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Name: Simon E Williams (P150613)

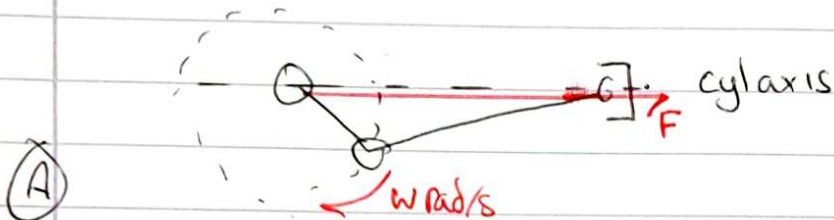
Date: 14/5/20 1 PM

Module: M6x00410 Advanced engine design

~~ADD~~ x 2

1)

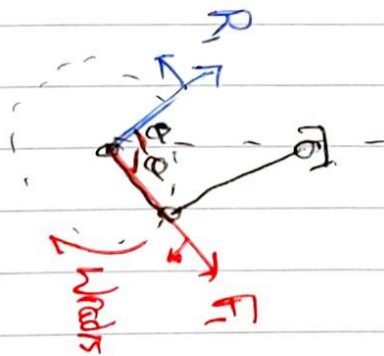
$$\begin{aligned} M_{rec} &= \frac{1}{3} (330) + 240 \\ &= \underline{0.350 \text{ kg}} \\ M_{rot} &= \frac{2}{3} 330 \\ &= \underline{0.240 \text{ kg}} \\ R &= 45 \text{ mm} \\ L &= 140 \text{ mm} \end{aligned}$$



Reciprocating piston mass creates a horizontal first order forces along the cyl axis
represented as

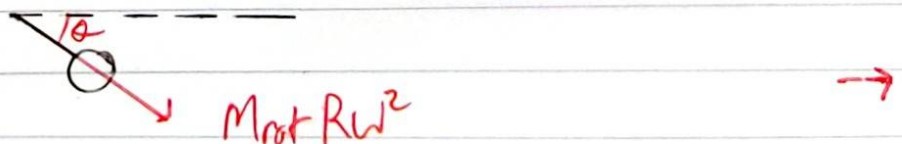
$$F = M_{rec} R \omega^2 \cos \theta$$

First order forces can be represented as two constant amplitude counter rotating vectors



$$R_1 = F_1 = \frac{M_{rec}}{2} R \omega^2$$

the rotating part of the con rod creates a centrifugal force of magnitude $M_{rot} R \omega^2$ along crank pin



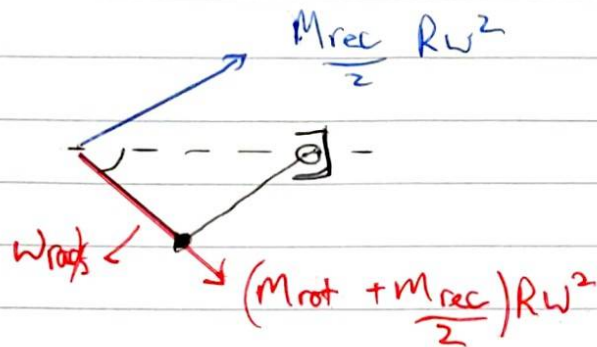
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So total first order force is:



$$M_{rec} 0.35$$

$$M_{rot} 0.24$$

$$R 45mm$$

$$L = 140$$

$$M_{crank} = 5kg$$

$$\text{first order mass moment} = (M_{rot} + \frac{M_{rec}}{2}) R \omega^2$$

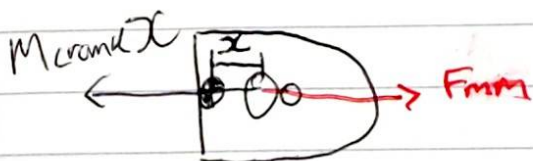
$$F_{mm} = (0.24 + \frac{0.35}{2}) \times 45$$

$$F_{mm} = 18.68 \text{ kgmm}$$

there's two pistons so 18.68×2

$$F_{mm} = \underline{37.36 \text{ kgmm}}$$

b) over balanced crank to balance
so $M_{crank} x$ must equal F_{mm}



$$M_{crank} x = 37.36$$

$$5 x = 37.36$$

$$x = \underline{\underline{7.47mm}}$$

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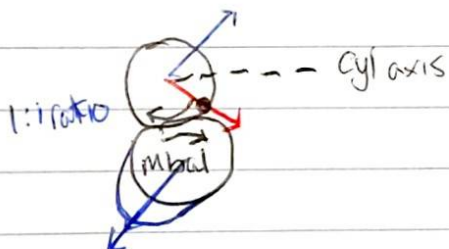
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$$c) \left(\left(\frac{M_{rec}}{2} \right) R \right) \times 2 = R_{First}$$

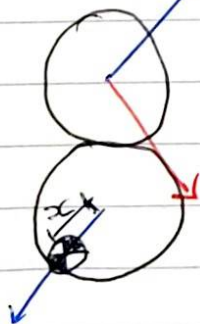
$$R_F = \left(\left(\frac{0.35}{2} \right) 45 \right) \times 2$$

$$R_F = 15.75 \text{ kg mm}$$

- d) drive with a 1:1 ratio gear set so bal shaft is counter rotating at same speed



e) $M_{bal} = 2.5 \text{ kg}$ 15.75 kg mm



$$\text{So } M_{bal} x = 15.75$$

$$\therefore 2.5 x = 15.75$$

$$x = 6.3 \text{ mm}$$

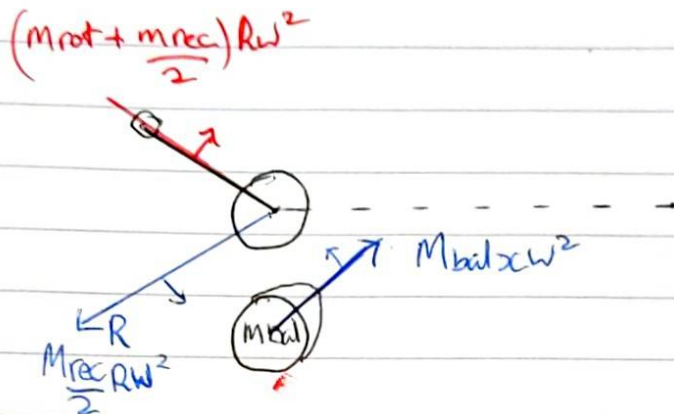
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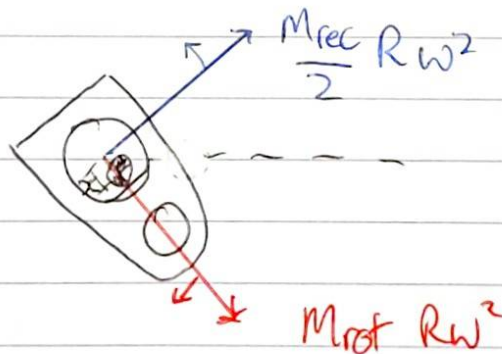
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f)



g) to cancel vertical forces the crank can be under balanced if no balance used



$$\text{make } M_{crank} x = M_{rot} R$$

$$S_x = (0.24) 45$$

$$S_x = 10.8 \text{ kg mm}$$

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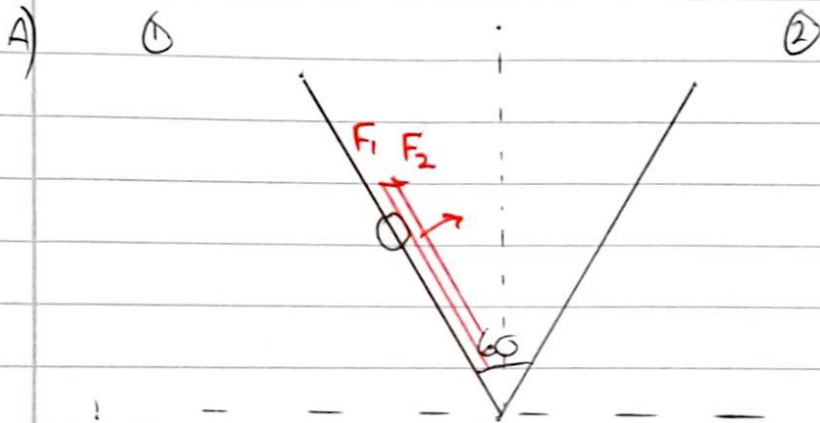
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$$2) \quad M_{rec} = \frac{1}{3}(360) + 240 \quad R = 40 \text{ mm} \\ = \underline{0.360 \text{ kg}} \quad L = 140 \text{ mm}$$

$$M_{rot} = \frac{2}{3}(360) \\ = \underline{0.240 \text{ kg}}$$



$$2 \times \left(M_{rot} + \frac{M_{rec}}{2} \right) R^2 = F_{1mm}$$

$$2 \times \left(0.24 + \frac{0.36}{2} \right) 40 = F_{1mm}$$

$$33.6 = F_{1mm}$$

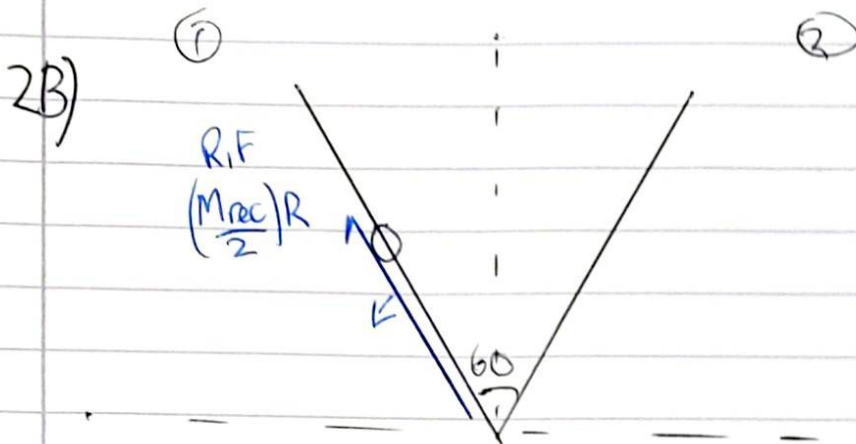


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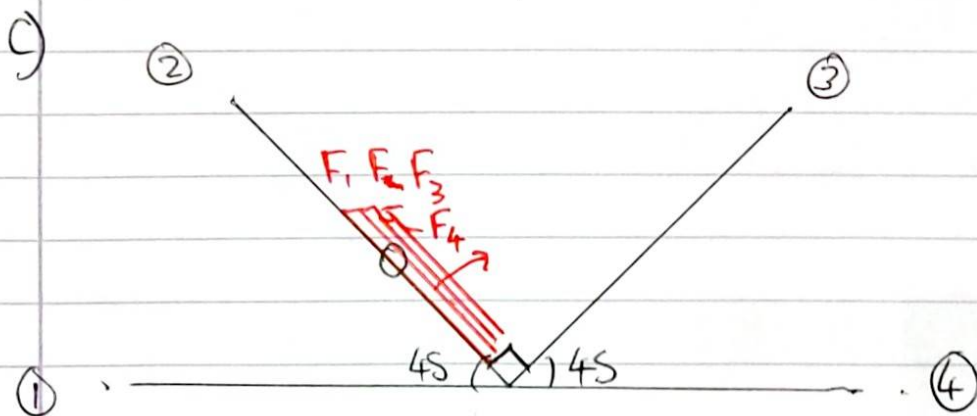
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$$R_{IF} = (\frac{M_{rec}}{2})R$$

$$R_{IF} = (\frac{0.36}{2}) 40$$

$$R_{IF} = 7.2 \text{ kgmm}$$



$$4 \times (\frac{M_{rot}}{2} + \frac{M_{rec}}{2}) R$$

$$4 \times (\frac{0.24}{2} + \frac{0.36}{2}) 40$$

$$= 67.2 \text{ kgmm}$$

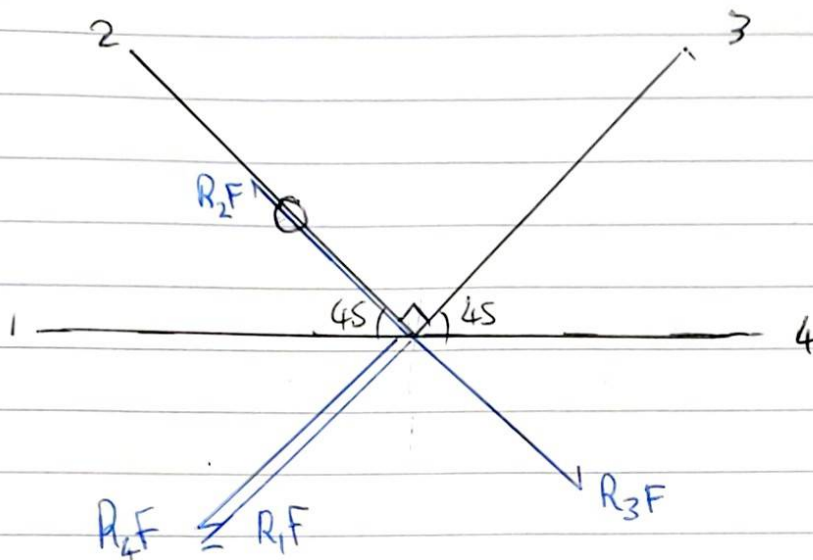
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2D)



$$M_{rot} = 0.24$$

$$M_{rec} = 0.36$$

$$r = 40$$

$$L = 140$$

$$\left(\frac{M_{rec}}{2} \right) R$$

resolve vertically:

$$\cancel{R_2 F \cos 45} - \cancel{R_3 F \cos 45}$$
$$\cancel{\left(\frac{0.36}{2} \right) 40 \cos 45} - \cancel{\left(\frac{0.36}{2} \right) 40 \cos 45}$$

$$\downarrow (R_4 F \cos 45) + (R_1 F \cos 45) + (R_3 F \cos 45) - \uparrow (R_2 F \cos 45)$$

$$\left(\left(\frac{0.36}{2} \right) 40 \times \cos 45 + \text{"} + \text{"} \right) - \left(\left(\frac{0.36}{2} \right) 40 \times \cos 45 \right)$$

$$(5.09 + 5.09 + 5.09) - (5.09)$$

$$(15.27) - (5.09)$$

$$= 10.18 \text{ kg mm}$$



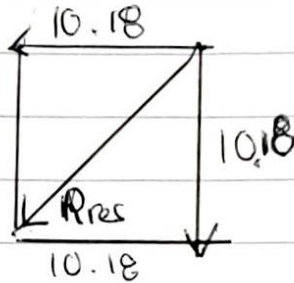
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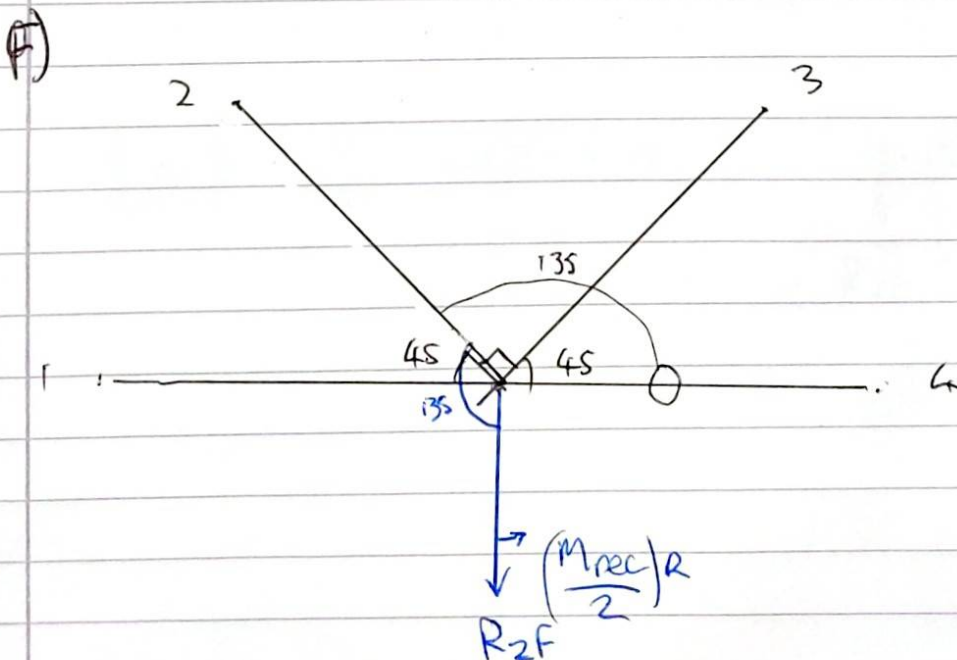
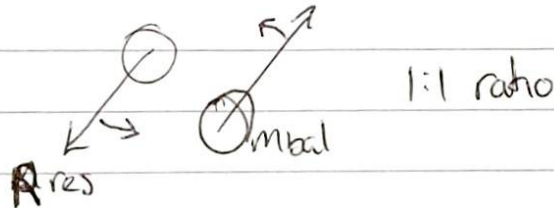
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2D cont



$$R_{res} = \sqrt{10.18^2 + 10.18^2}$$
$$= \underline{\underline{14.397 \text{ kg mm}}}$$

- e) to balance the R_{res} , use a balance shaft rotating counter clockwise at the same magnitude to R_{res} in the opposite direction at same speed
eg:



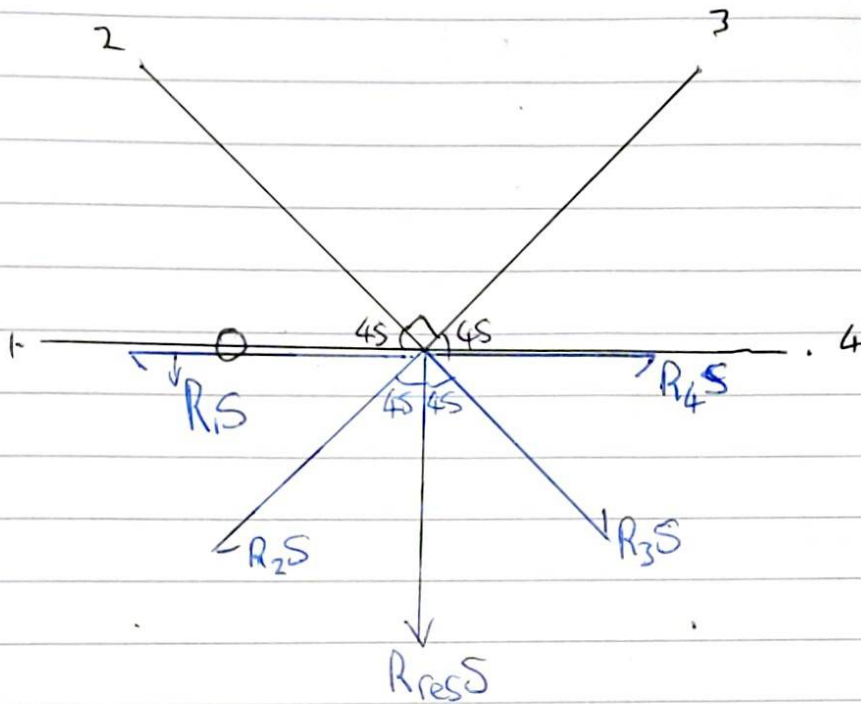
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g)



$$\frac{1}{2} \frac{R}{L} (m_{rec}) R \cos 45 + \frac{1}{2} \frac{R}{L} (m_{rec}) R = R_{res} S$$

$$\cancel{\frac{1}{2} \frac{R}{L} (m_{rec}) R} \frac{1}{2} \left(\frac{40}{140} \right) 40 \times \cos 45 + \frac{1}{2} \left(\frac{40}{140} \right) 40 \times \cos 45 = R_{res} S$$

$$4.04 + 4.04 = R_{res} S$$

$$R_{res} = \underline{8.08 \text{ kg mm}}$$

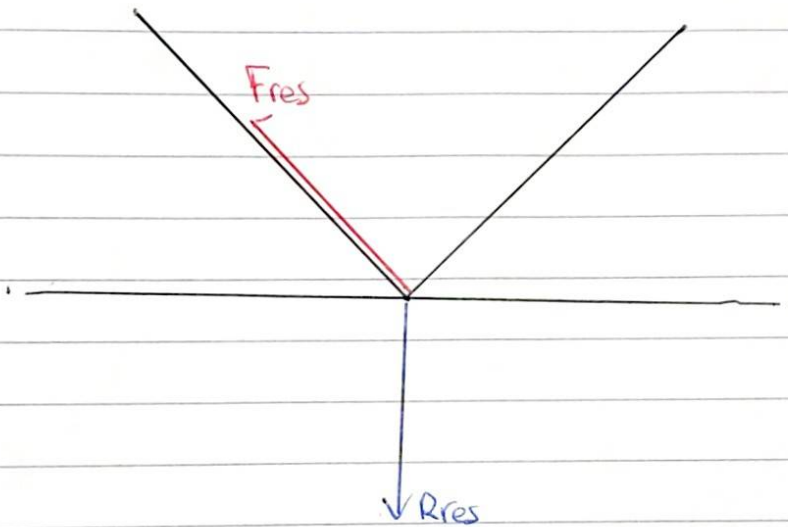
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1) $F_i = 16.8$ $F_{res} = \underline{67.2}$
 $R_{res} = \underline{80.8}$



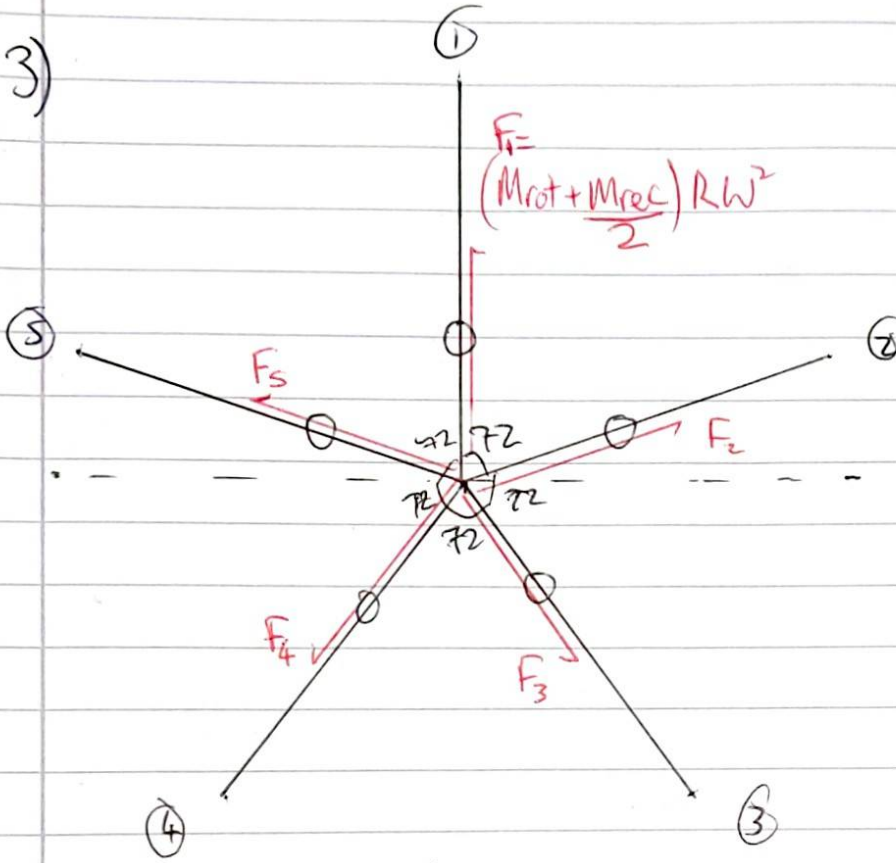
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3)



$$M_{\text{rec}} = \frac{1}{3}(270) + 240$$
$$= 0.33 \text{ kg}$$

$$M_{\text{rot}} = \frac{2}{3} (270) = 0.180$$

$$R = 42.5 \text{ mm}$$

$L = 140$

$$A) F_m = (m_{rot} + \frac{m_{ec}}{2}) R$$

$$= (0.180 + \frac{0.33}{2}) (42.5$$

$$F_m = 0.345 \times 42.5$$

$$F_m = \underline{14.66 \text{ Kg mm}}$$



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b) $m_{\text{crank}} = 3 \text{ kg}$



$$m_{\text{crank}} x = 14.66$$

$$3 x = \frac{14.66}{3}$$

$$x = 4.88 \text{ mm}$$