UPPSC-AE 2025

Uttar Pradesh Public Service Commission

Combined State Engineering Services Examination

Assistant Engineer

Mechanical Engineering

Engineering Materials

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY PUBLICATIONS

Engineering Materials

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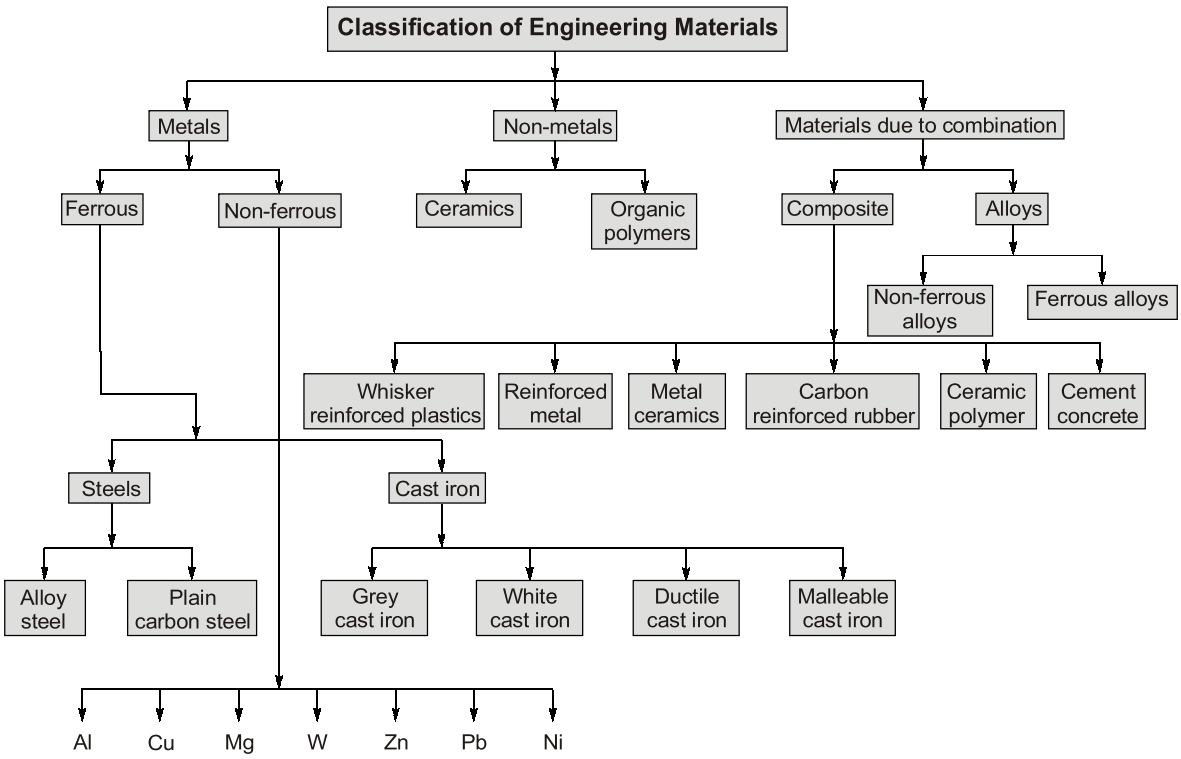
CHAPTER 1

Introduction

1.1 Materials Science

It can be defined as science dealing with the relationships that exist between the structures and properties of materials, which are useful in practice of engineer's profession.

1.1.1 Classification of Engineering Materials



(I) Three basic groups of solid engineering materials based on atomic bonds and structures are

(i) Metals (ii) Ceramics (iii) Polymers (Organic Materials)

(i) Metals

- Characteristics are owed to non-localized electrons (metallic bond between atoms) i.e. electrons are not bound to a particular atom.
- They are characterized by their high thermal and electrical conductivities.

- They are opaque, can be polished to high lustre. The opacity and reflectively of a metal arise from the response of the unbound electrons to electromagnetic vibrations at light frequencies.
- Relatively heavier, strong, yet deformable.

Example of metals: Steel, Aluminium, Brass, Bronze, Lead, Titanium, etc.

(ii) Ceramics

- They contain both metallic and nonmetallic elements.
- Characterized by their higher resistance to high temperatures and harsh environments than metals and polymers.
- Typically good insulators to passage of both heat and electricity.
- Less dense than most metals and alloys.
- They are harder and stiffer, but brittle in nature.
- They are mostly oxides, nitrides, and carbides of metals.
- Wide range: traditional (clay, silicate glass, cement) to advanced (carbides, pure oxides, non-silicate glasses).

Example of ceramics: Glass, Porcelain, Minerals etc.

(iii) Polymers

- Commercially called plastics; noted for their low density, flexibility and use as insulators.
- Mostly are of organic compounds i.e. based on carbon, oxygen and other nonmetallic elements.
- Consists large molecular structures bonded by covalent and van der Waals forces.
- They decompose at relatively moderate temperatures (100 - 400°C).
- Application : packaging, textiles, biomedical devices, optical devices, household items, toys, etc.

Example of polymers: Nylon, Teflon, Rubber, Polyester etc.

S.No.	Polymers	Trade Names	Application
1	Polyethylene	[PE, LDPE, HDP, LLDPE]	Flexible battle, toys and film
2	Polypropylene	[PP]	TV cabinate, luggage
3	Polystyrene	[Styron, styrofoam]	Battery cases, indoor lighting
4	Polyvinyl chloride	[PVC]	Pipes
5	Polytetrafluoroethane	[Teflon]	Anti-corrosive seals, anti-adhesive coating
6	Polymethyl methacrylate (Acrylite)	[PMMA, Lucite, Plexiglass]	Lenses, transparent aircraft window, drafting equipment
7	Polyester	[PET, PETE]	Beverage containers
8	Acrylonitrile Butadiene styrene	[ABS]	Refrigerator lining

(II) Classification can also be done based on either properties (mechanical, electrical, optical), areas of applications (structures, machines, devices). Further we can subdivide these groups, according to the present engineering needs.

(i) Composites (ii) Semiconductors (iii) Biomaterials

(i) Composites

- Consist more than one kind of material. They are made so as to benefit from combination of best characteristics of each constituent.
- Available over a very wide range: natural (wood) to synthetic (fiberglass).

- Many are composed of two phases; one is matrix, which is continuous and surrounds the other dispersed phase.
- Classified into many groups: (1) depending on orientation of phases; such as particle reinforced, fiber reinforced, etc. (2) depending on matrix; metal matrix, polymer matrix, ceramic matrix.

Example:

- Cement concrete
- Special purpose refractory bricks, plywood, etc.
- Fiberglass

Matrix phase/ Reinformement phase	Metal	Ceramic	Polymer
Metal	Powder metallurgy parts	Cermets	Brake pads
Ceramic	TiC, TiCN coated cemented carbide cermets	SiC reinforced	Fiber glass
Polymer	-	-	Araldite, Kelvar

(ii) Semiconductors

- Their electrical properties are intermediate when compared with electrical conductors and insulators.
- These electrical characteristics are extremely sensitive to the presence of minute amounts of foreign atoms.
- Semiconductors have found many applications in electronic devices over decades through integrated circuits. In can be said that semiconductors revolutionized the electronic industry for last few decades.

(iii) Biomaterials

- Those used for replacement of damaged or diseased body parts.
- Primary requirements: must be biocompatible with body tissues, must not produce toxic substances.
- Important materials factors: ability to support the forces, low friction, wear, density, reproducibility and cost.
- All the above materials can be used depending on the application.
- A classic example: hip joint.

Example:

- Stainless steel
- Ti-6Al-4V
- High purity dense Al-oxide, etc.
- Co-28Cr-6Mo
- Ultra high molecular weight polyethelene

1.2 Advanced materials

- Can be defined as materials used in high-tech devices i.e. which operates based on relatively intricate and sophisticated principles (e.g. computers, air/space-crafts, electronic gadgets, etc.).
- These are either traditional materials with enhanced properties or newly developed materials with high performance capabilities. Thus, these are relatively expensive.
- Typical applications: integrated circuits, lasers, LCDs, fiber optics, thermal protection for space shuttle, etc.

Example:
- Metallic foams
- Multicomponent alloys magnetic alloys
- Inter-metallic compounds
- Special ceramics & high temperature materials, etc.

1.3 Future materials

- 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
  - Piezoelectric ceramics
  - Magnetostrictive materials
  - Electro-/Magneto-rheological fluids
- Materials / Devices used as sensors:
  - Optical fibers
  - Piezoelectric materials
  - Micro-electro-mechanical systems (MEMS) etc.
- Typical applications:
  - By incorporating sensors, actuators and chip processors into system, researchers are able to stimulate biological humanlike 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.

1.4 Non Metals

- The materials in the eight portion of the periodic table are called non metals.
- These materials are usually brittle and poor conductor of electricity (except graphite).
- They goes not form alloys but combine chemically to forms compounds.

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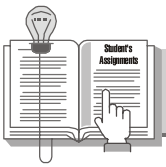

Student's Assignment

Q.1 Consider the following statements:

1. Material science deals with the strength and stiffness behaviour of components (buildings/machines/vehicle facilities) based on their response to imposed stresses (forces, moments, torque etc.).
2. Material properties are dependent on their microstructure and response to force fields and surface interaction.

Which of the above statements is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

Q.2 Which one of the following materials is used for car tyres as a standard material?

(a) Styrene-butadiene Rubber (SBR)
(b) Butyl rubber
(c) Nitrile rubber
(d) Any one of the above depending upon the need

Q.3 The molecular weight of vinyl chloride is 62.5. Thus the molecular weight of a polyvinyl chloride with a degree of polymerization of 20000 is

(a) $\frac{20000}{62.5}$ (b) $\frac{62.5}{20000}$
(c) 62.5×20000 (d) 20000

Q.4 Teflon is a

(a) Thermosetting fluorocarbon polymer
(b) Thermoplastic fluorocarbon polymer
(c) Inorganic compound of fluorine and carbon
(d) Laminated phenolic material

Q.5 Match **List-I (Hardness Test)** with **List-II (Measure of hardness)** and select the correct answer using the codes given below the lists:

List-I

A. Rockwell
B. Brinell
C. Vickers
D. Scleroscope

List-II

1. Surface area of indentation
2. Projected area of indentation
3. Depth of penetration
4. Height of rebound

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	3	1	2	4
(c)	3	1	4	2
(d)	1	3	4	2

Q.6 Which of the following is an amorphous material?

(a) mica (b) lead
(c) rubber (d) glass

Q.7 Thermosetting plastics have in general

(a) molecular chains that slip past one
(b) be a ceramic since all ceramics are glass and glass is a kind of ceramic
(c) have a monolithic crystal structure
(d) have no long range crystalline lattice structure

Q.8 Which one of the following is not a ceramic?

(a) Alumina (b) Porcelain
(c) Whisker (d) Pyrosil

Q.9 Phenol formaldehyde is a/an

(a) thermoplastic polymer
(b) thermoset polymer
(c) elastomer
(d) rubber

Q.10 What is the process by which two or more chemically different monomers are polymerized to form a cross link polymer together with a by-product such as water or ammonia, known as?

(a) Addition polymerization
(b) Co-polymerization
(c) Linear polymerization
(d) Condensation polymerization

Q.11 Composite material are classified based on
(a) Type of matrix
(b) Both
(c) Size of shape of reinforcement
(d) None

Q.12 Major load carrier in dispersion strengthened composites.
(a) Matrix (b) Fiber
(c) Both (d) None of these

Q.13 Which of the following is not an examples of laminar composite.
(a) Wood (b) Bimetallic
(c) Paints/Coating (d) Cladding
[UPPSC]

Q.14 Pick the thermoplastic from the following:
(a) Vinyls (b) Expoxis
(c) Resins (d) Vulcanized rubber
[UPPSC]

Q.15 Layered silicate structures in days consists of the following group.
(a) SiO_4^{4-} (b) $Si_2O_5^{2-}$
(c) $Si_2O_7^{6-}$ (d) SiO_4^{4+}

Q.16 Which of the following is a thermosetting polymer?
(a) Polystyrene (b) Polyelefins
(c) Nylons (d) Phenolic resins

Q.17 Which of the following reactants react to give amidatum reaction?
(a) Amine and acid
(b) Amine and alcohol
(c) Amine and alcohol
(d) Ester and alcohol [BPSC]

Q.18 Zeigler-Natta Catalyst is used in the polymerisation of
(a) Vinyle acelate (b) Vinyl Chloride
(c) Propylene (d) Styrene

Q.19 Polymethyl methacrylate is known as
(a) Bakelite (b) Teflon
(c) Perspex (d) Nylon-6 [DPSC]

Q.20 Which of the following is a copolymer?
(a) PVC (b) Bakelite
(c) Polythene (d) Teflon [UPPSC]

Q.21 The organic acid manomer in nylone 6-6 is
(a) Sebasic acid (b) Terephthalic acid
(c) Adipic acid (d) benzoic acid

Q.22 Which of the following polymers belong to the class of formadehyde resin?
(a) Melamine resins (b) Teflon
(c) Decron (d) None

Q.23 Which one of the following is the process intermediate to compression and injection moulding ?
(a) Reaction moulding
(b) Transfer moulding
(c) Pelleting
(d) Preheating

Q.24 Thermosetting plastics can be formed by which of the following processes?
(a) Injection moulding
(b) Transfer moulding
(c) Blow moulding
(d) Extrusion

ANSWER KEY // STUDENT'S ASSIGNMENT

1. (c)	**2.** (a)	**3.** (c)	**4.** (b)	**5.** (b)
6. (d)	**7.** (d)	**8.** (b)	**9.** (d)	**10.** (d)
11. (c)	**12.** (a)	**13.** (a)	**14.** (a)	**15.** (b)
16. (d)	**17.** (a)	**18.** (c)	**19.** (c)	**20.** (b)
21. (c)	**22.** (a)	**23.** (b)	**24.** (b)	

HINTS & SOLUTIONS // STUDENT'S ASSIGNMENT

1. (c)

Material science is the branch of engineering which deals with the study of structure, properties and applications of materials. Properties of materials are greatly influenced by the structure of materials.

2. (a)

Car tyres are manufactured by styrene butadine rubber (SBR).