AQA Examination-style questions

Chapter 1

1 **ISA**

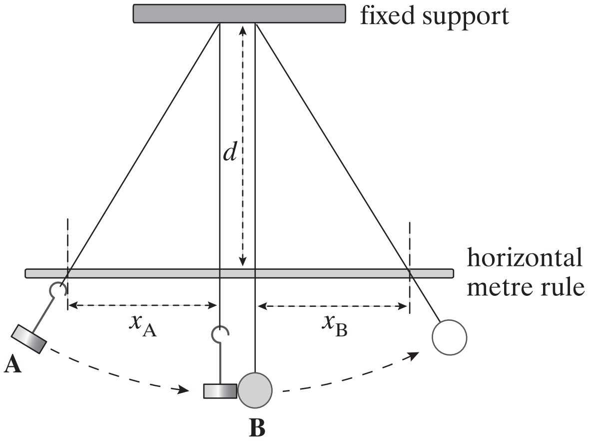

Figure 1

In an impact investigation by two students, a mass hanger **A** suspended on a thread was displaced from its equilibrium position by a certain distance and released so it collided with a ball **B** suspended on a thread. A horizontal metre ruler fixed in a clamp (not shown) was used to measure the horizontal displacements x_A and x_B of each thread from its equilibrium position at the level of the metre ruler, as shown in the diagram. The vertical distance, d, of the ruler below the upper end of the threads was measured.

The measurement of x_B was repeated without changing x_A and d for different additional masses added to the mass hanger.

(a) The measurements shown in Table 1 were made in preliminary tests using a total mass m for the mass of the hanger and the additional mass.

Table 1

m/kg	x_B/mm	
0.100	60	62
0.200	77	75
0.300	80	78

The students decided to make further measurements between 0.100 and 0.200 kg and above 0.300 kg. Why do you think they made this decision? *(4 marks)*

(b) Table 2 shows all their measurements.

Table 2

m/kg	x_B/mm	x_B/mm				$<x_B>$/mm	θ/°
0.100	60	62	58	58	60	59.6	8.47
0.120	67	68	68	65	62	66.0	9.37
0.150	68	73	70	68	70	69.8	9.90
0.200	77	75	78	71	76	75.4	10.67
0.300	80	78	79	80	80	79.4	11.22
0.600	86	85	88	85	88		

$d = 400$ mm, $x_A = 60$ mm

The maximum angular displacement θ of the thread from equilibrium can be calculated using the equation $\tan\theta = <x_B>/d$, where $<x_B>$ is the mean value of x_B. This has been done in Table 2 for all the rows except the last one.

Copy and complete Table 2 by calculating $<x_B>$ and θ for $m = 0.600$ kg.

(2 marks)

(c) (i) By considering the energy changes of B after the impact, show its velocity V immediately after the impact is given by $V = \sqrt{(2gh)}$ where h is B's maximum height gain from its equilibrium position. *(2 marks)*

(ii) The height gain h can be calculated using the trigonometry formula $h = l(1 - \cos\theta)$ where l is the distance along the thread from the point of suspension of the ball to its centre. This distance was measured to be 575 mm. For each mass m, Table 3 shows the results of these calculations except for the last row. Copy the table and complete this last row. The last 2 columns are for the next question.

Table 3

m/kg	θ/°	h/mm	V/m s^{-1}		
0.100	8.47	6.27	0.351		
0.120	9.37	7.67	0.388		
0.150	9.90	8.56	0.410		
0.200	10.67	9.95	0.442		
0.300	11.22	11.00	0.465		
0.600					

(2 marks)

(d) The students found a theoretical analysis of the impact which gave the following equation relating V and m:

$$\frac{1}{V} = \frac{kM}{m} + k$$

where M is the mass of the ball and k is a constant.

(i) Plot a suitable graph to see if this relationship is correct. Show the results of any further calculations you carry out in the last two columns of your own Table 3.

(ii) Using your graph or otherwise, determine values for k and M. *(9 marks)*

(e) (i) What conclusions do you draw from the graph?

(ii) Use your results to evaluate your conclusions.

(3 marks)

Extension question

The theoretical analysis is based on the diagram below in which an object (**A**) of mass m moving at velocity v collides with a stationary object (**B**) of mass M. After the impact, the two objects move apart at velocities v and V in the same direction as A's initial direction.

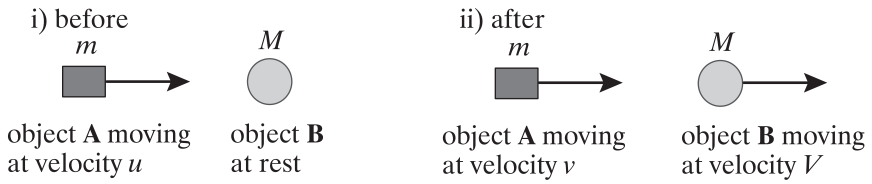

Figure 2

The theoretical analysis assumed that the velocity of **B** relative to **A** after the collision $(V - v) = eu$, where e is a constant that depends on the two objects.

(f) Combine the equation above with the equation representing conservation of momentum to derive the theoretical equation given in question 3

where $k = \dfrac{1}{(1 + e)u}$ *(5 marks)*

2 (a) Collisions can be described as *elastic* or *inelastic*.

State what is meant by an inelastic collision. *(1 mark)*

(b) A ball of mass 0.12 kg strikes a stationary cricket bat with a speed of 18 m s^{-1}. The ball is in contact with the bat for 0.14 s and returns along its original path with a speed of 15 m s^{-1}. Calculate:

(i) the momentum of the ball before the collision,

(ii) the momentum of the ball after the collision,

(iii) the total change of momentum of the ball,

(iv) the average force acting on the ball during contact with the bat,

(v) the kinetic energy lost by the ball as a result of the collision. *(6 marks)*

AQA, 2001

3 Two carts **A** and **B**, with a compressed spring between them, are pushed together and held at rest, as shown in **Figure 3**. The spring is not attached to either cart. The carts are then released.

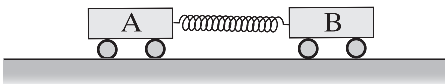

Figure 3

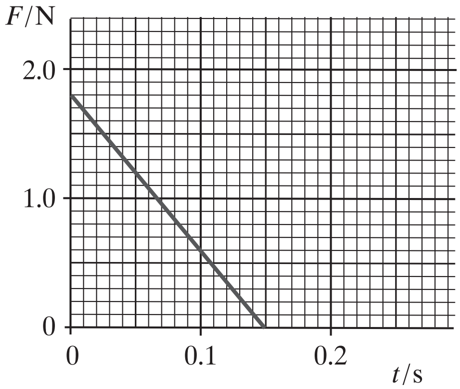

Figure 4

Figure 4 shows how the force, F, exerted by the spring on the carts varies with time, t, after release.

When the spring returns to its unstretched length and drops away, cart **A** is moving at 0.60 m s^{-1}.

(a) Calculate the impulse given to each cart by the spring as it expands.

(b) Calculate the mass of cart **A**.

(c) State the final total momentum of the system at the instant the spring drops away. *(5 marks)*

AQA, 2004

4 A railway engine is about to couple with a stationary carriage of mass 4.0×10^4 kg. When they have joined up, the engine and the carriage move at a constant speed. The engine has a mass of 6.2×10^4 kg and is moving at 0.35 m s^{-1} just before coupling.

(a) (i) Calculate the momentum of the engine.

(ii) Calculate the speed of the engine and carriage after coupling. *(5 marks)*

(b) **Figure 5** shows the engine and carriage as they strike a buffer with an initial speed of 0.15 m s^{-1}. Assuming that the buffer behaves like a spring of stiffness 320 kN m^{-1}, calculate the maximum compression of the 'spring'. *(4 marks)*

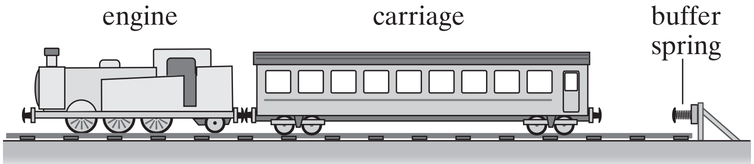

Figure 5

AQA, 2007

5 (a) State two quantities that are conserved in an elastic collision. *(2 marks)*

(b) A gas molecule makes an elastic collision with the walls of a gas cylinder. The molecule is travelling at $450\,\mathrm{m\,s^{-1}}$ at right angles towards the wall before the collision.

(i) What is the magnitude and direction of its velocity after the collision?

(ii) Calculate the change in momentum of the molecule during the collision if it has a mass of $8.0 \times 10^{-26}\,\mathrm{kg}$. *(4 marks)*

(c) Use Newton's laws of motion to explain how the molecules of a gas exert a force on the wall of a container. *(4 marks)*

AQA, 2006

6 (a) When an α particle is emitted from a nucleus of the polonium isotope $^{210}_{84}\mathrm{Po}$, a nucleus of lead (Pb) is formed. Complete the equation below.

$$^{210}_{84}\mathrm{Po} \longrightarrow \alpha + \mathrm{Pb}$$

(2 marks)

(b) The α particle in part (a) is emitted at a speed of $1.6 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

(i) The mass of the α particle is 4.0 u. Calculate the kinetic energy, in MeV, of the α particle immediately after it has been emitted. Ignore relativistic effects.

(ii) Calculate the speed of recoil of the daughter nucleus immediately after the α particle has been emitted. Assume the parent nucleus is initially at rest. *(6 marks)*

AQA, 2006

7 **Figure 6** shows how the force, F, on a steel ball varies with time, t, when the ball is dropped onto a thick steel plate and rebounds. The kinetic energy of the ball after the collision is the same as it was before the collision.

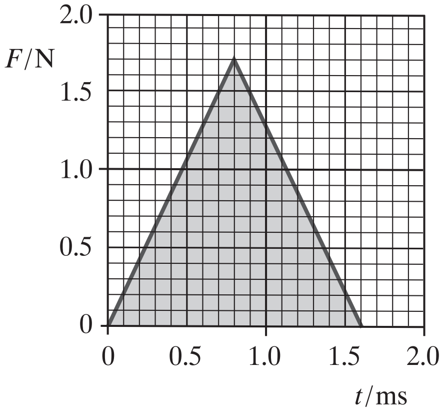

Figure 6

(a) State the name of the quantity that is obtained by determining the shaded area.

(b) Use the graph **Figure 6** to determine the initial momentum of the ball.

(c) Sketch a graph to show how the momentum of the ball varies between times $t = 0$ and $t = 2.0\,\mathrm{ms}$. *(6 marks)*

AQA, 2006

8 (a) Explain what is meant by the principle of conservation of momentum. *(2 marks)*

(b) A hose pipe is used to water a garden. The supply delivers water at a rate of $0.31\,\mathrm{kg\,s^{-1}}$ to the nozzle which has a cross-sectional area of $7.3 \times 10^{-5}\,\mathrm{m^2}$.

(i) Show that water leaves the nozzle at a speed of about $4\,\mathrm{m\,s^{-1}}$.

density of water $= 1000\,\mathrm{kg\,m^{-3}}$

(ii) Before it leaves the hose, the water has a speed of $0.68\,\mathrm{m\,s^{-1}}$. Calculate the force on the hose.

(iii) The water from the hose is sprayed onto a brick wall the base of which is firmly embedded in the ground. Explain why there is no overall effect on the rotation of the Earth. *(7 marks)*

AQA, 2005