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AQA, Edexcel, OCR

A Level

A Level Physics

MECHANICS: Momentum and Collisions (Answers)

Name:

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Total Marks: /30

1. Total for Question 1: 5

(a) Define momentum. Is it a vector or scalar quantity? [1]

Solution: Product of mass and velocity. Since velocity has magnitude and direction, it is a vector quantity.

(b) Use Newton's second law to explain the impulse of a force. [2]

Solution: N2L: $F = m\frac{\Delta v}{\Delta t}$. Impulse is $F\Delta t$ which equals change of momentum.

(c) Compare and contrast elastic and inelastic collisions. [2]

Solution: Elastic collisions conserve both momentum and kinetic energy.
Inelastic collisions conserve only momentum. However, total energy is conserved, since some kinetic energy will be converted into other forms.

2. Particle A, which is stationary, radioactively decays to create particle B and an α particle. The α particle weighs only 1.5% of particle B.

Total for Question 2: 13

(a) Show that kinetic energy and momentum can be linked by the equation $E_k = \frac{p^2}{2m}$, where p is momentum, m is mass and v is velocity. [2]

Solution: $E_k = \frac{1}{2}mv^2 = \frac{m^2v^2}{2m}$
But $p = mv$ so $E_k = \frac{p^2}{2m}$

(b) Use the principle of conservation of energy to express the total energy release in terms of the products' momenta and masses. Assume that energy is released only as kinetic energy. [1]

Solution: $E_{total} = E_B + E_\alpha = \frac{p_B^2}{2m_B} + \frac{p_\alpha^2}{2m_\alpha}$

(c) Write an expression for the conservation of linear momentum in this explosion. [1]

Solution: $0 = p_B + p_\alpha \rightarrow p_B = -p_\alpha$

(d) By considering the ratio $\frac{E_B}{E_\alpha}$, express E_B in terms of E_α, m_B and m_α. [3]

Solution: $E_B = \frac{E_\alpha m_\alpha}{m_B}$

(e) Using your answer to the previous part, show that $E_B = E_{total}\frac{m_\alpha}{m_B+m_\alpha}$ [3]

Solution: $E_B = \frac{E_\alpha m_\alpha}{m_B}$ can be put back into the expression pertaining to the total energy release. Working through gives the expression here.

(f) In this reaction, 5.00 MeV is released. Particle B has a mass of 4.00×10^{-25} Kg. Calculate the kinetic energies of both particles after the collision. [3]

Solution:
α: 4.93 MeV
B: 0.07 MeV

3. Air hockey is a game played by two players on a low-friction table using a paddle each and a puck. This question will explore the nature of collisions in one and two dimensions during a game.

Simon and Andrena are practising using two pucks of different masses. They hit their pucks towards each other. The resultant collision is head-on and is illustrated in Figure 1.

Total for Question 3: 12

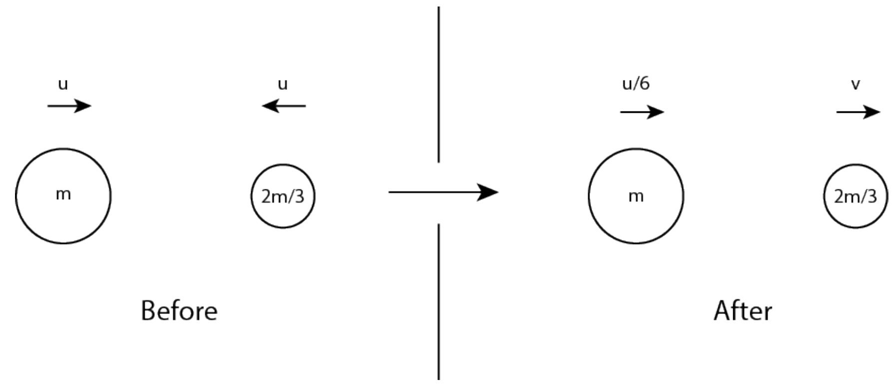

Figure 1: Head-on collision between pucks of different masses. The arrows show the direction of the pucks' motion.

(a) Use the principle of conservation of momentum to express the velocity v in terms of u. [2]

Solution: $v = \frac{u}{4}$

(b) Show that the collision is inelastic and calculate the amount of energy converted to forms other than kinetic. [2]

Solution: $\frac{115}{144}mu^2$

A little while later two different pucks collide elastically and obliquely, as is shown in Figure 2. This causes the once-stationary puck to move off in the direction of the dashed line.

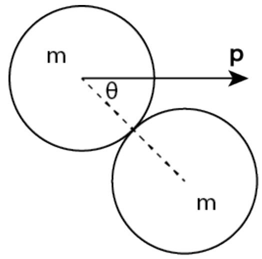

Figure 2: Oblique collision between pucks of equal masses.

(c) What is the total kinetic energy in the system before the collision? [1]

Solution: $\frac{p^2}{2m}$

(d) Explain using the principle of conservation of linear momentum why the pucks must move off at 90°to one another. [2]

Solution: The momentum of the moving particle can be resolved into two components: that along the line of collision and that perpendicular to it. All of the momentum along the line of collision is transferred to the other particle, since they are of equal masses and one is initially stationary. Thus, the particle that was initially moving only has momentum along an axis perpendicular to the collision line.

(e) Draw a diagram showing the momenta of the pucks after the collision. Ensure that you label any vectors with their magnitudes. [2]

> **Solution:** $p\cos\theta$ along the collision. $p\sin\theta$ perpendicular to the collision line.

(f) Show that kinetic energy is conserved in the collision. [3]

> **Solution:**
> Before collision: $E_k = \frac{p^2}{2m}$
> After collision: $E_k = \frac{p^2}{2m}\cos^2\theta + \frac{p^2}{2m}\sin^2\theta$. But, $\sin^2\theta + \cos^2\theta = 1 \rightarrow E_k = \frac{p^2}{2m}$