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, 03 DECEMBER 2021

1400 - 1600 hrs

Materials to be supplied by examination centre

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.

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. Simplify EACH of the following showing all working:

   (a) $\left(\frac{2}{3} + 3\frac{4}{5}\right) \times 2\frac{1}{2}$ $4\frac{5}{6}$ (4)

   (b) $\left(3\frac{4}{5} \div 1\frac{1}{9}\right) \times 2\frac{1}{2}$ $8\frac{11}{20}$ (4)

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

   (a) $4(2x - 2) - 3(2x + 2) = 0$ $x = 7$ (4)

   (b) $4x(2x - 3) \div 8x = 0$ $x = 0$ (4)

3. (a) Plot the graph of the equation $y = 2x^3 + 3$ between the limits of $x = -1$ and $x = 3$ indicating in the answer how the plotting points are obtained. (8)

   (b) Indicate on the graph plotted in Q3(a) the value of y when $x = 1.5$. (2)

4. For the shape given in FIG Q4 angle OBA is π/4 rads and angle OAC is π/3 rads.

Determine the angle ABC: 30° (8)

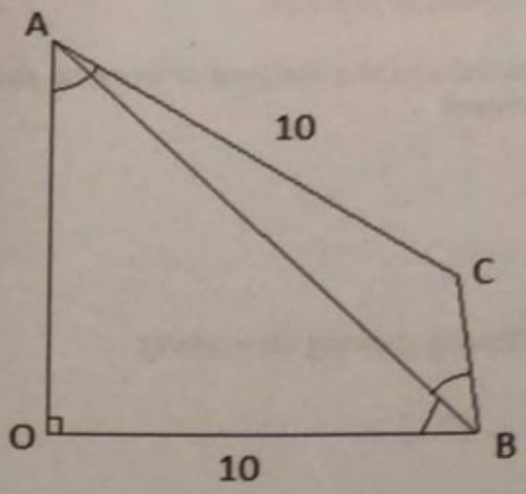


FIG Q4 (not to scale)

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

$$Area = \frac{L^2}{12}\left(\sqrt{3} - \frac{\pi}{3}\right)$$

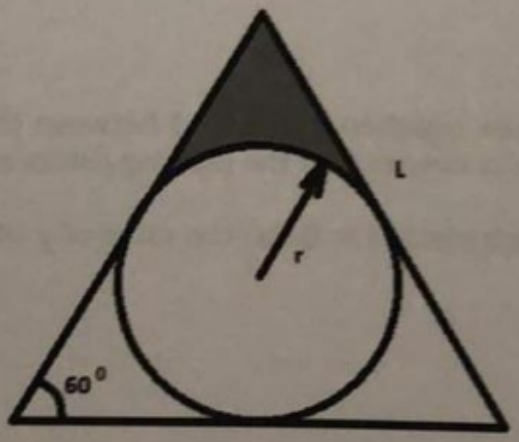


FIG Q5

Section B

7. (a) Define the relative density of a liquid. (2)

(b) 425 litres of fluid has a relative density of 0.88.

Determine EACH of the following:

(i) the volume of the fluid in standard SI derived units; $0.425\ m^3$ (4)

(ii) the mass of the fluid in SI fundamental units. 374kg (4)

8. An engine flywheel is accelerated from 1000 rpm to 2420 rpm in 16 seconds.

Determine EACH of the following:

(a) the angular acceleration in rad/s^2; $9.294\ rad/s^2$ (4)

(b) the final equivalent linear velocity of a point on the flywheel rim in m/s if the flywheel radius is 0.2 m. (4)

50.684 m/s

9. An oil transfer pump delivers heavy fuel oil through a 150 mm diameter pipe to a tank inlet at a height of 9.5 m at a constant velocity of 0.3 m/s.

Calculate EACH of the following:

(a) the power of the pump; 0.49kW (4)

(b) the overall power to drive the pump if the combined electrical and mechanical efficiency of the drive system is 80%. (4)

Note: the density of fuel oil is 990kg/m³. 0.61kW

10. 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)

11. A box 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; $2.616\ m/s^2$ (4)

(b) the acceleration of the body when a friction coefficient of 0.35 exists between the box and the surface. (4)

$0.915\ m/s^2$

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

(b) Indicate EACH of the following on the diagram sketched in Q12(a):

(i) limit of proportionality; (2)

(ii) yield point; (2)

(iii) maximum load. (2)

Section A

1. Simplify EACH of the following showing all working:

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

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

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

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

$\frac{10}{15} + \frac{57}{15} \times \frac{5}{2}$

$3\frac{\cancel{12}}{\cancel{15}} \times \frac{\cancel{5}}{2}$

$\frac{67}{6} = 11\frac{1}{6}$

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

$\left(\frac{19}{5} \div \frac{10}{9}\right) \times \frac{5}{2}$

$\left(\frac{19}{5} \times \frac{9}{10}\right) \times \frac{5}{2}$

$\frac{171}{50} \times \frac{5}{2}$

$\frac{171}{20} = 8\frac{11}{20}$

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

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

(b) $4x(2x-3)\div 8x=0$ (4)

a) $8x-8-6x-6=0$

$2x-14=0$

$x=7$

b) $\dfrac{4x(2x-3)}{2\cancel{8}\cancel{x}}=0$

$\dfrac{2x-3}{2}=0$

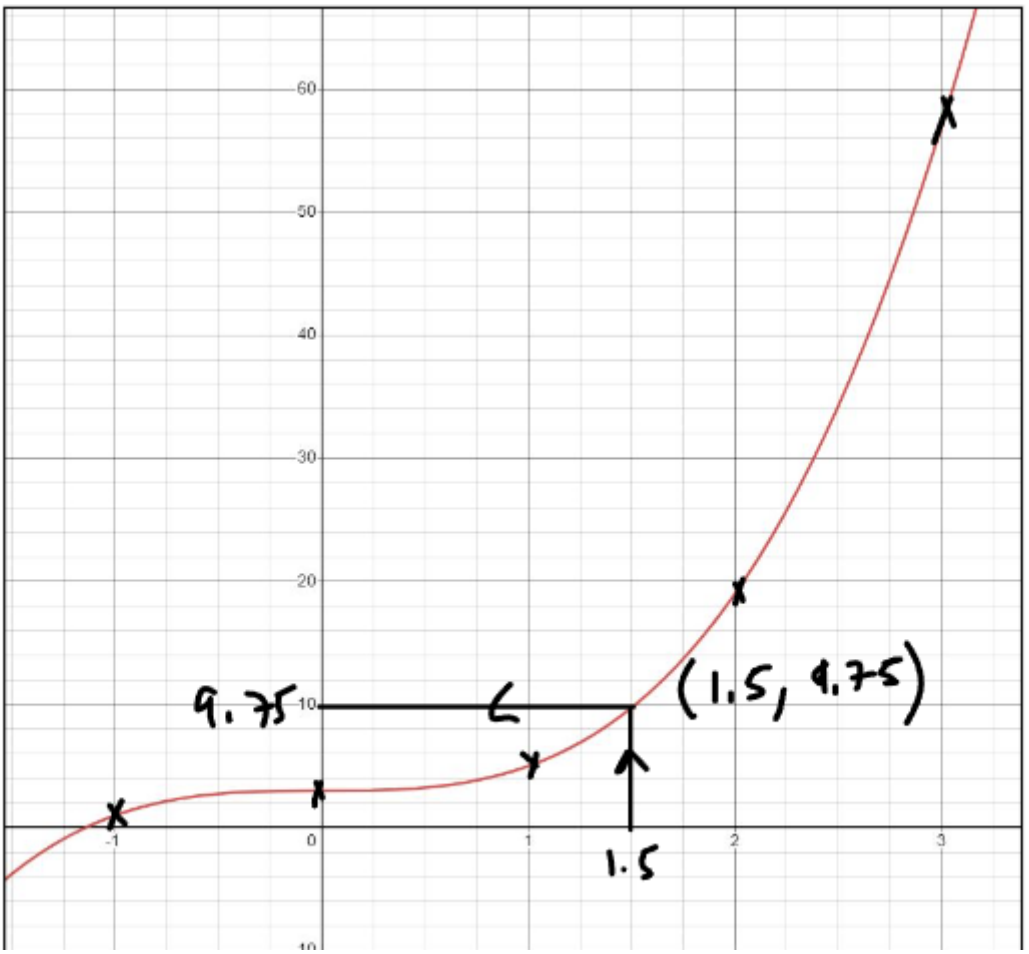
$2x=3$

$x=\dfrac{3}{2}=1.5$

3. (a) Plot the graph of the equation $y = 2x^3 + 3$ between the limits of $x = -1$ and $x = 3$ indicating in the answer how the plotting points are obtained. (8)

(b) Indicate on the graph plotted in Q3(a) the value of y when $x = 1.5$. (2)

x	$y = 2x^3 + 3$
-1	$2(-1)^3 + 3 = 1$
0	$2(0)^3 + 3 = 3$
1	$2(1)^3 + 3 = 5$
2	$2(2)^3 + 3 = 19$
3	$2(3)^3 + 3 = 57$



4. For the shape given in FIG Q4 angle OBA is π/4 rads and angle OAC is π/3 rads.

Determine the angle ABC: (8)

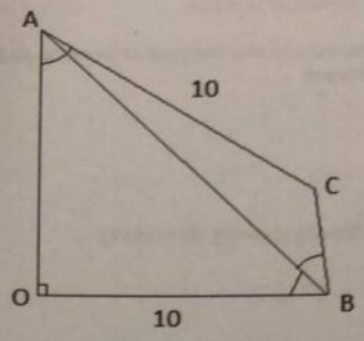
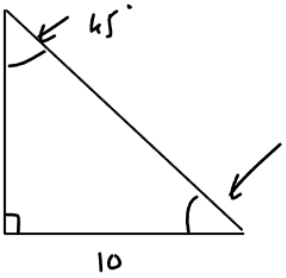


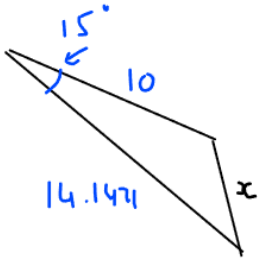
FIG Q4 (not to scale)



$\frac{\pi}{4} = 45°$ $\quad \frac{\frac{\pi}{4}}{2\pi} \times 360 = 45°$

$\sqrt{10^2 + 10^2} = \sqrt{200} = 10\sqrt{2} = 14.1421$

Find top angle



$\frac{\pi}{3} - \frac{\pi}{4}$

$60° - 45 = 15°$

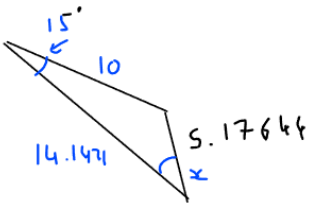
Use cosine Rule

$a^2 = b^2 + c^2 - 2bc \cos A$

$x^2 = 10^2 + 14.1421^2 - 2(10)(14.1421)\cos 15$

$x = 5.17644$

Use sin Rule



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

or

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

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

$$Area = \frac{L^2}{12}\left(\sqrt{3} - \frac{\pi}{3}\right)$$

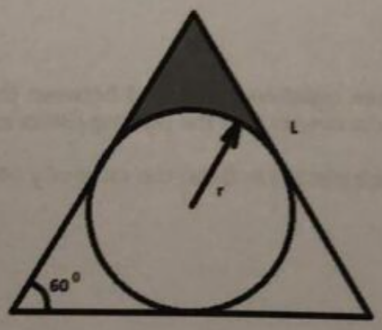
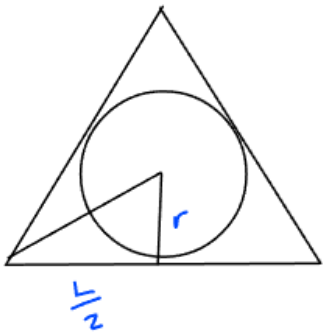


FIG Q5



Assume Equilateral triangle

$$\text{Area}_{\text{big triangle}} = 6 \times \left(\frac{\text{length} \times \text{height}}{2}\right)$$

$$\text{Area} = 6 \times \left(\frac{\frac{L}{2} \times r}{2}\right)$$

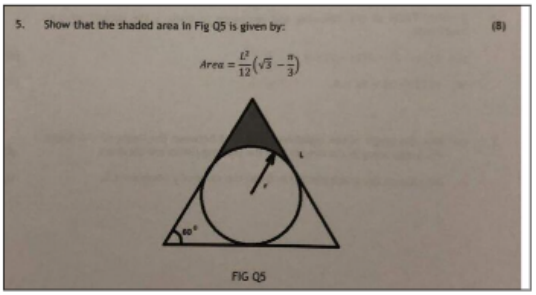
$$6\,\frac{Lr}{4}$$

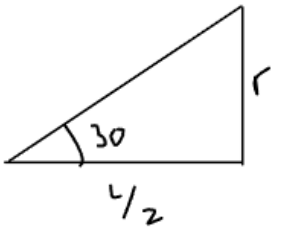
$$\boxed{\frac{3Lr}{2}}$$

$$\text{Area circle} = \pi r^2$$

$$\text{Shaded Region} \left(\frac{\frac{3Lr}{2} - \pi r^2}{3}\right)$$

$$\left(\frac{Lr}{2} - \frac{\pi r^2}{3}\right)$$





$$\tan 30 = \frac{r}{L/2}$$

$$\frac{\sqrt{3}}{3} = \frac{r}{L/2}$$

$$\frac{\sqrt{3}L}{6} = r$$

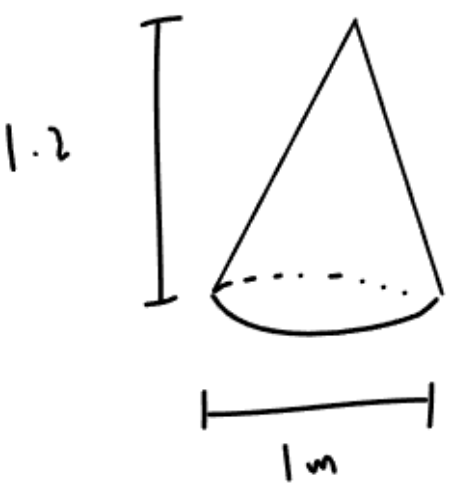
$$\frac{3L^2}{36} = r^2$$

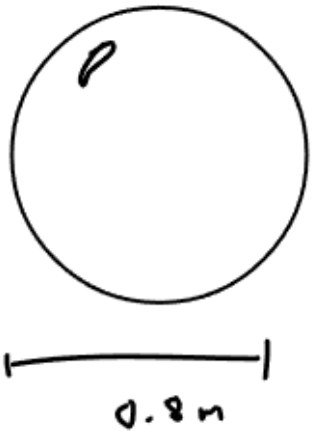
$$\left(\frac{Lr}{2} - \frac{\pi r^2}{3}\right) = \left(\frac{L\left(\frac{\sqrt{3}L}{6}\right)}{2} - \frac{\pi \frac{3L^2}{36}}{3}\right)$$

$$\left(\frac{L^2\sqrt{3}}{12} - \frac{\pi L^2}{36}\right)$$

$$\frac{L^2}{12}\left(\sqrt{3} - \frac{\pi}{3}\right)$$

6. A right cone has a height of 1.2 m and a base diameter of 1 m which is compared to a sphere with a diameter of 0.8 m. Show which object has the greater volume. (8)





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

$$\frac{\pi\, 0.5^2 \times 1.2}{3}$$

$$0.314159\ m^3$$

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

$$= \frac{4}{3}\pi (0.4)^3$$

$$= 0.26808\ m^3$$

CONE

Section B

7. (a) Define the relative density of a liquid. (2)

(b) 425 litres of fluid has a relative density of 0.88.

Determine EACH of the following:

(i) the volume of the fluid in standard SI derived units; (4)

(ii) the mass of the fluid in SI fundamental units. (4)

a)

relative density, is relative to water, if the number is greater than one, then the liquid is more dense than water, if it is less than one, then the liquid is less dense than water.

Relative density has no units, its just a numerical value

b)

i) $425L = 0.425m^3$

ii) $425 \times 0.88 = 374 kg$

8. An engine flywheel is accelerated from 1000 rpm to 2420 rpm in 16 seconds.

Determine EACH of the following:

(a) the angular acceleration in rad/s^2; (4)

(b) the final equivalent linear velocity of a point on the flywheel rim in m/s if the flywheel radius is 0.2 m. (4)

a)

$u = 1000$ Rpm $\times 2\pi \div 60 = 104.7197551$ Rad/sec

$v = 2420$ $\times 2\pi \div 60 = 253.1218074$ Rad/sec

$a = x$

$t = 16$

$v = u + at$

$253.1218074 = 104.7197551 + 16x$

$\frac{253.12 - 104.72}{16} = x$

9.2938 Rad/sec^2 = accel

b) linear vel = rad/sec $\times$ Radius

$253.1218 \times 0.2 = 50.684$ m/s

9. An oil transfer pump delivers heavy fuel oil through a 150 mm diameter pipe to a tank inlet at a height of 9.5 m at a constant velocity of 0.3 m/s.

Calculate EACH of the following:

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

(b) the overall power to drive the pump if the combined electrical and mechanical efficiency of the drive system is 80%. (4)

Note: the density of fuel oil is 990kg/m³.

a) $P = \frac{mgh}{t}$ vel

mass of water in pipe = vol × density

$vol = \pi r^2 h = \pi \left(\frac{0.15}{2}\right)^2 \times 9.5 = 0.16787885\ m^3$

$mass = 0.16787885 \times 990 = 166.2\ kg$

$P = 166.2 \times 9.81 \times 0.3 = 489.1268$ watts

$Eff = \frac{\text{theoretical}}{\text{Actual}}$

$0.8 = \frac{489.1268}{x}$

$x = \frac{489.1268}{0.8} = 611.41$ Watts

10. 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)

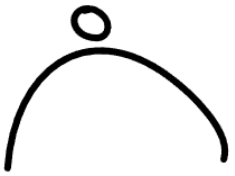
a)

Stable

a stable equilibrium will return to its inital conditions
eg: tennis ball in a valley

Neutral

Neutral equilibrium will remain where you put it. Eg tennis ball on flat surface



Unstable

Unstable equilibrium will not return to starting point or stay where you put it.
Eg: ball on a hill

b) Scalar =

just a number, or a quantity, such as 100 mph

Vector =

a number (magnitude) with a direction, so 100 mph NORTH would be a vector

c) Moments

a turning force about a point, same a torque.
the force multiplied by the effective distance

Moment= Force x Distance

Units Nm

d) Centroid

centre of gravity of a shape, or centre of mass. the centroid of a square would be the centre

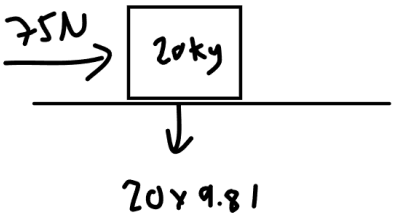
11. A box with a mass of 20 kg rests on a horizontal surface. The box has a force of 75 N applied to it parallel to the horizontal surface.

Determine EACH of the following:

(a) the acceleration of the body with no friction; (4)

(b) the acceleration of the body when a friction coefficient of 0.35 exists between the box and the surface. (4)

a)



$F = ma$

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

$3.75\ m/s^2$

b) $F_{fric} = \mu N$

$F_{fric} = 0.35 \times 20 \times 9.81 = 68.67$

Nt Horizontal force = Push − Fric

$75 - 68.67 = 6.33\ N$

Accel $F = ma$

$6.33 = 20a$

$\frac{6.33}{20} = a$

$0.3165\ m/s^2$

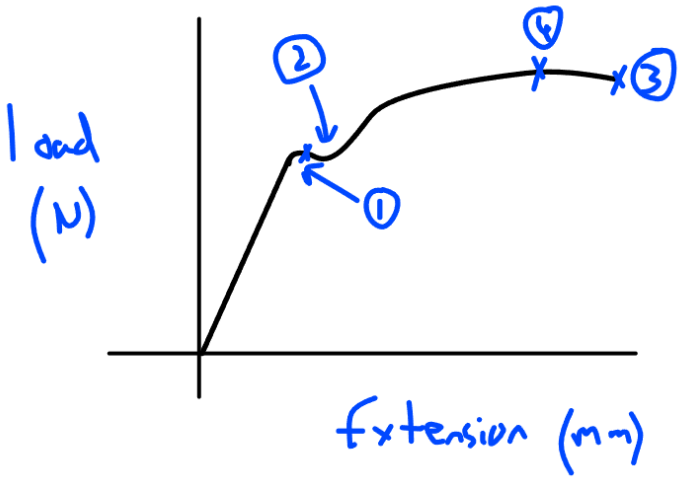
12. (a) Sketch a complete load/extension diagram for a typical low carbon steel specimen. (2)

(b) Indicate EACH of the following on the diagram sketched in Q12(a):

(i) limit of proportionality; (2)

(ii) yield point; (2)

(iii) maximum load. (2)



i (1) limit of proportionality

ii (2) yield point

(3) breaking point

iii (4) max load