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.

Q1 (A) Attempt any Three **Marks 12**

a) Define biomaterials. Give one example of metals, ceramics & polymers used as biomaterials. (1m defination, 1m for each example) **04**

A biomaterial is defined as any systemically, pharmacologically inert substance or combination of substances utilized for implantation within or incorporation with a living system to supplement or replace functions of living tissues or organs. In order to achieve that purpose, a biomaterial must be in contact with living tissues or body fluids resulting in an interface between living and nonliving substances.

Polymers: Polyolefins, Polyesters, Polyamides, Polyurethane, Polyacetals, Polyether,Silicone, Rubber.
Metal alloys: Steel, Cobalt-chromium, Platinum, Titanium.
Ceramics: Alumina, Hydroxyapatite, Zirconia, Calcium phosphate.

b) Give composition of stainless steels and two applications of Ti based alloys. **04**
(Any two composition 2m and two applications 2m)

Composition of austenitic stainless steels (balance % iron)

AISI	*%C*	*%Cr*	*%Ni*	*%Mn*	*% other elements*
301	0.15	16-18	6-8	2.0	1.0 Si
304	0.07	17-19	8-11	2.0	1-Si
316, 18–8sMo	0.07	16-18	10-14	2.0	2-3 Mo, 1.0 Si
316L	0.03	16-18	10-14	2.0	2-3 Mo, 0.75 Si,
430 F	0.08	16-18	1.0-1.5	1.5	1.0 Si, 0-6 Mo

Ti based alloy has been used for the production of hip prostheses and fracture equipment and has largely replaced pure metal in many situations.

c) Describe two routes for blood clot formation. (2M for each process) **04**

Two separate routes for activation of the cofactors leading to blood clotting are known as the extrinsic and intrinsic pathways.
The extrinsic pathway is so named because it requires a substance not normally present in the blood for activation.
Tissue factor is a lipoprotein found in the endothelial cells that line the vascular system and other organs. Damage to tissues or vessels releases tissue factor, which activates factor VII to VIIa in the presence of calcium. Factor VIIa is a protease that converts factor X to Xa.
All the factors in the intrinsic pathway are available in circulation.
Factor XII undergoes a conformational change when exposed to collagen, basement membrane or a variety of other foreign surfaces. Once activated XIIa initiates a series of reactions.
The central event in clotting is the cleavage of fibrinogen in the presence of the proteolytic enzyme thrombin to a fibrin monomer, and its polymerization to form a fibrin polymer.
A fibrin clot is cross-linked fibrinogen in a three-dimensional structure in conjunction with platelets and other wound factors. The generation of fibrin from fibrinogen and thrombin from prothrombin are a part of the common pathway of coagulation.
Prothrombin is cleaved to thrombin by a complex of factor Xa, factor Va, phospholipid, and calcium. Factor Xa is a serine protease that attacks prothrombin while factor Va is a cofactor that accelerates the reaction.

OR

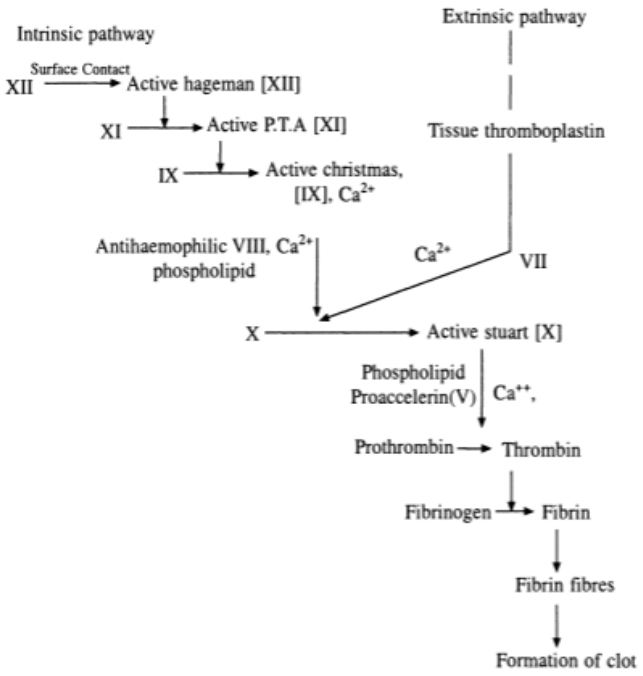


Fig 1- Two routes for blood clot formation

d) State mechanical properties of teeth. **04**

Enamel and dentine forms the major part of the teeth.
Mechanical properties of enamel and dentin are:

	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

(B) Attempt any One **Marks 06**

a) Give the testing and evaluation process of dental implants.
(Assign marks as per the points given) **06**

The testing and evaluation of dental implants involves several stages.

- First, materials are tested 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 stereophotographs to measure quantitatively, the extent of tissue swelling or resorption, as well as, migration of dental implants to an accuracy of 16 µm.

b) State the factors affecting bone formation and resorption. Give the mecahnical properties of bone. (3m for factors, 3m for properties any three properties) 06

Factors affecting bone formation and resorption

1. Vascular in growth: Fibronectin, endothelial cell growth factor (ECGF).
2. Bone formation: Insulin-like growth factor (IGF-1) somatomedin c, platelet-derived growth factor. (PDGF), Fibroblast growth factor (FGF) IL-1, ECGF, insulin, bone-derived growth factors (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), prostaglandin E_2.

Mechanical properties of bone

	Direction of test	*Modulus of elasticity (Gpa)*	*Tensile strength (Mpa)*	*Compressive strength (Mpa)*
Leg bones	Longitudinal			
Femur		17.2	121	167
Tibia		18.1	140	159
Fibula		18.6	146	123
Arm bones	Longitudinal			
Humerus		17.2	130	132
Radius		18.6	149	114
Ulna		18.0	148	117
Vertebrae	Longitudinal			
Cervical		0.23	3.1	10
Lumbar		0.16	3.7	5
Spongy bone		0.09	1.2	1.9
Skull	Tangential	–	–	–
	Radial			97

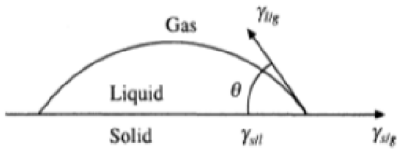
Q2 Attempt any four. Marks 16

a) Define i) Surface energy ii) Contact angle. State the importance of sterilization. 04
(1m for Surface energy, 2m Contact angle, 1m importance of sterilization)

Surface Energy: Surface energy is a measure of the extent to which bonds are unsatisfied at the surface of material. At the surface, there is an asymmetric force field, which results in a net attraction of surface atoms in to the bulk. This tends to deplete the surface of atoms putting the surface in tension.

Contact angle: When a liquid drop is placed onto a solid surface or another liquid surface two things may happen. The liquid may sit on the surface in the form of a droplet or it may spread out over the entire surface. Which event occurs depend on the interfacial free energies of the two substances. At equilibrium contact angle or Young-Dupree equation describes: **Fig2: depicting contact angle between the liquid and solid surface**

$\gamma s/g = \gamma s/l + \gamma l/g \cos\theta$



where γs/g, γs/l and γl/g are the interfacial free energy between the solid and gas; solid and liquid, liquid and gas respectively and θ the contact angle.

Importance of **Sterilization:** The surgical implants must be freed of microorganisms by postmanufacture sterilization. This must destroy most bacteria and spores, sterilization may be achieved by the use of dry heat, moist heat; irradiation or chemical agents according to established practices.

b) State the testing methods of biomaterials. (any 4 test each 1m) 04

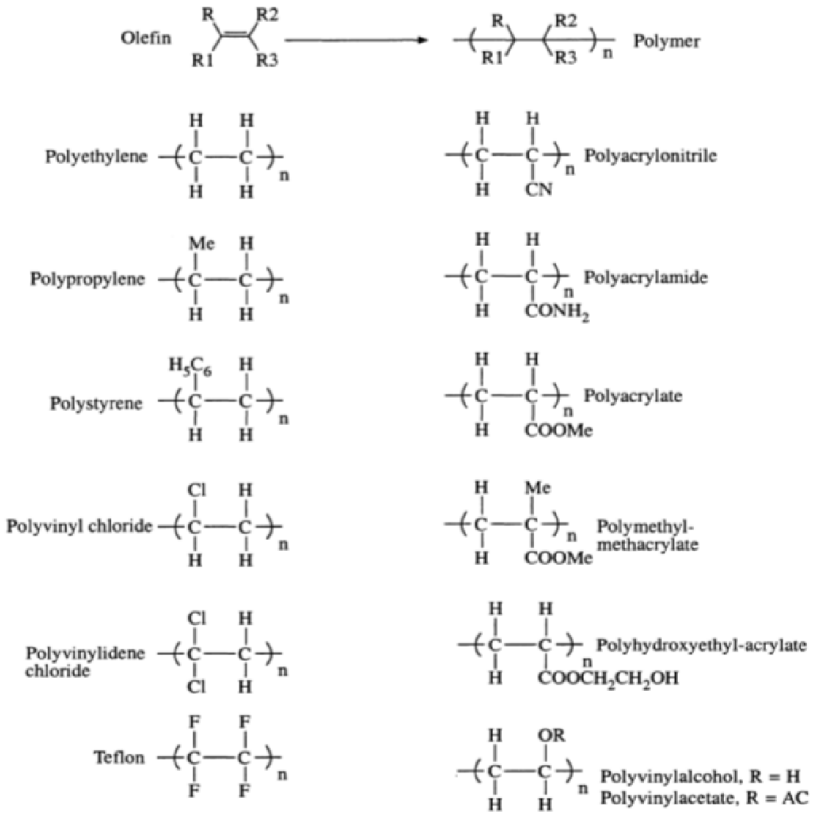
Evaluation type/Test methods	*Effect/Indication*
Toxicological	
In vitro: Mutagenicity/ Cell culture toxicity	Inhibition of growth or modification of cellular characteristic
In vivo: Intradermal and Mucus membrane irritation test	Inflammation/irritation
Systemic toxicity	Toxic nature
Carcinogenicity	Tumour formation/DNA mutation
Teratogenicity	Malformation of the fetus
Blood compatibility	
in vitro Hemolytic assay	Red cell rupture
Hemorheological assay	Effect on hemorheological parameters
Clotting time	Blood clotting
Protein absorption	Uptake of plasma proteins
Platelet adhesion	Blood clogging
Long term implantation	Retention of mechanical properties
Pyrogenicity	Microbial contamination
Immunocompatibility	Immunostimulation and rejection

c) Define polymer. State the types of polymer and give one example of each type of polymer. (1m for defining polymer, 1m for stating types,2m for examples) 04

Polymers (from the Greek: polys, many; meros, part or unit) are large molecules made up by the repetition of small, simple chemical units termed monomers. In some cases the repetition appears much as a chain is built up from its links. In other cases the chains are branched are interconnected to form three-dimensional networks

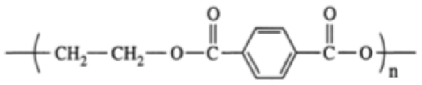
On the bases of the methods of polymeric synthesis they can be divided in two major groups namely the addition polymers and condensation polymers.

Addition polymers: (any 1)

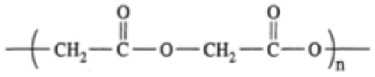


Condensation polymers: (any1)

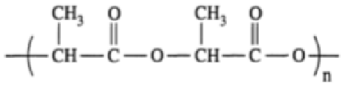
Polyester
Polyethylene terephthalate
(Dacron, terylene-fiber Mylar-film



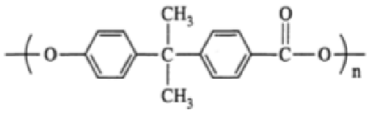
Polyglycolic acid (PGA)



Polylactic acid (PLA)

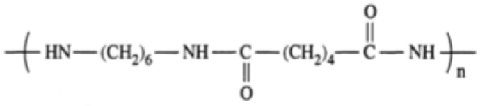


Polycarbonate (Lexan)(R)

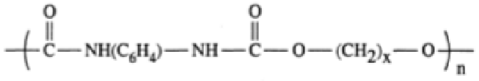


Polyamide

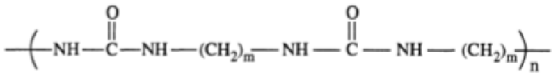
Polyhexamethylene adipamide
(Nylon 66)



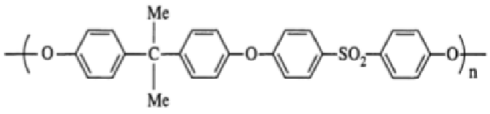
Polyurethane
(Esthane-sheet Ostamer-foam)



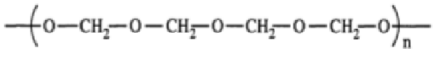
Polyurea



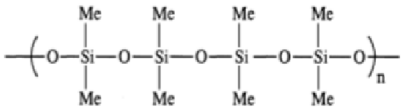
Polysulfone (Udel)(R)



Polyacetal, Polyether (Derlin)(R)
Polyoxymethylene, Polyformal-
dehyde



Silicone Rubber (Silastic)



d) Explain how analysis of ceramic surface is carried out. 04

(3m explaination,1m diagram)

Two approaches exist for analyzing the mechanisms and reactions at ceramic surfaces. In the first, one may examine the constituents that are released into the surrounding test environment or into the tissues. The traditional wet chemical techniques of atomic emission and atomic absorption permit one to determine the concentrations of ions released during the surface reactions.

The second approach is to examine the surface of the material with one of a number of tools, such as Infrared reflection spectroscopy (IRRS), electron microprobe analysis (EMP), energy dispersive X-ray analysis (EDXA), scanning electron microscope (SEM), Auger electron spectroscopy (AES) and secondary-ion mass spectroscopy (SIMS).

These surface analysis techniques can be classified in two groups (1) those sampling deep (up to 1.5 pm) into the surface (2) those that essentially examine only the outer surface (5-50 A) of the material. Ion milling (e.g. with-Ar) combined with these analytical techniques permit one to remove sequentially precalibrated layers from the surface such that analysis within the sample can be made.

Schematic of sampling depths for different surface analysis techniques:

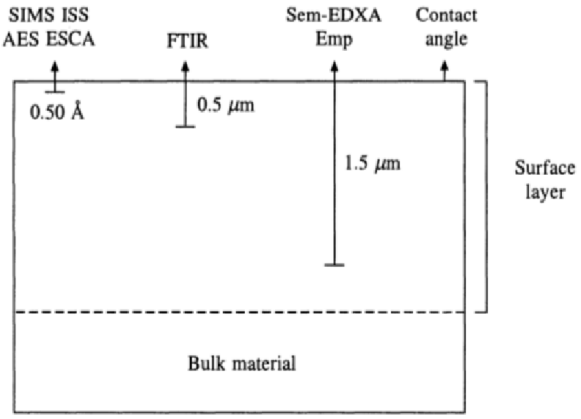


Fig 3 Schematic of sampling depths

e) Draw a labelled structure of kidney. **04**

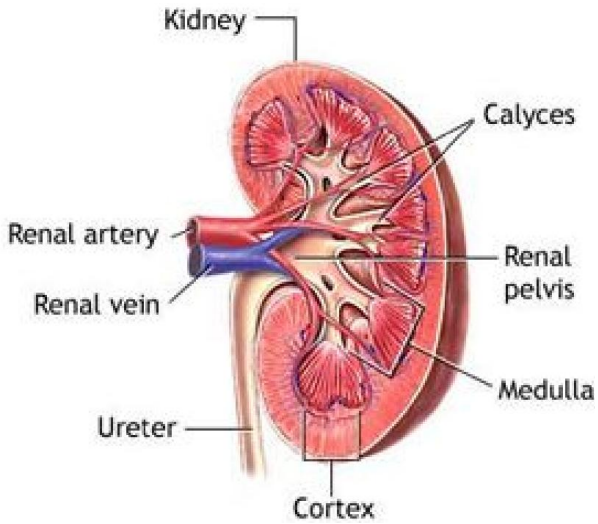


Fig 4 Structure of kidney

f) State the need of dental materials, also give the teeth composition. **04**

(need 2m, any two composition 2m)

Need for dental implants:

Dental materials generally are considered to comprise those materials, which are employed in restorative dentistry. These include impression materials to copy the contours of the gum, restorative materials to correct defects in natual materials, appliances and dentures to replace or correct deficiency of the grinding surfaces.

Teeth composition

Constituents[a]	*Dentine*	*Enamel*
Ca^{2+}	27.0	36.0
PO_4^{3-} as P	13.0	17.7
Na^+	0.3	0.5
K^+	0.05	0.08
Mg^{2+}	1.1	0.44
CO_3^{2-}	4.5	2.3
F^-	0.05	0.01
Cl^-	0.01	0.30
$P_2O_7^{4-}$	0.08	0.022
Ash[b]	70	97.0
Organic	20	1.0
H_2O[c]	10	1.55

Q3 Attempt any four: **Marks 16**

a) State the meaning of biocompatibility. Explain corrosion and wear. **04**
(1m biocompatibility, 2m corrosion with equation, 1m wear)

Biocompatibility is:

- Acceptance of artifical implant by surrounding tissur and body as whole.
- It should not irritate the surrounding structure,
- It should not provoke abnormal inflammatory response.
- It should not cause any allergic or immunologic reaction.
- It should not lead to causjing cancer.

Corrosion: It is a degradative process often associated with electrochemical and oxidation reaction of metal in electroytic solution as well as oxidation and degradation of polymeric materials.
The primary anodic and cathodic reactions are represented by equations A and B respectively.

$$M \rightarrow M^{n+} + ne^-$$

$$1/2\ O_2 + H_2O + 2e^- \rightarrow 2OH^-$$

First is A and second is B.

Wear is loss of material from a surface by means of some mechanical action. Wear can occur due to various reasons and thus have different types. Some of them are listed bellow:

Abrasive wear: It occurs when a hard rough surface slides across a softer surface. **Adhesive wear**: It can be found between surfaces during frictional contact and generally refers to unwanted displacement and attachment of wear debris and material compounds from one surface to another.

Fatigue wear: Wear of a solid surface caused by fracture arising from material fatigue.

b) State two properties and two applications of carbon. 04

(2m application, 2m properties)

Properties of Carbon:

- The carbons are inert ceramic materials.
- 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.
- All the carbons, currently of interest for use in medical devices have the quasi -crystalline turbostratic structure.
- Carbon has good biocompatibility with bone and other tissues.
- It also has high strength and an elastic modulus close to that of bone and so do not suffer from fatigue.

OR

Mechanical properties of carbon:

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

Application of carbon;

Carbon coatings find wide applications in heart valves, blood vessel grafts, percutaneous devices because of exceptional compatibility with soft tissues and blood.

Percutaneous carbon devices containing high-density electrical connectors have been used for the chronic stimulation of the cochlea for artificial hearing and stimulation of the visual cortex to aid the blind.

LTI carbon deposited on preformed graphite substrates or metal implants is used in restorative dentistry.

The ability of carbons to absorb proteins without alteration is thought to be an important factor contributing to the blood compatibility of carbon surfaces.

This causes reduction in critical surface tension and blood adhesion.

Platelet adhesion and activation is found to be least with carbon coated surfaces. Hence ULTI coated valves are most widely used.

c) Draw the neat labeled stress-strain curve for ductile material. 04

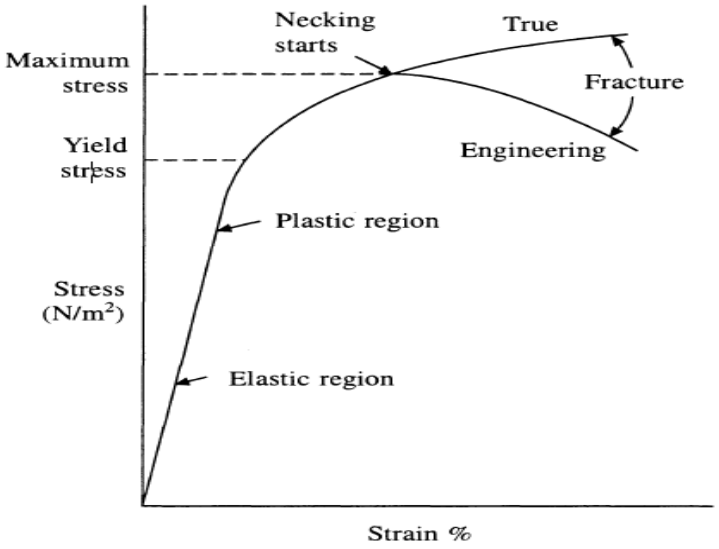


Fig 5 Stress-strain curve for ductile material

d) State the function of heart including valves. 04

Heart is an excellent pump, which maintains the blood supply tovarious parts of the body through blood vessels. The blood is pumped by the heart along arteries to the capillaries and is returned by veins

Function of heart valves:
Heart muscle contracts and relaxes, the valves open and shut, letting blood flow into the ventricles and atria at alternate times. And thus prevent the backward flow of blood.

Location of heart valves:

- tricuspid valve: located between the right atrium and the right ventricle
- pulmonary valve: located between the right ventricle and the pulmonary artery
- mitral valve: located between the left atrium and the left ventricle
- aortic valve: located between the left ventricle and the aorta

Opening and closing of valves:

- After the left ventricle contracts, the aortic valve closes and the mitral valve opens, to allow blood to flow from the left atrium into the left ventricle.
- As the left atrium contracts, more blood flows into the left ventricle.
- When the left ventricle contracts again, the mitral valve closes and the aortic valve opens, so blood flows into the aorta.

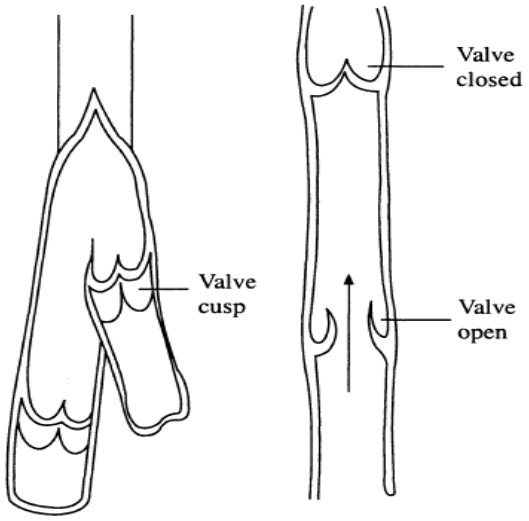


Fig 6: Depicting interior of vein- valves and cups, Arrow showing the direction of flow

e) Describe bone regeneration with resorbable material. 04
(2m for explanation and 2m for stating the materials)

A cancellous autograft is considered as the most suitable means for the reconstruction of bone defects.
Allogenic and xenogenic grafts are option for bone rgeneration but have short comings.
The costs of bone allografts, which require careful handling, are exceptionally high. Along with that, autogenous bone transplantation include prolongation of operation time, increased loss of blood, the risk of infection, nerve and vascular injury, thrombosis, fracture risk, additional scar, postoperative pain and cost of additional operation. Therefore bone replacement materials assume greater significance.
From experiments using more or less compact **calcium phosphate or apatite ceramics**, many researchers have showed that incorporation of these implants takes place without foreign body reactions and bone regeneration occurs on the surface and margins of the implant in contact with bone. However, when implanted in soft tissue without bone contact this material does not favor bone formation.
Collapat® is represents a very good bone substitute material. Collapat® is regarded as a strong bone regeneration-promoting medium in contact with bone. In general, Collapat® yields good vascularity and favorable bone replacement capability in bone beds and at bone surfaces.

A similar material, **Pyrost®,** is obtained from natural bone by using careful pyrolysis and sintering procedure. This material with natural bone structure and mineral content shows favorable osteoinductive activation.

4.A) Attempt any three. **Marks 12**

a) Explain electro kinetic theory in surface analysis. **04**
(3m explanation ,1mdiagram)

When a material with a charged surface is placed in a solution with ions, a diffused layer of oppositely charged ions (counterions) appears close to the surface.

The electrical double layer is the Stern theory, which describes the change in potential Ψ as the distance from the surface increases. The distance from the surface is Debye length γ.

Materials acquire charge due to many reasons, example: Metals develop a surface potential due to surface oxidation.

The presence of the electrical double layer gives rise to electrokinetic phenomena when either the particles or the medium moves.

The streaming potential and electroosmosis owe their existence to the electrical double layer. Electroosmosis is observed when an electrical potential is applied to the opposite ends of porous plug in a liquid medium.A flow of liquid through plug occurs.

The streaming potential is the converse. Forced motion of liquid through a porous plug generates an electrical potential, called Zeta potential (ζ). The Zeta potential is the electrical potential at the plane of shear in the liquid. Measurements of ζ potential have been useful for determining characteristics of blood vessels. The surface properties are among the most important material properties that a biomaterial possesses. This is due to the fact that when a device is implanted into tissues, the surface chemistry will determine to a large extent how the material and the tissues, or fluids interact.

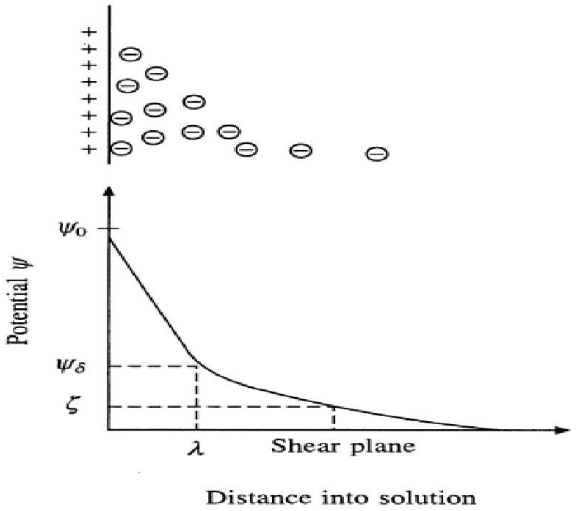


Fig 7: Graph potential vs shear plane

b) Give two properties and two applications of Zirconia. **04**
(2m properties, 2m application)

Properties of Zirconia:

At room temperature zirconia has monoclinic crystal structure. Upon heating, it transforms to Yttria oxide *(Y20'$_3$).*

The wear resistance is a function of the fine grain size, lack of surface roughness and residual compressive stresses is observed in monoclinic system.

The improved mechanical properties of yttria stabilized Zirconia Ceramics (V-TZP) combined excellent biocompatibility and wear properties.

Applications of Zirconia:
Yttria stabilized Zirconia Ceramics (V-TZP) combined is the best choice for the new generations of orthopedic prosthesis.
Zirconia ceramics are already widely used in orthopaedics in replacing alumina ceramics and to an extent, metals.
Zirconia ceramics are employed to develop new shoulder prosthesis, replacing conventional materials.
Hydroxyapatite coated Y-TZP dental implants are in used for more than ten years.

c) Draw a labelled structure of lungs. **04**

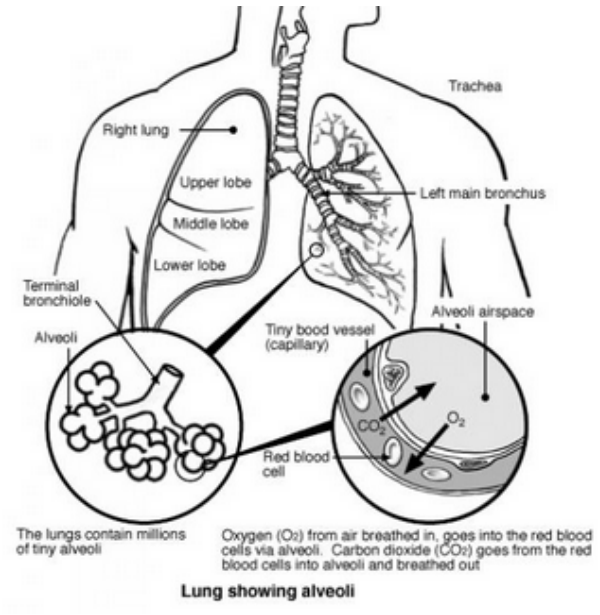


Fig 8: lungs

d) State and explain the use of collagen in dentistry.
(any four, 1m each) **04**

Material	*Observation*
Collagen	Collagen sponges decreased seepage of blood during periodontal mucoginvival surgery
Collagen	Collagen membranes have capacity to support regeneration of periodontal tissues
Collagen gel-allogeneic bone	Collagen gel-allogeneic bone implant encouraged ingrowth of regenerative tissue and new bone
Collagen tricalcium phosphate	Collagen-tricalcium phosphate grafts resulted in less soft tissue recession
Collagen coated root implants	Long lasting retention of collagen coated acrylic root implants
Collagen solution	Collagen solution applied to root surface suppressed epithelial migration and new tissue formation
Collagen graft	Collagen graft promoted formation of normal mucous membrane
Collagen allogenic bone	Bone collagen grafts reduced probing depths and gained new attachment
Collagen solution	Application of collagen solution to root surface suppressed epithelial migration and promoted new cementum formation
Collagen film + tetracycline	Topical administration of tetracycline on a collagen film remains active for two to three weeks

B) Attempt any one: **Marks 06**

a) State the procedure for reimplantation of natural teeth. **06**

The ideal implant is the tooth itself pulled from the socket, ifit can be replanted.With the natural tooth, collagen fibers of the periodontal ligament bridge the gap between the bone and the tooth root. The re-implantation studies have indicated that a highly cellular periodontal membrane can develop.Reattachment to both the bone and cementum is observed, but the reattached periodontal membrane often does not regain a functional orientation.The epithelial and underlying tissues reattach to the cement-enamel junction,unless there is considerable infection in the supporting tisues

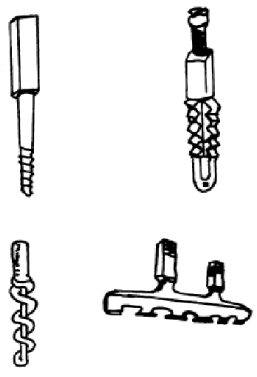


Fig 9: Various designs of self-tapping dental implants.

b) Describe temporary fixation of joints. Explain total knee replacement. 06 (3m+3m)

Temporary fixation of joints can be achieves by implementing tempory fixation devices.

The purpose of temporary fixation devices is to stabilize fractured bone until natural healing processes have restored sufficient strength so that the implant can be removed. These devices include pins, nails, wires, screws, plates, and intramedullary devices.

For example: Bone plates are used for joining bone fragments together during healing of load-bearing bones. The plate provides rigidity for the fixation of the fracture. Screws are used with the plates to secure them to the bone.

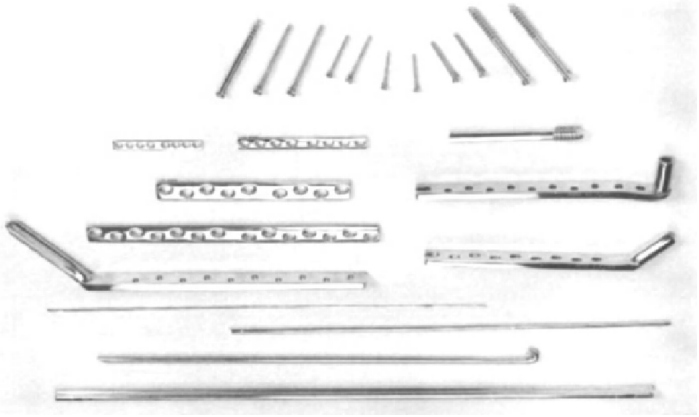


Fig 10: Design of bone screws, plates and nails

Total Knee Replacement (TKR)

The femoral component consists of a fairly thin, rigid shell with an attached fixation system to bone. The geometry of the femoral shell requires a stiff, high strength, low wear rate material such as metal.

The femoral component is fixed to the cortical bone of the femoral shaft. The fixation system may be either PMMA cement or a biological ingrowth type. The tibial portion consists of a broad plateau covering the tibia, consisting of a stiff metal tray supporting a polymeric or fiber reinforced polymer. Repeated tensile loading may cause failure ofPMMA-bone interface

TKR utilizes a limited number of metallic alloys including cobalt-chromium and titanium alloy.

Cobalt-chromium alloy combined with ultra high molecular weight polyethylene (UHMWPE) remains the contact surfaces of choice, despite some adverse effects on biocompatibility and mechanial problems.

These include creep and fatigue ofUHMWPE component due to high stresses and repeated loading and wear of polymeric contact surface due to adhesion of the polymeric surface to the metal.

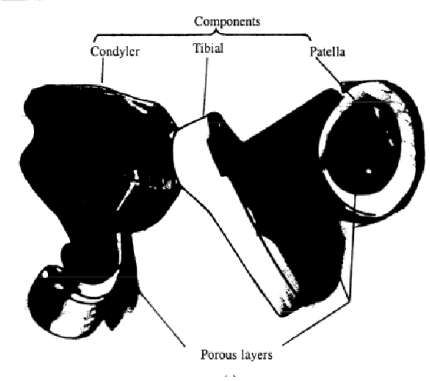
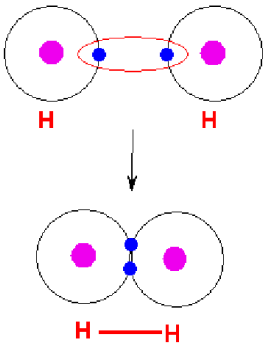


fig 11:Total knee Replacement parts

Q5. Attempt any four **Marks16**

a) Draw the structure of covalent bond and ionic bond of solid state crystals. **04**
(2m for each bond)

A **covalent** chemical bond results from the sharing of electrons between two atoms with similat electronegativities.



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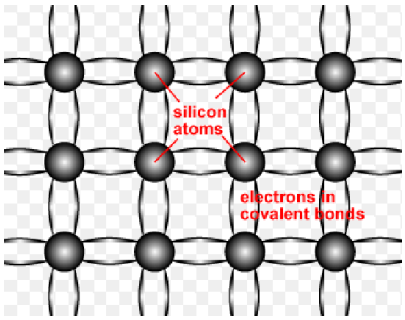

fig 12: covalent bond

Ionic bonding is a type of chemical bond that involves the electrostatic attraction between oppositely charged ions. These ions represent atoms that have lost one or more electrons (known as cations) and atoms that have gained one or more electrons (known as an anion).

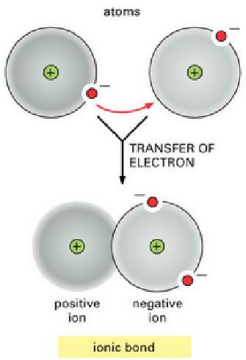

fig 13. Ionic bond

b) State different implant applications of ceramics and polymers. (two each)Describe their propeties. **04**
(1m for two implant and 1m for two properties for ceramic and Polymer each)

Ceramic

Any two applications along with properties of ceramic:

- **Carbon** coatings find wide applications in heart valves, blood vessel grafts, percutaneous devices because of exceptional compatibility with soft tissues and blood.
  The ability of carbons to absorb proteins without alteration is thought to be an important factor contributing to the blood compatibility of carbon surfaces. This causes reduction in critical surface tension and blood adhesion.
  Carbon does not provoke an inflammatory response in adjacent tissues and no foreign body reactions to the material have been observed. Bone and soft tissues are much more tolerant to carbon than other materials.

- High-density **alumina** is used in load-bearing hip prostheses and dental implants because of its combination of excellent corrosion resistance, good biocompatibility, high wear resistance and reasonable strength.

- **Zirconia** ceramics are employed to develop new shoulder prosthesis, replacin conventional materials. Zirconia in its momoclinical state has wear resistance, lack of surface roughness and residual compressive stresses.

Any two applications along with properties of Polymer:

Polymer	*Specific properties*	*Biomedical uses*
Polyethylene	Low cost, easy processibility, excellent electrical insulation properties, excellent chemical resistance, toughness and flexibility even at low temperatures	Tubes for various catheters, hip joint, knee joint prostheses
Polypropylene	Excellent chemical resistance, weak permeability to water vapors, good transparency and surface reflection	Yarn for surgery, sutures
Tetrafluoro-ethylene	Chemical inertness, exceptional weathering and heat resistance, nonadhesive, very low coefficient of friction	Vascular and auditory prostheses, catheters, tubes
Polyvinyl-chloride	Excellent resistance to abrasion, good dimensional stability, high chemical resistance to acids, alkalis, oils, fats, alcohols, and aliphatic hydrocarbons	Flexible or semi-flexible medical tubes, catheter, inner tubes, components of dialysis installation and temporary blood storage devices.
Polyacetals	Stiffness, fatigue endurance, resistance to creep, excellent resistance to action of humidity, gas and solvents	Hard tissue replacement
Polymethyl methacrylate	Optical properties, exceptional transparency, easy thermo-formation and welding	Bone cement, intraocular lenses, contact lenses, fixation of articular prostheses, dentures
Polycarbonate	Rigidity and toughness upto 140°C, transparency, good electrical insulator, physiological inertness	Syringes, arterial tubules, hard tissue replacement
Polyethylene terephthalate	Transparency, good resistance to traction and tearing, resistance to oils, fats, organic solvents	Vascular, laryngeal, esophageal prostheses, surgical sutures, knitted vascular prostheses
Polyamide	Very good mechanical properties, resistance to abrasion and breaking, stability to shock and fatigue, low friction coefficient, good thermal properties, good chemical resistance, permeable to gases	PA 6 tubes for intracardiac catheters, urethral sound; surgical suture, films for packages, dialysis devices components, PA66 heart mirtal valves, three way valve for perfusion, hypodermic syringes, sutures
Polyurethane	Exceptional resistance to abrasion, high resistance to breaking, very high elasticity	Adhesives, dental materials, blood pumps, artificial heart and skin

c) List one application of the following biomaterials:
1) Acrylic Polymer 2) Hydrogel 3) Silicon Rubber 4)Collagen 04
(1 Mark for 1 application of respective biomaterial)

1) Acrylic polymer:
- Used extensively in medico-surgical applications as contact lenses, implantable ocular lenses, bone cement for joint fixation, dentures and maxillofacial prostheses.

2) Hyrogel:
- Used in contact lenses
- Also used as a prime candidate material for synthetic articular cartilage in reconstructive joint surgery. As a semipermeable membrane it is not permeable to hyaluronic acid and thus concentrates synovial fluid in the joint.

3) Silicon Rubber:
- Used to make catheters
- The replacement of destroyed or diseased finger joints with silicone prostheses is carried routinely.
- Silicone rubber are the replacement of carpal bones, toe prostheses and capping temporomandibular joints.
- Breast augmentation with silicone rubber mammary prothesis is carried out routinely. Silicone rubber has been extensively used in maxillofacial surgery. Such uses include nasal supports, jaw augmentation, orbital floor repair, and chin augmentation.
- Silicone rubber such as artificial bladder, sphincters and testicles are being investigated.

4) Collagen: widely used in dentistry

Material	*Observation*
Collagen	Collagen sponges decreased seepage of blood during periodontal mucoginvival surgery
Collagen	Collagen membranes have capacity to support regeneration of periodontal tissues
Collagen gel-allogeneic bone	Collagen gel-allogeneic bone implant encouraged ingrowth of regenerative tissue and new bone
Collagen tricalcium phosphate	Collagen-tricalcium phosphate grafts resulted in less soft tissue recession
Collagen coated root implants	Long lasting retention of collagen coated acrylic root implants
Collagen solution	Collagen solution applied to root surface suppressed epithelial migration and new tissue formation
Collagen graft	Collagen graft promoted formation of normal mucous membrane
Collagen allogenic bone	Bone collagen grafts reduced probing depths and gained new attachment
Collagen solution	Application of collagen solution to root surface suppressed epithelial migration and promoted new cementum formation
Collagen film + tetracycline	Topical administration of tetracycline on a collagen film remains active for two to three weeks

d) Comment on electrical stimulation on bone healing. 04
(3m explanation, 1mdiagram)

The application of electrical energy can enhance osteogenic activity.The tissue can respond to the right amount of energy input (10-40 I1v) without excessive electrical potential (<1 V).
The stimulation is also closely related to the nature of electrode material, surface area and location. Noninvasive magnetic stimulators use a pair of Helmholtz coils, which are aligned across the wound site and a magnetic field with a monophasic 150-ms phase with a repetition rate of 75 Hz is applied. This pulse amplitude induces 1-2 m V/*cm* of potential in the bone.
The efficiency of both magnetic and direct current stimulation is about the same, over 70% success rate.
Recent studies indicate that direct electrical stimulation provides a significant improvement in bone ingrowth, while pulsed electromagnetic field and AC capacitivity coupled electrical stimulation do not help ingrowth enough to be noticed.

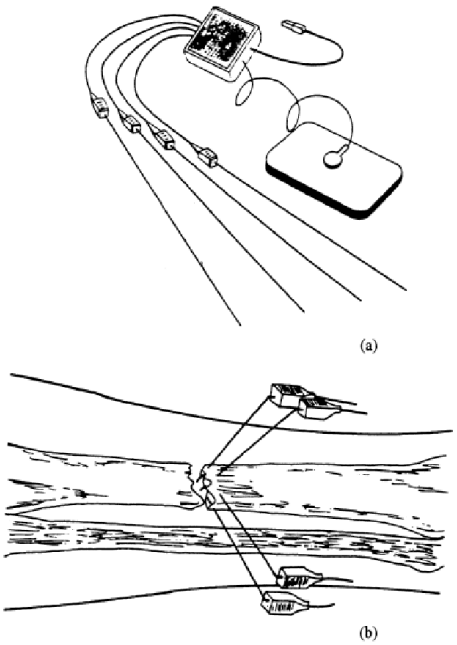

fig 14 a) quadripole electrical stimulator (b) of the use of an electrical stimulator for fracture fixation.

e)Explain the term Biological tolerance of implant metals with four examples. (any four) 04

Iron: The adult human body contains approximately 4 to 5 g of iron. Metabolically active iron is contained in circulating hemoglobin (about 66%), myoglobin (3%) and in heme containing enzymes less than 10% or is attached to transferrin in transit through the plasma. The remainder is held in storage either in ferritin, which is found in greater quantities in the liver, spleen and bone, or it is stored as insoluble intracellular granules of hemosiderin. The balance of iron in the body is maintained by adsorption at approximately lmg/day, with a similar quantity being lost per day.

Cobalt: It is an essential trace element and the function is confined to its role in vitamin B12. A daily intake of 3µm of vitamin B12 is adequate. Free cobalt has no obvious function and there is no apparent mechanism for controlling its uptake into or loss from the body. Eighty percent of dietary intake is unabsorbed and excreted in the faces unabsorbed and urinary excretion of the remainder is relatively fast. In cases of raised dietary cobalt levels it is possible for the cobalt absorbed to be located in the muscles of the heart leading in some cases to cardiomyopathy. It is not a particularly toxic metal and although there are theoretical and experimental grounds for assuming that cobalt based alloys could be quite toxic upon implantation, there is little evidence that they have any adverse effects on implantation in humans. Indeed these alloys offer very good biocompatibility properties, largely on account of the excellent corrosion resistance.

Chromium: Like many of the transition metals, chromium is both an essential dietary element that is required in low concentrations (blood level average 2.8µg/IOO g) and also a toxic substance if present in the raised amounts. Chromium compounds are only poorly absorbed after oral ingestion and storage of chromium (III) is largely confined to the reticuloendothelial systems. The hexavalent chromium ion is able to pass the plasma membrane freely, both in and out of the cell and the reduction takes place mainly in the mitochondria. The mechanism of chromium toxicity is not entirely clear but it has been suggested that the in vivo reduction from hexavalent to trivalent states may be important.

Molybdenum: It is an essential dietary element and has its highest concentration in the liver at I to 3 ppm. It is necessary for the function of certain enzymes. There are three principal molybdenum containing metallo-enzymes: xanthine oxidase, aldehyde oxidase and sulfite oxidase. In contrast to many metals, molybdenum is quite readily absorbed from the intestinal tract, excretion largely being via the kidneys. Molybdenum is toxic in large doses; the symptoms of toxicity include diarrhea, coma and cardiac failure, and inhibition of activity of ceruloplasmin, cytochrome oxidase, glutaminase, choline esterase and sulfite oxidase. High levels of molybdenum can also interfere with calcium and phosphorus metabolism.

Nickel: It is an essential element of limited biological activity with a wide-ranging distribution. In humans, it has a level of approximately 10 mg in adult human tissues. A normal blood level of nickel is around 5mg/l. In human inhalation of nickel may lead to renal effects but observation of toxicity are largely confined to carcinogenesis and hypersensitivity. It is sufficient to note here that nickel carcinogenesis in experimental animal is well established. While these facts are of some concern, their reference to implantation is not yet clear. Contact dermatitis for nickel and nickel alloys has been well established.

Manganese: It is at a level of 12 to 20 mg in a 70 kg man, and the normal blood level is 7.0 to 28.0 µg/ml. A higher concentration of manganese occurs in pituitary gland, pancreas, liver, kidney and bones, and accumulation occurs in hair. Within the cell manganese is associated with the mitochondria and it is largely protein bound in plasma. It is a co-factor for a number of enzymes, among them are carboxylases and phosphatases. Manganese is one of the least toxic trace elements. The divalent form is supposed to be more toxic than trivalent form. It has been shown that injected manganese elimination from the human body can be described by a curve with two exponents, the more rapid pathway having a half life of 4 days while 70% of the manganese had an average half-life of 39 days.

Titanium: Unlike nickel, titanium has a very good reputation for biocompatibility. Titanium and its compounds are not carcinogenic in experimental animals or in humans.

f)List temporary fixation devices. State their importance. 04
(2mfor listing, 2m for importance)

Temporary fixation devices include pins, nails, wires, screws, plates, and intramedullary devices. Bone plates are used for joining bone fragments together during healing of load-bearing bones.
The plate provides rigidity for the fixation of the fracture.
Screws are used with the plates to secure them to the bone.
The advantage of an intramedullary device is that it can be nailed through a small incision.
Plates of various sizes and shapes are available for the implantation in femoral and tibial part.

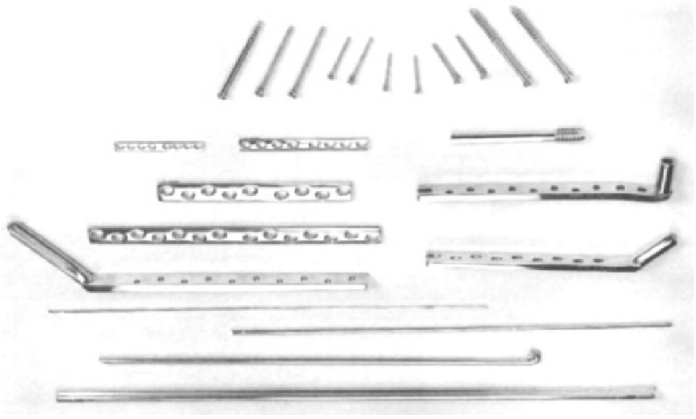

Fig 15:Various designs of bone screws, plates and intramedullary nails

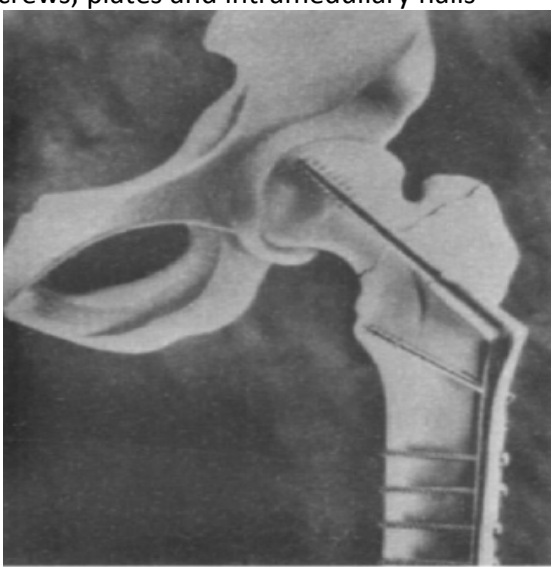

fig 16:Hip joint fracture fixation with compression bone plate.

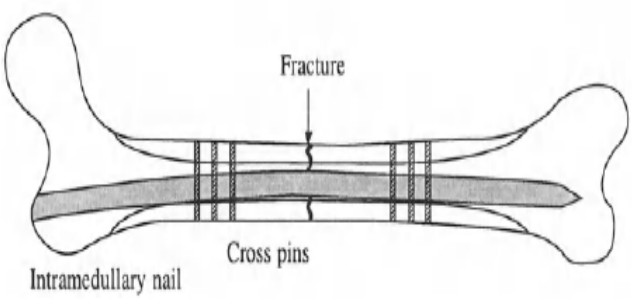

fig 17 Long bone fracture fixation with intramedullary nail.

6. Attempt any four. **Marks 16**

a) List advantages and disadvantages of PMMA and UHMPE with reference to total knee replacement. (1m for advantage and 1m for disadvantage for each of the two) **04**

TKR implements use of PMMA and UHMPE.

PMMA:

- The femoral component is fixed to the cortical bone of the femoral shaft. The fixation system may be either PMMA cement or a biological ingrowth type. The tibial portion consists of a broad plateau covering the tibia, consisting of a stiff metal tray supporting a polymeric or fiber reinforced polymer.
- Repeated tensile loading may cause failure ofPMMA-bone interface.

UHMPE

- Cobalt-chromium alloy combined with ultra high molecular weight polyethylene (UHMWPE) remains the contact surfaces of choice, despite some adverse effects on biocompatibility and mechanical problems.
- These include creep and fatigue ofUHMWPE component due to high stresses and repeated loading and wear of polymeric contact surface due to adhesion of the polymeric surface to the metal.

b) Draw the label structure of eye **04**

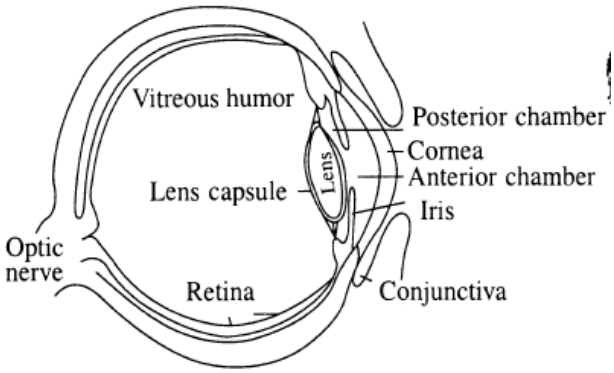

Fig 18: structure of eye

c) State and explain the biomaterial used for contact lenses. **04**
(Three types with atleast two examples in each must be covered)

The materials used for construction of contact lenses can be classified as **rigid, elastomeric and hydro gel.**
Rigid lenses can be subdivided into non oxygen-permeable polymethyl methacrylate lenses
and oxygen permeable lenses which include five types; cellulose acetatelbutyrate, siloxanyl alkyl methacrylate, silicone resin, alkyl styrene and fluorocarbon polymers.
Of the oxygen-permeable rigid contact lens materials, the lenses with the widest distribution are those made of siloxanyl- alkyl methacrylate copolymers with methyl methacrylate. Methacryloyl oxypropyl-tris (trimethylsilyl)-siloxane (TRIS) is a typical siloxanyl alkyl methacrylate used in the manufacture of oxygen-permeable rigid lenses as a comonomer with methyl methacrylate and other minor ingredients. The **elastomeric lenses** are of two types, silicone rubber and acrylic rubber. Most silicone rubber
contact lenses are made of crosslinked poly (methyl-phenyl-vinyl siloxanes) which has highest oxygen permeability of all contact lens materials. The acrylic rubber contact lenses are usually made of crosslinked copolymers of n-butyl acrylate with n-butyl methacrylate.
The **hydrogel lenses**, also known as soft contact lenses, can be classified as of low, medium and high water content. Most low water-content hydrogel contact lenses are made from cross linked 2-hydroxyethyl methacrylate polymer. They often contain some methacrylic acid, which determines the hydration and reactivity of lens to diverse contaminants. Other type of low-water content hydrogen contact lenses, which are most resistant to surface contamination than other hydrogel lenses, are made of crosslinked copolymers of glyceryl methacrylate and methyl methacrylate. Medium and high-water-content hydrogel lenses usually consist of copolymers of vinyl pyrrolidine with 2-hydroxyethyl methacrylate or methyl methacrylate. Another comonomer used in low and medium water content hydrogel contact lens materials is dialkyl-acrylamide.

Hydrogel contact lenses may also contain several other hydrophilic comonomers in minor proportion and various crosslinking agents. These polymers show fewer tendencies for lipid deposition.

d) Explain the terms: i) Blood clot: ii) Blood substitutes **04**
(2m for each term)

i) Blood clot:

A clot that has formed inside a blood vessel is referred as a thrombus or an embolus depending on whether the clot is fixed or floating, respectively.

ii) Blood substitutes.

One of the most urgent requirements in a patient suffering from acute blood loss is the re-establishment of a normal blood volume. This may be achieved satisfactorily with a number of plasma substitutes called blood substitues

e) List factors that effect blood compatibility of synthetic vascular implant materials. **04**
(1m each for each effect)

The factors that affect the blood cpmpatibility are:

- Clot formation
- Surface roughness
- Negatively charged surface
- Inert surfaces
- Solution perfused surfaces