COURSE FILE

MATERIAL SCIENCE AND METALLURGY

(Subject Code: C213)

II Year, I Sem B.TECH. (MECHANICAL ENGINEERING)

Submitted to

DEPARTMENT OF MECHANICAL ENGINEERING

BY

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NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY HYDERABAD

DEPARTMENT OF MECHANICAL ENGINEERING

(Name of the Subject/Lab Course): MATERIAL SCIENCE AND METALURGY

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Date:

Contents

3. VISION AND MISSION OF THE INSTITUTE

VISION

To impart quality technical education with strong ethics, producing technically sound engineers capable of serving the society and the nation in a responsible manner.

MISSION

M1: To provide adequate knowledge encompassing strong technical concepts and soft skills thereby inculcating sound ethics.

M2: To provide a conducive environment to nurture creativity in teaching- learning process.

M3: To identify and provide facilities which create opportunities for deserving students of all communities to excel in their chosen fields.

M4: To strive and contribute to the needs of the society and the nation by applying advanced engineering and technical concepts.

4. VISION AND MISSION OF MECHANICAL ENGINEERING DEPARTMENT

VISION

To achieve excellence in Mechanical Engineering by imparting technical and professional skills along with ethical values to meet social needs via industrial requirements.

MISSION

M1: To offer quality education with the supportive facilities to produce efficient and competent engineers through industry-institute interaction.

M2: To prepare the students with academic excellence, professional competence, and ethical behaviour for a lifelong learning.

M3: To inculcate moral & professional values among the students to cater the needs of the society and environment.

Program Educational Objectives

- Graduates will apply their engineering knowledge and problem solving skills to design mechanical systems and processes.
- Graduates will embrace leadership skills at various roles in their careers and establish excellence in the field of Mechanical Engineering.
- Graduates will provide engineering solutions to meet industrial requirements there byfull fill global and societal needs.

Program Specific Outcomes

- Implement new ideas on product design and development with the help of modern computer aided tools, while ensuring best manufacturing practices
- Impart technicalknowledge, ethical values and managerial skills to make successful mechanical engineers.
- Develop innovative attitude, critical thinking and problem solving approach for any domains of mechanical engineering.

PROGRAMMING OUTCOMES(PO'S):

1. **Engineering Knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem Analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. **Design/development of Solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct Investigations of Complex Problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern Tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

6. **The Engineer and Society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and Sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and Team Work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project Management and Finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long Learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Syllabus Copy
C213: MATERIAL SCIENCE AND METALLURGY
B.Tech. II Year I Sem.

Course code	Course Title				Core/Elective
C213	MATERIAL SCIENCE AND METALLURGY				Core
Prerequisite	Contact hours per week				
	L	T	P	D	Credits
	3	0	0	0	3

UNIT – I

Crystal Structure: Unit cells, Metallic crystal structures, Ceramics. Imperfection in solids: Point, line, interfacial and volume defects; dislocation strengthening mechanisms and slip systems, critically resolved shear stress.

UNIT – II

Alloys, substitutional and interstitial solid solutions- Phase diagrams: Interpretation of binary phase diagrams and microstructure development; eutectic, peritectic, peritectoid and monotectic reactions. Iron Iron-carbide phase diagram and microstrctural aspects of ledeburite, austenite, ferrite and cementite, cast iron

UNIT –III

Heat treatment of Steel: Annealing, Normalising, Hardening, Tempering and Spheroidising, Isothermal transformation diagrams for Fe-C alloys and microstructures development.

UNIT – IV

Continuous cooling curves and interpretation of final microstructures and properties- austempering, martempering, case hardening, carburizing, nitriding, cyaniding, carbo-nitriding, flame and induction hardening, vacuum and plasma hardening

UNIT – V

Alloying of steel, properties of stainless steel and tool steels, maraging steels- cast irons; grey, white, malleable and spheroidal cast irons- copper and copper alloys (Brass, bronze and cupro-nickel)-Aluminium and Al-Cu – Mg alloys- Titanium alloys

TEXT BOOKS:

1. V. Raghavan, “Material Science and Engineering’, Prentice Hall of India Private Limited, 1999.
2. W. D. Callister, 2006, “Materials Science and Engineering-An Introduction”, 6th Edition, Wiley India.

REFERENCE BOOKS:

1. Kenneth G. Budinski and Michael K. Budinski, “Engineering Materials”, Prentice Hall of India Private Limited, 4th Indian Reprint, 2002.
2. U. C. Jindal, “Engineering Materials and Metallurgy”, Pearson, 2011.

COURSE OUTCOME:

Students will be able to

CO1-Understand the concept of engineering materials with its classification and crystal structure as well as dislocation strengthening mechanisms and identify imperfections in various crystral structure.

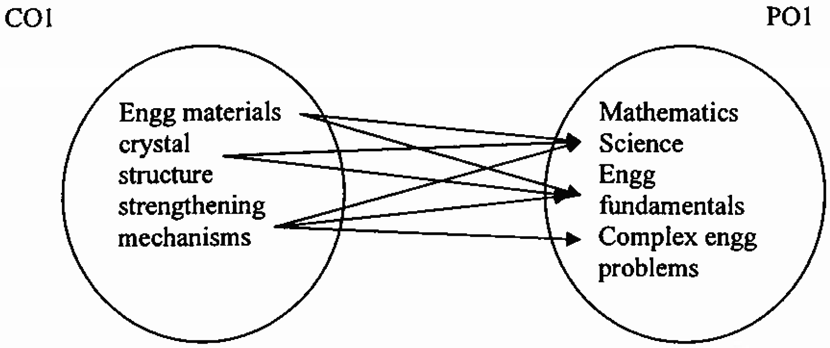
CO2-Illustrate the concept of solid solutions as well as concept of phase diagram & Iron-Carbon system.

CO3-Apply &analyze the process of Heat treatment of steels & its effects on final microstructures and their properties.

CO4-Evaluate knowledge for selection of materials in real life applications.

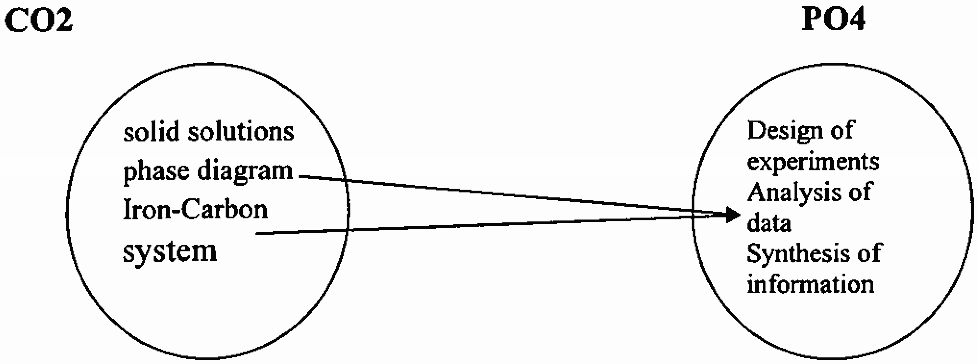
COURSE OUTCOME-PROGRAM OUTCOME MAPPING OF MATERIAL SCIENCE AND METALLURGY

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	1	0	0	1	1	0	1	1	2	2	1
CO2	3	3	1	2	1	0	0	0	0	1	0	0	2	2	2
CO3	3	3	3	3	1	0	0	1	1	0	0	2	2	1	3
CO4	3	3	2	2	2	1	1	1	3	0	0	3	2	2	3



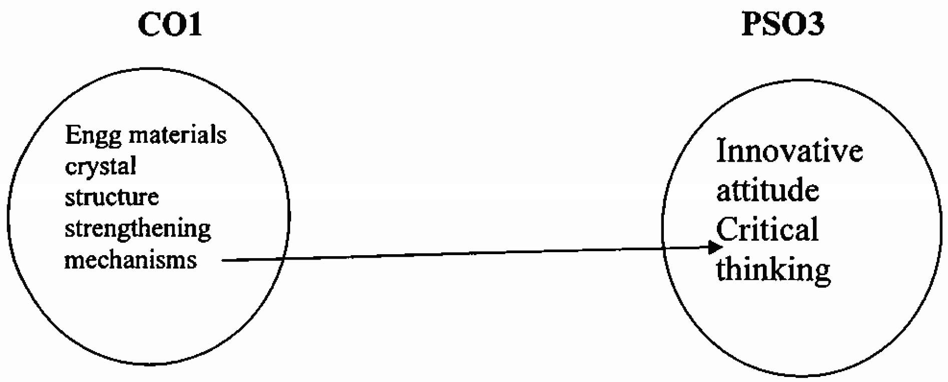
Probability of CO# to PO# $= P(K_1) + P(K_2) + P(K_3) + P(K_4) = 1/3+1/3+1/3 = 3/3 = 1$

Correlation - CO1 to PO1 = 3



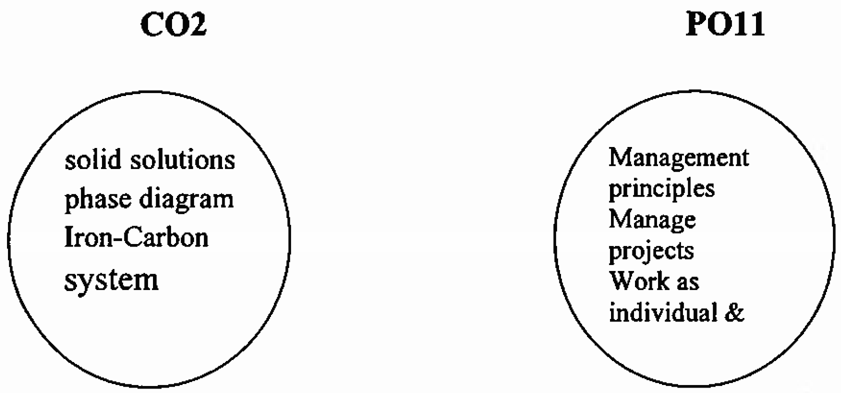
Probability of CO2 to PO4 $= P(K_1) + P(K_2) + P(K_3) + P(K_4) = 0/3+1/3+1/3 = 2/3 = 0.66$

Correlation – CO2 to PO4 = 2



Probability of CO1 to PSO3 $= P(K_1) + P(K_2) + P(K_3) + P(K_4) = 0/3+0/3+1/3 = 1/3 = 0.33$

Correlation - CO1 to PSO3 = 1



Probability of CO2 to PO11 $= P(K_1) + P(K_2) + P(K_3) + P(K_4) = 0/3+0/3+0/3 = 0/3 = 0$

Correlation – CO2 to PO11 =0

Probability (CO# to PO#) =	
< 0.25	**- No Correlation**
> 0.25 and <= 0.50	**- 1**
>0.50 and <= 0.75	**- 2**
>0.75 and <= 1.00	**- 3**

LECTURE SCHEDULE WITH METHODOLOGY BEING: REFERENCE TEXT BOOKS-

S.No	Class Period	Topic to be covered	Regular/Additional	Teaching adopted (Blackboard/PPT)	Remarks
		UNIT I			
1.	1-2	Crystal Structure: Unit cells, Metallic crystal structures	Regular	BB	Completed
2.	3	Ceramics	Regular	BB	Completed
3.	4	Imperfection in solids: Point, line, interfacial and volume defects;	Regular	BB	Completed
4.	5	dislocation strengthening mechanisms and slip systems, critically resolved shear stress.	Regular	BB	Completed
		UNIT II			
5.	6	Alloys, substitutional and interstitial solid solutions	Regular	BB	Completed
6.	7	Phase diagrams	Regular	BB	Completed
7.	7	Interpretation of binary phase diagrams and microstructure development	Regular	BB	Completed
8.	7	Eutectic, peritectic, peritectoid and monotectic reactions.	Regular	BB	Completed
9.	8-9	Iron Iron-carbide phase diagram	Regular	BB	Completed
10.	8-9	Microstrctural aspects of ledeburite,	Regular	BB	Completed

		austenite, ferrite and cementite, cast iron			
		UNIT 3			Completed
11.	10-11	Heat treatment of Steel	Regular	BB	Completed
12.	12-15	Annealing, Normalising,	Regular	BB	Completed
13.	16-17	Hardening	Regular	BB	Completed
14.	18-19	Tempering and Spheroidising,	Regular	BB	Completed
15.	20-22	Isothermal transformation diagrams for Fe-C alloys and microstructures development	Regular	BB	Completed
		UNIT 4			Completed
16.	23-25	Continuous cooling curves and interpretation of final microstructures and properties	Regular	BB	
17.	26-27	Austempering, martempering,	Regular	BB	Completed
18.	28-29	Case hardening	Regular	BB	Completed
19.	30-31	Carburizing, nitriding	Regular	BB	Completed
20.	32-34	Cyaniding, carbo-nitriding,	Regular	BB	Completed
21.	35-36	Flame and induction hardening, vacuum and plasma hardening	Regular	BB	Completed
		UNIT 5			
22.	37-39	Alloying of steel	Regular	BB	Completed
23.	40-43	Properties of stainless steel	Regular	BB	Completed

		and tool steels, maraging steels			
24.	44-46	Cast irons; grey, white, malleable and spheroidal cast irons	Regular	BB	Completed
25.	47-49	Copper and copper alloys (Brass, bronze and cupro-nickel)	Regular	BB	Completed
26.	50-51	Aluminium and Al-Cu – Mg alloys	Regular	BB	Completed
27.	52	Titanium alloys	Regular	BB	Completed

LESSON SCHEDULE

153BC/ME303PC: MATERIAL SCIENCE AND METALLURGY
B.Tech. II Year I Sem. L T/P/D C 3 0/0/0 3

UNIT – I

(1st week)-(15/07/2019-19/07/2019)

Crystal Structure: Unit cells, Metallic crystal structures, Ceramics.

(2nd week)-(22/07/2019-27/07/2019)

Imperfection in solids: Point, line, interfacial and volume defects;

(3rd week)-(30/07/2019-2/08/2019)

Dislocation strengthening mechanisms and slip systems, critically resolved shear stress.

UNIT – II

(4th week)-(5/08/2019-9/08/2019)

Alloys, substitutional and interstitial solid solutions-

(5th week)-(13/08/2019-16/08/2019)

Phase diagrams: Interpretation of binary phase diagrams and microstructure development; eutectic, peritectic, peritectoid and monotectic reactions.

(6th week)-(20/08/2019-23/08/2019)

Iron Iron-carbide phase diagram and microstrctural aspects of ledeburite, austenite, ferrite and cementite, cast iron

UNIT –III

(7th week)-(26/08/2019-30/08/2019)

Heat treatment of Steel: Annealing, Normalising, Hardening, Tempering and Spheroidising,

(8th week)-(3/09/2019-6/09/2019)

Isothermal transformation diagrams for Fe-C alloys and microstructures development.

UNIT – IV

(9th week)-(9/09/2019-20/09/2019)-FIRST MID ON 11/09/2019

Continuous cooling curves and interpretation of final microstructures and properties-

(10th week)-(23/09/2019-27/09/2019)

Austempering, martempering, case hardening, carburizing,

(11th week)-(21/10/2019-25/10/2019)

Nitriding, cyaniding, carbo-nitriding,

(12th week)-(28/10/2019-1/11/2019)

Flame and induction hardening, vacuum and plasma hardening

UNIT – V

(13th week)-(4/11/2019-8/11/2019)

Alloying of steel, properties of stainless steel and tool steels, maraging steels

(14th week)-(11/11/2019-15/11/2019)

Cast irons; grey, white, malleable and spheroidal cast irons

(15th week)-(18/11/2019-20/11/2019)-SECOND MID ON 22/11/2019

Copper and copper alloys (Brass, bronze and cupro-nickel)- Aluminium and Al-Cu – Mg alloys- Titanium alloys

NOTES
SUBJECT: MATERIAL SCIENCE

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UNIT- I

Introduction

Materials science, also commonly known as materials science and engineering, is an interdisciplinary field which deals with the discovery and design of new materials. This relatively new scientific field involves studying materials through the materials paradigm (synthesis, structure, properties and performance). It incorporates elements of physics and chemistry, and is at the forefront of nano science and nanotechnology research. In recent years, materials science has become more widely known as a specific field of science andengineering.

Importance of Materials

A material is defined as a substance (most often a solid, but other condensed phases can be included) that is intended to be used for certain applications. There are a myriad of materials around us—they can be found in anything from buildings to spacecrafts. Materials can generally be divided into two classes: crystalline and non-crystalline. The traditional examples of materials are metals, ceramics and polymers. New and advanced materials that are being developed include semiconductors, nanomaterials, biomaterialsetc.

The material of choice of a given era is often a defining point. Phrases such as Stone Age, Bronze Age, Iron Age, and Steel Age are great examples. Originally deriving from the manufacture of ceramics and its putative derivative metallurgy, materials science is one of the oldest forms of engineering and applied science. Modern materials science evolved directly from metallurgy, which itself evolved from mining and (likely) ceramics and the use of fire. A major breakthrough in the understanding of materials occurred in the late 19th century, when the American scientist Josiah Willard Gibbs demonstrated that the thermodynamic properties related to atomic structure in various phases are related to the physical properties of a material. Important elements of modern materials science are a product of the space race: the understanding and engineering of the metallic alloys, and silica and carbon materials, used in the construction of space vehicles enabling the exploration of space. Materials science has driven, and been driven by, the development of revolutionary technologies such as plastics, semiconductors, andbiomaterials.

UNIT– I

Introduction

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Metals: The valence electrons are detached from atoms, and spread in an 'electron sea' that "glues" the ions together. Metals are usually strong, conduct electricity and heat well and are opaque to light (shiny if polished). Examples: aluminum, steel, brass, gold.

Semiconductors: The bonding is covalent (electrons are shared between atoms). Their electrical properties depend extremely strongly on minute proportions of contaminants. They are opaque to visible light but transparent to the infrared. Examples: Si, Ge, GaAs.

Ceramics: Atoms behave mostly like either positive or negative ions, and are bound by Coulomb forces between them. They are usually combinations of metals or semiconductors with oxygen, nitrogen or carbon (oxides, nitrides, and carbides).Examples: glass, porcelain, many minerals.

Polymers: are bound by covalent forces and also by weak van der Waals forces, and usually based on H, C and other non-metallic elements. They decompose at moderate temperatures (100 – 400 C), and are lightweight. Other properties vary greatly. Examples: plastics (nylon, teflon, polyester) and rubber. Other categories are not based on bonding. A particular microstructure identifies

Composites: Composites made of different materials in intimate contact (example: fiberglass, concrete, wood) to achieve specific properties. **Biomaterials** can be any type of material that is biocompatible and used, for instance, to replace human body parts.

Advanced Materials

Materials used in "High-Tec" applications, usually designed for maximum performance, and normally expensive. Examples are titanium alloys for supersonic airplanes, magnetic alloys for computer disks, special ceramics for the heat shield of the space shuttle, etc.

Modern Material's Needs

- Engine efficiency increases at high temperatures: requires high temperature withstanding materials

The current model of the sub-atomic structure involves a dense nucleus surrounded by a probabilistic "cloud" of electrons

The **plum pudding model** was a model of the atom that incorporated the recently discovered electron, and was proposed by J. J. Thomson in 1904. Thomson had discovered the electron in 1897. The plum pudding model was abandoned after discovery of the atomic nucleus. The plum pudding model of the atom is also known as the "Blueberry Muffin" model.

In this model, the atom is composed of electrons (which Thomson still called "corpuscles", though G. J. Stoney had proposed that atoms of electricity be called electrons in 1894) surrounded by a soup of positive charge to balance the electrons' negative charges, like negatively charged "raisins" surrounded by positively charged "pudding". The electrons (as we know them today) were thought to be positioned throughout the atom, but with many structures possible for positioning multiple electrons, particularly rotating rings of electrons (see below). Instead of a soup, the atom was also sometimes said to have had a "cloud" of positivecharge.

With this model, Thomson abandoned his earlier "nebular atom" hypothesis in which the atom was composed of immaterial vortices. Now, at least part of the atom was to be composed of Thomson's particulate negative "corpuscles", although the rest of the positively charged part of the atom remained somewhat nebulous and ill-defined.

The 1904 Thomson model was disproved by the 1909 gold foil experiment of Hans Geiger and Ernest Marsden. This was interpreted by Ernest Rutherford in 1911 to imply a very small nucleus of the atom containing a very high positive charge (in the case of gold, enough to balance about 100 electrons), thus leading to the Rutherford model of the atom. Although gold has an atomic number of 79, immediately after Rutherford's paper appeared in 1911 Antonius Van den Broek made the intuitive suggestion that atomic number is nuclear charge. The matter required experiment to decide. Henry Moseley's work showed experimentally in 1913 (see Moseley's law) that the effective nuclear charge was very close to the atomic number (Moseley found only one unit difference), and Moseley referenced only the papers of Van den Broek and Rutherford. This work culminated in the solar-system-like (but quantum-limited) Bohr model of the atom in the cloud of (presumably) orbiting electrons. In this May 1911 paper, Rutherford only commits himself to a small central region of very high positive or negative charge in theatom.

For concreteness, consider the passage of a high speed α particle through an atom having a positive central charge N e, and surrounded by a compensating charge of Nelectrons.

From purely energetic considerations of how far particles of known speed would be able to penetrate toward a central charge of 100 e, Rutherford was able to calculate that the radius of his gold central charge would need to be less (how much less could not be told) than 3.4×10^{-14} metres. This was in a gold atom known to be 10^{-10} meters or so in radius—a very surprising finding, as it implied a strong central charge less than 1/3000th of the diameter of the atom.

The Rutherford model served to concentrate a great deal of the atom's charge and mass to a very small core, but didn't attribute any structure to the remaining electrons and remaining atomic mass. It did mention the atomic model of Hantaro Nagaoka, in which the electrons are arranged in one or more rings, with the specific metaphorical structure of the stable rings of Saturn. The plum pudding model of J.J. Thomson also had rings of orbiting electrons. Jean Baptiste Perrin claimed in his Nobel Lecture that he was the first one to suggest the model in his paper dated 1901.

The Rutherford paper suggested that the central charge of an atom might be "proportional" to its atomic mass in hydrogen mass units u (roughly 1/2 of it, in Rutherford's model). For gold, this mass number is 197 (not then known to great accuracy) and was therefore modeled by Rutherford to be possibly 196 u. However, Rutherford did not attempt to make the direct connection of central charge to atomic number, since gold's "atomic number" (at that time merely its place number in the periodic table) was 79, and Rutherford had modeled the charge to be about + 100 units (he had actually suggested 98 units of positive charge, to make half of 196). Thus, Rutherford did not formally suggest the two numbers (periodic table place, 79, and nuclear charge, 98 or 100) might be exactly thesame.

completely well defined for small orbits, because the emission process involves two orbits with two different periods, Bohr could determine the energy spacing between levels using rule 3 and come to an exactly correct quantum rule: the angular momentum L is restricted to be an integer multiple of a fixed unit:

$$L = n\frac{h}{2\pi} = n\hbar$$

where n = 1, 2, 3, ... is called the principal quantum number, and $\hbar = h/2\pi$. The lowest value of n is 1; this gives a smallest possible orbital radius of 0.0529 nm known as the Bohr radius. Once an electron is in this lowest orbit, it can get no closer to the proton. Starting from the angular momentum quantum rule, Bohr was able to calculate the energies of the allowed orbits of the hydrogen atom and other hydrogen-like atoms and ions. Other points are:

1. Like Einstein's theory of the Photoelectric effect, Bohr's formula assumes that during a quantum jump a discrete amount of energy is radiated. However, unlike Einstein, Bohr stuck to the classical Maxwell theory of the electromagnetic field. Quantization of the electromagnetic field was explained by the discreteness of the atomic energy levels; Bohr did not believe in the existence ofphotons.
2. According to the Maxwell theory the frequency ν of classical radiation is equal to the rotation frequency ν_{rot} of the electron in its orbit, with harmonics at integer multiples of this frequency. This result is obtained from the Bohr model for jumps between energy levels En and En−k when k is much smaller than n. These jumps reproduce the frequency of the k-th harmonic of orbit n. For sufficiently large values of n (so-called Rydberg states), the two orbits involved in the emission process have nearly the same rotation frequency, so that the classical orbital frequency is not ambiguous. But for small n (or large k), the radiation frequency has no unambiguous classical interpretation. This marks the birth of the correspondence principle, requiring quantum theory to agree with the classical theory only in the limit of large quantumnumbers.
3. The Bohr-Kramers-Slater theory (BKS theory) is a failed attempt to extend the Bohr model which violates the conservation of energy and momentum in quantum jumps, with the conservation laws only holding on average. Bohr's condition, that the angular momentumis

the electron's average momentum at that point, since high electron momentum at a given position tends to "localize" the electron in that position, via the properties of electron wave-packets (see the Heisenberg uncertainty principle for details of the mechanism).

This relationship means that certain key features can be observed in both drum membrane modes and atomic orbitals. For example, in all of the modes analogous to s orbitals (the top row in the animated illustration below), it can be seen that the very center of the drum membrane vibrates most strongly, corresponding to the antinode in all s orbitals in an atom. This antinode means the electron is most likely to be at the physical position of the nucleus (which it passes straight through without scattering or striking it), since it is moving (on average) most rapidly at that point, giving it maximal momentum.

A mental "planetary orbit" picture closest to the behavior of electrons in s orbitals, all of which have no angular momentum, might perhaps be that of a Keplerian orbit with the orbital eccentricity of 1 but a finite major axis, not physically possible (because particles were to collide), but can be imagined as a limit of orbits with equal major axes but increasing eccentricity.

Below, a number of drum membrane vibration modes are shown. The analogous wave functions of the hydrogen atom are indicated. A correspondence can be considered where the wave functions of a vibrating drum head are for a two-coordinate system $\psi(r, \theta)$ and the wave functions for a vibrating sphere are three-coordinate $\psi(r, \theta, \varphi)$.

Atomic bonding in solids

Primary Inter-atomic Bonds

Ionic Bonding

This is the bond when one of the atoms is negative (has an extra electron) and another is positive (has lost an electron). Then there is a strong, direct Coulomb attraction. An example is NaCl. In the molecule, there are more electrons around Cl, forming Cl- and less around Na, forming Na+. Ionic bonds are the strongest bonds. In real solids, ionic bonding is usually combined with covalent bonding.

Covalent Bonding

are metals, diamond and other precious stones, ice, graphite. Examples of amorphous solids are glass, amorphous carbon (a-C), amorphous Si, most plastics To discuss crystalline structures it is useful to consider atoms as being hard spheres, with well-defined radii. In this scheme, the shortest distance between two like atoms is one diameter.

Crystal Lattice is used to represent a three-dimensional periodic array of points coinciding with atom positions.

Unit cell is smallest repeatable entity that can be used to completely represent a crystal structure. It is the building block of crystal structure.

Bravais lattices

When the crystal systems are combined with the various possible lattice centerings, we arrive at the Bravais lattices. They describe the geometric arrangement of the lattice points, and thereby the translational symmetry of the crystal. In three dimensions, there are 14 unique Bravais lattices that are distinct from one another in the translational symmetry they contain. All crystalline materials recognized until now (not including quasicrystals) fit in one of these arrangements. The fourteen three-dimensional lattices, classified by crystal system, are shown above. The Bravais lattices are sometimes referred to as spacelattices.

The crystal structure consists of the same group of atoms, the basis, positioned around each and every lattice point. This group of atoms therefore repeats indefinitely in three dimensions according to the arrangement of one of the 14 Bravais lattices. The characteristic rotation and mirror symmetries of the group of atoms, or unit cell, is described by its crystallographic point group.

Metallic Crystal Structures

Important properties of the unit cells are

- The type of atoms and their radii$R$.
- Cell dimensions (side $a$in cubic cells, side of base a and height c in HCP) in terms of$R$.
- **n**, number of atoms per unit cell. For an atom that is shared with$m$ adjacent unit cells, only count a fraction of the atom,$1/m$.

Miller Indices: A system of notation is required to identify particular direction(s) or plane(s) to characterize the arrangement of atoms in a unit cell

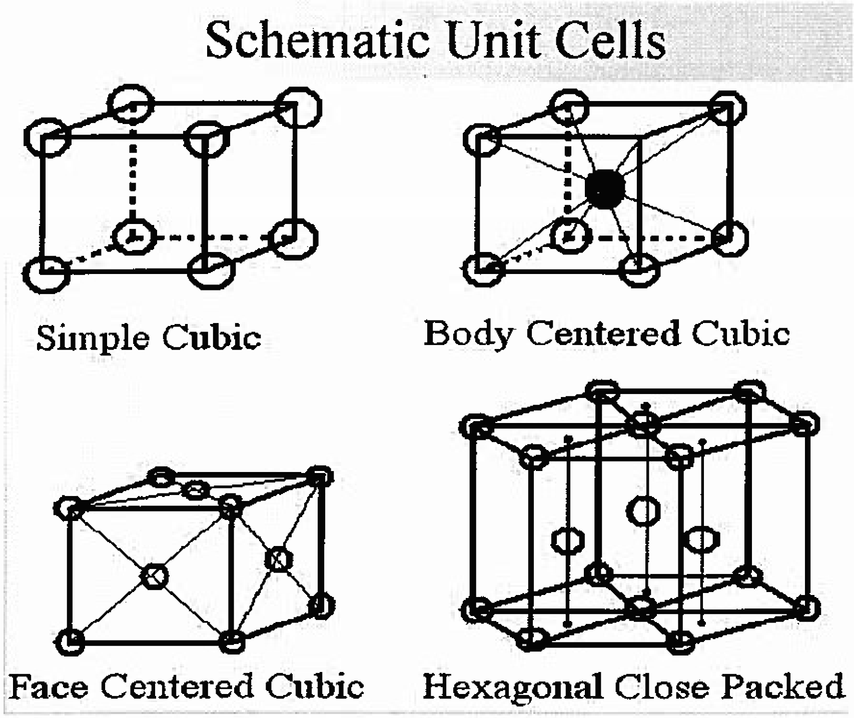
Rules for Miller Indices (Planes)

- Determine the intercepts of the face along the crystallographic axes, *in terms of unit dimensions.*
- Take thereciprocals
- Clearfractions
- Reduce to lowestterms
- Forexample,ifthex-,y-,andz-interceptsare2,1,and3,theMillerindicesarecalculatedas:
- Take reciprocals: 1/2, 1/1,1/3
- Clear fractions (multiply by 6): 3, 6,2
- Reduce to lowest terms (alreadythere)

Thus, the Miller indices are 3,6,2. If a plane is parallel to an axis, its intercept is at infinity and its Miller index is zero. A generic Miller index is denoted by *(hkl)*. A family of planes is represented by {hkl} If a plane has negative intercept, the negative number is denoted by a bar above the number. *Never alter negative numbers.* For example, do not divide -1, -1, -1 by -1 to get 1,1,1. This implies symmetry that the crystal may not have!

Miller Indices - Direction

- A vector of convenient length is placed parallel to therequireddirection
- The length of the vector projection on each of three axes aremeasured in terms of unit cell dimensions
- These three numbers are made to smallest integer values, known as indices, by multiplying or dividing by acommonfactor
- The three indices are enclosed in square brackets,[uvw].
- A family of directions is represented by<uvw>



Imperfections in Solids

Point Defects

Vacancies and Self-Interstitials

A vacancy is a lattice position that is vacant because the atom is missing. It is createdwhen the solid is formed. There are other ways of making a vacancy, but they also occur naturally as a result of thermal vibrations.

An interstitial is an atom that occupies a place outside the normal lattice position. It maybe the same type of atom as the others (self interstitial) or an impurity atom. In the case of vacancies and interstitials, there is a change in the coordination of atoms around the defect. This means that the forces are not balanced in the same way as for other atoms in the solid, which results in lattice distortion around the defect A hightemperature is needed to have a high *thermal* concentration ofvacancies.

Frenkel-defect is a vacancy-interstitial pair of cations

Schottky-defect is a pair of nearby cation and anion vacancies

- Dislocation form during plastic deformation, solidification or due to thermal stresses arising from rapidcooling.

Line Defects – Burger's Vector

- A dislocation in characterized by Burger's vector,b.
- It is unique to a dislocation, and usually has the direction of close packed lattice direction. It is also the slip direction of adislocation.
- It represents the magnitude and direction of distortion associated with that particular dislocation.
- Two limiting cases of dislocations, edge and screw, are characterized by Burger's vector perpendicular to the dislocation line (t) and Burger's vector parallel to the dislocation line respectively. Ordinary dislocation is of mixed character of edge and screwtype.

Edge dislocations occur when an extra plane is inserted. The dislocation line is at the end of the plane. In an edge dislocation, the Burgers vector is perpendicular to the dislocation line.

Line Defects – Edge Dislocation

- It is also called as Taylor-Orowandislocation.
- It will have regions of compressive and tensile stresses on either side of theplane containingdislocation.

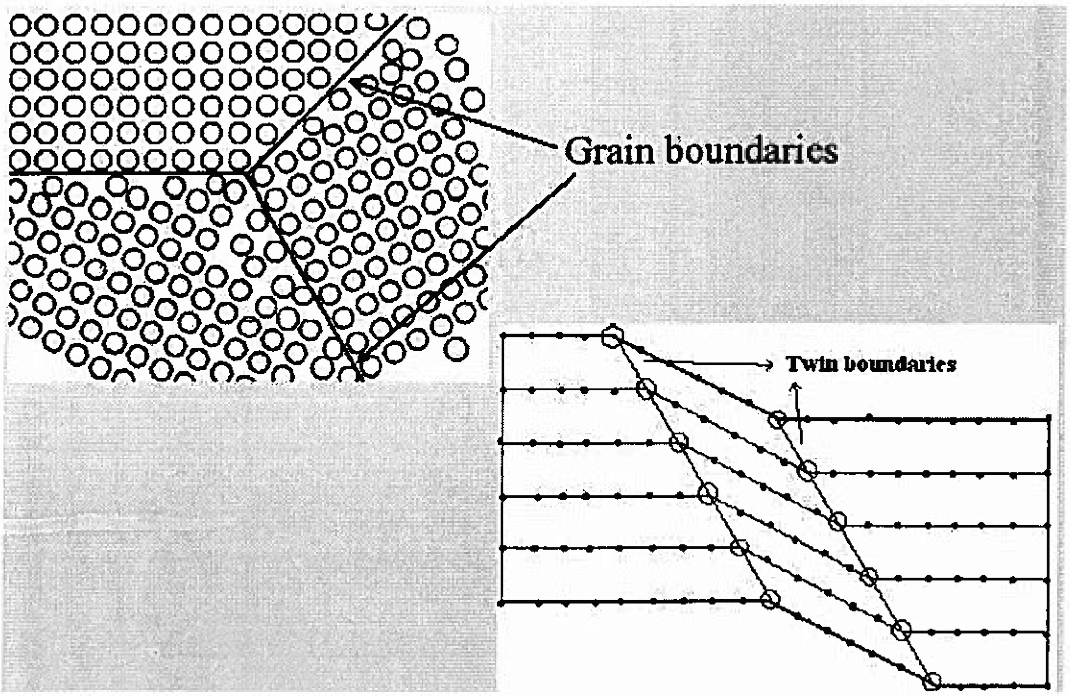
Screw dislocations result when displacing planes relative to each other through shear. In this case, the Burgers vector is parallel to the dislocation line.

Line Defects – ScrewDislocation

- It is also called as Burger'sdislocation.
- It will have regions of shear stress around the dislocationline
- For positive screw dislocation, dislocation line direction is parallel to Burger's vector, and viceversa.

Interfacial Defects

- An interfacial defect is a 2-D imperfection in crystalline solids, and havedifferent crystallographic orientations on either side ofit.
- Region of distortion is about few atomicdistances.
- They usually arise from clustering of line defects into aplane.
- These imperfections are not thermodynamically stable, but meta-stable innature.
- E.g.: External surface, Grain boundaries, Stacking faults, Twin boundaries,Phase boundaries.

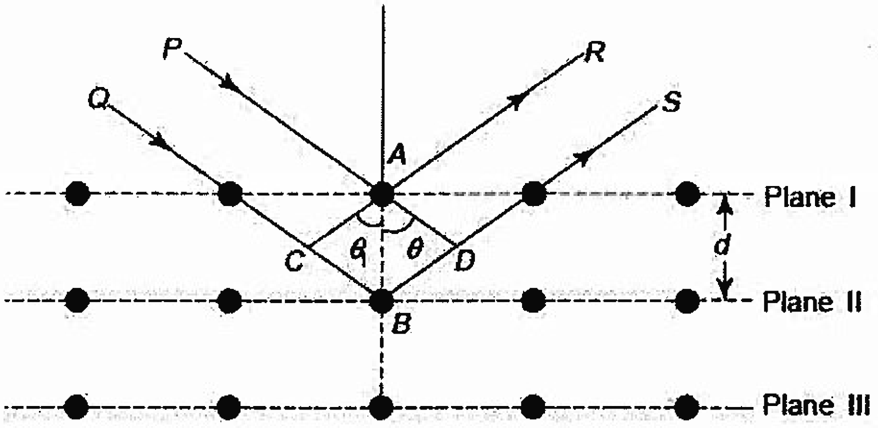


Bulk or Volume Defects :

Other defects exist in all solid materials that are much larger than those heretofore discussed. A typical volume defect is porosity, often introduced in the solid during processing. A common example is snow, which is highly porous ice.

Bulk or Volume Defects

Volume defects are three-dimensional in nature.These defects are introduced, usually, during processing and fabrication operations like casting, forming etc.E.g.: Pores, Cracks, Foreign



where, θ is the angle between the incident ray and the planes of reflection and called as *glancing angle*. Therefore, we have

$$2d \sin\theta = n\lambda \tag{11}$$

where d is the interplanar spacing of planes, i.e. distance between the same set of planes and $n = 1, 2, 3, \ldots$ stand for first order, second order, third order maxima respectively. Equation (11) is known as Bragg's law. We must note that the Bragg's reflection can occur only for $\lambda \leq 2d$.

The directions along which the maxima are observed can be obtained from Bragg's law, by giving different values of θ, i.e.,

for first maximum, $\sin\theta_1 = \dfrac{\lambda}{2d}$

for second maximum, $\sin\theta_2 = \dfrac{2\lambda}{2d}$

for third maximum, $\sin\theta_3 = \dfrac{3\lambda}{2d}$ and so on.

... ...

As the order of spectrum increases, the intensity goes on decreasing.

We must note that the Bragg equation is not limited to atomic planes parallel to the crystal surface. Sets of parallel atomic planes can be constructed through the crystal at different angles. The value of the grating space d is different for each set of parallel planes.

UNIT– II

Plastic deformation:

When the stress is removed, the material does not return to its previous dimension but there is a *permanent*, irreversible deformation. In tensile tests, if the deformation is *elastic*, the stress-strain relationship is called Hooke's law:

$$\sigma = E\,\varepsilon$$

That is, *E* is the slope of the stress-strain curve. E is *Young's modulus* or *modulus of elasticity*. In some cases, the relationship is not linear so that E can be defined alternatively as the local slope:

$$E = d\sigma/d\varepsilon$$

Shear stresses produce strains according to:

$$\tau = G\,\gamma$$

where*G* is the *shear modulus*. Elastic moduli measure the *stiffness* of the material. They are related to the *second* derivative of the interatomic potential, or the first derivative of the force vs. inter nuclear distance. By examining these curves we can tell which material has a higher modulus. Due to thermal vibrations the elastic modulus decreases with temperature. *E* is large for ceramics (stronger ionic bond) and small for polymers (weak covalent bond). Since the interatomic distances depend on direction in the crystal, *E* depends on direction (i.e., it is anisotropic) for single crystals. For *randomly* oriented policrystals, *E* is isotropic.

Yield criteria and macroscopic aspects of plastic deformation

Gross plastic deformation of a polycrystalline specimen corresponds to the comparable distortion of the individual grains by means of slip. During deformation, mechanical integrity and coherency are maintained along the grain boundaries; that is, the grain boundaries is constrained, to some degree, in the shape it may assume by its neighboring grains. Before deformation the grains are equiaxed, or have approximately the same dimension in all directions. For this particular deformation, the grains become elongated along the directions. For this particular deformation, the grains become elongated along the direction in which the specimen was extended.

True Stress and Strain

When one applies a constant tensile force the material will break after reaching the tensile strength. The material starts necking (the transverse area decreases) but the stress cannot increase beyond tensile strength. The ratio of the force to the initial area, what we normally do, is called the engineering stress. If the ratio is to the actual area (that changes with stress) one obtains the *true stress.*

Yield criteria and macroscopic aspects of plastic deformation

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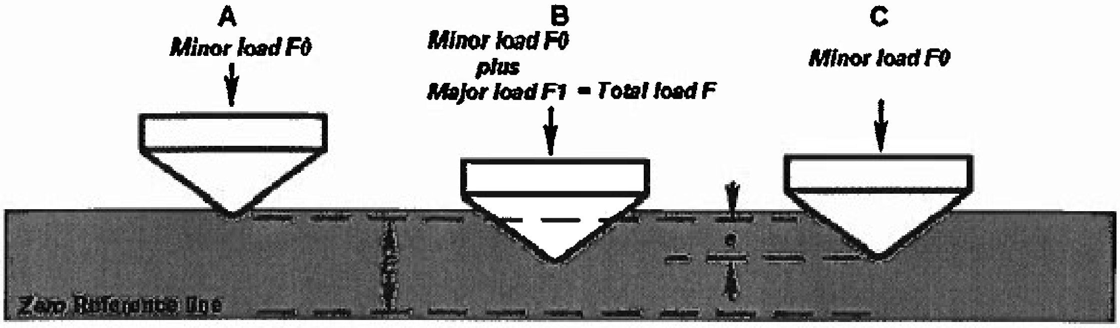
Mohs Hardness Scale

The Mohs hardness scale for minerals has been used since 1822. It simply consists of 10 minerals arranged in order from 1 to 10. Diamond is rated as the hardest and is indexed as 10; talc as the softest with index number 1. Each mineral in the scale will scratch all those below it asfollows:

Diamond	10
Corundum	9
Topaz	8
Quartz	7
Orthoclase (Feldspar)	6

reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number. Advantages of the Rockwell hardness method include the direct Rockwell hardness number readout and rapid testing time.



Vickers Hardness Test

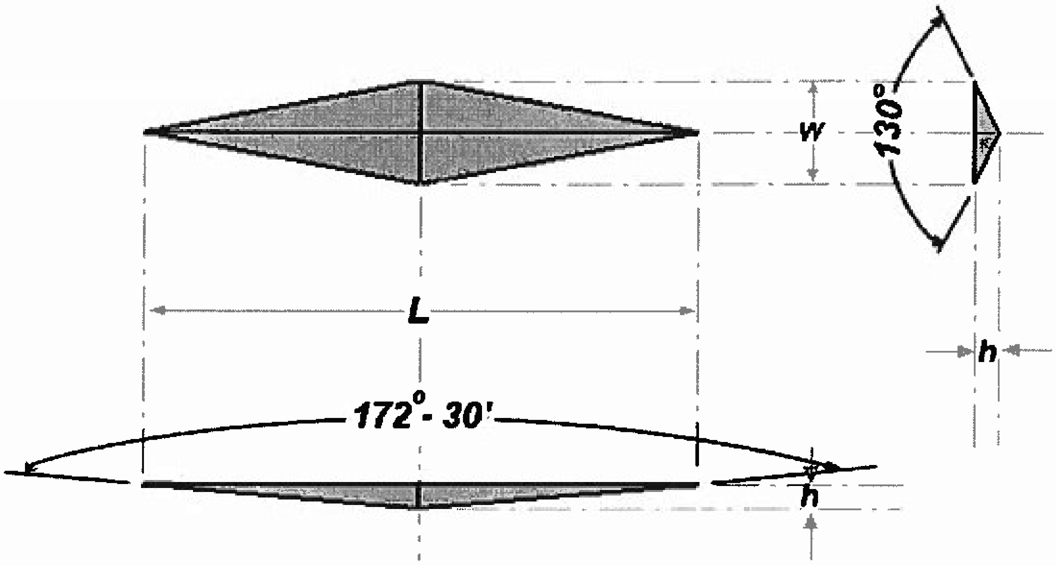
The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.

When the mean diagonal of the indentation has been determined the Vickers hardness may be calculated from the formula, but is more convenient to use conversion tables. The Vickers hardness should be reported like 800 HV/10, which means a Vickers hardness of 800, was obtained using a 10 kgf force. Several different loading settings give practically identical hardness numbers on uniform material, which is much better than the arbitrary changing of scale with the other hardness testing methods. The advantages of the Vickers hardness test are that extremely accurate readings can be taken, and just one type of indenter is used for all types of metals and surface treatments. Although thoroughly adaptable and very precise for testing the

Micro-hardness Test

Knoop Hardness Test

The term microhardness test usually refers to static indentations made with loads not exceeding 1 kgf. The indenter is either the Vickers diamond pyramid or the Knoop elongated diamond pyramid. The procedure for testing is very similar to that of the standard Vickers hardness test, except that it is done on a microscopic scale with higher precision instruments. The surface being tested generally requires a metallographic finish; the smaller the load used, the higher the surface finish required. Precision microscopes are used to measure the indentations; these usually have a magnification of around X500 and measure to an accuracy of ±0.5 micrometres. Also with the same observer differences of ±0.2 micrometres can usually be resolved. It should, however, be added that considerable care and experience are necessary to obtain this accuracy.



The Knoop hardness number KHN is the ratio of the load applied to the indenter, P (kgf) to the unrecovered projected area A (mm^2)

$$KHN = F/A = P/CL^2$$

Where:

F = applied load in kgf

A = the unrecovered projected area of the indentation in mm^2

Ductile Fracture

Stages of ductile fracture

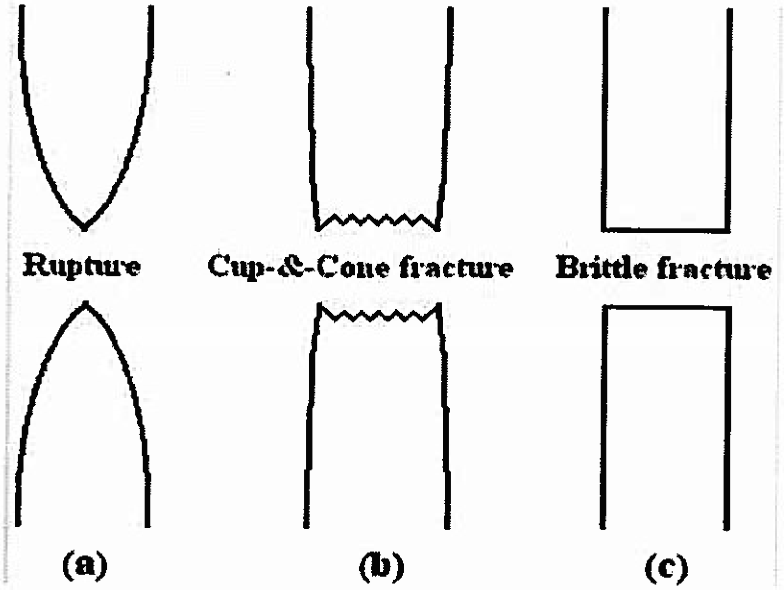
- Initialnecking
  - Small cavity formation (microvoids)
  - Void growth (ellipsoid) by coalescence into acrack
  - Fast crack propagation around neck. Shear strain at45$_o$
  - Final shear fracture (cup andcone)

The interior surface is fibrous, irregular, which signify plastic deformation.

Brittle Fracture

There is no appreciable deformation, and crack propagation is very fast. In most brittle materials, crack propagation (by bond breaking) is along specific crystallographic planes (***cleavage*** planes). This type of fracture is transgranular (through grains) producing grainy texture (or faceted texture) when cleavage direction changes from grain to grain. In some materials, fracture is intergranular.

Fracture occurs due to *stress concentration* at flaws, like surface scratches, voids,

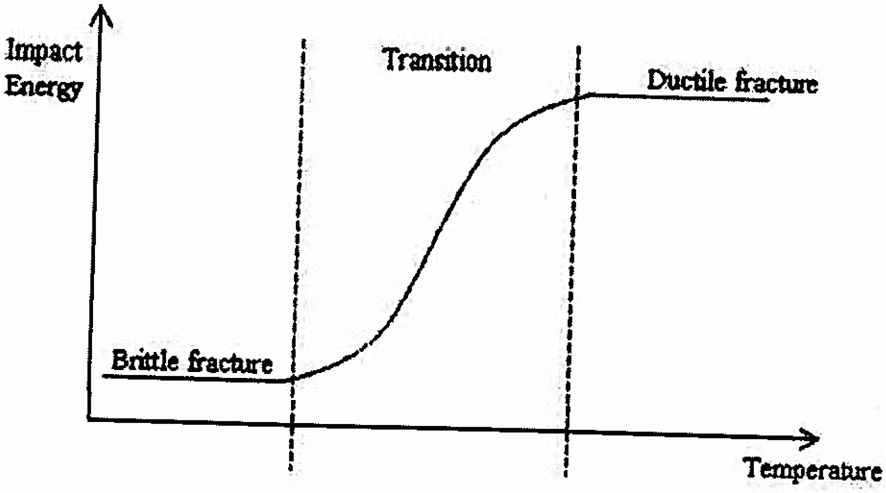


is lowered, the impact energy drops over a narrow temperature range as the fracture becomes more brittle.

The transition can also be observed from the fracture surfaces, which appear fibrous or dull for totally ductile fracture, and granular and shiny for totally brittle fracture. Over the ductile-to-brittle transition features of both types will exist.

While for pure materials the transition may occur very suddenly at a particular temperature, for many materials the transition occurs over a range of temperatures. This causes difficulties when trying to define a single transition temperature and no specific criterion has been established.

The ductile-brittle transition is exhibited in bcc metals, such as low carbon steel, which become brittle at low temperature or at very high strain rates. Fcc metals, however, generally remain ductile at low temperatures.



Fatigue:

Fatigue is the catastrophic failure due to dynamic (fluctuating) stresses. It can happen in bridges, airplanes, machine components, etc. The characteristics are: • long period of cyclic strain

- the most usual (90%) of metallic failures (happens also in ceramics andpolymers)
- is brittle-like even in ductile metals, with little plasticdeformation
- it occurs in stages involving the initiation andpropagation ofcracks.

The Creep Curve

Creep in metals is defined as time dependent plastic deformation at constant stress (or load) and temperature. The form of a typical creep curve of strain versus time is in Figure. The slope of this curve is the **creep rate** $d\varepsilon/dt$. The curve may show the instantaneous elastic and plastic strain that occurs as the load is applied, followed by the plastic strain which occurs over time. Three stages to the creep curve may beidentified:

Primary creep: in which the creep resistance increases with strain leading to a decreasing creep strain rate.

Secondary (Steady State) creep: in which there is a balance between work hardening and recovery processes, leading to a minimum constant creep rate.

Tertiary creep: in which there is an accelerating creep rate due to the accumulating damage, which leads to creep rupture, and which may only be seen at high temperatures and stresses and in constant load machines.

The minimum secondary creep rate is of most interest to design engineers, since failure avoidance is required and in this region some predictability is possible. In the USA two Standards are commonly used: (i) The stress to produce a creep rate of 0.0001% per hour (1% in 10,000 hours). (ii) The stress to produce a creep rate of 0.00001% per hour (1% in 100,000 hours or approximately 11.5 years). The first requirement would be typical of that for gas turbine blades, while the second for steam turbines. Constant load machines simulate real engineering situations more accurately, but as the specimen extends its cross section area reduces, leading to a rising stress. Machines designed to reduce the load to compensate for the reduced area and maintain constant stress may produce an extended steady stateregion.

Dislocations and Strengthening Mechanisms

Basic Concept of dislocation

Dislocations can be *edge dislocations, screw dislocations* and exist in combination of the two. Their motion (slip) occurs by sequential bond breaking and bond reforming . The number of dislocations per unit volume is the *dislocation density*, in a plane they are measured per unit area.

Characteristics of Dislocations

There is strain around a dislocation which influences how they interact with other dislocations, impurities, etc. There is *compression* near the extra plane (higher atomic density) and *tension* following the dislocation line. Dislocations interact among themselves. When they are in the same plane, they repel if they have the same sign and annihilate if they have opposite signs (leaving behind a perfect crystal). In general, when dislocations are close and their strain fields add to a larger value, they repel, because being close increases the potential energy (it takes energy to strain a region of the material). The number of dislocations increases dramatically during plastic deformation. Dislocations spawn from existing dislocations, and from defects, grain boundaries and surface irregularities.

Plastic Deformation

Slip directions vary from crystal to crystal. When plastic deformation occurs in a grain, it will be constrained by its neighbors, which may be less favorably oriented. As a result, *polycrystalline metals are stronger than single crystals* (the exception is the perfect single crystal, as in whiskers.)

Mechanisms of Strengthening in Metals

General principles. Ability to deform plastically depends on ability of dislocations to move. Strengthening consists in hindering dislocation motion. We discuss the methods of grain-size reduction, solid-solution alloying and strain hardening. These are for single phase metals. We discuss others when treating alloys. Ordinarily, strengthening reduces ductility.

NDT are: **magnetic dust method, penetrating liquid method, ultrasonic test and radiography**. All NDTs are used to detect various types of flaws on the surface of material or internal inclusions of impurities and these techniques are also very useful during preventive maintenance and repair. There are few techniques which do not require any special apparatus and are quite simple to handle and only a moderate skill being required. Some of the applications of NDTs are detecting: (i) surface cracks (ii) material composition (iii) internal inclusions (iv) internal voids and discontinuities and (v) condition of internal stresses.

Ultrasonic Test

High frequency ultrasonic (sound) waves are applied to the test piece by a Piezoelectric crystal. If the test piece is free from cracks, or flawless, then it reflects ultrasonic waves without distortion. If there are any flaws in the specimen, the time taken by the ultrasonic waves will be less as the reflection of these waves will be from flaw points and not from the bottom of the specimen. Cathode ray oscilloscope (CRO) is used to receive the sound signals, whose time base circuit is connected to it. Knowing the time interval between the transmission of the sound pulse and the reception of the echo signal, we can calculate the depth of the crack. This test is a very fast method of inspection and often used to test aerospace components and automobiles. This test is generally used to detect internal cracks like shrinkage cavities, hot tears, zones of corrosion and non-metallicinclusions.

Liquid-Penetration test

This test is employed for detection of small defects which are very small to detect with the naked eye. This test is used to detect surface cracks or flaws in non-ferrous metals. This test employs a visible colour contrast dye penetrant technique for the detection of open surface flaws in metallic and non-metallic objects. The penetrants are applied by spraying over the surface of material to be inspected. The excess penetrant is then washed or cleaned. Absorbent powder is then applied to absorb the penetrants in the cracks, voids which reveals the flaws. This test reveals flaws such as shrinkage cracks, porosity, fatigue cracks, grinding cracks, forging cracks, seams, heat treatment cracks and leaks etc., on castings, weldings, machined parts, cutting tools, pipes and tubes. If the fluorescent penetrant is used, the developed surface must be examined under ultra violet light to see the presence of defects. This technique is used for non-porous and non-absorbent materials. Care may be taken to clean the surface so that it is free from dust, scale, etc.

2. A castable resin/cold mounting (e.g. acrylics resins, epoxy resins and polyesterresins)

c) Grinding

Grinding is required to ensure the surface is flat & parallel and to reduce the damage created during sectioning. Grinding is accomplished by decreasing the abrasive grit size sequentially to obtain the required fine surface finish prior to polishing. It is important to note that the final appearance of the prepared surface is dependent on the machine parameters such as grinding/polishing pressure, relative velocity distribution and the direction of grinding/polishing.

d) Polishing

For microstructure examination a mirror/reflective finish is needed whereas a finely ground finish is adequate for macrostructure evaluation. Polishing can be divided into two mainsteps:

1. Roughpolishing

The purpose is to remove the damage produced during grinding. Proper polishing will maintain the specimen flatness and retain all inclusions or secondary phases by eliminating the previous damage and maintaining the specimen integrity.

2. Finepolishing

The purpose is to remove only surface damage.

e) Etching

Etchans are specially formulated for the specific material and evaluation objectives. Etching alters the microstructural features based on composition; stress or crystal structure and it will develop the surface topology, which can be visible in the microscope. Typically, chemical etching involve immersing the polished surface in the prepared chemical solution for a specified time (usually seconds) followed by rinsing the etched specimen under running tap water and drying.

the number of grains per square inch at a magnification of 100X by the relationship

$$N^{*} = 2^{n-1}$$

Table shown compares the ASTM grain-size numbers with several other useful measures of grain size.

ASTM #	Grains/in^2 @ 100X	Grains/mm^2	Grains/mm^3	Ave. Grain Dia. (mm)
-3	0.06	1	0.7	1,00
-2	0.12	2	2	0.75
-1	0.25	4	5.6	0.50
0	0.5	8	16	0.35
1	1	16	45	0.25
2	2	32	128	0.18
3	4	64	360	0.125
4	8	128	1020	0.091
5	16	256	2990	0.062
6	32	512	8200	0.044
7	64	1024	23000	0.032
8	128	2048	65000	0.022
9	256	4096	185000	0.016
10	512	8200	520000	0.011
11	1024	16400	1200000	0.008
12	2048	32800	1500000	0.00096

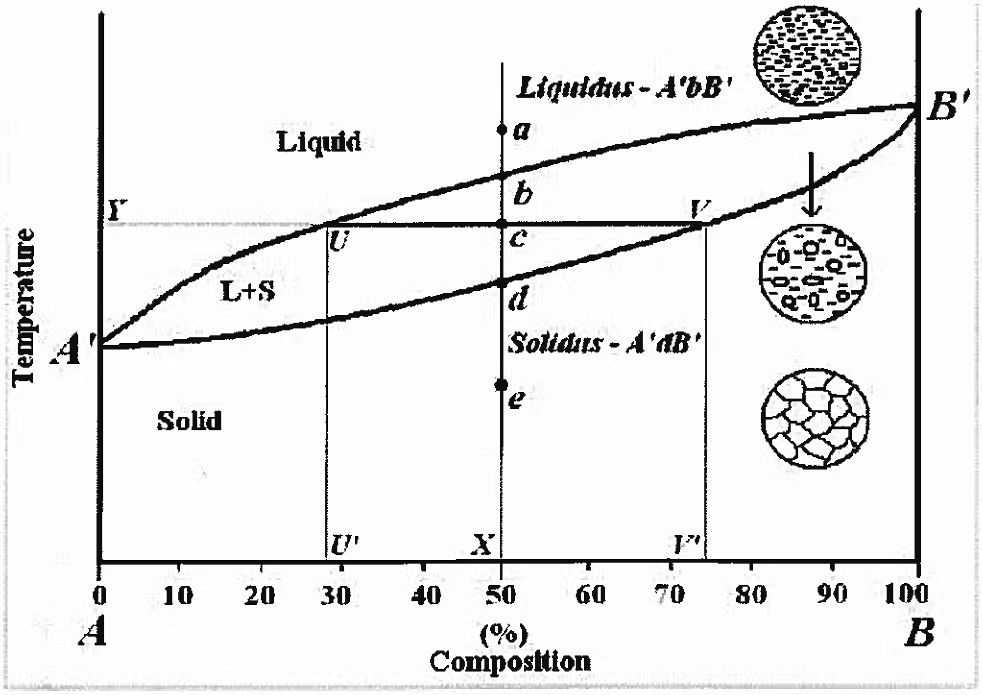
Phase Diagrams

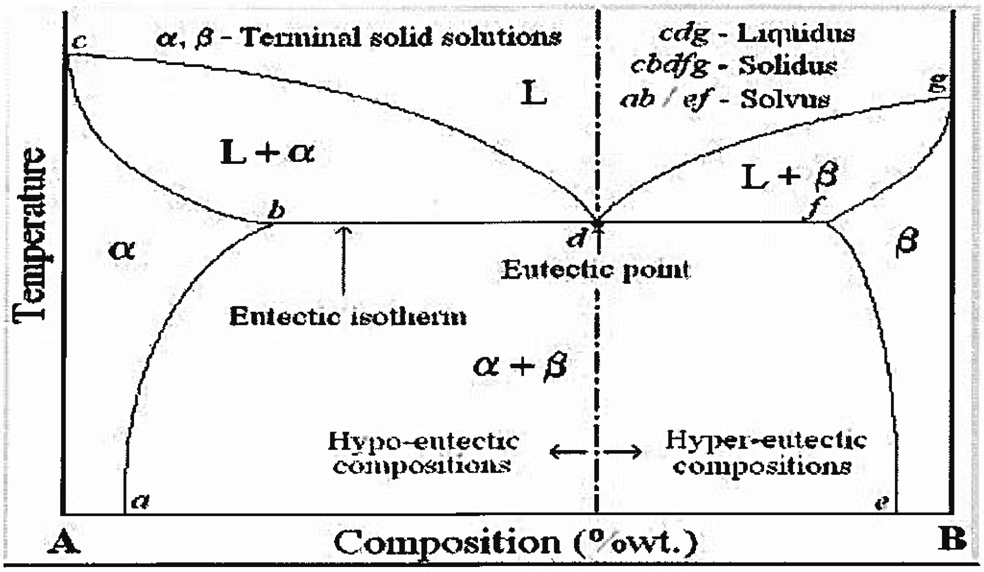
Equilibrium Phase Diagrams

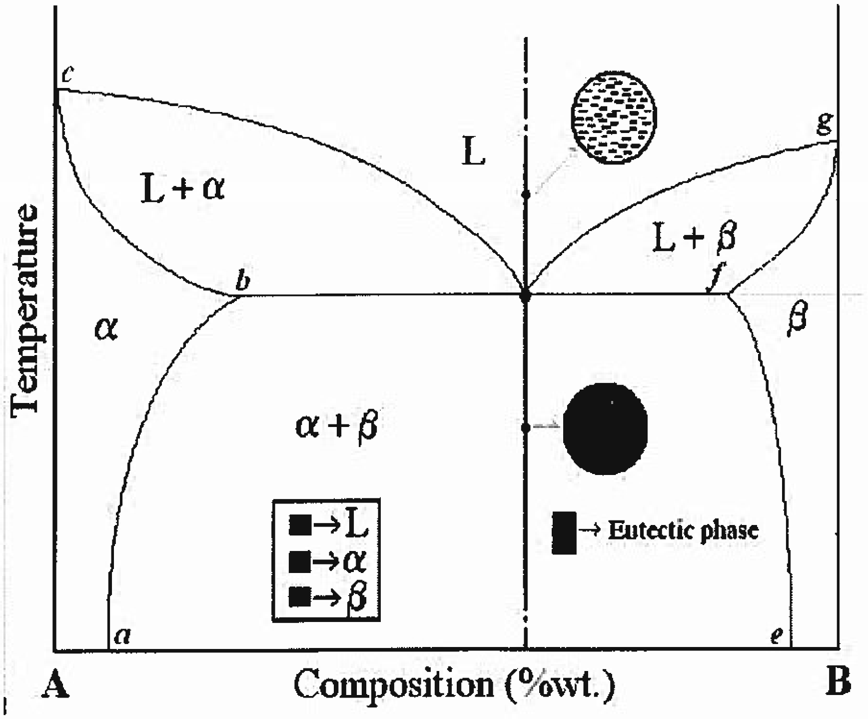
Give the relationship of composition of a solution as a function of temperatures and the quantities of phases in equilibrium. These diagrams do not indicate the dynamics when one phase transforms into another. Sometimes diagrams are given with pressure as one of the variables. In the phase diagrams we will discuss, pressure is assumed to be constant at one atmosphere.

Binary Isomorphous Systems

This very simple case is one complete liquid and solid solubility, an *isomorphous* system. The example is the Cu-Ni alloy of Fig. 9.2a. The complete solubility occurs because both Cu and Ni have the same crystal structure (FCC), near the same radii, electronegativity and valence. The *liquidus line* separates the liquid phase from solid or solid + liquid phases. That is, the solution is lower than that of the components (eutectic = easy to melt in Greek).• At most two phases can be in equilibrium within a phase field.• Single-phase regions are separated by 2-phase regions.



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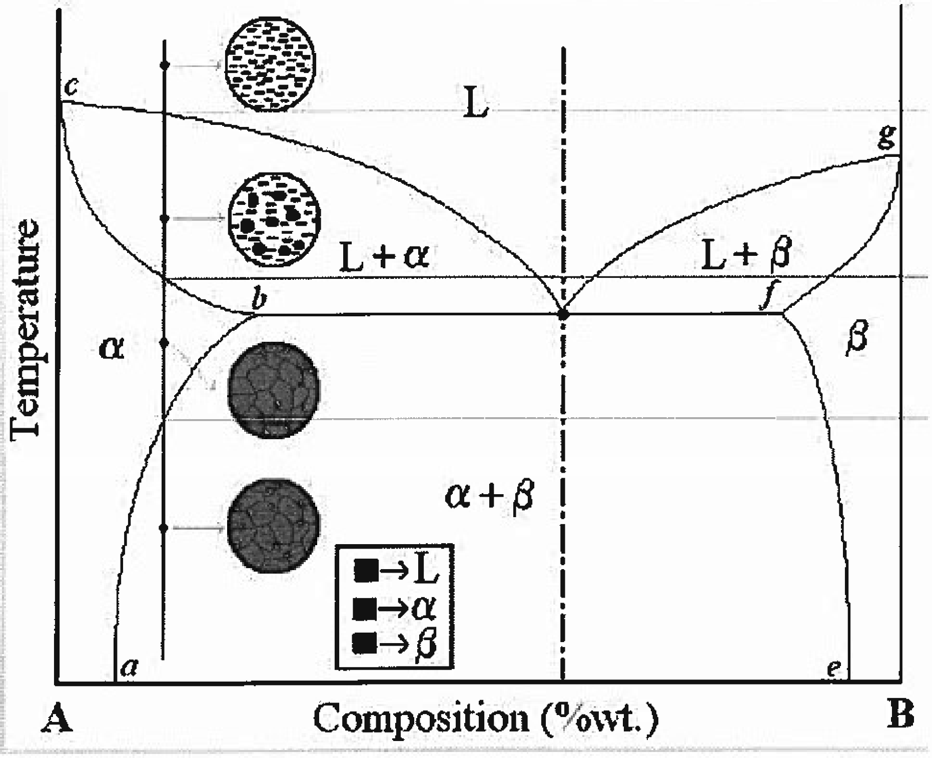
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Temperature
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Composition (%wt.)
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treatments. The process is called **precipitation hardening** because the small particles of the new phase are termed "precipitates". Precipitation hardening and the treating of steel to form tempered matrensite are totally different phenomena, even though the heat treatment procedures aresimilar.

Precipitation reactions

A precipitation reaction is a reaction in which soluble ions in separate solutions are mixed together to form an insoluble compound that settles out of solution as a solid. That insoluble compound is called a precipitate

Kinetics of nucleation and growth

From a micro structural standpoint, the first process to accompany a phase transformation **is nucleation-** the formation of very small particles or nuclei, of the new phase which are capable of growing. The second stage is **growth**, in which the nuclei increase in size; during this process, some volume of the parent phase disappears. The transformation reaches completion if growth of these new phase particles is allowed to proceed until the equilibrium fraction isattained.

As would be expected, the time dependence of the transformations rate (which is often termed the **kinetics** of a transformation) is an important consideration in the heat treatment of materials. With many investigations, the fraction of reaction that has occurred is measured as a function of time, while the temperature is maintained constant. Transformation progress is usually ascertained by either microscopic examination or measurement of some physical property. Data are plotted as the fraction of transformed material versus the logarithm of time; an S-shaped curve, represents the typical kinetic behavior for most solid statereactions.

Solid Solutions

A solid solution may be formed when impurity atoms are added to a solid, in which case the original crystal structure is retained and no new phases are formed.

- **Substitutional solid solutions:** impurity atoms substitute for host atoms, and appreciable solubility is possible only when atomic diameters and electronegativities for both atom types are similar, when both elements have the same crystal structure, and when the impurity atoms have a valence that is the same as or less than the hostmaterial.

The maximum solubility of C in α- ferrite is 0.022 wt%. δ−ferrite is only stable at high temperatures. It is not important in practice. Austenite has a maximum C concentration of 2.14 wt %. It is not stable below the eutectic temperature (727 C) unless cooled rapidly (Chapter 10). Cementite is in reality metastable, decomposing into α-Fe and C when heated for several years between 650 and 770C.

- **δ-ferrite:** – It is solid solution of carbon in δ-iron. Maximum concentration of carbon in δ-ferrite is 0.09% at 2719 °F (1493°C) which is the temperature of the peritectic transformation. The crystal structure of δ-ferrite is BCC (cubic bodycentered).
- **Austenite:** – Austenite is interstitial solid solution of carbon in γ-iron. Austenite has FCC (cubic face centered) crystal structure, permitting high solubility of carbon i.e. up to 2.06% at 2097 °F (1147 °C). Austenite does not exist below 1333 °F (723°C) and maximum carbon concentration at this temperature is0.83%.
- **α-ferrite:** – It is solid solution of carbon in α-iron. α-ferrite has BCC crystal structure and low solubility of carbon – up to 0.025% at 1333 °F (723°C). α-ferrite exists at room temperature.

- **Cementite** – Cementite is also known as iron carbide, is an intermetallic compound of iron and carbon, having fixed composition Fe_3C. Cementite is a hard and brittle substance, influencing the properties of steels and castirons.

Critical temperatures

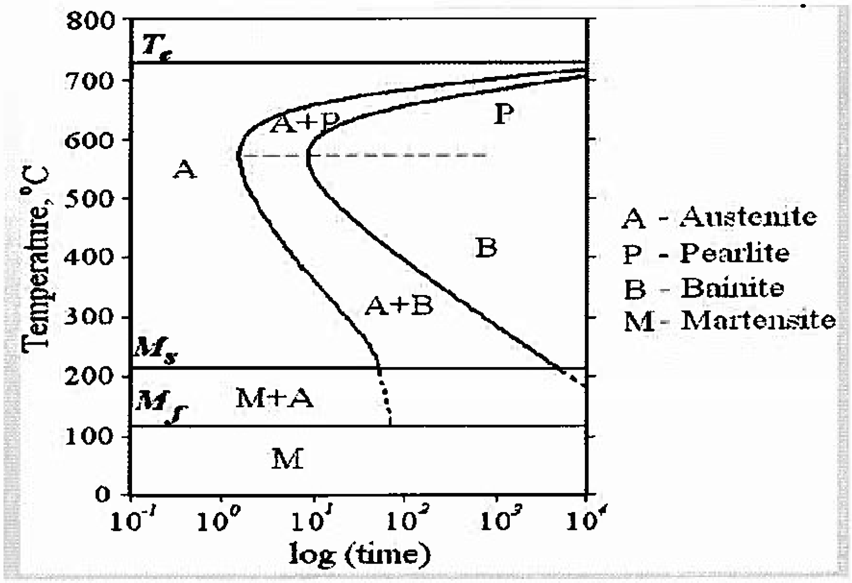
- **Upper critical temperature (point)** $A_3$is the temperature, below which ferrite starts to form as a result of ejection from austenite in the hypo-eutectoidalloys.
- **Upper critical temperature (point)** $A_{CM}$is the temperature, below which cementite starts to form as a result of ejection from austenite in the hyper-eutectoidalloys.
- **Lower critical temperature (point)** $A_1$is the temperature of the austenite-to-Pearlite eutectoid transformation. Below this temperature austenite does notexist.
- **Magnetic transformation temperature** $A_2$is the temperature below which α-ferrite isferromagnetic.

The Influence of Other Alloying Elements

Alloying strengthens metals by hindering the motion of dislocations. Thus, the strength of Fe–C alloys increase with C content and also with the addition of other elements.

Time-temperature transformation (TTT) diagrams measure the rate of transformation at a constant temperature. In other words a sample is austenitised and then cooled rapidly to a lower temperature and held at that temperature whilst the rate of transformation is measured, for example by dilatometry. Obviously a large number of experiments is required to build up a complete TTT diagram.

- An increase in carbon content shifts the TTT curve to the right (this corresponds to an increase in hardenability as it increases the ease of forming martensite - i.e. the cooling rate required to attain martensite is lesssevere).
- An increase in carbon content decreases the martensite starttemperature.
- An increase in Mo content shifts the TTT curve to the right and also separates the ferrite + pearlite region from the bainite region making the attainment ofa bainitic structure more controllable.



temperatures). This reduced grain growth leads to fine-grained microstructure **(fine pearlite).** At higher temperatures, diffusion allows for larger grain growth, thus leading to **coarse pearlite.**
At lower temperatures nucleation starts to become slower, and a new phase is formed, **bainite**. Since diffusion is low at low temperatures, this phase has a very fine (microscopic) microstructure.

Spheroidite is a coarse phase that forms at temperatures close to the eutectoid temperature. The relatively high temperatures caused a slow nucleation but enhances the growth of the nuclei leading to large grains.

A very important structure is **martensite**, which forms when cooling austenite very fast (**quenching**) to below a maximum temperature that is required for the transformation. It forms nearly instantaneously when the required low temperature is reached; since no thermal activation is needed, this is called an *athermal transformation.* Martensite is a different phase, a body-centered tetragonal (BCT) structure with interstitial C atoms. Martensite is *metastable* and decomposes into ferrite and pearlite but this is extremely slow (and not noticeable) at room temperature.
In the examples, we used an eutectoid composition. For hypo- and hypereutectoid alloys, the analysis is the same, but the proeutectoid phase that forms before cooling through the eutectoid temperature is also part of the final microstructure.

Various types of carbon steel

Carbon steel is steel in which the main interstitial alloying constituent is carbon in the range of 0.12–2.0%. The American Iron and Steel Institute (AISI) defines carbon steel as the following: "Steel is considered to be carbon steel when no minimum content is specified or required for chromium, cobalt, molybdenum, nickel, niobium, titanium, tungsten, vanadium or zirconium, or any other element to be added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40 percent; or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65, silicon 0.60, copper 0.60.

Types:

Carbon steel is broken down into four classes based on carbon content:

Mild and low-carbon steel

Mild steel also known as plain-carbon steel, is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications, more so than iron. Low-carbon steel contains approximately 0.05–0.320 % carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased throughcarburizing.

It is often used when large quantities of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm^3 (7850 kg/m^3 or 0.284 lb/in^3) and the Young's modulus is 210 GPa (30,000,000 psi).

Low-carbon steels suffer from yield-point run out where the material has two yield points. The first yield point (or upper yield point) is higher than the second and the yield drops dramatically after the upper yield point. If low-carbon steel is only stressed to some point between the upper and lower yield point then the surface may develop louder bands. Low-carbon steels contain less carbon than other steels and are easier to cold-form, making them easier to handle.

arbitrary: Smith and Has hemi define the difference at 4.0%, while Degarmo, et al., define it at 8.0%. Most commonly, the phrase "alloy steel" refers to low-alloy steels.

Types:

According to the World Steel Association, there are over 3,500 different grades of steel, encompassing unique physical, chemical and environmental properties.

In essence, steel is composed of iron and carbon, although it is the amount of carbon, as well as the level of impurities and additional alloying elements that determines the properties of each steel grade.

The carbon content in steel can range from 0.1-1.5%, but the most widely used grades of steel contain only 0.1-0.25% carbon. Elements such as manganese, phosphorus and sulphur are found in all grades of steel, but, whereas manganese provides beneficial effects, phosphorus and sulphur are deleterious to steel's strength anddurability.

Different types of steel are produced according to the properties required for their application, and various grading systems are used to distinguish steels based on these properties. According to the American Iron and Steel Institute (AISI), steels can be broadly categorized into four groups based on their chemical compositions:

1. CarbonSteels
2. AlloySteels
3. StainlessSteels
4. ToolSteels

1) CarbonSteels:

Carbon steels contain trace amounts of alloying elements and account for 90% of total steel production. Carbon steels can be further categorized into three groups depending on their carbon content:

- Low Carbon Steels/Mild Steels contain up to 0.3%carbon
- Medium Carbon Steels contain 0.3 – 0.6%carbon

Steel products can also be divided by their shapes and related applications:

- Long/Tubular Products include bars and rods, rails, wires, angles, pipes, and shapes and sections. These products are commonly used in the automotive and constructionsectors.
- Flat Products include plates, sheets, coils and strips. These materials are mainly used in automotive parts, appliances, packaging, shipbuilding, andconstruction.
- Other Products include valves, fittings, and flanges and are mainly used as piping materials.

Cast iron

Cast iron is iron or a ferrous alloy which has been heated until it liquefies, and is then poured into a mould to solidify. It is usually made from pig iron. The alloy constituents affect its colour when fractured: white cast iron has carbide impurities which allow cracks to pass straight through. Grey cast iron has graphite flakes which deflect a passing crack and initiate countless new cracks as the materialbreaks.

Carbon (C) and silicon (Si) are the main alloying elements, with the amount ranging from 2.1–4 wt% and 1–3 wt%, respectively. Iron alloys with less carbon content are known as steel. While this technically makes these base alloys ternary Fe–C–Si alloys, the principle of cast iron solidification is understood from the binary iron–carbon phase diagram. Since the compositions of most cast irons are around the eutectic point of the iron–carbon system, the melting temperatures closely correlate, usually ranging from 1,150 to 1,200 °C (2,100 to 2,190 °F), which is about 300 °C (572 °F) lower than the melting point of pureiron.

Cast iron's properties are changed by adding various alloying elements, or alloyants. Next to carbon, silicon is the most important alloying because it forces carbon out of solution. Instead the carbon forms graphite which results in a softer iron, reduces shrinkage, lowers strength, and decreases density. Sulfur, when present, forms iron sulfide, which prevents the formation of graphite and increases hardness. The problem with sulfur is that it makes molten cast iron sluggish, which causes short run defects. To counter the effects of sulfur, manganese is added because the two form into manganese sulfide instead of iron sulfide. The manganese sulfide is lighter than the melt so it tends to float out of the melt and into the slag. The amount of manganese required to neutralize sulfur is 1.7 × sulfur content + 0.3%. If more than this amount cementite which precipitates from the melt forms as relatively large particles, usually in a eutectic mixture, where the other phase is austenite (which on cooling might transform to martensite). These eutectic carbides are much too large to provide precipitation hardening (as in some steels, where cementite precipitates might inhibit plastic deformation by impeding the movement of dislocations through the ferrite matrix). Rather, they increase the bulk hardness of the cast iron simply by virtue of their own very high hardness and their substantial volume fraction, such that the bulk hardness can be approximated by a rule of mixtures. In any case, they offer hardness at the expense of toughness. Since carbide makes up a large fraction of the material, white cast iron could reasonably be classified as a cermet. White iron is too brittle for use in many structural components, but with good hardness and abrasion resistance and relatively low cost, it finds use in such applications as the wear surfaces (impeller and volute) of slurry pumps, shell liners and lifter bars in ball mills and autogenous grinding mills, balls and rings in coal pulverisers, and the teeth of a backhoe's digging bucket (although cast medium-carbon martensitic steel is more common for thisapplication).

It is difficult to cool thick castings fast enough to solidify the melt as white cast iron all the way through. However, rapid cooling can be used to solidify a shell of white cast iron, after which the remainder cools more slowly to form a core of grey cast iron. The resulting casting, called a chilled casting, has the benefits of a hard surface and a somewhat tougher interior.

High-chromium white iron alloys allow massive castings (for example, a 10-tonne impeller) to be sand cast, i.e., a high cooling rate is not required, as well as providing impressive abrasion resistance. These high-chromium alloys attribute their superior hardness to the presence of chromium carbides. The main form of these carbides are the eutectic or primary M7C3 carbides, where "M" represents iron or chromium and can vary depending on the alloy's composition. The eutectic carbides form as bundles of hollow hexagonal rods and grow perpendicular to the to the hexagonal basal plane. The hardness of these carbides are within the range of1500-1800HV

Malleable cast iron

Malleable iron starts as a white iron casting that is then heat treated at about 900 °C (1,650 °F). Graphite separates out much more slowly in this case, so that surface tension has time to form it into spheroidal particles rather than flakes. Due to their lower aspect ratio, spheroids are materials, exposure and other factors may dictate that different treatments be used to correct similar problems. Any material in question should be evaluated as a part of a larger system and treatment plans should be based upon consideration of all relevant factors.

Heat Treatment

Heat Treatment is the controlled heating and cooling of metals to alter their physical and mechanical properties without changing the product shape. Heat treatment is sometimes done inadvertently due to manufacturing processes that either heat or cool the metal such as welding or forming. Heat Treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives such as improve machining, improve formability, restore ductility after a cold working operation. Thus it is a very enabling manufacturing process that can not only help other manufacturing process, but can also improve product performance by increasing strength or other desirablecharacteristics.

Steels are particularly suitable for heat treatment, since they respond well to heat treatment and the commercial use of steels exceeds that of any other material. Steels are heat treated for one of the following reasons:

1. Softening
2. Hardening
3. Materialmodification

Softening: Softening is done to reduce strength or hardness, remove residual stresses, improve toughness, restore ductility, refine grain size or change the electromagnetic properties of the steel. Restoring ductility or removing residual stresses is a necessary operation when a large amount of cold working is to be performed, such as in a cold-rolling operation or wiredrawing. Annealing — full Process, spheroidizing, normalizing and tempering austempering, martempering are the principal ways by which steel issoftened.

Hardening: Hardening of steels is done to increase the strength and wear properties. One of the pre-requisites for hardening is sufficient carbon and alloy content. If there is sufficient Carbon with ferrite or Cementite (depending on whether hypo or hyper eutectoid). The steel becomes soft andductile.

Normalizing is the process of raising the temperature to over 60 ° C (108 °F), above line A_3 or line A_{CM} fully into the Austenite range. It is held at this temperature to fully convert the structure into Austenite, and then removed form the furnace and cooled at room temperature under natural convection. This results in a grain structure of fine Pearlite with excess of Ferrite or Cementite. The resulting material is soft; the degree of softness depends on the actual ambient conditions of cooling. This process is considerably cheaper than full annealing since there is not the added cost of controlled furnace cooling.

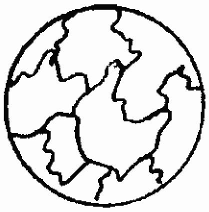
Process Annealing is used to treat work-hardened parts made out of low-Carbon steels (< 0.25% Carbon). This allows the parts to be soft enough to undergo further cold working without fracturing. Process annealing is done by raising the temperature to just below the Ferrite-Austenite region, line A_1on the diagram. This temperature is about 727 °C (1341 °F) so heating it to about 700 °C (1292 °F) should suffice. This is held long enough to allow recrystallization of the ferrite phase, and then cooled in still air. Since the material stays in the same phase through out the process, the only change that occurs is the size, shape and distribution of the grain structure. This process is cheaper than either full annealing or normalizing since the material is not heated to a very high temperature or cooled in a furnace.

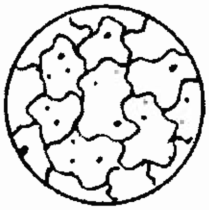
Stress Relief Anneal is used to reduce residual stresses in large castings, welded parts and cold-formed parts. Such parts tend to have stresses due to thermal cycling or work hardening. Parts are heated to temperatures of up to 600 - 650 °C (1112 - 1202 °F), and held for an extended time (about 1 hour or more) and then slowly cooled in stillair.

Spheroidization is an annealing process used for high carbon steels (Carbon > 0.6%) that will be machined or cold formed subsequently. This is done by one of the followingways:

Heat the part to a temperature just below the Ferrite-Austenite line, line A_1 or below the Austenite-Cementite line, essentially below the 727 °C (1340 °F) line. Hold the temperature for a prolonged time and follow by fairly slow cooling. **Or**

The heating for tempering is best done by immersing the parts in oil, for tempering upto 350 °C (662 °F) and then heating the oil with the parts to the appropriate temperature. Heating in a bath also ensures that the entire part has the same temperature and will undergo the same tempering. For temperatures above 350 °C (662 °F) it is best to use a bath of nitrate salts. The salt baths can be heated upto 625 °C (1157 °F). Regardless of the bath, gradual heating is important to avoid cracking the steel. After reaching the desired temperature, the parts are held at that temperature for about 2 hours, then removed from the bath and cooled in still air.


CEMENTITE


FERRITE

Hardening

Hardness is a function of the Carbon content of the steel. Hardening of a steel requires a change in structure from the body-centered cubic structure found at room temperature to the face-centered cubic structure found in the Austenitic region. The steel is heated to Autenitic region. When suddenly quenched, the Martensite is formed. This is a very strong and brittle structure. When slowly quenched it would form Austenite and Pearlite which is a partly hard and partly soft structure. When the cooling rate is extremely slow then it would be mostly Pearlite which is extremelysoft.

Usually when hot steel is quenched, most of the cooling happens at the surface, as does the hardening. This propagates into the depth of the material. Alloying helps in the hardening and by determining the right alloy one can achieve the desired properties for the particular application.

1. solution heat treatment where all the solute atoms are dissolved to form a single-phase solution.
2. rapid cooling across the solvus line to exceed the solubility limit. This leads to a supersaturated solid solution that remains stable (metastable) due to the low temperatures, which preventdiffusion.
3. precipitation heat treatment where the supersaturated solution is heated to an intermediate temperature to induce precipitation and kept there for some time (aging). If the process is continued for a very long time, eventually the hardness decreases. This is called overaging.

The requirements for precipitation hardening are:

- appreciable maximumsolubility
- solubility curve that falls fast withtemperature
- composition of the alloy that is less than the maximumsolubility

Precipitation Hardening

Hardening can be enhanced by extremely small precipitates that hinder dislocation motion. The precipitates form when the solubility limit is exceeded. Precipitation hardening is also called age hardening because it involves the hardening of the material over a prolonged time.

CaseHardening

Case hardening produces a hard, wear-resistant sur- face or case over a strong, tough core. The principal forms of casehardening are carburizing, cyaniding, and nitriding. Only ferrous metals are case-hardened. Case hardening is ideal for parts that require a wear-resistant surface and must be tough enough interally to withstand heavy loading. The steels best suited for case hardening are the low-carbon and low-alloy series. When high-carbon steels are case hardened, the hardness penetrates the core and causes brittleness. In case hardening, you change the surface of the metal chemically by introducing a high carbide or nitride content. The core remains chemically unaffected. When heat-treated, the high-carbon surface responds to hardening, and the coretoughens.

retain their original properties. Whether the process is manual or mechanical, a close watch must be maintained, since the torches heat the metal rapidly and the temperatures are usually determined visually. Flame hardening may be either manual or automatic. Automatic equipment produces uniform results and is more desirable. Most automatic machines have variable travel speeds and can be adapted to parts of various sizes and shapes. The size and shape of the torch depends on the part. The torch consists of a mixing head, straight extension tube, 90-degree extension head, an adjustable yoke, and a water-cooled tip. Practically any shape or size flame-hardening tip is available. Tips are produced that can be used for hardening flats, rounds, gears, cams, cylinders, and other regular or irregular shapes. In hardening localized areas, you should heat the metal with a standard hand-held welding torch. Adjust the torch flame to neutral for normal heating; however, in corners and grooves, use a slightly oxidizing flame to keep the torch from sputtering. You also should particularly guard against overheating in comers and grooves. If dark streaks appear on the metal surface, this is a sign of overheating, and you need to increase the distance between the flame and the metal. For the best heating results, hold the torch with the tip of the inner cone about an eighth of an inch from the surface and direct the flame at right angles to the metal. Sometimes it is necessary to change this angle to obtain better results; however, you rarely find a deviation of more than 30 degrees. Regulate the speed of torch travel according to the type of metal, the mass and shape of the part, and the depth of hardness desired. In addition, you must select the steel according to the properties desired. Select carbon steel when surface hardness is the primary factor and alloy steel when the physical properties of the core are also factors. Plain carbon steels should contain more than 0.35% carbon for good results inflame hardening. For water quench- ing, the effective carbon range is from 0.40% to 0.70%. Parts with a carbon content of more than 0.70% are likely to surface crack unless the heating and quenching rate are carefully controlled. The surface hardness of a flame-hardened section is equal to a section that was hardened by furnace heating and quenching. The decrease in hardness between the case and the core is gradual. Since the core is not affected by flame hardening, there is little danger of spalling or flaking while the part is in use. Thus flame hardening produces a hard case that is highly resistant to wear and a core that retains its original properties. Flame hardening can be divided into five general methods: stationary, circular band progressive, straight- line progressive, spiral band progressive, and circular bandspinning.

Steady-State Diffusion

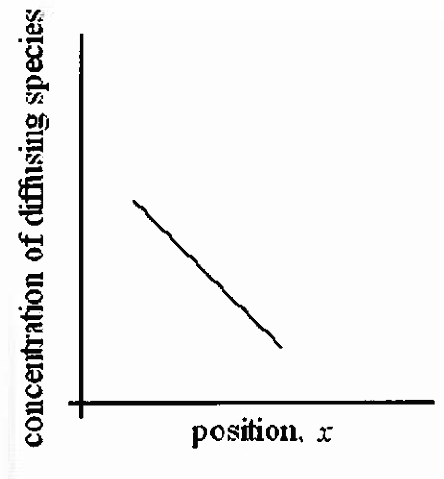
The flux of diffusing atoms, *J*, is expressed either in number of atoms per unit area and per unit time (e.g., atoms/m_2-second) or in terms of mass flux (e.g., kg/m_2-second).Steady state diffusion means that *J* does not depend on time. In this case, ***Fick's first law*** holds that the flux along direction *x* is:

$$J = -D\, dC/dx$$

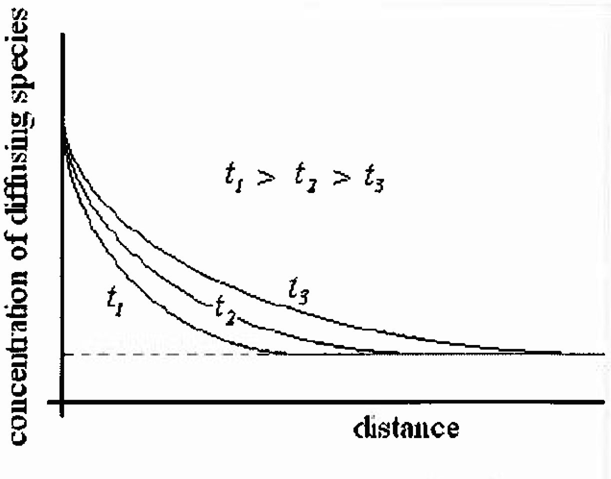
Where *dC/dx* is the gradient of the concentration *C*, and *D* is the diffusion constant. The concentration gradient is often called the *driving force* in diffusion (but it is not a force in the mechanistic sense). The minus sign in the equation means that diffusion is down the concentration gradient.

Nonsteady-State Diffusion

This is the case when the diffusion flux depends on time, which means that a type of atoms accumulates in a region or that it is depleted from a region (which may cause them to accumulate in another region).



Steady-state diffusion



Non-steady-state diffusion

Factors that influence diffusion

As stated above, there is a barrier to diffusion created by neighboring atoms that need to move to let the diffusing atom pass. Thus, atomic vibrations created by temperature assist diffusion. Also, smaller atoms diffuse more readily than big ones, and diffusion is faster in open lattices or in

- clutchdisk,
- diaphragm, fuse clips,
- springs
- Furniture,radiator
- fittings, batteryclamps,
- lightfixtures
- Bearings,bushings,
- valve seats andguards
- Electrical,valves,
- pumps
- Condenser, heatexchanger
- piping,
- valves
- Tin bronzeSn,
- Bearings,bushing,
- piston rings,gears

Aluminum

- Aluminum is a light metal & easily machinable; has wide variety of surface finishes; good electrical and thermal conductivities; highly reflective to heat andlight.
- Versatile metal - can be cast, rolled, stamped, drawn, spun, roll-formed, hammered, extruded and forged into manyshapes.
- Aluminum can be riveted, welded, brazed, or resinbonded.
- Corrosion resistant - no protective coating needed, however it is often anodized to improve surface finish,appearance.
- Al and its alloys - high strength-to-weight ratio (high specific strength) owing to lowdensity.
- Such materials are widely used in aerospace and automotive applications where weight savings are needed for better fuel efficiency andperformance.

Zinc

Zinc (symbol Zn), in commerce also spelter, is a metallic chemical element. It has atomic number 30. It is the first element of group 12 of the periodic table. In some respects zinc is chemically similar to magnesium: its ion is of similar size and its only common oxidation stateis +2. Zinc is the 24th most abundant element in the Earth's crust and has five stable isotopes. The most common zinc ore is sphalerite (zinc blende), a zinc sulfide mineral. The largest mineable amounts are found in Australia, Asia, and the United States. Zinc production includes froth flotation of the ore, roasting, and final extraction using electricity (electrowinning).

Brass, which is an alloy of copper and zinc, has been used since at least the 10th century BC in Judea and by the 7th century BC in Ancient Greece. Zinc metal was not produced on a large scale until the 12th century in India and was unknown to Europe until the end of the 16th century. The mines of Rajasthan have given definite evidence of zinc production going back to 6th century BC. To date, the oldest evidence of pure zinc comes from Zawar, in Rajasthan, as early as the 9th century AD when a distillation process was employed to make pure zinc. Alchemists burned zinc in air to form what they called "philosopher's wool" or "whitesnow".

Applications

Major applications of zinc include

- Galvanizing(55%)
- Alloys(21%)
- Brass and bronze (16%)
- Miscellaneous(8%)

The metal is most commonly used as an anti-corrosion agent. Galvanization, which is the coating of iron or steel to protect the metals against corrosion, is the most familiar form of using zinc in this way. In 2009 in the United States, 55% or 893 thousand tonnes of the zinc metal was used for galvanization.

Zinc is more reactive than iron or steel and thus will attract almost all local oxidation until it completely corrodes away. A protective surface layer of oxide and carbonate forms as the zinc corrodes. This protection lasts even after the zinc layer is scratched but degrades through timeas zinc with small amounts of copper, aluminium, and magnesium are useful in die casting as well as spin casting, especially in the automotive, electrical, and hardware industries. These alloys are marketed under the name Zamak. An example of this is zinc aluminium. The low melting point together with the low viscosity of the alloy makes the production of small and intricate shapes possible. The low working temperature leads to rapid cooling of the cast products and therefore fast assembly is possible. Another alloy, marketed under the brand name Prestal, contains 78% zinc and 22% aluminium and is reported to be nearly as strong as steel but as malleable as plastic. This superplasticity of the alloy allows it to be molded using die casts made of ceramics andcement.

Similar alloys with the addition of a small amount of lead can be cold-rolled into sheets. An alloy of 96% zinc and 4% aluminium is used to make stamping dies for low production run applications for which ferrous metal dies would be too expensiveIn building facades, roofs or other applications in which zinc is used as sheet metal and for methods such as deep drawing, roll forming or bending, zinc alloys with titanium and copper are usedUnalloyed zinc is too brittle for these kinds of manufacturingprocesses.

As a dense, inexpensive, easily worked material, zinc is used as a lead replacement. In the wake of lead concerns, zinc appears in weights for various applications ranging from fishing to tire balances and flywheels.

Cadmium zinc telluride (CZT) is a semi conductive alloy that can be divided into an array of small sensing devices. These devices are similar to an integrated circuit and can detect the energy of incoming gamma ray photons. When placed behind an absorbing mask, the CZT sensor array can also be used to determine the direction of the rays.

Other industrial uses

Zinc oxide is used as a white pigment in paints. Roughly one quarter of all zinc output in the United States (2009), is consumed in the form of zinc compounds; a variety of which are used industrially. Zinc oxide is widely used as a white pigment in paints, and as a catalyst in the manufacture of rubber. It is also used as a heat disperser for the rubber and acts to protect its polymers from ultraviolet radiation (the same UV protection is conferred to plastics containing zinc oxide) The semiconductor properties of zinc oxide make it useful invaristors and resists tarnishing, and has a high melting point. Chromium oxide was used by the Chinese in the Qin dynasty over 2,000 years ago to coat metal weapons found with the Terracotta Army. Chromium was discovered as an element after it came to the attention of the western world in the red crystalline mineral crocoite (lead(II) chromate), discovered in 1761 and initially used as a pigment. Louis Nicolas Vauquelin first isolated chromium metal from this mineral in 1797. Since Vauquelin's first production of metallic chromium, small amounts of native (free) chromium metal have been discovered in rare minerals, but these are not used commercially. Instead, nearly all chromium is commercially extracted from the single commercially viable orechromite, which is iron chromium oxide Chromite is also now the chief source of chromium for chromiumpigments.

Applications

The strengthening effect of forming stable metal carbides at the grain boundaries and the strong increase in corrosion resistance made chromium an important alloying material for steel. The high-speed tool steels contain between 3 and 5% chromium. Stainless steel, the main corrosion-proof metal alloy, is formed when chromium is added to iron in sufficient concentrations, usually above 11%. For its formation, ferrochromium is added to the molten iron. Also nickel-based alloys increase in strength due to the formation of discrete, stable metal carbide particles at the grain boundaries. For example, Inconel 718 contains 18.6% chromium. Because of the excellent high-temperature properties of these nickel superalloys, they are used in jet engines and gas turbines in lieu of common structural materials.

The relative high hardness and corrosion resistance of unalloyed chromium makes it a good surface coating, being still the most "popular" metal coating with unparalleled combined durability. A thin layer of chromium is deposited on pretreated metallic surfaces by electroplating techniques. There are two deposition methods: Thin, below 1 μm thickness, layers are deposited by chrome plating, and are used for decorative surfaces. If wear-resistant surfaces are needed then thicker chromium layers are deposited. Both methods normally use acidic chromate or dichromate solutions. To prevent the energy-consuming change in oxidation state, the use of chromium(III) sulfate is under development, but for most applications, the established process isused.

Wood preservative

Because of their toxicity, chromium(VI) salts are used for the preservation of wood. For example, chromated copper arsenate (CCA) is used in timber treatment to protect wood from decay fungi, wood attacking insects, including termites, and marineborers

Refractory material

The high heat resistivity and high melting point makes chromite and chromium(III) oxide a material for high temperature refractory applications, like blast furnaces, cement kilns, molds for the firing of bricks and as foundry sands for the casting of metals. In these applications, the refractory materials are made from mixtures of chromite and magnesite. The use is declining because of the environmental regulations due to the possibility of the formation of chromium(VI).

Brasses & Bronzes

Brass is an alloy made of copper and zinc; the proportions of zinc and copper can be varied to create a range of brasses with varying properties. Bronze is an alloy consisting primarily of copper, usually with tin as the main additive. It is hard and tough, and it was so significant in antiquity that the Bronze Age was named after the metal.

Admiralty brass contains 30% zinc, with 1% tin to inhibit dezincification in many environments. Alpha brasses with less than 35% zinc, are malleable, can be worked cold, and are used in pressing, forging, or similar applications. They contain only one phase, with face-centered cubic crystal structure. Alpha-beta brass (Muntz metal), also called duplex brass, is 35–45% zinc and is suited for hot working. It contains both α and β' phase; the β'-phase is body-centered cubic and is harder and stronger than α. Alpha-beta brasses are usually worked hot. Aluminium brass contains aluminium, which improves its corrosion resistance. Red brass is both an American term for the copper-zinc-tin alloy known as gunmetal, and an alloy which is considered both a brass and a bronze. It typically contains 85% copper, 5% tin, 5% lead, and 5% zinc.

Aluminium Bronze

A type of BRONZE in which aluminium is the main alloying metal added to copper. Small amounts of other elements such as iron, manganese, nickel and silicon are added to impart

Typical composition:

Copper 85%

Lead 5%

Tin 5%

Zinc5%

Bronze was especially suitable for use in boat and ship fittings prior to the wide employment of stainless steel owing to its combination of toughness and resistance to salt water corrosion. Bronze is still commonly used in ship propellers and submerged bearings.

In the 20th century, silicon was introduced as the primary alloying element, creating an alloy with wide application in industry and the major form used in contemporary statuary. Sculptors may prefer silicon bronze because of the ready availability of silicon bronze brazing rod, which allows color-matched repair of defects in castings. Aluminium is also used for the structural metal aluminiumbronze.

It is also widely used for cast bronze sculpture. Many common bronze alloys have the unusual and very desirable property of expanding slightly just before they set, thus filling in the finest details of a mold. Bronze parts are tough and typically used forbearings, clips, electrical connectors and springs.

Bronze also has very low metal-on-metal friction, which made it invaluable for the building of cannon where iron cannonballs would otherwise stick in the barrel. It is still widely used today for springs, bearings, bushings, automobile transmission pilot bearings, and similar fittings, and is particularly common in the bearings of small electric motors. Phosphor bronze is particularly suited to precision-grade bearings and springs. It is also used in guitar and pianostrings.

Unlike steel, bronze struck against a hard surface will not generate sparks, so it (along with beryllium copper) is used to make hammers, mallets, wrenches and other durable tools to be used in explosive atmospheres or in the presence of flammable vapors.

Bronze is used to make bronze wool for woodworking applications where steel wool would discolor oak.

UNIT– IV

Intrinsic dielectric strength

Another test term sometimes used is 'intrinsic dielectric strength', which is the maximum voltage gradient a homogeneous substance will withstand in a uniform electric field. This shows the ability of an insulating material to resist breakdown, but practical tests produce lower values for a number ofreasons:

- Defects, voids, and foreign particles introduced during manufacture which lower the dielectric strength locally, having the effect of reducing the test values as the area tested isincreased
- The presence of a stress concentration at the electrode edges or points where the electric field is higher thanaverage.
- Due to the damaging effect of an electric discharge duringtesting
- Because of dielectric heating, which raises the temperature and lowers the breakdown strength.

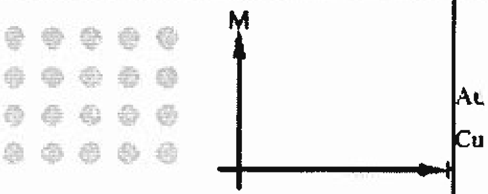
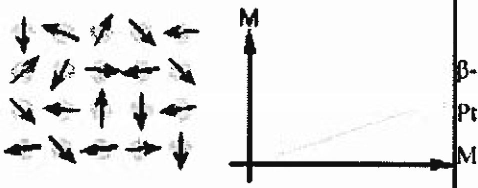
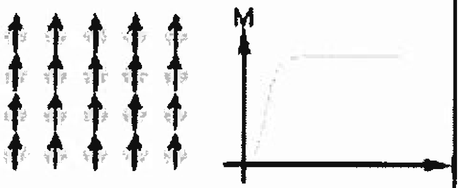
Magnetic Properties

Diamagnetism is a very weak form of magnetism that is nonpermanent and persists only while an external field is being applied. It is induced by a change in the orbital motion of electrons due to an applied magnetic field. The magnitude of the induced magnetic moment is extremely small and in a direction opposite to that of the applied field. Most elements in the periodic table, including copper, silver, and gold, are diamagnetic.

Paramagnetic material is one whose atoms do have permanent dipole moments, but the magic of ferromagnetism is not active. If a magnetic field is applied to such a material, the dipole moments try to line up with the magnetic field, but are prevented from becoming perfectly aligned by their random thermal motion. Because the dipoles try to line up with the applied field, the susceptibilities of such materials are positive, but in the absence of the strong ferromagnetic effect, the susceptibilities are rather small, say in the range to . When a paramagnetic material is placed in a strong magnetic field, it becomes a magnet, and as long as the strong magnetic field is present, it will attract and repel other magnets in the usual way. But when the strong magnetic fieldisremoved,thenetmagneticalignmentislostasthedipolesrelaxbacktotheirnormal

Ferrimagnetism

Some ceramics also exhibit a permanent magnetizations termed ferrimagentism. The macroscopic magnetic characteristics of ferromagnets and ferrimagents are similar; the distinction lies in the source of the net magnetic moments. The net ferrimagentic moment arises from the incomplete cancellation of spinmoments.

Type of Magnetism	*Susceptibility*	*Atomic / Magnetic Behaviour*	*Example / Susceptibility*
Diamagnetism	Small & negative.	Atoms have no magnetic moment 	Au -2.74x10^{-6} Cu -0.77x10^{-6}
Paramagnetism	Small &positive.	Atoms have randomly oriented magnetic moments 	β-Sn 0.19x10^{-6} Pt 21.04x10^{-6} Mn 66.10x10^{-6}
Ferromagnetism	Large & positive, function of applied field, microstructure dependent.	Atoms have parallel aligned magnetic moments 	Fe ~100,000
Antiferromagnetism	Small &positive.	Atoms have mixed parallel and anti-parallel aligned magnetic moments	Cr 3.6x10^{-6}

Influence of temperature on magnetic behavior:

Temperature can also influence the magnetic characteristics of materials. The atomic magnetic moments are free to rotate, hence with rising temperature, the increased thermal motion of the atoms tends to randomize the directions of any moments that may be aligned.

For ferromagnetic, antiferromagentic and ferrimagentic materials, the atomic thermal motions counteract the coupling forces between the adjacent atomic dipole moments, causing some dipole misalignment, regardless of whether an external field is present. The result is a decrease in the saturation magnetization for both ferro and ferrimagnets. The saturation magnetization is a maximum at) K, at which temperature the thermal vibrations are a minimum. With increasing temperature, the saturation magnetization diminishes gradually and then abruptly drops to zero at what is called the curie temperature Tc. The magnitude of the curie temparature varies from material to material; for example, for iron, cobalt, nickel., the respective values are 768,1120,335 and 585 degree Celsius. Antiferromagnetism is also affected by temperature; this behavior vanishes at what is called the Neel temperature. At temperatures above this point, antiferromagnteic materials also becomeparamagnetic.

Domains and Hysteresis:

Any ferromagnetic or ferromagnetic material that is at a temperature below Tc is composed of small-volume regions in which there is a mutual alignment in the same direction of all magnetic dipole moments. Such a region is called a domain, and each one is magnetized to its saturation magnetization. Adjacent domains are separated by domain boundaries or walls across which the direction of magnetization gradually changes. Normally, domains are microscopic in size and for a polycrystalline specimen, each grain may consist of a single domain. Thus, in a microscopic piece of material, there will be large number of domains and all may have different magnetizationorientations.

The Hysteresis Loop and Magnetic Properties

A great deal of information can be learned about the magnetic properties of a material by studying its hysteresis loop. A hysteresis loop shows the relationship between the induced magnetic flux density **(B)** and the magnetizing force **(H).** It is often referred to as the B-H loop. An example hysteresis loop is shown below.

As the magnetizing force is increased in the negative direction, the material will again become magnetically saturated but in the opposite direction (point "d"). Reducing **H** to zero brings the curve to point "e." It will have a level of residual magnetism equal to that achieved in the other direction. Increasing **H** back in the positive direction will return **B** to zero. Notice that the curve did not return to the origin of the graph because some force is required to remove the residual magnetism. The curve will take a different path from point "f" back to the saturation point where it with complete the loop.

From the hysteresis loop, a number of primary magnetic properties of a material can be determined.

1. **Retentivity** - A measure of the residual flux density corresponding to the saturation induction of a magnetic material. In other words, it is a material's ability to retain a certain amount of residual magnetic field when the magnetizing force is removed after achieving saturation. (The value of **B** at point b on the hysteresiscurve.)
2. **Residual Magnetism** or **Residual Flux** - the magnetic flux density that remains in a material when the magnetizing force is zero. Note that residual magnetism and retentivity are the same when the material has been magnetized to the saturation point. However, the level of residual magnetism may be lower than the retentivity value when the magnetizing force did not reach the saturationlevel.
3. **Coercive Force** - The amount of reverse magnetic field which must be applied to a magnetic material to make the magnetic flux return to zero. (The value of **H** at point c on the hysteresiscurve.)
4. **Permeability** - A property of a material that describes the ease with which a magnetic flux is established in thecomponent.

Magnetic Tapes*:* Magnetic tapes are extensively used for recording audio and video signals, although it is unclear how long this technology will continue to be used with the rising popularity of the digital versatile disk (DVD).

Tapes can be made with either a particulate media adhered to a plastic substrate or a metal evaporated (ME) film on the substrate. The magnetic layer on a particulate tape is only 40% magnetic material whereas ME tapes have a 100% magnetic layer. Therefore, ME tapes give band gaps depends on the type of atom (e.g., Si vs. Al), the distance between atoms in the solid, and the atomic arrangement (e.g., carbon vs. diamond).

In semiconductors and insulators, the valence band is filled, and no more electrons can be added, following Pauli's principle. Electrical conduction requires that electrons be able to gain energy in an electric field; this is not possible in these materials because that would imply that the electrons are promoted into the forbidden band gap. In metals, the electrons occupy states up to the *Fermi level*. Conduction occurs by promoting electrons into the *conduction band*, that starts at the Fermi level, separated by the valence band by an infinitesimalamount.

Electrical Resistivity ofMetals

The resistivity then depends on collisions. Quantum mechanics tells us that electrons behave like waves. One of the effects of this is that electrons do not scatter from a perfect lattice. They scatter by defects, which canbe:

- atoms displaced by latticevibrations
- vacancies andinterstitials
- dislocations, grainboundaries
- impurities

One can express the total resistivity ρ_{tot} by the Matthiessen rule, as a sum of resistivities due to thermal vibrations, impurities and dislocations. Fig. 19.8 illustrates how the resistivity increases with temperature, with deformation, and with alloying..

Semiconductivity

Intrinsic Semiconductor

Semiconductors can be *intrinsic* or *extrinsic*. Intrinsic means that electrical conductivity does not depend on impurities, thus intrinsic means pure. In extrinsic semiconductors the conductivity depends on the concentration of impurities. Conduction is by electrons and holes. In an electric field, electrons and holes move in opposite direction because they have opposite charges.

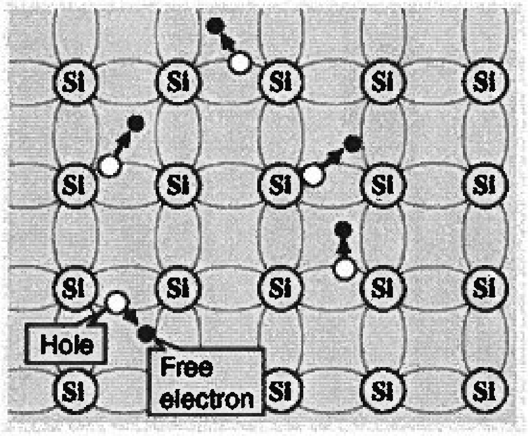
In an intrinsic semiconductor, a hole is produced by the promotion of each electron to the conduction band. Thus:

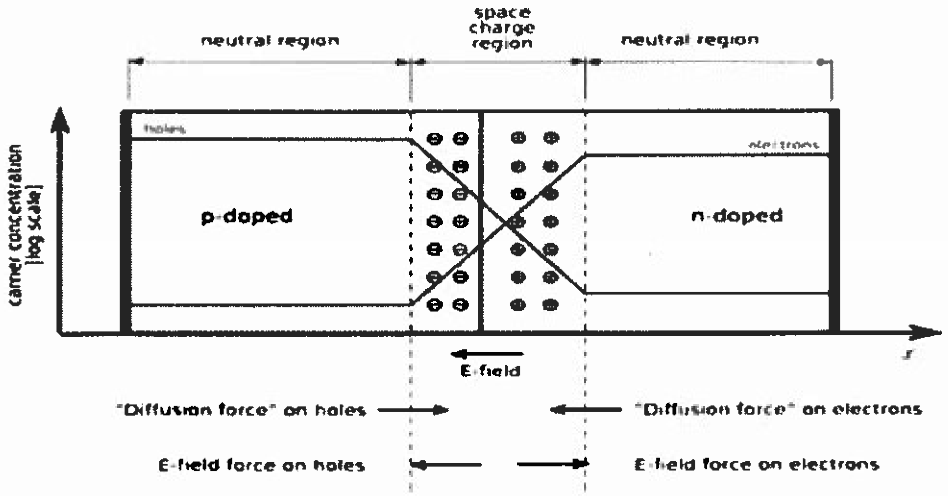
$$n = p$$

larger conductivity than intrinsic semiconductors. At high temperatures, both the impurity levels and valence electrons are ionized, but since the impurities are very low in number and they are exhausted, eventually the behavior is dominated by the intrinsic type of conductivity.

	INTRINSIC SEMICONDUCTORS	EXTRINSIC SEMICONDUCTORS
1.	It is pure semi-conducting material and no impurity atoms are added to it.	It is prepared by doping a small quantity of impurity atoms to the pure semi-conducting material.
2.	Examples: crystalline forms of pure silicon and germanium.	Examples: silicon "Si" and germanium "Ge" crystals with impurity atoms of As, Sb, P etc. or In B, Aℓ etc.
3.	The number of free electrons in the conduction band and the no. of holes in valence band is exactly equal and very small indeed.	The number of free electrons and holes is never equal. There is excess of electrons in n-type semi-conductors and excess of holes in p-type semi-conductors.
	Its electrical conductivity is low.	Its electrical conductivity is high.
4.	Its electrical conductivity is a function of temperature alone.	Its electrical conductivity depends upon the temperature as well as on the quantity of impurity atoms doped the structure.

Intrinsic semiconductor





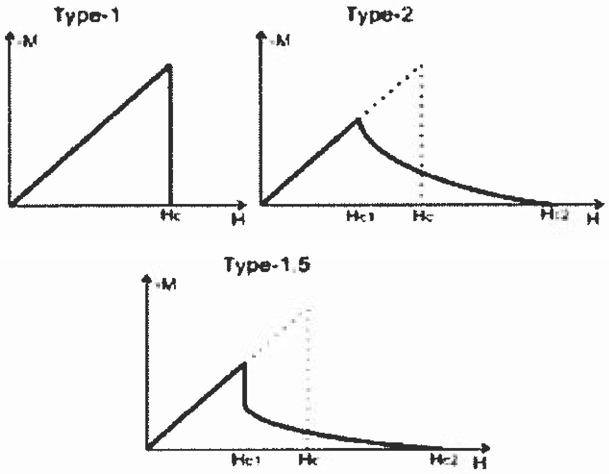
A **p-n-p junction transistor** contains two diodes back-to-back. The central region is very thin and is called the *base*. A small voltage applied to the base has a large effect on the current passing through the transistor, and this can be used to amplify electrical signals (Fig. 19.22). Another common device is the MOSFET transistor where a *gate* serves the function of the base in a junction transistor. Control of the current through the transistor is by means of the electric field induced by the gate, which is isolated electrically by an oxidelayer.

Conduction in Ionic Materials

In ionic materials, the band gap is too large for thermal electron promotion. Cation vacancies allow ionic motion in the direction of an applied electric field, this is referred to as *ionic conduction.* High temperatures produce more vacancies and higher ionic conductivity. At low temperatures, electrical conduction in insulators is usually along the surface, due to the deposition of moisture that contains impurityions.

Superconductivity:

Superconductivity is the ability of certain materials to conduct electrical current with no resistance and extremely low losses. This ability to carry large amounts of current can be applied to electric power devices such as motors and generators, and to electricity transmission in power lines. For example, superconductors can carry as much as 100 times the amount of electricity of ordinary copper or aluminum wires of the same size. Scientists had been intrigued with the concept of superconductivity since its discovery in the early 1900s, but the extreme low temperatures the phenomenon required was a barrier to practical and low-cost applications. This


Type-1
+M
Hc
H
Type-2
+M
Hc1
Hc
Hc2
H
Type-1.5
+M
Hc1
Hc
Hc2
H

Ceramics (Applications and Processing)

Ceramics encompass such a vast array of materials that a concise definition is almost impossible. However, one workable definition is: Ceramics can be defined as inorganic, nonmetallic materials. They are typically crystalline in nature and are compounds formed between metallic and nonmetallic elements such as aluminum and oxygen (alumina-Al_2O_3), calcium and oxygen (calcia - CaO), and silicon and nitrogen (silicon nitride-Si_3N_4).

Ceramics is a refractory, inorganic, and nonmetallic material. Ceramics can be divided into two classes: traditional and advanced. Traditional ceramics include clay products, silicate glass and cement; while advanced ceramics consist of carbides (SiC), pure oxides (Al_2O_3), nitrides (Si_3N_4), non-silicate glasses and many others. Ceramics offer many advantages compared to other materials. They are harder and stiffer than steel; more heat and corrosion resistant than metals or polymers; less dense than most metals and their alloys; and their raw materials are both plentiful and inexpensive. Ceramic materials display a wide range of properties which facilitate their use in many different productareas.

In general, most ceramics are:

- hard,
- wear-resistant,
- brittle,
- refractory,
- thermalinsulators,
- electricalinsulators,
- nonmagnetic,
- oxidationresistant,

suitable for the production of a range of advanced materials, including glass-ceramics with specified porosities and glass-ceramic matrix composites.

Using the petrurgic method, the slow cooling from the molten state causes nucleation and growth of certain crystalline phases. Therefore, the final microstructure, and hence the properties, depends mainly on the composition and the cooling rate.

Glass-Ceramics Based on Coal Ash

The very high iron oxide content of coal ash, table 1, indicates the potential for developing magnetic phases using appropriate processing - this was the aim of our work. We calcined the as-received ash at 800°C for two hours to remove any volatile Material compounds, including sulfur and carbon. The powder and petrurgic methods were explored, and gave us products with different phases and microstructures. For the sintering experiments, we mixed calcined ash powder with various amounts (10-50wt%) of borosilicate (Pyrex) glass. The powder mixtures were uniaxial cold pressed to a cylindrical shape and sintered in air at temperatures in the range of 1,000-1,500°C for periods of up to 15 hours. Using the petrurgic method, coal ash was mixed with sodalime glass powder. The mixture was melted at 1,500°C and cooled to room temperature at rates of between 1-10°C per minute.

Glass-Ceramic Composites

Work to date has largely concentrated on composites with a matrix of the slag-based Silceram glass-ceramic (a glass-ceramic for floor and wall tiles and wear components). We have investigated both particulate- (SiC and TiC) and fibre-reinforcement (SiC). Properties measured include the fundamental mechanical properties but also more complex properties such as thermal shock resistance and erosion resistance. As mentioned previously, the thermal shock resistance of glass-ceramics is superior to the parent glasses, and the shock resistance is further improved by particulate reinforcement. For example, monolithic Silceram has a thermal shock critical temperature of 180°C, whereas a 20wt%SiC composite has a value of 270°C. Erosion resistance may also be improved by particulate reinforcement, e.g., for TiC reinforced Silceram - the larger the reinforcement particle size and the greater the volume fraction, the lower the erosion rate. Results indicate a way for transforming vitrified silicate residues into useful products with broad

3) Abrasives- Abrasive cements are used to wear, grind or cut away other material, which necessarily is softer. Therefor, the prime requisite for this group of materials is hardness or wear resistancr; in addition, a hig degree of toughness is essential to ensure that the abrasive particles do not easily fracture. Furthermore, high temperatures may be produced from abrasive frictional forces, so some refractoriness is also desirable. Diamonds, both natural and synthetic, are utilized as abrasives; however, they are relatively expensive. The more common ceramic abrasives include silicon carbide, tungsten carbide(WC), aluminium oxide and silica sand. Abrasives are used in several forms-bonded to grinding wheels, as coated abrasives and as loose grains. Coated abrasives are those in which an abrasive powder is coated on some type of paper or cloth material; sandpaper is probably the mostly familiar example. Wood, metals, ceramics and plastics are all frequently ground and polished using this form of abrasive. Grinding, lapping and polishing wheels often employ loose abrasive grains that are delivered in some type of oil or water based vehicle. Diamonds, corundum, silicon carbide and rouge are used in loose form over a variety of grain sizeranges.

4) Cements: Several familiar ceramic materials are classified as inorganic cements:cements, plaster of paris, and lime, which as a group are produced in extremely large quantities. The characteristic feature of these materials is that when mixed with water, they form a paste that subsequently sets and hardens. This trait is especially useful in that solid and rigid structures having just about any shape may be expeditiouslyformed.

Portland Cement

Portland cement is a closely controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other compounds, to which gypsum is added in the final grinding process to regulate the setting time of the concrete. Some of the raw materials used to manufacture cement are limestone, shells, and chalk or marl, combined with shale, clay, slate or blast furnace slag, silica sand, and iron ore. Lime and silica make up approximately 85 percent of the mass The term "Portland" in Portland cement originated in 1824 when an English mason obtained a patent for his product, which he named Portland Cement. This was because his cement blend produced concrete that resembled the color of the natural limestone quarried on the Isle of Portland in the English Channel. Different types of Portland cement are manufactured to meet different physical and chemical requirements for specificpurposes.

that cause shape distortion and differential shrinkage. Proprietary 3D, finite-element code packing and compaction models, and process-control tools are now available to improve the production of ceramic components. Sandia has capabilities in the areas of hydrostatic and triaxial compaction testing to characterize materials properties, and x-ray radiography, ultrasound, and computed tomography for density characterization. In addition, expertise in slurry processing has enabled the development of direct-fabrication processes. Furthermore, we are developing phenomenological sintering models to enhance both ceramic component design and manufacturingcapability.

Applications and Processing of Polymers/ Plastics

Plastic covers a range of synthetic or semisynthetic polymerization products. They are composed of organic condensation or addition polymers and may contain other substances to improve performance or economics. There are few natural polymers generally considered to be "plastics". Plastics can be formed into objects or films or fibers. Their name is derived from the fact that many are malleable, having the property of plasticity. Plastic can be classified in many ways but most commonly by their polymer backbone (polyvinyl chloride, polyethylene, acrylic, silicone, urethane, etc.). Other classifications include thermoplastic vs. thermoset, elastomer, engineering plastic, addition or condensation, and Glass transition temperature or T_g.

A lot of plastics are partially crystalline and partially amorphous in molecular structure, giving them both a melting point (the temperature at which the attractive intermolecular forces are overcome) and one or more glass transitions (temperatures at which the degree of cross-linking is substantially reduced).

Plastics are polymers: long chains of atoms bonded to one another. These chains are made up of many repeating molecular units, or "monomers". The vast majority of plastics are composed of polymers of carbon alone or with oxygen, nitrogen, chlorine or sulfur in the backbone. (Some of commercial interest are silicon based.) The backbone is that part of the chain on the main "path" linking the multitude of monomer units together. To customize the properties of a plastic, different molecular groups "hang" from the backbone (usually they are "hung" as part of the monomers before linking monomers together to form the polymer chain).

Thermoset materials are generally stronger than thermoplastic materials due to this 3-D network of bonds, and are also better suited to high-temperature applications up to the decomposition temperature of the material. They do not lend themselves to recycling like thermoplastics Bakelite, a Phenol Formaldehyde Resin (used in electrical insulators and plastic wear)

Urea-formaldehyde foam (used in plywood, particleboard and medium-density fibreboard)

Melamine (used on worktop surfaces)

Polyester Resin (used in glass-reinforced plastics/fibreglass (GRP))

Epoxy Resin (used as an adhesive and in fibre reinforced plastics such as glass reinforced plastic and graphite-reinforced plastic)

A thermoplastic is a material that is plastic or deformable, melts to a liquid when heated and freezes to a brittle, glassy state when cooled sufficiently. Most thermoplastics are high molecular weight polymers whose chains associate through weak van der Waals forces (polyethylene); stronger dipole-dipole interactions and hydrogen bonding (nylon); or even stacking of aromatic rings (polystyrene). Thermoplastic polymers differ from thermosetting polymers (Bakelite; vulcanized rubber) which once formed and cured, can never be remelted and remolded. Many thermoplastic materials are addition polymers; e.g., vinyl chain-growth polymers such as polyethylene and polypropylene.

Thermoplastics are elastic and flexible above a glass transition temperature Tg, specific for each one — the midpoint of a temperature range in contrast to the sharp freezing point of a pure crystalline substance like water. Below a second, higher melting temperature, Tm, also the midpoint of a range, most thermoplastics have crystalline regions alternating with amorphous regions in which the chains approximate random coils. The amorphous regions contribute elasticity and the crystalline regions contribute strength and rigidity, as is also the case for non-thermoplastic fibrous proteins such as silk. (Elasticity does not mean they are particularly stretchy; e.g., nylon rope and fishing line.) Above Tm all crystalline structure disappears and the chains become randomly interdispersed. As the temperature increases above Tm, viscosity gradually decreases without any distinct phase change.

Polyester (PES)

fibres, textiles

Polyvinyl chloride (PVC)

plumbing pipes, flooring, shower curtains, erotic clothing

Polycarbonate (PC)

compact discs, eyeglasses

Acrylonitrile butadiene styrene (ABS)

electronic equipment cases (e.g., computer monitors, printers,keyboards)

Polyvinylidene chloride (PVDC)(Saran)

food packaging

Polytetrafluoroethylene (PTFE)(Teflon)

heat resistant, low-friction coatings, used in things like frying pans and water slides

Plastarch Material

biodegradable and heat resistant, thermoplastic composed of modified corn starch.

Polyurethane

insulation foam, upholstery foam

Bakelite

insulating parts in electrical fixtures (it is a thermosetting plastic, a.k.a. phenol formaldehyde or phenolic resin, that can be moulded by heat and pressure when mixed with a filler-like wood flour or can be cast in its unfilled liquid form.)

Polylactic acid

a biodegradable, thermoplastic, aliphatic polyester derived from lactic acid which in turn can be made by fermentation of various agricultural products such as corn starch.

Mechanical behavior of polymers

The description of stress-strain behavior is similar to that of metals, but a very important consideration for polymers is that the mechanical properties depend on the strain *rate*, temperature, and environmental conditions. The stress-strain behavior can be brittle, plastic and highly elastic (elastomeric or rubberlike). Tensile modulus (modulus) and tensile strengths are orders of magnitude smaller than those of metals, but elongation can be up to 1000 % in some cases. The tensile strength is defined at the fracture point and can be lower than the yield temperature) and that of a pure amorphous material (slight change in slope of density at the glass-transition temperature).

The glass transition temperature is between 0.5 and 0.8 of the melting temperature. The melting temperature increases with the rate of heating, thickness of the lamellae, and depends on the temperature at which the polymer was crystallized. Melting involves breaking of the inter-chain bonds, so the glass and melting temperatures depend on:

- chain stiffness (e.g., single vs. doublebonds)
- size, shape of sidegroups
- size ofmolecule
- side branches,defects
- cross-linking

Rigid chains have higher melting temperatures.

Processing of Plastics

Injection moulding (United States Injection Molding) is a manufacturing technique for making parts from thermoplastic material. Molten plastic is injected at high pressure into a mold, which is the inverse of the desired shape. The mold is made by a moldmaker (or toolmaker) from metal, usually either steel or aluminium, and precision-machined to form the features of the desired part. Injection moulding is very widely used for manufacturing a variety of parts, from the smallest component to entire body panels of cars. It is the most common method of production, with some commonly made items including bottle caps and outdoor furniture. The most commonly used thermoplastic materials are polystyrene (low-cost, lacking the strength and longevity of other materials), ABS or acrylonitrile butadiene styrene (a co-polymer or mixture of compounds used for everything from Lego parts to electronics housings), nylon (chemically resistant, heat-resistant, tough and flexible - used for combs), polypropylene (tough and flexible - used for containers), polyethylene, and polyvinyl chloride or PVC (more common in extrusions as used for pipes, window frames, or as the insulation on wiring where it is rendered flexible by the inclusion of a high proportion ofplasticiser).

Compression molding is a method of molding in which the molding material, generally preheated, is first placed in an open, heated mold cavity. The mold is closed with a top force or *used to make small medical and single serve bottles. The process is divided into three steps: injection, blowing and ejection.*

The injection blow molding machine is based on an extruder barrel and screw assembly which melts the polymer. The molten polymer is fed into a manifold where it is injected through nozzles into a hollow, heated preform mould. The preform mold forms the external shape and is clamped around a mandrel (the core rod) which forms the internal shape of the preform. The preform consists of a fully formed bottle/jar neck with a thick tube of polymer attached, which will form thebody.

The preform mold opens and the core rod is rotated and clamped into the hollow, chilled blow mold. The core rod opens and allows compressed air into the preform, which inflates it to the finished article shape.

After a cooling period the blow mold opens and the core rod is rotated to the ejection position. The finished article is stripped off the core rod and leak-tested prior to packing. The preform and blow mold can have many cavities, typically three to sixteen depending on the article size and the required output. There are three sets of core rods, which allow concurrent preform injection, blow molding andejection.

Another application of injection blow molding is in the production of soft elastic gelatin capsules for pharmaceutical applications. Two strips of gelatin are pressed together in a rotary die which cuts out the desired shape of capsule while the fill liquid is injected. Afterwards, they are cooled and dried to yield a firm, strong capsule.

Stretch blow molding In the Stretch Blow Molding (SBM) process, the plastic is first molded into a "preform" using the Injection Molded Process. These preforms are produced with the necks of the bottles, including threads (the "finish") on one end. These preforms are packaged, and fed later (after cooling) into an EBM blow molding machine. In the SBM process, the preforms are heated (typically using infrared heaters) above their glass transition temperature, then blown using high pressure air into bottles using metal blow molds. Usually the preform is stretchedwithacorerodaspartoftheprocess.Thestretchingofsomepolymers,suchasPET

$$E_c = E_m V_m + E_p V_p$$

where V_m and V_p are the volume fraction of the two phases. A lower bound is given by:

$$E_c = E_m E_p / (E_p V_m + E_m V_p)$$

Concrete

The most common large-particle composite is concrete, made of a cement matrix that bonds particles of different size (gravel and sand.) Cement was already known to the Egyptians and the Greek. Romans made cement by mixing lime (CaO) with volcanic ice. In its general from, cement is a fine mixture of lime, alumina, silica, and water. Portland cement is a fine powder of chalk, clay and lime-bearing minerals fired to 1500_0 C (calcinated). It forms a paste when dissolved in water. It sets into a solid in minutes and hardens slowly (takes 4 months for full strength). Properties depend on how well it is mixed, and the amount of water: too little - incomplete bonding, too much – excessiveporosity.

The advantage of cement is that it can be poured in place, it hardens at room temperature and even under water, and it is very cheap. The disadvantages are that it is weak and brittle, and that water in the pores can produce crack when it freezes in cold weather. Concrete is cement strengthened by adding particulates. The use of different size (stone and sand) allows better packing factor than when using particles of similar size.

Concrete is improved by making the pores smaller (using finer powder, adding polymeric lubricants, and applying pressure during hardening. *Reinforced concrete* is obtained by adding steel rods, wires, mesh. Steel has the advantage of a similar thermal expansion coefficient, so there is reduced danger of cracking due to thermal stresses. *Pre-stressed concrete* is obtained by applying tensile stress to the steel rods while the cement is setting and hardening. When the tensile stress is removed, the concrete is left under compressive stress, enabling it to sustain tensile loads without fracturing. Pre-stressed concrete shapes are usually prefabricated. A common use is in railroad or highway bridges.

Wood

This is one of the oldest and the most widely used structural material. It is a composite of strong and flexible cellulose fibers (linear polymer) surrounded and held together by a matrix of lignin and other polymers. The properties are anisotropic and vary widely among types of wood. Wood is ten times stronger in the axial direction than in the radial or tangential directions.

Smart materials

Smart materials are designed materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli, such as stress, temperature, moisture, pH, electric or magnetic fields.

Group of new and state-of-the-art materials now being developed, and expected to have significant influence on present-day technologies, especially in the fields of medicine, manufacturing and defense. Smart/Intelligent material system consists some type of sensor (detects an input) and an actuator (performs responsive and adaptive function).

Actuators may be called upon to change shape, position, natural frequency, mechanical characteristics in response to changes in temperature, electric/magnetic fields, moisture, pH, etc.

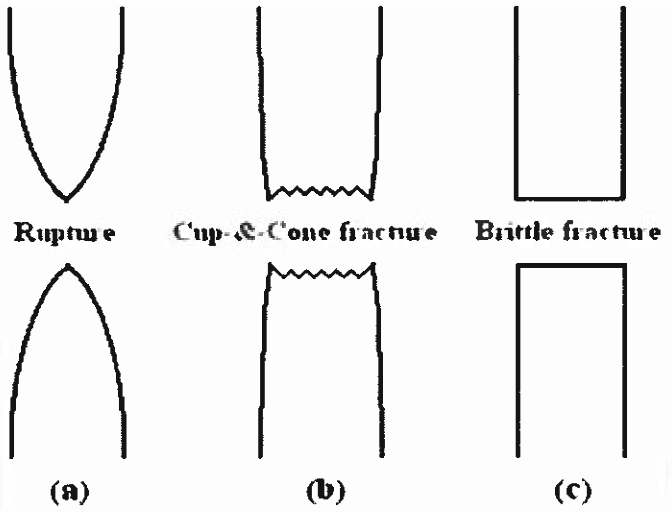
Four types of materials used as actuators: Shape memory alloys, Piezo-electric ceramics, Magnetostrictive materials, Electro-/Magneto-rheological fluids. Materials / Devices used as sensors: Optical fibers, Piezo-electric materials, Micro-electro-mechanical systems (MEMS), etc. Typical applications: By incorporating sensors, actuators and chip processors into system, researchers are able to stimulate biological human-like behavior; Fibers for bridges, buildings, and wood utility poles; They also help in fast moving and accurate robot parts, high speed helicopter rotor blades; Actuators that control chatter in precision machine tools; Small microelectronic circuits in machines ranging from computers to photolithography prints; Health monitoring detecting the success or failure of a product.

Nano-materials

Nanostructured materials are those materials whose structural elements—clusters, crystallites or molecules have dimensions in the range of 1-100 nm. These small groups of atoms, in general, go by different names such as nanoparticles, nanocrystals, quantum dots and quantum boxes. Substantial work is being carried out in the domain of nanostructured materials and nanotubes

This type of fracture is transgranular (through grains) producing grainy texture (or faceted texture) when cleavage direction changes from grain to grain. In some materials, fracture is intergranular.

Fracture occurs due to *stress concentration* at flaws, like surface scratches, voids,



Parameter	Ductile fracture	Brittle fracture
Strain energy required	Higher	Lower
Stress, during cracking	Increasing	Constant
Crack propagation	Slow	Fast
Warning sign	Plastic deformation	None
Deformation	Extensive	Little
Necking	Yes	No
Fractured surface	Rough and dull	Smooth and bright
Type of materials	Most metals (not too cold)	Ceramics, Glasses, Ice

Impact Fracture:

Impact fractures can best be described as a flute or strip of material that was cleanly sheared from a projectile point. The most common type of impact fracture starts at the tip of a point and runs down one blade edge possibly reaching the shoulder of a point. Some points were reworked

Corrosion and Degradation of Materials

Corrosion of Metals

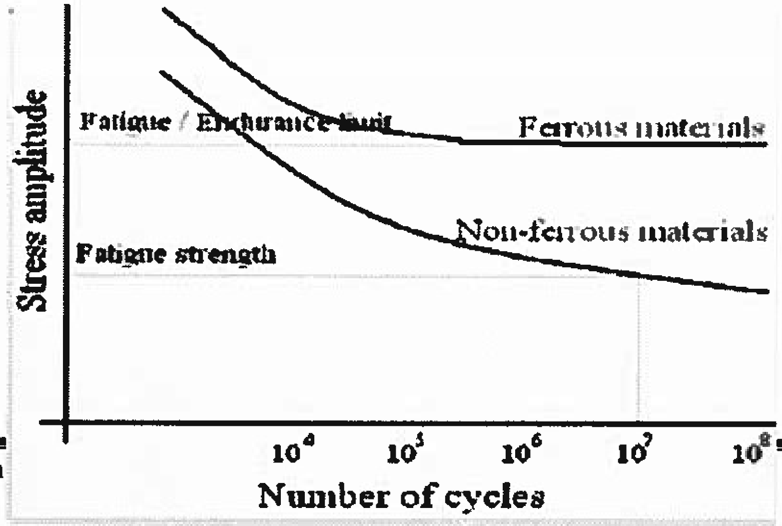
The ***corrosion resistance*** of metals and alloys is a basic property related to the easiness with which these materials react with a given environment. Corrosion is a natural process that seeks to reduce the binding energy in metals. The end result of corrosion involves a metal atom being ***oxidized***, whereby it loses one or more electrons and leaves the bulk metal. The lost electrons are conducted through the bulk metal to another site where they are reduced. In corrosion parlance, the site where metal atoms lose electrons is called the anode, and the site where electrons are transferred to the reducing species is called the cathode.

Pure metals are used in many applications. Copper, for example, is used to make the wire which goes inside electrical cables. Copper was chosen because it can be drawn into long thin wires very easily (it is ductile) and because it is a good conductor of electricity. Pure aluminum can also be used in wiring. It is also used as a cladding material for aluminum alloysubstrates.

Currently there are 86 known metals. Before the 19th century only 24 of these metals had been discovered and, of these 24 metals, 12 were discovered in the 18th century. Therefore, from the discovery of the first metals, gold and copper, until the end of the 17th century, some 7700 years, only 12 metals were known. Four of these metals, arsenic, antimony , zinc and bismuth , were discovered in the thirteenth and fourteenth centuries, while platinum was discovered in the 16th century. The other seven metals, known as the Metals of Antiquity, were the metals upon which civilization was based. These seven metals are Gold, Copper, Silver, Lead, Tin, Iron,Mercury.

Corrosion of Ceramics:

It is often said that one of the biggest advantages which ceramics have over other materials is



with it and form low-melting liquids (i.e. with eutectic point below ambient temperature).

The example of above situation is the system composed of metallurgical slag in contact with refractories. If the reaction is thermodynamically possible, the corrosion will proceed at a dramatic rate if the refractory is wetted by the slag.

with it and form low-melting liquids (i.e. with eutectic point below ambient temperature).

The example of above situation is the system composed of metallurgical slag in contact with refractories. If the reaction is thermodynamically possible, the corrosion will proceed at a dramatic rate if the refractory is wetted by the slag.

CLASS TIME TABLE

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
TIME TABLE

Acadmic year: 2019-2020 **Year-Semester:** II-I-A

Course: B.Tech **Room No. :** G-LH:3

	9:30 to10:20	10:20 to11:10	11:10 to 12:00	12:00 to12:50	12:50 to1:40	1:40 to 2:30	2:30 to 3:20	3:20 to 4:10
MONDAY	P&S		MMS		LUNCH BREAK	GENDER SENSITIZATION		
TUESDAY	TD		PT			MMS LAB/PT LAB		
WEDNESDAY	PT		P&S			MMS LAB/PT LAB		
THURSDAY	MOS		MMS			MD LAB		
FRIDAY	MOS		TD			MD LAB		

THEORY:		LABS:	
P&S	Dr. KHASIM ALI	MMS LAB	Mrs.PRATHIMA JOSHI/Mr.SYED AMER
MOS	Mr.AZFAR HASHMI		
TD	Mr.ABRAR HUSSAIN	PT LAB	Mr.MD RAFEEQ/Mr.NASER AHMED
PT	Dr. ZAHIR HASSAN	MD LAB	Mr.HAROON BAIG/Mr.MD TAHER
MMS	Mr.SYED AMER	GENDER SENSITIZATION	Mr.P.RAMULU

HOD **PRINCIPAL**

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
TIME TABLE

Acadmic year: 2019-2020 **Year-Semester:** II-I-B

Course: B.Tech **Room No. :** G-LH:3

	9:30 to10:20	10:20 to11:10	11:10 to 12:00	12:00 to12:50	12:50 to1:40	1:40 to 2:30	2:30 to 3:20	3:20 to 4:10
MONDAY	MMS	GENDER SENSITIZATION			LUNCH BREAK	P&S	MOS	
TUESDAY	TD	MMS LAB/PT LAB				PT	P&S	
WEDNESDAY	PT	MMS LAB/PT LAB				MOS	TD	
THURSDAY	MOS	MD LAB				TD	MMS	
FRIDAY	P&S	MD LAB				LIBRARY	PT	

THEORY:		LABS:	
P&S	Mrs. FARHEEN	MMS LAB	Mr.ABDUL RAHMAN/Mrs.TASLEEM BANU
MOS	Mr.SANGAMESH MUGLI		
TD	Mr.MOHAMMED TAHER	PT LAB	Mr.UMAIR ANSARI/Mr. HAMED KHAN
PT	Mr. IRFAN KHAN	MD LAB	Mr.HAROON BAIG/Mr.SYED AMER
MMS	Mr.ABDUL RAHMAN KHAN	GENDER SENSITIZATION	Mr.K . RAMULU

HOD **PRINCIPAL**

INDIVIDUAL TIME TABLE

Sec-A

	Name:Mr. SYED AMER							
	9:30-10:20	10:20-11:10	11:10-12:00	12:00-12:50		1:40-2:30	2:30-3:20	3:20-4:10
MON			MMS		LUNCH			
TUE								
WED								
THUR			MMS					
FRI								
SAT								

Sec-B

	Name: Mr. Abdul Rahman							
	9:30-10:20	10:20-11:10	11:10-12:00	12:00-12:50		1:40-2:30	2:30-3:20	3:20-4:10
MON	MMS				LUNCH			
TUE								
WED								
THUR							MMS	
FRI								
SAT								

QUESTION BANK

S. No.	Question	Blooms Taxonomy Level	Course Outcomes
Unit –I			
1	(a) What is a metallic bond? How does the type of bonding influences the properties of crystals? Distinguish between a family of planes and family of directions.. (b) Prove that FCC is closely packed than BCC by calculating atomic packing factor for both. (c)Explain the crystal imperfections in solids. (d)Explain dislocation strengthening mechanisms and slip systems.Explain Critically resolved shear stress. (d) Draw the unit cells of BCC,FCC,HCP crystal structures. (e) Discuss number of atoms,co-ordination number,and atomic packingfactor for each unit cell.	Application, Synthesis	1
2	(a) Describe solidification process for pure metal in termsof nucleation and grain growth of metals. (b) Explain MILLER INDICES and its importance.	Application	1
3	a) What is the ASTM grain size number of a material.What is the influence of grain size on mechanicalproperties. b) Discuss X-ray diffraction incrystallography.	Comprehension, Application	1
4	a) Discuss the Hume –Rothery rules for the solid solubility of one element inanother.. b) Explain the method of plotting an equilibrium diagram andderive the lever rule as applied to equilibrium diagram.	Comprehension, Application	1
5	(a) Explain methods to determine grain size (b) What is the mechanism for formation of grain boundary	Comprehension, Application	1
6	a) What is packing efficiency.How will you calculate density. b) How is the cored structure formed.How it can be eliminated.	Application, Synthesys	1
UNIT – II			
1	a)Differentiate substitutional and interstitial solid solutions with amples. a) What are intermediate phases.	Comprehension	2
2	(a) Explain the importance of equilibrium diagrams in the development ofnewalloys (b)Draw Cu-Ni phase diagram and indicate the phases, temperatures and compositions.	Comprehension, Evaluation	3
3	(a) Define peritectic,eutectoid and eutectic reactions. b) How is the cored structure formed.How it can be eliminated	Evaluation, Application	3
4	a) Explain with sketch isomorphous system and discuss the equilibrium cooling of any one alloy from the above diagram. (b)Draw equilibrium diagram for eutectic type of system and discuss its important features.	Evaluation, Application	3

5	(a) Define eutectic and peritecticreactions (b) Define eutectoid and peritectoidreactions	Application	3
6	(a)Explain electron compounds (b)Discuss interstitial compounds	Evaluation	3
7	(a)What are inter metallic compounds (b)Discuss binary alloy phasediagram	Application , Evaluation	3
8	(a) What is equilibrium cooling (b) Discuss non-equilibrium cooling	Application	3
9	(a) Explain cooling of Bi- Cd eutectic type Isystem (b) Discuss cooling of Pb-Sn eutectic type IIsystem.	Application	3
10	(a) Name the allotropic forms of iron and explain lattice structure of each (b) Define alpha ferrite, austenite, cementite, deltaferrite	Comprehension	3, 4
11	(a) Draw the iron-iron carbide equilibrium diagram and label all the regions. (b) Explain the phase reactions in iron-iron carbide phasediagram	Knowledge, Comprehension	3, 4
12	a) Describe structural changes that take place when plain carbon steels:0.8 %C,0.4%C,1.2%C are cooled from austenite region to room temperature b) What is the eutectic in iron –iron carbidesystem	Analysis, Comprehension	3, 4
13	a) Explain effect of small quantities of S,P,Mn,Si upon properties of steel (b) Distinguish between hypo eutectoid and hyper eutectoid steels	Comprehension	3, 4
	UNIT –III		
1	(a)Explain heat treatment of steel. (b)Explain (i)Annealing (ii)Normalising (iii)Hardening (iv)Tempering (v)Spheroidising (c) Explain isothermal transformation diagramfor Fe-C alloys and microstructure development.	Comprehension , knowledge	3
2	(a) Explain annealing heat treatment (b) Discuss Normalizing heat treatment	Analysis Synthesis	3
3	a) Discuss heat treatable and non-heat treatable aluminium alloys (b) Discuss duraluminium and its applications	Analysis, Application	3
4	(a)Draw aluminium—copper phase diagram.Explain precipitation hardening.	Comprehension	3
7	a) What is hardening heat treatment b) Recommend a heat treatment process to improve the machinability of high carbon steel. Explain the process and indicate the micro structures desired.	Analysis, Application	3
8	(a) What is tempering process and explain micro structuresdeveloped during Various temperingstages. (b) Describe aus temperingprocess		3
9	(a) Explain method of plotting isothermal transformation or TTT diagram (b) Draw TTT diagram for an eutectoid steel and indicate transformation products.	Synthesis	3, 4

	UNIT – IV		
1	(a) Explain continuous cooling curves and interpretation of final microstructures. (b) Explain (i)Austempering (ii)Martempering (iii)Case hardening (iv)Carburizing (v)Nitriding (vi)Cyaniding (vii)Carbo-nitriding (viii)Flame and induction hardening (ix)Vaccum and plasma hardening	Comprehension , Application	1
2	a) Describe martempering process b) What is hardenabilty.Explain Jominy end quench test used for determining the hardenabilty of steels	Synthesis, Comprehension	3, 4

S. No.	Question	**Blooms Taxonomy Level**	**Course Outcomes**
	UNIT V		
1	(a) What are cast irons (b)Define white cast iron and explain its uses	Application	1
2	(a) Define grey cast iron and its uses (b)Define malleable cast iron and its uses.	Comprehension , Knowledge	1
3	(a)What is nodular cast iron.Explain its uses (b)What factors control the structure of cast iron	Comprehension	1
4	(a) Explain Ni-resist cast iron (a) Discuss Ni-hard cast iron	Application	1
2	a) Explain importance of copper for engineeringapplications b) Discuss various types of brasses and their applications	Synthesis, Application	1
5	(a) Discuss tin bronzes and important applications (b) What is alclad. Explain itsadvantages	Synthesis, Application	1
6	a) Explain alpha titanium alloys and their uses. (b)Discuss importance of titanium alloys for strategic applications.	Synthesis, Application	1
7	(a) Explain alpha-beta titanium alloys and their uses (b) What are beta titanium alloys	Synthesis, Application	1
10	a) Discuss types of stainless steels and applications b) Explain tool steels,maraging steels,HSLA steels with applications	Comprehension, Knowledge	1

MID 1
OBJECTIVE EXAM

NAME:

HALL TICKET NO

					A				

SUBJECT:MATERIAL SCIENCE AND METALLURGY(153BC)

ANSWER ALL QUESTIONS. ALL QUESTIONS CARRIES EQUAL MARKS.TIME:20Min. MARKS: 10

I.CHOOSE THE CORRECT ALTERNATIVE.

1.Amorphous solids have ________structure.

(a)Regular (b)Linear (c)Irregular (d)Dendritic

2.Which of the following is not an amorphous material?

(a)Glass (b)Plastics (c)lead (d)Rubber

3.The crystal lattice has a _______arrangement.

(a)3-D (b)4-D (c)2-D (d)1-D

4.The portion i.e., smallest portion of the lattice is known as _______

(a)Lattice structure (b)Lattice point (c)Bravais crystal (d)Unit cell

5.Bravais lattice consists of _____space lattice.

(a)Eleven (b)Twelve (c)Thirteen (d)Fourteen

6.A unit cell that contains lattice points only at the corners is known as

(a)Primitive cell (b)Secondary cell (c)Layered unit cell (d)Derived unit cell

7.Lead is a metallic crystal having a _________structure.

(a)FCC (b)BCC (c)HCP (d)TCP

8.What is the coordination number of a simple cubic structure?

(a)6 (b)8 (c)10 (d)12

9.A solution of exchange of Impurities for solvent atoms is called a

(a)Interstitial solid solution (b)Substitutional solid solution (c)Saturated solid solution (d)Unsaturated Solid Solution

10.According to Hume-Rothery's rules,size of atoms must not differ by more than _________

(a)5% (b)15% (c)35% (d)55%

II Fill in the blanks:

11.The atomic packing factor of FCC structure is ______________

12.The defect that occurs due to a displacement of an ion is known as _________

13. _______ occurs when a foreign substance replaces an atom in a crystal.

14. _______ is coated onto aluminum to improve its soldering ability.

15.A luminum alloy is known as aircraft aluminum ___________

16. Cast iron is a _____ alloy.

17. High conductivity copper is used ______.

18. Brass is an alloy of copper and ______

19. Element is known as the softest heavy metal ___________

20. Soft solder is a _______ tin alloy.

ANSWER KEYS

1. c
2. c
3. c
4. d
5. d
6. a
7. a
8. a
9. b
10. b

Fill in the blanks(answers):

11.0.74
12.Frankel defect
13.Substitutional impurity
14.Tin
15.7075
16.Eutectic
17.In electrical engineering
18.Zinc
19.Lead
20.Eutectic

SUBJECT:MATERIAL SCIENCE AND METALLURGY(153BC)
DATE:13/09/2019 TIME:10.00AM to 11.30AM(FN)

ANSWERSANY TWO OF THE FOLLOWING QUESTIONS 2*5=10

Q.NO	QUESTIONS	BLOOM' S LEVEL
1	Define the APF(Atomic Packing Factor) & derive unit cell length & calculate APF for BCC,FCC if the radius of atom is r. (or) Explain different crystal imperfections with neat sketch	L1 L2
2	Explain with neat sketch critically resolved shear stress(CRSS). (or) Draw the following planes in a cubic unit cell:(i)(111) (ii)(011) (iii)(211) (iv)$(\bar{1}\bar{1}\bar{1})$ (v)(110)	L2 L3
3	State Hume-Rothery's rules for the formation of substitutional solid solution. (or) What is phase rule,lever rule and derive the lever rule w.r.t isomorphous binary phase system.	L3 L1
4	Construct a binary phase diagram using the following data: Melting point of A component=2800°C Melting point of B component=2500°C Eutectic temperature=1800°C Eutectic composition=35%A,65%b Solid solubility of A in B at eutectic point=15% Solid solubility of B in A at eutectic point=10% Solid Solubility of A in B at room temperature=8% Solid solubility of B in A at room temperature=3% (or) Draw the $Fe\text{-}Fe_3C$ phase diagram & label all the points,lines,temperatures& reactions.	L6 L3

MID-2
OBJECTIVE EXAM

NAME:

HALL TICKET NO

					A				

SUBJECT NAME & CODE:MATERIAL SCIENCE ANDMETALLURGY(153BC)

ANSWER ALL QUESTIONS. ALL QUESTIONS CARRIES EQUAL MARKS.TIME:20Min. MARKS: 10

1.CHOOSE THE CORRECT ALTERNATIVE.

1.Which process is used to remove material internal stress?
(a)Annealing (b)Cold working (c)Both a & b (d)None
2.Ductility mean ________
(a)Metals can be drawn into sheets
(b)Metals undergo elastic deformation under tensile loads
(c) Metals undergo plastic deformation under tensile loads
(d) All of the above
3.Malleability mean ————————
(a)Metals undergo plastic deformation under compressive stress
(b)Metals can be drawn into wires
(c) Both a & b
(d) None
4.Which type of cermets are used as an substitute for WC-Co alloy
(a) TiC-base cermets
(b)ThO2-W
(c) ThO2-Mo
(d)None
5.Which of the following is not a stage of annealing?
(a)Heating (b)Soaking (c) Tempering (d)Quenching
6.Which of the following is not a result of tempering?
(a)Increased ductility (b)Improved toughness (c) Increased electrical conductivity (d)Internal stresses are relieved
7.What are the applications of nitriding?
(a)Gears,Camshafts
(b)Valve guides & seatings
(c) Chain links,nuts,bolts& screws
(d)Gears,nuts ,bolts
8.Which of the following is not a method of carburizing
(a)Pack carburizing (b)Gas carburizing (c)Cyaniding (d)Nitriding
9.Which element causes cementite to behave in a stable manner?
(a)Silicon (b)Sulphur (c)Manganese (d)Carbon
10.Which of the following is not a property of magnesium
(a)Low strength (b)Vulnerable to corrosion (c)Expensive (d)Heavy weight

II.Fill in the blanks
1.Magnalium is an alloy of
2.Cast iron is a
3.Iron obtained from broken
4. is coated onto aluminium to improve its soldering ability
5.Brass is an alloy of copper &
6.Heating of hypoeutectoid steels results in formation of coarse pearlite with excess
7.The structure obtained by normalizing depends on
8.The treatment of steel to get a stronger casing while maintaining a soft core is called
9.Gas cyaniding is otherwise known as
10.Nitriding involves the addition of ————for the hardening of surface.

Answer keys:
1.a
2.c
3.a
4.a
5.c
6.c
7.b
8.d
9.b
10.d

Fill in the blanks
1.Nickel&Tin
2.Eutectic
3.Cementite
4.Tin
5.Zinc
6.Cementite
7.Thickness of cross section
8.Surface hardening
9.Carbonitriding
10.Nitrogen

SUBJECT: MATERIAL SCIENCE AND METALLURGY(153BC)

DATE:22/11/2019 TIME:10.00AM to 11.30AM (FN)

ANSWERSANY TWO OF THE FOLLOWING QUESTIONS 2*5=10

Q.NO	QUESTIONS	BLOOM' S LEVEL
1	Explain with neat sketch(a)Hardening (b)Tempering (or) Write short note on (a)Annealing (b) Normalising	L2 L1
2	Explain with neat Sketch time-temperature-transformation characteristics of eutectoid steel (or) Explain with neat sketch isothermal transformation diagram for Fe-C alloy & microstructure development.	L2 L2
3	Explain with neat sketch continuous cooling curve & its microstructure development. (or) Write short notes on any two (a)Flame hardening (b)Carburizing (c)Nitriding (d)Cyaniding (e)Case hardening (f) Austempering (g) Martempering (h)Carbo-nitriding	L2 L1
4	What are different non-ferrous alloys? Explain alloys of copper & Aluminium. (or) What are different types of cast iron? Explain any two alloys of cast iron	L1 L2 L1 L2

PREVIOUS YEAR QUESTION PAPERS

Code No: 113AQ

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B.Tech II Year I Semester Examinations, February/March-2016

METALLURGY AND MATERIALS SCIENCE

(Common to ME, MCT, AME)

Time: 3 Hours Max. Marks: 75

Note: This question paper contains two parts A and B.

Part A is compulsory which carries 25 marks. Answer all questions in Part A.

Part B consists of 5 Units. Answer any one full question from each unit.

Each question carries 10 marks and may have a, b, c as sub questions.

PART- A (25 Marks)

1.a) Distinguish between Unit cell and space lattice. [2]

b) What is ASTM-grain size number? [3]

c) Explain Lever rule with an example. [2]

d) What do you mean by Isomorphous system? [3]

e) What are the effects of non-equilibrium cooling of alloys? [2]

f) Distinguish between hardness and hardenability. [3]

g) Why is it easier to control the properties of cast irons as compared to steels?[2]

h) Why age hardening process is two step process? [3]

i) What is Isomerism? Explain with example. [2]

j) What is degree of polymerization? Explain its significance. [3]

PART-B (50 Marks)

2.a) Distinguish between single crystal and poly crystal. Explain their effect on properties of materials.

b) List out different types of Bravais lattice structures with their characteristics and examples. [5+5]

OR

3. What is co-ordination number? Find the co-ordination number for simple cubic, face central cubic and hcp systems. [10]

4.a) Explain the governing rules for the formation of substitutional solid solutions.

b) Distinguish between electron compounds and intermetallic compounds with examples. [5+5]

OR

5.a) Explain the relationship between equilibrium diagrams and properties of alloys.

b) Discuss about congruent melting phases. [5+5]

6. Draw Fe-Fe_3C phase diagram and explain the phase transformation reactions in the diagram. [10]

OR

7.a) Explain the effects of ferrite stabilizers and austenite stabilizers on Fe-Fe_3C phase diagram.

a) What is quench severity? Explain its role on hardenings of steels. [5+5]

8.a) Distinguish between α, β and α+β titanium alloys with respect to composition, microstructure, properties and applications.

b) Explain the role of solvus curve in phase diagrams for age hardenable alloys. [5+5]

OR

9.a) Draw the partial Al-Cu phase diagram (up to 10% Cu) and explain engineering significance of Al with 4-5% Cu.

b) Explain how the property of aluminium alloys changes on age-hardening. [5+5]

10.a) Explain the differences between crystallization of polymers and other solids.

b) What factors affect the crystallization of polymers? [5+5]

OR

11.a) Differentiate between thermoplastic polymers and thermosetting polymers. Give minimum two examples of each type.

b) What is vulcanization of rubber? Why it is done? [5+5]

--ooOoo--

Code No: 123AQ

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B.Tech II Year I Semester Examinations, November/December – 2016

METALLURGY AND MATERIALS SCIENCE

(Common to ME, MCT, AME)

Time: 3 Hours Max. Marks: 75

Note: This question paper contains two parts A and B. Part A is compulsory which carries 25 marks. Answer all questions in Part A. Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART- A

(25Marks)

1.a) What is electron compound? Give examples.

b) What is meant by miscibility gaps?

c) What is lever rule?

d) Differentiate between allotropy and polymorphism.

e) Define hardenability.

f) Differentiate between tool steel and Die steel.

g) Define ceramic and composite.

h) Differentiate between annealing and normalizing.

i) Explain why grain boundaries look darker under the microscope, while the grains look brighter.

j) Which alloy of Fe-Fe_3C system has the lowest melting point? Give its properties.

PART-B

(50Marks)

2.a) Explain about Hume Rother's rules.

b) Explain about the types of solid solution with neat sketch. [5+5]

OR

3.a) Explain the various allotropic forms of Iron and their properties.

b) Explain with neat diagrams how the micro structure of a pure metal may change with additions of alloying elements. [5+5]

4.a) Calculate the relative amounts of various phases that are present in 0.5 % C Steel, Just above and Just below the peritectic temperature.

b) Draw the copper rich portion of the Cu-Zn phase diagram and label the various points. [5+5]

OR

5.a) With a neat sketch explain about Fe-Fe_3C Diagram.

b) What are the micro constituents of Fe-Fe_3C diagram and define each one. [5+5]

6. What are coring? Explain types of coring and the mechanism associated with it, discuss the remedial acts to remove coring. [10]

OR

7. Explain about the following heat treatment operations:

a) Solution-heat treatment

b) Age hardening. [5+5]

8.a) Gray cast Iron is brittle, in spite of having soft phase (i.e.) Ferrite and graphite in its micro structure, Explain with suitable reason.

b) Differentiate between white cast iron and malleable cast iron. [5+5]

OR

9. Describe the composition, heat treatment methods and applications of the aluminium and its alloys. [10]

10. Give the definition, properties and applications of the following:

a) C-C composites

b) Fiber reinforced materials. [5+5]

OR

11. Write short notes on: a) Metal matrix composites b) Abrasive materials. [5+5]

---ooOoo---

Code No: 113AQ

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B.Tech II Year I Semester Examinations, March - 2017

METALLURGY AND MATERIALS SCIENCE

(Common to AME, ME, MCT)

Time: 3 Hours Max. Marks: 75

Note: This question paper contains two parts A and B.

PART- A

(25 Marks)

1.a) What is electron compound? Give examples [2]

b) What is congruent melting intermediate phase? [3]

c) Define allotropy and give examples. [2]

d) Differentiate between spheroidal graphite cast Iron and gray cast Iron. [3]

e) Differentiate between hardness and hardenability. [2]

f) What are α-Stabilizers in titanium alloys. [3]

g) Differentiate between crystallized ceramics and cermets. [2]

h) What is the role of grain boundaries on the properties of metal / Alloys. [3]

i) What is Lever rule? [2]

j) What is pendulum annealing? [3]

PART - B

(50 Marks)

2.a) State Hume-Roothery's rules for the formation of substitutional solid solutions.

b) Differential between metal and alloy. [5+5]

OR

3.a) What is the necessity of Alloying?

b) Distinguish between Intermetallic compound and Electron compound.

c) Differentiate between grain and atom. [3+3+4]

4. Draw the Fe-Fe$_3$C Diagram and label all the points, lines, temperatures and reactions. [10]

OR

5.a) Apply the Lever rule to phase equilibrium in an alloy of 15% B and 85% A when a liquid of 45% B is in equilibrium with a solid solution of 95% A.

b) What is Isomorphous alloy system? Explain with suitable example. [5+5]

6.a) Gray cast Iron is brittle, in spite of having soft phase (i.e.) Ferrite and graphite in its micro structure, Explain with suitable reason.

b) Differentiate between white cast iron and malleable cast iron. [5+5]

OR

7. Draw the C-curves for 0.8%C steel and explain the phase transformations that occur on different cooling rates. [10]

8. Describe the composition, heat treatment and applications of the following metals:

a) copper and its Alloys

b) Titanium and its alloys [5+5]

OR

9. Explain how a TTT diagrams is constructed? What is its relation to CCT diagrams? Draw a TTT diagram for 0.4%C steel and identify the microstructural phases. [10]

10. Write short notes on

a) Metal Matrix composites.

b) Fiber reinforced composites. [5+5]

OR

11. Enumerate the characteristics, properties and applications of composites and polymers. [10]

---ooOoo---

Code No: 113AQ

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B.Tech II Year I Semester Examinations, November/December - 2017

METALLURGY AND MATERIALS SCIENCE

(Common to ME, MCT, AME)

Time: 3 Hours Max. Marks: 75

Note: This question paper contains two parts A and B.

Part A is compulsory which carries 25 marks. Answer all questions in Part A.

Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART- A

(25 Marks)

1.a) Find the packing efficiency in HCP lattice. [2]

b) Lattice parameter of a FCC crystal is 3.61Ao calculate atomic density in (111), (110) and (100) planes. [3]

c) What is the necessity of Alloying? [2]

d) Distinguish between Intermetallic Compound and Electron compound. [3]

e) What is congruent melting phase? [2]

f) Define allotropy and give examples. [3]

g) What is ASTM-grain size number? What is its importance? [2]

h) Distinguish between ordered and disordered solid solution. [3]

i) What is coring and how it can be minimized? [2]

j) What are the general requirements of a reinforcing phase? [3]

PART- B

(50 Marks)

2.a) What is an interstitial solid solution, name the five elements which commonly form interstitial solid solutions?

b) What is a grain size? What is a fine grained and coarse-grained material? [5+5]

OR

3.a) What is crystal system and explain the Brevais lattices?

b) Write explanatory notes ASTM grain size measuring methods. [5+5]

4. Write a note on Transformations of solid state. [10]

OR

5. Draw and explain the phase diagram where two components are completely soluble in both liquid and solid state with suitable examples. [10]

6.a) What is the effect of alloying elements on Fe-Fe_3C diagram?

b) Draw the TTT diagrams and explain the different cooling rates. [5+5]

OR

7.a) What is hardenability and how it is measured?

b) Differentiate between Hardening and Tempering. [5+5]

8.a) What is cast Iron and explain the classification of cast irons?

b) Differentiate between Cu alloys and Al alloys with respect to properties, heat treatment, composition and microstructure. [5+5]

OR

9.a) Draw and Explain the Cu-Zn phase diagram.

b) Write short notes on Ti alloys. [5+5]

10. Enumerate the characteristics, properties and applications of Polymers. [10]

OR

11. Write Short notes on:

a) Metal ceramic mixtures.

b) C- Composites. [5+5]

---ooOoo---

Code No: 133BG

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B.Tech II Year I Semester Examinations, November/December - 2017

METALLURGY AND MATERIALS SCIENCE

(Common to ME, MCT, MSNT)

Time: 3 Hours Max. Marks: 75

Note: This question paper contains two parts A and B.

Part A is compulsory which carries 25 marks. Answer all questions in Part A.

Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART- A

(25 Marks)

1.a) Find the packing efficiency in HCP lattice. [2]

b) Lattice parameter of a FCC crystal is 3.61Ao calculate atomic density in (111), (110) and (100) planes. [3]

c) What is the necessity of Alloying? [2]

d) Distinguish between Intermetallic Compound and Electron compound. [3]

e) What is congruent melting phase? [2]

f) Define allotropy and give examples. [3]

g) What is ASTM-grain size number? What is its importance? [2]

h) Distinguish between ordered and disordered solid solution. [3]

i) What is coring and how it can be minimized? [2]

j) What are the general requirements of a reinforcing phase? [3]

PART- B

(50 Marks)

2.a) What is an interstitial solid solution, name the five elements which commonly form interstitial solid solutions?

b) What is a grain size? What is a fine grained and coarse-grained material? [5+5]

OR

3.a) What is crystal system and explain the Brevais lattices?

b) Write explanatory notes ASTM grain size measuring methods. [5+5]

4. Write a note on Transformations of solid state. [10]

OR

5. Draw and explain the phase diagram where two components are completely soluble in both liquid and solid state with suitable examples. [10]

6.a) What is the effect of alloying elements on Fe-Fe_3C diagram?

b) Draw the TTT diagrams and explain the different cooling rates. [5+5]

OR

7.a) What is hardenability and how it is measured?

b) Differentiate between Hardening and Tempering. [5+5]

8.a) What is cast Iron and explain the classification of cast irons?

b) Differentiate between Cu alloys and Al alloys with respect to properties, heat treatment, composition and microstructure. [5+5]

OR

9.a) Draw and Explain the Cu-Zn phase diagram.

b) Write short notes on Ti alloys. [5+5]

10. Enumerate the characteristics, properties and applications of Polymers. [10]

OR

11. Write Short notes on:

a) Metal ceramic mixtures.

b) C- Composites. [5+5]

---ooOoo---

Code No: 133BG

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B.Tech II Year I Semester Examinations, November/December - 2018

METALLURGY AND MATERIALS SCIENCE

(Common to ME, MCT, MSNT)

Time: 3 Hours Max. Marks: 75

Note: This question paper contains two parts A and B.

Part A is compulsory which carries 25 marks. Answer all questions in Part A.

Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART- A

(25 Marks)

1. a) Explain why grain boundaries look darker under the microscope, while the grains look brighter. [2]

b) Draw the plane (100). [3]

c) What is lever rule? [2]

d) Differentiate between tool steel and Die steel. [3]

e) Differentiate between annealing and normalizing. [2]

f) Distinguish between peritectoid and eutectoid reactions. [3]

g) Write the composition of cartridge brass. [2]

h) Copper and Al are highly ductile compare to Iron. Why? [3]

i) Differentiate between crystallize ceramics and cermet's. [2]

j) Define ceramic and composite. [3]

PART- B

(50 Marks)

2.a) Write about crystallization of meals.

b) What is the role of grain size on the properties of materials? [5+5]

OR

3.a) State Hume-Rothery's rules for the formation of substitutional solid solution.

b) How do you determine the Miller Indices? Explain it with suitable example. [5+5]

4.a) What is phase rule? Give suitable examples.

b) Draw and explain Isomorphous system. [5+5]

OR

5. Write short notes on Transformations in the solid state. [10]

6. Draw the Fe-Fe$_3$C Diagram and label all the points, lines, temperatures and reactions. [10]

OR

7. Draw neatly the TTT curves for Eutectoid steels. [10]

8.a) What is cast Iron and Classify it and write the properties.

b) Write notes on Al-Cu alloys. [5+5]

OR

9.a) Write about structure, properties, heat treatment cycles and Applications of Titanium and its alloys.

b) Explain why extensive coring occurs in bronzes compared to brasses. [5+5]

10. Enumerate the characteristics, properties and applications of cermet's and Glasses. [10]

OR

11. Write short notes on:

a) Metal Matrix composites.

b) Fiber reinforced materials. [5+5]

---ooOoo---

Code No: 153BC

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

B.Tech II Year I Semester Examinations, November/December - 2019

METALLURGY AND MATERIALS SCIENCE

(Common to ME, MCT, MSNT)

Time: 3 Hours **Max. Marks: 75**

Note: This question paper contains two parts A and B.

Part A is compulsory which carries 25 marks. Answer all questions in Part A.

Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART- A

(25 Marks)

1. a)) What is Atomic Packing Factor. [2]

b) Ho is pearlite different from bainite. [2]

c) What is normalizing? [2]

d)Why quenching is not done after nitriding . [2]

e)What are the main constituents in Brass and Bronze . [2]

f)Explain Scre dislocation. [3]

g) What is peritectoid reaction?Ho is different from peritectic reaction?[3]

h) What is importance of Isothermal Transformation diagram?[3]

i)What is martempering?. [3]

j) What is Age hardening. [3]

PART- B

(50 Marks)

2.a) Write about crystallization of meals.

b) What is the role of grain size on the properties of materials? [5+5]

OR

3.a) State Hume-Rothery's rules for the formation of substitutional solid solution.

b) How do you determine the Miller Indices? Explain it with suitable example. [5+5]

4.a) What is phase rule? Give suitable examples.

b) Draw and explain Isomorphous system. [5+5]

OR

5. Write short notes on Transformations in the solid state. [10]

6. Draw the Fe-Fe$_3$C Diagram and label all the points, lines, temperatures and reactions. [10]

OR

7. Draw neatly the TTT curves for Eutectoid steels. [10]

8.a) What is cast Iron and Classify it and write the properties.

b) Write notes on Al-Cu alloys. [5+5]

OR

9.a) Write about structure, properties, heat treatment cycles and Applications of Titanium and its alloys.

b) Explain why extensive coring occurs in bronzes compared to brasses. [5+5]

10. Enumerate the characteristics, properties and applications of cermet's and Glasses. [10]

OR

11. Write short notes on:

a) Metal Matrix composites.

b) Fiber reinforced materials. [5+5]

---ooOoo---

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
TIME TABLE

Acadmic year: 2019-2020
Course: B.Tech
Year-Semester: II-I-A
Room No. : G-LH:3

	9:30 to10:20	10:20 to11:10	11:10 to 12:00	12:00 to12:50	12:50 to1:40	1:40 to 2:30	2:30 to 3:20	3:20 to 4:10
MONDAY	P&S		MMS		LUNCH BREAK	CONSTITUTION OF INDIA		
TUESDAY	TD		PT			MMS LAB/PT LAB		
WEDNESDAY	PT		P&S			MMS LAB/PT LAB		
THURSDAY	MOS		MMS			MD LAB		
FRIDAY	MOS		TD			MD LAB		
SATURDAY	SPORTS					LIABARY		

THEORY:		LABS:	
Probability and Statistics & Complex Variables (P&S)	Dr. KHASIM ALI	Material Science and Mechanics of Solids Lab (MMS LAB)	Mrs.PRATHIMA JOSHI
Mechanics of Solids (MOS)	Mr.AZFAR HASHMI		
Thermodynamics (TD)	Mr.ABRAR HUSSAIN	Production Technology Lab (PT LAB)	Mr.MD RAFEEQ/Mr.NASER AHMED
Production Technology (PT)	Dr. ZAHIR HASSAN	Machine Drawing Practice (MD LAB)	Mr.HAROON BAIG/Mr.MD TAHER
Material Science and Metallurgy (MMS)	Mrs.PRATHIMA JOSHI	CONSTITUTION OF INDIA	Mr.P.RAMULU

HOD

HEAD
Dept. of Mech. Engineering,
Nawab Shah Alam Khan College
of Engineering & Technology
16-4-1/A, New Malakpet,
HYDERABAD-500 024

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Nawab Shah Alam Khan
College of Engineering & Technology
New Malakpet, Hyderabad-500 024.T.S

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
TIME TABLE

Acadmic year: 2020-2021

Course: B.E

Year-Semester: II-I-B

Room No. : ONLINE

	10:00 to 10:50	11:00 to 11:50	12:00 to 2:00	2:00 to 2:50	3:00 to 3:50
MONDAY	M-III		LUNCH BREAK	ETCE	
TUESDAY	TD			BE	F&A
WEDNESDAY	MMS			M-III	
THURSDAY	EM			BE	
FRIDAY	F&A			TD	
SATURDAY	MMS			ETEC	

THEORY:		LABS:	
EFFECTIVE TECHNICAL COMMUNICATION ENGLISH (ETCE)	Ms. ARIFA BEGUM	METALURGY & MATERIAL TESTING LAB (MMT LAB)	Mrs.PRATHIMA JOSHI
FINANCE & ACCOUNTING (F&A)	Ms. NOVERA	MACHINE DRAWING & MODELING LAB (MDM LAB)	MRr. MANSOOR HASAN/Ms.SARTAZ
MATHEMATICS-III (M-III)	Ms. FARHEEN SULTANA		
ENGINEERING MECHANICS (EM)	Mr. MANSOOR HASSAN		
BASICS ELECTRONICS (BE)	Ms. QUDSIA KAMAL		
METALURGY & MATERIAL SCIENCE (MMS)	Mr. SYED AMER		
THERMODYNAMICS (TD)	Mr. AHMAD HUSSAIN		

HOD

HEAD
Dept. of Mech. Engineering,
Nawab Shah Alam Khan College
of Engineering & Technology
Malakpet,

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NAWAB SHAH ALAM KHAN COLLEGE
OF ENGINEERING & TECHNOLOGY
16-4-1/A, New Malakpet, Hyderabad-500024

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
TIME TABLE

Acadmic year: 2020-2021

Course: B.E

Year-Semester: II-I-A

Room No. : ONLINE

	10:00 to 10:50	11:00 to 11:50	12:00 to 2:00	2:00 to 2:50	3:00 to 3:50
MONDAY	M-III		L U N C H B R E A K	ETCE	
TUESDAY	TD			BE	F&A
WEDNESDAY	MMS			M-III	
THURSDAY	EM			BE	
FRIDAY	F&A			TD	
SATURDAY	MMS			ETEC	

THEORY:		LABS:	
EFFECTIVE TECHNICAL COMMUNICATION ENGLISH (ETCE)	Ms. SABIHA KHATOON	METALURGY & MATERIAL TESTING LAB (MMT LAB)	Ms.TASLEEM BANU/Mr. SHABBIR AHMED
FINANCE & ACCOUNTING (F&A)	Mr TANVEER	MACHINE DRAWING & MODELING LAB (MDM LAB)	Mr. HAROON BAIG/Mr P RAMULU
MATHEMATICS-III (M-III)	Dr. KHASIM ALI		
ENGINEERING MECHANICS (EM)	Mr. AQEEL AHMED		
BASICS ELECTRONICS (BE)	Mr.AKBER HUSSAIN		
METALURGY & MATERIAL SCIENCE (MMS)	Dr. ZAHIR HASAN		
THERMODYNAMICS (TD)	Mr. ABRAR HUSSAIN		

HOD

HEAD
Dept. of Mech. Engineering,
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PRINCIPAL

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OF ENGINEERING & TECHNOLOGY
16-4-1/A, New Malakpet, Hyderabad-500024
College Code:1610

NAWABSHAH ALAM KHAN COLLEGE OF ENGINEERING AND TECHNOLOGY

B.TECH MECHANICAL ENGINEERING MID AWARD LIST FOR ACADEMIC YEAR 2019-2020.

MECHANICAL II YEAR II SEM MAXIMUM MARKS:20 (MARKS LIST=OBJECTIVE+DESCRIPTION)

S.NO	H.T. NO	NAME OF STUDENT	MID 1(25 MARKS)	MID 2(25MARKS)
1	18J31A0302	MOHD ASADUDDIN	24	22
2	17RT1A0322	MOHD ABDUL ARSHAD	25	23
3	17RT1A03C4	ZAIFULLAH HASAN	15	16
4	17RT1A0337	MOHAMMED AZAM	15	15
5	18D91A0316	MOHD ABDUL ROSHAN	24	23
6	18D91A0318	MAHMOOD NISAR AHMED	24	22
7	18RT1A0301	ABDUL MUQSITH	20	18
8	18RT1A0302	ABDUL RAHMAN	19	18
9	18RT1A0304	ABDULLAH BIN OMER	19	20
10	18RT1A0306	FAHAD AHMED	22	17
11	18RT1A0311	MOHAMMED PARWEZ	16	22
12	18RT1A0312	MD ADNAN HUSSAIN	19	14
13	18RT1A0313	MD SALEEMUDDIN KAMRAN	15	16
14	18RT1A0317	MOHAMMAD SHAKEEL	14	14
15	18RT1A0319	MOHAMMED ABDULLAH	23	18
16	18RT1A0321	MOHAMMED AKBER	17	17
17	18RT1A0325	MOHD ABDUL ATAH	17	14
18	18RT1A0327	MOHD ABDUL HASEEB	15	17
19	18RT1A0331	MOHD BASEER MOHI UDDIN	12	16
20	18RT1A0333	MOHD MOHSIN	13	16
21	18RT1A0334	MOHD MUDASIR	24	22
22	18RT1A0335	MOHD MUDDASSIR UDDIN	12	20
23	18RT1A0336	MOHD SHAMSUDDIN KHAN	21	17
24	18RT1A0338	MOHD SUFFIYAN	14	16
25	18RT1A0339	MOHD SUFYAN	24	23
26	18RT1A0341	MOHD ZUBAIR UDDIN	20	23
27	18RT1A0345	PEER LAYEEQ AHMED	21	22
28	18RT1A0346	S MD YOUSUF ABDULLAH	19	14
29	18RT1A0349	SHAIK NASEER BASHA, SHAL RAFEEQ	23	24
30	18RT1A0350	SHAIK TOWFEEQ HUSSAIN	12	14
31	18RT1A0354	SYED ABDUL PASHA QAUDARI	19	16
32	18RT1A0357	SYED MOOSA	24	23
33	18RT1A0360	SYED SAJJAD HUSSAIN	20	18
34	18RT1A0361	SYED SAMEER	24	22
35	18RT1A0362	SYED SHAH AFSAR ALAM	16	23
36	18RT1A0363	SYED SHAJIUDDIN	23	18
37	18RT1A0364	SYED SHOEB AHMED	23	18
38	18RT1A0365	SYED SHOHEL	23	22
39	18RT1A0366	SYED SOHEB MUSHRAF	23	23

40	18RT1A0398	MIR HIDAYATH ALI HASHMI	24	25
41	19RT5A0301	SYED MUNEERUDDIN	16	17
42	19RT5A0303	HIMANSHU DUBEY	12	21
43	19RT5A0304	IBRAHIM KHAN	17	20
44	19RT5A0305	IMRAN KHAN	23	19
45	19RT5A0307	MIRZA JAVEED ALI BAIG	19	18
46	19RT5A0308	MOHAMMED ABDUL MUQEET	18	16
47	19RT5A0311	MOHAMMED FARHAN ALAM	11	18
48	19RT5A0312	MOHAMMED KHAJA HASEEBUDDIN	21	19
49	19RT5A0313	MOHAMMED MUSAIB	23	24
50	19RT5A0314	MOHAMMED MUZAFFAR	18	20
51	19RT5A0315	MOHAMMED NASEER AHMED	19	22
52	19RT5A0316	MOHAMMED SALMAN ALI	20	23
53	19RT5A0317	MOHAMMED SUJA UDDIN	14	18
54	19RT5A0318	MOHAMMED WASIF ANWARUDDIN	19	22
55	19RT5A0319	MOHD ANSARUDDIN AHMED	22	23
56	19RT5A0320	MOHD AZHAR KHAN	17	20
57	19RT5A0321	MOHD FAIZAAN	18	18
58	19RT5A0322	MOHD HUSSAIN	19	21
59	19RT5A0323	MOHD RAGIB	17	18
60	19RT5A0324	MOHD RIYAN	23	23
61	19RT5A0325	QAZI ABDUL AHAD YASAR	20	22
62	19RT5A0326	QAZI ABDUL SAMAD USAMA	19	23
63	19RT5A0327	RAJ MOHAMMED	19	20
64	19RT5A0328	SHAIK MOHAMMED SHAROUZ	23	23
65	19RT5A0329	SHAIK MOIZ	22	23
66	19RT5A0330	SHAIK SHAHID	21	22
67	19RT5A0331	SHARGEEL MOHAMMED	20	22
68	19RT5A0332	SYED ABDUL HAQ	24	21
69	19RT5A0334	SYED ABUBAKER	16	20
70	19RT5A0335	SYED AIYAZ HASHMI	17	19
71	19RT5A0336	SYED ASADULLAH HUSSAINI	17	14
72	19RT5A0337	SYED IBRAHIM ALI	21	23
73	19RT5A0338	SYED SAJID	23	23
74	19RT5A0339	SYED SHOAIB AFNAN	17	24
75	19RT5A0340	SYED WAHAB QADRI	11	22
76	19RT5A0341	ZABIULLAH	24	20

Student list with slow learners & advance learners

Student list of advance learners 2019-20

S.NO	H.T. NO	NAME OF STUDENT	MID 1(25 MARKS)	MID 2(25MARKS)
1	18J31A0302	MOHD ASADUDDIN	24	22
2	17RT1A0322	MOHD ABDUL ARSHAD	25	23
3	18D91A0316	MOHD ABDUL ROSHAN	24	23
4	18D91A0318	MAHMOOD NISAR AHMED	24	22
5	18RT1A0301	ABDUL MUQSITH	20	18
6	18RT1A0302	ABDUL RAHMAN	19	18
7	18RT1A0304	ABDULLAH BIN OMER	19	20
8	18RT1A0306	FAHAD AHMED	22	17
9	18RT1A0311	MOHAMMED PARWEZ	16	22
10	18RT1A0312	MD ADNAN HUSSAIN	19	14
11	18RT1A0319	MOHAMMED ABDULLAH	23	18
13	18RT1A0334	MOHD MUDASIR	24	22
14	18RT1A0336	MOHD SHAMSUDDIN KHAN	21	17
15	18RT1A0339	MOHD SUFYAN	24	23
16	18RT1A0341	MOHD ZUBAIR UDDIN	20	23
17	18RT1A0345	PEER LAYEEQ AHMED	21	22
19	18RT1A0349	SHAIK NASEER BASHA, SHAL RAFEEQ	23	24
20	18RT1A0350	SHAIK TOWFEEQ HUSSAIN	12	14
21	18RT1A0354	SYED ABDUL PASHA QAUDAR	19	16
22	18RT1A0357	SYED MOOSA	24	23
23	18RT1A0360	SYED SAJJAD HUSSAIN	20	18
24	18RT1A0361	SYED SAMEER	24	22
25	18RT1A0362	SYED SHAH AFSAR ALAM	16	23
26	18RT1A0363	SYED SHAJIUDDIN	23	18
27	18RT1A0364	SYED SHOEB AHMED	23	18
28	18RT1A0365	SYED SHOHEL	23	22
29	18RT1A0366	SYED SOHEB MUSHRAF	23	23
30	18RT1A0398	MIR HIDAYATH ALI HASHMI	24	25
31	19RT5A0304	IBRAHIM KHAN	17	20

32	19RT5A0305	IMRAN KHAN	23	19
33	19RT5A0307	MIRZA JAVEED ALI BAIG	19	18
34	19RT5A0308	MOHAMMED ABDUL MUQEET	18	16
36	19RT5A0312	MOHAMMED KHAJA HASEEBUDDIN	21	19
37	19RT5A0313	MOHAMMED MUSAIB	23	24
38	19RT5A0314	MOHAMMED MUZAFFAR	18	20
39	19RT5A0315	MOHAMMED NASEER AHMED	19	22
40	19RT5A0316	MOHAMMED SALMAN ALI	20	23
41	19RT5A0317	MOHAMMED SUJA UDDIN	14	18
42	19RT5A0318	HAMMED WASIF ANWARUD	19	22
43	19RT5A0319	MOHD ANSARUDDIN AHMED	22	23
44	19RT5A0320	MOHD AZHAR KHAN	17	20
45	19RT5A0321	MOHD FAIZAAN	18	18
46	19RT5A0322	MOHD HUSSAIN	19	21
48	19RT5A0324	MOHD RIYAN	23	23
49	19RT5A0325	QAZI ABDUL AHAD YASAR	20	22
50	19RT5A0326	QAZI ABDUL SAMAD USAMA	19	23
51	19RT5A0327	RAJ MOHAMMED	19	20
52	19RT5A0328	SHAIK MOHAMMED SHAROUZ	23	23
53	19RT5A0329	SHAIK MOIZ	22	23
54	19RT5A0330	SHAIK SHAHID	21	22
55	19RT5A0331	SHARGEEL MOHAMMED	20	22
56	19RT5A0332	SYED ABDUL HAQ	24	21
57	19RT5A0334	SYED ABUBAKER	16	20
58	19RT5A0335	SYED AIYAZ HASHMI	17	19
59	19RT5A0336	SYED ASADULLAH HUSSAINI	17	14
60	19RT5A0337	SYED IBRAHIM ALI	21	23
61	19RT5A0338	SYED SAJID	23	23
62	19RT5A0339	SYED SHOAIB AFNAN	17	24
63	19RT5A0341	ZABIULLAH	24	20

Students list with slow Learners 2019-20

S.NO	H.T. NO	NAME OF STUDENT	MID 1(25 MARKS)	MID 2(25MARKS)
1	17RT1A03C4	ZAIFULLAH HASAN	15	16
2	17RT1A0337	MOHAMMED AZAM	15	15
3	18RT1A0311	MOHAMMED PARWEZ	16	22
4	18RT1A0313	MD SALEEMUDDIN KAMRAN	15	16
5	18RT1A0317	MOHAMMAD SHAKEEL	14	14
6	18RT1A0321	MOHAMMED AKBER	17	17
7	18RT1A0325	MOHD ABDUL ATAH	17	14
8	18RT1A0327	MOHD ABDUL HASEEB	15	17
9	18RT1A0331	MOHD BASEER MOHI UDDIN	12	16
10	18RT1A0333	MOHD MOHSIN	13	16
11	18RT1A0335	MOHD MUDDASSIR UDDIN	12	20
12	18RT1A0338	MOHD SUFFIYAN	14	16
13	18RT1A0350	SHAIK TOWFEEQ HUSSAIN	12	14
14	18RT1A0362	SYED SHAH AFSAR ALAM	16	23
15	19RT5A0315	MOHAMMED NASEER AHMED	19	22
16	19RT5A0316	MOHAMMED SALMAN ALI	20	23
17	19RT5A0317	MOHAMMED SUJA UDDIN	14	18
18	19RT5A0320	MOHD AZHAR KHAN	17	20
19	19RT5A0323	MOHD RAGIB	17	18
20	19RT5A0334	SYED ABUBAKER	16	20
21	19RT5A0335	SYED AIYAZ HASHMI	17	19
22	19RT5A0339	SYED SHOAIB AFNAN	17	24
23	19RT5A0340	SYED WAHAB QADRI	11	22

Attainments:

NAWAB SHAH ALAM KHAN COLLEGE OF ENGINEERING AND TECHNOLOGY, JNTUH Hyderabad
DEPARTMENT OF MECHANICAL ENGINEERING
B.Tech. II YEAR, I SEM - ATTAINMENT CALCULATIONS - Academic Year: 2019-20

Subject: METALLURGY AND MATERIAL SCIENCE Subject Code: C213 Faculty: SYED AMER

S.No.	Hall Ticket No.	MID -1											MID -2											MID		SEE
		ASG-1 (2.5M)	ASG-2 (2.5 M)	Quiz-1 (10 M)		Q 1 (5 M)	Q 2 (5 M)	BEST OF Q1&Q2	Q 3 (5 M)	Q 4 (5 M)	BEST OF Q3&Q4	Mid-1 TOTAL	ASG-3 (2.5M)	ASG-4 (2.5 M)	Quiz-2 (20 M)		Q 1 (5 M)	Q 2 (5 M)	BEST OF Q1&Q2	Q 3 (5 M)	Q 4 (5 M)	BEST OF Q3&Q4	Mid-2 TOTAL	Average MID	TOTAL Marks	End Exam
		CO1	CO2	CO1	CO2	CO1	CO1	CO1	CO2	CO2	CO2	(25 M)	CO3	CO4	CO3	CO4	CO3	CO3	CO3	CO4	CO4	CO4	(25 M)	(25 M)	(100 M)	(75 M)
1	17RT1A0322	2.5	2.5	5	5	5	0	5	5		5	25	2.5	2.5	4	4		5	5	5		5	13	19	48	29
2	17RT1A0337	2.5	2.5	3	2	5		5	0		0	15	2.5	2.5	3	3		5	5		0	0	11	13	39	26
3	17RT1A03C4	2.5	2.5	3	2		5	5		0	0	15	2.5	2.5	3	2		5	5		0	0	10	13	39	27
4	18D91A0316	2.5	2.5	5	4	5		5		5	5	24	2.5	2.5	5	4	4		4		5	5	14	19	48	29
5	18D91A0318	2.5	2.5	5	4		5	5	5		5	24	2.5	2.5	5	4	5		5		3	3	14	19	67	48
6	18RT1A0301	2.5	2.5	4	4		4	4		3	3	20	2.5	2.5	3	3		5	5		2	2	11	16	48	33
7	18RT1A0302	2	2	4	4	4		4	3		3	19	2.5	2.5	3	3		5	5	2		2	11	15	39	24
8	18RT1A0304	2.5	2.5	4	3	4		4		3	3	19	2.5	2.5	4	4		4	4		3	3	13	16	39	23
9	18RT1A0306	2.5	2.5	5	4		5	5		3	3	22	2.5	2.5	3	3	3		3	3		3	11	17	39	23
10	18RT1A0311	2	2	4	3	5		5			0	16	2.5	2.5	5	4	5		5	3		3	14	15	57	42
11	18RT1A0312	2	2	3	3	4		4		1	1	15	2	2	2	3	3		3	2		2	9	12	39	27
12	18RT1A0313	2	1	3	2	3		3	2		2	13	2	2	2	3	5		5	2		2	9	11	39	28
13	18RT1A0317	2	2	2	3		3	3	2		2	14	2	2	2	1		4	4	2		2	7	11	39	29
14	18RT1A0319	2	2	4	5	5		5		4	4	22	2.5	2.5	3	2	5		5	3		3	10	16	48	32
15	18RT1A0321	2.5	2.5	3	3	3		3	3		3	17	2	2	4	3	3		3		3	3	11	14	39	25
16	18RT1A0325	2	2	4	3		3	3		3	3	17	2.5	2.5	2	2	5		5	0		0	9	13	39	26
17	18RT1A0327	2	2	3	3		5	5			0	15	2.5	2.5	3	3	3		3	3		3	11	13	48	35
18	18RT1A0331	2	2	2	2	4		4			0	12	2.5	2.5	3	3	3		3		2	2	11	12	39	28
19	18RT1A0333	2	2	2	2		5	5			0	13	2	2	3	3		3	3	3		3	10	12	39	28
20	18RT1A0334	2.5	2.5	5	4	5		5		5	5	24	2	2	4	5	5		5		4	4	13	19	39	21
21	18RT1A0335	2	2	2	2		4	4			0	12	2.5	2.5	4	4		4	4		3	3	13	13	39	27
22	18RT1A0336	2	2	4	4	5		5		4	4	21	2.5	2.5	3	3	3		3	3		3	11	16	39	23
23	18RT1A0338	2.5	2.5	3	2	5		5	0		0	15	2.5	2.5	4	2	5		5	0		0	11	13	39	26
24	18RT1A0339	2.5	2.5	4	4		4	4		4	4	21	2.5	2.5	4	4		5	5	5		5	13	17	57	40
25	18RT1A0341	2.5	2.5	4	4		5	5		4	4	22	2.5	2.5	4	4		5	5		5	5	13	18	39	22
26	18RT1A0345	2.5	2.5	4	3	4		4	3		3	19	2.5	2.5	4	4		4	4		5	5	13	16	39	23
27	18RT1A0346	2.5	2.5	2	2	5		5	0		0	14	2.5	2.5	3	2	4		4	0		0	10	12	39	27
28	18RT1A0349	2.5	2.5	4	4		4	4		5	5	22	2.5	2.5	5	4	5		5		5	5	14	18	57	39
29	18RT1A0350	2	2	4	3	3		3		3	3	17	2.5	2.5	2	2	5		5	0		0	9	13	39	26
30	18RT1A0354	2	2	3	3		4	4		5	5	19	2	2	2	3		5	5	2		2	9	14	39	25
31	18RT1A0357	2.5	2.5	3	2	5		5	0		0	15	2.5	2.5	4	4		5	5		5	5	13	14	67	53
32	18RT1A0360	2.5	2.5	4	4		4	4		3	3	20	2.5	2.5	3	3	3		3	4		4	11	16	48	33
33	18RT1A0361	2	2	4	4		5	5		4	4	21	2.5	2.5	4	4		5	5		4	4	13	17	39	22
34	18RT1A0362	2	2	3	3	4		4		5	5	19	2.5	2.5	4	4		5	5	5		5	13	16	39	23
35	18RT1A0363	2.5	2.5	3	3	5		5	1		1	17	2	2	4	3	4		4		5	5	11	14	57	43

36	18RT1A0364	2.5	2.5	4	3		4	4	3		3	19	2.5	2.5	3	2	5		5	3		3	10	15	48	34
37	18RT1A0365	2.5	2.5	3	2	5		5	3		3	18	2.5	2.5	4	4	5		5		4	4	13	16	39	24
38	18RT1A0366	2.5	2.5	3	3	5		5	3		3	19	2.5	2.5	4	4		5	5		5	5	13	16	39	23
39	18RT1A0398	2.5	2.5	4	3		4	4		5	5	21	2.5	2.5	5	5	5		5	5		5	15	18	67	49
40	19RT5A0301	2.5	2.5	3	3	3		3	3		3	17	2.5	2.5	3	3	3		3	3		3	11	14	39	25
41	19RT5A0303	2.5	2.5	3	3	5		5	0		0	16	2.5	2.5	4	4		4	4		4	4	13	15	39	25
42	19RT5A0304	2.5	2.5	4	3		4	4	3		3	19	2.5	2.5	4	4		4	4		3	3	13	16	39	23
43	19RT5A0305	2.5	2.5	4	3		4	4	4		4	20	2	2	3	3	4		4		5	5	10	15	39	24
44	19RT5A0307	2.5	2.5	3	3	3		3		3	3	17	2.5	2.5	3	2	5		5	3		3	10	14	39	26
45	19RT5A0308	2.5	2.5	2	3	3		3		3	3	16	2.5	2.5	3	3	5		5	0		0	11	14	39	26
46	19RT5A0311	2.5	2.5	3	3		3	3	3		3	17	2.5	2.5	3	2	5		5	3		3	10	14	39	26
47	19RT5A0312	2.5	2.5	3	3		3	3	3		3	17	2.5	2.5	4	3	4		4		3	3	12	15	39	25
48	19RT5A0313	2.5	2.5	4	3	4		4		4	4	20	2.5	2.5	5	4	5		5	5		5	14	17	57	40
49	19RT5A0314	2.5	2.5	4	3		4	4		4	4	20	2.5	2.5	4	3		5	5	3		3	12	16	57	41
50	19RT5A0315	2.5	2.5	4	3	5		5		5	5	22	2.5	2.5	5	4	5		5		3	3	14	18	48	30
51	19RT5A0316	2.5	2.5	5	4	5		5		3	3	22	2.5	2.5	5	4	5		5		4	4	14	18	57	39
52	19RT5A0317	2.5	2.5	3	3	5		5	3		3	19	2.5	2.5	3	3	5		5		2	2	11	15	39	24
53	19RT5A0318	2.5	2.5	3	3	5		5		2	2	18	2.5	2.5	4	3	5		5		5	5	12	15	57	42
54	19RT5A0319	2.5	2.5	4	4		5	5		4	4	22	2.5	2.5	4	4	5		5		5	5	13	18	67	50
55	19RT5A0320	2.5	2.5	4	4		5	5	3		3	21	2.5	2.5	4	3	4		4		4	4	12	17	39	23
56	19RT5A0321	2.5	2.5	4	4		5	5		5	5	23	2.5	2.5	3	2	5		5	3		3	10	17	39	23
57	19RT5A0322	2.5	2.5	4	4	5		5		5	5	23	2.5	2.5	4	4		5	5	3		3	13	18	48	30
58	19RT5A0323	2.5	2.5	3	3	5		5	3		3	19	2.5	2.5	3	3	5		5		2	2	11	15	39	24
59	19RT5A0324	2.5	2.5	4	4		4	4		5	5	22	2.5	2.5	4	4	5		5		5	5	13	18	57	40
60	19RT5A0325	2.5	2.5	4	4		4	4	5		5	22	2.5	2.5	4	3	5		5		5	5	12	17	57	40
61	19RT5A0326	2.5	2.5	4	4		5	5	4		4	22	2.5	2.5	4	4	5		5		5	5	13	18	67	50
62	19RT5A0327	2.5	2.5	4	4	4		4		4	4	21	2.5	2.5	4	3	5		5	3		3	12	17	48	32
63	19RT5A0328	2.5	2.5	4	4	5		5		4	4	22	2.5	2.5	4	4	5		5		5	5	13	18	57	40
64	19RT5A0329	2.5	2.5	4	3		4	4		4	4	20	2.5	2.5	4	4		5	5	5		5	13	17	57	41
65	19RT5A0330	2.5	2.5	4	4		5	5	3		3	21	2.5	2.5	4	4		5	5	4		4	13	17	48	31
66	19RT5A0331	2.5	2.5	3	3	5		5	4		4	20	2.5	2.5	4	4	5		5	4		4	13	17	86	70
67	19RT5A0332	2.5	2.5	4	4		5	5	4		4	22	2.5	2.5	4	4		5	5	3		3	13	18	57	40
68	19RT5A0334	2.5	2.5	4	4		5	5	2		2	20	2.5	2.5	3	4		5	5	3		3	12	16	39	23
69	19RT5A0335	2.5	2.5	3	3	4		4	3		3	18	2.5	2.5	3	3	5		5	3		3	11	15	57	43
70	19RT5A0336	2.5	2.5	3	3	5		5		1	1	17	2.5	2.5	2	2	3		3		2	2	9	13	39	26
71	19RT5A0337	2.5	2.5	4	4	4		4		4	4	21	2.5	2.5	4	4		5	5	5		5	13	17	57	40
72	19RT5A0338	2.5	2.5	4	4		5	5	4		4	22	2.5	2.5	4	4		5	5		5	5	13	18	67	50
73	19RT5A0339	2.5	2.5	4	4	4		4		4	4	21	2.5	2.5	4	4	5		5	5		5	13	17	39	22
74	19RT5A0340	2.5	2.5	2	2		2	2			0	11	2.5	2.5	4	4		5	5	4		4	13	12	39	27
75	19RT5A0341	2.5	2.5	5	5		5	5	4		4	24	2.5	2.5	3	3		5	5	4		4	11	18	39	22
Average Marks		2.39	2.38	3.59	3.31	4.43	4.17	4.36	2.76	3.69	2.99	19.01	2.44	2.44	3.60	3.33	4.48	4.72	4.57	3.03	3.71	3.35	11.81	15.41	46.79	31.37

CIE (Mid Exam) CO Wise Percentage

COURSE OUTCOME	CO Wise Sum	CO Wise Percentage %
CO1	10.34	82.72
CO2	8.67	69.39
CO3	10.61	84.91
CO4	9.12	72.96
Average	9.69	77.49

CIE - CO Wise Sum Formula

CO1 = ASG(CO1) + Q1(CO1) + BestOfQ2&Q3(CO1)
CO2 = ASG(CO2) + Q1(CO2) + BestOfQ4&Q5(CO2)
CO3 = ASG(CO3) + Q1(CO3) + BestOfQ2&Q3(CO3)
CO4 = ASG(CO4) + Q1(CO4) + BestOfQ4&Q5(CO4)

CIE - CO Wise Percentage

CO1 % = (CO1 SUM/total CO1 Marks(12.5))*100
CO2 % = (CO2 SUM/total CO2 Marks(12.5))*100
CO3 % = (CO3 SUM/total CO3 Marks(12.5))*100
CO4 % = (CO4 SUM/total CO4 Marks(12.5))*100

Average Marks	31.37
Student Count >Avg	31
Total Students	75
Percentage	41.3333

SEE (End Exam) CO Wise Percentage

CO1-CO4	31.37	41.33

SEE - CO Wise Percentage

CO1-CO4 = End Exam Avg Marks

SEE - CO Wise Percentage

CO1-CO4 % = (End Exam Avg Marks/75)*100

CO ATTAINMENT	Internal Marks %	Internal Attainment	External Marks %	External Attainment	DIRECT ATTAINMENT LEVEL
CO1	83	3	41.33	1	1.5
CO2	69	2	41.33	1	1.25
CO3	85	3	41.33	1	1.5
CO4	73	2	41.33	1	1.25
Average					1.38

INTERNAL EXAM ATTAINMENT LEVEL SCALE

Attainment Levels	0	<=49
	1	50-64
	2	65-79
	3	>=80

EXTERNAL EXAM / FINAL ATTAINMENT LEVEL SCALE

Attainment Levels	0	<=39
	1	40-49
	2	50-59
	3	>=60

Direct Attainment %

CO1=(CO1IntAtn*0.25+CO1ExtAtn*0.75)
CO2=(CO2IntAtn*0.25+CO2ExtAtn*0.75)
CO3=(CO3IntAtn*0.25+CO3ExtAtn*0.75)
CO4=(CO4IntAtn*0.25+CO4ExtAtn*0.75)

CO-PO Matrix

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	Attainment
CO1	3	3	3	2	1	0	0	1	1	0	1	1	2	2	1	1.5
CO2	3	3	1	2	1	0	0	0	0	1	0	0	2	2	2	1.25
CO3	3	3	3	3	1	0	0	1	1	0	0	2	2	1	3	1.5
CO4	3	3	2	2	2	1	1	1	3	0	0	3	2	2	3	1.25
Average	3	3	2.25	2.25	1.25	1	1	1	1.67	1	1	2	2	1.75	2.25	1.375

Final Attainment %

CO1 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)
CO2 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)
CO3 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)
CO4 = (DIRECT ATTAINMENT*0.8) + (INDIRECT ATTAINMENT*0.2)

Course PO Attainments

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
Direct Attainment	1.38	1.38	1.03	1.03	0.6	0.46	0.46	0.46	0.76	0.46	0.46	0.92	0.92	0.80	1.03
Indirect Attainment	1.35	1.55	1.2	1.25	1.2	1.1	0.9	1.1	1.25	1.15	1.1	1.35	1.35	1.25	1.25
Final Attainment	1.37	1.41	1.07	1.08	0.70	0.59	0.55	0.59	0.86	0.60	0.59	1.00	1.00	0.89	1.08

PO ATTAINMENTS

DIRECT ATTAINMENT (PO1)= (Average of PO1*Average of CO Direct Attainment)/3
Similar for PO2 TO PO12 & PSO1 TO PSO3
INDIRECT ATTAINMENT (PO1) = (Average of PO1*Average of CO Direct Attainment)/2
Similar for PO2-PO12 & PSO1 TO PSO3
FINAL ATTAINMENT = (DIR ATNM-PO1)*0.8 + (INDIR ATNM-PO1)*0.2