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, 12 MARCH 2021

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.

Attempt ALL questions

Marks for each question are shown in brackets.

All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Section A

1. Simplify EACH of the following:

   (a) $\dfrac{6\frac{3}{4}}{3\frac{5}{6}}$ (4)

   (b) $\dfrac{3X}{2} \times \left(\dfrac{2X}{3} + \dfrac{4X}{5}\right)$ (4)

2. 0.05 m^3 of iron is recast into two solid shapes, a sphere and a right cone.

   Determine EACH of the following:

   (a) the diameter of the sphere if the volume of the sphere is to be 40% of the total volume of the original mass of iron; (4)

   (b) the base diameter of the cone if its height is to be 0.45 m. (4)

3. For the shape shown in Fig Q3, determine the lengths OA and AB. (8)

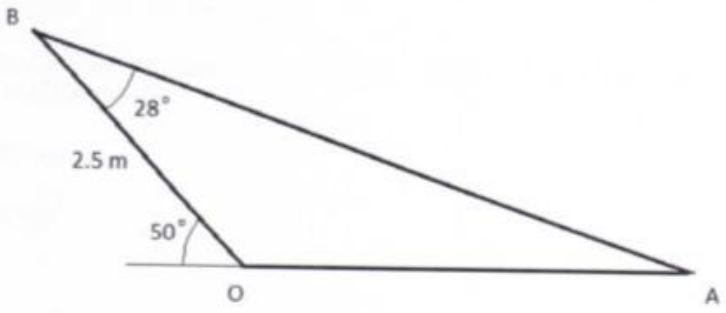


Fig Q3 (not to scale)

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

x	-2	-1	0	1	2	3
y	-4.4	-1.6	1.2	4	6.8	9.6

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

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

5. Show that the shaded area in Fig Q5 below is given by: (8)

$$Area = (4 - \pi)r^2$$

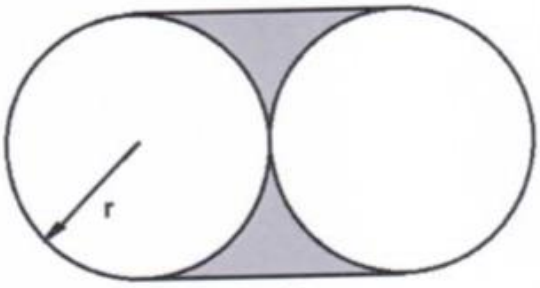


Fig Q5

6. Determine the value of 'n' in the following expression:

$$P_1V_1^n = P_2V_2^n$$

when $P_2 = 2 \times P_1$ and $V_1 = 3 \times V_2$ (8)

Section B

7. The rod in a hydraulic ram is 1.1 m long and has a diameter of 45 mm. When subjected to an axial pull of 210 kN the rod extends by 0.385 mm.

   Determine EACH of the following:

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

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

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

8. A uniform beam is loaded as shown in Fig Q8. The beam has a mass of 400 kg.

   Determine the reaction forces at the supports A and B. (10)

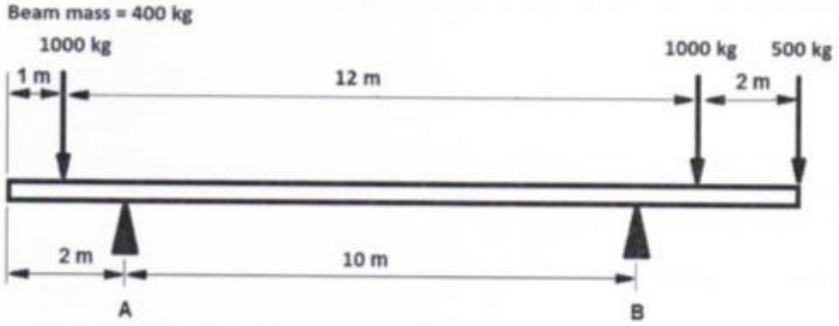


Fig Q8

9. (a) Sketch a load extension diagram for a typical low carbon steel undergoing a tensile test. On the same diagram sketch the load extension response for a brittle material such as cast iron. (4)

   (b) With reference to the diagram sketched in Q9(a) explain what is meant by EACH of the following:

   (i) Brittleness; (2)

   (ii) Ductility. (2)

10. (a) Explain the difference between *speed* and *velocity*. (2)

(b) A lift accelerates from rest at 1.2 m/s^2 until it reaches 3 m/s. It continues to move at 3 m/s for 6 seconds before decelerating at 1 m/s^2 until it stops.

(i) Draw a velocity time graph showing the motions. (3)

(ii) Determine the average velocity for this lift movement. (3)

11. (a) Explain what is meant by *torque*. (2)

(b) A winch has a drum diameter of 800 mm and is required to raise a load of 400 kg through a height of 22 m in 12 seconds at a uniform speed.

Determine EACH of the following:

(i) the torque required; (2)

(ii) the rotation required of the drum in radians; (2)

(iii) the winch power. (2)

12. Ignoring any effects of friction, the velocity of a 50 kg mass is uniformly increased from 1.5 m/s to 2.0 m/s in 5 seconds.

(a) Calculate the accelerating force required. (2)

(b) The mass is now uniformly retarded at 0.4 m/s^2 from 2.0 m/s until the mass just comes to rest.

Calculate, for the retardation period, EACH of the following:

(i) the time taken to come to rest; (3)

(ii) the distance travelled. (3)

Section A

1. Simplify EACH of the following:

(a) $\dfrac{6\frac{3}{4}}{3\frac{5}{6}}$ (4)

(b) $\frac{3x}{2} \times \left(\frac{2x}{3} + \frac{4x}{5}\right)$ (4)

a) $\dfrac{6\frac{3}{4}}{3\frac{5}{6}} = \dfrac{\frac{27}{4}}{\frac{23}{6}} = \frac{27}{4} \times \frac{6}{23} = \frac{162}{92} = \frac{81}{46} = 1\frac{35}{46}$

(b) $\frac{3x}{2} \times \left(\frac{2x}{3} + \frac{4x}{5}\right)$ (4)

$\frac{3x}{2}\left(\frac{5 \times 2x}{5 \times 3} + \frac{4x \times 3}{5 \times 3}\right)$

$\frac{10x}{15} + \frac{12x}{15}$

$\frac{3x}{2}\left(\frac{22x}{15}\right) = \frac{66x^2}{30} = \frac{11x^2}{5} = 2\frac{1}{5}x^2$

2. $0.05\ m^3$ of iron is recast into two solid shapes, a sphere and a right cone.

Determine EACH of the following:

(a) the diameter of the sphere if the volume of the sphere is to be 40% of the total volume of the original mass of iron; (4)

(b) the base diameter of the cone if its height is to be 0.45 m. (4)

$0.05\ m^3$

Sphere

$\frac{4}{3}\pi r^3 = 0.02$

$4.18879\ r^3 = 0.02$

$r^3 = \frac{0.02}{4.18879}$

$r = 0.1683\ m$

$d = 0.3367\ m$

Cone → $\frac{bh}{3}$

$0.03\ m^3$ cone

$\frac{1}{3}\pi r^2 h = 0.03$

$\frac{1}{3}\pi r^2 (0.45) = 0.03$

$r^2 = \frac{0.03}{(0.471238898)}$

$r^2 = 0.063661977\ 26$

$r = 0.25$

$d = 0.5m$

$1 \div 3\pi \times 0.45$ ×

$(1 \div 3)\pi \times 0.45$ ✓

3. For the shape shown in Fig Q3, determine the lengths OA and AB. (8)

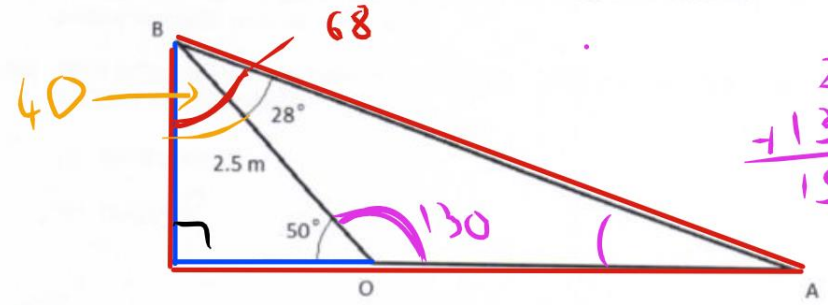


Fig Q3 (not to scale)

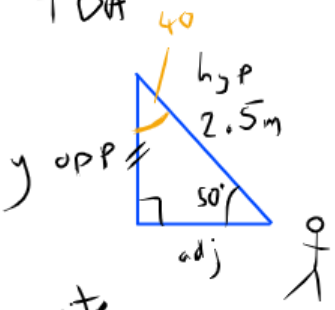
28 + 130 = 158

180 − 158 = 22

180 − 50 = 130

[OVER

SOH
CAH
TOA



opposite

$\sin\theta = \frac{opp}{hyp}$

$\sin 50 = \frac{y}{2.5}$

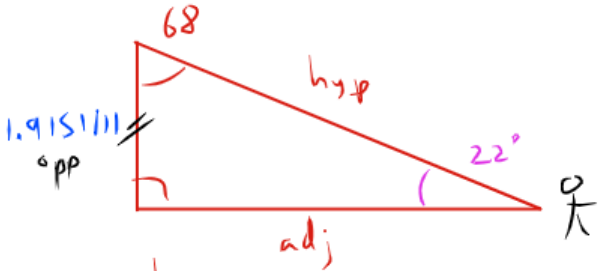
$2.5 \sin 50 = 1.9151111$

Adj

$\cos\theta = \frac{adj}{hyp}$

$2.5 \cos 50 = adj$

$= 1.606969$



hyp

$\sin\theta = \frac{opp}{hyp}$

$\sin 22 = \frac{1.9151111}{x}$

$x \sin 22 = 1.9151111$

$x = \frac{1.9151111}{\sin 22}$

$x = 5.1123$

$AB = 5.1123m$

TOA

adj

$$\tan\theta = \frac{opp}{adj}$$

$$\tan 22 = \frac{1.915111}{x}$$

$$x = \frac{1.915111}{\tan 22}$$

$$x = 4.74\,m$$

$$OA = 4.74 - 1.606969$$

$$3.133097\ m$$

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

x	-2	-1	0	1	2	3
y	-4.4	-1.6	1.2	4	6.8	9.6

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

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

5. Show that the shaded area in Fig Q5 below is given by: (8)

$Area = (4 - \pi)r^2$

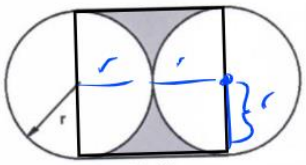
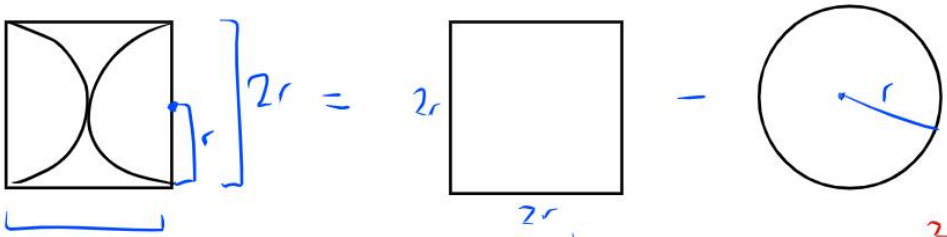


Fig Q5



2r

2r

Area = b × h

2r × 2r

$4r^2$ − πr^2

Area = πr^2

total = $4r^2 - \pi r^2$

$(4 - \pi)r^2$

Section B

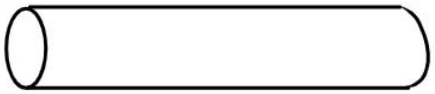
7. The rod in a hydraulic ram is 1.1 m long and has a diameter of 45 mm. When subjected to an axial pull of 210 kN the rod extends by 0.385 mm.

Determine EACH of the following:

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

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

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



45 mm = 0.045 m

1.1 m

$R = 0.0225$ m

$$\text{Area} = \pi r^2 = \pi (0.0225)^2 = 1.59043 \times 10^{-3} \text{ m}^2$$

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{210,000}{1.59043 \times 10^{-3}} = 132039656.5$$

$132,039,656.5 \text{ N/m}^2$

$$\text{Strain} = \frac{\text{Extension}}{\text{Original}} = \frac{0.385}{1100} = 3.5 \times 10^{-4}$$

$$\text{Elas} = \frac{\text{Stress}}{\text{Strain}} = 3.77256 \times 10^{11}$$

8. A uniform beam is loaded as shown in Fig Q8. The beam has a mass of 400 kg.

Determine the reaction forces at the supports A and B. (10)

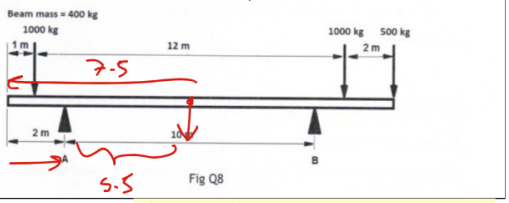
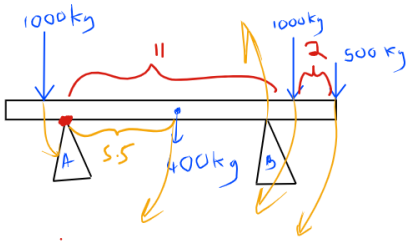


Fig Q8

Taking moments about A



$\frac{15}{2} = 7.5$

Name	Mass kg	Force N	Distance m	Moments Nm	Direction A/C
W_1	1000	9810	1	9810	A
W_2	1000	9810	11	107910	C
W_3	500	4905	13	63765	C
Beam	400	3924	5.5	21582	C
R_B		x	10	$10x$	A

sum of the anticlockwise moments = the sum of the clockwise moments

$$\left.\begin{matrix}107910\\63765\\21582\end{matrix}\right\} = 9810 + 10x$$

$$193257 = 9810 + 10x$$

$$18344.7 = x = R_B$$

$$\boxed{18344.7\ N = R_B}$$

sum of total downwards forces = sum of total upwards forces

$$\left.\begin{matrix}9810\\9810\\4905\\3924\end{matrix}\right\} = R_A + 18344.7$$

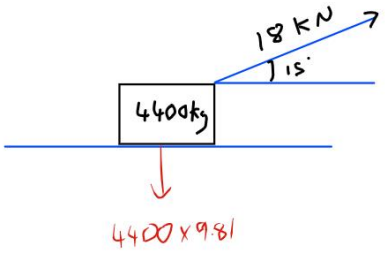
$$28449 = R_A + 18344.7$$

$$\boxed{R_A = 10104.3\ \text{N}}$$

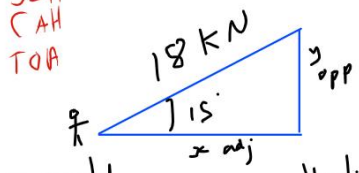
9. (a) State the difference between *static* and *dynamic* friction. (2)

(b) A stone block has a mass of 4400 kg and is pulled across a horizontal surface with a constant acceleration of 0.25 m/s² by a force of 18 kN applied at an angle of 15° above the horizontal.

Determine the coefficient of friction. (6)



SOH
CAH
TOA



$18{,}000 \cos 15 = x$

$x = 17726.5\ \text{N}$

$18000 \sin 15 = y$

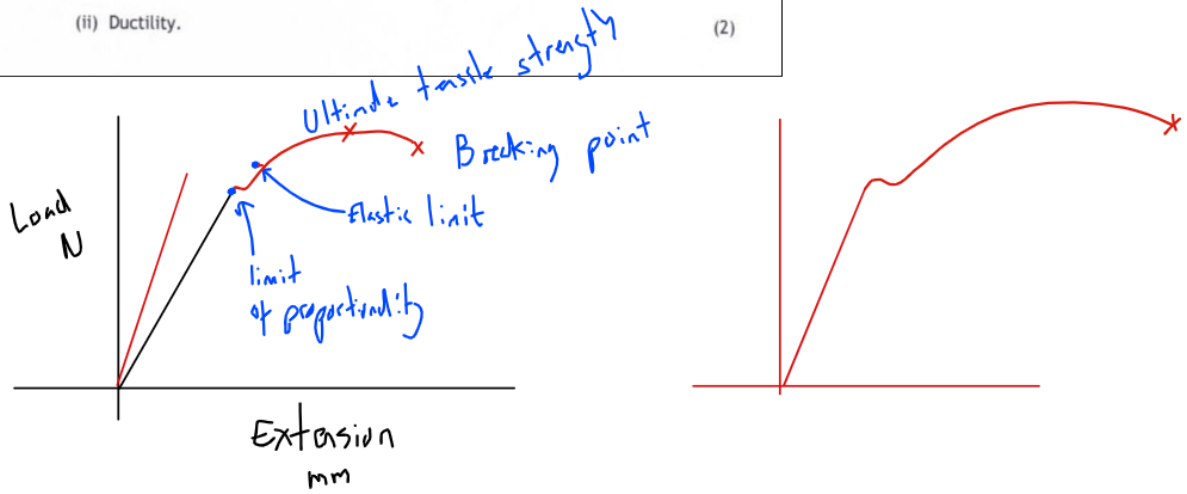
$y = 3125.667\ \text{N}$

9. (a) Sketch a load extension diagram for a typical low carbon steel undergoing a tensile test. On the same diagram sketch the load extension response for a brittle material such as cast iron. (4)

(b) With reference to the diagram sketched in Q9(a) explain what is meant by EACH of the following:

(i) Brittleness; (2)

(ii) Ductility. (2)



i) a material such as the cast iron has high brittleness. It can be seen from the graph that the material does not go through the plastic deformation stage, and will break without warning. It will snap.

ii) ductility is opposite of brittleness, we can see that the low carbon steel goes through a plastic deformation stage, this is due to the matertial having a higher m,easure of ductility than the cast iron.

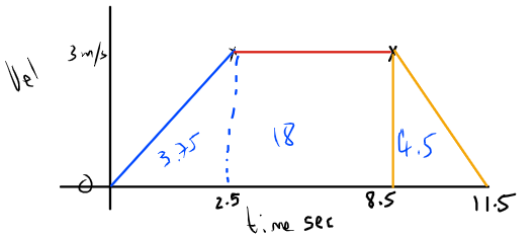
10. (a) Explain the difference between *speed* and *velocity*. (2)

(b) A lift accelerates from rest at 1.2 m/s² until it reaches 3 m/s. It continues to move at 3 m/s for 6 seconds before decelerating at 1 m/s² until it stops.

(i) Draw a velocity time graph showing the motions. (3)

(ii) Determine the average velocity for this lift movement. (3)

a)



Accel period

$s =$
$u = 0$
$v = 3$
$a = 1.2$
$t =$

$v = u + at$

$3 = 0 + 1.2t$

$\frac{3}{1.2} = t = 2.5$

Decel period

s
$u = 3$
$v = 0$
$a = -1$
$t = 3$

$v = u + at$

$0 = 3 - t$

ii) average vel $= \frac{\text{total distance}}{\text{total time}} = \frac{\quad}{11.5} = 2.2826$

11. (a) Explain what is meant by *torque*. (2)

(b) A winch has a drum diameter of 800 mm and is required to raise a load of 400 kg through a height of 22 m in 12 seconds at a uniform speed.

Determine EACH of the following:

(i) the torque required; (2)

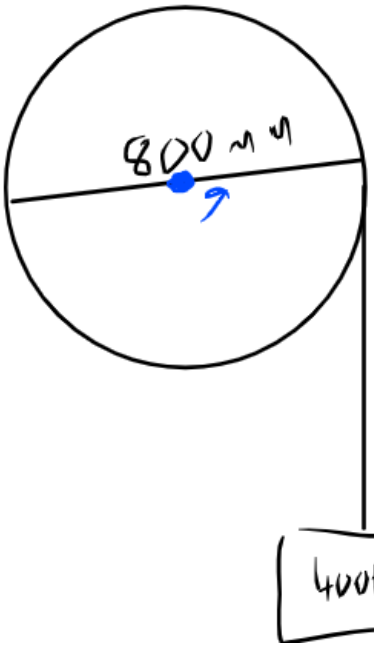
(ii) the rotation required of the drum in radians; (2)

(iii) the winch power. (2)

Formula

$$\tau = rF\sin\theta$$

τ = torque
r = radius
F = force
θ = angle between F and the lever arm



$mg \downarrow = 400 \times 9.81 = 3924\ N$

bi) $R = 400\ mm = 0.4\ m$

Torque = moments = Force x distance = $3924 \times 0.4 = 1569.6\ Nm$

bii) $\pi d = circ$

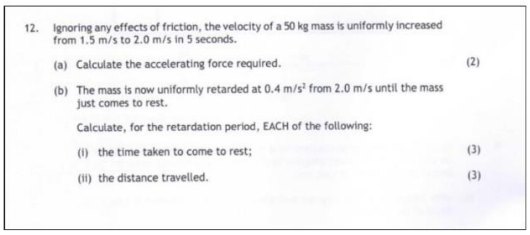
$\pi\ 0.8 = 2.513274\ m$ this is how far the load will rise for one rotation

height to be lifted / drum circum: $\frac{22}{2.51} = 8.753521\ 87\ Rev$ this is how many revolutions we need to raise the load 22 meters

$\times 2\pi$

55 Rads mult by 2pi to get into rads

biii $P = \frac{F \times d}{t} = \frac{3924 \times 22}{12} = 7194 = 7.194kw$



12. Ignoring any effects of friction, the velocity of a 50 kg mass is uniformly increased from 1.5 m/s to 2.0 m/s in 5 seconds.

(a) Calculate the accelerating force required. (2)

(b) The mass is now uniformly retarded at 0.4 m/s² from 2.0 m/s until the mass just comes to rest.

Calculate, for the retardation period, EACH of the following:

(i) the time taken to come to rest; (3)

(ii) the distance travelled. (3)

a)

50kg

s
u = 1.5
v = 2.0
a
t = 5

$v = u + at$

$2 = 1.5 + 5a$

$0.5 = 5a$

$\frac{0.5}{5} = a = 0.1\ m/s^2$

$F = ma$

$F = 0.1 \times 50 = 5\ N$

b) $s = Sm$

$u = 2.0$

$v = 0$

$a = -0.4$

$t = 5\ sec$

$v = u + at$

$\frac{-2}{-0.4} = 5\ sec$

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

$s = \left(\frac{2}{2}\right) 5$