WINTER-19 EXAMINATION

Model Answer

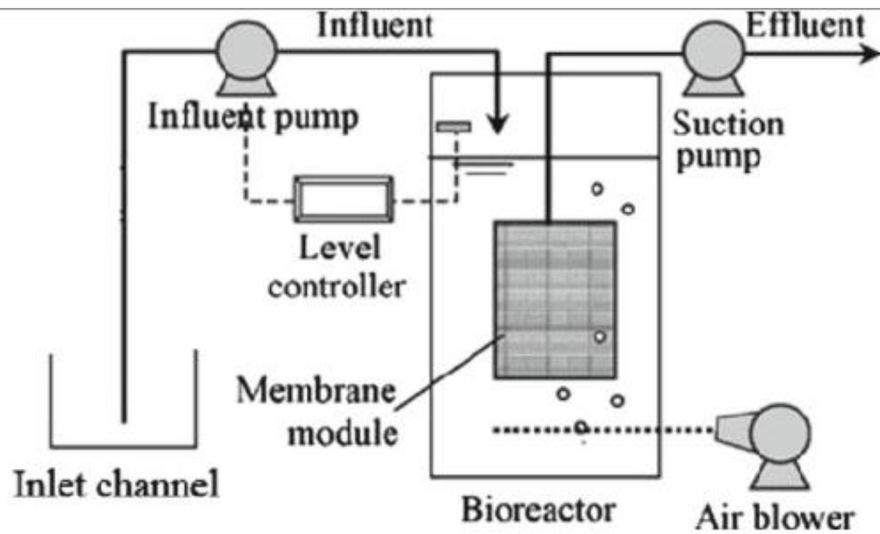
Subject title: Membrane Technology Subject code 22513

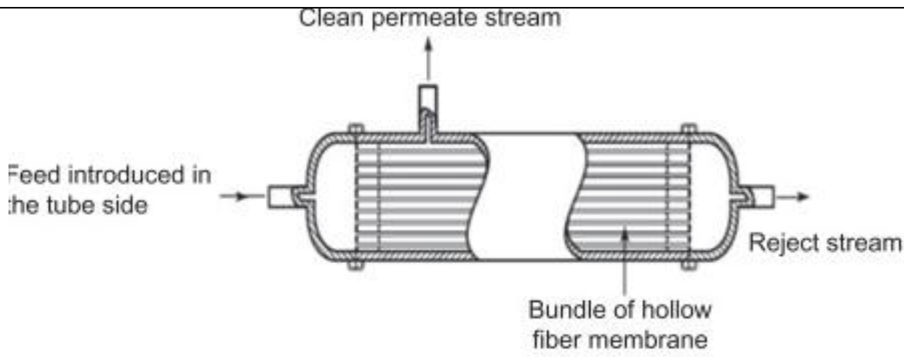
Important Instructions to examiners:

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.		Answer	Marking scheme
1		**Attempt any FIVE of the following**	**10**
1	a	**Fouling of membrane:** Membrane fouling is a process whereby a solution or a particle is deposited on a membrane surface or in membrane pores in a processes such as in a membrane bioreactor, reverse osmosis, forward osmosis, membrane distillation, ultrafiltration, microfiltration, or nanofiltration so that the membrane's performance is negatively affected.	2
1	b	**Applications of nano technology: (any 2)** 1. Medicine 2. Construction materials 3. Food 4. Fuel 5. Military goods 6. Electronics 7. Purification and environmental clean up 8. Biotechnology	1 mark each
1	c	**Hydrophilic membrane**: They are water loving. Hydrophilic membrane filters, are commonly used for clarification and sterilization of water-based fluids but are not typically used for venting applications. **Hydrophilic membrane** They are water repellent. While hydrophobic membrane filters are ideal for air and gas filtration, they are not suitable for filtering aqueous solutions.	1 1

1	d	**Membrane distillation separation process:** 1. Direct contact membrane distillation 2. Air gap membrane distillation 3. Sweeping gas distillation 4. Vacuum membrane distillation.	½ mark each
1	e	**Principle of membrane separation process:** It is a tool for separation of liquid mixtures, especially dehydration of liquid hydrocarbons. It is a membrane separation process in which one or more dissolved species flow across a selective barrier in response to a difference in concentration.	2
1	f	**Transmembrane pressure:** Transmembrane pressure is defined as the difference in pressure between two sides of a membrane. It is a valuable measurement because it describes how much force is needed to push water (or any liquid to be filtered -- referred to as the "feed") through a membrane. **Permeate flux:** The membrane permeation flux is defined as the volume flowing through the membrane per unit area per unit time. For the case of transport of gases and vapors, the volume is strongly dependent on pressure and temperature.	1 1
1	g	**Dead end and cross flow filtration:** **Dead-end filtration** means the fluids **flow** is vertical to the filter surface, and the retained particles rapidly solidify on the surface of the filter to form a so-called filter cake. **Cross-flow filtration** means turbulence will happen on the surface of the membrane.	1 1

2		**Attempt any THREE of the following**	**12**
2	a	**Submerged membrane bio reactor:** A submerged membrane bioreactor (SMBR) in which the membrane module is submerged inside the bioreactor and the permeate is suctioned directly by dead-end filtration. Note that membranes might be either submerged in the aeration tank or in the membrane tank. Wastewater is collected and treated in pre existing rotating biological contactors before passing to the primary aeration tank and then onto the submerged membrane bioreactor. The permeate is disinfected and stored in the grey water tank from where it is either pumped for direct use in the cooling tower and the washing system or diverted to a reverse osmosis plant for further treatment prior to use as boiler feed water  	4
2	b	**Hollow fibre membrane module:**	4

			
2	c	**Bio fouling of membrane**: Biofouling is the irreversible adhesion on a membrane of microorganisms and the extracellular polymers (ECPs, i.e., biofilm) that they produce. The process of adhesion involves three steps (2): bacterial adhesion, which can become irreversible in just hours, even without nutrients present. Biofouling can have several adverse effects on membrane systems such as: • Membrane flux decline due to the formation of a low permeability biofilm on the membrane surface. • Increased differential pressure and feed pressure being needed to maintain the same production rate due to biofilm resistance. • Membrane biodegradation caused by acidic by-products which are concentrated at the membrane surface. For example, cellulose acetate membrane has been found to be more susceptible to being biodegraded. • Increased salt passage through membrane and reduced quality of the product water due to the accumulation of dissolved ions in the biofilm	4

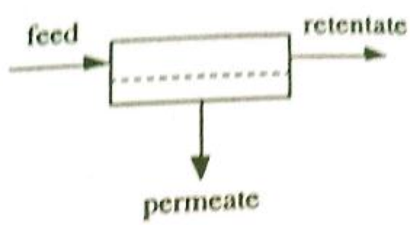
		at the membrane surface thus increasing the degree of concentration polarization. • Increased energy consumption due to higher pressure being required to overcome the biofilm resistance and the flux decline.	
2	d	**Ultrafiltration:** **Principle**: Ultrafiltration (UF) is a membrane filtration process similar to Reverse Osmosis, using hydrostatic pressure to force water through a semi-permeable membrane. Suspended solids and solutes of high molecular weight are retained, while water and low molecular weight solutes pass through the membrane. It is a type of membrane filtration in which hydrostatic pressure forces a liquid against a semipermeable membrane. A semipermeable membrane is a thin layer of material capable of separating substances when a driving force is applied across the membrane. **Working:** Ultrafiltration is one membrane filtration process that serves as a barrier to separate harmful bacteria, viruses, and other contaminants from clean water. An ultrafiltration water system forces water through a .02 micron membrane. Suspended particles that are too large to pass through the membrane stick to the outer membrane surface. Only fresh water and dissolved minerals pass through.	2 2
3		**Attempt any THREE of the following**	**12**
3	a	**Reversible and irreversible fouling of membrane:** Membrane fouling can be divided into reversible (removable, irremovable) and irreversible fouling based on the attachment strength of particles to the	4

		membrane surface. Removable fouling caused by loosely attached foulants can be eliminated by physical cleaning, whereas irremovable fouling can be eliminated by chemical cleaning Formation of a strong matrix of fouling layer with the solute during a continuous filtration process will result in reversible fouling being transformed into an irreversible fouling layer. Irreversible fouling is the strong attachment of particles which cannot be removed by physical or chemical cleaning. The cleaning procedure must be adapted to the type of substances responsible for fouling in each application, reducing the amount of irreversible fouling. However, identifying the foulants can be difficult, as the amount of material deposited on the membrane surface is usually small.	
3	b	**Microfiltration membrane process :** **Description:** Microfiltration is defined as a membrane separation process using membranes with a pore size of approximately 0.03 to 10 micronas (1 micron = 0.0001 millimeter), a molecular weight cut-off (MWCO) of greater than 1000,000 daltons and a relatively low feed water operating pressure of approximately 100 to 400 kPa (15 to 60psi) Materials removed by MF include sand, silt, clays, algae, and some bacterial species. Membrane filtration processes can be distinguished by three major characteristics: driving force, retentate stream and permeate streams. The microfiltration process is pressure driven with suspended particles and water as retentate and dissolved solutes plus water as permeate. The use of hydraulic pressure accelerates the separation process by increasing the flow rate (flux) of the liquid stream but does not affect the chemical composition of the species in	2

the retentate and product streams.

Microfiltration membranes can generally operate in one of two configurations- Cross flow filtration and dead-end filtration.

Cross flow filtration: where the fluid is passed through tangentially with respect to the membrane. Part of the feed stream containing the treated liquid is collected below the filter while parts of the water are passed through the membrane untreated



Dead-end filtration: all of the process fluid flows and all particles larger than the pore sizes of the membrane are stopped at its surface. All of the feed water is treated at once subject to cake formation. This process is mostly used for batch or semi continuous filtration of low concentrated solutions.

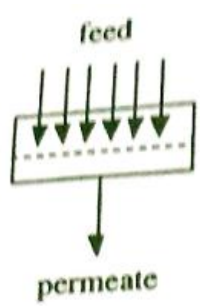
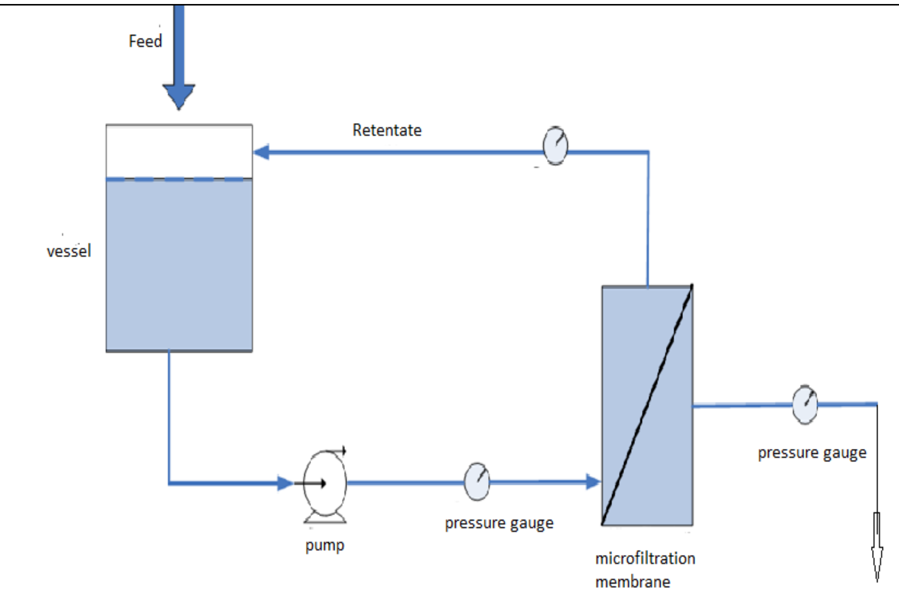
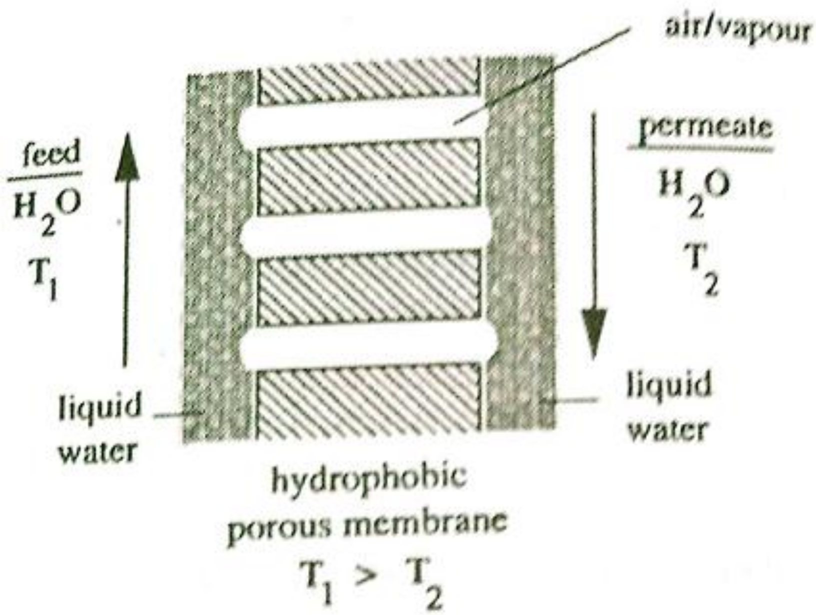


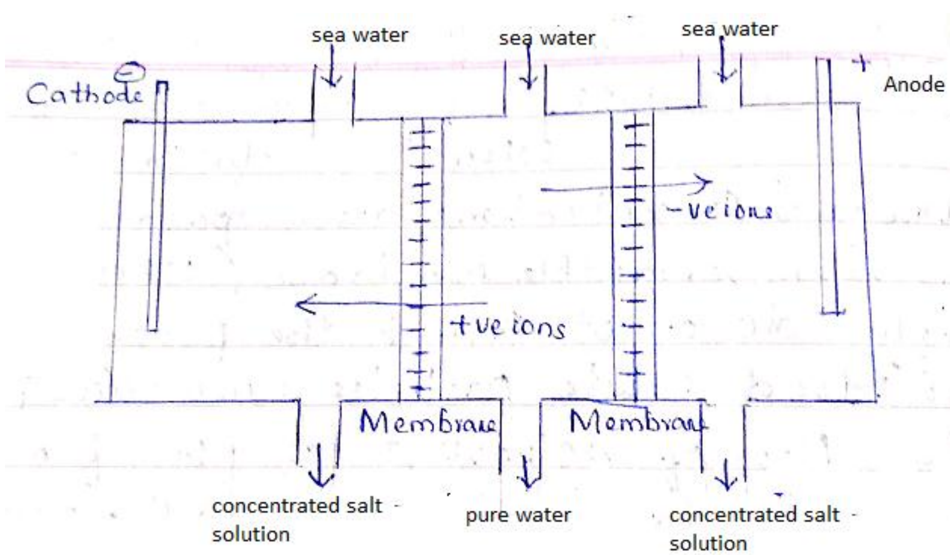
Diagram **:**

			2
3	c	**Air gap membrane distillation:** **Construction and working:**  Membrane distillation is a process in which two liquids or solutions at	4

		different temperatures are separated by a porous membrane. The liquids or solutions must not wet the membrane otherwise the pores will be filled immediately as a result of capillary action. ie hydrophobic membranes must be used in the case of aqueous solutions. If the temperature of one of the two phase is higher than that of the other, a temperature difference exists across the membrane, resulting in a vapour pressure difference. Thus vapour molecules will transport through the pores of the membrane from the high vapour pressure side , Such transport occurs in a sequence of three steps: evaporation on the high temperature side, transport of vapour molecules through the pores of the hydrophobic porous membrane, condensation on the low temperature side. The only function of the membrane is to act as a barrier between the two phases. Liquid to be treated is circulated in direct contact with the feed side of the membrane in the AGMD(Air Gap Membrane Distillation) cell. A cold liquid solution is circulated in direct contact with a cooling plate on the permeate side of the membrane. Both the feed and the cooling solutions are circulated tangentially while using pumps at low or no hydrostatic pressures. An air gap is created between the permeate side of the membrane and the cooling plate where permeate is condensed and collected through a permeate collection tube at the bottom of the gap.	
3	d	**Economic feasibility study of membrane based separation process (any one eg):** Membrane distillation (MD) is an emerging technology for brackish water desalination. MD is a thermal, vapor-driven transportation process through microporous and hydrophobic membranes. MD is applied as a nonisothermal	4

		membrane process in which the driving force is the partial pressure gradient across a membrane that is porous, not wetted by the process liquid. In this process, saline water is heated to increase its vapor pressure, which generates the difference between the partial pressure at both sides of the membrane. Hot water evaporates through nonwetted pores of hydrophobic membranes, which cannot be wetted by the aqueous solutions in contact with and only vapor and noncondensable gases should be present within the membrane pores. The passing vapor is then condensed on a cooler surface to produce fresh water. . The recovery of MD process is higher than the RO process for seawater desalination. Fouling and scaling are two important mechanisms that affect stability of the MD process and lead to reduce the overall efficiency. Membrane fouling increases the costs by increasing (1) energy consumption, (2) system down time, (3) necessary membrane area, and (4) construction, labor, time, and material costs for washing and cleaning processes. It is a general conclusion that pretreatment has an important positive influence on MD. In MD, desalination plant is operated in conjunction with a power plant or any other source of waste heat, the cost of energy for heating the feed water is negligible, hence thermally polluted water can be treated economically. Other sources of energy such as renewable solar or geothermal energy could be utilized to heat the feed water. As opposed to warm condenser water, use of renewable sources would involve higher capital investment. However, this investment may eventually be paid off by lower operating costs. MD could be convenient to utilize cheap heat sources such as solar energy, geothermal energy, and waste heat. Therefore, in combination with such cheap energy, MD was a process of phase transition, and utilization of heat energy could	

		decrease due to latent heat of vaporization. It has some significant advantages over RO process, including lower operating temperature and pressure, and thus possible to use energy sources such as renewable solar heat or waste heat, product quality, and higher resistance to fouling.	
4		**Attempt any THREE of the following**	**12**
4	a	**Polymerics and ceramics membrane materials:** **Polymeric membrane materials.** All polymers can be used as barrier or membrane material but the chemical and physical properties differ so much that only a limited number will be used in practice. A classification will be made between the open porous membrane, which are applied in micro filtration and ultrafiltration and the dense non porous membranes applied in gas separation and pervaporation. For the porous micro filtration / ultrafiltration membranes the choice of the material is mainly determined by the processing requirements, fouling tendency and chemical and thermal stability of the membrane. For the dense non porous membrane, the choice of the material directly determines the membrane performance Eg. Polyacrylonitrile, High density) polyethylene, Polytetrafluoroethylene **Ceramic membrane materials:** They are inorganic membranes formed by the combination of a metal with nonmetal in the form of an oxide, nitride or carbide. They are having good thermal and chemical resistance. Their melting points are very high. The high temperature resistant makes these materials very selective for gas separation at high temperatures. They can be used at any pH and in any organic solvent. It is easy to clean and all kinds of cleaning agents can be used, allowing strong acid and alkali treatment. Lifetimes of inorganic membranes are greater than that of	2 2

		polymeric membranes. Eg Aluminium oxide / Alumina, Silicon carbide, Titanium dioxide / Titania	
4	b	**Electrodialysis:** **Description:** Electrodialysis is a method in which ions are pulled out of the salt solution by passing direct current using electrodes and thin rigid plastic membrane pair (natural or synthetic). An electrodialysis cell consists of a large number of paired sets of rigid electrically charged plastic membranes. Salt water is passed under a pressure of about 5-6kgf /cm2 between membrane pairs and an electric field is applied perpendicular to the direction of water flow. When direct electric current is passed through the salt solution, ions are separated and they started moving towards oppositely charged electrode through the membrane. **Diagram:**  	2 2
4	c	**Industrial application of membrane bioreactor (any 4):**	1 mark

		1. For the treatment and reuse of industrial and municipal wastewater. 2. Production of organic chemicals. 3. Production of food products. 4. Production of pharmaceuticals, hormones, vitamins	each
4	d	**Membrane fouling control method (any one):** Some common preventative measures to avoid membrane fouling are 1. Scheduled cleaning 2. Pretreatment 3. System design **Scheduled cleaning** A systematic cleaning regimen can help to prevent foulants from building up on the membrane. Cleaning cycles should be scheduled monthly or at other regular intervals to provide the greatest benefit. Maintenance strategies can vary depending upon the membrane filtration system design and the types of contaminants involved, and can employ one or more cleaning methods, such as: (i). Mechanical cleaning involves the use of physical force to loosen contaminants from the membrane and flush them out of the system. Typical approaches include vibration, as well as backward or forward flushing, where water or a cleaning solution is run through the unit at a faster speed or higher pressure than in a normal service cycle, resulting in turbulence that removes foulants from the membrane. In a related process known as air scouring, air is added to the backwash/forward flush solution to further increase turbulence. (ii). Chemical cleaning involves the application of detergents, caustics, acids, antiscalants, or dispersants to loosen and remove foulants from the membrane	4

surface. Cleaning chemicals are selected based on the type of contaminants present, with consideration also given to the membrane material to ensure that the chemicals used do not damage it.

Pretreatment

RO/NF membranes have smaller pores than MF/UF membranes, therefore, they are more likely to require some form of pretreatment to avoid membrane fouling or other issues. Streams with high concentration of contaminants may also demand pre-treatment ahead of membrane filtration units in order to minimize the risk of membrane fouling. Pre-treatment options can include coagulation if colloidal particles are present, as well as gravity settling(sedimentation), flocculation and media filtration for the removal of larger or coagulated particles. Other types of pre-treatment can include chemical pH adjustment and ion exchange to prevent adsorption or deposition of foulants on the membrane.

System design

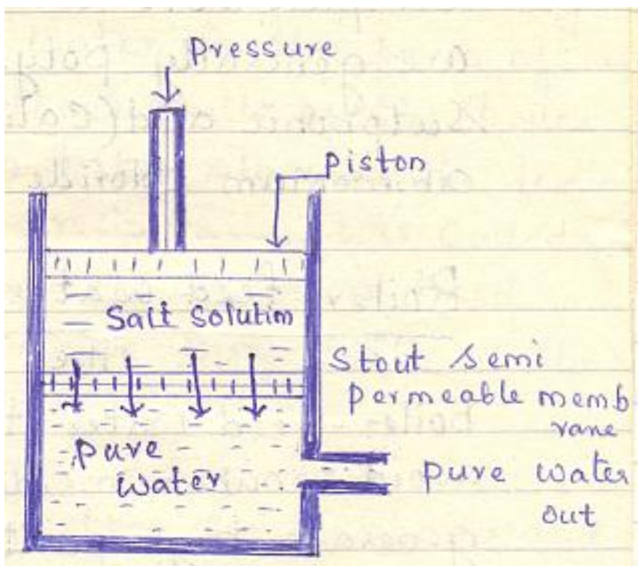
Preventing membrane fouling is best accomplished by good planning and design. There are many variables that play a role in proper system function for a membrane filtration system, each of which should be considered when replacing a membrane or installing a new system. These include:

(i) Membrane material: Filtration membranes may be fabricated from a wide variety of synthetic polymers, ceramic, and metallic materials. Properties of the membrane material, such as its surface ionic charge, hydrophobicity, and pH tolerance range, determine whether the membrane will be resistant to certain types of fouling, and how well it will withstand process conditions and the necessary maintenance regimen.

		(ii) Membrane pore size**:** Pore size is the key factor to ensuring efficient removal of targeted contaminants by a membrane filtration unit. Additionally, selection of the proper membrane pore size can help to avoid fouling by optimizing permeate flux in light of other factors, such as feed water quality, temperature, and salt concentration. (iii) Operating conditions: Membrane fouling can be exacerbated by certain ranges of temperature, pH, transmembrane pressure, and flow rate. A well-designed system will balance these variables to ensure that foulants do not collect on the membrane surface. Several approaches can be taken to minimize membrane fouling: a. Optimize pH and ionic strength of the feed solution to minimize the adsorption or deposition of the feed materials. b. Select an appropriate pre-filtration procedure or other means to remove large molecules, since the presence of larger molecules or particles could cause a steric hindrance to the passage of smaller molecules through the membrane. c. Select a membrane with an optimum pore size to result in good separation performance as well as optimized permeate flux. d. Optimize the operating conditions. This includes increasing transmembrane pressure to maximize flux without introducing more fouling potential. e. Increase the cross-flow velocity, which generally results in an improvement in permeate flux.	
4	e	**Economic feasibility study of membrane separation process for sea water desalination:** Reverse osmosis (RO) membranes are the leading technology for desalination of sea water because of their strong separation capabilities and exhibiting a	4

		great potential for treatment of waters worldwide A typical RO system consists of four major subsystems: pretreatment system, high-pressure pump, membrane module, and post treatment system. The membrane manufacturers offer high salt rejection membranes for RO plants, and the membranes do not retain the initial salt rejection throughout the membrane's lifetime (up to 7 years with effective pretreatment). Temperature, salinity, target recovery, and cleaning methods can affect salt passage through normal membrane. The main drawbacks of RO technology are the limited recovery and the environmental impact of rejected brines. Recovery and brine concentration are limited because increasing the brine concentration in RO would increase osmotic pressure and thus the energy consumption as well as scaling on the membrane surface. Recovery of the seawater RO plant is 35 to 45%. The key limiting factor to widespread use of inland desalination is the exorbitant cost of concentrate disposal. Membrane fouling is a major obstacle in RO. Fouling increases resistance, which in turn reduces permeate flux. Fouling can be controlled by feed pretreatment and membrane cleaning. Sometimes conventional pretreatment is not effective. An excessively advanced pretreatment system significantly increases the installation cost. In RO Plant, for occurrence of reverse osmosis, a very high pressure is to be applied on the concentrated solution and is directly related to the feed pressure and flow rate. The high salt concentrations found in seawater require elevated hydrostatic pressures (up to 7000 kPa); the higher the salt concentration, the greater the pressure and pumping power needed to produce a desired permeate flux. High-pressure pump sets and approximately 70% energy required for	

		these pump sets. As the recovery of a RO unit increases, the osmotic pressure increases on the feed side of the membrane, thus increasing the feed pressure required. However, as the recovery increases, the feed flow required decreases (for a specific product flux), and for lower recoveries (35–50%), the overall energy requirement decreases with increasing recovery. Thus, a minimum energy requirement exists, typically at a recovery between 50 and 55%, which varies with feed salinity. In RO process, the rejected brine effluent will be having high pressure and having a considerable percentage of feed pressure. This available residual brine pressure can advantageously be utilized to boost the feed pressure of the raw water by suitable arrangement/device. This is called energy recovery system.. Hydro turbines and impulse turbines are the two types of devices for recovering the residual energy available from the high-pressure feed stream. Energy recovery devices can provide net energy transfer efficiency from the concentrate stream to the feed stream of more than 95%. The coupling of energy sources with RO desalination plants has been an increased interest to development. Wind and photovoltaic solar energy are commonly paired with RO desalination. Overall, the energy sources most often used are solar energy (70% of market) and RO which has the majority (62%) of the renewable energy desalination market. The energy recovery devices installed in the RO process can lead to 25 to 30% of energy saving. Energy recovery devices play vital role in cost-effective production of fresh water by RO desalination.	
5		**Attempt any TWO of the following**	**12**
5	a	**Principle of reverse osmosis process:** When two solutions of unequal concentrations are separated by a semi	2

		permeable membrane and if a hydrostatic pressure in excess of osmotic pressure is applied on the concentrate side, the solvent is forced to move from the concentrated side to dilute side across the membrane. This is known as reverse osmosis. The effectiveness of the process depends on the density of the membrane. It is also important that the membrane be cleaned regularly for proper functioning. Membranes are made of cellulose acetate, polymethacrylate, polysulphone, polyamide polymers etc. Reverse osmosis is employed for desalination process 	2
		Composite Membrane: Thin-film composite membranes (TFC or TFM) are semipermeable membranes manufactured principally for use in water purification or water desalination systems. They also have use in chemical applications such as batteries and fuel cells. Thin film composite (T.F.C) membranes consist of a dense ultrathin barrier layer typically 0.2 mm thick on top of a microporous polsulfone support. The	2

		advantages of these membrane are that they operate at higher flux and lower pressure, have greater chemical stability, have higher salt rejection, they are not biodegradable, they have higher rejection of other materials (silica, nitrate, organics). Operating ranges of these membranes are pH of 2 to 12 and temperatures of 0°C to 40°C.	
5	b	**Differentiate between Inorganic and Organic nano particle: (any 6)**	1 mark each

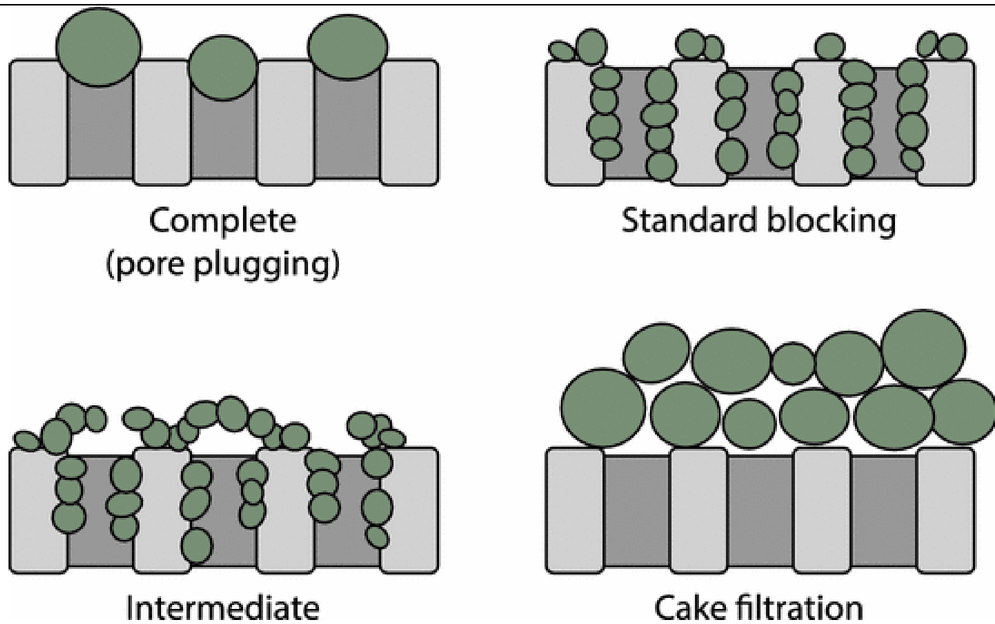
Inorganic nano particle	**Organic nano particle**
Inorganic nanoparticles are prepared by sol gel method, mechano-chemical processing and physical vapor synthesis etc., depending upon the type of inorganic nanoparticle	For starch nanoparticles, acid hydrolysis, reactive extrusion, gamma irradiation, ultrasonication, high power homogenization and nanoprecipitation are used for their preparation
Prepared with inorganic elements	Prepared with organic polymers
Less biodegradability	have an upper edge in terms of biodegradability
extensively used as antimicrobial agents in the food packaging	they result in bio-nanocomposites when

		systems. | blended with a biodegradable polymer titanium dioxide, zinc oxide, magnesium oxide, gold and silver are inorganic nano particles | starch and chitosan are organic nano particles Inorganic in nature | Organic in nature	
5	c	**Disadvantages of membrane separation process: (any 6)** 1. Membrane processes seldom produce 2 pure products, that is, one of the 2 streams is almost always contaminated with a minor amount of a second component. In some cases, a product can only be concentrated as a retentate because of osmotic pressure problems. In other cases the permeate stream can contain significant amount of materials which one is trying to concentrate in the retentate because the membrane selectivity is not infinite. 2. Membrane processes cannot be easily staged compared to processes such as distillation, and most often membrane processes have only one or sometimes two or three stages. This means that the membrane being used for a given separation must have much higher selectivities than would be necessary for relative volatilities in distillation. Thus the trade-off is often high selectivity/few stages for membrane processes versus low selectivity/many stages for other processes. 3. Membranes can have chemical incompatibilities with process solutions. This is especially the case in typical chemical	1 mark each

		industry solutions which can contain high concentrations of various organic compounds. Against such solutions, many polymer-based membranes (which comprise the majority of membrane materials used today), can dissolve, or swell, or weaken to the extent that their lifetimes become unacceptably short or their selectivities become unacceptably low. 4. Membrane modules often cannot operate at much above room temperature. This is again related to the fact that most membranes are polymer-based, and that a large fraction of these polymers do not maintain their physical integrity at much above 100 ^{o}C. This temperature limitation means that membrane processes in a number of cases cannot be made compatible with chemical processes conditions very easily. 5. Membrane processes often do not scale up very well to accept massive stream sizes. Membrane processes typically consist of a number of membrane modules in parallel, which must be replicated over and over to scale to larger feed rates. 6. Membrane processes can be saddled with major problems of **fouling** of the membranes while processing some type of feed streams. This fouling, especially if it is difficult to remove, can greatly restrict the permeation rate through the membranes and make them essentially unsuitable for such applications. 7. Membrane processes are limited to their upper solid limit. 8. Membrane processes are expensive compared to other processes.	

6		**Attempt any TWO of the following**	**12**
6	a	**Factors responsible for membrane fouling**: Membrane fouling in almost all membrane processes is normally caused by precipitation and deposition of molecules or particulates on the membrane surface or membrane pores. The consequences of membrane **fouling** are increased membrane separation resistances, reduced productivity, and/or altered membrane selectivity. These factors can be grouped into three categories, namely: membrane characteristics, operating conditions, and feed and biomass characteristics. **A. Membrane Characteristics:** 1. Membrane Material The material the membrane is made of has an impact on its fouling propensity in MBRs. Based on the membrane material, membranes can be classified into: ceramic membranes, polymeric membranes, and composite membranes. Ceramic membranes exhibit good filtration performance due to their high chemical resistance, integrity, inert nature and ease of cleaning leading to low operating costs Ceramic membranes are also highly hydrophilic which makes them more fouling resistant 2. Water affinity The water affinity (hydrophilicity or hydrophobicity) property of the membrane material affects fouling in MBRs. 3. Membrane surface roughness The surface roughness of the membrane material also has some influence on membrane fouling in MBRs. Membranes with homogeneous surfaces are less subject to be fouled	2

		than those with uneven surfaces. 4. Membrane surface charge The membrane surface charge is another property of importance in relation to membrane fouling especially if there are charged particles in the feed. 5. Membrane pore size Generally, membranes used in wastewater treatment are broadly grouped into two: porous membranes and non-porous membranes. **B. Operating conditions:** 1. Operating mode 2. Rate of aeration 3.Solid retention time 4. Hydraulic retention time 5.Food-microorganisms ratio 6.Organic loading rate 7. COD/N ratio 8. Temperature **C. Feed and biomass characteristics:** 1.Mixed liquor suspended solids 2.Sludge apparent viscosity 3.Extra cellular polymeric substances 4.Floc size 5. Alkalinity and pH 6.Salinity	1 1

			2
6	b	**Advantages of membrane separation process over conventional separation process(any 6)** 1.Because membrane processes can separate at the molecular scale up to a scale at which particles can actually be seen, this implies that a very large number **of** separation needs might actually be met by membrane processes. 2.Membrane processes generally do not require a phase change to make a separation (with the exception of pervaporation). As a result, energy requirements will be low unless a great deal of energy needs to be expended to increase the pressure of a feed stream in order to drive the permeating component(s) across the membrane. 3.Membrane processes present basically a very simple flowsheet. There are no	1 mark each

		moving parts (except for pumps or compressors), no complex control schemes, and little ancillary equipment compared to many other processes. As such, they can offer a simple, east-to-operate, low maintenance process option. 4.Membranes can be produced with extremely high selectivities for the components to be separated. In general, the values of these selectivities are much higher than typical values for relative volatility for distillation operations. 5.Because of the fact that a very large number of polymers and inorganic media can be used as membranes, there can be a great deal of control over separation selectivities. 6.Membrane processes are able to recover minor but valuable components from a main stream without substantial energy costs. 7.Membrane processes are potentially better for the environment since the membrane approach require the use of relatively simple and non-harmful materials.	
6	c	**Differentiate between reverse osmosis membrane process with ultra filtration membrane: (any 6)** The main **difference between reverse osmosis** and **ultrafiltration** is that **ultrafiltration** membranes have larger pore sizes than **reverse osmosis** membranes, ranging from 1 to 100 nm. **Ultrafiltration** membranes are used for the separation and concentration of macromolecules and colloidal	1 mark each

particles.

Points	**Reverse osmosis**	**Ultra filtration**
Pore size	Small pore size	have larger pore sizes than **reverse osmosis** membranes, ranging from 1 to 100 nm.
cost	Residential reverse osmosis systems cost about $200-400. The initial cost of reverse osmosis is going to be a little higher than the cost of an ultrafiltration system.	Ultrafiltration systems cost about $150-200 for the system itself. The ultrafiltration system is cheaper initially, but will cost more long term
Installation	A reverse osmosis system is more complex to install. More connections need to be made for the system to operate correctly	To install an ultrafiltration unit is very simple. You connect the feed supply and the other end of the filter.
Storage and	Reverse Osmosis is a	Ultrafiltration doesn't

		conservation	cross flow filtration. The system creates two water streams through the membrane. One path ends up in a storage tank	require a storage tank. It literally hooks directly up to a special faucet.	
		What it removes	Reverse osmosis eliminates the majority of the dissolved minerals in the water.	Ultrafiltration is not going to eliminate dissolved solids or salts. Ultrafiltration only filters out solid particulate matter, but it does so on a microscopic level.	
		What it uses	a semipermeable membrane that separates 95-98% of inorganic dissolved material from the water molecule.	The ultrafiltration system uses a hollow fiber membrane to stop solid debris and microscopic contaminants.	