

1. (a) Express the fraction $\frac{26}{11}$ as a decimal correct to 4 decimal places. (2)
- (b) Express the value 0.0034 as a percentage. (2)
- (c) Write the number 0.00784 in standard form. (2)
- (d) Simplify the following expression into a single fraction: (2)

$$\frac{27}{13} \div \frac{9}{4}$$

1 a) $\frac{26}{11} = 2.363636$
 $\boxed{2.3636}$

b) $0.0034 = 0.34\%$

c) $0.00784 = 7.84 \times 10^{-3}$

d) $\frac{27}{13} \div \frac{9}{4}$

$$\frac{27}{13} \times \frac{4}{9} = \frac{243}{52}$$

2. The time period of a pendulum is given by:

$$T = 2 \times \pi \sqrt{\frac{L}{g}}$$

(a) Rearrange the equation to make L the subject. (4)

(b) Evaluate T, when L is 1.3 m and g is 9.81 m/s² giving you answer to 2 decimal places. (4)

$$2a) \quad T = 2\pi \sqrt{\frac{L}{g}}$$

$$\frac{T}{2\pi} = \sqrt{\frac{L}{g}}$$

$$\left(\frac{T}{2\pi}\right)^2 = \frac{L}{g}$$

$$g\left(\frac{T}{2\pi}\right)^2 = L$$

$$b) \quad L = 1.3 \quad g = 9.81$$

$$T = 2\pi \sqrt{\frac{1.3}{9.81}}$$

$$2\pi \times 0.36402999$$

$$2.287$$

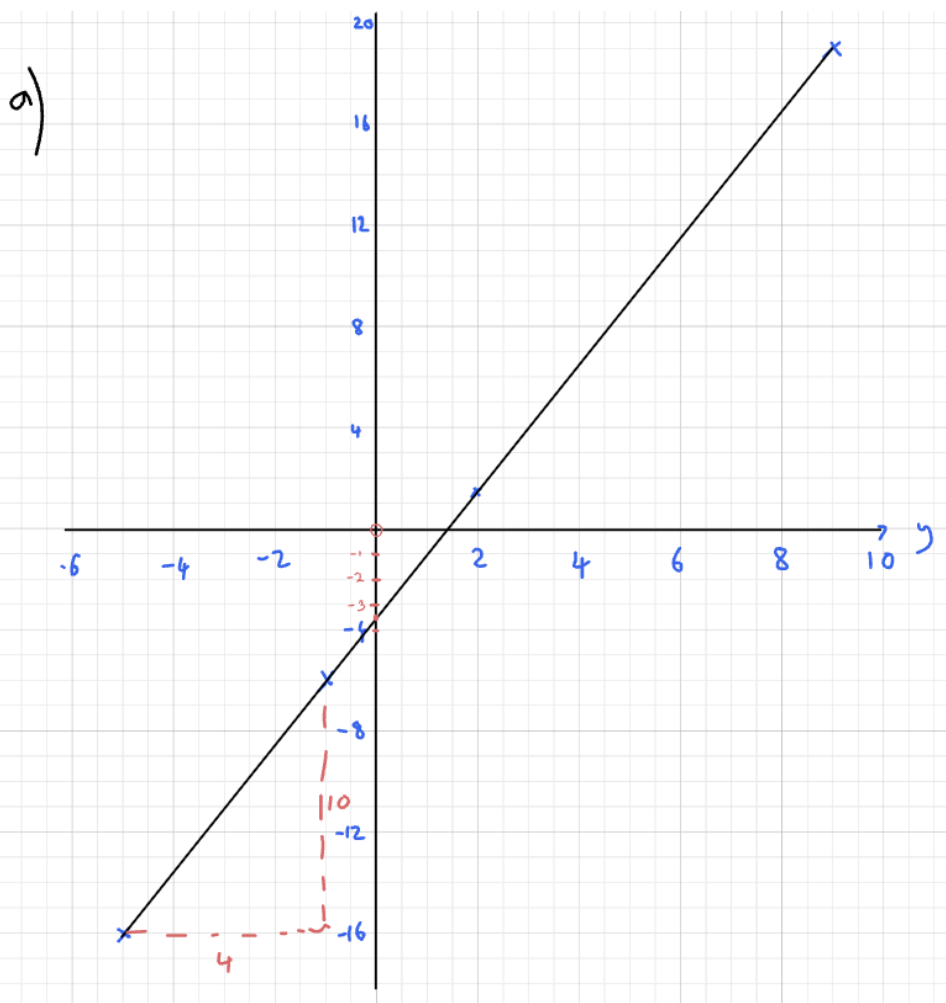
$$\boxed{2.29 \text{ sec}}$$

3. Data collected from an experiment is shown in Table Q3.

X	-5	-1	2	9
Y	-16	-6	1.5	19

Table Q3

- (a) Plot the points shown in Table Q3 using an appropriate scale and draw the best fit line of a straight line graph of the form $y = mx + c$. (2)
- (b) Determine the values of m and c from your graph. (3)
- (c) Determine the relationship of the variable x in terms of Y . (3)



b) $c = -3.5$

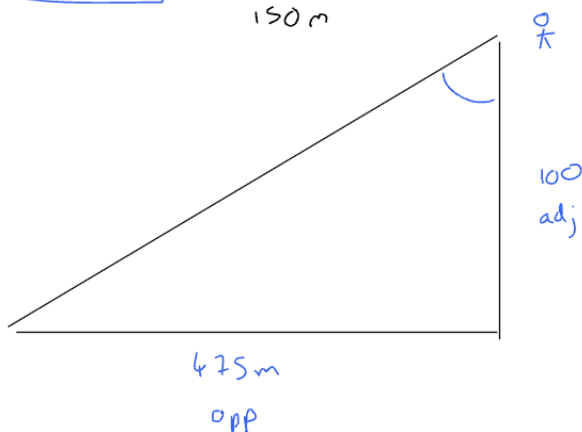
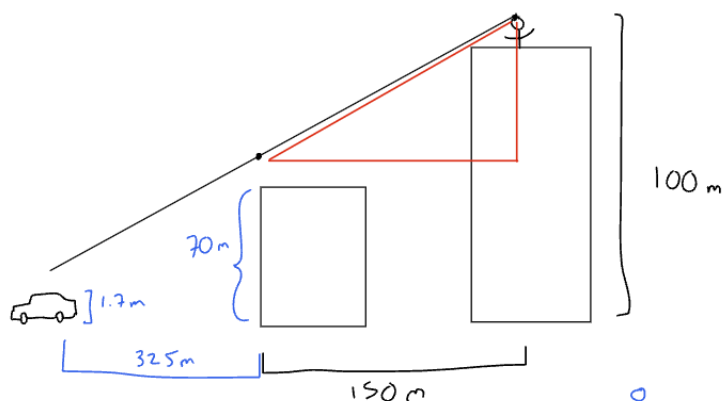
$$m = \frac{\text{Rise}}{\text{Run}} = \frac{10}{4} = \frac{5}{2} = 2.5$$

c) $y = 2.5x - 3.5$

4. A tourist is admiring the view from the top of a building giving them a viewpoint of 100 m elevation above level ground. The tourist can see a second building 150 m away that is 70 m high and remembers their car is parked some distance beyond the second building. The car is 1.7 m high and is parked 325 m beyond the second building, in a straight line of sight.

Provide working to demonstrate whether the tourist will be able to see their car.

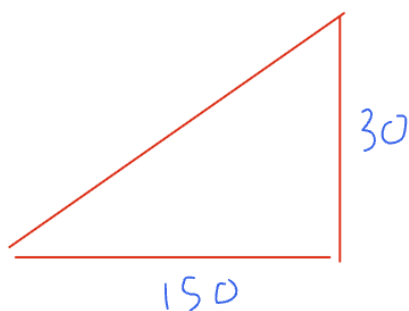
(8)



$$\tan \theta = \frac{o}{a}$$

$$\theta = \tan^{-1}\left(\frac{475}{100}\right)$$

$$\theta = 78.1113^\circ$$



$$\tan \theta = \left(\frac{150}{30}\right)$$

$$\theta = \tan^{-1}(5)$$

top
of building

$$\boxed{78.69^\circ}$$

the car requires a sharper angle to see it from where the tourist is standing, so he would NOT be able to see it, the building would block the view. It wouldn't matter how wide the building is, as view would be blocked.

5. Fig Q5 shows a square constructed within a square. Determine an expression for the area of the inner square in terms of the dimensions x and y shown. (8)

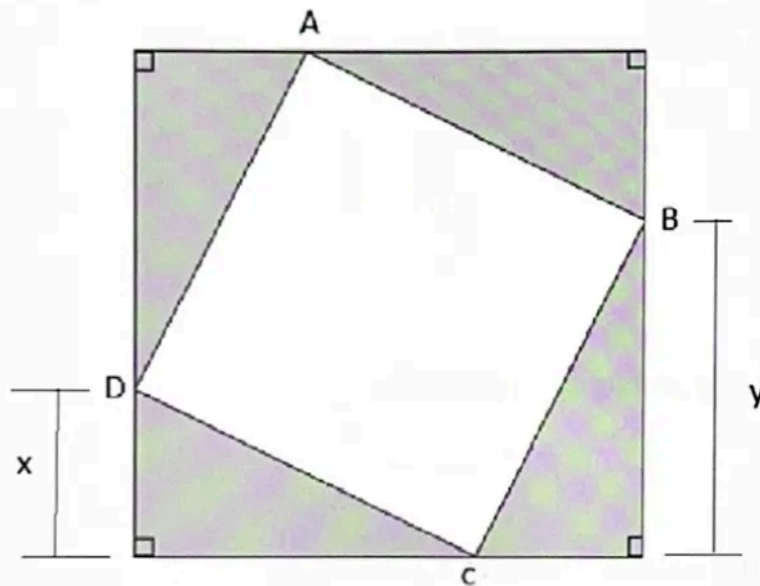
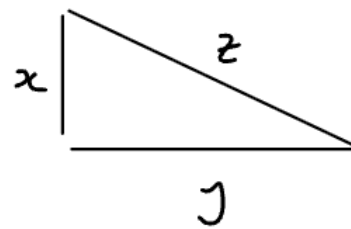
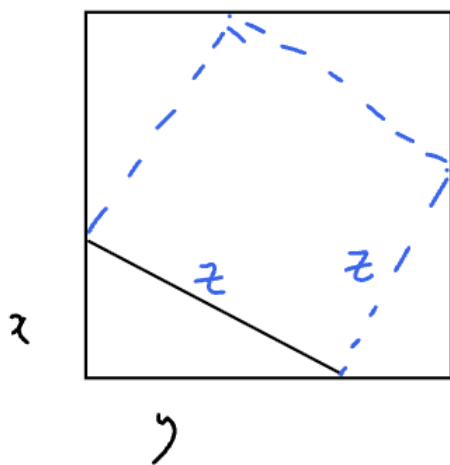


Fig Q5

5)



$$x^2 + y^2 = z^2$$

Area of square inside = $z^2 = \boxed{x^2 + y^2}$

6. Fig Q6 shows a cross section of a cone with a sphere inside it. The sphere contacts the cone surface tangentially. If the cone has a height of 26.7 cm, and a base radius of 16.5 cm.



Fig Q6

Determine EACH of the following:

- (a) the radius of the inscribed sphere;

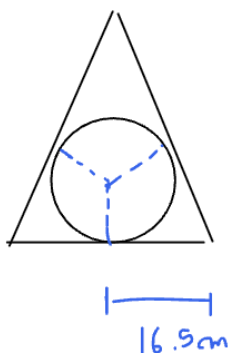
(5)

- (b) the mass of the combined body.

(5)

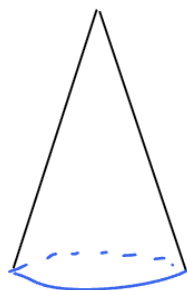
Note: the density of the sphere is 430 kg/m^3 and the density of the remaining cone is 750 kg/m^3

6



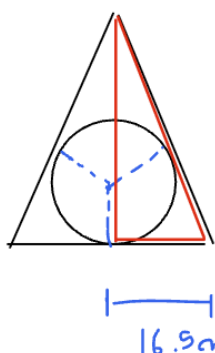
26.7 cm

16.5 cm



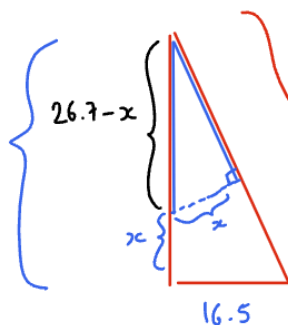
$$\text{Vol cone} = \frac{\pi r^2 h}{3}$$

$$= \frac{\pi 16.5^2 \times 26.7}{3}$$



26.7

16.5 cm

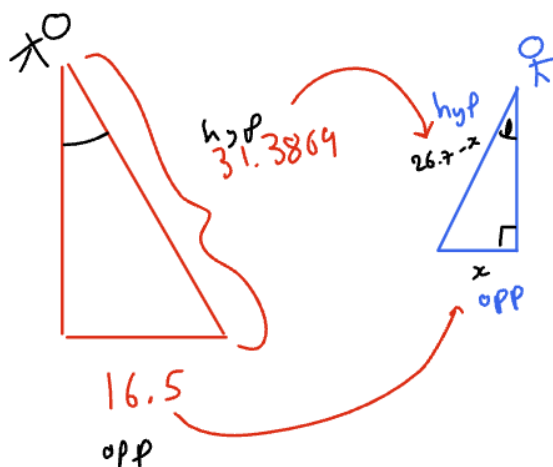


26.7 - x

16.5

31.3869 cm

$$\sqrt{26.7^2 + 16.5^2} = 31.3869 \text{ cm}$$



as these are mathematically similar triangles, they have the same angle. So we can work this out

So +

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

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$$\frac{16.5}{31.3869} = \frac{x}{(26.7 - x)}$$

$$16.5(26.7 - x) = x(31.3869)$$

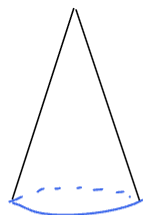
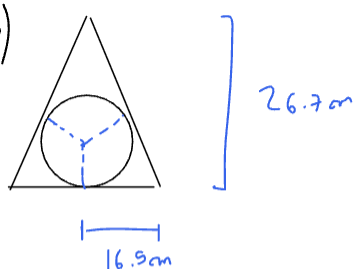
$$440.55 - 16.5x = 31.3869x$$

$$440.55 = 47.8869x$$

$$\frac{440.55}{47.8869} = x$$

$$\boxed{9.1998 \text{ cm} = x}$$

6 b)



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

$$= \frac{\pi 16.5^2 \times 26.7}{3}$$

$$= 7612.157 \text{ cm}^3$$

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

$$= \frac{4}{3} \pi (9.1998)^3$$

$$= 3261.548 \text{ cm}^3$$



mass sphere

$$m = d \times v$$

$$0.43 \times 3261.548$$

$$\boxed{1402.465 \text{ g}}$$

vol of cone - sphere

$$7612.157 - 3261.548 = 4350.609 \text{ cm}^3$$

mass hollow (core)

$$m = d \times v$$

$$m = 0.75 \times 4350.609$$

$$m = \boxed{3262.956 \text{ g}}$$

$$\text{total mass} = \boxed{4665.42 \text{ g}}$$

Section B

7. Fig Q7 shows a fastener with two forces, P and Q, acting on it.

Determine the magnitude and direction of a single force having the same effect as P and Q combined.

(8)

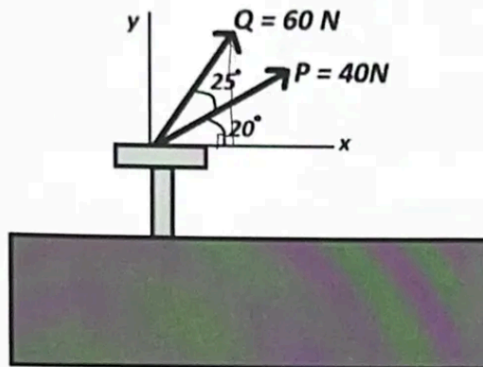
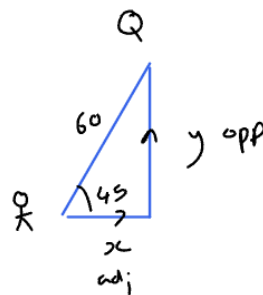
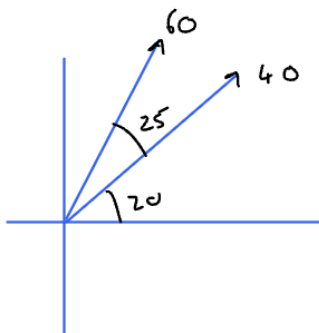
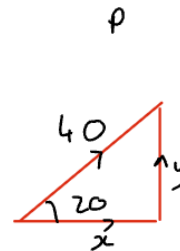


Fig Q7



SOH
CAH
TUA



x
CAH

y
SOH

x
CAH

y
SOH

$$\cos(25) = \frac{x}{60}$$

$$\sin(25) = \frac{y}{60}$$

$$60 \cos 25$$

$$60 \sin 25$$

$$40 \cos 20$$

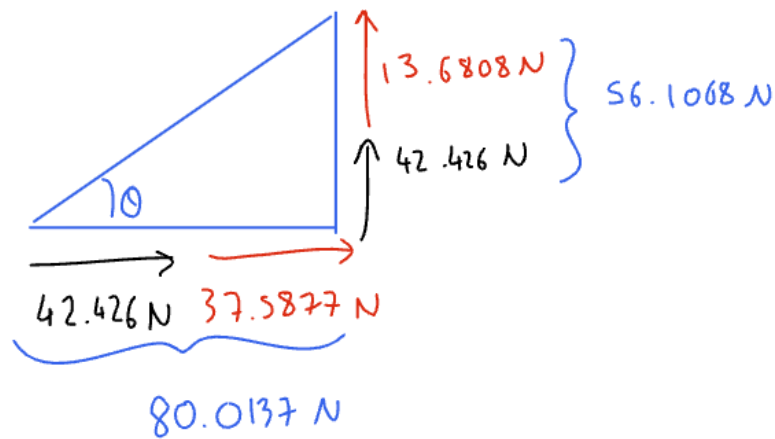
$$40 \sin 20$$

$$42.426 \text{ N}$$

$$\uparrow 42.426 \text{ N}$$

$$\rightarrow 37.5877 \text{ N}$$

$$\uparrow 13.6808 \text{ N}$$



to a $\tan \theta = \frac{\text{opp}}{\text{adj}}$

$$\theta = \tan^{-1} \left(\frac{56.1068}{80.0137} \right)$$

direction =

$$\boxed{35.0382^\circ}$$

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

$$c = \sqrt{80.0137^2 + 56.1068^2}$$

$$\boxed{c = 97.7249 \text{ N}}$$

8. An electric mooring winch is used to tension a rope. The drum has a diameter of 0.8 meters. The winch accelerates its load from rest to a line speed of 1.5 m/s over a period of 4 seconds.

- (a) Find the linear acceleration of the mooring line. (3)
- (b) Calculate the change in angular velocity per second of the winch drum during this time period. (3)
- (c) Determine the number of revolutions the drum makes during this time period. (2)

8. An electric mooring winch is used to tension a rope. The drum has a diameter of 0.8 meters. The winch accelerates its load from rest to a line speed of 1.5 m/s over a period of 4 seconds.

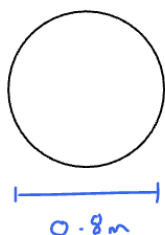
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- (b) Calculate the change in angular velocity per second of the winch drum during this time period. (3)
- (c) Determine the number of revolutions the drum makes during this time period. (2)

$$\text{linear vel} = \text{Rad/sec} \times \text{Radius}$$

$$\text{linear accel} = \text{Rad/sec}^2 \times \text{Radius}$$

$$\times 0.4$$

a)



$$\begin{aligned} S \\ u &= 0 \\ v &= 1.5 \text{ m/s} \\ a &= ? \\ t &= 4 \end{aligned}$$

mooring line
accel

$$v = u + at$$

$$1.5 = 0 + 4a$$

$$\frac{1.5}{4} = a$$

$$\boxed{0.375 \text{ m/s}^2}$$

b)

the change in angular velocity per second
is a fancy way to say acceleration

$$\begin{array}{l} \text{linear} \\ \text{accel} \end{array} = \text{Rad/sec}^2 \times \text{Radius}$$

$$0.375 = x \cdot 0.4$$

$$\frac{0.375}{0.4} = x$$

$$\boxed{0.9375 \text{ Rad/sec}^2} = x$$

c)

$$s = x$$

$$u = 0$$

$$v$$

$$a = 0.9375 \text{ Rad/sec}^2$$

$$t = 4 \text{ sec}$$

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

$$s = 0 + 0.5(0.9375)(4)^2$$

$$s = 7.5 \text{ Rads}$$

Deg	Rev	Rad
360	1	2π

$\div 2\pi$

$$7.5 \div 2\pi = \boxed{1.19366 \text{ Rev}}$$

9. A drum with a mass of 250 kg is being moved manually by sliding it across a steel deck. The coefficient of friction between the drum base and the deck is 0.35. A steady horizontal force of 1 kN is applied to the drum.

Determine EACH of the following:

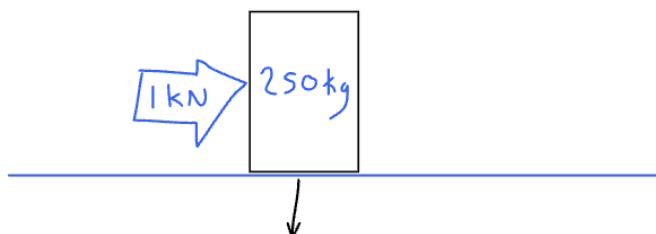
- (a) the normal force acting on the deck; (2)
- (b) the frictional force resisting motion; (2)
- (c) the acceleration of the drum when the horizontal force is applied; (2)
- (d) the angle of deck that would cause the drum to start moving if the horizontal force is removed (ignoring dynamic forces). (4)

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- (d) the angle of deck that would cause the drum to start moving if the horizontal force is removed (ignoring dynamic forces). (4)

a)



$$\begin{aligned} a) \quad mg &= 250 \times 9.81 \\ &= 2452.5 \text{ N} \end{aligned}$$

$$\begin{aligned} b) \quad F_{\text{fric}} &= \mu N \\ &= 0.35 \times 2452.5 \\ &= 858.375 \text{ N} \end{aligned}$$

$$\begin{aligned} c) \quad \text{Net Horizontal} \\ &= \text{Push} - \text{Fric} \end{aligned}$$

$$1000 - 858.375 = 141.625 \text{ N}$$

$$\begin{aligned} \text{Accel} \\ F &= ma \end{aligned}$$

$$141.625 = 250 \times$$

$$\frac{141.625}{250} = a$$

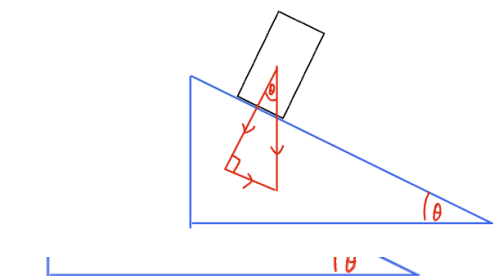
$$\boxed{0.5665 \text{ m/s}^2} \text{ Accel}$$

9. A drum with a mass of 250 kg is being moved manually by sliding it across a steel deck. The coefficient of friction between the drum base and the deck is 0.35. A steady horizontal force of 1 kN is applied to the drum.

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 (d) the angle of deck that would cause the drum to start moving if the horizontal force is removed (ignoring dynamic forces). (4)

d) Advanced :-



$$mg = 250 \times 9.81$$

$$= 2452.5 \text{ N}$$

$$F_{\text{fric}} = \mu N$$

Friction = horizontal (to slope) Driving Force

$$F_{\text{fric}} = \mu N$$

$$= 2452.5 \sin \theta$$

$$[2452.5 \cos(\theta)] 0.35 = 2452.5 \sin \theta$$

$$[\cancel{2452.5} \cos(\theta)] 0.35 = \cancel{2452.5} \sin \theta$$

$$0.35 \cos \theta = \sin \theta$$

$$\tan \theta = \frac{\sin \theta}{\cos \theta}$$

$$0.35 = \frac{\sin \theta}{\cos \theta}$$

$$0.35 = \tan \theta$$

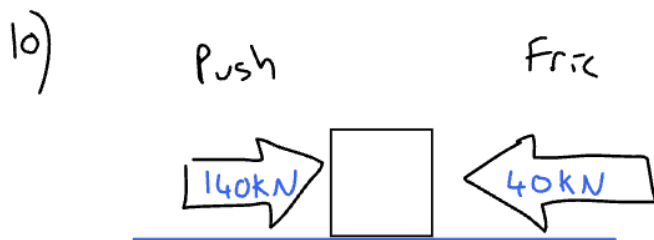
$$\tan^{-1}(0.35) = \theta$$

$$\boxed{19.29^\circ} = \theta$$

10. A service vessel of 3500 tonnes accelerates from rest under a constant propulsive force of 140 kN. The total drag forces acting against motion are 40 kN.

Determine EACH of the following:

- (a) the acceleration of the vessel; (2)
 (b) the vessel's velocity after 3 minutes; (2)
 (c) the power used. (4)



Net horizontal

$$\text{Push} - \text{Fric}$$

$$140 - 40 = 100 \text{ kN}$$

Accel

$$F = ma$$

$$100 = 3500x$$

$$\frac{100}{3500} = x$$

$$0.0285714 \text{ m/s}^2 = \text{accel}$$

b)

s

$$u = 0$$

$$v = x$$

$$a = 0.0285714 \text{ m/s}^2$$

$$t = 3 \times 60 = 180 \text{ sec}$$

$$v = u + at$$

$$x = 0 + 0.0285714 \times 180$$

$$5.1428 \text{ m/s}$$

$$18.5 \text{ kmph}$$

$\times 3.6$

$$c) \text{ Power} = \frac{W}{t} = \frac{J}{s} = \frac{\text{Work}}{\text{time}}$$

$$\text{Work} = \text{distance} \times \text{force}$$

$$140,000 \text{ N}$$

$$s = x$$

$$u = 0$$

$$v =$$

$$a = 0.0285714 \text{ m/s}^2$$

$$t = 3 \times 60 = 180 \text{ sec}$$

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

$$x = 0 + 0.5(0.0285714)(180)^2$$

$$\boxed{462.857 \text{ m}}$$

$$\text{Work} = 462.857 \text{ m} \times 140,000$$

$$64,799,935.2 \text{ (J)}$$

$$\text{Power} = \frac{\text{Work}}{\text{time}} = \frac{64,799,935.2 \text{ (J)}}{180}$$

10. A service vessel of 3500 tonnes accelerates from rest under a constant propulsive force of 140 kN. The total drag forces acting against motion are 40 kN.

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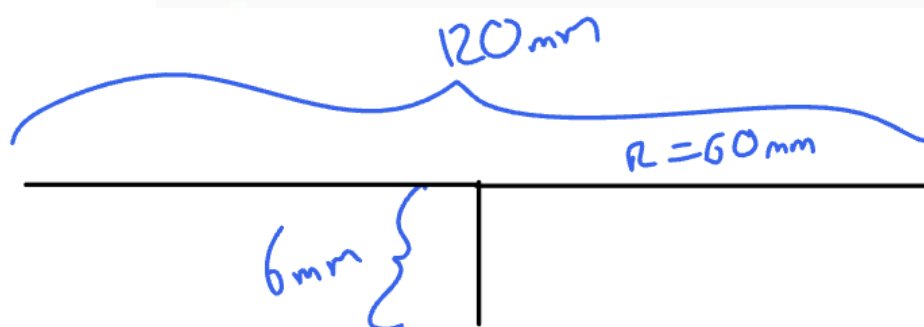
$$359,999 \text{ Watts}$$

$$\boxed{360 \text{ kW}}$$

11. A load of 500 kg is to be lifted using a screwjack. The jack has a single start square thread with a 6 mm pitch on an effective diameter of 120mm. The effective effort applied to make the lift is 100 N.

Determine EACH of the following:

- (a) the force ratio; (2)
 (b) the movement ratio; (3)
 (c) the mechanical efficiency. (3)



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

$$a) \text{ Force Ratio} = \frac{\text{Force to lift}}{\text{Force I apply}} = \frac{500 \times 9.81}{100} = \boxed{49.05}$$

$$b) \text{ movement Ratio} = \frac{\text{dist I travel}}{\text{dist load moves}} = \frac{\pi d}{\text{pitch}} = \frac{120\pi}{6} = \boxed{62.831}$$

$$c) \text{ Eff} = \frac{F}{M} = \frac{49.05}{62.831} \times 100$$

$$78.065 \%$$

12. A yoke joint shown in FIG Q12 is held together by a steel pin. It is to be made of steel throughout with an ultimate shear strength of 260 MPa and an ultimate tensile strength of 350 MPa. The key dimensions are given in the different views of the joint. The joint is in tension as shown by the arrows.

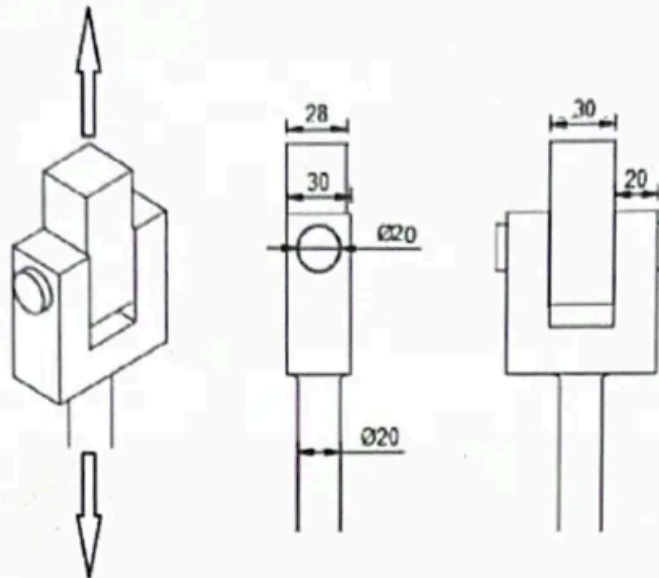


FIG Q12 (dimensions in mm)

Determine EACH of the following:

- (a) the maximum force that could be applied before the pin fails under shear if no other failure occurs; (3)
- (b) considering the whole joint, what is the maximum load that could be applied before failure occurs. (5)

a) $P_{in} = \pi R^2$ it has to shear twice

$\downarrow \times 2$ 

$2\pi(10)^2$

628.318 mm^2

$$\text{stress} = \frac{F}{A}$$

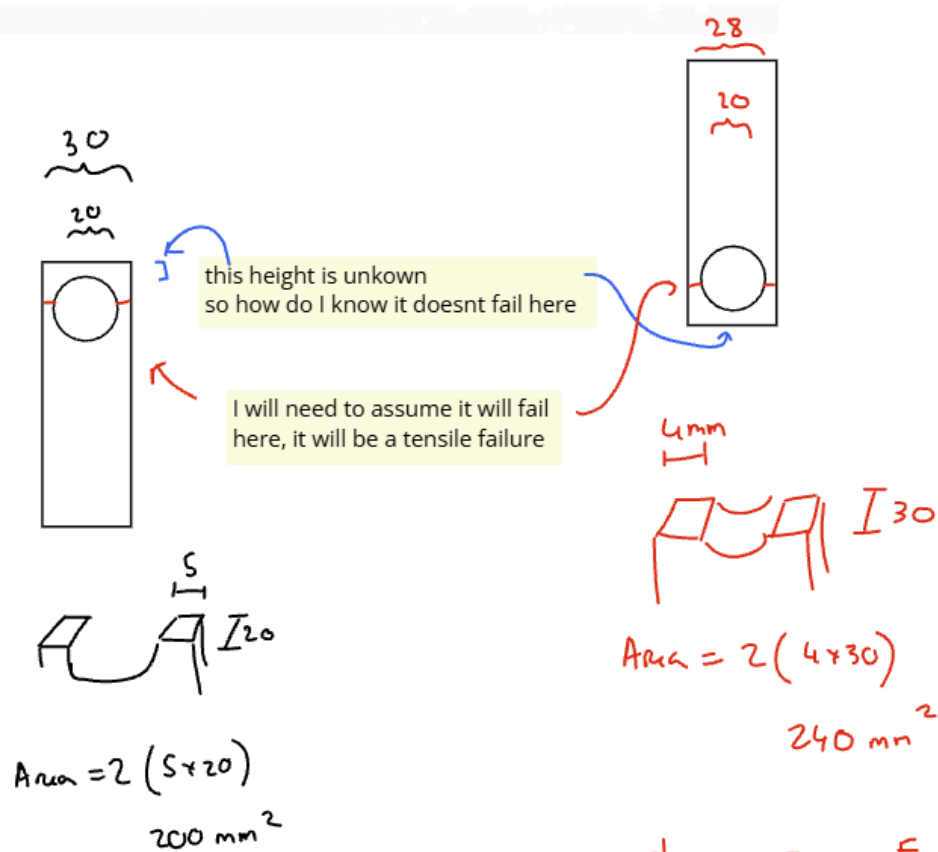
pin will shear

$$260 = \frac{x}{628.318}$$

$$260 \times 628.318 =$$

$163,362.68 \text{ N}$

b)



$$\text{stress} = \frac{F}{A}$$

$$350 \text{ N/mm} = \frac{x}{200}$$

$$\text{tensile} \rightarrow 350 = \frac{x}{240}$$

$$350 \times 240 = x$$

$$350 \times 200 =$$

$$70,000 \text{ N}$$

there are actually 2 of these

$$140,000 \text{ N}$$

 $\times 2$

$$84,000 \text{ N}$$

there is only one of these
this will fail first

$$b) \quad 84,000 \text{ N}$$

max load
before failure