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, 01 OCTOBER 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.

Maritime & Coastguard Agency

SQA

GENERAL ENGINEERING SCIENCE I

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. (a) The ratio of carbon : hydrogen : sulphur in a fuel is given as 26:4:1. Express these proportions as percentages. (4)

   (b) Simplify the following giving the answer as the simplest mixed fraction.

   $$\left(\frac{2}{3} + 3\frac{4}{5}\right) \times 2\frac{1}{2}$$ (4)

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

   (a) $3(x-2) + 2(2x+2) = 0$ (4)

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

3. (a) For the data in Table Q3 plot a graph. (4)

   (b) Derive the equation describing the data. (4)

   (c) Determine the value of y when x is 2.5. (2)

x	-1	0	1	2	3	4
y	-1	2	5	8	11	14

Table Q3

4. A triangle sail has a right angle between mast and boom. The length of the sail is 10 m up the mast and the length of the diagonal is 11 m.

Calculate EACH of the following:

(a) the length of the sail along the boom using Pythagoras Theorem; (4)

(b) the area of the sail in m^2. (4)

5. Find the area of the triangle in FIG Q5: (8)

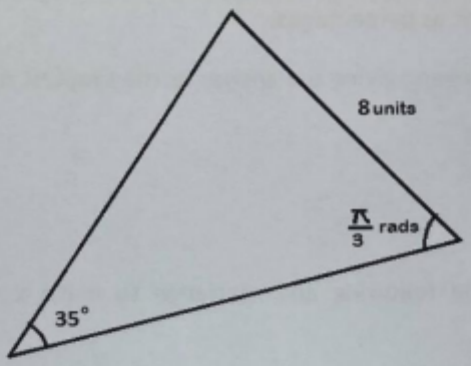


FIG Q5

6. A bronze ingot has a volume of 0.4 m^3. The ingot 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 55% of the total volume of the cubic ingot; (4)

(b) the perpendicular height of the cone if the base diameter is to be 0.8 m. (4)

Section B

7. A power winch raises a mass of 580 kg through a distance of 14.6 m in 32 seconds. The power input to the system is measured at 3.9 kW.

Calculate the system efficiency. (8)

8. A uniform beam 3.5 m long has a mass of 85 kg and is pivoted on a single point 1.2 m from the left end point. A point load of 834 N acts at the left end of the beam. A mass is to be added acting at a point 3 m from the left end point to balance the beam in a level condition.

(a) Sketch the beam showing relevant forces. (3)

(b) Determine the mass which needs to be added to give a balanced equilibrium condition about the fulcrum. (5)

9. Fig Q9 shows a worm and wheel with an overall efficiency of 78%.

The worm has a single start thread and carries an effort pulley with a diameter, d = 30 mm

The wheel has 120 teeth and a load pulley of diameter, D = 300 mm.

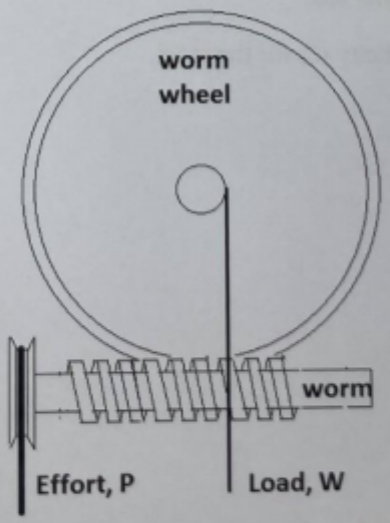


Fig Q9 (not to scale)

Determine the effort required to lift a load of 800 kg (8)

[OVER

10. A stationary body with a mass of 25 kg has a force of 140 N applied to it which causes an acceleration in a horizontal plane. The coefficient of friction between the body and the plane is 0.3.

Calculate EACH of the following:

(a) the acceleration of the body; (4)

(b) the distance the body will travel from rest in 5 seconds. (4)

11. (a) State TWO fundamental units. (2)

(b) Give an example of a derived unit. (2)

(c) A vertical cylinder with an internal cross sectional area of 4250 mm^2 contains fluid with a depth of 6 cm. The fluid has a mass of 300 grammes. Determine the density of the fluid in kg/m^3. (4)

12. A piston rod 1.2 m long has a diameter of 87 mm and when subjected to an axial load of 850 kN is compressed by 0.65 mm.

Determine EACH of the following:

(a) the direct stress in the rod; (4)

(b) the direct strain in the rod; (4)

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

Section A

1. (a) The ratio of carbon : hydrogen : sulphur in a fuel is given as 26:4:1. Express these proportions as percentages. (4)

(b) Simplify the following giving the answer as the simplest mixed fraction.

$\left(\frac{2}{3} + 3\frac{4}{5}\right) \times 2\frac{1}{2}$ (4)

a) Carbon $26/31 \times 100 = 83.871\%$.

Hydrogen $4/31 \times 100 = 12.903\%$.

Sulphur $1/31 \times 100 = 3.2258\%$.

total 31

b) $\left(\frac{2}{3} + 3\frac{4}{5}\right) \times 2\frac{1}{2}$

$\left(\frac{2\times5}{3\times5} + \frac{19\times3}{5\times3}\right) \times \frac{5}{2}$

$\left(\frac{10}{15} + \frac{57}{15}\right) \times \frac{5}{2}$

$\frac{67}{15} \times \frac{5}{2}$

$\frac{335}{30} = 11\frac{5}{30}$

$11\frac{1}{6}$

-2. Simplify EACH of the following and rearrange to make x the subject of the expression:

(a) $3(x-2)+2(2x+2)=0$ (4)

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

a) $3x-6+4x+4=0$

$7x-2=0$

$x=\frac{2}{7}$

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

$2(x-2)=0$

$x-2=0$

$x=2$

– 3. (a) For the data in Table Q3 plot a graph. (4)

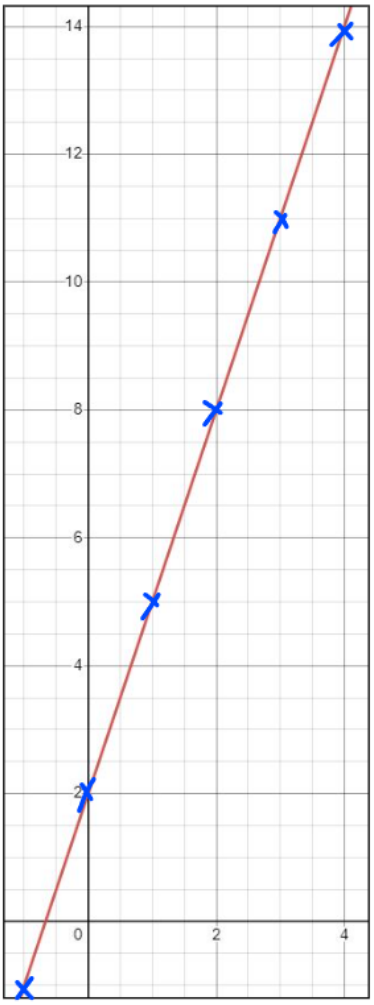
(b) Derive the equation describing the data. (4)

(c) Determine the value of y when x is 2.5. (2)

x	-1	0	1	2	3	4
y	-1	2	5	8	11	14

Table Q3

a)



b) $y = mx + c$

$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{5-2}{1-0} = \frac{3}{1} = 3$

$y = 3x + 2$

c) $y = 3(2.5) + 2$

$y = 9.5$

4. A triangle sail has a right angle between mast and boom. The length of the sail is 10 m up the mast and the length of the diagonal is 11 m.

Calculate EACH of the following:

(a) the length of the sail along the boom using Pythagoras Theorem; (4)

(b) the area of the sail in m^2. (4)

5. Find the area of the triangle in FIG Q5: (8)

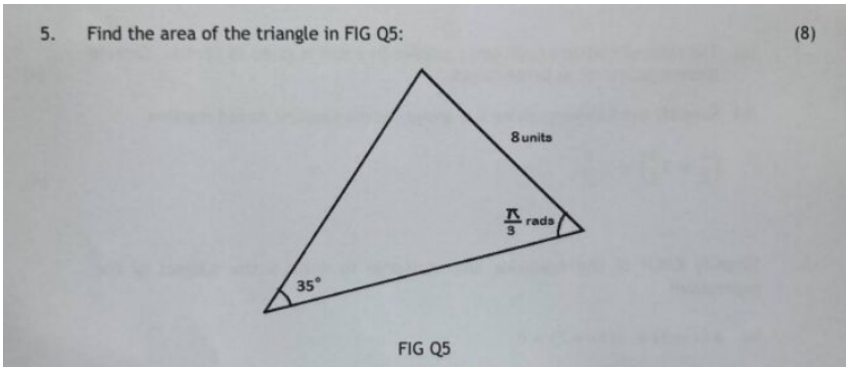
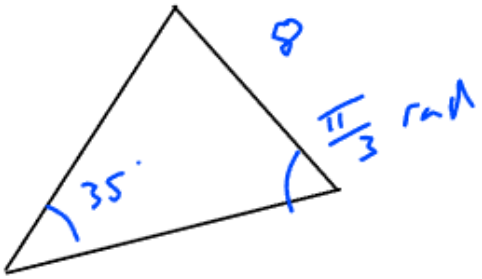
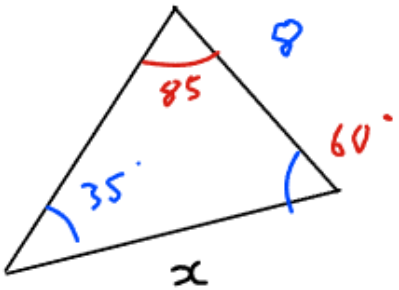


FIG Q5



$$\frac{\frac{\pi}{3}}{2\pi} \times 360 = 60°$$

$$180 - 35 - 60 = 85$$



$$\frac{a}{\sin A} = \frac{b}{\sin B}$$

$$\frac{8}{\sin 35} = \frac{x}{\sin 85}$$

$$\frac{8}{\sin 35} \times \sin 85 = x$$

$$13.89449963 = x$$

Sin Rule for Area

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

$$\frac{1}{2} \times 8 \times 13.89449963 \sin 60$$

$$\text{Area} = 48.132 \text{ units}^2$$

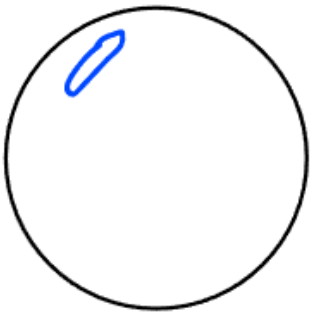
6. A bronze ingot has a volume of 0.4 m^3. The ingot is recast into two solid shapes, a sphere and a right cone.

Determine EACH of the following:

(a) the diameter of the sphere if the volume of the sphere is to be 55% of the total volume of the cubic ingot; (4)

(b) the perpendicular height of the cone if the base diameter is to be 0.8 m. (4)

a) $0.4 \times 0.55 = 0.22$



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

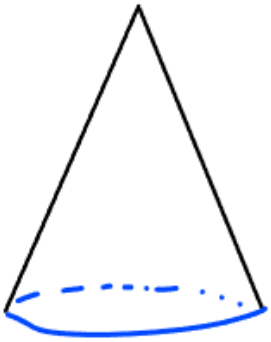
$$0.22 = \frac{4}{3}\pi r^3$$

$$\sqrt[3]{\frac{0.22 \times 3}{4\pi}} = r$$

$$0.37449385 = r$$

$$d = 0.74899 \text{ m}$$

b)



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

$$0.18 = \frac{\pi (0.4)^2 h}{3}$$

$$\frac{0.18 \times 3}{\pi (0.4)^2} = h$$

$$1.0743 \text{ m}$$

Section B

7. A power winch raises a mass of 580 kg through a distance of 14.6 m in 32 seconds. The power input to the system is measured at 3.9 kW.

Calculate the system efficiency. (8)

7) $P = \frac{mgh}{t} = \frac{580 \times 9.81 \times 14.6}{32}$

$= 2595.97$ Watts

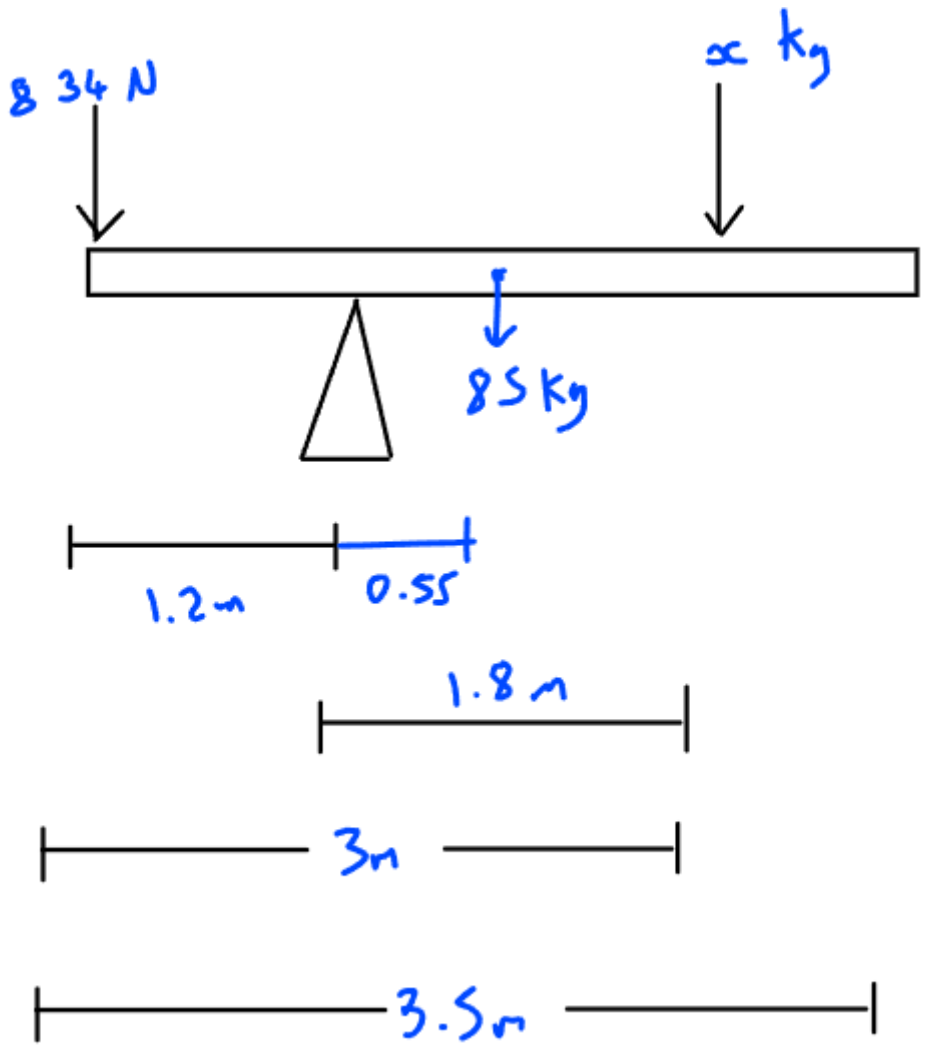
$Eff = \frac{2595.97}{3900} \times 100$

66.563 %.

8. A uniform beam 3.5 m long has a mass of 85 kg and is pivoted on a single point 1.2 m from the left end point. A point load of 834 N acts at the left end of the beam. A mass is to be added acting at a point 3 m from the left end point to balance the beam in a level condition.

(a) Sketch the beam showing relevant forces. (3)

(b) Determine the mass which needs to be added to give a balanced equilibrium condition about the fulcrum. (5)



$$\frac{\text{total beam}}{2} = \frac{3.5}{2} = 1.75$$

$$1.75 - 1.2 = 0.55$$

taking moments about the fulcrum

Name	Mass kg	Force N	Distance m	Moment Nm	Dir C/A
W_1		834	1.2	1000.8	A
Beam	85	833.85	0.55	458.6175	C
W_2	x	9.81x	1.8	17.658x	C

sum of anticlockwise moments = sum of clockwise moments

$$1000.8 = 458.6175 + 17.658x$$

$$\frac{542.1825}{17.658} = x$$

$$30.705 \text{ kg} = x$$

9. Fig Q9 shows a worm and wheel with an overall efficiency of 78%.

The worm has a single start thread and carries an effort pulley with a diameter, d = 30 mm

The wheel has 120 teeth and a load pulley of diameter, D = 300 mm.

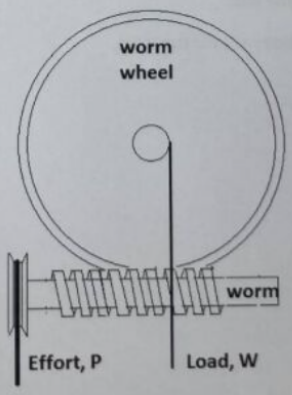


Fig Q9 (not to scale)

Determine the effort required to lift a load of 800 kg (8)

[OVER

$$\epsilon = \frac{F}{M}$$

$$\text{Force Ratio} = \frac{\text{lifted}}{\text{Applied}} = \frac{800 \times 9.81}{x}$$

$$\text{Movement} = \frac{\text{Distance 1 trawl}}{\text{Distance load moves}} \quad \frac{\pi d}{\pi D} \times \frac{\text{teeth}}{\text{teeth}}$$

$$\frac{\pi 30}{\pi 300} \times \frac{120}{1}$$

$$= 12$$

$$\epsilon ff = \frac{F}{M}$$

$$0.78 = \frac{\frac{800 \times 9.81}{x}}{12}$$

$$0.78 \times 12 = \frac{800 \times 9.81}{x}$$

$$x = \frac{800 \times 9.81}{0.78 \times 12} = \boxed{838.46\ N}$$

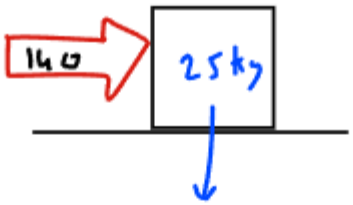
10. A stationary body with a mass of 25 kg has a force of 140 N applied to it which causes an acceleration in a horizontal plane. The coefficient of friction between the body and the plane is 0.3.

Calculate EACH of the following:

(a) the acceleration of the body; (4)

(b) the distance the body will travel from rest in 5 seconds. (4)

a)



$25 \times 9.81 = 245.25\ N$

$Fric = \mu N$

0.3×245.25

$= 73.575\ N$

Net horizontal

$Push - Fric = Net\ horizontal$

$140 - 73.575 = 66.425\ N$

Accel

$F = ma$

$66.425 = 25a$

$\frac{66.425}{25} = a$

$2.657\ m/s^2 = a$

b)

s

$u = 0$

v

$a = 2.657$

$t = 5$

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

$$s = 0 + \frac{1}{2} \times 2.657 \times 5^2$$

$$s = 33.2125 \text{ m}$$

11. (a) State TWO fundamental units. (2)

(b) Give an example of a derived unit. (2)

(c) A vertical cylinder with an internal cross sectional area of 4250 mm^2 contains fluid with a depth of 6 cm. The fluid has a mass of 300 grammes. Determine the density of the fluid in kg/m^3. (4)

a) metre

second

Newton

b) $mph = \frac{miles}{hour}$

c) ] 6cm

$4250\ mm^2$

$1\ m^2 = 1000 \times 1000$

$1 \times 10^6\ mm^2$

$4250 \div 10^6 = 4250 \times 10^{-6}$

$Vol = b \times h$

$4250 \times 10^{-6} \times 0.06 = 2.55 \times 10^{-4}\ m^3$

$density = \frac{mass}{vol} = \frac{0.3}{2.55 \times 10^{-4}}$

$= 1176.47\ kg/m^3$

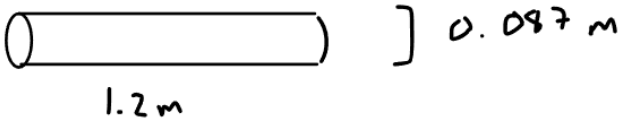
12. A piston rod 1.2 m long has a diameter of 87 mm and when subjected to an axial load of 850 kN is compressed by 0.65 mm.

Determine EACH of the following:

(a) the direct stress in the rod; (4)

(b) the direct strain in the rod; (4)

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



a) $\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{850,000}{\pi\left(\frac{0.087}{2}\right)^2} = 142,985,019.6 \ N/m^2$

b) $\text{Strain} = \frac{\Delta L}{L} = \frac{0.65}{1200} = 5.41667 \times 10^{-4}$

c) $E\text{las} = \frac{\text{Stress}}{\text{Strain}} \quad \frac{142,985,019.6}{5.41667 \times 10^{-4}} = 2.6397 \times 10^{11} \ N/m^2$