CANDIDATES ARE REQUIRED TO ATTEMPT ANY SIX (6) QUESTIONS FROM THE EIGHT QUESTIONS GIVEN.

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

A rotary screw conveyor is to be designed to discharge rouge powder from a bin, at a constant rate of 15 tonnes per hour, into a packaging system. The conveyor is a 30 m long inclined screw conveyor which elevates the material 15 m. It has a standard pitch screw and is to be selected from one of the standard diameters given in the tables.

Determine:

(i) The required screw diameter (mm),

(ii) The required screw speed (rpm),

(iii) The power required at the drive shaft (kW),

(iv) The maximum length this conveyor could be without exceeding the torsional ratings of standard pipe, shaft and coupling bolts listed in Table 2.4 – Torsional Ratings of Screw Conveyor.

(v) What special problems (list at least three) should be anticipated with this system?

(vi) How should the special problems of (v) be combated?
**Question 2: Pneumatic Handling**

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

- Particle/bulk properties of rape seed: median size, \( d_{50} = 0.8 \text{ mm} \), particle density, \( \rho_s = 1400 \text{ kg m}^{-3} \) and loose-poured bulk density, \( \rho_{bl} = 600 \text{ kg m}^{-3} \).
- Conveying rate, \( m_s = 18 \text{ t h}^{-1} \).
- Total length of conveying pipeline, \( L = 100 \text{ m} \).
- Internal diameter of conveying pipeline, \( D = 102 \text{ mm} \).
- Total pipeline air pressure drop, \( \Delta p_t = 60 \text{ kPa} \).
- Type of feeder: drop-through rotary valve (maximum rotor speed = 35 rpm).
- Air pressure inside feed bin on top of rotary valve feeder = 0 kPa g.
- Air pressure inside receiving bin at end of pipeline, \( p_{fe} = 0 \text{ kPa g} \).
- Conveying air temperature, \( t = 20 ^\circ \text{C} \).
- 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 (\( V_{f1} \)) and at the end of the pipeline (\( V_{fE} \)).

(b) For a maximum rotor speed of 35 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 18 t h\(^{-1} \) is achieved).

(c) From table 1 below, and based on item (b) above, select the smallest rotary valve model for this application. For this rotary valve and using Equ 7 of the lecture notes, "Design Requirements for Rotary Valves", (vis the method of Reed), determine the possible range of air leakage \( Q_1 \) based on static pressure data.

<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>
Question 3: Sampling and Weighing

(a) (i) Describe how a typical belt weigh-feeder operates, where it is used, what functions are typically available as an output from it?

(ii) With the aid of sketches (or reference to sketches) discuss the various control systems available for weigh-feeders.

(b) Referring to notes,
A weigh feeder having *four* (4) idlers in its weigh frame, indicates the following table of loads (after all corrections). The table is from a sequence of transducer readings taken at small time intervals:

<table>
<thead>
<tr>
<th>Indicated load (kg)</th>
<th>780</th>
<th>800</th>
<th>810</th>
<th>830</th>
<th>820</th>
<th>790</th>
<th>770</th>
<th>760</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belt speed (m/s)</td>
<td>1.1</td>
<td>1.0</td>
<td>0.95</td>
<td>0.95</td>
<td>0.95</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
</tr>
</tbody>
</table>

The idler spacing is 320 mm and the effective belt width is 900 mm. If the material is fly ash and the feed rate is intended to be 250 tonne per hour, determine the following actual instantaneous parameters:

(i) Instantaneous and average heights of material on the belt. (mm)

(ii) Volume feed rate. (m$^3$/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

An inclined troughed belt conveyor is to transport \textit{minus 75 mm crushed bauxite} at the rate of 800 tonne per hour through a distance of 1900 metres.

Choose a suitable belt width, trough angle and surcharge angle based on the material.

Other data:

- Height of lift = 150 m.
- Speed of belt = 200 m/min.
- Head pulley diameter = 915 mm lagged.
- Angle of wrap at head (drive) pulley = 250°.

(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) Check the frictional requirements between head pulley and belt.

(d) Initial tension is acquired by the use of a counterweight. Determine a weight necessary to provide the tension and sketch a possible tensioning arrangement.

(e) List any special problems that the material may present and suggest suitable corrective measures.
Question 5: Pumping of Slurries

A centrifugal pump for pumping sand/clay/gravel (containing 1% tin bearing minerals) is required for the following duty:

95 tonnes per hour of a material having a particle distribution approximated by the graph below.

- Specific gravity of solids, $S = 2.8$
- Concentration of solids, $C_w = 40\%$ by weight
- Static discharge head, $Z_d = 48$ metres
- Suction head, $Z_s = 2.5$ metres (+)
- Length of pipeline = 1100 metres
- Valve and fittings = 8 X $90^\circ$ LR bends, 4 X diaphragm valves

Material is both corrosive to steel and abrasive.

See Warman Fig 3.3 for arrangement.

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.
(f) Select a suitable Warman Pump.
(g) Comment on any special problems you envisage with this system.

![Particle size distribution for material.](image)
**Question 6: Bins and Hoppers, Fundamentals**

(a) Use the Janssen equation to estimate the side pressure at a distance of 3.3 m below the surface of the wheat in a square wheat bin of sides 450 mm assuming a specific weight of 8000 N/m³. Assume K = 0.2 Show all calculations and references.

(b) Determine the total weight on the floor of the bin if the total depth of wheat is 5 metres.

(c) What are the limitations of the Janssen Equation?

(d) Outline the main improvements from Janssen's work provided by later researchers.

**Question 7: Bins and Feeders**

(a) Differentiate between mass flow and funnel flow in bins and hoppers. Please illustrate with diagrams.

(b) Explain the mechanism of arching.

(c) Explain the cause of rat-holes in bulk materials handling systems. What problems do they give?

(d) Outline the various methods used to overcome the problems of rat-holes

(e) Why are feeders necessary in bulk materials handling systems?

(f) Suggest suitable feeders for the following materials:

   (i) Cashew nuts

   (ii) Coal char

   (iii) Cocoa powder
Question 8: Discrete Handling of Materials. See Q 10.11 (notes)

A rail guided vehicle system is being planned as part of an assembly cell. The system consists of two parallel lines, as in the figure below. In operation, a base part is loaded at station 1 and delivered to either station 2 or 4, where components are added to the base part. The RGV then goes to either station 3 or 5 respectively, where further assembly of components is accomplished. From station 3 or 5 the product moves to station 6 for removal from the system.

Vehicles remain with the products as they move through the station sequence; thus, there is no loading or unloading of parts at stations 2, 3, 4 and 5. After unloading parts at station 6, the vehicles then travel empty back to station 1 for reloading.

The hourly moves (parts/hour) and distances (ft) are listed in the table below. RGV speed = 100 ft/min.

Assembly cycle times at stations 2 and 3 = 4.0 min each and at stations 4 and 5 = 6.0 min each.

Load and unload times at stations 1 and 6, respectively are each 0.75 min.

Traffic factor = 1.0.

How many vehicles are required to operate the system? Assume A = 1.0.

<table>
<thead>
<tr>
<th>FROM \ TO</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0/0</td>
<td>14L/200</td>
<td>0/NA</td>
<td>9L/150</td>
<td>0/NA</td>
<td>0/NA</td>
</tr>
<tr>
<td>2</td>
<td>0/NA</td>
<td>0/0</td>
<td>14L/50</td>
<td>0/NA</td>
<td>0/NA</td>
<td>0/NA</td>
</tr>
<tr>
<td>3</td>
<td>0/NA</td>
<td>0/NA</td>
<td>0/0</td>
<td>0/NA</td>
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<td>14L/50</td>
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<tr>
<td>4</td>
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<td>0/NA</td>
<td>0/NA</td>
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<td>0/0</td>
<td>9L/100</td>
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<tr>
<td>6</td>
<td>23E/400</td>
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<td>0/NA</td>
<td>0/NA</td>
<td>0/NA</td>
<td>0/0</td>
</tr>
</tbody>
</table>

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