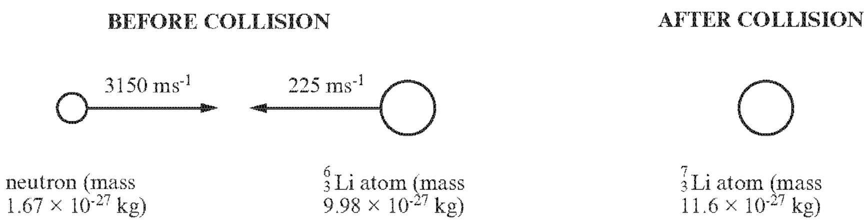
1. *(a)* State the *Principle of Conservation of Momentum.* [2]

*(b)* (i) A head-on inelastic collision occurs between a neutron and a lithium atom, $^{6}_{3}Li$.

The nucleus of the atom absorbs the neutron, to form the heavier isotope $^{7}_{3}Li$. Using the data in the diagram, calculate the *velocity* of the $^{7}_{3}Li$ atom, adding an arrow to the (right hand) diagram, to show its direction of motion. [4]

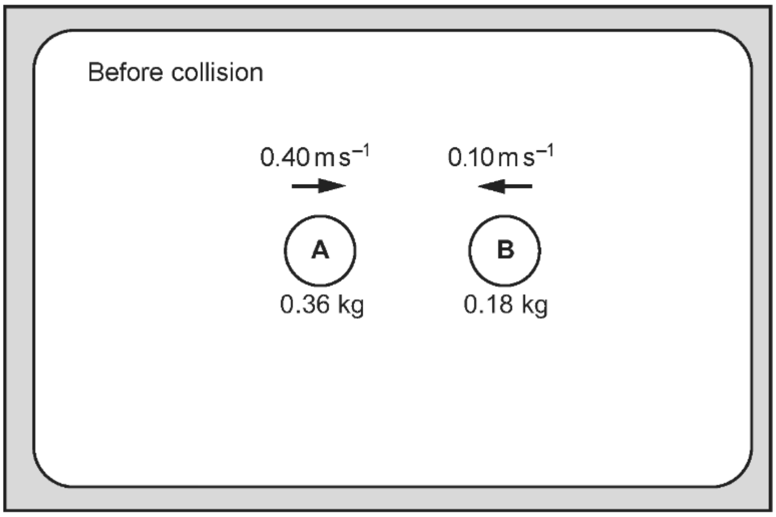



(ii) By calculating *energies* confirm that the collision is inelastic. [2]

*(c)* The nucleus of the $^{7}_{3}Li$ atom is formed in an excited state and loses excess energy by emitting a gamma ray photon of wavelength $1.71 \times 10^{-13}$ m. Calculate the recoil velocity of the $^{7}_{3}Li$ atom, **treating its initial velocity as negligible.** [2]

2.

*(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.




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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3.

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

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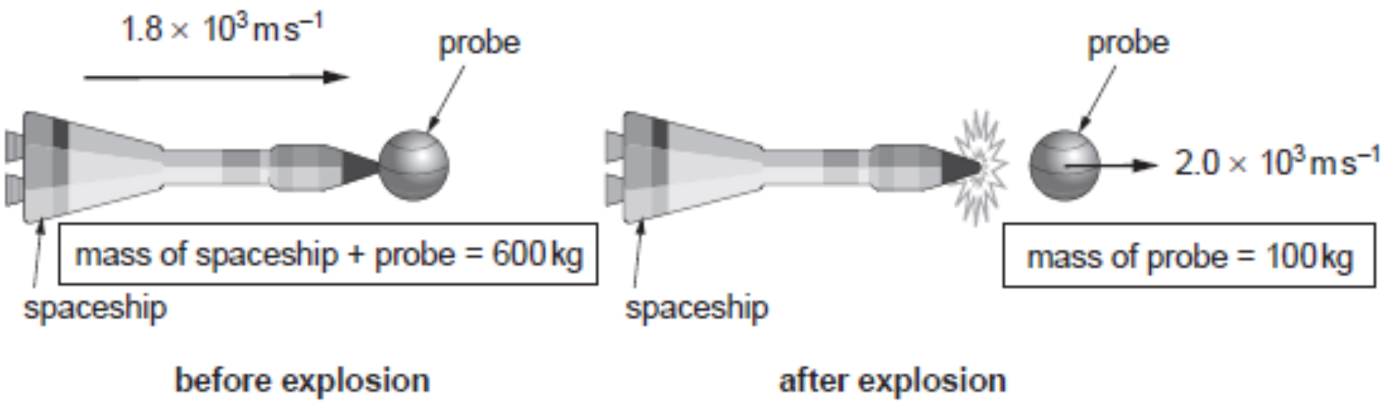
*(b)* A space probe is attached to a large spaceship as shown. The probe can be ejected from the space ship by an explosion. The spaceship and probe together have a mass of 600 kg and they travel in a straight line through deep space at $1.8 \times 10^3\,m\,s^{-1}$. Explosives are detonated, separating the probe from the spaceship. Immediately after the explosion the probe, of mass 100 kg, continues in the original straight line at $2.0 \times 10^3\,m\,s^{-1}$.




(i) Calculate the velocity of the spaceship immediately after the explosion. [2]

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(ii) Show that the kinetic energy possessed by the probe and spaceship after separation is **greater** than the kinetic energy they possessed before separation. [3]

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(iii) Account for this increase in kinetic energy. [1]

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*(c)* During the explosion, a mean force, $F$, acts on the probe for 2.0 ms. Calculate the value of $F$. [2]

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4.

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

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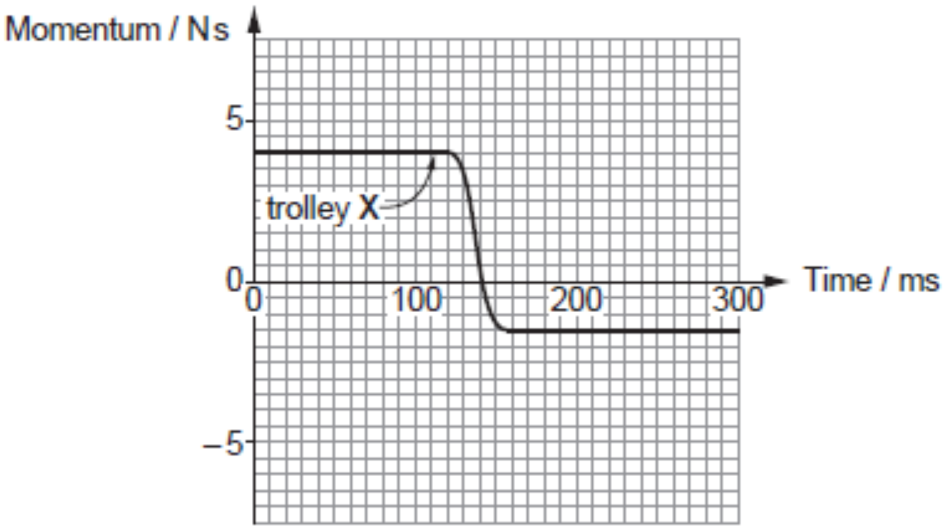
*(b)* A trolley, **X**, travels towards a stationary trolley, **Y**. See diagram.


The trolleys collide head-on. A momentum-time graph is given for trolley **X**.




(i) Trolley **Y** has a mass of 2.4 kg. Determine its velocity after the collision. [3]

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(ii) **Using the same graph grid (opposite)** carefully sketch a graph of **Y**'s momentum between 0 and 300 ms. [3]

(iii) Use the momentum-time graph for **X** to estimate the mean *force* on **X** during the collision. [2]

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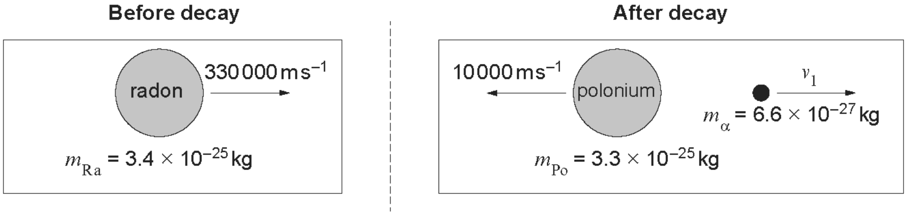
5.

*Answer* **all** *questions*.

A radon nucleus travelling at 330 000 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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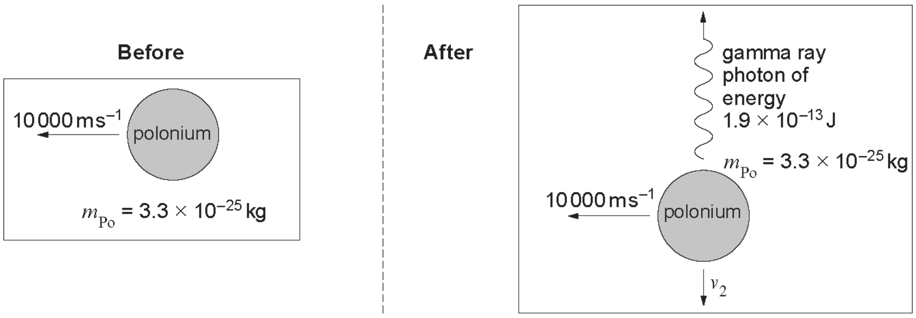
*(b)* The polonium nucleus then emits a gamma ray **perpendicular** to its direction of motion as shown.




(i) Explain why the horizontal velocity component (10 000 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 m s$^{-1}$. [4]

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

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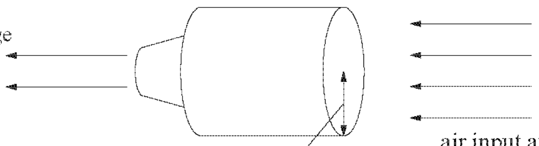
**6.**

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

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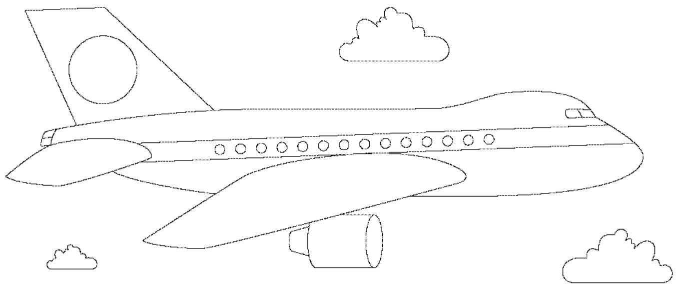

*(c)* Explain how the principle of conservation of momentum applies to the air - aeroplane system when the aeroplane is travelling at a **constant** velocity of $250\,m\,s^{-1}$. [2]

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7. **5.** *(a)* A law of motion can be expressed as:

$$\text{resultant force} = \frac{\text{change in momentum}}{\text{time}}$$

State the name of the law. [1]

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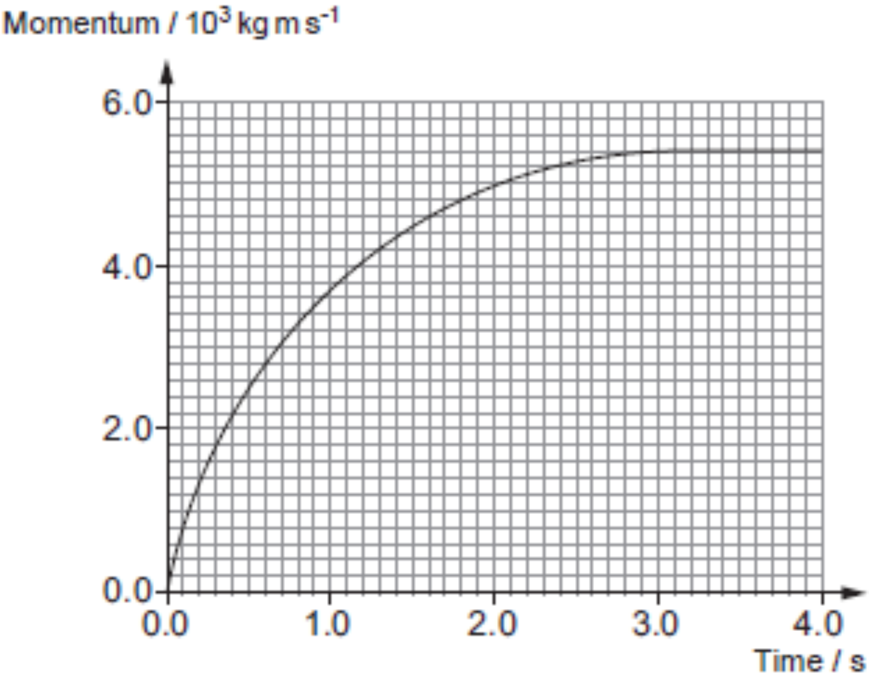
*(b)* The graph shows how the momentum of a spacecraft varies with time.




(i) By drawing a suitable tangent, show that the resultant force on the spacecraft at $t$ = 1.0 s is approximately 2 kN. [2]

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(ii) Hence show that the mass of the spacecraft is approximately 5000 kg, given that its acceleration at $t$ = 1.0 s is 0.4 m s$^{-2}$. [1]

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(iii) **Label, with the letter P**, a point on the graph where the resultant force on the spacecraft is zero. [1]

*(c)* At $t$ = 4.0 s the spacecraft 'docks' (collides) with another stationary spacecraft of mass 7000 kg. They join on impact.

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

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(ii) Calculate the velocity of both spacecraft after colliding. [3]

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