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, 17 JUNE 2022

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. (a) Determine the value of 'x' in the following expression if a = -4, b = -5, c = -3:

$$a^2x + bc = cx$$ (4)

(b) Simplify the following expression:

$$\left(\frac{4}{7} + 3\frac{4}{5}\right) \times 2\frac{1}{2}$$ (4)

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

$$s = ut + \frac{1}{2}at^2$$ (4)

(b) Simplify the following expression:

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

3. (a) Plot the points shown in Table Q3 using an appropriate scale and draw the best fit line. (4)

(b) State the general law of a straight line graph. (2)

(c) Determine the equation that best represents the data from your graph. (4)

x	-2.00	0.00	2.00	4.00	6.00	8.00
y	-1.67	-1.00	-0.33	0.33	1.00	1.67

Table Q3

4. (a) State Pythagoras's Theorum, for the triangle shown in FIG Q4. (2)

(b) Calculate EACH of the following:

(i) the length of AC; (3)

(ii) the angle at C. (3)

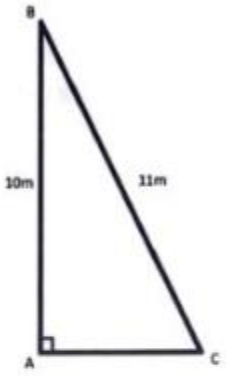


Fig Q4

5. (a) Define the term scalene triangle. (2)

(b) For the shape shown in FIG Q5, determine the angle MBD describing your reasoning. (6)

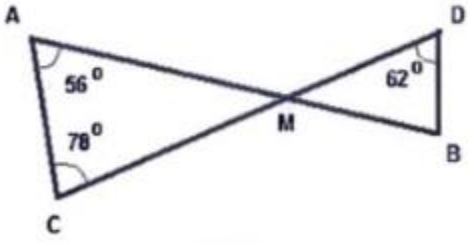


FIG Q5

6. For the diagram shown in FIG Q6, determine the area of the shaded section when r is 2 cm. (8)

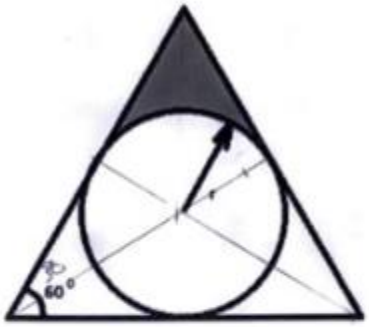


FIG Q6

Section B

7. A pump is accelerated from 200 rpm to 1000 rpm in 20 seconds.

Calculate EACH of the following:

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

(b) the final instantaneous linear velocity in m/s of a point on the pump impellor perimeter with an effective diameter of 0.3 m. (4)

8. A casting of mass of 26 kg has a horizontal force of 180 N applied to it which causes acceleration in a frictionless horizontal plane.

Calculate EACH of the following, ignoring friction:

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

(b) the distance the body will travel from rest in 8 seconds. (4)

9. FIG Q9 shows a loaded uniform beam with a mass 800 kg.

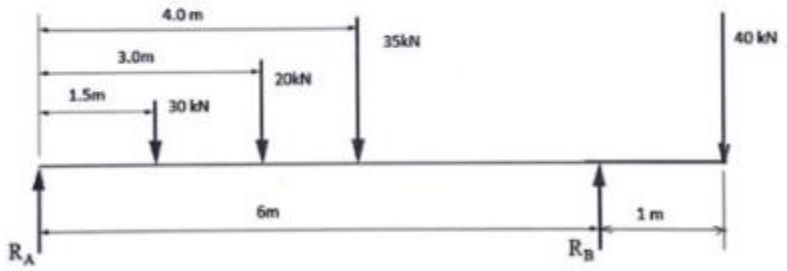


Fig Q9 (not to scale)

Calculate EACH of the reaction forces at A and B. (10)

10. (a) For a simple machine define the term Force Ratio. (2)

(b) For a simple machine define the term Velocity Ratio. (2)

(c) State the expression for mechanical efficiency of a simple machine in terms of force ratio and velocity ratio. (2)

(d) State why mechanical efficiency is always less than 100%. (2)

11. (a) Describe what is meant by shear stress. (2)

(b) A hydraulic press is used to punch rivet holes in metal plate. The plate is 5 mm thick and the holes required should have a diameter of 10 mm. A force of 40 kN is required to punch the hole.

Determine the shear stress at failure of the metal plate (6)

12. (a) State the difference between static and dynamic friction. (2)

(b) A container has a mass of 400 kg and is pulled along a horizontal plane by a cable. The cable makes an angle of 10° above the horizontal and has a tension of 1.8 kN when pulling the container at a constant speed.

Determine the coefficient of friction between the container and surface. (6)

Section A

1. (a) Determine the value of 'x' in the following expression if a = -4, b = -5, c = -3:

$a^2x + bc = cx$ (4)

(b) Simplify the following expression:

$\left(\frac{4}{7} + 3\frac{4}{5}\right) \times 2\frac{1}{2}$ (4)

1a) $(-4)^2 x + (-5)(-3) = (-3)x$

$16x + 15 = -3x$

$19x + 15 = 0$

$19x = -15$

$x = \frac{-15}{19}$

b) $\left(\frac{4}{7} + 3\frac{4}{5}\right) \times 2\frac{1}{2}$

$\left(\frac{4}{7} + \frac{19}{5}\right) \times \frac{5}{2}$

$\left(\frac{4 \times 5}{7 \times 5} + \frac{19 \times 7}{5 \times 7}\right) \times \frac{5}{2}$

$\left(\frac{20}{35} + \frac{133}{35}\right) \times \frac{5}{2}$

$\frac{153}{35} \times \frac{5}{2}$

$\frac{765}{70} = \begin{matrix}\div 5 \\ \div 5\end{matrix} = \frac{153}{14} = 10\frac{13}{14}$

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

$s = ut + \frac{1}{2}at^2$ (4)

(b) Simplify the following expression:

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

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

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

$2(s-ut) = 2 \times \frac{1}{2}at^2$

$2(s-ut) = at^2$

$\frac{2(s-ut)}{t^2} = a$

$a = \frac{2(s-ut)}{t^2}$

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

$$\frac{9x - 4x}{6} + \frac{4x}{5}$$

$$\frac{5x}{6} + \frac{4x}{5}$$

$$\frac{25x + 24x}{30} = \frac{49}{30}x$$

$$\left(1\ \frac{19}{30}\right)x$$

3. (a) Plot the points shown in Table Q3 using an appropriate scale and draw the best fit line. (4) ✓

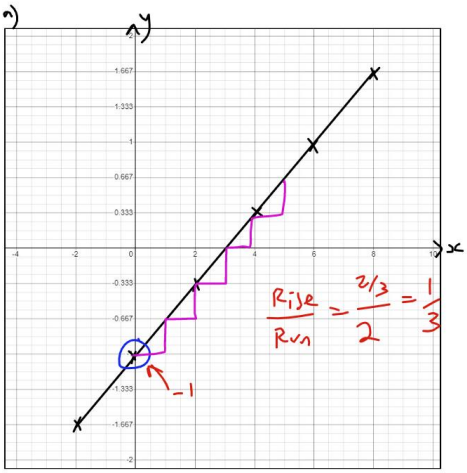
(b) State the general law of a straight line graph. (2)

(c) Determine the equation that best represents the data from your graph. (4)

x	-2.00	0.00	2.00	4.00	6.00	8.00
y	-1.67	-1.00	-0.33	0.33	1.00	1.67

Table Q3

a)



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

b) $y = mx + c$

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

4. (a) State Pythagoras's Theorum, for the triangle shown in FIG Q4. (2)

(b) Calculate EACH of the following:

(i) the length of AC; (3)

(ii) the angle at C. (3)

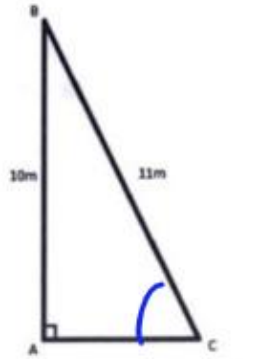


Fig Q4

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

$10^2 + (AC)^2 = 11^2$

bi)

$$AC^2 = 11^2 - 10^2$$

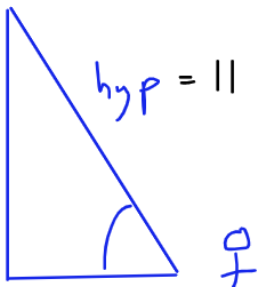
$$AC^2 = 121 - 100$$

$$AC^2 = 21$$

$$AC = \sqrt{21} = 4.5826 \text{ m}$$

bii)

10 = opp



SOH
CAH
TOA

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

$$\sin\theta = \frac{10}{11}$$

$$\theta = \sin^{-1}\left(\frac{10}{11}\right) = 65.38^\circ$$

5. (a) Define the term scalene triangle. (2)

(b) For the shape shown in FIG Q5, determine the angle MBD describing your reasoning. (6)

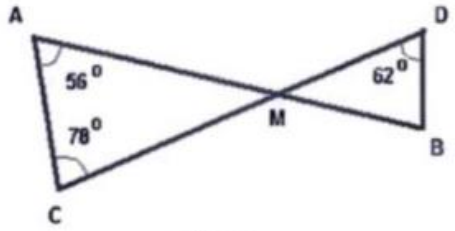
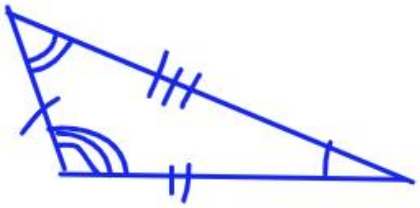


FIG Q5

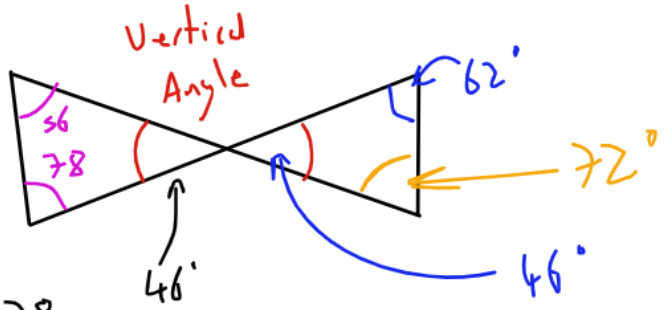
a)



All sides different

All angles different

b)



78 + 56 = 134

180 − 134 = 46

anlges in a triangle sum to 180°

vertical angles have the same value

46 + 62 = 108

180 − 108 = 72

6. For the diagram shown in FIG Q6, determine the area of the shaded section when r is 2 cm. (8)

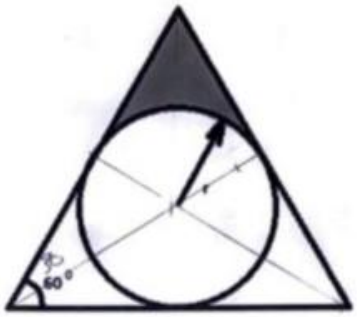
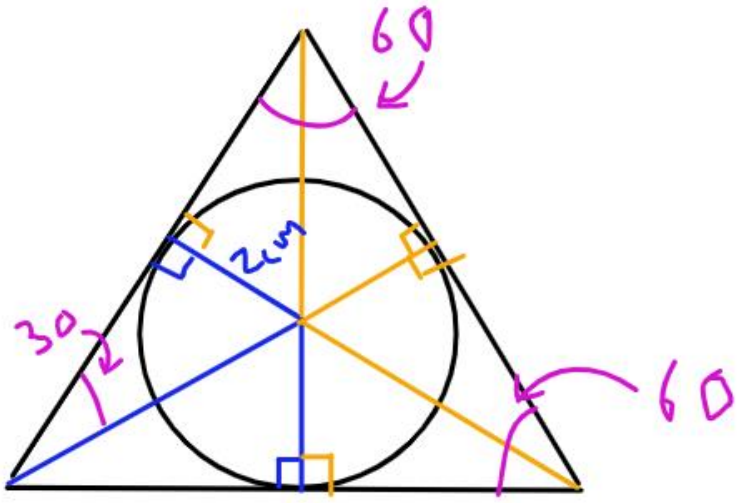
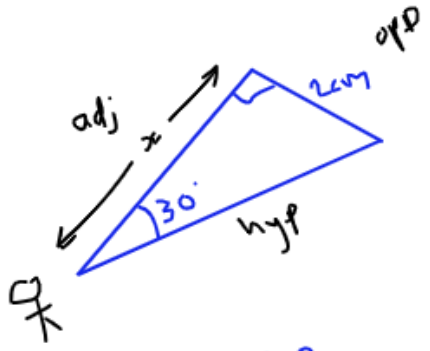


FIG Q6





SOH
CAH
TOA

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

$\tan 30 = \frac{2}{x}$

$x = \frac{2}{\tan 30} = 2\sqrt{3} = 3.464$

$\text{Area} = \frac{b \times h}{2} = \frac{2\sqrt{3} \times 2}{2} = 2\sqrt{3}$

Area of 6 triangles = 1 big triangle

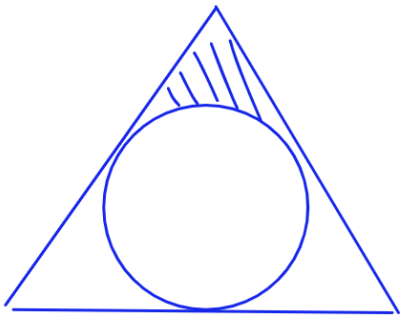
$6 \times 2\sqrt{3} = 20.7846\ cm^2$

Area of circle

$$\pi r^2 = \pi (2)^2 = 12.5663\ldots$$

$$\frac{(\text{triangle} - \text{circle})}{3} = 2.7394\ldots \text{ cm}^2$$

we divide by 3, as we only want a little section of it.



Section B

7. A pump is accelerated from 200 rpm to 1000 rpm in 20 seconds.

Calculate EACH of the following:

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

(b) the final instantaneous linear velocity in m/s of a point on the pump impellor perimeter with an effective diameter of 0.3 m. (4)

$\frac{200 \text{ Rev}}{1 \text{ min}} \xrightarrow{\times 2\pi} \frac{1256.637 \text{ Rd}}{60 \text{ sec}} \div 60 \div 60 = \frac{20.94395 \text{ Rads/sec}}{1}$

$\frac{1000 \text{ Rev}}{1 \text{ min}} = \frac{6283.1853 \text{ Rd}}{60 \text{ sec}} = \frac{104.719755 \text{ Rads sec}}{1}$

$s =$
$u = 20.94395$
$v = 104.719755$
$a =$
$t = 20$

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

$$v = u + at$$

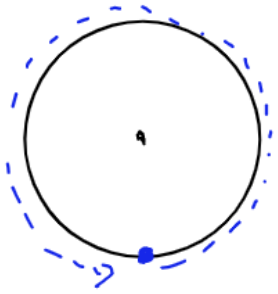
$$s = ut + \frac{1}{2}at^2$$

$$104.719755 = 20.94395 + a20$$

$$\frac{104.719755 - 20.94395}{20} = a$$

$$4.18879 \text{ Rads}/s^2$$

b)



$$\text{speed} = \frac{\text{dis}}{\text{time}}$$

$$\text{circ} = \pi d$$

$$\text{Vel} = 1000 \text{ rpm}$$

$$\text{Vel} = \frac{1000 \times \pi \, 0.3}{60 \text{ sec}} = \frac{942.4777961 \text{ m}}{60 \text{ sec}}$$

$$\frac{942.48}{60} \xrightarrow{\div 10} = \frac{15.7079 \text{ m}}{1 \text{ sec}} = \boxed{15.708 \text{ m/s}}$$

$\div 60$

8. A casting of mass of 26 kg has a horizontal force of 180 N applied to it which causes acceleration in a frictionless horizontal plane.

Calculate EACH of the following, ignoring friction:

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

(b) the distance the body will travel from rest in 8 seconds. (4)

a) $F = ma$

$180 = 26\ a$

$\frac{180}{26} = 6.923\ m/s^2$

b) $s = x$
$u = 0$
v
$a = 6.923$
$t = 8$

$v = u + at$

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

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

$x = 0 + \frac{1}{2} 6.923 (8)^2$

221.536 m

9. FIG Q9 shows a loaded uniform beam with a mass 800 kg.

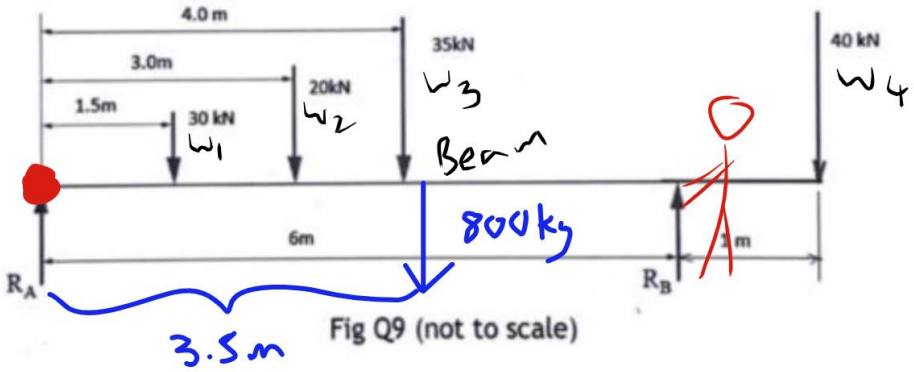


Fig Q9 (not to scale)

Calculate EACH of the reaction forces at A and B. (10)

Name	Mass (kg)	Force (kN)	Distance (m)	Moments (kNm)	Rotation (AC/C)
W_1		30	1.5	45	C
W_2		20	3	60	C
W_3		35	4	140	C
W_4		40	7	280	C
Beam	800	7.848	3.5	27.468	C
R B		x	6	6x	AC

sum of the anticlockwise moments = sum of the clockwise moments

$$6x = 45 + 60 + 140 + 280 + 27.468$$

$$6x = 552.468$$

$$R_B = x = 92.078\ kN$$

sum of the downwards forces = sum of the upwards forces

$$30 + 20 + 35 + 40 + 7.848 = R_A + 92.078$$

$$132.848 = R_A + 92.078$$

$$40.77\ kN = R_A$$

10. (a) For a simple machine define the term Force Ratio. (2)

(b) For a simple machine define the term Velocity Ratio. (2)

(c) State the expression for mechanical efficiency of a simple machine in terms of force ratio and velocity ratio. (2)

(d) State why mechanical efficiency is always less than 100%. (2)

(2)
(2)
(2)
(2)

a) Force Ratio (Mech adv) = $\frac{\text{Force lifted}}{\text{Force Applied}} = \frac{100\,N}{10\,N} = 10$ (eg)

This example would give a 10:1 ratio, which means for every 1 Newton applied, I could life 10 Newtons worth of force.

b) Velocity Ratio (movement Ratio) = $\frac{\text{Distance I travel}}{\text{Distance the object travels}} = \frac{10\,m}{1\,m} = 10$

This example would give a 10:1 ratio, which means I would have to travel 10 times further than the distance I lift the load.

c) Efficiency = $\frac{\text{Force Ratio}}{\text{Velocity Ratio}} \times 100 =$ 78 %

d) its a law of physics

you cannot exceed 100% efficiency, you cant even have a 100% efficent machine!

11. (a) Describe what is meant by shear stress. (2)

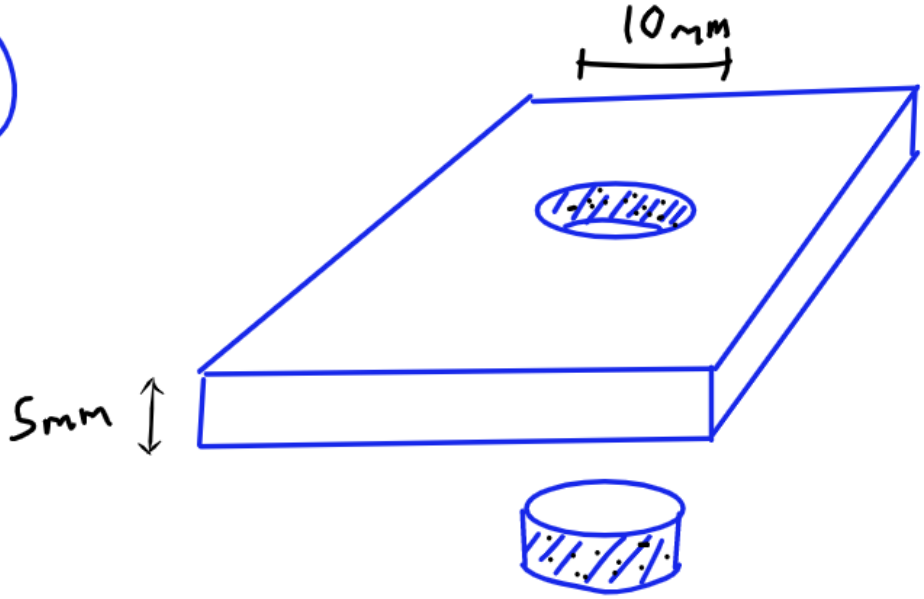
(b) A hydraulic press is used to punch rivet holes in metal plate. The plate is 5 mm thick and the holes required should have a diameter of 10 mm. A force of 40 kN is required to punch the hole.

Determine the shear stress at failure of the metal plate (6)

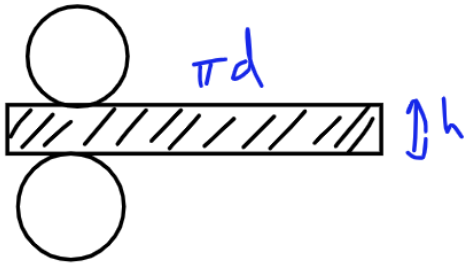
a) Stress $= \frac{F}{A} = N/m^2$

the stress required to shear or break a material

b)



$$\text{Stress} = \frac{40{,}000}{\text{Area}}$$



Area $= \pi dh$

$\pi \, 10 \times 5$

157.0796 mm^2

$$\text{stress} = \frac{40{,}000}{157.0796} = 254.64 \text{ N/mm}^2$$

12. (a) State the difference between static and dynamic friction. (2)

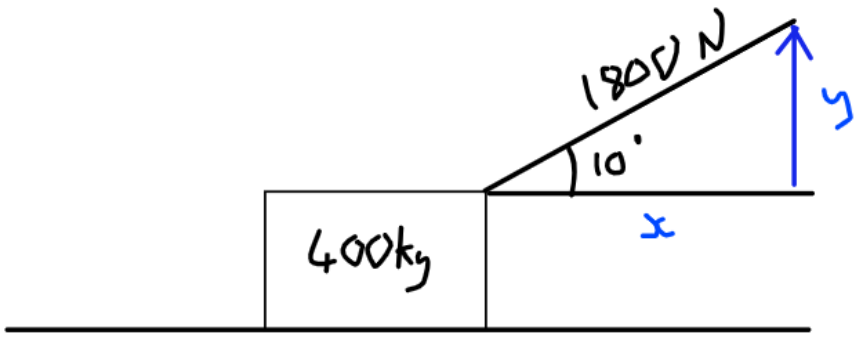
(b) A container has a mass of 400 kg and is pulled along a horizontal plane by a cable. The cable makes an angle of 10° above the horizontal and has a tension of 1.8 kN when pulling the container at a constant speed.

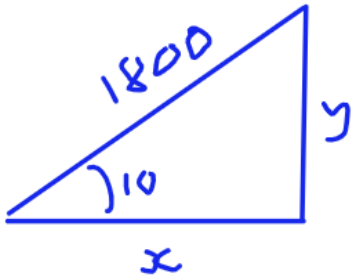
Determine the coefficient of friction between the container and surface. (6)

Static friction is the friction force felt while an object is still static

Dynamic friction is the friction force felt while the object is in motion. It is often less than the static friction.

b)





next we need to look at the vertical and horizontal forces.
The force being applied is at an angle, so lets break that down

Vertical

SOH

$\sin 10 = \frac{y}{1800}$

$1800 \sin 10 = y$

$312.5667\ N$ up

Box $400 \times 9.81 = 3924\ N$ down

gravity still pulls the box down

Net $3611.4333\ N$ down

$Fric = \mu N$

this is the total downwards force, and we will use it to work out friction.

Horizontal

CAH

$\cos 10 = \frac{x}{1800}$

$1800 \cos 10 = x$

1772.65

this is the pushing force

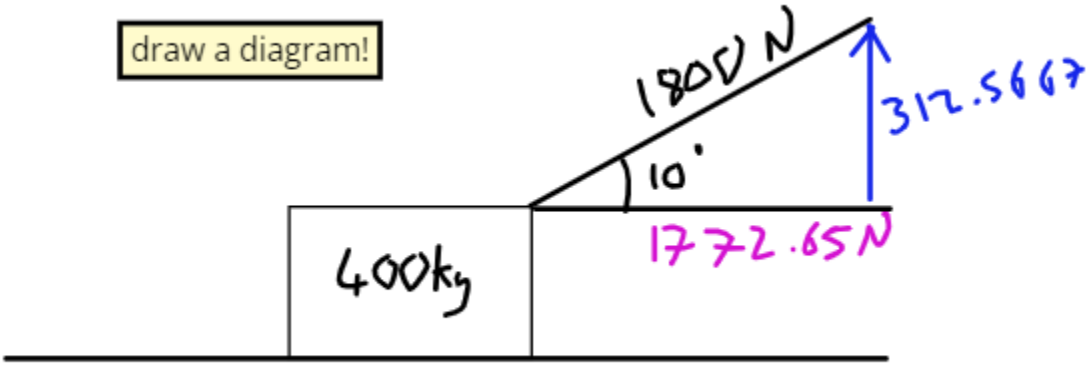
Friction

$Fric = \mu N$

$1772.65 = \mu\ 3611.4333$

$\frac{1772.65}{3611.4333} = \mu$

$0.4908 = \mu$


draw a diagram!
1800 N
312.5667
10°
400kg
1772.65N