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

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

**Semester** : **Fourth**

**Course Title** : **Engineering Materials and Metallurgy**

**Course Code** : **22449**

## 1. RATIONALE

Production Technology (PT) students always come across with the selection of material as per requirement. So, knowledge of their properties and composition is essential. This subject deals with the solidification of metals and alloys, equilibrium diagrams and their applications. It covers metallurgical aspects of metals and alloys such as micro and macroscopic examination of metals and alloys. The subject includes study of iron-iron carbon equilibrium diagrams, ferrous and non-ferrous metals, TTT diagram, various heat treatment processes and powder manufacturing processes.

## 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 relevant materials for the different applications.**

## 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. Interpret crystal structure of the material.
b. Use different types of equilibrium diagrams.
c. Use relevant materials as per the requirement.
d. Select heat treatment processes.
e. Prepare a job using relevant powder manufacturing process.

## 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.

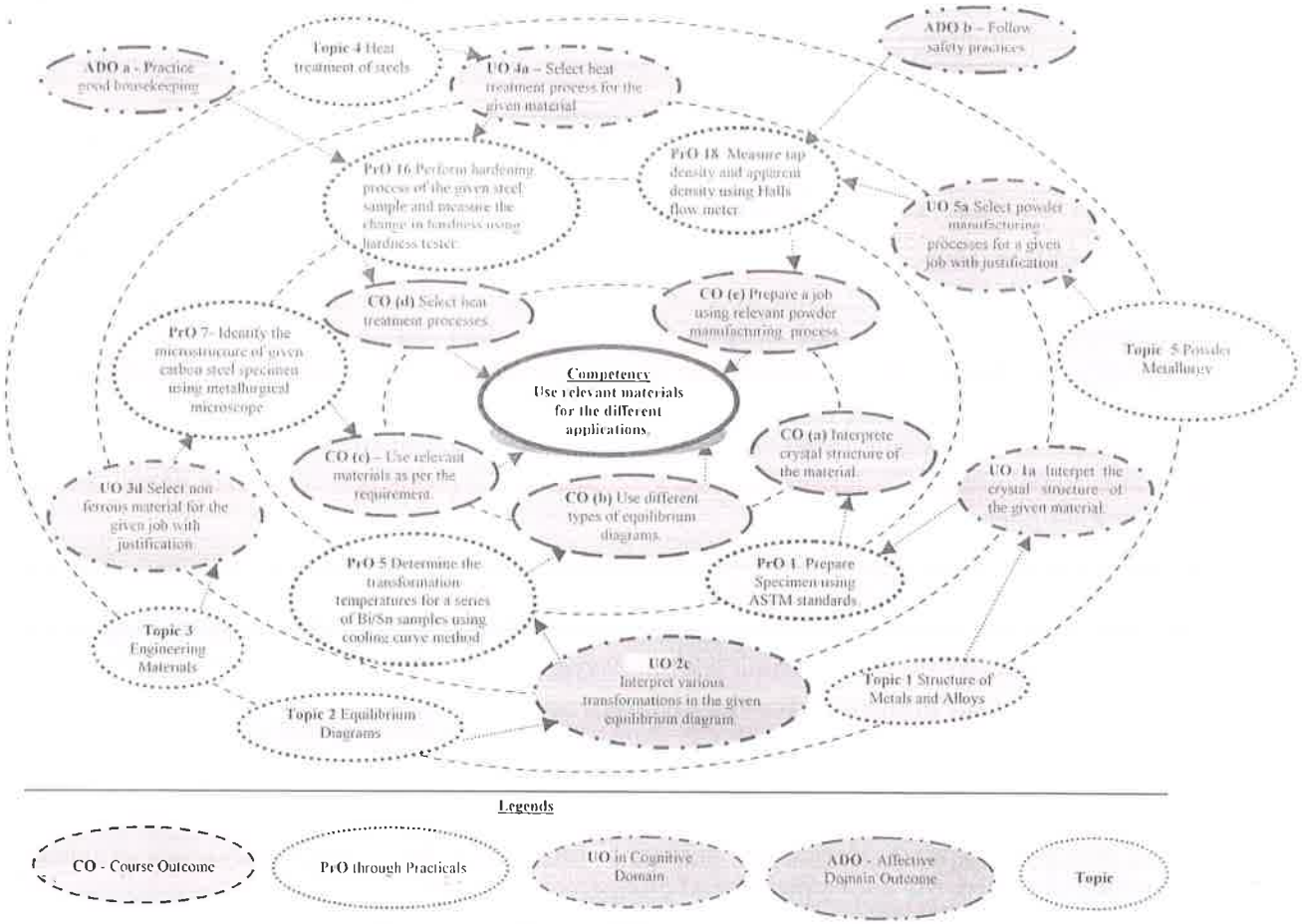


**Figure 1 - Course Map**

## 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 | Prepare Specimen using ASTM standards. | I | 02* |
| 2 | Use metallurgical microscope for microscopic examination of prepared specimen in PrO. No. 1. | I | 02 |
| 3 | Use the microscope to determine the lead-tin (Pb-Sn) equilibrium phase diagram to demonstrate phase equilibrium in a binary system. | II | 02 |
| 4 | Use the microscope to determine the effect of changes in composition on microstructure of the samples used in PrO no 3. | II | 02 |
| 5 | Use the microscope to determine the transformation temperatures for a series of Bi/Sn samples using cooling curve method. (Part I) | II | 02 |
| 6 | Use the microscope to determine the transformation temperatures for a series of Bi/Sn samples using cooling curve method. (Part II) | II | 02* |
| 7 | Identify the microstructure of the given Carbon Steel specimen | III | 02* |

| S. No. | Practical Outcomes (PrOs) | Unit No. | Approx. Hrs. Required |
|---|---|---|---|
| | using metallurgical microscope. | | |
| 8 | Identify the microstructure of the given specimen using metallurgical microscope. | III | 02 |
| 9 | Identify the microstructure of the given Alloy Steel specimen using metallurgical microscope. | III | 02* |
| 10 | Identify the microstructure of the given Alloy specimen using metallurgical microscope. | III | 02 |
| 11 | Identify the microstructure of the given Grey and Nodular Cast Iron specimen using metallurgical microscope. | III | 02* |
| 12 | Identify the Microstructure of the given White and Malleable Cast Iron specimen using metallurgical microscope. | III | 02 |
| 13 | Identify the Microstructure of the given non-ferrrous specimen using metallurgical microscope (Aluminium, Brass and Copper each). | III | 02 |
| 14 | Perform Annealing of the given steel sample and identify microstructural changes using metallurgical microscope. | IV | 02* |
| 15 | Perform normalizing process of the given steel sample and identify microstructural changes using metallurgical microscope. | IV | 02 |
| 16 | Perform hardening process of the given steel sample and measure the change in hardness using hardness tester. | IV | 02* |
| 17 | Measure hardenability of the given steel sample using Jominy End Quench test. | IV | 02 |
| 18 | Measure tap density and apparent density using Halls flow meter. | V | 02 |
| | **Total** | | **36** |

*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 % |
|---|---|---|
| 1 | Preparation of experimental set up | 20 |
| 2 | Setting and operation | 20 |
| 3 | Safety measures | 10 |
| 4 | Observations and recording | 10 |
| 5 | Interpretation of result and conclusion | 20 |
| 6 | Answer to sample questions | 10 |
| 7 | 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. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
e. 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.
- 'Organizing Level' in 2nd year.
- 'Characterizing Level' in 3rd year.

## 7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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. No. |
|---|---|---|
| 1 | Belt grinding machine for rough polishing. | 1 |
| 2 | Double disk variable speed polishing machine. | 1 |
| 3 | Metallurgical microscope with photographic attachment. | 2 to 15 |
| 4 | ASTM charts for grain size comparison. | 7 to10 |
| 5 | Standard steel specimens for microscopic examination. | 7 to 10 |
| 6 | Standard Cast Iron specimens for microscopic examination. | 11, 12 |
| 7 | Standard specimens of Aluminium, Brass and Copper for microscopic examination. | 13 |
| 8 | Heat treatment furnace with digital thermometer upto 1000 °C. | 14 to 17 |
| 9 | Hydraulic mounting press for specimen preparation. | 1 to 15 |
| 10 | Jominy End Quench test equipment. | 17 |
| 11 | Brinell or Rockwell Hardness tester. | 16, 17 |
| 12 | Thermocouple with extension wires and reference junctions. | 3 to 6 |
| 13 | Heater capable of heating the test tubes to 400°C. | 14 to16 |
| 14 | Recorder / DMM / scanner. | 3 to 6 |
| 15 | Test tubes to hold the samples. | 3 to 6 |
| 16 | Pure metals which are in either a granular or shot form. | 3 to 6 |
| 17 | Electronic balance with 0.01 gram sensitivity. | 3 to 6 |
| 18 | Insulated beakers (600 ml beakers filled with glass or ceramic wool). | 3 to 6 |
| 19 | Halls flow meter. | 18 |

## 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 (UOs) (in cognitive domain) | Topics and Sub-topics |
|---|---|---|
| **Unit – I Structur** | 1a. Interpet the crystal structure of the given material. | 1.1 Need and scope of metallurgy<br>1.2 Crystal Structures of metals: Space lattice. |

| Unit | Unit Outcomes (UOs) (in cognitive domain) | Topics and Sub-topics |
|---|---|---|
| **e of Metals and Alloys** | 1b. Distinguish the properties between the given types of solid solutions.<br>1c. Identify various imperfections in crystal structures of the given material.<br>1d. Explain with sketch the mechanism of crystallization for the given material. | Unit cell, Types of crystal structures, common crystal structure - BCC, FCC, HCP, No. of atoms per unit cell, Packing factor, Co-ordination number.<br>1.3 Mechanism of crystallization: Nuclei formation and crystal growth, dendritic structures<br>1.4 Structures of alloys: Solid Solution - types, Hume Rothery's rule<br>1.5 Imperfection of crystals: types - Point , Line, Surface |
| **Unit-II Equilibrium Diagrams** | 2a. Interpret the given cooling curves of the given metal.<br>2b. Calculate amount of phases using lever arm principle for the given data.<br>2c. Interpret various transformations in the given equilibrium diagram. | 2.1 Terminology, Cooling curves of metals and alloys, Plotting of Binary equilibrium diagram.<br>2.2 Gibbs Phase rule, Lever arm principle<br>2.3 Types of equilibrium diagram: Isomorphous and Eutectic system. |
| **Unit–III Engineering Materials** | 3a. Interpret the given phases of pure iron.<br>3b. Use Iron – Iron carbide equilibrium diagram for the given application.<br>3c. Select relevant type of steel and cast iron for the given job with justification.<br>3d. Select relevant type of non-ferrous material for the given job with justification.<br>3e. Interpret given type of material designations. | 3.1 Ferrous metals<br>a. Allotropic transformation of pure iron.<br>b. Iron - Iron carbide equilibrium diagram – critical temperatures, Peritectic, Eutectic and Eutectoid reaction.<br>c. Slow cooling of steel : Microstructures of slowly cooled carbon steels<br>d. Engineering materials : classification of ferrous metal.<br>e. Cast Iron: types, properties and applications.<br>f. Steel: properties and application of Plain carbon steel, stainless steel, heat resisting steel, High speed steel.<br>g. Designation and coding (BIS, ASME, EN, DIN, JIS) of cast iron, plain carbon and alloy steel.<br>3.2 Non-Ferrous metals and alloys : (composition , properties and applications)<br>a. Copper and its alloys: Naval brass, muntz metal, Gun metal and bronzes.<br>b. Aluminum and its alloys - Y-alloy and duralumin.<br>c. Bearing materials like white metals (Sn based) and aluminium bronzes.<br>d. Composite Materials - Properties and |

| Unit | Unit Outcomes (UOs) (in cognitive domain) | Topics and Sub-topics |
|---|---|---|
| | | applications of Laminated and Fibre reinforced materials |
| **Unit–IV Heat treatment of steels** | 4a. Select the relevant heat treatment process for the given material with justification.<br>4b. Identify the relevant Transformation for the given material with justification.<br>4c. Identify the heat treatment process by observing the microstructure of the given material with justification. | 4.1 Purpose and importance of heat treatment<br>4.2 TTT diagram: Significance and construction of TTT diagram for eutectoid steel<br>4.3 Introduction to Martensitic transformation.<br>4.4 Different heat treatments processes – (microstructure changes, advantages, limitations and applications)<br>a. Annealing<br>b. Normalising<br>c. Hardening and Hardenability<br>d. Tempering<br>e. Case hardening treatments: Carburising, Nitriding.<br>f. Surface hardening treatment: Flame hardening and Induction hardening.<br>g. Vaccume heat treatment |
| **Unit –V Powder Metallurgy** | 5a. Select the relevant powder manufacturing processes for a given job with justification.<br>5b. Discribe steps in powder metalurgy process.<br>5c. List the appliactions of powder metallurgy. | 5.1 Importance of powder metallurgy.<br>5.2 Steps in powder metallurgy process.<br>5.3 Powder manufacturing process: Mechanical, Electrolytic and Atomization.<br>5.4 Applications (Tungsten carbide tip tools and self impringnated porous bearing), merits and demerits of powder metallurgy. |

***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 FOR QUESTION PAPER DESIGN

| Unit No. | Unit Title | Teaching Hours | Distribution of Theory Marks | | | |
|---|---|---|---|---|---|---|
| | | | R Level | U Level | A Level | Total Marks |
| I | Structure of Metals and Alloys | 10 | 04 | 06 | 04 | 14 |
| II | Equilibrium Diagrams | 08 | 04 | 04 | 04 | 12 |
| III | Engineering Materials | 12 | 04 | 06 | 08 | 18 |
| IV | Heat treatment of steels | 10 | 04 | 04 | 06 | 14 |
| V | Powder Metallurgy | 08 | 02 | 04 | 06 | 12 |
| **Total** | | **48** | **18** | **24** | **28** | **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 based on practicals performed in Material Testing laboratory. Journal consist of drawing, observations, required materials, tools, equipments, date of performance with teacher signature.
b. Prepare/Download a specifications of followings:
   i. Tools and equipment in material testing laboratory.
   ii. Machineries in material testing laboratory
c. Undertake a market survey of materials available as per various standards like ASTM, BIS, EN etc
d. Visit to any Industrial Heat treatment shop and prepare a report consisting of -
   i. Types of heat treatment process
   ii. Types of furnaces
   iii. Types of quenching mediums used
   iv. Types of testing equipments
   v. Safety precautions observed.
   vi. list various components heat treated in the shop.
e. Collect information about ASTM standards
f. Collect any five objects (3 metallic and 2 non metallic ) and identify its material and properties which can be used in the laboratory.
g. Prepare the material list of the given tools and commonly used items such as razor blade, knife, scissor, hacksaw blade, carpentry chisel, fix spanner, etc. as per properties possessed by materials and discuss your answers with the teacher.
h. Compare the mechanical behaviour of a given vehicle component material against a new hybrid material.

## 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. Arrange visit to nearby industries for understanding various Heat treatment processes.
g. Show video/animation films to explain functioning of various hardness testing and heat treatment processes.
h. Draw Iron Carbon charts.
i. Give Micro projects.

## 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. Comparative study of various materials used in previous and current generation components of engineering equipments like I C Engine, Compressor, turbine, pumps, refrigerator, water cooler, Lathe Machine, Milling Machine, Drilling Machine grinding machine (any one) with proper justifications.
b. Determine the hardness of different metallic components (min. 5) and compare hardness and plot a bar chart indicating soft and hardest material in the given group.
c. Determine the microstructure of different metallic components (min. 5) using metallurgical Microscope and compare their microstructure in the given group.
d. Make a model of different crystal structures (BCC, FCC, HCP) with the help of plastc or steel balls and thin wires.

## 13. SUGGESTED LEARNING RESOURCES

| S. No. | Title of Book | Author | Publication |
|---|---|---|---|
| 1 | Introduction to Physical Metallurgy | Avner S. H. | McGraw Hill Education, New Delhi, ISBN : 978-00-746-3006-8 |
| 2 | Material Science and metallurgy | Kodgire V. D. | Everest publishing House , New Delhi, ISBN : 81 86314 008 |
| 3 | Engineering Material | Sharma C. P. | PHI publication, New Delhi ISBN : 978-81-203-2448-0 |
| 4 | Engineering Materials | Agrawal B. K. | Tata McGraw Hill Education, New Delhi, ISBN : 978-00-745-1505-1 |
| 5 | Material Science and metallurgy | Khanna O. P. | Dhanpat Rai and sons , New Delhi ISBN : 978-81-899-2831-5 |
| 6 | Material Science for Polytechnic | Rajput R. K. | S K Katariya and sons, New Delhi ISBN : 81-85749-10-8 |

## 14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a. http://vimeo.com/32224002
b. www.substech.com/dokuwiki/doku.php?id=iron-carbon_phase_diagram
c. www-g.eng.cam.ac.uk/mmg/teaching/typd/
d. www.ironcarbondiagram.com/
e. uk.ask.com/web?q=Who+Discovered+Carbon%3Fandqsrc=14097ando=41647924andl=dir

f. www.youtube.com/watch?v=cN5YH0iEvTo
g. www.youtube.com/watch?v=m9l1tVXyFp8
h. www.sakshat.ac.in/