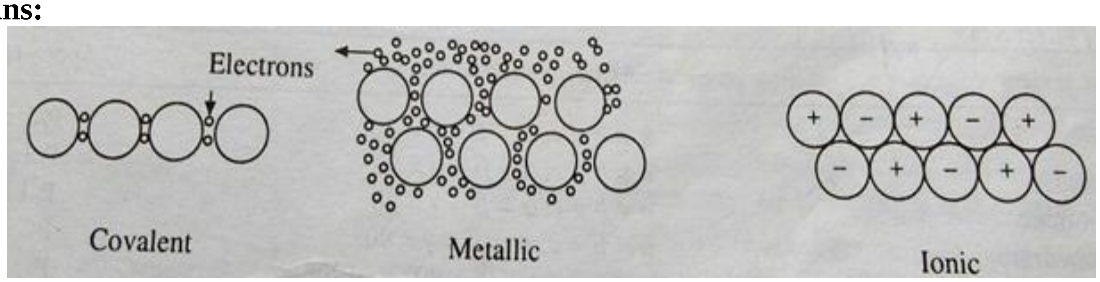
SUMMER – 2019 EXAMINATION

Subject Name: Applications of Biomaterials (ABI) **Model Answer** **Subject Code: 22219**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance. Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answer	Marking Scheme
1.		**Attempt any FIVE of the following:**	**10 M**
	a)	**Draw atomic and molecular bonds.** **Ans:**  **Fig: Atomic and molecular bonds**	**02 M**
	b)	**List any two application of stainless steel alloy.** **Ans:** **Applications of stainless steel alloy:** It is used to making: 1. Hip nails 2. Bone plates 3. Intramedullary pins 4. Heart valves 5. Cardiac pacemaker electrodes 6. Screws 7. Nuts, bolts 8. Orthopedic implants (knee, hip, ankle joint replacement).	**02 M**
	c)	**List four uses of biomaterial.** **Ans:** **Uses of biomaterial:** 1. Joint replacements 2. Bone plates 3. Bone cement 4. Artificial ligaments and tendons	**02 M**

5. Dental implants for tooth fixation
6. Blood vessel prostheses
7. Heart valves
8. Skin repair devices (artificial tissue)
9. Cochlear replacements

(Consider any relevant use of biomaterial)

d) Draw crystal structure of solid. — 02 M

Ans:

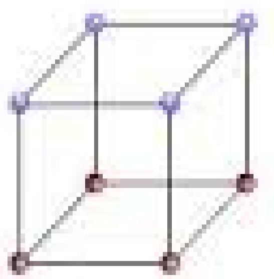
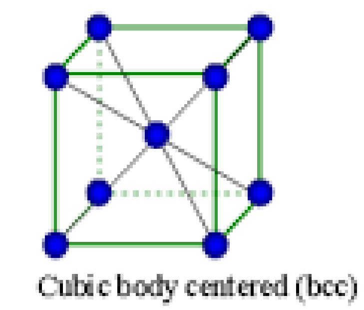
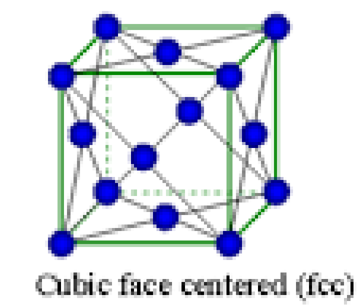
Simple cubic crystal structure	Body centered cubic crystal structure	Face centered cubic crystal structure
		

Fig: Crystal structure of solid

e) Define pacemaker. — 02 M

Ans:

Definition of pacemaker:

An electronic device that is implanted in the body to monitor heart rate and rhythm. It gives the heart electrical stimulation when it does not beat normally.

f) Give two application of Nitinol. — 02 M

Ans:

Application of Nitinol:

It is used to making:

1. Artificial muscles for an artificial heart.
2. Orthopedic implants
3. Dental implants
4. Medical devices
5. Catheter tubes
6. Arch-wires and other surgical instruments

g) Draw bone healing curve. — 02M

Ans:

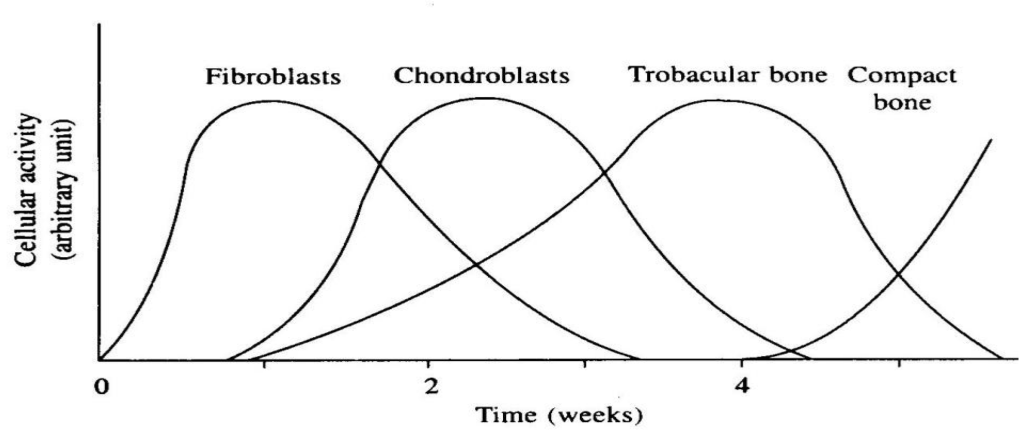
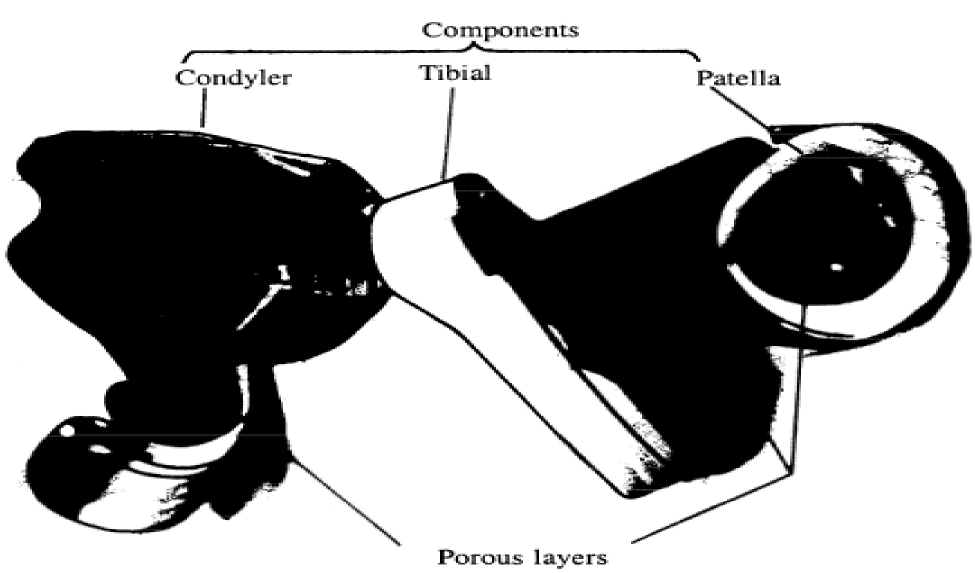


Fig: Bone healing curve

2.		**Attempt any THREE of the following:**	**12 M**
	a)	**Give two properties and two applications of hydrogel.** **Ans:** **Properties of Hydrogel:** 1. Hydrogel have inherently weak mechanical properties. 2. The soft, rubbery nature. 3. These polymers may have low or zero interfacial tension with surrounding biological fluids and tissues. 4. It is transparent when wet. 5. It can be easily machined while dry and it is very pliable when wet. **Applications of Hydrogel:** 1. It is used in making contact lenses. 2. It is used for synthetic articular cartilage in reconstructive joint surgery. 3. It is used in drug delivery system. 4. Making maxillofacial implants for jaw and chin augmentation. 5. It is used for making artificial skin.	**02 M** **02 M**
	b)	**List factors affecting in bone formation.** **Ans:** **Factors affecting in bone formation:** **1. Vascular in growth:** Fibronectin, endothelial cell growth factor (ECGF) **2. Bone formation:** Insulin-like growth factor (IGF-1) somatomedin c, plateletderived Growth factor (PDGF), Fibroblast growth factor (FGF) IL-1, ECGF, insulin, bone derived growth factor (BDGF II and I) bone morphogenetic protein (BMP). **3. Bone resorption:** IL-1, Osteoclast-activating factor: (OAF), parathyroid hormone, PDGF, transforming growth factor B (TGF-B), tumor necrosis factor (TNF), and prostaglandin E2.	**04 M**
	c)	**List any four material used for suture.** **Ans:** **Materials used for suture:** 1. Synthetic polymers 2. Collagen 3. Polypropylene 4. Polyamide (Nylon) 5. Polyethylene 6. Silicon 7. Wax 8. PTFE 9. Gelatin	**04 M**
	d)	**Define corrosion. Explain any two types.** **Ans:** **Definition of corrosion:** It is a degradative process often associated with electrochemical and oxidation reaction of metal in electrolytic solution as well as oxidation and degradation of polymeric materials. **Types of corrosion:** **1. Galvanic Corrosion:** Galvanic corrosion or dissimilar metal corrosion occurs when two different metals are located together in a corrosive electrolyte. A galvanic couple forms between the two metals, where one metal becomes the anode and the other the cathode.	**02 M**

		2. Uniform Corrosion: Uniform corrosion is considered an even attack across the surface of a material and is the most common type of corrosion. This type of corrosion typically occurs over relatively large areas of a material's surface. **3. Stress Corrosion:** Stress corrosion cracking (SCC) is a result of the combination of tensile stress and a corrosive environment, often at elevated temperatures. Stress corrosion may result from external stress such as actual tensile loads on the metal or expansion/contraction due to rapid temperature changes. It may also from during the manufacturing process such as from cold forming, welding, machining, grinding, etc. **4. Pitting Corrosion:** Pitting results when a small hole, or cavity, forms in the metal, usually as a result of de-passivation of a small area. This area becomes anodic, while part of the remaining metal becomes cathodic, producing a localized galvanic reaction. The deterioration of this small area penetrates the metal and can lead to failure. Pitting corrosion can be caused by a local break or damage to the protective oxide film or a protective coating. **5. Crevice Corrosion:** Similar to pitting, crevice corrosion occurs at a specific location. This type of corrosion is often associated with a stagnant microenvironment, like those found under gaskets and washers and clamps. Acidic conditions or a depletion of oxygen in a crevice can lead to crevice corrosion. Crevice corrosion can often occur at lower temperatures than pitting. Proper joint design helps to minimize crevice corrosion. **6. Intergranular Corrosion:** Intergranular corrosion is a chemical or electrochemical attack on the grain boundaries of a metal. It often occurs due to impurities in the metal, which tend to be present in higher contents near grain boundaries. These boundaries can be more vulnerable to corrosion than the bulk of the metal. **7. Fatigue Corrosion:** Environmental cracking is a corrosion process that can result from a combination of environmental conditions affecting the metal. Chemical, temperature and stress-related conditions can result in produce this type of corrosion. **8. Erosion Corrosion:** Erosion corrosion is a degradation of material surface due to mechanical action, often by impinging liquid, abrasion by slurry, particles suspended in fast flowing liquid or gas, bubbles or droplets, cavitation, etc.	**02 M**
3.		**Attempt any THREE of the following:**	**12 M**
	a)	**State biological tolerance of implant metal.** **i. Nitinol** **ii. Titanium** **Ans:** **Nitinol:** Nickel titanium, also known as Nitinol (shape memory alloy), is a metal alloy of nickel and titanium, where the two elements are present in roughly equal atomic percentages e.g. Nitinol 55, Nitinol 60. It gives good biological response. It is not having toxic or injurious effects on biological function. **Titanium:** Unlike nickel, titanium has a very good reputation for biocompatibility. Titanium and its compounds are not carcinogenic in experimental animals or in humans.	**02 M** **02 M**
	b)	**Name any two orthopedic and dental implants.** **Ans:** **Orthopedic implants:** Plates, screws, nails, pins, wires, intramedullary rod, Hip and knee implants. **Dental implants:** Endosteal implants (Endosseous implant), root form dental implants, plate form dental implants, Subperiosteal implants and Transosteal implants.	**02 M** **02 M**
	c)	**Describe the testing and evaluation process for dental implants.** **Ans:**	

		The testing and evaluation process for dental implants: First step is to test the materials for toxicity by implantation subcutaneously in rats for periods of time up to 30 days and through tissue culture tests. The second step is to test the devices in an animal model. Of all animals, the baboon is considered the most preferred experimental animal in dental-implant studies, since its physiology and immunological responses are very similar to those of humans. In general, the clinical condition of dental implants is evaluated by using radiographs, gingival tone, pocket depth and mobility. A stereo-photogrammetric method of measuring the extent of tissue changes and mobility of Subperiosteal implants technique utilizes stereo photographs to measure quantitatively, the extent of tissue swelling or resorption, as well as, migration of dental implants to an accuracy of 16 μm.	**04 M**
	d)	**List application of silicon rubber.** **Ans:** **Applications of silicon rubber:** 1. Used to make catheters. 2. Replacement of destroyed or diseased finger joints. 3. Replacement of carpal bones, toe prostheses and capping temporomandibular joints. 4. Breast augmentation. 5. Maxillofacial surgery (includes nasal supports, jaw augmentation, orbital floor repair, and chin augmentation). 6. Artificial bladder, sphincters and testicles. 7. Making artificial heart valves. 8. Drug delivery system. 9. Middle ear prosthesis.	**04 M**
4.		**Attempt any THREE of the following:**	**12 M**
	a)	**Draw neat sketch of total knee replacement.** **Ans:**  **Fig: Total knee replacement**	**04 M**
	b)	**List two properties and two application of carbon.** **Ans:** **Properties of carbon:** 1. The carbons are inert ceramic materials.	

2. In the quasi-crystalline forms, the degree of perfection of the crystalline structure and the morphological arrangements of the crystallites and pores are important in determining the properties of carbons.
3. All the carbons, currently of interest for use in medical devices have the quasi - crystalline turbostatic structure.
4. Carbon has good biocompatibility with bone and other tissues.
5. It also has high strength and an elastic modulus close to that of bone and so do not suffer from fatigue.

02 M

OR

Property	**Graphite**	**Glassy**	**Pyrolytic**
Density (g/ml)	1.5 to 1.9	1.5	1.5 to 2.0
Elastic modulus (GPa)	24	24	28
Compressive strength (MPa)	138	172	517 (575[a])

Table: Properties of carbon

Applications of Carbon:

1. Carbon coatings are used for making heart valves, blood vessel grafts and percutaneous devices.
2. The chronic stimulation of the cochlea for artificial hearing.
3. Stimulation of the cortex.
4. Dental implant.
5. Tissue Regeneration.
6. Drug delivery system.
7. Reduction in critical surface tension and blood adhesion.
8. Ultra low Temperature Isotropic Carbons (ULTI) coated valves are most widely used.

02 M

c) List any three uses of collagen in dentistry.

Ans:

Uses of collagen in dentistry:

1. Prevention of oral bleeding
2. Support of regeneration of periodontal tissues
3. Promotion of healing of mucosal lining
4. Prevention of migration of epithelial cells
5. Dressing materials
6. Carrier substance for immobilization of various active substances used in dentistry.
7. Decreased seepage of blood during periodontal mucoginvival surgery.

04 M

d) State need of orthopedic implants.

Ans:

Need of orthopedic implants:

Orthopedic implants are surgically placed into the body to restore function by replacing a damaged structure. For the treatment of back pain, orthopedic implants such as bone plates and bone screws are used. Also used for fixation of fractured bone segments, as well as orthopedic implants are used for hip and knee joint replacement.

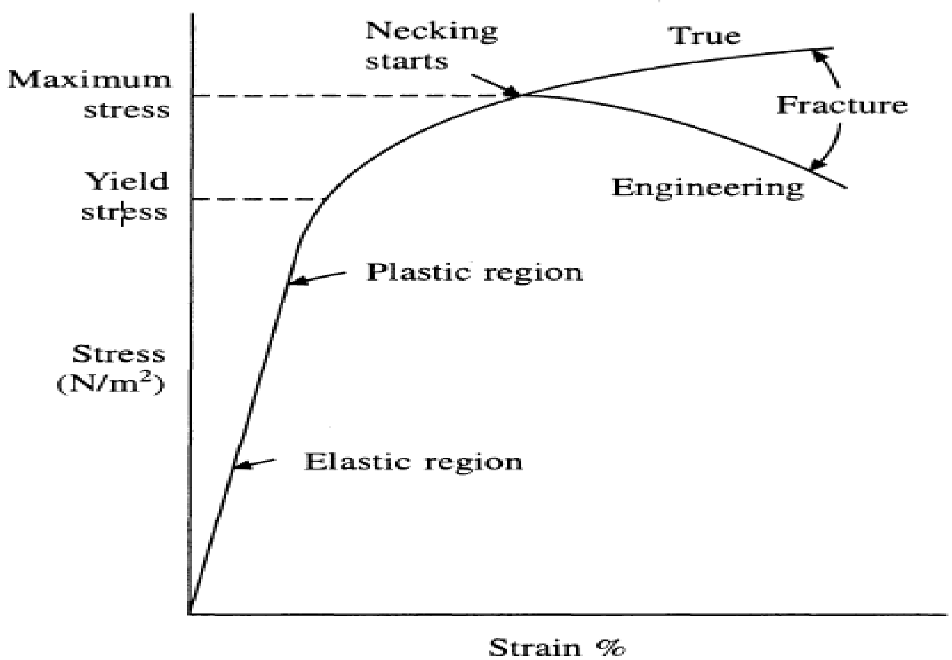
04 M

e) Relate the following application with stainless steel alloy Ti based alloy.

- **i. Long bone shaft**
- **ii. Bone plate**
- **iii. Cardiac cage valve**
- **iv. Femur ball**

		Ans: **i. Long bone shaft:** Stainless steel alloy **ii. Bone plate:** Stainless steel alloy **iii. Cardiac cage valve:** Ti based alloy **iv. Femur ball:** Ti based alloy	 **01 M** **01 M** **01 M** **01 M**
5.		**Attempt any TWO of the following:**	**12 M**
	a)	**Explain total hip replacement.** **Ans:** **Total hip replacement:** A hip replacement consists of femoral component that is a ball mounted on a shaft & an acetabular component having a socket into which ball is placed. Cobalt - Chromium & Titanium-Aluminum-Vanadium alloys or alpha alumina are used by different manufacturer for the femoral component & high molecular weight polyethylene to cover the socket. Several design types with different stem lengths are available. Boutin (1974) had reported several hundred successful clinical cases using a ceramic ball on a metallic stem femoral component & a matching alumina acetabular component. Boutins devices were all fixed in the bony tissues with standard PMMA cement. Subsequently the HDHMW polyethylene cups were introduced along with ceramic balls attached to metallic stem. The number of alternative combinations of materials are use in total hip replacement include Metal- Metal, Metal- HDHMW polyethylene, Ceramic- HDHMW polyethylene, Ceramic- Ceramic.	**06 M**
	b)	**Describe testing of biomaterial.** **Ans:** **Testing of biomaterial:** **In vitro method to test biomaterials:** **1. Tissue culture:** The growth of portion of the intact tissue without prior cellular dissociation. This method usually utilizes a substrate rather than a suspected technic; exposure to biomaterial is similar to that for true cell culture. **2. Cell culture:** Roth of initially free dissociated cell. These cells may be grown in to solution or on ager or other media substrate. Exposure to biomaterials may be through direct contact with the bulk materials, contact through an ager. **3. Organ culture:** The growth of intact organ in vitro. This may vary from the use of fetal bone implant, which can survive without external support system to the use of whole, adults, perfused organs such as kidney or heart. **4. Blood contact test:** Materials problem in cardiovascular devices are primarily those of inadequate biological performance. This is due to the acute nature of host response. These tests are generally comparative type and examine either coagulation times or homeless rate in either static or dynamic system during or after contact with the foreign material.	**03 M**
		In vivo method to test biomaterials: After in vitro test techniques to test new implant materials in extended times whole animal test is done. The site chosen is usually soft tissue. For joint replacement application, implantation is also performed in cortical bone. Specialized site such as the corneas are used for materials for limited applications. Commonly used expected applications are rabbit, dog, cat, sheep, goat, etc. Most popular sites are: Subcutaneous, Intramuscular, Intraperitonial (E. g. Supraspinatus), Transcortical (E.g. Femur), and Intramedullary (E.g. Femur and tibia). Tests are divided into two types: **1. Non Functional Test:** Implant is of arbitrary shape, perhaps in the form required for	**03 M**

		later mechanical tests of material response and floats passively in the tissue site. Focus on direct interaction between the substance of the material and chemical and biological species of the implant environment. **2. Functional Test:** Test of this type is obviously of much greater complexity and cost than the nonfunctional type. For total joint replacement, design of implant would be as per the animal requirement. Design, fabrication, mechanical testing and implantation may be more difficult than final production of device for human use. In addition to implantation, it is required that material be placed in functional mode with its wide experience in human implant service. Total hip joint replacement design has been made and tested in cats, dogs, sheep and goat.	
	c)	**Give any two properties and applications of acrylic and biodegradable polymers.** **Ans:** **Properties of acrylic polymer:** 1. High strength and toughness. 2. Highly biocompatible material. 3. Excellent light transparency (92% light transparency). 4. High index of refraction (1.49). 5. Excellent chemical resistivity. **Applications of acrylic polymer:** 1. It is used for making contact lenses. 2. Implantable ocular lenses. 3. Bone cement for joint fixation. 4. Dentures and maxillofacial prostheses. 5. It is suitable for the repairs of cranial defects. **Properties of biodegradable polymer:** 1. Stable and durable 2. Strong 3. Non-toxic 4. Good biocompatibility 5. Capable of controlled rates of degradation. 6. Capable of maintaining good mechanical integrity until degraded. **Applications of biodegradable polymer:** 1. Drug delivery system 2. Tissue engineering (making artificial tissue) 3. Orthopedic applications (knee, hip, ankle joint replacement) 4. Repair of cartilage, ligaments and tendons.	**01M** **02 M** **01M** **02 M**
6.		**Attempt any <u>TWO</u> of the following:**	**12 M**
	a)	**List types of polymers. Give two applications and properties of alumina.** **Ans:** **Types of polymers:** **Synthetic polymers:** Polyurethanes, PTFE, Polyethylene, Polypropylene, Polyacrylate, PMMA, PHEMA, Hydrogel, Silicon rubber. **Biopolymers:** Collagens, Elastin Mucopolysaccharides, Cellulose, Proteoglycans, Chitin. **Applications of alumina:** 1. The implant devices are prepared from purified alumina. 2. High density alumina is used in load bearing hip prostheses. 3. Dental implant. 4. Orthopedic uses of alumina consist of hip & knee joints, tibial plates, femur	**02 M** **02 M**

		shaft, shoulders, radius, vertebra, leg lengthening spacer & ankle joint prosthesis. 5. Reconstructive maxillofacial surgery to cover bone defects. 6. Porous alumina is also used in teeth roots. **Properties of alumina:** 1. It is insoluble in water & slightly soluble in strong alkali and acid. 2. Chemically stable and excellent corrosion resistant. 3. High melting point. 4. Highest hardness. 5. Highest mechanical strength 6. Good biocompatibility. 7. High wear resistance & reasonable strength.	**02 M**
	b)	**Draw and explain stress strain curve in detail.** **Ans:**  **Fig: Stress-strain curve**	**03 M**
		In Stress-Strain curve x-axis represent strain and y-axis represent stress. The stress is force per unit cross-sectional area and strain is change in length per original length. From a load-displacement curve a stress-strain diagram can be constructed by knowing cross-sectional area and length of rod. The stress-strain curve of a solid can be demarcated by the yield point or stress (YS) into elastic and plastic regions. In the elastic region, the strain increases in direct proportion to the applied stress whereas in the plastic region strain changes are no longer proportional to the applied stress. Further when the applied stress is removed, the material will not return to its original shape but will be permanently deformed. This phenomenon is termed as plastic deformation. The peak stress in fig. is often followed by an apparent decrease until a point is reached where the material ruptures. The peak stress is called as the tensile or ultimate tensile strength (TS or UTS) and the final stress where failure occurs is called the failure or fracture strength (FS). Hardness is the measure of plastic deformation and is defined as the force per unit area of indention or penetration and thus has the dimension of stress.	**03 M**
	c)	**Give any four mechanical properties of teeth and enlist filling and restoration materials for deep cavities.** **Ans:**	

Mechanical properties of teeth:

	Density (g/cm^3)	Compressive Strength (Mpa)	Young's Modulus (GPa)	Thermal Conductivity(W/mk)
Enamel	2.2	241	48	0.82
Dentin	1.9	138	13.5	0.59

Table: Mechanical properties of teeth

02 M

Dental filling materials for deep cavities:

1. Gold foil.
2. Platinum.
3. Aluminum.
4. Lead and tungsten.
5. Tin and iron.

02 M

Dental restoration materials for deep cavities:

1. Amalgam: is a metallic filling material composed from a mixture of mercury (from 43% to 54%) and powdered alloy made mostly of silver, tin, zinc and copper, commonly called the amalgam alloy.
2. Composite resin (also called white fillings).
3. Glass Ionomer Cement.
4. Resin modified Glass-Ionomer Cement (RMGIC).

02 M