Engineering Mechanics

FINAL TERM PAPER

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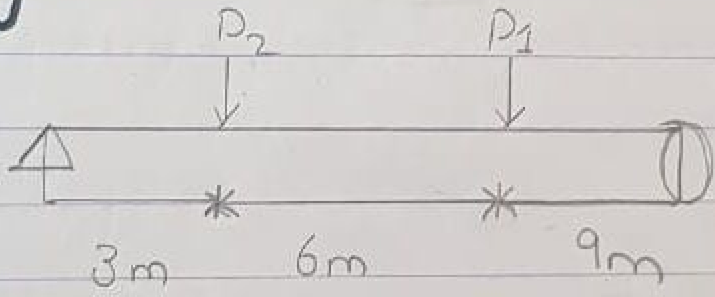
Q1:

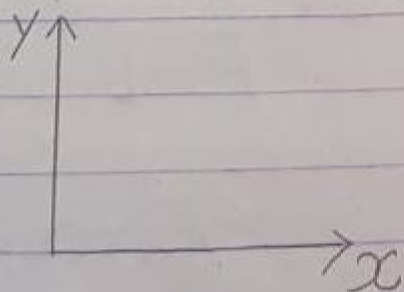


$P_1 = 200 + \text{Student id} = 16447\ KN$

$P_2 = 500 + \text{Student id} = 16747\ KN$

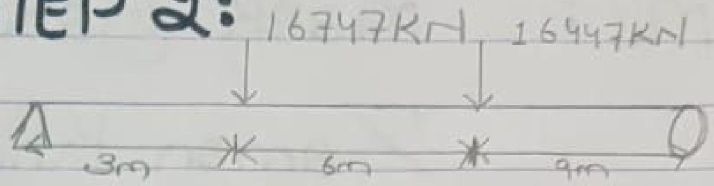
Solution:

STEP 1:



(2)

STEP 2:



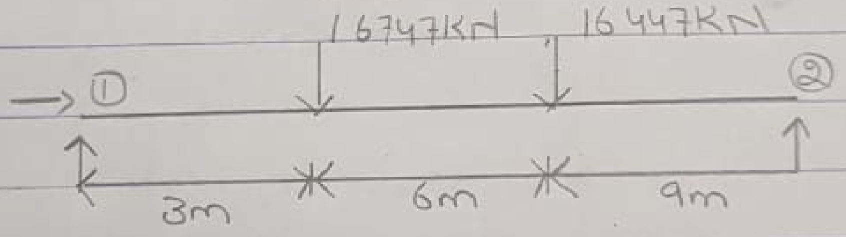
STEP 3:

△ → Hinge Support = 2 reactions

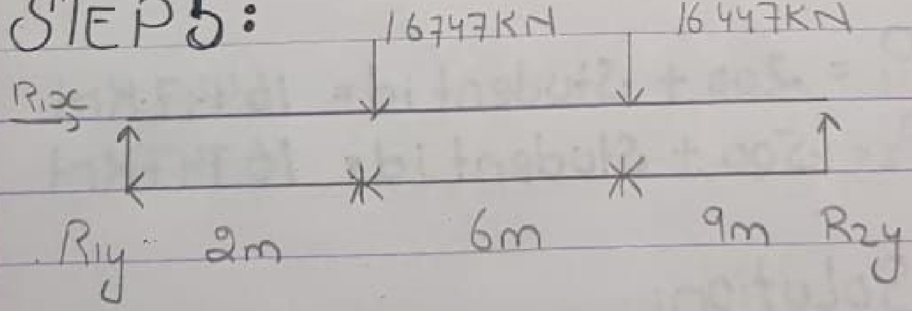
○ → Roller Support = 1 reaction

STEP 4:

FBD:



STEP 5:



STEP 6:

First Equation:

$$\sum F_x = 0$$

$$R_{1x} = 0$$

(3)

2^{nd} Equation:

$$\Sigma F_y = 0$$

$$R_{1y} + R_{2y} - 16447 - 16747 = 0$$

$$R_{1y} + R_{2y} = 33194 \text{ KN} \quad -eq\ 2)$$

THIRD EQUATION:

$$\circlearrowleft^{+} \Sigma M_1 = 0$$

$$(R_{2y} \times 18) - (16747 \times 3) - (16447 \times 9) = 0$$

$$R_{2y} = 11014.66 \text{ KN}$$

putting in eq 2)

$$R_{1y} + R_{2y} = 33194 \text{ KN}$$

$$R_{1y} + 11014.66 = 33194$$

$$R_{1y} = 33194 - 11014.66$$

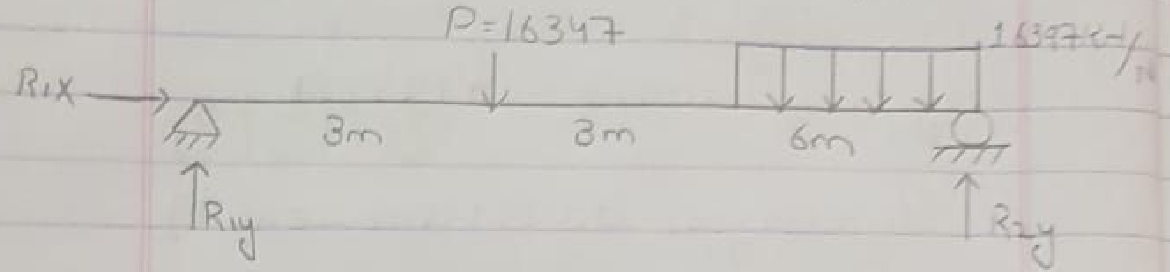
$$R_{1y} = 22179.34 \text{ KN}$$

(4)

Q2:

$P = 100 + 16247 = 16347\,KN$

$BDL = 150 + 16247 = 16397\,KN/m$



$\Sigma F_x = 0$

$R_{1x} = 0\,KN$

$\Sigma F_y = 0$

$R_{1y} + R_{2y} - 16347 - (16397 \times 6) = 0$

$R_{1y} + R_{2y} = 114,729\,KN$

$\Sigma M_1 = 0$ (+↻)

$12R_{2y} - (16347 \times 3) - (16397 \times 6 \times 9) = 0$

$\Rightarrow R_{2y} = \dfrac{49041 + 885438}{12}$

$R_{2y} = 77873.25\,KN$

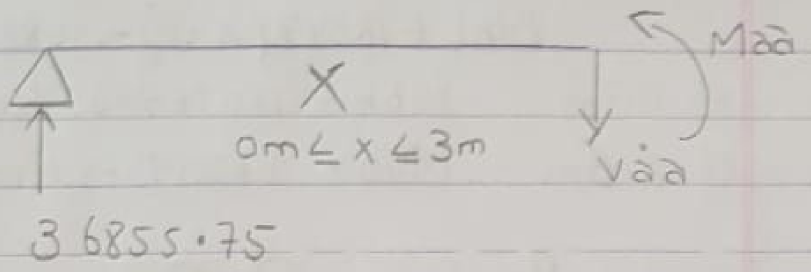
$\Rightarrow R_{1y} = 114729 - 77873.25$

$\Rightarrow R_{1y} = 36855.75\,KN$

(5)

PART: 2,

Section ⇒ a — a



$\Sigma F_y = 0$

$-V_{aa} + 36855.75 = 0$

$\Rightarrow V_{aa} = 36855.75\,KN$

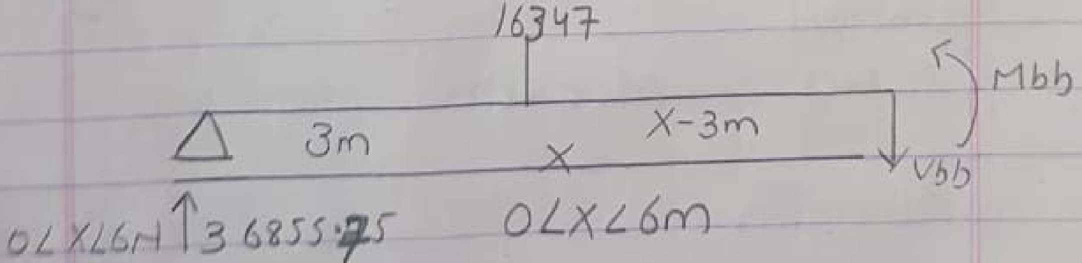
$\Sigma M = 0$

$M_{aa} - 36855.75(x) = 0$

At $x=0$ $M_{aa} = 0$

At $x=3$ $M_{aa} = 110567.25\,KN.m$

Section B-B



$\Sigma F_y = 0$

$36855.75 - 16347 - V_{bb} = 0$

(6)

$\Rightarrow V_{bb} = 20508.75\,KN$

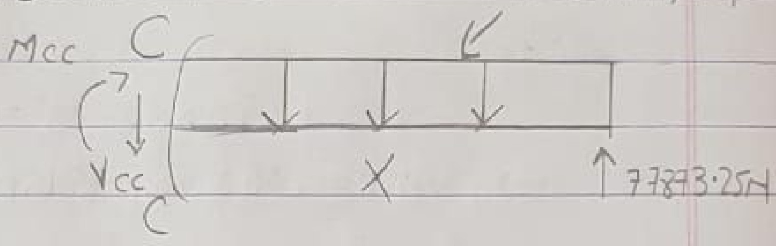
$\Sigma M = 0$

$$M_{bb} + 16347(X-3) - 36855.75X = 0$$

At $X = 3m$ $\quad M_{bb} = 110567.25\,KN{\cdot}m$

At $X = 6m$ $\quad M_{bb} = 172093.5\,KN{\cdot}m$

Section C-C :



$\Sigma F_y = 0$

$$-V_{cc} + 77873.25 = 0$$

$\Rightarrow V_{cc} = 77873.25\,KN$

$\Sigma M_{cc} = 0$

$$M_{cc} - 77873.25(x) + 16397 \times x^2/2 = 0$$

from right

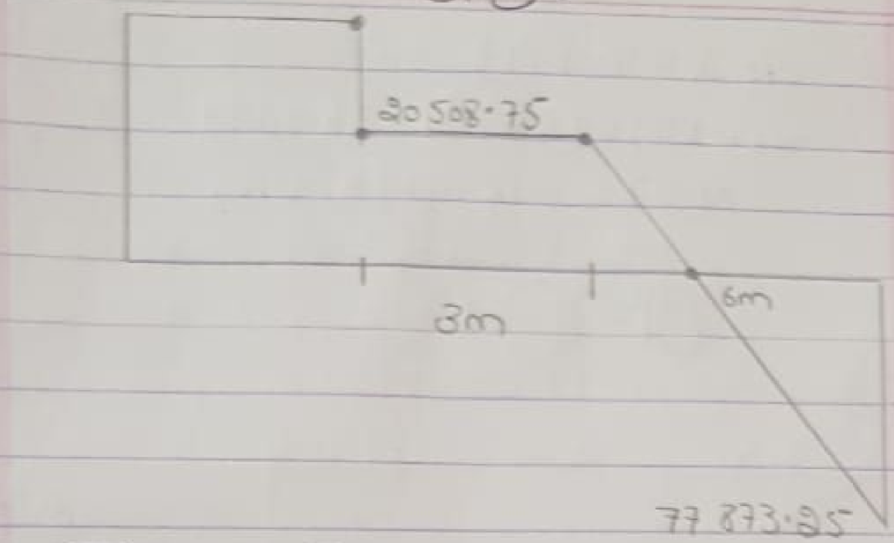
At $X = 0$ $\quad M_{cc} = 0$

At $X = 6m$

$$M_{cc} = 172093.5\,KN{\cdot}m$$

7

SFD:



To Find Zero Shear Point:

$$20508.75 - 16397(x) = 0$$

$$\Rightarrow x = 1.2507m$$

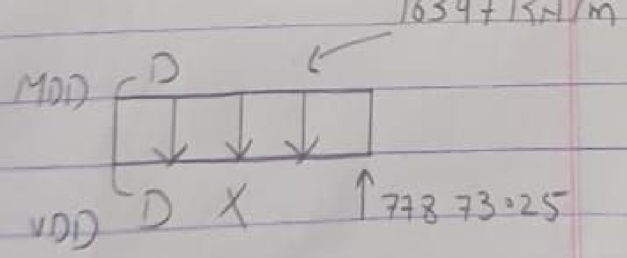
Zero Shear distance = $6m + 1.2507$

$= 7.2507m$

Here B.M will be maximum.

Section D-D:

4.7493m
from right



$$\Sigma M_{DD} = 0$$

$$M_{DD} - 77873.25 \times 16397 \times \frac{2}{2} = 0$$

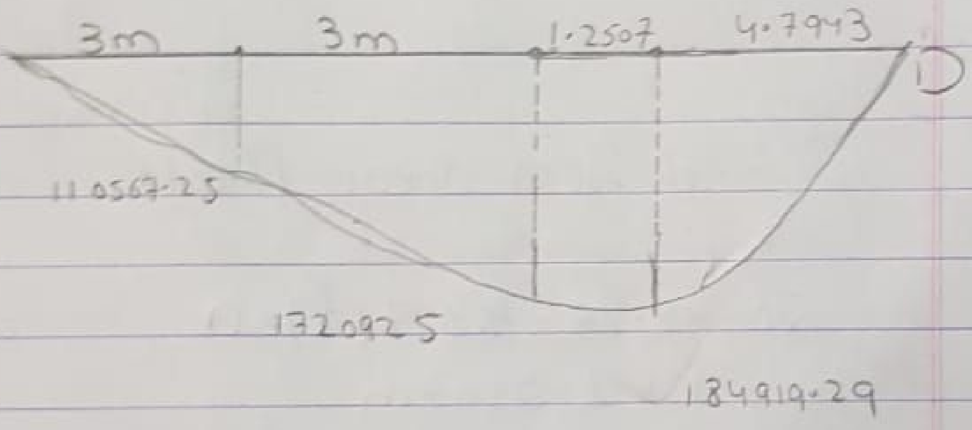
(8)

At $x = 4.7493$

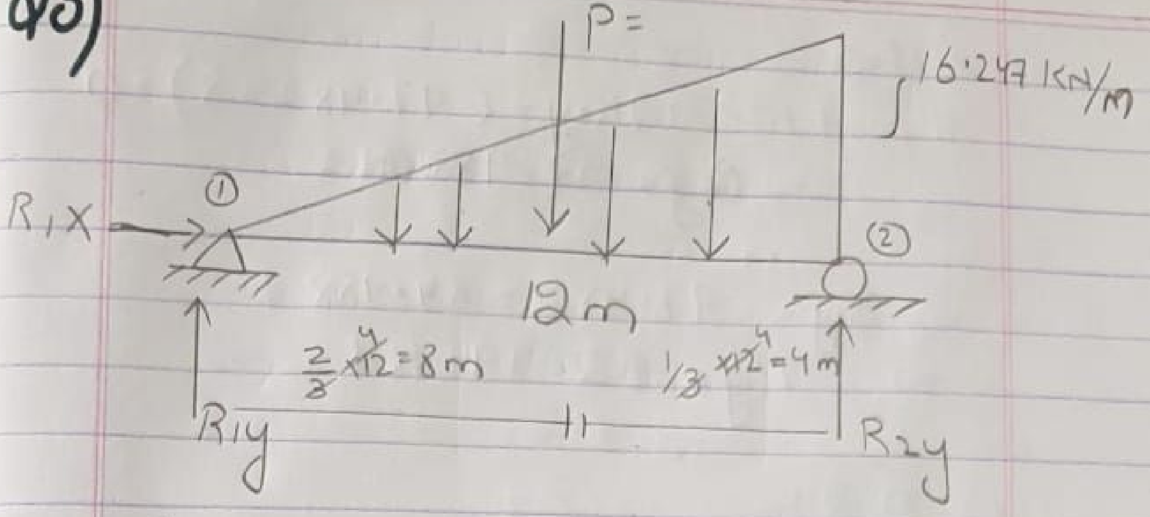
$\Rightarrow M_{DD} = 184924 - 369643$

$M_{DD} = -184919\ kN\cdot m$

BMD:



Q3)



Solution:

Step 1:

$$\text{Resultant} = P = \frac{16.247 \times 12}{2}$$

$$= 97.482 \text{KN}$$

This load will act at $\frac{1}{3}$ of length from maximum.

$\Sigma F_x = 0$

$R_1x = 0$

$\Sigma F_y = 0$

$R_1y + R_2y = 97.482$

$\Sigma M = 0$

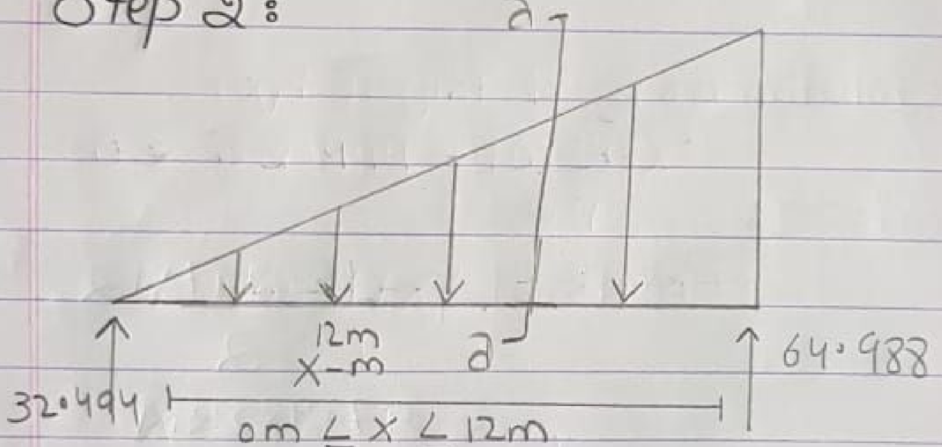
At point 1 $\Rightarrow 12R_{2y} - (97.482 \times 8) = 0$

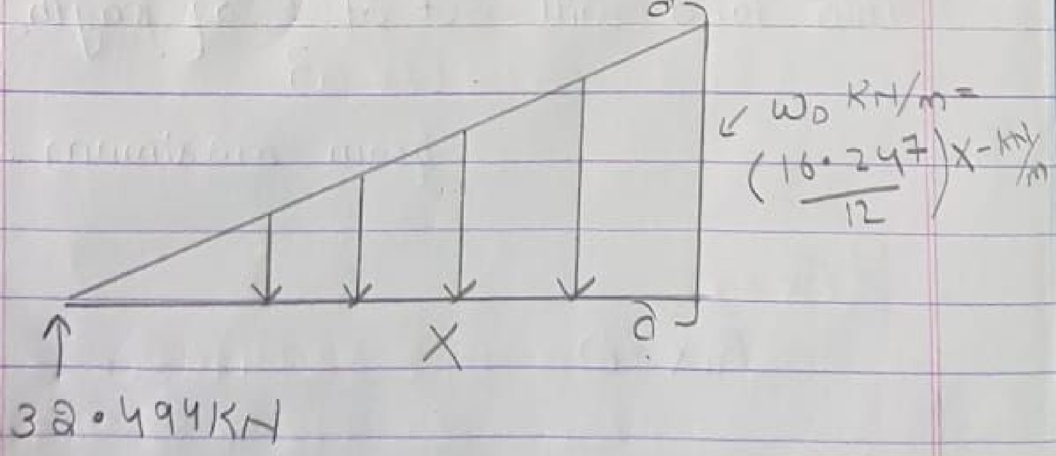
$\Rightarrow R_{2y} = 64.988\,KN$

$\Rightarrow R_{1y} = 97.482 - 64.988$

$\Rightarrow R_{1y} = 32.494\,KN$

Step 2:



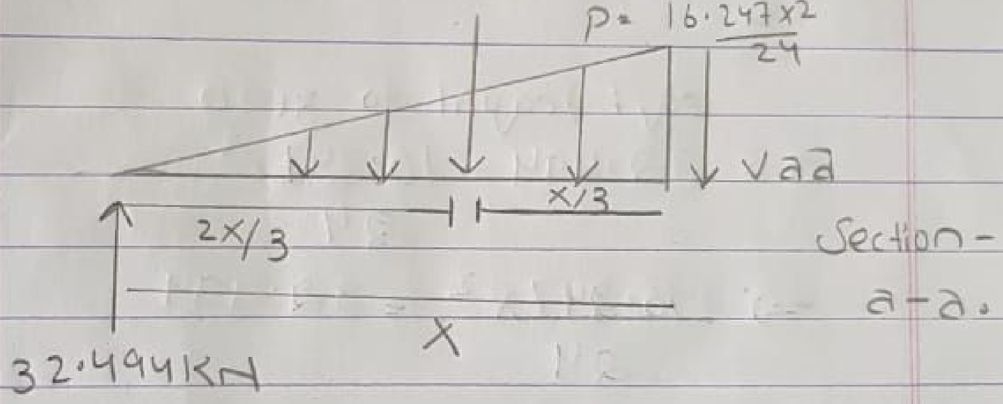


Section A-a

From law of Similar triangles

$$\frac{16.247}{12} = \frac{w_0 \, KN/m}{x\text{-}m}$$

$$\Rightarrow w_0 \left[\frac{16.247x}{12}\right] KN/m$$



Resultant $P_1 = [W_0 x]/2$

$$P_1 = \frac{16.247x^2}{24}$$

$\Sigma F_y = 0$

$$-v_{aa} - P_1 + 32.494 = 0$$

$$\Rightarrow -v_{aa} - \frac{16.247x^2}{24} + 32.494 = 0$$

$$v_{aa} = 32.494 - \frac{16.247x^2}{24} \quad \text{-eq 1)}$$

Step 3:

At $X = 0m$,

eq i) => $V_{aa} = 32.494 kN$

At $X = 12m$

eq i) => $V_{aa} = -64.988 kN$

To find point zero shear put

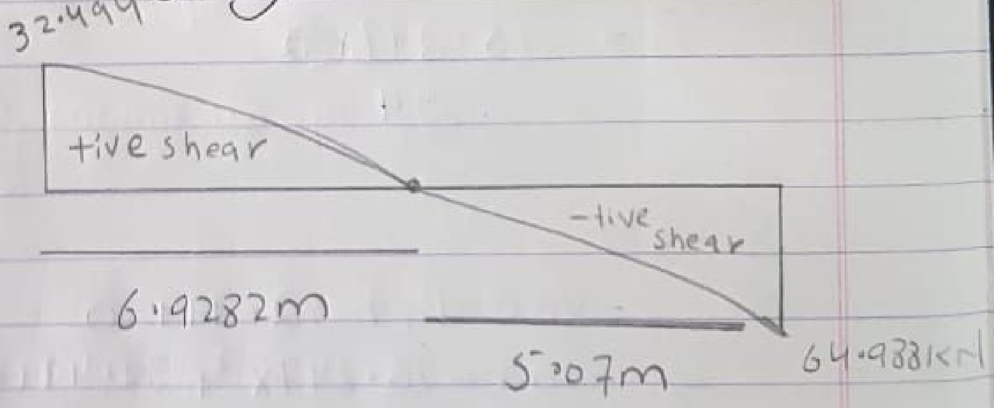
eq i) equal to zero

$$0 = 32.494 - \frac{16.247x^2}{24}$$

$$\Rightarrow \frac{16.247x^2}{24} = 32.494$$

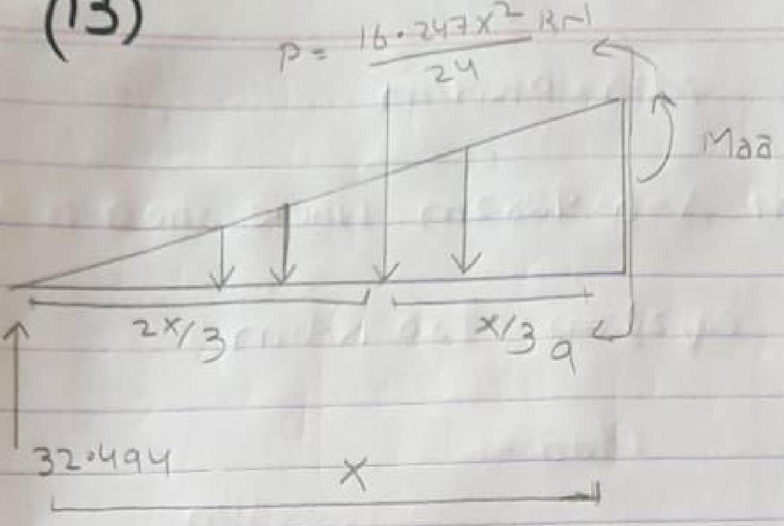
$$X = 6.9282m$$

SFD



Now for bending moment digram:

(13)



Section a-a

$\circlearrowleft + \sum M = 0$

$$M_{aa} + \left(\frac{x}{3}\right)P_1 - 32.494x = 0$$

$$\Rightarrow M_{aa} = \frac{-x}{3} P_1 + 32.494x$$

$$\Rightarrow M_{aa} = \frac{-x}{3}\left(\frac{16.247x^2}{24}\right) + 32.474x$$

$$\Rightarrow M_{aa} = \frac{-16.247x^3}{72} + 32.494x \quad \text{— eq 2)}$$

At $x = 0m$, eq 2) $\Rightarrow$

$M_{aa} = 0$ KN/m

At $x = 12m$ eq 2)

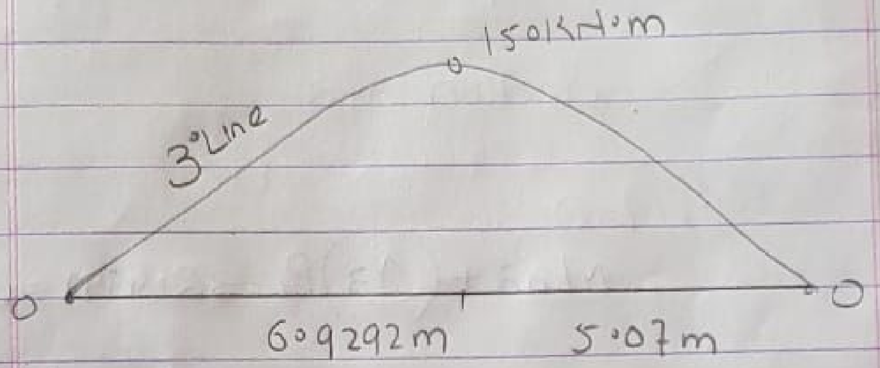
(14)

Mad = 0KN/m

At X = 6.9282m where shear is Zero

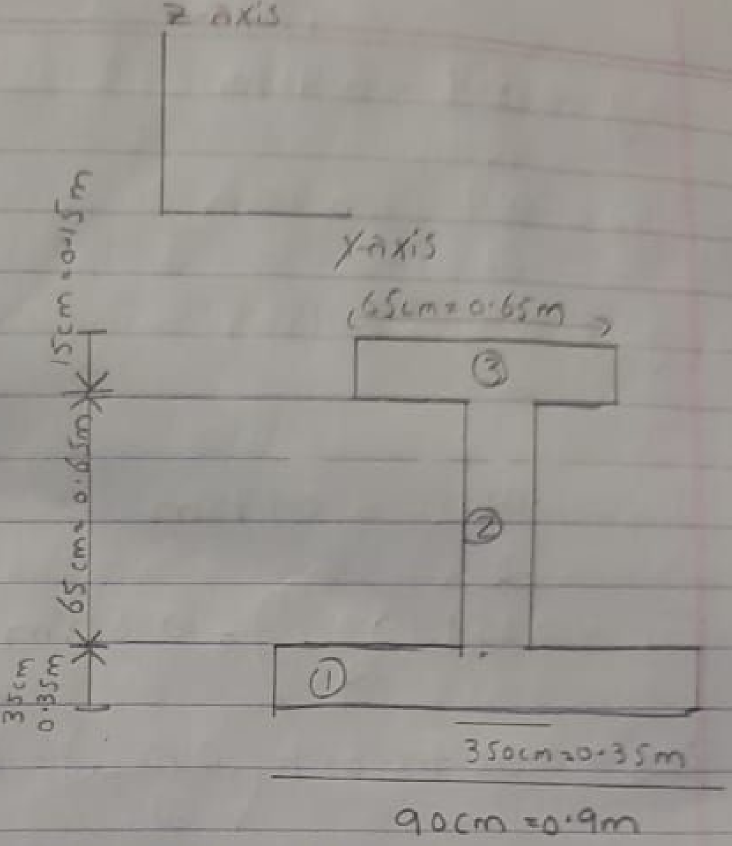
eq 2) => 150 KN·m

Mad =



BMD.

Q4a) (15)

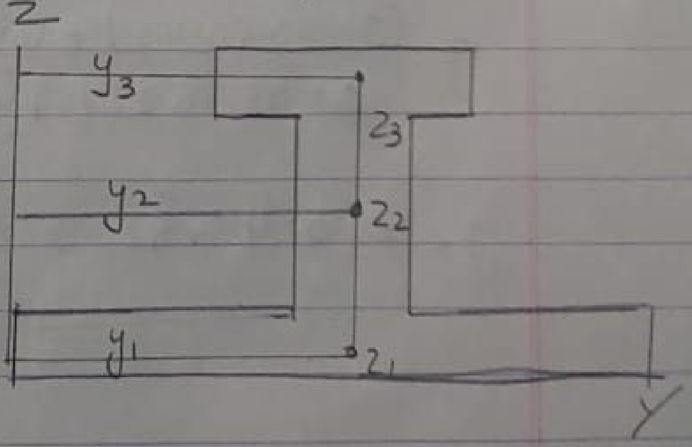


$A_1 = 0.35 \times 0.9 = 0.315 m^2$

$A_2 = 0.65 \times 0.35 = 0.2275 m^2$

$A_3 = 0.65 \times 0.15 = 0.0975 m^2$

$\Sigma A = 0.315 + 0.2275 + 0.0975 = 0.64 m^2$



(10)

$$y_1 = \frac{0.9}{2} = 0.45m$$

$$y_2 = \frac{0.9}{2} = 0.45m$$

$$y_3 = \frac{0.9}{2} = 0.45m$$

$$Z_1 = \frac{0.35}{2} = 0.175m$$

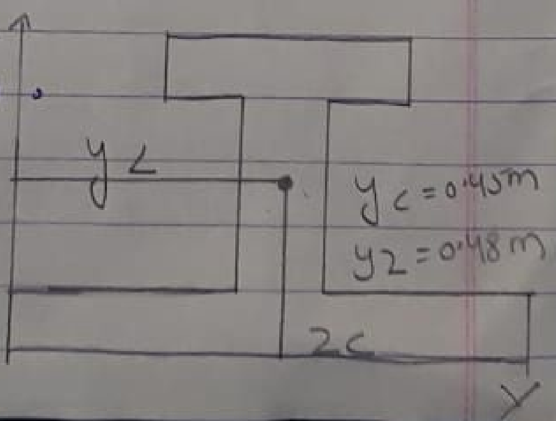
$$Z_2 = 0.35 + \left(\frac{0.65}{2}\right) = 0.675m$$

$$Z_3 = 0.35 + 0.65 + \left(\frac{0.15}{2}\right) = 1.075m$$

$$y_c = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1 + A_2 + A_3}$$

$$= \frac{(0.315 \times 0.45) + (0.2275 \times 0.45) + (0.0975 \times 0.45)}{0.315 + 0.2275 + 0.0975}$$

$$y_c = 0.45m.$$



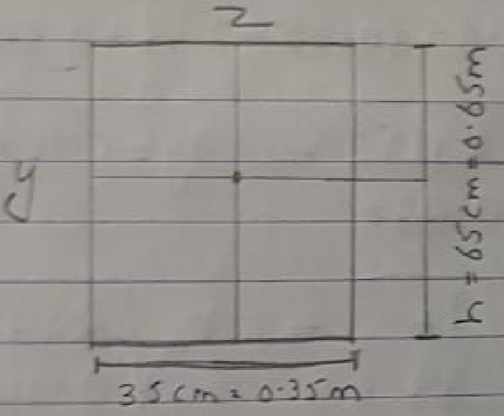
(17)

$$Z_c = \frac{A_1 Z_1 + A_2 Z_2 + A_3 Z_3}{A_1 + A_2 + A_3}$$

$$Z_c = \frac{(0.315 \times 0.175) + (0.2275 \times 0.675) + (0.0975 \times 1.075)}{0.315 + 0.2275 + 0.0975}$$

$$Z_c = 0.48 m$$

Q4b)



Moment of Inertia:

$$I_y = \frac{bh^2}{12} \text{ and } I_z = \frac{b^3 h}{12}$$

Here $h = 0.65m$ and $b = 0.35m$

$$I_y = \frac{0.35 \times (0.65)^3}{12}$$

$$I_y = 8 \times 10^{-3} m^4$$

(18)

$$I_z = \frac{b^3 h}{12} = \frac{(0.35)^3 \times 0.65}{12}$$

$$I_z = 2.32 \times 10^{-3} m^4$$

Radius of Gyration :=)

$$r_y = \sqrt{I_y / A} \text{ and } r_z = \sqrt{I_z / A}$$

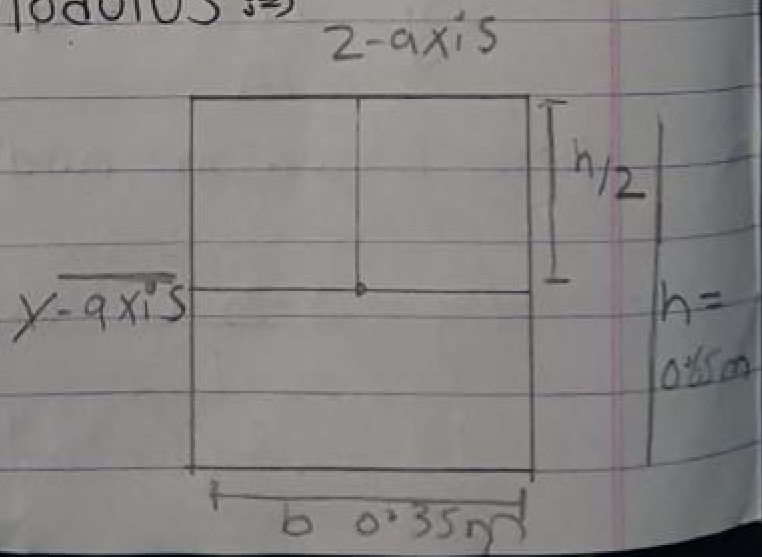
$$A = 0.65 \times 0.35 \Rightarrow A = 0.227 m^2$$

$$r_y \sqrt{\frac{8 \times 10^{-3}}{0.227}} \Rightarrow r_y = 0.187 m$$

$$r_z = \sqrt{\frac{I_z}{A}} \Rightarrow r_z \sqrt{\frac{2.32 \times 10^{-3}}{0.227}}$$

$$r_z = 0.101 m$$

Section Modulus :=)



(19)

$$S = Z_e = \frac{1}{6} bh^2$$

$$Z_e = \frac{1}{6} \times 0{\cdot}35 \times (0{\cdot}65)^2$$

$$Z_e = 0{\cdot}0246 m^3$$

$$Z_p = \frac{1}{4} hb^2$$

$$Z_p = \frac{1}{4} 0{\cdot}65 \times (0{\cdot}35)^2$$

$$Z_p = 0{\cdot}0199 m^3$$

$$f = \frac{Z_p}{Z_e}$$

$$= \frac{0{\cdot}0199 \cancel{m^3}}{0{\cdot}0246 \cancel{m^3}}$$

$$f = 0{\cdot}8$$

Ans 5:

Work: The application of a *force through certain distance is known as* work. It measured in Joules (J).

Work = Force × Distance Travelled in direction of force

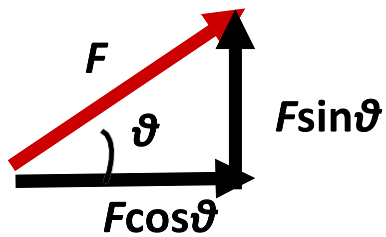
W = F.d

W is the work done (J), F is the force applied (N), d is the distance (m)

Work done at an angle θ

When calculating the work done by a force acting at an angle, it is useful to break the force down into components.

The tension in the rope can be broken down into a horizontal and a vertical component.



The vertical component does no work because the box does not move in that direction.

So to calculate work done by a force at an angle:

work done = force in direction of movement × distance moved W = Fscosθ

Energy: Energy is the measure of the ability of an object or a system to perform work. Its Unit is Joule and is denoted by J.

1 Joule (J) is the MKS unit of energy, equal to the force of one Newton acting through one meter.

1Joule (J) = 1N.m

There are many types of energy:

- **Kinetic energy** – energy of an object due to its speed

  kinetic energy = ½ × mass × speed^2, Ek = ½mv^2

  kinetic energy is measured in joules (J), mass is measured in kilograms (kg), speed is measured in meters per second (ms^{-1}).

- **Gravitational potential energy** – energy of an object due to position in a gravitational field

The Ep gained by a mass is proportional to the force used to lift it, and the distance it is lifted:

Ep = mgh

It is often talked about in terms of a change in an object's E_p due to a change in its height:

$\Delta E_p = mg\Delta h$

Energy is conserved, so

$\frac{1}{2}mv^2 = mgh,$

$v^2 = 2gh$

- **Elastic potential energy** – energy stored when an object is stretched or compressed
- **Chemical energy** – energy stored in chemical bonds

Rearranging these bonds can release energy (some reactions require energy to be put in). Typical numbers are 100–200 kJ per mole

- **Nuclear energy – energy stored in nuclei**
- **Heat energy** – Hot things have more energy than their cold counterparts

Heat is really just kinetic energy on microscopic scales: the vibration or otherwise fast motion of individual atoms/molecules. Even though it's kinetic energy, it's hard to derive the same useful work out of it because the motions are random. Heat is frequently quantified by calories (or Btu).

When work is done, energy is transferred. That energy might be

- gravitational potential energy – e.g. when an object changes height within a gravitational field
- kinetic energy – e.g. when an object changes speed
- light energy – e.g. when a light bulb is switched on
- heat and sound – e.g. when a car brakes sharply.

Conservation of energy

The law of conservation of energy states that:

Energy cannot be created, or destroyed; it can only be changed from one form into another form. In other words, the total energy of a system is constant.

When a man jumper's the gravitational potential energy is changed into kinetic energy as he comes down, and then stored as elastic potential energy as the rope stretches.

Power: Power is the rate at which work is done, or the rate at which energy is transferred.

Power = work done / time taken

P = W / t

Power is measured in watts (W), work done or energy transferred is measured in joules (J), time is measured in seconds (s).

Motive Power: The power outputted by a powered object, such as an engine or muscles, is called the motive power.

If the powered object is moving at a constant speed at a constant height:

Power = force × speed

P = Fv

At constant speed and height, the force produced by the powered object is equal but opposite to all resistive forces acting on the object, such as friction and air resistance.

Power: efficiency

Efficiency is the ratio of useful work done by the system, to that of the total work done (or the ratio of useful output energy to the total energy input).

Efficiency = useful work done / total work done Efficiency

= useful energy output / total energy input Efficiency is

often expressed as a percentage.

Efficiency is always less than 100%, as no device is perfect and some energy is always lost.

	Practical Examples
Work	Walking upstairs, pushing a shopping trolley, lifting heave objects
Energy	Moving Car(E_k), a book resting on table (E_p), burning a wooden match(Chemical energy),
Power	power exerted by the Space Shuttle rockets, crane lifting a load,