GENERAL ENGINEERING SCIENCE I

Attempt ALL questions.

Marks for each question are shown in brackets.

Section A

1. Simplify EACH of the following and rearrange to make x the subject of the expression:

(a)

$$y = \frac{bx^3}{x^2} \div \frac{x^4}{4b}$$ (4)

(b)

$$y = \frac{x^2 \times z^3}{z^2} \times \frac{2x^5 \times z}{x^2}$$ (4)

2. A cable stretched between to fixings sags under its own weight. The amount to which it sags is given by the approximate expression;

$$S = \sqrt{\left(\frac{3d(L-d)}{8}\right)}$$

Determine the value for L to 2 decimal places when S = 3.25 and d = 50. (8)

Note: Units can be ignored.

L

COVER

3. Determine the area of the shaded sector shown in Fig Q3 for the angles given.

$$Angle, a = \frac{\pi}{3}\ rads$$

$$Angle, b = \frac{2\pi}{3}\ rads$$

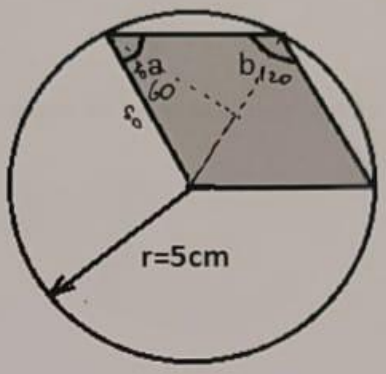


Fig Q3 (8)

SOH CAH TOA

4. (a) Plot the following (x,y) data on a graph. (4)

x	3	2	1	0	-1	-2
y	-9.4	-6.6	-3.8	-1	1.8	4.6

(b) Determine an expression relating the x and y coordinates. (4)

(c) Determine the value of y when x = 1.5. (2)

5. A concrete beam is shown in Fig Q5.

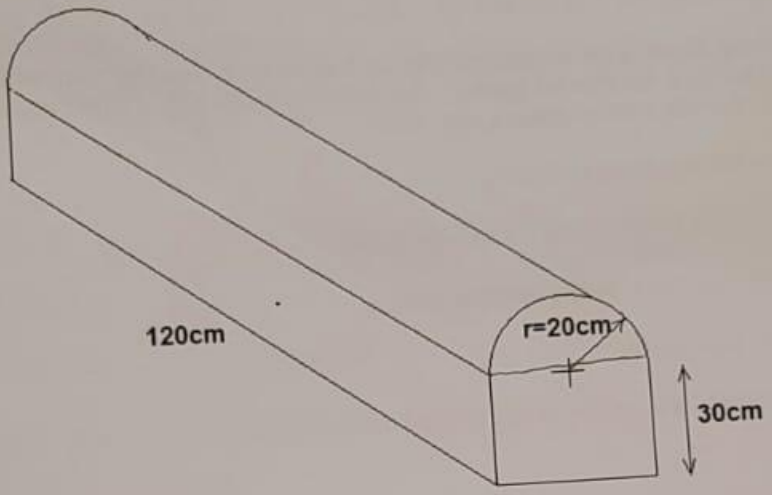


Fig Q5

Determine EACH of the following:

(a) the volume of the beam; (3)

(b) the total surface area of the beam. (5)

6. A sphere and a cone have the same volumes. The radius of the sphere is the same as the radius of the cone base.

Determine EACH of the following:

(a) the ratio of cone height to sphere radius; (4)

(b) check your answer to Q6(a) by calculation for a sphere of radius 2 cm. (4)

Section B .

7. A stationary block with a mass of 150 kg has a force applied to it which causes acceleration in a horizontal plane. The force of 1950 N is applied at an angle of 15° below the horizontal pulling the block.

Determine EACH of the following:

(a) the applied force in the horizontal plane; (1)

(b) the applied force in the vertical plane; (1)

(c) the net normal force; (2)

(d) the acceleration of the block if the coefficient of friction is 0.2. (4)

8. Fig Q8 shows a cross section of a wind turbine support column. The turbine rotor assembly has an effective mass of 30 tonnes on top of the column. The column has a rectangular central section of length 1 m joined by semi-circular ends.

(a) If the compressive stress limit is 350 MN/m^2 determine whether the column can withstand the load; (4)

(b) Calculate the strain in the column given that the Modulus of Elasticity E for the material is 196 GN/m^2.

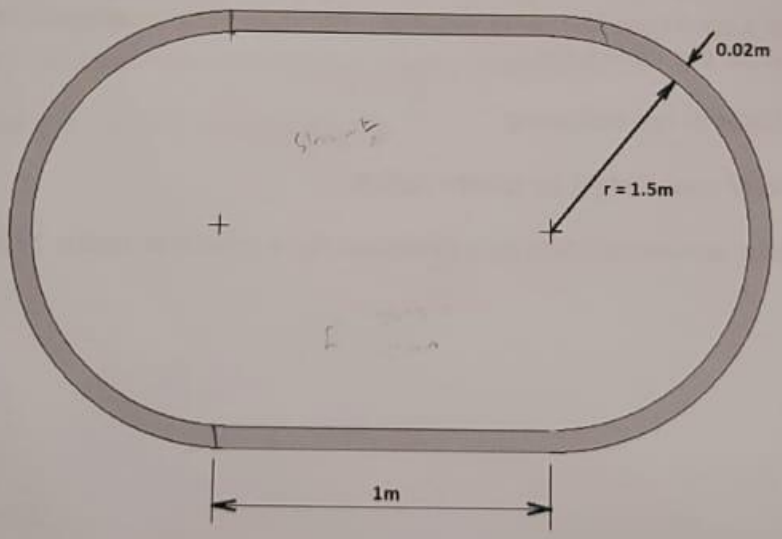


Fig Q8 (not to scale) (4)

9. (a) Define density and use the definition to derive the units for density. (2)

(b) Define work (work done) as it is used in engineering and use the definition to derive the units for work done. (4)

(c) State the law of conservation of energy. (2)

10. A pump on a water main discharges through a pipe of 100 mm diameter against a head of 32 m at a constant velocity of 3.5 m/s. You can ignore the effects of friction in the pump and pipe-work.

Note: Density of seawater 1025 kg/m^3

Determine EACH of the following:

(a) the power of the pump; (4

(b) the motor power to drive the pump if the combined electrical and mechanical efficiency is 88%.

11. (a) Explain what is meant by the term centroid.

(b) For the shape shown in Fig Q11, determine the position of the centre of area.

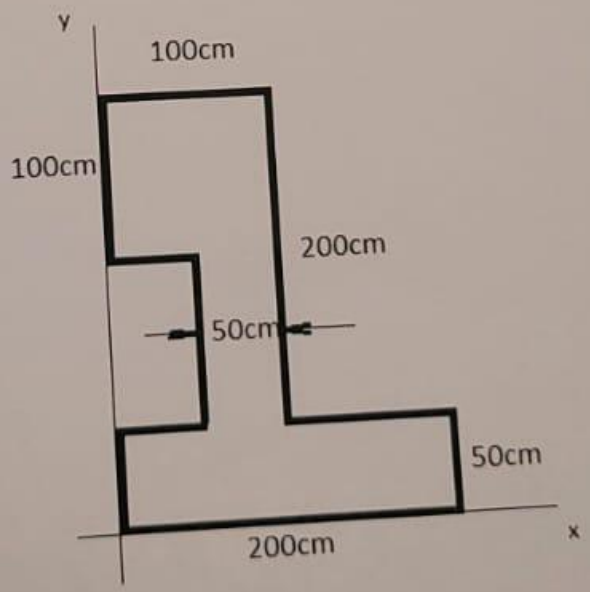


Fig Q11

12. A winch raises a mass of 500 kg through a distance of 12 m in 10 seconds. The power input to the system is measured at 7.5 kW.

Determine EACH of the following:

(a) the work done in lifting the load;

(b) the system efficiency.

$W = F \times d$

$= 500 \times 9.81 \times 12$

1. Simplify EACH of the following and rearrange to make x the subject of the expression:

(a)

$$y = \frac{bx^3}{x^2} \div \frac{x^4}{4b} \qquad (4)$$

(b)

$$y = \frac{x^2 \times z^3}{z^2} \times \frac{2x^5 \times z}{x^2} \qquad (4)$$

a) $y = \frac{bx^3}{x^2} \div \frac{x^4}{4b}$

$\frac{bx}{1} \times \frac{4b}{x^4}$

$y = \frac{4b^2x}{x^{4-3}}$

$y = \frac{4b^2}{x^3}$

$x^3 = \frac{4b^2}{y}$

$x = \sqrt[3]{\frac{4b^2}{y}}$

b) $y = \frac{x^2 z^3}{z^2} \times \frac{2x^5 z}{x^2}$

$y = z \cdot 2x^5 z$

$y = 2z^2x^5$

$\frac{y}{2z^2} = x^5$

$\sqrt[5]{\frac{y}{2z^2}} = x$

(2) A cable stretched between to fixings sags under its own weight. The amount to which it sags is given by the approximate expression;

$$S = \sqrt{\left(\frac{3d(L-d)}{8}\right)}$$

Determine the value for L to 2 decimal places when S = 3.25 and d = 50. (8)

Note: Units can be ignored.

$$S = \sqrt{\frac{3d(L-d)}{8}}$$

$$3.25 = \sqrt{\frac{3\times 50(L-50)}{8}}$$

$$10.5625 = \frac{150(L-50)}{8}$$

$$\frac{10.5625\times 8}{150} = L-50$$

$$0.5633333 = L-50$$

$$50.563333 = L$$

$$\boxed{50.56}$$

3. Determine the area of the shaded sector shown in Fig Q3 for the angles given.

$$Angle, a = \frac{\pi}{3}\ rads$$

$$Angle, b = \frac{2\pi}{3}\ rads$$

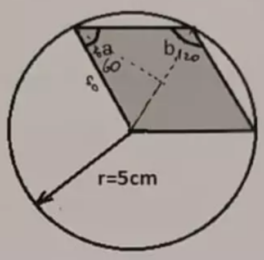
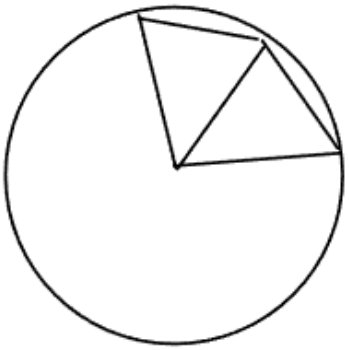
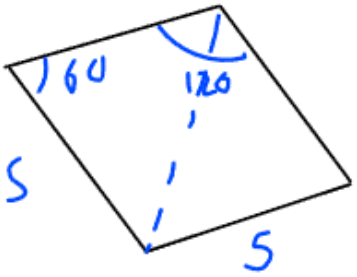


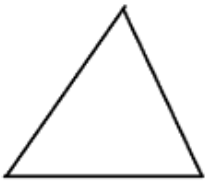
Fig Q3 (8)



$a = \frac{\pi}{3} = 60°$

$b = \frac{2\pi}{3} = 120°$





$Area = \frac{1}{2}\ ab \sin C$

$\left(\frac{1}{2} \times 5 \times 5 \sin 60\right) \times 2$

$Area = 21.65\ cm^2$

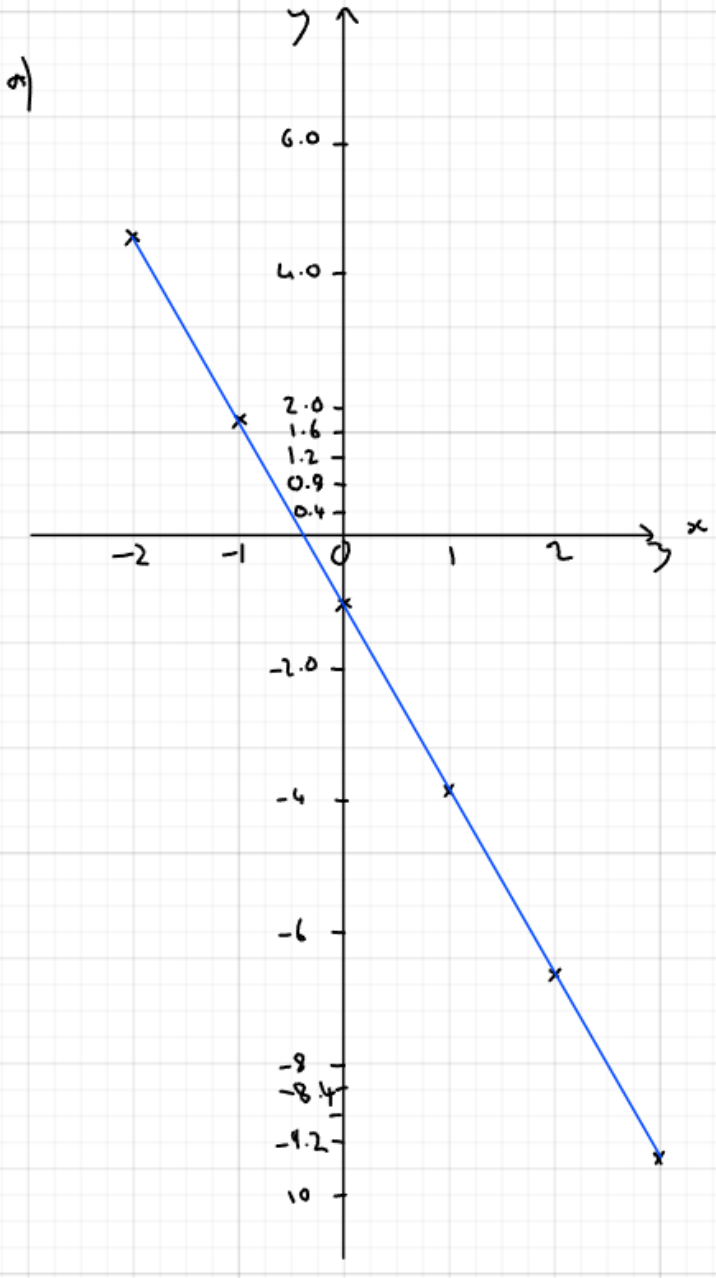
4. (a) Plot the following (x,y) data on a graph. (4)

x	3	2	1	0	-1	-2
y	-9.4	-6.6	-3.8	-1	1.8	4.6

(b) Determine an expression relating the x and y coordinates. (4)

(c) Determine the value of y when x = 1.5. (2)

a)



b) $y = mx + c$

$m = \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{-3.8 - -1}{1 - 0} = \frac{-2.8}{1} = -2.8$

$c = -1$

$y = -2.8x - 1$

c) $y = -2.8(1.5) - 1 = -5.2$

5. A concrete beam is shown in Fig Q5.

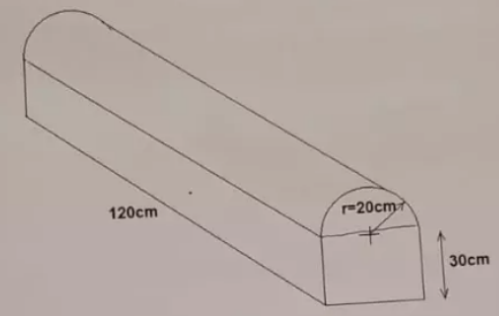


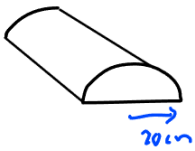
Fig Q5

Determine EACH of the following:

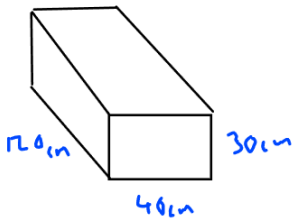
(a) the volume of the beam; (3)

(b) the total surface area of the beam. (5)

a) volume.



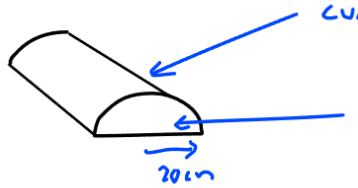
$$vol = \frac{\pi r^2 h}{2} = \frac{\pi (20)^2 \times 120}{2} = 75398.22$$



$$vol = 120 \times 40 \times 30 = 144000 cm^3$$

$$total\ vol = 219398\ cm^3$$

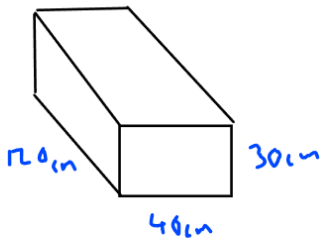
b) Surface Area



curved SA $= \frac{\pi dh}{2} = \frac{\pi \times 40 \times 120}{2}$

end caps $= \pi r^2 = \pi (20)^2$

} 8796.4594



Front + back $= (30 \times 40) \times 2$

left + Right $= (120 \times 30) \times 2$

base $= (120 \times 40)$

} 14400

$$total\ SA = 23196.5\ cm^2$$

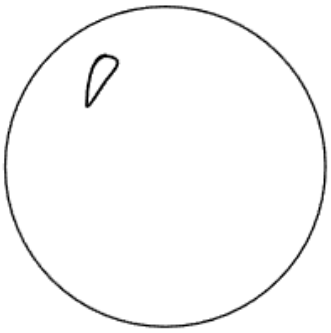
6. A sphere and a cone have the same volumes. The radius of the sphere is the same as the radius of the cone base.

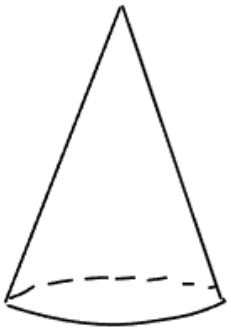
Determine EACH of the following:

(a) the ratio of cone height to sphere radius; (4)

(b) check your answer to Q6(a) by calculation for a sphere of radius 2 cm. (4)

a)





$V_1 = V_1$

$\frac{4}{3}\pi r^3 = \frac{\pi r^2 h}{3}$

$\frac{4}{\cancel{3}}\cancel{\pi} r^3 = \frac{\cancel{\pi} r^2 h}{\cancel{3}}$

$4 r^3 = \cancel{r^2} h$

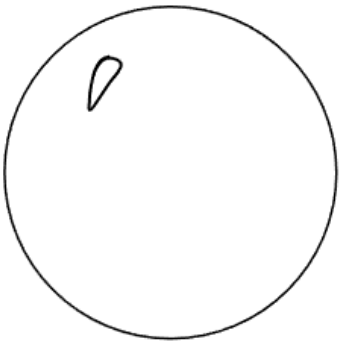
$4r = h$

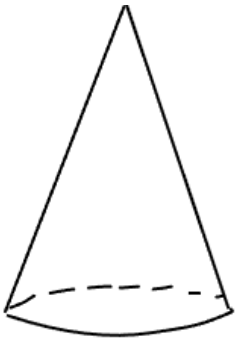
when $R = 1$ $h = 4$

height : radius

4 : 1

b)





$V_1 = V_1$

$\frac{4}{3}\pi(2)^3 = \frac{\pi(2)^2 h}{3}$

$33.51032 = 4.1887\,h$

$\frac{33.51032}{4.1887} =$

$7.9999 = h$

Yes, it works

(7) A stationary block with a mass of 150 kg has a force applied to it which causes acceleration in a horizontal plane. The force of 1950 N is applied at an angle of 15° below the horizontal pulling the block.

Determine EACH of the following:

(a) the applied force in the horizontal plane; (1)

(b) the applied force in the vertical plane; (1)

(c) the net normal force; (2)

(d) the acceleration of the block if the coefficient of friction is 0.2. (4)

15° below the horizontal pulling the block.

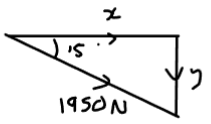
Determine EACH of the following:

(a) the applied force in the horizontal plane; (1)

(b) the applied force in the vertical plane; (1)

(c) the net normal force; (2)

(d) the acceleration of the block if the coefficient of friction is 0.2. (4)



Horizontal

x

CAH

$\cos 15 = \frac{x}{1950}$

$1950 \cos 15 = x$

$x = 1883.555\ N$

Push

Vertical

y

SOH

$\sin 15 = \frac{y}{1950}$

$1950 \sin 15 = y$

$y = 504.697\ N$

↓ Down

a) Horizontal force Applied 1883.555 N

b) Vertical 504.697 N

Net Vertical

mg + down

$150 \times 9.81 + 504.697$

c) 1976.197 N

Net normal

Friction = μN

$= 0.2 \times 1976.197$

$= 395.2394\ N$

Net Horizontal

Push − Friction

$1883.555 - 395.2394$

$1488.31557\ N$

Accel

$F = ma$

$\frac{1488.3155}{150} = 9.6554\ m/s^2$

8. Fig Q8 shows a cross section of a wind turbine support column. The turbine rotor assembly has an effective mass of 30 tonnes on top of the column. The column has a rectangular central section of length 1 m joined by semi-circular ends.

(a) If the compressive stress limit is 350 MN/m^2 determine whether the column can withstand the load; (4)

(b) Calculate the strain in the column given that the Modulus of Elasticity E for the material is 196 GN/m^2.

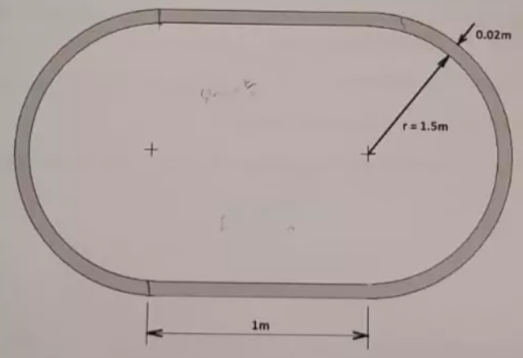


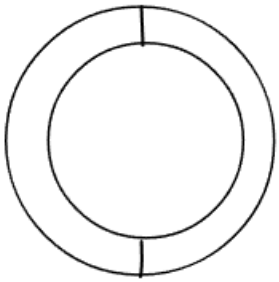
Fig Q8 (not to scale)

(4)

a) $\text{stress} = \frac{F}{A}$

b)

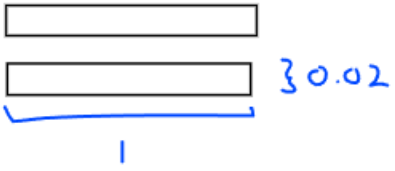
Area:



$\pi R^2 - \pi r^2$

$\pi(1.52)^2 - \pi(1.5)^2$

$= 0.1897521\ m^2$



$\text{Area} = (0.02 \times 1) \times 2$

$= 0.04\ m^2$

$\text{total Area} = 0.2297521\ m^2$

$\text{stress} = \frac{30{,}000 \times 9.81}{0.2297521} = 1{,}280{,}945.317\ N/m^2$

$1.28\ M\ N/m^2$

limit is $350\ M\ N/m^2$

Yes can withstand load

b) $\text{Elas} = \dfrac{\text{stress}}{\text{strain}}$

$$196 \times 10^9 = \frac{1\,280\,945.317}{\text{strain}}$$

$$\text{strain} = \frac{1\,280\,945.317}{196 \times 10^9}$$

$$= \boxed{6.5354 \times 10^{-6}}$$

9. (a) Define density and use the definition to derive the units for density. (2)

(b) Define work (work done) as it is used in engineering and use the definition to derive the units for work done. (4)

(c) State the law of conservation of energy. (2)

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \qquad \text{Units} = \frac{kg}{m^3}$$

a) Density is a measure of how tightly packed a mass (kg) is into a given space (meters cubed)

$$\text{work} = \text{Force} \times \text{distance}$$

$$J = N \times m$$

b)
work is a measure of Joules expended to get a job done. Usually calculated using the force applied multiplied by the distance over which it is applied. It is independent of time, and this is for a constant force. Units are Nm or Joules.

$$Q_{in} = Q_{out}$$

c)
energy is never created or destroyed, only transferred. So the total amount of energy entering a system must be equal to the total amount of energy leaving a system.

10. A pump on a water main discharges through a pipe of 100 mm diameter against a head of 32 m at a constant velocity of 3.5 m/s. You can ignore the effects of friction in the pump and pipe-work.

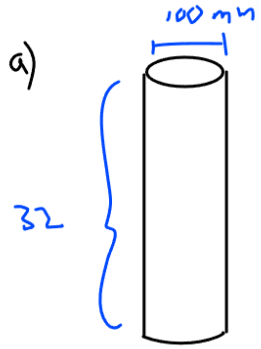
Note: Density of seawater 1025 kg/m³

Determine EACH of the following:

(a) the power of the pump; (4)

(b) the motor power to drive the pump if the combined electrical and mechanical efficiency is 88%. (4)

a)



$$P = \frac{mgh}{t} \quad \text{vel}$$

mass of water in pipe = vol × density

$\pi r^2 h \times 1025$

$\pi \left(\frac{100}{2000}\right)^2 \times 32 \times 1025 = 257.61$ kg

$P = 257.61 \times 9.81 \times 3.5$

8845.059 watts

b) $\text{Eff} = \frac{\text{theoretical}}{\text{Actual}}$

$0.88 = \frac{8845.059}{\text{Actual}}$

$\text{Actual} = \frac{8845.059}{0.88}$

10051.2 watts

11. (a) Explain what is meant by the term centroid.

(b) For the shape shown in Fig Q11, determine the position of the centre of area.

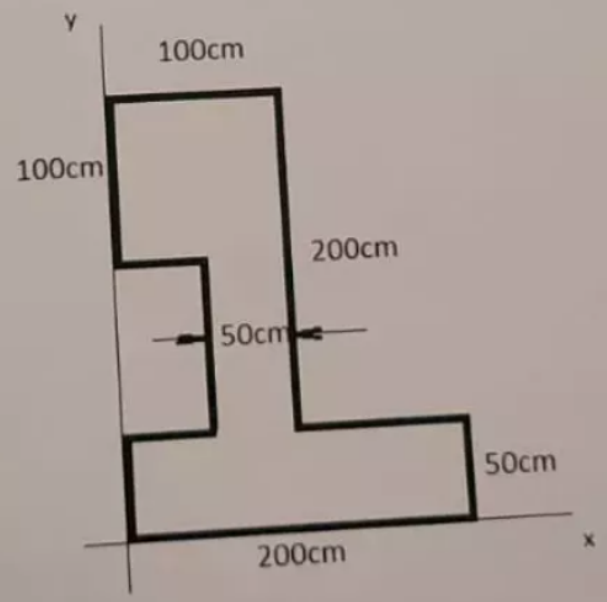


Fig Q11

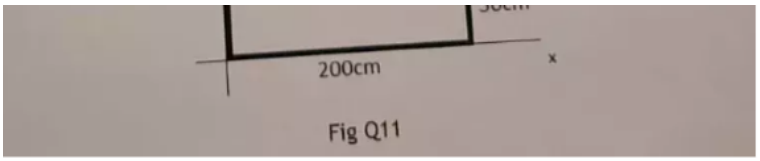
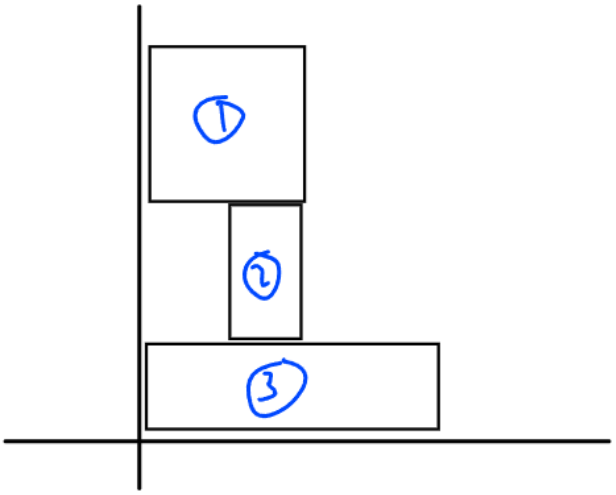


Fig Q11

Area = mass

area = mass



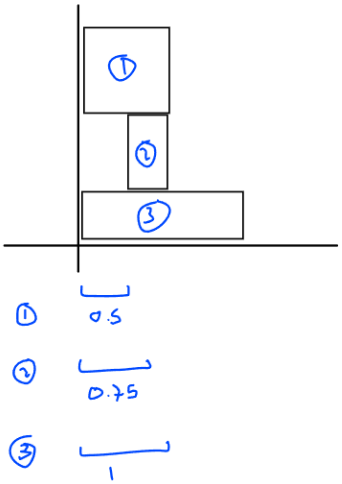
① $1\ m^2$

② $= 0.5 \times 1 = 0.5\ m^2$

③ $2 \times 0.5 = 1\ m^2$

Horizontal Centroid

taking moments from the left hand side.



sum of downwards force = sum of upwards forces

Name	Mass	Force	Distance	Moment	Direction
①	1		0.5	0.5	C
②	0.5		0.75	0.375	C
③	1		1	1	C
①+②+③	2.5		x	2.5x	A

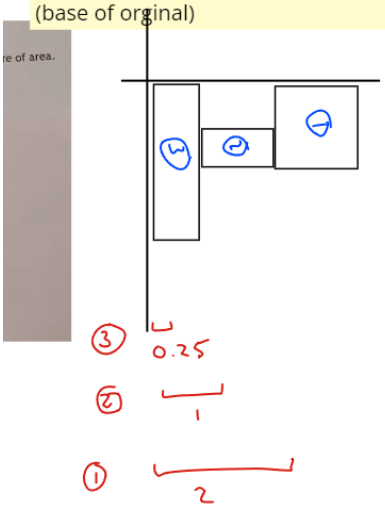
sum of clockwise moments = sum of anticlockwise moments

$0.5 + 0.375 + 1 = 2.5x$

$0.75 = x$

Vertical Centroid

taking moments from the left hand side. (base of orginal)



sum of downwards force = sum of upwards forces

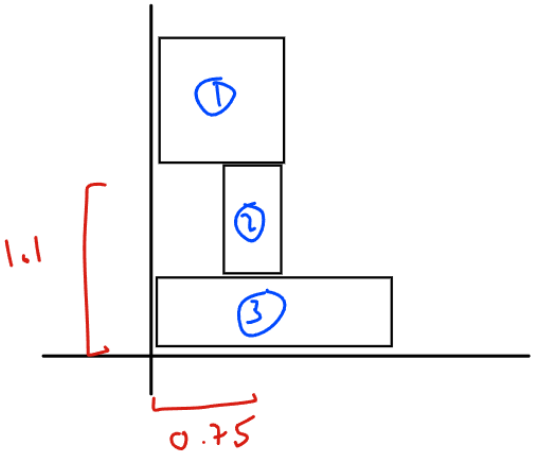
Name	Mass	Force	Distance	Moment	Direction
①	1		2	2	C
②	0.5		1	0.5	C
③	1		0.25	0.25	C
①+②+③	2.5		y	2.5y	A

sum of clockwise moments = sum of anticlockwise moments

$2 + 0.5 + 0.25 = 2.5y$

$2.75 = 2.5y$

$1.1 = y$



Centroid is

0.75 m from left hand side

1.1 m up from base.

12. A winch raises a mass of 500 kg through a distance of 12 m in 10 seconds. The power input to the system is measured at 7.5 kW.

Determine EACH of the following:

(a) the work done in lifting the load; (4

(b) the system efficiency. (4

a) work = mgh

$500 \times 9.81 \times 12$

58860 J

b) eff = theoretical / Actual

$P = \frac{mgh}{t} = \frac{58860}{10} = 5886$ watts

$\frac{5886}{7500} \times 100 = 78.48\%$