Program Name : **Diploma in Production Engineering / Diploma in Production Technology / Diploma in Mechanical Engineering**

Program Code : **PG / PT / ME**

Semester : **Third**

Course Title : **Thermal Engineering**

Course Code : **22337**

1. RATIONALE

Thermal engineering forms one of the core engineering subjects for mechanical engineering students. Diploma mechanical engineers (also called technologists) have to work with various power producing and power absorbing devices like boilers, turbines, compressor, I.C. engines, and refrigerators. The course will enable students to establish foundation required to design, operate and maintain these devices. Thermal power plants are still contributing major share in electricity production in India. Thiscourse emphasizes on steam boilers and allied components that are used in many industrial sectors. Students will be able to calculate various parameters required to determine the performance of these devices.

2. COMPETENCY

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

- **Use principles of thermal engineering to maintain thermal related equipment.**

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. Apply laws of thermodynamics to devices based on thermodynamics.
b. Use first law of thermodynamics for ideal gas in closed systems.
c. Use relevantsteam boilers.
d. Use relevant steam nozzles and turbines.
e. Use relevant steam condensers.
f. Use suitable modes of heat transfer.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					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.

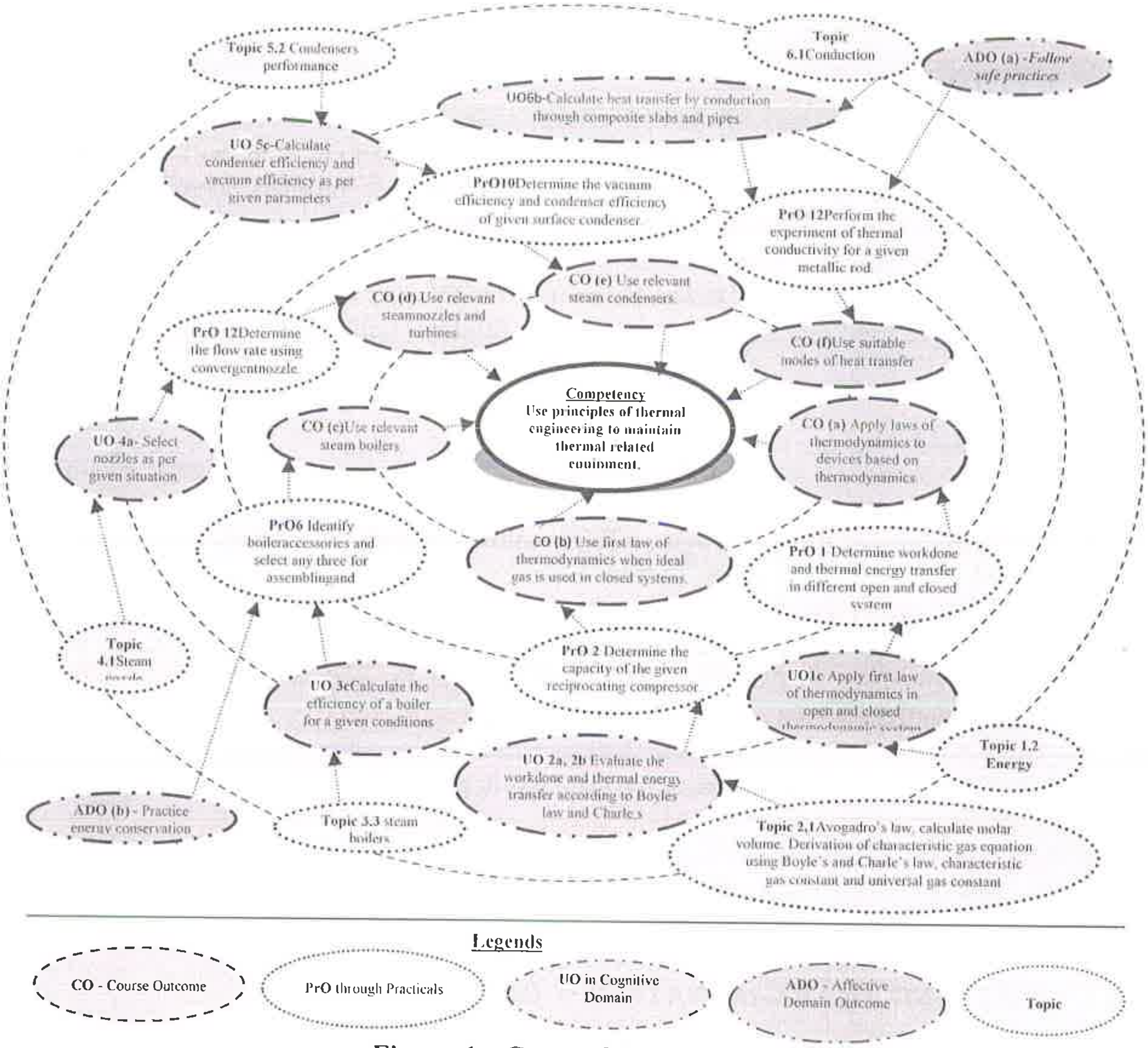

Figure 1 - Course Map

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:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Determination of actual volume per second at the suction of reciprocating air compressor.	II	02*
2	Trace the path of Flue Gases and Water/Steam circuit of the boiler.	III	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
3	Assembly and dismantling ofboiler mountings.	III	02
4	Assembly and dismantling ofboiler accessories.	III	02
5	Perform simulation of Thermal Power Plant and write specifications of boilers, turbines, condensers and electrical generators.	III	02
6	Determination of dryness fraction of a given sample of steam by using separating calorimeter.	III	02*
7	Plot steam properties on Mollier chart for a given sample of wet steam.	III	02*
8	Assembly and dismantling of impulse and reaction turbines (working Model).	IV	02
9	Assembly and dismantling of cooling tower (working Model).	IV	02
10	Dismantle given model of surface condenser, draw sketches of various parts and assemble it.	V	02
11	Perform simulation software to determinethe vacuum efficiencyandcondenserefficiencyof a surface condenser using advanced simulation software.	V	02
12	Calculate the thermal conductivity of Metallic Rod.	VI	02*
13	Identify different equipment in power engineering lab having heat exchangers and classify heat exchangers. Write construction and working any 03 of above heat exchangers.	VI	02*
14	Calculate mass flow rate of one fluid using energy balance equation in heat exchanger.	VI	02*
15	Calculate convective heat transfer coefficient for the given fluid.	VI	02
16	Determine the value of Stefan-Bolzman constant for radiation.	VI	02*
	Total		**32**

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.	Preparation of experimental set up	20
b.	Setting and operation	20
c.	Safety measures	10
d.	Observations and Recording	10
e.	Interpretation of result and Conclusion	20
f.	Answer to sample questions	10
g.	Submission of 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. Practice energy conservation.
d. Demonstrate working as a leader/a team member.
e. Maintain tools and equipment.
f. 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 1^{st} year
- 'Organizing Level' in 2^{nd} year
- 'Characterizing Level' in 3^{rd} 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 authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. S. No.
1	Two stage reciprocating air compressor with intercooler test rig. Maximum Pressure – 10 bar, digital watt meter.	2,3
2	Models of water tube and fire tube boilers (cut section models).	4
3	Various mountings and accessories of boilers for assembly and dismantling purpose.	5,6
4	Relevant simulation software.	4,
5	Cut section models of impulse turbine and reaction turbine.	9
6	Experimental setup with convergent and divergent nozzle.	12,13
7	Model of surface steam condenser with assembly and dismantling purpose.	14,15
8	Experimental setup of shell and tube steam condenser. (Minimum shell diameter 45cm).	14,15
9	Experimental set up for determination of thermal conductivity.	16,17, 18
10	Models of different heat exchangers.	19
11	Experimental set up to verify Stefan Boltzman law.	21
12	Experimental set up to determine convective heat transfer coefficient.	20

8. UNDERPINNING THEORY COMPONENTS

The following topicsare to betaught 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 (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Fundamentals of Thermodynamics	1a. Determine the properties of the given substance using thermodynamic tables. 1b. Explain the phenomena when thermodynamic principles is applied to the given condition of gas. 1c. Explain the phenomena when first law of thermodynamics in the given thermodynamic system. 1d. Determine the rate of workdone and thermal energy transfer during thermodynamic process in the given type of open system.	1.1 Basic Concepts - Concept of pure substance, types of systems , properties of systems, Extensive and Intensive properties, flow and non-flow processes, specific volume, temperature, density, pressure.Processes and cycles. 1.2 Energy - Work, Heat Transfer and Energy Thermodynamic definition of work and heat, difference between heat and work. energy –Potential Energy, kinetic Energy, internal Energy, Flow Work, concepts of enthalpy andphysical concept of entropy. 1.3 Laws of Thermodynamics- Zeroth law, first law of thermodynamics, second law of thermodynamics, Kelvin Planks, Clausius statements and their equivalence. Reversible and irreversible processes, factors making process irreversible, reversible carnot cycle for heat engine and refrigerator. 1.4 Application of Laws of Thermodynamics Steady flow energy equation and its application to boilers, engine, nozzle, turbine, compressor and condenser. Application of second law of thermodynamics to heat engine, heat pump and refrigerator.
Unit– II Ideal Gases and Ideal Gas Processes	2a. Evaluate the workdone and thermal energy transfer according to Boyles law for the given situation. 2b. Evaluate the workdone and thermal energy transfer according to Charle's law for the given situation. 2c. Calculate the mass of a gas and its final condition parameters after undergoing Polytropic process for the given situation.. 2d. Determinecharacteristic gas constant of commonly used gases for the given data. 2e. Calculatedifferent energy	**2.1** Avogadro's law, calculate molar volume. Derivation of characteristic gas equation using Boyle's and Charle's law, characteristic gas constant and universal gas constant. **2.2** Ideal gas processes –Isobaric, Isochoric, Isothermal, Isentropic, Polytropic, Throttling and their representation on P-V and T-S diagrams. Determination of work, heat, internal energy, enthalpy change and entropy change.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	changes during ideal gas processes for the given situation.	
Unit– III Steam and steam boiler	3a. Determine dryness fraction for the given steam sample. 3b. Represent different vapor processes on suitable co-ordinates in the given situation. 3c. Calculate the efficiency of given type of boiler for the given conditions. 3d. Calculate the rates of thermal energy transfer in the given type of boiler and superheater for the given conditions.	3.1 Steam fundamentals - Applications of steam, generation of steam at constant pressure with representation on various charts such as PV, T-S, H-S. Properties of steam and use of steam table, dryness fraction, degree of superheat, sensible and latent heat, boiler efficiency, Mollier chart. 3.2 Vapour processes - Constant pressure, constant volume, constant enthalpy, constant entropy process (numerical using steam table to determine dryness fraction and enthalpy), Rankine cycle. 3.3 Steam Boilers - Classification, Construction and working of - Cochran, Babcock and Wilcox, La-mont and Loeffler boiler, packaged boilers. Boiler draught. Indian Boiler Regulation (IBR) (to be covered in practical periods). 3.4 Boiler mountings and accessories. 3.5 Boiler instrumentation. 3.6 Methods of energy conservation in boilers.
Unit-IVSteam turbines	4a. Select the nozzles for the given situation. 4b. Determine thermal efficiency for the specified type of steam turbine for given conditions. 4c. Interpret thegiven types of steam cycles to estimate efficiencies in a steam power plant 4d. Compare the performance for the given steam turbine stages.	4.1 Steam nozzle - Continuity equation, types of nozzles, concept of Mach number, critical pressure and choked flow condition, application of steam nozzles. 4.2 Steam turbine - Classification of turbines, Construction and working of impulse and reaction turbine. 4.3 Compounding of turbines and its types. Regenerative feed heating, bleeding of steam, governing and its types, losses in steam turbines.
Unit –V Steam Condensers	5a. Identify the elements and processes of the given type of steam condensers. 5b. Identify the elements and processes of the given cooling towers.	5.1 Steam condensers - Dalton's law of partial pressure, function and classification of condensers, construction and working of surface condensers and jet condensers. 5.2 Condenser performance - Sources of

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	5c. Calculate condenser efficiency and vacuum efficiency for the given parameters. 5d. Evaluate the thermal performance for the given data of the team condenser 5e. Interpret the thermal design of the given type of cooling tower. 5f. Select condensers for the given situation with justification 5g. Select cooling tower for the given situation with justification	air leakage and its effect, concept of condenser efficiency, vacuum efficiency (Simple numerical). 5.3 Cooling Towers-Construction and working of forced, natural and induced draught cooling tower.
Unit-VI Heat transfer and heat exchangers.	6a. Calculate heat transfer by conduction through composite slabs and pipes for the given data. 6b. Use Stefan Boltzman law of radiation in the given situation. 6c. solve thermal engineering problems with the given data using principles of energy mechanisms. 6d. Explain construction and working of a given type of heat exchangers with sketches. 6e. Select heat exchangers for the given situation with justification.	6.1 Modes of heat transfer - Conduction, convection and radiation. 6.2 Conduction - Fourier's law, thermal conductivity, conduction through cylinder, thermal resistance, composite walls,list of conducting and insulating materials. 6.3 Convection - Newton's law of cooling, natural and forced convection. 6.4 Radiation- Thermal Radiation, absorptivity, transmissivity, reflectivity, emissivity, black and gray bodies, Stefan-Boltzman law. 6.5 Heat Exchangers - Classification, construction and working of shell and tube, shell and coil, pipe in pipe type and plate type heat exchanger, automotive heat exchanger and its applications.

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	Fundamentals of thermodynamics	08	02	02	04	08
II	Ideal gases and ideal gas processes	08	04	04	06	14
III	Steam and steam boilers	10	02	04	08	14
IV	Steam turbines	08	04	04	08	16
V	Steam condensers	08	02	04	04	10
VI	Heat transfer and heat exchangers	06	02	02	04	08
	Total	**48**	**16**	**20**	**34**	**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 journal of practical.
b. Prepare and present a seminar on boiler instrumentation using appropriate sources of information.
c. Prepare charts on compounding, regenerative feed heating processes.
d. Prepare charts of PV & TS charts of different ideal gas processes.
e. Prepare charts of PH, HS, TS diagrams for different steam processes.
f. Draw manually enthalpy-entropy (Mollier) chart and represent different vapor processes on the same using different color combinations.
g. Prepare a report on visit to Sugar Factory / Steam Power Plant / Dairy industry with specification of boiler and list of mountings and accessories along with their functions.
h. List insulating and conducting materials used in various applications.

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. Demonstrate students thoroughly before they start doing the practice.
g. Encourage students to refer different websites to have deeper understanding of the subject.
h. Observe continuously and monitor the performance of students in Lab.

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 are given here. Similar micro-projects could be added by the concerned faculty:

a. Prepare charts on fundamentals concepts of thermodynamics. E.g. First/Second law applications, heat and work transfer.
b. Investigate energy transfer in thermodynamic system.
c. Investigate combustion process and calorific values.
d. Prepare at least one model explaining ideal gas processes.
e. Prepare at least one model of boiler mountings and accessories.
f. Collect and analyze technical specifications of steam turbines, boilers from manufacturers' websites and other sources.
g. Prepare a report on steam traps used in steam piping.
h. Carry out comparative study of conventional cooling towers, cooling towers used in power plants and upcoming cooling towers. .
i. Make power point presentation including videos on heat exchangers commonly used.
j. Make models of Shell and Tube, Plate, tube in tube heat exchangers in workshop.
k. Organize a group discussion session on relative merits and demerits of different types of turbines, condensers, boilers.
l. Make a model of steam condenser and show how vacuum is created after steam condensation.
m. Undertake a 03 days training at Thermal Power Plant.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Thermal Engineering	Rathore, Mahesh M.	Tata McGraw-Hill Education, New Delhi 2010, ISBN: 9780070681132
2	Basic Thermodynamics	Nag, P. K.	McGraw-Hill Education, New Delhi
3	Thermal Engineering	Rajput, R. K.	Firewall Media, New Delhi 2005, ISBN: 978-8170088349
4	A Textbook of Thermal Engineering	Gupta, J. K.; Khurmi R. S.	S. Chand Limited, New Delhi 1997, ISBN: 9788121925730
5	A course in Thermal Engineering	Domkundwar, S; Kothandaraman, C. P;Domkundwar, A. V.	DhanpatRai and company, New Delhi, 2004, ISBN:9788177000214

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a. http://www.sfu.ca/~mbahrami/ENSC%20388/Notes/Intro%20and%20Basic%20Concepts.pdf
b. http://web.mit.edu/16.unified/www/FALL/thermodynamics/notes/node12.html
c. https://www.youtube.com/watch?v=9GMBpZZtjXM
d. https://www.youtube.com/watch?v=3dyxjBwqF-8
e. https://www.youtube.com/watch?v=02p5AKP6W0Q
f. http://www.learnengineering.org/2013/02/working-of-steam-turbine.html
g. https://www.youtube.com/watch?v=MulWTBx3szc
h. http://nptel.ac.in/courses/103106101/Module%20-%208/Lecture%20-%202.pdf
i. https://www.youtube.com/watch?v=Jv5p7o-7Pms
j. http://www.cdeep.iitb.ac.in/webpage_data/nptel/Mechanical/Heat%20and%20Mass%20Transfer/Course_home_1.html
k. http://www.rinfra.com/energy_generation.html