

DATE: 14 May 2020

TIME: 1:00 PM

MODULE: Advanced Engine Design (M6X00410)

STUDENT NAME: António Maria Paquete Januário

STUDENT NUMBER: 1805566

1 / 9

QUESTION 1

500cc -TWIN CYLINDER

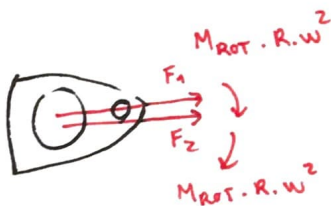


$$\begin{aligned} M_{\text{PISTON}} &= 0,24 \text{ kg} & M_{\text{BEARING}} &= 0,02 \text{ kg} & M_{\text{CRANK}} &= 5,0 \text{ kg} \\ M_{\text{CONROD}} &= 0,33 \text{ kg} & R &= 90/2 = 45 \text{ mm} & L &= 140 \text{ mm} \end{aligned}$$

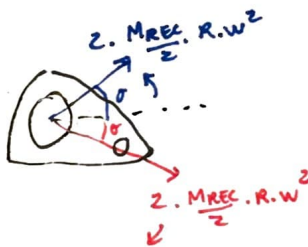
$$a) \quad M_{\text{ROT}} = \frac{2}{3} M_{\text{CONROD}} + M_{\text{BEARING}} = \frac{2}{3} 0,33 + 0,02 = 0,24 \text{ kg}$$

$$M_{\text{REC}} = \frac{1}{3} M_{\text{CONROD}} + M_{\text{PISTON}} = \frac{1}{3} 0,33 + 0,24 = 0,35 \text{ kg}$$

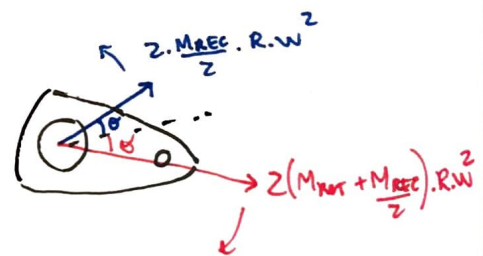
ROTATING FORCES



RECROCATING FORCES

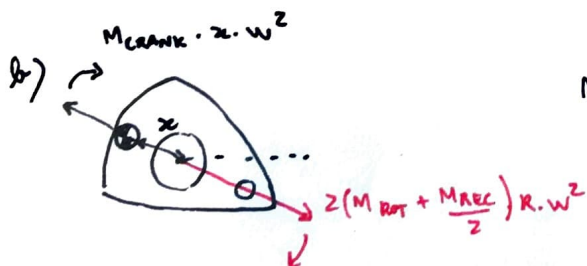


TOTAL FORCES



$\therefore$ TOTAL MASS MOMENT OF THE RESULTANT FIRST ORDER FORWARD ROTATING VECTOR:

$$MM_{\text{1st ORDER FORWARD}} = 2 \left(M_{\text{ROT}} + \frac{M_{\text{REC}}}{2} \right) \cdot R = 2 \left(0,24 + \frac{0,35}{2} \right) \cdot 45 = 37,35 \text{ kg} \cdot \text{mm}$$



$$M_{\text{CRANK}} \cdot x \cdot w^2 = 2 \left(M_{\text{ROT}} + \frac{M_{\text{REC}}}{2} \right) \cdot R \cdot w^2$$

$$5 \cdot x = 37,35$$

$$x = 7,47 \text{ mm}$$

$\therefore$ AN OFFSET CENTRE OF GRAVITY CRANK CREATES A BALANCING CENTRIFUGAL FORCE AS SHOWN ABOVE

DATE: 14 May 2020

TIME: 1:00 PM

MODULE: Advanced Engine Design (M6X00410)

STUDENT NAME: António Maria Paquete Januário

STUDENT NUMBER: 1805566

2/9

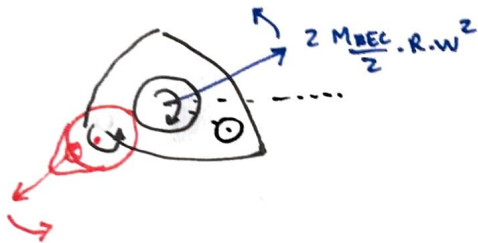
QUESTION 1

c)

$$M_{\text{1st ORDER REVERSE}} = 2 \cdot \frac{M_{\text{REL}}}{2} \cdot R = 2 \cdot \frac{0,35}{2} \cdot 45 = 15,75 \text{ Kg} \cdot \text{mm}$$

d)

I WOULD DRIVE THE BALANCE SHAFT USING A GEAR OF SAME DIAMETER, ROTATING CLOCK WISE AT THE SAME SPEED.



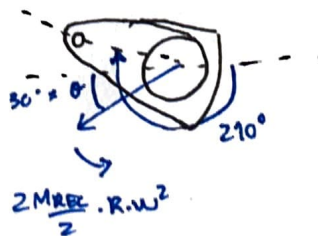
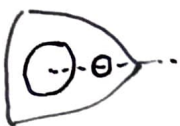
e)

$$M_{\text{BALANCE SHAFT}} \cdot y = 2 \frac{M_{\text{REL}}}{2} \cdot R \Leftrightarrow y = \frac{15,75}{2,5} = 6,3 \text{ mm}$$

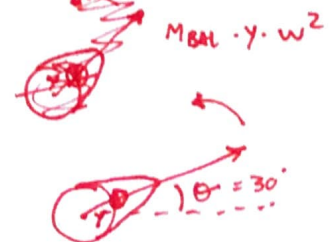
f)

TDC

→ AFTER 210°



BALANCE SHAFT ECCENTRIC POINTING:



DATE: 14 May 2020

TIME: 1:00 PM

MODULE: Advanced Engine Design (M6X00410)

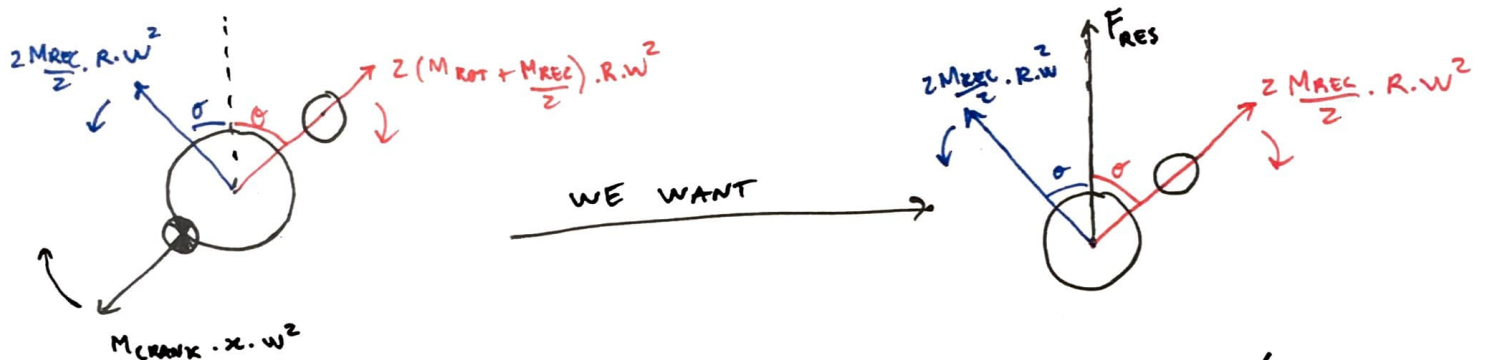
STUDENT NAME: António Maria Paquete Januário

STUDENT NUMBER: 1805566

3/9

QUESTION 1

g) IF NO BALANCE SHAFT IS USED, THE CRANK BALANCE SHOULD ELIMINATE ALL HORIZONTAL VIBRATIONS, BECAUSE IT IS A HORIZONTALLY MOUNTED ENGINE

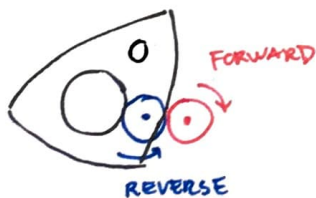


$$M_{CRANK} \cdot x \cdot \omega^2 - 2 \left(M_{ROT} + \frac{M_{REC}}{2} \right) \cdot R \cdot \omega^2 = 2 \frac{M_{REC}}{2} \cdot R \cdot \omega^2$$

$$M_{CRANK} \cdot x = 2 M_{ROT} \cdot R = 2 \cdot 0,24 \times 45 = 21,6 \text{ kg} \cdot \text{mm}$$

$$MM_{CRANK} = 25,92 \text{ kg} \cdot \text{mm}$$

h)



IT WOULD BE IMPLEMENTED WITH GEARS WITH HALF OF THE CRANKSHAFT DIAMETER ROTATING AT DOUBLE THE SPEED.

$$2 \cdot \left(\frac{1}{2} \frac{R}{L} \cdot M_{REC} \cdot R \omega^2 \right) = M_{BALANCE} \cdot y \cdot (2\omega)^2$$

$$\frac{R}{L} \cdot M_{REC} \cdot R = \left(M_{BALANCE} \cdot y \right) 4$$

MASS MOMENT EACH BALANCE SHAFT

$$MM_{BALANCE \text{ SHAFT}} = \frac{R}{4L} \cdot M_{REC} \cdot R$$

$$MM_{BS} = \frac{45}{4 \times 140} \times 0,35 \times 45 = 1,27 \text{ kg} \cdot \text{mm}$$

FOR EACH BALANCE SHAFT

DATE: 14 May 2020

TIME: 1:00 PM

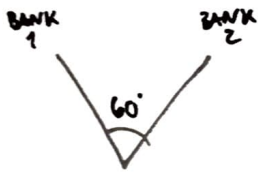
MODULE: Advanced Engine Design (M6X00410)

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STUDENT NUMBER: 1805566

4/9

QUESTION 2



• COMMON CRANKPIN

$$M_{\text{PISTON}} = 0,24 \text{ kg}$$

$$R = \frac{80}{2} = 40 \text{ mm}$$

$$M_{\text{ROT}} = \frac{2}{3} M_{\text{CONROD}} = 0,24 \text{ kg}$$

$$M_{\text{CONROD}} = 0,36 \text{ kg}$$

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

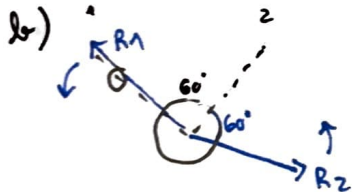
$$M_{\text{REC}} = \frac{1}{3} M_{\text{CONROD}} + M_{\text{PISTON}} = 0,36 \text{ kg}$$



$$F_1 = F_2 = (M_{\text{ROT}} + \frac{M_{\text{REC}}}{2}) \cdot R \cdot \omega^2$$

MM
RESULTANT
1st ORDER
FORWARD

$$= 2 (M_{\text{ROT}} + \frac{M_{\text{REC}}}{2}) \cdot R = 2 (0,24 + \frac{0,36}{2}) \times 40 = 33,6 \text{ kg} \cdot \text{mm}$$

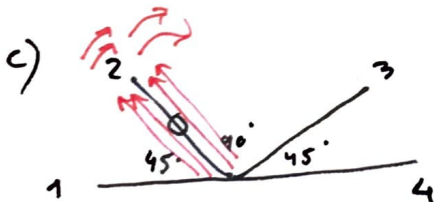


$$R_{\text{RESULTANT}} = R_1 \cos 60 + R_2 \cos 60$$

$$R_{\text{RESULTANT}} = M_{\text{REC}} \cdot R \cdot \omega^2 \cdot \cos 60$$

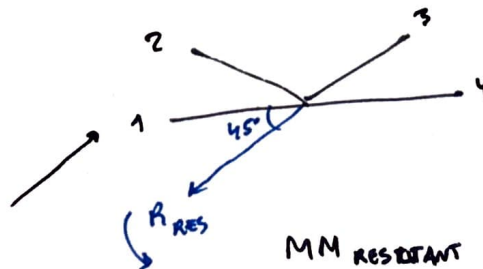
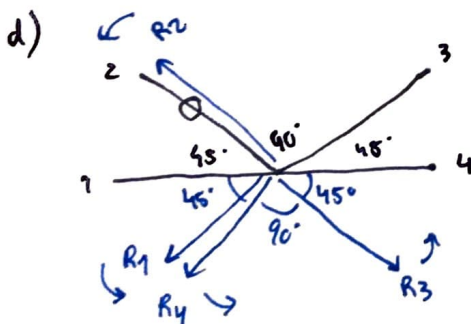
$$MM_{\text{RESULTANT}} = M_{\text{REC}} \cdot R \cdot \cos 60 = \frac{1}{2} 0,36 \times 40 = 7,2 \text{ kg} \cdot \text{mm}$$

1st ORDER
REVERSE



$$MM_R = 4 (M_{\text{ROT}} + \frac{M_{\text{REC}}}{2}) \cdot R = 4 (0,24 + \frac{0,36}{2}) \cdot 40 = 67,2 \text{ kg} \cdot \text{mm}$$

1st ORDER
FORWARD



$$MM_{\text{RESULTANT}} = 2 \frac{M_{\text{REC}}}{2} \cdot R =$$

1st ORDER
REVERSE

$$= 2 \frac{0,36}{2} \cdot 40 = 14,4 \text{ kg} \cdot \text{mm}$$

DATE: 14 May 2020

TIME: 1:00 PM

MODULE: Advanced Engine Design (M6X00410)

STUDENT NAME: António Maria Paquete Januário

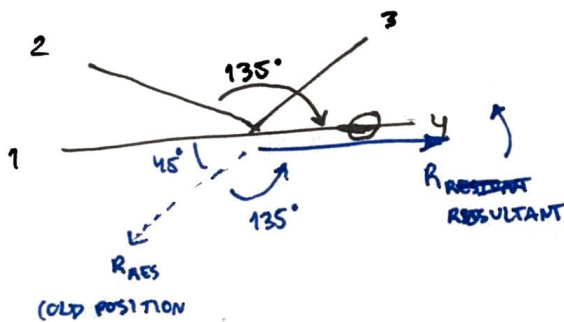
STUDENT NUMBER: 1805566

5/9

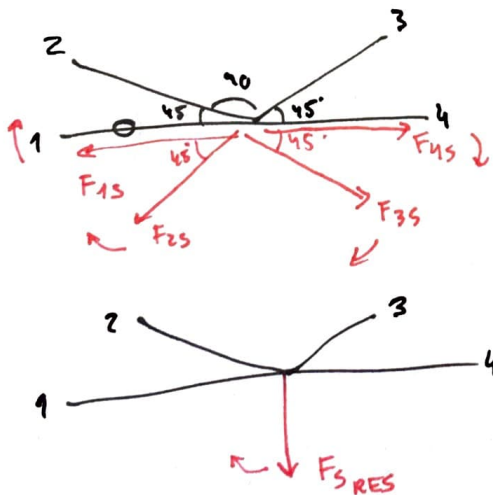
QUESTION 2

- 2) . THE FIRST ORDER FORWARD WOULD BE BALANCED WITH A CRAWSHAFT WITH AN OFFSET CG
- . THE REVERSE ROTATING FORCES WITH A COUNTER-ROTATING BALANCE SHAFT

f)



g)



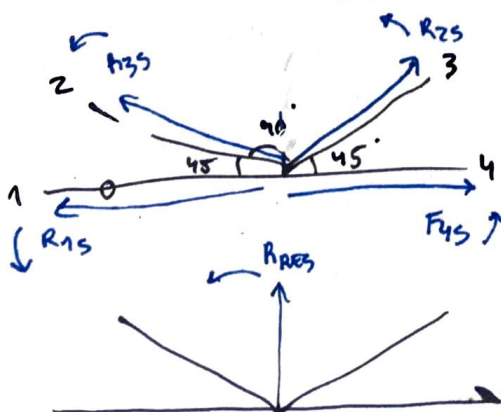
$$MM_{2nd \text{ ORDER}} = 2 (F_S \sin 45^\circ) =$$

$$= 2 \left(\frac{1}{2} \frac{R}{L} M_{REC} \cdot R \cdot \sin 45^\circ \right) =$$

$$= 2 \left(\frac{1}{2} \frac{40}{140} \cdot 0,36 \times 40 \times \sin 45^\circ \right) =$$

$$= 2,9 \text{ Kg} \cdot \text{mm}$$

h)



$$MM_{2nd \text{ ORDER REVERSE}} = 2 (R_S \sin 45^\circ) =$$

$$= 2,9 \text{ Kg} \cdot \text{mm}$$

DATE: 14 May 2020

TIME: 1:00 PM

MODULE: Advanced Engine Design (M6X00410)

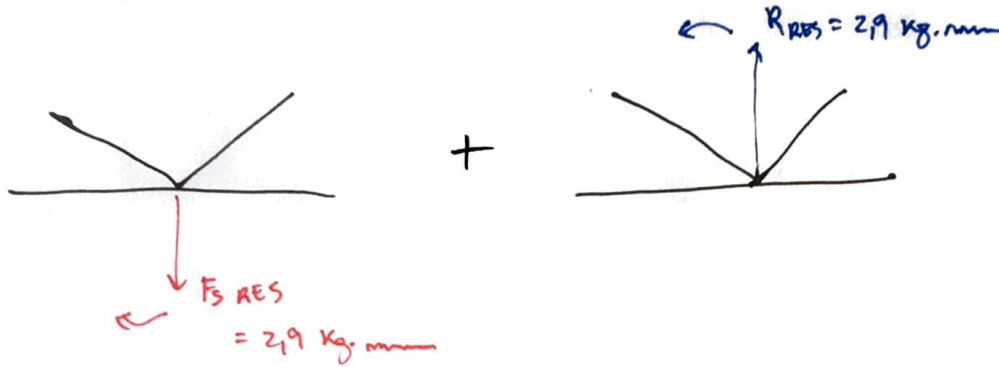
STUDENT NAME: António Maria Paquete Januário

STUDENT NUMBER: 1805566

6/9

QUESTION 2

i)



∴ THE TOTAL RESULTANT 2nd ORDER FORCE IS EQUAL TO ZERO!

DATE: 14 May 2020

TIME: 1:00 PM

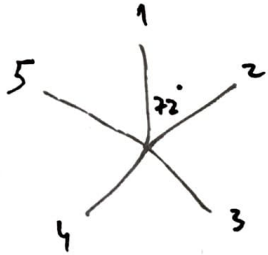
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STUDENT NAME: António Maria Paquete Januário

STUDENT NUMBER: 1805566

7/9

QUESTION ~~FOUR~~ 3



$$M_{\text{PISTON}} = 0,24 \text{ kg}$$

$$L_{\text{CENTERS}} = 92 \text{ mm}$$

$$M_{\text{CONROD}} = 0,27 \text{ kg}$$

$$M_{\text{ROT}} = \frac{2}{3} M_{\text{CONROD}} = 0,18 \text{ kg}$$

$$R = \frac{85}{2} = 42,5 \text{ mm}$$

$$M_{\text{REC}} = \frac{1}{3} M_{\text{CONROD}} + M_{\text{PISTON}} = 0,33 \text{ kg}$$

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

PART 1

a)

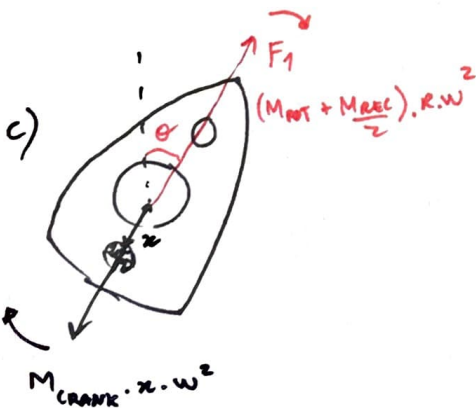
$$MM_{\text{1ST ORDER EACH}} = (M_{\text{ROT}} + \frac{M_{\text{REC}}}{2}) \cdot R = (0,18 + \frac{0,33}{2}) \cdot 42,5 = 14,66 \text{ kg} \cdot \text{mm}$$

b)

$$M_{\text{CRANKSPAN}} = 3,0 \text{ kg}$$

$$\text{FOR 100\% BALANCE } M_{\text{CRANKSPAN}} \cdot x = (M_{\text{ROT}} + \frac{M_{\text{REC}}}{2}) \cdot R$$

$$x = \frac{14,66}{3,0} \approx 4,9 \text{ mm}$$



∴ DENSITY OF TUNGSTEN IS 2X SUPERIOR THAN STEEL,
MEANS MASS OF TUNGSTEN 2X SUPERIOR THAN STEEL!
FOR THE SAME MASS MOMENT:

$$M_{\text{CRANK TUNGSTEN}} \cdot x_1 = 2 M_{\text{CRANK STEEL}} \cdot x_2$$

$$\Rightarrow x_1 = \frac{x_2}{2}$$

BECAUSE CRANK OF TUNGSTEN NEEDS SMALLER OFFSET
THE MOMENT OF INERTIA IS INFERIOR:

$$\text{MOMENT OF INERTIA} = M \cdot x^2$$

→ EQUALS BETTER ACCELERATION!

DATE: 14 May 2020

TIME: 1:00 PM

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STUDENT NUMBER: 1805566

QUESTION 3

PART 2

50% BALANCE

a)

$$F = 0,5 \left(M_{ROT} + \frac{M_{REC}}{2} \right) \cdot R \cdot \omega^2$$

$$MM_{\text{rotation}} = 0,5 \left(0,18 + \frac{0,33}{2} \right) \cdot 42,5 = 7,33 \text{ Kg} \cdot \text{mm}$$



$$F_1 = F_2 = F_3 = F_4 = F_5$$

VERTICALLY

$$F_1 + F_2 \cos 72 + F_5 \cos 72 = F_3 \cos \left(\frac{72}{2} \right) + F_4 \cos \left(\frac{72}{2} \right)$$

$$F_1 + 2 F_1 \cos 72 = 2 F_1 \cos 36$$

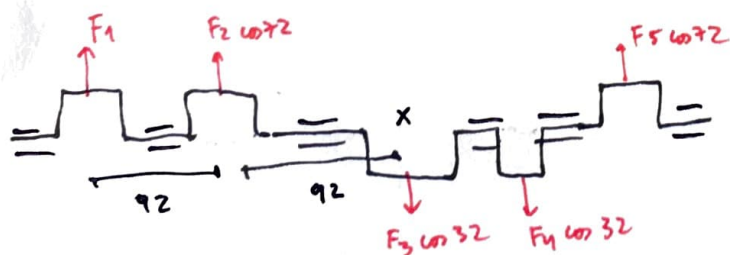
$$1,62 F_1 = 1,62 F_1 \rightarrow 0$$

HORIZONTALLY

$$F_5 \cos 32 + F_4 \cos 32 = F_2 \cos 32 + F_3 \cos 32$$

$$2 F_1 \cos(32) = 2 F_1 \cos(32) \rightarrow 0$$

LOCK SIDWAYS IN PLANE OF PIN //



MM AROUND CENTER

$$= F(2L) + F \cos 72 L + F \cos 32 \cdot F(2L) \cos 72$$

$$= (2F + 0,31 F + 0,85 - 0,62 F) L =$$

$$= 2,54 FL$$

$$= 2,54 \times 7,33 \times 92 = 1712,9 \text{ Kg} \cdot \text{mm}^2$$

↓ NEXT PAGE CONTINUES

DATE: 14 MAY 2020

9/9

TIME: 1:00 PM

MODULE: ADVANCED ENGINE DESIGN (M6X00470)

NAME: ANTÓNIO JANUÁRIO

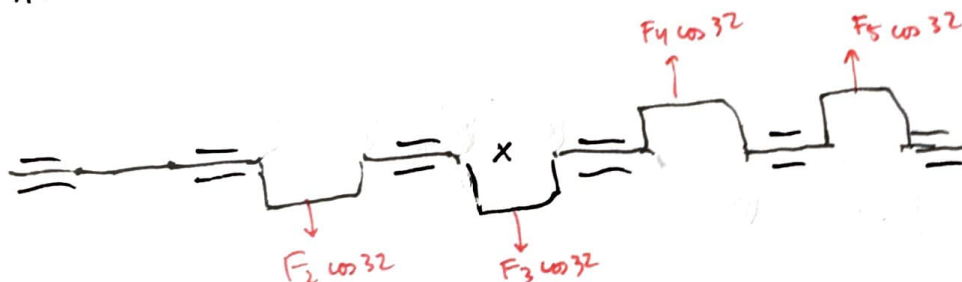
NUMBER: 180 5566

QUESTION 3

PART 2

a) CONTINUATION

AT RIGHT ANGLES TO PLANE $\perp$ OF PIN 1

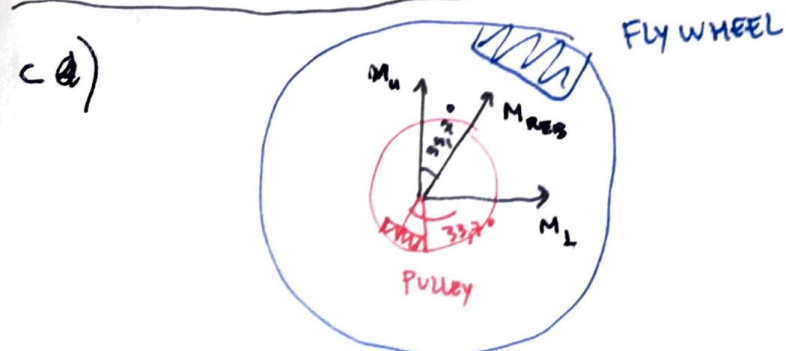


MM AROUND CENTER = (ANTI CLOCKWISE)

$$= F \cos 32 (2L) = 7,33 \times \cos 32 \times 2 \times 92 = 1143,8 \text{ Kg} \cdot \text{mm}^2$$

$$M_{RES} = \sqrt{M_L^2 + M_H^2} = \sqrt{1792,9^2 + 1143,8^2} = 2059,7 \text{ Kg} \cdot \text{mm}^2$$

b)  $\alpha = \tan^{-1} \left(\frac{M_L}{M_H} \right) = 33,7^\circ$



d) $MM_{FLYWHEEL} \cdot 480 = M_{RES}$

$$MM_{FLYWHEEL} = \frac{2059,7}{480} = 4,3 \text{ Kg} \cdot \text{mm}$$