CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

STCW 78 as amended SMALL VESSEL CHIEF ENGINEER <3000 GT, <9000 kW UNLIMITED

058-11 - GENERAL ENGINEERING SCIENCE I

FRIDAY, 08 MARCH 2024

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 showing working:

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

(b) $\left(5\frac{3}{6} - 2\frac{3}{4}\right) \times 3\frac{2}{3}$ (4)

2. A lifeboat davit has a straight arm pivoting at deck level as shown in Fig Q2. When launching the lifeboat, the davit arm makes an angle of 10° to the deck.

Determine the required length of the davit arm so that there is a clearance of 0.8 m between the ship and the lifeboat at launching. (8)

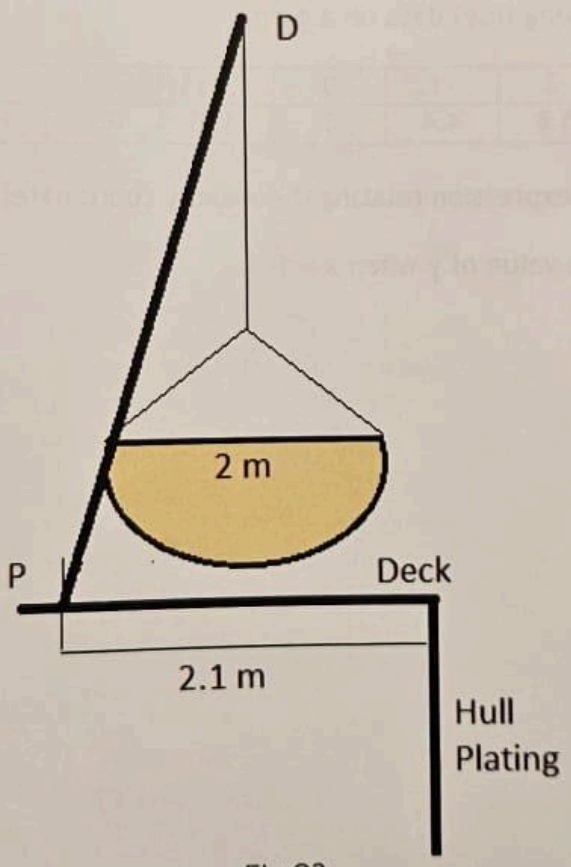


Fig Q2

3. A round copper rod 25 cm long with a diameter of 60 mm is to have a flat surface 36 mm wide ground along its length as shown in Fig Q3.

Determine the remaining mass of the copper rod. (8)

Note: the density of copper is 8750 kg/m³

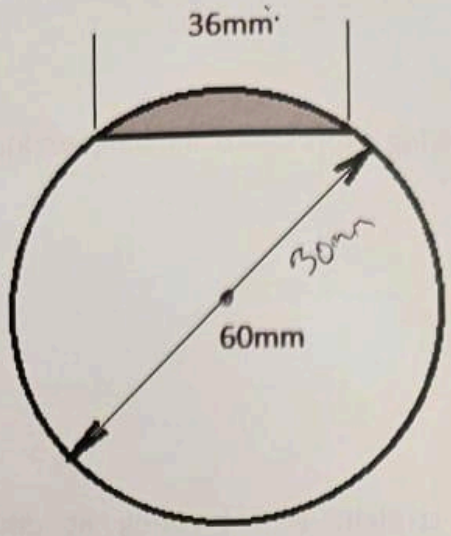


Fig Q3

4. (a) Plot the following (x,y) data on a graph: (4)

x	-2	-1	0	1	2	3
y	5.8	4.4	3	1.6	0.2	-1.2

(b) Determine an expression relating the x and y coordinates. (4)

(c) Determine the value of y when x = 1.5. (2)

5. Fig Q5 shows a diagram of a crane jib AB with load suspended from a cable OB.

Determine the angle at A that the jib makes with the wall when the cable length OB is 7 m. (8)

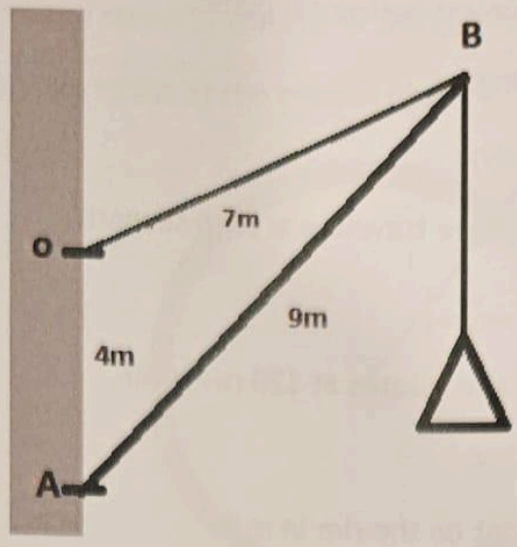


Fig Q5

6. A floating buoy is made by joining a hemispherical base to a round based cone as shown in Fig Q6. The cone height is 10 cm and the sphere has a diameter of 6 cm.

Determine EACH of the following:

(a) the total volume of the buoy; (4)

(b) the surface area of the completed buoy. (4)

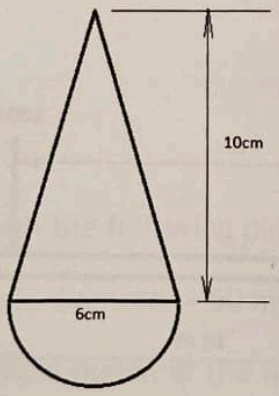


Fig Q6 (not to scale)

Section B

7. A stationary mass of 120 kg has a force of 625 N applied to it which causes accelerated motion on a frictionless horizontal plane.

Determine EACH of the following:

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

(b) the distance the body will have travelled after 6 seconds. (4)

8. A fan has a diameter of 0.5 m and rotates at 120 revs/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 fan in rads/s; (3)

(c) the number of radians turned when the fan rotates through 320°. (2)

9. A uniform beam with a mass of 800 kg is loaded as shown in Fig Q9.

Determine EACH of the following:

(a) the reaction force at the support A; (7)

(b) the reaction force at the support B. (3)

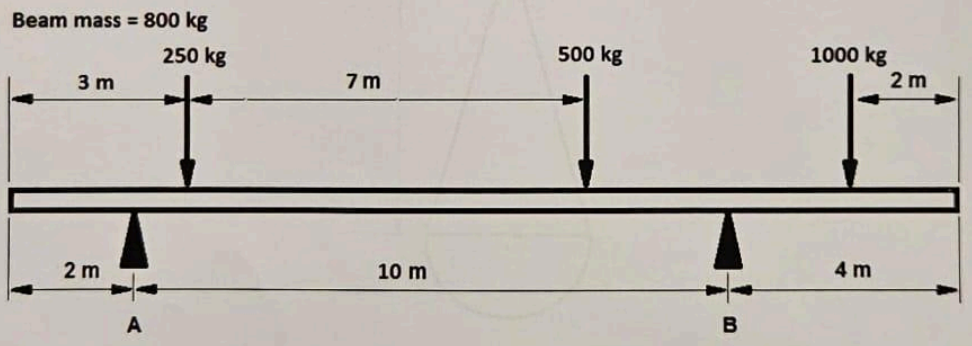


Fig Q9

10. Fig Q10 shows a section of a steel support column 20 m high. The column has a mass of 7.2 tonnes on top of it. The density of steel is 7600 kg/m^3

Determine EACH of the following:

(a) the compressive stress at the top of the column; (4)

(b) the compressive stress at the column base. (4)

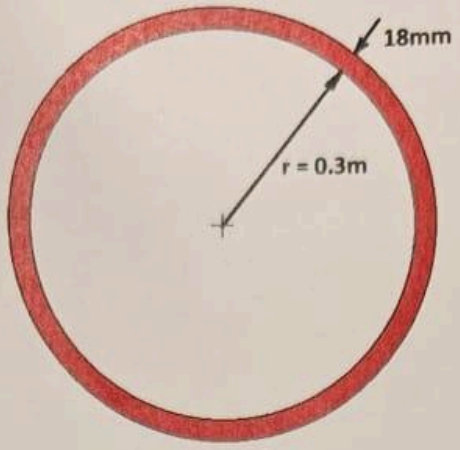


Fig Q10

11. In relation to the strength of materials explain what is meant by EACH of the following terms:

(a) Hooke's Law; (2)

(b) Young's Modulus; (2)

(c) Stress; (2)

(d) Strain. (2)

12. A hoist has a pulley and axle with the following dimensions:

Pulley diameter = 200 mm Axle diameter = 50 mm

(a) Produce a simple dimensioned sketch of the lifting machine. (2)

(b) Determine EACH of the following:

(i) the movement ratio of the machine; (3)

(ii) the efficiency of the machine if it requires an effort of 400 N to just lift a mass of 90 kg. (3)

Simplify EACH of the following expressions showing working:

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

(b) $\left(5\frac{3}{6} - 2\frac{3}{4}\right) \times 3\frac{2}{3}$ (4)

9) $\left(\frac{11}{4} \times \frac{33}{6}\right) + \frac{11}{3}$

$\frac{363}{24} + \frac{11}{3}$

$\frac{3 \times 121}{3 \times 8} + \frac{11 \times 8}{3 \times 8}$

$\frac{363}{24} + \frac{88}{24} = \frac{451}{24} = 18\frac{19}{24}$

1 Simplify EACH of the following expressions showing working:

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

(b) $\left(5\frac{3}{6} - 2\frac{3}{4}\right) \times 3\frac{2}{3}$ (4)

b) $\left(5\frac{3}{6} - 2\frac{3}{4}\right) \times 3\frac{2}{3}$

$\left(\frac{33}{6} - \frac{11}{4}\right) \times \frac{11}{3}$

$\frac{132}{24} - \frac{66}{24}$

$\frac{66}{24}$

$\frac{11}{4} \times \frac{11}{3} = \frac{121}{12}$

$= 10\frac{1}{12}$

(2) A lifeboat davit has a straight arm pivoting at deck level as shown in Fig Q2. When launching the lifeboat, the davit arm makes an angle of 10° to the deck.

Determine the required length of the davit arm so that there is a clearance of 0.8 m between the ship and the lifeboat at launching. (8)

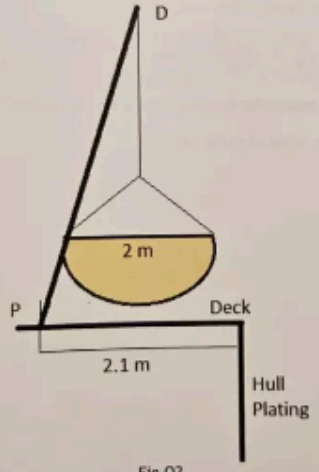
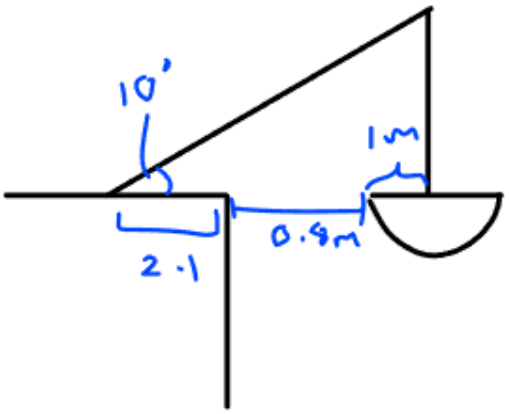
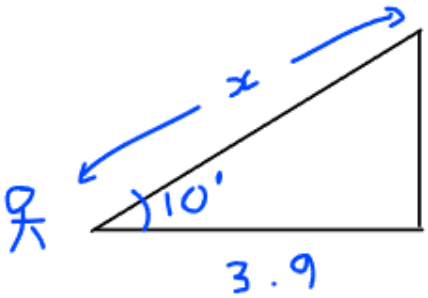


Fig Q2





CAH

$\cos 10 = \frac{3.9}{x}$

$x = \frac{3.9}{\cos 10}$

$x = 3.96016\text{m}$

3. A round copper rod 25 cm long with a diameter of 60 mm is to have a flat surface 36 mm wide ground along its length as shown in Fig Q3.

Determine the remaining mass of the copper rod. (8)

Note: the density of copper is 8750 kg/m³

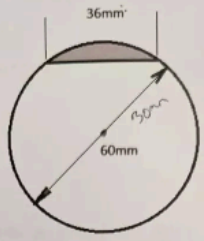
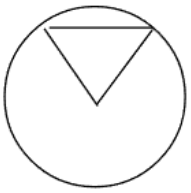
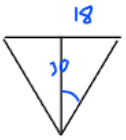
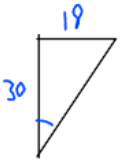


Fig Q3

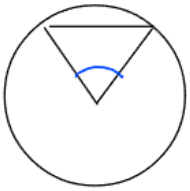
toa







$\tan^{-1}\left(\frac{18}{30}\right) = 30.963756^\circ$



$2 \times 30.963 = 61.9275^\circ$

Area of triangle $= \frac{b \times h}{2} = \frac{0.036 \times 0.030}{2} = 5.4 \times 10^{-4}\ m^2$

Area of Remaining Circle (sector) $= \frac{360 - 61.9275}{360} \times \pi r^2$

$\frac{298.075}{360} \times \pi (0.03)^2 = 2.341055941 \times 10^{-3}\ m^2$

Cross sectional Area $= 5.4 \times 10^{-4}\ m^2 + 2.341055941 \times 10^{-3} = 2.881055941 \times 10^{-3}$

Volume = Area × length

$2.881055941 \times 10^{-3} \times 0.25 = 7.202639851 \times 10^{-4}\ m^3$

Mass = Vol × density

$7.202639851 \times 10^{-4} \times 8750 = \boxed{6.3023\ kg}$

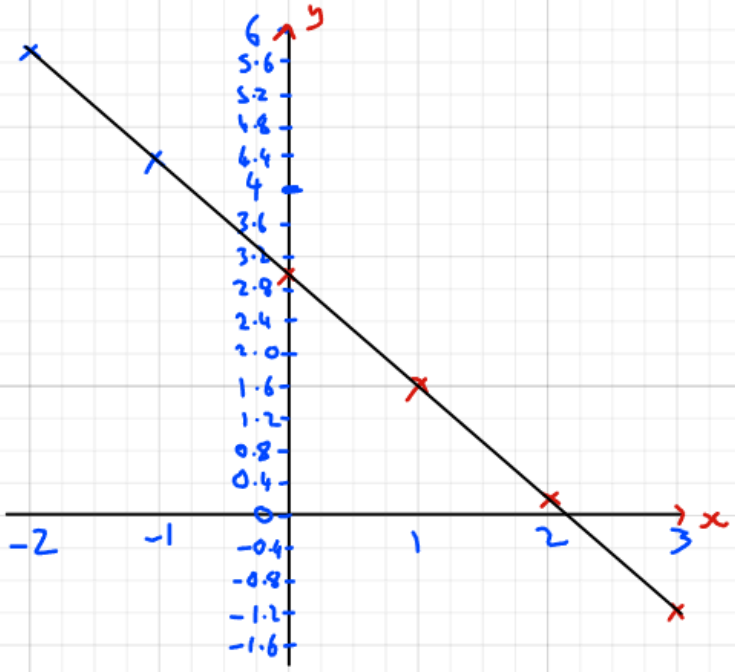
4. (a) Plot the following (x,y) data on a graph: (4)

x	-2	-1	0	1	2	3
y	5.8	4.4	3	1.6	0.2	-1.2

(b) Determine an expression relating the x and y coordinates. (4)

(c) Determine the value of y when x = 1.5. (2)

a)



b) $y = mx + c$

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\frac{1.6 - 3}{1 - 0}$$

$$= \boxed{-1.4}$$

$c = 3$

$y = -1.4x + 3$

c) $y = -1.4(1.5) + 3 = 0.9$

5. Fig Q5 shows a diagram of a crane jib AB with load suspended from a cable OB.

Determine the angle at A that the jib makes with the wall when the cable length OB is 7 m. (8)

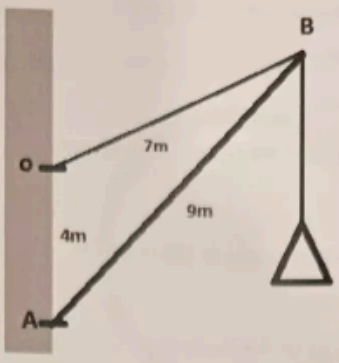
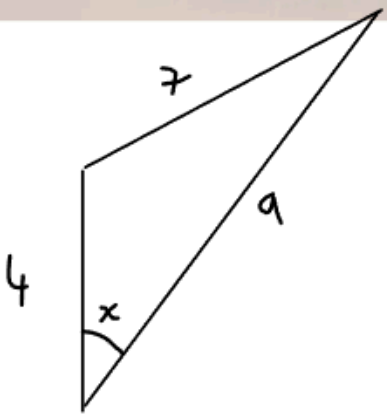


Fig Q5



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

$7^2 = 4^2 + 9^2 - 2(4)(9) \cos x$

$49 = 16 + 81 - 72 \cos x$

$49 = 97$

$\frac{49 - 97}{-72} = \cos x$

$\frac{2}{3} = \cos x$

$\cos^{-1}\left(\frac{2}{3}\right) = 48.1897°$

6. A floating buoy is made by joining a hemispherical base to a round based cone as shown in Fig Q6. The cone height is 10 cm and the sphere has a diameter of 6 cm.

Determine EACH of the following:

(a) the total volume of the buoy; (4)

(b) the surface area of the completed buoy. (4)

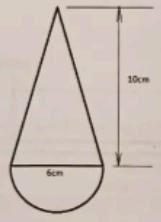
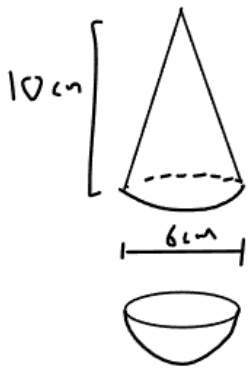


Fig Q6 (not to scale)

a)

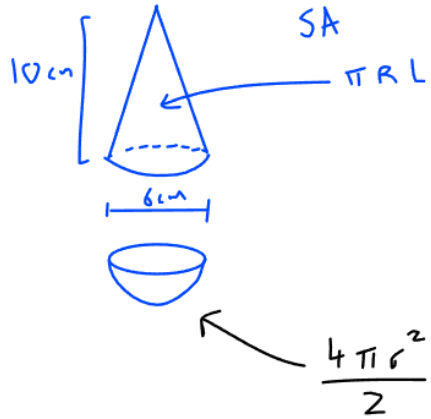


$$Vol = \frac{b \times h}{3} = \frac{\pi r^2 h}{3} = \frac{\pi 3^2 \times 10}{3} = 94.2477796\ cm^3$$

$$Vol = \frac{\frac{4}{3}\pi r^3}{2} = \frac{\frac{4}{3}\pi (3)^3}{2} = 56.54866776\ cm^3$$

$$\text{total } Vol = \boxed{150.79644\ cm^3}$$

b)



$$L = \sqrt{10^2 + 3^2} = \sqrt{109} = 10.4403\ cm$$

$$SA = \pi RL = \pi \times 3 \times 10.44 = 98.39757\ cm^2$$

$$\frac{4\pi r^2}{2} = 2\pi (3)^2 = 56.54866776\ cm^2$$

$$\text{total } SA = \boxed{154.9462\ cm^2}$$

Section B

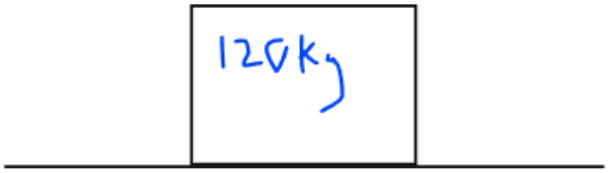
7. A stationary mass of 120 kg has a force of 625 N applied to it which causes accelerated motion on a frictionless horizontal plane.

Determine EACH of the following:

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

(b) the distance the body will have travelled after 6 seconds. (4)

a)



$F = ma$

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

$\frac{625}{120} = a$

5.20833 m/s^2

b)

s

$u = 0$

$v =$

$a = 0.192$

$t = 6$

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

$s = 0 + 0.5 \times 5.20833 \times 6^2$

$s = 93.75 \text{ m}$

8. A fan has a diameter of 0.5 m and rotates at 120 revs/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 fan in rads/s; (3)

(c) the number of radians turned when the fan rotates through 320°. (2)

a) linear vel = radius × rad/sec

$\frac{120 \text{ Rev}}{\text{min}} \xrightarrow{\times 2\pi} = \xrightarrow{\div 60} 12.5663 \text{ Rad/sec}$

$= 0.25 \times 12.5663$

$= 3.14159 \text{ m/s}$ (that's pi!)

b) 12.5663 Rad/sec

c) $\frac{320}{360} \times 2\pi = 5.585 \text{ Rads}$

Q. A uniform beam with a mass of 800 kg is loaded as shown in Fig Q9.

Determine EACH of the following:

(a) the reaction force at the support A; (7)

(b) the reaction force at the support B. (3)

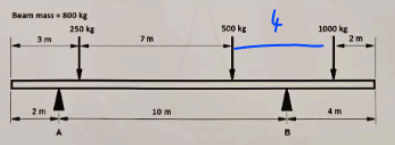
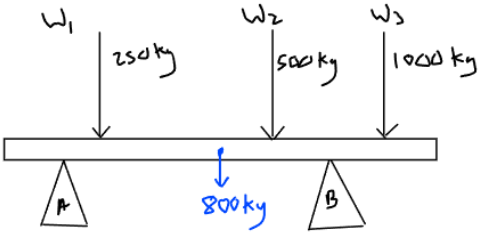


Fig Q9

16m



Beam = $\frac{16}{2}$

8 - 2 = 6

taking moments about A

Name	Mass (kg)	Force (N)	Distance (m)	Moment (Nm)	Direction C/A
W_1	250	2452.5	1	2452.5	C
W_2	500	4905	8	39240	C
W_3	1000	9810	12	117720	C
Beam	800	7848	6	47088	C
R_B		x	10	10x	A

sum of clockwise moments = sum of anticlockwise moments

2452.5
39240
117720
47088
} = 10x

206500.5 = 10x

20650.05 N = Reaction force at B

total down force = total up force

2452.5
4905
9810
7848
= $R_A + R_B$

20650.05 N

25015.5 = R_A + 20650.05

4365.45N = R_A

10. Fig Q10 shows a section of a steel support column 20 m high. The column has a mass of 7.2 tonnes on top of it. The density of steel is 7600 kg/m³

Determine EACH of the following:

(a) the compressive stress at the top of the column; (4)

(b) the compressive stress at the column base. (4)

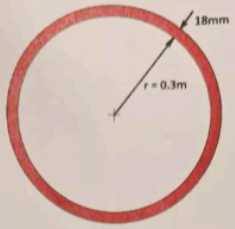
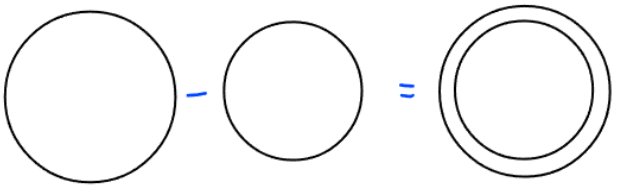


Fig Q10

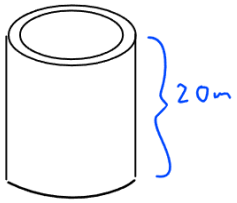
0.018
3

a) $\text{stress} = \frac{\text{Force}}{\text{Area}} = \frac{7200 \times 9.81}{0.034947} = 2{,}021{,}113.258\ N/m^2$

$\text{Area} =$  $=$

$\pi r^2 - \pi r^2 = 0.034947\ m^2$

$\pi (0.318)^2 - \pi (0.3)^2$

b) col 

$\text{Vol} = \text{Area} \times h$

$0.034947 \times 20 = 0.6989415336\ m^3$

$\text{Mass} = d \times v$

$7600 \times 0.6989415336 = 5311.9557 kg$

$\text{Stress} = \frac{F}{A} = \frac{(5311.9557 + 7200) \times 9.81}{0.034947} = 351{,}224{,}0.964\ N/m^2$

(11) In relation to the strength of materials explain what is meant by EACH of the following terms:

(a) Hooke's Law; (2)

(b) Young's Modulus; (2)

(c) Stress; (2)

(d) Strain. (2)

a)Hookes law states that the extension of a material is directly proportional to the force applied. This is still within its elastic limit

$$\text{Extension} = \text{Force} \times \text{Coefficient}$$

b) Youngs modulus is similar to Hookes law but provides us with a more detailed view

$$\text{Elasticity} = \frac{\text{stress}}{\text{strain}} = \frac{\frac{\text{Force}}{\text{Area}}}{\frac{\Delta \text{length}}{\text{length}}}$$

Youngs modulus of Elasticity has more input values than Hookes law. We need to calculate stress of strain, which can be done by dividing the force applied, over the cross sectional area (stress) then divided this by the change in length over the original length (Strain)

c) Stress is the compression, tensile of shearing force experience by an object, divided by its cross sectional area of the part affected.

The units are usually N/m^2

$$\text{stress} = \frac{\text{Force}}{\text{Area}}$$

d) Strain is effectively a measure of the extension or compression of an object. It has no units, and can be calcualted by the following formula

$$\text{Strain} = \frac{\Delta L}{L} = \frac{\text{change in length}}{\text{original length}}$$

12. A hoist has a pulley and axle with the following dimensions:

Pulley diameter = 200 mm Axle diameter = 50 mm

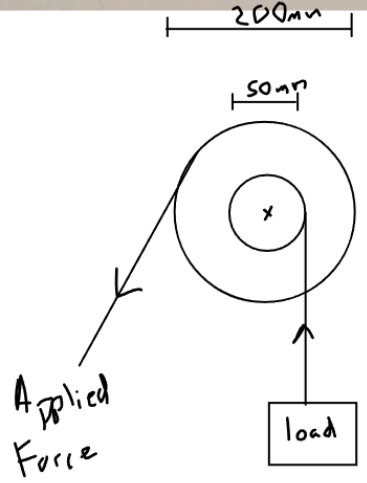
(a) Produce a simple dimensioned sketch of the lifting machine. (2)

(b) Determine EACH of the following:

(i) the movement ratio of the machine; (3)

(ii) the efficiency of the machine if it requires an effort of 400 N to just lift a mass of 90 kg. (3)

a)



bi) Movement Ratio $= \frac{\pi D}{\pi d} = \frac{200}{50} = 4$

bii) Force Ratio $= \frac{90 \times 9.81}{400} = 2.20725$

$\text{Eff} = \frac{F}{M} = \frac{2.20725}{4} = 55.18125\%$