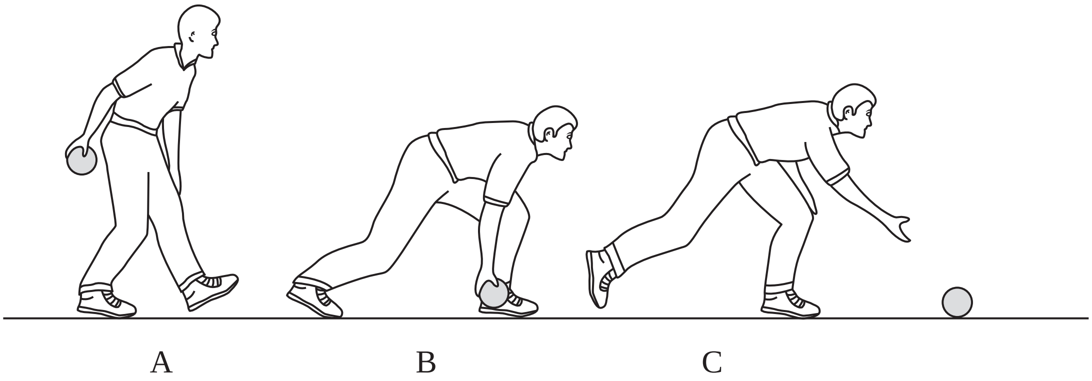
Mechanics II QP2

1 In a bowling game, a player rolls a small ball along the ground. The diagram shows the action of the player as he starts to swing his arm forward at A, to the point when the ball is rolling along the ground at C.

The player exerts a forward force on the ball between A and B.



(a) (i) State how the motion of the ball at C differs from that at B.

(2)

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(ii) The player applies a forward force for 0.20 s and the ball leaves the player's hand at a speed of 3.0 m s^{-1}.

Calculate the average forward force that the player applies to the ball.

mass of ball, m_1 = 1.5 kg

(2)

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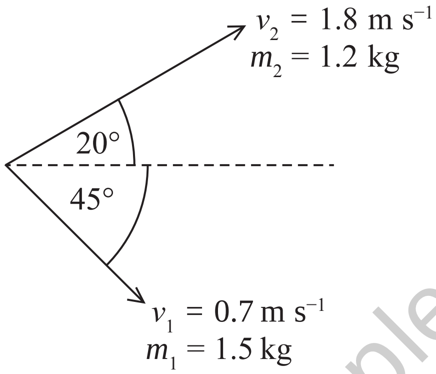
Average forward force = ...

(b) The ball rolls along the ground until it collides with a stationary ball of mass 1.2 kg. After the collision both balls roll off at an angle to the original direction of the moving ball as shown in the diagrams.

Before:

After:



After the collision:

- the 1.5 kg ball travels at 0.7 m s^{-1} at an angle of 45° to its original direction
- the 1.2 kg ball travels at 1.8 m s^{-1} at an angle of 20° to the original direction of the moving ball.

(i) Show that the velocity *v* of the first ball as it collides with the second ball is about 2 m s^{-1}.

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(ii) By means of a suitable calculation, show that the collision is inelastic.

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(Total for Question = 9 marks)

2 The International Space Station (ISS) is in orbit at a height of 400 km above the Earth's surface. The ISS completes 15.5 orbits in 24 hours.

(a) Calculate the angular velocity of the ISS in radians per second.

(2)

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Angular velocity = ... rad s^{-1}

*(b) A student suggests:

"*The ISS is travelling at a constant speed, so, according to Newton's laws, there will be no resultant force acting on it*."

Criticise this suggestion.

(3)

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(c) Calculate the magnitude of the centripetal force acting on the ISS.

mass of ISS = 4.19×10^5 kg
radius of Earth = 6400 km

(2)

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Force = ...

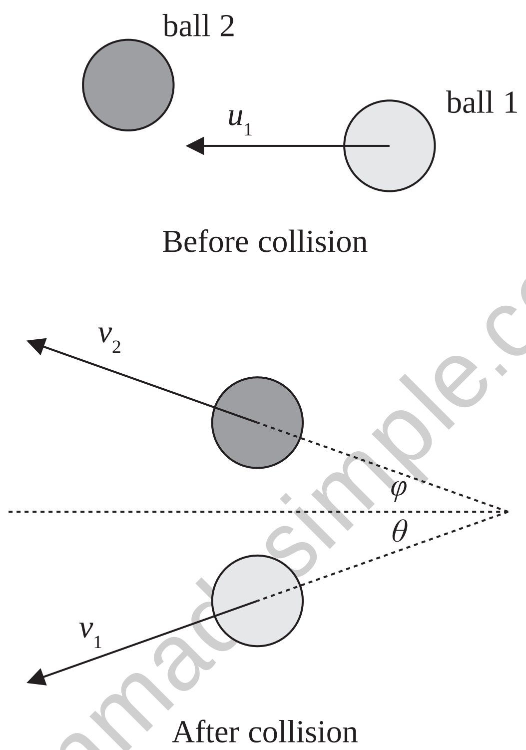
(Total for Question = 7 marks)

3 A student read the following extract from a textbook.

‘In an elastic collision between objects of equal mass, where one is initially stationary, the objects move off at 90° to each other after the collision.’

The student investigated this using a collision between two identical steel balls, each of mass 66 g.

(a) The diagrams illustrate the collision between the balls.



In one experiment u_1 was 0.72 m s^{-1} and θ was 29°. For such a collision it can be shown that, if the balls are to separate at 90°, then

$v_1 = 0.63\,\text{m s}^{-1}$

$\varphi = 61°$

$v_2 = 0.35\,\text{m s}^{-1}$

(i) Show that these values satisfy the conditions for conservation of momentum in the initial direction of ball 1.

(4)

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(ii) Show that these values satisfy the condition for elastic collisions.

(3)

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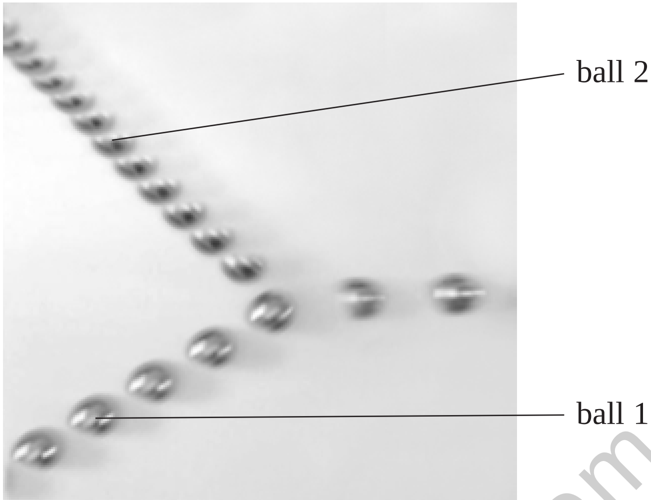
(b) The photograph shows the student's actual results for this experiment. The positions of the colliding balls at successive time intervals have been overlaid on a single image.



(i) State the additional information that the student needs in order to determine the speeds of the balls.

(2)

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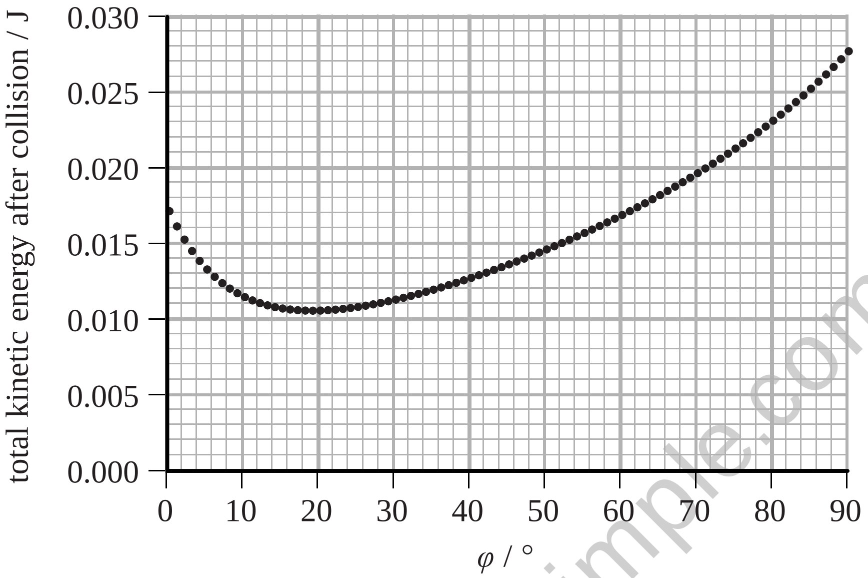
(ii) The student looked at the photograph and noticed that the angle between the paths of the two balls after the collision was not 90°. He modelled the collision on a computer.
He used the same initial conditions for ball 1 and the same value of θ. The computer calculated the total kinetic energy after the collision for a range of angles φ. The following graph was produced.



Measure φ from the photograph and use the graph to suggest why the angle between the paths is not 90°.

(3)

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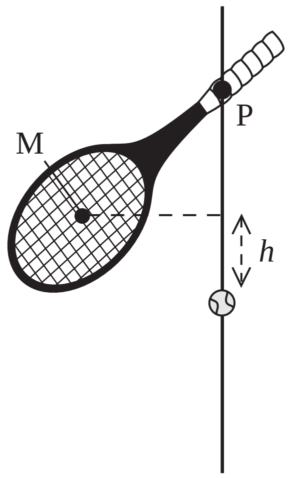
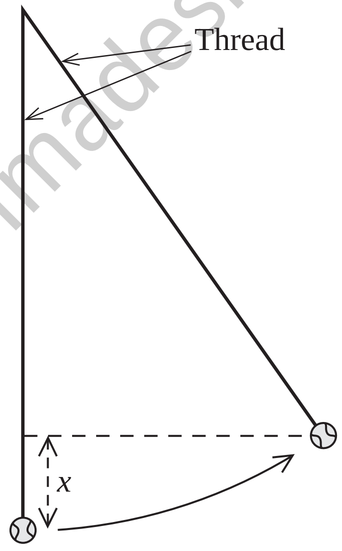
(Total for Question = 12 marks)

4 A student is carrying out an investigation into collisions between a bat and a ball.

The bat is pivoted at a point P so that it can swing freely. The centre of mass M of the bat swings through an arc and hits the ball. M moves through a height h as shown below.



The ball is suspended vertically by a thread. The bat hits the ball which swings to a maximum height x.



One set of measurements is $h = 0.030$ m $x = 0.10$ m

(a) Show that the speed of M just before the collision is about 0.8 m s^{-1}.

(2)

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(b) The student calculates the speed of the ball just after the collision to be 1.4 m s^{-1}.
The mass of the bat is 320 g and the ball is 55 g.

Calculate the speed of the bat just after the collision and state one assumption you make.

(4)

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Speed of bat = ...

Assumption: ....

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(c) Determine whether the collision was elastic or inelastic.

(3)

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(d) Discuss your conclusion with reference to possible uncertainties in the measurements of *x*.

(2)

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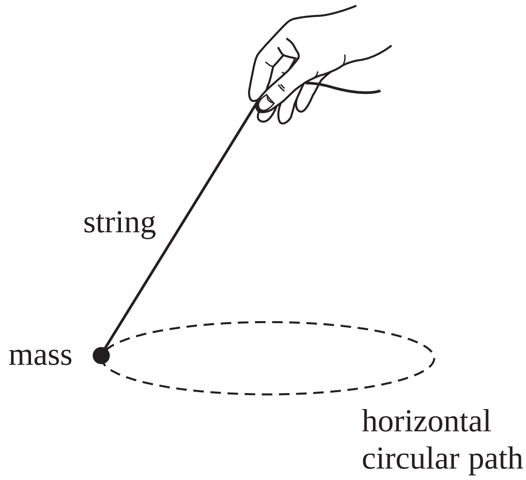
(Total for Question = 11 marks)

5 (a) A student holds a piece of string with a small spherical mass attached to the other end. She rotates the mass at a constant angular velocity, in a horizontal circular path which is below her hand.



Explain why it is not possible for the student to rotate the mass so that the string is horizontal.

(2)

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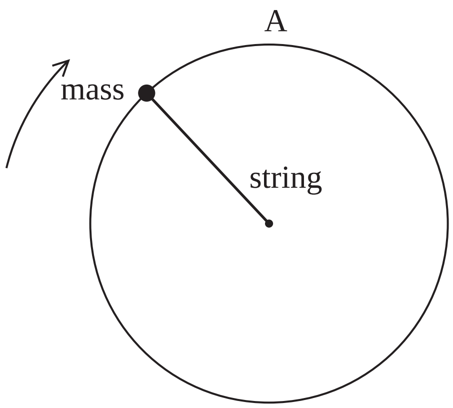
(b) The student now rotates the mass in a vertical plane as shown in the diagram.



(i) The string has a length of 25.0 cm and is attached to a mass of 204 g. It is rotated in a vertical circle with the string remaining taut at all times. When the mass is at the top of the circle it is moving with an angular velocity of 9.90 rad s^{-1}.

Calculate the tension in the string at this position.

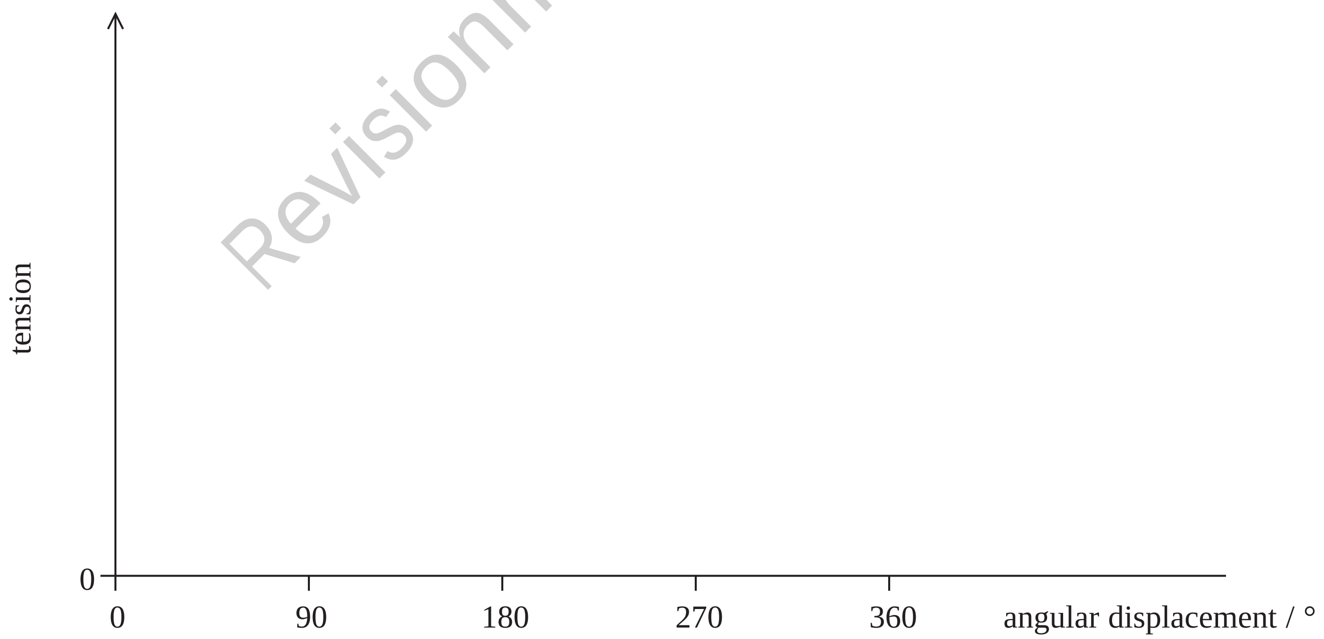
(4)

Tension = ...

(ii) As the mass completes one circuit of the vertical circle, its position can be identified by the angle it has moved through (its angular displacement). One complete revolution means that the mass has moved through an angle of 360°.

On the axes below sketch a graph of how the tension in the string varies as it completes a full circle starting from A.

(4)



(Total for Question = 10 marks)