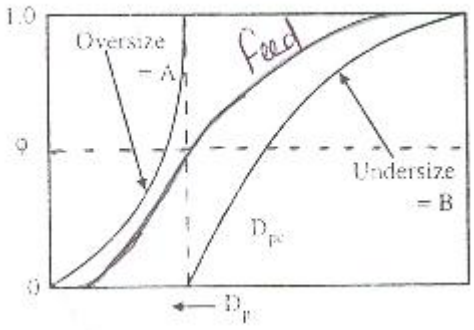
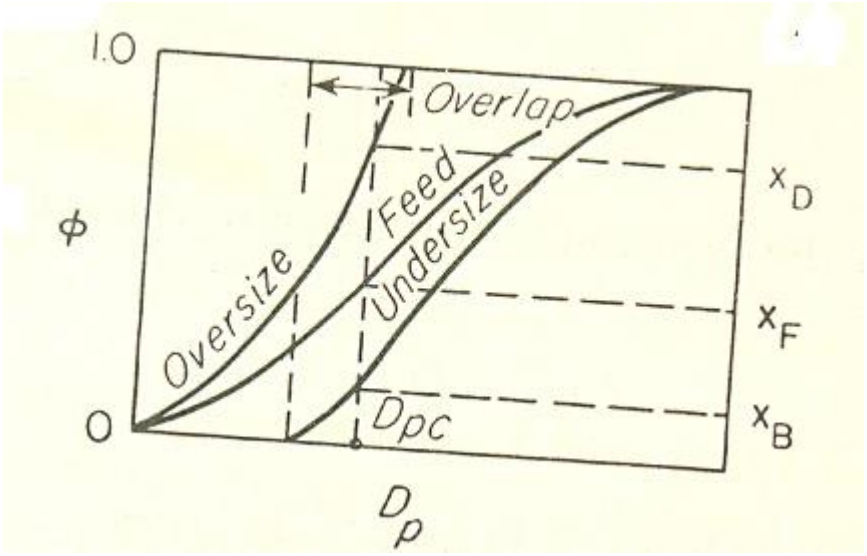
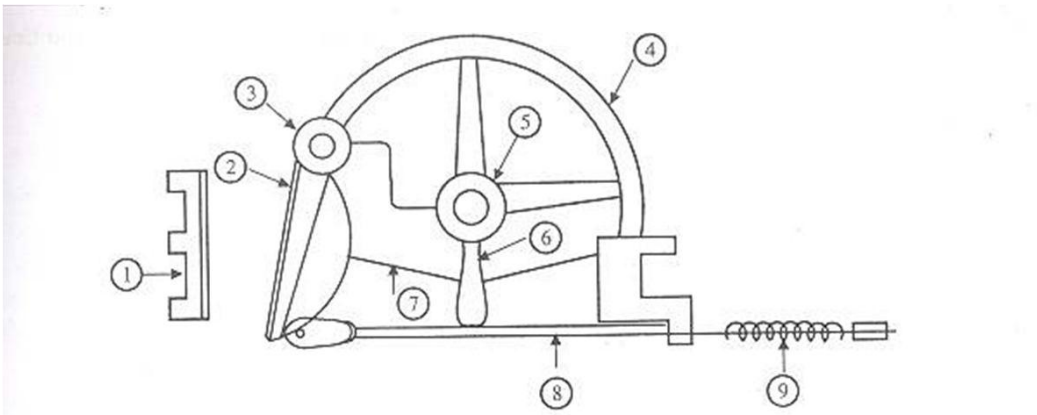
Important Instructions to examiners:

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. $\frac{P}{\dot{m}} = K_r(\frac{1}{\overline{D}_{sb}} - \frac{1}{\overline{D}_{sa}})$ where P is the power required $\dot{m}$ is mass flow rate K_r is Rittinger's constant $\overline{D}_{sa}$ = Volume surface mean diameter of feed $\overline{D}_{sb}$ = Volume surface mean diameter of product	1 1
1A-b	**Crushing efficiency:** It is the ratio of surface energy created by crushing to the energy absorbed by the solid.	2
1A-c	**Graphical representation of ideal and actual screen.** **Ideal screen**  	1

	Actual Screen  D_{pc} is the cut diameter and ϕ is the cumulative weight fraction.	1
1A-d	**Importance of screening in industry:** 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 for any 2 points
1A-e	**Axial flow impeller:** Impellers which generate current parallel to the axis of the impeller shaft are known as axial flow impellers **Rradial flow impellers:** Impellers which generate current in tangential or radial direction of the axis of the impeller is known as radial flow impellers	1 1
1A-f	**Separation of solids based on** **1)Specific gravity -** Jigging **2) Surface properties of materials** – Froth floatation	 1 1
1A-g	**Equipments used for magnetic separation(any two)**	

	Magnetic head pulley, magnetic drum separator, Ball Norton machine (usually it is used as concentrator)	1 mark each
1A-h	**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.	2
1 B	**Attempt any TWO of the following**	8
1B-a	**Jaw crusher:** **Construction:**  (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 &	2

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

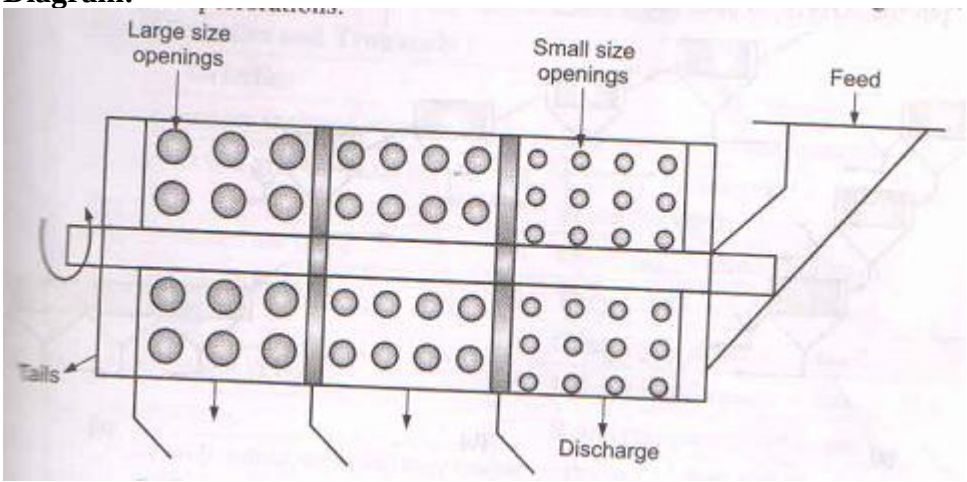
1B-b **Difference between crushing and grinding:**

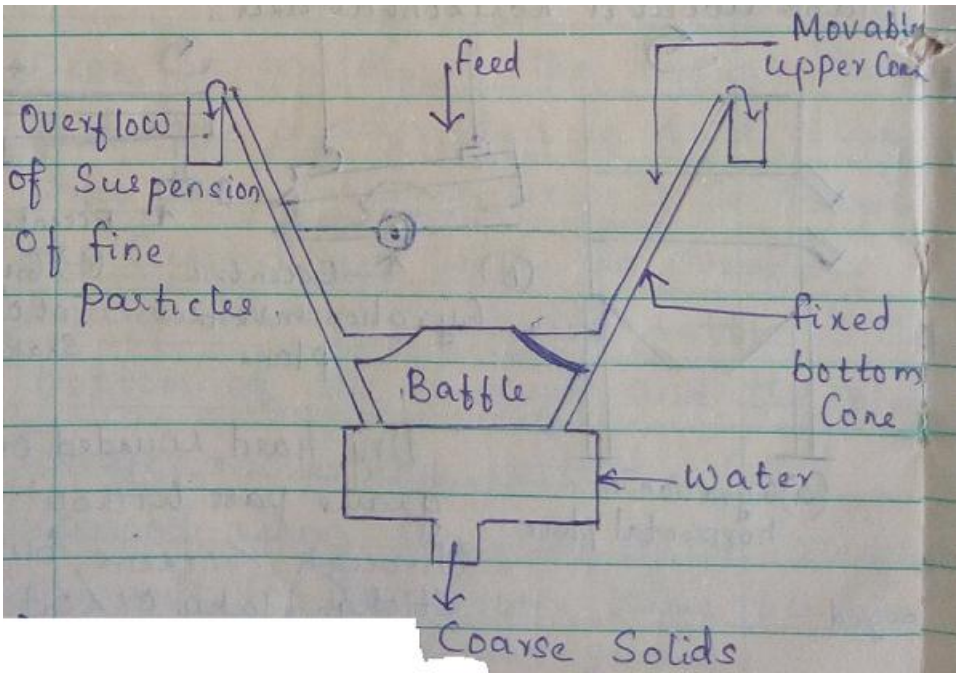
1 mark each for any 4 points

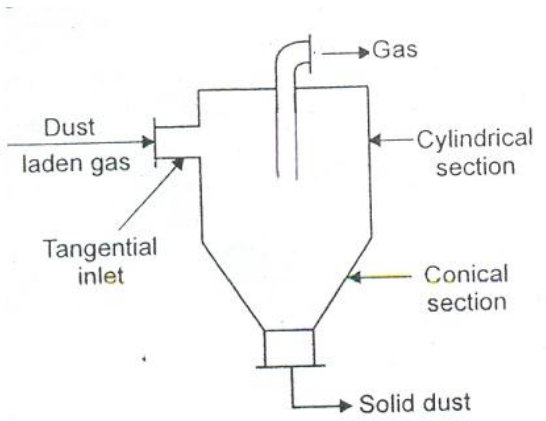
Sr.No.	Crushing	Grinding
1	Size reduction by compression	Size reduction by impact & attrition
2	Equipment operated in open-circuit	Equipment always operated in closed-circuit
3	Used for breaking of large pieces of solids into small lumps	Used for reducing crushed feed to powder
4	Reduction ratio usually 6 to 8.	Reduction ratio as high as 100 is possible
5	Crushers are heavy duty, low speed machines.	Grinders are light duty, high speed machines.
6	Feed size :1500 to 40 mm Product size: 50 to 5mm.	Feed size :5 to 2 mm Product size: 0.1mm.
7	Operation is performed on dry feed.	Operation can be performed on dry as well as wet feed.
8	Energy consumption per	Energy consumption per unit mass

			unit mass of product is low due to coarse particle production	of product is high due to fine particle production

1B-c	**Derivation for 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, 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 1 1
2	**Attempt any FOUR of the following**	**16**
2-a	D_{pa} = 50mm D_{pb} = 5mm P = 80Kw W_i = 6.73KwH/Ton	

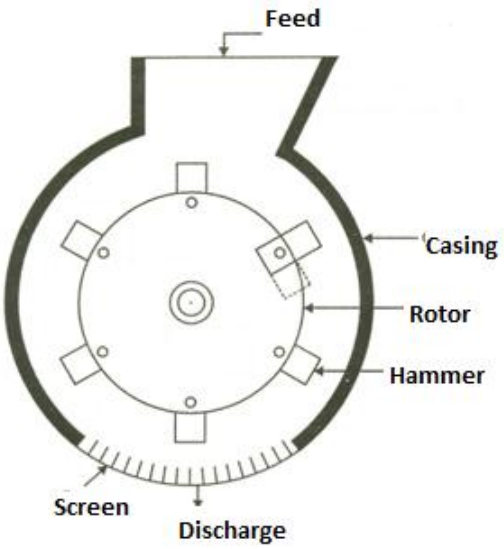
	$\frac{P}{\dot{m}}$ = 0.3162 $W_i\left(\frac{1}{\sqrt{D_{pb}}} - \frac{1}{\sqrt{D_{pa}}}\right)$ = 0.3162* 6.73$\left(\frac{1}{\sqrt{5}} - \frac{1}{\sqrt{50}}\right)$ $\frac{80}{\dot{m}}$ = 0.6507 $\dot{m}$ = **122.94 tons/hr**	2 2
2-b	**Trommel:** **Diagram:**  **Construction:** It consists of cylindrical frame surrounded by wire cloth or perforated plate. It is open at one or both ends and inclined at a slight angle to horizontal so that the material is advanced by the rotation of the cylinder **Working :** The material to be screened is fed at the upper end and gradually moves down the screening surface towards the lower end. The material passes over the apertures of gradually increasing size. For example, if single cylinder is provided with screen having three different size perforations, we get four fractions. The finest material is collected as underflow in compartment near to feed end and the coarsest is collected from discharge end.	2 1 1
2-c	**Classification:** It is the separation of solid particles (from slurry) into several fractions based on	2

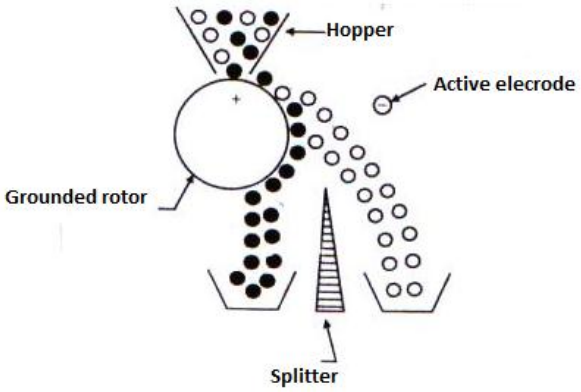
	terminal settling velocities. **Names of classifiers:** 1.. Spiral classifiers 2.Cone classifiers 3..Drag classifiers 4..Rake classifiers 5. Double cone classifiers.	½ mark each for any 4 classifiers
2-d	**Double cone classifier:** **Diagram:**  	2
	Construction: It consists of two cones- a fixed bottom cone and a movable upper cone. The upper cone can be lifted up or lowered down in a vertical plane inside the bottom cone so that a variable flow area is made available. **Working:**	1

	The feed material –slurry of suspended solids is fed to the upper cone. It moves downward and flows out of a baffle placed at the bottom of the movable cone. The slurry then moves up through the annular space. The fluid and the solids from the inner cone are mixed and then move up through the annular space with decreasing cross sectional area upwards. Classification occurs in the annular space – the larger particles settles to the bottom while the fine particles flow away with the overflow.	1
2-e	**Cyclone separator:** **Construction:**  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. **Working** The dust laden gas is introduced tangentially into a cylindrical vessel at a high velocity (30 m/s). Centrifugal force throws the solid particles out against the wall of	2 2

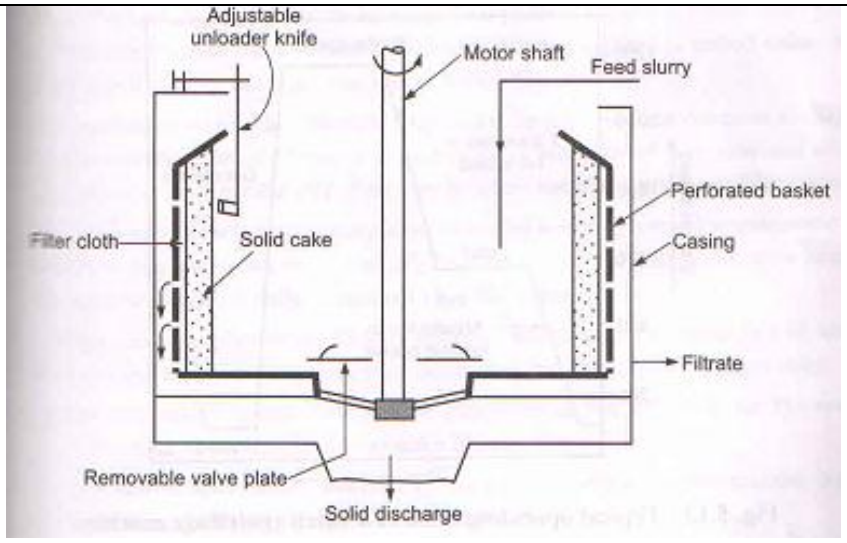
<table>
<tr><td></td><td>the vessel and they drop into a conical section of the cyclone and removed from the bottom opening. The clean gas is taken out through a central outlet at the top.</td><td></td></tr>
<tr><td>2-f</td><td>Difference between constant rate filtration and constant pressure filtration

<table><tr><th>Constant rate filtration</th><th>Constant pressure filtration</th></tr><tr><td>1.Rate of filtration is maintained constant</td><td>1. Rate of filtration varies</td></tr><tr><td>2. pressure drop is varying</td><td>2. Pressure drop is constant</td></tr><tr><td>3.Starts with low inlet pressure and continuously increasing the pressure to overcome the resistance of the cake</td><td>3. High inlet pressure is applied which is maintained throughout.</td></tr><tr><td>4. The first particles filtered will not be compacted into a tight mass.</td><td>4. The first particles filtered will be compacted into a tight mass due to the high initial pressure applied.</td></tr></table></td><td>1 mark each</td></tr>
<tr><td>3</td><td>Attempt any FOUR of the following</td><td>16</td></tr>
<tr><td>3-a</td><td>Hammer mill
Diagram</td><td></td></tr>
</table>

	 **Construction** It contains a high speed rotor rotating inside a cylindrical casing. A set of swing hammers are pinned to the rotor disk. The shaft is horizontal. Screen or grate is provided at the bottom for the discharge of the product. **Working** Feed is dropped into the top of the casing. Particle of feed is being struck by the set of swing hammers. The feed after being struck by the hammer fly against a stationary anvil plate inside the casing and break into still smaller fragments. They are again rubbed into powder by the hammers and pushed through the grate or screen which covers the discharge opening.	2 1 1
3-b	**Factors affecting the performance of screen**. 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.	1 mark each for any 4 points

	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 bearing life. 5) **Moisture in feed**: the moisture in feed adversely affects screening operation &should be removed.	
3-c	**Electrostatic separator** **Diagram**  **Working:**	2

	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.	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 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	**Working of basket centrifuge**	

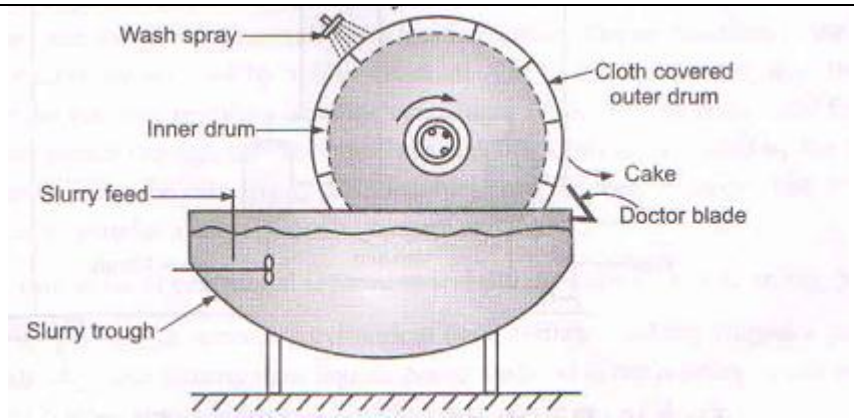
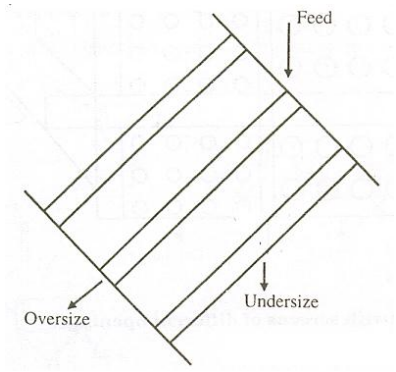


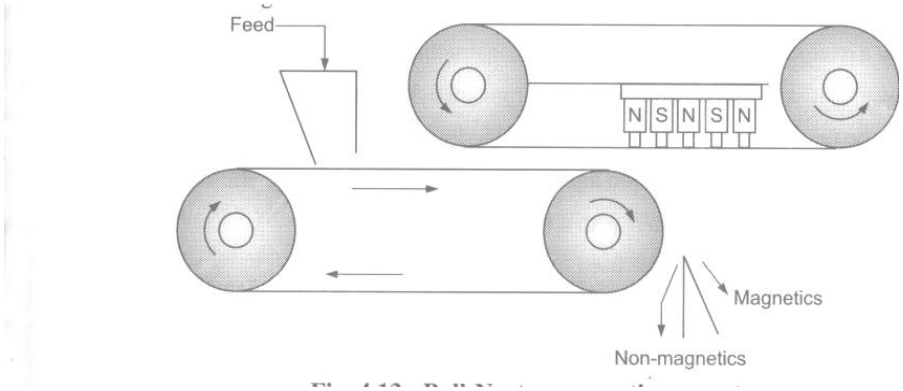
Slurry fed to rotating basket is forced against basket sides by centrifugal force. The liquid passes through the filter medium into the casing and out through a discharge pipe, while the solids form a filter cake on the filter medium. Cake is washed by spraying wash liquid to remove soluble material. Wash liquid leaves the centrifuge through discharge pipe. After washing, cake is spun at higher speed to remove water. The motor is turned off and at low basket speed; the cake is removed with the help of an unloader knife. — 4

3-f **Rotary drum vacuum filter:**

Construction:

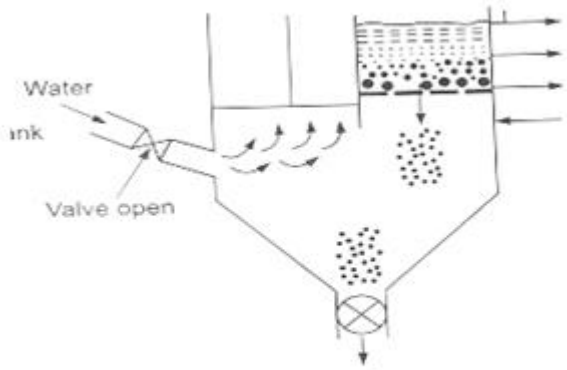
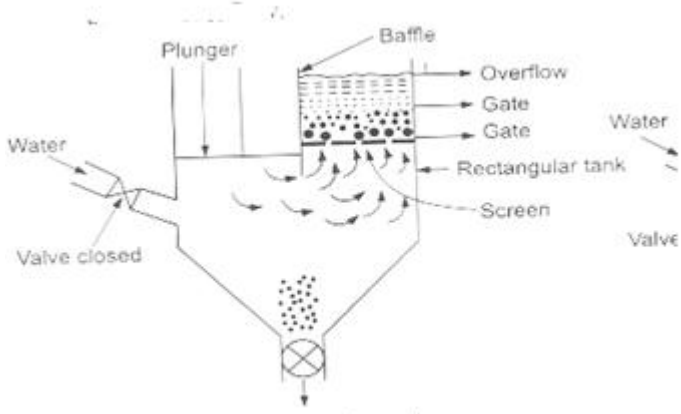
It consists of a cylindrical sheet metal drum mounted horizontally. Outer surface of drum is made up of a perforated plate. Filter medium (canvas cloth) covers the drum which turns at 0.1 to 2 rpm in an agitated slurry trough. Inside the outer drum is a smaller drum with a solid surface. Annular space between two drums is divided into compartments by radial partitions. As the drum rotates, vacuum & air are alternately applied to each compartment. — 2

	 **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 blown for removal of cake.	2
4	**Attempt any FOUR of the following**	**16**
4-a	**Grizzly screen** **Diagram**  **Construction** A grizzly is a grid of parallel metal bars set in an inclined stationary frame, with a	2

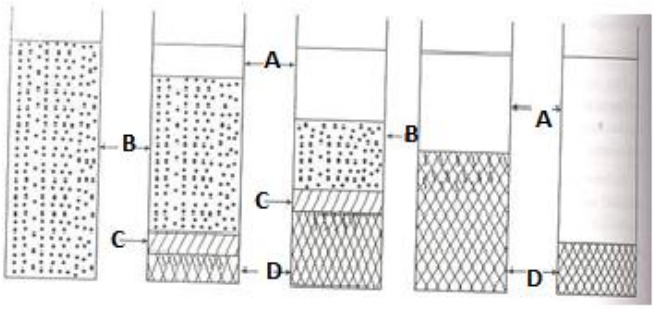
	slope of 30 to45^0. The slope & path of the material is parallel to the length of the bars. The length of bar is up to 3 m & spacing between the bars is 50 to 200mm. The material of construction of the bars is manganese steel to reduce wear. Usually the bar is shaped in such a way that its top is wider than the bottom, & hence the bars can be made fairly deep for strength without being choked by material passing through them.	2
4-b	**Working of Ball –Norton Machine**: It is used for separating magnetic ores from the associated mineral matter. 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.  	4
4-c	**Effect of the following factors on the rate of filtration:** 1) **Viscosity of filtrate**: Rate of filtration is inversely proportional to viscosity of filtrate. 2) **Area of filter**: Rate of filtration is directly proportional to area of filter surface.	1 mark each

	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.	
4-d	**Meaning of 1-2-3-2-1-2-3…… in filtration equipment** For quick identification & proper assembling, it is common practice to cast buttons on sides of plates & frames. No. of buttons on non-washing plate : 1 No. of buttons on frame : 2 No. of buttons on washing plate : 3 The press is assembled in the following order- non-washing plate, frame & then washing plate .ie 1-2-3-2-1-2-2-3-2-1.	4
4-e	**Concept of Terminal Settling Velocity**: For settling particles that are considered individually there are two main forces acting upon any particle. The primary force is an applied force, such as gravity, and a drag force (resisting force) that is due to the motion of the particle through the fluid. The applied force is usually not affected by the particle's velocity, whereas the drag force is a function of the particle velocity. For a particle at rest no drag force will be exhibited, which causes the particle to accelerate due to the applied force. When the particle accelerates, the drag force acts in the direction opposite to the particle's motion, retarding further acceleration. In the absence of other forces drag directly opposes the applied force. As the particle increases in velocity eventually the drag force and the applied force will equal approximately, causing no further change in the particle's velocity. In sedimentation, 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 settle t a definite constant velocity during remainder of the fall. This velocity is termed as terminal settling	4

	velocity.	
4-f	**Free Settling**: It is the settling wherein the fall of the particle in a gravitational field through a stationary fluid is not affected by walls of the container & other particles. (the particles are at sufficient distance from wall & other particles). **Hindered Settling** : If the fall of individual particle through stationary fluid is affected by other particles & wall of container, the process is called as hindered settling.	2 2
5	**Attempt any TWO of the following**	**16**
5-a	**Data:** Diameter of ball mill = 800 mm = 0.8 m Diameter of ball = 60 mm = 0.06 m Cririical speed of ball mill (Nc) $Nc = \frac{1}{2\pi}\sqrt{\frac{g}{R-r}}$ g = 9.81 m/s² R = 0.8/2 = 0.40 m r = 0.06/2 = 0.03 m $Nc = \frac{1}{2\pi}\sqrt{\frac{9.81}{0.40 - 0.03}}$ Nc = 0.82 r.p.s. (a) Operating speed is 55 % less than the critical speed. 55% of the critical speed = 0.55 X 0.82 = 0.45 r.p.s. **Operating speed = 0.82 – 0.45 = 0.37 r.p.s.** (b) Critical speed is 40 % more than the operating speed. Critical speed = 1.40 X (Operating Speed) **Operating speed = 0.82 /1.40 = 0.586 r.p.s.**	2 2 2 2

5-b	**Jigging:** Jigging is the process of separating solid materials of different specific gravity by the pulsation of a stream of liquid flowing through a bed of materials **Diagram:**  (b) Upward stroke  (a) Downward stroke **Construction :** Jig is a tank of rectangular cross section with tapered bottom. The tank is divided into two portions by a vertical baffle. In one compartment, the plunger is placed. It operates in a vertical direction giving pulsating motion to the liquid. In the other compartment, the screen is placed. The separation is carried out over the screen. It is	1 2

	provided with bottom discharge connection, gates at the sides and an overflow. **Working** The material to be separated is fed over the screen in dry form or in suspension. It is then subjected to pulsating action by liquid which is set in oscillation by means of plunger that reciprocates in a vertical direction. During the downward stroke of the plunger, the particles of the screen are brought into suspension. During this stroke, the water passes upward and the bed opens up. During the upward stroke, the input of water to the jig is adjusted in such a way that there is no flow through the bed of solids. During this stroke, the differential settling takes place. The denser material collects near the screen surface, above which is a layer of large particle of light material together with small particle of heavy material and the top layer is small particles of light material. The material constituting each of first two layers retained on the screen is removed through gates provided at the sides of the jig. The layer consisting of small particles of light material is carried away by the liquid and withdrawn from the overflow gate at the top. The small particles of heavy material which passes through the screen are removed from the bottom of the tank. **Industrial Application(any one)** 1) It is used to treat iron ores. 2)It is used treat lead –zinc ores & some non-metalic ores like barite and diamonds 3) It is used for coal concentration.	2 2 1
5-c	**Batch sedimentation:**	



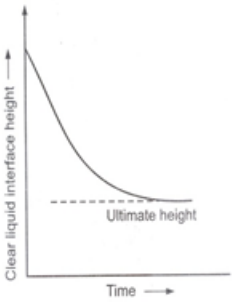
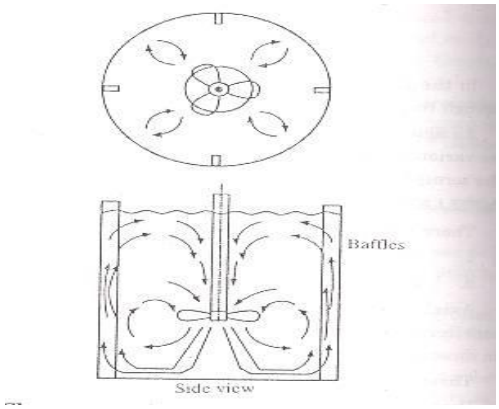
A- clear liquid
B- Original slurry
C- transition zone
D- settled solids

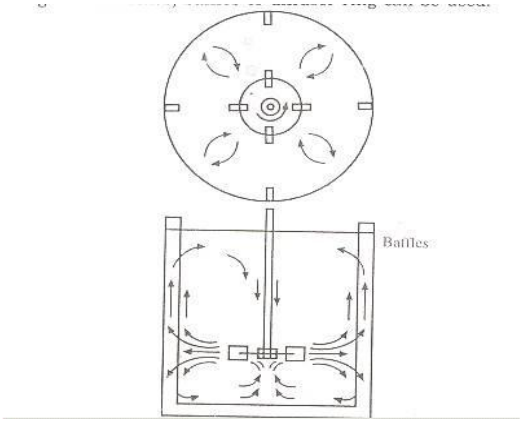
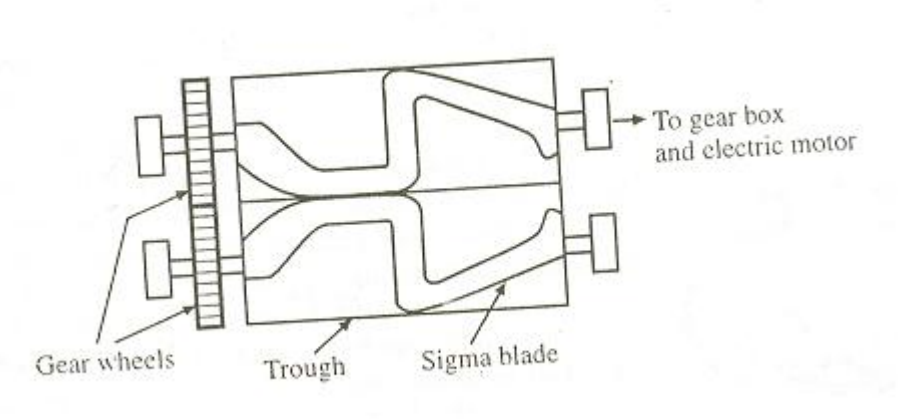
2

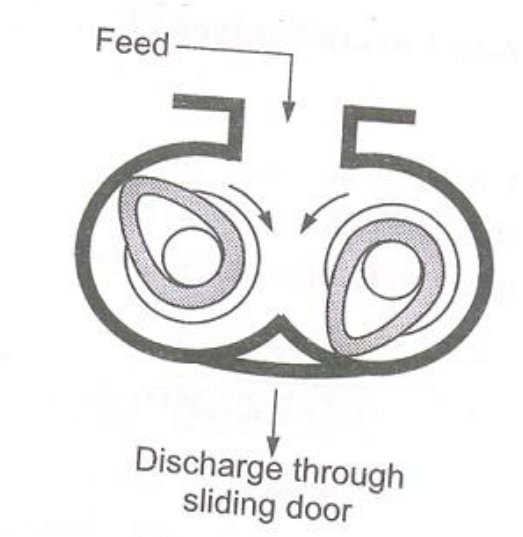
Prepare slurry of uniform concentration. The particles begin to settle and attain terminal settling velocity under hindered settling conditions. The heavier faster settling particles settled at the bottom are indicated by zone D. Above zone D forms another layer called zone C, which is a transition layer, 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

		1
6	**Attempt any FOUR of the following**	**16**
6-a	**Filter aid:** A filter aid is a granular or fibrous material which packs to form a bed of very high voidage. They are capable of increasing the porosity of the filter cake thus overcoming the problem of slow rate of filtration. **Methods of using Filter Aid:** 1) Adding a filter aid to the slurry before filtration 2) Precoating i.e. by depositing a layer of filter aid on the filter medium before filtration	2 2
6-b	**Sketch of flow patterns generated in Agitated vessel:** **1) Axial Flow impellers:**  3) **Radial Flow pattern:**	2

		2
6-c	**Prevention of 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.	1 mark each
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	**Mixer used for dispersion of rubber in liquid** Banbury mixer **Construction:**  It has two blades, each rotating in a cylinder. These cylinders partly intersect with each other. The blades are peer shaped, but the projection is spiral along the axis and	1 3

	the two spirals interlock. The clearance between the blades and the walls is extremely small. Cooling water is circulated through the hollow agitator shafts during operation to remove the heat generated.	
6-f	**Industrial application of Banbury Mixer** Used for 1) Compounding rubber 2) Mixing plastic solids 3) Devulcanize rubber scrap 4) Dispersion of rubber in liquid solutions 5) It is also used for reinforcing fillers in a resin system. 6) Mixing of asphalt	1 mark each for any 4