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AS PHYSICS

Paper 1

Tuesday 24 May 2016

Morning

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- a pencil
- a ruler
- a calculator
- a Data and Formulae booklet.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do **all** rough work in this book. Cross through any work you do not want to be marked.
- Show **all** your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70
- You are expected to use a calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.



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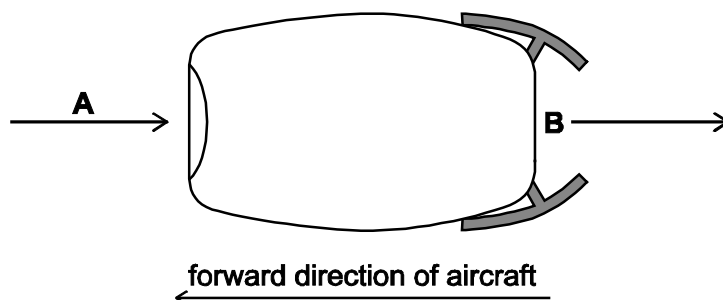
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Answer **all** questions.

0 1

Figure 1 shows a jet engine.

Figure 1



Air enters the engine at **A** and is heated before leaving **B** at a much higher speed.

0 1 . 1

State what happens to the momentum of the air as it passes through the engine. [1 mark]

The momentum of the air increases (its speed increases, so mv increases).

0 1 . 2

Explain, using appropriate laws of motion, why the air exerts a force on the engine in the forward direction. [3 marks]

The momentum of the air increases, so by Newton's second law there must be a resultant force acting on the air (force = rate of change of momentum), and this force acts backwards on the air, in the direction it is accelerated.

By Newton's third law, the air exerts a force on the engine that is equal in magnitude (same size) but opposite in direction, so the force on the engine is in the forward direction.



0 1 . 3

In one second a mass of 210 kg of air enters at **A**. The speed of this mass of air increases by 570 m s^{-1} as it passes through the engine.

Calculate the force that the air exerts on the engine.

[1 mark]

$$F = \Delta(mv)/\Delta t = (210 \times 570)/1$$

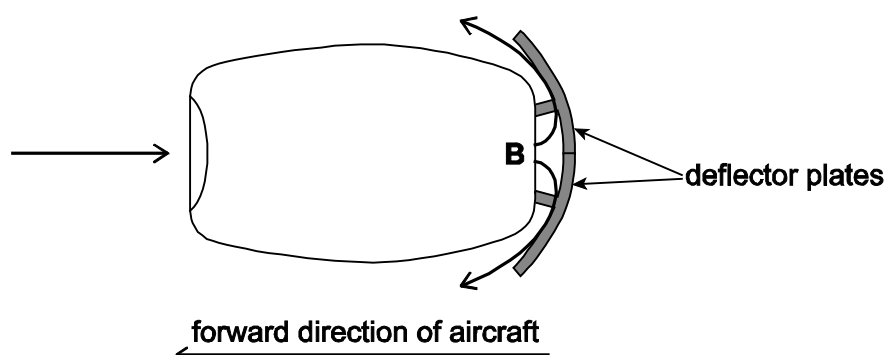
$$F = 119\,700 \text{ N}$$

$$\text{force} = 1.2 \times 10^5 \text{ N}$$

0 1 . 4

When an aircraft lands, its jet engines exert a decelerating force on the aircraft by making use of deflector plates. These cause the air leaving the engines to be deflected at an angle to the direction the aircraft is travelling as shown in **Figure 2**.

Figure 2



The speed of the air leaving **B** is the same as the speed of the deflected air.

Explain why the momentum of the air changes.

[2 marks]

Momentum is a vector, so it has direction as well as magnitude.

The deflector plates change the direction in which the air is travelling, so even though its speed is the same, its velocity and therefore its momentum change.



0 1 . 5

The total horizontal decelerating force exerted on the deflector plates of the jet engines is 190 kN.

Calculate the deceleration of the aircraft when it has a mass of 7.0×10^4 kg.

[1 mark]

$$F = ma, \text{ so } a = F/m = 190\,000 / 7.0 \times 10^4$$

$$a = 2.71 \text{ m s}^{-2}$$

$$\text{deceleration} = \underline{2.7} \text{ m s}^{-2}$$

0 1 . 6

The aircraft lands on the runway travelling at a speed of 68 m s^{-1} with the deflector plates acting.

Calculate the distance the aircraft travels along the runway until it comes to rest. You may assume that the decelerating force acting on the jet engines remains constant.

[2 marks]

$$v^2 = u^2 + 2as, \text{ with } v = 0, u = 68 \text{ m s}^{-1}, a = -2.7 \text{ m s}^{-2}$$

$$0 = 68^2 - 2 \times 2.7 \times s$$

$$s = 68^2 / (2 \times 2.7) = 4624 / 5.4 = 856 \text{ m}$$

$$\text{distance} = \underline{860 (856)} \text{ m}$$

0 1 . 7

Suggest why in practice the decelerating force provided by the deflector plates may not remain constant.

[2 marks]

As the aircraft slows down, the rate of intake of air into the engines decreases, so a smaller mass (volume) of air passes through the engines per second.

So the rate of change of momentum of the air is smaller, which means the decelerating force is smaller (also, air resistance decreases as the speed of the aircraft decreases).



Turn over for the next question

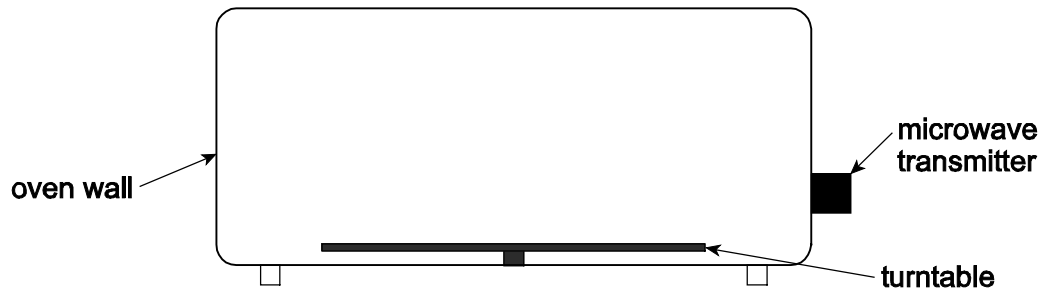
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0 2

Figure 3 is a diagram of a microwave oven.

Figure 3



A student wants to use the stationary waves formed in the microwave oven to measure the frequency of the microwaves emitted by the transmitter.

0 2 . 1

Suggest how stationary waves are formed in the microwave oven.

[2 marks]

The microwaves from the transmitter are reflected from the (metal) oven walls.

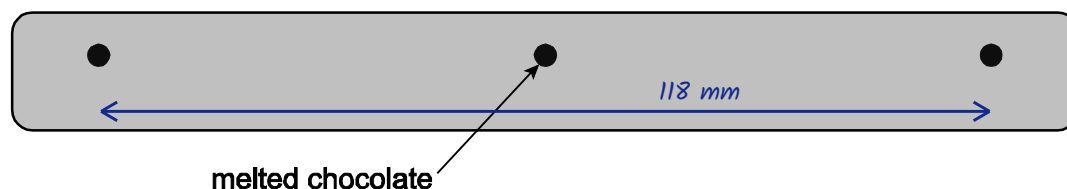
The reflected waves superpose (interfere) with the incident waves travelling in the opposite direction, which have the same frequency, forming a stationary wave with nodes and antinodes.



0 2 . 2

The student removes the turntable and places a bar of chocolate on the floor of the oven. He then switches the oven on for about one minute. When the chocolate is removed the student observes that there are three small patches of melted chocolate with unmelted chocolate between them. **Figure 4** is a full-sized diagram of the chocolate bar.

Figure 4



Suggest why the chocolate only melts in the positions shown.

[2 marks]

The chocolate melts at the antinodes, where the amplitude of the stationary wave and so the energy is a maximum.

At the nodes in between, the amplitude is zero, so little energy is transferred and the chocolate does not melt.

0 2 . 3

Calculate, by making suitable measurements on **Figure 4**, the frequency of the microwaves used by the oven.

[5 marks]

Distance from 1st to 3rd antinode = 118 mm = 0.118 m

Adjacent antinodes are $\lambda/2$ apart, so 1st to 3rd = λ , so $\lambda = 0.118$ m

$f = c/\lambda = 3.0 \times 10^8 / 0.118 = 2.54 \times 10^9$ Hz

frequency = 2.5×10^9 Hz

0 2 . 4

Explain why most microwave ovens contain a rotating turntable on which the food is placed during cooking.

[1 mark]

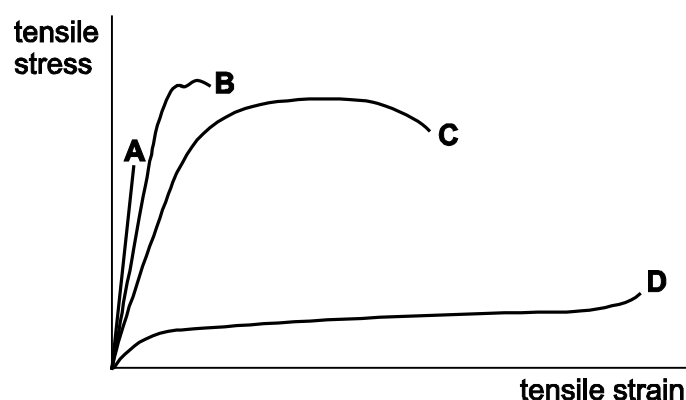
So that the positions of the antinodes (maximum energy) in the food continually change, so the food is heated evenly and not just at fixed hot spots.



0 3

Figure 5 shows the tensile stress–tensile strain graphs for four materials, **A**, **B**, **C** and **D**, up to their breaking stress.

Figure 5



0 3 . 1

State what is meant by tensile stress and tensile strain.

[2 marks]

tensile stress The force applied per unit cross-sectional area, stress = F/A .

tensile strain The extension per unit original length, strain = $\Delta L/L$.

0 3 . 2

Identify a property of material **A** using evidence from the graph to support your choice.

[2 marks]

property A is brittle

evidence The graph is a straight line (linear) all the way up to the breaking stress, so A shows no plastic behaviour before it breaks.



0 3 . 3

A cylindrical specimen of material **A** under test has a diameter of 1.5×10^{-4} m and a breaking stress of 1.3 GPa.

Calculate the tensile force acting on the specimen at its breaking point.

[3 marks]

$$A = \pi d^2 / 4 = \pi \times (1.5 \times 10^{-4})^2 / 4 = 1.77 \times 10^{-8} \text{ m}^2$$

$$F = \text{stress} \times A = 1.3 \times 10^9 \times 1.77 \times 10^{-8}$$

$$F = 23 \text{ N}$$

tensile force = 23 N

0 3 . 4

Discuss which of the four materials shown on the graph is most suitable for each of the following applications:

- the cable supporting a lift in a tall building
- a rope or cable attached to a person doing a bungee jump.

For each application, you should discuss the reason for your choice and why you rejected the other materials.

[6 marks]

Lift cable: B is the most suitable. It has the highest breaking

stress, so it can support the large weight of the lift without

breaking, and it has a high Young modulus (steep gradient), so it is

stiff and the cable stretches very little when loaded.

A is rejected because it has a lower breaking stress and it is

brittle, so it would fail suddenly without warning. C is rejected

because it has a lower breaking stress than B and it undergoes

large plastic deformation, so the cable would stretch permanently

and not return to its original length. D is rejected because it has a

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very low breaking stress and a large strain for a given stress, so the cable would stretch a lot and the lift would bounce.

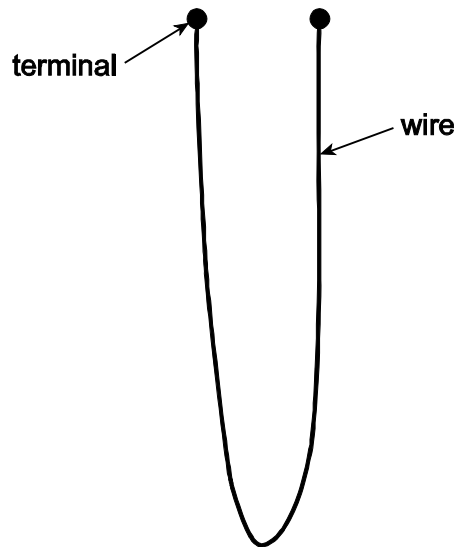
Bungee rope: D is the most suitable. It has a low Young modulus, so a given stress produces a large strain, meaning a large extension. This makes the time taken for the person to come to rest longer, so the deceleration and the force on the person are smaller. The large extension (large area under the graph) means D can store a large amount of energy before failure. (The rope must be thick enough that the stress stays below D's breaking stress.)

A, B and C are rejected because they all have a high Young modulus, so the rope would extend very little and the person would be stopped suddenly, resulting in very large forces. A is also brittle, so it has a limited strain and fails suddenly. C requires a large strain before it behaves plastically, and if it did behave plastically it would not return to its original length, so it could not be reused safely.



0 4

A wire probe is used to measure the rate of corrosion in a pipe carrying a corrosive liquid. The probe is made from the same metal as the pipe. **Figure 6** shows the probe. The rate of corrosion of the wire in the probe is the same as in the pipe.

Figure 6

0 4 . 1

The wire in an unused probe has a resistance of $0.070\ \Omega$ and a length of $0.50\ \text{m}$.

Calculate the diameter of the wire.

[3 marks]

resistivity of metal in the wire = $9.7 \times 10^{-8}\ \Omega\ \text{m}$

$$R = \rho L/A, \text{ so } A = \rho L/R$$

$$A = 9.7 \times 10^{-8} \times 0.50 / 0.070 = 6.93 \times 10^{-7}\ \text{m}^2$$

$$A = \pi d^2/4, \text{ so } d = \sqrt{4A/\pi}$$

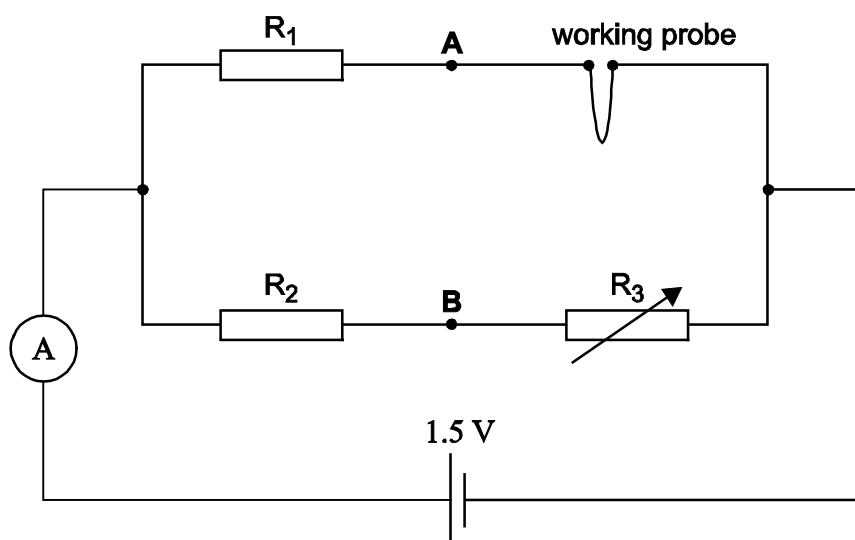
$$d = \sqrt{4 \times 6.93 \times 10^{-7} / \pi} = 9.39 \times 10^{-4}\ \text{m}$$

diameter = 9.4×10^{-4} m



0 4 . 2

In order to measure the resistance of a used working probe, it is connected in the circuit shown in **Figure 7**.

Figure 7

When R_3 is adjusted to a particular value the current in the cell is 0.66 A.

Calculate the total resistance of the circuit.
You may assume that the cell has a negligible internal resistance.

[1 mark]

$$R = V/I = 1.5 / 0.66 = 2.27 \, \Omega$$

resistance = 2.3 Ω

0 4 . 3

The resistance of R_2 is 22 Ω and the resistance of R_3 is 1.2 Ω .

Calculate the current in R_3 .

[1 mark]

$$\text{Lower branch: } R = 22 + 1.2 = 23.2 \, \Omega, \text{ pd across branch} = 1.5 \, \text{V}$$

$$I = V/R = 1.5 / 23.2 = 0.0647 \, \text{A}$$

current = 0.065 A



0 4 . 4

Calculate the resistance of the probe when the resistance of R_1 is 2.4Ω .

[3 marks]

$$\text{Current in } R_1 = 0.66 - 0.0647 = 0.595 \text{ A}$$

$$\text{Resistance of } R_1 + \text{probe} = 1.5 / 0.595 = 2.52 \Omega$$

$$\text{Resistance of probe} = 2.52 - 2.4 = 0.12 \Omega$$

$$\text{resistance} = \underline{0.12} \Omega$$

0 4 . 5

Calculate the percentage change in the diameter of the probe when its resistance increases by 1.6 %.

[2 marks]

$$R = \rho L/A, \text{ so } R \propto 1/A: R \text{ up by } 1.6\% \text{ so area down by } 1.6\%$$

$$A \propto d^2, \text{ so diameter decreases by } 1.6/2 = 0.8\%$$

$$\text{percentage change} = \underline{-0.8 \text{ (decrease)}} \%$$

0 4 . 6

A voltmeter is connected between points **A** and **B** in the circuit and R_3 stays at 1.2Ω .

Explain, without calculation, why the reading on the voltmeter does not change when the cell in the circuit is replaced with another cell of the same emf but a significant internal resistance.

[2 marks]

Lost volts reduce the terminal pd and current, but the resistors do

not change, so the ratio of resistances (and pds) in each arm is

constant. The pd between A and B is very small as the ratios are

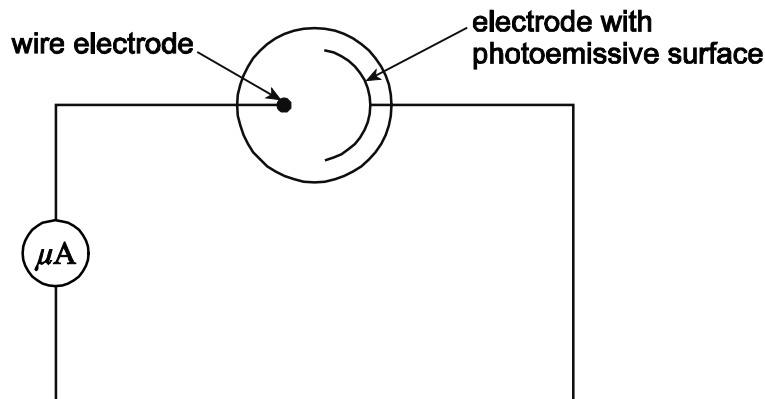
nearly equal, so any change is too small for the voltmeter to detect,

and its very high resistance means it does not affect the circuit.



0 5

Figure 8 shows a photocell which uses the photoelectric effect to provide a current in an external circuit.

Figure 8

0 5 . 1

Electromagnetic radiation is incident on the photoemissive surface.

Explain why there is a current only if the frequency of the electromagnetic radiation is above a certain value.

[3 marks]

Electromagnetic radiation consists of photons, each with energy $E = hf$, and one electron absorbs one photon.

An electron is only emitted if the energy of the photon is greater than (or equal to) the work function of the surface, so the frequency must be above the threshold frequency.

Only then are electrons emitted, giving a current.

0 5 . 2

State and explain the effect on the current when the intensity of the electromagnetic radiation is increased.

[2 marks]

The current increases (becomes greater).

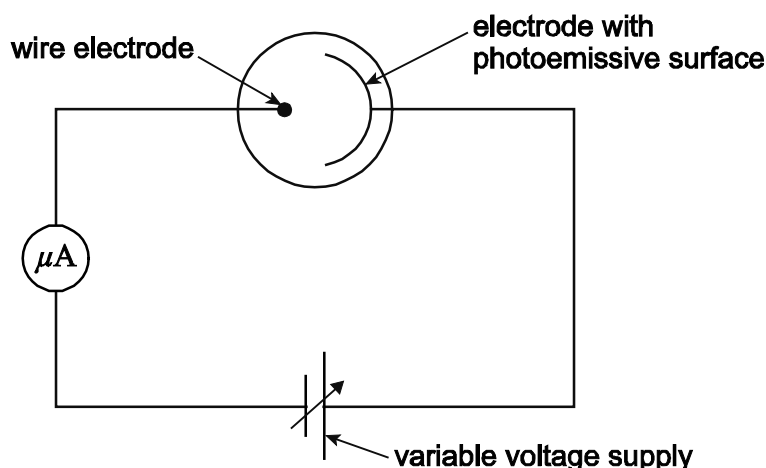
Increased intensity means more photons are incident per second, so more electrons are emitted per second.



0 5 . 3

A student investigates the properties of the photocell. The student uses a source of electromagnetic radiation of fixed frequency and observes that there is a current in the external circuit.

The student then connects a variable voltage supply so the positive terminal is connected to the electrode with a photoemissive surface and the negative terminal is connected to the wire electrode. As the student increases the supply voltage, the current decreases and eventually becomes zero. The minimum voltage at which this happens is called the stopping potential. The student's new circuit is shown in **Figure 9**.

Figure 9

The photoemissive surface has a work function of 2.1 eV. The frequency of the electromagnetic radiation the student uses is 7.23×10^{14} Hz.

Calculate the maximum kinetic energy, in J, of the electrons emitted from the photoemissive surface.

[3 marks]

$$hf = \phi + E_{k(max)}$$

$$\phi = 2.1 \times 1.6 \times 10^{-19} = 3.36 \times 10^{-19} \text{ J}$$

$$hf = 6.63 \times 10^{-34} \times 7.23 \times 10^{14} = 4.79 \times 10^{-19} \text{ J}$$

$$E_{k(max)} = 4.79 \times 10^{-19} - 3.36 \times 10^{-19} = 1.43 \times 10^{-19} \text{ J}$$

maximum kinetic energy = $\underline{1.43 \times 10^{-19}} \text{ J}$



0 5 . 4

Use your answer from **Question 5.3** to calculate the stopping potential for the photoemissive surface.

[1 mark]

$$eV_s = E_{k(max)}$$

$$V_s = 1.43 \times 10^{-19} / 1.6 \times 10^{-19} = 0.89 \text{ V}$$

stopping potential = 0.89 V

0 5 . 5

The student increases the frequency of the electromagnetic radiation.

Explain the effect this has on the stopping potential.

[3 marks]

The stopping potential would be greater (increase).

Increasing the frequency increases the energy of the photons, since

$E = hf$, while the work function stays the same.

So the maximum kinetic energy of the photoelectrons is greater, and

a larger pd is needed to stop them ($eV_s = E_{k(max)}$).



0 6

Helium is the second most abundant element in the universe. The most common isotope of helium is ${}^4_2\text{He}$ and a nucleus of this isotope has a rest energy of 3728 MeV.

In 2011, at the Relativistic Heavy Ion Collider, anti-helium nuclei were produced. Nuclei of anti-helium are made up of antiprotons and antineutrons. It is suggested that an antineutron can decay to form an antiproton in a process similar to β^- decay.

In one particular collision between an anti-helium nucleus and a helium nucleus, the nuclei are annihilated and two photons are formed.

0 6 . 1

State what is meant by isotopes.

[2 marks]

Atoms (nuclei) of the same element with the same number of protons (same atomic number) but different numbers of neutrons (different mass number).

0 6 . 2

Explain why two photons are formed instead of a single photon when a helium nucleus annihilates with the anti-helium nucleus.

[2 marks]

Momentum must be conserved. The total momentum of the helium and anti-helium nuclei before the collision is (approximately) zero. A single photon would carry momentum away in one direction, so the total momentum would not be zero. So two photons are needed, travelling in opposite directions with equal and opposite momenta.



0 6 . 3

Calculate, using data from the passage, the maximum frequency of the photons produced in this annihilation of a ${}^4_2\text{He}$ nucleus.

[4 marks]

$$\text{Total rest energy} = 2 \times 3728 = 7456 \text{ MeV}$$

$$= 7456 \times 10^6 \times 1.6 \times 10^{-19} = 1.193 \times 10^{-9} \text{ J}$$

$$\text{Energy of each photon} = 1.193 \times 10^{-9} / 2 = 5.97 \times 10^{-10} \text{ J}$$

$$E = hf, f = 5.97 \times 10^{-10} / 6.63 \times 10^{-34} = 9.00 \times 10^{23} \text{ Hz}$$

$$\text{frequency} = \underline{9.00 \times 10^{23}} \text{ Hz}$$

0 6 . 4

Complete this equation for the possible decay of an antineutron.

[2 marks]

$${}^1_0\bar{n} \rightarrow {}^1_{-1}\bar{p} + \frac{0}{+1}e + \underline{\nu_e}$$

0 6 . 5

What interaction would be responsible for the decay in **Question 6.4**?
Tick (✓) the correct answer in the right-hand column.

[1 mark]

	✓ if correct
electromagnetic	
gravitational	
strong nuclear	
weak nuclear	✓

END OF QUESTIONS



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