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, 16 JUNE 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) Engine A has a cubic capacity of 1.6 litres, Engine B has cubic capacity of 2.2 litres. Express as a percentage how much larger Engine B is compared to Engine A. (3)

   (b) Simplify the following giving your answer in a mixed number format.

$$x = \left(9\frac{5}{8} \div 1\frac{3}{4}\right) - 2\frac{2}{3}$$ (5)

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

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

   (b) Solve the following expression for x:

$$3\,(x-2) + 2(2x+2) = 0$$ (4)

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3. Consider the graph shown in FIG Q3.

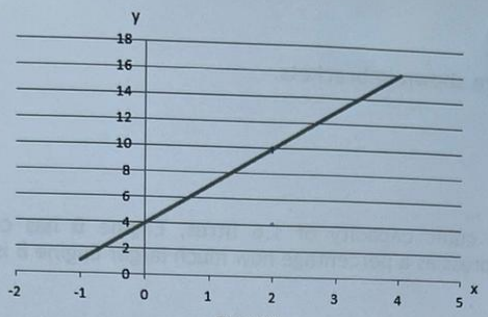


FIG Q3

(a) State the general equation that describes graphs of the type shown in FIG Q3, define the terms used in the equation. (2)

(b) Determine the variables defined in Q3(a) as they apply to FIG Q3. (3)

(c) State the specific equation that describes the graph shown in FIG Q3. (3)

(d) Determine the 'y' value when x = 2.5. (2)

4. The triangle shown in FIG Q4a is a copy of the 4 triangles joined as shown in FIG Q4b arranged to enclose the square ABCD.

Show that the area of ABCD is equal to x^2+y^2 (8)

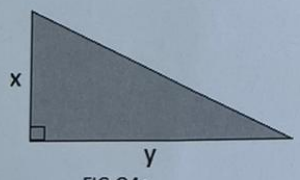


FIG Q4a

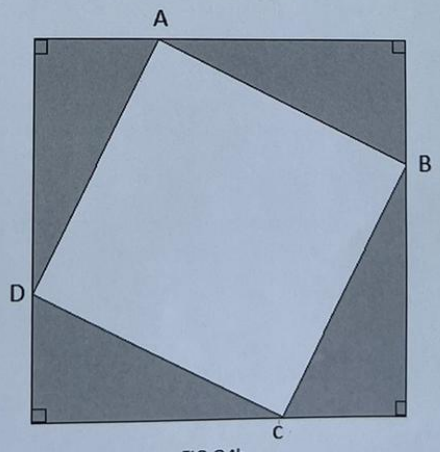


FIG Q4b

5. Describe EACH of the following with the aid of a diagram:

   (a) an equilateral triangle; (2)

   (b) a scalene triangle; (2)

   (c) an isosceles triangle; (2)

   (d) a tangent to a circle. (2)

6. A sphere has a diameter of 0.8 m which is compared to a solid cone with a height of 1.2 m and a base diameter of 1 m.

   Show which object has the greater total surface area. (8)

Section B

7. 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. There is a point load with a mass of 50 kg acting 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)

8. A vehicle wheel, with a diameter of 360 mm, has an angular velocity of 300 rev/min and is accelerated uniformly to 600 rev/min over a 15 second period.

   Determine EACH of the following:

   (a) the initial and final angular velocities of the wheel in rads/s; (2)

   (b) the angular acceleration of the wheel; (3)

   (c) the linear acceleration of a point on the wheel rim. (3)

9. A mass of 1250 kg is raised by a winch through a distance of 9.5 m in 32 seconds. The motor power input to the system is 4.2 kW.

   Determine EACH of the following:

   (a) the work done raising the load; (3)

   (b) the power required to raise the load; (3)

   (c) the system efficiency. (2)

10. (a) Sketch a complete load/extension diagram for a typical low carbon steel specimen. (2)

    (b) Indicate EACH of the following on your diagram:

    (i) limit of proportionality; (2)

    (ii) yield point; (2)

    (iii) maximum load. (2)

11. A screw jack is used to raise a load of 600 kg. The jack has a single start square thread with a 6mm pitch. The effort applied acts on an effective radius of 30 cm.

If the applied effort is 180 Newtons, determine EACH of the following:

(a) the force ratio; (3)

(b) the movement ratio; (3)

(c) the efficiency of the screw jack. (2)

12. A stationary body with a mass of 50 kg has a force applied to it which causes acceleration on a horizontal plane. The force of 120 N is applied at an angle of 10° below the horizontal pulling the block. There is a coefficient of friction is 0.2 between the block and the surface.

Determine EACH of the following:

(a) the effective normal force on the surface caused by the block; (4)

(b) the frictional force; (3)

(c) the acceleration of the block. (3)

1. (a) Engine A has a cubic capacity of 1.6 litres, Engine B has cubic capacity of 2.2 litres. Express as a percentage how much larger Engine B is compared to Engine A. (3)

Section A

1a Engine A = 1.6 Litres

Engine B = 2.2 Litres.

Difference $\frac{2.2 - 1.6}{1.6} \times 100 = 37.5\%$.

(b) Simplify the following giving your answer in a mixed number format.

$$x = \left(9\frac{5}{8} \div 1\frac{3}{4}\right) - 2\frac{2}{3} \qquad (5)$$

$$\left(9\frac{5}{8} \div 1\frac{3}{4}\right) - 2\frac{2}{3}$$

$$\left(\frac{77}{8} \div \frac{7}{4}\right) - \frac{8}{3}$$

$$\left(\frac{77}{8} \times \frac{4}{7}\right) - \frac{8}{3}$$

$$\frac{308}{56} - \frac{8}{3}$$

$$3 \times \frac{11}{2} - \frac{8}{3} \times 2$$

$$3 \times 2$$

$$\frac{33}{6} - \frac{16}{6} = \frac{17}{6} = 2\frac{5}{6}$$

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

$$12\ \frac{ab^3}{6bc} + \frac{2ab^2}{c^2}$$

(4)

$$\frac{12\ ab^3}{6\ bc} + \frac{2ab^2}{c^2}$$

$$\frac{12\ ab^3 c^2}{6\ bc\ c^2} + \frac{2ab^2\ 6bc}{c^2\ 6bc}$$

$$\frac{12\ ab^3c^2}{6bc^3} + \frac{12\ ab^3c}{6bc^3}$$

$$\frac{2\cancel{12}\ ab^{\cancel{3}\ 2}c^2 + 2\cancel{12}\ ab^{\cancel{3}\ 2}c}{\cancel{6}\cancel{b}c^3}$$

$$\frac{2ab^2c^{2\ 1} + 2ab^2\cancel{c}}{\cancel{c^3}^{\ 2}}$$

$$\frac{2ab^2c + 2ab^2}{c^2}$$

(b) Solve the following expression for x:

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

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

$7x-2=0$

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

3. Consider the graph shown in FIG Q3.

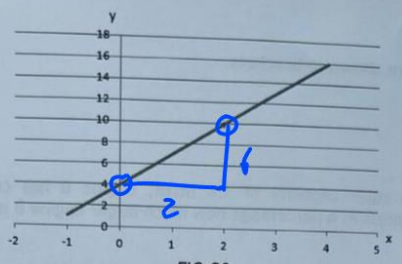


FIG Q3

(a) State the general equation that describes graphs of the type shown in FIG Q3, define the terms used in the equation. (2)

(b) Determine the variables defined in Q3(a) as they apply to FIG Q3. (3)

(c) State the specific equation that describes the graph shown in FIG Q3. (3)

(d) Determine the 'y' value when x = 2.5. (2)

a) $y = mx + c$

m = gradient or slope

c = y intercept

b) $m = \frac{6}{2} = 3$ $c = 4$

c) $y = 3x + 4$

d) $y = 3(2.5) + 4$

$y = 11.5$

4. The triangle shown in FIG Q4a is a copy of the 4 triangles joined as shown in FIG Q4b arranged to enclose the square ABCD.

Show that the area of ABCD is equal to x^2+y^2 (8)

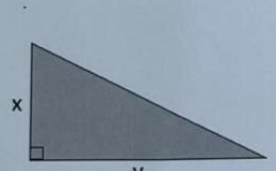


FIG Q4a

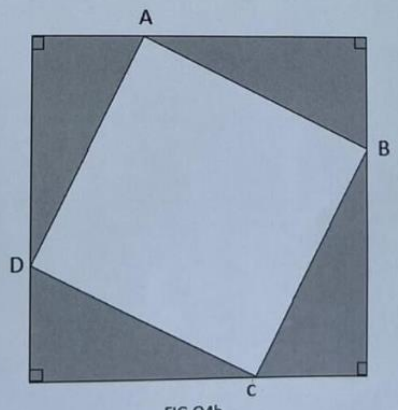
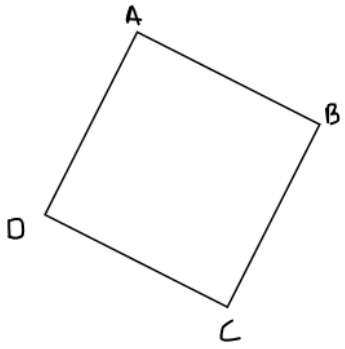


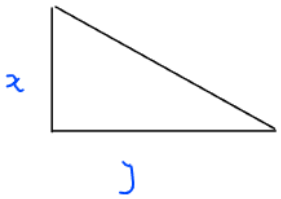
FIG Q4b

Area ABCD is this square



Area of square is one side x One side

The side of square can be found using triangle



$\sqrt{x^2+y^2}$ = length of hyp and length of side of square

Area of square

$\sqrt{x^2+y^2} \times \sqrt{x^2+y^2} = x^2+y^2$

5. Describe EACH of the following with the aid of a diagram:

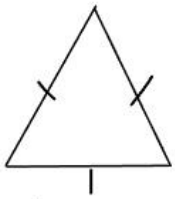
(a) an equilateral triangle; (2)

(b) a scalene triangle; (2)

(c) an isosceles triangle; (2)

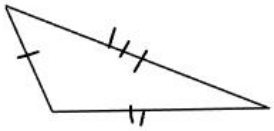
(d) a tangent to a circle. (2)

a)



3 sides same

b)

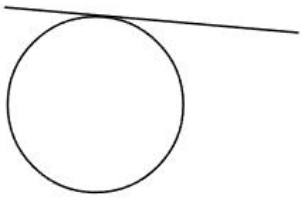


all sides diff

c)

2 sides same

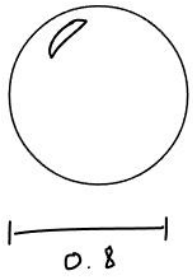
d)

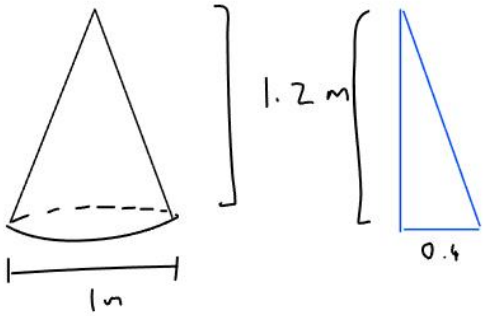


tangent touches circle

6. A sphere has a diameter of 0.8 m which is compared to a solid cone with a height of 1.2 m and a base diameter of 1 m.

Show which object has the greater total surface area. (8)





$\sqrt{1.2^2+0.4^2} = 1.3$

$SA = 4\pi r^2$

$SA = 4\pi (0.4)^2$

$SA = 2.0106\ m^2$

$SA = \pi r^2 + \pi RL$

$SA = \pi(0.4)^2 + \pi(0.4)(1.3)$

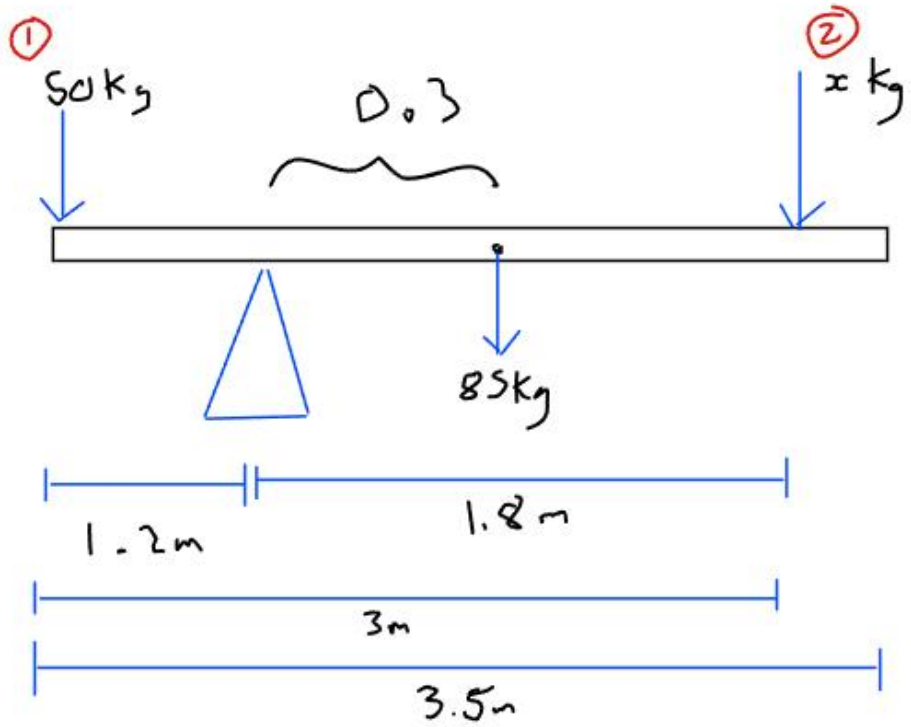
$SA = 2.136283\ m^2$

Cone has bigger SA

7. 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. There is a point load with a mass of 50 kg acting 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)



$$\text{Beam} = \frac{3m}{2} = 1.5 - 1.2 = 0.3$$

Name	mass	Force	Pistace	Mount	Direction
W_1	50	490.5	1.2	588.6	A
W_2	x	9.81x	1.8	17.658x	C
Beam	85	833.85	0.3	250.155	C

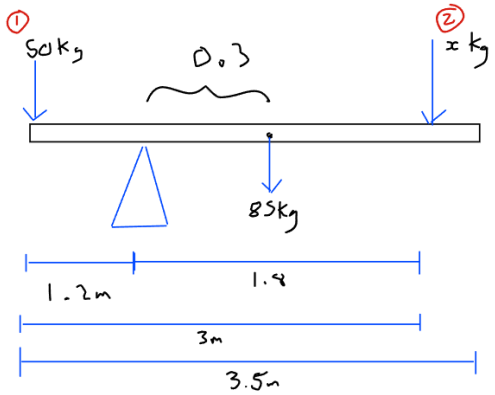
Sum of anticlockwise moments = Sum of clockwise moments

$$588.6 = 17.658x + 250.155$$

$$\frac{588.6 - 250.155}{17.658} = x$$

$$19.1667 \text{ kg} = x$$

Method 2 (Quick method)



Sum of anticlockwise moments = Sum of clockwise moments

$$50 \times 1.2 = 0.3 \times 85 + 1.8x$$

$$\frac{50 \times 1.2 - 0.3 \times 85}{1.8} = x$$

$$19.16667 \text{ kg} = x$$

$$\text{Beam} = \frac{3m}{2} = 1.5 - 1.2 = 0.3$$

8. A vehicle wheel, with a diameter of 360 mm, has an angular velocity of 300 rev/min and is accelerated uniformly to 600 rev/min over a 15 second period.

Determine EACH of the following:

(a) the initial and final angular velocities of the wheel in rads/s; (2)

(b) the angular acceleration of the wheel; (3)

(c) the linear acceleration of a point on the wheel rim. (3)

$v = u + at$

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

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

a)

s

$u = 300$ Rev/min $\div 60 \times 2\pi = 31.4159$ Rad/sec

$v = 600$ Rev/min $\div 60 \times 2\pi = 62.83185$ Rad/sec

a

$t = 15$ sec

b)

$v = u + at$

$62.83185 = 31.4159 + a(15)$

$$\frac{62.83185 - 31.4159}{15} = a$$

2.09439667 Rad/sec^2

c) Linear vel $= \theta \times r$

ok so this is new, they are asking for linear ACCEL not linear VEL, so lets put initial and final velocities into linear velocities and then do a SUVAT to find the accel

$$u = 31.4159 \times \frac{0.36}{2} = 5.654862 \text{ m/s}$$

$$V = 62.83185 \times \frac{0.36}{2} = 11.309733 \text{ m/s}$$

$$V = u + at$$

$$11.309733 = 5.654862 + a(15)$$

$$\frac{11.309733 - 5.654862}{15} = a$$

$$0.3769914 \text{ m/s}^2 = a$$

9. A mass of 1250 kg is raised by a winch through a distance of 9.5 m in 32 seconds. The motor power input to the system is 4.2 kW.

Determine EACH of the following:

(a) the work done raising the load; (3)

(b) the power required to raise the load; (3)

(c) the system efficiency. (2)

a) $Work = Fxd = 1250 \times 9.81 \times 9.5$

$= 116493.75J$

b) $P = \frac{W}{t} = \frac{116493.75}{32} = 3640.63$ Watts

c) $eff \quad \frac{3640.63}{4200} \times 100 = 86.677\%$.

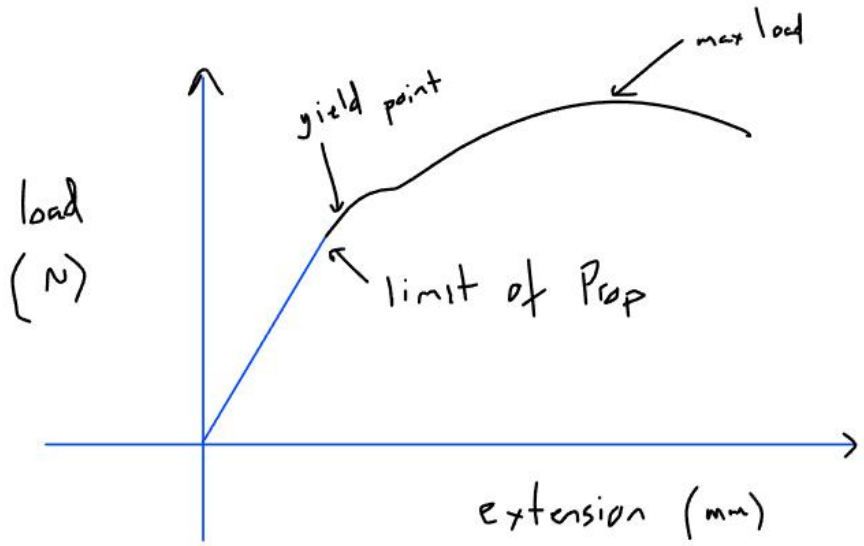
10. (a) Sketch a complete load/extension diagram for a typical low carbon steel specimen. (2)

(b) Indicate EACH of the following on your diagram:

(i) limit of proportionality; (2)

(ii) yield point; (2)

(iii) maximum load. (2)



11. A screw jack is used to raise a load of 600 kg. The jack has a single start square thread with a 6mm pitch. The effort applied acts on an effective radius of 30 cm.

If the applied effort is 180 Newtons, determine EACH of the following:

(a) the force ratio; (3)

(b) the movement ratio; (3)

(c) the efficiency of the screw jack. (2)

$\text{£} = \frac{F}{M}$

a) Force ratio $= \frac{600 \times 9.81}{180} = 3.27$

b) Movemt $= \frac{\pi d}{\text{pitch}} = \frac{\pi \times 300}{6} = 157.0796$

c) eff $= \frac{3.27}{157.0796} \times 100 = 2.0817\ \%$

12. A stationary body with a mass of 50 kg has a force applied to it which causes acceleration on a horizontal plane. The force of 120 N is applied at an angle of 10° below the horizontal pulling the block. There is a coefficient of friction is 0.2 between the block and the surface.

Determine EACH of the following:

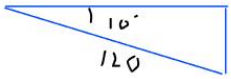
(a) the effective normal force on the surface caused by the block; (4)

(b) the frictional force; (3)

(c) the acceleration of the block. (3)

a) Normal $= mg = 9.81 \times 50 = 490.5\ N$

b) Friction



Horizontal: $120\cos 10 = 118.17693$

Vertical: $120 \sin 10 = 20.83778$

$$\text{Friction} = \mu N$$
$$0.2 \times (490.5 + 20.83778)$$
$$= 102.26755\ N$$

c) Accel

Push − Friction

$$118.17693 - 102.267 = 15.90993\ N$$

$$F = ma \qquad \frac{F}{m} = a$$

$$\frac{15.90993}{50} = 0.3181986\ m/s^2$$