H2 Physics Revision Topic : Forces

Structured Questions Name: ______________________________

1 **(a)** Define *upthrust*.

....

....

.... [2]

(b) A mass M with a wire attached to it is fully submerged in water as shown in Fig. 3.1. Mass M is 950 kg with a base area of 0.40 m^2 and a height of 0.50 m.

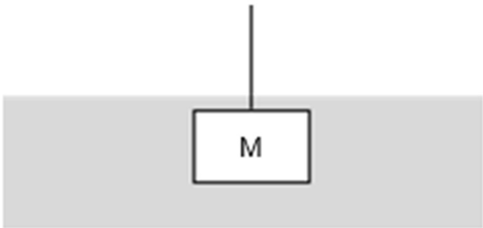

Fig. 3.1

Given that the density of water is 1000 kg m^{-3}, show that the tension in the wire is 7360 N.

[2]

1 **(c)** Mass M is actually being held up by a crane made of a uniform rigid beam AB hinged to the ground at A, and held in place by two wires CD and BE, as shown in Fig. 3.2.

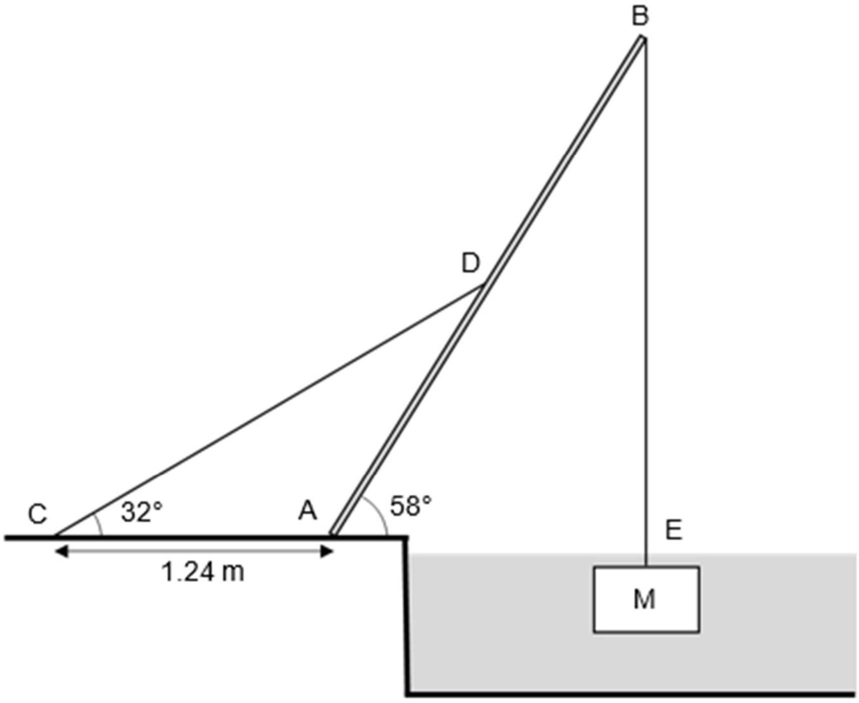

Fig. 3.2

The beam AB has a length of 3.00 m and a mass of 80.0 kg.

D is the midpoint of rod AB.

(i) Calculate the tension in the wire CD, T_{CD}.

T_{CD} = ………………………… N [2]

1 **(ii)** Explain why the hinge must exert a force on the beam at A to keep the beam in equilibrium.

....

....

....

.... [2]

(iii) With suitable calculations or otherwise, explain whether the direction of the force the hinge exerts on the beam at A is above AB (angle to the horizontal > 58°), along AB (angle to the horizontal = 58°), or below AB (angle to the horizontal < 58°).

....

....

.... [2]

2 **(a)** Determine the SI base units of the moment of a force.

SI base units : .... [1]

(b) A uniform square sheet of card ABCD is freely pivoted by a pin at a point P. The card is held in a vertical plane by an external force in the position shown in Fig. 3.1.

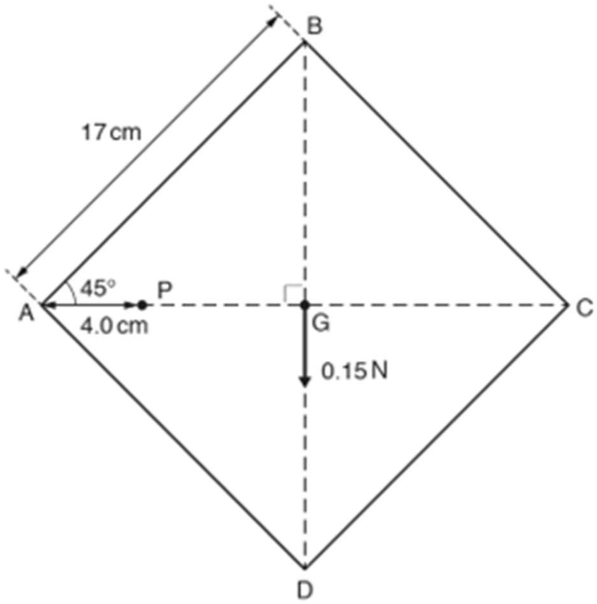

Fig. 3.1 (not to scale)

The card has weight 0.15 N which may be considered to act at the centre of gravity G. Each side of the card has length 17 cm. Point P lies on the horizontal line AC and is 4.0 cm from corner A. Line BD is vertical.

The card is released by removing the external force. The card then swings in a vertical plane until it comes to rest.

(i) Calculate the magnitude of the resultant moment about point P acting on the card immediately after it is released.

moment = ...N m [2]

2

(ii) Explain why, when the card has come to rest, its centre of gravity is vertically below point P.

....

....

....

.... [2]

(c) A spring is extended by a force. The variation with extension *x* of the force *F* is shown in Fig. 3.2.

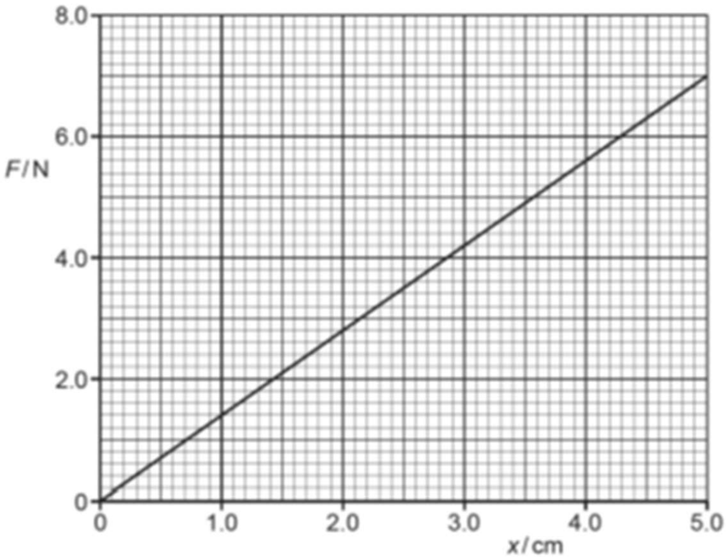

Fig. 3.2

One end of the spring is attached to a fixed point. A cylinder that is submerged in a liquid is now suspended from the other end of the spring, as shown in Fig. 3.3.

2

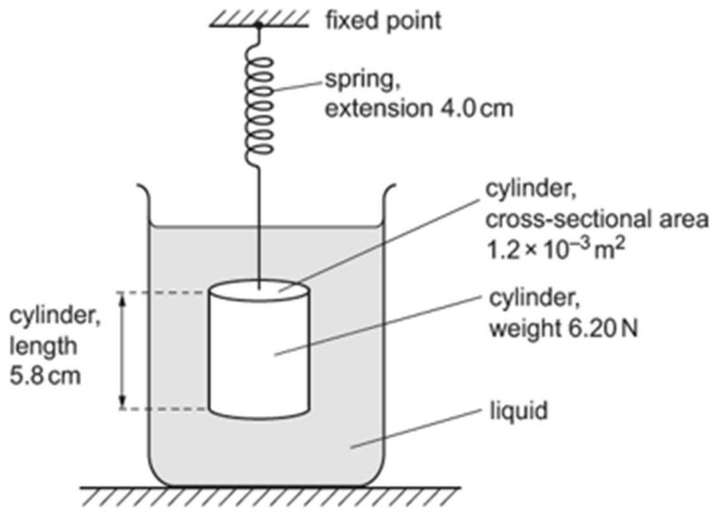

Fig. 3.3

The cylinder has length 5.8 cm, cross-sectional area 1.2×10^{-3} m^2 and weight 6.20 N. The cylinder is in equilibrium when the extension of the spring is 4.0 cm.

(i) Calculate the upthrust acting on the cylinder.

upthrust = ……………………………N [2]

(ii) Calculate the difference in pressure between the bottom face and the top face of the cylinder.

difference in pressure = ……………………………Pa [2]

2

(iii) The liquid in **(c)** is replaced by another liquid of greater density.

State and explain the effect, if any, of this change on the extension of the spring.

....

....

.... [2]

[Total: 11]

3 **(a)** Explain what is meant by *weight*.

....

.... [1]

(b) Fig. 2.1 shows a system of two pulleys with one pulley fixed to the ceiling but free to rotate. The other pulley is attached to a load.

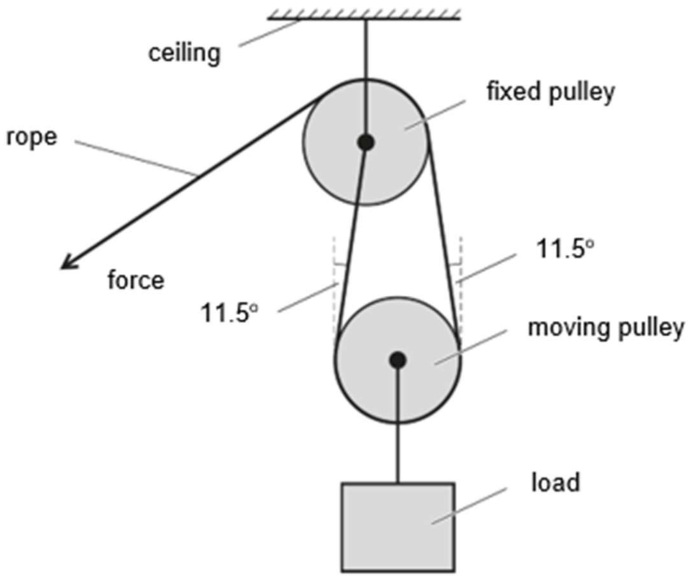

Fig. 2.1 (not to scale)

A force is used to pull the free end of the rope and this lifts the load at a constant speed. The air resistance and friction are negligible. The moving pulley has a mass of 2.40 kg and the load is a box of weight 960 N.

3

(i) The tension T in the rope is constant along its length. Calculate the tension T.

T = ………………………… N [3]

(ii) As the rope moves upwards, the tension in the rope changes. Explain how the tension changes.

……

……[2]

(c) When the pulley system is used, the work done by the force is greater than the gravitational potential energy gained by the load.

(i) Suggest one reason for this.

……

……[1]

(ii) Suggest one advantage for using the pulley system.

……

……[1]

4 Fig 3.1 shows a man pushing a wheelbarrow with a total weight of 100 N. At the instant shown, the wheelbarrow is stationary. The dimensions of the wheelbarrow, the contact force *R* exerted by the ground on the wheelbarrow, and the combined weight *W* of the wheelbarrow and the load it carries are shown in Fig. 3.2. The force *H* exerted by the person on the wheelbarrow is not given in the diagram.

Fig. 3.1

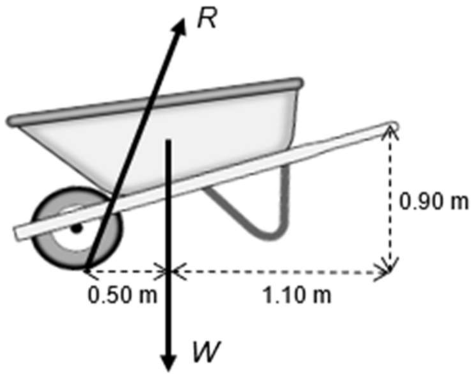

Fig. 3.2

(a) Given that the force *R* exerted by the ground on the wheelbarrow acts 73° above the horizontal, determine the magnitude of *R*.

R = …………………………………… N [2]

(b) Hence, determine the magnitude and direction of *H*.

magnitude of *H* = ……………………………………… N

direction of *H* = ………………………………………………………………… [3]

5 Fig. 2.1 shows a uniform pole of weight 3.0 N hinged to a wall at point X and tied to a spring at point Y, which is at a distance one-quarter its length.

The pole is inclined at 10° to the horizontal and the spring makes an angle of 20° with the wall.

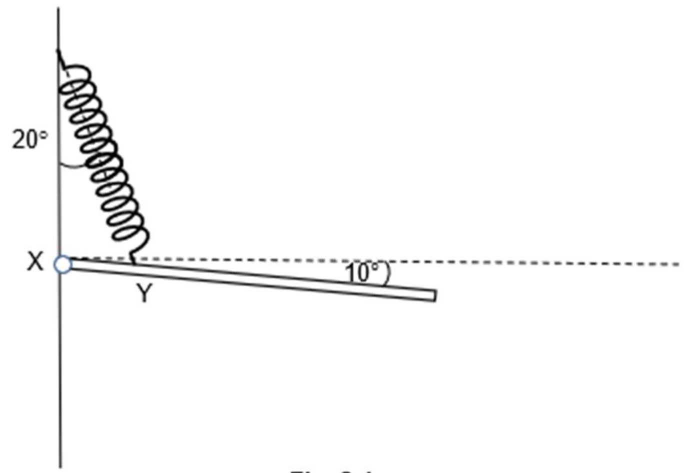

Fig. 2.1

(a) Show that the tension in the spring is 6.8 N.

[2]

(b) A student measures the length of the extended spring in Fig. 2.1 to be 38.0 cm. The unextended spring measures 30.0 cm.

(i) Determine the force constant of the spring.

force constant = ……………………… $N\ m^{-1}$ [2]

5 **(ii)** The uncertainty in each measurement of the length of the spring is ±1 mm. Given that the percentage uncertainty of the tension is 2.0 %, determine the percentage uncertainty in the force constant calculated in **(b)(i)**.

percentage uncertainty = ………………………. % [2]

(c) **(i)** The hinge exerts a force on the pole at point X. Draw an arrow on Fig. 2.1 to show the direction of this force. [1]

(ii) Calculate the magnitude of this force.

force = …………………………. N [2]

[Total: 9]

6 **(a)** Fig. 2.1 shows a liquid in a cylindrical container.

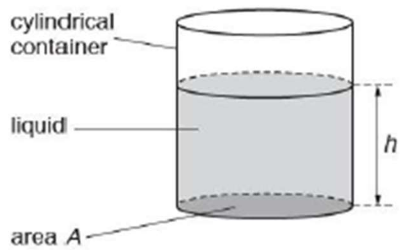

Fig. 2.1

The cross-sectional area of the container is A. the height of the column of liquid is h and the density of the liquid is ρ.

Show that the pressure p due to the liquid at the base of the cylinder is given by

$$p = h\rho g$$

[2]

(b) The variation with height h of the total pressure P on the base of the cylinder is shown in Fig. 2.2.

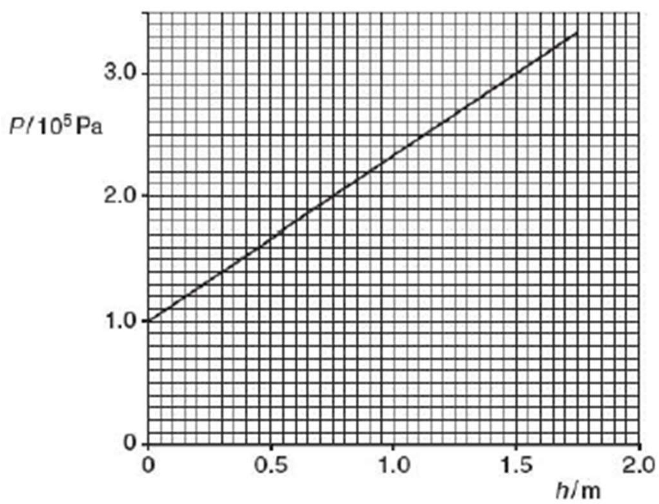

Fig. 2.2

6 **(i)** Explain why the line of the graph in Fig. 2.2 does not pass through the origin (0,0).

....

.... [1]

(ii) Use data from Fig. 2.2 to calculate the density of the liquid in the cylinder.

density = ... kg m^{-3} [3]

(c) An object is dropped into the liquid and it floats. Explain why the density of the object is lower than that of the liquid.

....

....

....

.... [2]

[Total: 8]

7 **(a)** State the conditions required for a body to be in equilibrium.

....

....

....

....[2]

(b) Fig. 2.1 shows a lamp weighing 5.0 N that is hung from the end of a beam 4.50 m long and weighing 1.0 N, making an angle of 25° below the horizontal.

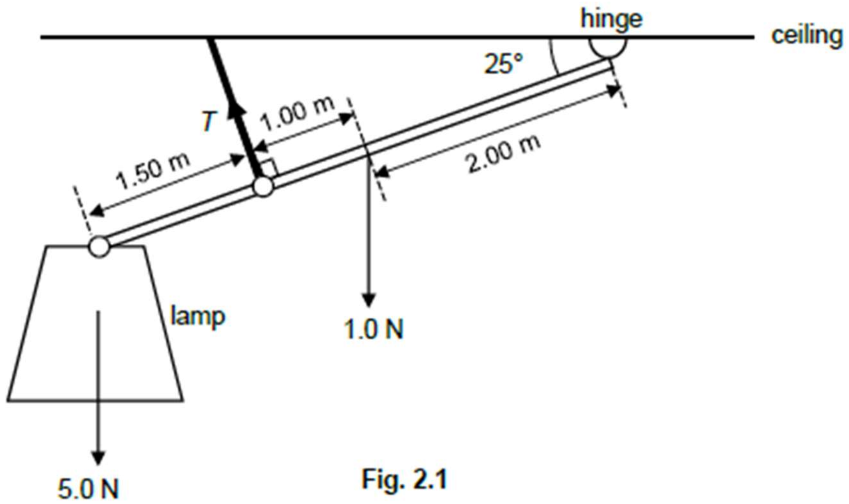

Fig. 2.1

The beam is held in position by a hinge at its upper end and by a cable 3.00 m lower down the beam and perpendicular to it. The centre of gravity of the beam is 2.00 m along the beam from the hinge.

(i) The position of the centre of gravity of the beam is not at its midpoint. Suggest what this implies about the distribution of the mass in the beam.

....

....

.... [1]

(ii) Show that the tension T in the cable is 7.4 N.

[2]

7 **(iii)** Determine the magnitude and the direction of the force acting on the beam at the hinge.

magnitude = ... N

direction = ...

[3]

[Total: 8]

8 Fig. 2.1 shows an airplane of mass 1.5×10^5 kg, flying horizontally at a constant velocity. The airplane has four engines, two located on each wing, which produce a combined forward thrust of 8.0×10^5 N. The other forces acting on the airplane are drag force, the combined lift of both wings and its weight. The horizontal separation of the lines of action of lift and weight is 0.75 m.

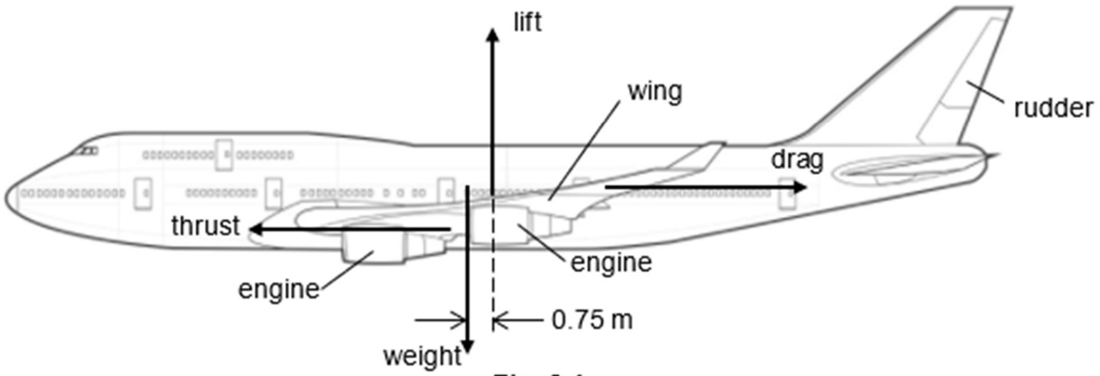

Fig. 2.1

(a) Define the moment of a force about a point.

....

.... [1]

(b) Determine the vertical separation of the lines of action of thrust and drag.

vertical separation = ... m [3]

(c) The airplane starts to accelerate forward. Using Newton's First Law of Motion, state and explain the direction of the frictional force acting on a box that is placed on the airplane floor.

....

....

....

.... [2]

8 **(d)** The engines of the airplane are located 10 m and 20 m perpendicularly from the midline of the airplane's body. In a training session, both engines on the right wing are shut down, leaving only the two engines on the left wing working. Each of these engines produce a forward thrust of 2.0×10^5 N. As a result, the airplane rotates in the horizontal plane. To counter this rotation, the rudder at the tail of the aircraft can be adjusted.

Fig. 2.2 shows the adjustment of the rudder to an angle such that a force *P* acts on the rudder at a point 30 m from centre of gravity C.G. along the midline of the airplane. P acts at an angle of 60° to the midline and is due to the airflow incident on the rudder.

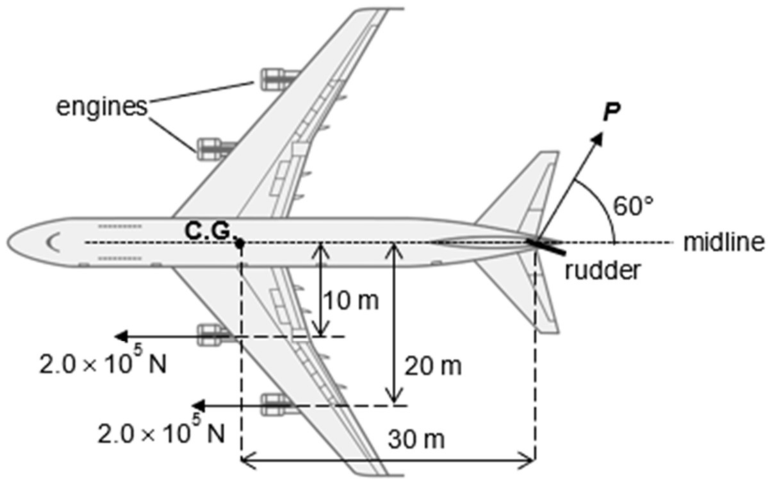

Fig 2.2

Calculate the value for *P* that will prevent the aircraft from rotating.

P = ... N [2]

9 **(a)** Define *moment of a force.*

....

....

.... [1]

(b) A person supports a load of 20 N in his hand as shown in Fig. 1.1. The system of the hand and load is represented by Fig. 1.2. The rod represents the forearm and *T* represents the tension exerted in the biceps. The forearm weighs 65 N.

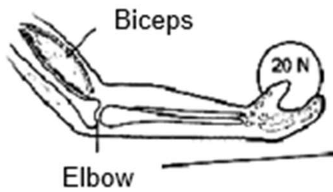

Fig. 1.1

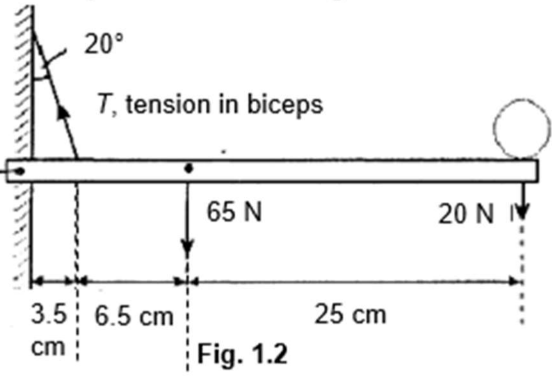

Fig. 1.2

(i) Show that the tension *T* in the biceps is 410 N.

[3]

(ii) Determine the magnitude and direction of the force acting at the elbow.

force acting at the elbow = ... N

direction of the force: .... [4]

10 **(a)** Define the *moment* of a force about a point.

....

.... [1]

(b) A fishing rod AB is shown in Fig. 4.1.

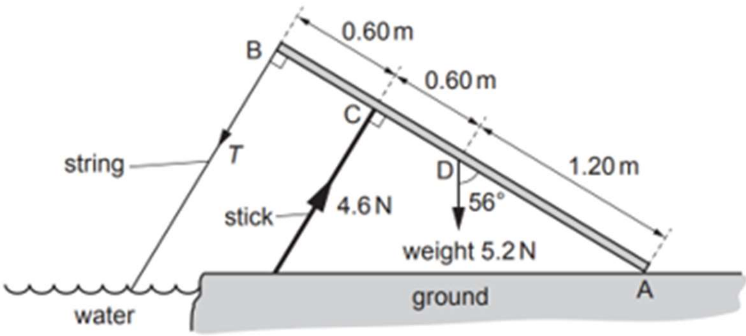

Fig. 4.1

End A of the rod fixed to the ground and a string is attached to the other end B. A support stick exerts a force perpendicular to the rod at point C. The weight of the rod acts at point D.

The tension T in the string is in a direction perpendicular to the rod. The rod is in equilibrium and inclined at an angle of 56° to the vertical.

The forces and the distances along the rod of points A, B, C and D are shown in Fig. 4.1.

(i) Calculate the tension T.

T = ... N [2]

10 **(ii)** Calculate the magnitude of the force acting on the rod at point A. State the angle of its direction with respect to the *rod*.

magnitude = ... N

angle = ... ° [3]

11 Fig. 1.1 shows a simplified catapult used to hurl projectiles a long way.

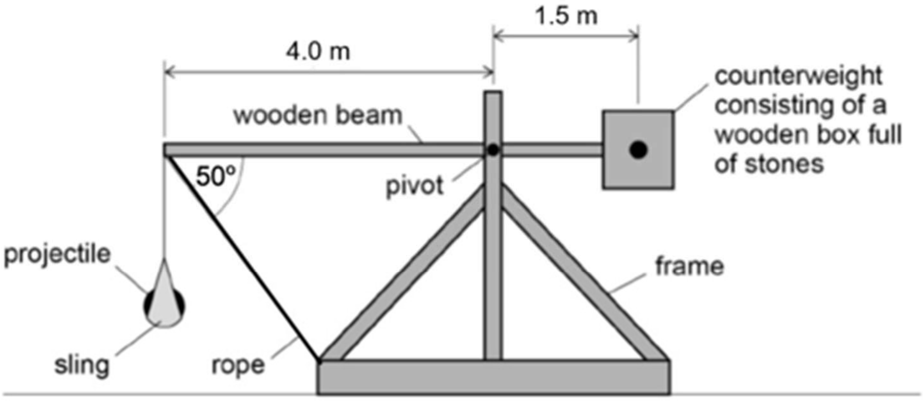

Fig. 1.1

The counterweight is a wooden box full of stones attached to one end of the beam. The projectile, usually a large rock, is in a sling hanging vertically from the other end of the beam. The weight of the sling is negligible.

(a) The catapult is designed so that the weight of the beam and the weight of the *empty* wooden box have no effect on the tension in the rope.

Suggest how the pivot position achieves this.

....

....

....

.... [2]

(b) The stones in the counterweight have a total mass of 610 kg and the projectile weighs 250 N.

The beam is held horizontal by a rope attached to the frame.

Calculate the tension in the rope.

tension = ... N [3]

11 **(iii)** For equilibrium to be reached, there is another force R acting on the beam at the pivot.

1. Sketch and label this force R on Fig. 1.1. [1]

2. Calculate the magnitude of the force R.
You may assume that the weight of the beam and empty box is negligible compared to the other forces.

R = ... N [4]

[Total: 10]

12 **(a)** State Hooke's law.

....

.... [1]

(b) An elastic cord has an un-extended length of 13.0 cm. One end of the cord is attached to a fixed point C. A small ball of weight 5.0 N is hung from the free end of the cord. The cord extends to a length of 14.8 cm, as shown in Fig. 4.1.

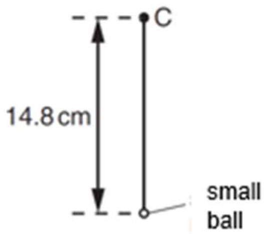

Fig. 4.1

The cord and ball are now made to rotate at constant angular speed ω in a vertical plane about point C. When the cord is vertical and above C, its length is the un-extended length of 13.0 cm, as shown in Fig. 4.2.

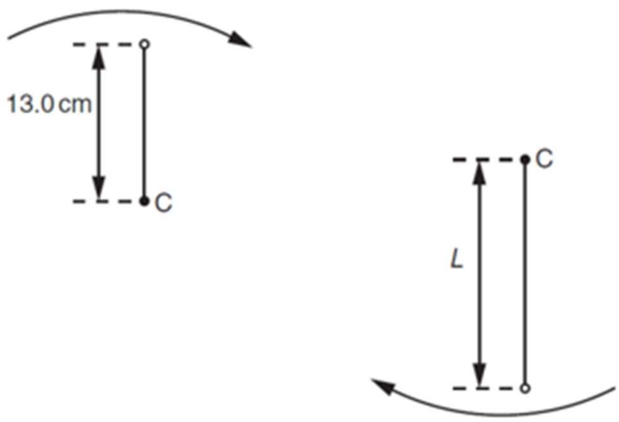

Fig. 4.2 **Fig. 4.3**

The cord and ball rotate so that the cord is vertically below C, with length L, as shown in Fig. 4.3.

(i) Explain whether the centripetal force on the ball in Fig. 4.2 is more than, equal to, or less than the weight of the ball.

....

....

.... [1]

12 **(ii)** Calculate the length L of the cord, assuming it obeys Hooke's law.

length = ... m [5]

[Total: 7]

13

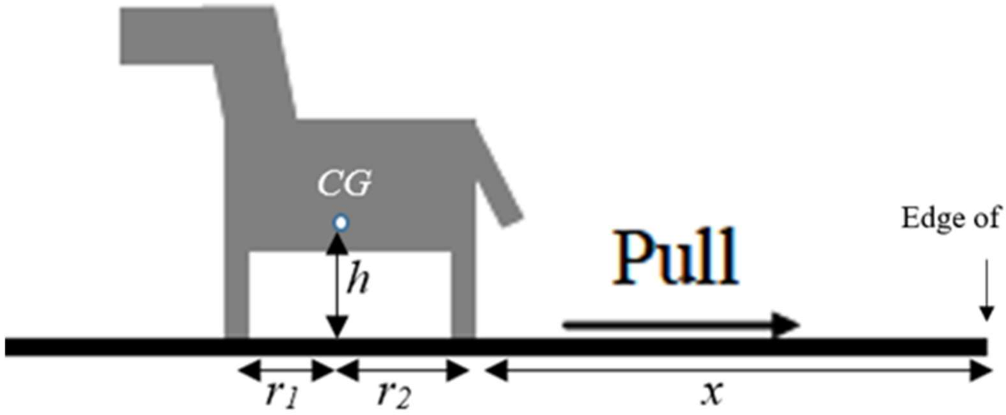

Fig. 7.1

A wooden toy horse rests on a tablecloth on a smooth table, with its back legs located at a distance $x = 0.300$ m from the edge of the table. It has a mass $m = 100$ g and its center of gravity (CG) is at distances $r_1 = 0.0500$ m from the front legs and $h = 0.0500$ m above ground. The distance between the front and back legs is 0.150 m. The coefficient of friction between the cloth and the horse is 0.750. The tablecloth is pulled horizontally.

(a) Describe a situation in which friction opposes motion and another in which it causes motion.

....

....

....

....

....

.... [2]

13 **(b)** The cloth is pulled such that the horse is on the verge of slipping. The coefficient of friction μ is a dimensionless number defined as the ratio of frictional force to normal force exerted by one surface on another. Show that the frictional force f between the cloth and the horse is approximately 0.736 N.

[2]

(c) Determine

(i) the acceleration of the horse relative to the table assuming the horse does not slip relative to the cloth.

Acceleration = …………………….. m s^{-2} [2]

(ii) the velocity of the horse when the back legs reach the edge of the table.

Velocity = ………………….. m s^{-1} [2]

13 **(d)** The table exerts a force N_1 and N_2 on the front and back legs of the horse respectively.

(i) Draw in and label all the forces acting on the horse in **Fig 7.1** as it is being pulled horizontally. Pay attention to the relative magnitudes of the vertical forces. [2]

(ii) Write down an expression to show

1. the vertical equilibrium of the horse

.... [1]

2. rotational equilibrium of the horse about its centre of mass while it is being pulled.

.... [1]

(iii) From your answers in **(ii)**, show that

$$N_2 = mg\frac{r_1 - \mu h}{r_1 + r_2}$$

[2]

(iv) Hence determine a value for N_2 and N_1.

N_2 = ... N [1]

N_1 = ... N [1]

13

(v) If the height of the center of gravity could be adjusted, determine the value above which the back legs of the horse would lose contact with the table.

Maximum height = …………………. m [2]

(vi) Apart from a low centre of gravity, suggest another two features which will make it less likely for the back legs of the horse to lose contact with the table.

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

……………………………………………………………………………… [2]