**Program Name** : **Diploma in Mechanical Engineering**

**Program Code** : **ME**

**Semester** : **Fifth**

**Course Title** : **Power Engineering and Refrigeration**

**Course Code** : **22562**

## 1. RATIONALE

Power producing and absorbing devices are essentials for mechanical engineering. It is necessary for mechanical engineering technologists to analyze working and plot the performance of devices like internal combustion engines, air compressors, gas turbines so that he will be able to operate them effectively in an industrial situation. This knowledge is also useful in selecting suitable prime mover for given application and to maintain and test the same. This course also gives basic exposure of refrigeration and air-conditioning equipment which play a vital role in maintaining controlled atmosphere in different domestic and industrial applications. A separate elective course on Refrigeration and Air-conditioning is also available in sixth semester for in-depth knowledge of the course.

## 2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain power engineering and refrigeration devices.**

## 3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Identify different components of I C engines and its auxiliaries.
b. Test the performance of I C Engine.
c. Maintain reciprocating air compressors.
d. Identify different components of gas turbines and jet engines.
e. Test the performance of refrigeration and air-conditioning systems.

## 4. TEACHING AND EXAMINATION SCHEME

| Teaching Scheme | | | Credit (L+T+P) | Examination Scheme | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | | | | | | Practical | | | | | |
| | | | | Paper Hrs. | ESE | | PA | | Total | | ESE | | PA | | Total | |
| L | T | P | | | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| 3 | - | 2 | 5 | 3 | 70 | 28 | 30* | 00 | 100 | 40 | 25# | 10 | 25 | 10 | 50 | 20 |

*(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.*

***Legends:** L-Lecture; T – Tutorial/Teacher Guided Theory Practice; P -Practical; C – Credit, ESE -End Semester Examination; PA - Progressive Assessment*

## 5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

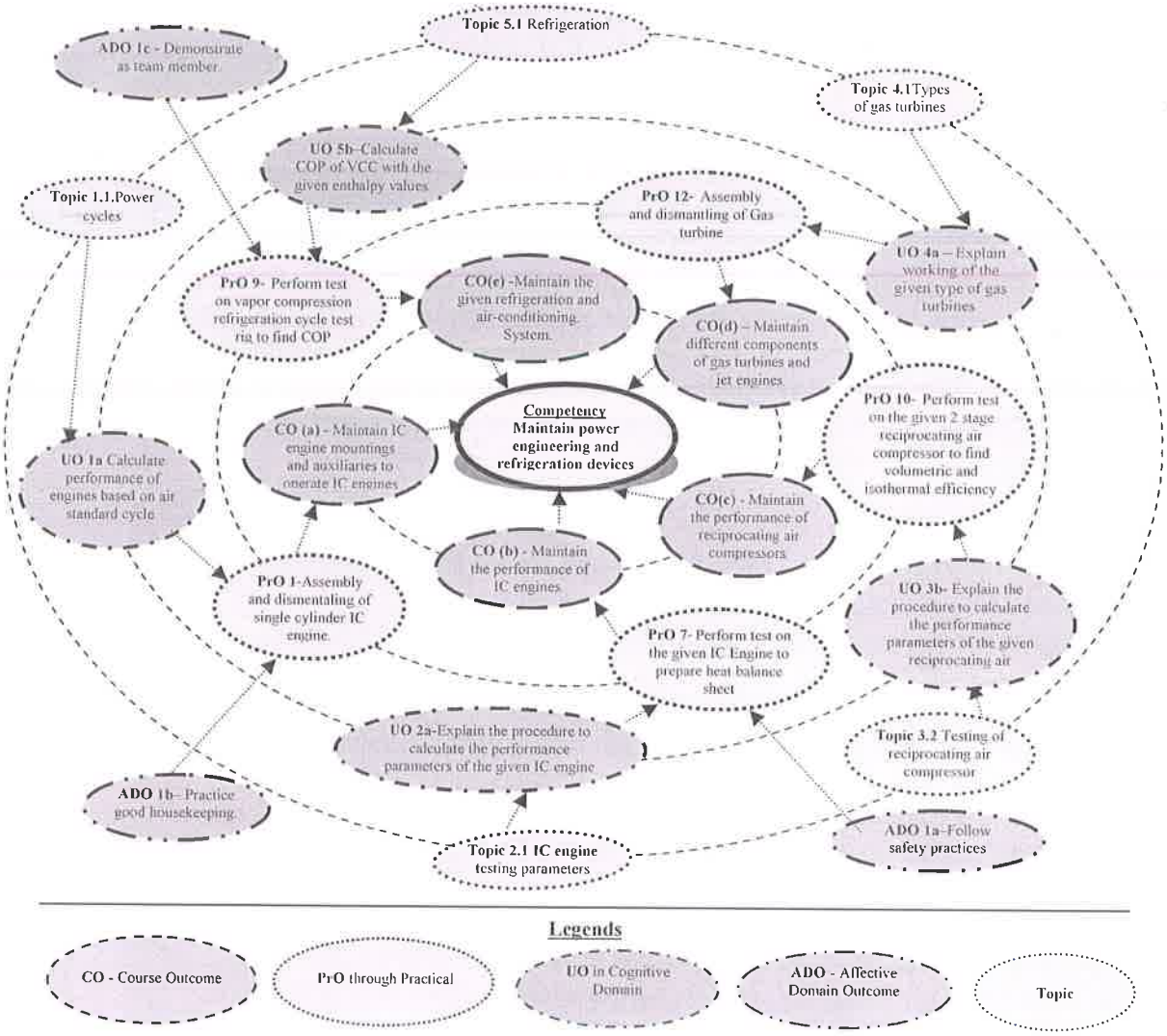


**Figure 1 - Course Map**

## 6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

| Sr. No. | Practical Outcomes (PrOs) | Unit No. | Approx. Hrs. Required |
|---|---|---|---|
| 1 | Assemble/Dismantle single cylinder IC Engine. (Part-I) | I | 02* |
| 2 | Assemble/Dismantle single cylinder IC Engine. (Part-II) | I | 02* |
| 3 | Assemble/Dismantle multi cylinder IC Engine. (Part-I) | I | 02 |
| 4 | Assemble/Dismantle multi cylinder IC Engine. (Part-II) | I | 02 |
| 5 | Assemble/Dismantle inline/rotary fuel injection pump in a diesel engine. | I | 02 |
| 6 | Perform test on the given IC Engine to prepare heat balance sheet and plot performance characteristics. (Part-I) | II | 02* |
| 7 | Perform test on the given IC Engine to prepare heat balance sheet and plot performance characteristics. (Part-II) | II | 02 |

| Sr. No. | Practical Outcomes (PrOs) | Unit No. | Approx. Hrs. Required |
|---|---|---|---|
| 8 | Perform Morse Test on the given IC Engine to perform Morse Test. | II | 02 |
| 9 | Use exhaust gas analyzer to measurement and analyze pollutants in the given IC engine. | II | 02 |
| 10 | Perform diagnosis test on given IC engine using Engine Control Unit | II | 02* |
| 11 | Perform test on the given two-stage reciprocating air compressor to find volumetric and isothermal efficiency. (Part-I) | III | 02* |
| 12 | Perform test on the given two-stage reciprocating air compressor to find volumetric and isothermal efficiency. (Part-II) | III | 02* |
| 13 | Assemble/Dismantle of Gas turbine model. | IV | 02 |
| 14 | Perform test on vapor compression refrigeration cycle test rig to find COP (Part-I) | V | 02* |
| 15 | Trace the refrigerant flow of domestic refrigerator and measure temperatures at critical points for different settings of thermostat. | V | 02 |
| 16 | Assemble/Dismantle various components of domestic refrigerator. | V | 02 |
| 17 | Assemble/Dismantle various components of Water Cooler and Window/Split air conditioning units. | V | 02 |
| | **Total** | | **34** |

***Note***

i. *A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

| S. No. | Performance Indicators | Weightage in % |
|---|---|---|
| a. | Preparing setup for experimentation | 20 |
| b. | Performing the practical and reading different instruments | 20 |
| c. | Measuring performance parameters | 30 |
| d. | Answer to sample questions | 20 |
| e. | Submit report in time | 10 |
| **Total** | | **100** |

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Work as a leader/a team member.
d. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year
- 'Characterising Level' in 3rd year.

## 7. MAJOR EQUIPMENT/ INSTRUMENTSREQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by administrators.

| S. No. | Equipment Name with Broad Specifications | PrO. S. No. |
|---|---|---|
| 1 | Single cylinder IC engine suitable for assembly / dismantling with necessary tool set. (Engine complying latest Euro Norms) | 1,2 |
| 2 | Multi cylinder IC engine suitable for assembly / dismantling with necessary tool set. (Engine complying latest Euro Norms) | 3,4 |
| 3 | Inline / Rotary fuel pump of a latest version with necessary tool set. | 5 |
| 4 | Test rig on single cylinder IC engine. 3/5/7 HP petrol / diesel engine with required accessories. | 6,7 |
| 5 | Test rig on multi cylinder IC engine. 3/5/7 HP petrol engine with required accessories. | 8 |
| 6 | Exhaust gas analyzer 3/5 gas analyzer. | 9 |
| 7 | Engine Control Unit | 10 |
| 8 | Test rig on two stage reciprocating air compressor. Pressure and temperature gauges at suitable locations with manometer. Minimum ½ HP compressor motor. | 11,12 |
| 9 | Gas turbine and Jet engine models (working model or scrap turbine). | 13 |
| 10 | Charts and videos on construction and working of different components of gas turbines and jet engines. | 23 |
| 11 | Test rig on vapor compression cycle to find different COPs. ¼ to ½ HP compressor, pressure gauges and temperature gauges at suitable locations. | 14, 15 |
| 12 | Domestic refrigerator. Minimum 165 ltrs. Water cooler, Ice plant and Cold storage, Deep freezer (Actual working or scrap units) | 16 |
| 13 | Refrigeration tools required for repair and maintenance process of refrigeration and air-conditioning units | 17 |
| 14 | Window and split air-conditioner units, central air-conditioning unit. (Actual working or scrap units) | 18,19 |
| 15 | AxCYCLE Software: Thermodynamic Simulation Software for heat balance calculations of heat production and energy conversion cycles | All |

## 8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

| Unit | Unit Outcomes (in cognitive domain) | Topics and Sub-topics |
|---|---|---|
| **Unit – I Internal Combustion Engines** | 1a. Calculate performance of given engine(s) based on corresponding air standard cycle. (Only Carnot and Otto Cycles)<br>1b. Explain with sketches valve timing diagrams for the given engine with sketches.<br>1c. Explain with sketch the | 1.1 **Power cycles:** Engine terminology, working of 4 stroke engines, Carnot cycle, Otto cycle, diesel cycle, dual cycle, actual indicator diagrams for 4 stroke engines.<br>1.2 **Basic of IC Engines:** Working and comparison of four stroke and two stroke cycle engines and SI and CI |

| Unit | Unit Outcomes (in cognitive domain) | Topics and Sub-topics |
|---|---|---|
| | construction and working of the given IC engine auxiliary (Turbo-Charger, Inline fuel injection pump, piezoelectric injectors, EGR, MPFI systems).<br>1d. Explain maintenance procedure of the given fuel injection pump, MPFI system and EGR and CRDI unit.<br>1e. Apply BS6 Norms to the given engine(s).<br>1f. State the procedure to undertake routine maintenance of the given IC engine | engines.<br>1.3 **IC Engines auxiliaries:** Valve timing diagrams, VVT-I engines – concept and arrangement, supercharging – objectives and advantages, Turbocharging, Variable Geometry Turbochargers, MPFI layout, various Sensors, rotary and inline fuel injection pump, piezoelectric injectors, EGR layout, viscous coupling for fan.<br>1.4 Common rail direct injection diesel engines (CRDI) controlled by electronic control unit.<br>1.5 Diagnostic tools used for fault finding of two wheelers.<br>1.6 List of Methods to reduce pollution in diesel engines as prescribed in BS6 |
| **Unit– II Testing of IC Engines and Emission Control** | 2a. Explain the procedure to calculate the performance parameters of the given IC engine.<br>2b. Explain the procedure to calculate indicated power of the given engine using Morse test.<br>2c. Explain procedure to measure emissions of exhaust gases in the given engine.<br>2d. Explain procedure to perform diagnosis using Engine Control Unit in the given engine.<br>2e. Explain methods to control exhaust emissions in the given engine. | 2.1 **IC engine testing parameters**: IP, BSFC, components of heat balance sheet, thermal and mechanical efficiency, Morse test.<br>2.2 Combustion in IC engines, Octane Number (RON, MON) & Knock Resistance.<br>2.3 **Exhaust emissions and control:** Polluting emissions in IC engines, effects on environment, measurement of exhaust emissions, effect of air-fuel ratio on exhaust emissions (with graph), Euro IV and Euro VI norms for M and N1 vehicles, catalytic converter, SCR.<br>2.4 **Engine Control Unit (ECU):** working and diagnosis procedure. |
| **Unit– III Air Compressors** | 3a. Explain with sketches working of the given compressor.<br>3b. Explain the procedure to calculate the performance parameters of the given compressor.<br>3c. Recommend the type of compressor for the given applications with justification.<br>3d. State the procedure to undertake routine maintenance of the given type of air compressor. | 3.1 **Reciprocating compressors** – applications, working of single stage and two stage compressors with PV diagrams. Intercooling.<br>3.2 **Testing of reciprocating air compressors:** Pressure ratio, compressor capacity, FAD, volumetric efficiency, isothermal efficiency, numerical. Methods of energy saving.<br>3.3 **Rotary compressors:** Screw, centrifugal, Lobe type, vane type compressors and Axial flow compressors. Comparison of rotary with reciprocating. |

| Unit | Unit Outcomes (in cognitive domain) | Topics and Sub-topics |
|---|---|---|
| **Unit-IV Gas Turbines and Jet Propulsion** | 4a. Explain with sketches working of the given type of gas turbines.<br>4b. Identify different components of the given engine with justification.<br>4c. Explain with sketches the working of given rocket propulsion systems.<br>4d. State the procedure to undertake routine maintenance of the given gas turbine.<br>4e. State the procedure to undertake routine maintenance of the given propulsion engine. | 4.1 **Types of Gas Turbines:** Constant pressure, open cycle and closed cycle gas turbines, Brayton cycle, applications, Aero derivative and heavy frame engines<br>4.2 **Jet propulsion:** Turbojet, Turboprop, engines.<br>4.3 **Rocket propulsion:** liquid and solid propellant systems. |
| **Unit –V Refrigeration and Air-conditioning** | 5a. Sketch Carnot cycle and Vapor compression cycle (VCC) with the given type of PV, TS, PH diagrams.<br>5b. Calculate COP of Vapor compression cycle (VCC) for the given enthalpy values.<br>5c. Choose the refrigerant based on properties for given application with justification.<br>5d. Explain with sketches construction and working of the given components of vapor compression systems.<br>5e. Select suitable VCC component of the given refrigeration systems using ASHRAE Handbook with justification.<br>5f. Determine the given property(s) of the given air using psychrometric chart.<br>5g. Explain with sketches construction and working of the given refrigeration and air conditioner.<br>5h. State the procedure to undertake routine maintenance of the given type of air compressor. | 5.1 **Refrigeration:** Unit of refrigeration, EER, SEER, Carnot cycle, Vapor compression cycle, sub cooling and superheating, components of vapor compression systems, refrigerant properties, concepts of GWP, ODP, TEWI, LCCP.<br>5.2 **Applications:** Specification, Working and construction of Domestic refrigerator, water cooler, ice plant and cold storage.<br>5.3 **Air-conditioning**: Definition, classification-comfort air conditioning, industrial air conditioning, applications .<br>5.4 **Psychrometry:** properties of air, psychrometric processes, psychrometric chart.<br>5.5 **Applications:** Specification, Working and construction of Window, split air-conditioner, central air-conditioning, |

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'*

## 9. SUGGESTED SPECIFICATION TABLE FORQUESTION PAPER DESIGN

| Unit No. | Unit Title | Teaching Hours | Distribution of Theory Marks | | | |
|---|---|---|---|---|---|---|
| | | | R Level | U Level | A Level | Total Marks |
| I | Internal combustion engines | 12 | 04 | 08 | 04 | 16 |

| Unit No. | Unit Title | Teaching Hours | Distribution of Theory Marks | | | |
|---|---|---|---|---|---|---|
| | | | R Level | U Level | A Level | Total Marks |
| II | Testing of IC engines and emission control | 12 | 04 | 04 | 08 | 16 |
| III | Air compressors | 08 | 02 | 04 | 08 | 14 |
| IV | Gas turbines and Jet propulsion | 04 | 02 | 02 | 04 | 08 |
| V | Refrigeration and Air-conditioning | 12 | 04 | 04 | 08 | 16 |
| **Total** | | **48** | **16** | **22** | **32** | **70** |

***Legends:*** *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
***Note****: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

## 10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare a power point presentation on emission norms.
b) Make charts for performance characteristics of IC Engine.
c) Make a chart showing heat balance sheet format to display in laboratory.
d) Collect specifications of gas turbine based engines used for power generation and for jet engines.
e) Collect specifications of domestic refrigerators and window air-conditioners from manufacturer's websites.
f) Collect information on different tests actually used for IC engines.
g) Measure DBT and WBT using thermometer and calculate rest of the properties of air using psychrometric chart.
h) Prepare trouble shooting chart for domestic refrigerator / window air-conditioner
i) Prepare electrical trouble shooting chart for refrigeration system.
j) Prepare trouble shooting chart for IC engine.
k) Prepare seminar report on dual fuel and hybrid engines.
l) Visit an industry where air compressors are monitored online using SACDA or similar system. Write a report on the same.
m) Collect IC Engine fuel characteristics including information on RON and MON.

## 11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).

d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Correlate subtopics with power engineering system utility and equipment.
g) Use proper equivalent analogy to explain different concepts.
h) Use Flash/Animations to explain various working of compressor, gas turbine and refrigerant flow in refrigerator and air conditioner.
i) Show different parts of various refrigeration and air conditioning units.
j) Show constructional details of various Gas turbines, Jet Engines, Reciprocation and Rotary Compressors.

## 12. SUGGESTED MICRO-PROJECTS

***Only one micro-project*** is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects is given here. Similar micro-projects could be added by the concerned faculty:

a) Display various components of MPFI system on wooden board with labels.
b) Prepare a report on OBD measurements.
c) Take sample of cooling load calculations sheet; list the components of cooling load along with percentage contribution of different loads in a refrigeration or air conditioning.
d) Display various parts of a hermetically sealed / open compressor on wooden board with labels.
e) Collect and display different gaskets required for a single cylinder /multi cylinder IC engine.
f) Prepare report on different types of lubricating oils, oil filters, coolants, for petrol engines wrt physical and chemical properties, cost, safety, disposal etc.
g) Make a working model of air compressor.
h) Prepare a step-by-step procedure for dismantling and assembly of multi cylinder IC engine. Tabulate different tools used in dismantling of IC engines against components for which these tools are used.
i) Collect information about electrical motor drives used in vehicles such as Tesla and Google's car.
j) Comparative study of hybrid vehicles and conventional vehicles.
k) Collect charts using internet regarding Combustion: combustion in SI engines, pre-ignition, detonation – concept, factors affecting detonation, Homogeneous Charged Compression Ignition Engine.
l) Collect working and constructional details of different types of Reciprocating and Rotary compressors.
m) Collect specifications, working and constructional details of different types of refrigeration and air conditioning units (Domestic refrigerator, water cooler, ice plant and cold storage, Window, split air-conditioner, central air-conditioning).

## 13. SUGGESTED LEARNING RESOURCES

| S. No. | Title of Book | Author | Publication |
|---|---|---|---|
| 1 | Internal Combustion Engines | Mathur M. I.; Sharma R. P. | Dhanpatrai Publications (P) Ltd, New Delhi 2012, ISBN: 1234567144047 |
| 2 | Thermal Engineering | Rajput R. K. | Laxmi Publications, New Delhi 2010, ISBN: 8131808041, 9788131808047 |
| 3 | A Textbook of Internal Combustion Engines | Rajput R.K. | Laxmi Publications; Third edition, New Delhi, (2016) ISBN-13: 978-8131800669 |
| 4 | IC Engines Combustion and Emissions | Pundir B. P. | Narosa Publishing House), New Delhi (2010) ISBN-13: 978-8184870879 |
| 5 | Refrigeration and Air Conditioning | Khurmi R. S.; Gupta J. K. | S. Chand Publications, New Delhi (2016), ISBN: 978-81-219-2781-9 |
| 6 | Thermal Engineering | Singh Sadhu, Pati Sukumar | Pearson Education; First edition, New Delhi, (2018) ISBN-13: 978-9352866687 |

## 14. SOFTWARE/LEARNING WEBSITES

a) https://jalopnik.com/how-variable-valve-timing-works-500056093
b) https://www.araiindia.com/pdf/Indian_Emission_Regulation_Booklet.pdf
c) http://www.fchart.com/ees/demo.php
d) http://industrial-ebooks.com/CBT_software/Aircompressor-Training91.php
e) https://www.gspteam.com/products.html