Q.1. Attempt any four.

A) DOF: Minimum number of Co-ordinates required to define motion of system or no of input required for constrained motion.

Kutzbach criteria: \( F = 3(N-1) - 2P_i \)

- For single slider, \( N = 4, P_i = 4 \)
  \[ F = 1 \]

B) Given \( \frac{PA}{PB} = \frac{9.8}{OA} \)

C) \( H \) is a Centre of rotation of body at an instant.

No of instantaneous centres \( N = \frac{N(n+1)}{2} \) where \( n \) = no of links.

D) Law of Gearing

Component of velocity & relative velocity along common normal

\[ V_{c\omega d} - V_d \cos \beta = 0 \]
\[ w_1 \cos x - w_2 \cos \theta = 0 \]
\[ w_1 \cos x - w_2 \cos \theta = 0 \]
\[ w_1 \frac{AE}{AE} - w_2 \frac{BF}{BD} = 0 \]
\[ w_1 \frac{AE}{AE} - w_2 \frac{BF}{BD} = 0 \]
\[ \frac{w_1}{w_2} = \frac{BF}{AE} = \frac{BP}{AP} \]
8.1 E) When centrifugal tension considered
\[ T - T_c = T_1 - \frac{a_0}{T_x} = \frac{T_1}{T_x} = k \times T_2 = \frac{T_1}{k} \]
\[ P = (T_1 - T_2) V = (T_1 - \frac{T_2}{k}) V = T_1 (1 - \frac{1}{k}) V \]
when \( T_2 \) rejected
French Tension on right side = \( T \)
\[ P = (T_1 - T_2) V = (T - \frac{T_2}{k}) V = T (1 - \frac{1}{k}) V \]
As \( T_1 < T \), power transmitted is less when centrifugal tension considered.

Q 2(a)
\[ R = \frac{mT}{2} = 250 \text{ mm} \]
\[ R_a = 250 + 10 = 260 \text{ mm} \]
\[ r = \frac{mT}{2} = 65 \text{ mm} \]

i) \[ R_{\text{max}} = \sqrt{(R \cos \varphi)^2 + (R \sin \varphi + r \sin \varphi)^2} = 258.45 \text{ mm} \]

The actual addendum \( R_a \) is more than \( R_{\text{max}} \), therefore interference occurs.

ii) \[ R_{\text{max}} = R \sqrt{1 + \frac{4}{3} \left( \frac{k+1}{k} \right) \sin^2 \varphi} = 258.45 \text{ mm} \]

The new value of \( \varphi \) can be found by taking \( R_{\text{max}} \) equal to \( R_a \)
\[ 260 = \sqrt{250 \cos^2 \varphi + (215 \sin \varphi)^2} \]
\[ \cos \theta = 0.928 \quad \text{and} \quad \varphi = 21.88^\circ \]

Thus if \( \varphi \) increases to \( 21.88^\circ \), the interference can be avoided.

Q 2(b) Law of Belting: The centre line of belt when it approaches a pulley must lie in the mid plane of that pulley. However, the belt leaving the pulley may be drawn out of plane of pulley.
A brake where no force is required to apply brake or just contact is enough to apply brake is a self-locking brake.

The moment of applied force and in moment of frictional force is a self-energizing brake.

\[ \frac{T_1}{T_2} = e^{\frac{\pi}{2}} \quad \text{and} \quad T_1 - T_2 = 1215 \text{ -- untwist power} \quad (3) \]

\[ \text{Contact angle} \quad \alpha = \pi - 2\beta = \pi - 2 \sin^{-1} \left( \frac{R_2 - R_1}{c} \right) \quad (2) \]

\[ \alpha = 2.79 \]

Using \( \frac{T_1}{T_2} = 0.35 \times 2.79 \)

\[ T_1 = 2418 \text{ N} \quad \text{and} \quad T_2 = 1203 \text{ N.} \quad (2) \]

\[ T_c = \frac{m}{L} \times v^2 = \text{mass/unit length} \times \text{velocity/unit length} \times \text{density} \times v^2 \\ = 6 \times 0.012 \times 1 \times 1000 \times (8.2^2) = 812.86 \text{ N} \]

\[ T = T_1 + T_c = 6 \times (b \times t) \\ 2.9167 \times t = 2418 \\ \therefore b = 82.8 \text{ mm} \quad (3) \]

**Dispacement diagram**

- Graphs showing displacement, velocity, and acceleration.
Q 4 (a) Any method—i) Tabular or ii) Relative velocity method.

i) Tabular method:

<table>
<thead>
<tr>
<th>Action</th>
<th>a</th>
<th>s</th>
<th>p</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>a fixed, s + 1 rev</td>
<td>0</td>
<td>1</td>
<td>(- \frac{80}{TP} )</td>
<td>(- \frac{80}{TP} )</td>
</tr>
<tr>
<td>a fixed, s + 2 rev</td>
<td>0</td>
<td>x</td>
<td>(- \frac{80x}{TP} )</td>
<td>(- \frac{80x}{TP} )</td>
</tr>
<tr>
<td>All given, y rev</td>
<td>y</td>
<td>2y</td>
<td>y (- \frac{80x}{TP} )</td>
<td>y (- \frac{80x}{TP} )</td>
</tr>
</tbody>
</table>

Given:
\( N_a = y = 160 \) rpm — speed of arm
\( N_s = y + x = 0 \)
\( N_A = y - \frac{80x}{TA} = 300 \)
\( x = -y = -180 \)
Solving for \( N_A \):
\( TA = 120 \)
The pitch diameters of wheel are proportional to number of teeth on them
\( Ts + 2Tp = TA \)
\( 80 + 2xP = 120 \)
\( xP = 20 \)

ii) Relative velocity method:
The ratio of relative speed is related as:
\[ \frac{Na - Na}{Ns - Na} = - \frac{Ts}{TP} \times \frac{TP}{TA} = - \frac{80}{TA} \]
\( 200 - 180 = \frac{80}{TA} \)
\( TA = 120 \)
The pitch diam are related to number of teeth on
\( Ts + 2Tp = TA \)
\( xP = 120 \)

Q 4 (b)

Let \( a = \text{linear acc} \) & \( \alpha = \text{angular acc} \). Assuming rolling without slipping:
\( a = Ta = 0.1 \alpha \)
\( I = m k^2 = 80 \times 0.075^2 = 0.16875 \text{ kg} \cdot \text{m}^2 \)
Applying Newton's Second Law / D'Alembert's principle:
\[ 100 - F = 0.1 m \alpha = 0.1 \times 30 \times \alpha = 3 \alpha \]
\[ F = 100 - 3 \alpha \] (1)

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Q 4(b) Continued

EMa = 0

\[ F \times 0.1 - 100 \times 0.07 = I \cdot \alpha = 0.16875 \alpha \]
\[ \therefore F = 70 + 1.6875\alpha \quad \text{(II)} \quad \text{(6)} \]

Solving (I = II)

\[ \alpha = 6.4 \text{ rad/s}^2 \quad \text{(2)} \]
\[ F = 80.8 \text{ N} \quad \text{(-)} \]

Q 5(a) i) For configuration scale 1:200

Relative velocity method:

\[ \omega \theta = 20.94 \text{ rad/s} \]
\[ V \theta = \omega \theta \cdot A = 6.28 \text{ m/s} \]

ii) Instantaneous centre method

\[ V_{\text{I2-I6}} = (I_{12-I6}) \cdot \omega \theta \]
\[ = (0.4 \times 200) \times 20.94 \]
\[ = 16782 \text{ m/s} \]

(o1)

\[ \text{ed} = 1.5 \text{ cm} \]
\[ V_{\text{ed}} = \text{velocity of slider} \]
\[ = 1.5 \text{ m/s} \]

(o1)

Centre Polygon

(o4)
\[ \text{Condition for correct gearing.} \]

\[ \text{Scale for velocity - 1:1} \]

\[ \text{Scale 1:10} \]

\[ \text{For Acc}^2, \text{ the vector table as below.} \]

<table>
<thead>
<tr>
<th>S No.</th>
<th>Vectors</th>
<th>Magnitude</th>
<th>Direction</th>
<th>Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( f_{p0} \text{ or } q_{p} )</td>
<td>( \frac{4.4}{0.2} = 22.2 )</td>
<td>( 11 \text{ OP} )</td>
<td>( \rightarrow 0 )</td>
</tr>
<tr>
<td>2</td>
<td>( f_{q1} \text{ or } q_{1p} )</td>
<td>( 2.10 \cdot V_p = 25.5 )</td>
<td>( 1 \text{ AQ} )</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>( f_{q1} \text{ or } q_{p q_{1}} )</td>
<td>(-)</td>
<td>( 11 \text{ AQ} )</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>( f_{q1} \text{ or } q_{12} )</td>
<td>( \frac{2.45}{0.52} = 4.7 )</td>
<td>( 11 \text{ AQ} )</td>
<td>( \rightarrow A )</td>
</tr>
<tr>
<td>5</td>
<td>( f_{r} \text{ or } q_{2} )</td>
<td>(-)</td>
<td>( 1 \text{ AQ} )</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>( f_{r} \text{ or } q_{23} )</td>
<td>( \frac{2.3}{0.3} = 7.7 )</td>
<td>( 11 \text{ AQ} )</td>
<td>( \rightarrow R )</td>
</tr>
</tbody>
</table>

The acc. of Slider = \( 2.6 \times 10^{-3} = 86 \text{ m/s}^2 \)

Angular acc. of link \( R_1 = \frac{2.3 \times 10^{-3}}{0.3} = 76 \text{ rad/sec} \)
The radius from centre of sprocket differs when chain engages in tangent position and when engages in chord. This will lead to fluctuation in speed, which lead to vibration in the chain.

The chordal achonic based on number of teeth in sprockets:

\[
\text{Ratio of speed change} = \frac{V_{\text{max}} - V_{\text{mm}}}{V_{\text{max}}} = 1 - \cos \left( \frac{180}{N} \right) \tag{4}
\]