058-11 - GENERAL ENGINEERING SCIENCE I

FRIDAY, 11 MARCH 2022

1400 - 1600 hrs

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 sample of exhaust gas analysed by volume, was found to be made up of 2 parts Sulphur Dioxide, 40 parts Oxygen, 98 parts of water vapour, 198 parts Carbon Dioxide and 770 parts Nitrogen.

   Calculate the percentage of EACH gas in the exhaust. (8)

2. Simplify EACH of the following expressions:

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

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

3. Consider the graph in Fig Q3:

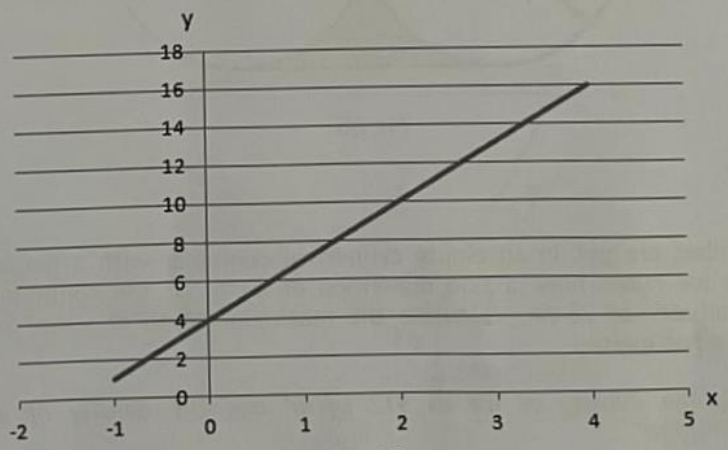

Fig Q3

(a) Determine the equation that describes the data plotted in Fig Q3; (6)

(b) Determine the y value for x = 2.5. (2)

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4. Using Pythagoras Theorum determine the length AC from Fig Q4. (8)

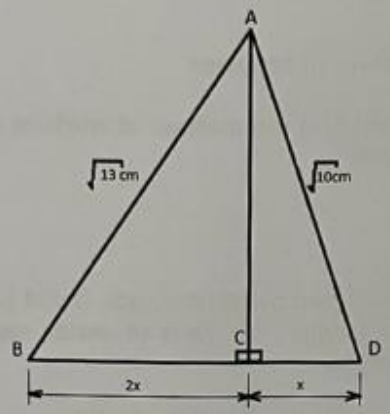


Fig Q4

5. Show that the shaded area in the diagram below is given by. (8)

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

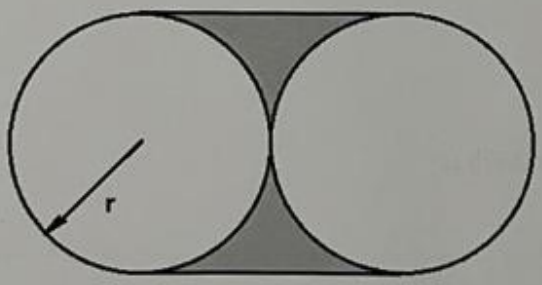


Fig Q5

6. 1000 ice cubes are put in an empty cylindrical container with a hemispherical base. The ice cubes have a side dimension of 2 cm. If the container has an internal diameter of 28 cm, calculate the maximum depth of water remaining after the ice has melted. (10)

Note: take the density of ice as 912 kg/m³ and the density of water as 1000 kg/m³

7. A pump is uniformly accelerated from 500 rev/min to 700 rev/min in 10 seconds.

Determine EACH of the following:

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

(b) the number of revolutions turned during the acceleration period. (4)

8. The velocity of a 70 kg mass is uniformly increased from stationary to 3.8 m/s in 10 seconds. The mass is then decelerated at 0.3 m/s^2 until it comes to a stop.

Determine EACH of the following:

(a) the accelerating force required; (4)

(b) the time taken in the deceleration phase; (4)

(c) the total distance travelled. (2)

Note: any effects of friction may be ignored

9. Fig Q9 shows a mass of 150 kg suspended from points A and B by chains.

Determine the tensile forces in chains AC and BC. (8)

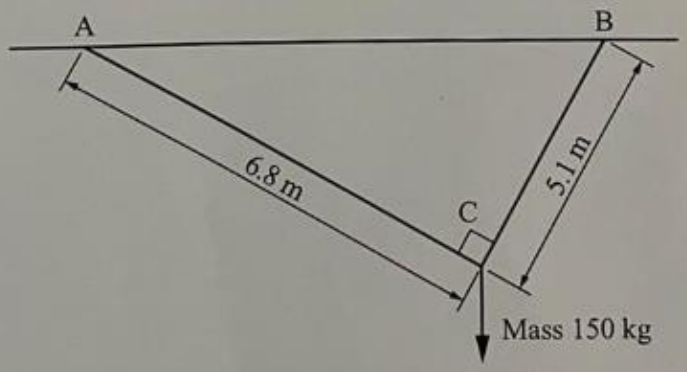


Fig Q9

10. A packing case with a mass of 50 kg has a force applied to it which causes acceleration in a horizontal plane. The force of 120 N is applied at an angle of 10° below the horizontal pulling the case.

Determine the acceleration of the case if the coefficient of friction is 0.2. (8)

11. A screw jack is used to support a load of 300 kg. The jack has a single start square thread with a 6 mm pitch on an effective diameter of 120 mm. If the applied effort is 80 Newtons.

Determine EACH of the following:

(a) the force ratio; (3)

(b) the movement ratio; (3)

(c) the efficiency. (2)

12. (a) Describe what is meant by Hooke's Law. (2)

(b) A round hole, 50 mm diameter, is to be punched through a metal plate 2 mm thick. The metal has an utimate shear strength of 120 MPa:

(i) determine the minimum force required to punch the hole; (3)

(ii) determine the maximum compressive stress on the punch during this process. (3)

2. Simplify EACH of the following expressions:

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

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

a) $\frac{2\cancel{12}\,ab^{\cancel{2}2}}{\cancel{6}\,\cancel{b}\,c} \div \frac{2ab^2}{c^2}$

$\frac{\cancel{2}ab^2}{\cancel{c}} \times \frac{c^{\cancel{2}}}{\cancel{2}ab^2}$

$\cancel{ab^2} \times \frac{c}{\cancel{ab^2}} = c$

b) $\frac{\cancel{12}ab^3}{6abc} \times \frac{2ab^2}{\cancel{12}abc^2}$

$\frac{b^3}{6\cancel{a}\cancel{b}c} \times \frac{2\cancel{a}b^{\cancel{2}}}{\cancel{b}c^2}$

$\frac{b^3 \times \cancel{2}}{3\cancel{6}c^2} = \frac{b^3}{3c^3}$

alt method

$\frac{2\cancel{12}\,ab^{\cancel{2}2}}{\cancel{6}\,\cancel{a}\,\cancel{b}c} \times \frac{\cancel{2}ab^{\cancel{2}}}{\cancel{12}\,\cancel{a}\,\cancel{b}c^2}$

$\frac{2b^2}{c} \times \frac{b}{6c^2} = \frac{\cancel{2}b^3}{3\cancel{6}c^3} = \frac{b^3}{3c^3}$

3. Consider the graph in Fig Q3:

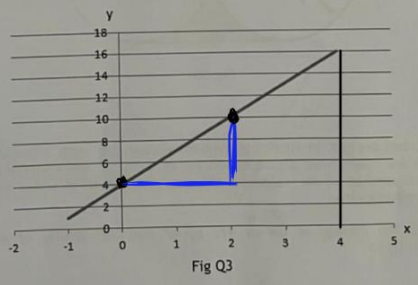


Fig Q3

(a) Determine the equation that describes the data plotted in Fig Q3; (6)

(b) Determine the y value for x = 2.5. (2)

3) $y = mx + c$

$m = \frac{\text{Rise}}{\text{Run}}$ $\frac{6}{2} = 3$

a) $y = 3x + 4$

b) $y = 3(2.5) + 4 = 11.5$

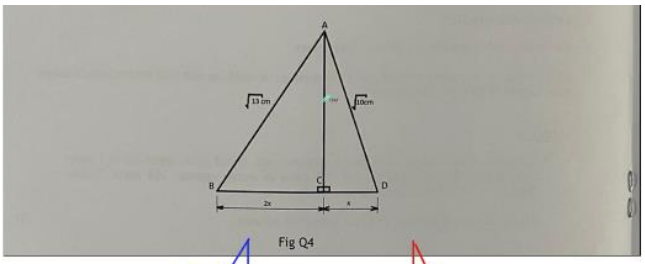
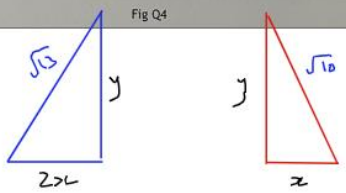


Fig Q4



$y^2 = (\sqrt{13})^2 - (2x)^2$

$13 - (2x)(2x)$

$y^2 = 13 - 4x^2$

$y^2 = (\sqrt{10})^2 - (x)^2$

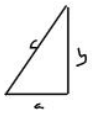
$y^2 = 10 - x^2$

$13 - 4x^2 = 10 - x^2$

$3 = 3x^2$

$1 = x^2$

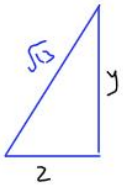
$1 = x$

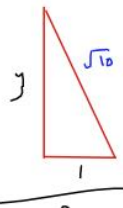


$a^2 + b^2 = c^2$

$b^2 = c^2 - a^2$

$b = \sqrt{c^2 - a^2}$





$y = \sqrt{(\sqrt{10})^2 - 1^2}$

$y = \sqrt{10 - 1}$

$y = \sqrt{9} = 3$

5. Show that the shaded area in the diagram below is given by. (8)

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

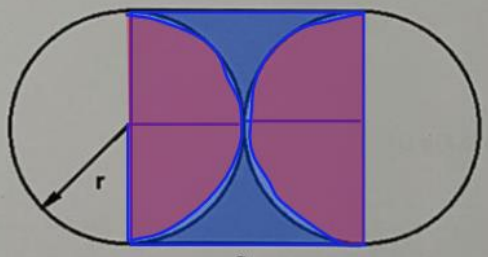


Fig Q5

Square − Circle

$(2r)^2 - \pi r^2$

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

$(4 - \pi)r^2$

6. 1000 ice cubes are put in an empty cylindrical container with a hemispherical base. The ice cubes have a side dimension of 2 cm. If the container has an internal diameter of 28 cm, calculate the maximum depth of water remaining after the ice has melted. (10)

Note: take the density of ice as 912 kg/m³ and the density of water as 1000 kg/m³

2cm
0.02

2cm
0.02

0.02
1000

Volume of 1000 ice cubes

$V = (0.02)^3 \times 1000 = 8 \times 10^{-3}\ m^3$

Mass of ice

$d = \frac{m}{v}$ $\quad dv = m$

$912 \times 8 \times 10^{-3} = \text{mass}$

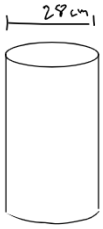
$7.296\ kg$

Volume of water

$d = \frac{m}{v}$

$1000 = \frac{7.296}{v}$

$v = \frac{7.296}{1000} = 7.296 \times 10^{-3}\ m^3$



$Vol = \pi r^2 h$

$r = 14cm = 0.14m$

$r = 14cm$ $\quad vol = \frac{\frac{4}{3}\pi r^3}{2}$

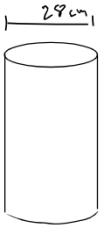
Hemisphere

$Vol = \frac{\frac{4}{3}\pi (0.14)^3}{2} = 5.74702 \times 10^{-3}\ m^3$

Water

total - hemisphere =

$7.296 \times 10^{-3} - 5.74702 \times 10^{-3} = 1.548898 \times 10^{-3}\ m^3$



$Vol = \pi r^2 h$

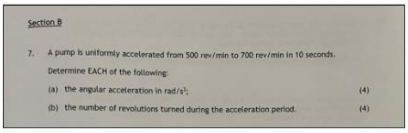
$r = 14cm = 0.14m$

$Vol = \pi r^2 h$

$1.548898 \times 10^{-3} = \pi (0.14)^2 h$

$h = 0.025154\ m$

$2.515\ cm$



Section B

7. A pump is uniformly accelerated from 500 rev/min to 700 rev/min in 10 seconds.
Determine EACH of the following:
(a) the angular acceleration in rad/s²; (4)
(b) the number of revolutions turned during the acceleration period. (4)

$\frac{500\ Rev}{1\ min} \xrightarrow{\times 2\pi} \frac{3141.59}{60} = 52.359878\ Rad/sec$

$\frac{700\ Rev}{1\ min} = \frac{4398.229715}{60} = 73.303828\ Rads/sec$

7a)

s

$u = 52.359878\ Rad/sec$

$v = 73.303828\ Rads/sec$

a

$t = 10$

$v = u + at$

$73.303828 = 52.359878 + a(10)$

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

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

$\frac{73.303828 - 52.359878}{10} = a = 2.094395\ Rads/sec^2$

b) s

$u = 500$

$v = 700$

a

$t = \frac{10}{60}$

$s = \left(\frac{500+700}{2}\right)\frac{1}{6} = 100\ Rev$

8. The velocity of a 70 kg mass is uniformly increased from stationary to 3.8 m/s in 10 seconds. The mass is then decelerated at 0.3 m/s² until it comes to a stop.

Determine EACH of the following:

(a) the accelerating force required; (4)

(b) the time taken in the deceleration phase; (4)

(c) the total distance travelled. (2)

Note: any effects of friction may be ignored

$v = u + at$

a)

$s =$
$u = 0$
$v = 3.8$
$a =$
$t = 10$

$3.8 = 0 + 10x$

$\frac{3.8}{10} = 0.38\ m/s^2 = a$

$F = ma$

$70 \times 0.38 = 26.6\ N$

b)

s
$u = 3.8$
$v = 0$
$a = -0.3$
t

$v = u + at$
$0 = 3.8 - 0.3t$
$t = 12.6667\ sec$

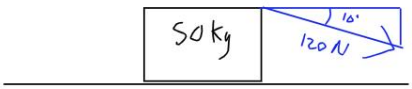
c) $s = \left(\frac{u+v}{2}\right) t$

$s = \left(\frac{3.8}{2}\right) 12.6667$

distance $= 24.06667\ m$

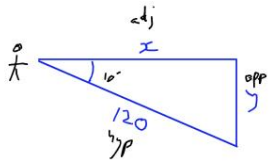
10. A packing case with a mass of 50 kg has a force applied to it which causes acceleration in a horizontal plane. The force of 120 N is applied at an angle of 10° below the horizontal pulling the case.

Determine the acceleration of the case if the coefficient of friction is 0.2. (8)



SOH
CAH
TOA

Horizontal



Vertical

CAH

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

$\cos 10 = \frac{x}{120}$

$x = 118.1769\ N$

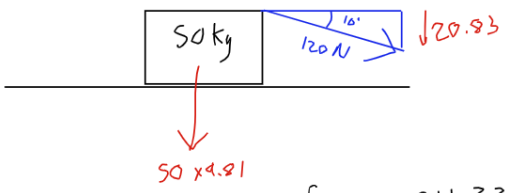
SOH

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

$\sin\theta = \frac{y}{120}$

$y = 20.83728\ N$

Vertical on Block



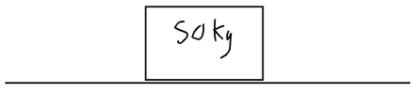
Sum of downwards forces = 511.33778 N

Friction $F = \mu N$

$F = 0.2 \times 511.33778$

$F = 102.26755$

Horizontal on Block



Net horizontal Force

Pull − Friction = Net Force

$118.1769 - 102.26755 = \boxed{15.909\ N}$

$F = ma$

$\frac{15.909}{50} = 0.3181868747\ m/s^2$

11. A screw jack is used to support a load of 300 kg. The jack has a single start square thread with a 6 mm pitch on an effective diameter of 120 mm. If the applied effort is 80 Newtons.

Determine EACH of the following:

(a) the force ratio; (3)

(b) the movement ratio; (3)

(c) the efficiency. (2)

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

Force Ratio = $\frac{\text{Force im lifting}}{\text{Force im applying}}$ $\frac{300 \times 9.81}{80} = 36.7875$

Movement Ratio = $\frac{\text{Distance I travel}}{\text{Distance load moves}} = \frac{\pi d}{6} = \frac{120\pi}{6} = 62.83185$

$Eff = \frac{36.7875}{62.83185} \times 100 = 58.547\%$

12. (a) Describe what is meant by Hooke's Law. (2)

(b) A round hole, 50 mm diameter, is to be punched through a metal plate 2 mm thick. The metal has an utimate shear strength of 120 MPa:

(i) determine the minimum force required to punch the hole; (3)

(ii) determine the maximum compressive stress on the punch during this process. (3)

1727

load

Youngs Modulus = $\frac{\text{stress}}{\text{strain}}$

Extension

1660

Hookes law

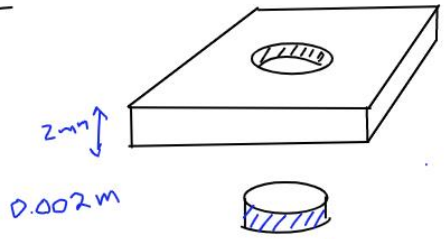
Force = konstant x (extension)

The extension of a spring is directly proportional to the force applied to it (with a spring contstant) That is to say, the more force applied to a spring, the more it will extend or compress

Area = $0.05 \times \pi \times 0.002$

$= 3.14159654 \times 10^{-4}$ m

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



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

$120 \times 10^6 = \frac{x}{3.14159654 \times 10^{-4}}$

$F = 37699.11184$ N

37.699 kN