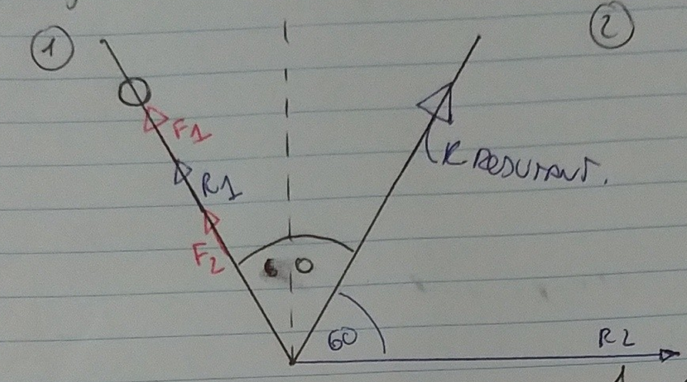
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Q2)

PISTON = 240 g = 0,24 kg
CONROD = 0,36 kg

STROKE = 80 mm $R = \frac{80}{2} = 40$ mm
l = C. LENGTH = 140

a)



$\underline{M_{VEC}}$ = PISTON + PIN + $\frac{1}{3}$ rod = $0,24 + \frac{1}{3} \cdot 0,36 = 0,36$ kg

$M_{ROT} = \frac{2}{3}$ conrod = $\frac{2}{3} \cdot 0,36 = 0,24$ kg

2) => FORWARD MAGNITUDE.

$F_{TOT} = 2\left(M_{ROT} + \frac{M_{EC}}{2}\right) \cdot R = 2\left(0,24 + \frac{0,36}{2}\right) \cdot 40$ (16,8)

$= 33,6$ kg·mm

b) R RESULTANT, is along BANK (2) (look. SKETCH ABOVE)

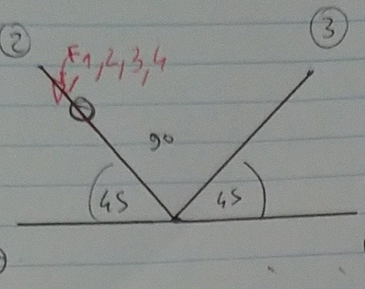
$R_{RESULT} = R_1 \cdot \cos(60) + R_2 \cdot \cos(60)$ $R_1 = R_2 = R$

$R = \frac{M_{VEC}}{2} \cdot R\omega^2 \Rightarrow \frac{0,36}{2} \cdot (40) = 7,2$

↳ $R_{RESULTANT} = 7,2 \cdot \left(\frac{1}{2}\right) + 7,2 \cdot \left(\frac{1}{2}\right) = 7,2$ kg·mm

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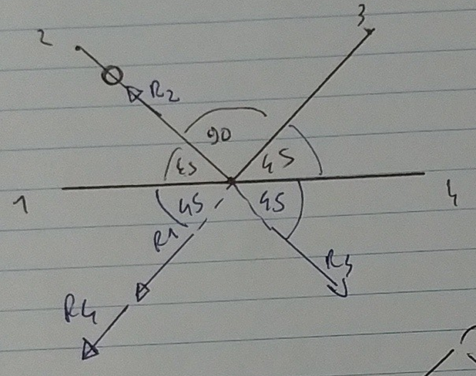
c)



$F_{TOT} = resultat = 4 \cdot F = 4 \cdot \left(M_{TOT} + \frac{M_{rec}}{2}\right) \cdot R$ (ω²)

$= 4 \left(16,8\right) \cdot \omega^2 = 67,2$ kg·mm

d)



$R_2 = R_3$ opposite — SIMMETRIC $R_2 - R_3 = 0$ they cancell.

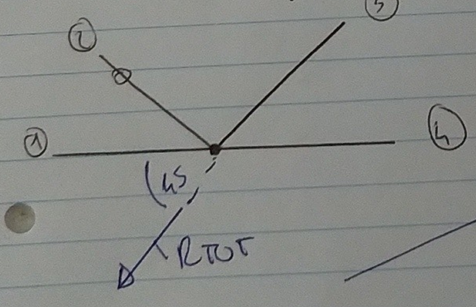
The resultat is 45° before BARE ①
AND is equal TO

$R_{TOT} = 2 \cdot (R_1 + R_4)$ $R_1 = R_4 = R$

resultat $2 \cdot (2R) = 4R$

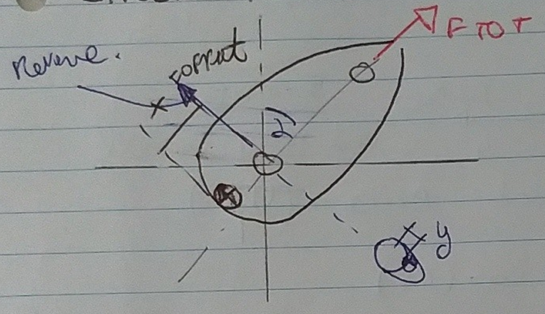
$\hookrightarrow = 4 \cdot \frac{M_{rec}}{2} \cdot (R)$

$= 4 \cdot \frac{0,36}{2} \cdot (40) = 28,8$ kg·mm

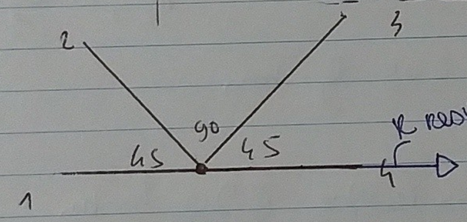


e). The FORWARD VECTOR can be balanced by an ECCENTRIC MASS ON the CRANKSHAFT.

- The RESULTANT 1ST order REVERSE can be balanced by a COUNTER ROTATING SHAFT, which ROTATES at the same speed of the engine. IT has to be placed with its ECCENTRIC opposite to the REVERSE VECTOR. direction.

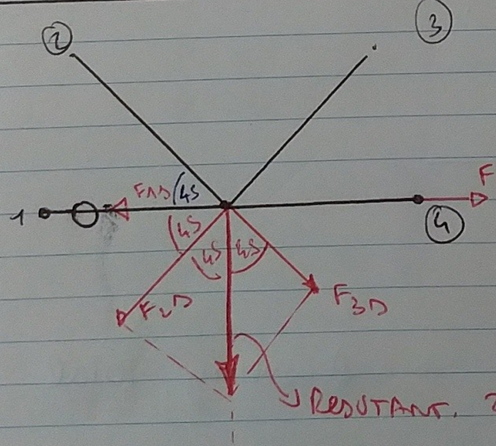


f)



RESULTAN REVERSE. ROTATES 135° COUNTER CLOCKWISE. AND LAYS ON BANK (4)

g)



- F_1 SIMMETRIC with F_4 so they cancelll

REMAINS F_3 with F_2

- RESULTANT is between F_2 and F_3.

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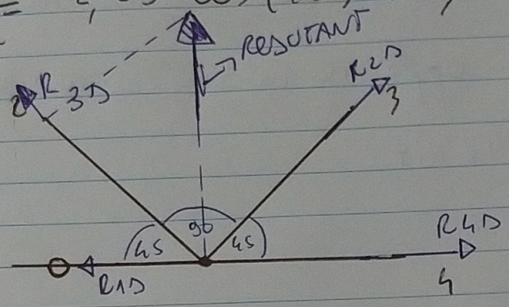
2ND order RESULTANT $= F_{2\gamma} \cdot \cos(45) + F_{3\gamma} \cos(45)$

$F_{2\gamma} = F_{3\gamma} = F_\gamma = \frac{1}{2} \frac{R}{L} \cdot M_{rec.R}$

$= 0,5 \cdot \frac{40}{140} \cdot 0,36 \cdot 40 = 2,05 \text{ kg} \cdot \text{mm}$

$F_{TOT\ vertical} = 2,05 \cdot \cos(45) + 2,05 \cos(45) = 2,90 \text{ kg} \cdot \text{mm}$

h)



$R_{1\gamma} = R_{4\gamma}$ symmetric. and they cancell

RESULTANT is Along the vertical AXIS (Up)

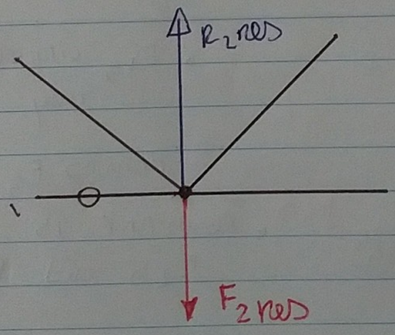
$R_{TOT} = R_{2\gamma} \cdot \cos(45) + R_{3\gamma} \cdot \cos(45)$

$R_{2\gamma} = R_{3\gamma} = R$

$R = \frac{1}{2} \cdot \frac{40}{140} \cdot (0,36) \cdot (40) = 2,05 \text{ kg} \cdot \text{mm}$

$R_{TOT} = 2,05 \cdot \cos(45) + 2,05 \cdot \cos(45) = 2,90 \text{ kg} \cdot \text{m}$

I)



$R_{2\ RESULTANT} = F_{RESULTANT}$ so CONDARY TOTAL FORCE $= 0$

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If the CRANK SHAFT ROTATES the TOTAL FORCE CHANGES ~~Force. V is equal to "0" 30SF~~

- The total ~~resi~~ FORCE. is equal to zero 30JF when the PIN is ON BANK (1) OR BANK (4).

~~If PIN is ON (2) or (3) ETC.~~

---

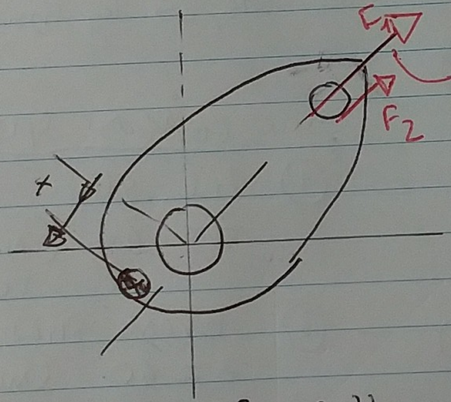
500 CC

Q1) ~~PISTON~~
INCLINE Parallel TWIN

- PISTON = 240 g = 0,24 kg.
- rod = 0,330 kg
- big END. bearing = 20 g

STROKE. = 90 mm
m CRANK = 5 kg
l = 140 mm

2)



- $M_{ROT} = \frac{2}{3}$ conrod $= \frac{2}{3} \cdot 0,33 = 0,22$ kg
- M_{REC} = PISTON + PIN + bearing + $\frac{1}{3}$ rod $= 0,24 + 0,02 + \frac{1}{3}(0,33) = 0,37$ kg

TOTAL MT. 1ST order. FORWARD: $2 \cdot \left(m_{ROT} + \frac{M_{REC}}{2}\right) \cdot R$

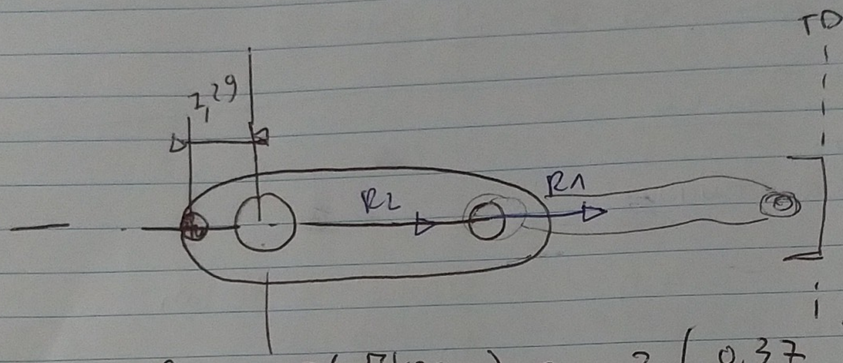
$= 2 \cdot \left(0,22 + \frac{0,37}{2}\right) \cdot \left(\frac{90}{2}\right) = 36,45$ kg·mm

b) For 100 % balance.

$$M_{CRANK\ OPPOSITE}(x) = 2\cdot\left(\pi_{TOT} + \frac{\pi_{REC}}{2}\right)\cdot R.$$

$$x_{COUNTW} = \frac{36,45\cdot}{5} = 7,29\ mm$$

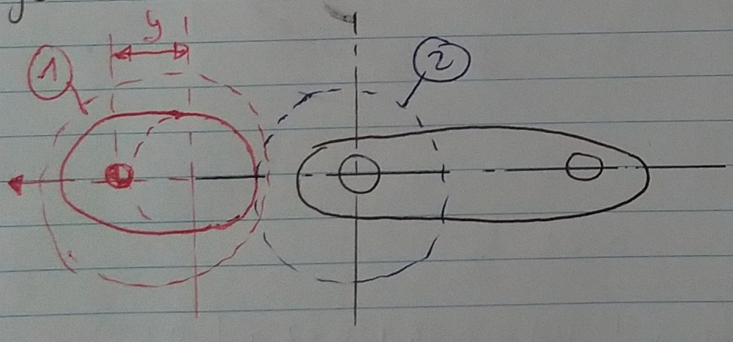
c)



$$R_{TOT} = R_1 + R_2 = 2\left(\frac{\pi_{REC}}{2}\right)\cdot R = 2\cdot\left(\frac{0,37}{2}\cdot\right)45$$

$$= 16,65\ kg\cdot mm$$

d) I would use a series of gears as follow:



GEARS SPEC

① bal. SHAFT
z = 40 (NUMBER of TEETH)

② CRANK SHAFT.
z = 40 (NUMBER of TEETH.

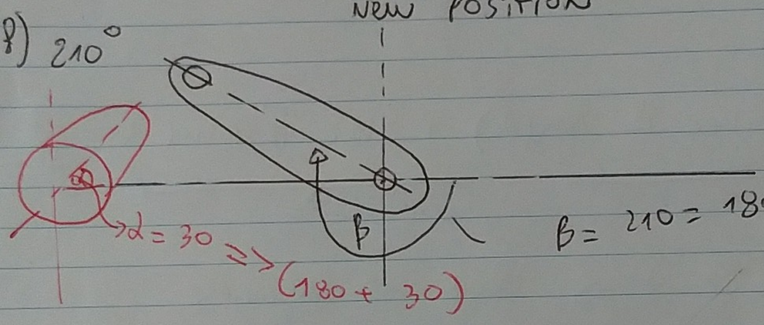
e) $m_{bal} = 2,5$ kg

For balance.

$m_{bal}(y)$ = TOTAL reverse vector

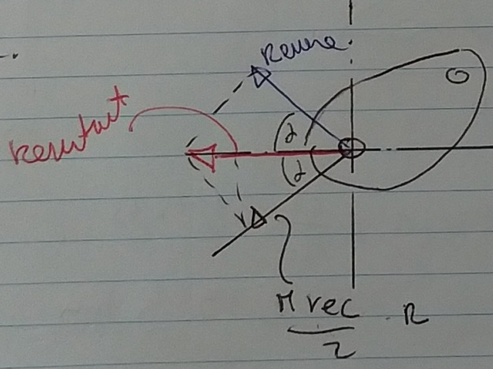
$$y = \frac{16,65}{2,5} = 6,66 \text{ mm}$$

f) 210°



$\beta = 210 = 180 + 30$

g) When balance shaft cannot be use, the AIM IS TO cancell the FORWARD vector (total horizontal), with CENTRIFUGAL CRANKSHAFT FORCE, TO have a RESULTANT FORCE between the reverse vector and the CENTRIFUGAL FORCE of the CRANK.



$m_{crank}(x)$ = FORWARD vector resultant

$$m_{crank}(x) = 2 \cdot \left(\frac{M_{rec}}{2} + M_{bot}\right) \cdot R$$

⇓

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$2(m_{rec} + m_{ROT}) \cdot R = 2\left(\frac{m_{rec}}{2} + m_{ROT}\right) \cdot R = 2 \cdot \frac{m_{rec}}{2} \cdot R = 2\left(\frac{m_{rec}}{2}\right) \cdot R$

reverse.

$m_{rec} \cdot R$.

$\frac{m_{rec}}{2}\, 2 m_{rec}(R) + 2 R_{OT}(R) = m_{rec} R - 2 m_{ROT} \cdot R =$ reverse

$2\, m_{rec} \cdot R - m_{rec} \cdot R = m_{reverse} \cdot R$

$2 - 1 = 1$

$[m_{rec} \cdot R = m_{rec} \cdot R]$

↓

RESULTAT

(pied HORIZONTAL)

RESULTAT $= m_{rec} \cdot R \cdot \sin(\alpha) + m_{rec} \cdot R \cdot \sin(\alpha$

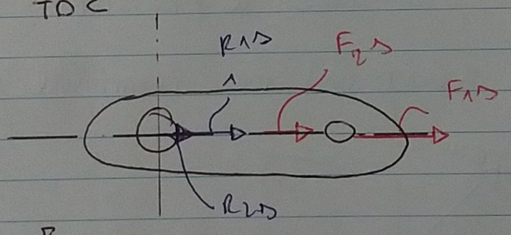
$=$

$=$

For a small value of $\alpha \Rightarrow \sin\alpha$ is negligible

$R_{esultant} = 2 \cdot m_{rec} \cdot R = 2(0{,}37)\,45 = \boxed{33{,}3\ kg \cdot m}$

(h) ENGINE AT TDC



FORWARD

$F_1 = F_2 = \frac{1}{2} \frac{R}{L} \cdot m_{rec} \cdot R$

TOTAL FORWARD $= 2 \cdot \left(\frac{1}{2}\right) \cdot \frac{R}{L} m_{rec} \cdot R = \frac{45}{140} \cdot 0{,}37 \cdot 45$

$= 5{,}35\ kg \cdot m$

Which is equal value to the Reverse TOTAL

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Reverse ratio = 5,35

Imbal shaft. $(y)(2w)^2 = \frac{R}{L} \cdot M_{rec} \cdot R \cdot w^2$

$M_{bal}\ y \cdot 4\ w^2 = \frac{R}{L} \cdot M_{rec} \cdot R w^2$

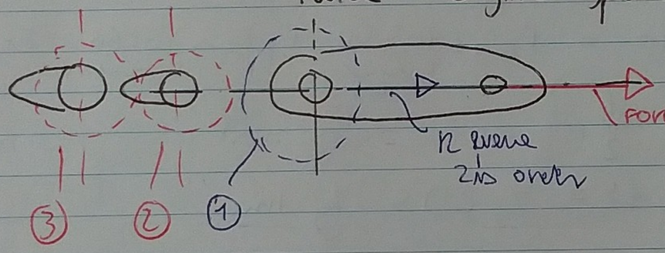
$M_{bal} \cdot 4(y) = \frac{R}{L} \cdot M_{rec} \cdot R$

$M_{bal}(y) = \frac{R}{4L} M_{rec} \cdot R.$

$= \frac{45}{4 \cdot (140)} \cdot 0{,}37 \cdot 45 \cdot$

$= \boxed{1{,}337 \text{ kg} \cdot \text{mm}}$

SCHEMATIC ↓ • The two balance shaft will rotate at twice engine speed.



	GEARS	TEETH
1	z = 40	40
2	z = 20	20
3	z = 20	20

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SERIE 1

Q4)

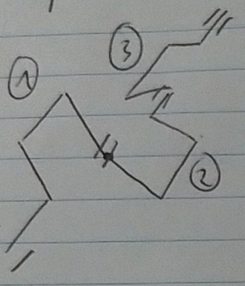
PISTON: 240 g = 0,240

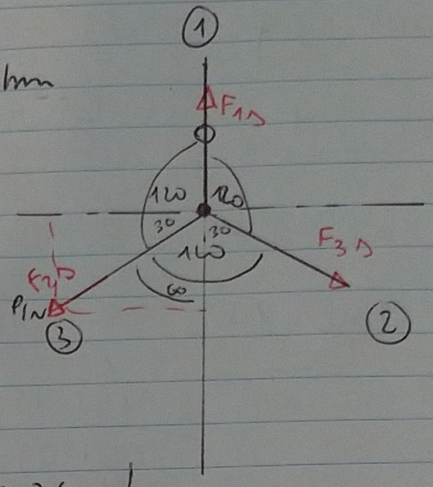
CONROD = 0,3 kg.

C. GRAV = 150 mm

STROKE = 90 mm R = 45 mm

bore sp. = 100 mm





2) $M_{REC} = \frac{1}{3}\,0,3 + \underset{0,240}{PISTON} = 0,34$ kg

$M_{ROT} = \frac{2}{3} \cdot C.rod = \frac{2}{3}\,0,3 = 0,2$ kg.

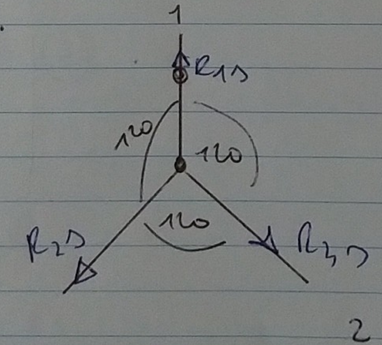
FREQUENCY 2ND ORDER $= F_3 \cdot \underbrace{\cos 60}_{0,5} + F_2 \underbrace{\cos 60}_{0,5} = F_1$

$= F_1 \Rightarrow \frac{1}{2}$

$= \frac{1}{2} \cdot \frac{45}{150} \cdot 0,34 \cdot 45 = 2,295$ kg.mm

FORWARD RESULTANT 2ND ORDER IS "0" because they are SIMMETRICAL.

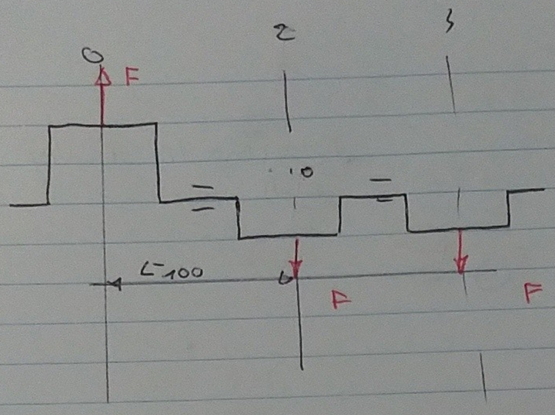
b)

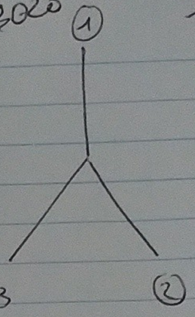


RESULTANT = 0

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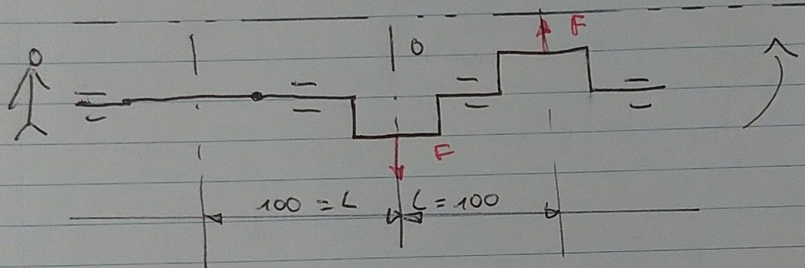
c)





$M_{//} = F \cdot L + F \cos 60 \cdot L$

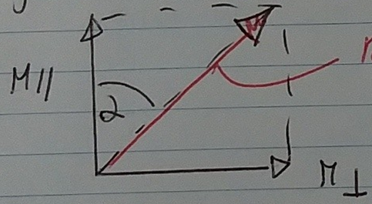
$= FL \cdot \frac{3}{2} = 2{,}295 \cdot (100) \cdot \frac{3}{2} = 344{,}25$ kg · mm · mm



$M_{\perp}$ = Perpendicular

ANTIclockwise = $F \cdot \cos(30)\ 100 = 2{,}295 \cdot \left(\frac{\sqrt{3}}{2}\right) \cdot 100 = 198{,}75$ kg · mm

. The $M_{\perp}$ (perp) moves the front of the crane TO the right. So follo following ✱ Diagram



d)

resultat => ?

$\tan \alpha = \frac{M_{\perp}}{M_{//}} = \frac{198{,}75}{344{,}25} = 0{,}577$

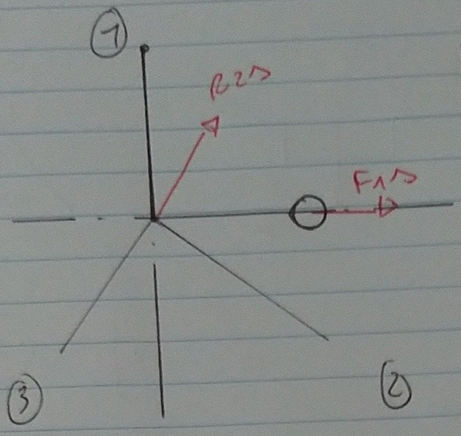
$\alpha = \tan^{-1}(0{,}577)$

$= \underline{30^{\circ}}$

All INLINE 3 CYLINDER

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e)



RESULTANT IS ALWAYS "0"

b) The overall ~~RES~~ RESULTANT MOMENT of the second order ROTATE, as the PIN ROTATE.

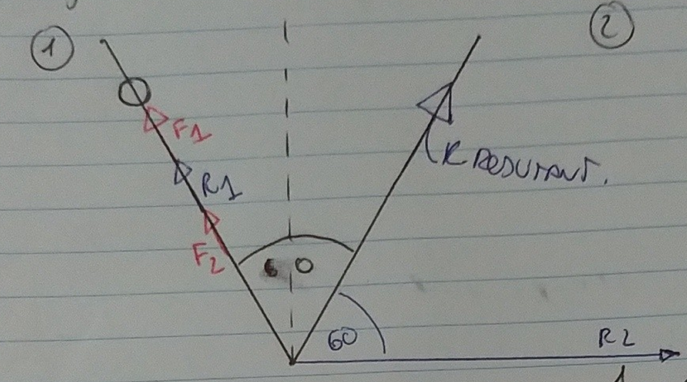
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Q2)

PISTON = 240 g = 0,24 kg
CONROD = 0,36 kg

STROKE = 80 mm $R = \frac{80}{2} = 40$ mm
l = C. LENGTH = 140

a)



$\underline{M_{VEC}}$ = PISTON + PIN + $\frac{1}{3}$ rod = $0,24 + \frac{1}{3} \cdot 0,36 = 0,36$ kg

$M_{ROT} = \frac{2}{3}$ conrod = $\frac{2}{3} \cdot 0,36 = 0,24$ kg

2) => FORWARD MAGNITUDE.

$F_{TOT} = 2\left(M_{ROT} + \frac{M_{EC}}{2}\right) \cdot R = 2\left(0,24 + \frac{0,36}{2}\right) \cdot 40$ (16,8)

$= 33,6$ kg·mm

b) R RESULTANT, is along BANK (2) (look. SKETCH ABOVE)

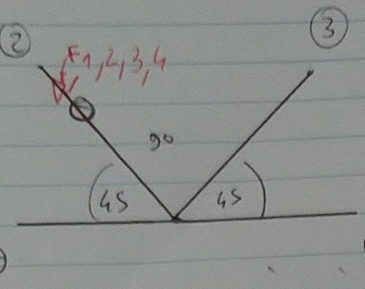
$R_{RESULT} = R_1 \cdot \cos(60) + R_2 \cdot \cos(60)$ $R_1 = R_2 = R$

$R = \frac{M_{VEC}}{2} \cdot R\omega^2 \Rightarrow \frac{0,36}{2} \cdot (40) = 7,2$

↳ $R_{RESULTANT} = 7,2 \cdot \left(\frac{1}{2}\right) + 7,2 \cdot \left(\frac{1}{2}\right) = 7,2$ kg·mm

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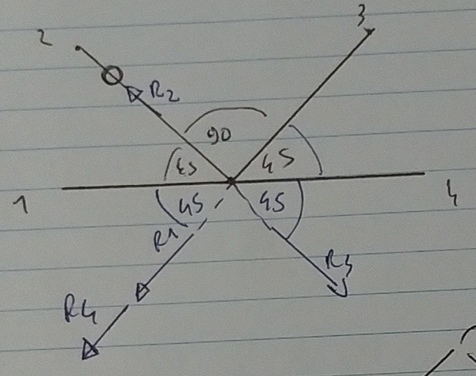
c)



$F_{TOT} = resultat = 4 \cdot F = 4 \cdot \left(M_{TOT} + \frac{M_{rec}}{2}\right) \cdot R$ (ω²)

$= 4 \left(16,8\right) \cdot \omega^2 = 67,2$ kg·mm

d)



$R_2 = R_3$ opposite — SIMMETRIC $R_2 - R_3 = 0$ they cancell.

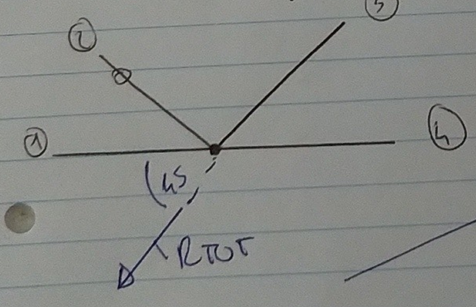
The resultat is 45° before BARE ①
AND is equal TO

$R_{TOT} = 2 \cdot (R_1 + R_4)$ $R_1 = R_4 = R$

resultat $2 \cdot (2R) = 4R$

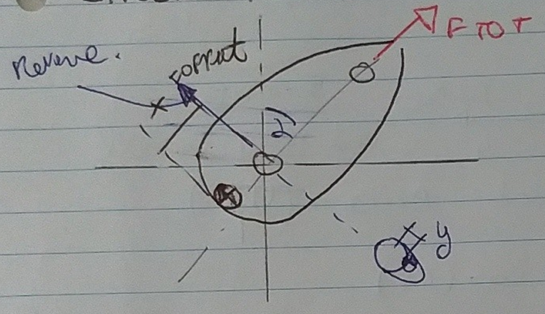
$\hookrightarrow = 4 \cdot \frac{M_{rec}}{2} \cdot (R)$

$= 4 \cdot \frac{0,36}{2} \cdot (40) = 28,8$ kg·mm

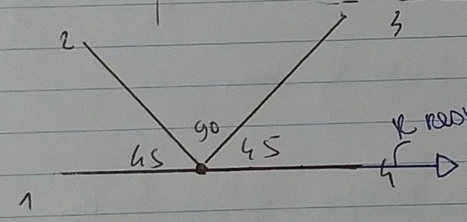


e). The FORWARD VECTOR can be balanced by an ECCENTRIC MASS ON the CRANKSHAFT.

- The RESULTANT 1ST order REVERSE can be balanced by a COUNTER ROTATING SHAFT, which ROTATES at the same speed of the engine. IT has to be placed with its ECCENTRIC opposite to the REVERSE VECTOR. direction.

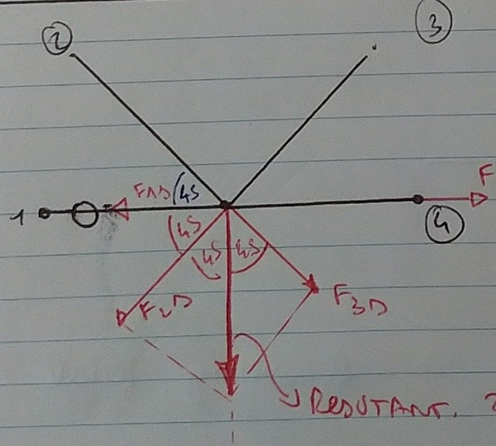


f)



RESULTAN REVERSE. ROTATES 135° COUNTER CLOCKWISE. AND LAYS ON BANK (4)

g)



- F_1 SIMMETRIC with F_4 so they cancelll

REMAINS F_3 with F_2

- RESULTANT is between F_2 and F_3.

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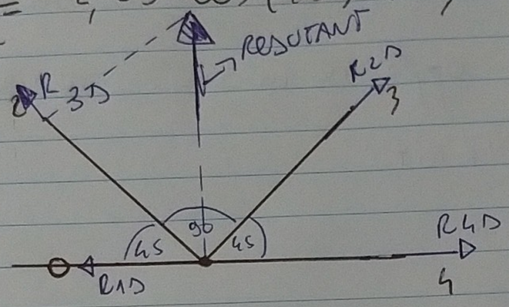
2ND order RESULTANT $= F_{2\gamma} \cdot \cos(45) + F_{3\gamma} \cos(45)$

$F_{2\gamma} = F_{3\gamma} = F_\gamma = \frac{1}{2} \frac{R}{L} \cdot M_{rec.R}$

$= 0,5 \cdot \frac{40}{140} \cdot 0,36 \cdot 40 = 2,05 \text{ kg} \cdot \text{mm}$

$F_{TOT\ vertical} = 2,05 \cdot \cos(45) + 2,05 \cos(45) = 2,90 \text{ kg} \cdot \text{mm}$

h)



$R_{1\gamma} = R_{4\gamma}$ symmetric. and they cancell

RESULTANT is Along the vertical AXIS (Up)

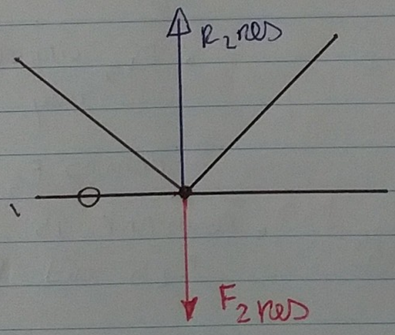
$R_{TOT} = R_{2\gamma} \cdot \cos(45) + R_{3\gamma} \cdot \cos(45)$

$R_{2\gamma} = R_{3\gamma} = R$

$R = \frac{1}{2} \cdot \frac{40}{140} \cdot (0,36) \cdot (40) = 2,05 \text{ kg} \cdot \text{mm}$

$R_{TOT} = 2,05 \cdot \cos(45) + 2,05 \cdot \cos(45) = 2,90 \text{ kg} \cdot \text{m}$

I)



$R_{2\ RESULTANT} = F_{RESULTANT}$ so CONDARY TOTAL FORCE $= 0$

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If the CRANK SHAFT ROTATES the TOTAL FORCE CHANGES ~~Force. V is equal to "0" 30SF~~

- The total ~~resi~~ FORCE. is equal to zero 30JF when the PIN is ON BANK (1) OR BANK (4).

~~If PIN is ON (2) or (3) ETC.~~

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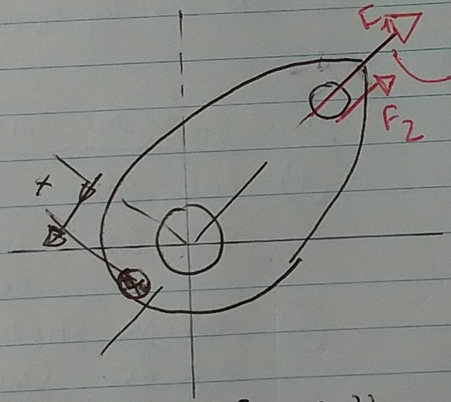
500 CC

Q1) ~~PISTON~~
INCLINE Parallel TWIN

- PISTON = 240 g = 0,24 kg.
- rod = 0,330 kg
- big END. bearing = 20 g

STROKE. = 90 mm
m CRANK = 5 kg
l = 140 mm

2)



- $M_{ROT} = \frac{2}{3}$ conrod $= \frac{2}{3} \cdot 0,33 = 0,22$ kg
- M_{REC} = PISTON + PIN + bearing + $\frac{1}{3}$ rod $= 0,24 + 0,02 + \frac{1}{3}(0,33) = 0,37$ kg

TOTAL MT. 1ST order. FORWARD: $2 \cdot \left(m_{ROT} + \frac{M_{REC}}{2}\right) \cdot R$

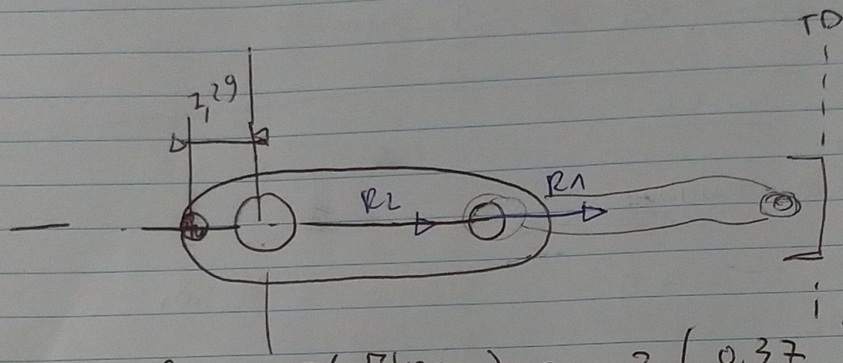
$= 2 \cdot \left(0,22 + \frac{0,37}{2}\right) \cdot \left(\frac{90}{2}\right) = 36,45$ kg·mm

b) For 100 % balance.

$$M_{CRANK\ OPPOSITE}(x) = 2\cdot\left(\pi_{TOT} + \frac{\pi_{REC}}{2}\right)\cdot R.$$

$$x_{COUNTW} = \frac{36,45\cdot}{5} = 7,29\ mm$$

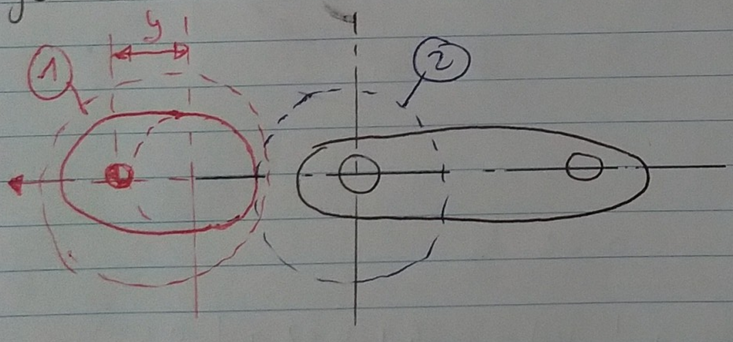
c)



$$R_{TOT} = R_1 + R_2 = 2\left(\frac{\pi_{REC}}{2}\right)\cdot R = 2\cdot\left(\frac{0,37}{2}\cdot\right)45$$

$$= 16,65\ kg\cdot mm$$

d) I would use a series of gears as follow:



GEARS SPEC

① bal. SHAFT
z = 40 (NUMBER of TEETH)

② CRANK SHAFT.
z = 40 (NUMBER of TEETH.

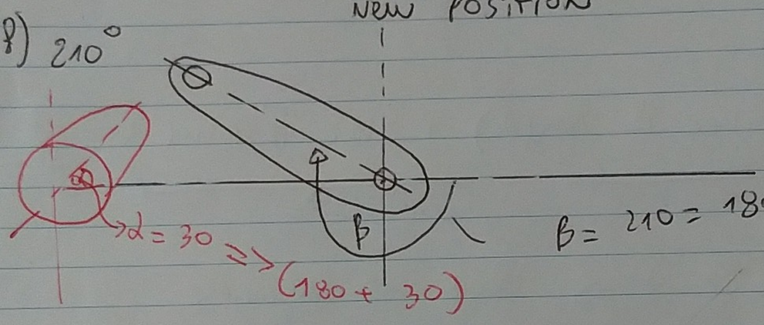
e) $m_{bal} = 2,5$ kg

For balance.

$m_{bal}(y)$ = TOTAL reverse vector

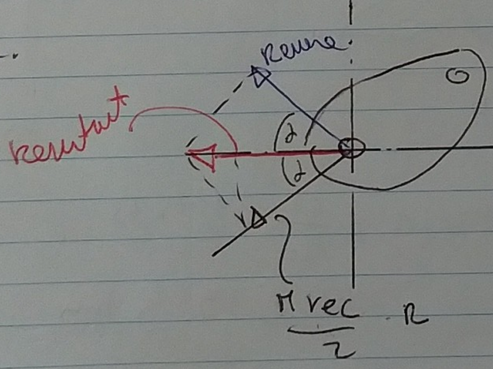
$$y = \frac{16,65}{2,5} = 6,66 \text{ mm}$$

f) 210°



$\beta = 210 = 180 + 30$

g) When balance shaft cannot be use, the AIM IS TO cancell the FORWARD vector (total horizontal), with CENTRIFUGAL CRANKSHAFT FORCE, TO have a RESULTANT FORCE between the reverse vector and the CENTRIFUGAL FORCE of the CRANK.



$m_{crank}(x)$ = FORWARD vector resultant

$$m_{crank}(x) = 2 \cdot \left(\frac{M_{rec}}{2} + M_{bot}\right) \cdot R$$

⇓

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$2(m_{rec} + m_{ROT}) \cdot R = 2\left(\frac{m_{rec}}{2} + m_{ROT}\right) \cdot R = 2 \cdot \frac{m_{rec}}{2} \cdot R = 2\left(\frac{m_{rec}}{2}\right) \cdot R$

reverse.

$m_{rec} \cdot R$.

$\frac{m_{rec}}{2}\, 2 m_{rec}(R) + 2 R_{OT}(R) = m_{rec} R - 2 m_{ROT} \cdot R =$ reverse

$2\, m_{rec} \cdot R - m_{rec} \cdot R = m_{reverse} \cdot R$

$2 - 1 = 1$

$[m_{rec} \cdot R = m_{rec} \cdot R]$

↓

RESULTAT

(pied HORIZONTAL)

RESULTAT $= m_{rec} \cdot R \cdot \sin(\alpha) + m_{rec} \cdot R \cdot \sin(\alpha$

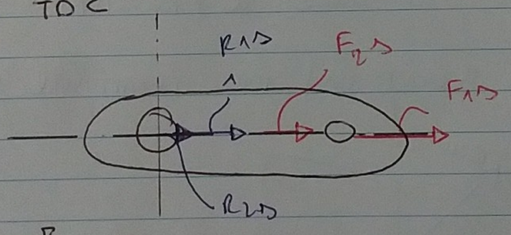
$=$

$=$

For a small value of $\alpha \Rightarrow \sin\alpha$ is negligible

$R_{esultant} = 2 \cdot m_{rec} \cdot R = 2(0{,}37)\,45 = \boxed{33{,}3\ kg \cdot m}$

(h) ENGINE AT TDC



FORWARD

$F_1 = F_2 = \frac{1}{2} \frac{R}{L} \cdot m_{rec} \cdot R$

TOTAL FORWARD $= 2 \cdot \left(\frac{1}{2}\right) \cdot \frac{R}{L} m_{rec} \cdot R = \frac{45}{140} \cdot 0{,}37 \cdot 45$

$= 5{,}35\ kg \cdot m$

Which is equal value to the Reverse TOTAL

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Reverse ratio = 5,35

Imbal shaft. $(y)(2w)^2 = \frac{R}{L} \cdot M_{rec} \cdot R \cdot w^2$

$M_{bal}\ y \cdot 4\ w^2 = \frac{R}{L} \cdot M_{rec} \cdot R w^2$

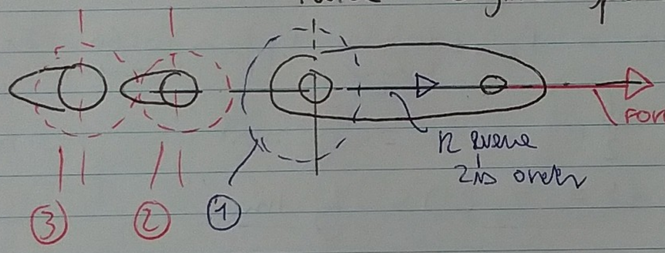
$M_{bal} \cdot 4(y) = \frac{R}{L} \cdot M_{rec} \cdot R$

$M_{bal}(y) = \frac{R}{4L} M_{rec} \cdot R.$

$= \frac{45}{4 \cdot (140)} \cdot 0{,}37 \cdot 45 \cdot$

$= \boxed{1{,}337 \text{ kg} \cdot \text{mm}}$

SCHEMATIC ↓ • The two balance shaft will rotate at twice engine speed.



	GEARS	TEETH
1	z = 40	40
2	z = 20	20
3	z = 20	20

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SERIE 1

Q4)

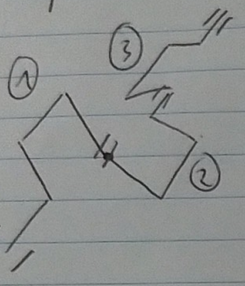
PISTON: 240 g = 0,240

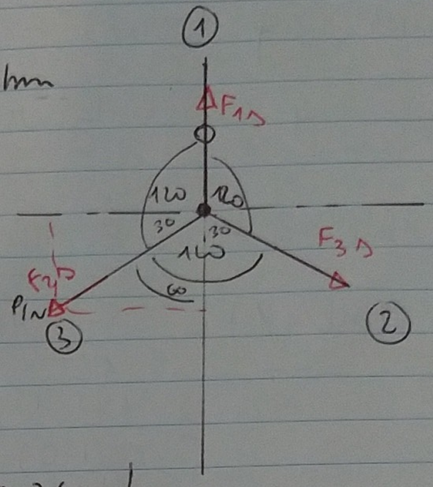
CONROD = 0,3 kg.

C. GRAV = 150 mm

STROKE = 90 mm R = 45 mm

bore sp. = 100 mm





2) $M_{REC} = \frac{1}{3}\,0,3 + \underset{0,240}{PISTON} = 0,34$ kg

$M_{ROT} = \frac{2}{3} \cdot C.rod = \frac{2}{3}\,0,3 = 0,2$ kg.

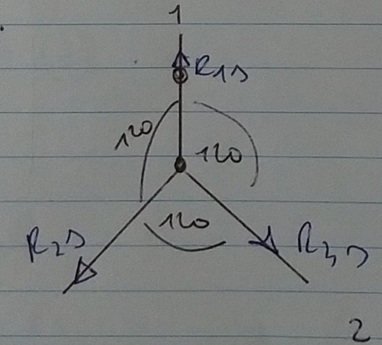
FREQUENCY 2ND ORDER $= F_3 \cdot \underbrace{\cos 60}_{0,5} + F_2 \underbrace{\cos 60}_{0,5} = F_1$

$= F_1 \Rightarrow \frac{1}{2}$

$= \frac{1}{2} \cdot \frac{45}{150} \cdot 0,34 \cdot 45 = 2,295$ kg.mm

FORWARD RESULTANT 2ND ORDER IS "0" because they are SIMMETRICAL.

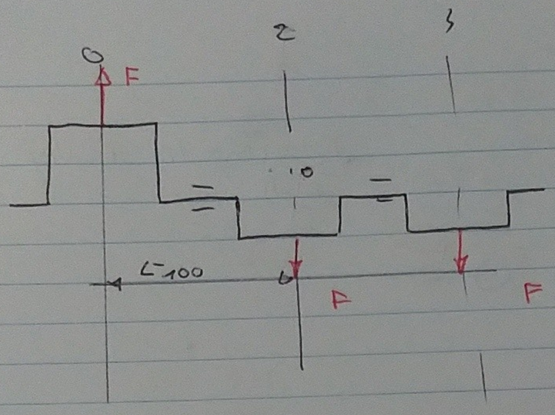
b)

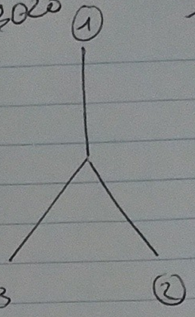


RESULTANT = 0

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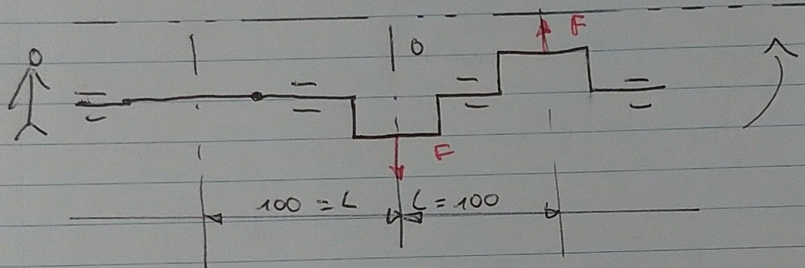
c)





$M_{//} = F \cdot L + F \cos 60 \cdot L$

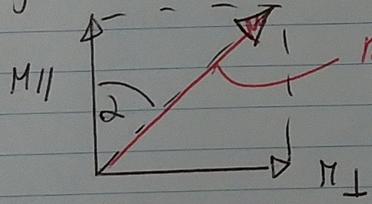
$= FL \cdot \frac{3}{2} = 2{,}295 \cdot (100) \cdot \frac{3}{2} = 344{,}25$ kg · mm · mm



$M_{\perp}$ = Perpendicular

ANTIclockwise = $F \cdot \cos(30)\ 100 = 2{,}295 \cdot \left(\frac{\sqrt{3}}{2}\right) \cdot 100 = 198{,}75$ kg · mm

. The $M_{\perp}$ (perp) moves the front of the crane TO the right. So follo following ✱ Diagram



d)

resultat => ?

$\tan \alpha = \frac{M_{\perp}}{M_{//}} = \frac{198{,}75}{344{,}25} = 0{,}577$

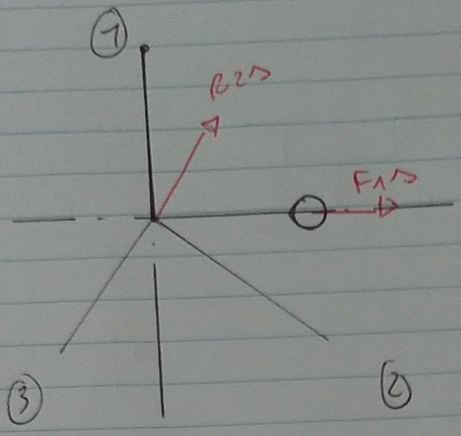
$\alpha = \tan^{-1}(0{,}577)$

$= \underline{30^{\circ}}$

All INLINE 3 CYLINDER

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e)



RESULTANT IS ALWAYS "0"

b) The overall ~~RES~~ RESULTANT MOMENT of the second order ROTATE, as the PIN ROTATE.