

Name	Date started	Target end date
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GCE AS/A LEVEL – DYNAMICS QUESTION PACK

PH1 + PH4 (Legacy)

PHYSICS – PH1 & PH4

Dynamics – Newton’s laws & momentum

Every dynamics-flavoured question from the legacy WJEC papers (PH1 2009–2016 & PH4 2010–2016)

LEGACY 2008 SPECIFICATION

Estimated time for entire question pack: ~4 hours

Derived from the legacy paper pace (~1.3 min/mark) applied across both PH1 and PH4 content.

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

For Examiner’s use only

Q	Source	Max	Mark	Q	Source	Max	Mark
1	PH1 Jan 09 Q1	7		10	PH4 Jan 14 Q1	16	
2	PH1 Jan 11 Q4	8		11	PH4 Jun 10 Q5	12	
3	PH1 Jun 09 Q6	10		12	PH4 Jun 11 Q1	10	
4	PH1 Jun 11 Q1	12		13	PH4 Jun 12 Q2	21	
5	PH1 Jun 13 Q6	9		14	PH4 Jun 13 Q5	12	
6	PH1 Jun 16 Q1	9		15	PH4 Jun 14 Q1	17	
7	PH4 Jan 10 Q2	9		16	PH4 Jun 15 Q4	13	
8	PH4 Jan 12 Q3	7		17	PH4 Jun 16 Q1	20	
9	PH4 Jan 13 Q3	10		Total		202	

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It draws on two legacy unit papers because the 2015 spec consolidated *Newton’s laws, $F = ma$ and momentum & collisions* into a single Topic 3 – under the old spec these are split between **PH1** (AS, Newton’s laws) and **PH4** (A2, momentum).

INSTRUCTIONS

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

A calculator is required. The Data Booklet is allowed.

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Dynamics – what the legacy spec asks

WJEC GCE AS/A Level Physics (from 2008). Dynamics content is split across two units: **PH1.1 Basic Physics** (Newton's laws, $F = ma$, free-body diagrams) and **PH4.2 Momentum Concepts** (linear momentum, conservation, collisions, photon momentum).

PH1.1(d) Newton's 3rd law **A**

- Appreciate the concept of force and understand Newton's 3rd law of motion.
- Action-reaction: equal magnitude, opposite direction, on different bodies, same line of action, same type of force.

PH1.1(e) (f) Free-body & $F = ma$ **A**

- Use free body diagrams to represent forces on a particle or body.
- Recall and use the relationship $\Sigma F = ma$ in situations where mass is constant.

PH1.1(g) (h) Adding & resolving forces **A**

- Add and subtract coplanar vectors; calculations limited to two perpendicular vectors.
- Resolve a vector into two perpendicular components.

PH4.2(a) (b) Linear momentum & Newton's laws **B**

- Define linear momentum as the product of mass and velocity: $p = mv$.
- Recall Newton's laws of motion and know that *force = rate of change of momentum*, applying this in situations where mass is constant.

PH4.2(c) Conservation of momentum **B**

- State the principle of conservation of momentum and use it to solve problems in one dimension involving *elastic* collisions (no loss of kinetic energy) and *inelastic* collisions (loss of kinetic energy).

PH4.2(d) (e) Photon momentum **B**

- Use the formula for the momentum of a photon: $p = h/\lambda = hf/c$.
- Appreciate that the absorption or reflection of photons gives rise to radiation pressure.

Section index for this question pack

A	Newton's laws & $F = ma$ (PH1)	Resolving forces, free-body analysis and applying $\Sigma F = ma$ to single bodies on horizontal surfaces, slopes and under crosswinds.	55 marks · pp 4–15
B	Momentum & collisions (PH4)	Conservation of linear momentum, elastic vs inelastic collisions, impulse, photon momentum and radiation pressure.	147 marks · pp 16–35

Dynamics in one page

Quick-reference notes – revisit before each section.

Newton's 1st Law

A body remains at rest or moves with *constant velocity* unless acted on by a resultant force.

- Implies **inertia** – resistance to change of motion.
- Equilibrium: $\Sigma F = 0 \Rightarrow$ constant velocity (which can be zero).

Newton's 2nd Law

Resultant force = *rate of change of momentum*:

$$F = \Delta p / \Delta t$$

For constant mass: $F = ma$.

- SI: F in N, p in kg m s^{-1} .

Newton's 3rd Law

If A exerts a force on B, B exerts an *equal & opposite* force on A.

Pair conditions:

- Same magnitude, opposite direction.
- Same *type* of force.
- Acting on *different bodies*.
- Same line of action.

Free body diagrams

Isolate one body. Show *all* forces acting on it as labelled arrows; length proportional to magnitude.

- Common forces: weight (mg), normal, tension, friction, drag, applied.
- Don't include reaction forces on *other* bodies.

Resolving forces

A force F at angle θ to the horizontal:

- Horizontal: $F \cos \theta$
- Vertical: $F \sin \theta$

Equilibrium \Rightarrow resolve in two perpendicular directions; set each $\Sigma = 0$.

F = ma applied

From a free-body diagram: $\Sigma F_{\text{net}} = ma$.

- Friction $\leq \mu N$ (static), $= \mu_k N$ (kinetic).
- On an incline of angle θ : weight component along slope $= mg \sin \theta$, normal component $= mg \cos \theta$.

Linear momentum

$$p = mv$$

- **Vector** – direction matters; sign indicates direction in 1D.
- Units: kg m s^{-1} (or N s).

Impulse

Impulse = force \times time = change in momentum.

$$F \Delta t = \Delta p = m \Delta v$$

- Area under $F-t$ graph = impulse.
- Crumple zones / airbags *increase* Δt to reduce peak F .

Conservation of momentum

For an isolated system (no external resultant force):

$$\Sigma p_{\text{before}} = \Sigma p_{\text{after}}$$

- Always true in collisions and explosions.
- Resolve into 1D components – remember signs!

Elastic vs inelastic

ELASTIC p and KE both conserved.

INELASTIC p conserved; KE *not* conserved (lost to heat, sound, deformation).

Perfectly inelastic: bodies stick together.

Use $m_1 u_1 + m_2 u_2 = (m_1 + m_2)v$.

Explosions / decays

Initially at rest (or moving as one): total p stays constant after separation.

- Fragments fly apart with *equal & opposite* momenta (in CoM frame).
- **KE increases** (released from stored / nuclear PE).
- Useful identity: $m_1 v_1 = -m_2 v_2$.

Photon momentum & pressure

$$p = \frac{h}{\lambda} = \frac{hf}{c} = \frac{E}{c}$$

- Absorption: $\Delta p = p_{\text{photon}}$.
- **Reflection** (perfect mirror): $\Delta p = 2p_{\text{photon}}$.
- Radiation pressure on area A from intensity I : $P_{\text{abs}} = I/c$; $P_{\text{ref}} = 2I/c$.

SECTION A

Newton's laws & $F = ma$ (PH1)

Questions 1 - 6 · 55 marks

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Examiner
only

1. (a) Newton's second law of motion can be expressed by the equation

$$\Sigma F = ma$$

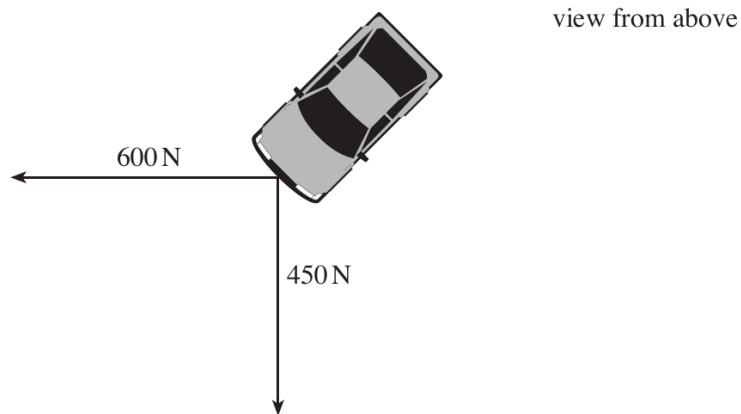
Identify and name the vector quantities in this equation. [2]

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- (b) A car is stuck in sand. Two ropes are attached securely to the car's bumper as shown. One rope is pulled with a force of 600 N due west. The other is pulled with a force of 450 N due south.



- (i) Calculate the magnitude and direction of the resultant of these two forces. [3]

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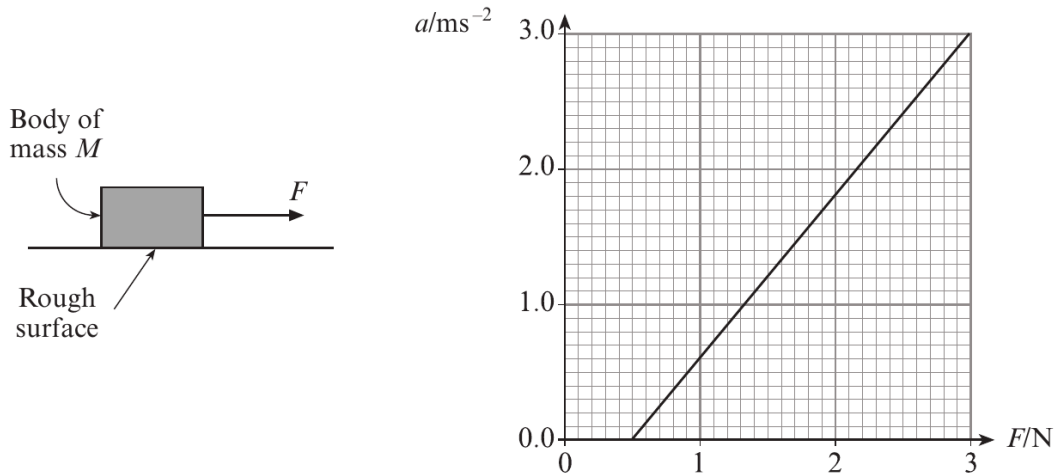
- (ii) The car remains stationary but the bumper suddenly breaks away. Calculate the initial acceleration of the bumper if its mass is 5.0 kg. [2]

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4. A body of mass M is placed on a rough surface and a horizontal force, F , is applied to it as shown. Data-logging apparatus is used to determine the acceleration of the body for different values of F . The results are shown in the graph.



- (a) (i) Explain why the acceleration of the body is 0 when the applied force F is less than 0.5N. [1]

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- (ii) Use your graph to determine the value of M . [3]

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Examiner
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(b) (i) Label forces (A) and (B) also acting on the body. [2]



(ii) State the Newton third law reaction to force (B) and the body upon which it acts. [2]

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6. High-sided lorries are vulnerable to cross-winds when crossing motorway bridges. The force, F , exerted by wind on the side of a lorry can be given by

$$F = \rho Av^2$$

where ρ = density of air (kg m^{-3}), A = side area of the lorry and v = speed of the wind.

- (a) (i) Show that the equation is correct in terms of units (or dimensions).

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[3]

- (ii) The side of a certain lorry is (effectively) 15.0 m long and 4.2 m high. The force exerted on one side of the lorry by a cross-wind is $2.8 \times 10^4 \text{ N}$. Use this information to estimate the speed of the wind. (Density of air = 1.2 kg m^{-3}).

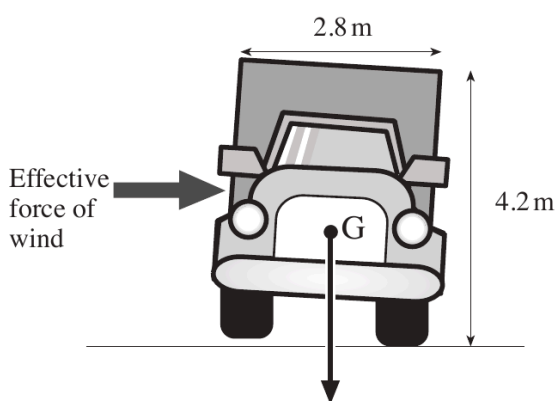
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[2]

- (b) When crossing a bridge, the lorry experiences a different cross-wind which causes it just to tilt as shown in the diagram.



- (i) 'G' represents that point where the weight of the lorry is considered to act. Name this point.

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[1]

- (ii) If the lorry stays tilted as shown, the sum of the clockwise moments about the pivot must equal the sum of the anticlockwise moments about the same pivot. Clearly label the pivot on the diagram.

[1]

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Examiner
only

- (iii) Taking the force of the wind to act at a point midway up the side of the lorry, calculate the force needed to maintain the tilt as shown. The weight of the lorry is 1.0×10^5 N and its width is 2.8 m.

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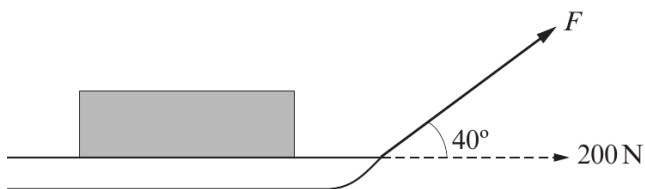
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[3]

1. A heavy sledge is pulled across a level snowfield by a force F as shown. To keep the sledge moving at constant velocity a **horizontal** force component of 200 N is required.



- (a) Calculate the force F needed to produce a horizontal component of 200 N on the sledge. [2]

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- (b) (i) Define *work done* and use this definition to explain why no work is done in the vertical direction. [3]

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- (ii) It takes 30 minutes to pull the sledge a distance of 2.0 km across level ground. Calculate

- (I) the work done; [2]

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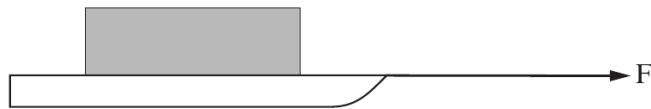
- (II) the mean power needed. [2]

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Examiner
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- (c) Assume the force F calculated in (a) is now applied horizontally as shown. Calculate the initial acceleration of the sledge given that its mass is 40.0 kg and assuming that the frictional force stays the same. [3]



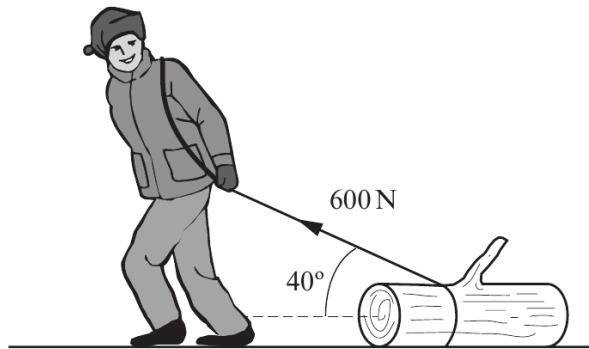
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6. A man pulls a tree trunk with a force of 600 N inclined at 40° to the horizontal.



Examiner
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(a) (i) Calculate the horizontal component of the 600 N force pulling the tree trunk forwards. [2]

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(ii) Calculate the vertical component of the 600 N force. [1]

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(b) Using your answer to (a)(ii) and taking the mass of the tree trunk to be 90 kg, determine the vertical force between the tree trunk and the ground. [2]

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- (c) The **horizontal frictional force** acting on the tree trunk is $0.8 \times$ the vertical force between the tree trunk and the ground. Calculate the acceleration of the tree trunk. [3]

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- (d) The weight of the tree trunk is a measure of the Earth's gravitational pull on the tree trunk. Identify the Newton third law 'equal and opposite' force to the weight of the tree trunk. [1]

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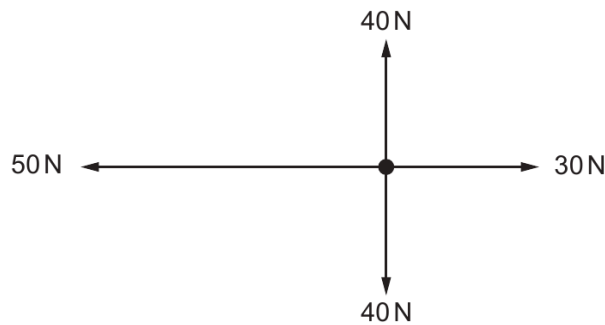
Answer **all** questions.

Examiner only

1. (a) Newton's second law of motion can be expressed by the equation:

$$\Sigma F = ma$$

Showing your reasoning, determine ΣF in the free body diagram below. [2]

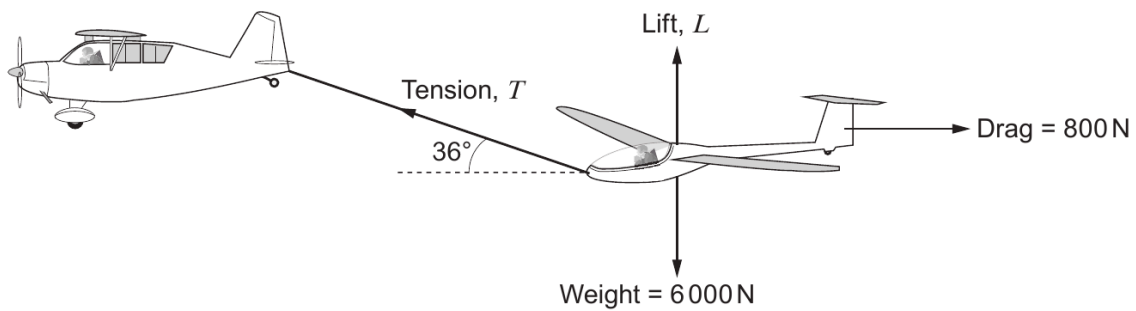


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- (b) A glider is being towed **horizontally** through the air **at constant velocity**. The diagram shows the forces acting on the glider.



- (i) Calculate the tension, T , in the tow line. [2]

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(ii) Calculate the lift force, L , on the glider.

[3]

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(c) The power used to tow the glider is 40 kW. Determine the horizontal velocity of the towing aircraft.

[2]

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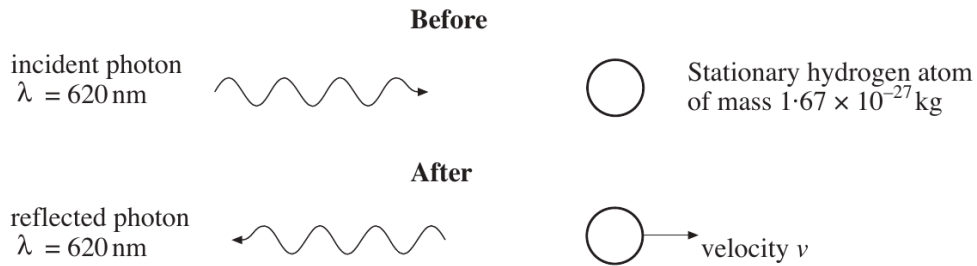
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SECTION B

Momentum & collisions (PH4)

Questions 7 - 17 · 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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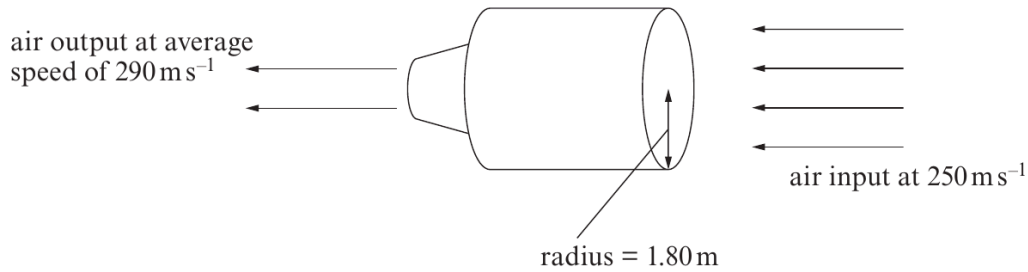
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- (ii) If the wavelength information were given to a greater precision, state how the wavelengths of the incident and reflected photons would compare. [1]

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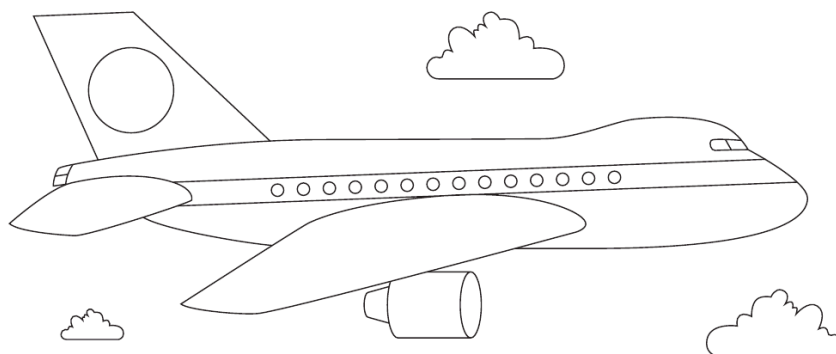
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- (b) Calculate the forward thrust produced by this jet engine. [2]

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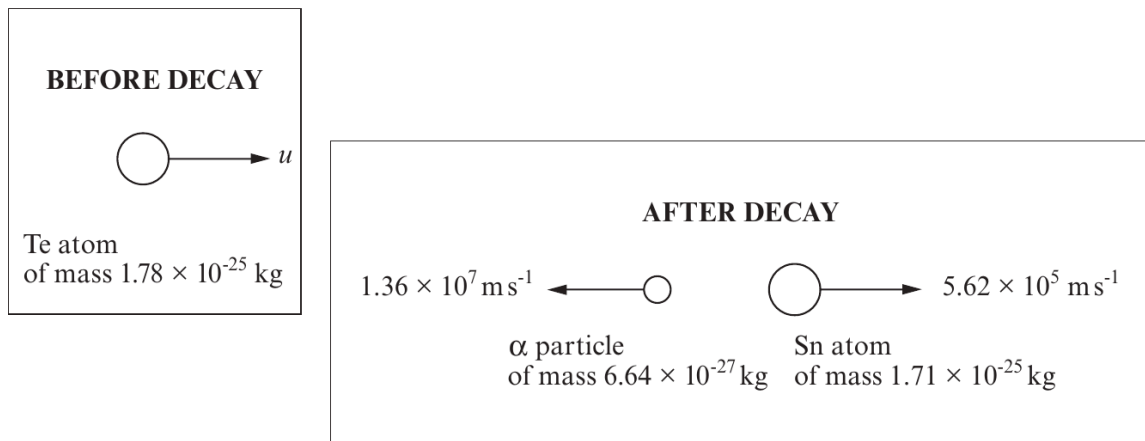
3. (a) State the *Principle of Conservation of Momentum*. [2]

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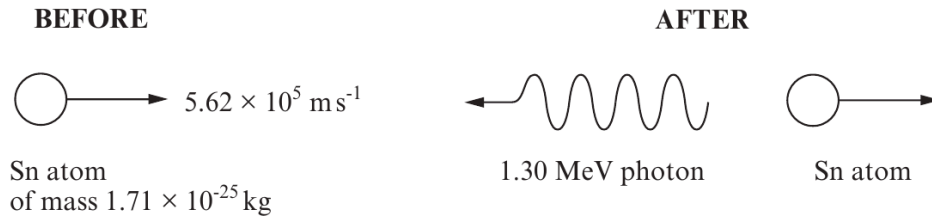
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- (iii) Use the equation $E = pc$ to calculate the **percentage** change in the momentum of the tin (Sn) atom when it emits a gamma ray photon of energy 1.30 MeV as shown. [3]



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Answer all questions.

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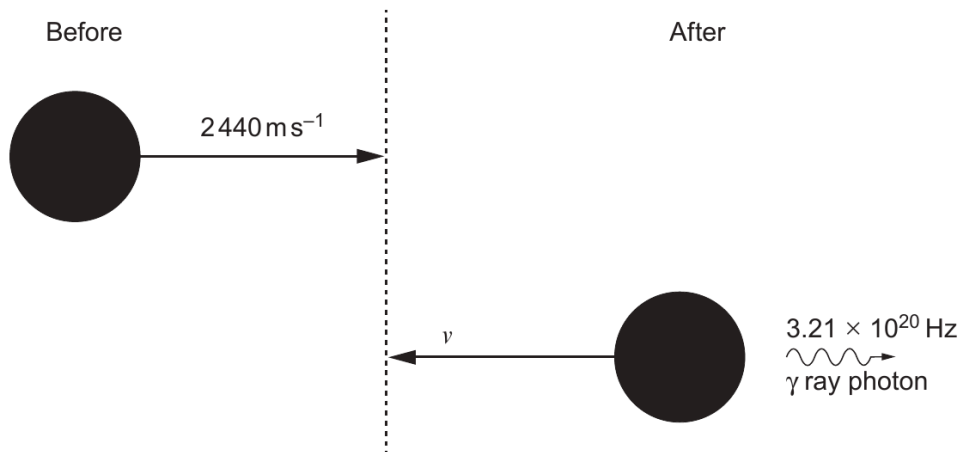
1. (a) State the principle of conservation of momentum. [2]

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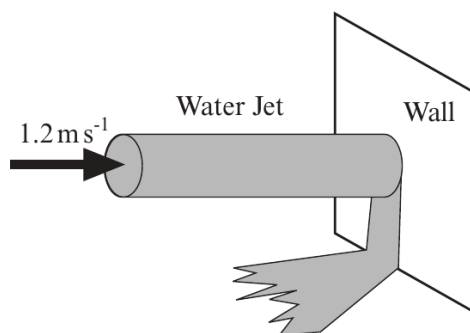
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5. (a) A horizontal jet of water strikes a vertical wall perpendicularly. The speed of the water is 1.2 m s^{-1} and the cross-sectional area of the jet is $2.0 \times 10^{-4} \text{ m}^2$. After striking the wall the water runs down the wall.
(Density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

(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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(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]

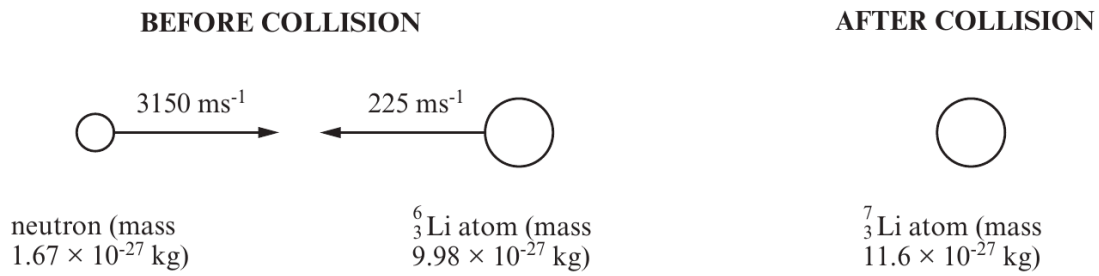
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(b) (i) A head-on inelastic collision occurs between a neutron and a lithium atom, ${}^6_3\text{Li}$.

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]

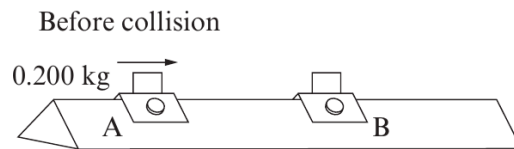
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2. (a) In a laboratory experiment two gliders A and B lie on a linear air track (friction-free). Glider A, of mass 0.200 kg, is accelerated from rest by a force of 3.00 N acting for 0.150 s.



- (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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Examiner
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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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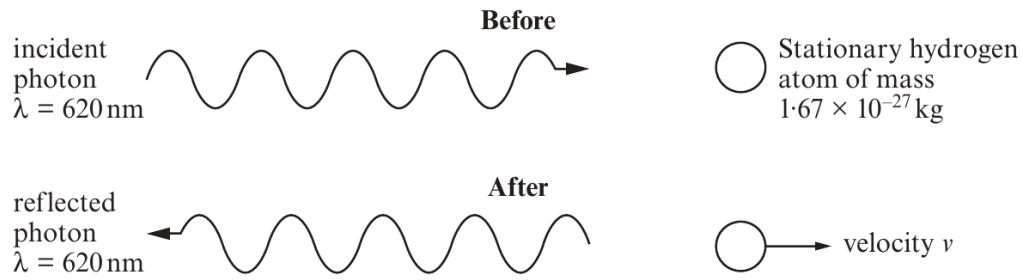
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Examiner only

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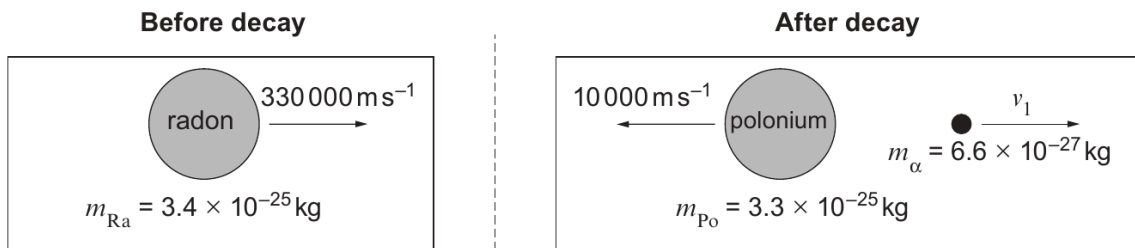
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(ii) Identify the type of electromagnetic radiation of **this** photon. [1]

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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]

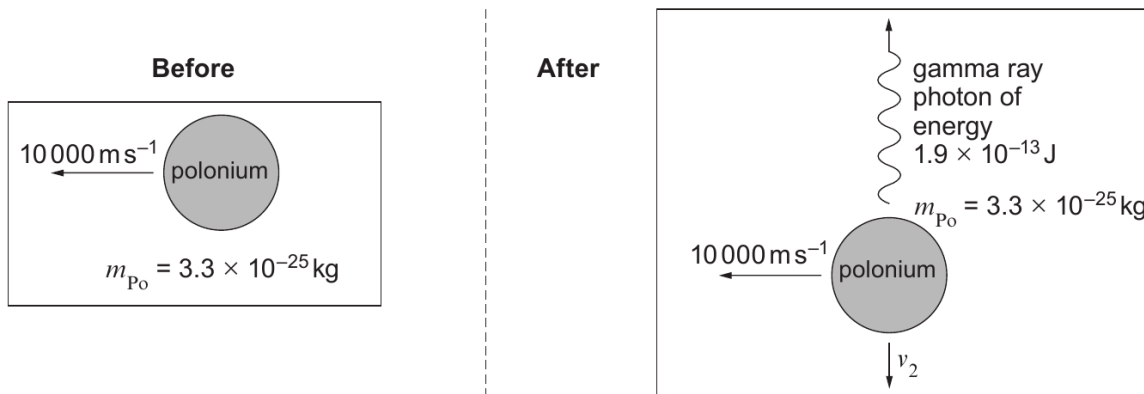
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- (b) The polonium nucleus then emits a gamma ray **perpendicular** to its direction of motion as shown.



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

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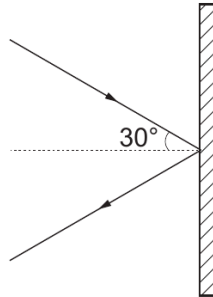
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- (b) A red laser beam of power 1 mW and wavelength 633 nm is incident at an angle of 30° on a **perfectly reflecting** mirror.

Examiner only



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.

Examiner
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1. (a) State:

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

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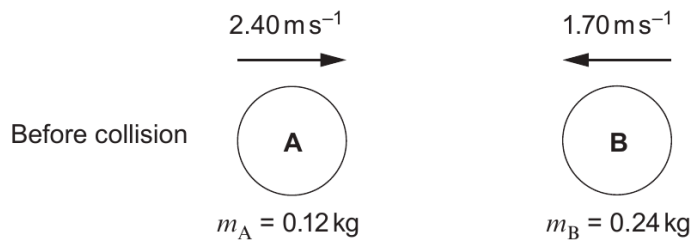
(ii) the principle of conservation of momentum. [2]

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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

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