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, 10 MARCH 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. Simplify EACH of the following expressions:

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

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

2. (a) Rearrange the following expression to make 'c' the subject:

   $2c = pq + cs$ (4)

   (b) Simplify the following expression:

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

3. A graph is shown in FIG Q3, where 'Y' values are on the vertical axis and 'x' values are on the horizontal axis.

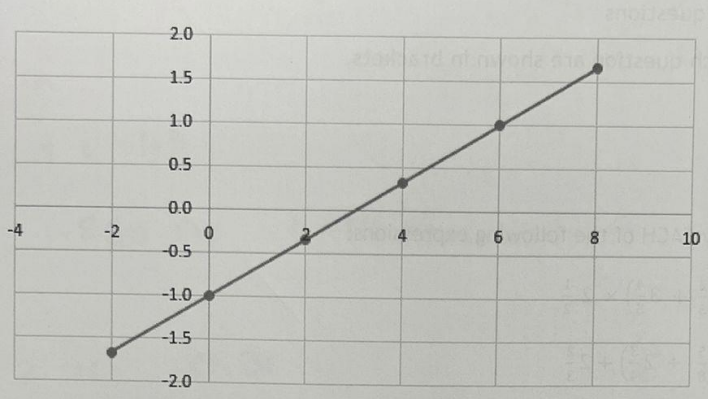


FIG Q3

(a) From the graph create a data table for the points shown. (2)

(b) Derive an expression relating the points shown. (3)

(c) Using the expression derived in Q3(b), determine the value of y when x = -3. (3)

4. Consider the shape given in FIG Q4 (not to scale) where AC and BD are parallel:

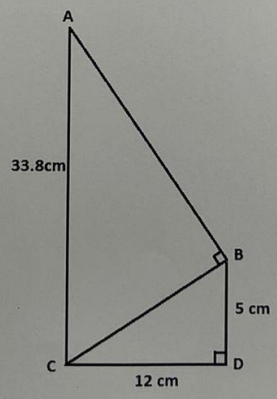


FIG Q4

(a) determine the angle CAB; (4)

(b) determine the area of the whole shape ACDB. (4)

5. The diagram in FIG Q5 shows two intersecting circles EACH with a radius of 5 cm. The length AB is 8 cm.

Determine the area of the shaded section. (8)

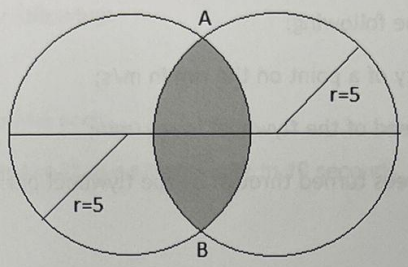


FIG Q5

6. A right pyramid has an equilateral triangle base with sides of 200 mm and a perpendicular height of 300 mm.

Calculate EACH of the following:

(a) the volume of the pyramid in m^3; (6)

(b) the area of any ONE of the triangular faces, excluding base, in mm^2. (4)

Section B

7. An engine flywheel has a diameter of 1.2 m and rotates at 5530 rads/min.

   Determine EACH of the following:

   (a) the linear velocity of a point on the rim in m/s; (3)

   (b) the rotational speed of the flywheel in rev/min; (3)

   (c) the angle in degrees turned through by the flywheel per second. (2)

8. FIG Q8 shows a steel bar, of uniform cross section, 2.57 m long having a mass of 11.05 kg.

   Determine the value of W kg to give a balanced equilibrium condition about the fulcrum. (8)

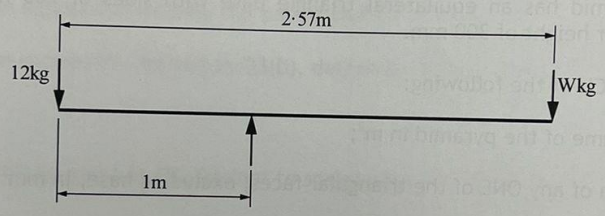


FIG Q8

9. A vehicle accelerates uniformly from rest over 5 seconds to a constant speed of 8 m/s. After 15 seconds it decelerates at 0.8 m/s^2 until it is stationary:

   (a) sketch and label the velocity time graph representing this motion; (4)

   (b) calculate the average speed. (4)

10. 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 in measured at 3.9 kW.

    Determine the system efficiency. (8)

11. A container of a mass of 32.6 kg has a horizontal force of 122.5 N applied to it which causes acceleration in a horizontal plane.

The friction coefficient between the container and the plane is 0.34.

Determine EACH of the following:

(a) the friction force; (3)

(b) the acceleration of the body; (3)

(c) the distance the body will travel from rest in 10 seconds. (4)

12. FIG Q12 shows two strips of metal 30 mm wide and 4 mm thick. They are joined by a 10 mm diameter pin which goes through 10.5 mm holes in the plate.

The ultimate shear stress for the pin is 60 MPa and the ultimate tensile strength of the plate is 100 MPa.

(a) Under increasing load calculate which will fail first, the plate or the pin; (6)

(b) Determine the failure load, F for the system. (2)

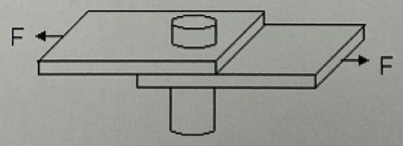


FIG Q12

1. Simplify EACH of the following expressions:

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

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

1a) $\left(\frac{8}{3} + \frac{19}{5}\right)$

$\left(\frac{40 + 57}{15}\right) \times \frac{5}{2}$

$\frac{97}{15} \times \frac{5}{2} = \frac{97}{6} = 16\frac{1}{6}$

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

$\left(\frac{77}{8} \div \frac{11}{4}\right) + \frac{8}{3}$

$\frac{77}{8} \times \frac{4}{11}$

$\frac{7}{2} + \frac{8}{3}$

$\frac{21 + 16}{6} = \frac{37}{6} = 6\frac{1}{6}$

2. (a) Rearrange the following expression to make 'c' the subject:

$2c = pq + cs$ (4)

(b) Simplify the following expression:

$\frac{4a^2b^3}{6bc} \div \frac{2ab^2}{3c^2}$ (4)

2) $2c = pq + cs$

$2c - cs = pq$

$c(2-s) = pq$

$c = \frac{pq}{2-s}$

b) $\frac{4a^2b^3}{6bc} \times \frac{3c^2}{2ab^2}$

$= \frac{12a^2b^3c^2}{12ab^3c}$

$= ac$

3. A graph is shown in FIG Q3, where 'Y' values are on the vertical axis and 'x' values are on the horizontal axis.

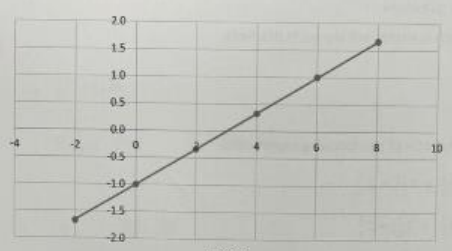


FIG Q3

(a) From the graph create a data table for the points shown. (2)

(b) Derive an expression relating the points shown. (3)

(c) Using the expression derived in Q3(b), determine the value of y when x = -3. (3)

a)

x	-2	0	2	4	6	8
y	-1.66	-1	-0.33	0.33	1	1.66

b) using easy to see points

$(0,-1)$ $(6,1)$ $m = \frac{y_2-y_1}{x_2-x_1} = \frac{1--1}{6-0} = \frac{2}{6} = \frac{1}{3}$

$y = \frac{1}{3}x - 1$

c) $y = \frac{1}{3}(-3) - 1 = -1 - 1 = -2$

4. Consider the shape given in FIG Q4 (not to scale) where AC and BD are parallel:

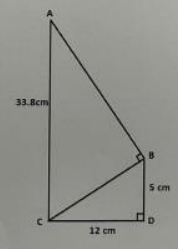
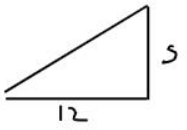


FIG Q4

(a) determine the angle CAB; (4)

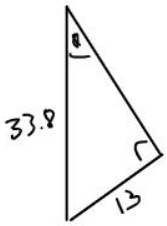
(b) determine the area of the whole shape ACDB. (4)

a)



$a^2+b^2=c^2$

$\sqrt{12^2+5^2} = 13$



SOH

$\sin^{-1}\left(\frac{13}{33.8}\right) = \theta$

$27.619°$

b) Area

$\frac{12 \times 5}{2} = 30\ cm^2$

$\sqrt{33.8^2 - 13^2} = 31.2$

$\frac{31.2 \times 13}{2} = 202.8\ cm^2$

total $232.8\ cm^2$

5. The diagram in FIG Q5 shows two intersecting circles EACH with a radius of 5 cm. The length AB is 8 cm.

Determine the area of the shaded section. (8)

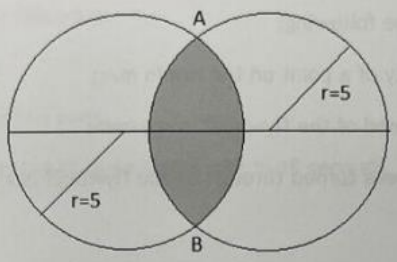
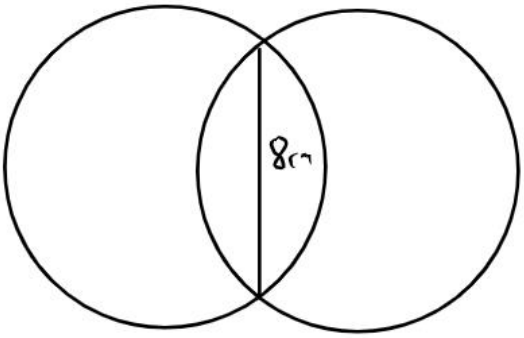
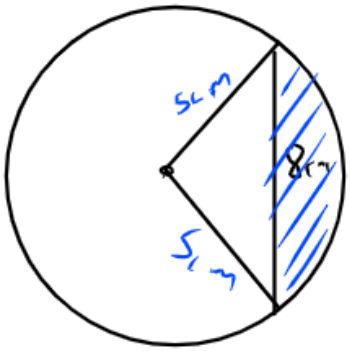
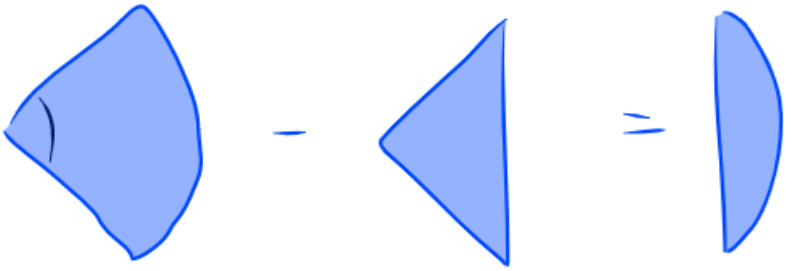
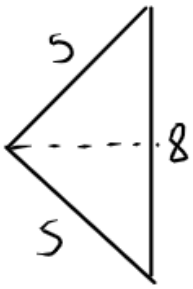


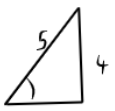
FIG Q5




5cm
8cm
5cm




5
8
5

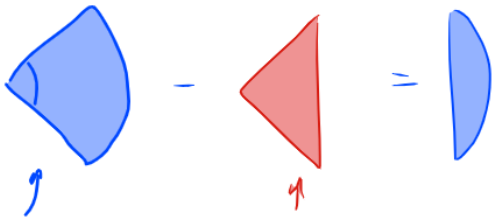


SOH

$\sin\theta = \frac{opp}{hyp}$ $\theta = \sin^{-1}\left(\frac{4}{5}\right)$

$\theta = 53.13010235^\circ$

$2\theta = 106.26$



$\frac{106.26}{360} \times \pi r^2$ $\frac{1}{2}ab\sin C$ =

$\frac{106.26}{360} \times \pi (5)^2 - \frac{1}{2}(5\times5)\sin 106.26$ =

$23.1823 - 12 = 11.1823$

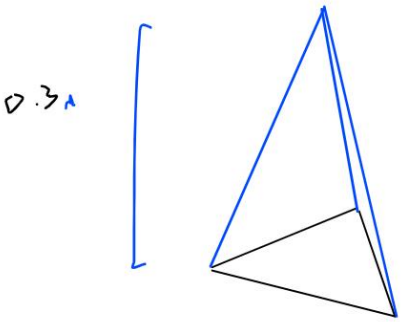
$2 \times 11.1823 = 22.3646\ cm^2$

6. A right pyramid has an equilateral triangle base with sides of 200 mm and a perpendicular height of 300 mm.

Calculate EACH of the following:

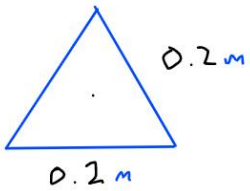
(a) the volume of the pyramid in m^3; (6)

(b) the area of any ONE of the triangular faces, excluding base, in mm^2. (4)



$$Vol = \frac{b \times h}{3}$$

base

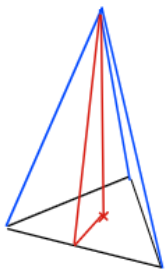


$$\frac{1}{2} ab \sin C$$

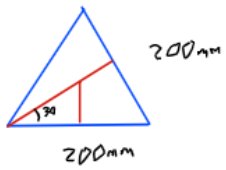
$$0.5 \times 0.2 \times 0.2 \sin 60 = 0.01732 \ m^2$$

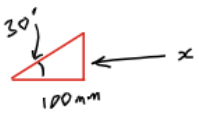
$$Vol = \frac{bh}{3} = \frac{0.01732 \times 0.3}{3} = 1.7321 \ m^3$$

b) Area one face (advanced!)



base

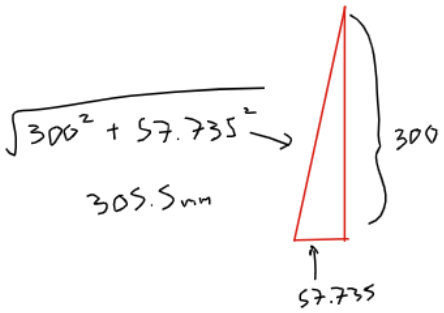


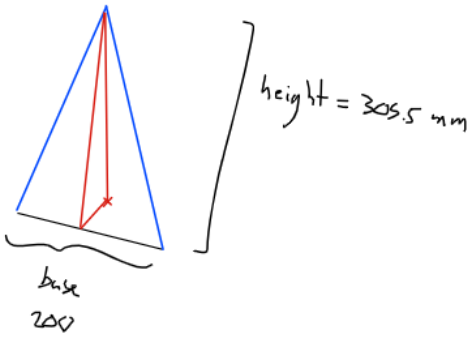


$$\tan\theta = \frac{opp}{adj}$$

$$\tan 30 = \frac{x}{100}$$

$$100 \tan 30 = x = 57.735 \ mm$$





$$\text{Area} = \frac{305.5 \times 200}{2} = 30550\ mm^2$$

Section B

7. An engine flywheel has a diameter of 1.2 m and rotates at 5530 rads/min.

Determine EACH of the following:

(a) the linear velocity of a point on the rim in m/s; (3)

(b) the rotational speed of the flywheel in rev/min; (3)

(c) the angle in degrees turned through by the flywheel per second. (2)

a) Liner vel = rad/sec x radius

$\frac{5530}{60} \times 0.6 = 55.3 \text{ m/s}$

b) $\frac{5530 \text{ Rev}}{\text{min}} \div 2\pi = 880.1268 \text{ Rev/min}$

c) $\frac{5530 \text{ Rad}}{1 \text{ min}} \xrightarrow{\div 2\pi} \frac{880.116 \text{ Rev}}{1 \text{ min}} \xrightarrow{\times 360} \frac{316845 \text{ degree}}{60} = 5280.76 \text{ deg/sec}$

8. FIG Q8 shows a steel bar, of uniform cross section, 2.57 m long having a mass of 11.05 kg.

Determine the value of W kg to give a balanced equilibrium condition about the fulcrum. (8)

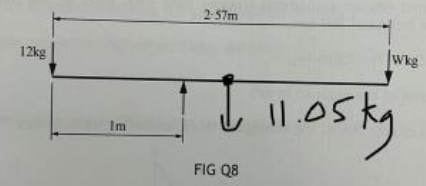


FIG Q8

$\frac{2.57}{2} = 1.285$

Name	Mass	Force	Distce	Mmnt	Dir
Beam	11.05	108.4005	0.285	30.8941	C
W_1	12	117.72	1	117.72	A
W_2	w	9.81w	1.57	15.4017w	C

Anti = clock

117.72 = 15.4017w + 30.8941

5.8324 kg = W

9. A vehicle accelerates uniformly from rest over 5 seconds to a constant speed of 8 m/s. After 15 seconds it decelerates at 0.8 m/s² until it is stationary:

(a) sketch and label the velocity time graph representing this motion; (4)

(b) calculate the average speed. (4)

$v = u + at$

1)

s
$u = 0$
$v = 8$
a
$t = 5$

s
$u = 8$
$v = 8$
a
$t = 15$

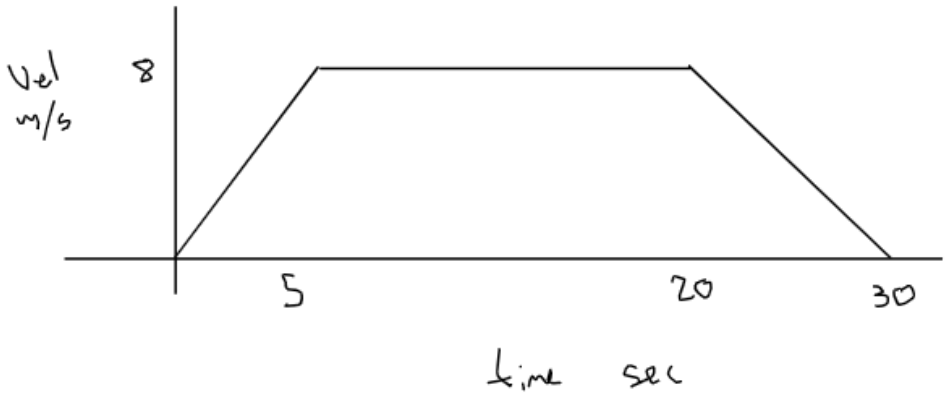
s
$u = 8$
$v = 0$
$a = -0.8$
$t =$

$v = u + at$

$0 = 8 - 0.8t$

$0.8t = 8$

$t = \frac{8}{0.8} = 10$ sec



5)

s
u = 0
v = 8
a
t = 5

s
u = 8
v = 8
a
t = 15

s
u = 8
v = 0
a = −0.8
t =

$v = u + at$

$0 = 8 - 0.8t$

$0.8t = 8$

$t = \frac{8}{0.8} = 10$

$s = \left(\frac{0+8}{2}\right)5$

$s = 20\text{m}$

$s = \left(\frac{8+8}{2}\right)15$

$s = 120\text{m}$

$s = \left(\frac{8+0}{2}\right)10$

40m

total distance $= 180$

total time $= 30$

$= 6\ \text{m/s}$

Average speed $= 6\ \text{m/s}$

10. 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 in measured at 3.9 kW.

Determine the system efficiency. (8)

$$P = \frac{mgh}{t} = \frac{580 \times 9.81 \times 14.6}{32} = 2595.97 \text{ Watts}$$

$$Eff = \frac{2595.97}{3900} \times 100 = 66.563\%$$

11. A container of a mass of 32.6 kg has a horizontal force of 122.5 N applied to it which causes acceleration in a horizontal plane.

The friction coefficient between the container and the plane is 0.34.

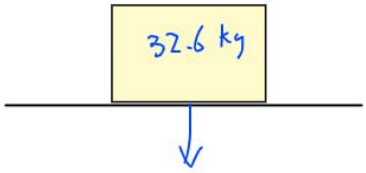
Determine EACH of the following:

(a) the friction force; (3)

(b) the acceleration of the body; (3)

(c) the distance the body will travel from rest in 10 seconds. (4)

a)



$32.6 \times 9.81 = 319.806 N$

$Fric = \mu N$

$= 0.34 \times 319.806$

$= 108.734 N$

b) $F = ma$

Push − Fric = Net horizontal

$122.5 - 108.73404 = 13.76596 N$

$F = ma$

$13.76596 = 32.6a$

$a = 0.4222687 \text{ m/s}^2$

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

$0 + \frac{1}{2} 0.4222687 \times 10^2$

$s = 21.1134\,m$

12. FIG Q12 shows two strips of metal 30 mm wide and 4 mm thick. They are joined by a 10 mm diameter pin which goes through 10.5 mm holes in the plate.

The ultimate shear stress for the pin is 60 MPa and the ultimate tensile strength of the plate is 100 MPa.

(a) Under increasing load calculate which will fail first, the plate or the pin; (6)

(b) Determine the failure load, F for the system. (2)

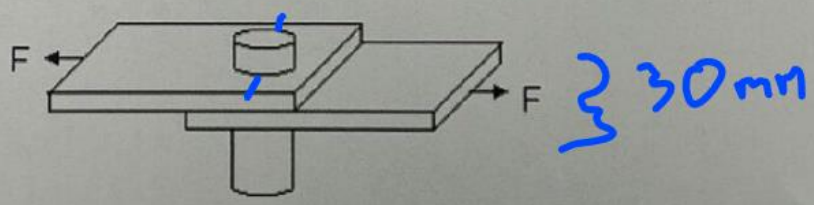
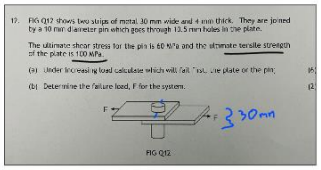
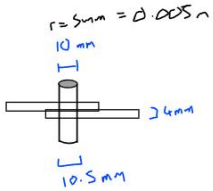


FIG Q12





Pin

Stress = $\frac{F}{A}$

60 MPa

Stress = 60×10^6 N/m² ✓

Area $\pi r^2 = \pi (0.005)^2$

$= 7.85398 \times 10^{-5}$ m² ✓

From the ultimate sheer stress, and the cross sectional area, I can calcualte the force require to BREAK the pin

Area × Stress = F

$7.85398 \times 10^{-5} \times 60 \times 10^6 = 4712.388$ N

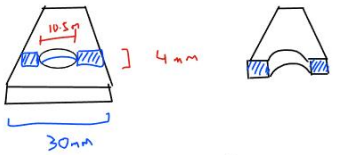
So, I need 4712.388N to break the Pin

Plate

stress = $\frac{F}{A}$

stress = 100 MPa

100×10^6 N/m²



Area $(30 - 10.5) \times 4 = 78 mm^2$

length × height

$0.0195 \times 0.004 = 7.8 \times 10^{-5}$ m²

Stress × Area = Force

$100 \times 10^6 \times 7.8 \times 10^{-5} = 7800$ N

So I need 7800 N to break the plate.