

Owan Lyndon Lord

M62000410

P150216

1.00pm

14/05/2020

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Advanced Engine Design

Q1

$$\begin{aligned} a) M_{rec} &= \frac{1}{3} r_{rod} + P_{shn} \\ &= \frac{1}{3} (0.33) + 0.24 \\ &= 0.35 \text{ kg} \times 2 = 0.7 \text{ kg} \end{aligned}$$

$$\begin{aligned} M_{rot} &= \frac{2}{3} r_{rod} + 6 \text{ clear shes 915} \\ &= \frac{2}{3} (6.33) + 0.62 \\ &= 0.24 \text{ kg} \times 2 = 0.48 \text{ kg} \end{aligned}$$

$$P_{shn} = 240 \text{ g}$$

$$C_{on} = 330 \text{ g}$$

$$BEB = 20 \text{ g}$$

$$\text{Stroke} = 90 \text{ mm}$$

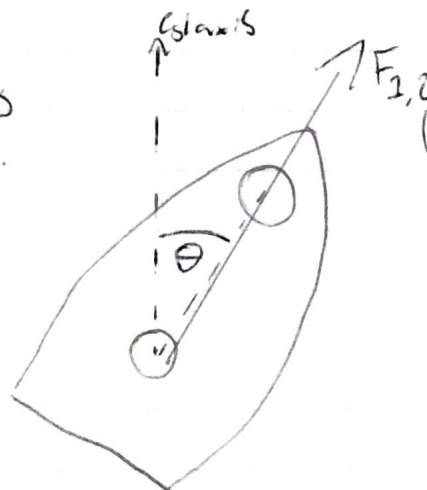
$$= 0.09 \text{ m}$$

$$M_{crank} = 5.0 \text{ kg}$$

$$C_{en L} = 140 \text{ mm}$$

$$= 0.14 \text{ m}$$

Forward 1st order
along axis along
Crank Pin axis.



$$\begin{aligned} R &= \frac{\text{Stroke}}{2} \\ &= 0.045 \text{ m} \\ (M_{rot} + \frac{M_{rec}}{2}) R^2 &= 45 \text{ mm} \end{aligned}$$

$$\text{Total Forward 1st M-SS Moment} = (M_{rot} + \frac{M_{rec}}{2}) R^2$$

$$\begin{aligned} &= (0.48 + \frac{0.7}{2}) 45 \\ &= 18.675 \text{ kg} \cdot \text{mm} = 37.35 \text{ kg} \cdot \text{mm} \end{aligned}$$

$$\begin{aligned} M_{crank} &= 5 \text{ kg} \\ M_{rod} &= 18.675 \text{ kg} \cdot \text{mm} \end{aligned}$$

$$\begin{aligned} \text{Total 1st order balance moment} &= (M_{rot} + \frac{M_{rec}}{2}) R^2 \\ &= 37.35 \text{ kg} \cdot \text{mm} \end{aligned}$$

$$\begin{aligned} M_{crank} &= 5 \text{ kg} \\ M_{rod} &= 18.675 \text{ kg} \cdot \text{mm} \end{aligned}$$

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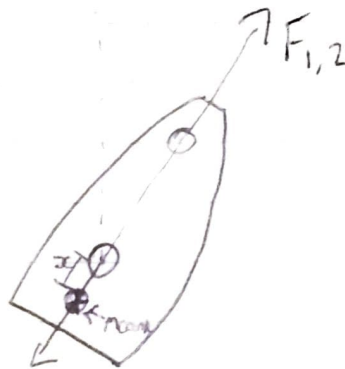
Q1) b) To Fully balance 1st order Forward on crank:

$$M_{crank} x = (m_{rot} + \frac{m_{rec}}{2}) R \omega^2$$

x = offset for
Crank mass
For balance

$$\therefore x = \frac{(m_{crank})}{(m_{rot} + \frac{m_{rec}}{2}) R}$$

$$\frac{18.675}{3.739} = \frac{37.35}{5} = \underline{7.47mm}$$

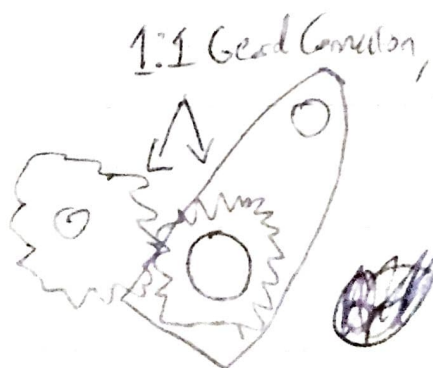


c) Reverse 1st order = $(\frac{m_{rec}}{2}) R \omega^2$

$$= (\frac{0.7}{2}) 45$$

$$= \underline{15.75 \text{ kg.m}}$$

d)



direct shaft balance shaft
turns 100% engine speed, counter
rotating.

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Q1

e) To balance 1st Reverse Make:

$$M_{bal} y_G = \left(\frac{m_{rec}}{2} \right) R_{up}$$

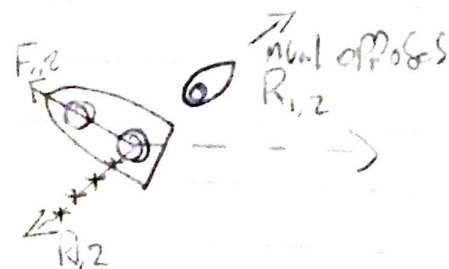
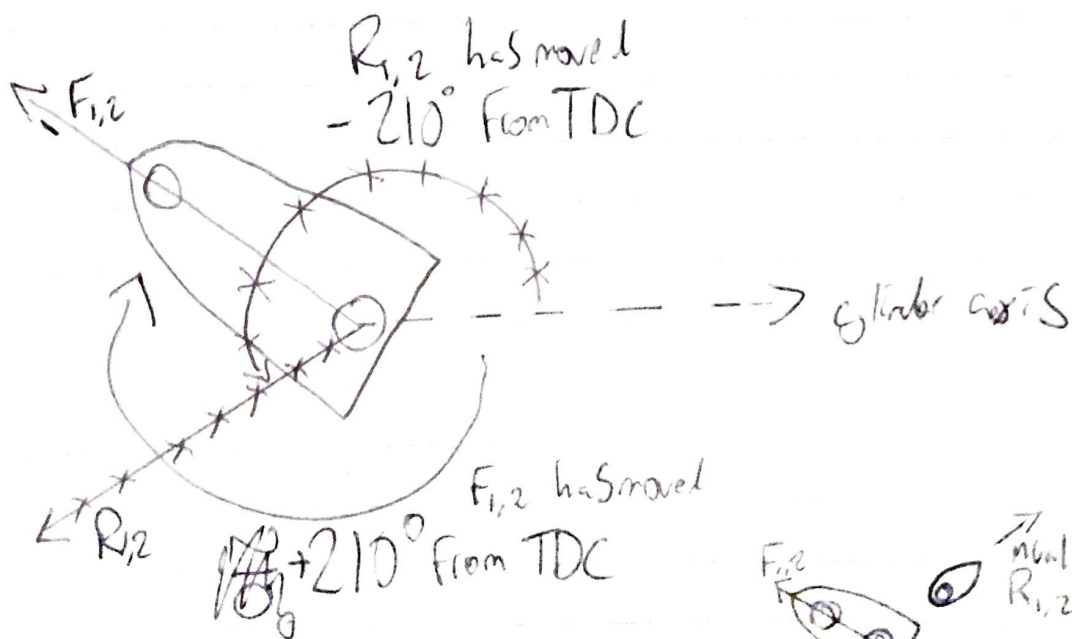
y = offset
for balance
shaft

$$\therefore y = \frac{M_{bal} \left(\frac{m_{rec}}{2} \right) R}{M_{bal}}$$

$$b = \frac{15.75}{2.5}$$

$$y = \underline{\underline{6.3 \text{ mm}}}$$

f)

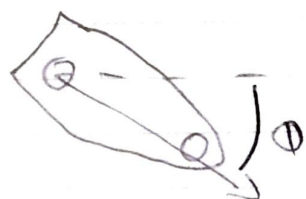


$\therefore \theta_{Mbal}$ would be pointed
at +330° From TDC

Q₁ g) To move Vibrations into the HORIZONTAL
Fully (Along the cylinder axis in this case)
the crank would nulllobe

"Under Balanced" :

* Horizontal Forces
Can be minimised
by engine markings
and aren't usually
felt by the operator



Horizontal
Cylinder axis

$$M_{crank} \propto \omega^2 = M_{rot} R \omega^2$$

$$\therefore M_{crank} \propto = (0.48) 45$$

$$M_{crank} = 21.6 \text{ kg.m}$$

h) Second Order Can only be removed with shafts
rotating double engine speed due to
second order force vectors moving at 2θ

Drive the balance
shafts 2:1

off the crank
with gears.

Each shaft must
be "clocked" to

the crank at TDC

during installation to ensure they cancel at 2θ exactly

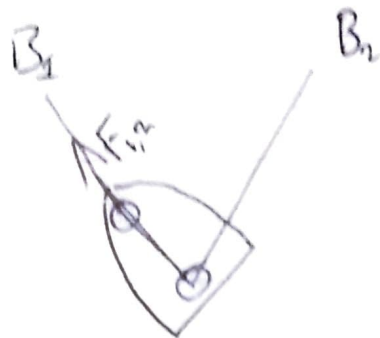
$$4 m_{bal} \omega^2 = \frac{1}{2} R \omega^2 m_{crank}$$

$$\therefore m_{bal} = \frac{1}{8} \frac{R}{L} m_{crank}$$

$$m_{bal} = \frac{1}{8} \frac{45}{140} (0.7) 45$$

$$m_{bal} = 1.266 \text{ kg.m}$$

Q2 a)

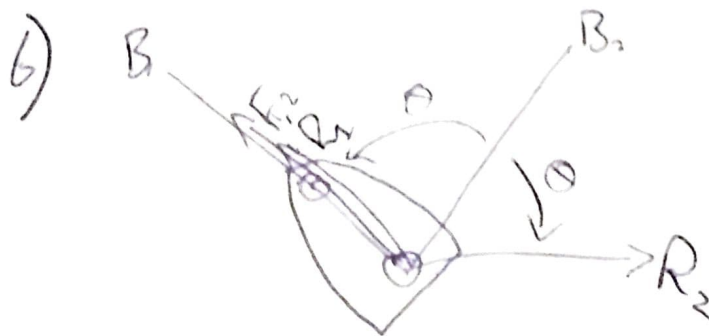


$$F_1 = F_2 \quad F_{12} = (m r \omega + \frac{m r \omega^2}{2}) R$$

MM resultant for 1st order vector =

$$= 2 \left(0.48 + \frac{0.72}{2} \right) 40$$

$$= \underline{\underline{67.2 \text{ kNm}}}$$



$$\theta = 60^\circ$$

$$R_1 = R_2 = \left(\frac{m r \omega^2}{2} \right) R$$

Resultant Residual vector =

$$= \frac{m r \omega^2}{2} R \cos 60^\circ + \frac{m r \omega^2}{2} R \cos 60^\circ$$

$$= \frac{m r \omega^2}{2} R \cdot 0.5 + \frac{m r \omega^2}{2} R \cdot 0.5$$

$$= \frac{m r \omega^2}{2} R + \frac{m r \omega^2}{2} R$$

$$= m r \omega^2 R$$

$$= 0.72 \times 40 = \underline{\underline{28.8 \text{ kNm}}}$$

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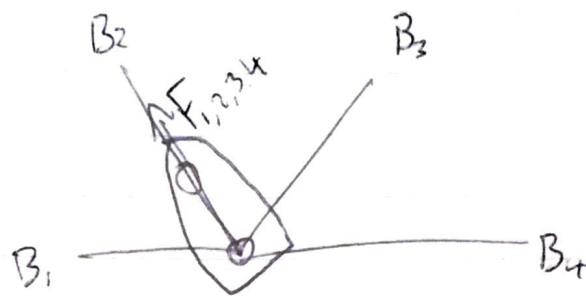
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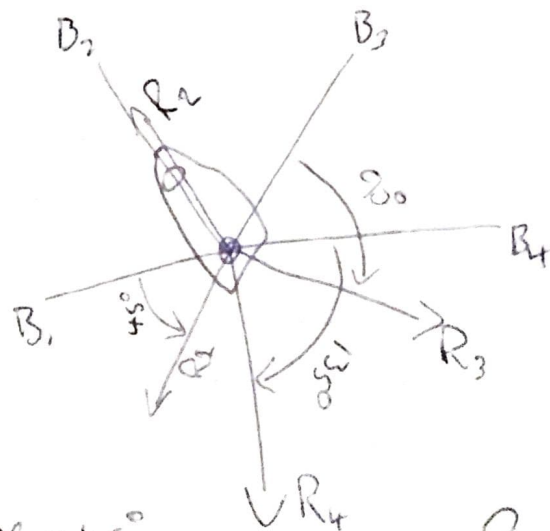
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c)



$$\begin{aligned}
 1^{st} \text{ Forward Mass moment along bank 2} &= 4 \left(\left(m_{rot} + \frac{m_{rec}}{2} \right) R \right) \\
 &= 4 \left(\left(0.96 + \frac{1.44}{2} \right) 40 \right) \\
 &= \underline{\underline{268.8 \text{ kg.m}}}
 \end{aligned}$$

d)



$$R_1 = B_1 \text{ TDC} - 45^\circ$$

$$R_2 = B_2 \text{ TDC}$$

$$R_3 = B_3 \text{ TDC} + 90^\circ$$

$$R_4 = B_4 \text{ TDC} + 135^\circ$$

Mass moment

$$= 1.414 \left(\frac{m_{rec}}{2} \right) R$$

$$= 28.8 \times 1.414$$

$$= \underline{\underline{40.72 \text{ kg.m}}}$$

$$R_3 - R_2 + R_1 \sin 45 + R_4 \sin 135$$

$$= R - R + R \frac{\sqrt{2}}{2} + R \frac{\sqrt{2}}{2}$$

$$= R \frac{\sqrt{2}}{2} + R \frac{\sqrt{2}}{2}$$

$$= R \sqrt{2}$$

$$= \underline{\underline{1.414 R \text{ Down}}}$$

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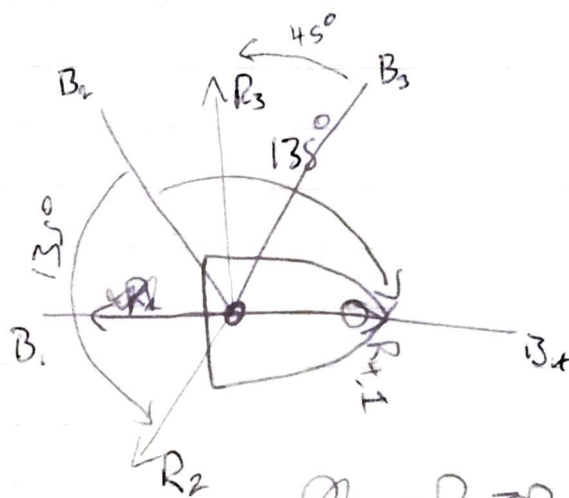
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Q₂

- e) Balance First order Forces on crank using offset CG
Balance Resultant Reverse First order with
Crank rotating shaft

f)



Resultant Reverse along Bank 2

g)

Q3

Part 1

$$a) \left(m_{rot} + \frac{m_{rec}}{2} \right) R_{ax} = 1^{st} Forward$$

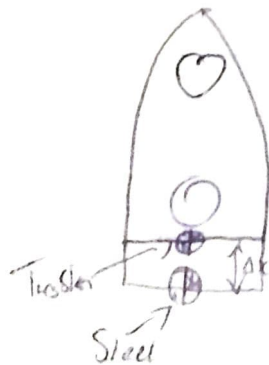
$$= \left(0.18 + \frac{0.33}{2} \right) 425 = \underline{14.66 \text{ kg} \cdot \text{mm}}$$

~~$$b) 2.5 \times m_{comp} L_{HCS} = 7.5 \text{ kg} \cdot \text{mm}$$

$$\therefore x = \frac{14.66}{7.5} = \underline{1.955 \text{ mm}}$$~~

$$x = \frac{14.66}{3} = 4.89 \text{ mm}$$

c)



Tungsten is significantly denser than steel

Due to the increased density of tungsten it can have a smaller offset compared to steel

So, if $M_{tung} = 2m_{steel}$
For same balance

$$\underline{\underline{x_{tung} = 0.5 x_{steel}}}$$

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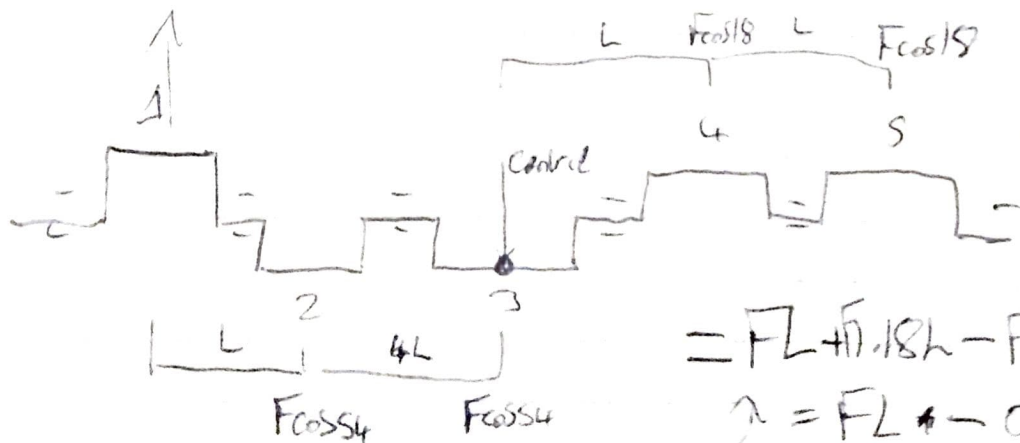
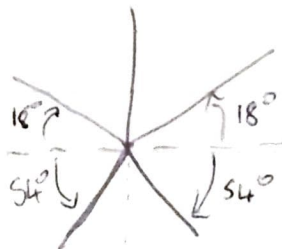
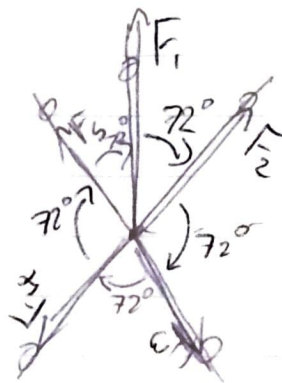
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Q4

Part 2

a) First order mass moments along crank pins



$$= FL + 11.18L - F1.94L$$

$$= FL - 0.72FL$$

$$= 0.28FL$$

$$FL + F \cos 54L + F \cos 54L + F \cos 18L + F \cos 18L$$

$$FL + F0.59L + F0.59L + F0.94L + F0.94L$$

$$= FL + 1.18FL - F1.94L = 0.28FL$$

Answer = 0.28 L

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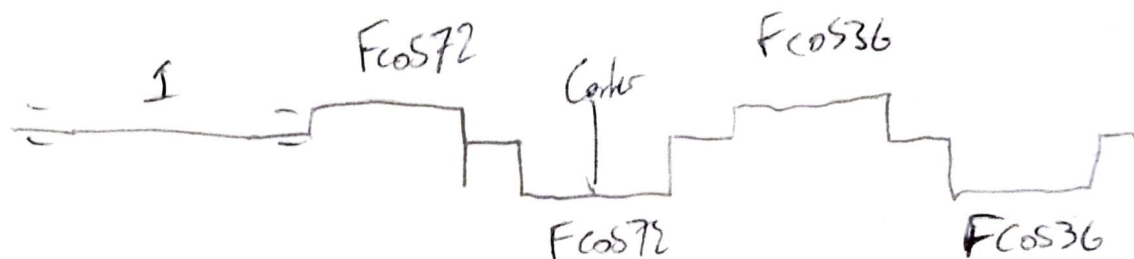
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Q4

a) cont)



$$= \cancel{F \cos 72} - F \cos 72 - F \cos 36 + F \cos 36$$

$$= 0.31 - 0.31 - 0.81 + 0.81$$

$$= M_{\perp} = 0 \therefore 0.28 FL$$

$\therefore$

Resultant

$$= \sqrt{M_{\parallel}^2 + M_{\perp}^2}$$

$$= \sqrt{0.28^2 + 0^2}$$

$$= \sqrt{0.0784 + 0}$$

$$= \sqrt{0.0784}$$

$$= 0.28 \text{ kg} \cdot \text{m} \cdot \text{s}^{-2}$$

0.28x