A

ENGINEERING TRIPOS Part IB 2001

Paper 1 – MECHANICS

Q1 (b) Relative sliding velocity at A = 190 mms^{-1}

Relative sliding velocity at B = 550 mms^{-1}

Angular velocity of link ABC = 2.0 $rads^{-1}$, clockwise

Angular velocity of link OB = 7.4 $rads^{-1}$, clockwise

(c) Relative sliding acceleration at B = 2700 mms^{-2}

Angular acceleration of link ABC = 11.75 $rads^{-2}$, clockwise

Angular acceleration of link OB = 28.0 $rads^{-2}$, clockwise

Q2 (b) $\mathbf{v}_B = \dot{\theta}(R + a\sin\phi)\,\mathbf{e}_\theta$

$\mathbf{a}_B = \ddot{\theta}(R + a\sin\phi)\,\mathbf{e}_\theta - \dot{\theta}^2(R + a\sin\phi)\,\mathbf{e}_r$

(c) $\omega_{DISC} = \dot{\phi}\,\mathbf{e}_\theta + \dot{\theta}\,\mathbf{k}$

$\dot{\omega}_{DISC} = -\dot{\phi}\dot{\theta}\,\mathbf{e}_r + \ddot{\phi}\,\mathbf{e}_\theta + \ddot{\theta}\,\mathbf{k}$

(d) $\mathbf{v}_B = \dot{\phi}a\cos\phi\,\mathbf{e}_r + \dot{\theta}(R + a\sin\phi)\,\mathbf{e}_\theta - \dot{\phi}a\sin\phi\,\mathbf{k}$

$$\begin{aligned}\mathbf{a}_B = & [-\dot{\theta}^2(R + a\sin\phi) + \ddot{\phi}a\cos\phi - \dot{\phi}^2 a\sin\phi\,]\mathbf{e}_r \\ & + [\ddot{\theta}(R + a\sin\phi) + 2\dot{\theta}\dot{\phi}a\cos\phi\,]\mathbf{e}_\theta \\ & - [\,\ddot{\phi}a\sin\phi + \dot{\phi}^2 a\cos\phi\,]\mathbf{k}\end{aligned}$$

Q3 (a) $\omega_{BC} = \dfrac{\omega}{2}$, anticlockwise

$\omega_{DC} = \omega$, anticlockwise

$v_E = \dfrac{l\omega}{2}\mathbf{i} + \dfrac{l\omega}{2}\mathbf{j}$

$a_E = -\dfrac{l\omega^2}{4}\mathbf{i} + \dfrac{3l\omega^2}{4}\mathbf{j}$

(b) $T = \dfrac{mgl}{2} + \dfrac{ml^2\omega^2}{4}$

(c) $T_i = \dfrac{mgl}{2} + \dfrac{5ml^2\omega^2}{12}$

(d) $T_{ai} = 2Q$

B

Q4 (b) $\beta = \frac{3g}{5l}$; tension, $T = \frac{\sqrt{2}}{5}mg$

(c) $S_B = \frac{-mg}{5}$; $S_c = M_B = M_c = 0$

(d) $F = \frac{mg}{10l}(x - \frac{3x^2}{2l} + \frac{l}{2})$; $M = \frac{mg}{20l}(-l^2 + lx + x^2 - \frac{x^3}{l})$

Q5 (b) ω_f= 171 rpm; Energy lost = 0.9J.

(c) No.

(d) ω_D = 343 rpm

Q6 (b) Relative to pulley A, B at 90° clockwise and C at 233° clockwise

(c) $F_Q = F_P$ = 76N

(d) Radius = 0.23m; relative to pulley A, mass at C added at 38° clockwise and mass at A added at 218° clockwise

ENGINEERING TRIPOS PART IB Paper 1 MECHANICS Question 1

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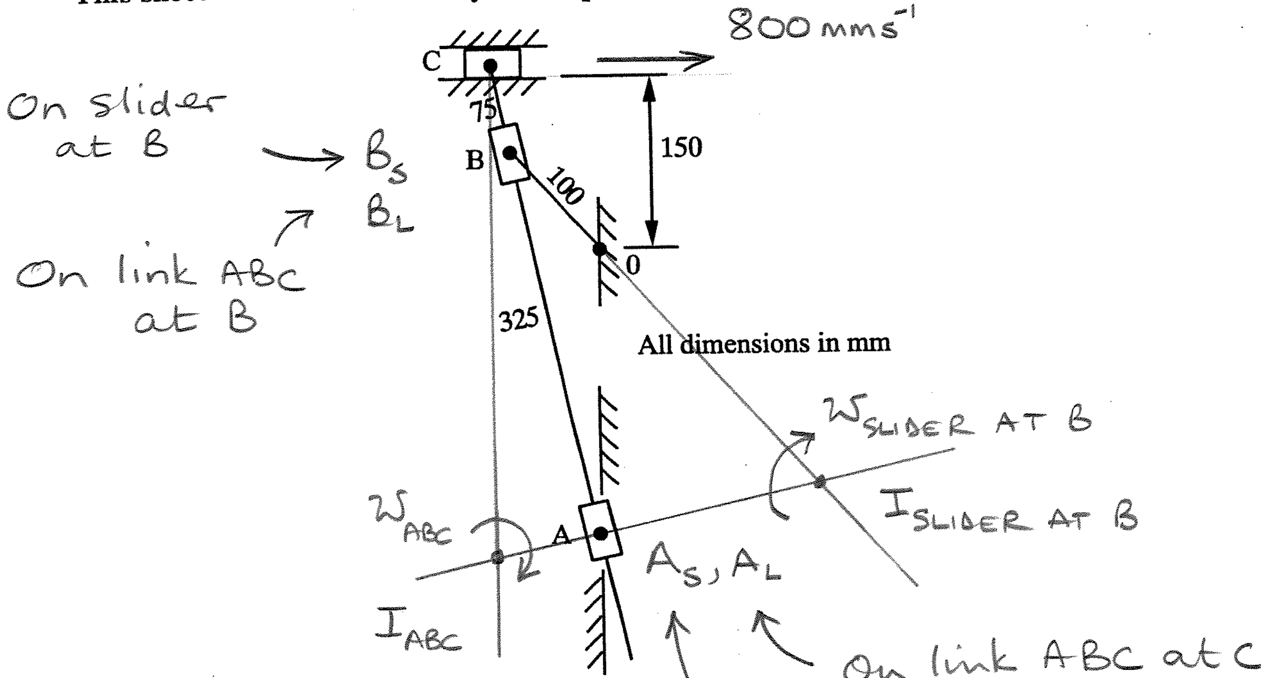
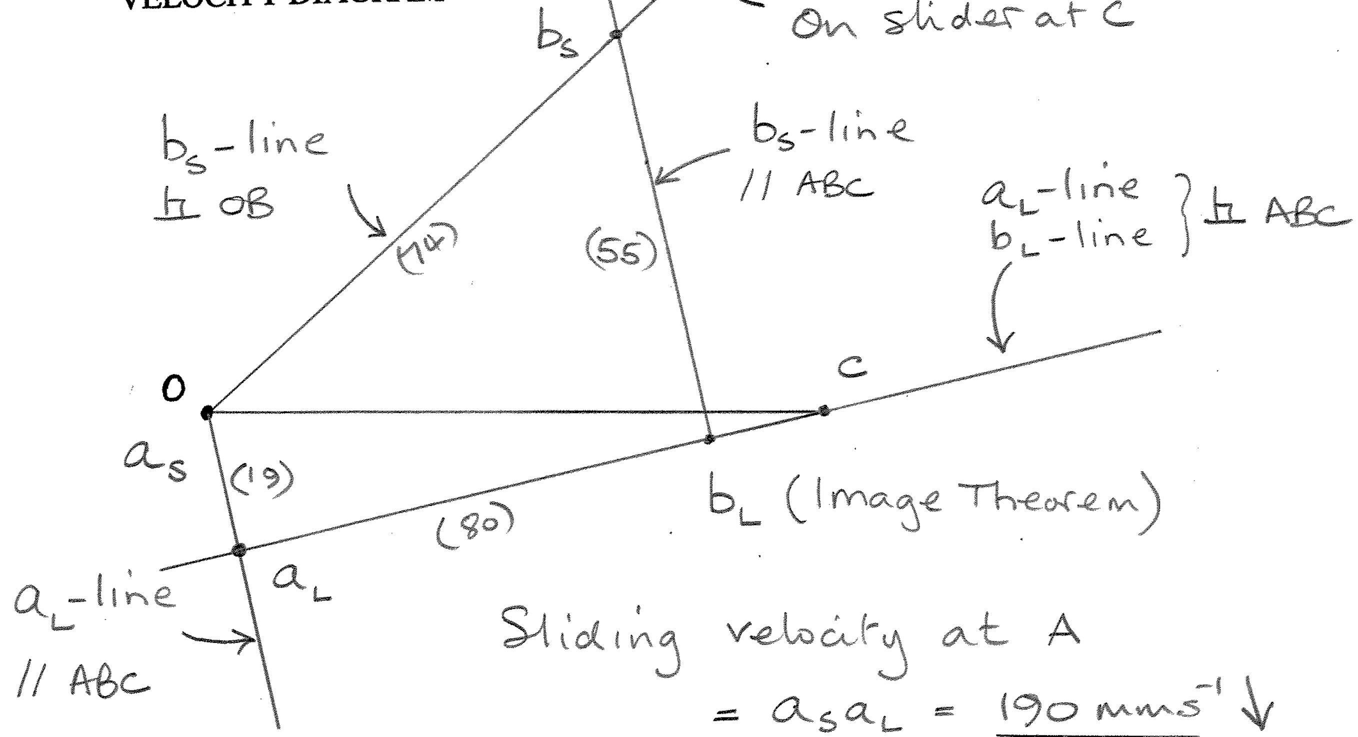


VELOCITY DIAGRAM



Sliding velocity at A $= a_s a_L =$ 190 mms^{-1} ↓

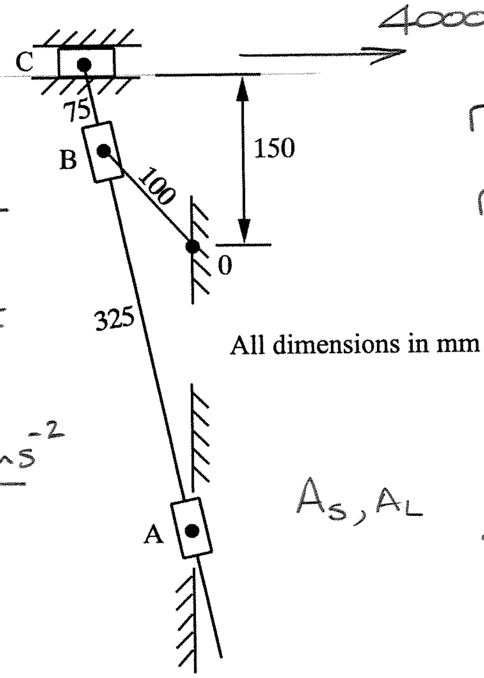
Sliding velocity at B $= b_s b_s =$ 550 mms^{-1} ↓

$$\omega_{ABC} = \frac{a_L c}{AC} = \frac{800}{400} = \underline{\underline{2 \cdot 0 \text{ rads}^{-1}}}$$

$$\omega_{OB} = \frac{Ob_s}{OB} = \frac{740}{100} = \underline{\underline{7 \cdot 4 \text{ rads}^{-1}}}$$

(TURN OVER

$4000\,\mathrm{mm\,s^{-2}}$



$r\dot{\theta}^2_{OB} = 100 \times 7.4^2 \doteqdot \underline{5500\,\mathrm{mm\,s^{-2}}}$

$r\dot{\theta}^2_{A_LC} = 400 \times 2^2 = \underline{1600\,\mathrm{mm\,s^{-2}}}$

Coriolis at B:
<u>Slider relative to link</u>

$2\dot{r}\dot{\theta} = 2 \times 550 \times 2$

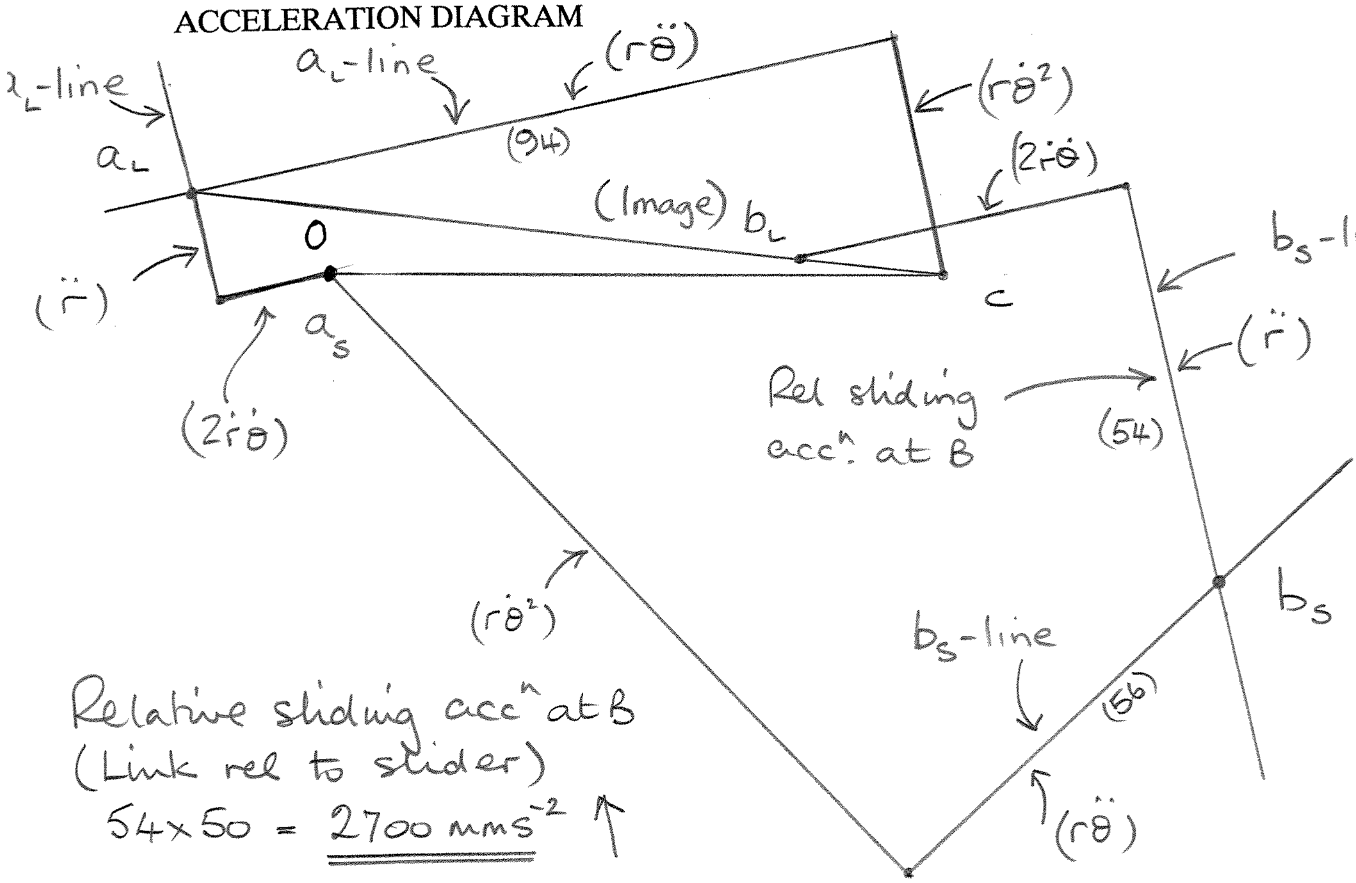
$= \underline{2200\,\mathrm{mm\,s^{-2}}}$

Coriolis at A:
<u>Link relative to slider</u>

A_S, A_L

$2\dot{r}\dot{\theta} = 2 \times 190 \times 2 = \underline{760\,\mathrm{mm\,s^{-2}}}$

ACCELERATION DIAGRAM



Relative sliding acc^n at B
(Link rel to slider)

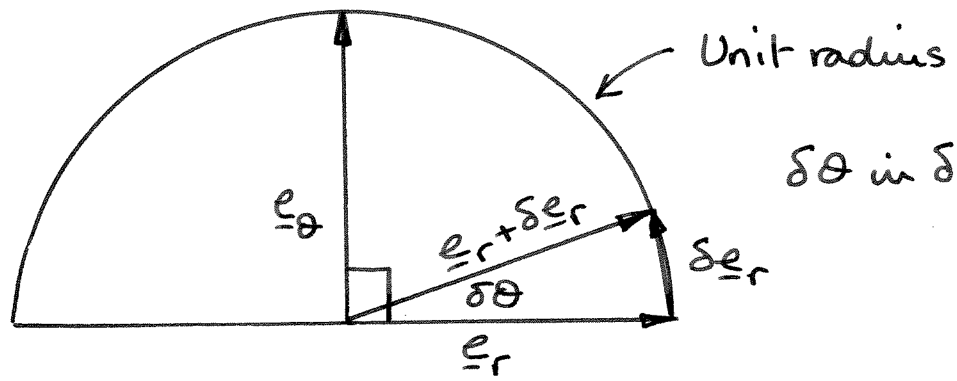
$54 \times 50 = \underline{\underline{2700\,\mathrm{mm\,s^{-2}}}}$

$$\dot{\omega}_{ABC} = \frac{94 \times 50}{400} = \underline{\underline{11.75\ \mathrm{rad\,s^{-2}}}}$$

$$\dot{\omega}_{OB} = \frac{56 \times 50}{100} = \underline{\underline{28\ \mathrm{rad\,s^{-2}}}}$$

2

(a)



$$\frac{d\underline{e}_r}{dt} = \lim_{\delta t \to 0} \frac{\delta \underline{e}_r}{\delta t}$$

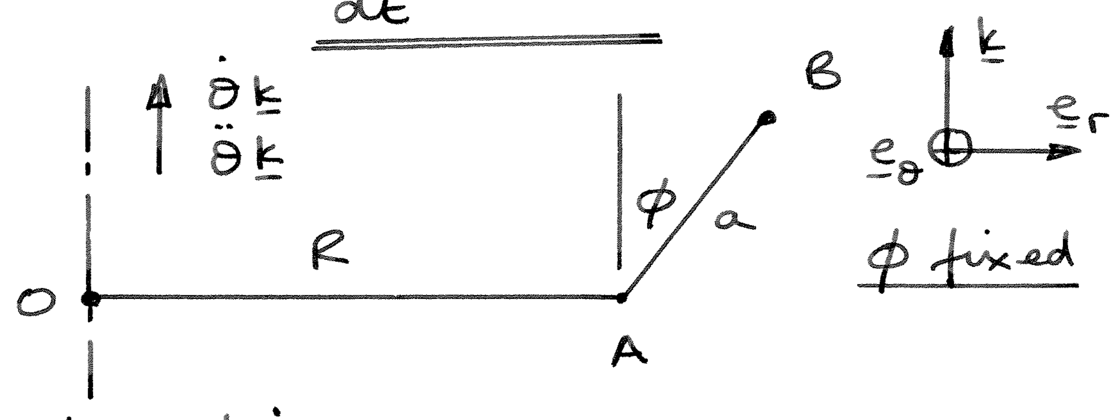
For small $\delta\theta$,

$$\left.\begin{array}{l}\text{Magnitude of } \delta\underline{e}_r \to 1 \times \delta\theta \\ \text{Direction of } \delta\underline{e}_r \to \underline{e}_\theta\end{array}\right\} \delta\underline{e}_r = \delta\theta\, \underline{e}_\theta$$

$$\therefore \lim_{\delta t \to 0} \frac{\delta \underline{e}_r}{\delta t} = \lim_{\delta t \to 0} \frac{\delta\theta}{\delta t}\underline{e}_\theta$$

$$\therefore \underline{\underline{\frac{d\underline{e}_r}{dt} = \dot{\theta}\,\underline{e}_\theta}}$$

(b)



By inspection :

$$\underline{\underline{\underline{v}_B = \dot{\theta}(R + a\sin\phi)\,\underline{e}_\theta}}$$

$$\underline{\underline{\underline{a}_B = \ddot{\theta}(R + a\sin\phi)\,\underline{e}_\theta - \dot{\theta}^2(R + a\sin\phi)\,\underline{e}_r}}$$

(c) $$\underline{\omega}_{DISC} = \underline{\underline{\dot{\theta}\underline{k} + \dot{\phi}\underline{e}_\theta}}$$

$$\dot{\underline{\omega}}_{DISC} = (\ddot{\theta}\underline{k} + \dot{\theta}\underbrace{\cancel{\dot{\underline{k}}}}_{=0}) + (\ddot{\phi}\underline{e}_\theta + \dot{\phi}\dot{\underline{e}}_\theta)$$

$$\dot{\underline{\omega}}_{DISC} = \underline{\underline{-\dot{\phi}\dot{\theta}\underline{e}_r + \ddot{\phi}\underline{e}_\theta + \ddot{\theta}\underline{k}}}$$

Note this term

(d) One of three approaches can be adopted to solve this part of the question:

(1) Start with the position vector $\underline{OB}$ and differentiate twice
(2) Use the Data Book expressions making the arm the rotating body
(3) Use the Data Book expressions making the disc the rotating body.

Adopting (2), along with the 'coincident points' method, is the approach used below.

Data Book expressions:

$$\underline{v}_P = \underline{v}_Q + \underline{\omega} \times \underline{r} + \left[\frac{d\underline{r}}{dt}\right]_R$$

$$\underline{a}_P = \underline{a}_Q + \frac{d\underline{\omega}}{dt} \times \underline{r} + \underline{\omega} \times (\underline{\omega} \times \underline{r}) + 2\underline{\omega} \times \left[\frac{d\underline{r}}{dt}\right]_R + \left[\frac{d^2\underline{r}}{dt^2}\right]_R$$

Let the arm be the rotating body, so $\underline{\omega} = \dot{\theta}\underline{k}$ and $\frac{d\underline{\omega}}{dt} = \ddot{\theta}\underline{k}$

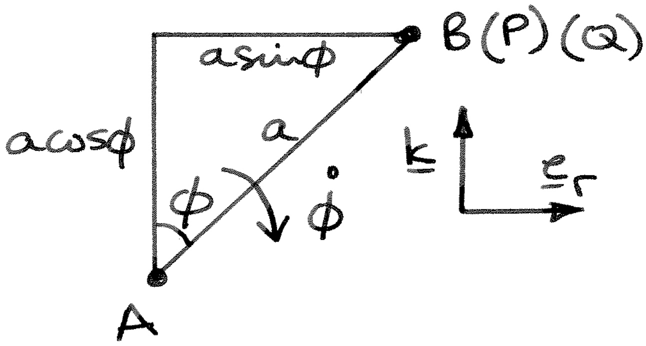
P will be point B on the disc

Place Q coincident with B (i.e. P), but in the rotating body (i.e. arm extended)

In this case $\underline{r} = 0$, and

$$\underline{v}_P = \underline{v}_Q + \left[\frac{d\underline{r}}{dt}\right]_R$$

$$\underline{v}_Q = \dot{\theta}(R + a\sin\phi)\,\underline{e}_\theta \quad \longleftarrow$$



$$\left[\frac{d\underline{r}}{dt}\right]_R = \dot{\phi}\,a\cos\phi\,\underline{e}_r - \dot{\phi}\,a\sin\phi\,\underline{k} \quad \longleftarrow$$

$$\underline{v}_P = \dot{\phi}\,a\cos\phi\,\underline{e}_r + \dot{\theta}(R + a\sin\phi)\underline{e}_\theta - \dot{\phi}\,a\sin\phi\,\underline{k}$$

i.e. b

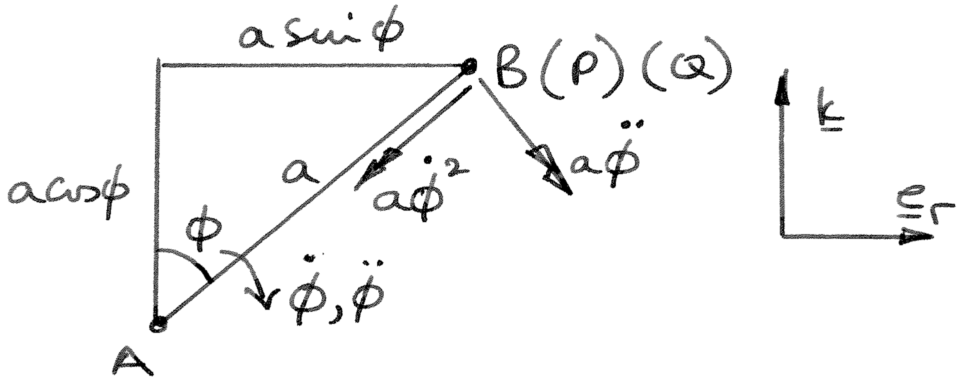
Since $\underline{r} = 0$

$$\underline{a}_P = \underline{a}_Q + 2\underline{\omega} \times \left[\frac{d\underline{r}}{dt}\right]_R + \left[\frac{d^2\underline{r}}{dt^2}\right]_R$$

$$\underline{a}_Q = -\dot{\theta}^2(R + a\sin\phi)\,\underline{e}_r + \ddot{\theta}(R + a\sin\phi)\,\underline{e}_\theta \longleftarrow$$

$$2\underline{\omega} \times \left[\frac{d\underline{r}}{dt}\right]_R = 2\dot{\theta}\underline{k} \times (\dot{\phi}\,a\cos\phi\,\underline{e}_r - \dot{\phi}\,a\sin\phi\,\underline{k})$$

$$= 2\dot{\theta}\dot{\phi}\,a\cos\phi\,\underline{e}_\theta \quad \longleftarrow$$

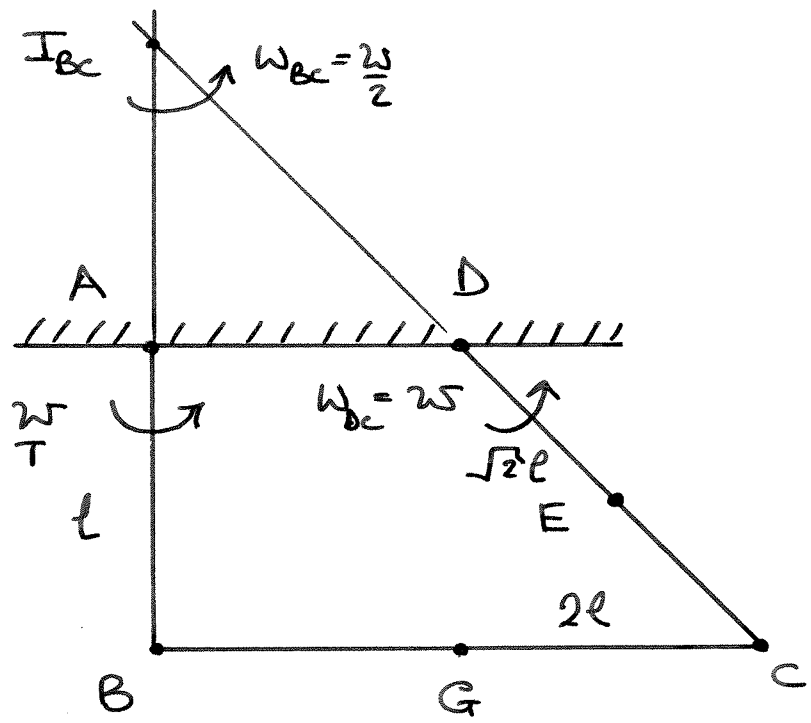


$$\left[\frac{d^2\underline{r}}{dt^2}\right]_R = \left.\begin{aligned} &\ddot\phi\, a\cos\phi\, \underline{e}_r - \ddot\phi\, a\sin\phi\, \underline{k} \\ &-\dot\phi^2 a\sin\phi\, \underline{e}_r - \dot\phi^2 a\cos\phi\, \underline{k} \end{aligned}\right\} \leftarrow$$

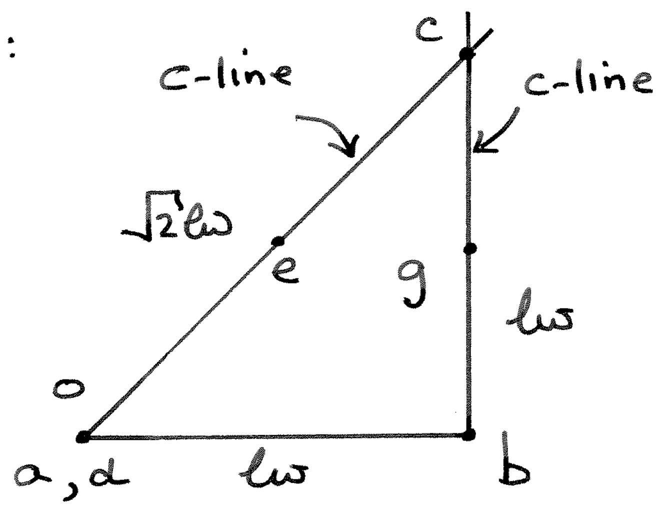
So, in components, $\underline{a}_P =$ ↖ i.e. b

$\underline{e}_r$	$\underline{e}_\theta$	$\underline{k}$
$-\dot\theta^2(R + a\sin\phi)$	$\ddot\theta(R + a\sin\phi)$	
	$2\dot\theta\dot\phi\, a\cos\phi$	
$(\ddot\phi\, a\cos\phi - \dot\phi^2 a\sin\phi)$		$-(\ddot\phi\, a\sin\phi + \dot\phi^2 a\cos\phi)$

3



(a) <u>Velocity diagram:</u>

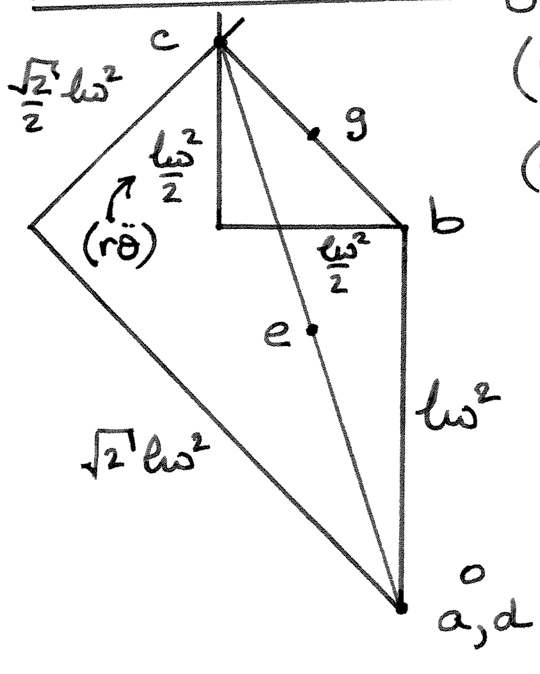


$$\omega_{BC} = \frac{bc}{BC} = \frac{l\omega}{2l} = \underline{\underline{\frac{\omega}{2}}}$$

$$\omega_{DC} = \frac{dc}{DC} = \frac{\sqrt{2}\,l\omega}{\sqrt{2}\,l} = \underline{\underline{2\omega}}$$

$$\underline{\underline{V_E = l\omega \rightarrow \; ; \; \frac{l\omega}{2} \uparrow}}$$

<u>Acceleration diagram:</u>



$$(r\dot{\theta}^2)_{BC} = 2l\left(\frac{\omega}{2}\right)^2 = \frac{l\omega^2}{2}$$

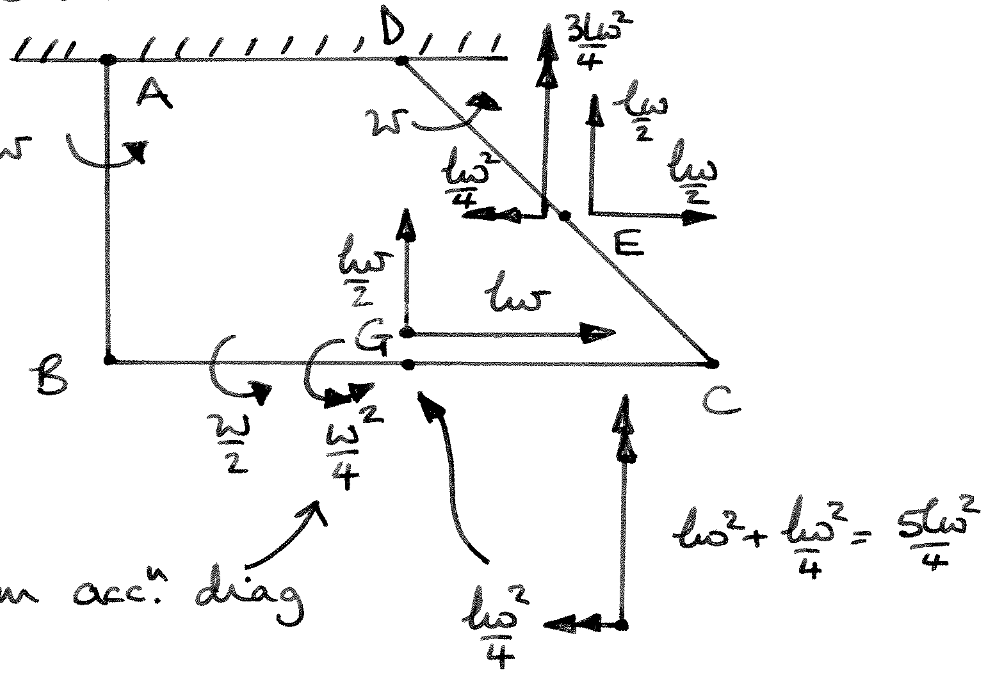
$$(r\dot{\theta}^2)_{CD} = \sqrt{2}\,l\omega^2$$

$$a_E = \frac{l\omega^2}{4} \leftarrow \; ; \; \frac{l\omega^2}{2}\left(1 + \frac{1}{2}\right) \uparrow$$

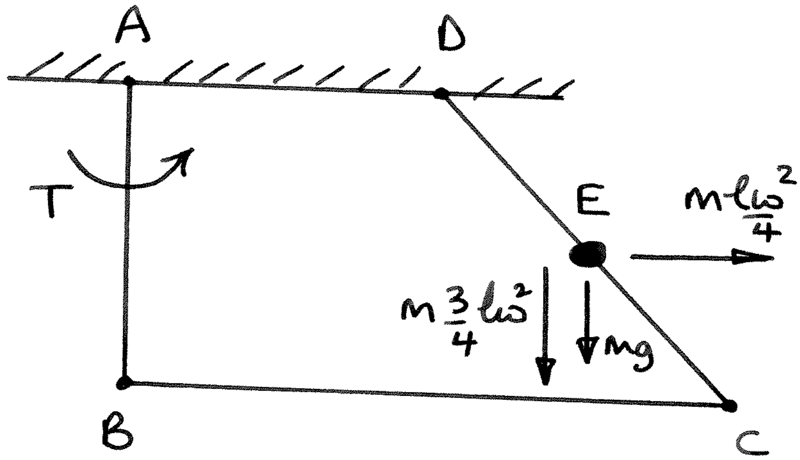
$$\underline{\underline{a_E = \frac{l\omega^2}{4} \leftarrow \; ; \; \frac{3}{4} l\omega^2 \uparrow}}$$

$$\dot{\omega}_{BC} = \frac{\frac{l\omega^2}{2}}{2l} = \frac{\omega^2}{4}$$

Velocities and accelerations:



(b) Forces:



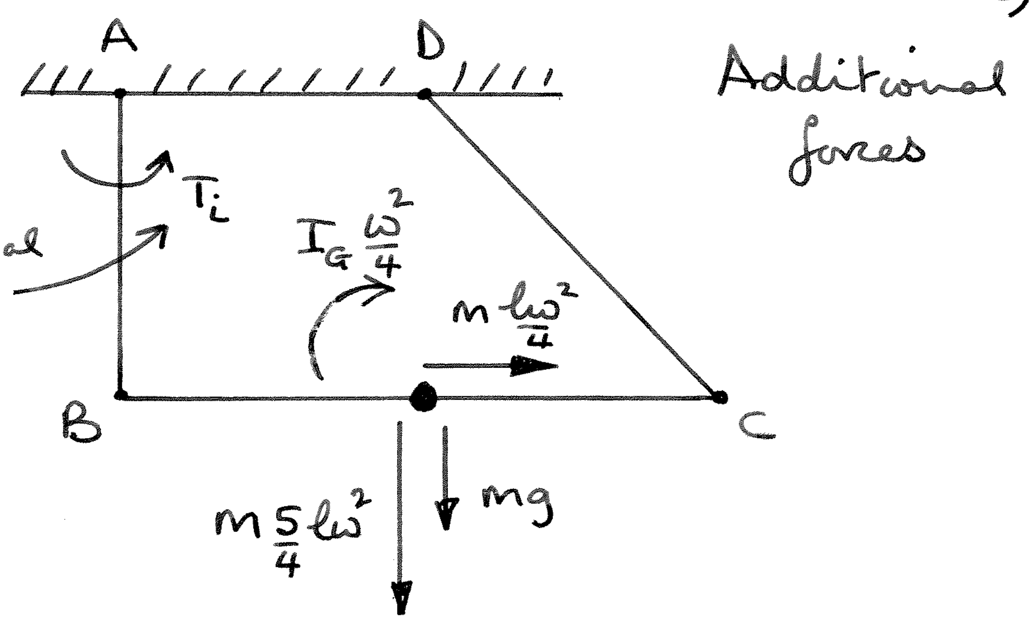
$$\sum \text{Instantaneous powers} = 0$$

$$T\omega - \left(mg + m\frac{3}{4}l\omega^2\right)\frac{l\omega}{2} + \left(m\frac{l\omega^2}{4}\right)\frac{l\omega}{2} = 0$$

$$T = \frac{1}{2}mgl + \frac{3}{8}ml^2\omega^2 - \frac{1}{8}ml^2\omega^2$$

$$\underline{\underline{T = \frac{1}{2}mgl + \frac{1}{4}ml^2\omega^2}}$$

(c)



$$I_G = \frac{1}{12}m(2l)^2 = \frac{ml^2}{3}$$

$\sum$ Instantaneous powers $= 0$

$$T_i\omega - mg\left(\frac{l\omega}{2}\right) + m\frac{l\omega^2}{4}(l\omega) - m\frac{5}{4}l\omega^2\left(\frac{l\omega}{2}\right) - I_G\frac{\omega^2}{4}\left(\frac{\omega}{2}\right) = 0$$

$$T_i = \frac{1}{2}mgl + ml^2\omega^2\left(\frac{1}{24} + \frac{15}{24} - \frac{6}{24}\right)$$

$$\underline{\underline{T_i = \frac{1}{2}mgl + \frac{5}{12}ml^2\omega^2}}$$

(d) The angular velocities of all the bars are in the <u>same sense</u>, i.e. anticlockwise

So "Subtract."

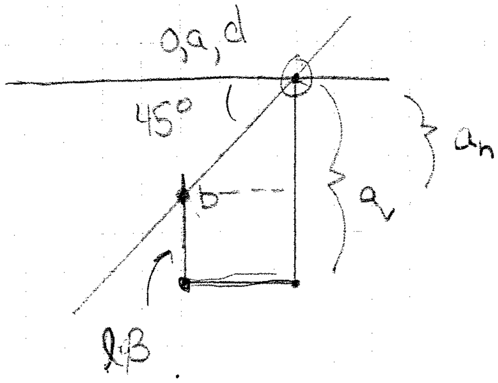
<u>Additional</u> input power = Friction power

$$T_{ai}\,\omega = \underbrace{Q\left(\omega - \frac{\omega}{2}\right)}_{B} + \underbrace{Q\left(\omega - \frac{\omega}{2}\right)}_{C} + \underbrace{Q\omega}_{D}$$

$$\underline{\underline{T_{ai} = 2Q}}$$

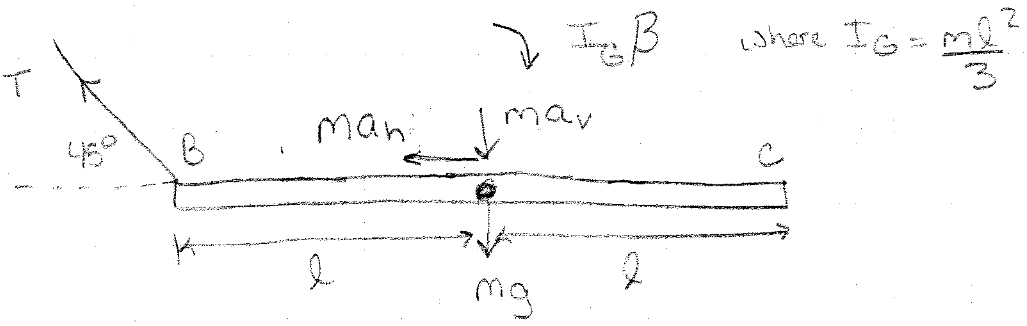
4.

(a) Acceleration Diagram:



$\therefore a_v = a_h + l\beta$ (1)

(b)



where $I_G = \frac{ml^2}{3}$

$+\uparrow \quad T\sin 45 - ma_v - mg = 0$ (2)

$\overset{\leftarrow}{+} \quad T\cos 45 + ma_h = 0$ (3)

$\underset{G}{\overset{+}{\circlearrowleft}} \quad T\cos 45\, l + \left(\frac{ml^2}{3}\right)\beta = 0$ (4)

(3) $\Rightarrow \quad -T\cos 45 = ma_h$

from (2) $\quad -ma_h - ma_v = mg$

$a_h + a_v = -g$ (5)

from (4) $\quad -\cancel{m}a_h\cancel{l} = -\frac{\cancel{m}l^{\cancel{2}}}{3}\beta$

$\therefore \beta = \frac{3a_h}{l}$ (6)

from (1) $\quad a_v = a_h + l\beta$

(1), (5) & (6) $\Rightarrow \quad a_v = (-g - a_v) + \frac{\cancel{l}3}{\cancel{l}}(-g - a_v) = 4(-g - a_v)$

$\therefore a_v = -4g/5$

so, $a_h = -g - a_v = -g + \frac{4g}{5} = -\frac{g}{5}$

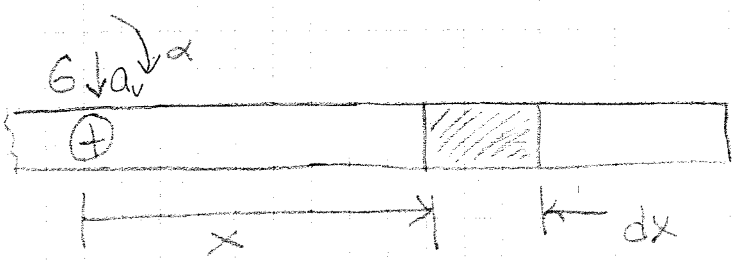
from (3) $T = \frac{-m a_h}{\cos 45} = \frac{mg}{5\cos 45}$ from (6) $\beta = \frac{3h}{l}$

$\therefore T = \frac{\sqrt{2}}{5} mg$ & $\beta = \frac{3g}{5l}$

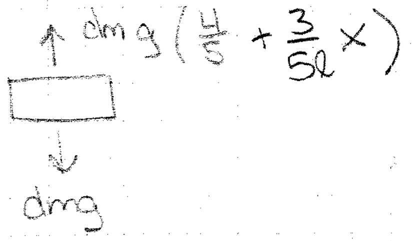
(c) $S_B = -\frac{T}{\sqrt{2}} = -\frac{mg}{5}$

$S_C = M_B = M_C = 0$

(d)



$a = a_v + x\beta = \frac{4}{5}g + \frac{3g}{5l}x$



where $dm = \frac{m}{2l}dx$

$w = dmg\left(1 - \frac{4}{5} - \frac{3x}{5l}\right)\frac{1}{dx}$

$w = \frac{mg}{10l}\left(1 - \frac{3x}{l}\right)$

integrating

$\rightarrow F = \frac{mg}{10l}\left(x - \frac{3x^2}{2l} + A\right)$

$F = 0$ at $x = l$ $\Rightarrow$

$0 = \frac{mg}{10l}\left(l - \frac{3l}{2} + A\right)$ $\therefore A = \frac{l}{2}$

$\therefore F = \frac{mg}{10l}\left(x - \frac{3x^2}{2l} + \frac{l}{2}\right)$ check $F(x=-l) = -\frac{mg}{5}$ ✓

integrate again $M = \frac{mg}{10\ell}\left(\frac{\ell x}{2} + \frac{x^2}{2} - \frac{x^3}{2\ell} + B\right)$

but $M=0$ when $x=\ell$

$$0 = \frac{\ell^2}{2} + \frac{\ell^2}{2} - \frac{\ell^2}{2} + B \qquad \therefore B = -\frac{\ell^2}{2}$$

$\therefore \underline{M = \frac{mg}{20\ell}\left(-\ell^2 + \ell x + x^2 - \frac{x^3}{\ell}\right)}$ check $M(x=-\ell) = 0$ ✓

-or-

$$M = -\frac{mg\ell}{20} + \frac{Mgx}{20} + \frac{mgx^2}{20\ell} - \frac{mgx^3}{20\ell^2}$$

5. • linear impulse - integrating a force, F, over a period of time gives an impulse which using $\underline{F} = m\underline{a}$ equates an impulse to a change in momentum.

• conservation of the moment of momentum - The moment of momentum about a point P is conserved if the moments of all external forces about P sum to zero.

(b) Polar moment of inertia of a disc $= \dfrac{mr^2}{2}$

For discs A & B, the moment of momentum (angular momentum) is conserved about the axes of their shafts as the clutch C is engaged.

<u>Before</u>

$$J_A \omega_A = (J_A + J_B)\omega_F$$

$$J_A = \frac{0.5 \cdot 30^2 \cdot 10^{-6}}{2} \text{ kgm}^2 = 225 \cdot 10^{-6} \text{ kgm}^2$$

$$J_B = \frac{0{,}25 \cdot 20^2 \cdot 10^{-6}}{2} \text{ kgm}^2 = 50 \cdot 10^{-6} \text{ kgm}^2$$

$$\omega_F = \frac{225 \cdot 10^{-6} \cancel{\text{kgm}^2} \cdot 2000 \text{ rpm}}{(225 \cdot 10^{-6} + 50 \cdot 10^{-6}) \cancel{\text{kgm}^2}}$$

$$\therefore \underline{\omega_F = 1636 \text{ rpm}} \cdot \left(\frac{2\pi}{60}\right) = 171 \text{ rad} \cdot \text{s}^{-1}$$

$$\text{Kinetic energy} = \tfrac{1}{2} J \omega^2$$

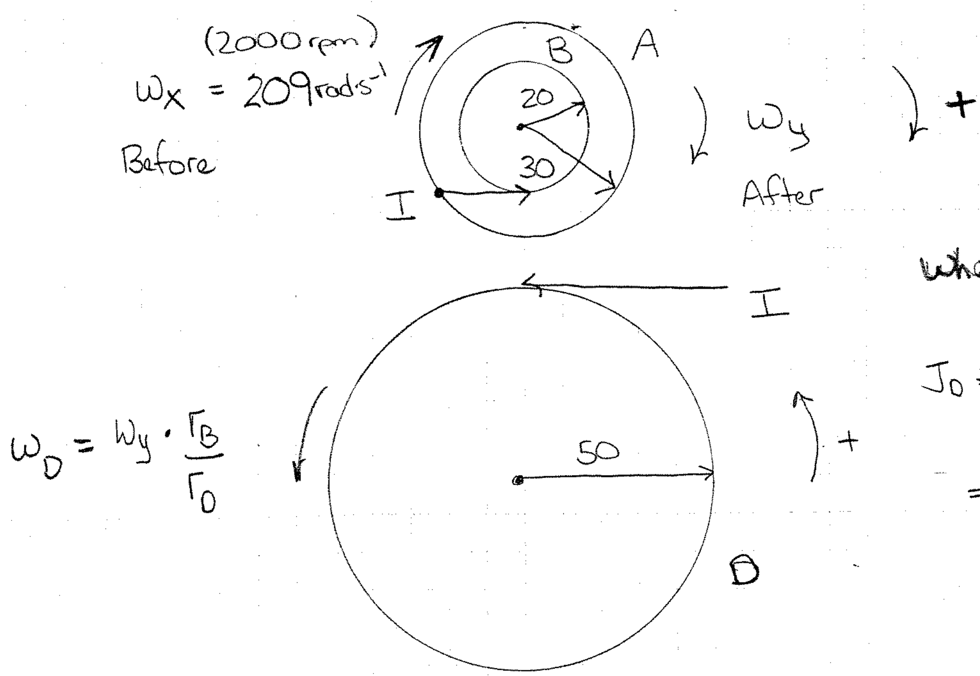
$$(KE)_{BEFORE} = \tfrac{1}{2} J_A \omega_A^2 = \tfrac{1}{2} \cdot 225 \cdot 10^{-6} \text{ kgm}^2 \cdot \Big(\overbrace{2000 \text{ rpm} \cdot \tfrac{2\pi}{60}}^{209 \text{ rad} \cdot \text{s}^{-1}}\Big)^2 = 4.9 \text{ J}$$

$$(KE)_{AFTER} = \tfrac{1}{2}(J_A + J_B)\omega_F^2 = \tfrac{1}{2}(225 \cdot 10^{-6} + 50 \cdot 10^{-6})(171)^2 = 4.0 \text{ J}$$

$$\therefore \text{Energy lost} = 0.9 \text{ J}$$

(c) The speed of engagement makes no difference. The solution depends only on the angular momentum before being equal to the angular momentum after.

(d) There is no axis about which moment of momentum is conserved. At the point of contact between B and D the <u>impulses</u> are equal and opposite.



where $I = \int P\,dt$

$$J_D = \frac{1.25 \cdot 50^2}{2} \cdot 10^{-6}$$

$$= 1563 \cdot 10^{-6}\ \text{kg m}^2$$

For A and B: $\left[I r_A = J_A(\omega_x - \omega_y) \ \& \ I r_A - I r_B = J_B \omega_y \right]$

$$-I r_B = \underset{\text{After}}{(J_A + J_B)\,\omega_y} - \underset{\text{Before}}{J_A \omega_x}$$

For D:

$$I r_D = \underset{\text{After}}{J_D \overbrace{\omega_y \cdot \frac{r_B}{r_D}}^{\omega_D}} - \underset{\text{Before}}{\cancel{J_D \cdot 0}}$$

Inserting the numbers and eliminating I (to solve for ω_y):

$$\frac{J_A \omega_x}{r_B} - (J_A + J_B)\frac{\omega_y}{r_B} = J_D \omega_y \cdot \frac{r_B}{r_D^2}$$

$$\frac{J_A \omega_x}{r_B} = \omega_y \left(\frac{(J_A + J_B)}{r_B} + \frac{J_D r_B}{r_D^2} \right)$$

$$\frac{225 \cdot 2000}{20} = \omega_y \left(\frac{275}{20} + \frac{1563 \cdot 20}{50^2} \right)$$

$$22500 = \omega_y \left(13.75 + 12.5 \right)$$

$$\therefore \omega_y = 857 \text{ rpm} \quad (\sim 90 \text{ rad.s}^{-1})$$

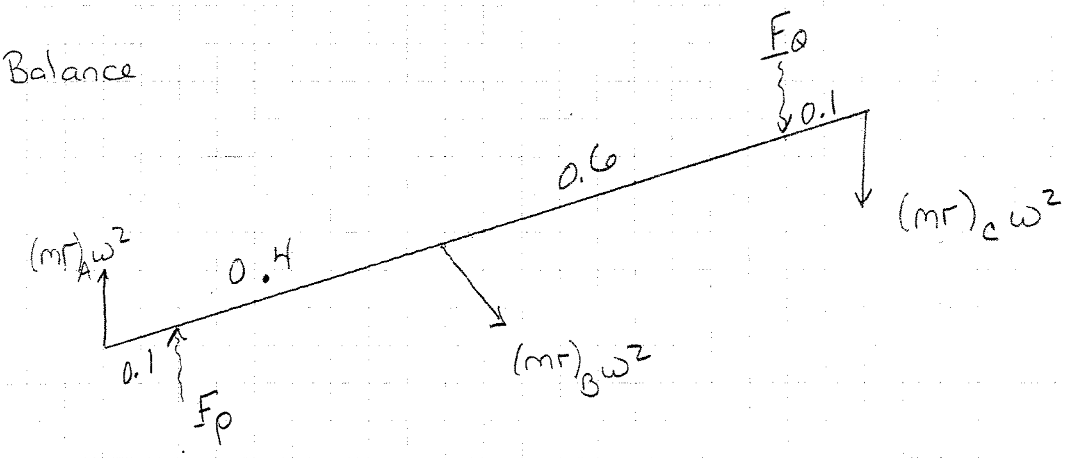
$$\therefore \underline{\omega_p} = 857 \cdot \frac{20}{50} = \underline{343 \text{ rpm}} \quad (\sim 36 \text{ rad.s}^{-1})$$

6.

(a) Statically balanced - the centre of mass of the rotating mass lies along the centreline so that the shaft will sit in equilibrium at any angular position

dynamically balanced - for constant rotation, the bearing forces are each equal to zero. This eliminates undesireable bearing reactions.

(b) Static Balance

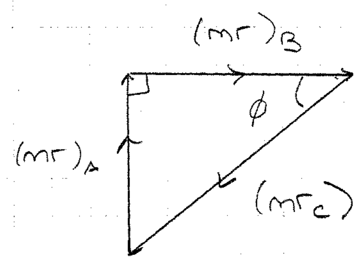


$(mr)_A = 0.018$ kgm $\times 500$ (9)

$(mr)_B = 0.024$ kgm   (12)

$(mr)_C = 0.030$ kgm   (15)

9 : 12 : 15   Drawn to scale 500:1



$F_P + F_Q = 0$

3:4:5 $\Delta \Rightarrow \tan\phi = 3/4 \Rightarrow \phi = 36.9^\circ$

$\therefore$ relative to pulley A, out of balance at B must be 90° clockwise

out of balance at C $(270 - \phi) = 233^\circ$ clockwise

(c) Dynamic Balance

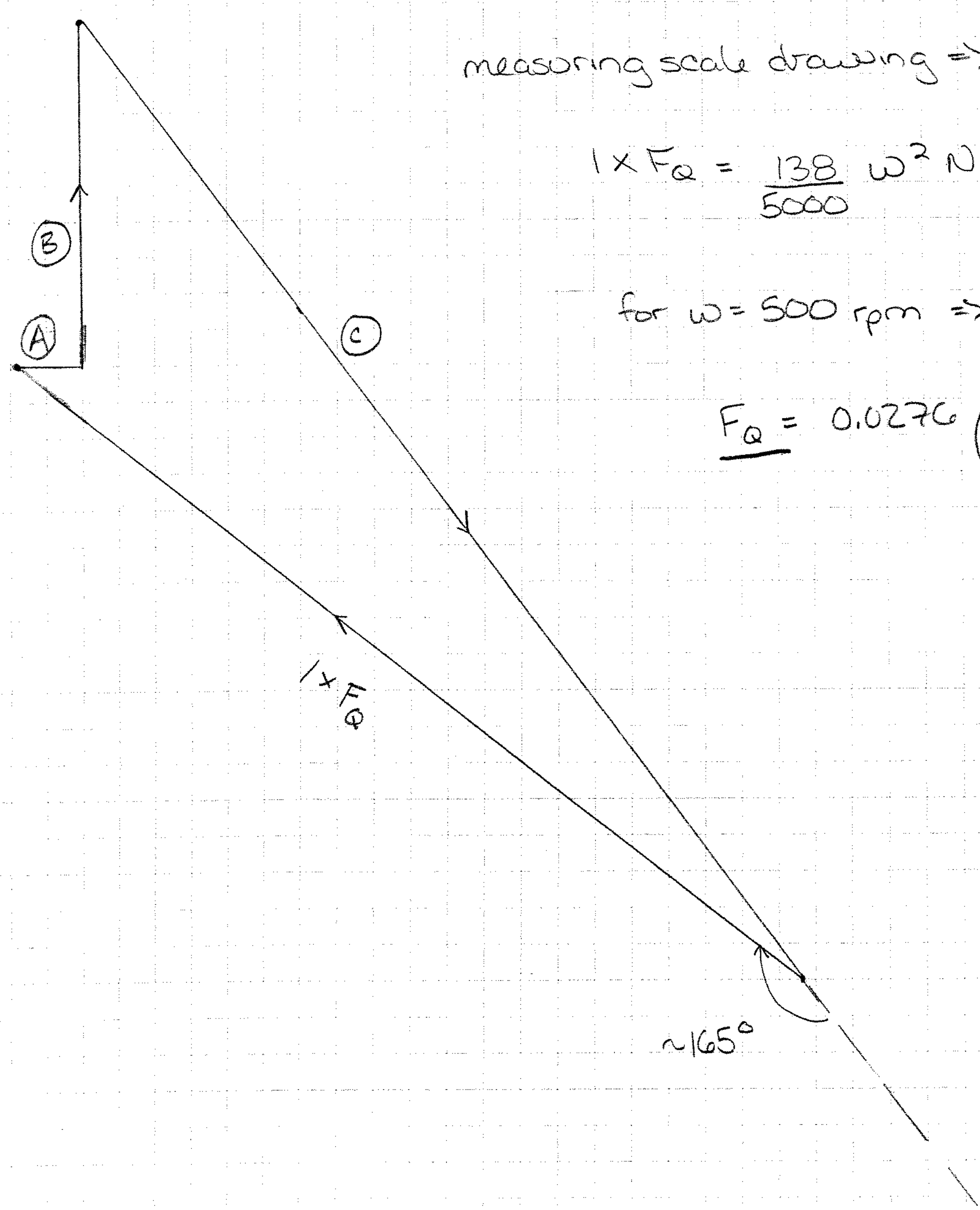
Take moments about one bearing, say P. Since all moment arms lie along the shaft axis, moment vectors are all 90° from corresponding force vectors. $\omega = 52 \text{ rad.s}^{-1}$

Moments at P :

		(×5000)
mass at A	$0.018 \cdot 0.1 \cdot \omega^2 = 0.0018\,\omega^2$ Nm (4,867)	(9)
mass at B	$0.024 \cdot 0.4 \cdot \omega^2 = 0.0096\,\omega^2$ Nm (25.96)	(48)
mass at C	$0.030 \cdot 1.1 \cdot \omega^2 = 0.033\,\omega^2$ Nm (89.23)	(165)

$$|\underline{PQ} \times \underline{F}_Q| \rightarrow 1 \times F_Q$$

Drawn to scale 5000:1



measuring scale drawing =>

$$1 \times F_Q = \frac{138}{5000}\,\omega^2 \text{ Nm} = 0.0276\,\omega^2 \text{ Nm}$$

for $\omega = 500$ rpm =>

$$\underline{F_Q} = 0.0276\left(\frac{500 \cdot 2\pi}{60}\right)^2 = \underline{76 \text{ N}}$$

To bring the shaft into dynamic balance while maunting static balance two masses must be added of equal magnitude, equal radius and 180° out of phase.

given $m = 0.1$ kg (equal masses)

$$(0.1 \cdot r \cdot 1.1)\omega^2 + (0.1 \cdot r \cdot 0.1)\omega^2 = 0.0276\,\cancel{\omega^2}$$

$$0.12\,r = 0.0276$$

$$\therefore \underline{r = 0.23\text{ m}}$$

Positions:

From sketch ∡ between mass at C and F_a is 165° clockwise.
So, 233° (∡ from A→C) + 165° (C→ out of balance) = 398° = 38° relative to position A.

∴ mass at C is added at position 38° rel. to A clockwise
mass at A is added at position 38° + 180° = 218° rel. to A clockwise

KS
June 2001