SUMMER-18 EXAMINATION

Model Answer

Subject Title: Mechanical Operation | Subject code: 17313 |

Important Instructions to examiners:

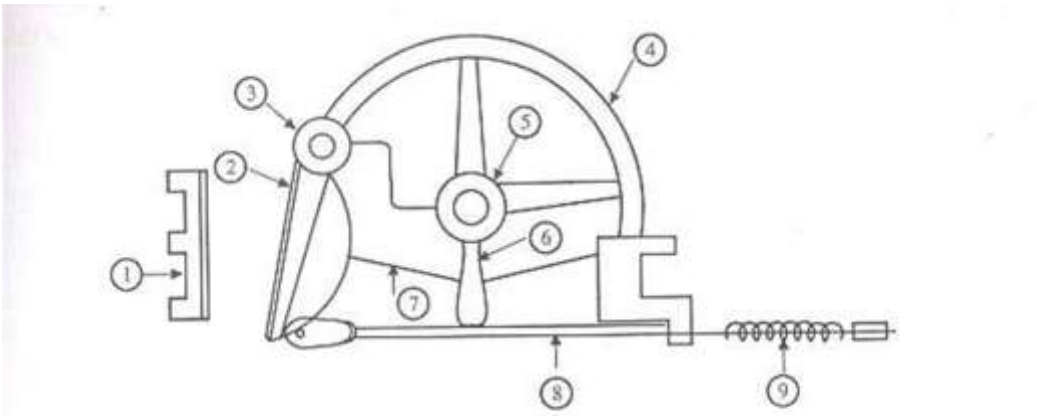
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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	**Rittinger's law** It states that the work required in crushing is proportional to the new surface created. $\frac{P}{\dot{m}} = K_r(\frac{1}{\bar{D}_{sb}} - \frac{1}{\bar{D}_{sa}})$ **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. $\frac{P}{\dot{m}} = K_k \ln\frac{D}{d}$	1 1
1A-b	**Classification of size reduction equipment** Size reduction equipment can be classified into 1. Crushers 2. Grinders 3. Ultrafine grinders 4.Cutters.	2
1A-c	**Difference between ideal screen and actual screen:**	1 mark each for any two points

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%

1A-d	**Screening:** Screening is the method of separating solid particles based on size. **Application (any two):** 1. mining and mineral processing industry 2. Pharmaceutical production 3. Agriculture 4. Food processing	1 ½ mark each
1A-e	**Types of impellers:** Propellers, paddles and turbines.	2
1A-f	**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
1A-g	**Electrostatic Separation:** It is the method of separation of solid particles based on differential attraction or repulsion of charged particles under the influence of an electric field.	2
1A-h	**Importance of mixing in process industries: (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.	1 mark each

	3. To carry out physical change- formation of crystals from a supersaturated solution. 4. To accomplish dispersion in which a homogeneous material is produced from two or more immiscible fluids and from one or more fluids with finely divided solids.	
1 B	**Attempt any TWO of the following**	8
1B-a	**Critical speed of ball mill :** Critical speed is the speed at which centrifuging occurs in a ball mill. When centrifuging occurs no grinding takes place. **Formula:** $N_c = \frac{1}{2\pi}\sqrt{\frac{g}{(R-r)}}$ Where N_c is the critical speed, R is the radius of the ball mill r is the radius of the ball. **Criteria for selecting the operating speed of ball mill (any one)** 1. Size of the product 2. Type of lining provided for the shell	1 2 1
1B-b	**Jaw crusher:** **Construction:** 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.	2

	Diagram  (1) Fixed jaw, (2) Movable jaw, (3) Shaft, (4) Fly wheel, (5) Eccentric, (6) Pitman, (7) Toggle, (8) Tie rod, (9) Spring	2
1B-c	**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.	1
	Let *F*, *D*, and *B* be the mass flow rates of feed, overflow, and underflow, respectively, and x_F, x_D, and x_B be the mass fractions of material A in the feed, overflow and underflow respectively.	
	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 $E_A = \frac{Dx_D}{Fx_F}$	1
	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 $E_B = \frac{B(1-x_B)}{F(1-x_F)}$	1

	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
2	**Attempt any FOUR of the following**	**16**
2-a	**Sphericity:** Sphericity(φ_s **)** is the ratio of surface-volume ratiofor a sphere of diameter Dp to the surface–volume ratio for the particle whose nominal size is Dp. (OR) It is the ratio of surface area of sphere of same volume as particle to surface area of particle **Formula** For spherical particle $\varphi_s = 1$ And for non-spherical particle $\varphi_s = \frac{6/Dp}{Sp/Vp}$ whereDp is the normal diameter of the particle, Sp is the surface area of one particle Vp is the volume of one particle. **Significance:** Shape of irregular particles is expressed in terms of sphericity, which is independent of particle size.	2 1 1

2-b **Comparison of grizzlies and trammels** — 1 mark each

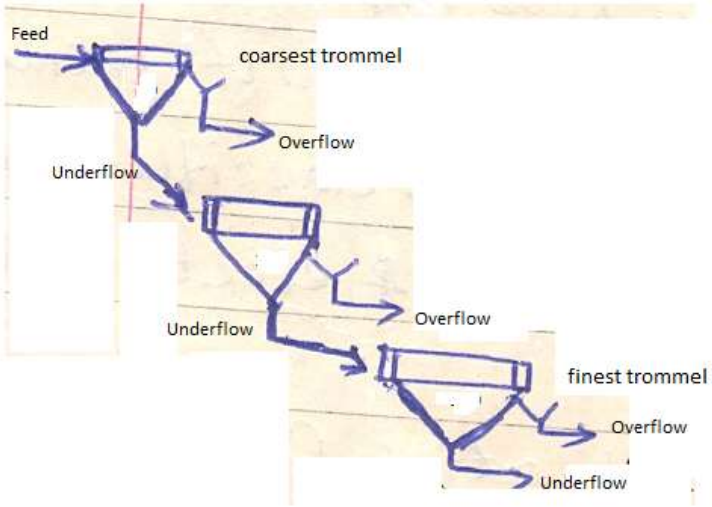
	Grizzlies	Trommels
1.Screen arrangement	Stationary inclined screen. Screen is a grid of parallel metal bar	Revolving screens. Screen is perforated cylinder.
2.Openings in screen	large	small
3.Size of feed handled	Large size feed	Small size feed
4.Capacity	large	small

2-c **Trommel:** — 1

Trommels are revolving screens used for separting particles based on size.

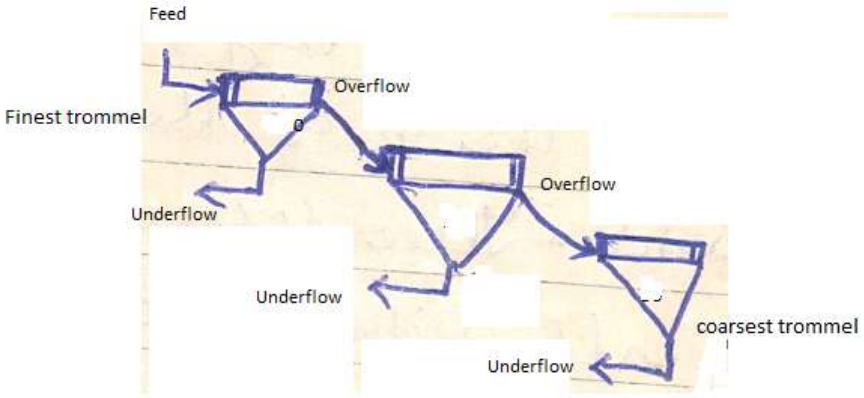
Four arrangements of trommel

a. One size screen to each trommel.Trommel is arranged in such a way that coarsest trommelis kept first. The underflow from the first trammel is the feed to the second trommel and so on.



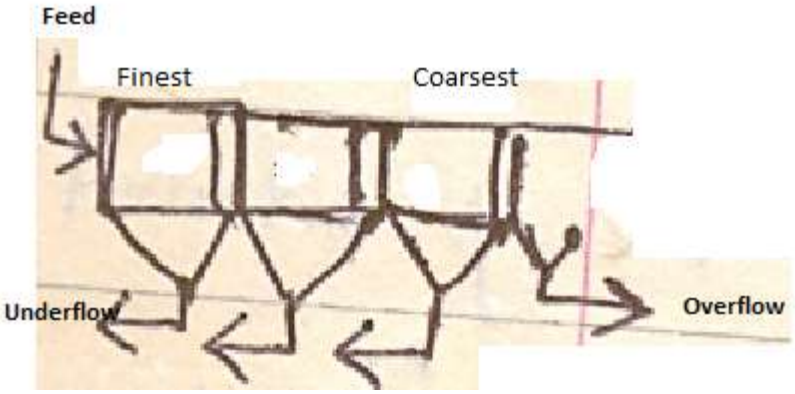
b. One size screen to each trommelFirst trammel is the finest.

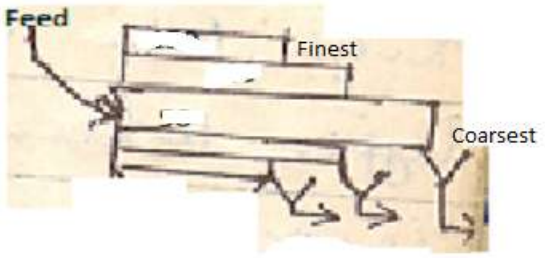
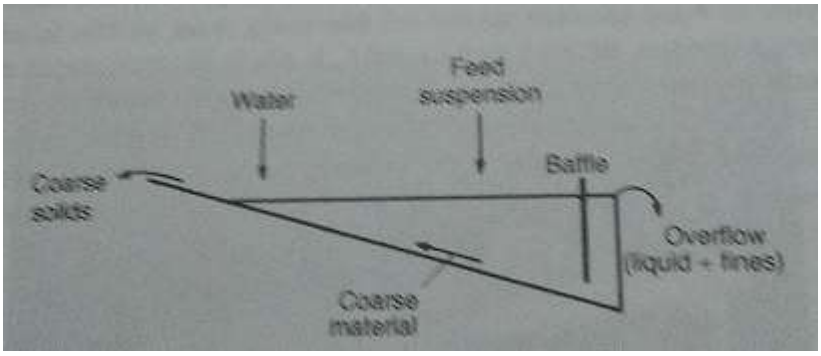
The overflow from the first trommel is the feed to the next trammel and so on. 1

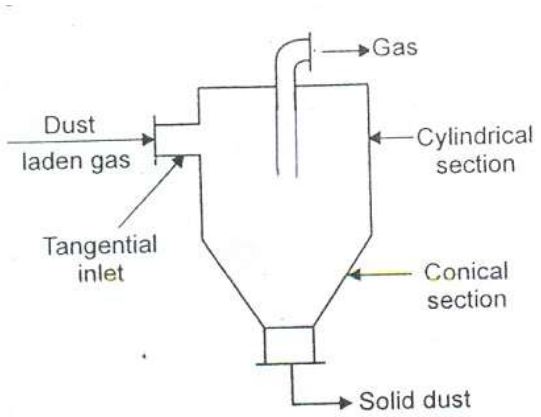


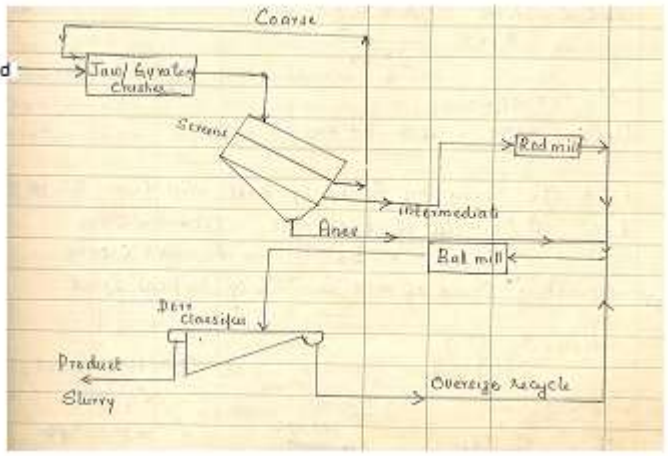
c. Single trommel with different perforations.

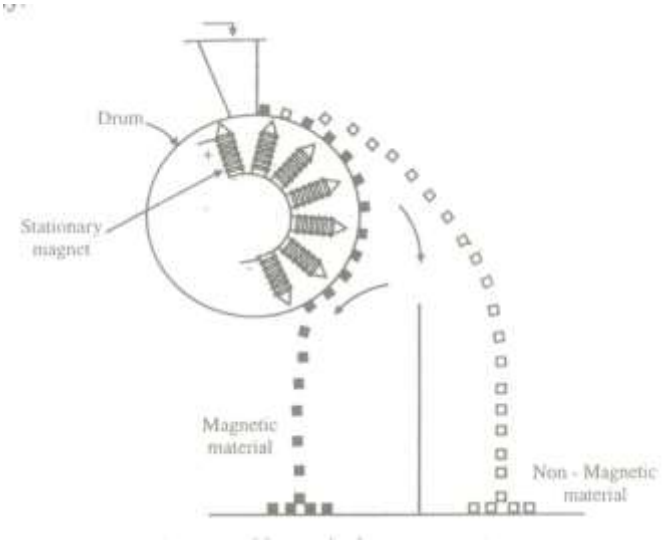
The perforations near the feed end will be the finest. 1



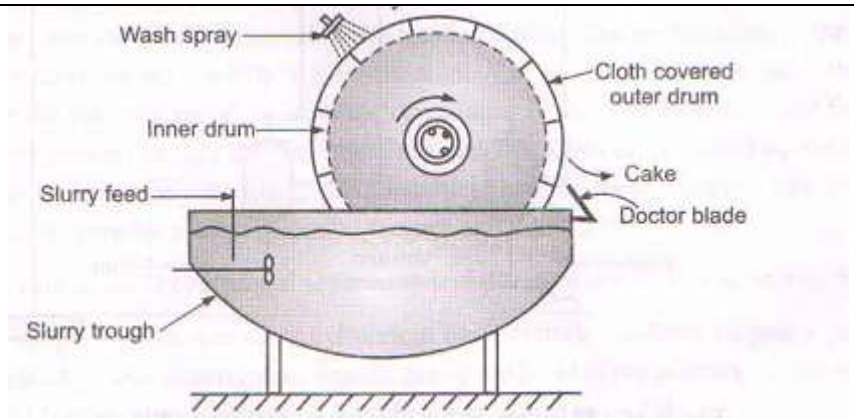
	d) Different size screen on concentric trommels.  The innermost one is the longest and has coarsest perforations. The outer ones are successively shorter and have finer perforations.	1
2-d	**Rake classifier:** **Diagram:**  	4
2-e	**Cyclone separator:** **Explanation:** It consists of a tapering cylindrical vessel. The cylindrical vessel consists of a top vertical section and lower conical section terminating in an apex opening. It is provided with a tangential feed inlet nozzle in the cylindrical section near the top and an outlet for the gas, centrally on the top. The outlet is provided with a downward extending pipe to prevent the gas short circuiting directly from the inlet to the outlet and for cutting the vortex. The dust laden gas is introduced tangentially into a cylindrical vessel at a high	2

	velocity (30 m/s). Centrifugal force throws the solid particles out against the wall of the vessel and they drop into a conical section of the cyclone and removed from the bottom opening. The clean gas is taken out through a central outlet at the top. **Diagram**  	2
2-f	**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 proportion 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

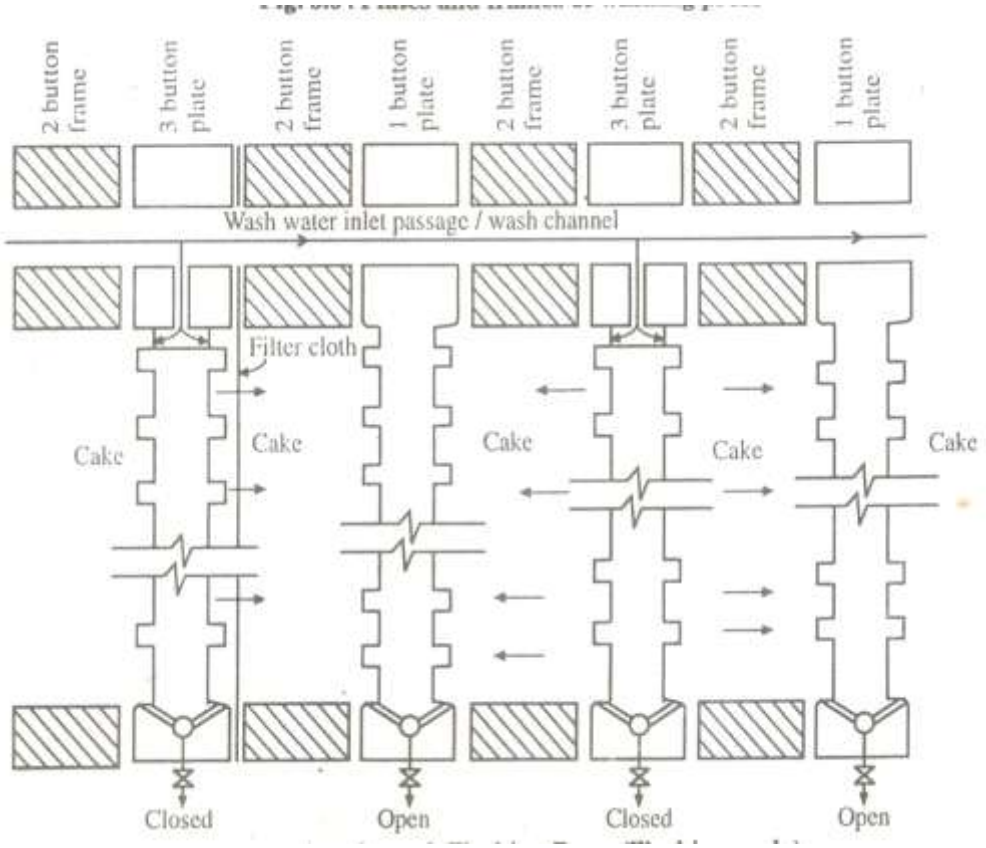
3	Attempt any FOUR of the following	16
3-a	**Open circuit grinding:** If the feed material is passed only once through the size reduction machine and no attempt is made to return the oversize material to it for further reduction , the process is known as open circuit grinding **Closed Circuit grinding:** 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
3-b	**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 a slow velocity as possible. 2) **Screen slope**: As the slope increases, the rate at which the materials travels over the screening	1 mark each for any 4 points

	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 blinding of screen &for long bearing life. 5) **Moisture in feed**: The moisture in feed adversely affects screening operation &should be removed.	
3-c	**Magnetic Drum Separator**: **Diagram:**  **Construction:** It consists of a rotating drum incorporating a stationary magnet assembly, The	2

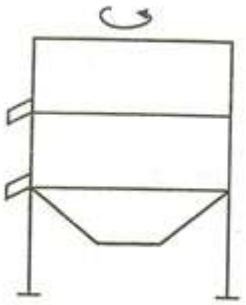
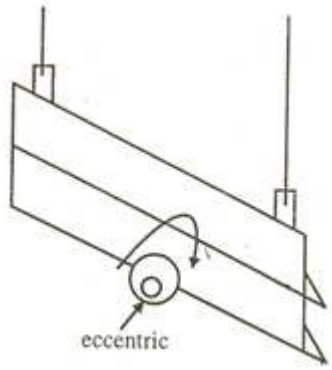
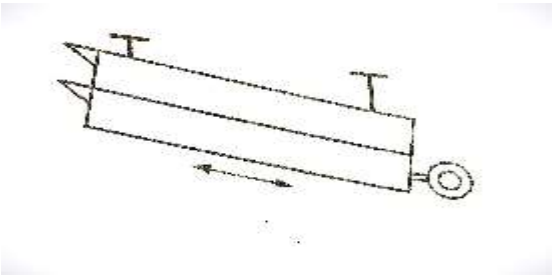
	magnet arc covers approximately165^0 towards the discharge side of the drum. The feed (mixture of magnetic & non-magnetic materials) is admitted at the top & is allowed to fall on the rotating drum. The non-magnetic material is discharged in a normal manner. The magnetic material adheres to the drum & falls off underside when the drum loses the contact of the magnet assembly.	2
3-d	**Classification of filter** **i)based on Driving force**: 1) Gravity filters 2) Vacuum filters 3) Pressure filters 4) Centrifugal filters ii) **Based on mode of filtration:** 1) Batch filters 2) Continuous filters	2 2
3-e	**Rotary drum vacuum filter:** **Working:** Filter drum is immersed in slurry, vacuum applied to filter medium causes cake to deposit on outer surface of drum. Cake is washed by spraying wash liquid; wash liquid is collected in a separate tank. Then cake enters into drying zone as drum rotates where cake is partially dried by sucking air through cake of solids. Then vacuum is cut off & cake removed with a doctor's knife. Air is blown for removal of cake.	4

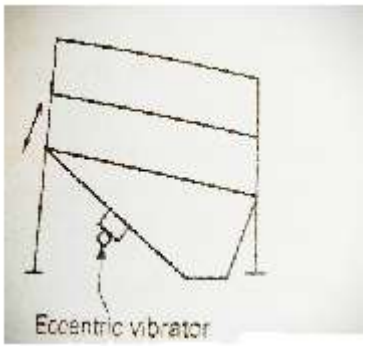
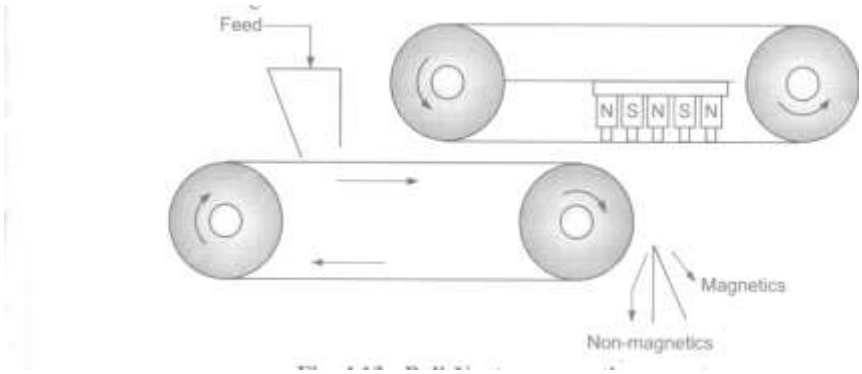


3-f **Washing type of plate and frame filter press.**



4

4	**Attempt any FOUR of the following**	**16**
4-a	**Diagram of motion of screen** **(i)Gyration in horizontal Plane.**  **(ii) Gyration in vertical Plane.**  **(iii) Shaking:** 	1 1 1

	(iv) Mechanically vibrated:  	1
4-b	**Ball –Norton separator**: **Explanation:** It consists of two horizontally staggered belt conveyors running parallel, one above the other. A hopper is provided for feeding the feed to the lower belt and a stationary magnet assembly is incorporated in the upper belt conveyor near the discharge end. The material to be separated is fed to the lower belt in the form of a thin sheet & is conveyed under the second belt where it is subjected to a magnetic field.The non-magnetic material is discharged in the normal manner,whereas the magnetic material adheres to the lower side of the upper belt & thus carried some distance away from the discharge point of nonmagnetic materials.It ultimately drops-off the belt in to the separate compartment when the belt loses the contact with magnet assembly  	2 2

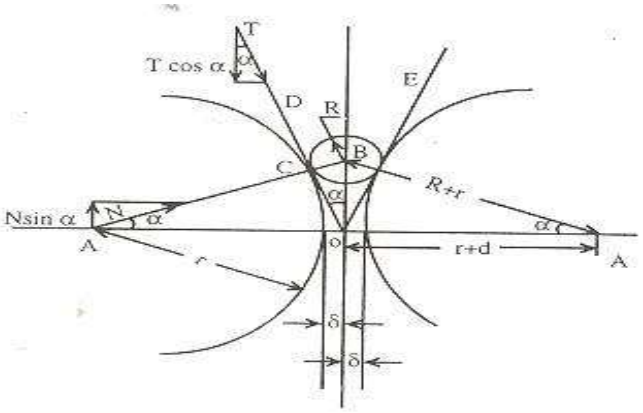
4-c	**Vacuum filter:** **Advantages:** 1) Low labour requirement 2) Filtering surface is accessible for inspection and repair as it is open to atmosphere. 3) Low maintenance cost **Disadvantages:** 1) Vacuum system is difficult to maintain 2) Not suitable for filtering hot liquids. 3) Cannot be employed for materials forming relatively impermeable cakes or cakes that cannot be easily removed from cloth	1 mark each for any two points 1 mark each for any two points
4-d	**Significance of cake resistance:** If the resistance offered by the cake is more, the rate of filtration decreases. It is denoted by $\alpha = \frac{\Delta P_{CA}}{\mu U M_C}$ Where ΔP_{CA} is the pressure drop over the cake. A is the area of filter medium. μ is the viscosity of the filtrate. M_C is the total mass of solids deposited in the cake. **Method of reducing cake resistance: (any one)** 1) Back-flushing of cake deposited on filter medium 2) Use of filter aids (like diatomaceous earth, ,skeletons asbestos fibers)	1 2 1

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
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,thickeners

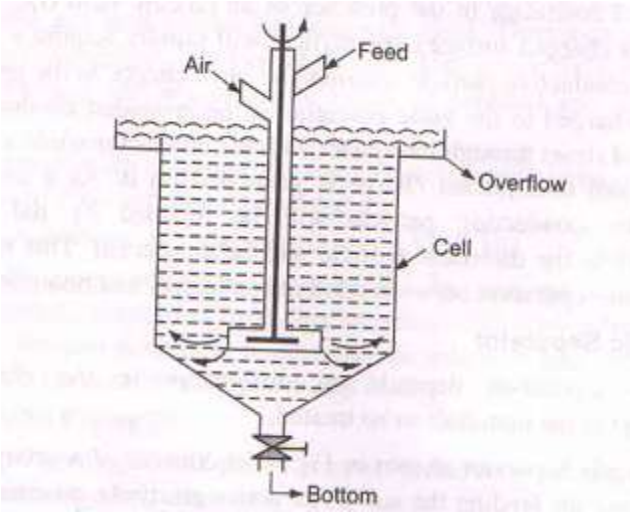
4-f **Free settling:** — 2

Free settling is the settling of the particle unaffected by other particle and the boundary of the container. Practically free settling conditions exist if the concentration of the particles in suspension is less than 1% wt.by solid.

	Hindered settling: Hindered settling is the settling of particles affected by other particles and by the boundary of the container. When the concentration of the solid particles is large(> 1% by wt.),the particles are so close to each other that the surrounding particles will interfere with the motion of other particles.	2
5	**Attempt any TWO of the following**	**16**
5-a	**Expression relating size of crushing roll, size of feed ,size of product (Derivation)** Consider a feed particle B caught between the rolls as shown in figure Let A and A'be the centre of the 2 rolls. C and C' are the points where the particle is in contact with left hand roll and right hand roll respectively. Let the angle between line AB and AA' be α. Line OD and OE are tangents to the rolls.  Neglecting the force of gravity, the two forces acting at the point C are vertical component of tangential force and vertical component of radial force. Vertical component of tangential force = T cos α Vertical component of radial force = Nsin α. The vertical components of forces T and N are opposed. Force Nsinα tends to expel the particle from the rolls and force Tcosα tends to draw the particle between the rolls. If the particle is to be drawn between the rolls and crushed,	3

	$T\cos\alpha \geq N\sin\alpha$ T and N are related through $T = \mu N$ $\mu N\cos\alpha \geq N\sin\alpha$ $\mu \geq \tan\alpha$ Let R be the radius of the feed particle, r the radius of the roll and 2d the distance between the rolls. Then in triangle ABO, the angle BAO is α,AO is r+d and AB is r+R. Then, from the simple geometry of figure $\text{Cos } \alpha = \frac{r+d}{r+R}$ Where, α= half of angle of nip **Problem:** r = 100 / 2 = 50cm 2d = 1.4cm d=0.7 cm $2\alpha = 32^o$ $\alpha = 16^0$ R= ? $\cos\alpha = \frac{r+d}{r+R}$ $\cos 16 = \frac{50+0.7}{50+R}$ R =2.7411cm Maximum permissible size of feed =**5.482cm**	2 2 1
5-b	**Froth flotation:** 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.	2

Diagram:



2

Construction:

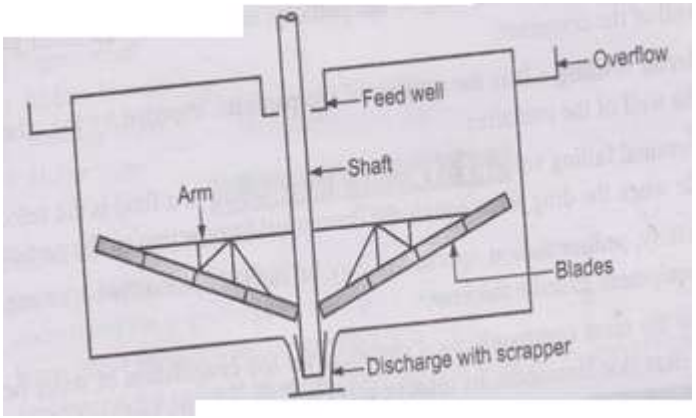
The mechanically agitated cell consists of a tank having square or circular cross-section. It is provided with an agitator which violently agitates the pulp. The air from a compressor is introduced into the system through a downpipe surrounding the impeller shaft. The bottom of the tank is conical and is provided with a discharge for tailing. An overflow is provided at the top for mineralized froth removal.

2

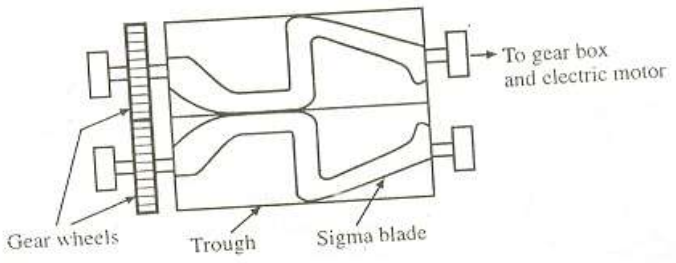
Working:

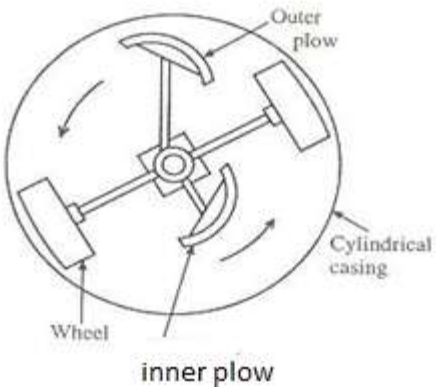
Water is taken into the cell; material is fed to the cell. Then promoters and frothers are added. Agitation is given and air is bubbled in the form of fine bubbles. Air-avid particles(hydrophobic) due to reduction in their effective density, will rise to the surface and be held in the froth before they are discharged from the overflow. Hydrophilic particles will sink to the bottom and removed from the discharge for tailing.

2

5-c	**Dorr thickener:** **Diagram:**  Dorr Thickener consist of a flat bottomed, large diameter shallow depth tank. It is a continuous type thickener. It is provided with slow moving radial rakes driven from a central shaft for removing the sludge. The slurry is fed at the center of tank at a depth of 0.3m to 1m below the surface of the liquid, with a very little disturbance. The clarified liquid is continuously removed from an overflow which runs around the top edge of the tank and the thickened liquor is continuously withdrawn from the outlet at the bottom. The slowly revolving rakes scrape the sludge toward the centre of the bottom for discharge and remove water from the sludge as it stir only the sludge layer. Thus the solids are continuously moving downwards and then inwards to the sludge outlet whereas the liquid is moving upwards, and then rapidly outwards.	3 5
6	**Attempt any FOUR of the following**	**16**
6-a	**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.	1 mark each for any 4 points

	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.	
6-b	**Swirling and Vortexing:** If low viscosity liquid is stirred in an unbaffled tank by a 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 1 mark each for any two points
6-c	**Mixing:** It is the process of taking at least two different materials and causing them to distribute randomly through one another. Or Mixing is a process in which at least two separate materials which may be present in the same or different phases are taken and forced them to be randomly distributed through one another by some mechanical means. **Homogeneous mixture** A mixture which is uniform throughout in physical state and chemical composition	2

	is called homogeneous mixture. Example: A liquid mixture of methanol and water. **Heterogeneous mixture:** A mixture which is not uniform throughout in physical state and chemical composition is called heterogeneous mixture. Example: A liquid mixture of benzene and water forms a heterogeneous mixture made up of two immiscible liquid phase.	1 1
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 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	**Muller mixer:** **Construction and Working:**  It consists of a pan incorporating muller wheels. In some designs, pan is stationary & wheels rotate, while in other designs, pan is rotated & axis of wheels is held stationary. In stationary pan muller mixer, central vertical shaft is driven, causing the muller wheels to roll in a circular path over a layer of solids on pan floor. Plows guide the solids under muller wheels during mixing or to an opening in pan floor for discharge of mixer at the end of cycle. The rubbing action results from the slip of the wheels on the solids.	2 2
6-f	**Data :** Da = Impeller diameter = 60 cm =0.6m μ = Viscosity = 10 Cp = 0.10 poise =0.01 Pa.s ρ = 1.45 g/cm³ =1.45X 10^3 kg/m^3 N = Revolution per second $= \frac{\text{Speed in rpm}}{60} = \frac{90}{60} = 1.5$ r.p.s.	

	Reynolds number = $N_{Re} = \frac{N\,Da^2\,\rho}{\mu}$ $= \frac{1.5 \times 0.6^2 \times 1.45 \times 10^3}{0.01} = 78300$ Np = Power number = 1.05 for $N_{Re} > 300$ $P = NpDa^5\,N^3\rho$ $P = 1.05 \times 0.6^5 \times 1.5^3 \times 1.45 \times 10^3$ P = **399.6 watts**	2 2