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| D:\VK\GIET LOGO.jpg | **GIET UNIVERSITY, GUNUPUR – 765022**  B. Tech (Fourth Semester – Regular) Examinations, April / May – 2021  **Sub. Code BBTPC 5020 – Sub. Name Upstream Process Engineering**  **(Branch - Biotechnology)** |
| Time: 3 hrs Maximum: 70 Marks | |

**Answer ALL Questions**

**The figures in the right hand margin indicate marks.**

**PART – A: (Multiple Choice Questions) (1 x 10 = 10 Marks)**

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| Q.1. Answer ***ALL*** questions | | | [CO#] | [PO#] |
| a. | Which of the following works on the principle of shearing? | |  |  |
|  | 1. Ball mill | 1. Roll crusher |  |  |
|  | 1. Toothed crusher | 1. Rod mill |  |  |
| b. | The two basic methods of analysis are | |  |  |
|  | 1. Cumulative and Affirmative | 1. Cumulative and Frequency |  |  |
|  | 1. Frequency and Affirmative | 1. Affirmative and Conservative |  |  |
| c. | The fluid will rise in capillary when the capillary is placed in fluid, if | |  |  |
|  | 1. the adhesion force between molecules of fluid and tube is less than the cohesion between liquid molecules | 1. the adhesion force between molecules of fluid and tube is more than the cohesion between liquid molecules |  |  |
|  | 1. the adhesion force between molecules of fluid and tube is equal to the cohesion between liquid molecules | 1. None of these |  |  |
| d. | Which of the following is a shear-thickening fluid? | |  |  |
|  | 1. Bingham plastic | 1. Thixotropic |  |  |
|  | 1. Dilatant | 1. Pseudoplastic |  |  |
| e. | What is the unit of viscosity of fluids in C.G.S? | |  |  |
|  | 1. ml/s | 1. l/s |  |  |
|  | 1. Poise | 1. Newton |  |  |
| f. | Bernoulli’s principle is derived from which of the following? | |  |  |
|  | 1. Conservation of mass | 1. Conservation of energy |  |  |
|  | 1. Newton’s law of motion | 1. Conservation of momentum |  |  |
| g. | The famous Fourier series is named after | |  |  |
|  | 1. Diller and Ryan | 1. J.B. Joseph Fourier |  |  |
|  | 1. Stefan- Boltzmann | 1. Wein’s |  |  |
| h. | For inclined plates we multiply Grashoff number with | |  |  |
|  | 1. Cos 2 α | 1. Sin 2 α |  |  |
|  | 1. Sin α | 1. Cos α |  |  |
| i. | Find the permeability if diffusivity is 2 units and solubility coefficient is 5 units assume all are in SI units. | |  |  |
|  | 1. 10 units | 1. 1.5 units |  |  |
|  | 1. 0.4 units | 1. None of the mentioned |  |  |
| j. | How is it possible to shift the equilibrium to advantage in azeotropic mixture? | |  |  |
|  | 1. Changing the volume | 1. Adding more mixture |  |  |
|  | 1. Adding one of the component more | 1. Changing the pressure. |  |  |

**PART – B: (Short Answer Questions) (2 x 10 = 20 Marks)**

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| Q.2. Answer ***ALL*** questions | | [CO#] | [PO#] |
| a. | Water flows between two plates of which the upper one is stationary and the low one is moving with a velocity V. What will be the velocity of the fluid in contact with the upper plate.  According to the No-Slip condition, the relative velocity between the plate and the fluid in contact with it must be zero. Thus, the velocity of the fluid in contact with the upper plate is 0 and that with the lower plate is V. |  |  |
| b. | What is the value of the bulk modulus and shear modulus for an ideal fluid  Bulk modulus is zero and Shear modulus is also zero.  An ideal fluid has zero viscosity, and it is incompressible.  In an ideal fluid there is no resistance to shearing motions and the shear modulus (μ) is zero |  |  |
| c. | In a U-tube mercury manometer, one end is exposed to the atmosphere and the other end is connected to a pressurized gas. The gauge pressure of the gas is found to be 40 kPa. Now, we change the manometric fluid to water. The height difference changes by: (ρmercury = 13600 kg/m3, ρwater = 1000 kg/m3)  Since the gauge pressure remains the same ρ\*(h2 – h1) = constant. The height difference in mercury manometer is 0.30 m and that in a water manometer is 4.08 m. Percent change is thus, 1260%. |  |  |
| d. | Why is it necessary to assume that the flow is steady before integrating Euler’s equation to derive Bernoulli’s equation?  For Bernoulli's equation to be applied, the following assumptions must be met: The flow must be steady. (Velocity, pressure and density cannot change at any point). The flow must be incompressible – even when the pressure varies, the density must remain constant along the streamline |  |  |
| e. | Where does the maximum stress occur in case of laminar flow of incompressible fluid in a closed conduit of diameter “d”  At the wall |  |  |
| f. | What is the principle cause of action of buoyant force on a body submerged partially or fully in fluid  The principal cause of action of buoyant force on a body submerged partially or fully in fluid is the force equal in magnitude to the weight of the volume of displaced fluid. |  |  |
| g. | What is critical insulation?  The thickness upto which heat flow increases and after which heat flow decreases is termed as critical thickness. The thicker the insulation, the lower the heat transfer rate. This is due to the fact the outer surface have always the same area. |  |  |
| h. | What is the difference between convective mass transport and diffusive mass transport  The convective mass transport causes due to bulk motion of molecule while diffusive mass transport causes due to difference in chemical potential (e.g. concentration difference) |  |  |
| i. | State the assumptions of penetration theory  Assumptions:  • All action (fluid flow and mass transfer) occurs in a thick film at the interface  • Bulk fluid (e.g. gas) – FILM – bulk fluid (e.g. liquid)  • Steady-state flux across film  • Diffusion is important in z-direction  • Convection is important in x-direction  Find the position of centre of buoyancy for a wooden block of width 3.5 m and depth 1 m, when it floats horizontally in water. The density of wooden block is 850 kg and its length 7 m. |  |  |
| j. | State the column used for differential distillation  Still is the distillation column used for differential distillation. |  |  |

**PART – C: (Long Answer Questions) (10 x 4 = 40 Marks)**

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| --- | --- | --- | --- | --- |
| Answer ***ALL*** questions | | Marks | [CO#] | [PO#] |
| 3. a. | Explain the properties and handling of particulate solids  Properties of particulate solids: There are a number of properties of particles that are of interest besides its size and shape. Particles can repel or attract each other due to static charge build up, they are affected by van der Waals forces (when they are small enough), they can stick, agglomerate, break up, bounce off of each other, chemically react with each other, and they are effected by the surrounding fluid phase due to drag an buoyant forces  Handling:  “A powder is a group of solid particles not filling completely the space they occupy; the space not filled by particles is filled by gas.”  A powder does not exert uniform pressure on all directions in confinement. The exerted pressure is minimal at the perpendicular direction of the applied pressure. An applied shear force on the surface of a mass of powder is transmitted through all the static mass, unless a fracture occurs.  The density of a mass of powder varies depending on its degree of packaging; it increases if the powder is compacted by vibration, shaking, taping, and so on. |  |  |  |
| b. | Discuss screening operation in particle analysis  Screening :*Sieve analysis*  The sieve analysis, commonly known as the gradation test, is a basic essential test for determination of the gradation of a polydisperse aggregate. Gradation is the term used for the distribution of aggregate particles, by size, within a given sample. In practice a known weight of material, the amount being determined by the largest size of aggregate, is placed upon the top of a group of nested sieves (the top sieve has the largest screen openings and the screen opening sizes decrease with each sieve down to the bottom sieve which has the smallest opening size screen for the type of material specified) and shaken by mechanical means for a period of time. After shaking the material through the nested sieves, the material retained on each of the sieves is weighed. The total weight obtained after sieving is compared to the initial weight of the sample to calculate any material loss. |  |  |  |
|  | (OR) |  |  |  |
| c. | Describe the working principle of grinder  In grinders combine shear and impact with compressive forces.  Grinders: (a) hammer mill, (b) plate mill  Hammer mills In a hammer mill, swinging hammerheads are attached to a rotor that rotates at high speed inside a hardened casing. The material is crushed and pulverized between the hammers and the casing and remains in the mill until it is fine enough to pass through a screen which forms the bottom of the casing. Both brittle and fibrous materials can be handled in hammer mills, though with fibrous material, projecting sections on the casing may be used to give a cutting action. Plate mills In plate mills the material is fed between two circular plates, one of them fixed and the other rotating. The feed comes in near the axis of rotation and is sheared and crushed as it makes its way to the edge of the plate. The plates can be mounted horizontally as in the traditional Buhr stone used for grinding corn, which has a fluted surface on the plates. The plates can be mounted vertically also. Developments of the plate mill have led to the colloid mill, which uses very fine clearances and very high speeds to produce particles of colloidal dimensions.  Grinding is a metal cutting operation performed by means of abrasive particles rigidly mounted on a rotating wheel. Each of the abrasive particles act as a single point cutting tool and grinding wheel acts as a multipoint cutting tool. The grinding operation is used to finish the workpieces with extremely high quality of surface finish and accuracy of shape and dimension. Grinding is one of the widely accepted finishing operations because it removes material in very small size of chips 0.25 to 0.50 mm. It provides accuracy of the order of 0.000025 mm.  Principle of Grinding: Work piece is fed against the rotating abrasive wheel. Due to action of rubbing or friction between the abrasive particles and work piece material is removed.  Types of Grinding On the basis of quality of grinding, it is classified as rough grinding and precision grinding. Rough Grinding and Precision Grinding  Rough Grinding:- It involves removal of stock without any reference to the accuracy of results.  Precision Grinding:- Precision grinding removes negligible amount of metal. It is used to produce finished parts and accurate dimensions.  Various elements of a Grinding Wheel The various main elements of a grinding wheel are abrasive; bonds and structure which are described below. Abrasive:- Generally abrasive properties like hardness, toughness and resistance to fracture uniformly abrasives are classified into two principal groups:- Natural abrasives, Artificial abrasive  Natural abrasive:- There are a few examples of natural abrasives which include sand stone (solid quartz), emery, & diamond.  Artificial abrasive:- Main artificial abrasive are silicon carbide and aluminium oxide. Artificial abrasive are preferred in manufacturing of grinding wheels because of their uniformity and purity. |  |  |  |
| d. | Describe the working principle of pulveriser  Dry pulverization is used in a wide range of fields because of its features. The size of pulverized products is generally reduced to micron level. In some cases, pulverization to submicron level is possible, but there are problems, such as aggregation and difficulty of collection.  Wet pulverization is capable of grinding to submicron level (ultrafine pulverization), which is difficult with dry pulverization. In addition to the pulverization of primary particles, wet pulverization also includes disintegration (= mechanical pulverization) and dispersion. In recent years, miniaturization of materials is often required, and not only pulverization but also disintegration and dispersion operations have become more and more important. (\* Disintegration (= mechanical pulverization) is one of the processes of dispersion. An external mechanical force is applied to agglomerated particles to loosen them almost without the formation of new particle surfaces and to reduce the size of agglomerated particles.)  The particle size that can be reduced by a single machine differs depending on the pulverizer. There are also a wide variety of pulverization methods, such as continuous pulverization versus batch pulverization (batch type) and dry pulverization (dry milling or grinding) versus wet pulverization (wet milling or grinding).  Pulverization may be classified into rough, medium, small crushing, coarse, fine, and ultrafine grinding.  The rotation and revolution nano-pulverizer is a batch-type wet pulverizer that can perform pulverization and disintegration into about 1 mm or less or even about 100 nm (several dozens of nm by disintegration). It is a type of planetary ball mill (planetary mill) or bead mill. Introduce balls (also called beads), which are grinding media, into a grinding container together with slurry. The grinding container revolves clockwise at a high speed with a 45° tilt angle while rotating counterclockwise at the same time (see “Mixing”). Please refer to the figure below. This high-speed revolution and rotation cause the grinding media in the container to concentrate on the bottom outer periphery of the container. There, the slurry undergoing convection motion in the container are affected by a combination of shear force, friction force, impact force, and become fine particles. Because the grinding container is inclined at 45°, the concentration of the grinding media on the bottom outer periphery of the container becomes higher. Therefore, only a small amount of grinding media is required. Furthermore, this inclination can suppress the rise of the slurry, enabling efficient pulverization without waste. |  |  |  |
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| 4. a. | Explain the concept of fluid as continuum  *Concept of Continuum*   * + The concept of continuum is a kind of idealization of the continuous description of matter where the properties of the matter are considered as continuous functions of space variables. Although any matter is composed of several molecules, the concept of continuum assumes a continuous distribution of mass within the matter or system with no empty space, instead of the actual conglomeration of separate molecules.   + Describing a fluid flow quantitatively makes it necessary to assume that flow variables (pressure , velocity etc.) and fluid properties vary continuously from one point to another. Mathematical description of flow on this basis have proved to be reliable and treatment of fluid medium as a continuum has firmly become established. For example density at a point is normally defined as  |  |  | | --- | --- | | https://nptel.ac.in/content/storage2/courses/112104118/lecture-1/1-5-concept-continum_files/image002.gif |  |   Here Δhttps://nptel.ac.in/content/storage2/courses/112104118/lecture-1/images/symb1.gif is the volume of the fluid element and m is the mass   * + If Δhttps://nptel.ac.in/content/storage2/courses/112104118/lecture-1/images/symb1.gif is very large ρ is affected by the inhomogeneities in the fluid medium. Considering another extreme if Δhttps://nptel.ac.in/content/storage2/courses/112104118/lecture-1/images/symb1.gif is very small, random movement of atoms (or molecules) would change their number at different times. In the continuum approximation point density is defined at the smallest magnitude of Δhttps://nptel.ac.in/content/storage2/courses/112104118/lecture-1/images/symb1.gif, before statistical fluctuations become significant. This is called continuum limit and is denoted by Δhttps://nptel.ac.in/content/storage2/courses/112104118/lecture-1/images/symb1.gifc. |  |  |  |
| b. | List atleast four pressure measuring devices and explain working principle of any one.  List of Pressure Measuring Devices. And the devices are:  1. The Barometer  2.Piezometer or Pressure Tube  3. Manometers  4. The Bourdon Gauge  5. The Diaphragm Pressure Gauge  6. Micro Manometer (U-Tube with Enlarged Ends) .  1. The Barometer:  The barometer is a device meant for measuring the local atmospheric pressure. Fig. shows a mercury barometer which consists of a 1 metre long glass tube closed at one end and completely filled with mercury and kept inverted in a bowl of mercury. A small quantity of mercury will drop into the bowl and thus a vacuum forms at the upper end of the tube.  **[https://www.engineeringenotes.com/wp-content/uploads/2018/06/clip_image002_thumb-4.jpg](https://www.engineeringenotes.com/wp-content/uploads/2018/06/clip_image002-8.jpg)**  The atmospheric pressure acting on the surface of mercury in the bowl will support a mercury column in the tube. Let h be the height of mercury column in the tube measured above the surface of mercury in the bowl. 2. Piezometer or Pressure Tube: The piezometer is used to measure the static pressure head of a liquid flowing at any section of a pipe. It consists of a tube whose open lower end is mounted flush with the inside wall of the pipe. The other end of the tube is exposed to the atmosphere. In the arrangement shown in Figs the height h to which the liquid rises in the tube represents the pressure head at the level A where the tube is connected to the pipe.  **[https://www.engineeringenotes.com/wp-content/uploads/2018/06/clip_image008_thumb-1.jpg](https://www.engineeringenotes.com/wp-content/uploads/2018/06/clip_image008-3.jpg)**  The piezometer may also be so shaped and connected to the pipe so that the pressure head at the level of the centre of the pipe may be directly obtained. 3. Manometers: **U-Tube Manometer (The Double Column Manometer):**  Manometers are pressure gauging devices using columns of different liquids. The fluid whose pressure is to be determined is called the metered fluid while the other fluid is called the manometer fluid. The manometer fluid may be of higher density or lower density than that of the metered fluid. These devices can be used to gauge pressures of liquids as well as gases. Manometers have connecting U-shaped tubes containing different fluids.  In a manometer when one limb of the device is open to the atmosphere it records the pressure of the source connected to the other limb. When both the limbs are connected to pressure sources, the manometer records the difference of pressure between the two pressure sources. Accordingly, these manometers are called simple manometer and differential manometer.  The pressure of a fluid in a pipe may be measured by using a glass U-tube containing a heavier liquid which does not mix with the fluid in the pipe.  Suppose the pipe contains water, and mercury is used as the measuring liquid. Let the level EF correspond to the surface of contact of the two liquids. Let X be the centre of the pipe.  **[https://www.engineeringenotes.com/wp-content/uploads/2018/06/clip_image011_thumb.jpg](https://www.engineeringenotes.com/wp-content/uploads/2018/06/clip_image011-1.jpg)** 4. The Bourdon Gauge: This device consists of a metallic tube of elliptical section closed at one end A, the other end B being fitted to the gauge point where the pressure is to be measured. As the fluid enters the tube, the tube tends to straighten.  By using a pinion-sector arrangement the small elastic deformation of the tube is communicated to a pointer in an amplified manner. The pointer moves over a graduated dial. The device is calibrated by subjecting it to various known pressures.  The Bourdon gauge is suitable for measuring not only high pressures such as those in a steam boiler or a water main but also negative or vacuum pressures. A gauge which is so devised to measure positive as well as negative pressures is called a compound gauge. |  |  |  |
|  | (OR) |  |  |  |
| c. | ***List atleast four flow measuring devices in pipe and Explain any one***  Flow measuring devices in pipes are:  1. Venturimeter  2. Pitot Tube  3. Orifice Plate or Orifice Meter  4.Flow Nozzle  5. Free Jets.   1. The Venturimeter: A Venturimeter is a device meant for measuring the quantity of a liquid flowing through a pipe. In its simplest form, the device consists of a short converging section leading to a throat and followed by a diverging section. The entrance and the exit diameters will be the same as that of the pipe line to which it is fitted.  Tubes are provided which enter the pipe at the entrance section (also called the enlarged end) and at the throat. These tubes are meant for measurement of pressure. Pressure can be measured by piezometer tubes. Alternatively, the tubes may be connected to a U-tube containing a heavy liquid like mercury.  As the liquid flows through the venturimeter, the velocity at the throat section is increased due to the decrease in the area of flow. This increase in velocity is accompanied by a consequent reduction of pressure. 2. The Pitot Tube: A pitot tube is a simple device meant for measuring the velocity of a liquid at any point. In its simple form the pitot tube consists of a glass tube whose lower end is bent at right angles (Fig. 7.72). The device is placed in a moving liquid with the lower opening directed in the upstream direction.  The liquid level in the pitot tube will depend on the velocity of the stream. The pitot tube in the form shown in the figure is meant for measuring the velocity at any point in a stream of liquid whose surface is open to the atmosphere. 3. Orifice Plate or Orifice Meter: An orifice meter is another device to gauge the flow of a liquid through a pipe. It consists of a flat plate containing a circular orifice provided concentrically with the pipe across the flow. It is fitted to the pipe by flanged joint. This device works on the same principle as that of the venturimeter. As the flow passes through the orifice the moving stream converges passing through a somewhat stagnant fluid and later spreads to fill the pipe. Generally the diameter of the orifice is about half of the pipe. 4. The Flow Nozzle: This is another device for the measurement of flow in pipes. The design features of this device are intermediate to the venturimeter and the orifice meter. It is similar to the venturimeter with a smooth converging approach but without any diverging zone. The discharge equation is the same as that of the venturimeter. |  |  |  |
| d. | State the principle and Derive Bernoulli equation for fluid flow.  Bernoulli’s equation: Principle of conservation of energy.     * The density of the incompressible fluid remains constant at both points. * The energy of the fluid is conserved as there are no viscous forces in the fluid.   Therefore, the work done on the fluid is given as:  dW = F1dx1 – F2dx2  dW = p1A1dx1 – p2A2dx2  dW = p1dV – p2dV = (p1 – p2)dV  We know that the work done on the fluid was due to conservation of gravitational force and change in kinetic energy. The change in kinetic energy of the fluid is given as:  dK = \frac{1}{2}m\_{2}v\_{2}^{2}-\frac{1}{2}m\_{1}v\_{1}^{2}=\frac{1}{2}\rho dV(v\_{2}^{2}-v\_{1}^{2})  The change in [potential energy](https://byjus.com/physics/potential-energy/) is given as:  dU = mgy2 – mgy1 = ρdVg(y2 – y1)  Therefore, the energy equation is given as:  dW = dK + dU  (p1 – p2)dV = \frac{1}{2}\rho dV(v\_{2}^{2}-v\_{1}^{2}) + ρdVg(y2 – y1)  (p1 – p2) = \frac{1}{2}\rho (v\_{2}^{2}-v\_{1}^{2}) + ρg(y2 – y1)  Rearranging the above equation, we get  p\_{1}+\frac{1}{2}\rho v\_{1}^{2}+\rho gy\_{1}=p\_{2}+\frac{1}{2}\rho v\_{2}^{2}+\rho gy\_{2}  ***This is Bernoulli’s equation.*** |  |  |  |
|  |  |  |  |  |
| 5. a. | Discuss about natural and forced convection.  ***Natural convection:*** When convection takes place due to buoyant force as there is a difference in densities caused by the difference in temperatures it is known as natural convection.  Examples of natural convection are oceanic winds.   * **Sea breeze**: This phenomenon occurs during the day. The sun heats up both the sea surface and land. As the sea has a greater heating capacity, it absorbs much of the sun’s energy but gets warmed up much slower than the land. As a result, the temperature above the land rises and heats the air in the atmosphere above it. Warm air is less dense, and hence, it expands, creating a low-pressure area over the land near the coast. Meanwhile, there is relatively high pressure over the sea. The difference in air pressure causes the air to flow from sea to land. The sudden gush of wind felt due to this is known as the sea breeze. * **Land Breeze**: This phenomenon occurs during the night when the situation reverses. As the sun sets, the land and sea start cooling down. The land quickly loses heat when compared to water due to the differences in heat capacity. Consequently, the temperature of the sea is relatively higher, which creates low air pressure there. This sets up a flow of cool breeze offshore, known as the land breeze.   Natural convection occurs as a result of buoyancy-driven flow caused by density gradients due to temperature variations. And it is a very important mechanism that is operative in a variety of environments from cooling electronic circuit boards in computers, cooling of reactor cores in nuclear power plant, Heat loss from steam pipe lines in power plants and heat gain in refrigerant pipe lines in air conditioning applications. Natural convection within a sealed device is considered Internal and around a device in a large enclosure or open environment is considered External. Natural convection flows may be laminar or turbulent.  ***Forced convection:*** When external sources such as fans and pumps are used for creating induced convection, it is known as forced convection.  Examples of forced convection are using water heaters or geysers for instant heating of water and using a fan on a hot summer day.  Forced convection is related to ***Newton’s law of cooling,*** which is given as:   |  | | --- | | P=dQdt=hA(T−T0) |   Where,   * P=dQdt is the rate at which heat is transferred * h is the convection heat-transfer coefficient * A is the exposed surface area * T is the temperature of the immersed object * T0 is the temperature of the fluid which is under convection   The value of the heat-transfer coefficient h depends on:   * Density * Viscosity * Thermal conductivity * Specific heat capacity   Forced convection analysis refer to type of heat transfer in which fluid motion is generated by an external source like pump, fans, suction devices and it is considered as the main method of useful heat transfer, as significant amount of heat energy can be transferred by this process. Forced convection is typically used to increase the rate of heat exchange. Forced convection is often encountered for designing or analyzing pipe flow, flow over a plate, heat exchanger, and Computer case cooling. The examples of forced convection include a water pump in an automobile engine, suction devices, forced air heating systems, etc. |  |  |  |
| b. | Discuss the steady-state one dimensional heat conduction through composite structures. |  |  |  |
|  | (OR) |  |  |  |
| c. | Write a short note about overall heat transfer coefficient  **The overall heat transfer coefficient, or U-value, refers to how well heat is conducted through over a series of resistant mediums. Its units are the W/(m2°C) [Btu/(hr-ft2°F)].**  **Calculating the U-value**  Several equations can be used to determine the U value, one of which is:  Overall Heat Transfer Coefficient  where  h = convective heat transfer coefficient, W/(m2°C) [Btu/(hr-ft2°F)] L = thickness of the wall, m [ft] λ = thermal conductivity, W/(m°C) [Btu/(hr-ft°F)]  **Heat transfer through a metal wall**  Overall Heat Transfer Coefficient  In the case of creating hot water for example, heat transfer basically occurs from fluid 1 (source of heat) through a conductive solid (metal wall) to fluid 2 (water, the product being heated). However, film resistance must also be considered. That is why the convective heat transfer coefficient (h), sometimes referred to as the film coefficient, is included when calculating heat transfer between a fluid and a conductive wall.  Additionally, in certain unique applications such as pharmaceutical or biotechnology process heating, that heat transfer can occur through several layers of wall material. In such instances, the above equation can be adapted by incorporating each layer of the solid’s thickness (L) divided by its thermal conductivity (λ). |  |  |  |
| d. | Consider a **parallel-flow heat exchanger,** which is used to cool oil from 70°C to 40°C using water available at 30°C. The outlet temperature of the water is 36°C.  The rate of flow of oil is 1 kg/s. The specific heat of the oil is 2.2 kJ/kg K. The overall heat transfer coefficient **U = 200 W/m2 K.** Calculate the**logarithmic mean temperature difference.** Determine the **area** of this heat exchanger required for this performance.  https://thermal-engineering.org/wp-content/uploads/2019/05/example-heat-exchanger-calculation-LMTD.png   1. **LMTD**   The logarithmic mean temperature difference can be calculated simply using its definition:  https://www.thermal-engineering.org/wp-content/uploads/2019/05/LMTD-example.png   1. Area of Heat Exchanger   To calculated the area of this heat exchanger, we have to calculate the heat flow rate using mass flow rate of oil and LMTD.  https://www.thermal-engineering.org/wp-content/uploads/2019/05/Energy-Balance-Example.png  The required area of this heat exchanger can be then directly calculated using general heat transfer equation:  https://www.thermal-engineering.org/wp-content/uploads/2019/05/heat-exchanger-calculation.png |  |  |  |
|  |  |  |  |  |
| 6. a. | Explain Fick’s law and its uses.  Fick’s law of diffusion explains the diffusion process (movement of molecules from higher concentration to lower concentration region). In 1855, Adolf Fick described the Fick’s Law of Diffusion. A diffusion process that obeys Fick’s laws is called normal diffusion or Fickian diffusion. A diffusion process that does NOT obey Fick’s laws is known as Anomalous diffusionor non-Fickian diffusion.  Fick’s Law of Diffusion is used to solve the diffusion coefficient D.  There are two laws that are interrelated ie; Fick’s first law is used to derive Fick’s second law which is similar to the diffusion equation.  According to Fick’s law of diffusion,  **“The molar flux due to diffusion is proportional to the concentration gradient”.**  The rate of change of concentration of the solution at a point in space is proportional to the second derivative of concentration with space. Fick’s First Law Movement of solute from higher concentration to lower concentration across a concentration gradient.  J=−Ddφdx  Where,  J: diffusion flux  D: diffusivity  φ: concentration  x: position Fick’s Second Law Prediction of change in concentration along with time due to diffusion.  ∂φ∂t=D∂2φ∂x2  Where,  D: diffusivity  t: time  x: position  Φ: concentration Application Fick’s Law  * + Biological application:   flux=−P(c2−c1) (from Fick’s first law)  Where,  P: permeability  c2-c1: difference in concentration   * Liquids: Fick’s law is applicable for two miscible liquids when they are brought in contact and diffusion takes place at a macroscopic level. * Fabrication of semiconductor: Diffusion equations from Fick’s law are used to fabricate integrated circuits. * Pharmaceutical application * Applications in food industries |  |  |  |
| b. | Write a note on binary solution  A binary solution is a kind of homogeneous mixture, in which the mixture of two liquids is completely miscible with each other. In binary solutions, the boiling points depend on the composition of the solution, and the three different cases are as follows:  Case 1: The boiling point of the binary solutions of some compositions should lie below the boiling point of the clean liquids  Case 2: The boiling point of the binary solutions of any compositions should lie above the boiling point of the clean liquids  Case 3: The boiling point of the binary solutions of all compositions should lie between the boiling point of the clean liquids |  |  |  |
|  | (OR) |  |  |  |
| c. | Explain about azeotropes.  An azeotrope is a mixture of two or more liquids which displays the same level of concentration in the liquid and vapour phase. Simple [distillation](https://byjus.com/chemistry/distillation/) cannot alter their proportions. These mixtures can either have a lower boiling point or a higher boiling point of the components.  An azeotrope is a mixture that, at a given pressure (the azeotropic pressure), boils at a constant temperature (the azeotropic temperature), and has the same composition (azeotropic composition) in the equilibrium vapour and liquid phases.    They are termed as constant boiling mixtures as their composition remains unchanged by distillation. That is the constitutions stays in the same proportion even when the azeotrope is boiled. When distillation cannot alter a fraction of a liquid, it results in azeotropes. Azeotrope Mixture An azeotropic compound is a mixture of two substances which distil at the same temperature. An azeotrope is a mixture of compounds with the same composition in the vapour as in the liquid. In other words, an azeotrope is a liquid mixture that has a constant boiling point and whose vapour has the same composition as the liquid. Several compounds, such as [toluene](https://byjus.com/chemistry/toluene/), benzene, and cyclohexane, form suitable azeotropes with water. Azeotrope Distillation Azeotropic distillation as on early and important special distillation process is commonly used in laboratory and industry. Azeotropic distillation is accomplished by adding to the liquid phase a volatile third component which changes the volatility of one of the two components more than the other so that the components are separated by distillation.   * An azeotropic distillation performed in a laboratory is normally done in batches in a conventional fractional distillation column. In such a case, an excess of the usually required amount of the azeotropic agent is added with the charge to the still. * The mixture is then distilled in the same manner as a conventional fractional distillation. If the mixture of [binary compound](https://byjus.com/chemistry/binary-compounds/) and azeotrope is a minimum boiling point type then the distillate product should contain only one of the original components and the azeotropic agent. * The composition of the distillate product then changes as the distillation proceeds since the separation taking place is between the different azeotropes. * Then the distillation should proceed until all other components have been removed as a distillate product leaving the bottom product as the remaining component and the azeotropic agent. |  |  |  |
| d. | Write a note on flash vaporization  Flash Vaporization:- It is a simple unit operation in which a heated liquid mixture is throttled through a valve in order to vaporize the liquid mixture.  The vaporization is done in order to separate the constituents of the liquid mixture. Flash vaporization can be seen as a single stage distillation process.    First, the Feed, which can be a mixture of constituents in liquid phase or in partially vapour-liquid phase, is heated in order to increase its temperature. In the figure it can be seen that the feed is made to pass through a heat exchanger thus the temperature of the feed can be easily controlled as per requirement and utility.  Then the heated feed is made to pass through a throttling valve. The purpose of the throttling valve is to partially vaporize the feed passing through it. If the feed is a liquid mixture then vapours are produced and if partially vaporized feed is passed through the valve then more vapours are produced.  If we consider the feed material which is present inside the valve as a system, we see that there are no devices present which lead to work interactions across the boundaries of the system. In a throttling process it is assumed that the system is Figure: Schematic of a Flash distillation unit adiabatic, meaning that there is no heat interaction across the boundaries of the system. When we apply energy balance on the system we deduce the following equation,  **U + PV = Constant**  Here, **U** is the internal energy, **P** is the pressure and **V**is the specific volume.  Also, **H = U + PV**, H is enthalpy, we find that **H** = Constant  It means that a throttling process is a constant enthalpy process or isenthalpic process.  If internal energy (U) is assumed to remain constant then we can rewrite the equation as **PV** = Constant.**P** and **V** are the only variables which can change and they will have to change accordingly in order to keep the product of the terms as a constant.  In throttling process the Pressure (P) decreases, it means the specific volume (V) has to increase. Since the liquid is heated to a higher Temperature (T), the pressure decreases and reaches a value which corresponds to the saturation temperature after which vaporization occurs.  The partially vaporized feed is then passed to a flash drum; the pressure of the drum is adjusted accordingly so that some more separation also occurs inside the Flash drum. During separation some quantity of liquid may get carried away along with vapour, this is called entrainment. In order to separate the entrained droplets there are De-entrainment mesh pads inside the drum. The vapour is obtained from the top of the drum, it is called top product and liquid is collected from the bottom, it is called bottom product.  It is often assumed that the vapour phase and liquid phase obtained are in equilibrium with each other.  If we assume the feed is a binary mixture made of components A and B then the notations in the figure indicate (Assuming A is more volatile component):  **F** is the molar flow rate of feed stream.  **D** is the molar flow rate of top product.  **W** is the molar flow rate of top product.  **ZF** is the mole fraction of component A in feed.  **XD** is the mole fraction of component A in top product.  **XW** is the mole fraction of component A in bottom product.  **HF**is the enthalpy of the feed.  **HW**is the enthalpy of the bottom product.  **HD** is the enthalpy of the top product.  Material and Energy Balances are given by:  Total Material Balance, F =*D*+*W*  Component A balance, *FzF*​=*DxD*​+*Wxw*​  Enthalpy Balance , *FHF*​+*Q*=*DHD*​+*WHW*​ |  |  |  |

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