DAVID MIGLIORATI N'DOUA - P1503420

ADVANCE ENGINE DESIGN. EXAM 14/05/2020

M6X00410

Q2)

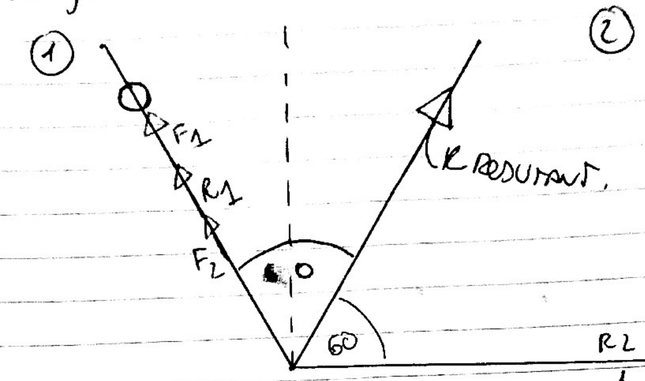
PISTON = 240 g = 0,24 kg

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

d) => 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)

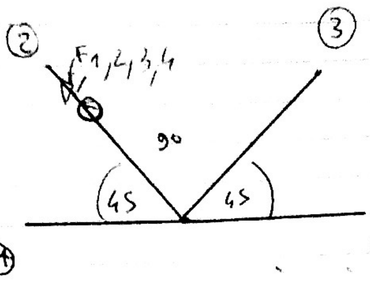
$R_{Resultat} = R_1 \cdot \cos(60) + R_2 \cdot \cos(60)$ $\quad R_1 = R_2 = R$

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

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



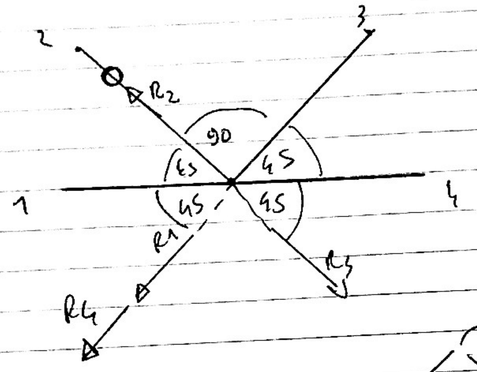
c)



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

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

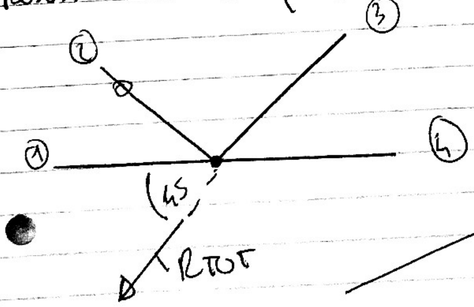
d)

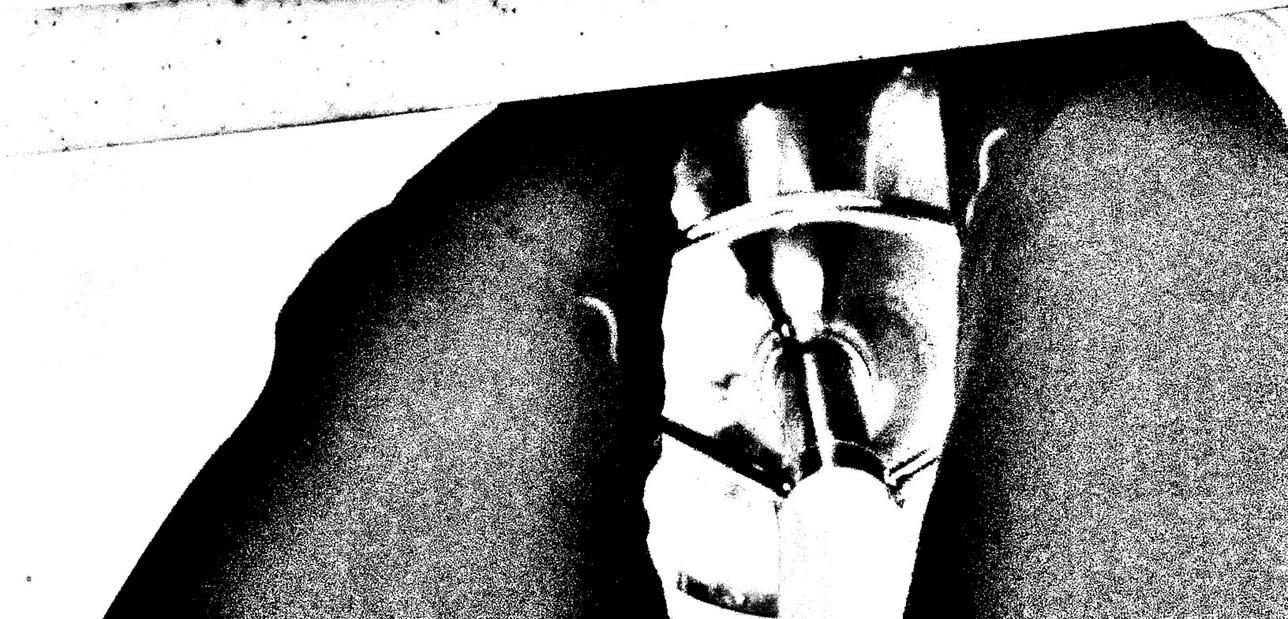


- $R_2 = R_3$ opposite — SIMMETRIC — $R_2 - R_3 = 0$ they cancell

The resultant is 45° before BAND ①
AND is equal TO

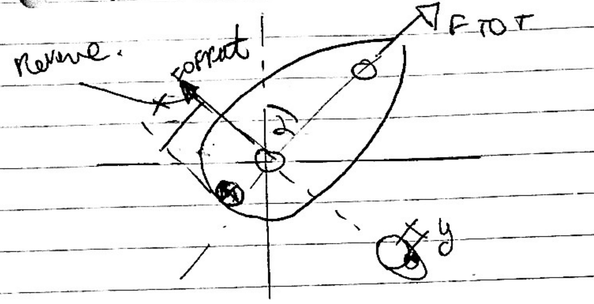
$R_{TOT} = 2 \cdot (R_1 + R_4)$ $\quad R_1 = R_4 = R$
resultant $2 \cdot (2R) = 4R$
$\hookrightarrow = 4 \cdot \frac{M_{rec}}{2} \cdot (R)$
$= 4 \cdot \frac{0,36}{2} \cdot (40) = 28,8$ kg·mm



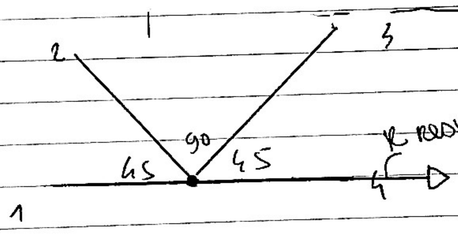


c). The FORWARD VECTOR can be balanced by a/m ECCENTRIC MASS ON the CRANK.SHAFT.

- 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.

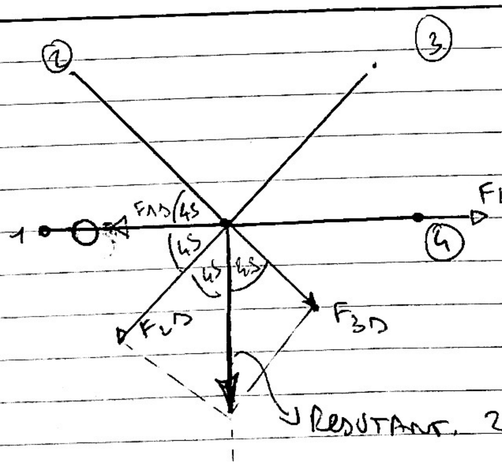


f)



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

g)



- F_{1D} SIMMETRIC WITH F_{4D} SO they cancell

REMAINS F_{3D} WITH F_{2D}. RESULTANT is between F_{2D} and F_{3D}.



DAVID MIGLIORATI N'DOUA - P150320

Advance engine design exam. 14/05/2020 4/12

M6x00410

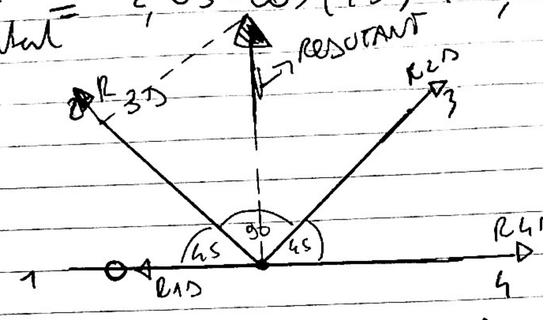
2ND order resultant $= F_{2\gg} \cdot \cos(45) + F_{3\gg} \cos(45)$

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

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

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

h)



$R_{1\gg} = R_{4\gg}$ Simmetric. and they cancell

Resultant is along the vertical axis (up)

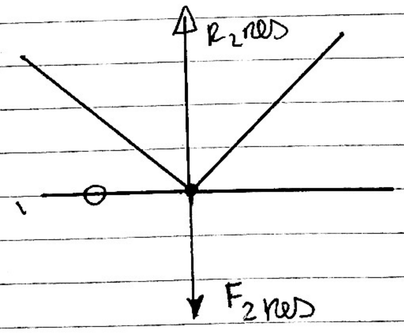
$R_{TOT} = R_{2\gg} \cdot \cos(45) + R_{3\gg} \cdot \cos(45)$

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

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

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

I)



$R_{2\ resultant} = F_{resultant}$ So ~~X~~ company total force $= 0$



DAVID MIGLIORATI N'DOUA - P1500320
ADVANCE ENGINE DESIGN. EXAM 14/05/2020 5/12 of

M6X00410

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

- The total ~~resi~~ FORCE. is equal to zero 30JT when the PIN is ON BANK ① OR BANK ②.

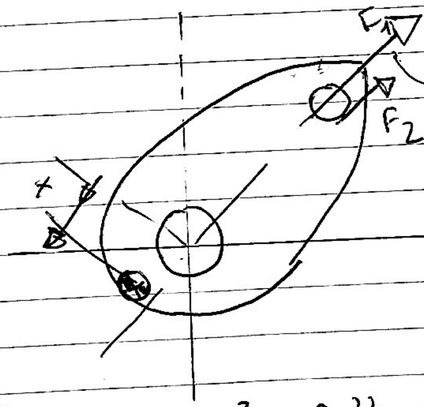
~~If PIN is ON ② or ③ the.~~

500 CC

Q1) ~~PISTON~~
INCLINE Parallel TWIN

- PISTON = 240 g = 0,24 kg. STROKE. = 90 mm
- rod = 0,330 kg m CRANK = 5 kg
- big END. bearing = 20 g 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: $2.\left(m_{rot} + \frac{m_{rec}}{2}\right).l$

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

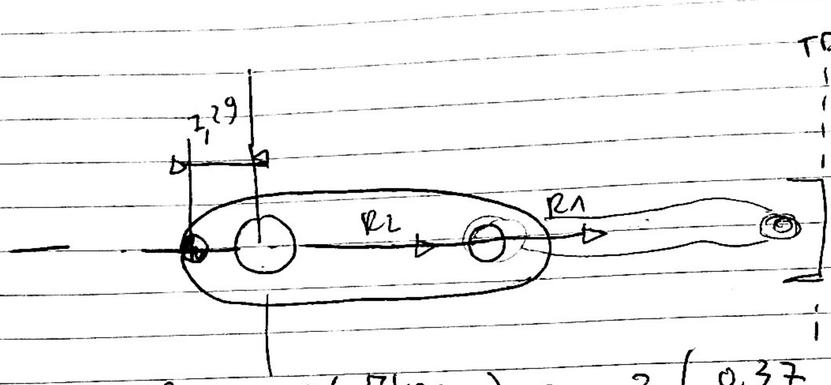


b) For 100 % balance.

$$M_{CRANK\ (x)\ OPPOSITE} = 2 \cdot \left(m_{ROT} + \frac{m_{REC}}{2}\right) \cdot R$$

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

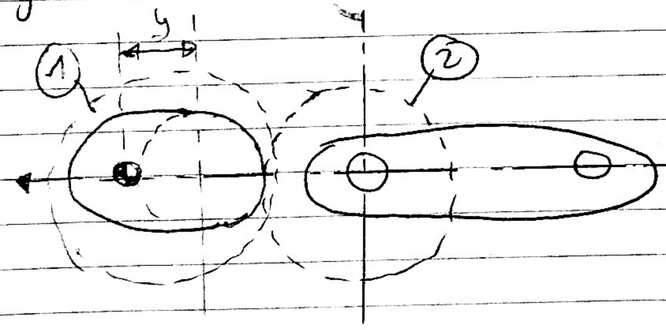
c)



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

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

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



GEARS SPEC

① bal. GEAR
$z = 40$ (NUMBER of TEETH)

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

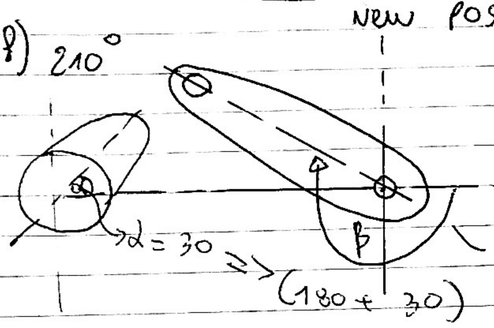
e) $m_{bal} = 2,5$ kg

For balance.

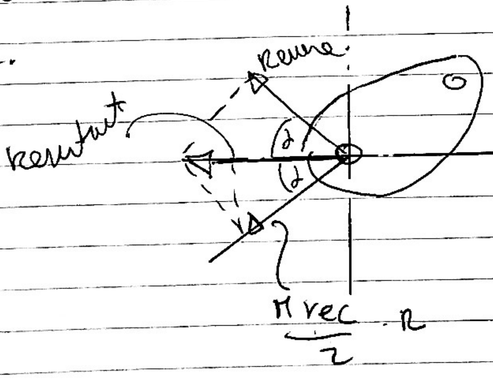
$m_{bal.}(y)$ = TOTAL reverse vector

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

f) 210°



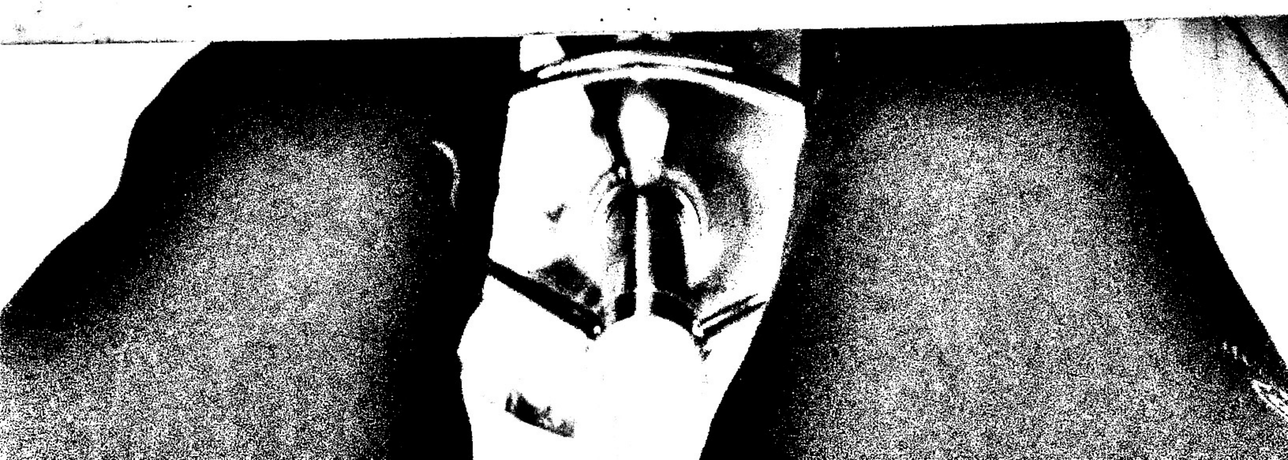
g) When balance shaft cannot be use., the AIM IS TO cancell the FORWARD (total) VECTOR, with CENTRIFUGAL (horizontal) CRANKSHAF. FORCE, TO have a RESULTAT. FORCE between the reverse vector and the CENTRIFUGAL FORCE of the CRANK.



$m_{crank} \cdot (x)$ = FORWARD (resultat) vector

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

⇓



MGX00610

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

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

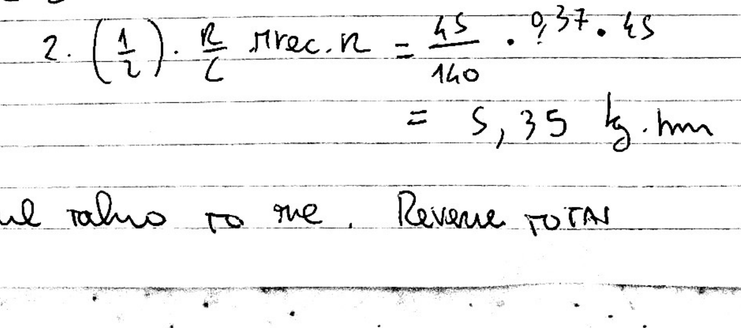
$=$

$=$

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

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

(h) ENGINE AT TDC



FORWARD

$F1> = F2> = \frac{1}{2} \frac{R}{L} \cdot m_{rec} \cdot R$

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

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

Which is equal value to the Reverse TOTAL



DAVID MIGLIORATI N'DOUA P1500320
ADVANCE ENGINE DESIGN 14/05/2020
M6*00G10

9/12

Reverse ratio = 5,35

$m_{bal\ shaft} \cdot (y)(2\omega)^2 = \frac{R}{L} \cdot m_{rec} \cdot R\ \omega^2$

$m_{bal} \cdot y \cdot 4\omega^2 = \frac{R}{L} \cdot m_{rec} \cdot R\omega^2$

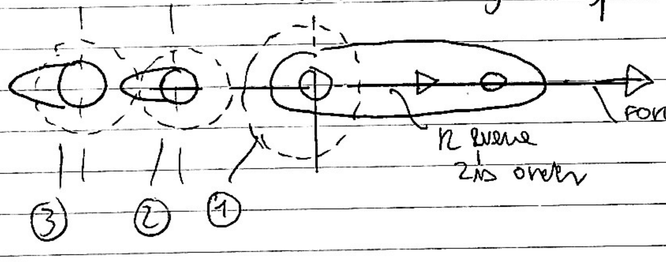
$m_{bal} \cdot 4(y) = \frac{R}{L} \cdot m_{rec} \cdot R$

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

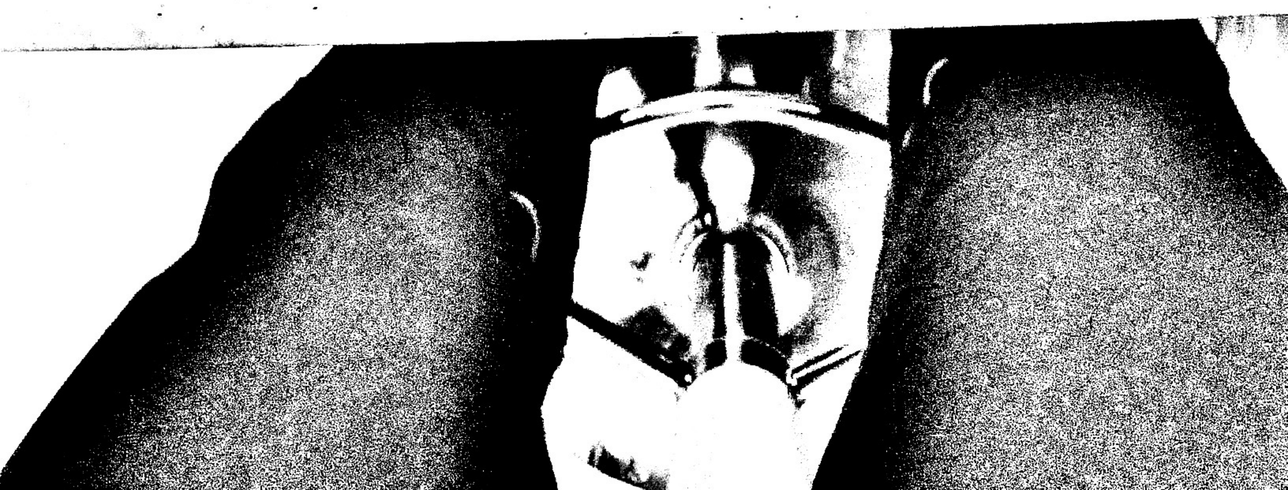
$= \frac{45}{4 \cdot (140)} \cdot 0,37 \cdot 45$

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

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



SERIE 1

Q4)

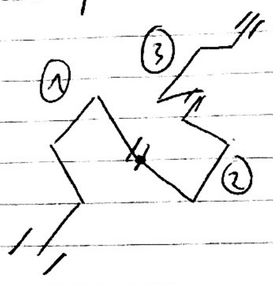
PISTON : 240 g = 0,240

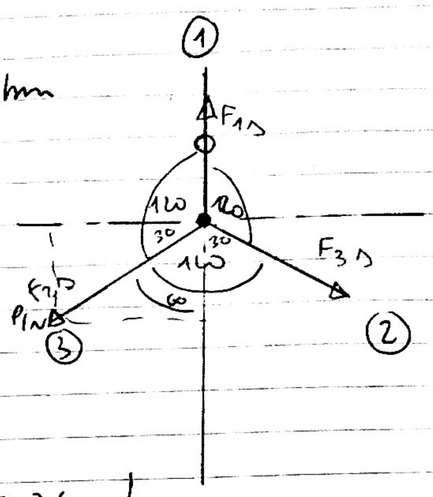
CONROD = 0,3 kg.

C. GRAV = 150 mm

STROKE = 90 mm R = 45 mm

bore sp. = 100 mm





2) $M_{rec} = \frac{1}{3}\,0,3 + \underbrace{0,240}_{\text{PISTON}} = 0,34$ kg

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

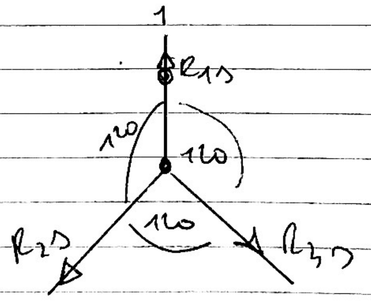
Frequ. 2nd order $= F_{3/1} \cdot \underbrace{\cos 60}_{0,5} + F_{2/1} \underbrace{\cos 60}_{0,5} = F_{1/1}$

$= F_{1/1} \Rightarrow \frac{1}{2}$

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

Formula. resultat. 2nd. order is "0" because they are. sinusoidal.

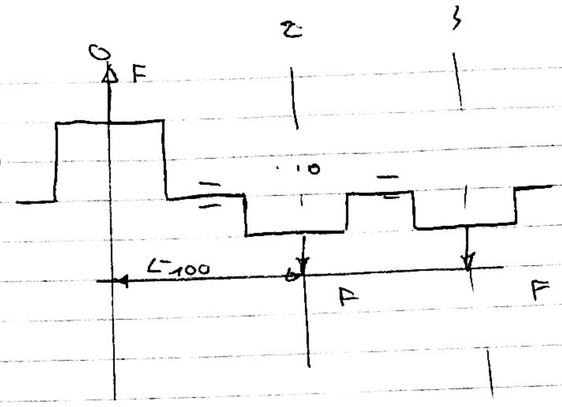
b)



RESULTANT = 0

DAVID MIGLIORANZI P150320 14/5/2020 11/72

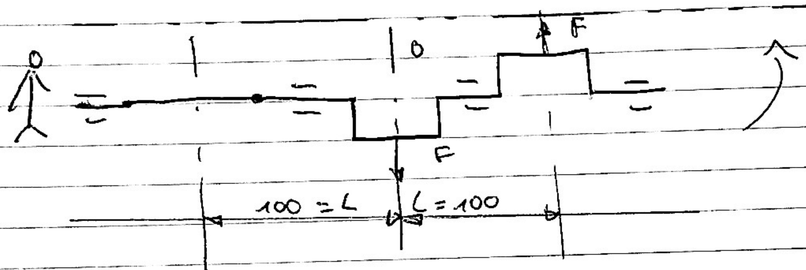
c)





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

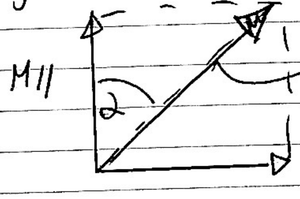
$= FL \cdot \frac{3}{2} = 2{,}295 \cdot (100) \cdot \frac{3}{2} = 344{,}25$ kg · mm · mm



$M_{\perp}$ = 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 crank FRONT to the right. So follo following ↓ Diagram



d)

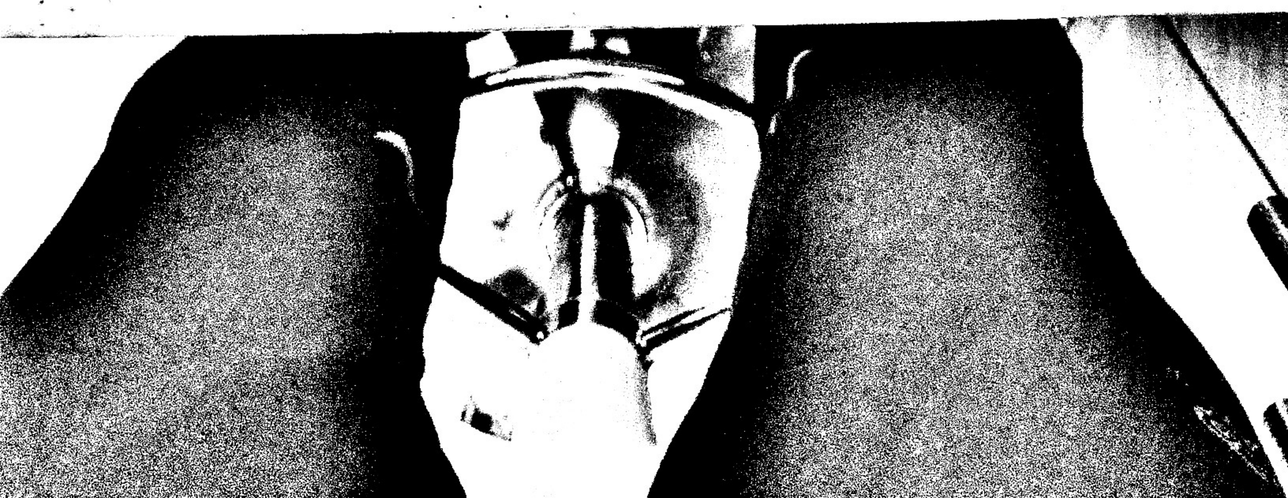
$\alpha = \tan^{-1}(0{,}577)$

risultato => ?

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

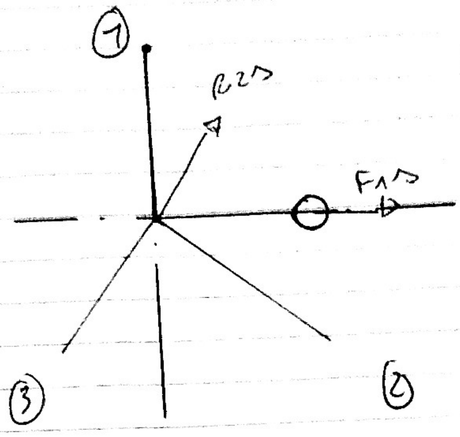
$= \underline{30^{\circ}}$

All INLINE 3 CYLINDER



DAVID Migliorati PASOZZO 14 12/12

e)



RESULTANT IS ALWAYS "0"

b) The overall ~~RES~~ RESULTAT. MOMENT of the second order ROTATE, as the FIN ROTATE.

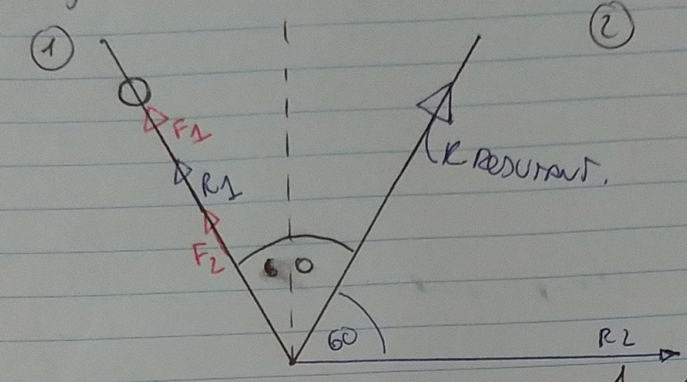
DAVID MIGLIORATI N'DOUA - P150320
ADVANCE ENGINE DESIGN. EXAM. 14/05/2020
M6X00410

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)

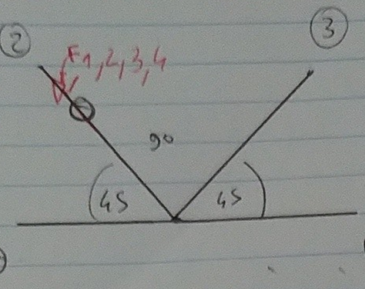
$R_{RESULT} = R_1 \cdot \cos(60) + R_2 \cdot \cos(60)$ $R_1 = R_2 = R$

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

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

MGX00410

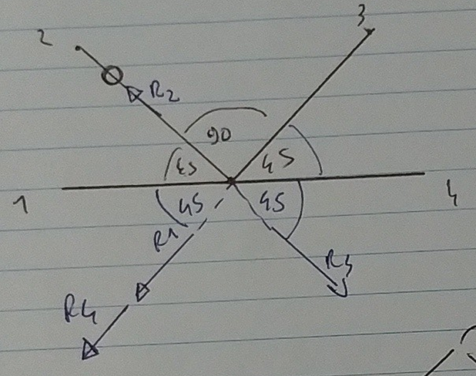
c)



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

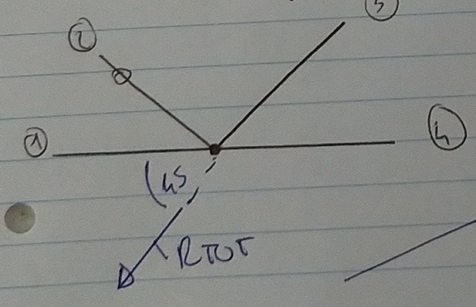
The resultat is 45° before BARE ①
AND is equal TO

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

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

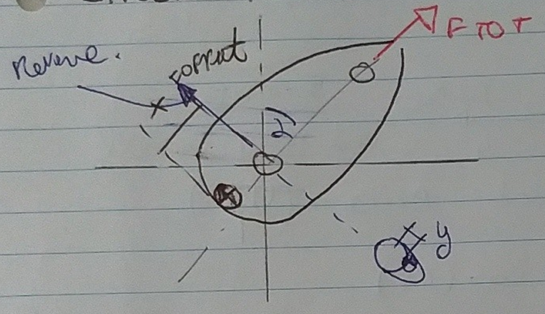
$\hookrightarrow = 4 \cdot \frac{M_{rec}}{2} \cdot (R)$

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

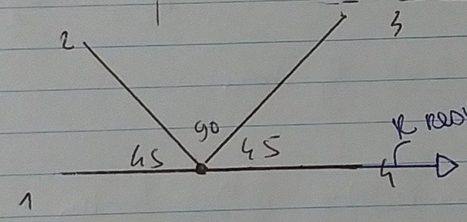


e). The FORWARD VECTOR can be balanced by an ECCENTRIC MASS ON the CRANKSHAFT.

- 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.

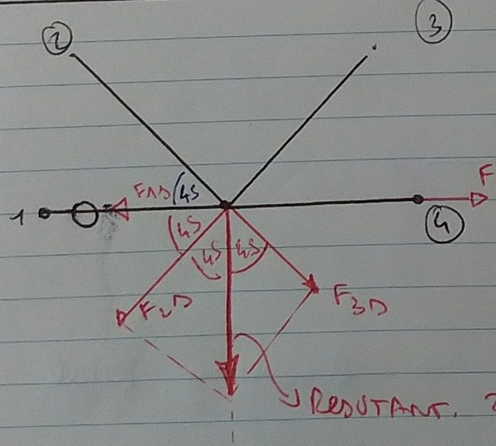


f)



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.

DAVID MIGLIORATI N'DOUA - P150320

ADVANCE ENGINE design EXAM. 14/05/2020 4/12

M6X00410

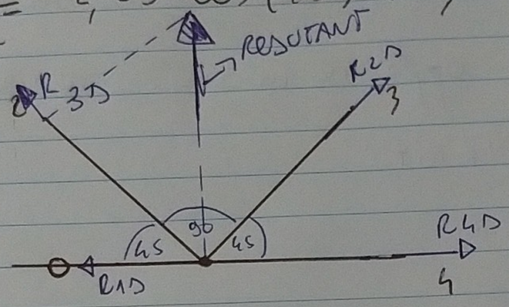
2ND order RESULTANT $= F_{2\gamma} \cdot \cos(45) + F_{3\gamma} \cos(45)$

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

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

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

h)



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

RESULTANT is Along the vertical AXIS (Up)

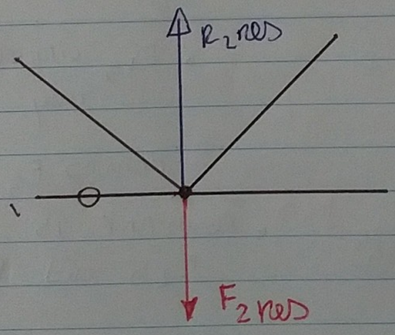
$R_{TOT} = R_{2\gamma} \cdot \cos(45) + R_{3\gamma} \cdot \cos(45)$

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

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

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

I)



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

DAVID MIGLIORATI N'DOUA - P1500320
ADVANCE ENGINE DESIGN. EXAM 14/05/2020 5/12 of

M6X00410

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.~~

---

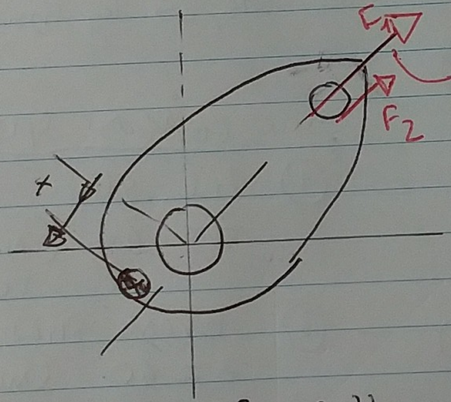
500 CC

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: $2 \cdot \left(m_{ROT} + \frac{M_{REC}}{2}\right) \cdot R$

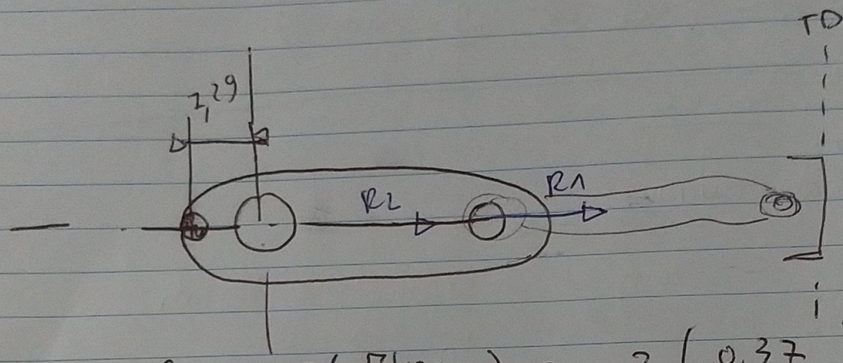
$= 2 \cdot \left(0,22 + \frac{0,37}{2}\right) \cdot \left(\frac{90}{2}\right) = 36,45$ kg·mm

b) For 100 % balance.

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

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

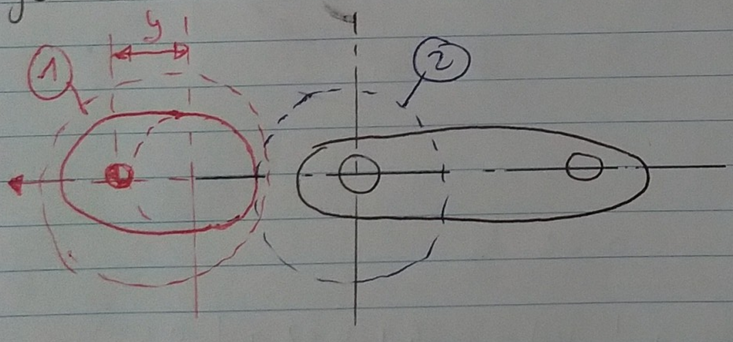
c)



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

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

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.

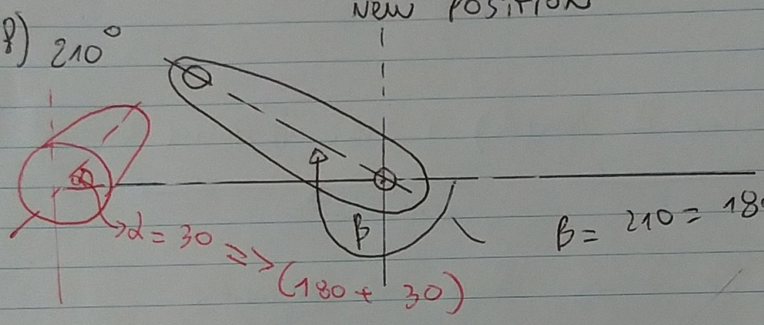
e) $m_{bal} = 2,5$ kg

For balance.

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

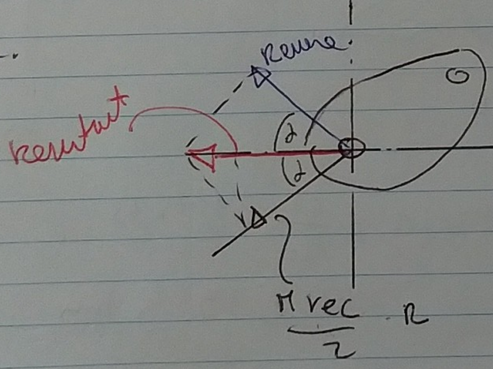
$$y = \frac{16,65}{2,5} = 6,66 \text{ mm}$$

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

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

⇓

MGX00510

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

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

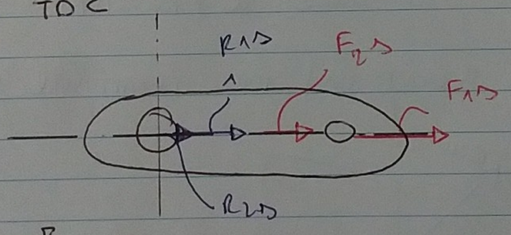
$=$

$=$

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

DAVID MIGLIORATI N°DOVA P1S0320
ADVANCE ~~ENGINE~~ ENGINE design 14/05/2020

M6×00410

Reverse ratio = 5,35

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

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

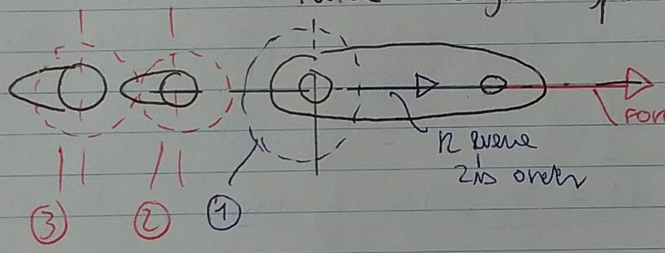
$M_{bal} \cdot 4(y) = \frac{R}{L} \cdot M_{rec} \cdot R$

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

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

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

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

DAVID MIGLIORATI N'DOUA P1503L0

ADVANCE ENGINE design. EXAM. 14/05/2020 10/12

M6X00410

SERIE 1

Q4)

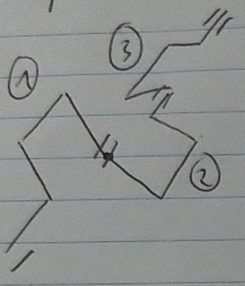
PISTON: 240 g = 0,240

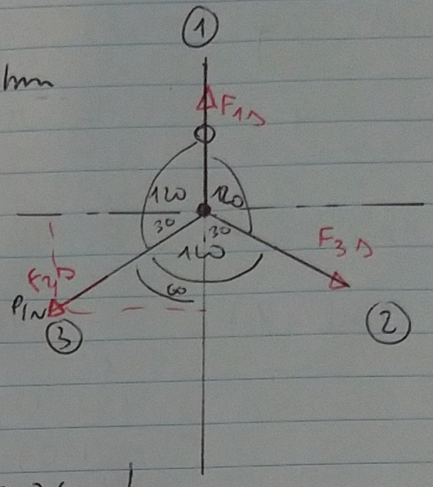
CONROD = 0,3 kg.

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.

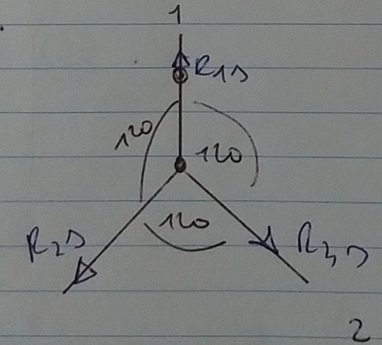
FREQUENCY 2ND ORDER $= F_3 \cdot \underbrace{\cos 60}_{0,5} + F_2 \underbrace{\cos 60}_{0,5} = F_1$

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

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

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

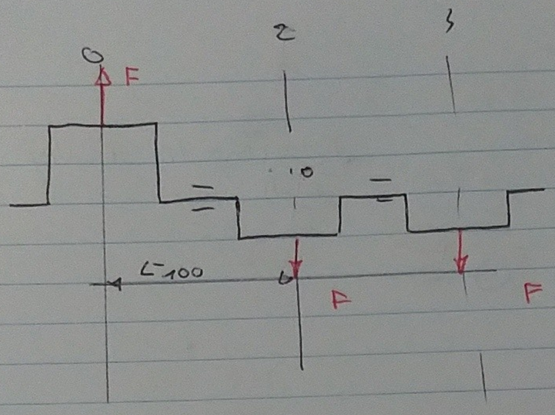
b)

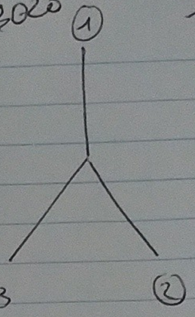


RESULTANT = 0

DAVID MIGLIORATI P150320 14/5/2020 11/72

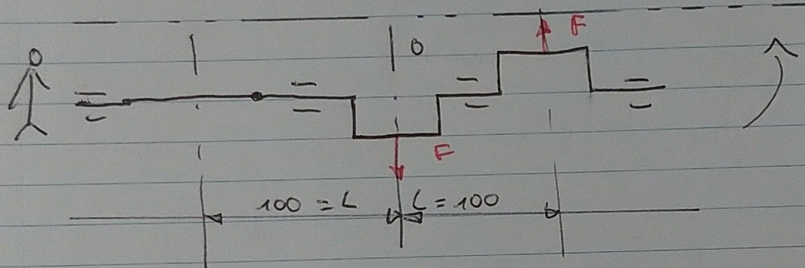
c)





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

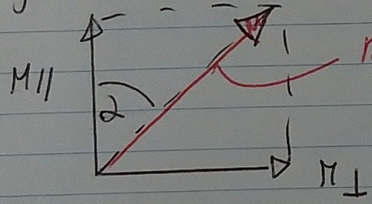
$= FL \cdot \frac{3}{2} = 2{,}295 \cdot (100) \cdot \frac{3}{2} = 344{,}25$ kg · mm · mm



$M_{\perp}$ = 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 => ?

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

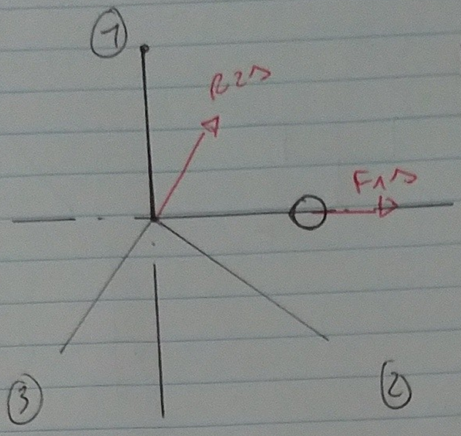
$\alpha = \tan^{-1}(0{,}577)$

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

All INLINE 3 CYLINDER

DAVID Migliorati P1502220 14 12/12

e)



RESULTANT IS ALWAYS "0"

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

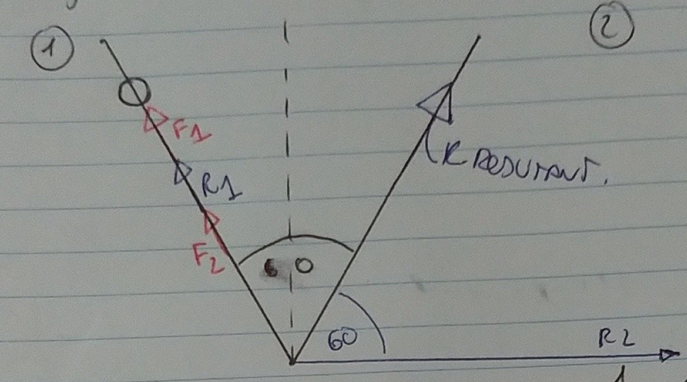
DAVID MIGLIORATI N'DOUA - P150320
ADVANCE ENGINE DESIGN. EXAM. 14/05/2020
M6X00410

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)

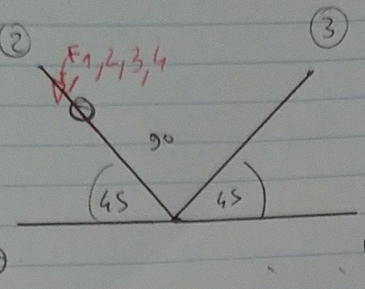
$R_{RESULT} = R_1 \cdot \cos(60) + R_2 \cdot \cos(60)$ $R_1 = R_2 = R$

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

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

MGX00410

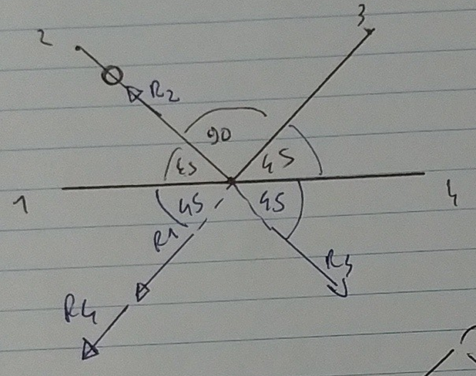
c)



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

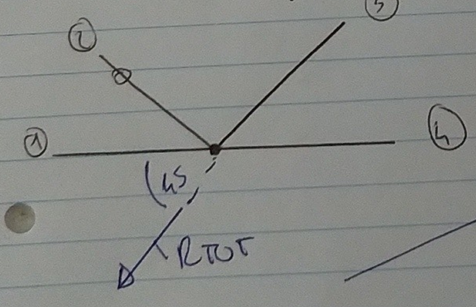
The resultat is 45° before BARE ①
AND is equal TO

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

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

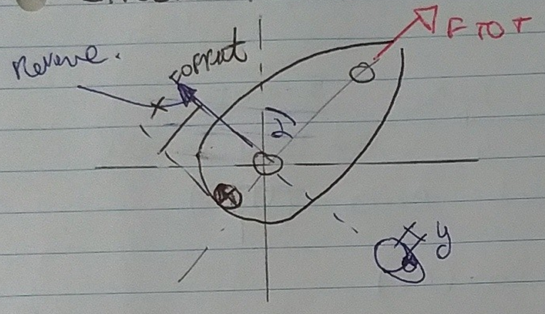
$\hookrightarrow = 4 \cdot \frac{M_{rec}}{2} \cdot (R)$

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

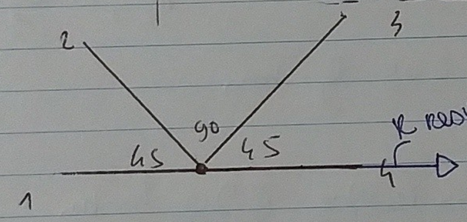


e). The FORWARD VECTOR can be balanced by an ECCENTRIC MASS ON the CRANKSHAFT.

- 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.

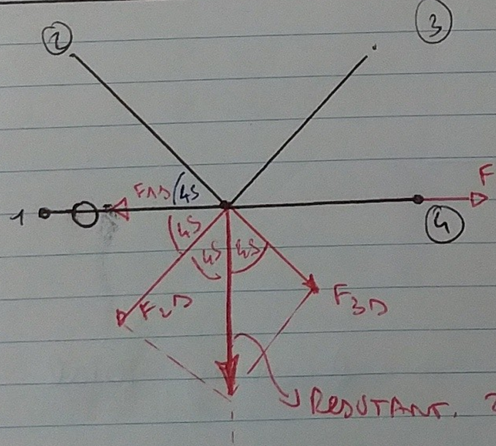


f)



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.

DAVID MIGLIORATI N'DOUA - P150320

ADVANCE ENGINE design EXAM. 14/05/2020 4/12

M6X00410

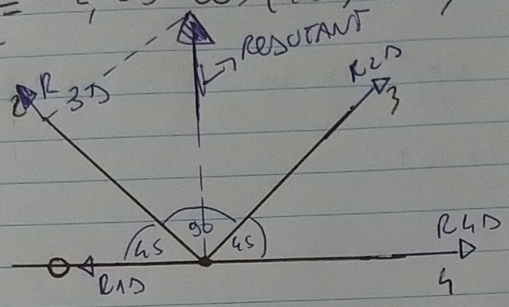
2ND order RESULTANT $= F_{2\gamma} \cdot \cos(45) + F_{3\gamma} \cos(45)$

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

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

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

h)



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

RESULTANT is Along the vertical AXIS (Up)

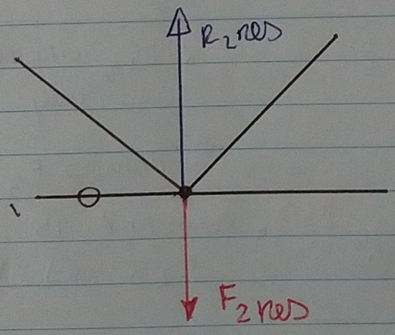
$R_{TOT} = R_{2\gamma} \cdot \cos(45) + R_{3\gamma} \cdot \cos(45)$

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

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

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

I)



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

DAVID MIGLIORATI N'DOUA - P1500320
ADVANCE ENGINE DESIGN. EXAM 14/05/2020 5/12 of

M6X00410

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.~~

---

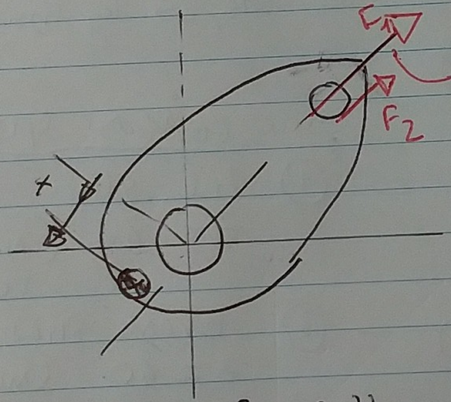
500 CC

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: $2 \cdot \left(m_{ROT} + \frac{M_{REC}}{2}\right) \cdot R$

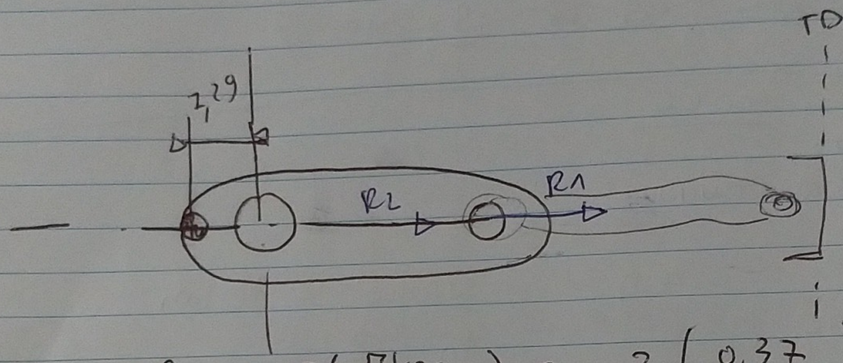
$= 2 \cdot \left(0,22 + \frac{0,37}{2}\right) \cdot \left(\frac{90}{2}\right) = 36,45$ kg·mm

b) For 100 % balance.

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

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

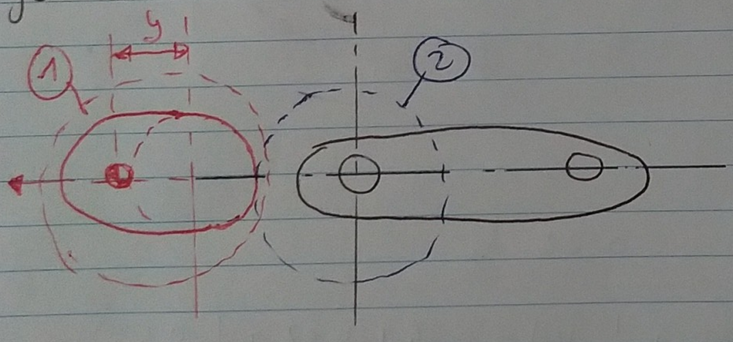
c)



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

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

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.

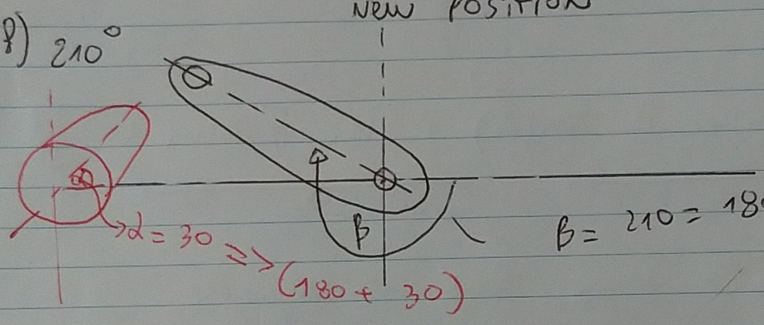
e) $m_{bal} = 2,5$ kg

For balance.

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

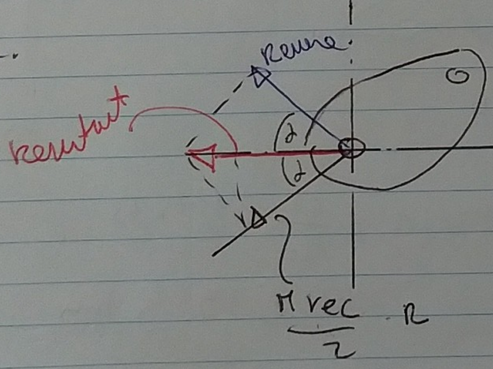
$$y = \frac{16,65}{2,5} = 6,66 \text{ mm}$$

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

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

⇓

MGX00510

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

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

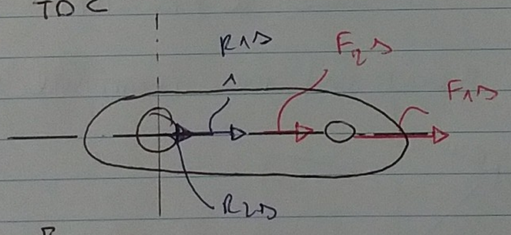
$=$

$=$

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

DAVID MIGLIORATI N°DOVA P1S0320
ADVANCE ~~ENGINE~~ ENGINE design 14/05/2020

M6×00410

Reverse ratio = 5,35

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

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

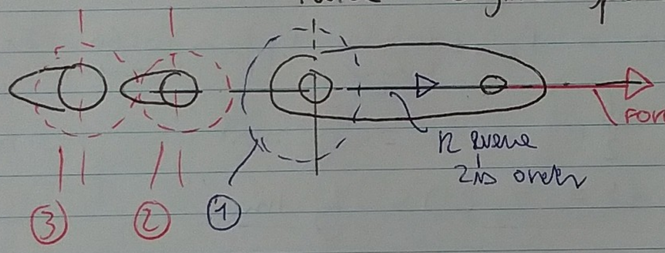
$M_{bal} \cdot 4(y) = \frac{R}{L} \cdot M_{rec} \cdot R$

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

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

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

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

DAVID MIGLIORATI N'DOUA P1503L0

ADVANCE ENGINE design. EXAM. 14/05/2020 10/12

M6X00410

SERIE 1

Q4)

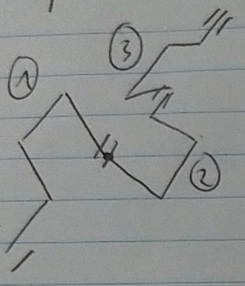
PISTON: 240 g = 0,240

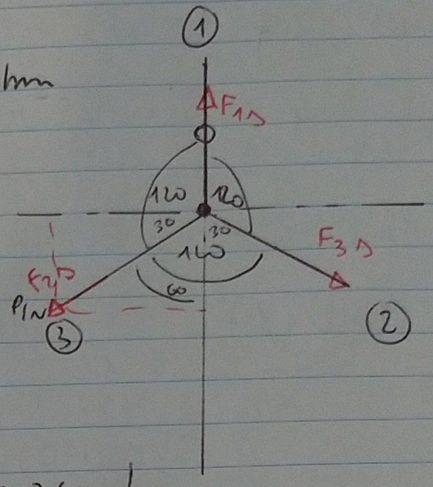
CONROD = 0,3 kg.

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.

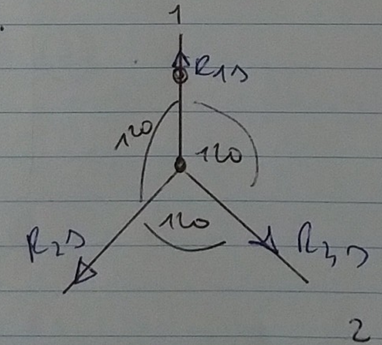
FREQUENCY 2ND ORDER $= F_3 \cdot \underbrace{\cos 60}_{0,5} + F_2 \underbrace{\cos 60}_{0,5} = F_1$

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

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

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

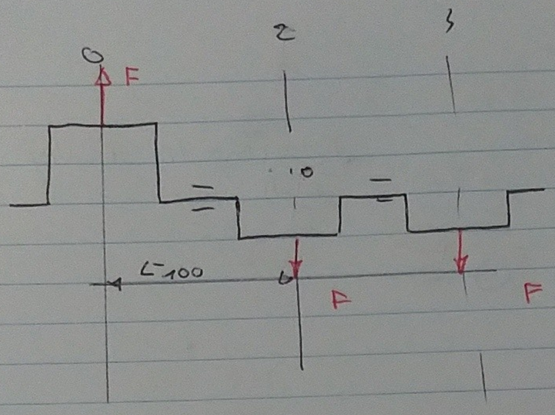
b)

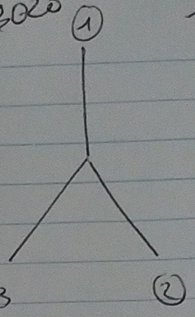


RESULTANT = 0

DAVID MIGLIORATI P150320 14/5/2020 11/72

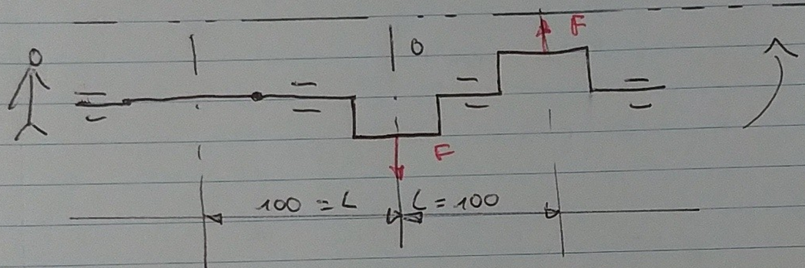
c)





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

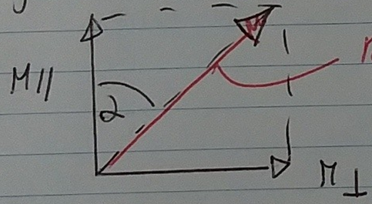
$= FL \cdot \frac{3}{2} = 2{,}295 \cdot (100) \cdot \frac{3}{2} = 344{,}25$ kg · mm · mm



$M_{\perp}$ = 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 => ?

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

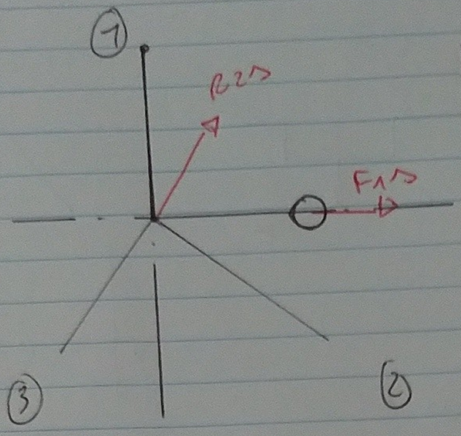
$\alpha = \tan^{-1}(0{,}577)$

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

All INLINE 3 CYLINDER

DAVID Migliorati P1502220 14 12/12

e)



RESULTANT IS ALWAYS "0"

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