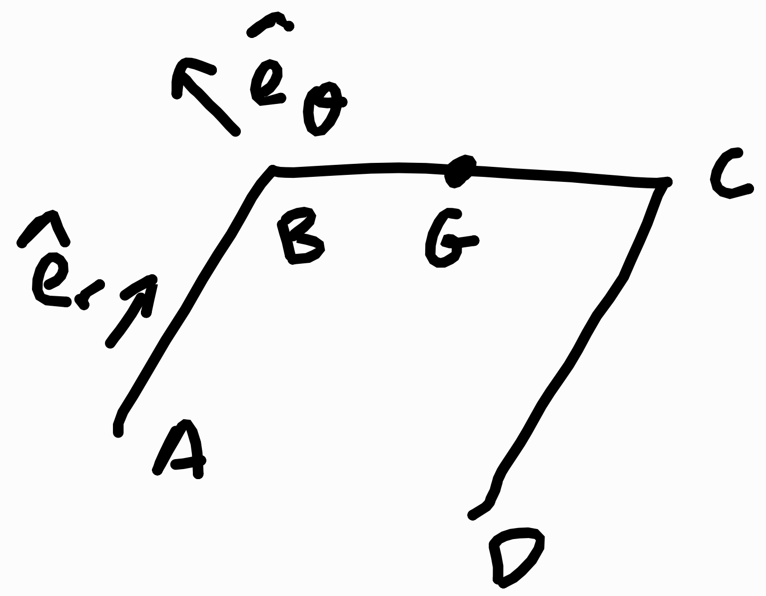
(a) $\vec{F} = m\vec{a}_\theta$



$\vec{v}_B = v_B \hat{e}_\theta$

$= v_B \angle 150°$

$\vec{v}_c = v_c \hat{e}_\theta$

$= v_c \angle 150°$

$\vec{v}_{B|c} = \vec{v}_B - \vec{v}_c$

$= (v_B - v_c)\cos 150° \underset{\sim}{i} + (v_B - v_c)\sin 150° \underset{\sim}{j}$

Since B is in circular motion about C,

$\vec{v}_{B|C} = v_{B|C} \underset{\sim}{j}$

$\therefore (v_B - v_c)\cos 150° = 0$

$(v_B - v_c)\sin 150° = v_{B|c}$

$v_B = v_c,\ v_{B|c} = 0$

1a) $\vec{v}_B = r_{AB}\omega_{AB}\angle 150°$

$\vec{v}_C = r_{DC}\omega_{DC}\angle 150°$

$\vec{v}_B = \vec{v}_C$

$\therefore \omega_{AB} = \omega_{DC}$

$\vec{a}_B = -r_{AB}\omega_{AB}^2\angle 60° + r_{AB}\alpha_{AB}\angle 150°$

$\vec{a}_C = -r_{DC}\omega_{DC}^2\angle 60° + r_{DC}\alpha_{DC}\angle 150°$

$\vec{a}_{C/B} = \vec{a}_C - \vec{a}_B$

$= \cancel{(-r_{DC}\omega_{DC}^2 + r_{AB}\omega_{AB}^2)\angle 60°}$

$+ (r_{DC}\alpha_{DC} - r_{AB}\alpha_{AB})\angle 150°$

$\vec{a}_{C/B} = \cancel{-r_{BC}\omega_{BC}^2\,\underset{\sim}{i}} + r_{BC}\alpha_{BC}\,\underset{\sim}{j}$

$= r_{BC}\alpha_{BC}\,\underset{\sim}{j}$

$(r_{DC}\alpha_{DC} - r_{AB}\alpha_{AB})\angle 150° = r_{BC}\alpha_{BC}\,\underset{\sim}{j}$

$\underset{\sim}{i}: (r_{DC}\alpha_{DC} - r_{AB}\alpha_{AB})\cos 150° = 0$

$\therefore \alpha_{DC} = \alpha_{AB}$

1a) $j: \underbrace{(r_{DC}\alpha_{DC} - r_{AB}\alpha_{AB})}_{0}\sin 150° = r_{BC}\alpha_{BC}$

$\therefore \alpha_{BC} = 0$

$\vec{a}_B = \vec{a}_C \rightarrow \vec{a}_B = \vec{a}_C = \vec{a}_G$?

C is in circular motion about B,

$\vec{a}_{C/B} = -r_{CB}w^2 \underset{\sim}{i} + r_{CB}\alpha \underset{\sim}{j} = \vec{a}_C - \vec{a}_B$

$= 0$

$\therefore w = 0, \alpha = 0$

$\Downarrow$

$\vec{a}_{G/B} = -r_{GB} w \underset{\sim}{i} + r_{GB}\alpha \underset{\sim}{j}$

$= 0 \quad \because w = \alpha = 0$

$= \vec{a}_G - \vec{a}_B$

$\therefore \vec{a}_G = \vec{a}_B$

1a) $\vec{F} = m\vec{a}_G$

$$\alpha = 0$$

$$\vec{a}_G = \vec{a}_B = \cancel{r_{AB}\alpha \angle 150^\circ} - r_{AB}\,\omega_{AB}^2 \angle 60^\circ$$

$$= -0.200\left[(180)\left(\frac{2\pi}{60}\right)\right]^2 \angle 60^\circ$$

$$= -71.06115169 \angle 60^\circ$$

$$\vec{F} = m\vec{a}_G$$

$$= 7(-71.06115169 \angle 60^\circ)$$

$$= 497.4280618 \angle -120^\circ \text{ N}$$

1b) For rod BC, $\alpha = 0$, $\therefore M_G = 0$

2a) $I_A = I_G + m r_{GA}^2$

$= \frac{1}{12} mL^2 + m\left(\frac{L}{2}\right)^2$

$= \frac{1}{3} mL^2$

$= 0.375 \, kgm^2$

$\vec{M} = I \vec{\alpha}$

$\alpha = \frac{8}{3}(12 \times 0.750)$

$= 24 \, rads^{-2}$

2b) $\vec{a}_G = \vec{\alpha} \times \vec{r}_{GA}$

$$= -24\underset{\sim}{k} \times \left(-\frac{0.75}{2}\underset{\sim}{j}\right)$$

$$= -9\underset{\sim}{i}$$

$\vec{F} = m\vec{a}_G$

$$F_x\underset{\sim}{i} + F_y\underset{\sim}{j} - 12\underset{\sim}{i} - 2g\underset{\sim}{j} = 2(-9\underset{\sim}{i})$$

$$F_x\underset{\sim}{i} + F_y\underset{\sim}{j} - 12\underset{\sim}{i} - 19.62\underset{\sim}{j} = -18\underset{\sim}{i}$$

$\underset{\sim}{i}$: $F_x - 12 = -18$

$F_x = -6N$

$\underset{\sim}{j}$: $F_y - 19.62\underset{\sim}{j} = 0$

$F_y = 19.62N$

3a) $\vec{M} = I\vec{\alpha}$

$\circlearrowleft +$

$4(0.125) = \frac{1}{2}(7)(0.125)^2 \alpha$

$\alpha = \frac{64}{7}$ rads - 2

$\approx 9.143 \text{ rads}^{-2}$

b) $\vec{F} = m\vec{a_G}$

$4 = (7) a_G$

$a_G = \frac{4}{7} \text{ ms}^{-2}$

$\approx 0.571 \text{ ms}^{-2}$

c) $\vec{a}_{A/G} = \vec{\alpha} \times \vec{r}_{AG}$

$= \frac{64}{7} \underset{\sim}{k} \times (0.125 \underset{\sim}{i})$

$= \frac{8}{7} \underset{\sim}{j}$

$s = \frac{1}{2} a t^2$

$= \frac{1}{2}\left(\frac{8}{7}\right)(2)^2$

$= \frac{16}{7} \text{ m} \approx 2.2858 \text{ m}$

4) (i) $I_O = I_G = 10\,kgm^2$

a) $\alpha = \frac{M}{I}$

$= \frac{981(0.2)}{10}$

$= 19.62\,rads^{-2}$

b) $w = \alpha t$

$= 19.62(3)$

$= 58.86\,rads^{-1}$

c) $s = \frac{1}{2}at^2$

$t^2 = \frac{2s}{\alpha r}$

$w = \alpha t$

$= \alpha\sqrt{\frac{2s}{\alpha r}}$

$= 19.62\sqrt{\frac{2(3)}{19.62(0.2)}}$

$= 24.26107994$

$\approx 24.26\,rads^{-1}$

4) (2)

$$I_o = 10 + 100(0.2)^2$$

$$= 14 \, kgm^2$$

a) $\alpha = \frac{M}{I} = \frac{981(0.2)}{14}$

$$= \frac{981}{70} \, rads^{-2}$$

b) $w = \alpha t = \frac{981}{70}(3)$

$$= \frac{2943}{70} \, rads^{-1}$$

c) $w = \alpha \sqrt{\frac{2s}{\alpha r}}$

$$= \frac{981}{70} \sqrt{\frac{2(3)}{\frac{981}{70}(0.2)}}$$

$$= 20.5043549 4 \, rads^{-1}$$

4) (3)

$$I_0 = 10 + 500(0.2)^2$$

$$= 30 kgm^2$$

a) $$\alpha = \frac{M}{I} = \frac{981(0.2)}{30}$$

$$= 6.54 \, rads^{-2}$$

b) $$w = \alpha t$$

$$= 6.54(3)$$

$$= 19.62 \, rads^{-1}$$

c) $$w = \alpha \sqrt{\frac{2s}{\alpha r}}$$

$$= 6.54 \sqrt{\frac{2(3)}{6.54(0.2)}}$$

$$= 14.00714104 \, rads^{-1}$$

4) (4)

$$I_0 = 10 + 50(0.4)^2$$
$$= 18\,kgm^2$$

a) $\alpha = \frac{M}{I} = \frac{0.5(981)(0.4)}{18}$

$$= 10.9\,rads^{-2}$$

b) $w = \alpha t = 10.9(3)$

$$= 32.7\,rads^{-1}$$

c) $w = \alpha\sqrt{\frac{2s}{\alpha r}}$

$$= 10.9\sqrt{\frac{2(3)}{10.9(0.4)}}$$
$$= 12.78671185\,rads^{-1}$$

5) $\vec{v}_A = v_A \underset{\sim}{i}$

$$\vec{v}_p = \vec{v}_{p/A} + \vec{v}_A$$

$$= v_{p/A} \angle 210^\circ + v_A \underset{\sim}{i}$$

$$= v_{p/A} \cos 210^\circ \underset{\sim}{i} + v_A \underset{\sim}{i} + v_{p/A} \sin 210^\circ \underset{\sim}{j}$$

$$v_p^2 = \left(v_A - \frac{\sqrt{3}}{2} v_{p/A}\right)^2 + \left(-\frac{1}{2} v_{p/A}\right)^2$$

$$= v_A^2 - \sqrt{3}\, v_A v_{p/A} + \frac{3}{4} v_{p/A}^2 + \frac{1}{4} v_{p/A}^2$$

$$= v_A^2 - \sqrt{3}\, v_A v_{p/A} + v_{p/A}^2$$

$$E_1 = mgS \sin 30^\circ$$

$$E_2 = \frac{1}{2} m v_p^2 + \frac{1}{2} I_G \omega^2 + \frac{1}{2} M v_A^2$$

$$= \frac{1}{2}(500)\left(v_A^2 - \sqrt{3}\, v_A v_{p/A} + \frac{5}{4} v_{p/A}^2\right) +$$

$$\frac{1}{2}\left(500(0.5)^2\right)\left(\frac{v_{p/A}}{0.5}\right)^2 + \frac{1}{2}(300) v_A^2$$

$$= 250\left(v_A^2 - \sqrt{3}\, v_A v_{p/A} + v_{p/A}^2\right) +$$

$$250 v_{p/A} + 150 v_A^2$$

$$= 400 v_A^2 - 250\sqrt{3}\, v_A v_{p/A} + 500 v_{p/A}^2$$

5) $L_1 = 0$

$$L_2 = m(v_{P/A}\cos 210° + v_A) + Mv_A$$

$$-250\sqrt{3}\, v_{P/A} + 800 v_A = 0$$

$$v_A = \frac{250\sqrt{3}}{800} v_{P/A}$$

$$= \frac{5\sqrt{3}}{16} v_{P/A} \quad -(1)$$

$$E_1 = mgS\sin 30°$$

$$= 250gS$$

$$E_1 = E_2$$

$$250gS = 400 v_A^2 - 250\sqrt{3}\, v_A v_{P/A} + 500 v_{P/A}^2 \quad -(2)$$

Sub (1) into (2)

$$250gS = 400\left(\frac{5\sqrt{3}}{16}\right)^2 v_{P/A}^2 - 250\sqrt{3}\left(\frac{5\sqrt{3}}{16}\right) v_{P/A}^2 + 500 v_{P/A}^2$$

$$250gS = 382.8125\, v_{P/A}^2 \quad -(3)$$

$$\int a\,ds = \int v\,dv$$

$$as = \frac{v^2}{2}$$

$$2as = v^2$$

5) $2a_{P|B}s = v_{P|A}^2$ — (4)

Sub (4) into (3)

$$250g\cancel{s} = 382.8125(2a_{P|B}\cancel{s})$$

$$a_{P|B} = \frac{3924}{1225}\ ms^{-2}$$

From (1):

$$v_A = \frac{5\sqrt{3}}{16} v_{P|A}$$

$$a_A = \frac{5\sqrt{3}}{16} a_{P|A}$$

$$a_A = 1.733818206\ ms^{-2}$$

$$\approx 1.7338\ ms^{-2}$$

6a) $2x_B + x_D = \text{constant}$

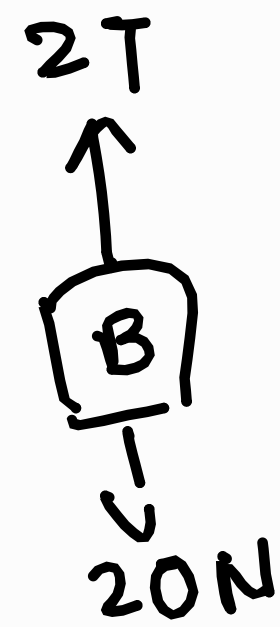
$$2\dot{x}_B + \dot{x}_D = 0$$

$$2\ddot{x}_B + \ddot{x}_D = 0$$

$$\ddot{x}_G = r\alpha$$
$$= 0.15\alpha$$

$$\ddot{x}_D = 2r\alpha$$
$$= 0.3\alpha$$

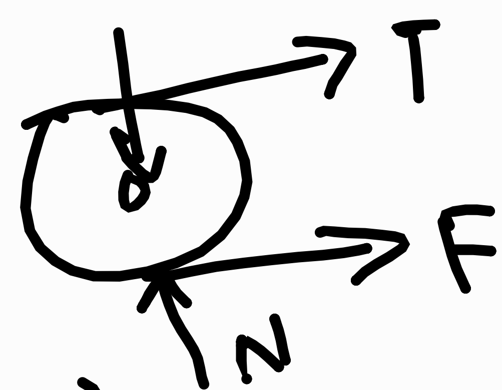
$$\ddot{x}_B = -0.5\ddot{x}_D$$
$$= -0.5\ddot{x}_D$$



$$20 - 2T = \frac{20}{g}\ddot{x}_B$$

$$20 - 2T = \frac{20}{g}(-0.15\alpha)$$

$$\frac{100}{327}\alpha - 2T = -20 \quad -(1)$$



$\underset{\sim}{i}$: $T + F = -\frac{50}{g}\ddot{x}_G = -\frac{50}{g}(0.15\alpha)$

$$\frac{250}{327}\alpha + T + F = 0 \quad -(2)$$

$\underset{\sim}{j}$: $N = 50N \quad -(3)$

$\underset{\sim}{k}$: $(F - T)r = I_G\alpha$

$$(F - T)(0.15) = \frac{1}{2}\left(\frac{50}{g}\right)(0.15^2)\alpha$$

$$-\frac{25}{436}\alpha - 0.15T + 0.15F = 0 \quad -(4)$$

b) Solving (1), (2), (4),

$$\alpha = -\frac{1308}{95} \text{ rads}^{-2}$$

$$T = \frac{150}{19} N$$

$$F = \frac{50}{19} N$$

Since $F = \mu_s N$,

$$\mu_s = \frac{F}{N}$$

$$= \frac{\frac{50}{19}}{50}$$

$$= \frac{1}{19}$$