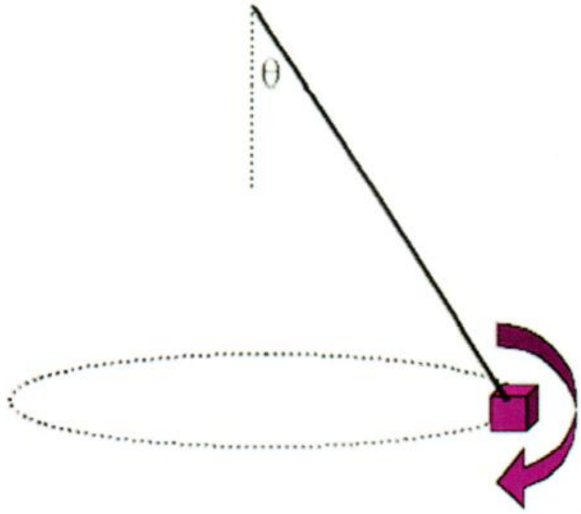
1. [2, 1, 1 mark]

Janice is swinging a cube at the end of a light string as shown below. The cube is moving at 20 revolutions per minute. Calculate;



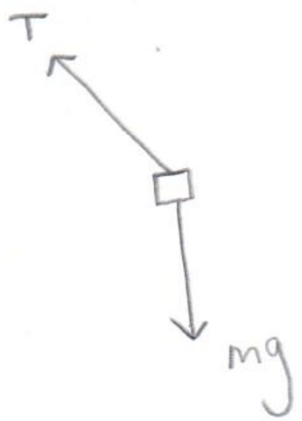
(a) Its frequency in Hz.

$$f = \frac{20}{60} = \underline{0.333 \text{ Hz}}$$

(b) Its period.

$$T = \frac{1}{f} = \underline{3 \text{ s}}$$

(c) Draw the forces acting on the cube. Ignore air resistance.



2. [3, 3, 2, 2 marks]

A car of mass 1100 kg is travelling around a horizontal bend of radius 150 m. The maximum frictional force that the road surface can apply to the four tyres is 1.00 kN.

(a) What is the maximum velocity at which this car can negotiate the bend?

$$F = \frac{mv^2}{r}$$

$$1000 = \frac{1100 v^2}{150}$$

$v = 11.7$ m/s perpendicular to radius

(b) What is the magnitude and direction of the acceleration of the car at its maximum velocity?

$$a_c = \frac{v^2}{r}$$

$$= \frac{11.7^2}{150}$$

$a_c = 0.909$ m/s^2 towards centre of circle

(c) If the car hits an oil slick on the road that is sufficient to practically eliminate all friction, describe its subsequent speed and direction of motion.

11.7 m/s tangential to the circle

(d) If the radius of the curved section of the road was doubled, state, with justification, how this would affect the maximum safe velocity of the car.

$$F = \frac{mv^2}{r}$$

$$1000 = \frac{1100 v^2}{r}$$

If $r \uparrow$ then v would also increase since F and m don't change.

3. [4 marks]
A model plane is whirled in a vertical circle of radius 1.20 m by means of a cord attached to the plane. At what minimum speed must it travel at the top of the path in order to keep the cord just firm?

At top: $F_{net} = mg + T$

For min v, $T = 0$

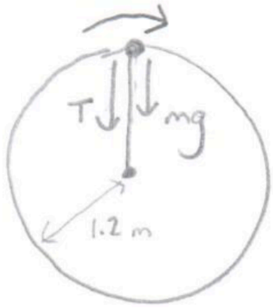
$F_{net} = mg$

$\frac{\cancel{m}v^2}{r} = \cancel{m}g$

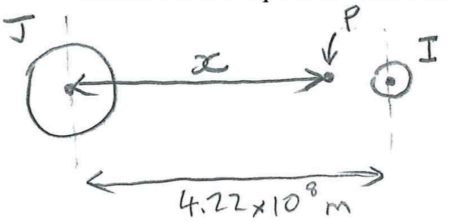
$v = \sqrt{gr}$

$= \sqrt{9.8 \times 1.20}$

$v = 3.43 \text{ m/s}$



8. The average distance between Jupiter and one of its moons, Io, is 4.22×10^8 m. The mass of Jupiter is 1.90×10^{27} kg and the mass of Io is 8.93×10^{22} kg. A lost astronaut is between Jupiter and Io. Calculate the distance from Jupiter at which an astronaut would experience true weightlessness.



At P, $g_{net} = 0$

so, $g_J = g_I$

$\frac{GM_J}{x^2} = \frac{GM_I}{(4.22\times10^8 - x)^2}$

$M_I x^2 = M_J(4.22\times10^8 - x)^2$

$0 = M_J(4.22\times10^8 - x)(4.22\times10^8 - x) - M_I x^2$

$0 = M_J(1.78\times10^{17} - 8.44\times10^8 x + x^2) - M_I x^2$

$0 = 1.78\times10^{17} M_J - 8.44\times10^8 M_J x + M_J x^2 - M_I x^2$

we have $0 = ax^2 + bx + c$

where:

$a = M_J - M_I = 1.90\times10^{27}$

$b = -1.60\times10^{36}$

$c = 3.38\times10^{44}$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

sub a, b and c:

$x = 4.25\times10^8$ m

or

$x = 4.19\times10^8$ m

$\therefore x = 4.19\times10^8$ m

5

Using the data provided in **question 8**, calculate the average orbital speed of Io around Jupiter. (You do not need your answer to question 8). Assume the orbit is circular.

$$F_g = F_c$$

$$\frac{G M_J M_I}{r^2} = \frac{M_I v^2}{r}$$

$$v = \sqrt{\frac{G M_J}{r}}$$

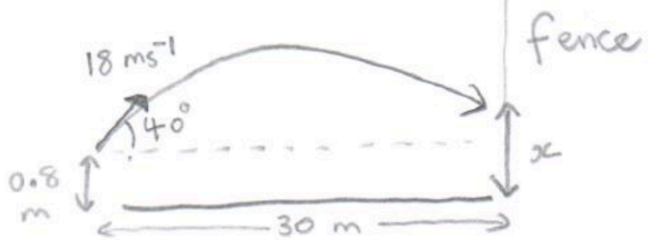
$$= \sqrt{\frac{6.67\times10^{-11} \times 1.90\times10^{27}}{4.22\times10^{8}}}$$

4

$$v = 1.73 \times 10^{4} \text{ m/s}$$

5. [6 marks]
A baseball batter hits a ball from a height of 0.80 m at a speed of 18 ms^{-1} and an angle of 40^0 towards a vertical metal fence that is 30 m away.

How far above the ground does the ball strike the fence?



Horizontally

$v = 18\cos 40$

$$t = \frac{30}{18\cos 40}$$

$t = 2.18\ s$

Vertically

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

$= (18\sin 40)(2.18) + \frac{1}{2}(-9.8)(2.18)^2$

$= 1.97\ m$

$x = 1.97 + 0.8$

$x = 2.78$ m above the ground

6. [4 marks]

vertical motion

$u = 17.52\ ms^{-1}$ (1)

$a = -9.8\ ms^{-2}$

(4) $s = -3.50$

$t = ?$

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

$-3.50 = 17.52t - 4.9t^2$

ie $4.9t^2 - 17.52t - 3.50 = 0$

so $t = \underline{3.77\ sec}$ (1)

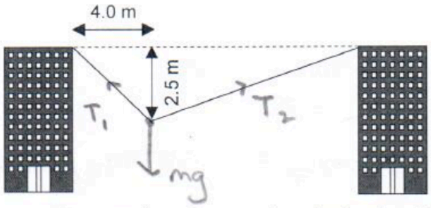
Range $R = v_H . t$ (1)

$= 28.03 \times 3.77$ (1)

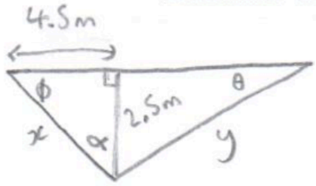
$= \underline{105.7\ m}$ (1)

(3)

6. [4 marks]
A 70 kg tight rope walker is carefully walking a 16 m cable. At one point the walker is 4.0 m from one building and 2.5 m below the level of the buildings.



Determine the tension in both sides of the cable.



$\phi = \tan^{-1}\left(\frac{2.5}{4}\right) = 32.0^\circ$

$x = \sqrt{4^2 + 2.5^2} = 4.72$ m

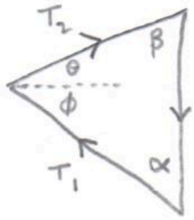
$y = 16 - x = 11.28$ m

$\theta = \sin^{-1}\left(\frac{2.5}{11.28}\right) = 12.8^\circ$

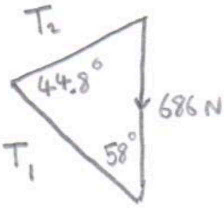
$W = mg = (70)(9.8) = 686$ N

$\alpha = 90^\circ - \phi = 58.0^\circ$

Forces (head to tail)



$\Rightarrow$



$\frac{T_2}{\sin 58^\circ} = \frac{686}{\sin 44.8^\circ}$

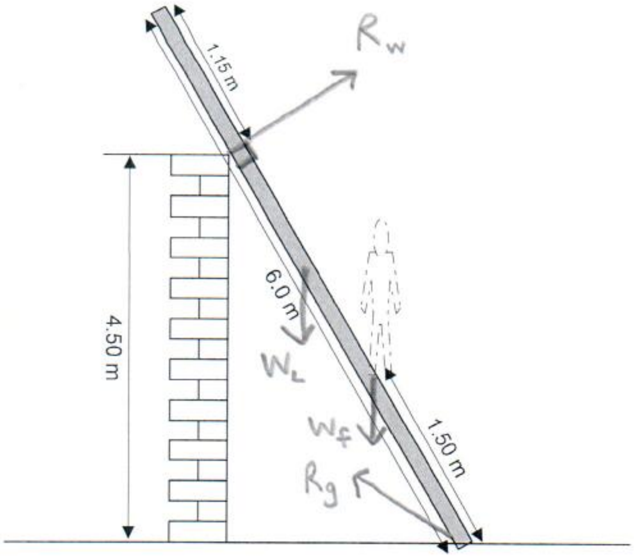
$\therefore$ $T_2 = 825$ N along wire

$\beta = 180^\circ - 44.8^\circ - 58^\circ = 77.2^\circ$

$\frac{T_1}{\sin 77.2^\circ} = \frac{686}{\sin 44.8^\circ} \rightarrow T_1 = 471$ N

$\therefore$ along wire

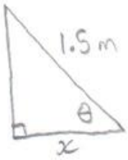
7. [1,3,3,2 marks]
A 90 kg fireman is scaling the wall outside of burning building. The ladder is a uniform 20 kg 6.0 m length and at one particular moment the fireman is 1.50 m from the base of the ladder. The wall is 4.50 m high and is overhanging the wall by 1.15 m.

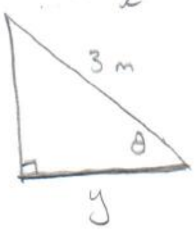


a. Draw the Forces in the system.

see above

b. Determine the force exerted by the wall on the top of the ladder.





$\theta = \sin^{-1}\left(\frac{4.5}{4.85}\right) = 68.1^\circ$

$x = 1.5 \cos 68.1^\circ = 0.559 \text{ m}$

$y = 2x = 1.12 \text{ m}$

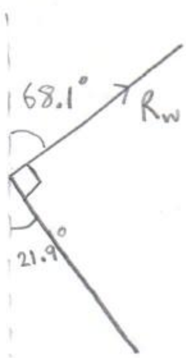
Choose pivot at R_g

$\tau_{AC} = \tau_C$

$(1.12 W_L) + (0.559 W_f) = 4.85 R_w$

$R_w = 147$ N at 90° to ladder

c. What is the Reaction Force exerted by the ground?



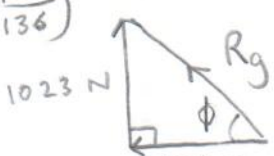
$R_w(v) = 147 \times \cos 68.1^\circ$
$= 54.8$ N up

$\Sigma F_v = 0 : W_L + W_f = 54.8 + R_g(v)$

$R_g(v) = 1023$ N up

$\Sigma F_H = 0 : R_g(h) = 147 \sin 68.1^\circ$
$= 136$ N left

$\phi = \tan^{-1}\left(\frac{1023}{136}\right)$
$= 82.4^\circ$



$R_g = \sqrt{136^2 + 1023^2} = 1032$ N

$\therefore R_g = 1032$ N @ 82.4° to ground