WINTER-17 EXAMINATION

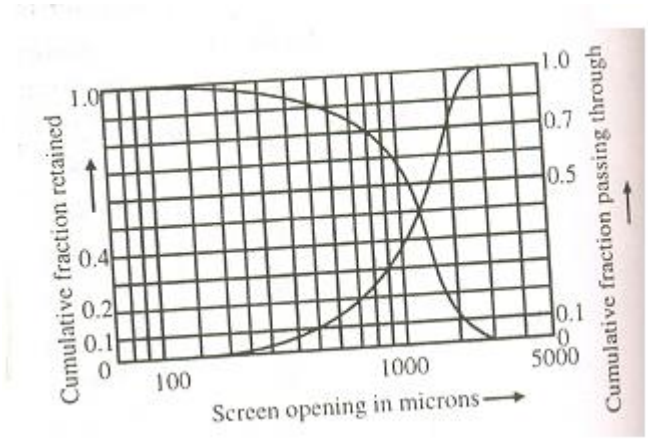
Model Answer

Subject Title: Mechanical Operation | Subject code: 17313 |

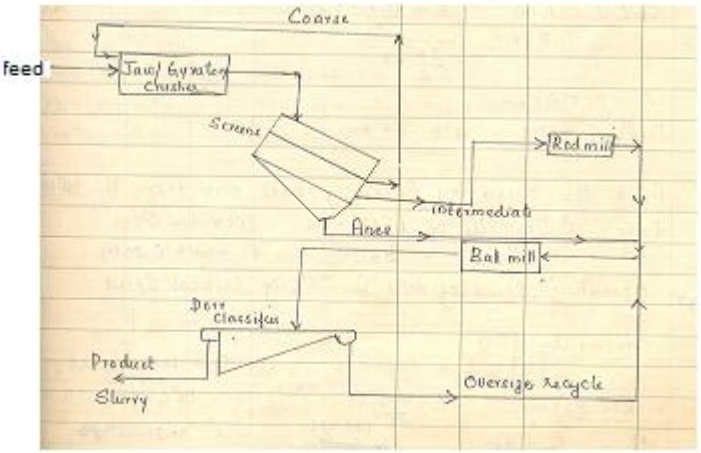
Important Instructions to examiners:

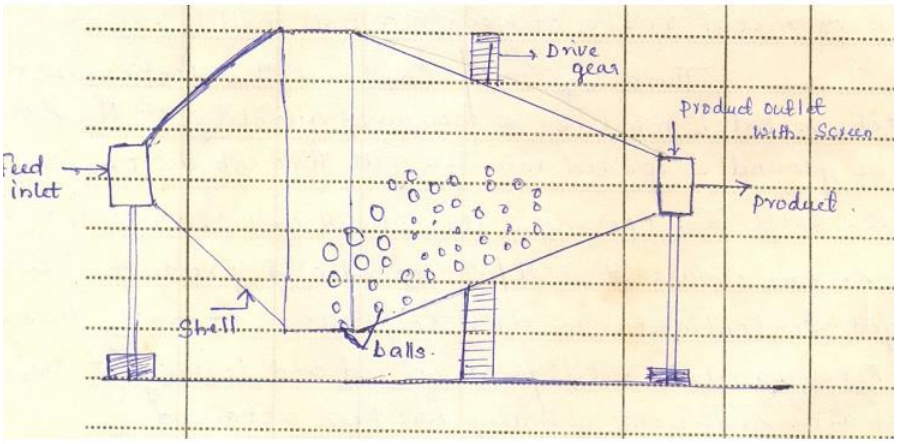
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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	Marks
1	**Attempt any SIX of the following**	**12**
1A-a	**Importance of size reduction in chemical industries (2points):** Size reduction is done 1. To increase the surface area in order to increase the rate of physical or chemical process 2. To improve mixing of constituents in solid-solid mixing 3. To improve solubility 4. Easy packing and handling	1 mark each
1A-b	**Rittinger's law** It states that the work required in crushing is proportional to the new surface created. $\frac{P}{\dot{m}} = K_r(\frac{1}{\bar{D}_{sb}} - \frac{1}{\bar{D}_{sa}})$ where P is the power required $\dot{m}$ is mass flow rate K_r is Rittinger's constant $\bar{D}_{sa}$ = Volume surface mean diameter of feed $\bar{D}_{sb}$ = Volume surface mean diameter of product	2
1A-c	**Importance of screening in chemical industry(any two):** Screening is carried out in industry to i. Remove fines from the feed material before sending it for size reduction. ii. Prevent the oversize material from entering into any other unit operation iii. Produce a commercial grade material to meet particle size specification. iv. Remove fines from a finished product prior to shipping	1 mark each
1A-d	**Cumulative screen analysis:** It is obtained by adding cumulatively the individual weight fraction retained on each	2

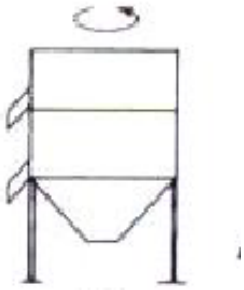
	screen and plotting the cumulative sums against the screen opening of the retaining screen. It can also be reported by incorporating cumulative fraction passing through screen  	
1A-e	**Importance of mixing and agitation: (two points)** 1. To promote a chemical reaction, since intimate contact between reacting phases is necessary for reaction. 2. To produce simple physical mixtures – of two or more uniformly divided solids, two or more miscible liquids etc. 3. To carry out physical change- formation of crystals from a supersaturated solution. 4. To accomplish dispersion in which a quasi-homogeneous material is produced from two or more immiscible fluids and from one or more fluid with finely divided solids.	1 mark each
1A-f	**Homogeneous mixture** A mixture which is uniform throughout in physical state and chemical composition is called homogeneous mixture. **Heterogeneous mixture:** A mixture which is not uniform throughout in physical state and chemical	1 1

	composition is called heterogeneous mixture.	
1A-g	**Equipment used for magnetic separation(any two)** Magnetic head pulley, magnetic drum separator, Ball Norton machine (usually it is used as concentrator)	2
1A-h	**Classification:** It is the separation of solid particles (from slurry) into several fractions based on terminal settling velocities. **Types of classifiers (any two):** 1.. Spiral classifiers 2.Cone classifiers 3..Drag classifiers 4..Rake classifiers 5. Double cone classifiers.	1 ½ mark each
1 B	**Attempt any TWO of the following**	8
1B-a	**Open circuit grinding:** If the feed material is passed only once through the size reduction machine and no attempt is made to return the oversize material to it for further reduction , the process is known as open circuit grinding **Closed Circuit grinding:** If the partially ground material from the size reduction equipment is sent to the size separation unit, from where undersize material is withdrawn as product and oversize material is returned to the machine for regrinding, the process is known as closed circuit grinding.	2 2

		
1B-b	**Ball mill:** **Principle:** Ball mill works on the principle of impact. **Construction and working:** The ball mill consists of a steel lined cylindrical shell containing steel balls with its axis horizontal. Feed enters from left through a 60^0 cone in to the primary grinding zone where the diameter of the shell is maximum and the product leaves through a 30^0 cone to the outlet. The balls act as the grinding medium. Inside of the shell is lined with abrasion resistant material. When the mill is rotating, the balls are picked up by the mill wall and are carried near the top of the mill. The balls then break contact with the wall and drop to the bottom. Grinding takes place due to the impact of the balls on the feed material.	1 3

		
1B-c	**Factors affecting the performance of screen (any four)**. 1) **Method of feeding**: Particles should approach the screening surface in a direction parallel to the longitudinal axis (perpendicular) of the screen. Particles should be fed at as low velocity as possible. 2) **Screen slope**: As the slope increases, the rate at which the materials travels over the screening surface increases thereby reducing bed thickness and allowing the fines to come in contact with the screening surface. But if the slope is increased too much, the material will travel down the screen very fast without getting properly screened. 3. **Number of Screening Surfaces**: Use of single-deck screens in series results into most efficient operation. In the case of multiple –deck screens, lower decks are not fed, so their entire area is not used & each separation requires a different combination of angle, speed & amplitude of vibration for the best performance. 4. **Amplitude &frequency of Vibration**: Proper amplitude of vibration is selected to prevent binding of screen &for long	1 mark each

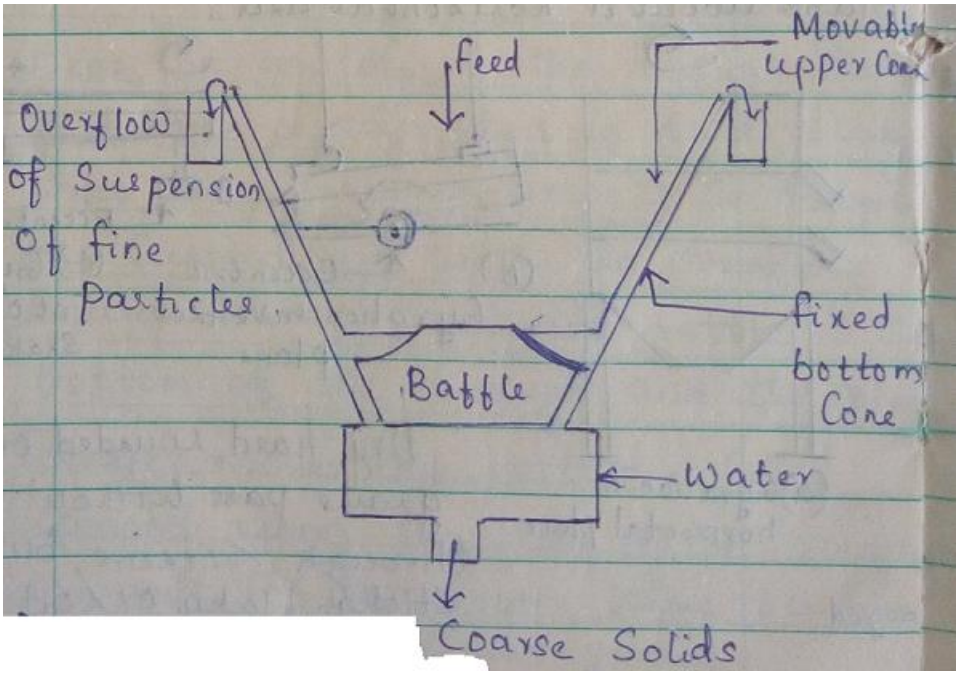
	bearing life. 5) **Moisture in feed**: the moisture in feed adversely affects screening operation &should be removed.	
2	**Attempt any FOUR of the following**	**16**
2-a	**Crushing efficiency:** It is the ratio of surface energy created by crushing to the energy absorbed by the solid. **Kick's law:** Kick's law states that the work required for crushing a given mass of material is the log of ratio of initial particle size to final particle size. $\frac{P}{\dot{m}} = K_k \ln\frac{D}{d}$ where P is the power required $\dot{m}$ is mass flow rate K_k is Kick's constant D = diameter of feed d= diameter of product	2 2
2-b	**Difference between ideal screen and actual screen:**	1 mark each
	Ideal screen / Actual screen 1. The overflow will contain only particles larger than cut diameter / The overflow may also contain particles smaller than cut diameter 2. Underflow will contain only particles smaller than cut diameter / Underflow may also contain particles larger than cut diameter 3. Yields sharp separation / Does not yield sharp separation 4. Efficiency is 100% / Efficiency is less than 100%	
2-c	**Working of gyrating screen:**	4

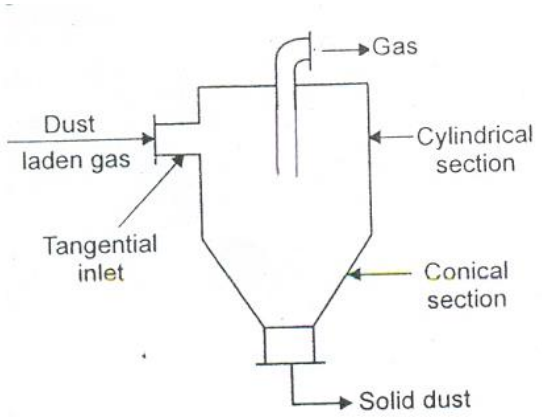


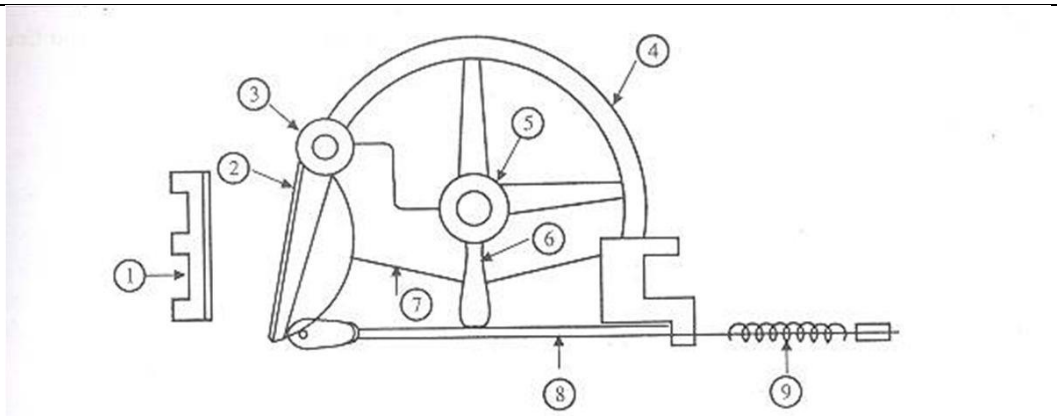
It consists of several decks of screen, one above the other, held in a box or casing. The coarsest screen is at the top and the finest at the bottom with suitable discharge ducts to permit removal of several fractions. Screens and casings are gyrated to push the particles through screen openings. Normally the casing is inclined at an angle to the horizontal. Feed mixture to be screened is fed on the top screen. When the screens and casings are gyrated, the particles pass through the screen openings

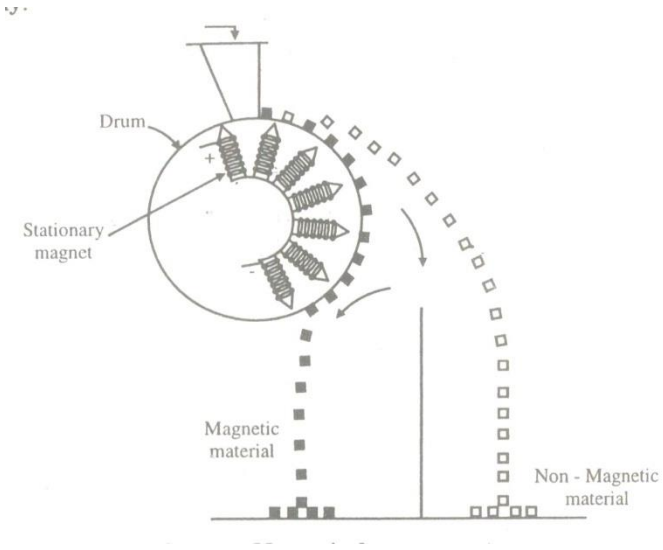
2-d **Diagram of any one type of classifier:** 4

Double cone classifier:

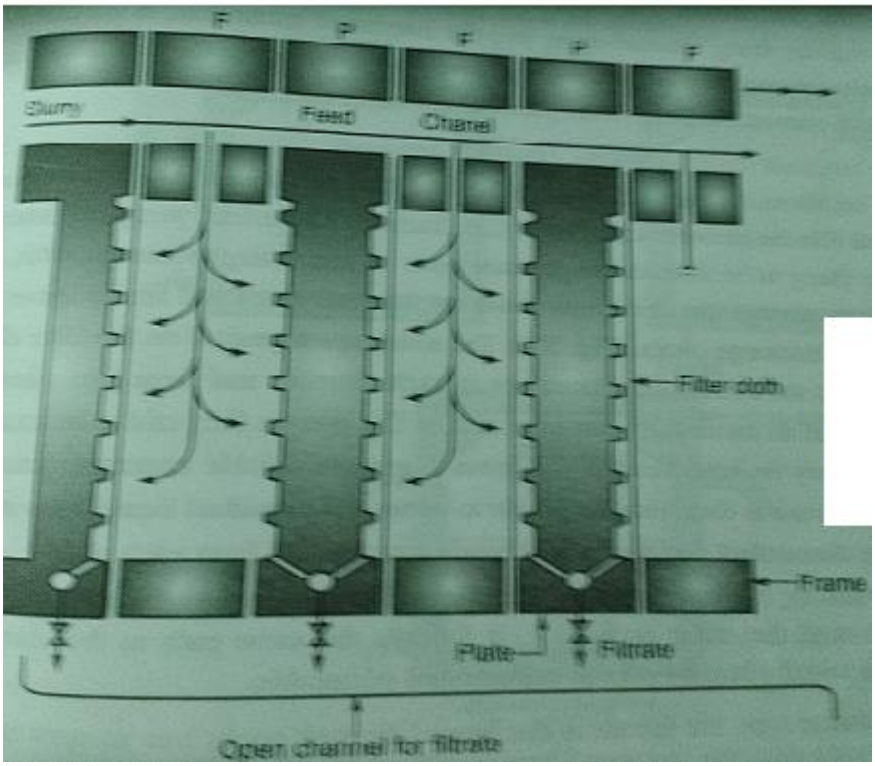


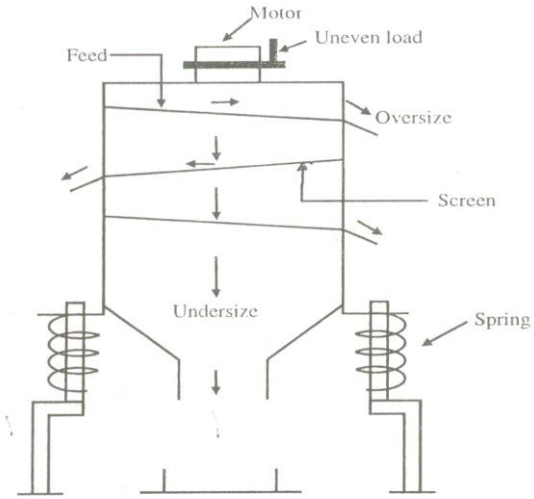
	(*Due consideration should be given for the diagram of any other type of classifier)*	
2-e	**Constant rate and constant pressure filtration:** The method of filtration in which the pressure drop over the filter is held constant throughout the run so that the rate of filtration is maximum at the start of filtration and decreases continuously towards the end of the run is called Constant pressure filtration. The filtration in which the pressure drop is varied usually from minimum at the start of filtration to a maximum at the end of filtration so that the rate of filtration is constant throughout the run is called constant rate filtration.	2 2
2-f	**Cyclone separator:** 	2 marks for diagram and 2 marks for labeling
3	**Attempt any FOUR of the following**	**16**
3-a	**Jaw crusher:** **Principle:** :Size reduction achieved by compression. **Construction:**	1

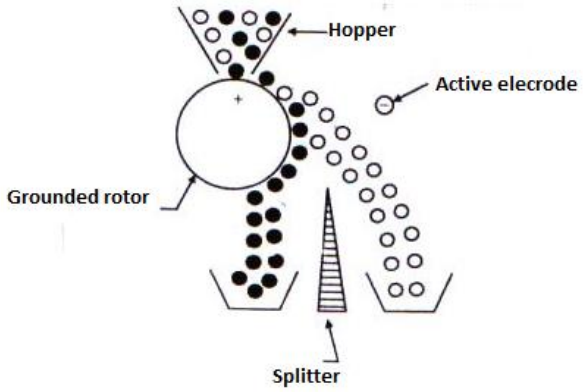
	 (1) Fixed jaw, (2) Movable jaw, (3) Shaft, (4) Fly wheel, (5) Eccentric, (6) Pitman, (7) Toggle, (8) Tie rod, (9) Spring It has a fixed jaw and a movable jaw which is pivoted at the top. The jaws are set to form a V open at the top. The movable jaw which reciprocates in a horizontal plane usually makes an angle of 20 to 30 ^{O} with fixed jaw. The jaws are usually made of manganese steel. The faces of the jaw are usually corrugated for concentrating the pressure on relatively small areas. It also consists of pitman, toggles, flywheel, eccentric shaft. Eccentric causes the pitman to oscillate in a vertical direction & this movement is communicated horizontally to movable jaw by the toggles. Toggles act as fuse to the machine. **Working:** The material to be crushed is admitted between two jaws from the top. The material caught between the upper parts of the jaws is crushed to a smaller size during forward motion by compression. The crushed material then drops into narrower space below during the backward motion.	2 1
3-b	**Derivation for finding out the effectiveness of a screen:** Let feed consists of material A & B, where A is the oversize & B is the undersize material. Let *F*, *D*, and *B* be the mass flow rates of feed, overflow, and underflow,	1

	respectively, and x_F, x_D, and x_B be the mass fractions of material A in the streams. **Screen effectiveness based on the oversize material A (E_A)** is the ratio of oversize material A that is actually in the overflow to the amount of A in the feed. Thus $E_A = \frac{Dx_D}{Fx_F}$ **Screen effectiveness E_B based on the undersize material** is the ratio of undersize material B that is actually in the under flow to the amount of B in the feed $E_B = \frac{B(1-x_B)}{F(1-x_F)}$ **Overall effectiveness is** $E = E_A E_B = (DX_D / FX_F) / (B[1- X_B] / F[1- X_F])$ But $\frac{B}{F} = \frac{xD - xF}{xD - xB}$ and $\frac{D}{F} = \frac{xF - xB}{xD - xB}$ $E = E_A E_B = \frac{(x_F - x_B)(x_D - x_F)x_D(1-x_B)}{(x_D - x_B)^2(1-x_F)x_F}$	1 1 1
3-c	**Magnetic Drum Separator**:  	2

	The feed (mixture of magnetic & non-magnetic materials) is admitted at the top & is allowed to fall on the rotating drum. The non-magnetic material is discharged in a normal manner. The magnetic material adheres to the drum & falls off underside when the drum loses the contact of the magnet assembly.	2
3-d	**Cake filtration:** In the Case of cake filtration, the proportion of solids in suspension is large and most of the solid particles are collected in the cake which can subsequently be detached from a filter medium. In cake filtration, during the initial period of flow, solid particles are trapped within the pores of a medium forming the true filter medium. The liquid passes through the bed of solids and through the filter medium. In the early stage of filtration, the rate of filtration is high. **Deep bed filtration:** In the case of deep bed filtration, the portion of solids in suspension is very small and the particles of the solids being smaller than the pores of a filter medium will penetrate to a considerable depth and ultimately get trapped inside the filter medium and usually no layer of solids will appear on the surface of the medium	2 2
3-e	**Diagram of plate and frame filter press**	4

		
3-f	**Factors affecting the rate of filtration:** 1) Viscosity of filtrate: Rate of filtration is inversely proportional to viscosity of filtrate. 2) Area of filter medium: Rate of filtration is directly proportional to area of filter surface. 3) Porosity of cake: Porosity of cake increases the rate of filtration. 4) Pressure drop across the filter medium: If pressure drop across the feed inlet & far side of the filter medium is more, filtration rate is more. 5) Resistance of cake: As resistance of cake increases, rate of filtration decreases. 6) Resistance of filter medium: As resistance of cake increases, rate of filtration decreases.	1 mark each for any 4 points

4	**Attempt any FOUR of the following**	**16**
4-a	**Vibrating screen** .**Diagram:**  **Explanation:** Generally the screens are provided with one, two & maximum three decks, with the coarsest screen at the top, either horizontally or inclined up to 45^0 .Each screen is provided with a separate over flow. The undersize material from the last screen is collected from bottom. Due to inclination to screen, the oversize material travels along the screen. The screens are vibrated mechanically or electrically with a frequency of 1800 to 3600 per minute. Mechanical vibrations are transmitted from the high speed eccentrics to casing & from there to screens so that the whole assembly is vibrated. In electrically vibrated screens, vibrations are transmitted from heavy duty solenoids directly to the screens.	2 2
4-b	**Working of electrostatic separator**	4

	 The solids to be separated are fed on a rotating drum either charged or grounded from a hopper. Conductive particles assume potential of drum, opposite to that of active electrode, hence get attracted towards active electrode. Non-conductive particles get repelled by electrode, attracted by drum and then fall straight in the collecting bin due to gravity.	
4-c	**Vacuum filtration**: The filtration method in which the filter operate with less than atmospheric pressure on the downstream side of the filter medium and atmospheric pressure on the upstream side of the filter medium is called as vacuum filtration **Pressure filtration** The filtration method in which the filter operate with super-atmospheric pressure on the upstream side of the filter medium and atmospheric on the downstream side of the filter medium is called as pressure filtration	2 2
4-d	**Role of filter aids in filtration:** Filter aids are granular or fibrous materials added or applied to the filter medium to overcome the problem of slow rate of filtration, rapid medium blinding or unsatisfactory filtrate clarity. Slurries containing very finely divided solids form a dense impermeable cake that quickly blocks any filter medium. Hence the practical requirement for filtration of such material is that cake porosity should be increased to permit the passage of clear liquid at reasonable rate. If filter aids are added or applied to the filter medium in such cases it will form a highly impermeable cake	4

retaining the troublesome solids.

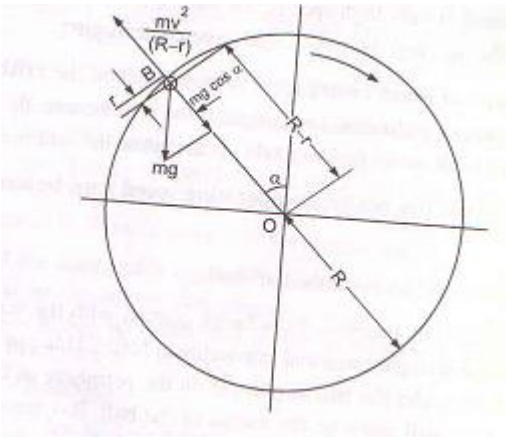
Eg for filter aids: diatomaceous earth, purified wood cellulose etc

4-e **Difference between filtration and sedimentation (4 points).** — 1 mark each

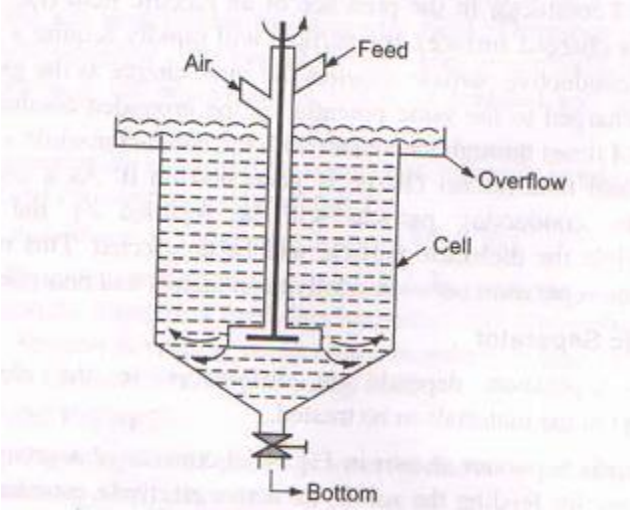
Sr.No.	Basis	Filtration	Sedimentation
1	Principle	Separation of solids from suspension using a porous medium which retains solids & allows liquid to pass.	Removal of solids by settling under gravity
2	Driving force	Pressure difference across filter medium	Gravitational force is responsible
3)	Use of filter medium	Required	Not required
4)	Concentration of solids	Very large quantities of solids in cake filtration	Low concentration of solids
5)	Product	Wet cake of solids on the filter medium and clear liquid on the downstream side of the filter medium	Clear liquid at the top and thickened sludge at the bottom
6)	Equipment	Filter press, rotary drum filter	Sedimentation basins, thickners

4-f **Type of settling:**

Free Settling and hindered settling — 1

	Terminal settling velocity: As the particle falls, its velocity increases and will continue to increase until the resisting force and the accelerating force (force of gravity) are equal. When this point is reached, the particle will fall at a definite constant velocity during remainder of the fall. This velocity is termed as terminal settling velocity. In sedimentation, the particles begin to settle and attains terminal settling velocity under hindered settling conditions	3
5	**Attempt any TWO of the following**	**16**
5-a	**Derivation for calculating critical speed of ball mill** The minimum speed at which centrifuging occurs is known as critical speed.  Consider the ball at point B on the periphery of the ball mill. Let R – radius of mill, r- radius of ball R-r - distance between the center of ball and axis of the mill. Let α be the angle between OB and vertical through the point O. The forces acting on the ball are 1. Force of gravity - mg 2. The centrifugal force - $mv^2/(R-r)$	2 2

	The component of gravity opposing the centrifugal force is mgcosα As long as the centrifugal force exceeds the centrifugal component of force of gravity, particle will not lose contact with the wall. Unless the speed crosses the critical value the above opposing forces are equal and ball is ready to fall down from the wall. The angle at which the above said phenomenon occurs is found out by equating the two opposing forces $mg\cos\alpha = mv^2/(R-r)$ $\cos\alpha = v^2/(R-r)g$ The relationship between the peripheral speed and speed of rotation is $v = 2\pi N(R-r)$ Putting value of v, $\cos\alpha = 4\pi^2N^2(R-r)/g$ At critical speed $\alpha=0$, And $\cos\alpha=1$ and $N=N_c$ $\text{Cos } \alpha=1= 4\pi^2N_c^2(R-r)/g$ $N_c^2 = g/4\pi^2(R-r)$ $N_c=1/2\pi\sqrt{\frac{g}{R-r}}$	2 2
5-b	**Froth flotation:** **Principle:** Floatation refers to an operation in which one solid is separated from another by floating one of them at or on the liquid surfaces. Separation of a mixture of solids using froth flotation methods depends on the difference in surface properties of the materials involved. **Diagram:**	2



2

Construction:

1.The mechanically agitated cell consists of a tank having square or circular cross-section.

2.It is provided with an agitator which violently agitates the pulp.

3.The air from a compressor is introduced into the system through a downpipe surrounding the impeller shaft.

4.The bottom of the tank is conical and is provided with a discharge for tailing.

5. An overflow is provided at the top for mineralized froth removal.

2

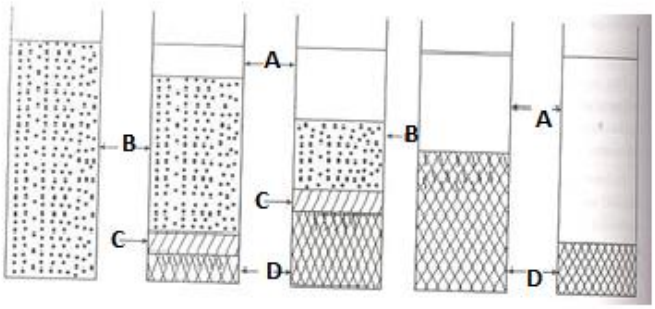
Working:

1. Water is taken into the cell; material is fed to the cell.
2. The promoters and frothers are added.
3. Agitation is given and air is bubbled in the form of fine bubbles.
4. Air-avid particles due to reduction in their effective density, will rise to the surface and be held in the froth before they are discharged from the overflow

Hydrophilic particles will sink to the bottom and removed from the discharge for tailing

2

5-c	**Batch sedimentation:**	



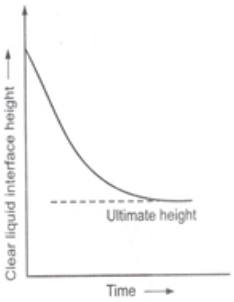
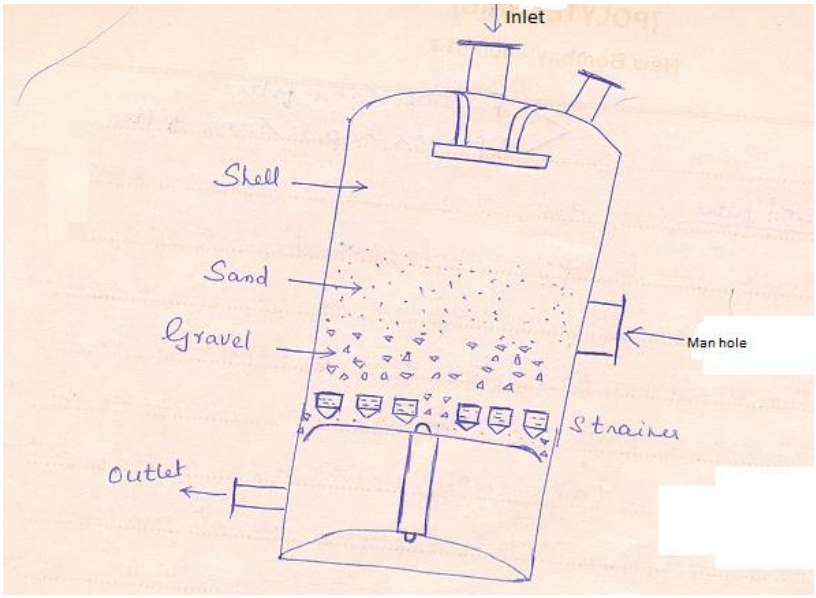
A- clear liquid
B- Original slurry
C- transition zone
D- settled solids

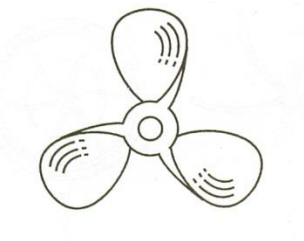
3

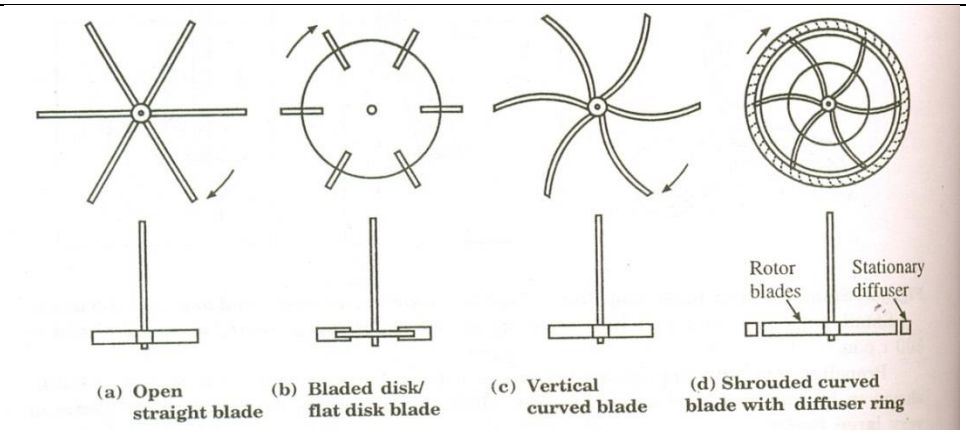
Prepare slurry of uniform concentration. The particles begin to settle and attain terminal settling velocity under hindered settling conditions. The heavier faster settling particles settled at the bottom are indicated by zone D. Above zone D forms another layer called zone C, which is a transition layer, the solid content of which varies from that in the original pulp to that in zone D. Above zone C is zone B which has the same concentration as the original pulp. Above zone B is zone A, which is a zone of clear liquid.

As sedimentation continues, the depth of zone A and D increases, that of zone C remains constant and zone B decreases. After further settling, zone B and C disappear and all the solids are in zone D. Then a new effect called compression begins. In compression, a portion of the liquid which has accompanied the solids into the zone D is expelled and the thickness of this zone decreases. After some time, the sludge reaches ultimate height. The entire process is called sedimentation.

5

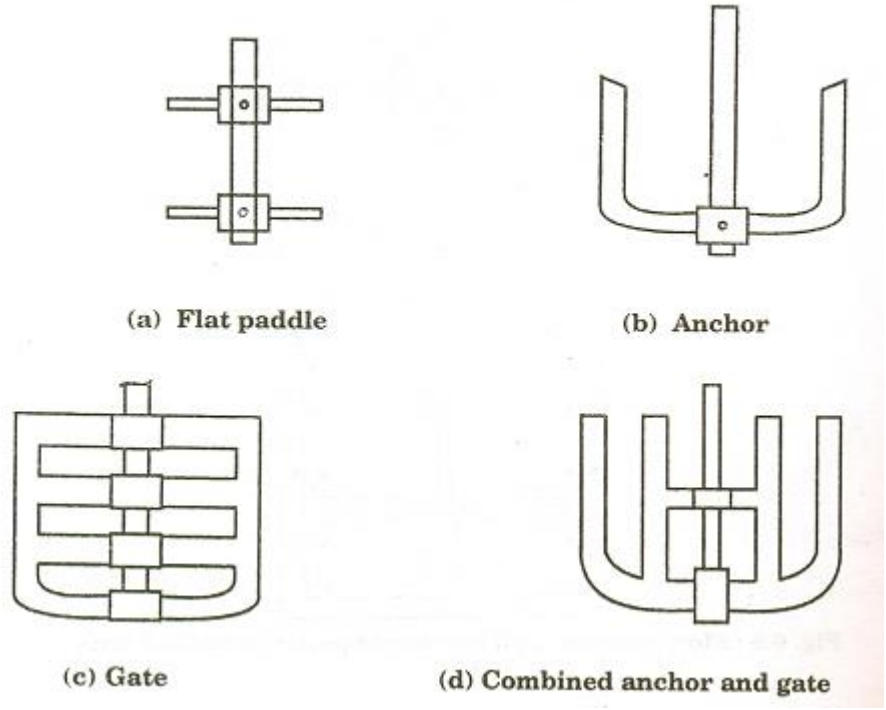
		
6	**Attempt any FOUR of the following**	**16**
6-a	**Sand filter** **Diagram:**  At the bottom of the tank embedded in concrete are a number of strainers. They are made of brass and have narrow slots in them. Over the strainers is a layer of several inches of moderately coarse gravel and the top of it there is the sand that forms the actual filter medium. The feed to be filtered is introduced at the top on to baffle which prevents disturbance of the sand bed directly. The feed passes through several	2 2

	layers of sand and gravel. The filtered liquid comes out through the strainer at the bottom.	
6-b	**Swirling and Vortexing:** If low viscosity liquid is stirred in an unbaffled tank by centrally mounted agitator, there is a tendency for nearly pure rotary flow pattern to be developed and lighter liquid, ie air is usually drawn in to form a vortex and the degree of agitation is very much reduced. This phenomenon which takes place in an unbaffled tank regardless of the type of impeller is known as vortexing. **Prevention of swirling and Vortex Formation:** There are four methods of prevention of swirling and vortex formation a) Off-center mounting of the impeller. b) Use of Baffles c) Use of diffuser ring with turbines d) Angular entry of agitators.	2 2
6-c	**Types of impellers:** Propellers, paddles and turbines **Diagram:**  **Propeller**	1 1



Turbine

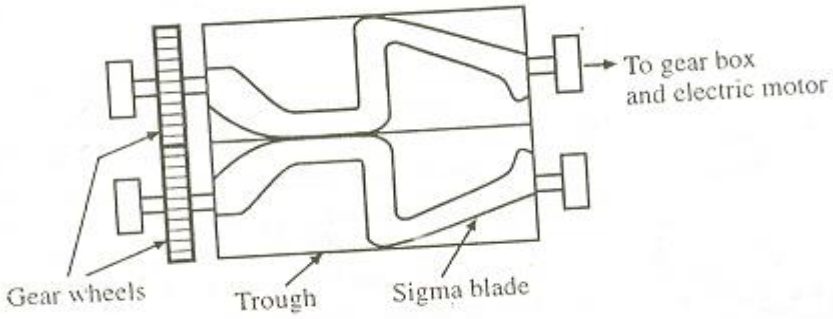
1 mark for any one diagram

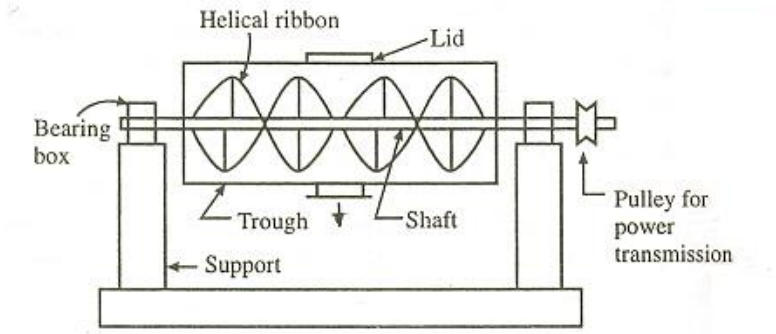


Paddle

1 mark for any one diagram

6-d	**Sigma Mixer:**	

	Construction:  It consists of a short rectangular trough with saddle shaped bottom. Two counter rotating heavy blades are incorporated in the trough. Blades are so placed and so shaped that the material turned up by one blade is immediately turned under adjacent one. The edges of the blades may be serrated to give a shredding action The blades are driven by through a gear mechanism provided at either ends. The trough may be open or closed and may be jacketed for heating or cooling. The machine can be emptied through a bottom valve. **Working:** The material to be kneaded is dropped into the trough. The blades turn towards each other at the top, drawing the mass downward, then shearing it between the wall and blades of the trough. It is mixed for about 5 to 20 minutes or longer. The trough is then unloaded by tilting it.	2 2
6-e	**Ribbon blender:**	4

		
6-f	**Application of** **Muller Mixer (any two):** 1) It is used for handling batches of pastes. 2) It is used for handling batches of heavy solids. 3) It is used for uniform coating the particles of granular solids with a small amount of liquid. **Sigma mixer (any two):** 1. It is used for sticky materials 2. for heavy plastic materials 3. It is used to disperse powder or liquids into plastic or to rubbery masses 4. It is used in food and confectionery products industry.	1mark each 1mark each