CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

STCW 78 as amended CHIEF ENGINEER REG. III/2 - "YACHT 2"
STCW 78 as amended SMALL VESSEL CHIEF ENGINEER <3000 GT, <9000 kW UNLIMITED

058-11 - GENERAL ENGINEERING SCIENCE I

FRIDAY, 29 SEPTEMBER 2023

1400 - 1600 hrs

Materials to be supplied by examination centres

Candidate's examination workbook
Graph paper

Examination Paper Inserts

Notes for the guidance of candidates:

1. Examinations administered by SQA on behalf of the Maritime & Coastguard Agency.
2. Candidates are required to obtain 50% of the total marks allocated to this paper to gain a pass **AND** also obtain a minimum 40% in Sections A and B of the paper.
3. Non-programmable calculators may be used.
4. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Maritime & Coastguard Agency

SQA

GENERAL ENGINEERING SCIENCE I

Attempt ALL questions

Marks for each question are shown in brackets.

Section A

1. (a) Evaluate x in the following expression giving your answer to 2 decimal places when a=3, b=9 and m=0.5. Show all working stages.

$$x = \left(\frac{a \times b}{a}\right)^{m} \div \left(\frac{a \times b}{a^2}\right)^{\frac{m+0.5}{m}}$$ (4)

(b) Determine the value of 'n' using logarithms in the following expression when $P_2 = 2P_1$ and $T_1 = 3T_2$

$$P_1 T_1^n = P_2 T_2^n$$ (4)

2. (a) Simplify the following expression to a single fraction:

$$\frac{12\,a\,b^3}{6\,a\,b\,c} - \frac{2\,a\,b^2}{12\,a\,b\,c^2}$$ (4)

(b) Solve the following expression for x:

$$4x\,(x-2) \div 2x = 0$$ (4)

3. (a) State the general equation for a straight line graph. (2)

(b) Plot points shown in Table Q3 and draw the best fit line. (3)

(c) Determine the values of m and c from your graph. (3)

(d) State the equation for the plotted straight line. (1)

X	-2	-1	0	1	2
Y	1	-1	-3	-5	-7

Table Q3

4. A mast, CD, is found to be 28 m high after being measured by observers at points A and B who measured the observation angles shown in FIG Q4.

Determine the distance AB between the two observers. (8)

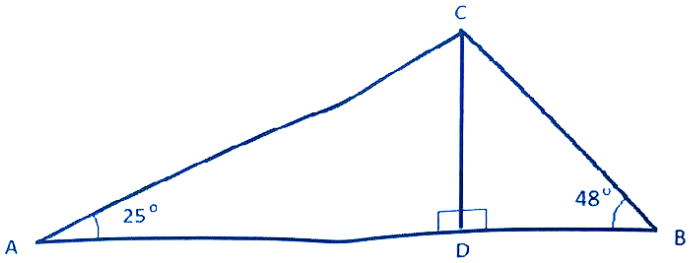


FIG Q4

5. The sketch shown in FIG Q5, is not accurately drawn but shows a quadrilateral ADCE joined to an isosceles triangle ABC. Line FAD is a straight line.

Determine EACH of the following with reasons:

(a) the angle at x; (3)

(b) the angle at y; (3)

(c) the angle at z. (3)

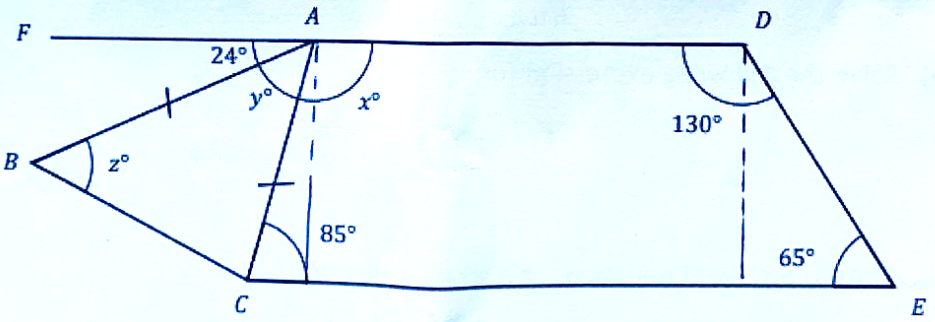


FIG Q5 (not to scale)

6. The steel shell of a condenser can be considered cylindrical with flat, round ends. It has an overall length of 1.5 m, with a bore (diameter) of 700 mm, and a wall thickness of 10 mm.

Determine EACH of the following:

(a) the mass of the steel condenser shell; (4)

(b) the mass of sea water that would completely fill the condenser ignoring all interior fittings; (2)

(c) the direct force that would be exerted by the condenser when full of water. (2)

Note: the density of sea water is 1025 kg/m^3;
the density of steel is 7800 kg/m^3.

Section B

7. Define EACH of the following terms with examples:

(a) Stable, Neutral and Unstable equilibrium; (2)

(b) Scalar and Vector Quantities; (2)

(c) Moments; (2)

(d) Centroid. (2)

8. A body starts from rest and accelerates with constant acceleration of 2.0 m/s^2 to a speed of 9.0 m/s. It then travels at 9 m/s for 15 seconds after which it is retarded to a speed of 1 m/s. If the complete motion takes 24.5 seconds:

Determine EACH of the following:

(a) sketch the velocity/time diagram; (2)

(b) the time taken to reach 9m/s; (3)

(c) the retardation (Deceleration); (3)

(d) the total distance travelled. (2)

9. A circulation pump delivers sea water through a 150 mm diameter pipe to a tank inlet at a height of 6.8 m at a constant velocity of 0.42 m/s.

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 85%. (4)

Note: the density of sea water is 1025 kg/m^3

10. A strut 1.1 m long has a diameter of 45 mm and when subjected to an axial pull of 210 kN extends by 0.385 mm.

Determine EACH of the following:

(a) the direct stress in the strut; (3)

(b) the direct strain in the strut; (3)

(c) the Modulus of Elasticity (E) for the steel. (2)

11. A crate with a mass of 20 kg, rests on a horizontal surface. The box has a force of 75 N applied to it parallel to the horizontal surface.

Determine EACH of the following:

(a) the acceleration of the body with no friction; (3)

(b) the acceleration of the body when a friction coefficient of 0.35 exists between the box and the surface. (5)

12. FIG Q12 shows a loaded uniform beam with a mass 800 kg.

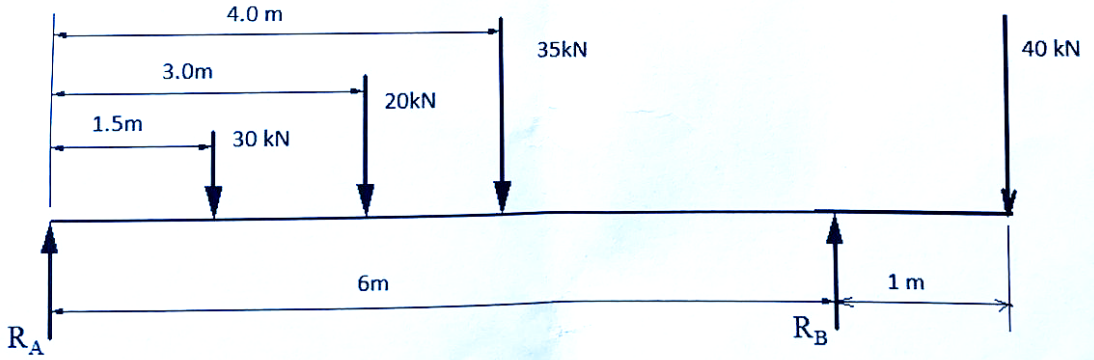


FIG Q12 (not to scale)

Determine EACH of the following:

(a) the reaction force, RA; (6)

(b) the reaction force, RB. (2)

1. (a) Evaluate x in the following expression giving your answer to 2 decimal places when a=3, b=9 and m=0.5. Show all working stages.

$$x = \left(\frac{a \times b}{a}\right)^{m} \div \left(\frac{a \times b}{a}\right)^{\frac{m+0.5}{m}}$$

(4)

a)

$$x = \left(\frac{3 \times 9}{3}\right)^{0.5} \div \left(\frac{9}{3}\right)^{\frac{0.5+0.5}{0.5}}$$

$$3 \div 3^{\frac{1}{0.5}}$$

$$3 \div 3^{2}$$

$$3 \div 9$$

$$\frac{3}{9} = \frac{1}{3} = 0.33 \text{ 2dp}$$

(b) Determine the value of 'n' using logarithms in the following expression when $P_2 = 2P_1$ and $T_1 = 3T_2$

$$P_1T_1^n = P_2T_2^n \qquad (4)$$

b) $P_1(T_1)^n = P_2(T_2)^n$

$P_2 = 2P_1 \qquad T_1 = 3T_2$

$P_1(3T_2)^n = 2P_1(T_2)^n$

$P_1(3T_2)^n = 2P_1(T_2)^n$

$3^n(T_2)^n = 2(T_2)^n$

$3^n(T_2)^n = 2(T_2)^n$

$3^n = 2$

$\log_3 3^n = \log_3 2$

$n = \log_3 2 = 0.63093$

2. (a) Simplify the following expression to a single fraction:

$$\frac{12\,a\,b^3}{6\,a\,b\,c} - \frac{2\,a\,b^2}{12\,a\,b\,c^2}$$

(4)

$$2\,\frac{12\,a\,b^{3\,2}}{6\,a\,b\,c} - \frac{2\,a\,b^2}{6\,12\,a\,b\,c^2}$$

$$\frac{2b^2}{c} - \frac{b}{6c^2}$$

$$6c\,\frac{2b^2}{6c\;c} - \frac{b}{6c^2}$$

$$\frac{12b^2c}{6c^2} - \frac{b}{6c^2}$$

$$\boxed{\frac{12b^2c - b}{6c^2}}$$

(b) Solve the following expression for x:

$$4x\,(x-2) \div 2x = 0 \qquad (4)$$

$$\frac{4x(x-2)}{2x} = 0 \qquad x \neq 0$$

$$\frac{2\cancel{4x}(x-2)}{\cancel{2x}} = 0$$

$$2(x-2) = 0$$

$$x-2 = 0$$

$$\boxed{x = 2}$$

3. (a) State the general equation for a straight line graph. (2)

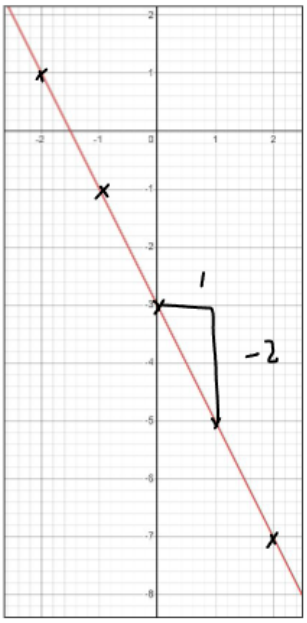
(b) Plot points shown in Table Q3 and draw the best fit line. (3)

(c) Determine the values of m and c from your graph. (3)

(d) State the equation for the plotted straight line. (1)

X	-2	-1	0	1	2
Y	1	-1	-3	-5	-7

Table Q3



a) $y = mx + c$

b)

c) $m = \frac{\text{Rise}}{\text{Run}} = \frac{-2}{1} = -2$

$c = -3$

d $y = -2x - 3$

4. A mast, CD, is found to be 28 m high after being measured by observers at points A and B who measured the observation angles shown in FIG Q4.

Determine the distance AB between the two observers. (8)

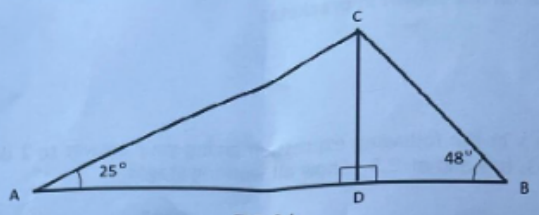
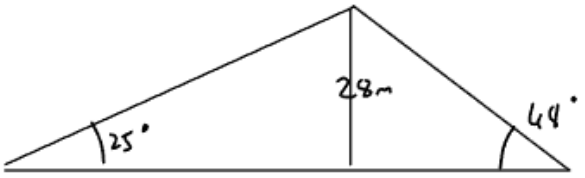
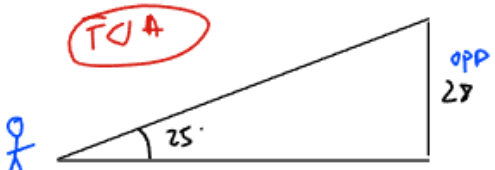
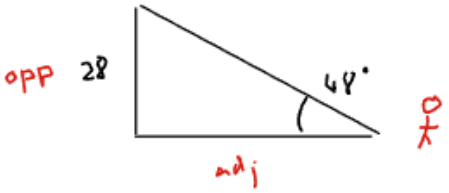


FIG Q4



SOH
CAH
TOA





$\tan 25 = \frac{28}{adj}$

$adj = \frac{28}{\tan 25}$

$adj = 60.0461$

$\tan 48 = \frac{28}{adj}$

$adj = \frac{28}{\tan 48}$

$adj = 25.2113$

$total = 85.2575\ m$

5. The sketch shown in FIG Q5, is not accurately drawn but shows a quadrilateral ADCE joined to an isosceles triangle ABC. Line FAD is a straight line.

Determine EACH of the following with reasons:

(a) the angle at x; (3)

(b) the angle at y; (3)

(c) the angle at z. (3)

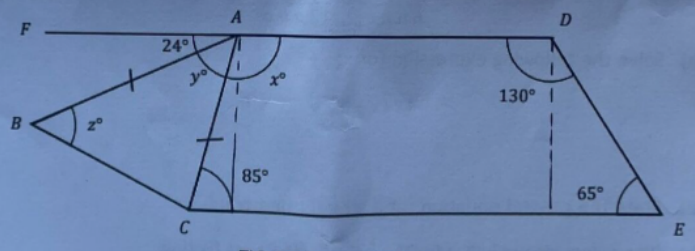


FIG Q5 (not to scale)

sum of angles inside of a quadrilateral must sum to 360°

a) $x = 360 - (85 + 130 + 65)$

$360 - 280 = 80$

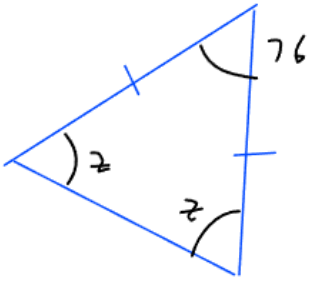
b) angles on a straight line sum to 180°

$24 + y + x = 180$

$24 + y + 80 = 180$

$y = 180 - 80 - 24 = 76$

c) this triangle is isosceles, so the two base angles are "z" and the top is 76, all angles must sum to 180°



$$\frac{180 - 76}{2} = z$$

$52° = z$

6. The steel shell of a condenser can be considered cylindrical with flat, round ends. It has an overall length of 1.5 m, with a bore (diameter) of 700 mm, and a wall thickness of 10 mm.

Determine EACH of the following:

(a) the mass of the steel condenser shell; (4)

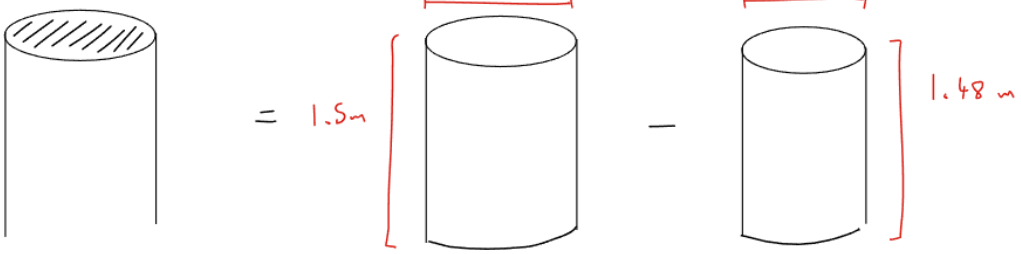
(b) the mass of sea water that would completely fill the condenser ignoring all interior fittings; (2)

(c) the direct force that would be exerted by the condenser when full of water. (2)

Note: the density of sea water is 1025 kg/m³;
the density of steel is 7800 kg/m³.

c)

Does it have flat end caps or are they open? If they are open its easier, if there are end caps we must include them, which is a little harder. Lets put end caps



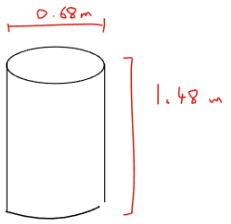
$\pi r^2 h \quad - \quad \pi r^2 h$

$\pi (0.35)^2 (1.5) \quad - \quad \pi (0.34)^2 (1.48) = 0.039778846\ m^3$

Mass = Vol x density

$0.039778846 \times 7800 = 310.275\ kg$

b)



internal vol $= \pi (0.34)^2 (1.48)$

$= 0.5374888\ m^3$

Mass = vol x density

$0.5374888 \times 1025 = 550.976\ kg$

c) Mass x 9.81 =

$(310.275 + 550.976) \times 9.81 = \boxed{8448.38\ N}$

Section B

7. Define EACH of the following terms with examples:

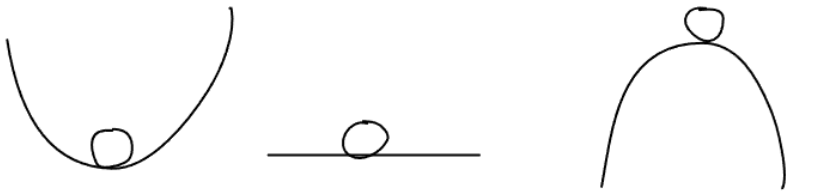
(a) Stable, Neutral and Unstable equilibrium; (2)

(b) Scalar and Vector Quantities; (2)

(c) Moments; (2)

(d) Centroid. (2)

a)



Stable

returns to start point. A tennis ball in a valley

Neutral

stays where you put it, does not move. A tennis ball on flat ground

Unstable

does not return to start point. A tennis ball on a hill

b) Scalar

Just a magnitude, so just an amount, such as 100 mph

Vector

a magnitude plus a direction, so 100 mph NORTH would be a vector

c) Moments = Force x distance

moments are the turning force felt upon a point, the are calculated by multiplying the force by the effective leverage length they have.

Units are usually given in Nm

d) Centroid = centre of gravity of an object

these are found by setting both the horizontal and vertical moments as equilibriums, and then solving each one to find the centre of gravity in both the x and y (horizontal and vertical) the combination of these gives the centroid for the shape.

8. A body starts from rest and accelerates with constant acceleration of 2.0 m/s² to a speed of 9.0 m/s. It then travels at 9 m/s for 15 seconds after which it is retarded to a speed of 1 m/s. If the complete motion takes 24.5 seconds:

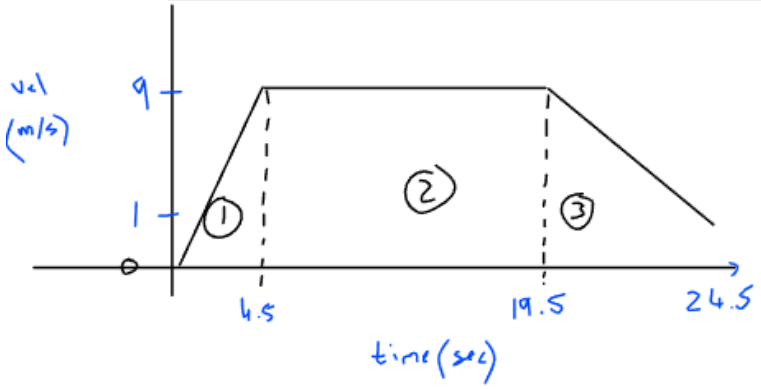
Determine EACH of the following:

(a) sketch the velocity/time diagram; (2)

(b) the time taken to reach 9m/s; (3)

(c) the retardation (Deceleration); (3)

(d) the total distance travelled. (2)



$v = u + at$

$s = ut + \frac{1}{2}at^2$

$s = \left(\frac{u+v}{2}\right)t$

① ② ③

① $s =$, $u = 0$, $v = 9$, $a = 2$, $t = 4.5$

② s, $u = 9$, $v = 9$, $a = 0$, $t = 15$

③ $s =$, $u = 9$, $v = 1$, $a =$, $t = 5$

$v = u + at$

$9 = 0 + 2t$

$t = 4.5$

$v = u + at$

$1 = 9 + a \times 5$

$\frac{-8}{5} = a$

$-1.6\ m/s^2 = a$

b) 4.5 sec

c) $-1.6\ m/s^2$

8)

① ② ③

$s =$ s $s =$
$u = 0$ $u = 9$ $u = 9$
$v = 9$ $v = 9$ $v = 1$
$a = 2$ $a = 0$ $a = -1.6$
$t = 4.5$ $t = 15$ $t = 5$

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$s = \left(\frac{u+v}{2}\right)t$

$s = \left(\frac{u+v}{2}\right)t$ $s = \left(\frac{9+9}{2}\right)15$ $s = \left(\frac{9+1}{2}\right)5$

$s = \left(\frac{0+9}{2}\right)4.5$

$(4.5 \times 4.5) + (9 \times 15) + (5 \times 5) = 180.25\ m$

(9) A circulation pump delivers sea water through a 150 mm diameter pipe to a tank inlet at a height of 6.8 m at a constant velocity of 0.42 m/s.

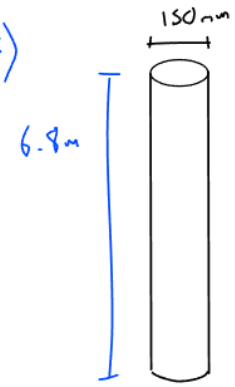
Determine EACH of the following:

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

(b) the motor power to drive the pump if the combined electrical and mechanical efficiency is 85%. (4)

Note: the density of sea water is 1025 kg/m³

a)



$vel = 0.42$

$P = \frac{mgh}{t} \times vel = mgv$

Mass of water in pipe = vol × density

$vol = \pi r^2 h = \pi \left(\frac{0.15}{2}\right)^2 \times 6.8 = 0.120165919\ m^3$

$Mass = 0.120165919\ m^3 \times 1025 = 123.17\ kg$

$P = 123.17 \times 9.81 \times 0.42 = 507.485$ watts

b) $Eff = \frac{Theoretical}{Actual}$

$0.85 = \frac{507.485}{x}$

$x = \frac{507.485}{0.85}$

597.042 watts

10. A strut 1.1 m long has a diameter of 45 mm and when subjected to an axial pull of 210 kN extends by 0.385 mm.

Determine EACH of the following:

(a) the direct stress in the strut; (3)

(b) the direct strain in the strut; (3)

(c) the Modulus of Elasticity (E) for the steel. (2)

a) $\text{Stress} = \frac{F}{A} = \frac{210{,}000}{\pi\left(\frac{0.045}{2}\right)^2} = 132{,}039{,}656.5 \ N/m^2$

$132.04 \ MN/m^2$

b) $\text{Strain} = \frac{\Delta L}{L} = \frac{0.385}{1100} = 3.5 \times 10^{-4}$

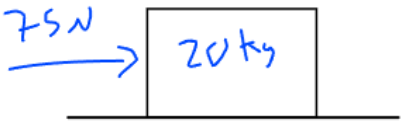
c) $\text{Elas} = \frac{\text{Stress}}{\text{Strain}} = \frac{132{,}039{,}656.5}{3.5 \times 10^{-4}} = 3.7726 \times 10^{11} \ N/m^2$

11. A crate with a mass of 20 kg, rests on a horizontal surface. The box has a force of 75 N applied to it parallel to the horizontal surface.

Determine EACH of the following:

(a) the acceleration of the body with no friction; (3)

(b) the acceleration of the body when a friction coefficient of 0.35 exists between the box and the surface. (5)



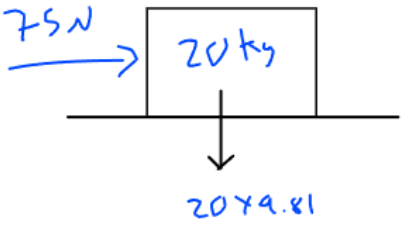
a) $F = ma$

$75 = 20a$

$\frac{75}{20} = a$

$3.75\ m/s^2 = a$

b)



$F_{fric} = \mu N$

$= 0.35 \times 20 \times 9.81$

$= 68.67\ N$

Net Horizontal Force

$75 - 68.67 = 6.33\ N$

Accel

$F = ma$

$6.33 = 20a$

$\frac{6.33}{20} = a = \boxed{0.3165\ m/s^2}$

12. FIG Q12 shows a loaded uniform beam with a mass 800 kg.

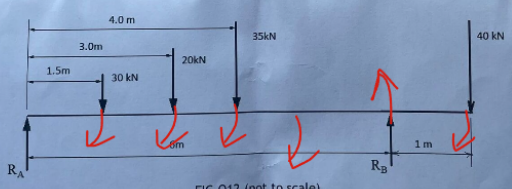
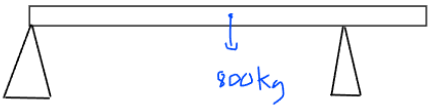


FIG Q12 (not to scale)

Determine EACH of the following:

(a) the reaction force, RA; (6)

(b) the reaction force, RB. (2)



taking moments about A

Name	Mass(t)	Force (kN)	Distance (m)	Moment	Direction
W_1		30	1.5	45	C
W_2		20	3	60	C
W_3		35	4	140	C
W_4		40	7	280	C
Beam	0.8	7.848	3.5	27.468	C
R_B		x	6	$6x$	A

sum of anticlockwise moments = sum of clockwise moments

$6x = 45 + 60 + 140 + 280 + 27.468$

$x = \frac{552.468}{6}$

$x = 92.078\ kN = R_B$

Sum of downwards forces = sum of upwards forces

$30 + 20 + 35 + 40 + 7.848 = R_A + R_B$

$132.848 = R_A + 92.078$

$40.77\ kN = R_A$