - 0.95
Dining Halls - SHR : 0.65 - 0.80
Computer Rooms - SHR : 0.80 - 0.95
Hospital Patient Rooms, Nursing Home, Patient Rooms - SHR : 0.75 - 0.85
Kitchens - SHR : 0.60 - 0.70
Libraries, Museums - SHR : 0.80 - 0.90
Malls, Shopping Centers - SHR : 0.65 - 0.85
Medical/Dental Centers, Clinics and Offices - SHR : 0.75 - 0.85
Police Stations, Fire Stations, Post Offices - SHR : 0.75 - 0.90
Precision Manufacturing - SHR : 0.80 - 0.95
School Classrooms - SHR : 0.65 - 0.80

## GRAND SENSIBLE HEAT FACTOR (GSHF)

Grand sensible heat load = Room sensible heat load + (Ventilation) outside air sensible heat load

$$\text{RSHR} = \frac{\dot{Q}_{R,S}}{\dot{Q}_{R,S} + \dot{Q}_{R,L}}$$

$$\text{GSHR} = \frac{\dot{Q}_{G,S}}{\dot{Q}_{G,S} + \dot{Q}_{G,L}}$$

$$\text{ERSHR} = \frac{\dot{Q}_{R,S} + B_F\dot{Q}_{O,S}}{[\dot{Q}_{R,S} + B_F\dot{Q}_{O,S}] + [\dot{Q}_{R,L} + B_F\dot{Q}_{O,L}]}$$

## BY PASS FACTOR (B.F)

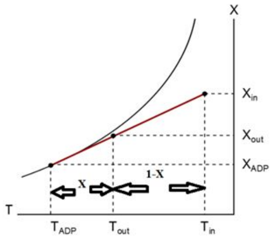
- Amount of air leaving the coil without cooling. (Uncontacted air with Coil).
- The contacted air is cooled by the refrigerant but uncontacted air remains in the initial condition.
- This rate of uncontacted air is defined by Bypass factor.

## BY PASS FACTOR (B.F)

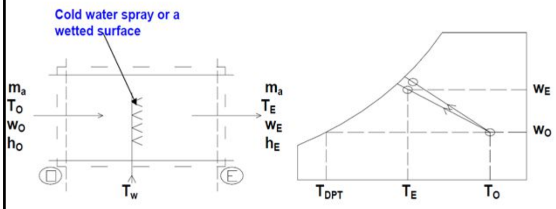
$X = (T_{out} - T_{adp}) / (T_{mix} - T_{adp})$

$= (\omega_{out} - \omega_{adp}) / (\omega_{mix} - \omega_{adp})$

$= (h_{out} - h_{adp}) / (h_{mix} - h_{adp})$




## Cooling and Dehumidification




## Heating and Humidification

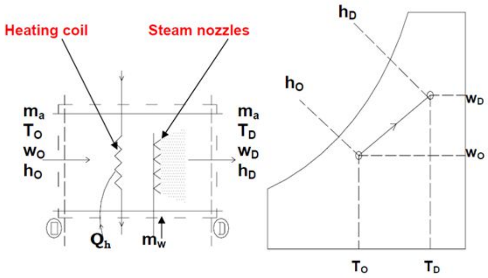
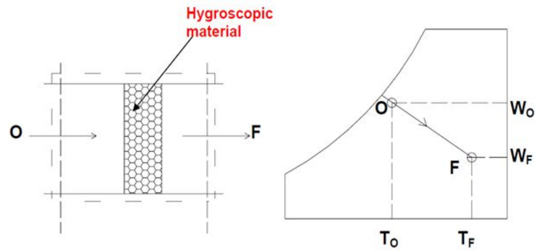
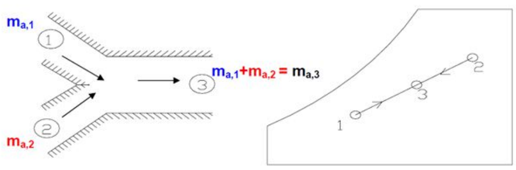



***Fig.28.5***: *Heating and humidification process*

## Heating and Dehumidification




## ADIABATIC MIXING OF TWO STREAMS




From the mass balance of dry air and water vapor:

$$m_{a,1}w_1 + m_{a,2}w_2 = m_{a,3}w_3 = (m_{a,1} + m_{a,2})w_3$$

From energy balance:

$$m_{a,1}h_1 + m_{a,2}h_2 = m_{a,3}h_3 = (m_{a,1} + m_{a,2})h_3$$

## ADIABATIC MIXING OF TWO STREAMS

when very cold and dry air mixes with warm air at high relative humidity, the resulting mixture condition may lie in the two-phase region, as a result there will be condensation of water vapor and some amount of water will leave the system as liquid water.

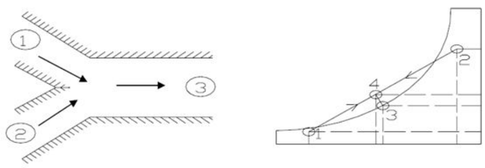
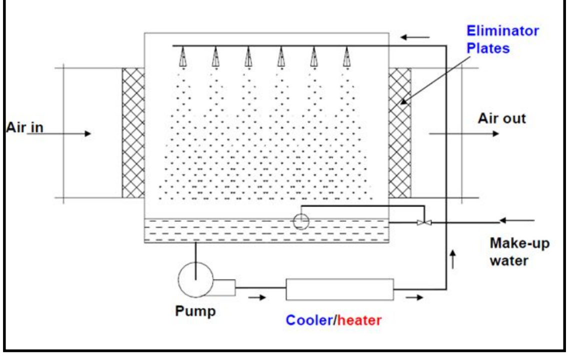



***Fig.28.9***. *Mixing of two air streams with condensation*

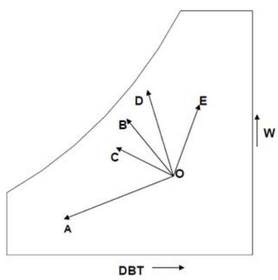
## AIR WASHER

- An air washer is a device for conditioning air. In an air washer air comes in direct contact with a spray of water and there will be an exchange of heat and mass (water vapour) between air and water. The outlet condition of air depends upon the temperature of water sprayed in the air washer. Hence, by controlling the water temperature externally, it is possible to control the outlet conditions of air, which then can be used for air conditioning purposes.

## AIR WASHER




## VARIOUS PSYCHROMETRIC PROCESSES THAT CAN TAKE PLACE IN AN AIR WASHER




1. **Cooling and dehumidification (OA)**
2. **Adiabatic saturation (OB)**
3. **Cooling and humidification (OC)**
4. **Cooling and humidification (OD)**
5. **Heating and humidification (OE)**

## AIR WASHER IMPORTANCE

- An air washer works as a year-round air conditioning system. Though air washer is a and extremely useful simple device, it is not commonly used for comfort air conditioning applications due to concerns about health resulting from bacterial or fungal growth on the wetted surfaces. However, it can be used in industrial applications.

## REQUIREMENTS OF COMFORT AIR CONDITIONING

**Air conditioning**

- **For human comfort ,air should have the following properties :**
  1. Temperature -22 °C to 27 °C
  2. Humidity - 55% to 65% Relative Humidity
  3. Velocity - 0.3 -0.5 m/s.
- **Air conditioning systems cool/heat the air, humidify/dehumidify the air to the above human comfort conditions depending on the temperature and humidity of the outside atmospheric air**

•Indoor air quality ( Purity of moist air) is the major important factor.

Inside design conditions for Winter:

$T_{op}$ between 20.0 to 23.5°C at a RH of 60%

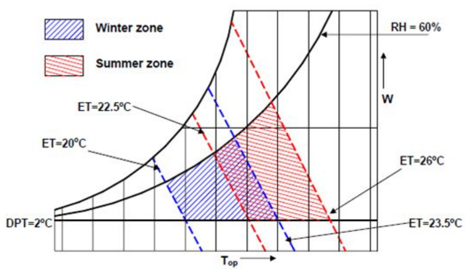
$T_{op}$ between 20.5 to 24.5°C at a DPT of 2°C

Inside design conditions for Summer:

$T_{op}$ between 22.5 to 26.0°C at a RH of 60%

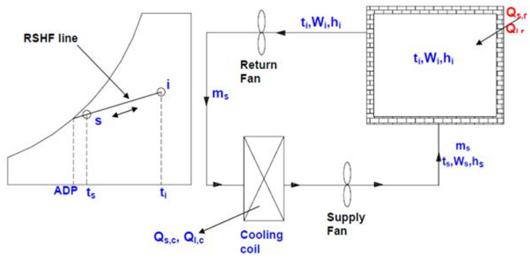
$T_{op}$ between 23.5 to 27.0°C at a DPT of 2°C

## ASHRAE COMFORT CHART FOR A SEDENTARY PERSON



## SUMMER AIR CONDITIONING SYSTEMS

**1. SIMPLE SYSTEM WITH 100 % RE-CIRCULATED AIR**




## SUMMER AIR CONDITIONING SYSTEMS

- It can be seen that cold and dry air is supplied to the room and the air that leaves the condition space is assumed to be at the same conditions as that of the conditioned space.
- Assuming no heat gains in the supply and return ducts and no energy addition due to fans, and applying energy balance across the room.
- Sensible and latent heat transfer rates at the cooling coil are exactly equal to the sensible and latent heat transfer rates to the conditioned space

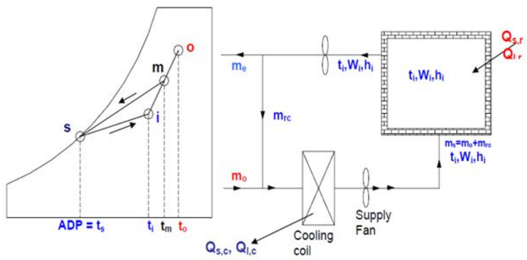
## SUMMER AIR CONDITIONING SYSTEMS

**2. SYSTEM WITH OUTDOOR AIR FOR VENTILATION:**

In actual air conditioning systems, some amount of outdoor (fresh) air is added to take care of the ventilation requirements. Normally, the required outdoor air for ventilation purposes is known from the occupancy data and the type of the building (e.g. operation theatres require 100% outdoor air). Normally either the quantity of outdoor air required is specified in absolute values or it is specified as a fraction of the re-circulated air

## SUMMER AIR CONDITIONING SYSTEMS

**2. SYSTEM WITH OUTDOOR AIR FOR VENTILATION: CASE I) BY-PASS FACTOR OF THE COOLING COIL IS ZERO**

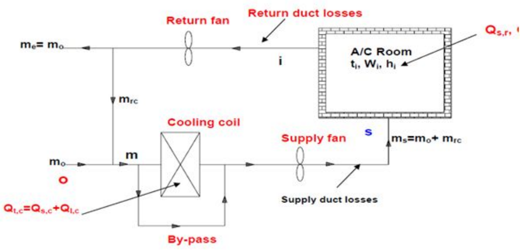



## 2. SYSTEM WITH OUTDOOR AIR FOR VENTILATION: CASE I) BY-PASS FACTOR OF THE COOLING COIL IS ZERO

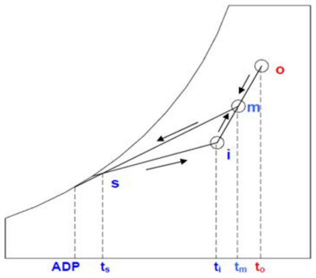
- when the by-pass factor X is zero. Since the sensible and latent cooling loads on the conditioned space are assumed to be known from cooling load calculations.
- The load on the cooling coil is always greater than load in the conditioned room. This is due to the fact that during mixing, some amount of hot and humid air is added.

## 2. SYSTEM WITH OUTDOOR AIR FOR VENTILATION: CASE II) BY-PASS FACTOR OF THE COOLING COIL > 0

- For actual cooling coils, the bye pass factor greater than zero, as a results the air temperature at the exit of the cooling coil is always greater than coil ADP



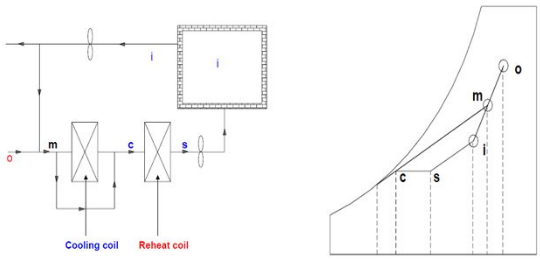
## 2. SYSTEM WITH OUTDOOR AIR FOR VENTILATION: CASE II) BY-PASS FACTOR OF THE COOLING COIL > 0




## 3. HIGH LATENT COOLING LOAD APPLICATIONS (LOW RSHF)

- When the latent load on the building is high due to either high outside humidity or large ventilation requirements (e.g. hospitals) or high internal latent loads (e.g. presence of kitchen or laundry), then the simple system discussed above leads to very low coil ADP. A low coil ADP indicates operation of the refrigeration system at low evaporator temperatures. Operating the system at low evaporator temperatures decreases the COP of the refrigeration system leading to higher costs. Hence a reheat coil is sometimes used so that the cooling coil can be operated at relatively high ADP, and at the same time the high latent load can also be taken care

## 3. HIGH LATENT COOLING LOAD APPLICATIONS (LOW RSHF)



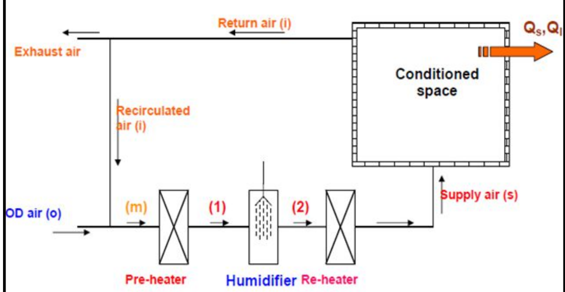

## ADVANTAGES AND DISADVANTAGES OF REHEAT COIL

- Refrigeration system can be operated at reasonably high evaporator temperatures leading to high COP and low running cost.
- However, mass flow rate of supply air increases due to reduced temperature rise ($t_i$-$t_s$) across the conditioned space
- Wasteful use of energy as air is first cooled to a lower temperature and then heated. Energy is required for both cooling as well as reheat coils. However, this can be partially offset by using waste heat such as heat rejected at the condenser for reheating of air.

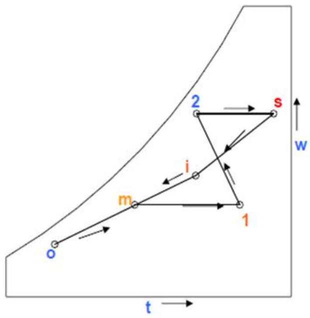
## WINTER AIR CONDITIONING SYSTEMS

- In winter, the building sensible heat losses are partially compensated by solar heat gains and the internal heat gains such those from occupancy, lighting , etc.
- **Thus in winter, the heating load is less than the cooling load in summer.**
- In general, the processes in the conditioning apparatus for winter air conditioning for comfort involve heating and humidifying.

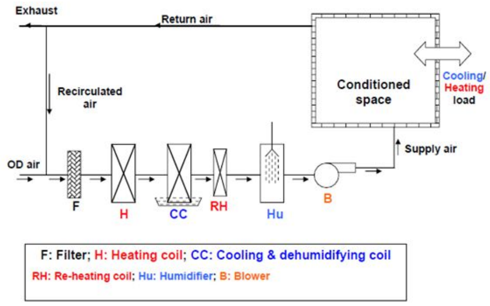
## WINTER AIR CONDITIONING SYSTEMS

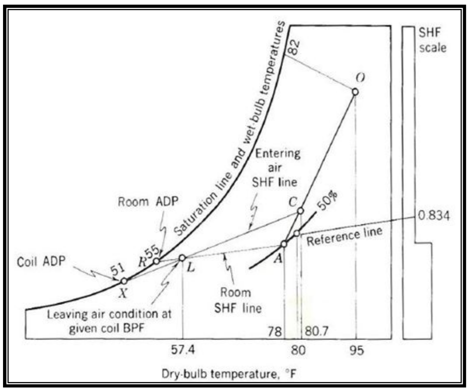


## WINTER AIR CONDITIONING SYSTEMS




## YEAR AROUND AIR CONDITIONING SYSTEMS




## AIR CONDITIONING SYSTEMS

## AIR CONDITIONING SYSTEMS

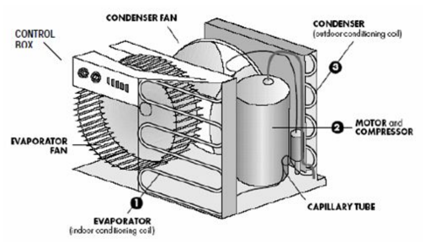
- **Working principles of –**
  - **Centralised Air conditioning systems,**
  - **Split, Ductable split, Packaged Air conditioning,**
  - **VAV & VRV Systems.**
- **Cooling load calculation**
- **Duct Design by equal friction method**
- **Indoor Air quality concepts.**

## TYPES OF AIR CONDITIONING SYSTEMS

- According to the purpose
  - Comfort A/C
  - Industrial A/C
- According to season of the year
  - Winter A/C
  - Summer A/C
  - Year around A/C
- According to the arrangement of equipment
  - Unitary A/C
  - Centralised A/C

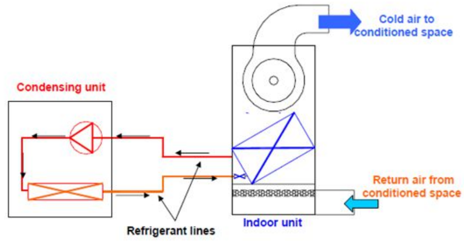
## WINDOW AIR CONDITIONER

0.3 TR TO ABOUT 3.0 TR

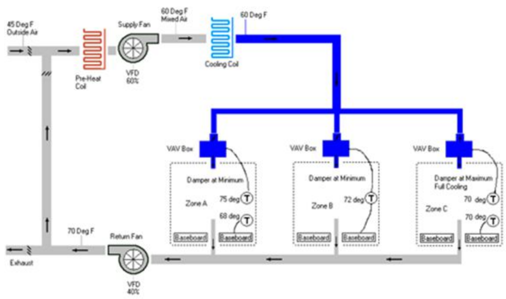



## PACKAGED AIR CONDITIONING SYSTEMS

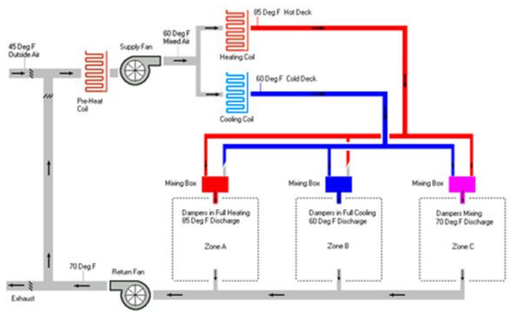
5 TR TO UPTO ABOUT 100 TR



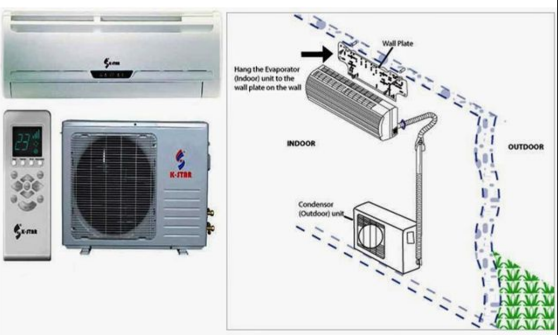

## CENTRALISED AIR CONDITIONING SYSTEMS



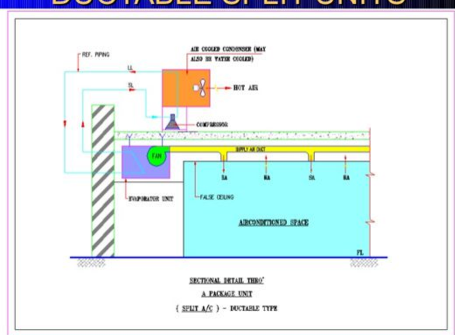

## CENTRALISED AIR CONDITIONING SYSTEMS



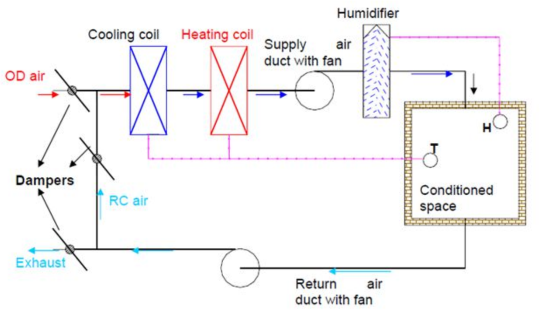

## SPLIT AIR CONDITIONING SYSTEMS



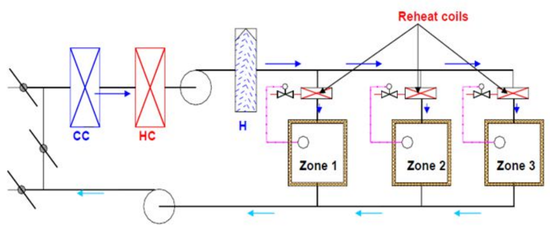

## DUCTABLE SPLIT UNITS



## SINGLE DUCT, CONSTANT VOLUME, SINGLE ZONE SYSTEMS




## SINGLE DUCT, CONSTANT VOLUME, MULTIPLE ZONE SYSTEMS



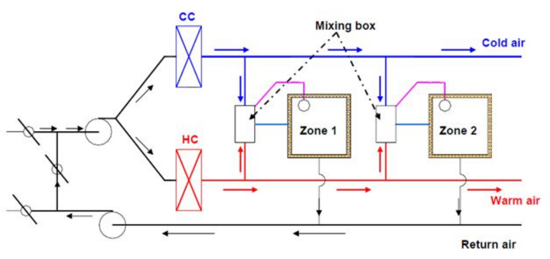

## Advantages of single duct, multiple zone, constant volume systems with reheat coils

1. Relatively small space requirement
2. Excellent temperature and humidity control over a wide range of zone loads
3. Proper ventilation and air quality in each zone is maintained as the supply air amount is kept constant under all conditions

## Disadvantages of single duct, multiple zone, constant volume systems with reheat coils

- High energy consumption for cooling, as the air is first cooled to a very low temperature and is then heated in the reheat coils. Thus energy is required first for cooling and then for reheating. The energy consumption can partly be reduced by increasing the supply air temperature, such that at least one reheat coil can be switched-off all the time. The energy consumption can also be reduced by using waste heat (such as heat rejected in the condensers) in the reheat coil.
- Simultaneous cooling and heating is not possible.

## DOUBLE DUCT, CONSTANT VOLUME, MULTIPLE ZONE SYSTEMS



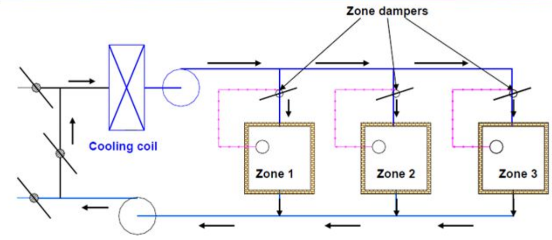

## ADVANTAGES OF DOUBLE DUCT, CONSTANT VOLUME, MULTIPLE ZONE SYSTEMS

- Since total airflow rate to each zone is constant, it is possible to maintain proper IAQ and room air distribution.
- Cooling in some zones and heating in other zones can be achieved simultaneously
- System is very responsive to variations in the zone load, thus it is possible to maintain required conditions precisely.

## DISADVANTAGES OF DOUBLE DUCT, CONSTANT VOLUME, MULTIPLE ZONE SYSTEMS

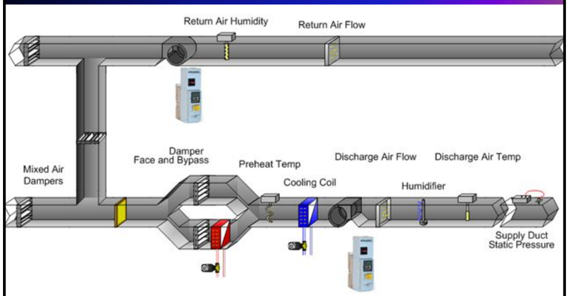
- Occupies more space as both cold air and hot air ducts have to be sized to handle all the air flow rate, if required.
- Not very energy efficient due to the need for simultaneous cooling and heating of the air streams. However, the energy efficiency can be improved by completely shutting down the cooling coil when the outside temperature is low and mixing supply air from fan with hot air in the mixing box. Similarly, when the outside weather is hot, the heating coil can be completely shut down, and the cold air from the cooling coil can be mixed with supply air from the fan in the mixing box.

## SINGLE DUCT, VARIABLE AIR VOLUME (VAV) SYSTEMS

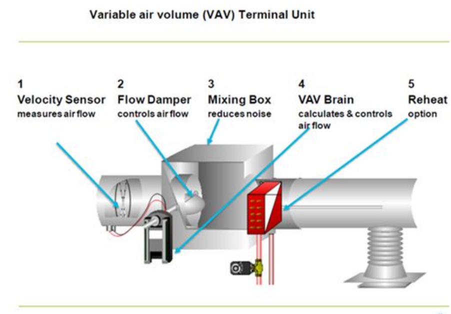



**The amount of air supplied to each zone is controlled by a zone damper, which in turn is controlled by that zone thermostat as shown in the figure. Thus the temperature of supply air to each zone remains constant, whereas its flow rate varies depending upon the load on that particular zone.**

## VARIABLE AIR VOLUME (VAV) SYSTEMS




## VARIABLE AIR VOLUME (VAV) SYSTEMS




## ADVANTAGES OF VARIABLE AIR VOLUME (VAV) SYSTEMS

- Compared to constant volume systems, the variable air volume systems offer advantages such as:
- Lower energy consumption in the cooling system as air is not cooled to very low temperatures and then reheated as in constant volume systems.
- Lower energy consumption also results due to lower fan power input due to lower flow rate, when the load is low. These systems lead to significantly lower power consumption, especially in perimeter zones where variations in solar load and outside temperature allows for reduced air flow rates.

## VARIABLE REFRIGERANT FLOW (VRF) SYSTEMS

- Variable refrigerant flow (VRF) is an air-condition system configuration where there is one outdoor condensing unit and multiple indoor units. The term variable refrigerant flow refers to the ability of the system to control the amount of refrigerant flowing to the multiple evaporators (indoor units), enabling the use of many evaporators of differing capacities and configurations connected to a single condensing unit. The arrangement provides an individualized comfort control, and simultaneous heating and cooling in different zones.

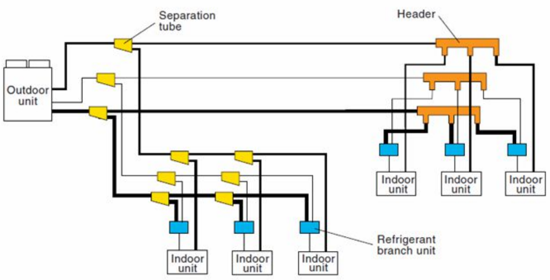
## VARIABLE REFRIGERANT FLOW (VRF) SYSTEMS

- VRF systems operate on the direct expansion (DX) principle meaning that heat is transferred to or from the space directly by circulating refrigerant to evaporators located near or within the conditioned space. Refrigerant flow control is the key to many advantages as well as the major technical challenge of VRF systems.
- VRF systems are similar to the multi-split systems which connect one outdoor section to several evaporators. However, multi-split systems turn OFF or ON completely in response to one master controller, whereas VRF systems continually adjust the flow of refrigerant to each indoor evaporator.

## VARIABLE REFRIGERANT FLOW (VRF) SYSTEMS

- The control is achieved by continually varying the flow of refrigerant through a pulse modulating valve (PMV) whose opening is determined by the microprocessor receiving information from the thermistor sensors in each indoor unit. The indoor units are linked by a control wire to the outdoor unit which responds to the demand from the indoor units by varying its compressor speed to match the total cooling and/or heating requirements.
- VRF systems promise a more energy-efficient strategy (estimates range from 11% to 17% less energy compared to conventional units) at a somewhat higher cost.

## VARIABLE REFRIGERANT FLOW (VRF) SYSTEMS




## THANK YOU

## *UNIT I -STEAM NOZZLES TURBINES*

**1. What are the various types of nozzles and their functions?**

Nozzle is a duct of varying cross-sectional area in which the velocity increases with the corresponding drop in pressure.

**2. What are the effects of friction on the flow through a steam nozzle?**

**1.** The final fraction of the steam is increased as the part of the kinetic energy gets converted into heat due to friction and absorbed by steam with n increase in enthalpy.

**2.** The expansion is no more isentropic and enthalpy drop is reduced thereby resulting in lower exit velocity.

**3.** The specific volume of steam is increased as the steam becomes drier due to this frictional reheating.

**3. Define nozzle efficiency and critical pressure ratio.**

**Nozzle efficiency:** It is defined as the ratio of actual enthalpy drop to the isentropic enthalpy drop

**Nozzle efficiency** = Actual enthalpy drop / Isentropic enthalpy drop

**Critical pressure ratio**: There is only one value of the ratio (P2/P1) which produces maximum discharge from the nozzle. The ratio is called critical pressure ratio.

Critical pressure ratio $P_2 / P_1 = (2/n+1)^{n/n+1}$

Where,

$P_1$ = Initial pressure

$P_2$ = Throat pressure.

**4. Explain the phenomenon of super saturated expansion in steam nozzle.**

**Or**

**What is Meta stable flow**?

When the supersaturated steam is expanded in the nozzle, the condensation should occur in the nozzle. Since the steam has a great velocity, the condensation does not take place at the expected rate. So the equilibrium between the liquid and vapour phase is delayed and the steam continues to expand in a dry state.

The steam in such set of condition is said to be supersaturated or meta stable flow.

**5. What are the conditions that produce super saturation of steam in nozzles?**

When the superheated steam expands in the nozzle, the condensation will occur in the nozzle. Since, the steam has more velocity, the condensation will not take place at the expected rate. So, the equilibrium between the liquid and vapour phase is delayed and the steam continues to expand in a dry state.

The steam in such set of condition is said to be supersaturated or meta stable flow.

**6. What are the effects of super saturation in a steam nozzle?**

The following effects in a nozzle on steam, in which super saturation occurs, may be summarized as follows.

**1.** The dryness fraction of the steam is increased.
**2.** Entropy and specific volume of the steam are increased.
**3.** Exit velocity of the steam is reduced.
**4.** Mass of stream discharged is increased.

**7. What are the differences between supersaturated flow and isentropic flow through steam nozzles?**

| **Supersaturated flow** | **Isentropic flow** |
|---|---|
| **1.** Entropy is not constant | Entropy is constant |
| **2.** Reduce in enthalpy drop . | No reduce in enthalpy drop |
| **3.** We cannot use mollier diagram to solve problems | We can use mollier diagram to solve problems. |

**8. The critical pressure ratio initially dry saturated steam is.**

$P_2$
$/P_1$=0.577

**9. The critical pressure ratio for initially super heated steam is _ __as compared to initially dry saturated steam.**

Less.

**10. When the backpressure of a nozzle is below the designed value of pressure at exit of nozzle, the nozzle is said to be______**

Under damping.

## DEPARTMENT OF MECHANICAL ENGINEERING
## THERMAL ENGINEERING QUESTION BANK FOR 13 MARKS

| Q.No | UNIT III | In Notes / Answer Key |
|---|---|---|
| 1 | 3. A convergent divergent nozzle receives steam at 7bar and 200°c and it expands isentropically into a space of 3bar neglecting the inlet velocity calculate the exit area required for a mass flow of 0.1Kg/sec . when the flow is in equilibrium through all and super saturated with $PV^{1.3}$=C. | ANSWER KEY |
| 2 | Dry saturated steam at 6.5 bar with negligible velocity expands isentropically in a convergent divergent nozzle to 1.4 bar and dryness fraction 0.956. Determine the final velocity of steam from the nozzle if 13% heat is loss in friction. Find the % reduction in the final velocity. | ANSWER KEY |
| 3 | A convergent divergent adiabatic steam nozzle is supplied with steam at 10 bar and 250°c.the discharge pressure is 1.2 bar. Assuming that the nozzle efficiency is 100% and initial velocity of steam is 50 m/s. find the discharge velocity. | ANSWER KEY |
| 4 | Steam enters a group of nozzles of a steam turbine at 12 bar and 2200 C and leaves at 1.2 bar. The steam turbine develops 220 Kw with a specific steam consumption of 13.5 Kg/ KwHr. If the diameter of nozzle at throat Is 7mm . Calculate the number of nozzle | ANSWER KEY |

## *UNIT-I-STEAM NOZZLE -ANSWER KEY FOR 13 MARK*

***Q.NO:1*** **Given Data:**

Initial pressure ($P_1$) = 7bar = $7\times10^5 N/m^2$

Initial temperature ($T_1$) = $200^oC$

Pressure ($P_2$) = 3bar = $3\times10^5 N/m^2$

Mass flow rate (m) = 0.1Kg/sec

$PV^{1.3}=C$

**To Find**:

Exit area

**Solution:**

From steam table for P1 = 7bar and T1 = $200^oC$ $V_1$ =

0.2999

$h_1$ = 2844.2

$S_1$ = 6.886

Similarly for $P_2$ = 3bar

$V_{f2}$ = 0.001074 $V_{g2}$ = 0.60553 $h_{f2}$ = 561.5 $h_{fg2}$ = 2163.2

$S_{f2}$ = 1.672 $S_{fg2}$ = 5.319

We know that, $S_1 = S_2 = S_t$

$$S_1 = S_{f2} + X_2 S_{fg2}$$

6.886 = 1.672 + $X_2$ (5.319) $X_2$ =

0.98

Similarly,

$$h_2 = h_{f2} + X_2 h_{fg2}$$

$$h_2 = 561.5 + 0.98 (2163.2)$$

(i) <u>Flow is in equilibrium through all:</u>

$$V_2 = \sqrt{2000 (h_1 - h_2)}$$

$V_2 = \sqrt{2000 (2844.2 - 2681.99)}$ $V_2$ =

569.56

$$\nu_2 = X_2 \times \nu_{g2}$$

= 0.98×0.60553 = 0.5934

$$m = \frac{[(A]_2 \times V_2)}{\nu_2}$$

$$A_2 = \frac{[m \times V_2)}{\nu_2} = \frac{0.5934 \times 0.1}{569.56}$$

$$A_2 = 1.041 \times 10^{-4} m^2$$

For saturated flow:

$$v_2 \sqrt{\frac{2n}{n-1}\ (P_1 v_1)(1-(\frac{P_2}{P_1})^{\frac{n-1}{n}}}$$

$$\boxed{m \times V_2}\qquad 0.1$$

$$v_2 = \sqrt{\frac{2(1.3)}{1.3-1}\ (7 \times 10^5 \times 0.2999)\ (1-\frac{3\times10^5}{7\times10^5})^{\frac{1.3-1}{1.3}}}$$

$v2 = 568.69$
m/s

specific volume of steam at exit. For super saturated flow, $P_1 v_1^n = P_2$

$$\left(\frac{v_2}{v_1}\right)^n = \frac{P1}{P2}$$

$$v_2 = \left(\frac{7}{3}\right)^{\frac{1}{1.3}} \times 0.2999$$

$$v_2 = 0.5754$$

$$= \frac{0.1 \times 0.5754}{568.69}$$

***Q.NO:2*** **Given data:**

Exit pressure (P2) = 1.4 bar

Dryness fraction (X2) = 0.956

Heat loss = 13%

**To Find:**

The percent reduction in final velocity

**Solution:**

From steam table for initial pressure P1 = 6.5bar, take values $h_1$ =

$h_1 = 2758.8$KJ/Kg

Similarly, at 1.4 bar,

$h_{fg2} = 2231.9$ KJ/Kg

$h_{f2} = 458.4$KJ/Kg $h_2$

$= h_{f2} + X_2 h_{fg2}$

$= 458.4 + (0.956)\ 2231.6$

$h_2 = 2592.1$ KJ/Kg

Final velocity (V2) = $\sqrt{2000(h_1 - h_2)}$

$= \sqrt{2000(2758.8 - 2592.1)}$ V2 =

577.39 m/s

Heat drop is 13%= 0.13

Nozzle efficiency ($\eta$) = 1- 0.13 = 0.87

Velocity of steam by considering the nozzle efficiency,

V2 = $\sqrt{2000(h_1 - h_2) \times \eta}$

V2 = $\sqrt{2000(2758.8 - 2592.1) \times 0.87}$

V2 = 538.55 m/s

% reduction in final velocity = $\frac{577.39 - 538.55}{577.39} \times 100\ \%$

= 6.72%

**Q-3 Answer:**

Initial pressure($p_1$)=10bar Initial

Temperature($T_1$)=250°c

Exit pressure($p_2$)=1.2 bar

Nozzle efficiency($\eta_{nozzle}$)=100%

Initial velocity of steam($v_1$)=50m/s

**To Find:-**

Discharge velocity ($v_2$)

**Solution:-**

From steam table, For 10 bar, 250°c, $h_1$=2943 KJ/kg $s_1$=6.926 KJ/kgk

From steam table, For 1.2 bar,

$h_{f2}$ =439.3 KJ/kg ; $h_{fg2}$=2244.1 KJ/kg;

$s_{f2}$=1.361 KJ/kg K ; $s_{fg2}$=5.937 KJ/kgK.

Since $s_1=s_2,$

$S_1=s_{f2}+x_2 s_{fg2}$

$6.926=1.361+x_2(5.937)$

$X_2=0.9373$

We know that,

Exit velocity (V2) =

$h_2=h_{f2}+x_2 h_{fg2}$

$= 439.3+(0.9373)2244.1$ $h_2 = 2542$KJ/Kg

$\sqrt{2000(2943-2542)+50^2}$

= 896.91m/s.

$A_2 = \frac{[m \times V_2)}{v_2}$ $A_2 = 1.011 \times 10^{-4} m^2$

## *UNIT I -STEAM NOZZLES TURBINES*

## *UNIT III - TURBINES*

**1. What is a steam turbine?**

Steam turbine is a device which is used to convert kinetic energy of steam into mechanical energy.

**2. What is the fundamental difference between the operation of impulse and reaction steam turbines?**

| Impulse Turbine | Reaction turbine |
|---|---|
| **1.** It consists of nozzles and moving blades. | It consists of fixed blades and moving blades. |
| **2.** Pressure drop occurs only in nozzles not in moving blades. | Pressure drop occurs in fixed as well as moving blades. |
| **3.** Steam strikes the blades with kinetic energy. | Steam passes over the moving blades with pressure and kinetic energy. |
| **4.** It has constant blade channels area. | It has varying blade channels area. |
| **5.** Due to more pressure drop per blade, number of stages required is less. | Number of stages required is more due to more pressure drop. |

**3. Explain the need of compounding in steam turbines.**

**(Or)**

**Explain the purpose of compounding in steam turbines.**

In simple impulse turbine, the expansion of steam from the boiler pressure to condenser pressure takes place in a single stage turbine. The velocity of steam at the exit of turbine is very high. Hence, there is a considerable loss of kinetic energy (i.e. about 10to 12%). Also the speed of the rotor is very high (i.e. up to 30000rpm). There are several methods of reducing this speed to lower value. Compounding is a method of absorbing the jet velocity in stages when the steam flows over moving blades.

**4. What are the different methods of compounding?**

**1.** Velocity compounding

**2.** Pressure compounding

**3.** Pressure-velocity compounding

**5. What is meant by carry over loss?**

The velocity of steam at exit is sufficiently high thereby resulting in a kinetic energy loss called "Carry over loss" or "Leading velocity loss".

## DEPARTMENT OF MECHANICAL ENGINEERING
## THERMAL ENGINEERING QUESTION BANK FOR 13 MARKS

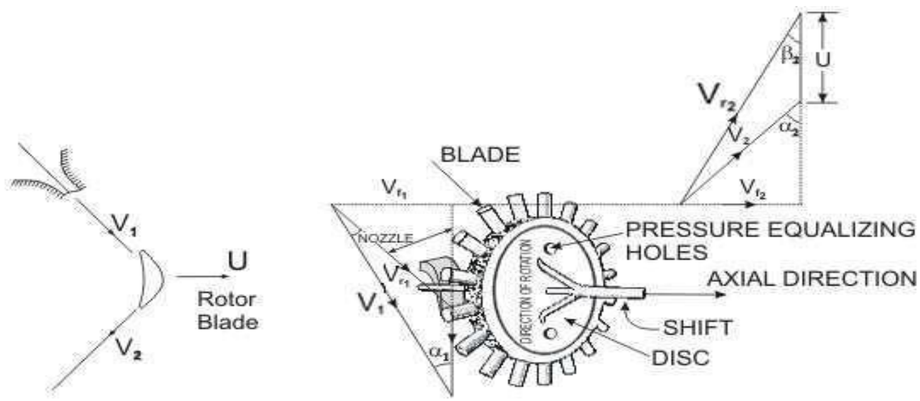
| Q.No | UNIT III | In Notes / Answer Key |
|---|---|---|
| 1 | Drive an expression for Impulse Turbine with Velocity diagram | ANSWER KEY |
| 2 | Explain the method of governing in steam turbine | NOTES |
| 3 | Explain various type of compounding in Turbine | NOTES |
| 4 | A 50% reaction turbine running at 400 rpm has the exit angle of blades as 20° and the velocity of steam relative to the blade at the exit is 1.35 times mean speed of the blade. The steam flow rate is 8.33 kg/s and at a particular stage the specific volume is 1.38m3/kg. Calculate, suitable blade height, assuming the rotor mean diameter 12 times the blade height, and diagram work. | ANSWER KEY |
| 9 | The blade angle of a single ring of an impulse turbine is 300m/s and the nozzle angle is 200.The isentropic heat drop is 473kJ/kg and nozzle efficiency is 85%.Given the blade velocity coefficient is 0.7 and the blades are symmetrical, Draw the velocity diagram and calculate for a mass flow of 1 kg/s i) axial thrust on balding ii) steam consumption per BP hour if the mechanical efficiency is 90% iii) blade efficiency and stage efficiency. | NOTES |

## *UNIT-III- TURBINE-ANSWER KEY FOR 13 MARK*

### Q.No:1 Impulse Turbines

¾ Impulse turbines (single-rotor or multirotor) are simple stages of the turbines.
¾ Here the impulse blades are attached to the shaft.
¾ Impulse blades can be recognized by their shape.
¾ The impulse blades are short and have constant cross sections.

**Schematic diagram of an Impulse Turbine**




$V_1$ and $V_2$ = Inlet and outlet absolute velocity

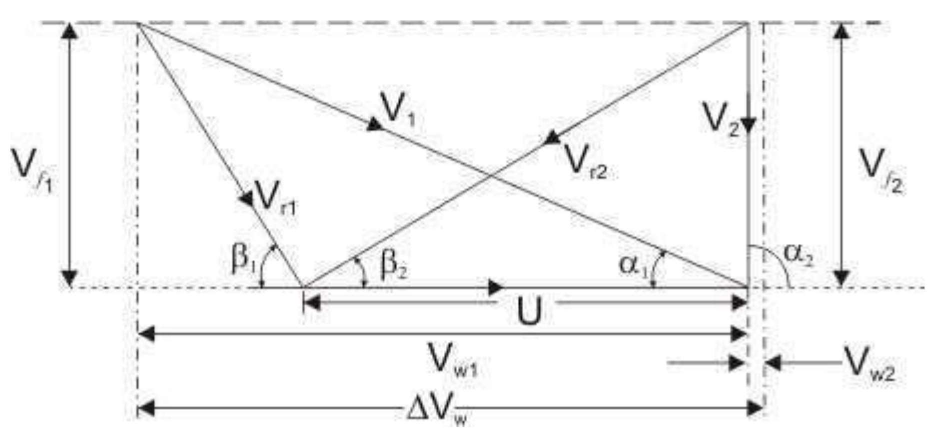
$V_{r1}$ and $V_{r2}$ = Inlet and outlet relative velocity (Velocity relative to the rotor blades.)

U = mean blade speed

$\alpha_1$ = nozzle angle, $\alpha_2$ = absolute fluid angle at outlet

It is to be mentioned that all angles are with respect to the tangential velocity ( in the direction of U )

**Velocity diagram of an Impulse Turbine**



$\beta_1$ and $\beta_2$ = Inlet and outlet **blade angles**

$V_{w1}$ and $V_{w2}$ = Tangential or whirl component of absolute velocity at inlet and outlet

$V_{f1}$ and $V_{f2}$ = Axial component of velocity at inlet and outlet

Tangential force on a blade,

$$F_u = \dot{m}(V_{w1} - V_{w2}) \qquad (22.1)$$

(mass flow rate X change in velocity in tangential direction)

or,

$$F_u = \dot{m}\Delta V_w \qquad (22.2)$$

$$\text{Power developed} = \dot{m}U\Delta V_w \qquad (22.3)$$

Blade efficiency or Diagram efficiency or Utilization factor is given by

$$\eta_b = \frac{\dot{m} \cdot U \cdot \Delta V_w}{\dot{m}(V_1^2/2)} = \frac{\text{Workdone}}{\text{K.E supplied}}$$

or,

$$\eta_b = \frac{2U\Delta V_w}{V_1^2} \qquad (22.4)$$

**The Single-Stage Impulse Turbine**

¾ The *single-stage impulse turbine* is also called the *de Laval turbine* after its inventor.
¾ The turbine consists of a single rotor to which impulse blades are attached.
¾ The steam is fed through one or several convergent-divergent nozzles which do not extend completely around the circumference of the rotor, so that only part of the blades is impinged upon by the steam at any one time.

The nozzles also allow governing of the turbine by shutting off one or more them

***Q.No:4*** GIVEN DATA:-

Dia of cylinder (d)=300mm=0.3m

Engine stroke(l)=500mm=0.5m

Clearance volume($v_c$)=6750/$100^3$=6.75 $\times 10^{-3}$ $m^3$

Explosions per minute(n)=100/minute=i.67/sec

$P_{min}$=765 $KN/m^2$

Brake drum dia($D_1$)=1.5m

Rope dia($d_1$)=0.025m

Work load on the brake(w)=190kg=1.86KN

TO FIND:-

Compression ratio (r)

Mechanical efficiency ($\eta_{mech}$)

Indicated thermal efficiency ($\eta_{it}$)

Air standard efficiency ($\eta_{air}$)

Relative efficiency ($\eta_{rel}$)

SOLUTION:-

(1).Compression Ratio (r):-

$$r = \left(\frac{V_s}{V_c}\right) + 1$$

$$= \left(\frac{l \times a}{vc}\right) + 1$$

$$= \frac{0.5 \times \left(\frac{\pi}{4}\right) 0.3^2}{0.75 \times 10^{-3}} + 1$$

$$= 5.23 + 1$$

$$(r) = 6.23$$

(2).Air Standard Efficiency ($\eta_{air}$):-

$$\eta_{air} = 1 - \left(\frac{1}{r^{\gamma - 1}}\right)$$

$$= 1 - \left(\frac{1}{6.23^{1.4-1}}\right)$$

$$= 51.89\%$$

(3).Indicated Thermal Efficiency ($\eta_{it}$):-

$$(\eta_{it}) = \frac{IP}{Fc \times Cv}$$

Here, indicated power (IP)= $p_{mi} \times l \times a \times n \times k$

$$= 765 \times 0.5 \times 0.0706 \times 1.67 \times 1$$

$$= 45.09\,KW$$

Therefore, $$\eta_{it} = \frac{45.09}{\left(\frac{30}{3600}\right) \times 22515}$$

$$= 24.03\%$$

(4).Relative Efficiency ($\eta_{rel}$):-

$$(\eta_{rel}) = \acute{\eta}it/\acute{\eta}air$$

$$= \frac{[illegible]}{51.85}$$

$$= 46.30\%$$

(5).Mechanical Efficiency ($\eta_{mech}$):-

$$(\eta_{mech}) = \frac{\eta BT}{\eta it}$$

$$= \frac{[illegible]}{24.03}$$

$$= 79.02\%$$

## *UNIT V- REFRIGERATION AND AIR–CONDITIONING*

**1. Define tonne of refrigeration.**

A tonne of refrigeration is defined as the quantity of heat required to be removed from one tonne of water (1000kg) at 0 C to convert that into ice at 0 C in 24 hours. In actual practice,

1 tonne of refrigeration= 210kJ/min=3.5kW

**2. Define tonne of refrigeration. Heat is removed from a space at a rate of 42,000kJ/h. Express this heat removal rate in tons.**

A tonne of refrigeration is defined as the quantity of heat required to be removed from one tonne of water (1000kg) to convert that into ice at 0˚ C 24 hours.

**3. The vapour compression refrigerator employs the ---- cycle.**

Reversed Carnot.

**4. The door of a running refrigerator inside a room was left open. What will happen?**

The room will be gradually warmed up.

***5. In a vapor compression refrigeration system, where the lowest temperature will occur?***

*At inlet of evaporator*

**6. How does the actual vapour compression cycle differ from that of the ideal cycle?**

**1.** In actual cycles, pressure losses occur in both condenser and evaporator.

**2.** Friction losses occur in compressor.

**7. Name four important properties of a good refrigerant.**

**1.** Low boiling point.

**2.** High critical temperature and pressure.

**3.** Low specific heat of liquid.

**8. What is the difference between air conditioning and refrigeration?**

Refrigeration is the process of providing and maintaining the temperature in space below atmospheric temperature.

Air conditioning is the process of supplying sufficient volume of clean air containing a specific amount of water vapour and maintaining the predetermined atmospheric condition with in a selected enclosure.

**9. What is the function of the throttling valve in vapour compression refrigeration system?**

The function of throttling valve is to allow the liquid refrigerant under high pressure and temperature to pass to controlled rate after reducing its pressure and temperature.

**10. In a vapour compression refrigeration system, where the highest temperature will occur?**

After compression.

**11. The vapour absorption system can use low-grade heat energy in the generator. Is true or false?**

True.

**12. Name any four commonly used refrigerants.**

**1.** Ammonia (NH3)
**2.** Carbon dioxide (CO2).

**13. Explain unit of Refrigeration.**

Unit of refrigeration is expressed in terms of tonne of refrigeration.

A tonne of refrigeration is defined as the quantity of heat required to be removed from one tonne of water (1000kg) to convert that into ice at 0˚ C in 24 hours.

**14. Why throttle valve is used in place of expansion cylinder for vapour compression refrigerant machine.**

In throttling process, enthalpy remains constant and pressure is reduced so throttle valve is used.

**15. What are the effect pf superheat and sub cooling on the vapour compression cycle?**

Superheating increases the refrigeration effect and COP may be increased or decreased. But sub cooling always increase the COP of the refrigeration and also decrease the mass flow rate of refrigerant.

**16. What are the properties of good refrigerant?**

An ideal refrigerant should possess the following desirable properties.

1. The refrigerant should have low freezing point.
2. It must have high critical pressure and temperature to avoid large power requirements.
3. It should have low-specific volume to reduce the size of the compressor.
4. It should be nonflammable, non-explosive, non-toxic and non-corrosive.

**17. What is net refrigerating effect of the refrigerant?**

Refrigerating effect is the total heat removed from the refrigerant in the evaporator.

$$\text{COP} = \frac{\text{Refrigeration effect}}{\text{Work done}}$$

**Refrigeration effect= COP * Work done.**

**18. Name the various components used in simple vapour absorption system.**

1. Absorber
2. Pump
3. Generator
4. Condenser.
5. Throttle valve.
6. Evaporator.

**19. Define refrigerant.**

Any substance capable of absorbing heat from another required substance can be used as refrigerant.

**20. How does humidity affect human comfort?**

If the humidity is above a certain level, water vapour from human body moisture cannot be absorbed by the atmospheric air. It results in discomfort because of sweating.

## DEPARTMENT OF MECHANICAL ENGINEERING
## THERMAL ENGINEERING QUESTION BANK FOR 13 MARKS

| **Q.No** | **UNIT V** | **In Notes / Answer Key** |
|---|---|---|
| 1 | A sling psychrometer gives reading of $25^0$c dry bulb temperature $15^0$c wet bulb temperature. The barometer indicates 760 mm of hg assuming partial pressure of the vapour as 10 mm of Hg. Determine 1. Specific humidity 2. Saturation ratio. | ANSWER KEY |
| 2 | A two stages, single acting air compressor compresses air to 20bar. The air enters the L.P cylinder at 1bar and $27^o$c and leaves it at 4.7bar. the air enters the H.P. cylinder at 4.5bar and $27^o$c. the size of the L.P cylinder is 400mm diameter and 500mm stroke. The clearance volume In both cylinder is 4% of the respective stroke volume. The compressor runs at 200rpm, taking index of compression and expansion in the two cylinders as 1.3, estimate 1. The indicated power required to run the compressor; and The heat rejected in the intercooler per minute | ANSWER KEY |
| 3 | In an oil gas turbine installation , air is taken as 1 bar and $30^oC$ . The air is compressed to 4bar and then heated by burning the oil to a temperature of $500^oC$ . If the air flows at the rate of 90Kg/min . Find the power developed by the plant take $\gamma$ for air as 1.4 $C_p$ as 1KJ/KgK . If 2.4Kg of oil having calorific value of 40,000 KJ/Kg if burned in the combustion chamber per minute. Find the overall efficiency of the plant. | ANSWER KEY |
| 4 | Explain with sketch the working principle of AIR CONDITIONER | ANSWER KEY |
| 5 | Draw neat sketch of simple vapor compression refrigeration system and explain | ANSWER KEY |
| 6 | Explain with sketch the working principle of water-Lithium bromide refrigeration system | ANSWER KEY |
| 7 | Explain any four psychometric processes with sketch. | NOTES |
| 8 | A sling psychrometer in a lab test recorded the following readings DBT=35°C, WBT=25°CCalculate the following 1. Specific humidity 2. Relative humidity 3. Vapor density in air 4. Dew point temperature 5. Enthalpy of mixing per kg of air .take atmospheric pressure=1.0132 bar. | NOTES |
| 9 | A refrigeration system of 10.5 tonnes capacity at an evaporator temperature of -12°C and a condenser temperature of 27°C is needed in a food storage locker. The refrigerant Ammonia is sub cooled by 6°C before entering the expansion valve. The compression in the compressor is of adiabatic type. Find 1. Condition of vapor at outlet of the compressor.2. Condition of vapor at the entrance of the Evaporator 3.COP &power required. | ANSWER KEY |
| 10 | Derive the performance of Refrigeration. | ANSWER KEY |

*UNIT-V-REFRIGERATION & AIR CONDITIONING-ANSWER KEY FOR 16MARK*

***Q.No:1*** **Given Data:**

Dry bulb temperature $t_d = 25^0c$
Wet bulb temperature $t_w = 15^0c$
Barometer pressure $p_b = 760$mm of Hg
Partial pressure $p_v = 10$mm of Hg

**To Find:**

Specific humidity

Saturation ratio.

**Solution:**

**Specific humidity:**

We know that Specific humidity

$$W = \frac{.622 P_v}{P_b - P_v} = \frac{.622 \times 10}{760 - 10}$$

$= 0.0083$ kg/kg of dry air

**Saturation ratio:**

From steam table corresponding to dry bulb temperature $t_d = 25^0c$

We find the partial pressure $p_s = 0.03166$ bar

$$= \frac{0.03166}{0.00133}$$

$= 23.8$ mm of Hg

We know that Saturation ratio.

$$\mu = \frac{pv(pb - ps)}{ps(pb - pv)}$$

$$= \frac{10(760 - 23.8)}{23.8(760 - 10)}$$

**= 0.41**

**Result:**

1. Specific humidity = 0.0083 kg/kg of dry air

**2.** Saturation ratio. **= 0.41**

**Q.No:2 Given data:**

Pressure (P4)= 20bar

Pressure (P1) = 1bar = $1\times10^5$ N/m$^2$

Temperature (T1) = 27$^o$C = 27+273 = 300K Pressure (P2) = 4.7bar

Pressure (P3) = 4.5bar

Temperature (T3) = 27$^o$C = 27+273 = 300K Diameter (D1) = 400mm 0.4m

Stroke (L1) = 500mm = 0.5m

$$K = \frac{v_{c1}}{v_{s1}} = \frac{v_{c3}}{v_{s3}} = 4\% = 0.04$$

N = 200rpm ; n = 1.3

**To Find:**

Indicated power required to run the compressor

**Solution :**

We know the swept volume of the L.P cylinder

$$v_{s1} = \frac{\pi}{4} (D_1)^2 L_1 = \frac{\pi}{4} (0.4)^2\ 0.5$$

$$= 0.06284 \text{ m}^3$$

And volumetric efficiency,

$$\eta v \quad = 1 + K - K \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$$

$$= 1 + 0.04 - 0.04 \left(\frac{4.7}{1}\right)^{\frac{1}{1.3}}$$

= 0.9085 or 90.85% Volume of air sucked by air pressure compressor,

$$v_1 = v_{s1} \times \eta_v = 0.06284 \times 0.9085 = 0.0571 \frac{m^3}{stroke}$$

$$= 0.0571 \times N_w = 0.0571 \times 200 = 1$$

$$=1.42 \text{ m}^3/\text{min}$$

And volume of air sucked by H.P compressor,

$$v_3 = \frac{P_1 V_1}{P_3} = \frac{1 \times 11.42}{4.5} = 2.54 \frac{m^3}{min}$$

We know that indicated work done by L.P compressor

$$W_L = \left(\frac{n}{n-1}\right) P_1 v_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$= \left(\frac{1.3}{1.3-1}\right) 1 \times 10^5 \times 11.42 \left[\left(\frac{4.7}{1}\right)^{\frac{1.3-1}{1.3}} - 1\right]$$

$$= 2123.3 \times 10^3 \text{ J/min} = 2123.3 \text{ KJ/min}$$

And indicated workdone by H.P compressor,

$$W_H = \left(\frac{n}{n-1}\right) P_3 v_3 \left[ \left(\frac{P_4}{P_3}\right)^{\frac{n-1}{n}} - 1 \right]$$

$$= \left(\frac{1.3}{1.3-1}\right) 4.5 \times 10^5 \times 2.54 \left[ \left(\frac{4.20}{4.5}\right)^{\frac{1.3-1}{1.3}} - 1 \right]$$

$= 2043.5 \times 10^3$ J/min = 2034.5 KJ/min

Total indicated work done by the compressor,

$W = W_L + W_H$ = 2123.3 + 2034.5

= 4157.8 KJ/min

Indicated power required to run the compressor = 4157.8 / 60

= 69.3KW

**Q.NO:3 Given Data:**

Pressure (P4 = P3) = 1bar
Pressure (P1 = P2) = 4bar
Temperature (T2) = $500^oC$ = 500+273 = 773K
Mass flow rate of air($m_a$) = 90Kg/min = 1.5Kg/sec
Mass flow rate of fuel ($m_f$) = 2.4Kg/min = 0.04Kg/sec
Temperature (T4) = $30^oC$ = 30+273 = 303K
$\gamma$ = 1.4 ; $C_p$ = 1KJ/KgK ; $C_v$= 40,000 KJ/Kg

**To Find:**

Power developedby the plant
Performance of the gas turbine
Overall efficiency of the plant

**Solution:**

**Power developed by the plant:**

Let T1,T3 = temperature of air at points 1 and3

Weknow that isentropic expansion 2-3,

$$\frac{T_3}{T_2} = \left(\frac{P_3}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{1}{4}\right)^{\frac{1.4-1}{1.4}} = 0.673$$

$T_3 = T_2 \times 0.673 = 773 \times 0.673 = 520K$

Similarly for isentropic compression 4-1:

$$\frac{T_4}{T_1} = \left(\frac{P_4}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{1}{4}\right)^{\frac{1.4-1}{1.4}} = 0.673$$

$T_1 = T_4 / 0.673 = 303/0.673 = 450K$

**Performance of the gas turbine:**

We know that work developed by the turbine,

$$W_T = mC_p(T_2 - T_3) = 1.5 \times 1(773 - 520)$$

= 379.5KJ/s

And work developed by the compressor,

$$W_c = mC_p(T_1 - T_4) = 1.5 \times 1(450 - 303)$$

= 220.5/s

Net work or power of the turbine,

$P = W_T - W_C = 379.5 – 220.5 = 159KJ/s = 159KW$

**Overall efficiency of the plant:**

We know that the heat supplied per second

$= m_f \times C = 0.04 \times 40,000 = 1600$ KJ/s

Therefore, overall efficiency of the plant,

$\eta_o = 159/1600 = 0.099$ or 9.99%

## Q.No:4 AIR CONDITIONERS CONCEPT OF AIR CONDITIONING

Air conditioning (often referred to as aircon, AC or A/C) is the process of altering the properties of air (primarily temperatureand humidity) to more favourable conditions, typically with the aim of distributing the conditioned air to an occupied space to improve thermal comfort and indoor air quality.

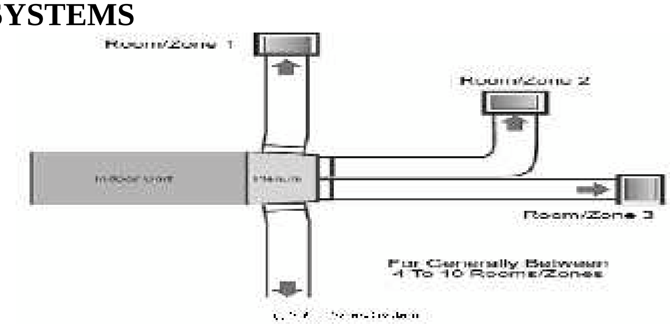
### TYPES OF AIR CONDITIONERS

- Room air conditioners
- Zoned Systems
- Unitary Systems
- Window Air-conditioning System
- Split Air-conditioning System
- Central air conditioning systems

### ROOM AIR CONDITIONER

- Room air conditioners cool rooms rather than the entire home.
- Less expensive to operate than central units
- Their efficiency is generally lower than that of central air conditioners.
- Can be plugged into any 15- or 20-amp, 115-volt household circuit that is not shared with any other major appliances

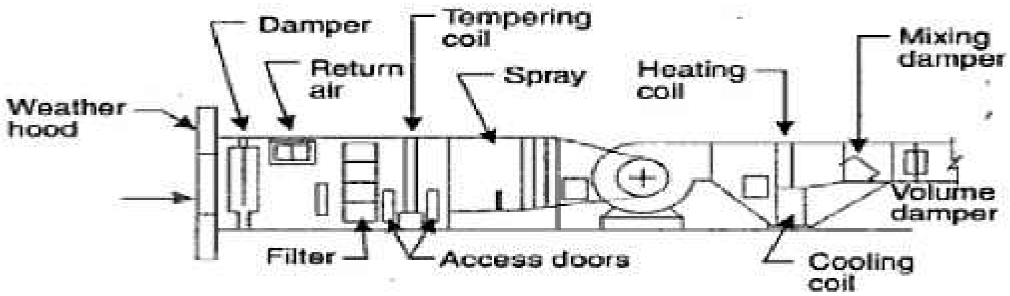
### ZONED SYSTEMS




### CENTRAL AIR CONDITIONING

- Circulate cool air through a system of supply and return ducts. Supply ducts and registers (i.e., openings in the walls, floors, or ceilings covered by grills) carry cooled air from the air conditioner to the home.

- This cooled air becomes warmer as it circulates through the home; then it flows back to the central air conditioner through return ducts and registers




[illegible]

## UNITARY SYSTEMS

A unitary air conditioning system comprises an outdoor unit including a compressor for compressing a refrigerant, an outdoor heat exchanger for heat exchange of the refrigerant and an expander connected to the outdoor heat exchanger, for expanding the refrigerant; a duct installed inside a zone of a building; a central blower unit having a heat exchanger connected to the outdoor unit through a first refrigerant pipe and a blower for supplying the air heat-exchanged by the heat exchanger to the duct; and an individual blower unit including a heat exchanger connected to the outdoor unit through a second refrigerant pipe and a fan for sending the air heat exchanged by the heat exchanger and disposed in a zone in the building, for individually cooling or heating the zone. Accordingly, cooling or heating operation is performed on each zone of the building, and simultaneously, additional individual heating or cooling operation can be performed on a specific space, so that a cost can be reduced and cooling or heating in the building can be efficiently performed.

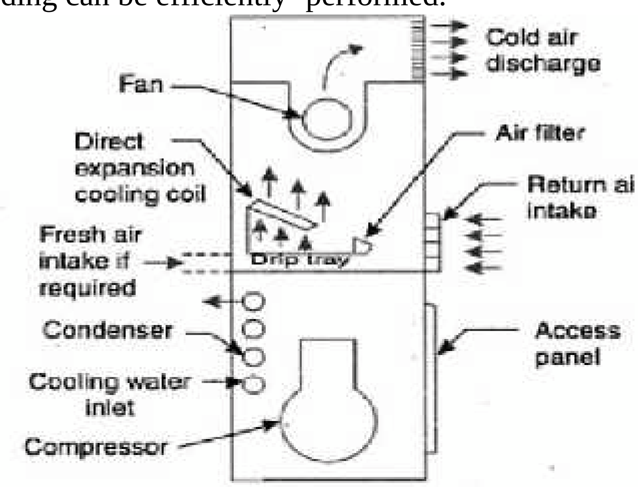
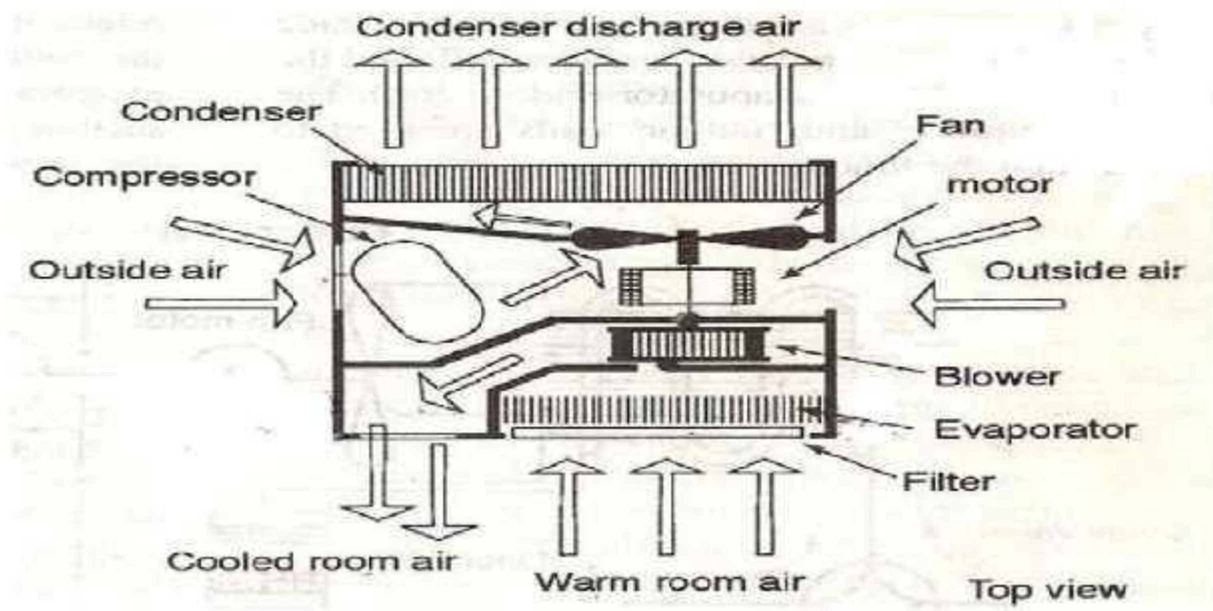



Fig.[illegible] Unitary Systems

## WINDOW AIR-CONDITIONING SYSTEM

It is the most commonly used air conditioner for single rooms. In this air conditioner all the components, namely the compressor, condenser, expansion valve or coil, evaporator and cooling coil are enclosed in a single box. This unit is fitted in a slot made in the wall of the room, or often a window sill. Windows air conditioners are one of the most widely used types of air conditioners because they are the simplest form of the air conditioning systems. Window air conditioner comprises of the rigid base on which all the parts of the window air conditioner are assembled. The base is assembled inside the casing which is fitted into the wall or the window of the room in which the air conditioner is fitted. The whole assembly of the window air conditioner can be divided into two compartments: the room side, which is also the cooling side and the outdoor side from where the heat absorbed by the room air is liberated to the atmosphere. The room side and outdoor side are separated from each other by an insulated partition enclosed inside the window air conditioner assembly. In the front of the window air conditioner on the room side there is beautifully decorated front panel on which the supply and return air grills are fitted (the whole front panel itself is commonly called as front grill). The louvers fitted in the supply air grills are adjustable so as to supply the air in desired direction. There is also one opening in the grill that allows access to the Control panel or operating panel in front of the window air conditioner.




**TYPES OF CENTRAL AC**

- **split-system**
    - An outdoor metal cabinet contains the condenser and compressor, and an indoor cabinet contains the evaporator

- **Packaged**
    - The evaporator, condenser, and compressor are all located in one cabinet.

**SPLIT AIR-CONDITIONING SYSTEM:**

The split air conditioner comprises of two parts: the outdoor unit and the indoor unit. The outdoor unit, fitted outside the room, houses components like the compressor, condenser and expansion valve. The indoor unit comprises the evaporator or cooling coil and the cooling fan. For this unit you don't have to make any slot in the wall of the room. Further, the present day split units have aesthetic looks and add to the beauty of the room. The split air conditioner can be used to cool one or two rooms.

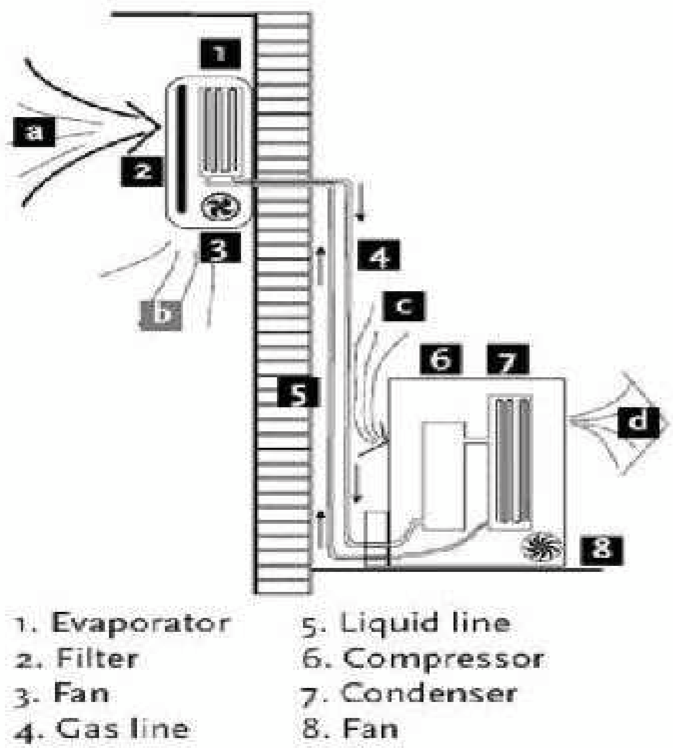



Fig.5.11 Split Air-conditioning System

**Energy Consumption**

- Air conditioners are rated by the number of British Thermal Units (Btu) of heat they can remove per hour. Another common rating term for air conditioning size is the "ton," which is 12,000 Btu per hour.
- Room air conditioners range from 5,500 Btu per hour to 14,000 Btu per hour.

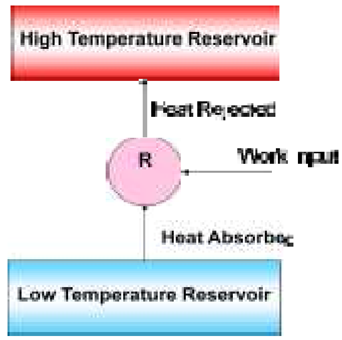
**Energy Efficiency**

- Today's best air conditioners use 30% to 50% less energy than 1970s
- Even if your air conditioner is only 10 years old, you may save 20% to 40% of your cooling energy costs by replacing it with a newer, more efficient model

**Q.No: 5&6 CONCEPT OF REFRIGERATION**

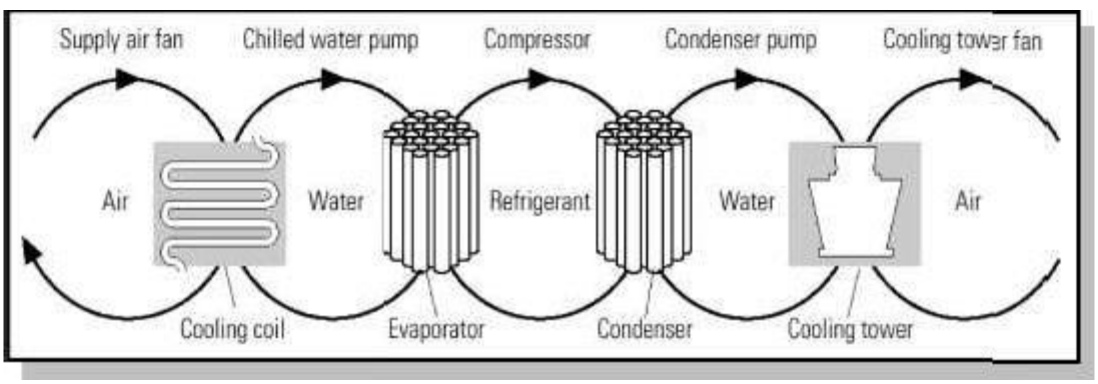
**Refrigeration** is a process in which work is done to move heat from one location to another. The work of heat transport is traditionally driven by mechanical work, but can also be driven by heat, magnetism, electricity, laser, or other means.

**How does it work?**




**Thermal energy moves from left to right through five loops of heat transfer:**

1) Indoor air loop
2) Chilled water loop
3) Refrigerant loop
4) Condenser water loop
5) Cooling water loop




**SIGNIFICANCE**

Refrigeration has had a large importance on industry, lifestyle, agriculture and settlement patterns. The idea of preserving food dates back to the ancient Roman and Chinese empires. However, refrigeration technology has rapidly evolved in the last century, from ice harvesting to temperature-controlled rail cars. In order to avoid food spoilage, refrigeration plays an important role in day to day life, similarly, Air conditioning is also an important technological system to prevent the human from the hot atmosphere during summer seasons.

**CLASSIFICATION OF REFRIGERATION**

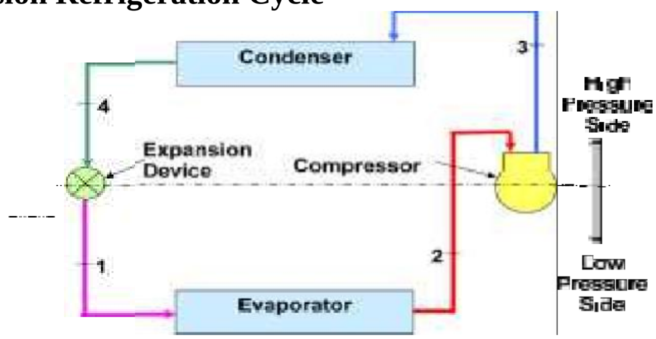
**SYSTEM Types of Refrigeration**

- Vapour Compression Refrigeration (VCR): uses mechanical energy
- Vapour Absorption Refrigeration (VAR): uses thermal energy

**VAPOUR COMPRESSION REFRIGERATION**

- Highly compressed fluids tend to get colder when allowed to expand
- If pressure high enough
    - Compressed air hotter than source of cooling
    - Expanded gas cooler than desired cold temperature
- Lot of heat can be removed (lot of thermal energy to change liquid to vapour)
- Heat transfer rate remains high (temperature of working fluid much lower than what is being cooled)

**Vapour Compression Refrigeration Cycle**




**Evaporator**

Low pressure liquid refrigerant in evaporator absorbs heat and changes to a gas

**Compressor**

The superheated vapour enters the compressor where its pressure is raised

**Condenser**

The high pressure superheated gas is cooled in several stages in the condenser

**Expansion**

Liquid passes through expansion device, which reduces its pressure and controls the flow into the evaporator

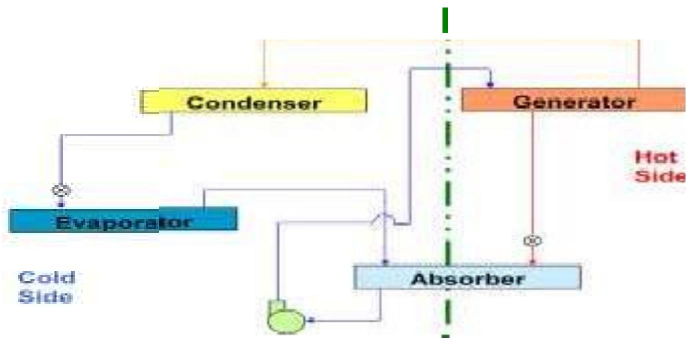
**Type of refrigerant**

- Refrigerant determined by the required cooling temperature
- Chlorinated fluorocarbons (CFCs) or freons: R-11, R-12, R-21, R-22 and R-502

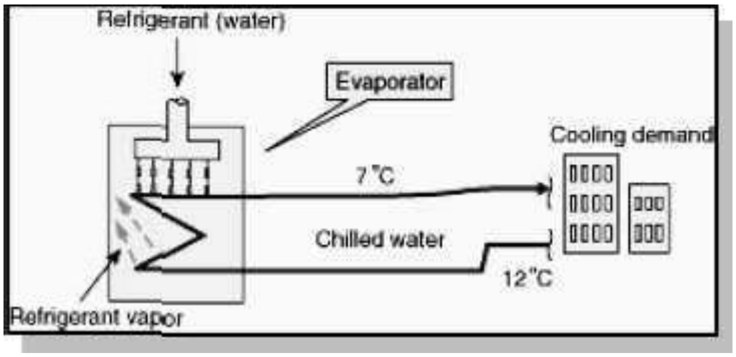
**Choice of compressor, design of condenser, evaporator determined by**

- Refrigerant
- Required cooling
- Load
- Ease of maintenance
- Physical space requirements
- Availability of utilities (water, power)

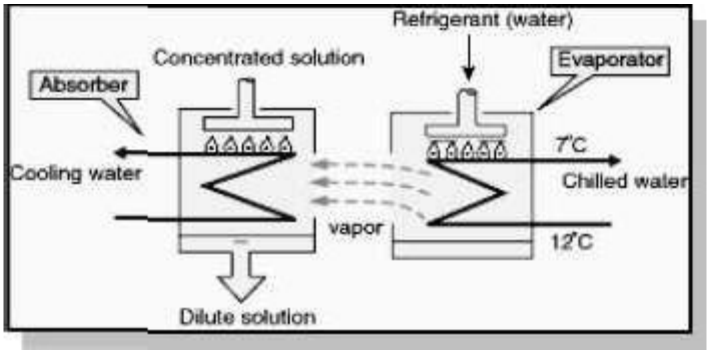
**Vapour Absorption Refrigeration**



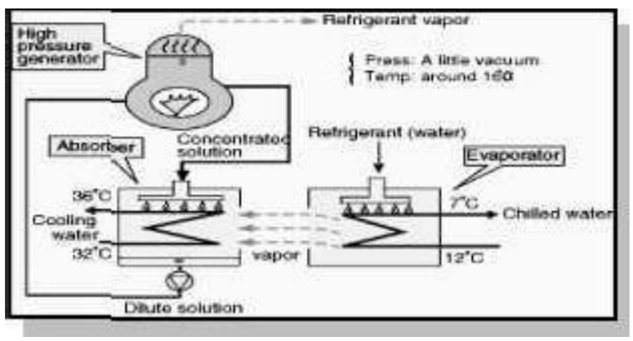

**Evaporator**



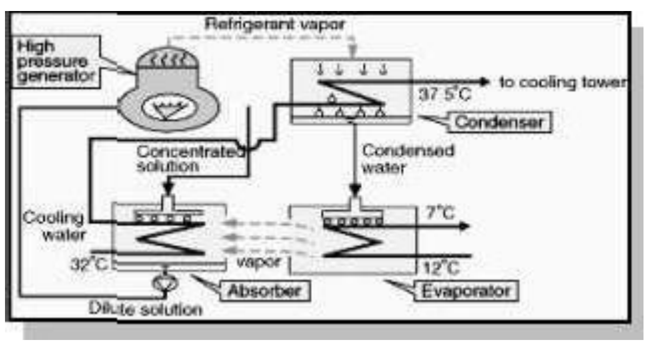
**Absorber**




**High pressure generator**




**Condenser**




**Evaporative Cooling**

- Air in contact with water to cool it close to ‘wet bulb temperature’
- Advantage: efficient cooling at low cost
- Disadvantage: air is rich in moisture

**COMPARISON BETWEEN VAPOR COMPRESSION AND ABSORPTION SYSTEM**

| Absorption system | Compression System |
|---|---|
| a) Uses low grade energy like heat. Therefore, may be worked on exhaust systems from I.C engines, etc. | a) Using high-grade energy like mechanical work. |
| b) Moving parts are only in the pump, which is a small element of the system. Hence operation is smooth. | b) Moving parts are in the compressor. Therefore, more wear, tear and noise. |
| c) The system can work on lower evaporator pressures also without affecting the COP. d) No effect of reducing the load on performance. | c) The COP decreases considerably with decrease in evaporator pressure. d) Performance is adversely affected at partial loads. |
| e) Liquid traces of refrigerant present in piping at the exit of evaporator | e) Liquid traces in suction line may damage the compressor. |

**Q.No:10 PERFORMANCE Assessment of Refrigeration**

- **Cooling effect: Tons of Refrigeration 1 TR = 3024 kCal/hr heat rejected**
- **TR is assessed as:**

**TR = Q x˜ Cp x˜ (Ti – To) / 3024**

Q = mass flow rate of coolant in kg/hr

Cp = is coolant specific heat in kCal /kg °C

Ti = inlet, temperature of coolant to evaporator (chiller) in 0°C

To = outlet temperature of coolant from evaporator (chiller) in 0°C

**Specific Power Consumption (kW/TR)**

- Indicator of refrigeration system's performance
- kW/TR of centralized chilled water system is sum of
    - Compressor kW/TR
    - Chilled water pump kW/TR
    - Condenser water pump kW/TR
    - Cooling tower fan kW/TR

**Coefficient of Performance (COP)**

- The performance of refrigerators and heat pumps is expressed in terms of coefficient of performance (COP), defined as
-

$$COP_R = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Cooling effect}}{\text{Work input}} = \frac{Q_L}{W_{net,in}}$$

$$COP_{HP} = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Heating effect}}{\text{Work input}} = \frac{Q_H}{W_{net,in}}$$

**Measure**

- Airflow Q (m3/s) at Fan Coil Units (FCU) or Air Handling Units (AHU): anemometer
- Air density ∪ (kg/m3)
- Dry bulb and wet bulb temperature: psychrometer
- Enthalpy (kCal/kg) of inlet air ($h_{in}$) and outlet air ($H_{out}$): psychrometric charts