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, 03 OCTOBER 2025

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

Attempt ALL questions

Marks for each question are shown in brackets.

Section A

1. Simplify EACH of the following giving the answer as a mixed number:

(a) $\left(2\frac{4}{9} + 4\frac{2}{3}\right) \div 2\frac{4}{7}$ (4)

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

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

$$Y = \frac{W^3 X^4 Z^3}{X Y^2} \div \frac{W^3 X Y^2}{X^3 Z^2}$$ (4)

(b) Simplify the following expression:

$$\frac{3}{2} \times \frac{2X}{3} + \frac{4X}{5}$$ (4)

3. (a) State the law of a straight line graph explaining the terms. (3)

(b) Plot and join the pairs of points shown in Table Q3. (3)

(c) From the graph, determine the equation linking X and Y. (2)

X	-2	-1	0	1	2	3
Y	-9	-5.5	-2	1.5	5	8.5

Table Q3

24

[OVER

4. A right cone has a sloping side of 340 mm and a perpendicular height of 300 mm.

   (a) Calculate EACH of the following:

   (i) the volume of the cone in m^3; (2)

   (ii) the angle of the sloping side; (3)

   (iii) the surface area of the cone in mm^2 (excluding the base). (3)

5. (a) State Pythagoras' theorem. (2)

   (b) 3 circles are shown in Fig Q5 resting on a flat surface. The two larger circles have the same diameter. For the arrangement shown determine the size of the smaller circle relative to the larger circles. (8)

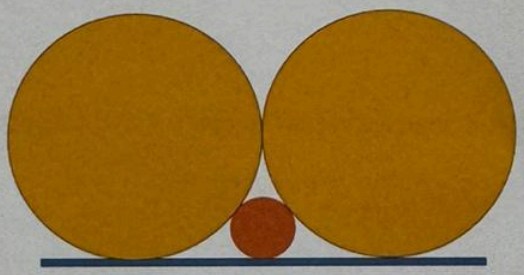

Fig Q5

6. A brass rod of 100 mm diameter is to be melted to cast a sphere and a cube. The diameter of the sphere is to be 6 cm and the cube is to have the same mass as the sphere.

   Determine the length of bar stock required with no material wasted. (8)

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Section B

7. A vehicle has a maximum acceleration of 5.2 m/s^2 and a maximum deceleration (retardation) of 7.2 m/s^2.

   (a) Draw a velocity / time diagram representing the maximum distance the vehicle can travel in 10 seconds starting and finishing at rest and never moving at constant velocity. (4)

   (b) Determine the maximum distance the vehicle can travel in 10 seconds starting and finishing at rest. (3)

   (c) Determine the maximum velocity of the vehicle. (3)

8. A beam has a mass of 100 kg and is loaded as shown in FIG Q8.

   Determine the reaction forces at the supports A and B. (8)

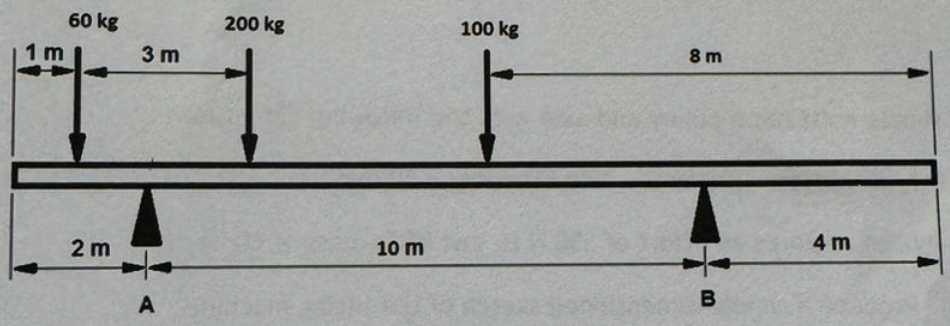


FIG Q8

9. A block with a mass of 1.5 kg is placed at the top of a sloping surface with a length of 3 m. The slope makes an angle of 38° to the horizontal and has a coefficient of friction of 0.3. When the block is released it slides down the slope.

   Determine EACH of the following:

   (a) the friction force; (2)

   (b) the accelerating force; (2)

   (c) the time taken to slide down to the bottom of the slope; (2)

   (d) the velocity of the block at the bottom of the slope. (2)

10. A generator flywheel has a diameter of 0.85 m and rotates at 9500 rad/min.

Calculate 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 number of radians turned when the flywheel rotates through 150°. (2)

11. (a) State Hookes Law. (2)

(b) A round hole, 65 mm diameter, is to be punched through a metal plate 1.5 mm thick. The metal has a shear strength of 220 MPa.

Determine EACH of the following:

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

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

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

Pulley diameter = 200 mm Axle diameter = 50 mm

The hoist requires an effort of 550 N to just lift a mass of 60 kg.

(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. (3)

1. Simplify EACH of the following giving the answer as a mixed number:

(a) $\left(2\frac{4}{9} + 4\frac{2}{3}\right) \div 2\frac{4}{7}$ (4)

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

a) $\left(2\frac{4}{9} + 4\frac{2}{3}\right) \div 2\frac{4}{7}$

$\left(\frac{22}{9} + \frac{14 \times 3}{3 \times 3}\right) \div \frac{18}{7}$

$\left(\frac{22}{9} + \frac{42}{9}\right)$

$\frac{64}{9} \times \frac{7}{18} = \frac{448}{162} = \frac{224}{81}$

$= \boxed{2\frac{62}{81}}$

1. Simplify EACH of the following giving the answer as a mixed number:

(a) $\left(2\frac{4}{9} + 4\frac{2}{3}\right) \div 2\frac{4}{7}$ (4)

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

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

$$\left(\frac{14}{5} \div \frac{13}{9}\right) \times \frac{5}{3}$$

$$\left(\frac{14}{5} \times \frac{9}{13}\right) \times \frac{5}{3}$$

$$\frac{126}{65} \times \frac{5}{3} = \frac{630}{195} = \frac{42}{13}$$

$$\boxed{3\frac{3}{13}}$$

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

$$Y = \frac{W^3X^4Z^3}{XY^2} \div \frac{W^3XY^2}{X^3Z^2} \quad (4)$$

(b) Simplify the following expression:

$$\frac{3}{2} \times \frac{2X}{3} + \frac{4X}{5} \quad (4)$$

a) $$Y = \frac{W^3X^4Z^3}{XY^2} \div \frac{W^3XY^2}{X^3Z^2}$$

$$Y = \frac{W^3X^4Z^3}{XY^2} \times \frac{X^3Z^2}{W^3XY^2}$$

$$y = \frac{W^3X^7Z^5}{W^3X^2y^4}$$

$$y = \frac{x^5z^5}{y^4}$$

$$y^5 = x^5z^5$$

$$\frac{y^5}{z^5} = x^5$$

$$\sqrt[5]{\frac{y^5}{z^5}} = x$$

you could be done here, as the question doesnt say simplify FULLY,

or.....

$$\boxed{\frac{y}{z} = x}$$

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

$$Y = \frac{W^3X^4Z^3}{XY^2} \div \frac{W^3XY^2}{X^3Z^2} \quad (4)$$

(b) Simplify the following expression:

$$\frac{3}{2} \times \frac{2X}{3} + \frac{4X}{5} \quad (4)$$

b) $\frac{3}{2} \times \frac{2x}{3} + \frac{4x}{5}$

$\frac{5 \times x}{5 \times 1} + \frac{4x \times 1}{5 \times 1}$

$\frac{5x}{5} + \frac{4x}{5} = \boxed{\frac{9x}{5}}$

3. (a) State the law of a straight line graph explaining the terms. (3)

(b) Plot and join the pairs of points shown in Table Q3. (3)

(c) From the graph, determine the equation linking X and Y. (2)

X	-2	-1	0	1	2	3
Y	-9	-5.5	-2	1.5	5	8.5

Table Q3

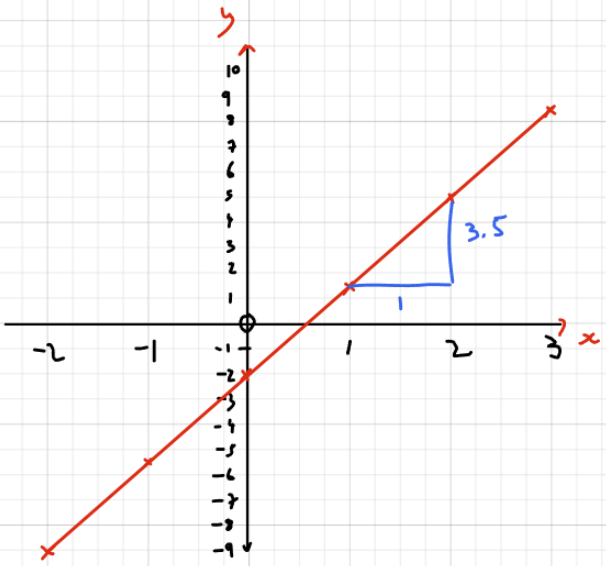
a) $y = mx + c$

m = gradient or slope

$$\frac{\text{Rise}}{\text{Run}} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

c = y intercept

b)



c) $y = mx + c$

$m = \frac{\text{Rise}}{\text{Run}} = \frac{3.5}{1} = 3.5$

$c = -2$

$y = 3.5x - 2$

4. A right cone has a sloping side of 340 mm and a perpendicular height of 300 mm.

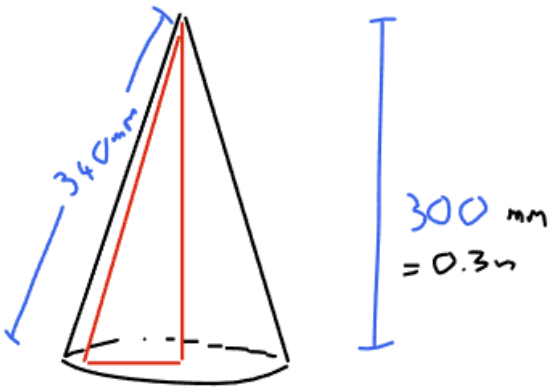
(a) Calculate EACH of the following:

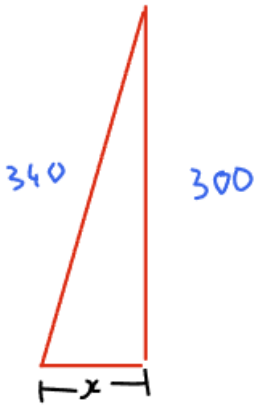
(i) the volume of the cone in m^3; (2)

(ii) the angle of the sloping side; (3)

(iii) the surface area of the cone in mm^2 (excluding the base). (3)

a)





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

$300^2 + x^2 = 340^2$

$x = \sqrt{340^2 - 300^2}$

$x = 160$ mm

0.16 m

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

$$= \frac{\pi (0.16)^2 \times 0.3}{3}$$

$$= \boxed{8.042477 \times 10^{-3}\ m^3}$$

OR $0.00804247\ m^3$

4. A right cone has a sloping side of 340 mm and a perpendicular height of 300 mm.

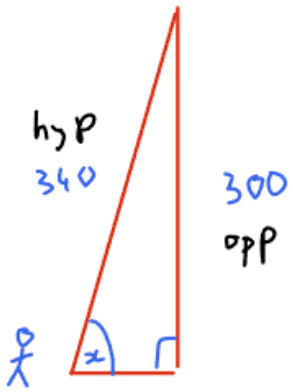
(a) Calculate EACH of the following:

(i) the volume of the cone in m^3; (2)

(ii) the angle of the sloping side; (3)

(iii) the surface area of the cone in mm^2 (excluding the base). (3)

ii)



the angle of the sloping side? from the horizontal, or the vertical?

SOH
CAH
TOA

$\sin\theta = \frac{O}{H}$

$\sin x = \frac{300}{340}$

$x = \sin^{-1}\left(\frac{300}{340}\right)$

$x = 61.928^\circ$

degrees of elevation from horizontal.

5. (a) State Pythagoras' theorem. (2)

(b) 3 circles are shown in Fig Q5 resting on a flat surface. The two larger circles have the same diameter. For the arrangement shown determine the size of the smaller circle relative to the larger circles. (8)

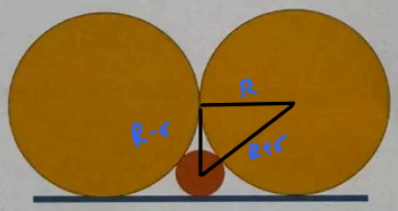
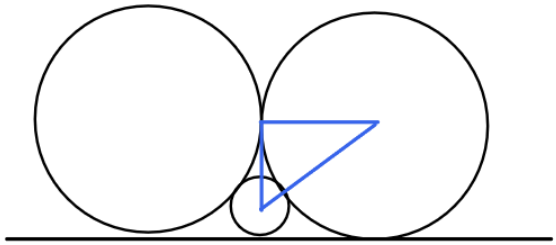
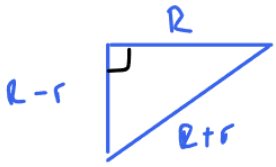


Fig Q5

5a) $a^2+b^2=c^2$





$$(R-r)^2+(R)^2=(R+r)^2$$

$$(R-r)(R-r)+R^2=(R+r)(R+r)$$

$$R^2-2Rr+r^2+R^2=R^2+2Rr+r^2$$

$$-2Rr+R^2=2Rr$$

$$R^2=4Rr$$

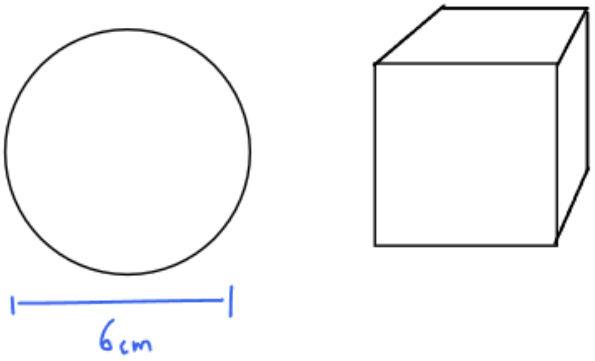
$$R=4r$$

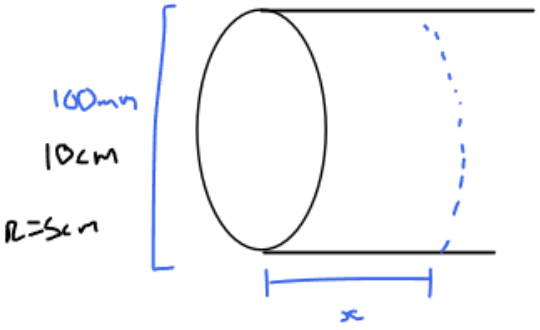
Small Radius : Large Radius

1 : 4

6. A brass rod of 100 mm diameter is to be melted to cast a sphere and a cube. The diameter of the sphere is to be 6 cm and the cube is to have the same mass as the sphere.

Determine the length of bar stock required with no material wasted. (8)





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

$\left(\frac{4}{3}\pi 3^3\right) \times 2$

$(113.097) \times 2$

$226.19467\ cm^3$

$Vol = \pi R^2 h$

$226.19467 = \pi (5^2) x$

$226.19467 = 78.5391\, x$

$\frac{226.19467}{78.5391} = x$

$2.879999 = x$

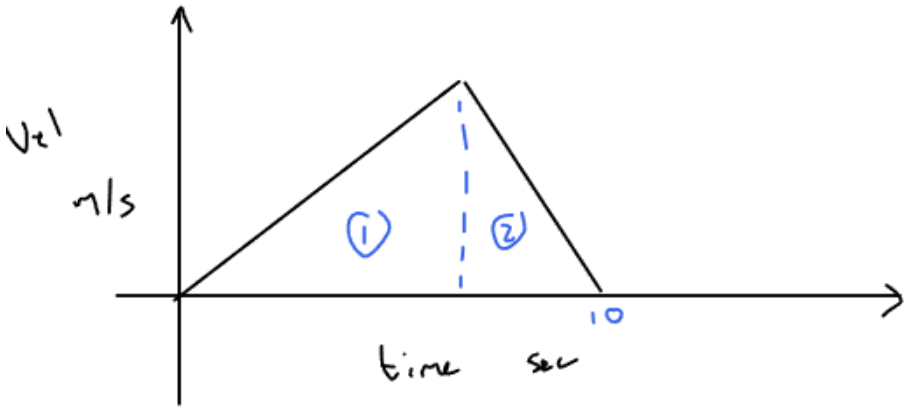
$2.88\ cm$

7. A vehicle has a maximum acceleration of 5.2 m/s² and a maximum deceleration (retardation) of 7.2 m/s².

(a) Draw a velocity / time diagram representing the maximum distance the vehicle can travel in 10 seconds starting and finishing at rest and never moving at constant velocity. (4)

(b) Determine the maximum distance the vehicle can travel in 10 seconds starting and finishing at rest. (3)

(c) Determine the maximum velocity of the vehicle. (3)



$V = u + at$

① ②

① s, $u = 0$, $v = z$, $a = 5.2\ m/s^2$, $t = x$

② s, $u = z$, $v = 0$, $a = 7.2\ m/s^2$, $t = y$

the same

$v = u + at$ $\qquad$ $v = u + at$

$z = 0 + 5.2x$ $\qquad$ $0 = z + 7.2y$

$z = 5.2x$ $\qquad$ $-7.2y = z$

$$5.2x = -7.2y$$

x and y are the times for the acceleration period, and the retardation period, we also know they sum to 10 as its given in the question

$x + y = 10$ $\qquad$ $x = y - 10$

$$5.2(x) = -7.2y$$

$$5.2(y - 10) = -7.2y$$

$$5.2y - 52 = -7.2y$$

$$12.4y = 52$$

$$y = 4.193548 \text{ sec}$$

$$x = 10 - 4.193548 = 5.80645 \text{ sec}$$

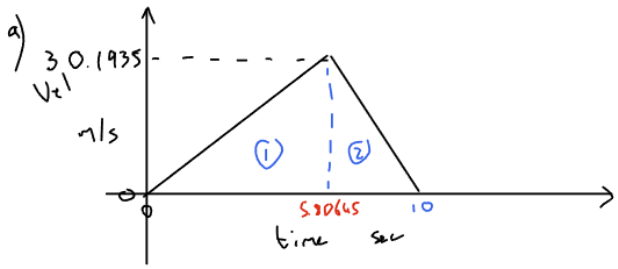
now we can find vel

$z = 5.2x$

$z = 5.2 \times 5.80645$

30.1935 m/s

a)



7. A vehicle has a maximum acceleration of 5.2 m/s² and a maximum deceleration (retardation) of 7.2 m/s².

(a) Draw a velocity / time diagram representing the maximum distance the vehicle can travel in 10 seconds starting and finishing at rest and never moving at constant velocity. (4)

(b) Determine the maximum distance the vehicle can travel in 10 seconds starting and finishing at rest. (3)

(c) Determine the maximum velocity of the vehicle. (3)

b) $\text{dis} = \text{Area under graph} = \frac{10 \times 30.1935}{2} = 150.97 \text{ m}$

c) $\text{vel} = 30.1935 \text{ m/s}$

this is a load?

8. A beam has a mass of 100 kg and is loaded as shown in FIG Q8.

Determine the reaction forces at the supports A and B. (8)

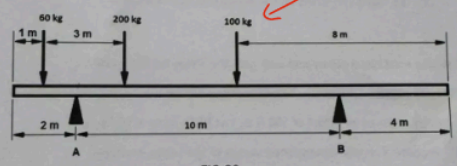
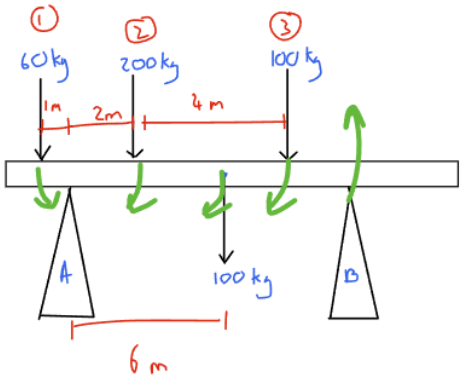


FIG Q8



Beam/2 − overhang

16/2 − 2

8 − 2 = 6

Taking moments about A

Name	Mass (kg)	Force (N)	Dist (m)	Moment (N_m)	Dir A/C
W_1	60	588.6	1	588.6	A
W_2	200	1962	2	3924	C
W_3	100	981	6	5886	C
Beam	100	981	6	5886	C
R_B		x	10	10x	A

Sum of clockwise moments = Sum of anticlockwise moments

3924
5886
5886 } = 588.6 + 10x

15696 = 588.6 + 10x

1510.74 = 10x

1510.74 N = R_B

Sum of down forces = Sum of Upwards Forces

588.6
1962
981
981 } = $R_A + R_B$

4512.6 = R_A + 1510.74

3001.86 N = R_A

9. A block with a mass of 1.5 kg is placed at the top of a sloping surface with a length of 3 m. The slope makes an angle of 38° to the horizontal and has a coefficient of friction of 0.3. When the block is released it slides down the slope.

Determine EACH of the following:

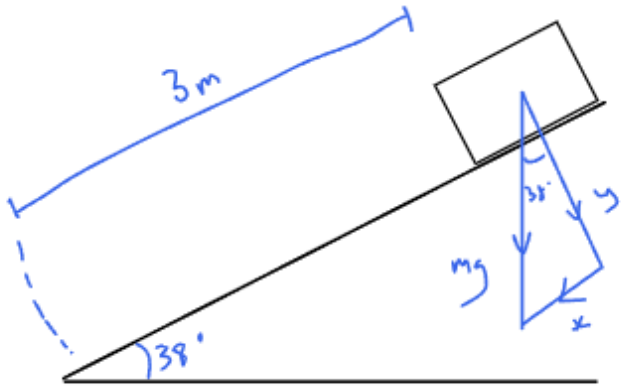
(a) the friction force; (2)

(b) the accelerating force; (2)

(c) the time taken to slide down to the bottom of the slope; (2)

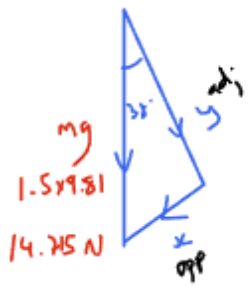
(d) the velocity of the block at the bottom of the slope. (2)

the slope is 3m long, and the box is at the top?! how wide is the box? I will assume you mean this setup I have drawn



SOH
CAH
TOA

OK



Force x	Force y
SOH	CAH
$\sin\theta = \frac{opp}{hyp}$	$\cos 38 = \frac{y}{14.715}$
$\sin 38 = \frac{x}{14.715}$	$14.715 \cos 38 = y$
$14.715 \sin 38 = x$	
9.05945 N ←	11.595578 N ↓
Push	down
down slope	into slope (Normal)

9. A block with a mass of 1.5 kg is placed at the top of a sloping surface with a length of 3 m. The slope makes an angle of 38° to the horizontal and has a coefficient of friction of 0.3. When the block is released it slides down the slope.

Determine EACH of the following:

(a) the friction force; (2)

(b) the accelerating force; (2)

(c) the time taken to slide down to the bottom of the slope; (2)

(d) the velocity of the block at the bottom of the slope. (2)

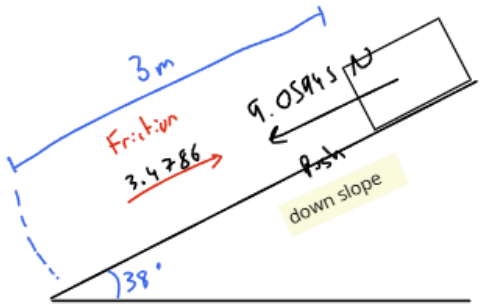
c)

a) Friction = μN

$0.3(11.595578)$

$\boxed{3.4786\ N}$

b)



Net (Almost) Horizontal

Push - Fric

$9.05945 - 3.4786 = \boxed{5.58077\ N}$

this is accel force

c) $F = ma$

$5.58077 = 1.5x$

$\frac{5.58077}{1.5} = x$

$3.7205\ m/s^2$ correct

$s = 3$

$u = 0$

v

$a = 3.7205$

$t = x$

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

$3 = 0 + 0.5(3.7205)x^2$

$\frac{3}{1.86025} = x^2$

$\sqrt{1.61267} = x$

$1.2699\ sec$

d) $s = 3$

$u = 0$

$v = x$

$a = 3.7205$

$t = 1.2699\ sec$

$v = u + at$

$x = 1.2699 \times 3.7205$

$x = 4.72471\ m/s$

10. A generator flywheel has a diameter of 0.85 m and rotates at 9500 rad/min.

Calculate 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 number of radians turned when the flywheel rotates through 150°. (2)

a) lin vel = Rad/sec × Radius

$\frac{9500 \text{ Rad}}{\text{min}} \div 60 = 158.333 \text{ Rad/s}$

dia = 0.85 m Radius = 0.425 m

lin vel = 0.425×158.333

$\boxed{67.292 \text{ m/s}}$

10. A generator flywheel has a diameter of 0.85 m and rotates at 9500 rad/min.

Calculate 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 number of radians turned when the flywheel rotates through 150°. (2)

b)

Deg	Rev	Rad
360	1	2π

$\div 360$ $\times 2\pi$ $\div 2\pi$

$9500 \div (2\pi) = 1511.97$ Rev/min

c) $\frac{150}{360} \times 2\pi =$ **2.61799 Radians**

11. (a) State Hookes Law. (2)

(b) A round hole, 65 mm diameter, is to be punched through a metal plate 1.5 mm thick. The metal has a shear strength of 220 MPa.

Determine EACH of the following:

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

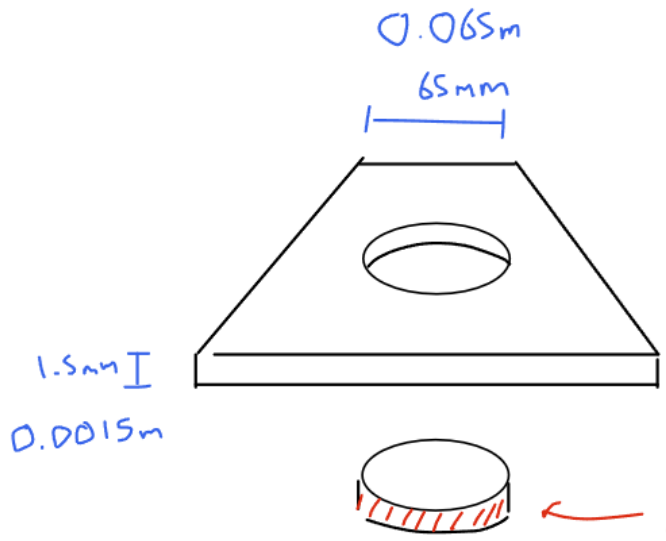
(ii) the maximum stress on the punch during this process. (3)

a)

hookes law states that the extension of a spring is directly proportional to the force applied to it

$$\text{extension} = \frac{\text{Spring}}{\text{constant}} \times \text{Force}$$

b)



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

$\text{Stress} = 220\ MPa$

$220 \times 10^6\ N/m^2$

$\text{Area} = \pi dh$

$\text{Area} = \pi\ 0.065 \times 0.0015$

$= 3.06305 \times 10^{-4}\ m^2$

$\text{Stress} \times \text{Area} = \text{Force}$

$220 \times 10^6 \times 3.06305 \times 10^{-4} = \text{Force}$

$\boxed{67,387.16\ N}$

11. (a) State Hookes Law. (2)

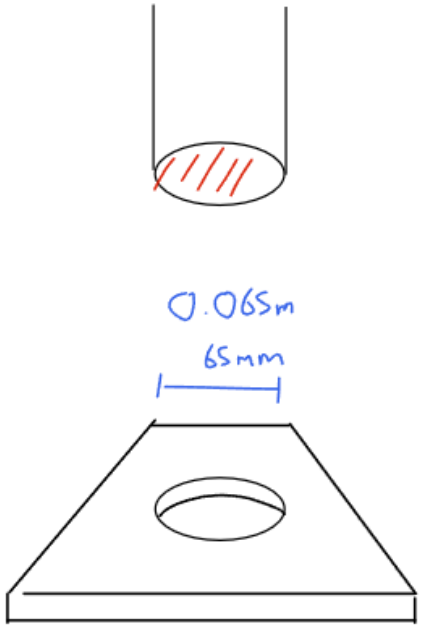
(b) A round hole, 65 mm diameter, is to be punched through a metal plate 1.5 mm thick. The metal has a shear strength of 220 MPa.

Determine EACH of the following:

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

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

bii)



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

$$\text{Force} = 67,387.16\ N$$

$$\text{Area} = \pi R^2 = \pi \left(\frac{65}{2000}\right)^2$$

$$3.3183 \times 10^{-3}$$

$$\text{Stress} = \frac{67,387.16}{3.3183 \times 10^{-3}}$$

$$= 20,307,691.58\ N/m^2$$

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

Pulley diameter = 200 mm Axle diameter = 50 mm

The hoist requires an effort of 550 N to just lift a mass of 60 kg.

(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. (3)

12. A simple hoist has a pulley and axle with the following dimensions:
Pulley diameter = 200 mm Axle diameter = 50 mm
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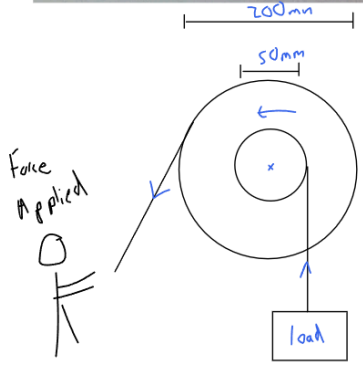
(a) Produce a simple dimensioned sketch of the lifting machine. (2)
(b) Determine EACH of the following:
(i) the movement ratio of the machine; (3)
(ii) the efficiency of the machine. (3)

a)



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

$\text{Force Ratio} = \frac{\text{Force to lift load}}{\text{Force I Apply}} = \frac{60 \times 9.81}{550} = 1.0701818$

b) i) $\text{movement ratio} = \frac{\text{Distance I move}}{\text{Dist load moves}} = \frac{\pi D}{\pi d} = \frac{200}{50} = 4$

ii) $Eff = \frac{F}{M} = \frac{1.0701818}{4} \times 100 = 26.754\%$