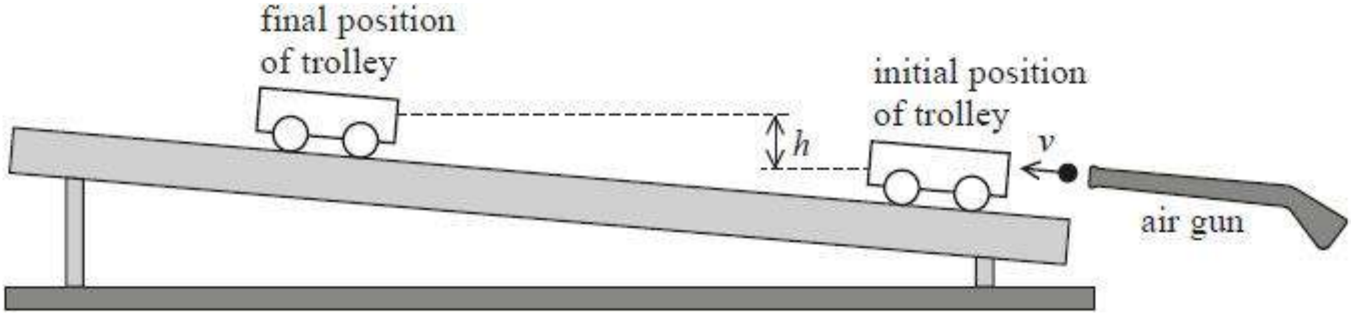
Questions

Q1. The diagram shows an experiment to determine the speed at which a pellet is fired from an air gun. The pellet moves parallel to the track and hits the trolley. The trolley and pellet move off together along the track, before coming to rest. The change in vertical height of the trolley is *h*.



The pellet was fired into the trolley, and *h* measured, several times. A mean value of *h* was calculated.

(a) State why the experiment should be repeated and a mean value for *h* calculated.

(1)

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(b) (i) The mean value of *h* was 0.16 m.

Show that the speed of the trolley immediately after being hit by the pellet was about 2 m s^{-1}. Assume that resistive forces were negligible.

(2)

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(ii) Calculate the speed of the pellet immediately before it hit the trolley.
mass of trolley = 0.125 kg
mass of pellet = 1.88×10^{-3} kg

(3)

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Speed of pellet = ...

(iii) Determine by calculation whether the collision between the pellet and the trolley was elastic.

(3)

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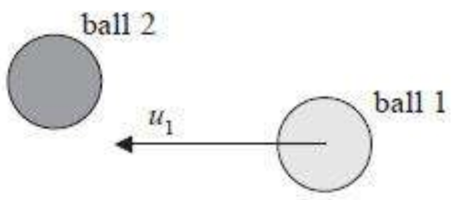
(Total for question = 9 marks)

Q2. A student read the following extract from a textbook.

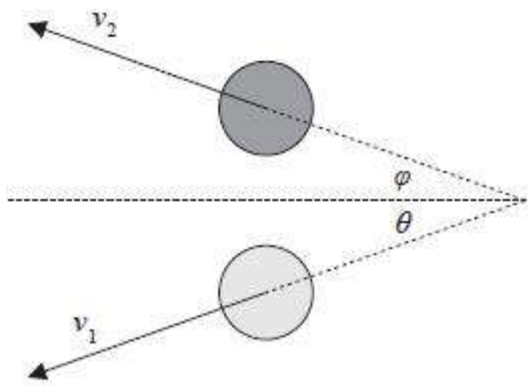
'In an elastic collision between objects of equal mass, where one is initially stationary, the objects move off at 90° to each other after the collision.'

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.



Before collision



After collision

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 m s^{-1}

φ = 61°

v_2 = 0.35 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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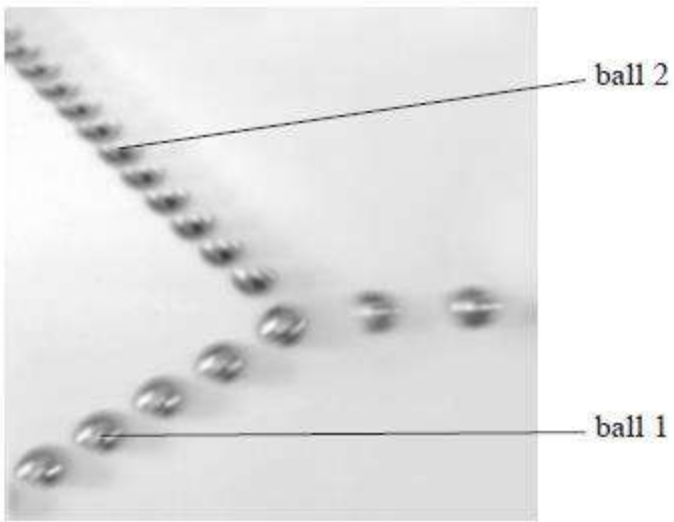
(b) The photograph shows the student's actual results for this experiment. The positions of the colliding balls at successive time intervals have been overlaid on a single image.



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

(2)

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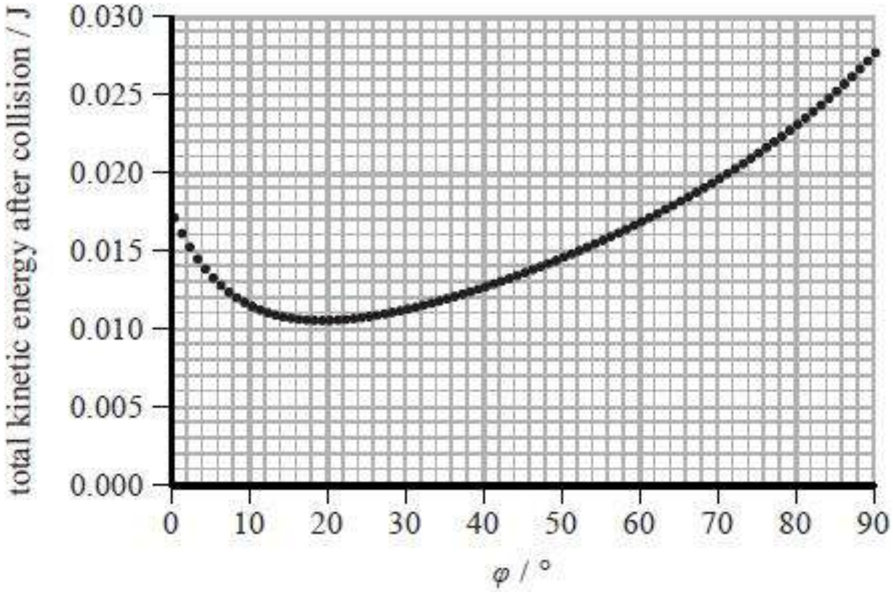
(ii) The student looked at the photograph and noticed that the angle between the paths of the two balls after the collision was not 90°. He modelled the collision on a computer.
He used the same initial conditions for ball 1 and the same value of θ. The computer calculated the total kinetic energy after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

Q3. An electron has a momentum of 1.9×10^{-24} kg m s^{-1}. The kinetic energy of the electron is

- **A** 1.1×10^{-21} J
- **B** 2.0×10^{-18} J
- **C** 4.0×10^{-18} J
- **D** 1.0×10^{6} J

Q4. (a) State the principle of conservation of momentum.

(2)

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(b) State the relationship between the resultant force acting on an object and the momentum of the object.

(1)

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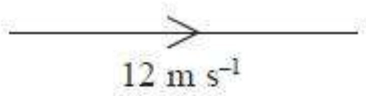
(c) A car is travelling due east with a velocity of 12 m s^{-1}. The driver of the car changes direction to travel due north with a velocity of 15 m s^{-1}.

(i) The initial velocity is shown in the diagram.
Complete the vector diagram to represent the change in velocity. You do not need to draw it exactly to scale.

(2)



(ii) Determine the change in velocity of the car.

(3)

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Magnitude of change of velocity = ...

Direction of change of velocity = ...

(iii) The mass of the car is 1500 kg and the change in velocity took 4.0 s.
Calculate the average force that was needed.

(2)

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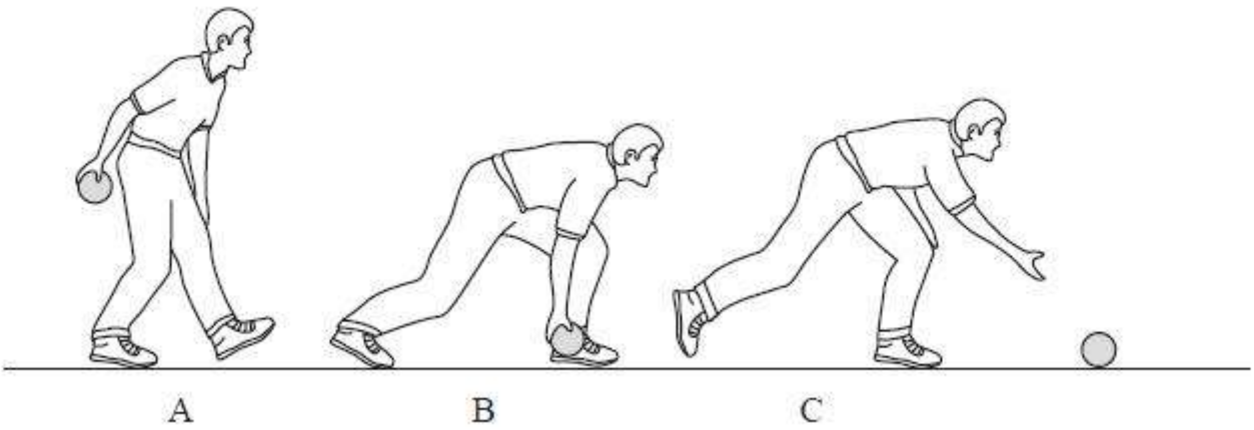
Force = ...

Q5. 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 0.20s 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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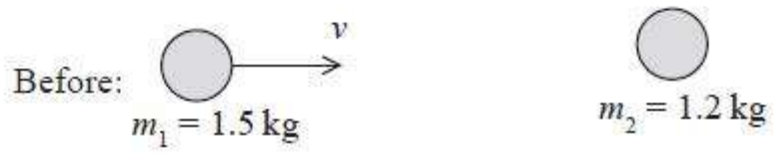
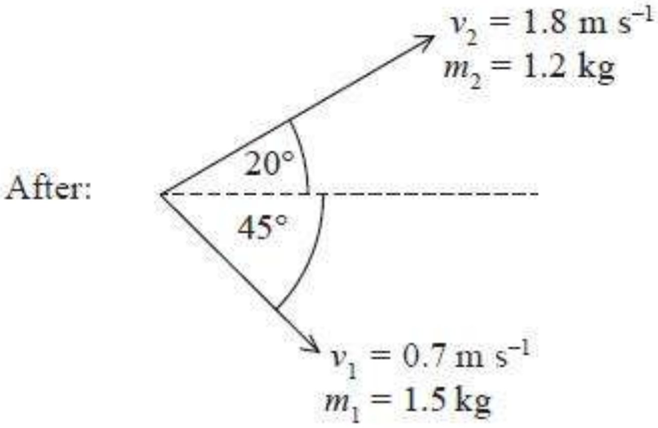
Average forward force = ...

(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.





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}.

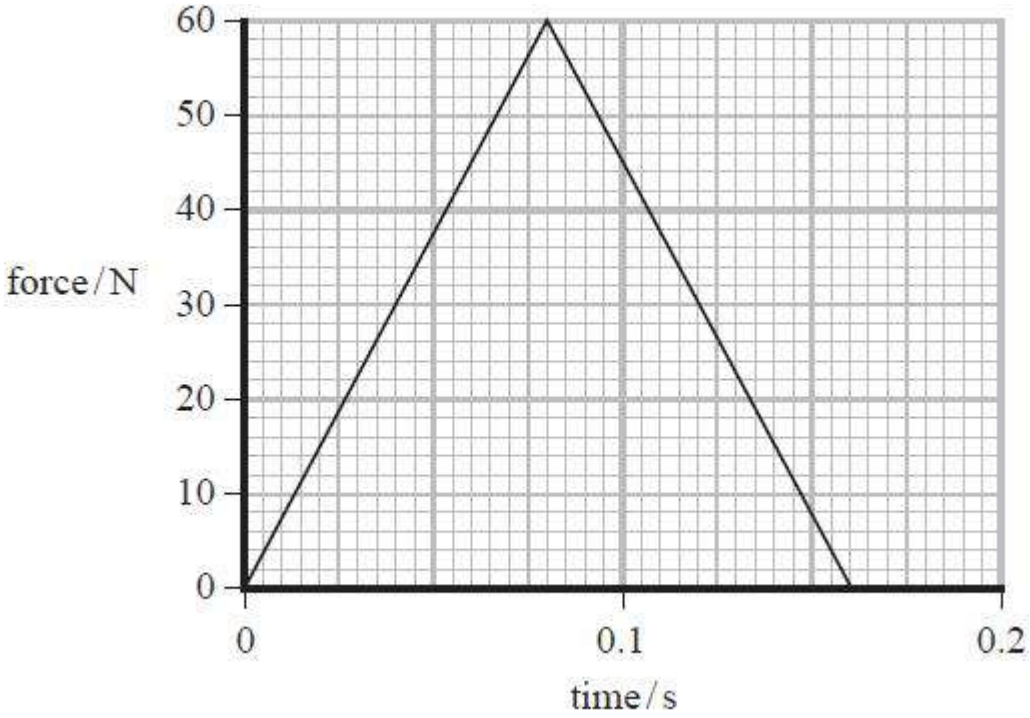
(3)

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

(2)

(Total for question = 9 marks)

Q6. A tennis racket is used to hit a tennis ball. The graph shows how the horizontal force exerted by the racket on the ball varies with time.



(a) The ball was initially moving horizontally towards the racket with a velocity of 45 m s^{-1}.

Calculate the horizontal velocity of the ball immediately after it left the racket.
mass of ball = 56 g

(4)

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Horizontal velocity = ...

(b) A student recorded a video of the ball before it was hit by the racket.

Explain how you could use the video recording to determine the velocity of the ball before it was hit by the racket.

(2)

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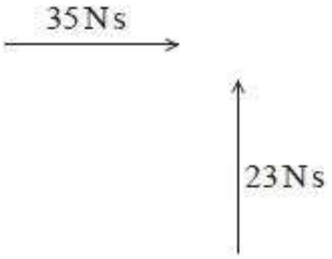
Q7. An object moving north with momentum 23 N s collides with an object moving east with momentum 35 N s.



After the collision, the objects move off together.

Which of the following will give the magnitude of the final momentum in N s?

- ☐ **A** $\frac{(35 + 23)}{2}$
- ☐ **B** $35 + 23$
- ☐ **C** $35^2 + 23^2$
- ☐ **D** $\sqrt{(35^2 + 23^2)}$

(Total for question = 1 mark)

Q8.

It is thought that an asteroid on a collision course with Earth could be deflected by making a fast moving spacecraft collide with it when it is still very far away.

To test this idea, there are plans to send a spacecraft, DART, to collide with a small asteroid. After the collision, DART and the asteroid will stick together.

DART will have a relative speed of 6250 m s^{-1} when it collides with the asteroid. This is expected to cause a change in the asteroid's velocity of 0.40 mm s^{-1}.

(a) Show that the mass of the asteroid is about 5×10^9 kg.

mass of DART = 300 kg

(3)

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(b) Suppose that DART will collide at 90° to the direction of the asteroid's velocity.

The asteroid is orbiting at a speed of 0.16 m s^{-1} about a larger partner.
Calculate the angle through which the velocity of the asteroid is deflected.

(2)

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Angle = ...

(Total for question = 5 marks)

Q9. (a) State the principle of conservation of momentum.

(2)

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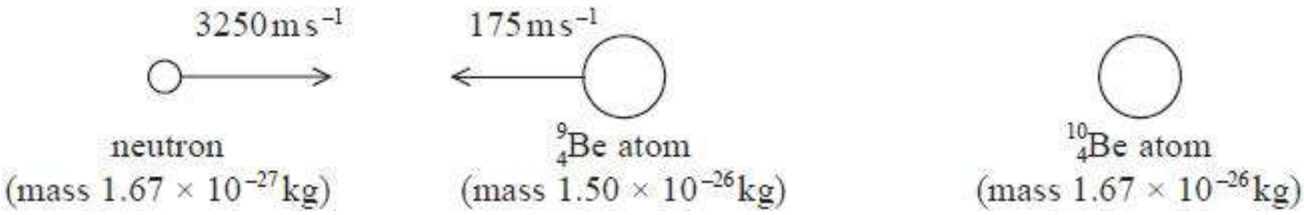
(b) A head-on collision occurs between a neutron and a beryllium atom $^{9}_{4}\mathrm{Be}$. The nucleus of the beryllium atom absorbs the neutron to form the isotope $^{10}_{4}\mathrm{Be}$.



(i) Calculate the velocity of the $^{10}_{4}\mathrm{Be}$ atom, indicating its direction by adding an arrow to the diagram.

(4)

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Velocity = ...

(ii) Using a suitable calculation, determine whether the collision was elastic or inelastic.

(2)

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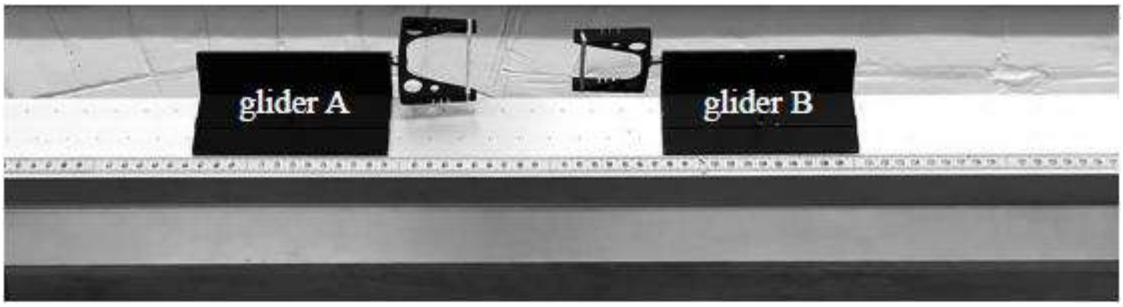
(Total for question = 8 marks)

Q10. A student investigated elastic collisions using an air track as shown. The friction between the gliders and the air track was negligible.

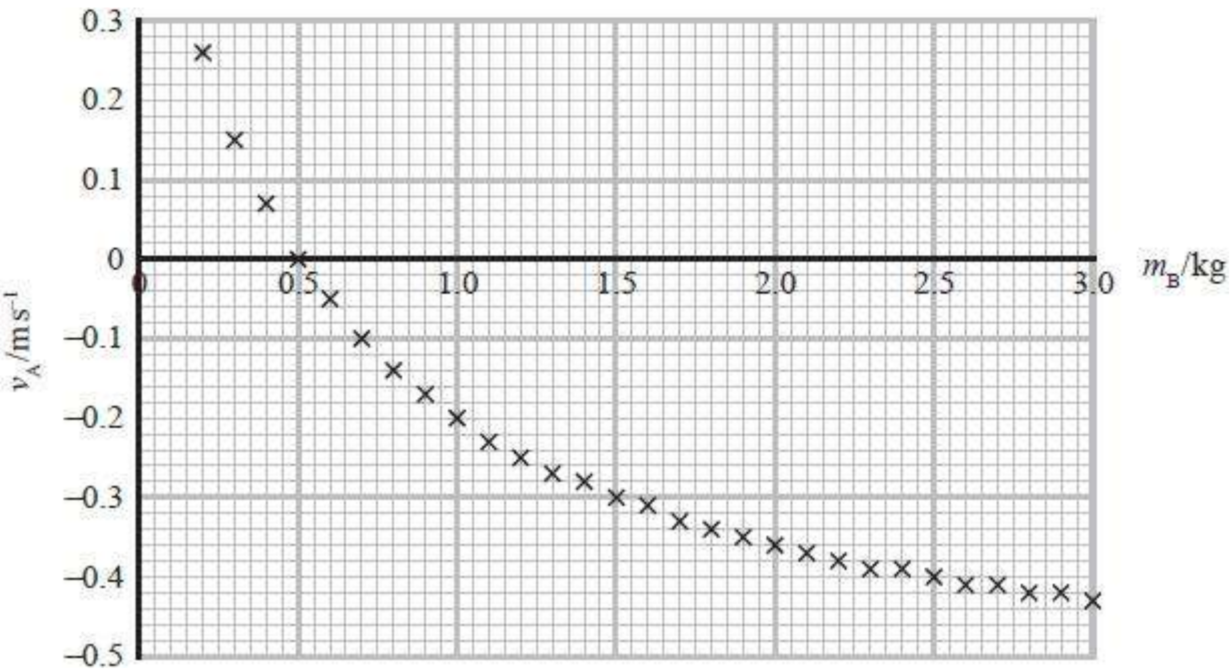


Glider A had mass m_A = 0.50 kg and moved towards glider B at a speed of 0.60 m s^{-1}.
Glider B was initially at rest.

The gliders collided and the velocity v_A of glider A after the collision was measured.

The process was carried out for various masses m_B of glider B. The mass and initial speed of glider A were kept the same.

The results are shown on the graph.



(a) Describe the motion of glider A and glider B after the collision

(i) when $m_B < m_A$

(1)

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(ii) when $m_B = m_A$

(1)

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(iii) when $m_B > m_A$.

(1)

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(b) (i) Calculate the velocity v_B of glider B after the collision when m_B = 1.4 kg. Do not assume that the collision is elastic.

(4)

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v_B = ...

(ii) Determine whether the collision was elastic when m_B = 1.4 kg.

(3)

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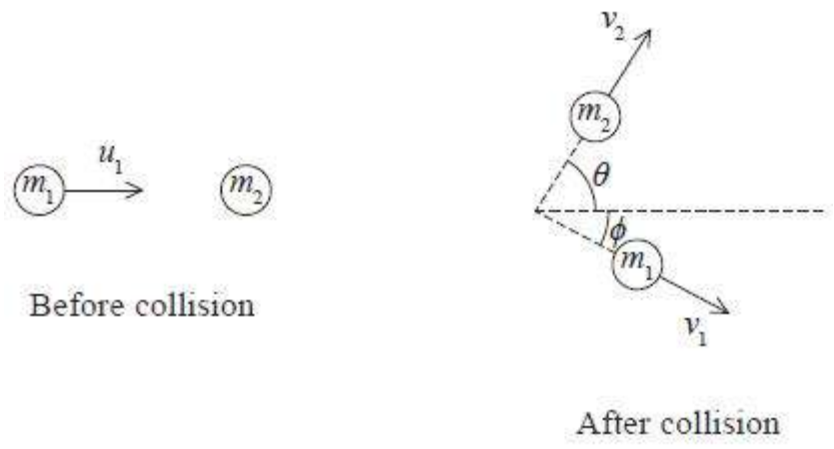
(Total for question = 10 marks)

Q11.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

This question refers to an elastic collision between two spheres.

A sphere of mass m_1 moving with velocity u_1 collides elastically with a stationary sphere of mass m_2. The spheres then move apart at different velocities as shown.



Which of the following equations applies in the direction of u_1?

☐ **A** $m_1u_1 = m_1v_1 \cos \varphi + m_2v_2 \cos \theta$

☐ **B** $m_1u_1 = m_1v_1 \cos \theta + m_2v_2 \cos \varphi$

☐ **C** $m_1u_1 = m_1v_1 \sin \varphi + m_2v_2 \sin \theta$

☐ **D** $m_1u_1 = m_1v_1 \sin \theta + m_2v_2 \sin \varphi$

(Total for question = 1 mark)

Q12.

The wavelength associated with a moving particle, known as the de Broglie wavelength, depends on the momentum of the particle.

(a) Show that momentum and kinetic energy are related by the equation $E_k = p^2/2m$

(2)

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(b) Hence determine the de Broglie wavelength for a proton with kinetic energy 18.8 keV.

(4)

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de Broglie wavelength =..

(Total for question = 6 marks)