THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

TERM 3 – JULY 2016
EEE 3112 - ELECTRICAL ENGINEERING PRACTICE

ANSWER ALL QUESTIONS　　　　TIME ALLOWED　2 HOURS
CLOSED BOOK

Question 1

A 4m long beam supported by pin joints at its ends, carries two 40kg motors at ¼ and 3/4 of the span of the beam. All motors rotating in the same direction, deliver 60kw at 3000rpm to downstream applications. Find:

(a) The reactions at the pin joints (6 marks)
(b) expressions for the slope of the beam at each end in terms of EI. (10 marks)
(b) expression for the maximum deflection in terms of EI. (9 marks)

40 40

Question 2

You have been commissioned to design the suspension for a new light truck. The net weight of the light truck up is 3200kg, distributed 35% on the rear axle and 65% on the front axle. When fully loaded an additional 7000kg is added to the light truck, distributed 80% on the rear axle and 20% on the front axle. You are using, on the front axle 2 identical helical close coiled springs in parallel, and on the rear axle 2 identical leaf springs in parallel. Your design constraint is, completely unloaded to fully loaded, the maximum static deflection on either axle should not exceed 15 cm. given for:

60kw

3000rpm

Helical spring:

Mean coiled diameter	=	30cm
Modulus of rigidity	=	83.5 GN/m^2
Wire diameter	=	35mm

Regina. T. Nyirenda

Leaf spring:

Length	=	1 m
Number of leaves	=	8
Width to thickness ratio	=	8:1
Elastic modulus	=	125 GN/m^2

Find:

(a) the number of complete coils required in the helical springs (6 marks)
(b) the width of the leaf springs (6 marks)
(c) the deflection at both axles when acted upon the net weight of the pickup only. (6 marks)

11007.36

(d) If the distance between the rear and front axle is 6 m what is the magnitude and direction of the shift in the centre gravity of the pickup when loaded with the additional 5000kg. (7 marks)

Question 3

A solid 1m shaft of radius 60 mm and density 4 g/cm^3 carries 4 unbalanced masses spaced as follows:

Masses A, B, C, and D are 13, 12, 11, and 10kg respectively, rotating at radii 10, 11, 12, 13cm respectively, and spaced from one end of the shaft at 30, 45, 60, and 75 cm respectively. the angular spacing from A to B, C, and D are 60, 120, and 180° respectively.

(a) Balance the shaft using two 15 kg masses at either end (9 marks)

(b) If before balancing, the shaft rotated at 3000 rpm what will be its rotation after balancing. (7 marks)

(c) If all masses are removed from the shaft and the power transmitted is 150 kW, determine the maximum shear stress on the shaft. (9 marks)

Note: Uniform disc or cylinder, radius r. I about the central axis is $\frac{mr^2}{2}$ and $k = \frac{r}{\sqrt{2}}$

Question 4

You are designing the spring damper system for a 1850 kg 4X4 Luxury vehicle. The test road is sinusodially undulated with a maximum displacement of 36cm. If the maximum allowable displacement of the vehicle relative to the road is 42cm, determine:

(a) the damping ratio and state whether it is over, critically or under damped (6 marks)

If the length of one undulation is 2m, and the damping coefficient is 9500kg/s, determine:

(b) the stiffness of the suspension (5 marks)

(c) the speed in km/h of the vehicle at maximum displacement (7 marks)

(d) the maximum displacement of the vehicle if the and the vehicle is moving a 140km/h (7 marks)

END OF TEST

$$\frac{x}{y} = \sqrt{\frac{1 + (2\xi r)^2}{(1-r^2)^2 + (2\xi r)^2}}$$

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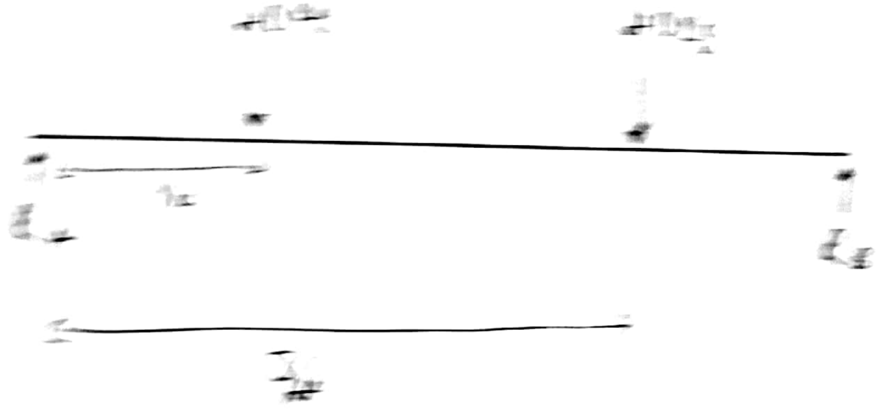
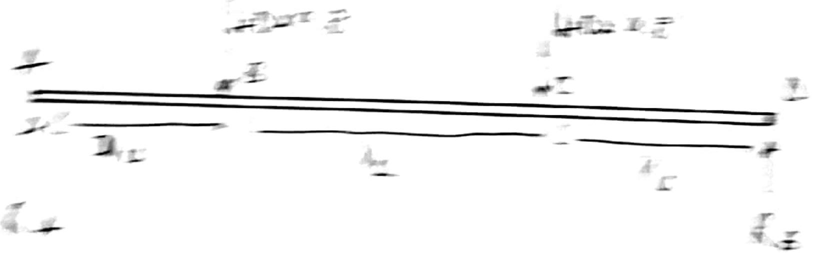
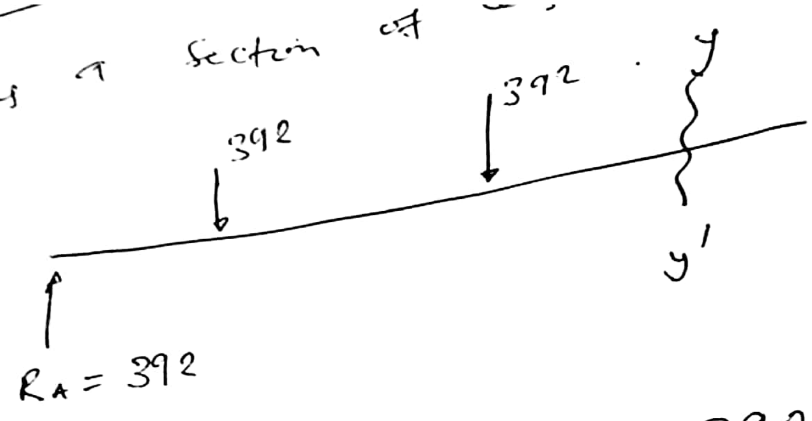




(b) Choosing a section of y y'



$$M = 392x - 392(x - \tfrac{1}{4}l) - 392(x - \tfrac{3}{4}l)$$

$$EI\frac{d^2y}{d^2x} = M$$

$$EI\frac{d^2y}{d^2x} = 392x - 392(x - \tfrac{1}{4}l) - 392(x - \tfrac{3}{4}l).$$

$$EI\frac{dy}{dx} = \frac{392x^2}{2} - \frac{392}{2}(x - \tfrac{1}{4}l)^2 - \frac{392}{2}(x - \tfrac{3}{4}l)^2 + C$$

$$EIy = \frac{392}{6}x^3 - \frac{392}{6}(x - \tfrac{1}{4}l)^3 - \frac{392}{6}(x - \tfrac{3}{4}l)^3 + Cx + D$$

at ends, $y = 0$ say at $x = l$ and $x = 0$ ...

at $x = 0$

$\underline{0 = D}$

$x = l$

$$0 = \frac{392l^3}{6} - \frac{392}{6}(l - \tfrac{1}{4}l)^3$$

$$- \frac{392}{6}(l - \tfrac{3}{4}l)^3 + Cl$$

(2)

$$-Cl = \frac{392}{6} l^3 - \frac{392}{6} l^3\left(\frac{27}{64}\right) - \frac{392}{6} l^3\left(\frac{1}{64}\right)$$

$$-C = \frac{392}{6} l^2 - 27.5625 l^2 - 1.020 l^2$$

$$C = -36.75 l^2$$

Expression for slope of beam

$$EI\frac{dy}{dx} = \frac{392x^2}{2} - \frac{392}{2}\left(x - \frac{1}{4}l\right)^2 - \frac{392}{2}\left(x - \frac{3}{4}l\right)^2 - 36.75l^2$$

end 1 where $x = 0$

$$EI\frac{dy}{dx} = -36.75l^2$$

$$\frac{dy}{dx} = \frac{-36.75l^2}{EI}$$

for end 2 where $x = l$

$$EI\frac{dy}{dx} = \frac{392 l^2}{2} - \frac{392}{2}\left(l - \frac{1}{4}l\right)^2 - \frac{392}{2}\left(l - \frac{3}{4}l\right)^2 - 36.75l^2$$

$$EI\frac{dy}{dx} = 196 l^2 - \frac{441}{4} l^2 - \frac{49}{4} l^2 - 36.75 l^2$$

$$EI\frac{dy}{dx} = 32.75 l^2$$

$$\therefore \frac{dy}{dx} = \frac{32.75\,l^2}{EI}$$

(c) Expression for Maximum Slope.

the max ~~Slope~~ deflection is between $\frac{1}{4}l$ and $\frac{3}{4}l$

for $\frac{dy}{dx} = 0$

$$\frac{392}{2}x^2 - \frac{392}{2}\left(x - \frac{1}{4}l\right)^2 - 36.75l^2 = 0$$

$$\frac{392}{2}x^2 - \frac{392}{2}\left(x^2 - \frac{1}{2}xl + \frac{l^2}{16}\right) - 36.75l^2 = 0$$

$$\frac{392}{2}\left[+\frac{1}{2}xl - \frac{l^2}{16}\right] - 36.75l^2 = 0$$

$$98xl - \frac{196}{16}l^2 - 36.75l^2 = 0$$

$$\underline{\underline{x = 0.5l}}$$

Max deflection

$$y = \frac{\frac{392}{6}(0.5l)^3 - \frac{392}{6}\left(0.5l - \frac{1}{4}l\right)^3 - 36.75l^2}{EI}$$

$$y = \cancel{8E} \quad \frac{8.1667c^3 - 10.2c^3 - 36.75c^2}{EI}$$

Question 2

net weight = 3200 Kg $\delta = 15cm$

35% on rear axle

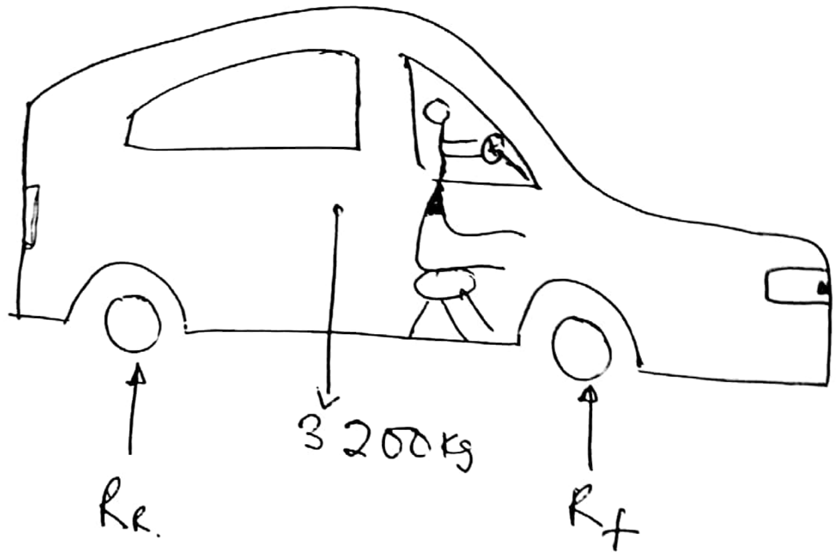
65% on front axle

Loading = 7000 Kg

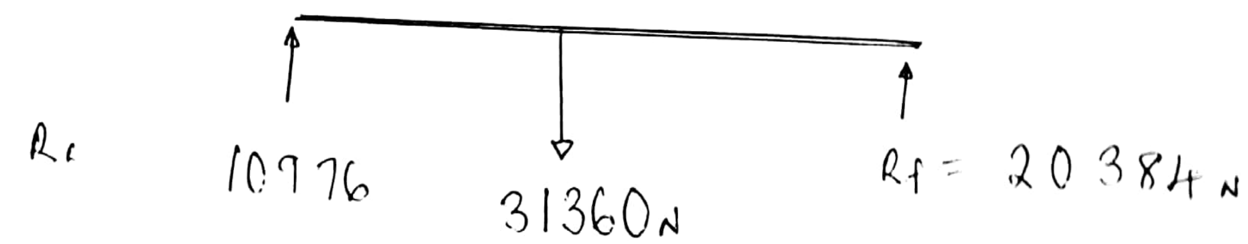
80% on rear axle

20% on front axle

(a) diagram



free body diagram



Question 2

net weight = 3200 Kg $\delta = 15$ cm

35% on rear axle

65% on front axle

Loading = 7000 Kg

80% on rear axle

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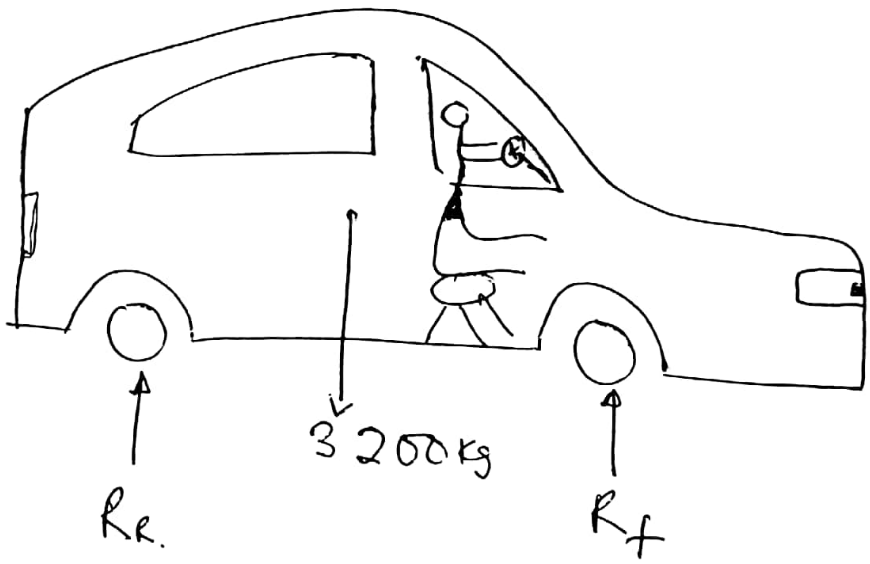
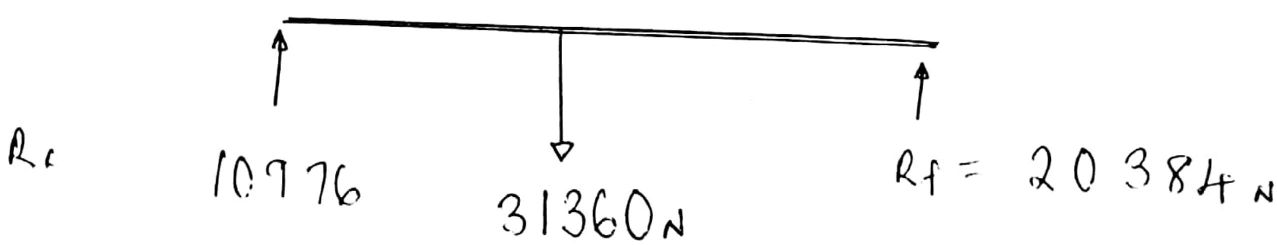
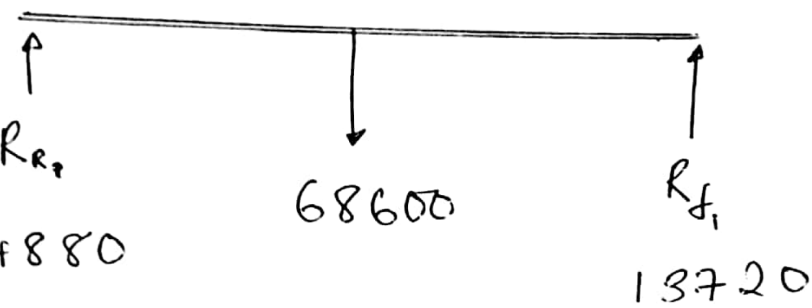
a. diagram



free body diagram



for the loads



Total force on Rear axle $= 54880 + 10976$

$= 65856 \, N$

Total force on front axle $= 13720 + 20384$

$= 34104 \, N$

(a) Number of complete coils in helical springs.

Since springs are in parallel

Load/Spring $= \dfrac{\text{load}}{2} = 17052 \, N$

$$\delta = \frac{64 W R^3 n}{G d^4}$$

$$64 * 17052 * (0.15)^3$$

$$n = \frac{18.795 \times 10^3}{3683.232}$$

$$n = 5.1028$$

number of complete springs, if we choose. 5 the 0.1028 will cause extra deflection

$\therefore$ Complete coils better be in design

$$\underline{n = 5}$$

(3)

(b) $$\delta = \frac{3WL^3}{8ENbt^3}$$

Load per spring $= \frac{65856}{2} = 32928$

$L = 1m$

$N = 8$

$E = 125 \times 10^9$

$\frac{b}{t} = \frac{8}{1}$

$b = 8t$

$t = \left(\frac{b}{8}\right)$

$$\therefore \quad 0.15 = \frac{(3)(32928)(1)^3}{(8)(125 \times 10^9)(8)(b)\left(\frac{b}{8}\right)^3}$$

$$\frac{1.2 \times 10^{12} \cdot b^4}{512} = 98784$$

$b^4 = 4.214 \times 10^{-5}$

$b = 0.08057m$

$\underline{\underline{b = 8.057cm}}$

(c) Deflection when acted upon by net weight only.

front axle.

$$\delta = \frac{64WR^3n}{Gd^4} = \frac{64 * 10192 * (0.15)^3 * 5}{(83.5 \times 10^9) \times (0.035)^4}$$

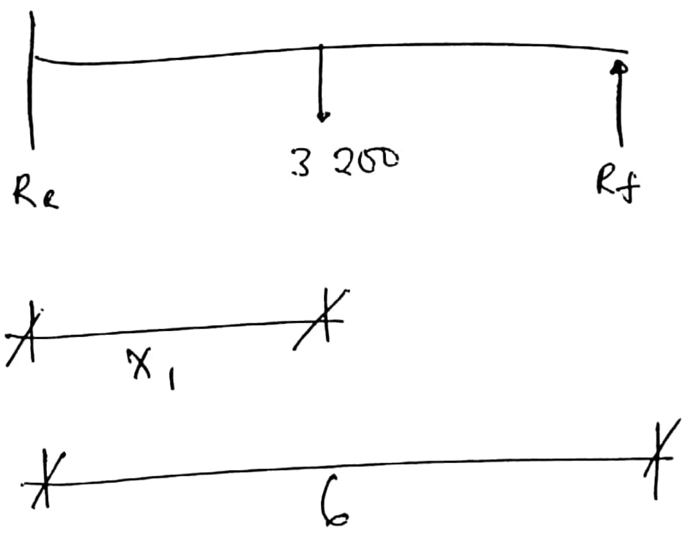
$\underline{\underline{\delta = 8.784cm}}$

deflection on Rear axle.

$$\delta = \frac{3Wl^3}{8ENbt^3} = \frac{3 * 5488 * 1^3}{8 * 125 \times 10^9 * 8 * 0.08057 * (0.01)^3}$$

$$\underline{\delta = 2.500\,cm}$$

(d) centre of gravity shift

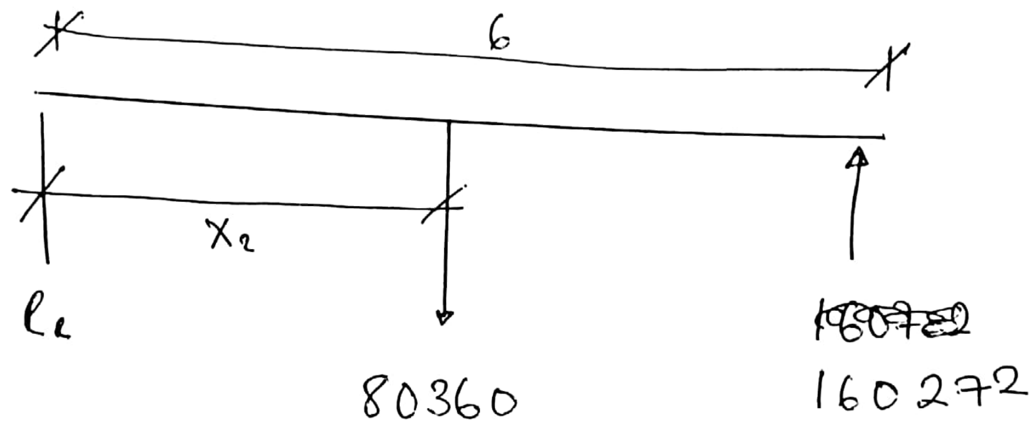


$$\sum M_{RR} = 0$$

$$(31360 \times x_1) = (20348 \times 6)$$

$$\underline{X_1 = 3.9\,cm}$$

After 5000 loading



provided that after loading the share of weights is as given in question on 7000 kg.

Say 80% rear

20% front

$$\sum M_{Re} = 0$$

$$80360 x_2 = 1607.2 \times 6 \times 10$$

$$X_2 = 0.12 \text{cm} \times 10$$

$$X_2 = 1.2 \text{cm}$$

from the two calculations

the centre of gravity shifts towards the rear axle by ~~(3.9 - 0.12) = 3.78~~ cm

$$3.9 - 1.2 = \underline{\underline{2.7 \text{ cm}}}$$

A	13	0	0.1	0.3	1.3	0.39	0.39	0
B	12	60	0.11	0.45	1.32	0.594	0.297	0.514
C	11	120	0.12	0.6	1.32	0.792	-0.396	0.686
D	10	180	0.13	0.75	1.3	0.975 ~~0.0225~~	-0.975 ~~-0.0225~~	0
X	15			0				
Y	15			1				
Σ							-0.684	1.2

$$\Sigma Mrl \cos\theta = -0.684$$

$$\Sigma Mrl \sin\theta = 1.2.$$

$$Mrl = \left[(1.2)^2 + (0.684)^2\right]^{1/2} = 1.381$$

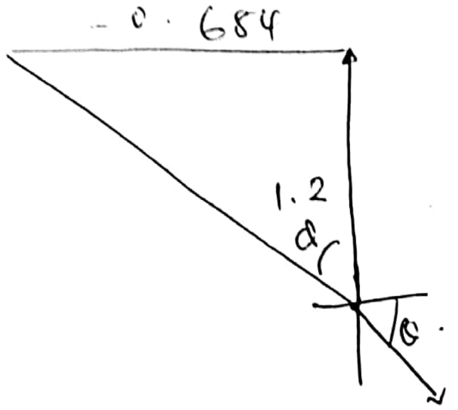
for y

$l = 1$ $\qquad r = \dfrac{1.381}{15} = \underline{\underline{9.208\,cm}}$

$m = 15$

$$\theta = \tan^{-1}\left(\frac{1.2}{-0.684}\right)$$

$$= -60.316^\circ$$



$\therefore \theta = 300°$

Solving for mass X using mr

θ	Mass	mr	mr cos θ	mr sin θ
0	A	1.3	1.3	0
60	B	1.32	0.66	1.143
120	C	1.32	-0.66	1.143
180	D	1.3	-1.3	0
300	y	1.3812	0.6906	-1.196
	X			

$$\sum mr\cos\theta = 0.6906$$

$$\sum mr\sin\theta = 1.09$$

$$Mr = \left[(1.09)^2 + (0.6906)^2\right]^{1/2}$$

$$Mr = 1.29$$

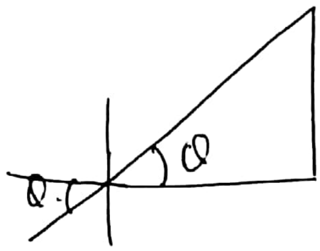
for X

$$m = 15$$

$$\therefore r = \frac{1.29}{15} = \underline{\underline{8.60\text{ cm}}}$$

$$\theta = \tan^{-1}\left(\frac{1.09}{0.6906}\right)$$

$$\theta = 57.64^\circ$$



$$\therefore \theta = 180 + 57.64$$

$$= \underline{\underline{237.64^\circ}}$$

$\therefore$ Balancing of Masses is

X = 15 Kg, radius = 8.60 cm, $l = 0$ m

$\theta = 237.64^\circ$

Y = Mass = 15 Kg, radius = 9.208 cm, $l = 1$ m

$$\underline{\underline{\theta = 300^\circ}}$$

Initial rotation = 3000 rpm

using Conservation of Momentum

$$L_i = L_f$$

$$L_i = \left(I_s + \sum I_m\right)\omega$$

$$I_s = \frac{Mr^2}{2} = \frac{m \times \left(\frac{60}{1000}\right)^2}{2}.$$

Calculations for m

$$\rho = 4 \, g/cm^3$$

$$V = \pi r^2 L. \quad = 6^2 . \pi . 4 \times 100$$

$$m = \rho V = 45.24 \, Kg$$

$$I_s = \frac{(45.24)\left(\frac{60}{1000}\right)^2}{2} = 0.081432 \, Kg m^2$$

$$\sum I_m = \sum M_i r_i^2 = (13)(0.1)^2 + 12(0.11)^2 + 11(0.12)^2$$
$$+ 10 \times (0.13)^2$$
$$= \underline{\underline{0.6026}} \, Kg m^2$$

(4)

$$L_i = (0.6026 + 0.081432)\,3000$$

$$L_f = \omega_f(0.081432 + \Sigma I_m)$$

$$= \omega_f(0.081432 + 0.6026 + 0.2381)$$

$$L_i = L_f$$

$$\omega_f = \frac{2052.096}{0.9221528}$$

$$\underline{\underline{\omega_f = 2225.33 \text{ rpm}}}$$

(c) again conserving momentum.

$$(2225.33)(0.922132) = 0.081432(\omega_f)$$

$$\underline{\underline{\omega_f = 25.19952 \times 10^3 \text{ rpm}}}$$

$$P = \frac{2\pi N T}{60}$$

$$T 2\pi N = P . 60$$

$$T = \frac{P . 60}{2\pi N} = \frac{(150\ 000)(60)}{2 * \pi * 25.19952 \times 10^{3}}$$

$$\underline{T = 56.842\ Nm}$$

$$\frac{T}{J} = \frac{\tau}{R}$$

$$\tau = \frac{TR}{J} = \frac{(56.842)(0.06)}{\frac{\pi}{32}(0.12)^{4}}$$

$$\boxed{J = \frac{\pi}{32} D^{4}}$$

$$\tau = \frac{3.41052}{2.035 \times 10^{-5}} = \underline{\underline{167.531\ KN/m^{2}}}$$

6

Question 11

mass $m = 1850\ \text{Kg}$

$y = 36\text{cm}$

$x = 42\text{cm}$

(a) Since data given is at maximum, this implies that $\omega = \omega_n$

$$\therefore \frac{\omega}{\omega_n} = 1$$

using "transmisibility ratio T_d."

$$T_d = \frac{x}{y} = \left[\frac{1 + (2\zeta r)^2}{(1-r^2)^2 + (2\zeta r)^2}\right]^{1/2}$$

where ζ = damping ratio

$$\left(\frac{42}{36}\right)^2 = \frac{1 + 4\zeta^2}{(1-1) + 4\zeta^2} \qquad r = 1$$

$$\left(\frac{42}{36}\right)^2 = \frac{1}{4\zeta^2} + 1$$

$\Rightarrow$ [illegible]

$$0.3611 = \frac{1}{4\zeta^2}$$

$$\zeta = 0.832$$

$$\frac{13}{9}\zeta^2 = 1$$

$\therefore$ it is underdamped

Length of one modulation is 2m

$C = 9500\ Kg/s$

(b) Stiffness.

$$\omega_n = \sqrt{\frac{K}{m}}$$

$$K = (\omega_n)^2 m$$

using $$\zeta = \frac{c}{m\,2\omega_n}$$

$$2\zeta\omega_n m = c$$

$$\omega_n = \frac{c}{m2\zeta} = \frac{9500}{(1850)(2)(0.832}$$

$$\omega_n = 3.0858\ rads/s$$

$$K = (\omega_n)^2 \cdot m = (3.0858)^2 \cdot 1850$$

$$\underline{\underline{K = 17616.37\ N/m}}$$

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(c) The speed in Km/hr at max displacement.

$\omega_n = 3.086 \, rad/s$

$\omega = 2\pi f$

$f = \frac{\omega_n}{2\pi} = \frac{3.086}{2\pi} = 0.4911 \, Hz.$

Speed $= 2 * 0.4911$

$= 0.9823 \, m/s$

$= \underline{\underline{3.536 \, Km/h}}$

(d) Displacement given speed $= 140 \, Km/h$

$140 \, Km/h$

$= 38.889 \, m/s$

using ratios

$x - 38.89$

$42 - 3.536$

They are inversely proportional

$x = \frac{42 \times 3.536}{38.89}$

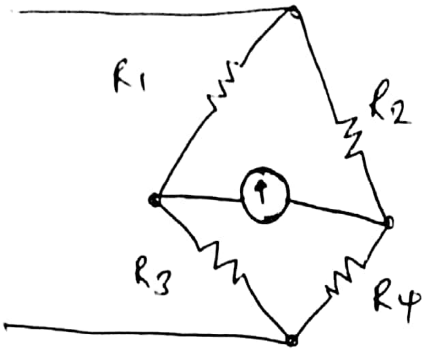
$\cancel{x/1} \cancel{3.18}$

$\underline{x = 3.8188 \, cm}$

digital.

Jasper

Signals



at balance.

$I_1 = I_3 \qquad I_2 = I_4$

$$\frac{\cancel{I_1} R_1 = \cancel{I_2} R_2}{\cancel{I_1} R_3 = \cancel{I_2} R_4}$$

$$\frac{R_1}{R_3} = \frac{R_2}{R_4}. \qquad R_4 R_1 = R_3 R_2$$

$$R_x = \frac{R_3 R_2}{R_1}$$

$$R_x = \frac{4.5 \times 10}{15} = \frac{45}{15}$$

$$= 3$$

$\log_2 8 = 3$

$\log_2 8 = x.$

$= 2^x = 8$

EE 392 TUTORIAL

November 2006 — Ref: 1/2/2006

Question 1

A beam, which is supported through pin joints at its ends, is acted upon by a couple M in a plane containing the axis of the beam, applied at a point two thirds of the span from one end. Find expressions for the slope of the beam at both ends, and the maximum deflection.

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done

Question 2

Compare the weights of equal lengths of hollow and solid shaft to transmit a given torque for the same maximum shear stress, if inside diameter is ¾ of the outside. done

Question 3

You have been commissioned to design the suspension for a new light truck. The net weight of the light truck up is 3000kg, distributed 38% on the rear axle and 62% on the front axle. When fully loaded an additional 5000kg is added to the light truck, distributed 75% on the rear axle and 25% on the front axle. You are using, on the front axle 2 identical helical close coiled springs in parallel, and on the rear axle 2 identical leaf springs in parallel. Your design constraint is, completely unloaded to fully loaded, the maximum static deflection on either axle should not exceed 15 cm. given for:

Helical spring:

Mean coiled diameter	=	25cm
Modulus of rigidity	=	83.5 GN/m^2
Wire diameter	=	35mm

done

Regina. T. Nyirenyo

Leaf spring:

Length	=	1 m
Number of leaves	=	6
Width to thickness ratio	=	8:1
Elastic modulus	=	125 GN/m^2

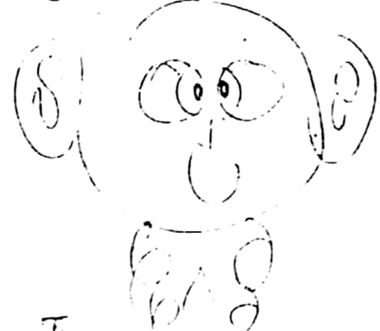
Find:

(a) the number of coils required in the helical springs (5 marks)

(b) the width of the leaf springs (5 marks)

(c) the deflection at both axles when acted upon by the net weight of the pickup only. (4 marks)

(d) If the distance between the rear and front axle is 6 m what is the magnitude and direction of the shift in the centre of gravity of the pickup when loaded with the additional 5000kg. (6 marks)



$\varepsilon = \frac{L}{C_c}$

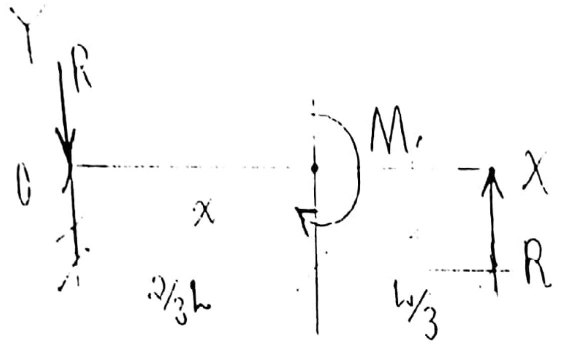
student Engineer JERRY ZEE

BEng, MEng, PEng, MEIZ, Ph.D

SOLUTIONS TO TUTORIALS

WE 302 (2006) NOVEMBER

QUESTION 1



$RL = M$; $\boxed{R = \frac{M}{L}}$

Moment, M_x = ?

$$EI\frac{d^2y}{dx^2} = M_x = -Rx + M\left[x - \frac{2L}{3}\right]^0$$

$$EI\frac{dy}{dx} = -\left(\frac{R}{2}\right)x^2 + M\left(x - \frac{2L}{3}\right) + A$$

$$EIy = -\left(\frac{R}{6}\right)x^3 + \frac{M}{2}\left(x - \frac{2L}{3}\right)^2 + Ax + B$$

Applying BC's

$x = 0;\ y = 0;$ | $0 = -\left(\frac{R}{6}\right)0 + A(0) + B;$ $\boxed{B = 0}$

$x = L;\ y = 0;$ | $0 = -\left(\frac{R}{6}\right)L^3 + \frac{M}{2}\left(\frac{L}{3}\right)^2 + AL + 0$

$$\Rightarrow AL = \left(\frac{M}{6L}\right)L^3 - \frac{ML^2}{18} = \frac{(3-1)ML^2}{18}$$

$$\therefore \boxed{A = \frac{ML}{9}}$$

at $x = 0$; $EI\frac{dy}{dx} = -\left(\frac{R}{2}\right)x^2 + \frac{ML}{9} \Rightarrow EI\frac{dy}{dx} = \frac{ML}{9}$,

i.e. $\boxed{\frac{dy}{dx} = \frac{ML}{9EI}}$ done. $= \frac{L^2}{9}$

at $x = L$; $EI\frac{dy}{dx} = \cancel{-\left(\frac{M}{6L}\right)x^2 + \frac{M}{2}\left(x - \frac{2L}{3}\right)^2} + \left(\frac{ML}{9}\right)x$

cancelled

$$\Rightarrow EI\frac{dy}{dx} = -\frac{ML}{6} + \frac{ML^2}{18} + \frac{ML^2}{9} - \frac{\cdots}{18}$$

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$x = L$; $EI\frac{dy}{dx} = -\left(\frac{M}{2L}\right)x^2 + M\left[x - \frac{2L}{3}\right] + \frac{ML}{9}$

$EI\frac{dy}{dx} = -\frac{ML}{2} + \frac{ML}{3} + \frac{ML}{9} = \left(\frac{-9+6+2}{18}\right)ML$

$EI\frac{dy}{dx} = -\frac{ML}{18}$; $\boxed{\frac{dy}{dx} = -\frac{ML}{18EI}}$

Maximum deflection should be at

$x < \left(\frac{3}{2}\right)L$; $\frac{dy}{dx} = 0$ at the point.

$0 = -\frac{R}{2}x^2 + \frac{ML}{9}$; $x^2 = \left(\frac{2}{9}\right)\frac{ML}{R} = \left(\frac{2}{9}\right)\frac{ML}{\frac{M}{L}} = \left(\frac{2}{9}\right)L^2$

$\Rightarrow \boxed{x = \frac{\sqrt{2}}{3}L}$ done.

Regina T. Nyirongo

at $x = \frac{\sqrt{2}}{3}L$

$EIy = -\left(\frac{R}{6}\right)x^3 + \left(\frac{ML}{9}\right)x$;

$EIy = -\left(\frac{M}{6L}\right)\left(\frac{\sqrt{2}}{3}L\right)^3 + \left(\frac{ML}{9}\right)\left(\frac{\sqrt{2}}{3}L\right) = \left(-\frac{2\sqrt{2}L^2}{2(3)(3^3)} + \frac{L^2\sqrt{2}}{27}\right)M$

$EIy = +\frac{\sqrt{2}ML^2}{1}\left(\frac{-1+3}{81}\right)$; $\boxed{y = +\frac{2\sqrt{2}ML^2}{81}}$

$\therefore \boxed{y = \frac{2\sqrt{2}ML^2}{81}}$ done.

[illegible]

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L} \quad \text{— (i)} ; \quad \frac{T}{\hat{\tau}} = \frac{2J}{D} \quad \text{— (ii)} \quad \left(r = \frac{D}{2}\right)$$

Solid shaft:

$$J = \frac{\pi D^4}{32}, \quad \frac{T}{\hat{\tau}} = 2\left(\frac{\pi D^4}{32}\right)\left(\frac{1}{D}\right) = \frac{\pi D^3}{16} \quad \text{— (iii)}$$

Hollow cylindrical shaft

$$\frac{T}{\hat{\tau}} = \frac{2}{D_1}\left(\frac{\pi(D_1^4 - d^4)}{32}\right) ; \quad \text{But } \boxed{d = \frac{3}{4}D_1}$$

$$\Rightarrow \frac{T}{\hat{\tau}} = \left(\frac{\pi}{16 D_1}\right)\left[D_1^4 - \left(\tfrac{3}{4}D_1\right)^4\right] = \frac{\pi D_1^3}{16}\left(\frac{175}{256}\right) \quad \text{— (iv)}$$

equating eqn (iii) and (iv)

$$\frac{\pi D^3}{16} = \frac{\pi D_1^3}{16}\left(\frac{175}{256}\right) ; \quad D_1^3 = \left(\frac{256}{175}\right)D^3 ; \quad D_1 = D\sqrt[3]{\left(\frac{256}{175}\right)}$$

$$\Rightarrow \boxed{D_1 = 1.1352\, D} \quad \text{database}$$

Ratio of weights ; $w = \rho g V = \rho g\left(\frac{\pi D^2}{4}\right)L$ solid shaft.

$= \rho g V = \rho g\left[\frac{\pi}{4}(D_1^2 - d^2)\right]L$ hollow shaft.

$$\Rightarrow \text{Ratio} = \frac{(D_1^2 - d^2)}{D^2}\left(\frac{\rho g \frac{\pi L}{4}}{\rho g \frac{\pi L}{4}}\right) = \left(\frac{D_1^2 - \left(\frac{3}{4}\right)^2 D_1^2}{D^2}\right) = \left(\frac{D_1}{D}\right)^2\left(1 - \frac{9}{16}\right)$$

$$\text{Ratio of weights} = \left(\frac{7}{16}\right)\left(\frac{D_1}{D}\right)^2 = \left(\frac{7}{16}\right)(1.1352)^2$$

$$= \underbrace{0.5638}$$ done.

QUESTION 3

	Weight	% JF	% JR	FRONT axle	Rear axle
UN	3000kg	62%	38%	1860	1140
LOAD	5000kg	25%	75%	1250	3750
Total				3110	4890
in Newtons.				30 509.1	47 970.9
One side				15 254.55	23,985.45

deflection = $\delta = 15cm = 0.15\,m$. Regina. T. Alyirongo

(a) $\frac{8WD}{\pi d^4} = \frac{\hat{\tau}}{d} = \frac{Gx}{\pi D^2 n}$; $n = \frac{Gx\pi d^4}{\pi 8WD^3} = \frac{G(x)d^4}{8WD^3}$

$n = \frac{(83.5\times10^9)(0.15)(0.035)^4}{8(15\,254.55)(0.25)^3} = 9.856.$

for x not to exceed 15cm; $\boxed{n = 9 \text{ coils}}$ [5 marks]

$x = \frac{8WD^3 n}{Gd^4} = \frac{8(15254.55)(0.25^3)(9)}{(83.5\times10^9)(0.035)^4}$; $\boxed{x = 0.137\,m}$

(c) (i) $W_a = \frac{(9.81)(1860)}{2} = 9123.3[N]$

$x = \frac{8W_aD^3n}{Gd^4}$; $x = \frac{(8)(9123.3)(0.25^3)(9)}{(83.5\times10^9)(0.035)^4}$;

$\boxed{x = 0.0819\,m}$ correct.

$K = \frac{W}{\delta}$

$\frac{1}{2} T\theta$

$\frac{1}{2} \tau^2$

$\frac{1}{4C} \tau^2 \cdot Vol_{(wire)}$

Helical

$d = 12mm$

$R = 60mm$

$n = 10$

$K = ?$

$K = \frac{W}{\delta}$

$K = \frac{W}{\delta}$

$\delta = R\theta$

spring constant
stiffness

$K = \frac{Cd^4}{64 R^3 n}$

$\frac{T}{I_p} = \frac{C\theta}{L}$

$\frac{TL}{C I_p} = \theta$

$\frac{WR\, 2\pi R n\, 32}{C \cancel{\pi} d^4}$

$\theta = \frac{64 W R^2 n}{C d^4}$

$$\delta = y_0 - y = \left(\frac{3}{8}\right)\frac{Wl^3}{nbt^3E} \quad ; \quad \frac{b}{t} = \frac{8}{1} \ ; \ \boxed{b = 8t} \ \boxed{t = \frac{b}{8}}$$

$$\delta\left(\frac{b}{8}\right)^3 b = \frac{3}{8}\frac{Wl^3}{nE} \ ; \ \boxed{b^4 = \frac{3(8)^2 Wl^3}{\delta n E}}$$

$$b^4 = \frac{3(8)^2(23\,985.45)(1)^3}{(0.15)(6)(125\times10^9)} \ ; \ b^4 = 4.0935\times10^{-05}$$

$b = 0.07999$; $\boxed{b = 0.08\ m}$ done. [5 marks]

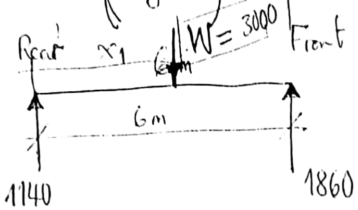
Regina T. Nyirongo

c(ii) $W_b = \frac{(1140 \times 9.81)}{2} = 5591.7\ N$.

$$\delta = \frac{(3)(5591.7)(1^3)}{(8)(6)\left(\frac{(0.08)^4}{8^3}\right)(125\times10^9)} \ ; \ \boxed{\delta = 0.03495\ m}$$ too right

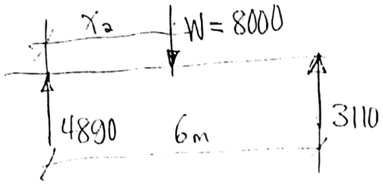
[4 marks]

(d)



$3000x = 1860(6)$

$\boxed{x_1 = 3.72\ m}$



$8000x = 3110(6)$

$\boxed{x = 2.33\ m}$

$x_1 - x_2 = (3.72 - 2.33) = \underline{1.39}\ m$ too too right

towards the rear axle.

$\frac{mm'}{l} = \frac{R\theta}{l} = \frac{\tau}{c}$ $\frac{n}{60}$

resist twist of material

$\emptyset = \frac{mm'}{l} = \frac{R\theta}{l} = \frac{\tau}{c}$

$P = T2\pi N$

$P = T2\pi N$

$\emptyset = \frac{mm'}{l} = \frac{R\theta}{l} = \frac{\tau}{c}$

$\boxed{P = T2\pi N}$ τ

$P = 25kw$

$N = 200$ r.p.m $= \frac{n}{60}$

$D = ?$ Shaft — Solid — Hollow

$l = 2$

$\theta = \frac{\pi}{180} = 0.017$ rad

$T = F.R$

$\pi = 180°$

$x - 1°$

$P = T2\pi N$

$\frac{P}{2\pi N} = T$

$N = \frac{n}{60}$

$\frac{\pi}{32} d^4$ $l = 2\pi R n$

$\frac{\tau}{R} = \frac{C\theta}{l} = \frac{T}{I_p}$ Comparison

- Absorb shocks.
- supply and control motions.
- Store Energy

$\frac{T}{I_p} = \frac{\tau}{R} = \frac{C\theta}{l}$

twist.

$\frac{P}{2\pi N I_p} = \frac{\tau}{R}$

$\frac{T}{I_p} = \frac{\tau}{R} = \frac{C\theta}{l}$

$R = \frac{\tau 2\pi N I_p}{P}$

$D = \frac{4\tau\pi N I_p}{P}$

$1 \cancel{D} = 4 \times 50 \times 10^6 \times \pi \times \frac{200}{60} \times \frac{\pi}{32} D^4$

$1 = D^3$

590.2

3:8 d D

$\tau_{max} = 1.8 \tau_{mean}$

20% greater than the mean

$8d = 3D$ $T = 2.2kNm$

deflection!

stiffness of the spring

$K = \frac{W}{\delta}$

$\gamma = \frac{1}{2} T\theta$

$\frac{l}{R} = \frac{\alpha}{l}$

$\alpha = \frac{T l}{C I_p}$

$\delta = \tan\theta \cdot \delta$

$R\theta = \delta$

$\frac{l}{R} = \frac{T}{C I_p}$

$\theta = \frac{Tl}{C I_p}$

$\frac{WR \, 2\pi R n \, 32}{C \pi d^4}$

$T = WR$

Question 8

A solid 1m shaft of radius 90 mm and density 6 g/cm^3 carries 4 unbalanced masses spaced as follows:

Masses A, B, C, and D are 11, 7, 10, and 13kg respectively, rotating at radii 10, 8, 9, 7cm respectively, and spaced from one end of the shaft at 20, 40, 60, and 80 cm respectively. the angular spacing from A to B, C, and D are 120, 200, and 300° respectively.

(a) Balance the shaft using two 5 kg masses at either end (9 marks)

(b) If before balancing, the shaft rotated at 600 rpm what will be its rotation after balancing. (5 marks)

(c) If all masses are removed from the shaft and the power transmitted is 12 kW, determine the maximum shear stress on the shaft. (6 marks)

Note: Uniform disc or cylinder, radius r. I about the central axis is $\frac{mr^2}{2}$ and $k = \frac{r}{\sqrt{2}}$

Question 9 Regina . T. Nyirenda

You are designing the spring damper system for a 1850 kg 4X4 Luxury vehicle. The test road is sinusodially undulated with a maximum displacement of 36cm. If the maximum allowable displacement of the vehicle relative to the road is 42cm, determine:

(a) the damping ratio and state whether it is over, critically or under damped (5 marks)

If the length of one undulation is 2m, and the damping coefficient is 9500kg/s, determine:

(b) the stiffness of the suspension (4 marks)

(c) the speed in km/h of the vehicle at maximum displacement (5 marks)

(d) the maximum displacement of the vehicle if the ~~and~~ the vehicle is moving at 140km/h (6 marks)

$\omega = T \cdot 2\pi n$

$\frac{12\,000 = T \cdot 2\pi}{2\pi \times 93.26}$

$K = \frac{Tr^2}{}$

J

718.

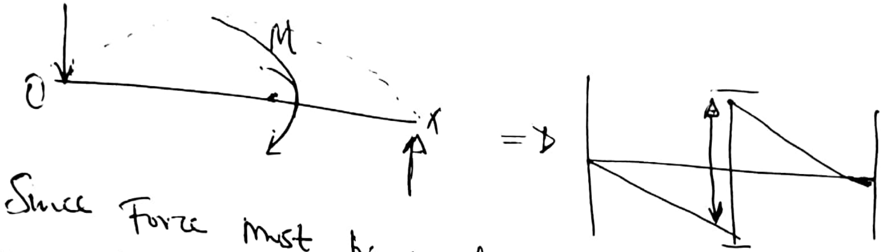
618.35 kg m^{-2}

km/s / min × 60

km/s / km
5

0978535090

Question 1



Since Force must be equal and opposite, then the Moments about O (M+)

$$M - RL = 0$$

$$R = \frac{M}{L}$$

It follows that

$$EI\frac{d^2y}{dx^2} = -Rx + M\left[x - \frac{2L}{3}\right]^0$$

$$EI\frac{dy}{dx} = -\frac{R}{2}x^2 + M\left[x - \frac{2L}{3}\right] + A$$

$$EIy = -\frac{Rx^3}{6} + \frac{M}{2}\left[x - \frac{2L}{3}\right]^2 + Ax + B.$$

Boundary conditions

$x = 0,\ y = 0$ . . . . . (i)

$x = L$ at $y = 0$ . . . (ii)

Using the first boundary condition $B = 0$.

Using the second boundary condition.

$$AL = \frac{RL^3}{6} - \left(\frac{M}{2}\right)\left(\frac{L}{3}\right)^2$$

$$= \frac{ML^3}{L6} - \frac{ML^2}{18} \Rightarrow \frac{ML^2}{6} - \frac{ML^2}{18}$$

$$A = \frac{ML}{9}$$

At $x = \frac{2L}{3}$

$$EI\frac{dy}{dx} = \left(-\frac{R}{2}\right)\left(\frac{2L}{3}\right)^2 + \frac{mL}{9}$$

$$EI\frac{dy}{dx} = \frac{-mL}{9}$$

Slope $= \frac{dy}{dx} = \frac{-mL}{9EI}$ and pointing downwards to the right.

Deflection $= y =$ $EIy = -\left(R/6\right)\left(\frac{2L}{3}\right)^3 + \left(\frac{mL}{9}\right)\left(\frac{2L}{3}\right)$

$$y = \frac{2mL^2}{81EI} \text{ upwards}$$

For $x < \frac{2L}{3}$ (a point of zero slope must exist.

$$-\frac{Rx^2}{2} + A = 0$$

$$x = \left(\frac{\sqrt{2}}{3}\right)L$$

$\therefore$ the maximum deflection $= \dfrac{\left[-\left(\frac{m}{6L}\right)\left(\frac{2\sqrt{2}}{27}\right)L^3 + \left(\frac{mL}{9}\right)\left(\frac{\sqrt{2}}{3}\right)L\right]}{EI}$

Max deflection $= \frac{2\sqrt{2}\,mL^2}{81\,EI}$

Question 2

$d = \frac{3}{4}D$

J for a solid shaft $= \frac{\pi D^4}{32}$

J for a hollow shaft $= \frac{\pi (D^4 - d^4)}{32}$

$\frac{T}{\tau} = \frac{\pi}{32}(D^4 - d^4)\frac{2}{D_1}$

$= \frac{\pi}{16 D_1}(D^4 - d^4)$

$= \frac{\pi D_1^3}{16}\left(1 - \frac{81}{256}\right)$

$= \frac{\pi D_1^3}{16}\left(\frac{175}{256}\right)$

equating diameters

$\frac{\pi D^3}{16} = \frac{\pi D_1^3}{16}\left(\frac{175}{256}\right)$

$D_1 = D\,1.1352$

$D = D_1 \sqrt[3]{\frac{175}{256}}$

$D = D_1\, 0.881$

Ratio of weights 'equal length

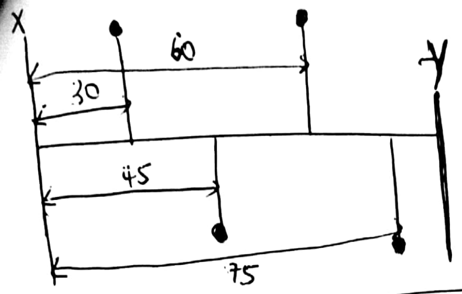
$$\frac{D_1^2 - d^2}{D^2}$$

$$\left(\frac{D_1}{D}\right)\left(1 - \frac{9}{10}\right)$$

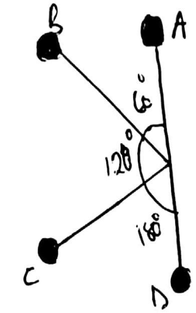
$$(1.352)^2 \left(\frac{16-9}{10}\right)$$

$= 0.5637$

Question 3



Distances in Cm.



	M	r	Mr	x	Mrx	mrx cos θ	mrx sin θ
X	11	r_1	$11r_1$	0	0	0	0
A	10	0.12	1.2	0.30	0.36	0.36	0
B	12	0.10	1.2	0.45	0.54	0.27	0.467
C	10	0.12	1.2	0.60	0.72	-0.36	0.624
D	12	0.10	1.2	0.75	0.9	-0.90	0
Y	11	r_2	$11r_2$	2.00	$22r_2$	$22r_2\cos\theta$	$22r_2\sin\theta$

$\Sigma M r x \cos\theta = -0.63$

$\Sigma M r x \sin\theta = 1.091$

$R = \sqrt{(0.63)^2 + (1.091)^2}$

$R = 1.260.$

$\theta = \tan^{-1}\left(\frac{1.091}{-0.63}\right)$

$\theta = -60°$

$\frac{22r_2}{22} = \frac{1.260}{22}$

$\underline{r_2 = 0.0573\,m}$

On the y plane, 11 Kg should be placed

at a radius of 5.13cm at an angle of 300
A.

	Mr	Mr Cos θ	Mr Sin θ
X	11r1	0	0
A	1.2	1.2	0
B	1.2	0.6	1.04
C	1.2	-0.6	1.04
D	1.2	-1.2	0
Y	0.63	0.32	0.55

Σ Mr Cos θ = 0.32 $\quad$ Σ mr Sin θ = 1.53

$$11r_1 = \sqrt{(0.32)^2 + (1.53)^2}$$

$$= \sqrt{2.4433}$$

$$11r_1 = 1.563 \qquad \theta = Tan^{-1}\left(\frac{1.53}{0.32}\right)$$

$$\frac{11r_1}{11} = \frac{1.563}{11} \qquad \theta = 258.19°$$

$$r_1 = 0.142m$$

$$r_1 = 14.21cm$$

∴ the 11 kg mass must be placed at a radius of 14.21 cm ~~from~~ and at 258.19° from A.

$$m_1 r_1 \omega^2 = m_2 r_2 \omega^2$$

$$4.8(2000)^2 = 6.993(\omega_2)^2$$

$$\omega = \underline{\underline{1656.97 \text{ rpm}}}$$

c) $I = \dfrac{Mr^2}{2}$ $\quad K = \dfrac{r}{\sqrt{2}}$

LATE

THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 3112 – ELECTRICAL ENGINEERING PRACTISE

ASSIGNMENT ONE

$= \frac{0}{40} + \frac{0}{40}$

$= \frac{0}{80}$

NAME: PATEL ARJUN

COMPUTER NO: 13064177

LECTURER: MR. GOMA

$\frac{20}{40} = \frac{2}{4}$

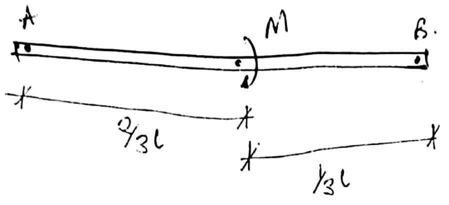
$= \frac{1}{2}$

Greag – berg – transf

Tazio Manzeny

A – A = Ω.

Question 1



78

72

55

54

51.

42.42

30

20

6

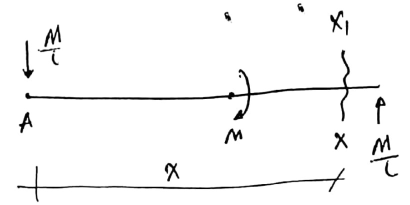
$\Sigma M_A = 0.$

$M = R_B l.$

$R_B = \frac{M}{l}.$

$\Sigma F_y = 0$

$R_B = \frac{M}{l} = -R_A = \frac{M}{l}.$



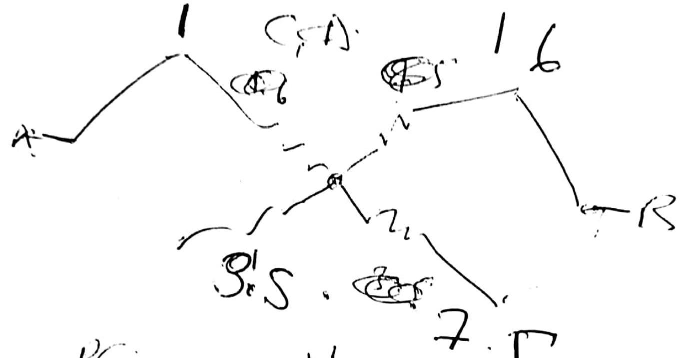
Considering a section on the right of xx' of length x

$EI \frac{d^2y}{d^2x} = M.$ $\quad M = -\frac{M}{l}x + M(x - \frac{2}{3}l)^0.$

$EI \frac{d^2y}{d^2x} = -\frac{Mx}{l} + M(x - \frac{2}{3}l)^0$

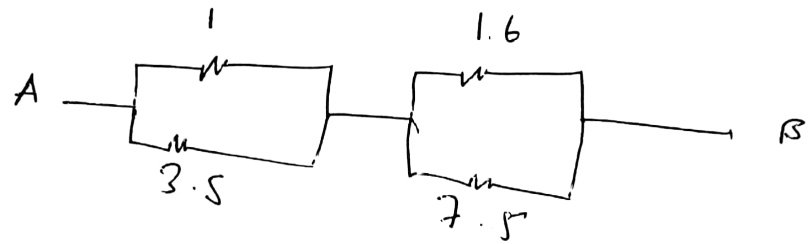
$EI \frac{dy}{dx} = -\frac{Mx^2}{2l} + M(x - \frac{2}{3}l)^1 + C$

$\underline{1.2\,mA}$



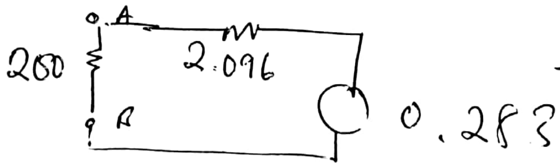
~~$R_{AB} = 1.6 \parallel 1 + 3.5 \parallel 7.5$~~

$1 \parallel 3.5$



$2.096 = R_{TH}$

$\underline{1.2 \times 10^{-3}\,A}$



$$EIy = -\frac{Mx^3}{6L} + \frac{M}{2}(x - \tfrac{2}{3}L)^2 + Cx + D$$

at point A where $x = 0$, $y = 0$.

$\Rightarrow D = 0$.

at point B where $x = L$, $y = 0$.

$$0 = -\frac{ML^3}{6L} + \frac{M}{2}(\tfrac{1}{3}L)^2 + CL$$

$$0 = \frac{ML^2}{18} - \frac{ML^2}{6} + CL$$

$$C = \frac{ML}{9}.$$

the equation of slope becomes

$$EI\frac{dy}{dx} = \frac{-Mx^2}{2L} + M(x - \tfrac{2}{3}L) + \frac{ML}{9}$$

the equation of deflection is

$$EIy = -\frac{Mx^3}{6L} + \frac{M}{2}(x - \tfrac{2}{3}L)^2 + \frac{ML}{9}x$$

the slope of the beam at the ends

say $x = 0$ and $x = L$.

$x = 0$

$$EI\frac{dy}{dx} = \frac{ML}{9}$$

$$\left.\frac{dy}{dx}\right|_{x=0} = \frac{ML}{9EI}$$

at $x = L$

$$EI\frac{dy}{dx} = \frac{-ML^2}{2L} + M(\tfrac{1}{3}L) + \frac{ML}{9}$$

$$EI\frac{dy}{dx} = -\frac{ML}{2} + \frac{ML}{3} + \frac{ML}{9}$$

$$EI\frac{dy}{dx} = -\frac{ML}{18}$$

$$\therefore \left.\frac{dy}{dx}\right|_{x=L} = \frac{-ML}{18EI}$$

for maximum deflection, there must be a point of slope = 0 within $x < \tfrac{2}{3}L$.

$\frac{dy}{dx} = 0$ for $x_p < \tfrac{2}{3}L$.

$$0 = -\frac{Mx^2}{2L} + \frac{ML}{9}$$

$$\frac{Mx^2}{2l} = \frac{Ml}{9}$$

$$x^2 = \frac{2l^2}{9}$$

$$x = \frac{\sqrt{2}\,l}{3}$$

$$\boxed{EIy = \frac{-M\left[\frac{\sqrt{2}}{3}l\right]^3}{6l} + \frac{Ml}{9}\,\frac{\sqrt{2}}{3}l.}$$

Now, for maximum deflection

$$EIy = \frac{-M\,2\sqrt{2}\,l^3}{162l} + \frac{Ml^2\sqrt{2}}{27}$$

$$EIy = \frac{Ml^2\sqrt{2}}{27} - Ml^2\sqrt{2}\,\frac{2}{162}.$$

$$= \frac{2\sqrt{2}\,Ml^2}{81}$$

$$\therefore\ y = \frac{2\sqrt{2}\,Ml^2}{81EI}$$

$R_1 = R_h - \dfrac{I_{fsd} R_m R_h}{V}$

$R_2 = \dfrac{I_{fsd} R_m R_h}{V - I_{fsd} R_h}$

$R_m = 100\,\Omega$

$I_{fsd} = 1mA$

$V = 3V$

$R_h = 2000\,\Omega$

$R_1 = 2000 - \dfrac{(1\times10^{-3})(100)(2000)}{3}$

$\underline{R_1 = 1933.3\,\Omega}$

$R_2 = \dfrac{(1\times10^{-3})(100)(2000)}{3 - (1\times10^{-3})(2000)}$

$= \underline{\underline{200\,\Omega}}$

(2) 5% drop $= 5\% \times 3 = 0.15V$

drop $= 3 - 0.15 = \underline{\underline{2.85}}$

$R_2 = \dfrac{I_{fsd} R_m R_h}{V - I_{fsd} R_h} = \dfrac{(1\times10^{-3})(100)(2000)}{2.85 - (1\times10^{-3})(2000)}$

$= \underline{\underline{235.57\,\Omega}}$

Calculation 2

Same length, same torque for a same shear stress because they have same material.

Let D_H = Outer diameter of hollow

d_H = inner diameter of hollow

D_s = diameter of solid

W_H = Weight of hollow

W_s = Weight of solid

Comparison ratio $\frac{W_H}{W_s} = \frac{\text{weight of hollow}}{\text{weight of solid}}$

weight $W = mg = \rho V = \rho A L$, for the materials with same length and same density

$$\frac{W_H}{W_s} = \frac{A_H}{A_s} = \frac{\frac{\pi}{4} D_H^2 - \frac{\pi}{4} d_H^2}{\pi/4 \, D_s^2}$$

$$\frac{W_H}{W_s} = \frac{A_H}{A_s} = \frac{D_H^2 - d_H^2}{D_s^2}$$

for the special case

$d_H = 3/4 \, D_H$

$$\frac{W_H}{W_S} = \frac{D_H^2 - \left[\frac{3}{4} D_H\right]^2}{D_S^2} = \frac{D_H^2\left(1 - \left(\frac{3}{4}\right)^2\right)}{D_S^2}$$

$$= \frac{D_H^2 (0.4375)}{D_S^2} \quad \text{- - - - } *$$

from the Torsion equation

$$\frac{\tau}{R} = \frac{G\theta}{L} = \frac{T}{J}$$

to transmitt a given torque for same shear force.

$$\therefore \quad \frac{J}{R} = \frac{T}{\tau} = \text{Constant}$$

$$\frac{J_H}{R_H} = \frac{J_S}{R_S}$$

$$\frac{\frac{\pi}{32}\left(D_H^4 - \left[\frac{3}{4} D_H\right]^4\right)}{D_H/2} = \frac{\frac{\pi}{32} D_S^4}{D_S/2}$$

$$D_H^3 \left(\frac{175}{256}\right) = D_S^3$$

$$D_S = 0.8807 \, D_H$$

replacing in * for D_S

STION 2:

$102 KN/m^2 = 102\times10^3 N/m^2$

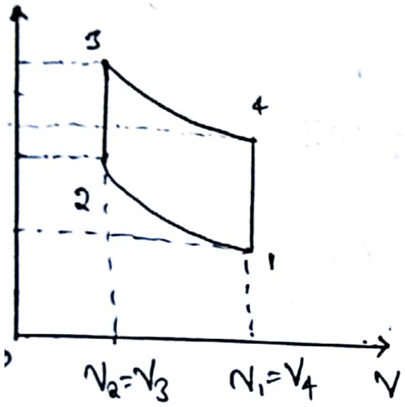
$0.0025 m^3$

$= 19^\circ C \equiv (19+273.15)K = 292.15K.$

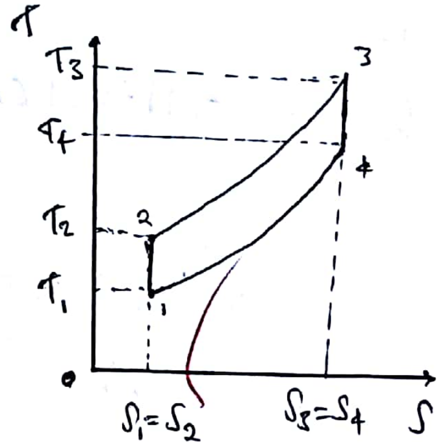
$x = 4.6 MN/m^2 = 4.6\times10^6 N/m^2$

$v = 9$

$p = 1.006 KJ/KgK \qquad C_v = 0.716 KJ/KgK$



PV Diagram



TS Diagram

cess 1 to 2:

$= ? \qquad P_1V_1^\gamma = P_2V_2^\gamma$

$$\Rightarrow P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma \qquad \text{and} \quad V_2 = \frac{V_1}{r_v}$$

$$\Rightarrow P_2 = P_1\left(\frac{\cancel{V_1}}{\cancel{V_1}/r_v}\right)^\gamma = P_1 r_v^\gamma \; \cancel{2235.1717}$$

$$P_2 = 102 KN/m^2 (9)^{1.4050}$$

$$P_2 = 2235.1717 KN/m^2$$

$$\therefore P_2 \cong \underline{2235 KN/m^2}$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_1 r_v^{\gamma-1} = 292.15(9)^{0.4050}$$

$$\therefore T_2 = 711.33488K = 438.1849^\circ C \cong \underline{438^\circ C}.$$

Process 2 to 3:

$$v_2 = \frac{v_1}{r_v} = \frac{0.0025}{9} = 2.7778 \times 10^{-4}\,m^3$$

$$v_3 = v_2 = 2.78 \times 10^{-4}\,m^3.$$

$$P_{max} = P_3 = 4.6 \times 10^6\,N/m^2$$

$$\frac{P_2}{T_2} = \frac{P_3}{T_3}$$

$$T_3 = T_2\left(\frac{P_3}{P_2}\right) = 711.33488\left(\frac{4.6\times 10^6}{2235171.7}\right)$$

$$= 1463\,K = 1190.7825^\circ C$$

$$\therefore T_3 \cong \underline{\underline{1190^\circ C}}$$

Process 3 to 4

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1}$$

$$= r_v^{(\gamma-1)}$$

$$T_4 = \frac{T_3}{r_v^{(\gamma-1)}} = \frac{P_3}{P_2}T_1 = \frac{4.6\times10^6}{2235171.7} \times 292.15 = 601.2469\,K$$

$$\therefore T_4 = 328.0969^\circ C \cong \underline{\underline{328^\circ C}}$$

$$P_4 V_4^{\gamma} = P_3 V_3^{\gamma}$$

$$P_4 = P_3\left(\frac{V_3}{V_4}\right)^{\gamma} = P_3\left(\frac{1}{r_v}\right)^{\gamma} = \frac{4.6\times10^6\,N/m^2}{1}\left(\frac{1}{9}\right)^{1.4}$$

$$= 209916.7558\,N/m^2 \cong \underline{\underline{210\,kN/m^2}}$$

from diagram $v_1 = V_4 = \underline{\underline{0.0025\,m^3}}.$

Process

$P_1 =$

$v_1 =$

$T_1 =$

$P_1 = 1$

$P_2 =$

$P_3 =$

$P_4 =$

(ii)

(iii)

$\Rightarrow$

PROCESS 4 to 1.

$P_1 = 102 \times 10^3\ N/m^2$
$V_1 = 0.0025 m^3$
$T_1 = 292.15K$.

$P_1 = 102 \cancel{\times 10^3}\ KN/m^2$ $T_1 = \cancel{292.15K}\ 19°C$ $V_1 = 0.0025 m^3$
$P_2 = 2235 KN/m^2$ $T_2 = 438°C$ $V_2 = 2.78 \times 10^{-4} m^3$
$P_3 = 4.6 MN/m^2$ $T_3 = 1190°C$ $V_3 = 2.78 \times 10^{-4} m^3$.
$P_4 = 210 KN/m^2$ $T_4 = 328°C$ $V_4 = 0.0025 m^3$

(ii) $\eta = \left(1 - \frac{T_1}{T_2}\right) \times 100\% = \left(1 - \frac{T_4}{T_3}\right) \times 100\% = \left(1 - \left(\frac{T_4 - T_1}{T_3 - T_2}\right)\right) \times 100\%$

$= \left(1 - \frac{1}{r_v^{\gamma-1}} \cancel{(\gamma-1)}\right) \times 100\% = \left(1 - \frac{1}{r_v^{\gamma-1}}\right) \times 100\%$

$\eta = 1 - \frac{T_1}{T_2} = \left(1 - \frac{292.15\ K}{711.3349\ K}\right) \times 100\% = 58.929\% \cong \underline{\underline{59\%}}$.

4.69 (iii) Mean effective pressure $= \frac{\oint w}{V} = \frac{\oint w}{V_1 - V_2}$ $R = C_p - C_v$ $= 0.29 KJ/KgK$

$\oint w = mc_v\ [(T_3 - T_2) - (T_4 - T_1)]$ and $P_1V_1 = mRT_1$

$\Rightarrow m = \frac{P_1V_1}{RT_1} = \frac{(102 \times 10^3 \times 0.0025)\ Nm}{0.29 KJ/kgK \times 292.15K} = \frac{255}{84723.5} = 3.0098 \times 10^{-3}$

$\cong \underline{\underline{3.01 \times 10^{-3} kg}}$

$\oint = 3.0098 \times 10^{-3} \times 716 \cdot [(1463 - 711.3349) - (601.2469 - 292.15)]$
$= 953.7419\ J$.

Mean effective pressure $= \frac{953.7419}{(0.0025 - 0.000278)} = 429\ 226.7\ J/m^3$

$\therefore$ Mean effective pressure $= \underline{429.2 \, kN/m^2}$.

(iv) Carnot efficiency $= \left(\frac{T_3 - T_1}{T_3}\right) \times 100\%$

$$= \left(\frac{1463K - 292.15K}{1463K}\right) \times 100\%$$

$\therefore$ Carnot efficiency $= 80.03\% \cong \underline{80.0\%}$

9

QUESTION 4. [Same sketch as in question 2].

$P_1 = 1 \, bar = 1\times10^5 N/m^2$ $\qquad P_3 = 43 \, bar = 43\times10^5 N/m^2$

$P_2 = 18 \, bar = 18\times10^5 N/m^2$

$T_1 = 290K$ $\qquad C_v = 0.717 kJ/kgK$ $\qquad R = 0.287 kJ/kgK$

$$\gamma = \frac{C_p}{C_v} = \frac{R + C_v}{C_v} = \frac{0.287kJ/kgK + 0.717kJ/kgK}{0.717kJ/kgK}$$

$$= 1.4003.$$

Thermal efficiency $= 1 - \frac{1}{(r_v)^{\gamma - 1}}$ and $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma}$

$$\Rightarrow r_v = \left(\frac{P_2}{P_1}\right)^{1/\gamma} = \left(\frac{18\times10^5}{1\times10^5}\right)^{\frac{1}{1.4003}}$$

$$= 7.8783 = \underline{7.88}.$$

$$\eta = \left(1 - \frac{1}{\cancel{7.88}\; 7.8783^{0.4003}}\right) \times 100\%$$

$$= 56.23\%$$

$$\cong 56.2\%.$$

Mean effective pressure $= \dfrac{\oint w}{V_1 - V_2}$.

$P_4 V_4^{\gamma} = P_3 V_3^{\gamma} \Rightarrow P_4 = P_3 \left(\dfrac{V_3}{V_4}\right)^{\gamma}$

$= 43 \times 10^5 \left(\dfrac{1}{7.8783}\right)^{1.4003}$

$= 238\ 887.8191\ N/m^2$

$\dfrac{V_1}{V_2} = r_v \Rightarrow V_1 = V_2 r_v$; $V_3 = V_2$; $V_1 = V_4$

$\oint w = \dfrac{(43 \times 10^5 V_2 - 238\ 887.8191 V_1) - (18 \times 10^5 V_2 - 1 \times 10^5 \times 7.8783 V_2)}{1.4003 - 1}$

$= 3.5 V_2\ MJ$

Mean effective pressure $= \dfrac{3.5 V_2 \times 10^6}{r V_2 - V_2}$ since $V_1 = r_v V_2$.

$= \dfrac{3.5 \times 10^6}{7.8783 - 1}$

9

$= 508\ 846.6627\ N/m^2$

$\simeq \underline{\underline{508\ KN/m^2}}$

*__QUESTION 7.__

$d = 145mm$ clearance volume = 10% of swept volume.

stroke $= 205mm$

(i) Compression ratio $= \dfrac{V_1}{V_2}$ $V_1 = V_{total} = \pi r^2 \times 205$

$= 205 \pi r^2 mm^3$

ratio $= \dfrac{V_1}{0.9 V_1} = \underline{1.11}$ $V_2 = \dfrac{100 - 10}{100} \times V_1 = 0.9 V_1$

$\therefore$ Compression ratio $= \underline{\underline{1.11}}$.

(iii) $V_2 = \frac{6}{100} \pi r^2 h = \cancel{203\ 109} \cdot \frac{6}{100} \times \pi \times (145mm)^2 \times (205mm)$

$= 203109.8555 mm^3$

$= 203.1 \times 10^{-6} m^3$

$V_3 = V \times 6\% \times V_4$

$= \cancel{0.00}\ 203.1 \times 10^{-6} + 0.00339$

$= 3.593 \times 10^{-3} m^3$

$P = \frac{V_3}{V_2}$. $\Rightarrow P = \frac{0.0035934}{0.0002034} = 1.7665$.

$\eta = \left[1 - \frac{1}{r_v^{(\gamma-1)}}\right]\left[\frac{\beta^{\gamma}-1}{\gamma(\beta-1)}\right] \times 100\%$

$= \left[\left(1 - \frac{1}{10^{0.405}}\right)\left(\frac{1.7665^{1.405} - 1}{1.405(1.7665-1)}\right)\right] \times 100\%$

$= 68.9380\%$

$= \underline{\underline{68.9\%}}$.