

Name	Date started	Target end date
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GCE AS / A LEVEL – MOMENTUM & COLLISIONS QUESTION PACK

Legacy PH4 · New spec Unit 1 Topic 3b · AS unit, 20% of A-level

REVISE
.wales

PHYSICS – UNIT 1 · MOMENTUM & COLLISIONS

PH1.3 Dynamics – linear momentum, impulse and conservation

Defining momentum and impulse, applying conservation of momentum to one-dimensional collisions and explosions, plus elastic vs. inelastic distinctions (sourced from legacy PH4 papers).

NEW 2015 SPEC · UNIT 1 TOPIC 3B

Estimated time for entire question pack: ~3 h 26 min

Derived from the legacy PH4 paper's pace of 120 marks in 1½ hours.

You are advised to **not** attempt to complete all of this in one sitting.

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC PH4 papers (2008 modular spec) that maps onto new-spec Unit 1 Topic 3b (1.3).

Questions are ordered chronologically within each section.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

The number of marks is given in brackets at the end of each question or part-question. A calculator is required. The Data Booklet is allowed.

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Q	Source	Max	Mark	Q	Source	Max	Mark
7	PH4 Jan 10 Q2	9		13	PH4 Jun 12 Q2	21	
8	PH4 Jan 12 Q3	7		14	PH4 Jun 13 Q5	12	
9	PH4 Jan 13 Q3	10		15	PH4 Jun 14 Q1	17	
10	PH4 Jan 14 Q1	16		16	PH4 Jun 15 Q4	13	
11	PH4 Jun 10 Q5	12		17	PH4 Jun 16 Q1	20	
12	PH4 Jun 11 Q1	10					
						Total	147

Momentum & Collisions – what the new spec asks

WJEC GCE AS / A Level Physics (from 2015) · Unit 1: Motion, Energy & Matter · Topic 1.3.

Defining momentum A

- Linear momentum $p = mv$; vector nature of momentum.
- Impulse = change of momentum = $F \cdot \Delta t$ = area under F - t graph.

Conservation of momentum A

- State the principle for an isolated system.
- Apply to one-dimensional collisions and explosions.

Collisions A

- Distinguish elastic and inelastic collisions by KE conservation.
- Special case: equal masses, one initially at rest (elastic).

Newton's 2nd law (momentum form) A

- $F = dp/dt$ – rate of change of momentum.
- Variable-mass / continuous-flow problems (jets, rockets, hoses).

Momentum & Collisions in one page

Quick-reference notes – revisit before each section.

Linear momentum

Vector quantity in same direction as velocity.

Units kg m s^{-1} .

Change of momentum: $\Delta p = m(v - u)$.

Impulse

For constant force: $F \cdot \Delta t = \Delta p$.

For varying F: area under F-t graph.

Same units ($\text{N s} \equiv \text{kg m s}^{-1}$).

Conservation

If no external force, total p is conserved.

$\Sigma mu = \Sigma mv$.

Apply component-wise for 2D problems.

Elastic vs inelastic

Elastic: KE conserved as well as p.

Inelastic: some KE lost as heat / sound.

Perfectly inelastic \Rightarrow stick together.

$F = dp/dt$

Newton II in momentum form: $F = (m \cdot \Delta v + v \cdot \Delta m) / \Delta t$.

Useful for hoses, rockets, jets.

Force on a wall by a jet: $F = \rho Av^2$.

Strategy

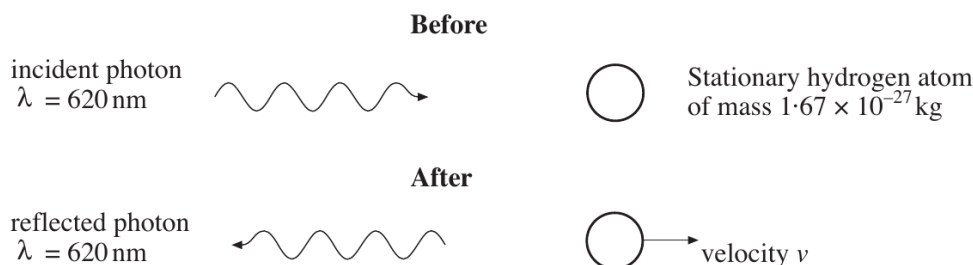
1. Pick a positive direction.
2. List masses and velocities before / after.
3. $\Sigma mu = \Sigma mv \Rightarrow$ solve.
4. Check ΔKE if asked about elasticity.

Section index

Use this index to jump straight to the section you need.

Section	Questions	Marks
A Momentum & collisions	Qs 1-11	147 marks

2. A photon of red light of wavelength 620 nm is incident upon a stationary hydrogen atom of mass 1.67×10^{-27} kg. It then rebounds in the opposite direction with approximately the same wavelength (within 2 significant figures).



- (a) Show that the momentum of the incident photon is approximately 1.1×10^{-27} kg m s⁻¹. [1]

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- (b) Use the principle of conservation of momentum to calculate the speed of the hydrogen atom after the collision with the photon. [3]

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- (c) (i) Explain briefly how the above collision seems inconsistent with the principle of conservation of energy. [2]

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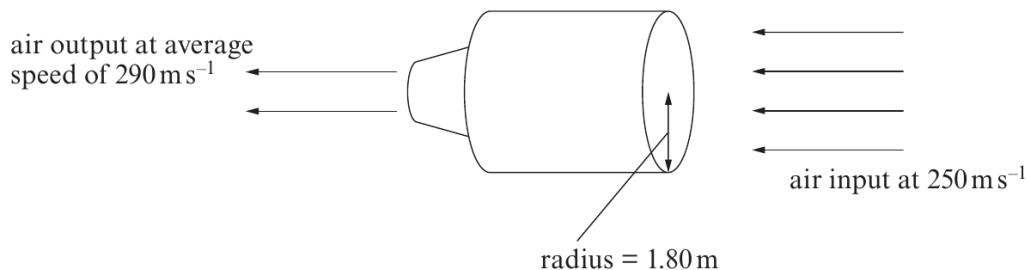
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- (ii) If the wavelength information were given to a greater precision, state how the wavelengths of the incident and reflected photons would compare. [1]

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3. A Rolls Royce jet engine operates by collecting air into the jet engine at a speed of 250 m s^{-1} and ejecting it with an average speed of 290 m s^{-1} .



- (a) The radius of the jet engine is 1.80 m as shown and the density of air entering it is 0.4 kg m^{-3} . Show that the mass of air entering the jet engine per second is approximately 1 000 kg. [3]

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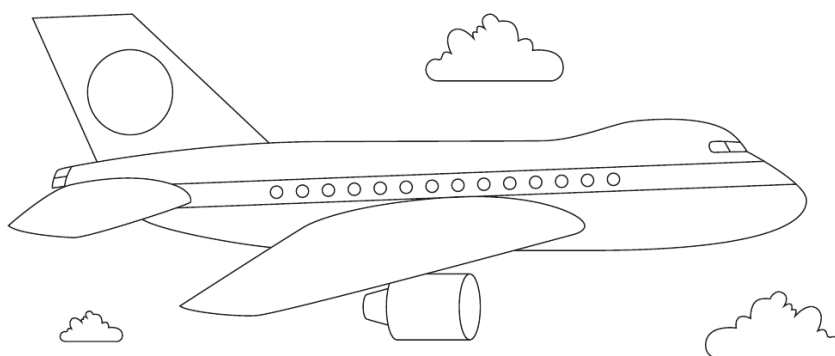
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- (b) Calculate the forward thrust produced by this jet engine. [2]

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- (c) Explain how the principle of conservation of momentum applies to the air - aeroplane system when the aeroplane is travelling at a **constant** velocity of 250 m s^{-1} . [2]

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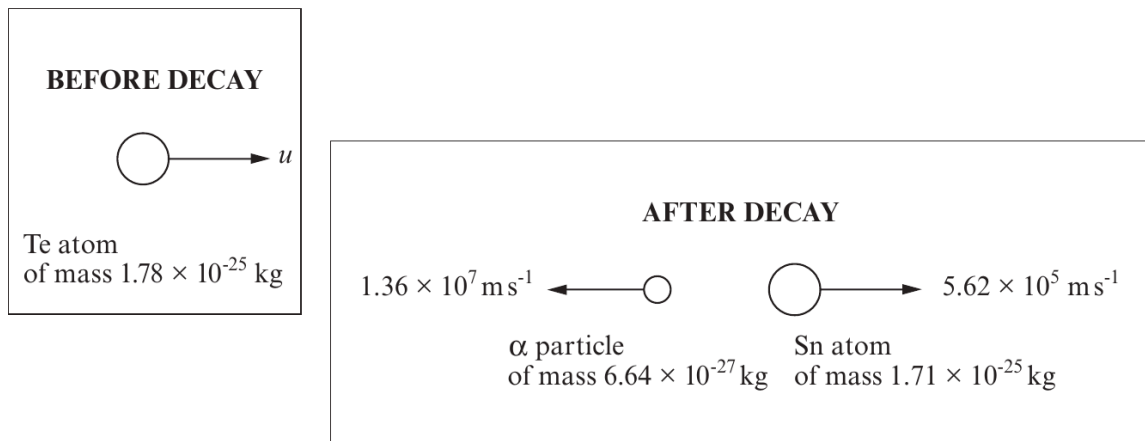
3. (a) State the *Principle of Conservation of Momentum*. [2]

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(b) A tellurium (Te) atom undergoes alpha (α) decay into tin (Sn) as shown below.



(i) Calculate the initial speed, u , of the tellurium (Te) atom. [3]

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(ii) Show that the momentum, p , of a photon is related to its energy, E , by the equation [2]

$$E = pc$$

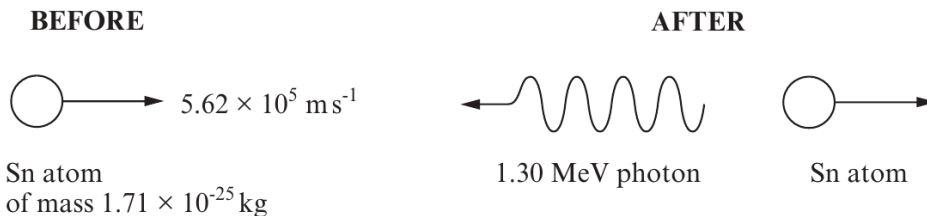
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- (iii) Use the equation $E = pc$ to calculate the **percentage** change in the momentum of the tin (Sn) atom when it emits a gamma ray photon of energy 1.30 MeV as shown. [3]



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Answer all questions.

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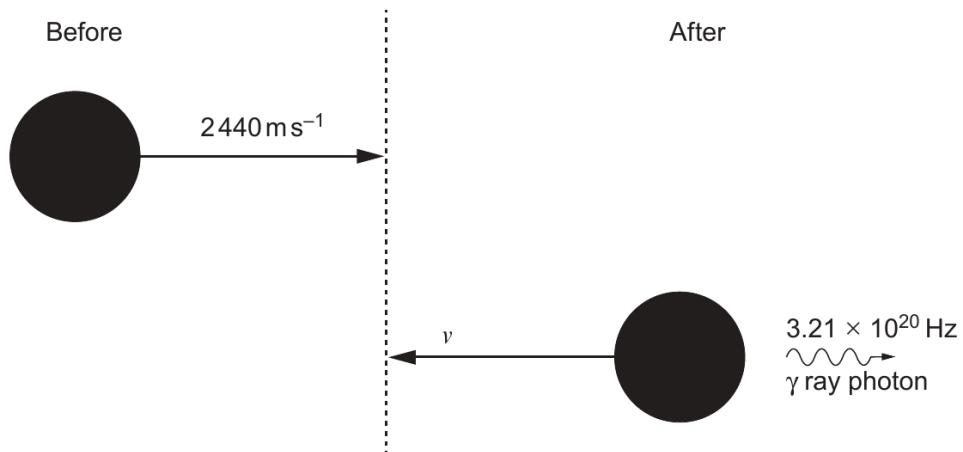
1. (a) State the principle of conservation of momentum. [2]

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A nickel nucleus emits a γ ray photon as shown.



- (b) Show that the γ ray photon has a momentum of approximately $7 \times 10^{-22} \text{ kg m s}^{-1}$. [3]

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(c) Calculate the final speed (v) of the nickel nucleus ($m_{\text{nickel}} = 9.95 \times 10^{-26} \text{ kg}$).

[3]

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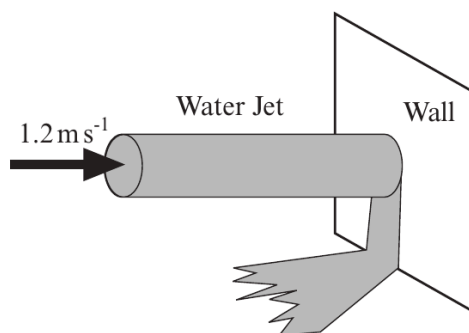
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5. (a) A horizontal jet of water strikes a vertical wall perpendicularly. The speed of the water is 1.2 m s^{-1} and the cross-sectional area of the jet is $2.0 \times 10^{-4} \text{ m}^2$. After striking the wall the water runs down the wall.
(Density of water = $1.00 \times 10^3 \text{ kg m}^{-3}$)



Examiner only

- (i) Pressure = Force / Area. State the SI unit for pressure.

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 [1]

- (ii) Show that the mass of water that strikes the wall in 1.0 s is 0.24 kg.

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 [1]

- (iii) Show clearly that the decrease in the horizontal momentum of the water each second is approximately 0.3 kg m s^{-1} .

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 [1]

- (iv) Find the pressure exerted on the wall.

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 [2]

Examiner
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(b) A beam of light with wavelength 660 nm from a laser of output power 1 mW is incident normally on a screen where it is totally absorbed.

(i) Determine the momentum of a single photon in the beam.

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[3]

(ii) If the beam is incident on an area of $1.0 \times 10^{-6} \text{ m}^2$ determine the pressure exerted by the light on the screen.

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[4]

1. (a) State the *Principle of Conservation of Momentum*. [2]

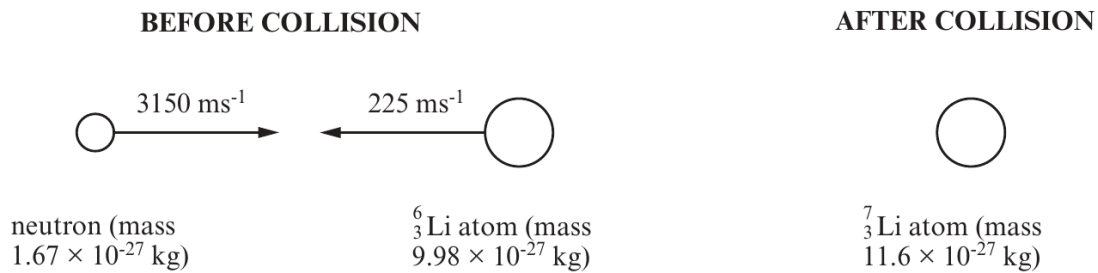
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- (b) (i) A head-on inelastic collision occurs between a neutron and a lithium atom, ${}^6_3\text{Li}$.

The nucleus of the atom absorbs the neutron, to form the heavier isotope ${}^7_3\text{Li}$. Using the data in the diagram, calculate the *velocity* of the ${}^7_3\text{Li}$ atom, adding an arrow to the (right hand) diagram, to show its direction of motion. [4]



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- (ii) By calculating *energies* confirm that the collision is inelastic. [2]

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Examiner
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- (c) The nucleus of the ${}^7_3\text{Li}$ atom is formed in an excited state and loses excess energy by emitting a gamma ray photon of wavelength 1.71×10^{-13} m. Calculate the recoil velocity of the ${}^7_3\text{Li}$ atom, **treating its initial velocity as negligible.** [2]

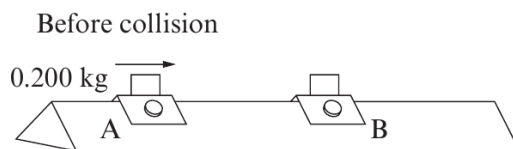
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2. (a) In a laboratory experiment two gliders A and B lie on a linear air track (friction-free). Glider A, of mass 0.200 kg, is accelerated from rest by a force of 3.00 N acting for 0.150 s.



- (i) Show that the velocity of glider A after acceleration is 2.25 m s^{-1} to the right. [1]

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- (ii) Glider A then collides with a stationary glider B. They stick together and move with a velocity of 1.20 m s^{-1} to the right. Show that the mass of glider B is 0.175 kg. [2]

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- (iii) A second demonstration is used to show an elastic collision. The initial conditions for the acceleration of glider A are exactly the same as in part (i). If the velocities of gliders A and B after the collision are 0.15 m s^{-1} and 2.40 m s^{-1} respectively to the right, show that the collision is elastic. [3]

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(b) A scientist investigates the possibility of using a **totally reflecting** solar sail to power a small spacecraft. Sunlight of typical wavelength 500 nm and intensity 1500 W m^{-2} falls on a sail of area 100 m^2 .

(i) Calculate the energy of a photon of wavelength 500 nm. [2]

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(ii) Determine the number of photons arriving at the sail each second. [1]

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(iii) Calculate the force exerted by the sunlight on this totally reflecting sail. [3]

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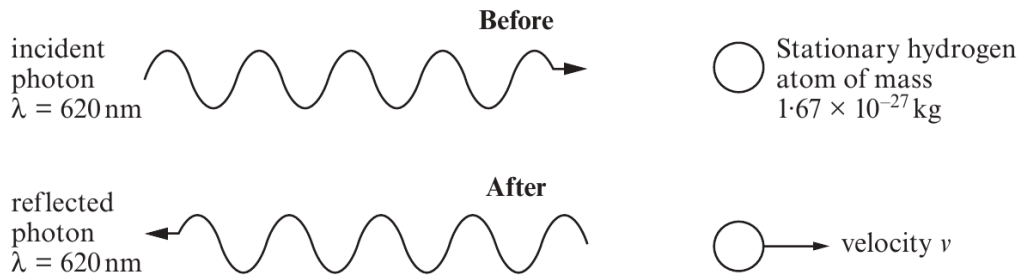
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(a) A photon of wavelength 620 nm strikes a stationary hydrogen atom head-on and rebounds directly backwards. Assume that the wavelength of the photon is unchanged.

(i) State the principle of *conservation of momentum*. [2]

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(ii) Show that the speed of the hydrogen atom immediately after impact is 1.28 m s^{-1} . [2]

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(iii) Calculate the energy of the photon. [1]

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(b) (i) Determine the wavelength of a photon that has the same momentum as a hydrogen atom moving with the speed of 1.28 m s^{-1} . [2]

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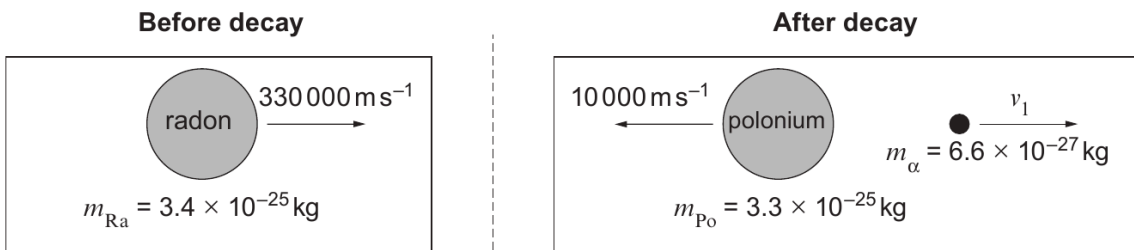
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(ii) Identify the type of electromagnetic radiation of **this** photon. [1]

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Answer all questions.

1. A radon nucleus travelling at $330\,000\text{ m s}^{-1}$ decays to produce a polonium nucleus and an alpha particle as shown.



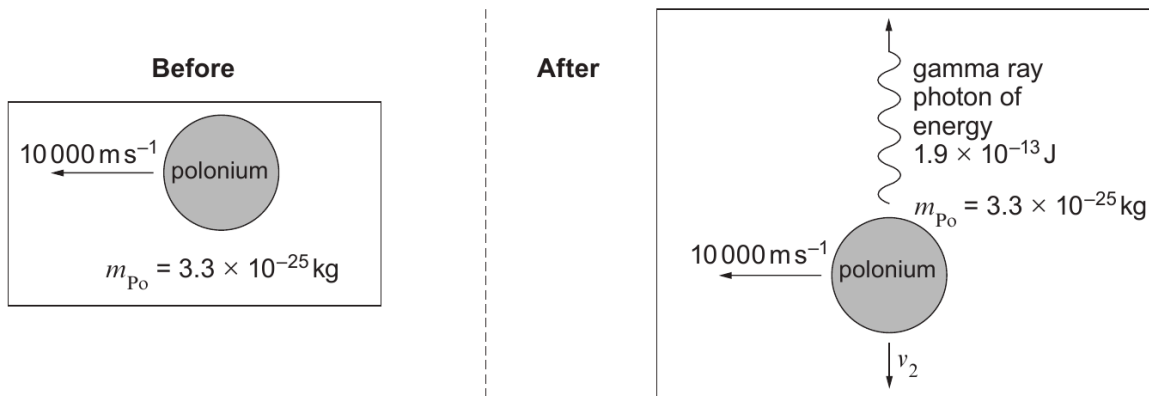
- (a) Use the principle of conservation of momentum to calculate the velocity (v_1) of the alpha particle. [3]

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- (b) The polonium nucleus then emits a gamma ray **perpendicular** to its direction of motion as shown.



- (i) Explain why the horizontal velocity component ($10\,000\text{ m s}^{-1}$) of the polonium nucleus is unchanged. [1]

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(ii) Show that the downward velocity component (v_2) of the polonium nucleus after emitting the gamma ray photon is approximately 2000 ms^{-1} . [4]

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(iii) Calculate the final resultant velocity (magnitude and direction) of the polonium nucleus. [4]

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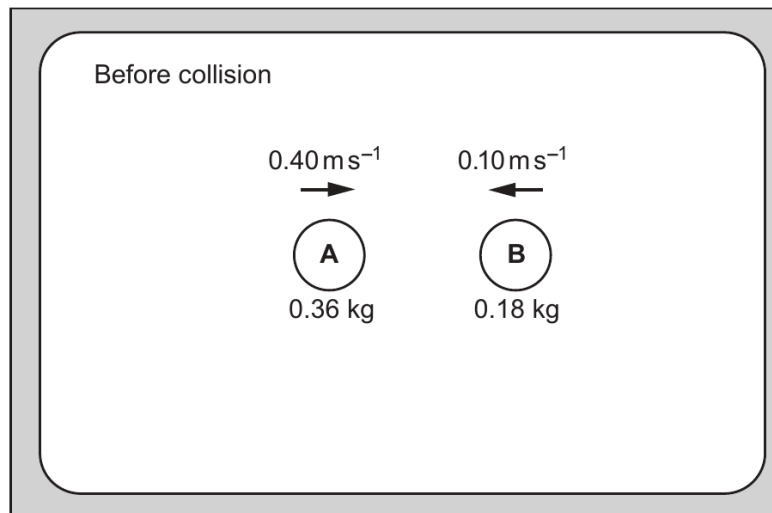
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4. (a) Two discs, **A** and **B**, on a frictionless air table collide head-on. Disc **A** has a mass of 0.36 kg and disc **B** a mass of 0.18 kg. Before colliding, disc **A** has a velocity of 0.40 m s^{-1} and disc **B** a velocity of 0.10 m s^{-1} in the opposite direction. On colliding they stick together.

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Calculate:

- (i) the velocity of the discs after the collision; [3]

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- (ii) the kinetic energy **lost** during the collision expressed as a percentage of the initial kinetic energy. [3]

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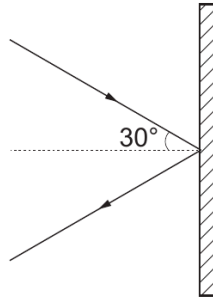
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- (b) A red laser beam of power 1 mW and wavelength 633 nm is incident at an angle of 30° on a **perfectly reflecting** mirror.

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Determine:

- (i) the energy of a single photon of this wavelength; [2]

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- (ii) the number of photons incident on the mirror per second; [2]

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- (iii) the component of the momentum of an individual incident photon perpendicular to the mirror; [1]

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- (iv) the force exerted by the photons on the mirror. [2]

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Answer **all** questions.

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1. (a) State:

(i) Newton's second law of motion; [2]

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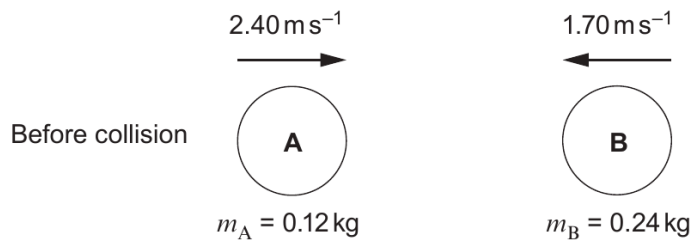
(ii) the principle of conservation of momentum. [2]

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(b) Two discs **A** and **B** of masses $m_A = 0.12 \text{ kg}$ and $m_B = 0.24 \text{ kg}$ on a frictionless horizontal surface slide directly towards each other and collide head-on. Before the collision the speed of disc **A** is 2.40 ms^{-1} and the speed of disc **B** is 1.70 ms^{-1} .



(i) After the collision the direction of disc **A** is reversed. Its speed is 2.24 ms^{-1} . Determine the speed of disc **B** after collision. [3]

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(ii) Calculate the total kinetic energy lost during the collision.

[3]

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(iii) The collision duration is 0.30 s. Calculate the mean force on disc **A** and state its direction.

[3]

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END OF QUESTION PACK

11 questions · 147 marks · ~3 h 26 min

Source: WJEC PH4 (2008 modular spec)

Curated for WJEC Physics 2015 spec AS Unit 1 – Topic 3b (1.3)

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