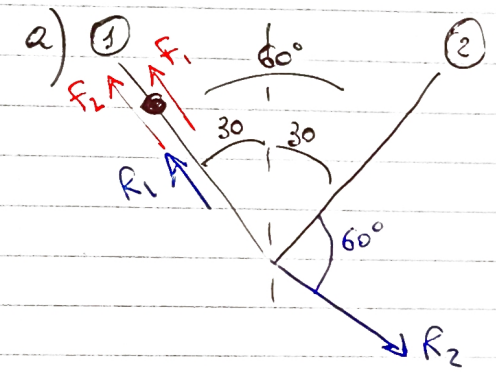
14/09/2020 13:15:00
M6 X00410 ADVANCED ENGINE DESIGN
ESAME DI CROSTA P151088

Q2

PISTON = 0,24 Kg
CONROD = 0,36 Kg
STROKE = 80 mm
R = 40 mm
L = 140 mm

a)



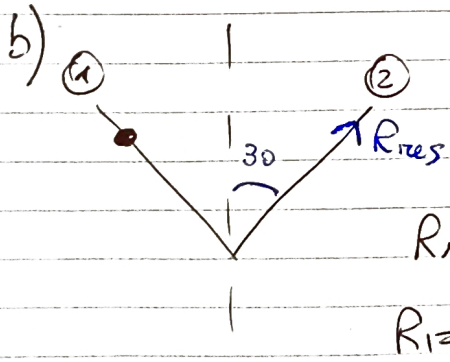
m_{rec} = PISTON + PIN + $\frac{1}{3}$ ROD
= 0,24 + $\left(\frac{1}{3}\right)$ 0,36
= 0,36 Kg

$m_{rot} = \frac{2}{3}$ ROD = $\frac{2}{3} \cdot 0,36 = 0,24$ kg

$f_T = f_1 + f_2$
$f_1 = f_2 = F$
$f_T = 2F$
$F = \left(\frac{m_{rec}}{2} + m_{rot}\right) R = 16,8$

- $f_T = 2\left(0,24 + \frac{0,36}{2}\right) 40 = 33,6$ Kg mm

b)



Reverse Resultant is along bank 2

$R_{res} = R_2 \cos(60) + R_1 \cos(60)$

$R_1 = R_2 = R$
$R = \frac{m_{rec}}{2} R\omega^2 = 7,2$

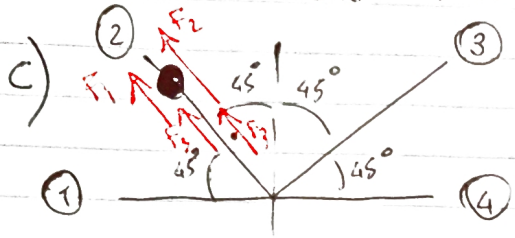
$R_{res} = \left(\frac{0,36}{2} \cdot 40\right) 0,5 + \left(\frac{0,36}{2} \cdot 40\right) 0,5$
$= 7,2$ Kg mm

14/05/2020 13:00 - 15:00

M6 x 00410 ADVANCE ENGINE DESIGN

EMANUELE DI COSTA PISICCHIO

c)



$F_{res} = ?$

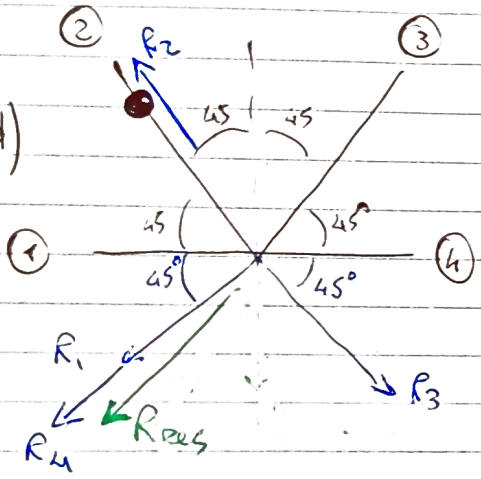
$F_{res} = 4F \qquad F_1 = F_2 = F_3 = F_4$

$= 4\left(m_{rot} + \frac{m_{rec}}{2}\right)R$

$= \left(0,24 + \frac{0,36}{2}\right)4 \cdot 40 =$

$= 67,2 \text{ Kg mm}$

d)



$R_2 = R_3$ OPPOSITE & SYMMETRICAL

$R_2 - R_3 = 0$

RESULTANT IS ALONG R_1 & R_4

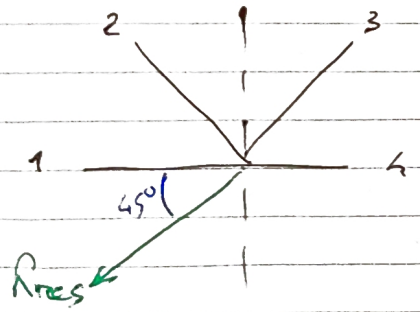
$R_{res} = 2(R_1 + R_4)$

$R_1 = R_4 = R$

$4R = 4 \cdot \left(\frac{m_{rec} R}{2}\right)$

$= 4 \cdot \frac{0,36 \cdot 40}{2}$

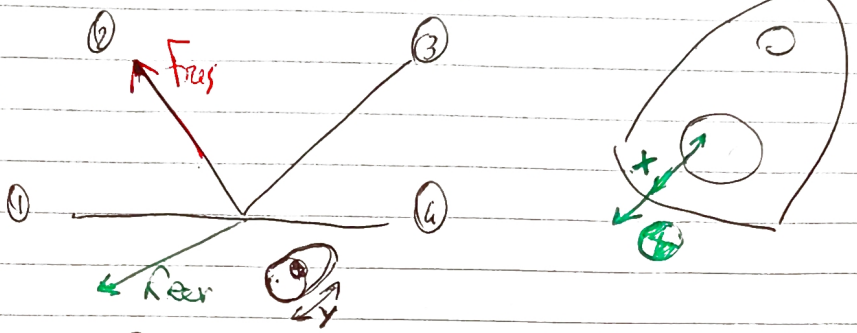
$= 28,8 \text{ Kg mm}$



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MECC410 ADVANCE ENGINE DESIGN
EMANUELE DI CROSTA P1510888

3

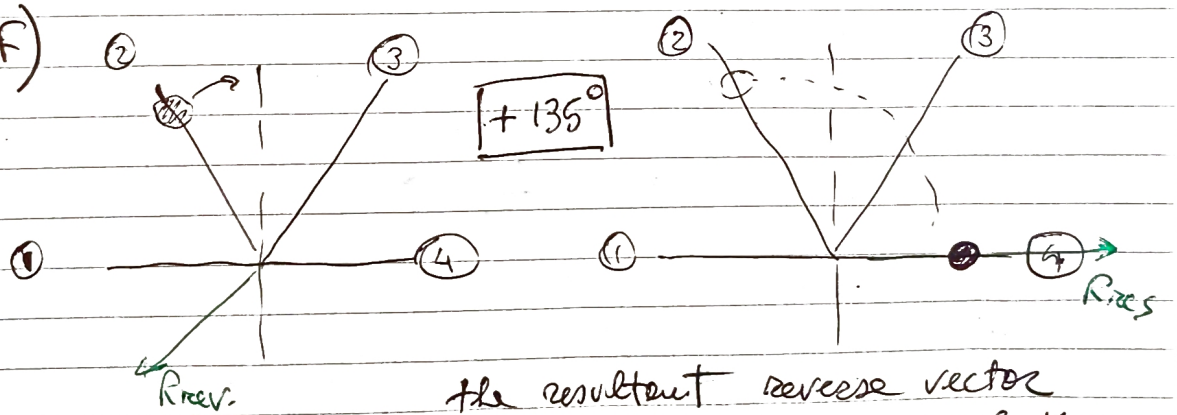
e)



THE FORWARD VECTOR IS BALANCED BY A CENTRIFUGAL FORCE GENERATED BY AN OFFSET OF THE COM OF THE CRANK (x)

THE REVERSE VECTOR RESULTANT IS BALANCED BY A COUNTER ROTATING BALANCE SHAFT THAT ROTATES AT THE SAME VELOCITY (ω) OF THE CRANK AND ITS ECCENTRIC IS POINTING OPPOSITE THE RESULTANT REVERSE VECTOR

f)



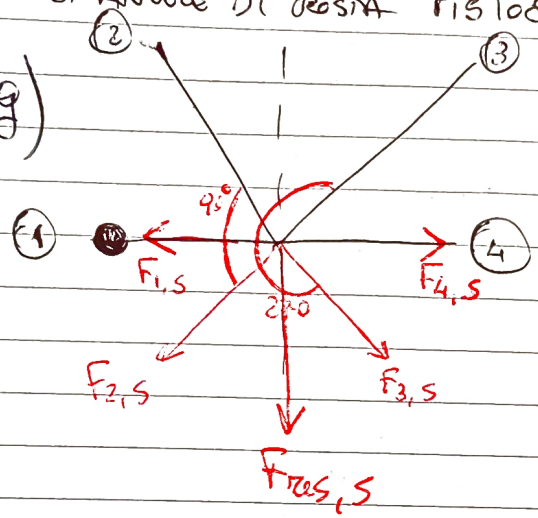
the resultant reverse vector rotates 135° counterclockwise and ends upon bank 4

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M6 100410 ADVANCE ENGINE DESIGN

EMANUELE DI ROSA P1510088

g)



$F_{2,S}$ is 2

$f_{3,S}$

$f_{4,S}$ is

$f_{1,S}$ & $F_{4,S}$ are symmetric and opposite, therefore cancel

Resultant forward second order vector is in between $F_{2,S}$ & $f_{3,S}$ therefore is vertical pointing downwards

$$F_{res} = F_{2,S}\cos(45°) + F_{3,S}\cos(45°)$$

$$F_{2,S} = F_{3,S} = F_S = \frac{1}{2}\frac{R}{L} M_{max} R$$

$$= 0,5\,\frac{40}{140}\,0,36 \cdot 40$$

$$= 2,05 \text{ Kg mm}$$

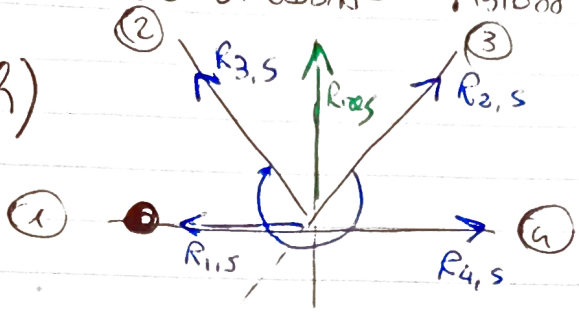
$$F_{res,S} = \underbrace{2,05 \cdot \cos 45°}_{1,45} + \underbrace{2,05 \cdot \cos 45°}_{1,45}$$

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

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MG X00410 ADVANCE ENGINE DESIGN
EMANUELE DI CROSTA P1510188

(5)

h)



$R_{4,s}$ & $R_{1,s}$ are opposite and equal therefore balance out

$R_s = \frac{1}{2}\frac{R}{L} m_{rec} R$ $\quad R_{3,s} = R_{2,s} = R_s$

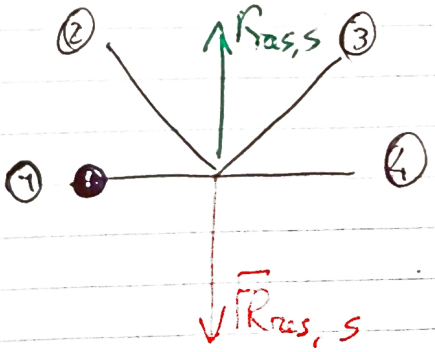
Resultant vertical, between bank 2 and 3

$R_{s,res} = R_{3,s}\cos(45) + R_{2,s}\cos(45)$

$2{,}05 \cdot \cos(45) + 2{,}05 \cos(45)$

$= 2{,}90$ Kg mm

i)



Both second order forward and reverse vectors are equal and opposite along the vertical axis therefore they balance out

IF THE CRANK ROTATES THE DIRECTION CHANGES

IF the crank rotates the two vectors balance out only when

$(=0)$

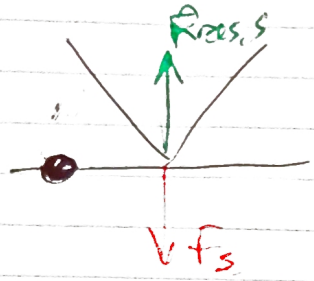
crankpin is on bank 1 or 4
ON bank 2 or 3 the resultant vectors are at 90° between them

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MG X00410 ADVANCE ENGINE DESIGN

EMANUELE DI CROSTA PISICO8

(6)



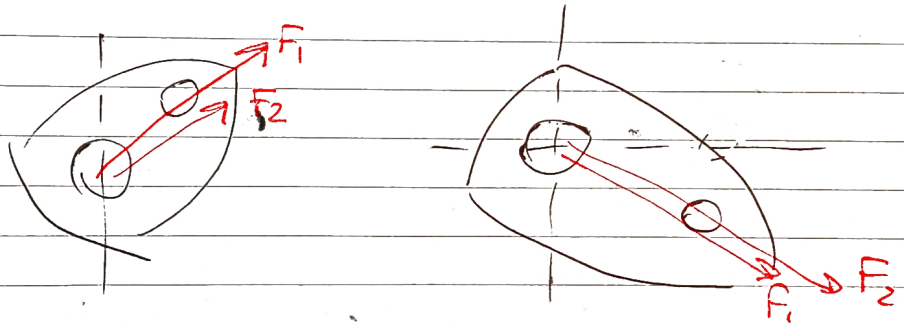
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EMANUELE DI CROSTA P151088

(7)

Q1) 500 cc HORIZONTALLY INSTALLED
IN-LINE PARALLEL
TWIN CYLINDER 1 PW
2 CONROD

PISTON + PW = 0,24 Kg
ROD = 0,33 Kg
big end = 0,02 Kg
STROKE = 90 mm
R = 45 mm
M CRANK = 9 Kg
L = 140 mm

a)



$M_{roff} = \frac{2}{3} m_{rod} = \frac{2}{3} \cdot 0,3 = 0,22$ Kg

M_{rec} = PISTON + PW + BIG BEARING + $\frac{1}{3}$ ROD

$0,24 + 0,02 + \frac{1}{3} 0,33 = 0,37$ Kg

$F_T = 2 \cdot f$ $F_1 = F_2 = F$

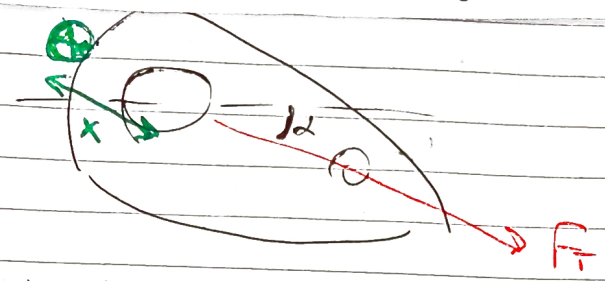
$F = \left(\frac{M_{rec}}{2} + M_{roff}\right) R = 18,225$ Kg mm

$F_T = 2 \cdot 18,225 = 36,45$ Kg mm

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EMANUELE DI CROSTA P151088

(8)

b)



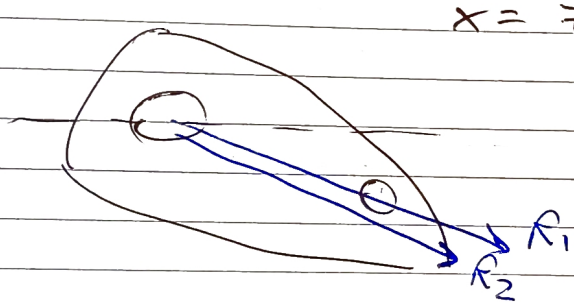
FOR 100% BALANCE:
YOU OFFSET

$M_{crank} \cdot x = F_T$

$5 \cdot x = \frac{36,45}{5}$

$x = 7,29$ mm

c)

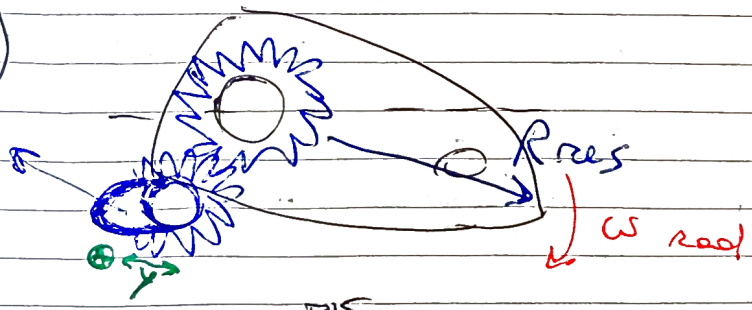


BECAUSE AT TDC SIMULTANEOUSLY

$R_1 = R_2 = R \quad R = \frac{M_{rec} R_{eq}}{2} = \frac{0,37}{2} \cdot 45 = 8,325$ Kg mm

$R_T = 2R = 16,65$ Kg mm

d)



I WOULD DRIVE THE BALANCE SHAFT BY GEARS.
THE BALANCE SHAFT WILL ROTATE ANTI-CLOCKWISE IN RESPECT TO THE ENGINE & AT THE SAME SPEED
THE GEARS WILL HAVE SAME NUMBER OF TEETH AND THE ECCENTRIC WILL POINT OPPOSITE THE REVERSE RESULTANT VECTOR

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EMANUELE DI CROSTA P1510388

(9)

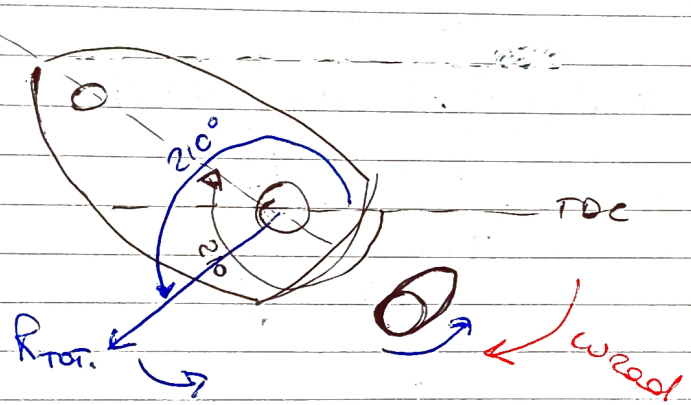
e) $M_{balance} = 2,5\ Kg$

$$M_{bal.} \cdot y = R_{ecc\,TOT.}$$

$$2,5 \cdot y = 16,65$$

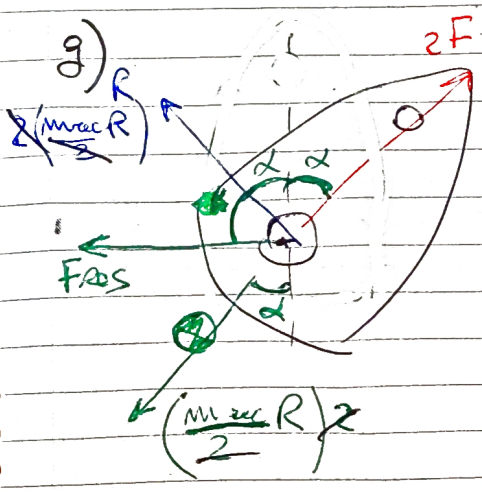
$$y = \frac{16,65}{2,5} = 6,66\ mm$$

f)



THE ECCENTRIC HAS REVOLVED 210° ANTI-CLOCKWISE

g)



WHEN BALANCE SHAFT CAN'T BE USE THE AIM IS TO CANCEL THE FORWARD VECTOR, WITH THE CENTRIFUGAL CRANKSHAFT FORCE, SO TO END UP WITH AN HORIZONTAL RESULTANT FORCE BETWEEN THE CENTRIFUGAL CRANK FORCE & THE REVERSE

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EMANUELE DI CROSTA P1510388

(10)

$M_{crank} \cdot x$ = FORWARD resultant

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

$2\left(M_{rec} + M_{rot}\right)R - 2\left(\frac{M_{rec}}{2} + M_{rot}\right)R =$

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

$2M_{rec}R + 2M_{rot}R - M_{rec}R - 2M_{rot}R =$

$= M_{rec}R$

$M_{rec}R = M_{rec}R$

HORIZONTAL Resultant $= \left(M_{rec}R \sin(\alpha)\right)2$

FOR $\sin\alpha$ SMALL = NEGLIGIBLE

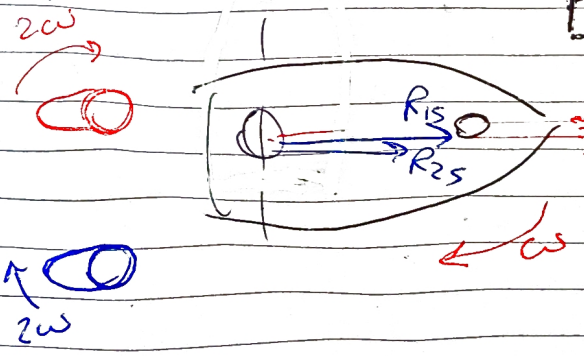
HORIZONTAL RESULTANT $= M_{rec}R \cdot 2$

MASS MOMENT OF CRANK SHAFT = $0{,}37 \cdot 45 \cdot 2$

$= 33{,}3$ Kg mm

PUT ENGINE TDC

b)



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$$F_S = \frac{1}{2}\frac{R}{L} m_{rec} R$$

$$F_{S\,TOTAL} = 2\left(\frac{1}{2}\frac{R}{L} m_{rec} R\right) =$$

$$\frac{45}{140}\ 0{,}37\ 45 \simeq 5{,}35\ Kg\,mm$$

$$R_{S\,TOTAL} = F_{S\,TOTAL} = 5{,}35\ Kg\,mm$$

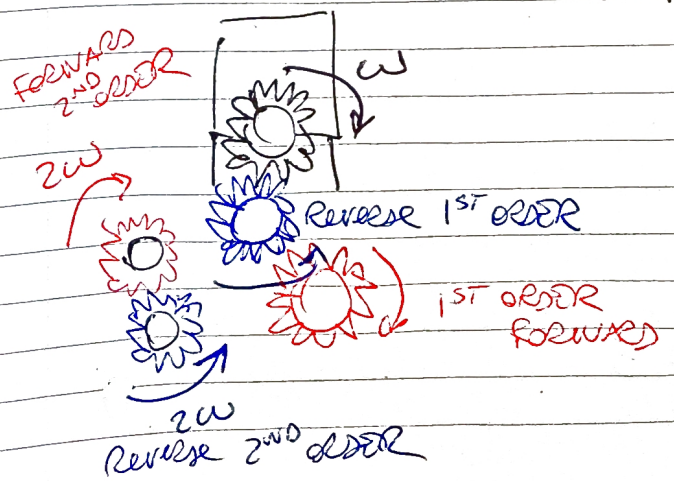
$$m_{BAL} \cdot y \cdot (2\omega)^2 = \frac{R}{L} m_{rec} R$$

$$4 m_{BAL} \cdot y = \frac{R}{L} m_{rec} R$$

$$m_{BAL} \cdot y = \frac{R}{4L} m_{rec} R$$

$$m_{BAL} \cdot y = 1{,}33\ Kg$$

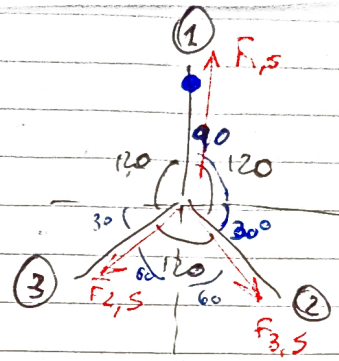
the balance shaft must rotate Twice engine speed, therefore they will have half the teeth



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Q4) IN LINE 3

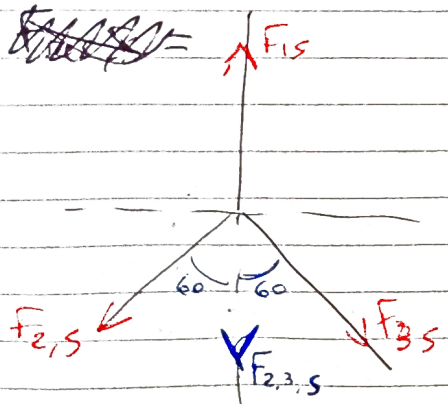
PISTON = 0,24 Kg
ROD = 0,3 Kg
L = 150 mm
STROKE = 90 mm
R = 45 mm
BORE SPACING = 100 mm





$M_{rec} = \frac{1}{3} rod + PIST = \frac{1}{3} 0,3 + 0,24 = 0,34$ Kg

$M_{rot} = \frac{2}{3} rod = \frac{2}{3} 0,3 = 0,2$ Kg



$F_{1,S} = F_{2,S} \cos(60) + F_{3,S} \cos(60)$

$F_{2,S} = F_{3,S} =$

$F_{S,S} = \frac{1}{2} \frac{45}{150} \cdot 0,34 \cdot 45 = 2,295$ Kg mm

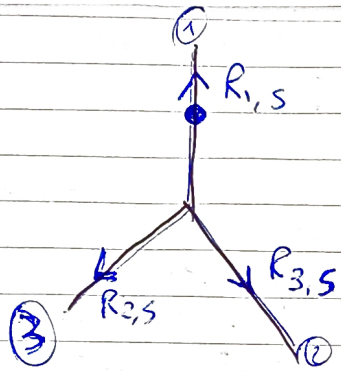
$F_{RES} = 0$

the resultant of second forward rotating vector is zero
therefore it is balanced

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EMANUELE DI CROSTA P151033

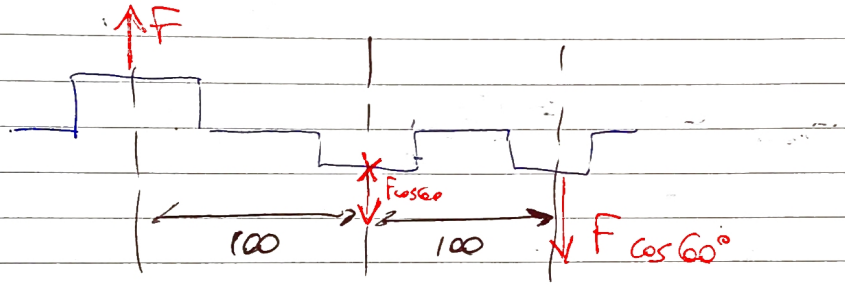
13

b)

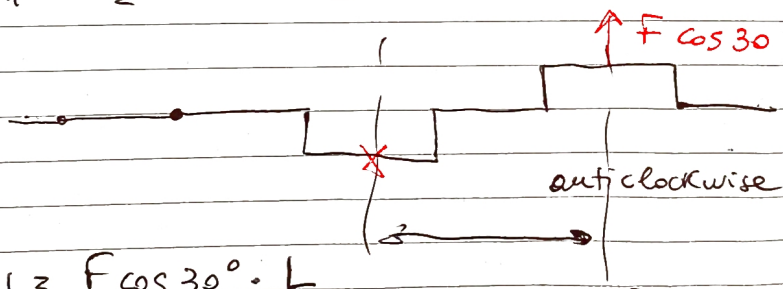


the reverse second order vector resultant is equal to zero

c)

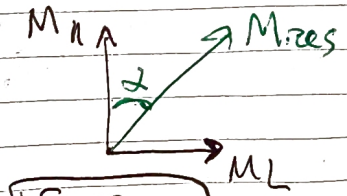


$M_{II} = \frac{3}{2} FL = \frac{3}{2} \cdot 2,295 \cdot 100 = 344,25$ Kg mm mm



$M_{\perp} = F \cos 30° \cdot L$

$2,295 \cdot \cos 30° \cdot 100 = 198,75$ Kg mm mm



$\tan \alpha = \frac{M\perp}{M_{II}} = \frac{198,75}{344,25} = 0,57$

$\alpha = 29,99 \equiv 30°$

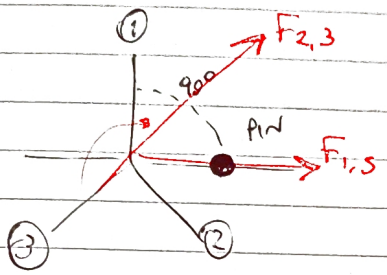
front view

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EMANUELE DI CROSTA P1910338

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30° AS ALL INLINE 3 CYLINDERS
OR ALL V6

e)



FORWARD

~~the resultant is still zero even if the pin rotates 90°~~

F)

~~the~~