Candidates are required to attempt any SIX (6) questions from the eight questions given

Each question carries equal marks. (16 marks each)

**Time Allowed:** 3 Hours plus 10 minutes reading time.

**Permitted Material:** Calculators and drawing instruments are permitted.

**This is a open book examination.**

Rough work can be done on the three blank pages at the end of each answer book.

**This question paper must not be removed from the Examination centre**
**Question 1: Screw Conveyor - refer Fig. 1**

(a) A rotary screw conveyor is to be designed to elevate dry sand from the truck un-loader pit as illustrated in Fig 1, at a rate of 20 tonnes per hour, into the chute of the bucket elevator. The conveyor is a 6 m long inclined screw conveyor which elevates the material 2 m. It has a standard pitch screw and is to be selected from one of the standard diameters given in the tables.

(part (a), 10 marks)

Determine:

(i) The required screw diameter (mm),
(ii) The required screw speed (rpm),
(iii) The power required at the drive shaft (kW),
(iv) What special problems (list at least three) should be anticipated with this system? How should the special problems be combated?

(b) The bucket elevator of Fig. 2 is to elevate 20 tonnes per hour of anhydrous potassium carbonate a height of 15 m to the bulk storage bin. The bucket elevator is fed by an under floor screw conveyor shown (fully enclosed). Estimate the motor power required to drive the system.

(part (b), 6 marks)
Question 2:  Pneumatic Handling

Cement is to be conveyed pneumatically in a positive-pressure dilute-phase system according to the following specification.

- Particle/bulk properties: Refer to tables and make approximations where necessary
- Conveying rate, \( \dot{m}_S \): refer Fig. 1
- Total length of conveying pipeline, \( L = 50 \text{ m} \).
- Internal diameter of conveying pipeline, \( D = 102 \text{ mm} \).
- Total pipeline air pressure drop, \( \Delta p_t = 50 \text{ kPa} \).
- Type of feeder: drop-through rotary valve (maximum rotor speed = 40 rpm).
- Air pressure inside feed bin on top of rotary valve feeder = 0 kPa g.
- Air pressure inside receiving bin at end of pipeline, \( p_{fe} = 5 \text{ kPa g} \).
- Mass flow rate of air flowing through pipeline \( \dot{m}_f = 0.30 \text{ kg s}^{-1} \).
- Conveying air temperature, \( t = 50 ^\circ \text{C} \).
- Atmospheric air pressure, \( P_{atm} = 101 \text{ kPa abs} \).
- Atmospheric air temperature, \( t_{atm} = 20 ^\circ \text{C} \).
- Gas constant for air, \( R = 287.1 \text{ N m kg}^{-1} \text{ K}^{-1} \).

(a) By using the continuity equation and the ideal gas law, determine the superficial air velocity at the feed point (\( V_{fi} \)) and at the end of the pipeline (\( V_{fe} \)).

(b) For a maximum rotor speed of 40 rpm and using Eq (6) of the Lecture Notes “Design Requirements for Rotary Valves”, determine the minimum swept volume (\( \psi \)) of rotary valve for this application (ie to ensure that a conveying rate of at least 12 t h\(^{-1} \) is achieved).

(c) Based on available sizes of rotary valve with 8 rotor pockets (viz \( \psi = 6, 13, 22 \) and 36 litres/rev), select the smallest rotary valve size for this application. Also, for this valve, determine a suitable rotor speed to achieve the desired conveying rate. Hint: determine the required value of “\( \alpha N \)” and then by considering various values of \( N \), use iteration with minimum values of filling factor \( \alpha \).

<table>
<thead>
<tr>
<th>Model</th>
<th>Swept Vol, ( \psi ) (litres/rev)</th>
<th>Rotor dia (mm)</th>
<th>Rotor length (mm)</th>
<th>Clearance (mm)</th>
<th>Drive power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.0</td>
<td>203</td>
<td>190</td>
<td>0.10</td>
<td>0.37</td>
</tr>
<tr>
<td>B</td>
<td>13.0</td>
<td>255</td>
<td>304</td>
<td>0.12</td>
<td>0.37</td>
</tr>
<tr>
<td>C</td>
<td>22.0</td>
<td>300</td>
<td>380</td>
<td>0.14</td>
<td>0.75</td>
</tr>
<tr>
<td>D</td>
<td>36.0</td>
<td>343</td>
<td>462</td>
<td>0.16</td>
<td>0.75</td>
</tr>
</tbody>
</table>

(16 marks)
Question 3: Sampling and Weighing

(a) (i) Describe how the horizontal force component is eliminated in a belt weigh feeder. Illustrate two methods. (2 marks)
(ii) With the aid of sketches (or reference to sketches) discuss the potential sources of error in measuring with weigh-feeders. (2 marks)
(iii) How may the weight of the weigh frame, belt and weigh idlers be compensated? (2 mark)
(iv) Discuss the problems of material segregation in two practical situations. (2 mark)

(b) A variable gate weigh feeder (Figure 1) is being commissioned to control feed rate of cement clinker to a process. Records are as indicated below.

![Figure 3: Variable gate weigh feeder](image)

<table>
<thead>
<tr>
<th>Indicated load (net) (kg)</th>
<th>136</th>
<th>140</th>
<th>142</th>
<th>137</th>
<th>122</th>
<th>155</th>
<th>144</th>
<th>129</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belt speed (m/s)</td>
<td>2.0</td>
<td>2.1</td>
<td>1.95</td>
<td>2.15</td>
<td>1.85</td>
<td>1.8</td>
<td>2.0</td>
<td>1.85</td>
</tr>
</tbody>
</table>

The idler spacing even over the weighing region and the effective belt width is 900 mm. If the feed rate is intended to be 450 tonnes per hour, determine the following actual parameters:

(2 marks ea)

(i) The average height of material on the belt (mm) during the period recorded.
(ii) Average volume feed rate. (m³/s).
(iii) Mass feed rate. (kg/s and tonne / hr).
(iv) Is the feed rate satisfactory? If not, what could be done to correct to situation? Discuss the options.
Question 4: Belt Conveyor (approximately 3 marks each part)

Using the Dunlop procedure to carry coal at 1000 tonnes/hour:
Select a belt width based on a reasonable belt velocity, trough angle of 30° and
surcharge angle of 20° based on the material which is coal of size < 3 mm and bulk
density 0.96 tonne/m³.

Other data:

- Length of belt = 650 m
- Height of lift = 150 m.
- Speed of belt = ? m/min.
- Head pulley diameter = 915 mm lagged.
- Angle of wrap at head (drive) pulley = 310°.

(a) Determine the total power requirement at the head shaft.

(b) Select a suitable motor power for the job and calculate the belt tensions assuming
full motor power is being used at the head shaft.

(c) Select a suitable friction coefficient between head pulley and belt.

(d) Initial tension is acquired by the use of a counterweight. Determine a weight
necessary to provide the tension for the tensioning arrangement below. Describe
the factors influencing belt stretch and hence H in Fig 4

(e) List any special problems that the material may present and suggest suitable
corrective measures.

Figure 4
Question 5: Pumping of Slurries

A centrifugal sand pump is required for the following duty:

100 tonnes per hour of a material having a particle distribution approximated by the graph (Figure 5) below.

- Specific gravity of solids, \( S \) = 2.65
- Concentration of solids, \( C_w \) = 40% by weight
- Static discharge head, \( Z_d \) = 50 metres
- Suction head, \( Z_s \) = 2.5 metres (+)
- Length of pipeline = 180 metres
- Valve and fittings = 5 X 90° LR bends, 2 X diaphragm valves

Refer to relevant Warman notes for procedure.

Determine the following:

(a) Specific gravity of slurry mixture, \( S_m \)
(b) Concentration of solids by volume, \( C_v \)
(c) Volumetric flow of slurry.
(d) Pipeline size.
(e) Total dynamic head on the pump.

![Particle size distribution for sand.](image)

Figure 5
**Question 6: Bins and Hoppers, Fundamentals**  
(4 marks each)

(a) Derive the Janssen equation to estimate the side pressure at a distance of \( x \) m below the surface of the bulk material in a square bin of sides \( s \) mm assuming a specific weight of \( w \) N/m\(^3\).

(b) Discuss the importance of material internal friction and wall friction. Relate these parameters to the efficiency of equipment such as screw conveyors and belt conveyors.

(c) Outline a laboratory exercise to determine the effect of wall friction.

(d) How does bulk material consolidation effect flow characteristics? Fully discuss.

**Question 7: Bins and Feeders**  
(approximately 2.5 marks ea, total 16 marks)

IN YOUR ANSWERS USE DIAGRAMS OR REFER TO DIAGRAMS IN NOTES

(a) Explain the importance of “mass flow” when feeding from a bin on to a belt feeder. Discuss three factors influencing mass flow.

(b) What are the problems caused by rat holes and arching in bins? Discuss in terms of material properties and bin geometry.

(c) Describe in terms of material properties and bin geometry how a wedge shaped hopper is useful?

(d) A screw feeder is used to supply 5 tonnes of sugar per hour from a bin to a food process plant. Select a suitable screw diameter(s) and its operating speed.

(e) For the screw feeder above, determine a suitable electric motor power rating assuming a suitable gear reducer of and a feeder length of 1.8 M.

(f) Suggest suitable feeders for the following materials:

   (i) Cashew nuts.

   (ii) Wet sewage.

   (v) Tree bark, < 30 mm.
(a) Four forklift trucks are used to deliver pallet loads of parts between work cells in a factory. Calculate the maximum hourly delivery rate based on the data below.

Data:
- Average travel distances (loaded and empty) = 100 m
- Speed = 5 km/hr (loaded) and 7 km/hr (empty)
- Terminal time per average delivery = 1.0 min (0.5 min each of load and unload)
- Traffic factor = 0.9
- Availability = 1.0
- Work efficiency = 0.95

(10 marks)

(b) Discuss the major trend in industrial materials handling. Refer to practical examples.

(6 marks)