DRONACHARYA
College of Engineering

LABORATORY MANUAL

B.Tech. Semester- IV

MATERIALS LAB
Subject code: LC-ME-218G

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DEPARTMENT OF MECHANICAL ENGINEERING
DRONACHARYA COLLEGE OF ENGINEERING
KHENTAWAS, FARRUKH NAGAR, GURUGRAM (HARYANA)

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Vision and Mission of the Institute

Vision:

To impart Quality Education, to give an enviable growth to seekers of learning, to groom them as World Class Engineers and managers competent to match the expending expectations of the Corporate World has been ever enlarging vision extending to new horizons of Dronacharya College of Engineering.

Mission:

1. To prepare students for full and ethical participation in a diverse society and encourage lifelong learning by following the principle of 'Shiksha evam Sahayata' i.e. Education & Help.

2. To impart high-quality education, knowledge and technology through rigorous academic programs, cutting-edge research, & Industry collaborations, with a focus on producing engineers& managers who are socially responsible, globally aware, & equipped to address complex challenges.

3. Educate students in the best practices of the field as well as integrate the latest research into the academics.

4. Provide quality learning experiences through effective classroom practices, innovative teaching practices and opportunities for meaningful interactions between students and faculty.

5. To devise and implement programmes of education in technology that are relevant to the changing needs of society, in terms of breadth of diversity and depth of specialization.

Vision and Mission of the Mechanical Department

Vision:

"To become a Centre of Excellence in teaching and research in the field of Mechanical Engineering for producing skilled professionals having a zeal to serve society."

Mission:

M1: To create an environment where students can be equipped with strong fundamental concepts, various experiments and problem solving skills.

M2: To provide an exposure to emerging technologies by providing hands on experience for generating competent professionals.

M3: To promote Research and Development in the frontier areas of Mechanical Engineering and encourage students for pursuing higher education

M4: To inculcate in students ethics, professional values, team work and leadership skills.

Programme Educational Objectives (PEOs)

PEO 1: Engineers will practice the profession of engineering using a systems perspective and analyze, design, develop, optimize & implement engineering solutions and work productively as engineers, including supportive and leadership roles on multidisciplinary teams.

PEO 2: Continue their education in leading graduate programs in engineering & interdisciplinary areas to emerge as researchers, experts, educators & entrepreneurs and recognize the need for, and an ability to engage in continuing professional development and life-long learning.

PEO 3: Engineers, guided by the principles of sustainable development and global interconnectedness, will understand how engineering projects affect society and the environment.

PEO 4: Promote Design, Research, and implementation of products and services in the field of Engineering through Strong Communication and Entrepreneurial Skills.

PEO 5: Re-learn and innovate in ever-changing global economic and technological environments of the 21st century.

Programme Outcomes (POs)

Over completion of the Course our graduates will have ability to

1. Apply knowledge of computing, mathematical foundations, algorithmic principles, and engineering theory in the modeling and design of systems to real-world problems (fundamental engineering analysis skills).
2. Apply and integrate knowledge and understanding of other engineering disciplines to support study of their own engineering discipline.
3. Design and conduct experiments, as well as to analyze and interpret data (information retrieval skills). Practical application of engineering skills, combining theory and experience, and use of other relevant knowledge and skills.
4. Analyze a problem, identify, formulate and use the appropriate computing and engineering requirements for obtaining its solution(engineering problem solving skills).
5. Understand the appropriate codes of practice and industry standards.
6. Identify, classify and describe the performance of systems and components through the use of analytical methods and modeling techniques.
7. Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.
8. Communicate effectively, both in writing and orally (speaking / writing skills).
9. Understand professional, ethical, legal, security and social issues and responsibilities (professional integrity).
10. Understand customer and user needs and the importance of considerations such as Aesthetics.
11. Use creativity to establish innovative solutions.
12. Adapt to a rapidly changing environment by having learned and applied new skills and new technologies.
13. To Significantly contribute to delivery of desired component, product, or process.
14. Formulate and solve moderately complex engineering problems, accounting for hardware/software/human interactions.
15. Recognize the importance of professional development by pursuing postgraduate studies or face competitive examinations that offer challenging and rewarding careers in computing.
16. Apply the Knowledge of management techniques which may be used to achieve engineering Objectives within that context.

Program Specific Outcomes (PSOs)

On successful completion of the Mechanical Engineering Degree programme, the Graduates shall exhibit the following:

PSO1: Apply the knowledge gained in Mechanical Engineering for design and development and manufacture of engineering systems.

PSO2: Apply the knowledge acquired to investigate research-oriented problems in mechanical engineering with due consideration for environmental and social impacts

PSO3: Use the engineering analysis and data management tools for effective management of multidisciplinary projects.

University Syllabus

List of Experiments:

1. To study crystal structures of a given specimen.

2. To study crystal imperfections in a given specimen.

3. To study microstructures of metals/ alloys.

4. To prepare solidification curve for a given specimen.

5. To study heat treatment processes (hardening and tempering) of steel specimen.

6. To study microstructure of heat-treated steel.

7. To study thermo-setting of plastics.

8. To study the creep behavior of a given specimen.

9. To study the mechanism of chemical corrosion and its protection.

10. To study the properties of various types of plastics.

11. To study Bravais lattices with the help of models.

12. To study crystal structures and crystals imperfections using ball models.

Note:- 1. At least eight experiments are to be performed in the semester.

Course Outcomes (COs)

CO218.1 Learn the principles of materials science and engineering though lab investigation.

CO218.2 formal laboratory reports describing the results of experiments.

CO218.3 Operate basic instruments in materials science and engineering

CO218.4 Understand the basics structure of materials and ability to interpret the data from the

CO-PO Mapping

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PO14	PO15	PO16
C218.1	3	3	3	-	2	-	3	3	3	2	-	3	3	-	-	3
C218.2	-	3	-	-	2	3	-	-		2	-	3	-	-	2	3
C218.3	-	-	3	3		3	-	-	3	-	3	-	3	3	-	
C218.4	3	-	3	-	2	-	3	3	-	2	-	3	-	3	2	3
C218.5	3	3	-	3	-	3	-	-	3	2	3	-	3	3	-	3

CO-PSO Mapping

	PSO1	PSO2	PSO3
C218.1	3	2	-
C218.2	2	3	-
C218.3	3	2	-
C218.4	3	2	3
C218.5	2	3	3

Course Overview

Material Engineering, also known as Materials Science and Engineering, is a field that explores the structure, properties, processing, and applications of materials. It encompasses a wide range of materials, including metals, ceramics, polymers, composites, semiconductors, and biomaterials. Throughout the course, students typically engage in laboratory experiments, design projects, and case studies to gain hands-on experience in material characterization, processing, and selection. The course aims to provide a strong foundation in understanding the behavior and properties of materials, enabling students to develop innovative materials and contribute to various industries such as aerospace, automotive, electronics, energy, and healthcare.

LIST OF EXPERIMENTS mapped with COs

S.No.	NAME OF EXPERIMENTS	COs
1.	To study thermo-setting of plastics.	CO218.1
2.	To study the properties of various types of plastics	CO218.1
3.	To study crystal structures and crystals imperfections using ball models.	CO218.2
4.	To study Bravais lattices with the help of models.	CO218.4
5.	To study heat treatment processes (hardening and tempering) of steel specimen.	CO218.3
6.	To study microstructures of metals/ alloys.	CO218.4
7.	To study the mechanism of chemical corrosion and its protection.	CO218.1
8.	To study the creep behavior of a given specimen.	CO218.1
9.	Specimen preparation for Microstructural examination- cutting, grinding, polishing etc itching.	CO218.1
10.	To study microstructure of welded component and HAZ(Heat Afeected Zones) macro and micro examination.	CO218.2

DOs and DON'Ts

DOs

1. Work deliberately and carefully.
2. Keep your work area clean.
3. Students must wear college uniform and carry their college ID.
4. Students should have separate note book for practical.
5. Students should have their own pencil, eraser, scale, along with pen and lab note book.
6. Handle the equipment /models carefully.

DON'Ts

1. Do not wander around the room, distract other students, startle other students or interfere with the laboratory experiments of others.
2. Do not eat food, drink beverages or chew gum in the laboratory.
3. Do not open any irrelevant internet sites on lab computer.

General Safety Precautions

Precautions (In case of Injury or Electric Shock)

1. To break the victim with live electric source, use an insulator such as fire wood or plastic to break the contact. Do not touch the victim with bare hands to avoid the risk of electrifying yourself.
2. Unplug the risk of faulty equipment. If main circuit breaker is accessible, turn the circuit off.
3. If the victim is unconscious, start resuscitation immediately, use your hands to press the chest in and out to continue breathing function. Use mouth-to-mouth resuscitation if necessary.
4. Immediately call medical emergency and security. Remember! Time is critical; be best.

Precautions (In case of Fire)

1. Turn the equipment off. If power switch is not immediately accessible, take plug off.
2. If fire continues, try to curb the fire, if possible, by using the fire extinguisher or by covering it with a heavy cloth, if possible, isolate the burning equipment from the other surrounding equipment.
3. Sound the fire alarm by activating the nearest alarm switch located in the hallway.

Emergency: Reception

Security : Main Gate

Guidelines to students for report preparation

All students are required to maintain a record of the experiments conducted by them. Guidelines for its preparation are as follows:

1) All files must contain a title page followed by an index page. The files will not be signed by the faculty without an entry in the index page.

2) Student's Name, Roll number and date of conduction of experiment must be written on all pages.

) For each experiment, the record must contain the following

(i) Aim/Objective of the experiment

(ii) Pre-experiment work (as given by the faculty)

(iii) Lab assignment questions and their solutions

(iv) Test Cases (if applicable to the course)

(v) Results/ output

Note:

1. Students must bring their lab record along with them whenever they come for the lab.
2. Students must ensure that their lab record is regularly evaluated.

Lab assessment criteria

An estimated 10 lab classes are conducted in a semester for each lab course. These lab classes are assessed continuously. Each lab experiment is evaluated based on 5 assessment criteria as shown in following table. Assessed performance in each experiment is used to compute CO attainment as well as internal marks in the lab course.

GradingCriteria	**Exemplary (4)**	**Competent (3)**	**Needs Improvement (2)**	**Poor (1)**
AC1: Pre-Lab written work (this may be assessed through viva)	Complete procedure with underlined concept is properly written	Underlined conceptis written but procedure is incomplete	Not able to writeconcept and procedure	Underlined concept is not clearly understood
AC2: Manual Writing/ Modeling	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/tools are applied, Program/solution written is readable	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied	Assigned problem is properly analyzed &correct solution designed	Assigned problem is properly analyzed and corrected
AC3: Identification & Removal of errors	Able to identify errors and remove them	Able to identify errors/and remove them with little bit of guidance	Is dependent totallyon someone for identification of errors and their removal	Unable to understand the reason for errors even after they are explicitly pointed out
AC4:Execution & Demonstration	All variants of input /output are tested,Solution is well demonstrated and implemented concept is clearlyexplained	All variants of input /output are not tested, However, solution is well demonstrated and implemented concept is clearly explained	Only few variants of input /output are tested, Solution is well demonstrated but implemented concept is not clearly explained	Solution is not well demonstrated and implemented concept is not clearly explained

AC5:Lab Record Assessment	All assigned problems are well recorded with objective, design constructs and solution along with Performance analysis using all variants of input and output	More than 70 % ofthe assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants ofinput and output	Less than 70 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output	Less than 40 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants ofinput and output

EXPERIMENT NO.-1

AIM:- To study thermo-setting of plastics.

INTRODUCTION & THEORY:- Organic materials are covalent (polar) bounded. Polymers such as plastics, synthetic rubber and wood . organic materials may be natural or synthetic.

Natural organic materials:- Petroleum, Rubber, wood, coal, Biological fibre, food etc. cotton, Flax.

Synthetic organic material:-oil, solvent, Lubricant, adhesive, Dye, synthetic rubber, Plastics, Explosive etc.

Plastics:- A group of synthetic organic materials that become plastic by application of heat and are capable of being formed to shape under pressure are known as plastics.

Classification of Plastics:- Plastics and synthetic resins may be broadly classified as-A- Thermosetting Plastics

B- Thermoplastic Plastics

THERMOSETTING PLASTICS:- They have a three-dimensional network of primary bonds in all the directions. These types of plastics, on application of heat, First become soft and then hard, and after that they can't be softened again by application of heat. This permanent hardening called **curing** is a chemical change.

Some of the common thermosetting compounds are as follows:-

(i) Phenol Formaldehyde

(ii) Urea Formaldehyde

(iii) Phenol Furfural

(iv) Melamines

(v) Epoxides

(vi) Polyesters

(vii) Silicones

APPLICATIONS:-

(i) Synthetic fibre

(ii) Machine and structural components of composites

(iii) Telephone receivers

(iv) Foams

(v) Crockeries

(vi) High temperature resisting components.

VIVA-QUESTIONS:-

1. What is difference between thermosetting & Thermoplastic Plastic?
2. What is Bakelite?
3. What are basic differences between PVC and Bakelite?
4. Can we use plastic powder as raw material instead of grains?
5. To which category and type of plastics, do the Araldite and Favicon belong to ?

EXPERIMENT NO.-2

AIM:- To study the properties of various types of plastics.

INTRODUCTION & THEORY :- A group of synthetic organic materials that become plastic by application of heat and are capable of being formed to shape under pressure are known as plastics.

Classification of Plastics:- Plastics and synthetic resins may be broadly classified as-

(i) Thermosetting Plastics

(ii) Thermoplastic Plastics

Those plastics that are formed to shape under pressure and heat, resulting in an article which is permanently hard, are known as thermosetting plastics.

Those plastics which undergo no chemical change during moulding and do not become permanently hard with the application of heat and pressure, are known as thermoplastic plastics.

PROPERTIES AND APPLICATIONS OF THERMOSETS :

(1) Phenol Formaldehyde:- This is made by reaction of phenol with formaldehyde. Its chief properties are hardness, high strength, high heat and water resistance and good electrical insulating properties. Its uses include making of coating materials, grinding wheels, laminated products, metal and glass bonding materials and casting into many useful articles like electrical components, cases, dials, radio cabinets etc.

(2) Urea Formaldehyde:- It is a colourless resin formed by the chemical combination of urea and formaldehyde. Its chief properties are good bonding quality, good hardness and strength , high water resistance and high dielectric strength . its uses include tableware, buttons, light fixtures, instruments dials, binder for core in moulding forhigh metals, veneer bonds. Etc.

(3) Phenol Furfural:- It is obtained by processing waste farm products like corncobs and hubs from rice and cotton seeds with certain acids. Its chief quantities are water resistance, excellent electrical insulation and dark colour. Its commercial products include instrument housings, electric parts. Brake lining, binder for abrasive wheels and varnish for impregnating laminates.

(4) **Melamines:**- These are principally melamine formaldehyde and are made from carbon , nitrogen and hydrogen. Their chief properties are excellent, shock and water resistance, arc resistance and dielectric strength. These are used for parts of telephone sets, circuit breakers, terminal blocks, laminated products, table ware and enamel.

(5) **Epoxides:**- These are cross-linked polythers. Their chief properties are excellent chemical resistance, adhesion to glass and metals, resistance to wear and impact and electrical insulation. These are used in manufacture of laminates, panels for printed circuits, jigs and press dies for metal forming operations, etc

(6) **Polyesters:**- These are made by reacting a dihydric alcohol with an unsaturated diabasic acid. There is a wide range of resins which can be tailor-made for special purposes. These are used mainly in the glass reinforced industry for car bodies, boat hulls, etc; and for applications like surface coatings, castings, flooring etc;

(7) **Silicones:**- Silicone-base polymer differ much from other polymers which are based on carbon atom. Their outstanding properties include stability. Resistance to high temp. over long periods of time, good low temp. and high electric characteristics, and water repellence. These may be used for mouldings, laminated products, coating, and formingfoam sheets and blocks.

PROPERTIES AND APPLICATIONS OF THERMOPLASTS :

(1) **Polystyrene:-** Styrene can be polymerized to give polystyrene. Its chief properties are high resistivity, resistance to water and most chemicals, and availability in colours from clear to opaque. It is an excellent rubber substitute. Its uses include such products as battery boxes, dishes, radio parts, lenses, wall tiles and electrical insulation.

(2) **Polyethylene**:- It is a vinyl resin. It is very flexible, tough and moisture resistant, and possesses good electrical insulation properties. Its applications include products like ice-tube trays, developing trays, fabrics, film for packaging, collapsible nursing bottles, co-axial cable etc.

(3) **Polyvinyl Chloride:-** It is a vinyl resin. Its chief properties are a high degree of resistance to many solvents, low flammability and toughness, and electrical insulation.It is used for cable jackets, lead wire insulation, fabric coating.

(4) **Polyvinyl Butyral: -** It is a vinyl resin. It is a clear, tough resin with resistance to moisture, great adhesiveness, and stability towards light and heat. It is used for inter-layers in shatter less (safety) glass, raincoat and sealing fuel tanks.

(5) **Acrylics:**- The acrylic resin commonly used is methyl-methacrylate, but is commonly known as Plexiglas, Lucite, etc. its applications include aero plane windows, shower doors, gauge covers, transparent models, toilet articles etc.

(6) **Cellulose Nitrate:** - It is a cellulose compound. It is highly inflammable. Its applications include fountain pens, handles for tooth brushes, ping-pong balls and jewellery, etc.

(7) **Cellulose Acetate:**- It is a more stable cellulose compound. Fabricated into sheets or moduled articles. Its applications include display packaging, toys, knobs, radio panels, flash light cases, bristle coating for paint brushes and extruded strips.

(8) **Cellulose Acetate-Butyrate:-** This cellulose derivative has low moisture absorption, toughness, dimensional stability and ability to be continuously extruded. Its applications include steering wheels, goggle frames, football helmets, trays, belts, furniture trims and insulation foil.

(9) **Ethyl Cellulose:-** It is lightest of cellulose derivates. Its other outstanding properties are surface hardness, good electrical insulation properties and mechanical strength. It is used as a base for coating materials.

(10) **Cellophane:**- It is regenerated cellulose. It is produced in thin sheets by an extruding process and is useful for packaging materials. This material is also being usedfor curtains etc.

VIVA-QUESTIONS :-

- Classify plastics. Compare thermosets and thermoplasts.
- Explain the mechanical behaviour of plastics.
- Write applications of plastics.
- Define to monomers.
- Discus the deformation of polymer

EXPERIMENT NO.-3

AIM:- To study crystal structures and crystals imperfections using ball models.

INTRODUCTION & THEORY:- The solids are either crystalline or non-crystalline. The majority of engineering materials, many ceramics, most minerals, some plastics and all metals are crystalline is structure. The type of their crystal structure bears significantly on the physical properties of these materials. The various defects which arise in the formation of crystals of a material are further responsible for certain aspects of chemical and physical behaviour of these crystalline materials.

Crystal structure:- A regular and repetitious pattern in which atoms or groups of atoms (i.e. molecules) of a crystalline material arrange themselves is known as a crystal structure.

All crystalline solids may be classified into seven crystal systems or structures, which are described below.

(1) Cubic Structure:- In this crystal arrangement, three equal axes are at right angles.

(2) Tetragonal Structure:- In this crystal arrangement, three axes are at right angles, two of these axes are equal while third one is different.

(3) Orthorhombic Structures:- In this crystal arrangement, three unequal axes are at right angles.

(4) Rhombohedral Structures:- In this crystal arrangement, three equal axes are equally included but at an angle other than a right angle.

(5) Hexagonal Structure:- In this crystal arrangement, three equal axes are in one plane at 120º to each other, and a fourth axis normal to this plane. The interval along the fourth axis is unique.

(6) Monoclinic Structure:- In this crystal arrangement, there are three unequal axes. One of the axes is at right angles to the other two axes, but the other two axes are not at right angles to each other.

(7) Triclinic Structure:- In this crystal arrangement, three unequal axes are unequally inclined and none being at right angles.

Crystal Structures for Metallic Elements:- Generally, the metallic elements crystallize in one of the following three structures.

(i) **Body centred cubic structure (B.C.C) :-** In this type crystal structure, the unit cell has one atom at each corner of the cube and one at body centre of the cube. Examples- α-iron(below 910º C), δ-iron(1400ºC to 1539ºC),W,V,Mo,Cr,Li,Na,K.

(ii) **Face centred cubic structure (F.C.C) :-** In this type of crystal structure, the unit cell has an atom at each corner of the cube and in addition has one atom at the centre of each face. Examples- γ-iron(910ºC to 1400ºC), Cu, Ag, Al, Ni, Pb, Pt.

(iii) **Hexagonal close-packed structure (H.C.P) :-** In this type of crystal structure, the unit cell has one atom at each of the twelve corners of the hexagonal prism, one atom at the centre of the two hexagonal faces and three atoms symmetrically arranged in the body of the cell. Examples- Mg, Zn, Ti, Zr, Cd.

Crystal Imperfection:- Any irregularity in the structure of a crystalline material is known as crystal imperfection.

There are various types of structure imperfections in crystals, and these are conveniently classified as follows:-

(A) Point defects :- The imperfect point like regions in a crystal are known as point defects.

The different kinds of point defects are as given below :-

(i) Vacancy (ii) Interstitialcy (iii) Frenkel defect (iv) Substitutional Impurity (v) Schottky Defect (vi) Phonon

(B) Line defects:- The continuous paths of defective structure running through a crystal lattice are termed as line defects. Dislocations are termed as line defects in crystal.

(i) Edge dislocation, and

(ii) Screw dislocation.

(C) Surface defects:- The imperfect two dimensional regions in a crystal are known as surface defects.

(i) Grain Boundary (ii) Tilt Boundary (iii) Twin Boundary (iv) Low Angle Boundary (v) Twist Boundary (vi) Stacking Faults

VIVA-QUESTIONS :-

1. Define ‘crystal’.
2. The co-ordinate number of FCC.
3. Define the interplaner spacing.
4. Define planer density.
5. How many atoms in unit cell of BCC, FCC

EXPERIMENT NO.-4

AIM:- To study Bravais lattices with the help of models.

REQUIREMENTS:- Models of different types of Bravais lattices.

INTRODUCTION & THEORY:- The locations of atoms and their particular arrangement in a given crystal are described by means of a space lattice. A distribution of points (or atoms) in three dimensions is said to form a space lattice if every point has identical surroundings.

Bravais Lattices:- The fourteen distinguishable three dimensional space lattice that can be generated by repeated translation of three non-coplanar vectors a, b, and c of a unit cell in three dimensional space, are known as **Bravais lattices**, named after their originator.

Conventional unit cells of 14 Bravais lattices are described below:-

1- **Simple Cubic Lattice :-** It possesses lattice point at the eight corners of the unit cell. It has vectors a= b=c , and inter axial angles α=β=γ =90º.
2- **Body Centred Cubic Lattice :**- It possesses lattice points at the eight corners and at the body centre. It has vectors a=b=c and inter axial angle α=β=γ =90º.
3- **Face Centred Cubic Lattice :**- It possesses lattice points at the corners and at the face centres of the unit cell. It has vectors a=b=c and inter axial angle α=β=γ
=90º.
4- **Simple Tetragonal Lattice :**- It possesses lattice point at the eight corners of the unit cell. It has vectors a = b ≠ c , and inter axial angles α=β=γ =90º.
5- **Body Centred Tetragonal Lattice :**- It possesses lattice points at the eight corners and at the body centre. It has vectors a = b ≠ c and inter axial angle α=β=γ =90º.
6- **Simple Orthorhombic Lattice :-** It possesses lattice point at the eight corners of the unit cell. It has vectors a ≠ b ≠ c , and inter axial angles α=β=γ =90º.
7- **End Centred Orthorhombic Lattice :**- It possesses lattice point at the eight corners and at two face centres opposite to each other. This lattice is also knownas side centred or base central orthorhombic lattice. It has vectors a ≠ b

≠ c , andinter axial angles α=β=γ =90º.

8- **Body Centred Orthorhombic Lattice :**- It possesses lattice points at the eight corners and at the body centre. It has vectors a ≠ b ≠ c and inter axial angle α=β=γ =90º.

9- **Face Centred Orthorhombic Lattice :**- It possesses lattice points at the corners and at the six face centres of the unit cell. It has vectors a ≠ b ≠ c and inter axial angle α=β=γ =90º.

10- **Simple Rhombohedral Lattice :-** It possesses lattice point at the eight corners of the unit cell. It has vectors a = b = c , and inter axial angles α=β=γ ≠90º.

11- **Simple Hexagonal Lattice :-** It possesses lattice points at the twelve corners of the hexagonal prism and at the centres of the two hexagonal faces of the unit cell. It has vectors a = b ≠ c and inter axial angle α=β=90º and γ =120º

12- **Simple Monoclinic Lattice :-** It possesses lattice point at the eight corners of the unit cell. It has vectors, a ≠ b ≠ c and inter axial angles α=β= 90º ≠ γ

13- **End Centred Monoclinic Lattice :-** It possesses lattice point at the eight corners and at two face centres opposite to each other. It has vectors a ≠ b ≠ c , and inter axial angles α=β= 90º ≠ γ.

14- **Simple Triclinic Lattice :-** It possesses lattice point at the eight corners of the unit cell. It has vectors, a ≠ b ≠ c and inter axial angles α ≠ β≠ γ ≠ 90º

VIVA-QUESTIONS :-

1. Define the crystals, atoms and electrons?
2. What are whiskers?
3. Define atomic packing factor. Obtain its expression for SC, FCC and BCC.

EXPERIMENT NO.-5

AIM:- To study heat treatment processes (hardening and tempering) of steel specimen.

EQUIPMENTS:- Electrically heated temperature controlled oven, cooling bath or bucket, Job holding tong, steel specimen, Brinell hardness testing machine, an optical microscope.

THEORY:- Properties of metals and alloys can be changed by heating followed by cooling under definite conditions to make them suitable for specific applications. Accordingly steel can be hardened to resist cutting action and prevent abrasion. The rate of cooling and the manner of cooling are the controlling factors in heat treatment processes. Heat treatment not only increases the hardness but also increases the tensile strength and toughness. Different heat treatment processes are carried-out in temperature controlled furnaces and ovens.

Hardening :- To perform hardening process, steel is heated to a temperature (800ºC) above its critical range. It is held at this temperature for a considerable time and then allowed to cool by quenching in water, oil or brine solution. On heating above the high critical temp., the basic structure changes into austenite which contains considerable parts of cementite. On rapid cooling this austenite change into martensite that imparts hardness in steel. The objectives of hardening are:

i- To improve the strength of steel.

ii- To develop hardness in the metal to resist wear, abrasion and to enable it to cut other metals.

Tempering :- Steel after hardening becomes brittle, develops non-visible micro-cracks and is strained due to residual (internal) stresses. These undesired symptoms are reduced by tempering the steel. This process involves reheating of the hardened steel to a certain temp. below lower critical temp. followed by a slow cooling rate. Tempering process serves the following objectives.

i. It reduces brittleness of hardened steel.

ii. It increase ductility.

iii. It relieves internal stresses.

iv. It improves toughness of steel

The tempering process may be sub-classified as

1. Low temp. tempering (to about 200ºC)
2. Medium temp. tempering (175ºC to 275ºC) and
3. High temp. tempering (275ºC to 375ºC)

Some special tempering process are-

1- Austempering or Isothermal quenching (700ºC) and
2- Mar tempering or stepped quenching (600ºC)

PROCEDURE :- First determine the hardness of given specimen at room temp. if we are conducting hardening of the specimen by quenching, then

(i) Heat the specimen about 800ºC to 1000ºC

(ii) Maintain it at this temp. for about 10 minutes.

(iii) Now take it out of the oven and suddenly dip in the cooling bucket. This is quench hardening process during which 'martensite' will form. The surface will become much harder than earlier.

(iv) When the job cools, take it onto Brinell hardness testing machine and determine the hardness in usual manner.

OBSERVATION :- A typical observation is presented below.

- Heating temp. = 950ºC
- Quenching rate = 30ºC/min,
- Quenching medium is water at room temp.

RESULT :- The effect of quench hardening is to increase the hardness from about ------------to about ---------.

PRECAUTIONS :- The oven is electrically heated. Therefore take care to avoid burning from heat of the furnace and shock due to electricity.

- Do not hold the hot specimen by hand . always use tongs to hold it.
- The handle of tong should be plastic insulated. Do not use it bared.

VIVA-QUESTIONS :-

1. What is heat treatment ?
2. What are the needs of performing annealing and normalizing on metals (steels)
3. Name some components which are produced by case hardening process. Wheredo we apply this process ?
4. Why does the hardness of steel increase after quench hardening ?
5. What are the melting points of steel and C.I. ? Which factor influences theirmelting point ?

EXPERIMENT NO.-6

AIM :-To study microstructures of metals / alloys.

EQUIPMENTS: - Properly polished and etched specimen, metallurgical microscopes of 1500x to 2400x, an air drier (optional) to dry the specimen.

THEORY :- Levels of material structure may be both – macro or micro. Whereas the macro-structure can be seen with naked eye or with an optical microscope of low magnification, the microstructures can be observed with high magnification metallurgical microscopes. In this experiment we shall visualize the crystals, grain boundaries, and solid phases in the material.

In steel and gray C.I., different microstructures can be seen as given in figures. These are due to presence of carbon in different forms viz. copper and zinc can be seen in random mixing as shown in fig. in copper, different solid phases viz. α-phase, β-phase, γ-phase and their combinations will be visible.

TEST SET-UP SPECIFICATIONS OF MICROSCOPES :- Different types of microscopes are employed for study of microstructures of metals, alloys, and other materials. Depending upon the facility of viewing heads, type of construction, purpose served and other salient features, these microscope are classified into various types.

Microscopes are normally equipped with various attachments and accessories for versatility and additional features. Theirs magnification may be expressed in dry type or in wet type such as when immersed in oil. A binocular metallurgical microscope shown in fig. Its specifications are as follows.

- Mechanical tube length : 170mm
- Eye pieces : Paired 10x and 15x
- Objectives : 10x, 45x and 100x (spring) oil immersion
- Magnifications : 100x to 1500x
- Focusing : Coarse and fine adjustments
- Illumination : Episcopic illuminator with 6V, 15W precentred lamp
- Other features : 45º inclined binocular head, Rota table360º quadruple nose piece.

PROCEDURE: - Polish and etch the specimen. Make it dry . put it on the microscope base.

(i) Make the power supply ON to microscope. Select an appropriate objective lens for vision.

(ii) Focus the microscope, first by using general knob and then by fine tuning knob. Seethe surface of specimen through eyepiece lens.

OBSERVATIONS: - Depending upon whether the microscope is binocular or trinocular, use each objective lens to study the microstructure.

- Sketch the visible structures. Measure their dimensions on horizontal and vertical scales, if provided on microscope. Metallurgical microscope are generally providedwith vernier scales.
- The probable picture of microstructures of some metals and alloys are illustrated. Find out as to metals/alloys they belong to: copper, nodular C.I. and HSS.

PRECAUTIONS :-

(i) The specimen must be completely dry, otherwise the microstructure will notbe clearly visible.

(ii) The movement of etchant can be seen there.

VIVA-QUESTIONS:-

1. Microstructure of metals are different from each other-why ?
2. What are the effects of microstructure of steel and C.I. on their mechanical properties?
3. What the shape of microstructures of steel / C.I. will look like for carboncontent varying from purest to 4.3%?
4. In which way is the microstructure of copper different from the microstructure of brass?

EXPERIMENT NO.-7

AIM:-To study the mechanism of chemical corrosion and its protection.

RQUIREMENTS: - Metals, electrolyte etc.

THEORY: - Corrosion is a chemical or electrochemical decay of metals. It occurs in almost all metals which are at anodic end in a galvanic cell (formation). It is affected by environmental conditions. Corrosion can be 'wet corrosion' (electrochemical corrosion) or Dry corrosion (Direct chemical corrosion) depending upon whether the environment is liquid (or water) or gas. Corrosion at high temp. is called 'oxidation'. Wet corrosion is very common in metals. It occurs due to formation of galvanic cell. In this cell, a metal at anodic end corrodes but the metal at catholic end does not. Gold is most catholic of all known metals, hence never corrodes.

Direct chemical corrosion :- The type of corrosion involving direct combination between the metal and the dry gases is known as direct chemical corrosion.

Mechanism of Direct chemical corrosion :- Metal + O_2 = Metal oxide

Generally speaking, oxidation involves a positive increase in valence of the metal. Thus the metal may be oxidized in the absence of air if there is an environment which will remove electrons.

Firstly oxidation takes place at the surface of a metal, and resulting scale forms a barrier that tends to resists further oxidation, for oxidation to continue either the metal must diffuse through the scale to the surface, or the oxygen must diffuse through the scale to the underlying metal.

Inward diffusion of oxygen, because metal iron(Me^{++}) is usually smaller than oxygen (O^{-}). Consequently, metal iron has much more mobility. The metal and oxygen diffuse in the scale as charged ions rather than as atoms. The net reaction involves two separate reactions and a transfer of electrons through the scale from the metal to oxygen :-

(i) Me(metal) ---------------- Me^{++} - $2e^{-}$

(ii) $2e^{-}$ + ½ O_2 ----------------- O^{-}

Mechanism of Electro-chemical Corrosion :- The type of corrosion involving flow of electrical current from one point to another point through some perceptible distance, is known as electro-chemical corrosion.

Most commonly the driving force that causes the corrosion reaction to place is electro-chemical. At the point from which current flows, called anode, metal dissolve or corrodes. At the point to which current flows called cathode, no corrosion takes place. The metal is dived into anodic and cathodic area. But these pairs may exist in large number per unit area, with corresponding small spatial (of space) separation. Some separation is always essential and it is also essential that an electrolyte be present to conduct the current. The electrolyte may be moisture or liquid.

Progress of corrosion gets retarded or completely stopped when the corrosion product form an impervious adherent film on the metal. These are two types of mechanism-

- Hydrogen Evolution Corrosion Reaction
- Oxygen Absorption Corrosion Reaction

PROTECTION OF CORROSION :- Corrosion can be prevented by various means. These means are by :

1. Painting
2. Metallic (Electroplating, Cladding, Cementation Processes)
3. Non-metallic coatings
4. Using the inhibitors
5. Cathodic protection

VIVA-QUESTIONS :

1. What is rusting ? How is it different from corrosion?
2. Approximately how much is the corrosion rate of mild steel in dry and sea environments?
3. What is the composition of stainless steel utensils used in domestic environment?
4. A fancy article of aluminium has to be coated for corrosion prevention. Among Ni, Mg, Ag, and Zn ; which metals can be used for this purpose ? justify your answer.
5. Exhaust valves of I.C. engines are made of 12% to 17% Cr alloy steel-why ?

EXPERIMENT NO.-8

AIM :-To study the creep behavior of a given specimen.

EQUIPMENTS :- A creep testing machine equipped with loading and heating systems, and strain measuring arrangement.; a specimen of steel, aluminium or any other metal.

THEORY :- The permanent deformation (strain) of a material under steady load as a function of time is called creep. A very common observation in which length of our waist belt increases after some duration, is due to creep effect. It is thermally actuated process, and hence is influenced by temp. It is, however, appreciable at temp. above **0.4Tm** where **Tm** is melting point of material in degree Kelvin.

Creep occurs at room temp. in many materials such as lead, zinc, solder wire (an alloy of Pb and Sn), white metals, rubber, plastics and leather etc.

The load (hence stress) and temp. influence the creep behaviour of a material. So we obtain different curve profiles as shown in fig. Three separate curves A, B and C for the same material are shown. If the temperature is constant, the curves A, B and C are obtained at stresses σ_1, σ_2 and σ_3 respectively. Similarly if the stress is kept constant, the curves A, B and C are noticed at temperatures T_1, T_2 and T_3.

MACHINE SET-UP AND PROCEDURE :- The specimen is placed inside the furnace and heated for 4 to 5 hours so that its temperature becomes uniform throughout. It is then subjected to a constant load by a lever and a dead weight system. In due course of time, creep deformation (strain) starts in the specimen which is recorded at certain interval of time. Marten's optical extensometer records the strain in the specimen to an accuracy of 0.001mm. The observations may be taken for few hours, few days, few months, few years or full life according to the importance and need. Hence the tests are known as

1. Short duration test,
2. medium duration test
3. long duration test, and
4. life duration test

OBSERVATION AND RESULT :- The recorded strain ε and time t curve is plotted for a constant stress σ at an uniform temp. T. The likely shapes of ε versus t curve will be one of the types already shown in fig. Creep rate, permissible strain and service life of some components are shown in table

Component	**Creep rate (mm/hour)**	**Permissible strain (mm)**	**Service life (hours)**
Turbine rotor shrunk on a shaft	10^{-9}	0.0001	100 000
Boiler, welded joint	10^{-7}	0.003	100 000
Pipe carrying superheated steam	10^{-6}	0.02	20 000

VIVA-QUESTIONS :-

1. what is creep in metals ? Draw a typical creep curve and explain the three stages ofcreep.
2. What relationship exists grain size and creep within a metal ?
3. Distinguish between ductile and brittle fracture.
4. Define breaking stress ?
5. Name two ductile and brittle metallic materials ?

EXPERIMENT NO.-9

AIM:- Specimen preparation for micro structural examination –cutting, grinding, polishing, etching.

RQUIREMENTS :- Cutting saw/hand saw, grinding machine, polishing machine, dry belt grinder, aluminium or any other metallic/alloy specimen, etchant, liquid soap.

THEORY :- Grain boundaries are not visible in an ordinary piece of metal machine, dry belt grinder or cored surface. Their removal is essential for preparation of the specimen to be viewed under a microscope. Therefore, grinding (rough and fine), polishing and etching are done on them. Fine grinding is done by abrasive papers of finer grades viz. 400, 600 grits and 33, 23, 17 micron particle size. Emery papers of grades 100,200,-----,600 are also used. Polishing is done by polishing compound (Al_2O_3 powder) of 0.05 micron, placed on a cloth that covers the wheel. Water is used as lubricant. Etching is done to make the grain boundaries visible.

TEST SET-UP AND SPECIFICATIONS OF M/C. :- The experiment is carried out on a series of machines is given below:

1. **Cut-off machine :-** This is an open type abrasive cut-off machine capable of cutting up to 60mm, 80mm, 100mm round bar and square.
2. **Belt-grinder :-** This is used for initial rough grinding of specimen. It is mounted with ¼ hp, 200V, 1-phase motor, endless belt of 100mm width and 915mm length on dynamically well balanced rollers.
3. **Hand Polishing Stand :-** It consists of 4-surface plates to fix 3” x 11” (75mm x 275mm.) size of different kinds of water-emery papers. It also facilitates swift polishing of specimen with various grades of emery.
4. **Grinding/Polishing Machine :-** It is a variable speed double disc machine for fine grinding and super polishing (lapping). It is mounted with a ½ hp or 1hp motor having continuous step less variable speed up to 1400 rpm, digit rpm indicator, and discs of 200mm/250mm dia.

PROCEDURE :- The experiment is conducted in the following sequential steps.

(i) Cut a cylindrical or square piece of aluminium of any size between 10 mm to 25 mm diameter / side as specimen.

(ii) Do its grinding on grinding machine.

(iii) Do its fine grinding on dry belt grinder. Continue grinding till the scratches disappear.

(iv) Do rough polishing by using emery paper of fine grade. Use liquid soap as lubricant.

(v) Perform fine polishing on polishing machine to get scratch free surface.

(vi) Now etch the specimen by immerging it in an etchant. Etchant for aluminium is a blend of 1% hydrofluoric acid + 1.5% hydrochloric acid + 2.5% nitric acid + distilled water. Etching should be done for 15 to 30 seconds.

(vii) The specimen is ready for microscopic study.

OBSERVATION :- Note down the grades and sizes of emery papers and polishing compound, composition of etchant and etching time. Know the specifications of machines used. Learn the names of etchants their composition, concentration, and etching time for iron and steel, Cu and its alloys, and other metals and alloys. Following observations taken in a test are presented for a ready reference.

- Grade and size of

(i)	Particles	320	420	600 grits
(ii)	Emery paper	33	23	17 microns

- Polishing compound for
  - (i) Rough polishing : Diamond powder in oil lubricant
  - (ii) Fine polishing : Aluminium powder in oil lubricant
- Composition of etchant
  - (i) 1% HF + 1.5% HCl + 2.5%HNO3 + distilled water
- Etching time
  - (i) 15 to 30 seconds

CAUTION : - Work carefully on grinding machine, polishing machine, and with the etchant. The etchant is acidic in nature, so avoid excessive and unnecessary contact. Do not touch your eyes and other body parts until the hands are washed properly.

VIVA-QUESTIONS:-

- What are the specifications of grinding and polishing machines?
- What is lapping? Which degree of accuracy can be achieved in metals, by polishing?
- Why is grinding performed before polishing?

EXPERIMENT NO.-10

AIM:- Study of microstructure of welded component and HAZ(Heat Affected Zone) macro and micro examination.

EQUIPMENTS :-

1. Welded components of different types viz. arc welded, gas welded, lap welded, buttwelded, seam welded, thermit welded etc.
2. Welded sheets, wires, rods of ferrous and non-ferrous metals and alloys.
3. Heat affected zone (HAZ) of some metals and alloys.
4. Metallurgical microscope.

THEORY :- Various techniques are adopted to manufacture varieties of products. Welding is one important technique among them. It refers to intimate joining of metals and alloys by heating to suitable temp. with or without the use of pressure or/and filler material. Welded components are made by several methods. These are-

1. Electric arc welding : carbon arc, metal arc, submerged arc, plasma arc, tungsten inert gas (TIG), metal inert gas (MIG) etc.
2. Gas welding : oxyacetylene, air-acetylene, oxy-hydrogen.
3. Thermit welding : which is used to weld rails.
4. Resistance welding : spot, projection, seam etc.
5. Butt welding, lap welding, fillet welding or corner/edge welding.
6. U, V, J or bevel type and single or double type welding
7. Welding all around, flush contour, convex contour or other types
8. Flat welded ; upward, downward, overhead, leftward or rightward.

The microstructure of welded components made by different methods vary widely due to different chemical compositions and other manufacturing parameters. Their macro and micro structures are also quite different.

PROCEDURE :- Study different welded components one by one : first from macro view point and then from micro view point.

In macro examination:-

- Check the type of weld whether arc welded, gas welded or else.
- Check the size and throat of the weld.
- See whether the weld is butt type, lap type, or any other type.
- If butt welding, see whether its edge preparation is of U-type (single or double), V-type

(single or double) or any other type.

- Check whether the welding has any defect such as cracks, pores, blow-holes, sag, slag, inclusions, undercuts, incomplete penetration etc.
- Examine the contour of weld and the welding method by which the component has been made.
- Perform the macro-crack test, weld tensile test, and impact test also.

In micro-examination :-

- View the components under microscope by adopting the procedure as outlined in microscope related experiments.
- Perform different non-destructive tests.

Study of HAZ (Heat Affected Zone) :-

The region of base metal which has undergone a metallurgical change as a result of exposure to welding heat (during welding process) is called HAZ. The mechanical properties of metal in this zone is also affected considerably. The heating and cooling through a wide range of temp. brings changes in metallic structure also. While welding mild steel, this change may vary from overheated area near the weld to under-annealed structure away from the weld. However, complex structural changes take place within HAZ in alloy steels due to rapid rate of cooling. In case of welding of non-ferrous metals and alloys, the grain growth may occur in HAZ. Visualization of carbon steel, alloy steel, non-ferrous metals and alloys under HAZ through microscope will show different structures. In some of these metals and alloys, the structuremay be dendritic.

RESULT/CONCLUSION :- The findings of macro-examination may be of the kinds as shown in And those of micro-examination as given in the microstructures of welded components and HAZ can be similar to as depicted.

VIVA-QUESTIONS :-

- Where does the maximum and minimum shearing stress occur in the cross-section of abeam ?
- Where does the maximum and minimum bending stress occur in the cross-section of abeam ?
- Microstructures of metals are different from each other-why ?
- What are the effects of microstructure of steel and C.I. on their mechanical properties ?