QUESTION ONE

A hammer thrower launches a heavy ball on the end of a fixed length of wire by rotating his body about a vertical axis as shown in the illustration below:

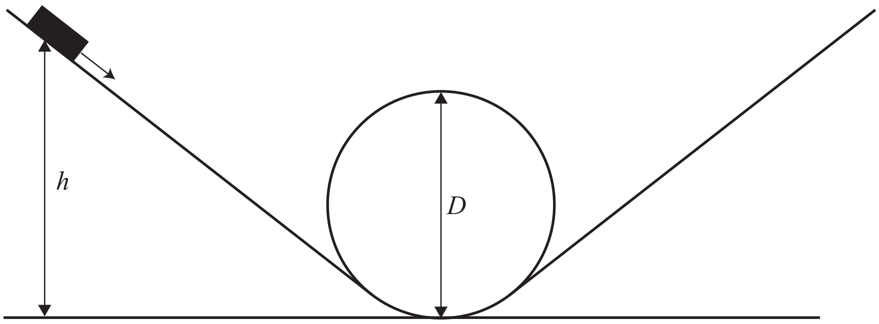
(i) Assuming the ball is moving at a constant speed in a horizontal circle, explain why the wire from the thrower's hands to the ball cannot be parallel to the ground.

(ii) Explain how the hammer thrower is able to increase the speed of the ball as he winds up for the throw.

QUESTION TWO: THE SLIDING TOY (8 marks)

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

Benjamin is playing with his toy slider and track. The track has a circular loop of diameter, *D*, as shown in the diagram. Friction between the slider and the track is negligible.



(a) Explain the physical conditions under which the slider can travel around the loop without losing contact with the track.

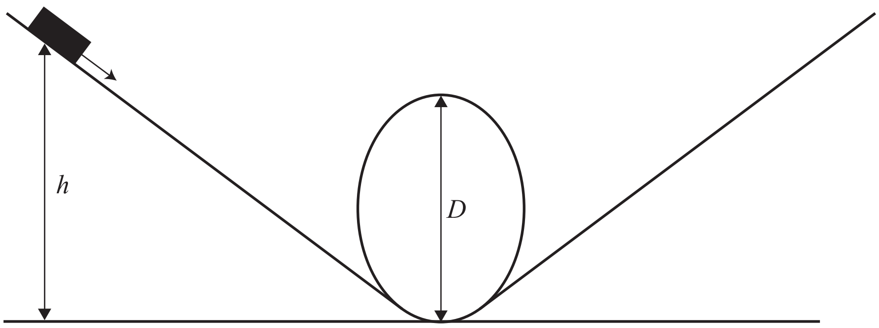
(b) If Benjamin releases the slider from rest, derive an expression for the minimum height, *h*, so that the slider does not lose contact with the track.

(c) Explain how the minimum height changes for the following three different cases:

(i) Benjamin pushes the slider as he releases it.

(ii) Benjamin replaces the slider with one that has greater mass, but is otherwise identical.

(iii) Benjamin replaces the loop with an elliptical one with the same height as the circular one, as shown in the diagram.



(8)

QUESTION THREE: SATELLITES

Universal Gravitational Constant	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
Mass of the Earth	$= 5.98 \times 10^{24}$ kg
Radius of the Earth	$= 6.37 \times 10^{6}$ m
Acceleration due to gravity	$= 9.81$ m s^{-2}

A satellite, in a circular orbit around the Earth, has a rotational period of 2.00 hours. The satellite is orbiting above the Equator, and is moving in the same rotational direction as the Earth.

(a) All satellites, at any height, are said to be weightless.

Explain.

(b) Calculate the height, above the Earth's surface, of the satellite.

(c) Calculate the angular velocity of the satellite relative to the Earth.

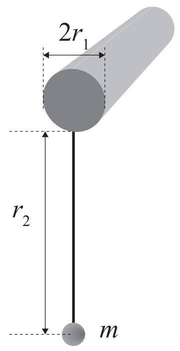
(d) Calculate the angle, measured with respect to the centre of the Earth, through which the satellite will be visible to the observer at the Equator.

(e) There are limits to the largest and smallest periods of an Earth satellite.

Discuss this statement.

(8)

QUESTION FOUR: THE VERTICAL CIRCLE



A small ball of mass m, hangs from a light, inextensible string attached to a fixed horizontal post of radius r_1, as shown.

The ball is hit horizontally with a large bat so that the ball wraps the string around the post.

(a) Show that the ball's speed at the top of its first swing must be at least

$v_{top} = \sqrt{g\left(r_2 - \frac{\pi r_1}{2}\right)}$ so that the string remains taut.

(b) For the speed of the ball in (a), show that the initial speed must be at least

$$v_{initial} = \sqrt{g\left(5r_2 - \left(\frac{3\pi}{2} - 2\right)r_1\right)}.$$

(c) Assuming an elastic collision, show that the speed of the bat is approximately half that of the ball's initial speed.

State any other assumptions made, and the reasons for them.

(d) As the ball completes its first orbit around the post, explain why the ball appears to be travelling at a speed greater than its initial value.

(8)

QUESTION FIVE: THE PENDULUM (8 marks)

A pendulum bob (mass M) is released from the horizontal position shown in the diagram ($\theta = 0°$) and swings down to the vertical position ($\theta = 90°$).

(a) Explain why the motion of this pendulum will not be a simple harmonic motion.

(b) Show that the tension in the cord (which was originally zero) has increased to $3Mg$, as the bob passes through the lowest point.

(c) The pendulum cord is replaced with a thinner string, and is again released from rest when $\theta = 0°$.

If the string breaks when the tension is twice the weight of the bob, at what angle does it break?

(d) The bob of a pendulum is given a positive charge and oscillates with a small amplitude above a large, earthed, metal plate.

Explain how the period differs from the case where the metal plate is absent.

(8)