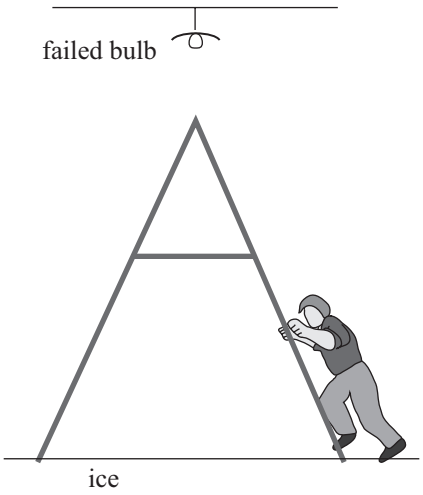
ASSESSOR'S USE ONLY

QUESTION ONE: THE A-FRAME LADDER



The acceleration due to gravity = 9.81 m s^{-2}

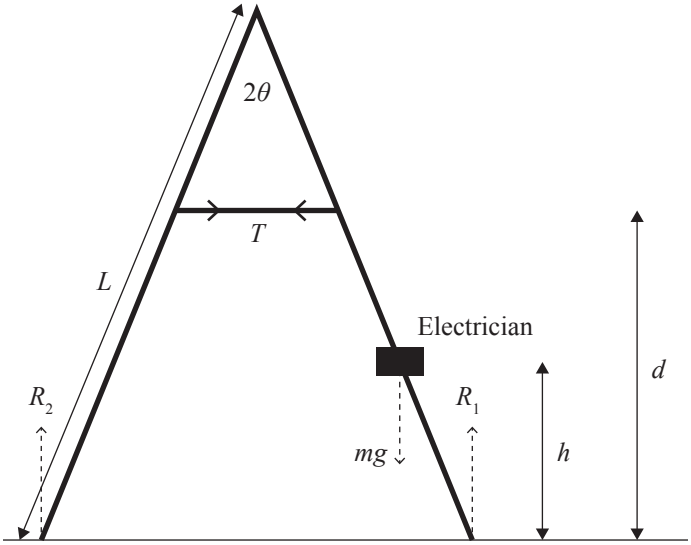
At the local ice rink one of the light bulbs has failed and must be replaced. A lightweight ladder is placed on the frictionless ice so that it is directly under the light bulb, and an electrician climbs the ladder to reach the bulb. Treat the ladder as having zero mass.

(a) For the initial position of the ladder and electrician shown in the diagram, the electrician will not be able to reach the light bulb.

Explain.

(b) With no friction acting on the base of the ladder, the only force preventing the collapse of the ladder is the tension, T, in the cross-tie bar.

The angle between the legs of the ladder is 2θ, and the reaction forces acting on these legs are shown in the diagram. The vertical distance to the cross-tie bar is d and the length of each leg is L. The mass of the electrician is m.



By taking moments about the top of the ladder, show that when the electrician is at a height, h, above the ground the tension in the cross-tie bar will be:

$$T = \frac{mgh\tan\theta}{2(L\cos\theta - d)}$$

(c) The angle, 2θ, between the legs of the ladder is 60º, and the cross-tie bar is one third the way down the leg.

(i) Calculate the maximum tension in the cross-tie bar when the electrician has a mass of 70 kg and the legs of the ladder are 3 m long.

(ii) Explain what effect increasing the angle will have on this maximum tension assuming the cross-tie bar remains fixed to the same points on the ladder.

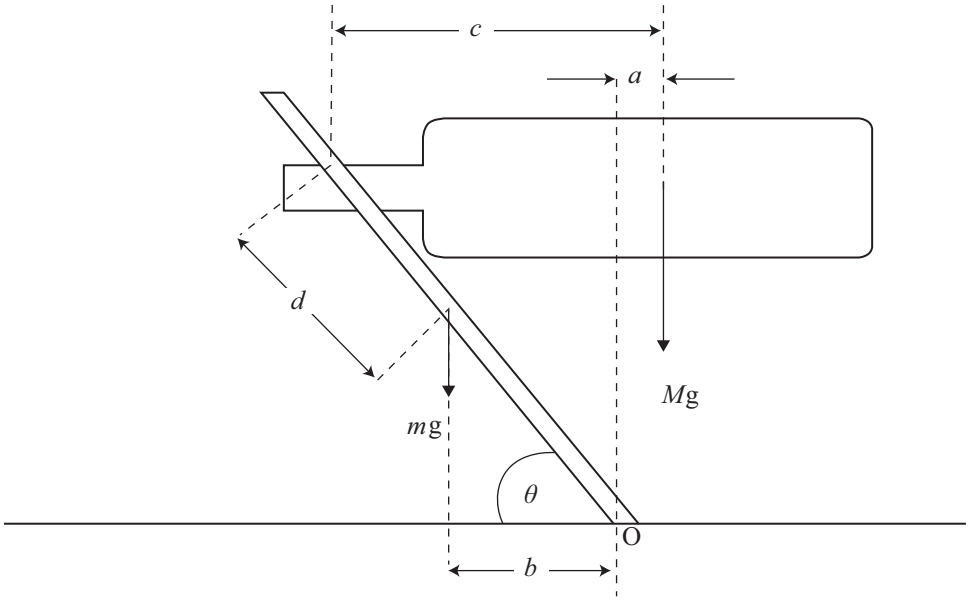
(d) Explain why it is important that the electrician climbs the ladder at a slow and steady speed.

(8)

QUESTION TWO: THE WINE BUTLER (8 marks)

The "Wine Butler" is a simple device, usually made of wood or plastic, that is used to hold a bottle of wine in an attractive and interesting manner. The neck of the wine bottle is placed through a hole in the wine butler, and the butler is set at an angle so that the whole assembly is balanced, as shown.

The wine butler has a length of $2L$ and it can be assumed that its centre of mass is in the middle, L from either end. In the diagram, the distances from the top of the hole to the centres of mass of the bottle and the butler are indicated, along with the horizontal distances from the respective centres of mass to the point of balance, O.



(a) (i) By taking torques, show that the wine butler is in rotational equilibrium if:

$$\frac{b}{a} = \frac{M}{m}$$

(ii) Show that $\cos\theta = \dfrac{Mc}{(m + M)L + Md}$

(b) Under what conditions will it **not** be possible to make the system stable?

(c) If L is increased, what will happen to the angle? Explain, using physical arguments.

(d) After the contents of the bottle have been removed, can the bottle be replaced in the same equilibrium position or must the neck of the bottle be moved to the left or right? (Assume that the centre of mass of the bottle stays in the same place when the wine is removed.)

(8)

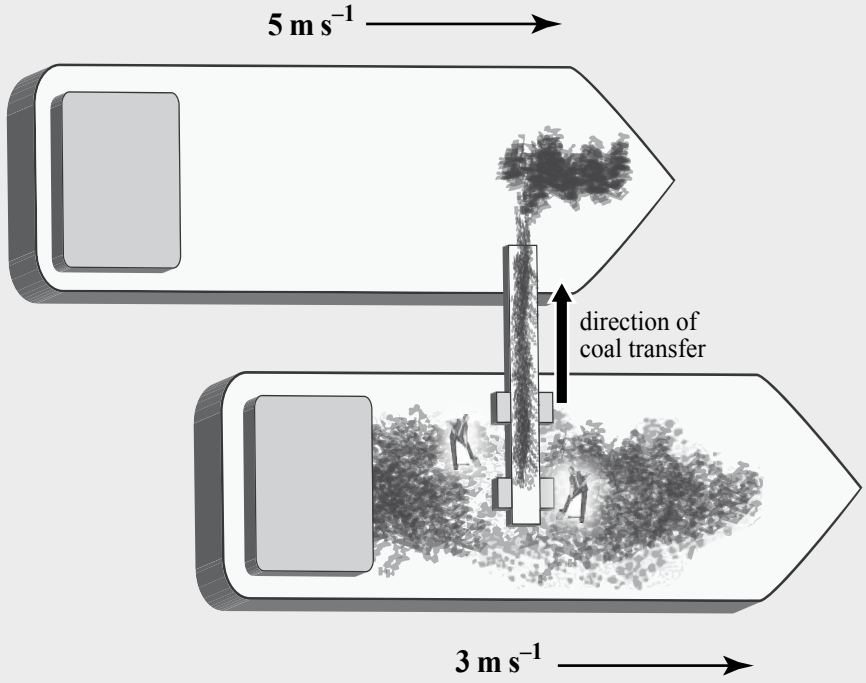
QUESTION THREE: MECHANICS (8 marks)

Acceleration due to gravity = 9.80 m s^{-2}

(a) Two long barges are moving in the same direction in still water, one with a speed of 3 m s^{-1}, and the other with a speed of 5 m s^{-1}. While they are passing each other, coal is transferred from the slower barge to the faster one at a rate of 20 kg s^{-1}.

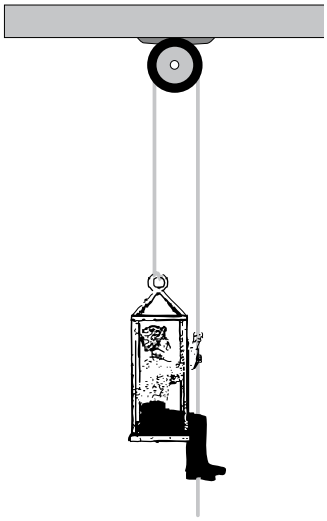
How much additional force, if any, must be provided by the engines of each of the barges if neither barge is to change speed?

Assume that the transfer is always **perfectly sideways** and that the frictional forces remain constant.



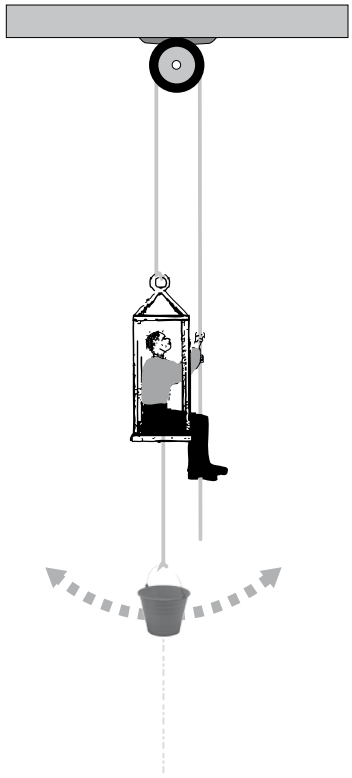
(b) A window cleaner sitting in a cage is supported by a rope and pulley system. The combined mass of the window cleaner and cage is 115 kg.

Calculate the magnitude of the force required to be exerted by the window cleaner on the rope in order for the cage to rise with constant velocity. Ignore friction and the mass of the pulley and rope.



(c) Another window cleaner has a bucket full of water, which is suspended from his cage by a rope. The bucket is set in motion and swings as a pendulum. However, there is a hole in the bottom of the bucket, and the water slowly drains away.

Describe how the period of the swinging motion changes as the bucket goes from full to empty.



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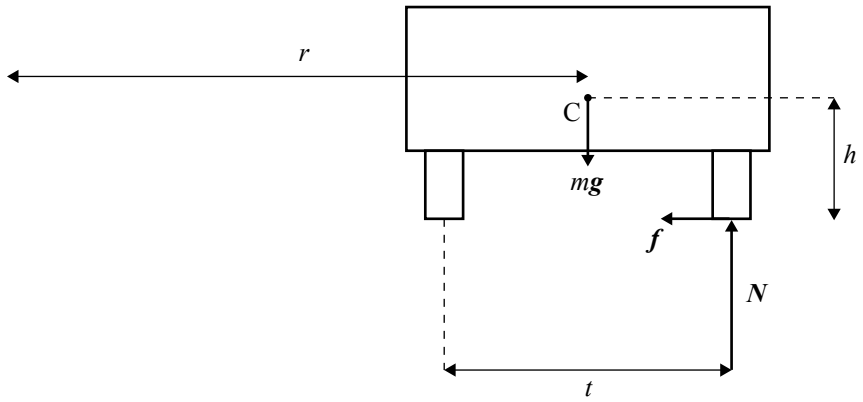
QUESTION FOUR: SPORT UTILITY VEHICLES (8 marks)

Acceleration due to gravity = 9.80 m s^{-2}

In recent years a large number of sport utility vehicles (SUVs) have appeared on New Zealand roads. SUVs can be susceptible to rolling under certain conditions. The diagram below is a representation of an SUV rounding a left-handed curve.



In the diagram, m = mass of the SUV, $\boldsymbol{g}$ = acceleration due to gravity, $\boldsymbol{f}$ = total frictional force on the two outside wheels, $\boldsymbol{N}$ = total normal force on the two outside wheels, C = centre of gravity of the SUV, t = track width, h = height of the centre of gravity, and the radius of the curve is r.

(a) Explain why the frictional force on the left-hand wheels is not considered here and why the frictional force on the right-hand wheels is in the direction shown.

(b) By taking moments about C, derive the condition for the vehicle to roll over.

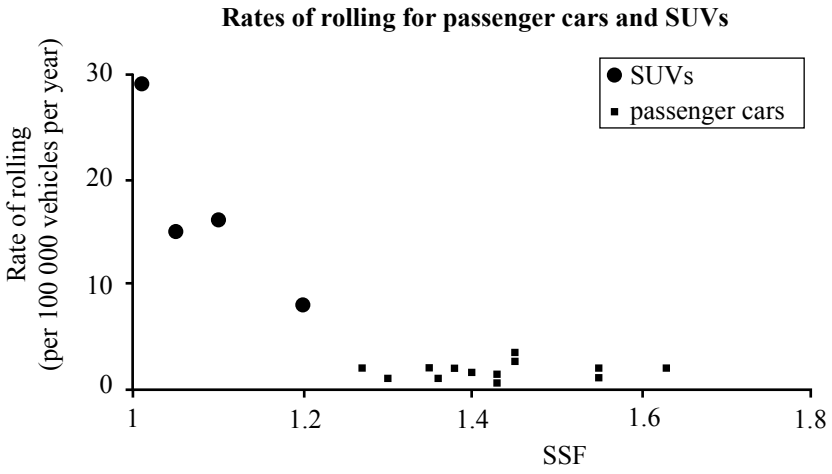
$$\frac{t}{2h} = \frac{v^2}{rg}$$

The term $\frac{t}{2h}$ is referred to as the Static Stability Factor (SSF).

One particular unloaded vehicle has t = 1.7 m and h = 0.8 m. Its capacity is five passengers and it has storage at the back of the vehicle and on a roof-rack. The vehicle has to take three passengers and their camping equipment.

(c) Explain the effect of this load on the stability of the SUV and on the way the vehicle should be driven.

(d) Data has been collected for the rates at which various cars and SUVs roll. This data is shown below. Comment on the relationship between the rate of rolling, the SSF and the type of vehicle, and make a recommendation on the minimum SSF that should be allowed.



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