WJEC A-LEVEL PHYSICS

PHYSICS



EXAM QUESTION PACK

UNIT PH5 OLD SPECIFICATION PAPERS

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Surname	Centre Number	Candidate Number
Other Names		2

GCE A level

1325/01

S16-1325-01

PHYSICS – PH5
Electromagnetism, Nuclei & Options

A.M. TUESDAY, 28 June 2016

1 hour 45 minutes

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010001

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator, a **Case Study Booklet** and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use pencil or gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet. If you run out of space, use the continuation page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 3 sections, **A**, **B**, and **C**.

Section A: 60 marks. Answer **all** questions. You are advised to spend about 1 hour on this section.

Section B: 20 marks. The Case Study. Answer **all** questions. You are advised to spend about 20 minutes on this section.

Section C: Options; 20 marks. Answer **one option only.** You are advised to spend about 20 minutes on this section.

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SECTION A

Answer **all** *questions.*

1. Polonium-211 decays to lead-207 with a decay constant (λ) of $1.343\,s^{-1}$.

(a) Calculate the half-life of polonium-211. [2]

(b) Calculate the initial activity of 4.22×10^{-11} kg of polonium-211. (The molar mass of polonium-211 is $0.211\,kg\,mol^{-1}$.) [3]

(c) Calculate the percentage of polonium-211 nuclei remaining after 2.4 s. [2]

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(d) Calculate the time taken for the number of polonium nuclei to decrease to 0.1% of their initial number. [2]

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(e) Explain why 4.22×10^{-11} kg of polonium-211 could be highly dangerous even though it emits alpha particles which cannot penetrate human skin. [2]

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2. An oxygen fusion reaction that occurs in red supergiants is given below.

$$^{16}_{8}\mathrm{O} + {}^{16}_{8}\mathrm{O} \rightarrow {}^{28}_{14}\mathrm{Si} + {}^{4}_{2}\mathrm{He} + 9.594\ \mathrm{MeV}$$

mass of $^{16}_{8}\mathrm{O}$ = 15.9905 u, mass of $^{4}_{2}\mathrm{He}$ = 4.0015 u

(a) Calculate the binding energy **per nucleon** of a $^{16}_{8}\mathrm{O}$ nucleus. [3]

mass of neutron = 1.0087 u, mass of proton = 1.0073 u, 1 u = 931 MeV

(b) Taking account of the energy released in the reaction, calculate the mass of a $^{28}_{14}\mathrm{Si}$ nucleus to 6 significant figures. [4]

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(c) Explain without calculation, whether the total binding energy of $^{28}_{14}\mathrm{Si}$ and $^{4}_{2}\mathrm{He}$ is greater or less than that of two $^{16}_{8}\mathrm{O}$ nuclei. [3]

(d) The following nuclear reaction would release considerably more energy but cannot occur.

$$^{16}_{8}\mathrm{O} + {}^{16}_{8}\mathrm{O} \rightarrow {}^{32}_{16}\mathrm{S} + 16.5\ \mathrm{MeV}$$

Explain why this is impossible in terms of **simple conservation laws**. (Hint: consider the following set up.) [3]



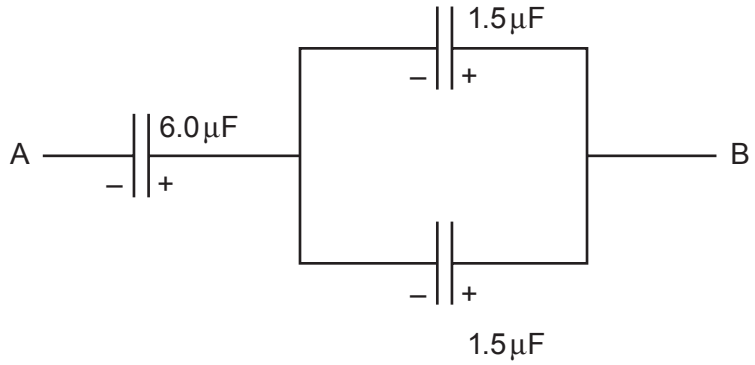
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3. *(a)* Calculate the capacitance of the combination of capacitors shown. [3]



(b) Explain why the 6.0 μF capacitor stores the same amount of energy as one of the 1.5 μF capacitors. [2]

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(c) When the 6.0 μF capacitor is discharged through an unknown resistor, its charge drops from 74.4 μC to 37.2 μC in a time of 35 ms. Calculate:

(i) the unknown resistance; [3]

(ii) the initial current in the circuit as the 6.0 μF capacitor discharges. [3]

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4. *(a)* State the laws of electromagnetic induction (Faraday's law and Lenz's law). [2]

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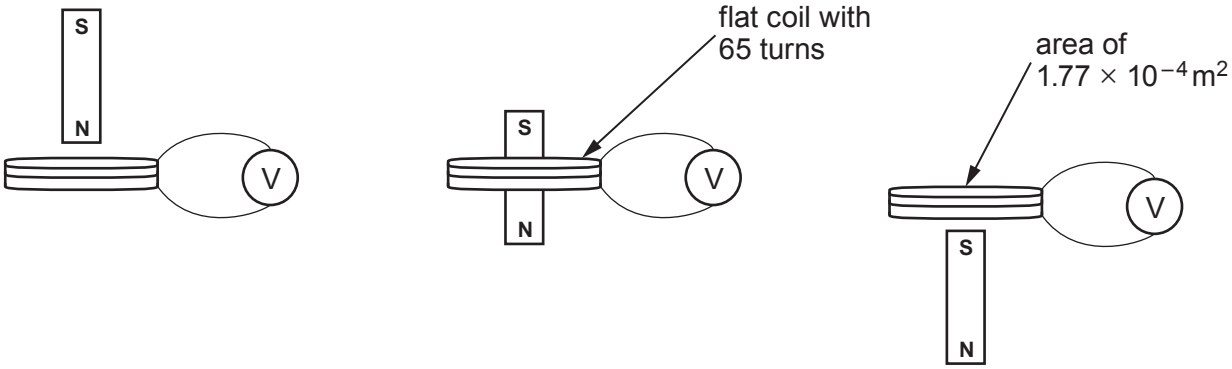
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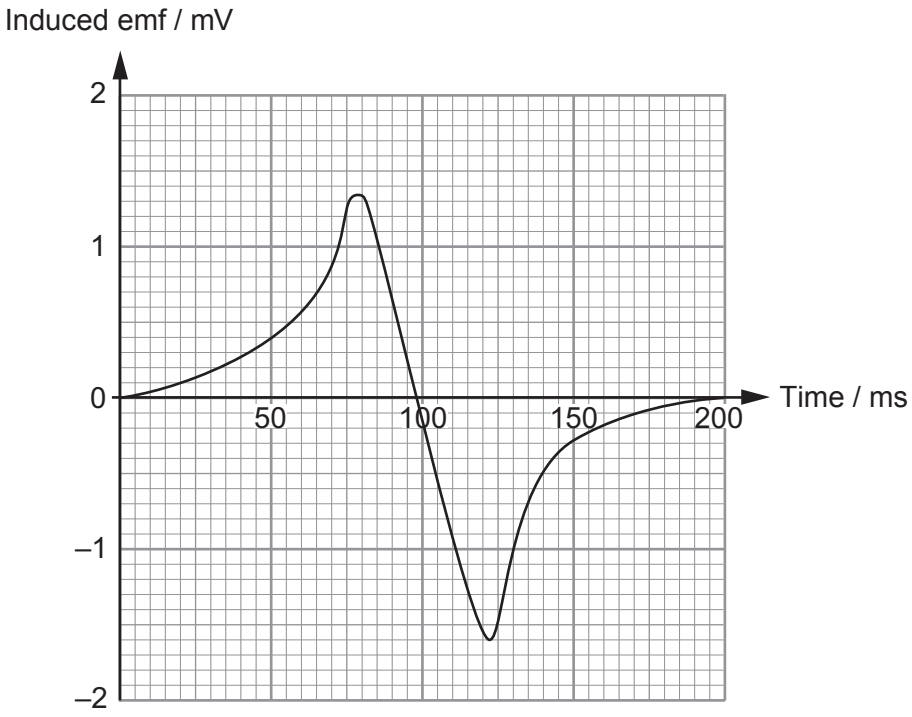
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(b) A strong magnet drops vertically through a flat coil.



The emf induced in the coil is recorded using a voltmeter.



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(i) Use the laws of Faraday and Lenz to explain why the measured emf varies as shown in the graph opposite. [3]

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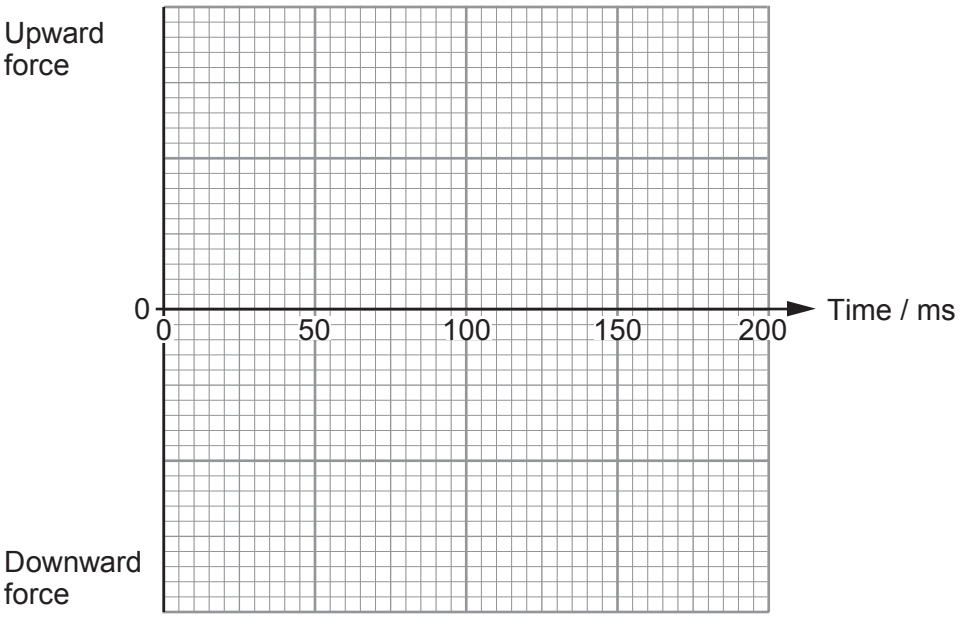
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(ii) The voltmeter is now removed and the ends of the flat coil connected so that current can flow. Sketch a graph showing the variation of force exerted by the coil on the magnet against time (no calculations are required). [3]



(iii) Use the data in the diagrams of the dropping magnet on the opposite page to calculate the length of wire used to make the coil. [3]

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5. *(a)* An electron-positron pair is produced by a photon of energy 1.04 MeV.

(i) Show that the energy required to produce an electron-positron pair is 1.02 MeV. [2]

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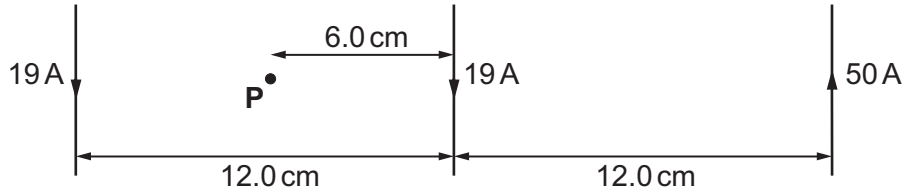
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(ii) State what happens to the remaining 0.02 MeV of the photon energy in this electron-positron pair production. [1]

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(b) Point **P** is half way between two long wires each carrying a current of 19 A and 18.0 cm away from a third long wire carrying a current of 50 A. Show that the resultant magnetic flux density due to the **three** long wires at point **P** is approximately 6×10^{-5} T and **state its direction**. [4]



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(c) A positron travels with velocity, v perpendicularly to a uniform magnetic field, B.

(i) Show in clear steps that the radius of the circular motion of the positron is given by: [4]

$$r = \frac{m_e v}{Be}$$

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(ii) Calculate the radius of motion of a positron moving perpendicularly to a uniform magnetic flux density (B) of 6.0×10^{-5} T when the speed of the positron is $6.0 \times 10^{7}\,\text{m s}^{-1}$. [1]

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(iii) Hence, explain why a positron produced at point **P** initially moving to the left will not travel with uniform circular motion. [2]

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SECTION B

Answer **all** *questions.*

The questions refer to the case study.
Direct quotes from the original passage will not be awarded marks.

6. *(a)* Describe very briefly the evidence Edwin Hubble gathered and how it supports the Big Bang Theory (paragraphs 3 and 10). (Do not include a diagram in your answer.) [3]

(b) What does the author mean when it is stated that *'... particles were at relativistic speeds'*? (paragraph 5). [1]

(c) Explain briefly why *'baryogenesis, a reaction that we know little about'* is required to explain the current content of the universe (paragraph 5). [2]

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(d) Explain why the production of electron-positron pairs stops at a later time than proton-antiproton pairs (paragraph 6). [2]

(e) Explain briefly what the term *'Big Bang nucleosynthesis'* means and what enabled this process to take place (paragraph 7). [2]

(f) In your own words, explain briefly why the universe became transparent after 380 000 years (paragraph 8). [3]

(g) Show clearly how **equation 3** is derived (paragraphs 10-12). [3]

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(h) Use **equation 3** to confirm that the critical density of the universe corresponds to around 5 hydrogen atoms per cubic metre (paragraphs 10-12). [2]

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(i) Use **figure 2** to confirm that the mean temperature of the universe is approximately 2.725 K. [2]

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SECTION C: OPTIONAL TOPICS

Option A: **Further Electromagnetism and Alternating Currents** ☐

Option B: **Revolutions in Physics – Electromagnetism and Space-Time** ☐

Option C: **Materials** ☐

Option D: **Biological Measurement and Medical Imaging** ☐

Option E: **Energy Matters** ☐

Answer the question on **one topic only.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

You are advised to spend about 20 minutes on this section.

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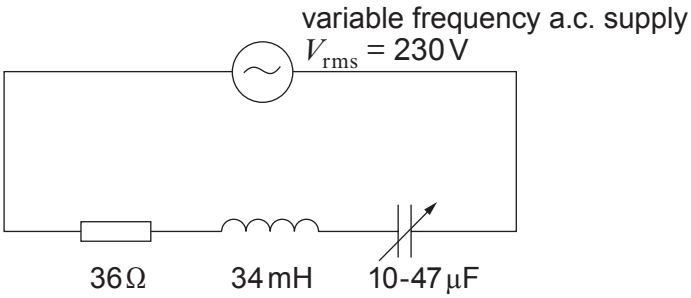
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Option A: Further Electromagnetism and Alternating Currents

7. *(a)* (i) Explain how the design of a transformer reduces energy losses. [4]

(ii) Suggest why transformers employing superconducting coils might be beneficial even though there is considerable cost in liquid nitrogen for cooling. [1]

(b) In the following circuit, both the Q factor and the resonance frequency can be changed by changing the capacitance between the values shown in the diagram. However, the inductance and resistance are constant.



(i) Show that the maximum and minimum resonance frequencies of the above circuit are approximately 273 Hz and 126 Hz respectively. [3]

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(ii) Explain what happens to the Q factor of the circuit when the capacitance is increased. [2]

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(iii) Calculate the rms pd across the 10 μF capacitor at the maximum resonance frequency of 273 Hz. [4]

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(iv) Explain why the rms pd across the 47 μF capacitor at the minimum resonance frequency of 126 Hz is less than that calculated in *(b)*(iii). [3]

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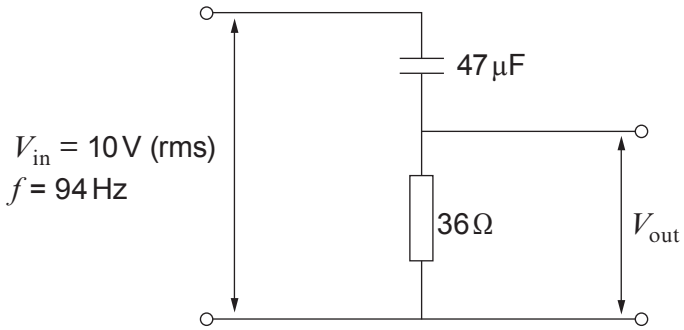
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(c) In the high pass filter shown, calculate the output pd (V_{out}). [3]



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Option B: Revolutions in Physics – Electromagnetism and Space-Time

8. *(a)* In the following passage, Thomas Young explained the positions of the fringes formed when light from a single source is diffracted by two closely spaced apertures (at equal distances from the source) and the diffracted light overlaps.

"The brighter stripes on each side [of the central bright stripe] are at such distances that the light coming to them from the apertures must have passed through a longer space than that which comes from the other, by an interval which is equal to the breadth of one, two, three or more of the supposed undulations, while the intervening dark spaces correspond to a difference of half a supposed undulation, of one and a half, or two and a half or more."

(i) What is meant by *'the breadth of an undulation'*? [1]

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(ii) Put Young's condition for the **third dark** fringe (from the centre) into the form of an equation, giving a simple labelled diagram to help you explain the meanings of terms in the equation. [3]

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(b) (i) Describe briefly one discovery which Ampère made by experiment. [2]

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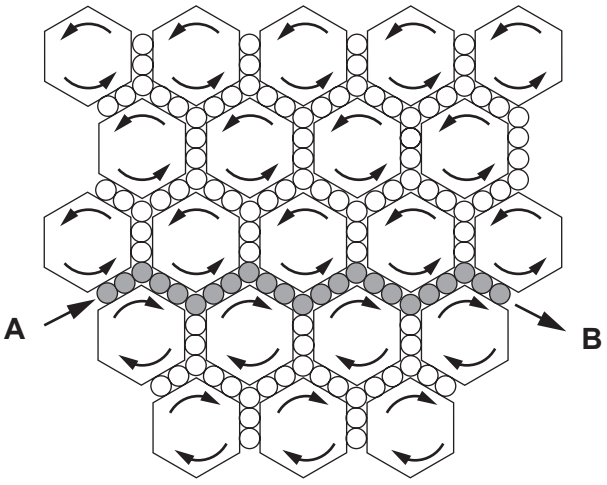
(ii) What did Ampère believe was occurring inside a magnet to give rise to its magnetic properties? [2]

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(c) In the diagram of Maxwell's vortex ether, an external agency is pushing the shaded zigzag line of idlers steadily in the direction from **A** to **B**.



Describe in detail what the pattern of vortex rotation represents in electromagnetic terms. Remember that the diagram is a section through a three-dimensional ether. [3]

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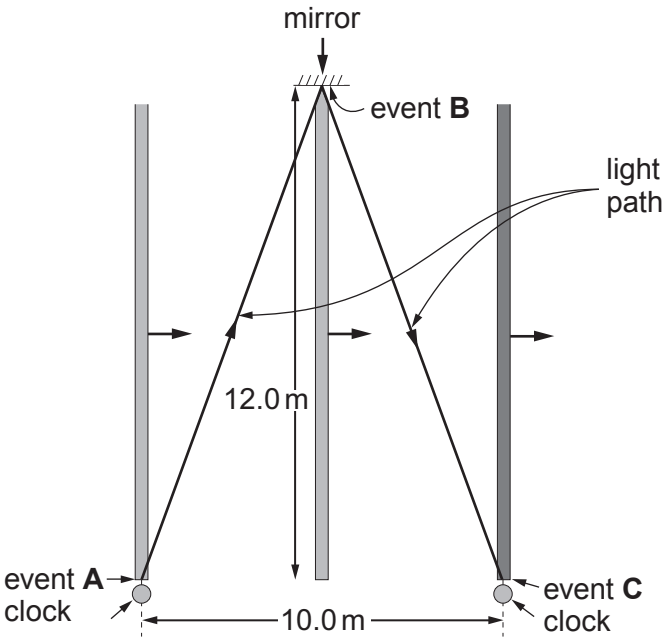
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(d) In a thought-experiment, a rod of length 12.0 m moves at a constant velocity through a laboratory, in a direction at right angles to its own length. The rod carries a mirror at one end. A flash of light is sent (event **A**) from the other end, reflects (event **B**) off the mirror and arrives back (event **C**) at the other end. In the laboratory frame of reference the events occur at the places shown.



(i) Calculate the total length of the light path and **hence** show clearly that the time between events **A** and **C**, as measured by synchronised clocks (with suitable sensors), placed as shown in the laboratory, is approximately 87 ns. Give your answer to 3 significant figures. [3]

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(ii) By considering the total length of the light path in the rod's frame (the frame of reference in which the rod is stationary), calculate the time between events **A** and **C** in the rod's frame. [1]

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(iii) State the difference between a *proper* and an *improper* time, referring to parts *(d)*(i) and (ii). [2]

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(iv) Calculate to three significant figures the rod's speed in the laboratory frame and hence check the ratio of your answers to parts *(d)*(i) and (ii) using the time dilation equation. [3]

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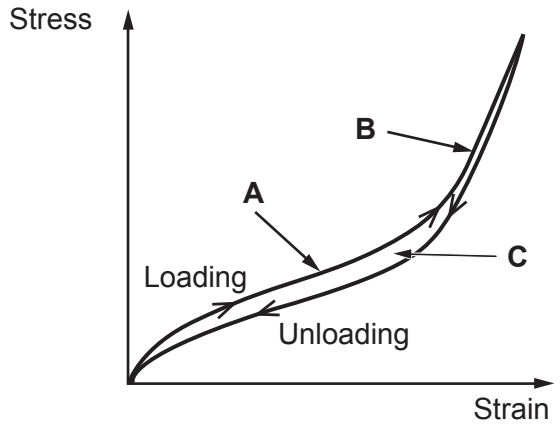
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Option C: Materials

9. *(a)* A specimen of rubber is gradually loaded and then unloaded. A stress-strain diagram for the specimen is shown.



(i) State the feature of the graph which confirms that the rubber was deformed elastically. [1]

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(ii) By referring to the molecular structure of rubber explain why the gradient at **A** is less steep than the gradient at **B**. [3]

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(iii) Write down the name given to the effect represented by the area enclosed between the loading and unloading curve, **C** and explain the significance of this area. [3]

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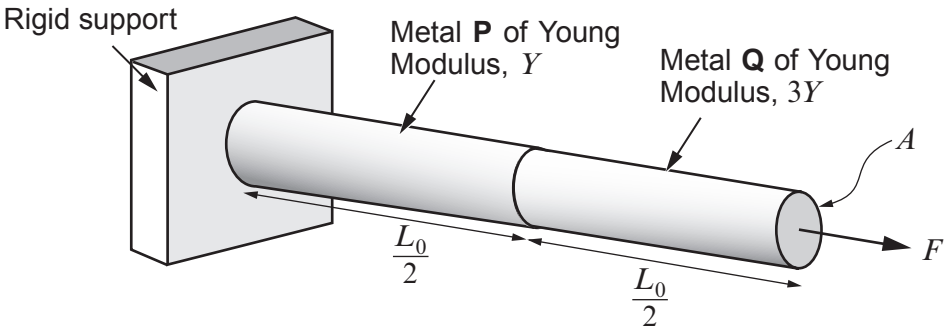
(iv) With reference to your answer to part *(a)*(iii), explain why it is inadvisable to drive cars with tyres which are under-inflated, that is, with less than the recommended air pressure. [1]

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(b) The bar in the figure below is made from two different metals, **P** and **Q**, of equal length $\frac{L_0}{2}$ and cross-sectional area, A. The metals are welded securely to each other and to the rigid support.



(i) By considering the total extension of both metals under the action of a common force, F, show in clear steps that the energy, W, stored in the combination can be given by: [4]

$$W = \frac{F^2 L_0}{3AY}$$

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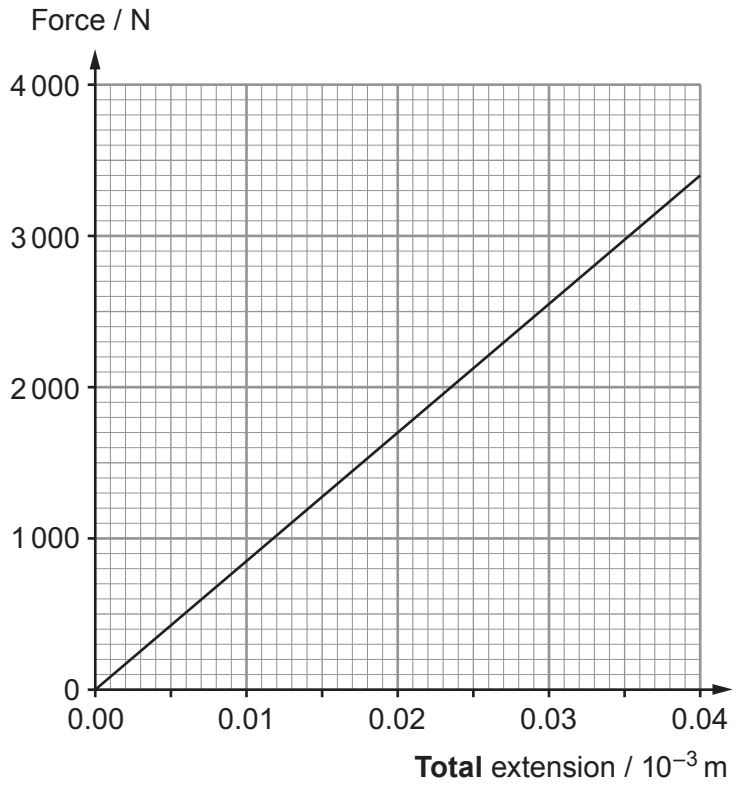
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(ii) A force-extension graph for the combination is shown below.



Use the graph to determine the energy stored in the combination when the applied force = 2 800 N. [2]

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(iii) Using the equation in part *(b)*(i) and your answer to part *(b)*(ii) (or otherwise), determine Y (the Young modulus of metal **P**). (L_0 = 0.300 m and the diameter of the bars = 14.5 mm.) [3]

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(iv) Explaining your reasoning carefully, determine the ratio: [3]

$$\frac{\text{extension of metal } \mathbf{P}}{\text{extension of metal } \mathbf{Q}}$$

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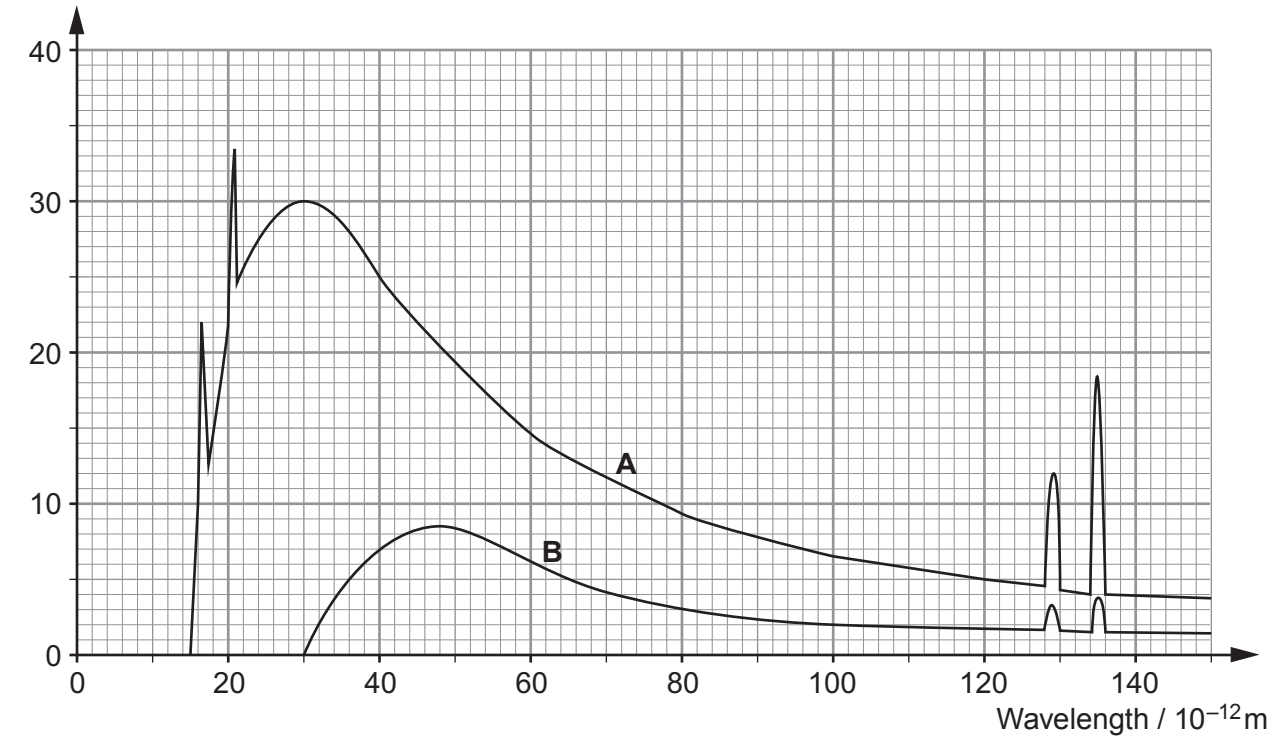
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Option D: Biological Measurement and Medical Imaging

10. The diagram below shows two X-ray spectra produced by X-ray tubes.



(a) (i) Without calculation compare the accelerating voltages used to produce the two spectra, **A** and **B**. Explain your reasoning. [2]

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(ii) The target used was of the same material in the two cases. State how the graphs support this statement. [1]

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(iii) Spectrum **A** was produced using an accelerating voltage of 84 kV. Use this to calculate a value for the Planck constant, h (show your working). [2]

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(iv) Calculate the accelerating voltage used to produce spectrum **B**. [2]

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(b) Both MRI and CT scans can be used in diagnostic medicine. Give **one** advantage and **one** disadvantage (other than cost) of using MRI scans over CT scans. [2]

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(c) An ultrasound probe is used to study the flow of blood from the heart.

(i) Explain how the probe produces ultrasound. [3]

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(ii) The wavelength of ultrasound used is 0.40 mm and it travels through the blood at 1 200 m s^{-1}. If the wavelength shift of the received ultrasound is 0.60 μm, calculate the speed of flow of the blood. [2]

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(d) An ECG recorder is used to check a patient's heart. Sketch the expected ECG trace for a healthy heart. Both axes should be labelled. [2]



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(e) Explain the difference between *absorbed dose* and *dose equivalent* and explain how the *dose equivalent* would be different for exposure to alpha particles and gamma rays. [4]

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Option E: Energy Matters

11. *(a)* The largest **pumped-storage** hydroelectric scheme in the UK is the Dinorwig power station which is a 1.8 GW facility in Llanberis, North Wales.

Dinorwig



(i) Explain why the **mean** output power of the Dinorwig station is negative. [2]

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(ii) Explain briefly why the Dinorwig station is extremely useful even though its mean output power is negative. [1]

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(b) The hydroelectric system that produces the greatest energy output in the world is the 7 km long Itaipu dam in South America which has a mean output power of around 11 GW.

Itaipu Dam



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(i) State **three** advantages and **one** disadvantage of a hydroelectric power station over a wind farm. [3]

(ii) The height of the Itaipu dam is 118 m and its mean output power is 11 GW. Determine the mass of water that passes through the Itaipu hydroelectric system daily, stating any assumption that you make. [4]

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(c) (i) Calculate a value for the Solar Constant from the following data. [3]

Temperature of the Sun = 5 780 K, Radius of the Sun = 6.96×10^8 m,
Distance from the Earth to the Sun = 1.50×10^{11} m.

(ii) The actual value of the light intensity incident upon the Earth's surface having passed through the atmosphere is 1.12 kW m^{-2}. Estimate the area of land required to produce the same mean power output as the Itaipu hydroelectric system (11 GW) from solar panels. Explain your reasoning carefully. [3]

(iii) The cost per square metre of solar panels is around £200 but they have a guaranteed lifetime of 25 years. Compare the cost of producing electricity using solar panels with the normal cost of producing electricity (£40-60 per MWh). [4]

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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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GCE A level

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PHYSICS – PH5

Electromagnetism, Nuclei & Options

A.M. TUESDAY, 28 June 2016

CASE STUDY FOR USE WITH SECTION B

Examination copy

To be given out at the start of the examination.

The pre-release copy must not be used.

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The Big Bang Theory Paragraph

(Freely modified from various Wikipedia pages)

The **Big Bang** theory is the prevailing cosmological model for the early development of the universe. The key idea is that the universe is expanding. Consequently, the universe was denser and hotter in the past. Moreover, the Big Bang model suggests that at some moment all matter in the universe was contained in a single point, which is considered the beginning of the universe. Modern measurements place this moment at approximately 13.8 billion years ago, which is thus considered the age of the universe. After the initial expansion, the universe cooled sufficiently to allow the formation of subatomic particles, including protons, neutrons, and electrons. Though simple atomic nuclei formed within the first three minutes after the Big Bang, thousands of years passed before the first electrically neutral atoms formed. The majority of atoms produced by the Big Bang were hydrogen, along with helium and traces of lithium. Giant clouds of these primordial elements later coalesced through gravity to form stars and galaxies, and the heavier elements were synthesized either within stars or during supernovae. 1

The Big Bang theory offers a comprehensive explanation for a broad range of observed phenomena, including the abundance of light elements, the cosmic microwave background radiation (CMBR), large scale structure, and Hubble's Law. Today, the distances between galaxies is increasing hence, in the past, galaxies were closer together. The known laws of nature can be used to calculate the characteristics of the universe in detail back to a time when densities and temperatures were extreme. While large particle accelerators can replicate such conditions, resulting in confirmation and refinement of the details of the Big Bang model, these accelerators can only probe so far into high energy conditions. Consequently, the state of the universe in the earliest instants of the Big Bang expansion is poorly understood and still an area of open investigation. The Big Bang theory does not provide any explanation for the initial conditions of the universe; rather, it describes and explains the general evolution of the universe going forward from that point on. 2

Belgian Catholic priest and scientist Georges Lemaître proposed what became the Big Bang theory in 1927. Over time, scientists built on his initial idea of cosmic expansion, which, his theory went, could be traced back to the origin of the cosmos and which led to the formation of the modern universe. The framework for the Big Bang model relies on Albert Einstein's theory of general relativity and on simplifying assumptions such as homogeneity and isotropy of space. In 1929, Edwin Hubble discovered that the distances to faraway galaxies were strongly correlated with their red shifts. Hubble's observation was taken to indicate that all distant galaxies and clusters have an apparent velocity directly away from our vantage point: that is, the farther away, the higher the apparent velocity, regardless of direction. The interpretation is that all observable regions of the universe are receding from each other. 3

While the scientific community was once divided between supporters of two different expanding universe theories – the Big Bang and the Steady State theory – observational confirmation of the Big Bang scenario came with the discovery of the CMBR in 1964, and later when its spectrum was found to match that of thermal radiation from a black body. 4

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The History of the Universe

Paragraph

Inflation

The earliest phases of the Big Bang are subject to much speculation. In the most common models the universe was filled homogeneously and isotropically with an incredibly high energy density and huge temperatures and pressures and was very rapidly expanding and cooling. Approximately 10^{-37} seconds into the expansion, a phase transition caused a cosmic inflation, during which the universe grew exponentially. After inflation stopped, the universe consisted of a quark-gluon plasma, as well as all other elementary particles. Temperatures were so high that the random motions of particles were at relativistic speeds, and particle-antiparticle pairs of all kinds were being continuously created and destroyed in collisions. At some point baryogenesis, a reaction that we know little about, violated the conservation of baryon number, leading to a very small excess of quarks and leptons over antiquarks and antileptons – of the order of one part in 30 million. This resulted in the predominance of matter over antimatter in the present universe. 5

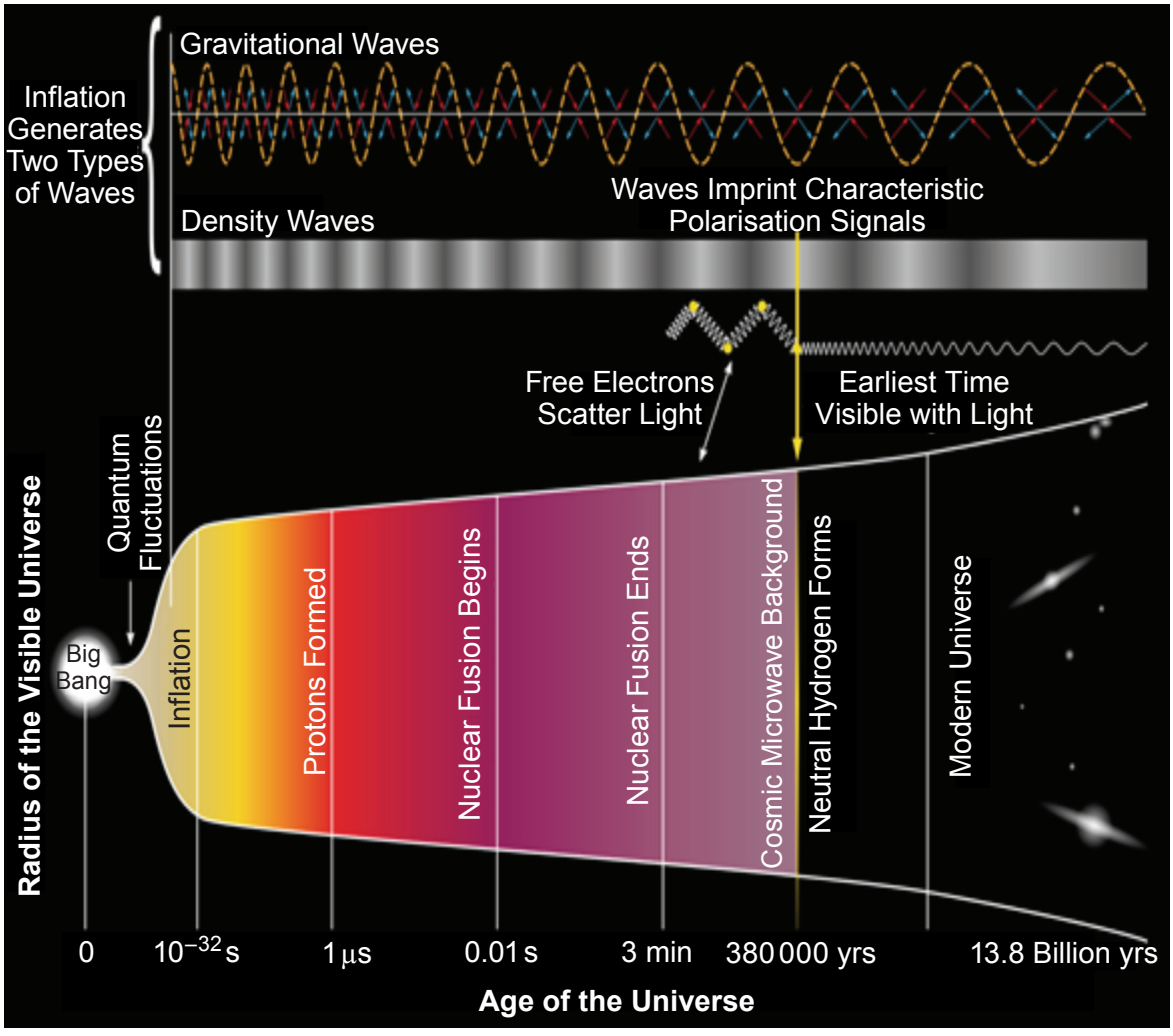


Figure 1

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Protons Forming Paragraph

The universe continued to decrease in density and fall in temperature, hence the typical energy of each particle was decreasing. After about 10^{-11} seconds, the picture becomes less speculative, since particle energies drop to values that can be attained in particle physics experiments. At about 10^{-6} seconds, quarks and gluons combined to form baryons such as protons and neutrons. The small excess of quarks over antiquarks led to a small excess of baryons over antibaryons. The temperature was now no longer high enough to create new proton-antiproton pairs (similarly for neutrons-antineutrons), so a mass annihilation immediately followed, leaving just one in 10^{10} of the original protons and neutrons, and none of their antiparticles. A similar process happened at about 1 second for electrons and positrons. After these annihilations, the remaining protons, neutrons and electrons were no longer moving relativistically and the energy density of the universe was dominated by photons (with a minor contribution from neutrinos). 6

Nuclear Fusion Begins and Ends

A fraction of a second into the expansion, when the temperature was about a hundred billion kelvin (100 GK), neutrons combined with protons to form the universe's deuterium and helium nuclei in a process called Big Bang nucleosynthesis. However, around 3 minutes after the Big Bang the universe had cooled further so that fusion was no longer possible. The Big Bang theory itself predicts mass abundances of about 75% of hydrogen-1, about 25% helium-4, about 0.01% of deuterium, trace amounts (in the order of 10^{-10}) of lithium and beryllium, and no other heavy elements. That the observed abundances in the universe are generally consistent with these abundance numbers is considered strong evidence for the Big Bang theory. 7

The Universe Becomes Transparent

After about 380 000 years the universe cooled to a temperature of around 3 000 K. The electrons and nuclei combined into atoms (mostly hydrogen). This meant that radiation could travel freely without forcing free charges to oscillate and continued through space largely unimpeded. This relic radiation is known as the CMBR. It is frequently stated that the CMBR that is detected today started as gamma radiation shortly after the Big Bang. This is not strictly true because these photons were scattered and absorbed a long time ago. The CMBR that we can detect now started as mainly infra-red radiation 380 000 years after the Big Bang when the universe suddenly became transparent. Although the universe previously had been hot enough to emit gamma rays (as a black body radiator), this radiation was not able to travel very far. 8

The Modern Universe and The Big Bang Theory

In today's universe, the earliest and most direct observational evidence of the validity of the theory are the expansion of the universe according to Hubble's law (as indicated by the red shifts of galaxies), discovery and measurement of the CMBR and the relative abundances of light elements produced by Big Bang nucleosynthesis. More recent evidence includes observations of galaxy formation and evolution, and the distribution of large-scale cosmic structures. These are sometimes called the "four pillars" of the Big Bang theory. 9

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Paragraph

Observations of distant galaxies and quasars show that these objects are red shifted – the light emitted from them has been shifted to longer wavelengths. This can be seen by taking a frequency spectrum of an object and matching the spectroscopic pattern of emission lines or absorption lines corresponding to atoms of the chemical elements interacting with the light. These red shifts are distributed evenly among the observed objects in all directions. If the red shift is interpreted as a Doppler shift, the recessional velocity of the object can be calculated. When the recessional velocities are plotted against these distances, a linear relationship known as Hubble's law is observed:

$$v = H_0 D \qquad \textbf{Equation 1}$$

where:

- v is the recessional velocity of the galaxy or other distant object;
- D is the distance to the object;
- H_0 is the Hubble constant, measured to be 2.2685×10^{-18} s^{-1}.

If Hubble's law, $v = H_0 D$, is combined with a simple calculation for the escape velocity from a spherical universe, the so-called critical density of the universe can be calculated:

$$\frac{1}{2}mv_{\text{esc}}^2 - \frac{GMm}{R} = 0 \qquad \textbf{Equation 2}$$

where v_{esc} is the escape velocity of an arbitrary mass, m, which is a distance, R, from the 'centre' of the universe and M is the mass of the universe contained inside the sphere of radius R (upon whose surface the arbitrary mass lies). When the volume of the sphere of radius R is also included, this leads to:

$$\rho_c = \frac{3H_0^2}{8\pi G} \qquad \textbf{Equation 3}$$

The critical density, ρ_c, of the universe can be calculated from this equation and corresponds to 5 hydrogen atoms per cubic metre. The observed mass of the universe (based on counting stars) also leads to a similar value of density.

Not only can we calculate a mean density for the modern universe, we can also calculate a mean temperature. From the CMBR, if the universe is assumed to be a black body then a temperature of (2.725 ± 0.001)K is obtained. Moreover, the microwave spectrum follows a perfect black body spectrum shape.

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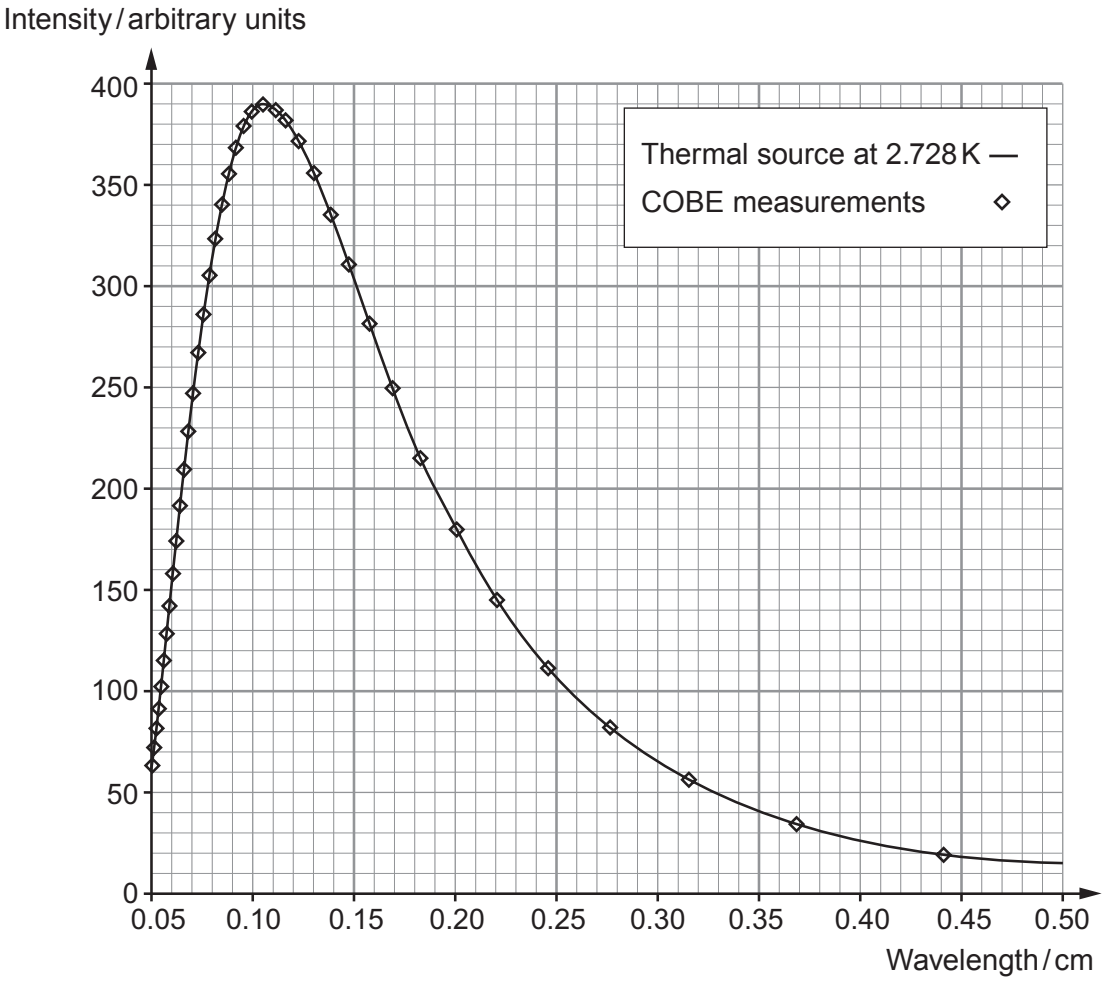


Figure 2

Since the early 1980s more and more evidence for larger scale order of matter in the universe has been discovered. Stars are organised into galaxies, which in turn form galaxy groups, galaxy clusters, superclusters, sheets, walls and filaments, which are separated by immense voids, creating a vast foam-like structure sometimes called the "cosmic web". All these enormous scale structures have been simulated by computer and all seem to agree with the Big Bang theory. 14

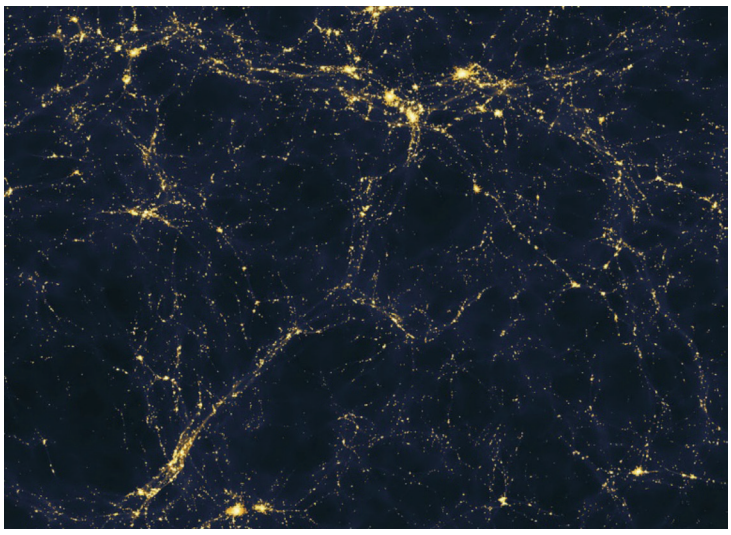


Figure 3

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GCE MARKING SCHEME

SUMMER 2016

PHYSICS PH5
1325/01

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INTRODUCTION

This marking scheme was used by WJEC for the 2016 examination. It was finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conference was held shortly after the paper was taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conference was to ensure that the marking scheme was interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conference, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about this marking scheme.

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Question			Marking details	Marks Available
1	*(a)*		$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ used	1
			answer = 0.516 [s]	1
	(b)		$A = \lambda N$ used	1
			Correct method for finding N (i.e. 1.2×10^{14}) e.g. $n = \frac{4.22\text{x}10^{-11}}{0.211}$ and $N = n \times N_A$	1
			Answer = 1.62×10^{14} [Bq]	1
	(c)		$e^{-1.343\times2.4}$ or $\frac{1}{2^{4.65}}$	1
			Answer = 3.98[%]	1
	(d)		$0.001 = e^{-1.343t}$ (allow factor 10 slips) or ~10 half-lives	1
			Answer = 5.14 [s] (accept 5.1 s -5.2 s)	1
	(e)		[Can be] ingested (accept inhaled) Large activity / short half-life) **and** [alpha highly] ionising Accept high equivalent dose Don't accept high dose only (needs ionising too) and treat reference to daughter nuclei as neutral	1 1
			Question 1 Total	**[11]**

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Question			Marking details	Marks Available
2	*(a)*		Attempt at 8n + 8p - mass of oxygen nucleus	1
			×931 and ÷16 or use of mc^2 and ÷16	1
			Correct answer = 8.0 [MeV/nucleon] or 1.28×10^{-12} [J]	1
	(b)		Conversion of energy to mass e.g. $\frac{9.594}{931} = 0.0103$ [u]	1
			Correct application of conservation of mass-energy e.g. $(15.9905 \times 2) - (4.0015 + 0.0103)$	1
			Answer approx correct e.g. 28 u ****unit mark**** or 4.6×10^{-26} kg	1
			27.9692 (accuracy mark, also available for 27.9898 and without unit) Accept 4.64289×10^{-26} [kg]	1
	(c)		The reaction releases [9.594 MeV of] energy or is exothermic (some mention must be made of the energy on the RHS) Don't accept 9.594 MeV is lost or left over	1
			Products are more stable OR mass must have been lost or PE is lost	1
			Binding energy of [RHS / Si and He] greater or converse	1
	(d)		Conservation of momentum **and** energy mentioned	1
			Momentum states the products must be stationary or final momentum equals zero or accept products have KE > 16.5 MeV	1
			but this contravenes conservation of energy or only works if two products are present or 16.5 MeV can't be released or accept KE of product contravenes conservation of momentum	1
			Question 2 Total	**[13]**

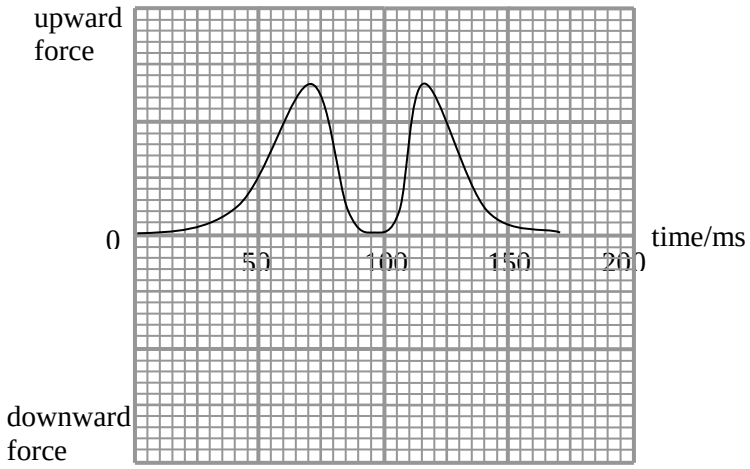
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Question			Marking details	Marks Available
3	*(a)*	(i)	Adding 1.5 μF	1
			Attempting $\frac{1}{6.0} + \frac{1}{\text{others}}$	1
			Correct answer 2 [μF] (allow 1/3 for 6.75 μF)	1
	(b)		Correct method e.g. using $\frac{Q^2}{2C}$ or $0.5CV^2$ or $0.5QV$	1
			Correct explanation e.g. 1.5 μF has twice the pd but 4× less C Or 1.5 μF has half the charge and a quarter of the C Or 6.0 μF has half the pd but twice the charge Or 3.0 μF has twice the pd, half the charge and energy shared between 2 × 1.5 μF	1
	(c)	(i)	Using $T_{½} = \ln 2 \times RC$ or taking logs correctly e.g. $\ln\frac{Q}{Q_0} = \frac{-t}{RC}$	1
			Algebra i.e. $R = \frac{T_{\frac{1}{2}}}{C\ln 2}$	1
			Answer = 8 420 [Ω]	1
		(ii)	$I_0 = \frac{V_0}{R}$ used	1
			$V_0 = \frac{Q_0}{C}$ used (i.e. V_0 = 12.4 V)	1
			I_0 = 1.47 [mA] **ecf**	1
			Question 3 Total	**[11]**

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Question			Marking details	Marks Available
4	*(a)*		Emf is (or proportional to) the rate of change of flux [linkage]	1
			Emf / current opposes (tends to) change to which it is due Accept equation with terms defined	1
	(b)	(i)	Any 3 of: • Emf initially increases as [rate of] flux [linkage increases OR current flows to make top of coil N to oppose motion • Emf decreases when the rate of increase drops • Emf is zero when the flux is max or in middle when no cutting • Emf reverses when S pole due to reversed magnetic field or Lenz • The second peak is higher due to a higher speed	3
		(ii)		
			Upward force only	1
			No force when $V = 0$	1
			Basic shape i.e. two smooth humps, peaks near original max Min & minimum also close to 98 ms	1
		(iii)	Correct attempt at using πr^2 to obtain the radius (7.5 mm)	1
			Use of $2\pi r$	1
			$2\pi \times 0.0075 \times 65 = 3.1$ [m]	1
			Question 4 Total	**[11]**

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Question			Marking details	Marks Available
5	*(a)*	(i)	Attempt at $E = mc^2$ or $931 \times m_e$ (with m_e in u)	1
			$2 \times 9.11 \times 10^{-31} \times \frac{9x10^{16}}{1.6x10^{-19}}$ seen or $2 \times 931 \times \frac{1}{1836}$	1
		(ii)	KE [of particles]	1
	(b)		$B = \frac{\mu_0 I}{2\pi a}$ used	1
			Realising two 19 A fields cancel (or evident in calculations)	1
			5.56×10^{-5} [T] (6.33×10^{-5} T only score 1 of first 3 marks)	1
			Out of paper (independent) Don't accept upwards	1
	(c)	(i)	$Bqv = \frac{mv^2}{r}$	1
			Explanation of what this means e.g. equating magnetic force and centripetal force	1
			Must have m_e and e in final equation	1
			Clear algebra leading to correct final version of equation	1
		(ii)	Answer = 5.7 [m]	1
		(iii)	Field not uniform or field changes	1
			Over 5.7 m or even though motion perpendicular to B or reference to the circle being too big	1
			Question 5 Total	**[14]**

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Question			Marking details	Marks Available
6	*(a)*		Red shift (accept Doppler) shifts of starlight / galaxies [measured] but not for planets	1
			The further the galaxy the greater the red-shift / velocity (or red-shift is proportional to galaxy distance)	1
			Consistent with initial explosion e.g. expansion is consistent with the Big Bang (or consistent with matter starting from a point)	1
	(b)		Speeds near the speed of light <u>not</u> greater than the speed of light accept velocities are large fractions of the speed of light Don't accept at or greater than the speed of light	1
	(c)		Current content of universe explained clearly i.e. baryons (& leptons) not antibaryons (and anti-leptons)	1
			Argument for symmetry breaking (Violation of Cons of Baryon not enough) - e.g. must have slight excess of baryons etc.	1
	(d)		Smaller mass linked to less energy	1
			Less energy or lower temperature linked to the later time Smaller masses produced at lower temperatures – 1 mark	1
	(e)		Fusion [of nuclei] stated	1
			Due to high T (or velocity or energies) [around 10^{-6} (to 3 min) after Big Bang]	1
	(f)		Universe was cooler or electrons or protons have lower energy	1
			Electrons combined with protons (accept nuclei)	1
			Photon energy too low for atoms/electrons to absorb Accept em radiation was no longer absorbed [by electrons/ions] or em radiation is no longer being scattered	1

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Question			Marking details	Marks Available
	(g)		Substitution of $v_{\text{esc}} = H_0 R$ (or equivalent algebraic step)	1
			$M = \frac{4}{3}\pi R^3 \rho$ (or equivalent)	1
			Clear algebra leading to $\rho_C = \frac{3H_0^2}{8\pi G}$	1
	(h)		Correct substitution of H_0 and G	1
			$\frac{9.21\text{x}10^{-27}}{1.66\text{x}10^{-27}}$ seen or 5.55 seen	1
	(i)		$\lambda_{\text{max}} = 0.105\,\text{cm}$	1
			$\text{T} = \frac{2.90\text{x}10^{-3}}{0.00105} = 2.76\,[\text{K}]$	1
			Question 6 Total	**[20]**

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Question			Marking details	Marks Available
7	*(a)*	(i)	Core - avoids flux leakage or extra detail	1
			Low resistance coils - avoids Ohmic heating or WTTE (extra detail low resistivity wires)	1
			Laminations - avoids eddy currents (insulation between laminations)	1
			Suitable alloy - avoids hysteresis losses (named alloy e.g. silicon steel)	1
		(ii)	Valid good comment regarding LN_2 e.g. efficiency gains outweigh LN_2 costs Accept: larger B-fields due to larger currents, Oil free, Lower weight/mass, Smaller volume	1
	(b)	(i)	$\omega L = \frac{1}{\omega C}$ or $f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ used	1
			Answers shown clearly e.g. $\frac{1}{2\pi}\sqrt{\frac{1}{0.034\times47\times10^{-6}}}$ etc. (1 mark each) Or 272.9 [Hz] or 125.9 [Hz]	2
		(ii)	ω decreases (if using $Q = \frac{\omega L}{R}$) or quoting $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$	1
			Or ω decreases less than C increases if using $Q = \frac{1}{\omega CR}$ Q factor decreases (independent)	1
		(iii)	$I = \frac{230}{36}$ or $V_L = V_C$ or all pd across resistor etc.	1
			I = 6.38 [A]	1
			$V_C = \mathrm{I} \times \frac{1}{\omega C}$ or $V_L = \mathrm{I} \times \omega L$ used	1
			V_C = 373 [V]	1
		(iv)	Current is the same (or calculated correctly)	1
			Reactance/impedence of inductor is less (lower frequency) or calculated correctly) or $\frac{1}{\omega C}$ used/calculated correctly	1
			Hence, pd across capacitor is less (not an independent mark) (or calculated correctly) **Alternative:** Q factor smaller (1) same V_R (1) hence smaller V_C (1)	1

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Question			Marking details	Marks Available
7	*(c)*		$Z = \sqrt{{X_C}^2 + R^2}$ used or X_C calculated (36 Ω)	1
			Current = $\frac{10}{50.9}$ = 196 mA or correct method e.g. vectors or $\frac{36}{\sqrt{36^2+36^2}} \times 10$	1
			Answer = 7.07[V]	1
			Question 7 Total	**[20]**

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Question			Marking details	Marks Available
8	*(a)*	(i)	wavelength	1
		(ii)	$\frac{5\lambda}{2}$ or equivalent appears...	1
			... equated to "path difference" or to path difference described in words or to $x - y$ or to $S_1P - S_2P$ even if these symbols not properly explained.	1
			Diagram clearly showing meanings of whatever symbols used in equation.	1
	(b)	(i)	Compass points at right angles to current-carrying wire	1
			if Earth's field cancelled out	1
			or	
			current-carrying wires (or currents) exert forces on each other (1)	
			For currents in same direction, attraction and/or for currents in opposite directions, repulsion (1)	
			or	
			[current-carrying] coils behave like magnets (1)	
			either ends of coils attract/repel like poles of magnets, or pivoted coil behaves like compass (1)	
		(ii)	there are [electric] currents inside	1
			circulating in [closed] loops.	1
	(c)		[Vortex rotation represents] magnetic field. Accept em wave propagating.	1
			Field directions opposite above and below shaded line of idlers.	1
			Suggests field lines to be circles around line of idlers or accept reference to right hand grip rule or equivalent.	1
	(d)	(i)	Correct strategy (i.e. attempt to use Pyth. or a valid trig. method to find light path length, then division by c). Tolerate slips.	1
			Light path length = 26.0 m [accept 26 m, 26.00 m ...]	1
			Time = 86.7 n[s] (accept 86.6 ns. **Ecf** on slips in calculating light path, provided wrong answer (e.g. 43.3 ns) is commented on.	1
		(ii)	80.0 n[s]. No sf penalty. **Ecf** on 40.0 ns if similar penalised in (i) (1)	1
		(iii)	improper time: events in different places; proper time: events in same place.	1
			d(i) is improper, OR d(ii) is proper	1

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Question			Marking details	Marks Available
		(iv)	$v = 1.15 \times 10^8\ \text{m s}^{-1}$ [$1.25 \times 10^8\ \text{m s}^{-1}$ is WRONG]	1
			$\gamma = \frac{1}{\sqrt{(1-\frac{v^2}{c^2})}} = 1.08$ **ecf** on v	1
			$\frac{\text{time(i)}}{\text{time(ii)}} = 1.08$ + comment on agreement with gamma or by implication if consistency check carried out differently.	1
			Question 8 total	**[20]**

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Question			Marking details	Marks Available
9	*(a)*	(i)	No permanent set. Accept: rubber returns to original length (not position) when load is removed or strain returns to origin or no strain after load is removed.	1
		(ii)	At (A) molecules unravel (accept untangle) under the action of a force.	1
			At (B) molecules fully stretched/ strong forces between atoms within molecule. Accept – also C-C bond rotates	1
			Either: Small force (or stress) produces large extension (or strain) hence shallow gradient initially/ or at A **Or:** Large force (or stress) produces small extension (or strain) hence steep gradient finally/ or at B	1
		(iii)	Hysteresis	1
			Area (between loading and unloading curve) represents difference between energy stored in the rubber band when it is stretched and (useful) energy recovered from it when it is unstretched or energy dissipated (lost) in one cycle of loading and unloading.	1
			'Lost' energy transferred to internal energy (accept heat) of molecules	1
		(iv)	Repeated **large** deformation **increases** energy loss as internal energy (heat) or larger hysteresis curve leads to increasing temperature in tyres.	1
	(b)	(i)	Understanding shown that $W = ½\ F\ (e_P + e_Q)$	1
			$e_P = \frac{FL_0}{2AY}$ and $e_Q = \frac{FL_0}{6AY}$ seen	1
			$W = ½\ F\left\{\frac{FL_0}{2AY} + \frac{FL_0}{6AY}\right\}$ {award 3 marks if only this seen}	1
			Clear mathematical step leading to final equation e.g. Factorisation or fraction addition: e.g. $W = ½\ \frac{F^2L_0}{AY}\left\{\frac{1}{2} + \frac{1}{6}\right\}$	1
			Alternative: W in P found W in Q found Addition to find total W – clear mathematical step Leading to final equation	
		(ii)	$W = ½ \times 2\ 800 \times 0.033 \times 10^{-3}$	1
			$= 0.0462$ [J]	1
			[No marks for 0.03×10^{-3} used] [-1 for power of 10 slip]	

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Question			Marking details	Marks Available
		(iii)	Correct manipulation and substitution $Y = \frac{2800^2 \times 0.3}{3 \times 1.65 \times 10^{-4} \times 0.0462}$ (**ecf** on 0.0462 J)	1
			Use of $A = \pi r^2$ or $\frac{\pi d^2}{4}$ (1.65×10^{-4} m^2)	1
			$Y = 1.03 \times 10^{11}$ [N m^{-2}] [0 marks for if area incorrect]	1
		(iv)	3 $Y_Q = 3Y_P$ For same F, L and A	1 1 1
			Question 9 total	**[20]**

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Question			Marking details	Marks Available
10	(a)	(i)	Voltage for A is higher Smaller minimum wavelength Accept the converse and accept $V_A = 2V_B$ Ignore any reference to intensity	1 1
		(ii)	Line spectra are in the same place Accept peaks for line spectra	1
		(iii)	$h = \frac{eV\lambda}{c}$ / identification of $\lambda_{min} = 15 \times 10^{-12}$ [m] $h = 6.72 \times 10^{-34}$ [J s]	1 1
		(iv)	$V = \frac{hc}{e\lambda}$ (**ecf** on h if wrong h used) / identification of $\lambda_{min} = 30 \times 10^{-12}$ [m] V = 42 000 V /42 kV / 41.4 kV must have units	1 1
	(b)		Advantage better soft tissue contrast / no exposure to radiation / [good] imaging of the brain Disadvantage Claustrophobia / cost / not with a pacemaker/ Not good for imaging bone Ignore references to time	1 1
	(c)	(i)	Alternating high frequency (MHz) voltage / p.d. applied To piezoelectric crystal Crystal oscillates / vibrates (to produce ultrasound) (because crystal deforms when pd applied)	1 1 1
		(ii)	$v = \frac{\Delta\lambda c}{2\lambda}$ / 1.8 m s^{-1} must have units v = 0.9 m s^{-1} must have units	1 1
	(d)		Axis labelled with units Correct shape graph	1 1
	(e)		Absorbed dose is energy absorbed per unit mass/ kg Dose equivalent = absorbed dose × quality factor Dose equivalent of alpha bigger than gamma / larger Q factor for alpha than gamma) Alpha far more ionising	1 1 1 1
			Question 10 total	**[20]**

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Question			Marking details	Marks Available
11	(a)	(i)	Uses energy to pump water to higher reservoir / to raise the water/to give the water GPE	1
			Less than 100% efficient (of pumping or KE→ electric conversion) /not all the stored GPE becomes kinetic/electrical	1
		(ii)	Immediate high output power when increase in demand/at peak times/to cover surges in demand	1
	(b)	(i)	At least 3 good advantages and 1 clear disadvantage	3
			3 good advantages OR 2 advantages & 1 disadvantage	2
			At least 1 good advantage or 1 disadvantage	1
			Advantages: Reliable, High[er] power/output, Easily switched on and off /can adjust to levels of demand/controllable output NOTE: costs are very similar \$64 and \$72 per MWh Disadvantages Changes environment (of waterfall), Difficult to design/construct Dangerous (when dam fails 150 000 deaths in China, 1975) /risk of flooding	
		(ii)	Assumption: efficiency is 50% (accept 20-100) – must be stated	1
			mgh = power × time or equivalent	1
			1 day = 24 × 3 600	1
			Answer = 1.6×10^{12} [kg] (dependent on efficiency) Can get ¾ marks if h = 59 m used, but otherwise correct	1
	(c)	(i)	$P = \sigma AT^4$ used	1
			$A = 4\pi r^2$ used twice	1
			Answer = 1.36 [kW m^{-2}]	1
		(ii)	11 GW divided by 1.12 kW m^{-2}	1
			Factor of daylight hours /efficiency explained (efficiency can be forgiven here)	1
			Answer correct e.g. 1.5×10^8 [m^2] (if 8h and 20% efficient panels)	1
			(wide range acceptable dependent on assumptions)	

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Question			Marking details	Marks Available
		(iii)	Attempt at energy of solar panel for 25 years i.e. $1.12 \times 25 \times 365 \times 24$ (**ecf** on efficiency & daylight)	1
			division by kWh or MWh (3.6×10^6 or 3.6×10^9)	1
			Correct cost = e.g £12.50 per MWh if 8h per day and 20% efficient	1
			Correct comparison with **ecf** e.g. £12.50 per MWh considerably cheaper - Accept comments regarding maintenance of panels e.g. moving costs etc	1
			Question 11 total	**[20]**

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Surname	Centre Number	Candidate Number
Other Names		2

GCE A level

1325/01

S15-1325-01

PHYSICS – PH5
Electromagnetism, Nuclei & Options

A.M. THURSDAY, 18 June 2015

1 hour 45 minutes

1325
010001

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator, a **Case Study Booklet** and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use pencil or gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet. If you run out of space, use the continuation pages at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 3 sections, **A**, **B**, and **C**.

Section A: 60 marks. Answer **all** questions. You are advised to spend about 1 hour on this section.

Section B: 20 marks. The Case Study. Answer **all** questions. You are advised to spend about 20 minutes on this section.

Section C: Options; 20 marks. Answer **one option only.** You are advised to spend about 20 minutes on this section.

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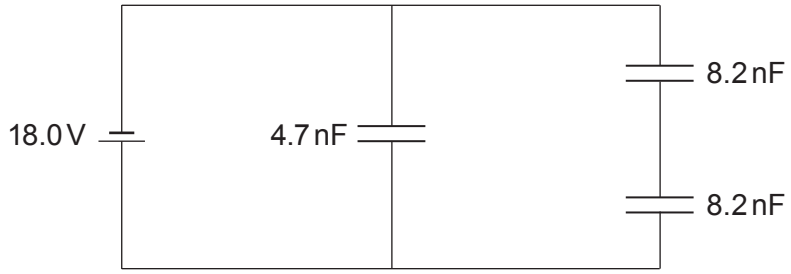
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SECTION A

Answer **all** *questions.*

1. This question is about capacitors in the following circuit.



(a) (i) Calculate the charge stored by each of the capacitors. [2]

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(ii) Calculate the total energy stored by all three capacitors. [2]

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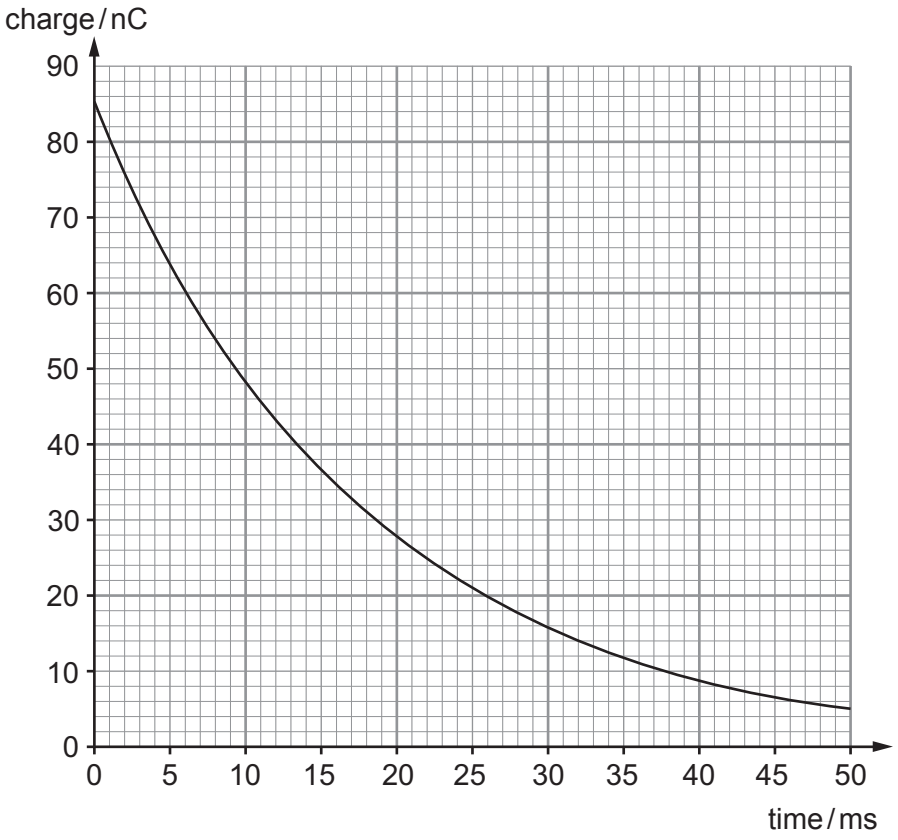
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(b) The 4.7 nF capacitor is discharged through an unknown resistor and the following graph is obtained.



(i) Calculate the resistance of the resistor. [3]

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(ii) Calculate the current when t = 0 s. [2]

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(iii) By estimating the time taken for the capacitor to lose 90% of its charge or otherwise, calculate the time taken for the capacitor to lose 99% of its charge. [2]

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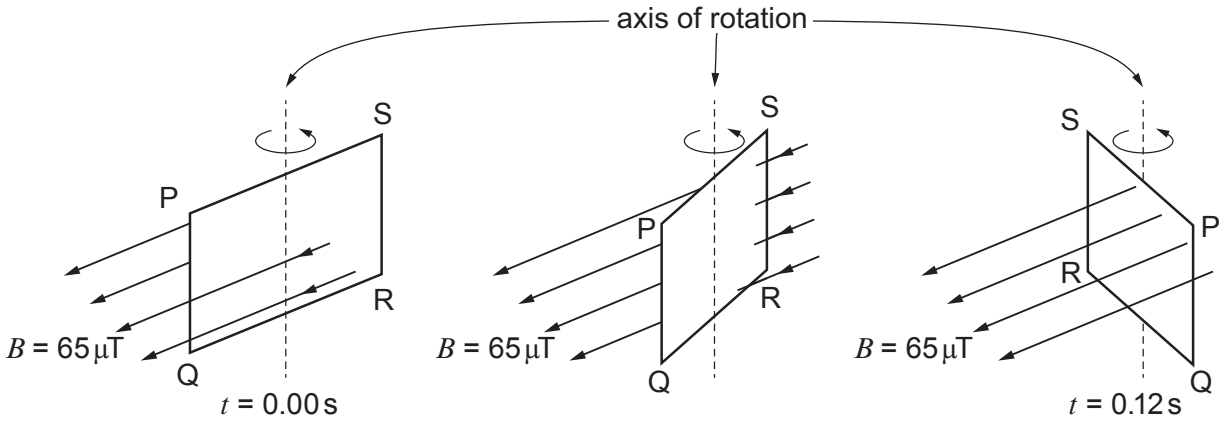
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2. A large square loop has sides of length 0.815 m and is rotated through 90° in a uniform magnetic field of 65 μT. The diagrams show the same square loop at different times.



(a) Determine the magnetic flux through the square loop: [3]

(i) when t = 0.00 s (sides QR and SP are parallel to the B-field);

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(ii) and when t = 0.12 s (PQ, QR, RS and SP are perpendicular to the B-field).

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(b) The square loop is made of copper. Explain why there is a current in the loop as it is rotated. [2]

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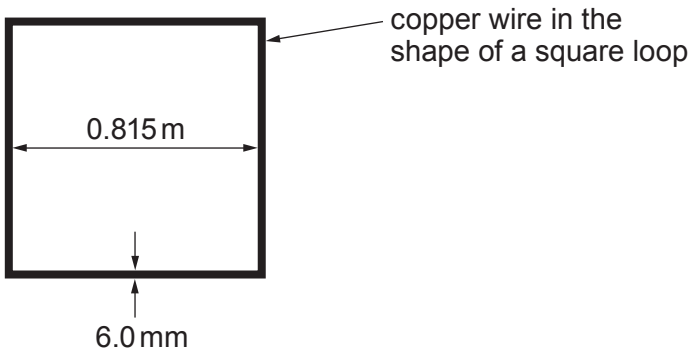
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(c) Explain how Lenz's law will give the direction of the forces acting on the sides PQ and RS as the square loop is rotated. [2]

(d) The copper wire from which the square loop is made has a circular cross-section of diameter 6.0 mm. The resistivity of copper is $1.67 \times 10^{-8} \Omega$m. Calculate the **mean** current flowing through the square loop as it is rotated between t = 0.00 s and t = 0.12 s. [5]

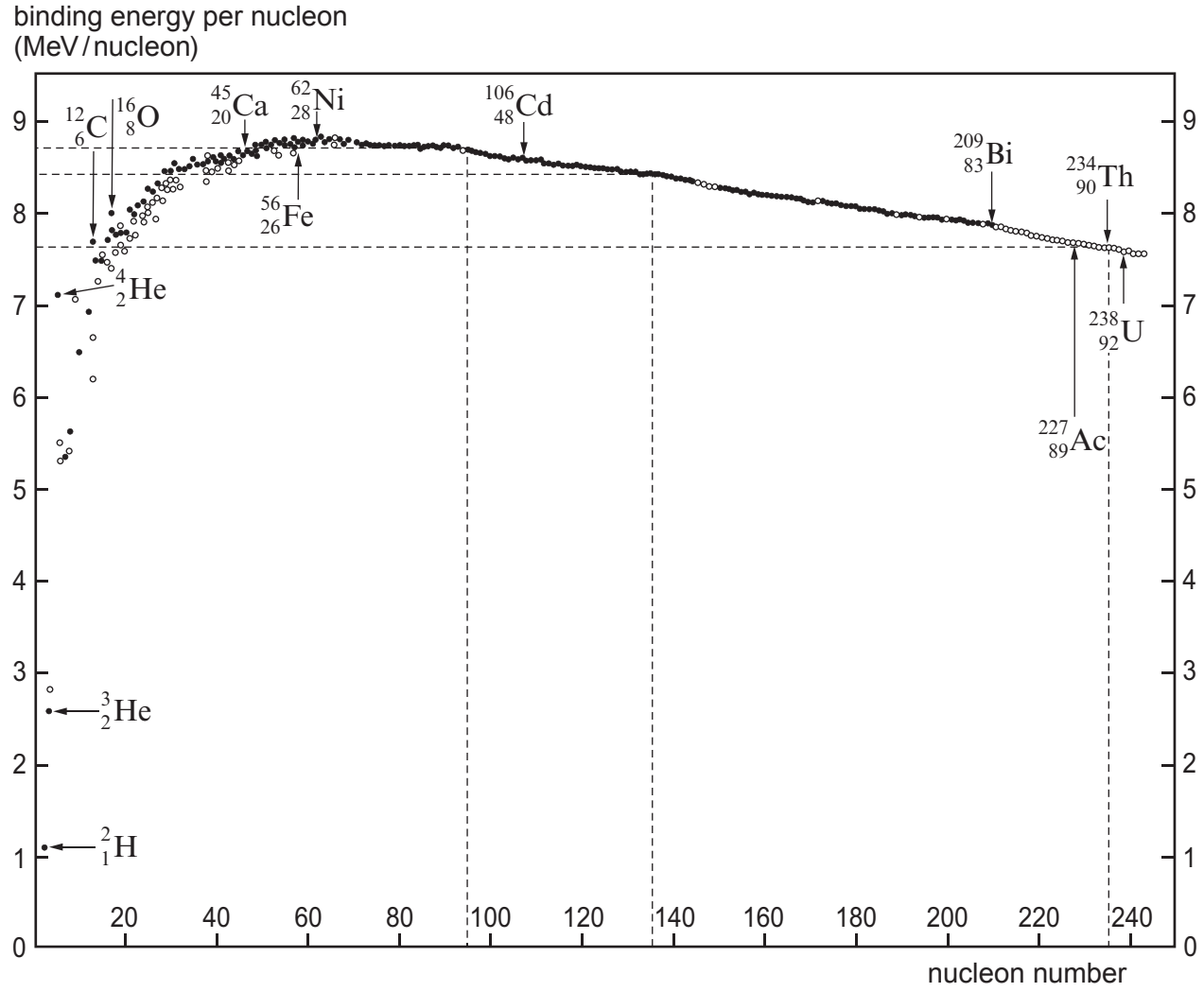


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3. *(a)* Some nuclei undergo fusion while others undergo fission. Both processes can result in the release of energy. Discuss these processes in terms of energy and stability. The binding energy per nucleon graph is provided to assist your answer. [4]



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(b) Use data from the graph to estimate the energy released in the reaction. [2]

$$^{1}_{0}\mathrm{n} + {}^{1}_{1}\mathrm{p} \longrightarrow {}^{2}_{1}\mathrm{H}$$

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(c) Use the graph to estimate the energy released in the following reaction. (Hint: use the binding energies on both sides of the reaction equation.) [4]

$$^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \longrightarrow {}^{137}_{55}\mathrm{Cs} + {}^{96}_{37}\mathrm{Rb} + 3\,{}^{1}_{0}\mathrm{n}$$

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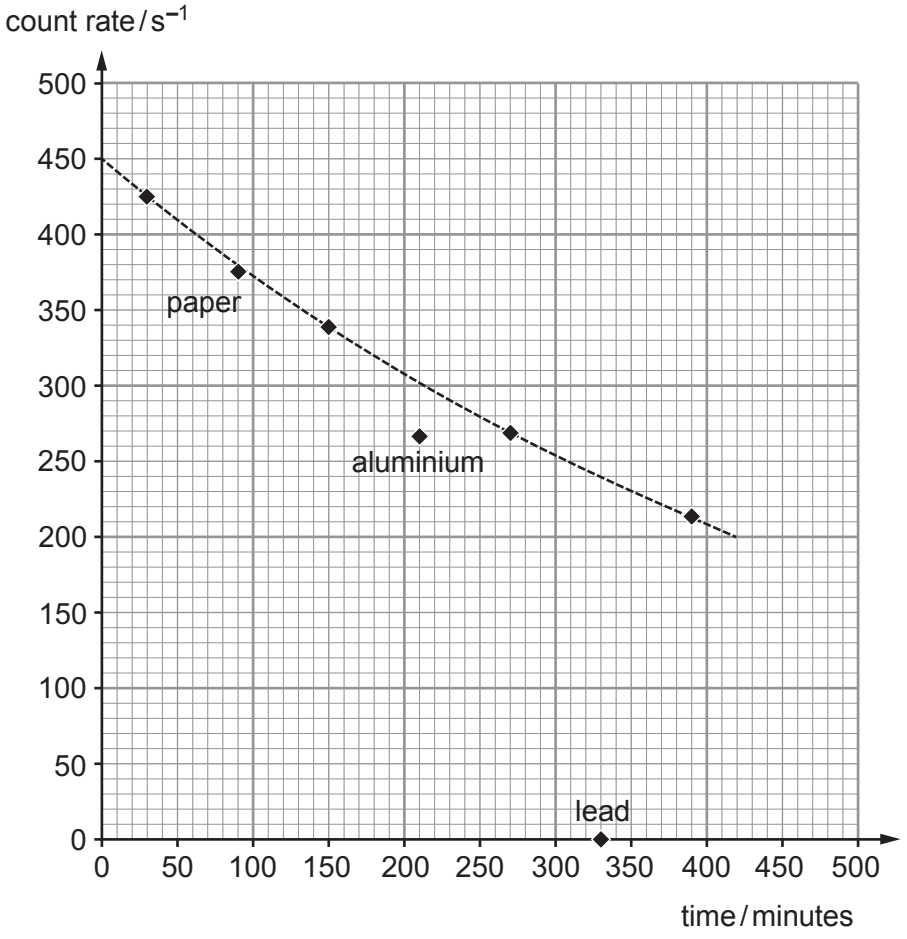
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4. Technetium-99 emits **only** γ (gamma) radiation. An experiment was carried out to show this. Various absorbers were placed between the source and detector at the times shown in the table below and the mean count rate was obtained.

Absorber	Time from the start of the experiment / min	Count rate / s^{-1}
none	30	425
1 sheet (0.1 mm) of paper	90	374
none	150	338
3 mm of aluminium	210	267
none	270	268
10 cm of lead	330	1
none	390	213

These results were plotted on a graph. The decay curve of the technetium-99 itself is plotted as a dotted line which shows the activity dropping continuously as the experiment proceeded.



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(a) Determine the half-life of technetium-99. [1]

(b) Explain why the results are consistent with technetium-99 only emitting γ radiation. [3]

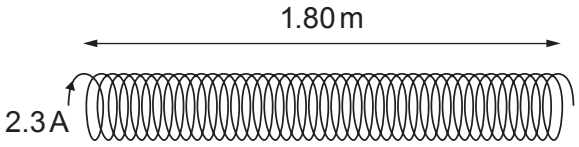
(c) The detector only detects 0.6% of the γ radiation emitted by the source. Use the graph and the half-life of technetium-99 to calculate the initial mass of technetium-99 (the mass of a technetium-99 atom is 99 u). [4]

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5. *(a)* A long thin solenoid carries a current of 2.3 A, has 12 000 turns and a length of 1.80 m. Calculate the magnetic field strength (B) in the centre of the long solenoid. [2]



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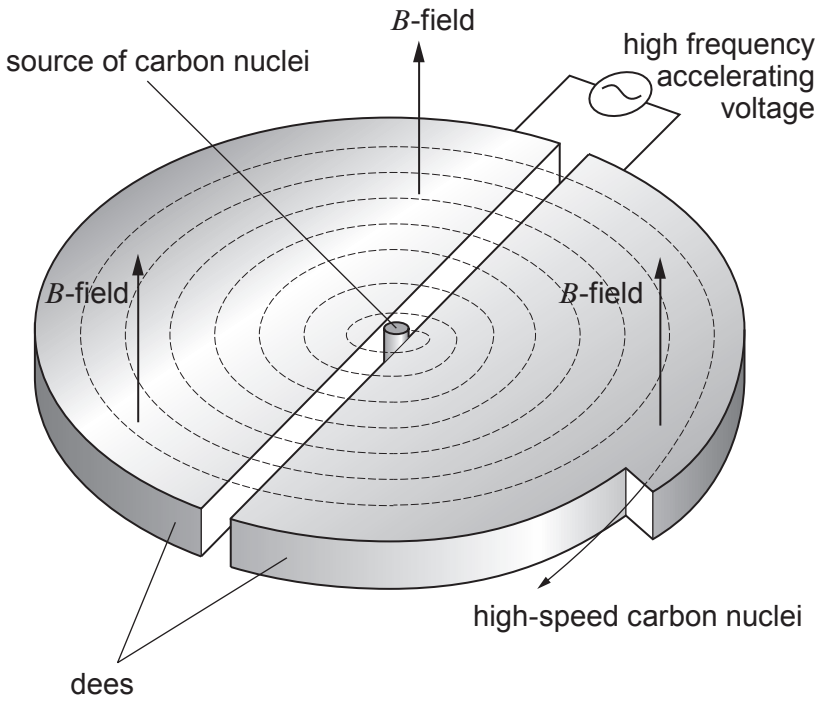
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(b) In a cyclotron a uniform magnetic field (B) provides a centripetal force while an electric field accelerates the charged particles as they cross between the dees. The resulting motion is a spiral as shown.



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(i) By equating the centripetal force to the magnetic force, show that the frequency of the a.c. supply is given by: [3]

$$f = \frac{Bq}{2\pi m}$$

where q is the charge and m is the mass of the particle.

(ii) Calculate the cyclotron frequency for a carbon nucleus with $q = 6e$ and mass $m = 12\,\text{u}$ in a strong B-field of 3.3 T. [2]

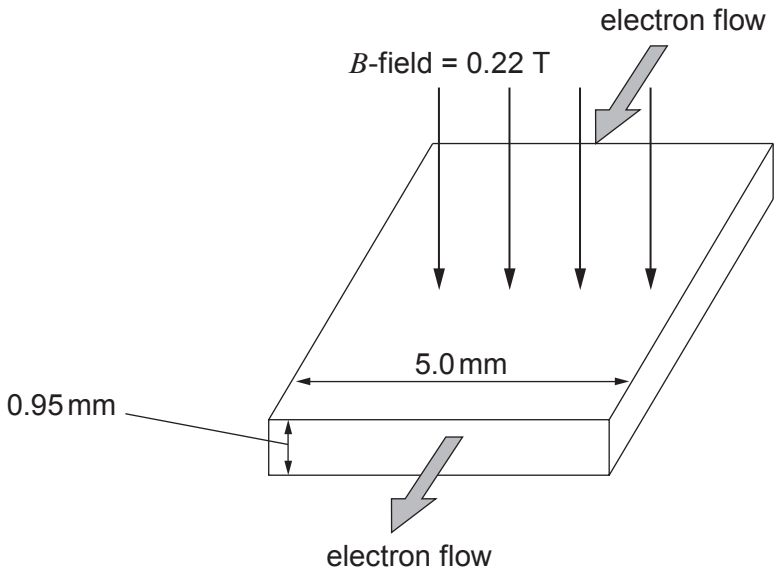
(iii) Calculate the final speed of a carbon nucleus after it has completed 12 'orbits' of the cyclotron and the potential difference between the dees is 14.5 kV (assume that the carbon nucleus starts from rest). [4]

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6. Electrons flow through a semiconductor slice which is used as a Hall probe.



(a) Indicate on the above diagram:

(i) the face of the slice that becomes positively charged; [1]

(ii) a voltmeter suitably connected to measure the Hall voltage. [1]

(b) Calculate the Hall voltage if the drift velocity of the free electrons is $5.7 \times 10^{-3}\,\text{m}\,\text{s}^{-1}$. [3]

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(c) As electrons move through the slice, explain why no work is done on them by the Hall voltage. [1]

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(d) The concentration of free electrons in the semiconductor slice is 7.0×10^{22} m^{-3}. Calculate the current in the slice. [2]

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SECTION B

Answer **all** *questions.*

The questions refer to the case study.
Direct quotes from the original passage will not be awarded marks.

7. *(a)* Give two reasons why only a **small** fraction of the work done in compressing the gas is transferred to gravitational potential energy of the football (paragraphs 3 & 4). Note that losses due to heat and sound are negligible. [2]

(b) Use the values $u = 20\,\text{m s}^{-1}$, $m_0 = 1.5\,\text{kg}$ and $\frac{\Delta m}{\Delta t} = 5.9\,\text{kg s}^{-1}$ to calculate the speed of the rocket after 0.175 s (paragraph 11 and equation 2). [2]

(c) Check that the units (or dimensions) of equation 4 are correct.

$$\frac{\Delta m}{\Delta t} = \pi r^2 \rho u$$

[2]

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(d) Calculate the exhaust speed of water from the rocket assuming a rate of change of mass of 9.5 kg s^{-1} and the radius of the bottle neck is 1.1 cm using equation 4 (density of water = 1 000 kg m^{-3}). [2]

(e) Using your own words explain why 'the actual rocket does not keep up with its theoretical counterpart' (paragraphs 16-19 and equation 6). [3]

(f) Calculate the initial exhaust speed of water leaving a bottle pumped to a pressure of 7.8×10^5 Pa (the outside atmospheric pressure is 1.0×10^5 Pa) using equation 6 (density of water = 1 000 kg m^{-3}). [2]

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(g) The table below refers to the terms on the right hand side of equation 8.

$$F_{\text{res}} = \pi r^2 \rho u^2 - mg - 0.0107v^2$$

Complete the table, the first row has been completed for you (paragraphs 20-22). [3]

Term	Description	During the first 0.2 s, this term		
		increases	remains constant	decreases
$\pi r^2 \rho u^2$	*Thrust force from exhaust water*			✓
mg				
$0.0107v^2$				

(h) Show that the first term ($\pi r^2 \rho u^2$) in equation 8 can be written as $2(p - p_{\text{atm}}) \times A_{\text{neck}}$ where A_{neck} is the cross-sectional area of the bottle opening (see equation 5 or 6). [2]

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(i) In practice, using Boyle's law is inappropriate because the gas cools as it expands.

(i) Explain why little or no heat flows when the gas in the bottle expands. [1]

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(ii) Use the first law of thermodynamics to explain why the temperature of the gas decreases. [1]

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SECTION C: OPTIONAL TOPICS

Option A: **Further Electromagnetism and Alternating Currents** ☐

Option B: **Revolutions in Physics – The Newtonian Revolution** ☐

Option C: **Materials** ☐

Option D: **Biological Measurement and Medical Imaging** ☐

Option E: **Energy Matters** ☐

Answer the question on **one topic only.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

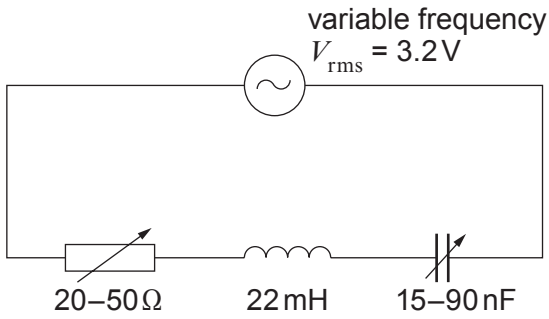
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Option A: Further Electromagnetism and Alternating Currents

8. *(a)* In the following circuit, both the Q factor and the resonance frequency can be varied by varying the capacitance and the resistance. However, the inductance remains constant.



(i) Show that the maximum and minimum resonance frequencies are approximately 8 800 Hz and 3 600 Hz respectively. [3]

(ii) Calculate the maximum Q factor and the minimum Q factor. [4]

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(b) When R = 35 Ω and C = 15 nF, the frequency of the supply is adjusted to twice the resonance frequency (approximately 17 600 Hz). Calculate the rms current. [3]

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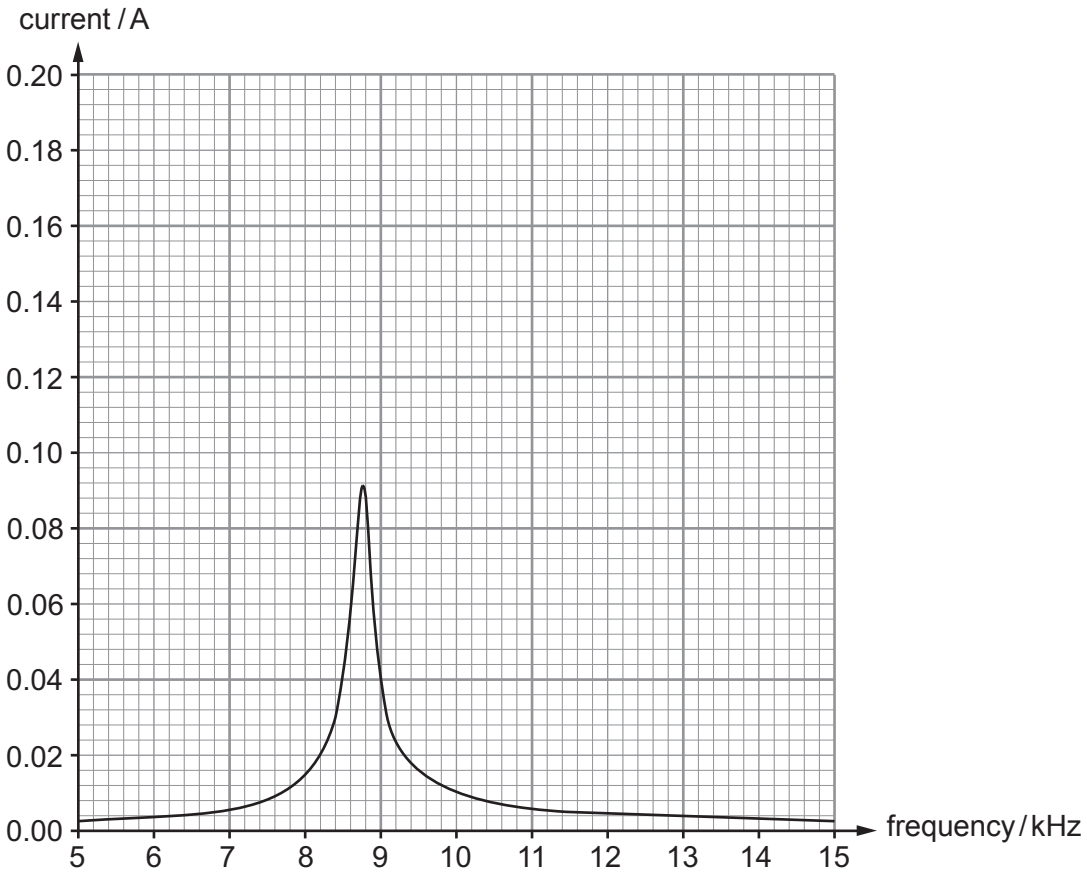
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(c) The resonance curve for the circuit with R = 35 Ω and C = 15 nF is shown below.



(i) Add **two labelled** curves to the graph showing the variation of current against frequency when R = 20 Ω and C = 15 nF and when R = 50 Ω and C = 15 nF. [4]

Space for your calculations if needed.

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Turn over.

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(ii) Use the equation $Z = \sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2 + R^2}$ to explain in detail why the current varies with frequency as shown in the graph (no calculations are required). [6]

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Option B: Revolutions in Physics – The Newtonian Revolution

9. *(a)* (i) Tycho Brahe and another astronomer, 570 km away, were able to make simultaneous angle measurements on heavenly bodies. They could measure parallax down to about $\frac{1}{60}$ degree (0.017°) due to their different locations. Show clearly, **giving a labelled diagram**, that the furthest distance away of a body for which they could measure parallax was about 2×10^6 km. Assume the body to be directly overhead. [3]

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(ii) Tycho Brahe and his associate could easily measure parallax for the Moon (0.40×10^6 km away) but were barely able to detect the parallax of a comet which appeared in 1577. Explain why this provided evidence against Aristotle's division of the universe into sublunary and superlunary (beyond the Moon) regions, where different laws applied. [2]

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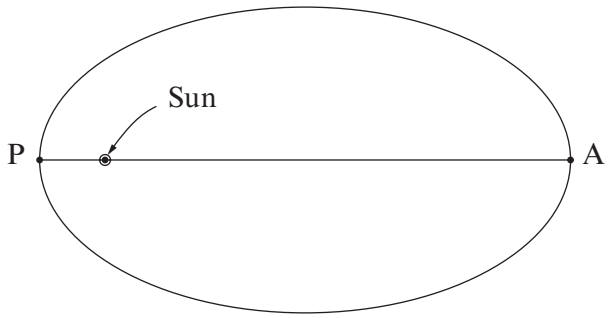
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(b) (i) A planet's speed and distance from the Sun at perihelion (P) and aphelion (A) are related by:

$$r_P v_P = r_A v_A$$

Derive this from Kepler's *equal area* law (Kepler's second law), **adding to the diagram** to assist your explanation. [3]



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(ii) For Jupiter, r_P = 7.41 × 10^8 km and r_A = 8.16 × 10^8 km. Evaluate the **percentage** change in Jupiter's speed as it goes from A to P. [2]

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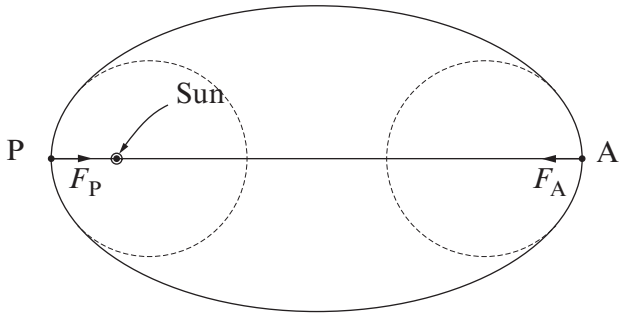
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(iii) At P and A a planet's elliptical path coincides with circles of equal radius.



I. Show that the ratio of forces $\frac{F_P}{F_A}$ on the planet at P and A is $\frac{v_P^2}{v_A^2}$. [1]

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II. Use the relationship in *(b)*(i) to show clearly that this is consistent with an inverse square law force between the Sun and planet. [1]

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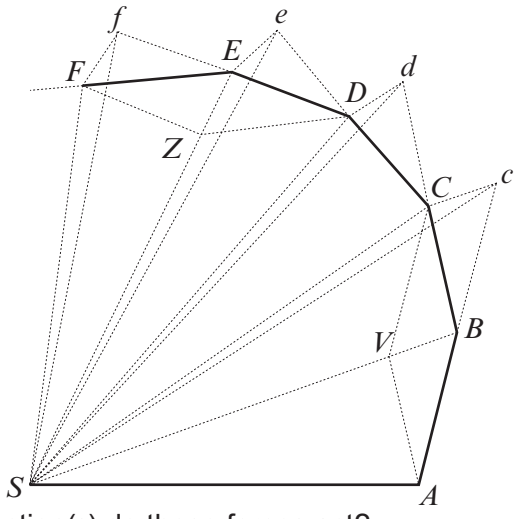
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(c) The diagram, from Newton's *Principia,* shows the motion of a body acted upon by short, sharp forces at regular intervals.



(i) In which direction(s) do these forces act? [1]

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(ii) State what Newton was able to show about the triangles ASB, BSC, CSD and how the argument could be applied to the motion of planets. [3]

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(iii) Over forty years before Newton published the *Principia,* Descartes had proposed a quite different explanation for why planets orbited the Sun. What was Descartes' explanation, why did many people find it more satisfying than Newton's, and why is it now almost forgotten? [4]

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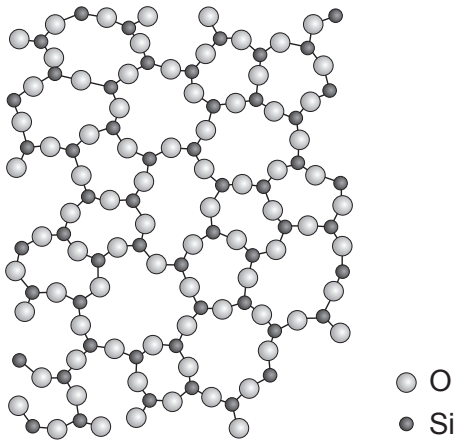
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Option C: Materials

10. *(a)* The picture shows the microscopic structure of glass, an amorphous solid.



Explain the following macroscopic properties of glass.

(i) Glass fibres are brittle, showing no plastic deformation before fracture. [2]

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(ii) A sheet of glass can be fractured accurately and cleanly if its surface is scratched and then the glass is bent slightly. [You may wish to draw a labelled diagram to support your answer.] [2]

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(iii) During production, car windscreens are strengthened by using jets of cold air to cool the outer surfaces of the hot glass. This causes the outside to contract quickly while the inside remains soft. Later, the inside cools and contracts. Explain how this process makes the windscreen difficult to break. [2]

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(b) Advanced aircraft and spacecraft applications require aluminium based alloys which are able to operate under extremely diverse conditions. The properties of three of these alloys are given in the table.

Aluminium alloy	Young modulus / GPa	Yield strength / MPa	Maximum tensile strain / %
Alloy A	80	800	9
Alloy B	80	1 000	5
Alloy C	60	600	15

The graph opposite shows the stress against strain graph for **alloy A**.

(i) Use information from the graph to confirm that the Young modulus of alloy A is 80 GPa. [1]

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(ii) Alloy A is in the form of a cylinder of length 2.5 m and diameter 2.5 mm. Determine the work done to stretch this alloy to breaking point. [3]

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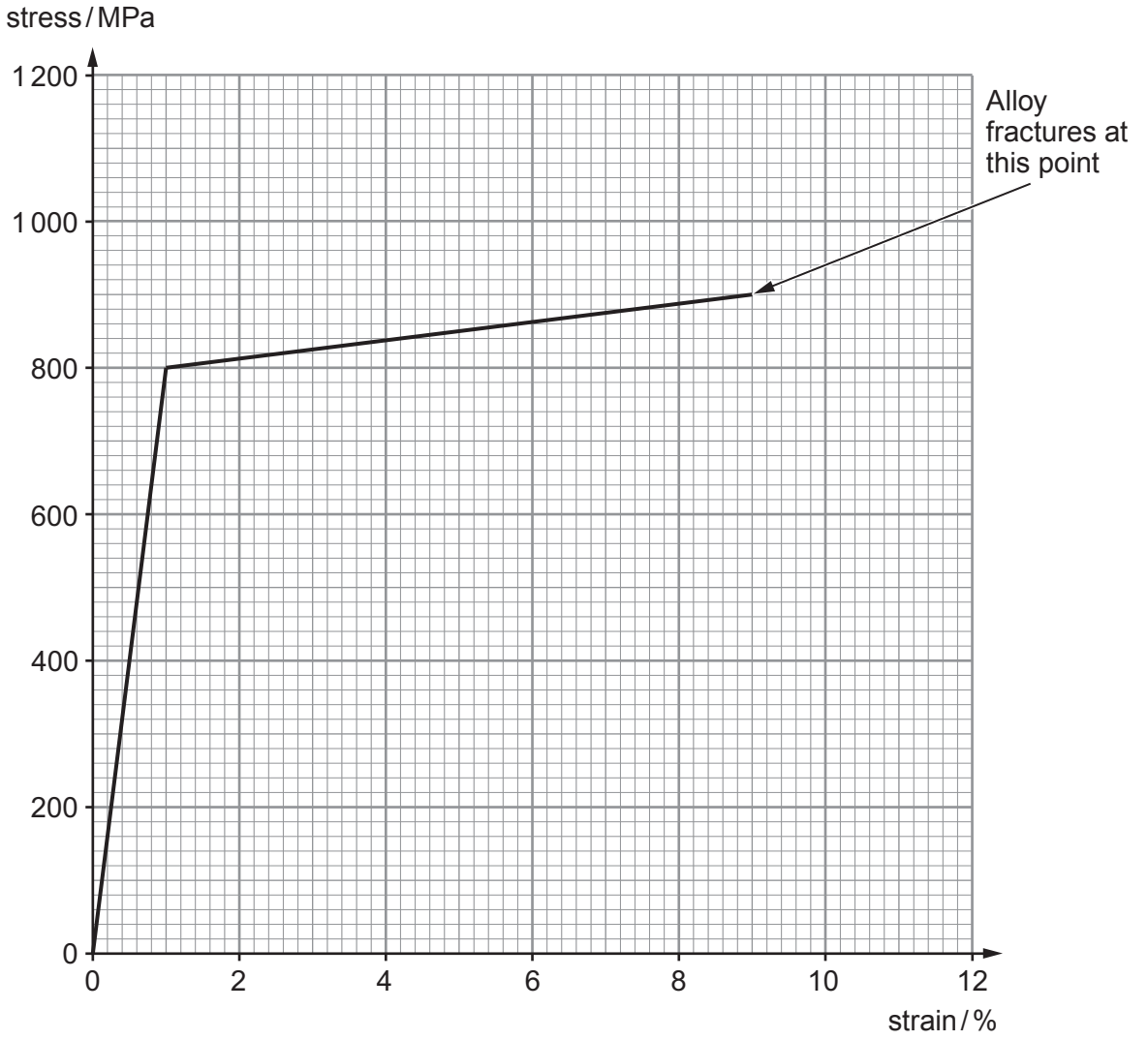
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(iii) Draw, on the same axes, a simplified stress against strain graph for **alloy B** using data from the table opposite. [3]

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(iv) When these alloys are placed under a constant stress over a long period of time all three undergo *creep* leading to *necking* and eventually fracture.

I. Explain the terms in italics. [2]

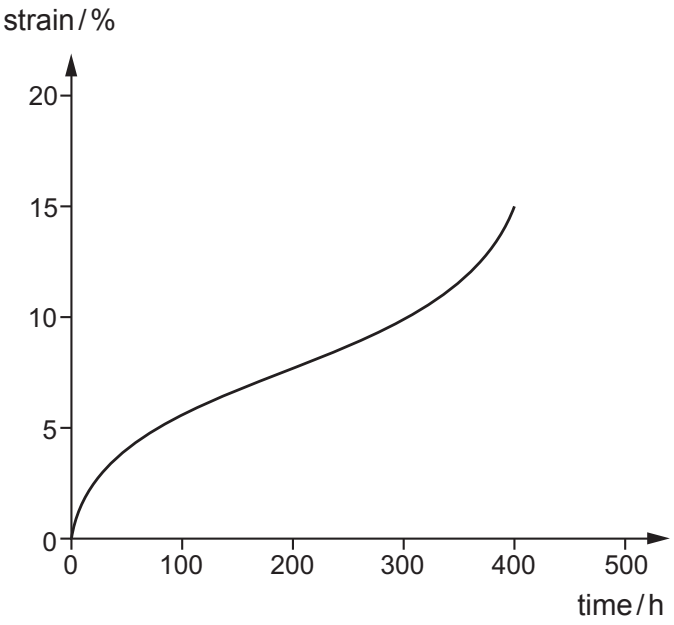
Creep: .....

.....

Necking: .....

.....

II. A creep curve for **alloy C** is shown. The alloy was subjected to a constant stress of 100 MPa. Using information in the table on page 28, sketch on the same graph (below) a creep curve which could represent alloy C when it is subjected to a constant stress of 120 MPa. [2]



(v) During production the strength of the alloy is controlled by a process called cold working (or work hardening). Describe this process and explain how it increases the strength of the alloy under production. [3]

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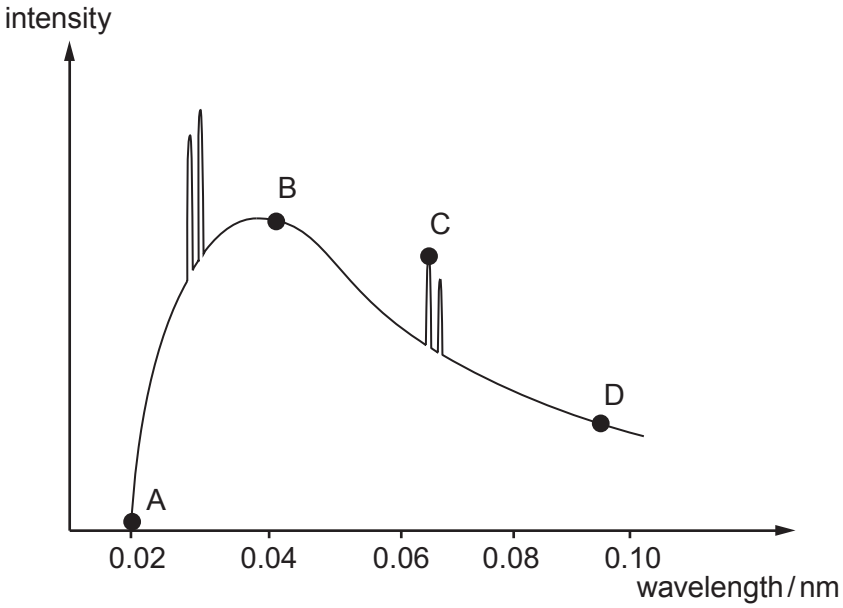
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Option D: Biological Measurement and Medical Imaging

11. An X-ray spectrum is shown.



(a) Which of the above points correspond to X-ray photons produced:

(i) by rapidly decelerating electrons; ..... [1]

(ii) after knocking out the inner electrons of the target atom; ..... [1]

(iii) with the greatest energy per photon? ..... [1]

(b) Use information from the graph to calculate the accelerating pd used in the X-ray tube. [2]

.....

.....

.....

.....

(c) Before taking an X-ray photograph the X-ray beam emerging from the tube is passed through an aluminium filter. Explain why it is necessary for the X-rays to be filtered. [2]

.....

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(d) (i) Name the region of the electromagnetic spectrum used in MRI scans. [1]

.....

(ii) Briefly explain the function of this electromagnetic radiation in the working of an MRI scan. [2]

.....

.....

.....

.....

(iii) Describe one disadvantage of MRI scanning as an imaging technique. [1]

.....

.....

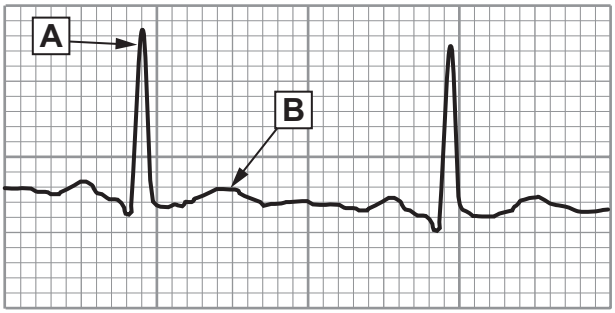
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(e) The following diagram shows an ECG trace for a healthy person.



State what electrical event and physical change occur at:

(i) Point A; [2]

Electrical event

.....

.....

Physical change

.....

.....

(ii) Point B. [2]

Electrical event

.....

.....

Physical change

.....

.....

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(f) Ultrasound can be used to measure the speed at which blood is flowing. When reflected off a red blood cell, the wavelength of the ultrasound changes.

(i) What is the name given to this effect? [1]

.....

(ii) If ultrasound of wavelength 500 μm is used, its speed when travelling through blood is 1500 m s^{-1} and the wavelength received at the detector is 500.4 μm. Calculate the speed of the flow of blood. [2]

.....

.....

.....

.....

(g) (i) PET scans are often used to detect tumours. What part of the electromagnetic spectrum do PET scanners detect? [1]

.....

(ii) Why are PET scanners **not** commonly used in district hospitals? [1]

.....

.....

.....

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Option E: Energy Matters

12. *(a)* Explain why it is important to enrich uranium before it is suitable to be used in a fission nuclear power station. [3]

(b) In a breeder nuclear reactor uranium-238 is changed into plutonium. Explain the advantage of this and how it is achieved. [2]

(c) State **two** possible advantages of deuterium-tritium fusion over uranium-235 fission. [2]

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(d) For nuclear fusion to be a viable energy resource a deuterium-tritium plasma must have a large enough confinement time (τ), a high enough temperature (T) and a high enough concentration (number per m^3) of deuterium and tritium particles (n). These conditions are usually expressed as:

$$\tau T n \geq 3.5 \times 10^{28} \text{ s K m}^{-3}$$

(i) Explain why a high temperature (T) is necessary. [3]

(ii) A confinement time (τ) of 0.9 s and a temperature of 120 million Kelvin are attainable. Calculate the minimum density of plasma required in kg m^{-3} (the mean mass of deuterium and tritium ions is 2.5 u). [3]

(e) The energy that can be produced from 1 kg of uranium-235 is 8.3×10^{13} J whereas the energy available from 1 kg of deuterium-tritium is 3.4×10^{14} J. Calculate the energy that can be produced from 1 kg of anti-matter (remember that anti-matter and matter annihilate). [2]

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(f) Coal, biomass, uranium-235, natural gas and wind are five energy resources with similar mean costs per MWh of energy production (£40-£60 per MWh). Discuss other advantages **and** disadvantages of all five energy resources. [5]

END OF PAPER

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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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GCE A level

1325/01-B

S15-1325-01B

PHYSICS – PH5

ASSESSMENT UNIT

A.M. THURSDAY, 18 June 2015

CASE STUDY FOR USE WITH SECTION B

Examination copy
To be given out at the start of the examination.
The pre-release copy must not be used.

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01B001

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Paragraph

Rocket Science without the Chemistry

Introduction

It's quite remarkable how much analysis of rocket motion can be done when one is armed with some physics, a bit of mathematics and a spread sheet.

A simple rocket system that converts plastic bottles to rockets can be bought relatively cheaply. A good example is the aquapod®, upon which the system in the photograph is based. It's an upside-down, pressurised plastic bottle, half filled with water. When released, water is ejected at high speed from its tail end resulting in the rocket accelerating upwards. Because downward momentum is given to the water, the rocket gains upward momentum. Early on in the investigations into these rockets, it was discovered that a ball placed on top of the bottle was far easier to investigate and model.



Diagram 1

Energy Analysis Considering Gravity

The simplest possible analysis that can be done to the rocket is to apply conservation of energy. We could approximate that the work done in compressing the gas eventually becomes gravitational potential energy of the ball. How much energy is stored in the compressed gas? For this, we need a bit of A level Maths in order to calculate the area below an isothermal compression in a p-V diagram. This is the result of the integration (that doesn't require learning).

$$W = p \times V \times \ln\left(\frac{p}{p_{\text{atm}}}\right) \qquad \textbf{Equation 1}$$

where p is the high pressure inside the bottle, V is the volume of compressed air inside the bottle and p_{atm} is atmospheric pressure.

So a 2 litre bottle half filled with water and with a pressure of 4.4×10^5 Pa inside it can supply around 650 J of energy. If all this energy were transferred to a 0.45 kg ball, the ball should attain a height of some 150 m. In practice, however, only a small fraction of this energy is transferred to the ball.

This experiment was carried out with a set of plastic bottles varying in volume from 500 ml to 3.0 litre. Each bottle was half full of water at take-off and each bottle was pumped to a pressure of 4.4×10^5 Pa (from an initial atmospheric pressure of 1.0×10^5 Pa). The results are shown in the graph (diagram 2).

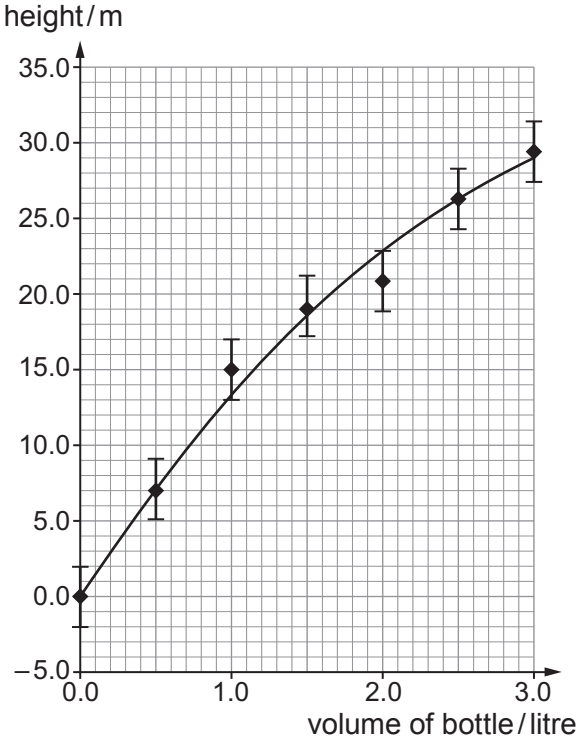


Diagram 2

Paragraph

Unsurprisingly perhaps, this simplistic conservation of energy argument has not been successful and the relationship between maximum height of the rocket and volume of the bottle is not directly proportional as was predicted by conservation of energy. 6

Ideal Rocket Theory (fixed exhaust speed and ignoring gravity)

Now for some more detailed analysis. We need to look at what causes the acceleration of the rocket. In effect, we need to apply Newton's second law to the rocket and to do that we need to know the rate of change of momentum of water leaving the bottle. First, let's define some terms: 7

m_0 = total initial mass of the rocket;
t = time counting from blast-off;
$\frac{\Delta m}{\Delta t}$ = constant rate of ejecting of mass; 8
u = constant speed of the water leaving the bottle (relative to the rocket).

The resultant force exerted on the water is equal to its rate of change of momentum. The momentum gained by the water per second is $u\frac{\Delta m}{\Delta t}$ (remember, $\frac{\Delta m}{\Delta t}$ is the mass leaving the bottle per second). This, therefore, is the force experienced by the water and by Newton's 3rd law, this is also the force experienced by the rocket. So, we now know that the thrust force acting on the rocket is $u\frac{\Delta m}{\Delta t}$. 9

The mass of the rocket is decreasing at a constant rate of $\frac{\Delta m}{\Delta t}$ so its mass at any time t is given by $\left(m_0 - \frac{\Delta m}{\Delta t}t\right)$. 10

This is enough information to use Newton's 2nd law ($F = ma$) to give an equation for the acceleration. Mathematics (that won't require learning) then leads to solutions for both velocity and height. Here are the equations: 11

$$v = -u\ln(1-\alpha t) \qquad \textbf{Equation 2}$$

$$h = \frac{u}{\alpha}[(1-\alpha t)\ln(1-\alpha t) + \alpha t] \qquad \textbf{Equation 3}$$

α is the ratio of the rate of loss of mass to the initial mass, $\left(\alpha = \frac{\frac{\Delta m}{\Delta t}}{m_0}\right)$.

We can now try to apply these equations to a typical 2 litre bottle. The total mass of the water, bottle and ball is around 1.5 kg (i.e. m_0 = 1.5 kg). Of this, 1.0 kg is water, 0.45 kg for the ball and the bottle has a mass of 0.05 kg. From high speed video analysis of the rocket, all 1.0 kg of the water is expelled in 0.14 s so that we can calculate the mean rate of decrease of mass of the rocket: 12

$$\frac{\Delta m}{\Delta t} = k = \frac{1.0}{0.14} = 7.1\ \text{kg s}^{-1}$$

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Paragraph

We can also use these figures to determine the exhaust speed of the water when we know that the radius of the bottle neck is 1.1 cm.



Diagram 3

The mass of the water (Δm) in the cylinder of length $u \times \Delta t$ is:

$$\text{volume} \times \text{density} = \pi r^2 \times u \times \Delta t \times \rho$$

which gives us a relationship between the rate of mass loss and the exhaust velocity:

$$\frac{\Delta m}{\Delta t} = \pi r^2 \rho u \qquad \textbf{Equation 4}$$

13

When this expression is equated to the actual rate of loss of mass (7.1 kg s^{-1}), it gives a value of u of around 19 m s^{-1} (remembering that the density of water is rather conveniently 1 000 kg m^{-3}).

Comparison Between Ideal Rocket Theory and Experiment

This is enough information to put into the rocket equations (2 & 3) and compare with the motion of an actual rocket. The easiest way of doing this is to use a spreadsheet - we can enter both the rocket equations and actual data and compare the two. In the graph shown (diagram 4), the actual 2 litre rocket data is shown as a continuous line. The theoretical rocket equation is represented by the dotted lines. The data for the height of the actual rocket was gathered by using a comparatively cheap digital camera set to 220 frames per second. The video of the rocket motion was then analysed frame by frame using a 30 cm ruler to measure distances on the screen and the continuous curve in the graph obtained.

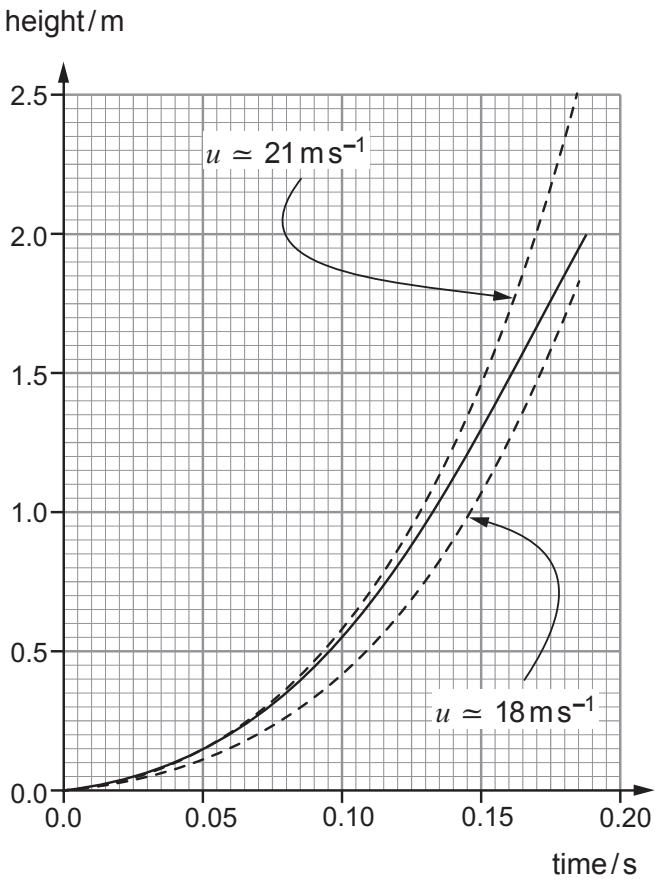


Diagram 4

14

15

Interestingly, when these data and the rocket equations were put into a spreadsheet, the value of exhaust speed (u) of 19 m s^{-1} did not produce an ideal fit (see diagram 4). The best fit for the early motion of the rocket was provided by an exhaust speed of around 21 m s^{-1} whereas the later motion of the rocket fits better with an exhaust speed of around 18 m s^{-1}. This may seem like a bad agreement but, on the other hand, these discrepancies could be pointing toward the reason for the disagreement.

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Paragraph

Rocket Theory with Decreasing Pressure and Exhaust Speed

The rocket equation fits well for the first 0.10 s of its flight with an exhaust speed of around 21 m s^{-1} but then the actual rocket does not keep up with its theoretical counterpart and the actual rocket seems to fit better with an exhaust speed of around 18 m s^{-1}. What could be the reason for this? Put simply, it's the decrease in pressure of the air inside the bottle as the water is leaving. But how can we model the pressure inside the bottle? Simplistically, we can use Boyle's law. Robert Boyle in the mid 1600s said for a fixed mass of gas at constant temperature: 16

$$\text{pressure} \times \text{volume} = \text{constant}$$

We know that the initial volume of the gas is around 1 litre (for the 2 litre bottle). The final volume of the gas rather obviously will be 2 litre. Boyle's law therefore tells us that the pressure at the start will be approximately double the final pressure. In between these two stages, each gramme of water that is expelled provides an extra 1 cm^3 of air in the bottle and the corresponding pressure drop can easily be calculated using Boyle's law. 17

Now that we have the details to model the pressure drop in the bottle, it is possible to calculate the speed of the water coming out of the bottle. All we have to do is use Bernoulli's equation.

$$p_{\text{atm}} = p - \tfrac{1}{2}\rho u^2 \qquad \textbf{Equation 5}$$

Surprisingly enough, this means that the exit speed of the water is independent of the size of the bottle opening! 18

$$u = \sqrt{\frac{2(p - p_{\text{atm}})}{\rho}} \qquad \textbf{Equation 6}$$

Now we can use this equation to calculate the exhaust speed of the water. The density of water (ρ) is 1 000 kg m^{-3} and the initial (p–p_{atm}) was 3.4×10^5. This gives an initial exhaust speed of around 26 m s^{-1}. 19

For completion, gravity and air resistance should also be incorporated into our model. Gravity is easy enough but what about air resistance? A simple theory for air resistance is that the increase in air resistance is proportional to velocity squared. In fact, if we look up the air resistance of a sphere, we should find: 20

$$F_{\text{drag}} = 0.47 \times \tfrac{1}{2}\rho_{\text{air}} v^2 \times A \qquad \textbf{Equation 7}$$

where A is the maximum cross-sectional area of the sphere, ρ_{air} is the density of air and v is the speed of the sphere.

Another great advantage of placing a football on top of the water bottle rocket is that the air resistance can be modelled based on the dimensions of the football. This assumes that the bottle underneath the football has no effect on the air resistance but should be a reasonable approximation considering that the cross-sectional area of the football is far greater than that of the bottle. The density of air (ρ_{air}) is 1.20 kg m^{-3} and the diameter of the football is 22.0 cm and they can both be inputted into the air resistance equation. 21

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Paragraph

All this information should give us a final resultant force acting on the rocket of:

$$F_{\text{res}} = \pi r^2 \rho u^2 - mg - 0.0107v^2 \qquad \textbf{Equation 8}$$

where: u = instantaneous exhaust speed of the water
r = radius of the bottle opening
ρ = density of water ($1\,000\,\text{kg m}^{-3}$)
m = instantaneous mass of the rocket (including the water and football)
v = instantaneous speed of the rocket

22

Final Comparison between Theory and Experiment

When all this data is put into a spreadsheet with time going up in steps of 1/220th of a second (to match the digital camera) and all rocket data calculated for all the time intervals. This is the end result. 23

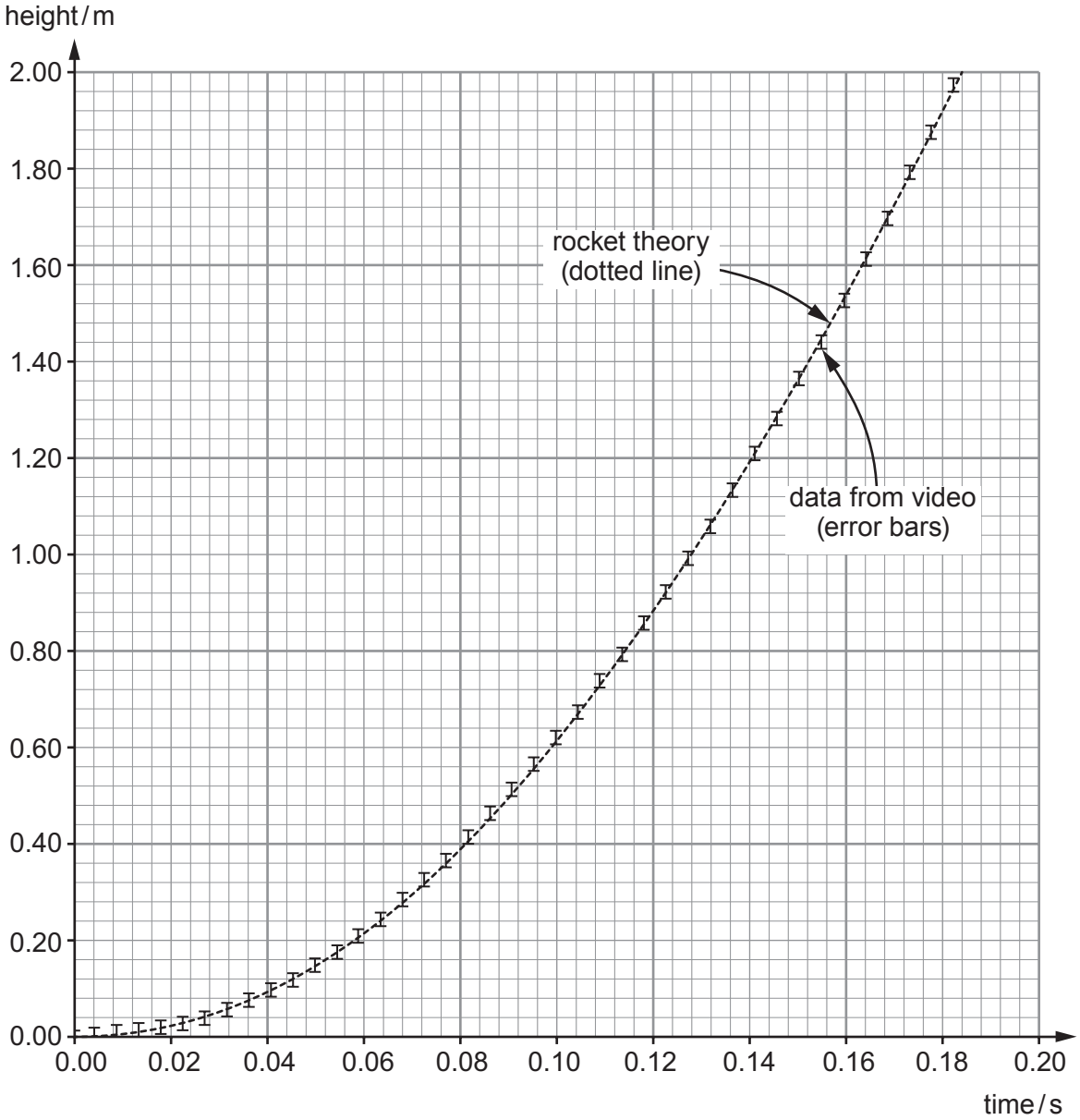


Diagram 5

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Here, the rocket theory (dotted line) is in excellent agreement with the experimental results (error bars). At no point is the computed model data outside the error bars corresponding to the actual motion of the rocket (these error bars simply correspond to ±0.5 mm reading from the ruler next to the computer screen). The final best fit parameters used were m_0 = 1.52 kg, initial pressure = 4.7×10^5 Pa and radius of bottle opening = 1.019 cm. 24

In conclusion, the motion of a plastic water bottle rocket has been analysed using purely A level Physics with a touch of Bernoulli's equation and drag theory. Although the mathematics used can be complicated, this is relatively easily remedied by using numerical methods in a computer spreadsheet. The results are astonishingly accurate and were aided hugely by the novel idea of a football on top of the rocket. 25

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GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2015

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INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2015 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

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PH3	12
PH4	17
PH5	24
PH6	39

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SECTION A

Question			Marking details	Marks Available
1	*(a)*	(i)	84.6×10^{-9} [C] [for 4.7 nF] (1) 73.8×10^{-9} [C][and 73.8 nC or clearly stated same for other 8.2 nF] (1)	2
		(ii)	$E = \frac{1}{2}CV^2$ or other equation used correctly or C total = 8.8 nF (1) Answer $= 1.43 \times 10^{-6}$ [J] **ecf** on Q but not V (1)	2
	(b)	(i)	Points taken from the curve e.g. Q_0 = 85 nC and (50 ms, 6 nC) (or 85 nC/e = 31 nC) (1) Values substituted correctly e.g. $6 = 85e^{-0.05/CR}$ or CR = 18 ms (1) Answer $R = 3.8 \times 10^6$ [Ω] (1) **Award 1 mark** for use of $\frac{\Delta Q}{t}$ t **or** 11 MΩ **Alternative:** Tangent (1) Current (1) $R = 3.8 \times 10^{-6}$ [Ω] (1)	3
		(ii)	$I = \frac{V}{R}$ used or tangent drawn at t = 0 (1) Answer $= 4.7 \times 10^{-6}$ [A] **ecf** (1)	2
		(iii)	After 41 ± 1 ms 10% charge left [or 90% discharged] Or other valid method e.g. taking logs and getting time (1) 83×10^{-3} [s] (first step can be implied) **ecf** (1)	2
			Question 1 Total	**[11]**

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Question			Marking details	Marks Available
2	*(a)*	(i)	0	1
		(ii)	$\varphi = B \times l^2$(1)	
			Answer = 4.32×10^{-5} [Wb] (1)	2
	(b)		Change in flux or Faraday's law gives emf (1)	
			Complete circuit or accept emf gives current (1) **Award 1 mark only for:** Current due to Faraday's law	2
	(c)		Force / current / emf **opposes the change** (1)	
			Force on PQ opposite to SR **or** the force is clockwise (1)	2
	(d)		$I = \frac{V}{R}$ used (1)	
			$A = \pi\frac{d^2}{4}$ *or* $\pi \times 3^2(\times 10^{-6})$ i.e. πr^2 used (1)	
			$R = \frac{\rho \times l}{A}$ used (1)	
			$V = \frac{\Delta N\phi}{\Delta t}$ used (1)	
			Answer = 0.19 [A] **ecf** on ϕ and πd^2 (1)	5
			Question 2 Total	**[12]**

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Question			Marking details	Marks Available
3	*(a)*		Low *A* numbers do fusion (or arrow / label used) (1) High *A* numbers do fission (or arrow / label used) (1) Moving toward high BE/nucleon (around Fe-56) or Fe-56 is the most stable (or low PE/nucleon or accept work done by strong nuclear force) (1) Higher BE/nucleon is more stable (or low PE/nucleon more stable or more work done more stable) (1)	4
	(b)		1.1 ± 0.1 MeV identified from graph for $^{2}_{1}H$ (1) × 2 = 2.2 [MeV] **ecf** (1)	2
	(c)		7.6 ± 0.2, 8.4 ± 0.2, 8.7 ± 0.2 (1) Correct multipliers for each i.e. 235 × 7.6, 137 × 8.4, 96 × 8.7 (1) RHS – LHS or reverse (1) Correct answer e.g. 201 MeV **UNIT mark (**1) [dependent on BE/*A* approximations]	4
			Question 3 Total	**[10]**

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Question			Marking details	Marks Available
4	*(a)*		360 ± 10 [minutes]	1
	(b)		No [significant] drop after paper [no α] (1) [Small drop after aluminium] so small amount <u>of γ</u> being absorbed / most γ passes through i.e. could be β but some γ would be absorbed ok **Or** accept drop could be attributable to randomness of decay (1) γ present because something gets through 3 mm Al **or** γ present because **bigger** drop after 10 cm Pb [than 3 mm Al] **or** γ present because <u>only</u> absorbed by the Pb (1)	3
	(c)		Activity = $\frac{450}{0.006}$ = 75 000 (1) Activity = λN or $t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ used (1) $N = 2.34 \times 10^{9}$ (1) Mass = $99 \times 1.66 \times 10^{-27} \times 2.34 \times 10^{9} = 3.84 \times 10^{-16}$ kg **UNIT mark** (1) **ecf** on A and $t_{\frac{1}{2}}$ and N	4
			Question 4 Total	**[8]**

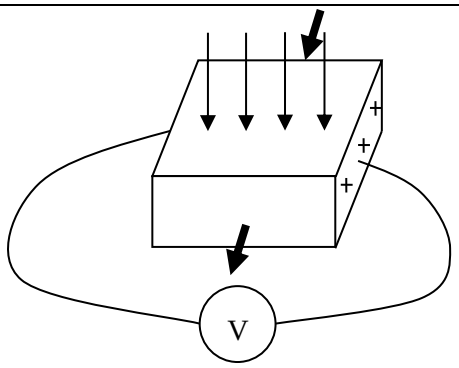
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Question			Marking details	Marks Available
5	*(a)*		$n = \frac{12\,000}{1.8}$ (1) $B = \mu_0 nI = 0.019$ [T] (1)	2
	(b)	(i)	Either $Bev = \frac{mv^2}{r}$ *or* $Bev = m\omega^2 r$ (1) $v = \omega r$ *and* $\omega = 2\pi f$ quoted (1) Clear algebra (if not immediately understandable then not clear) (1)	3
		(ii)	$f = \frac{3.3\times6\times1.6\times10^{-19}}{2\pi\times12\times1.66\times10^{-27}}$ (1) Answer = 25.3×10^6 [Hz] (1)	2
		(iii)	$6e \times 14.5$ kV $\times 24$ [= 2.09 MeV] (1) Conversion to J i.e. look out for $\times 1.6 \times 10^{-19}$ (1) Equating some related energy to $\frac{1}{2}mv^2$ e.g. $\frac{1}{2}mv^2$=14 500 (1) Answer = 5.8×10^6 [m s^{-1}] (1) (**ecf** on these values only 2.4×10^6 and 4.1×10^6 which correspond to q =1e and 12 kicks respectively)	4
			Question 5 Total	**[11]**

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Question			Marking details	Marks Available
6	*(a)*	(i)	+ve correct 	1
		(ii)	voltmeter correct	1
	(b)		$V = Ed$ or $V_H = Bvd$ (1) $Bev = eE$ quoted or $d = 5 \times 10^{-3}$ (1) Answer = 6.3×10^{-6} [V] (1)	3
	(c)		Electrons do not move in the direction of the Hall field (or accept in the direction of the Hall voltage)	1
	(d)		Correct use of $I = nAve$ or $n = \frac{BI}{V_H te}$ (or equiv equation) (1) Answer $I = 0.30 \times 10^{-3}$ [A] (1)	2
			Question 6 Total	**[8]**

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SECTION B

Question			Marking details	Marks Available
7				
	(a)		KE given to water (1) Air resistance (1) **Award 2 marks for:** Water runs out before pressure drops to 1 atm Accept PE given to water [even though water runs out in 1.6 m] Accept viscosity [or friction] of water Accept KE given to bottle [only 1/10th of mass of ball] Don't accept heat or sound	2
	(b)		$v = -20\ln\left(1 - \frac{5.9}{1.5} \times 0.175\right)$ (1) $v = 23.3$ [m s^{-1}] (1)	2
	(c)		kg s^{-1}, m^2, kg m^{-3} and m s^{-1} (0 or 1 unit correct 0 marks) (2 or 3 units correct 1 mark) (All 4 correct 2 marks) If all 4 units correct but algebra is incorrect then deduct 1 mark	2
	(d)		Rearranging i.e. $u = \frac{\Delta m/\Delta t}{\pi r^2 \rho}$ (1) Answer = 25 [m s^{-1}] (1)	2
	(e)		**Any 3 × (1) from:** Rocket equation assumes constant *u* Volume increasing so pressure decreasing Pressure is decreasing so *u* is decreasing Thrust is decreasing	3

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Question			Marking details	Marks Available
	(f)		$\Delta p = 6.8 \times 10^5$ [Pa] (1) $u = \sqrt{\frac{2\times6.8\times10^5}{1000}} = 36.9$ [m s^{-1}] (1)	2
	(g)		*mg* - weight or gravitational force **and** $0.0107v^2$ - air resistance / drag accept <u>skin / air</u> friction (1) Weight decreases (1) Air resistance increases (1)	3
	(h)		Squaring equation 6 or rearranging equation 5 (1) Convincing algebra (1)	2
	(i)	I	Fast process or no time for heat to flow or equivalent	1
		II	The gas does <u>work</u> so <u>internal energy</u> decreases **Or** $\Delta U = -W$	1
			Question 7 Total	**[20]**

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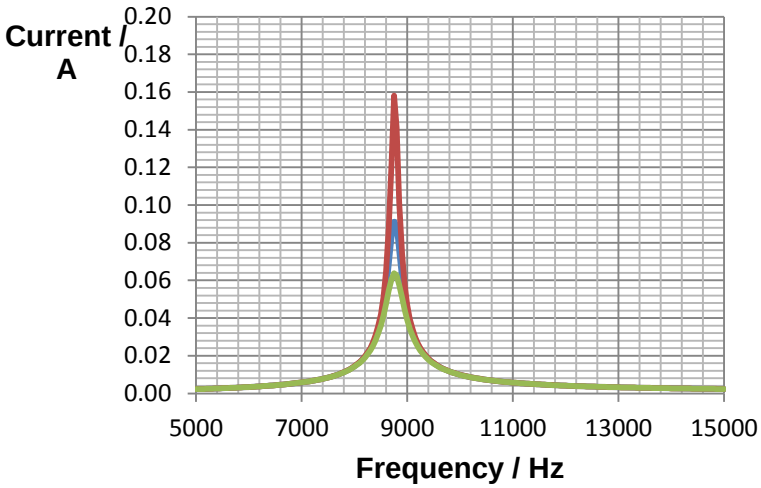
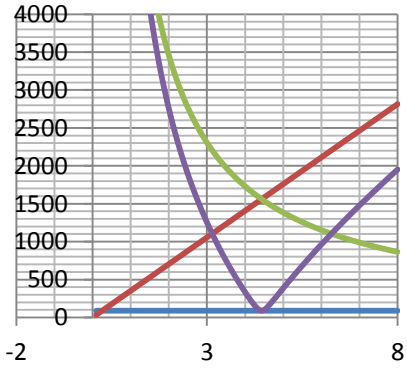
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SECTION C

Question			Marking details	Marks Available
8	*(a)*	(i)	$\omega L = \frac{1}{\omega C}$ *or* $f = \frac{1}{2\pi\sqrt{LC}}$ (1)	
			$= \frac{1}{2\pi\sqrt{0.022\times15\times10^{-9}}}$ or $f = \frac{1}{2\pi\sqrt{0.022\times90\times10^{-9}}}$ (1)	3
			8 761 [Hz] and 3 577 [Hz] (1)	
		(ii)	$Q = \frac{2\pi fL}{R}$ *or* $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$ (1)	
			Correct matching of f and R or R and C (1)	
			61 (1)	
			10 (1)	4
	(b)		$Z = \sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2 + R^2}$ used (1)	
			$I = \frac{3.2}{Z}$ i.e. $I = \frac{V}{Z}$ used (1)	
			1.7 [mA] (1)	3

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Question			Marking details	Marks Available
8	*(c)*	(i)	 Shapes similar and asymptotic to original (1) 20 Ω with higher peak and 50 Ω with lower (implied if not labelled) (1) 20 Ω with peak current of 160 mA (1) 50 Ω with peak current of 64 mA (1)	4
		(ii)	ωL increases (wrt f) or graph (1) $\frac{1}{\omega C}$ decreases (wrt f) (1) low frequency behaviour explained e.g. X_C very large, Z large at low freq (1)  high frequency behaviour explained e.g. X_L very large, Z large at high freq (1) $\omega L - \frac{1}{\omega C} = 0$ at resonance making Z a minimum (1) $I \propto \frac{1}{Z}$ or equivalent equation etc. (1)	6
			Question 8 Total	**[20]**

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Question			Marking details	Marks Available
9	*(a)*	(i)	Diagram showing either angle (accept θ) or baseline (1) Attempt to use $b = r\theta$ and indication that θ must be in radians, Or attempt to use $b/2 = r \tan(\theta/2)$ or equiv. Or by implication. (1) $r = 1.96 \times 10^6$ [km] or 1.92×10^6 [km] or convincing answer. (1)	3
		(ii)	Showed comet (far) beyond Moon. (1) But according to Aristotle nothing changes beyond Moon [yet comet was new – and went away]. (1)	2
	(b)	(i)	Diagram showing relevant areas (1) r_P, r_A, $v_P\Delta t$, $v_A\Delta t$ marked on diagram or meanings otherwise shown (1) $(\frac{1}{2})r_P v_P \Delta t = (\frac{1}{2})r_A v_A \Delta t$ or equivalent (1)	3
		(ii)	Use of $\frac{v_P}{v_A} = \frac{r_A}{r_P}$ [= 1.10] or by implication (1) 10 % [increase] (1)	2
		(iii)	Explicit use of $\frac{mv^2}{r}$ (1) $\frac{v_P}{v_A} = \frac{r_A}{r_P}$ used convincingly to give $\frac{F_P}{F_A} = \frac{r^2_A}{r^2_P}$ or equiv. (1)	2
	(c)	(i)	Towards S or equivalent	1
		(ii)	Any 3 of ... • Sun at S, planet's path ABCDEF... • If time interval is shrunk, path becomes smooth • Equal areas swept out in equal times • Showed that for an elliptical path ... • ... force had to vary as inverse square of Sun-planet distance	3
		(iii)	Planets swirled in whirlpool (vortex) around the Sun (1) Any 2 of …. (2) • easy to understand • gave a *mechanism* • Newton didn't say what *caused* gravitation Descartes' vortex theory can't be made to account for actual orbits [that is for Kepler's laws] or Newton's theory accounted for so many phenomena so economically [or similar point] (1)	4
			Question 9 Total	**[20]**

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Question				Marking details	Marks Available
10	*(a)*	(i)		Strong (covalent) bonds between ions in structure. Accept molecules arranged irregularly or amorphous structure present (1) [No dislocations present] so no slip (accept no movement of dislocations). Accept different sized atoms seize up the structure (1) Do not accept 'untangle'.	2
		(ii)		Scratches (on surface) weaken material or break surface bonds. Scratches have stress concentrations at their tips- can be awarded from diagram. Cracks propagate through material. Correct direction of bending is to open the crack [ANY 2] (credit well annotated diagrams) [Local] stress cannot be relieved by slip / plastic flow/ dislocation movement.	2
		(iii)		Compression (1]) [Do not accept 'stress] More difficult for cracks to develop/ widen/ propagate (1)	2
	(b)	(i)		Gradient shown = 80 GPa e.g. $\frac{800 \times 10^6}{0.01}$ seen.	1
		(ii)		Area under graph = [½ × 0.01 × 800 × 10^6 + ½ × 0.08 × 100 × 10^6 + 0.08 × 800 × 10^6] = 72 [MJ m^{-3}] (1) Volume = $\pi \times (1.25 \times 10^{-3})^2 \times 2.5 = 12.3 \times 10^{-6}$ [m^3] (1) Work done = 72 × 10^6 × 12.3 × 10^{-6} = 884 [J] (1) (**ecf** on both area and volume).	3
		(iii)		Initial straight line of same gradient. (1) Yield point at 1 000 MPa. (1) Linear plastic region of small slope (accept zero slope) stopping at 5% strain. (1)	3
		(iv)	(I)	Creep: **[Gradual/slow/Over time]** AND **[extension/stretching/deformity or increase in strain]** (1) (under a constant load). Necking: **Localised** (or reference to 'section' or 'region') **thinning** (of structure/material before breaking- accept diagram) (1)	2
			(II)	Same shaped curve but steeper gradient (1) Stopped at 15% and t < 400 hrs (approx.) (1)	2
		(v)		Repeated bending, stretching or hammering of metal alloy (1) Dislocations become tangled / traffic jam effect **or** new dislocations created (1) Stopping each other from moving (or inhibiting plastic deformation or collect at grain boundaries) (1)	3
				Question 10 Total	**[20]**

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Question			Marking details	Marks Available
11	*(a)*	(i)	A/B/D	1
		(ii)	C	1
		(iii)	A	1
	(b)		$V = \frac{hc}{e\lambda}$ (must rearrange) (1) 6.2×10^4 V (must have valid unit) (1)	2
	(c)		Reduces scattering/ spreading accept 'ensures (X-rays) are all parallel / perpendicular [to the patient] (1) [leading to] sharper image / better resolution (1)	2
	(d)	(i)	Radio (waves)	1
		(ii)	Cause Hydrogen atoms to resonate (1) Flip alignment producing a magnetic field (1)	2
		(iii)	Not good for dense objects/bone/ Uncomfortable/ Claustrophobic/cannot be used with pacemakers/ expensive	1
	(e)	(i)	Depolarization of ventricles/ repolarisation of atria (1) Contraction of ventricles (1)	2
		(ii)	Repolarization of ventricles (1) Relaxation of ventricles/ ventricles return to normal (1) Do NOT accept ventricles expand	2
	(f)	(i)	Doppler	1
		(ii)	$0.4 \times \frac{1500}{500} = 2v$ (1) $v = 0.6$ [m s^{-1}] allow 1 mark only for 1.2 m s^{-1} (1)	2
	(g)	(i)	Gamma /γ	1
		(ii)	Very expensive/need a cyclotron / particle accelerator Ignore any reference to radiation dose	1
			Question 11 Total	**[20]**

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Question			Marking details	Marks Available
12	*(a)*		Any 3 of: More than one isotope of uranium Only U-235 fissile / U-238 unsuitable for fission Need higher concentration of U-235 Get rid of U-238 since neutron absorber/'sink'	3
	(b)		More fissile nuclei obtained (1) U-238 captures neutrons **or** decays to plutonium 239 via beta (1)	2
	(c)		Any 2 of: More easily controllable or no chain reaction Hydrogen & deuterium more plentiful / more easily sourced / can be extracted from sea water No [long term] radioactive products. More energy released per fusion	2
	(d)	(i)	Overcome electrostatic repulsion /forces (1) Needs high / enough (K)E (or velocity, speed) of deuterium/tritium (1) <u>KE proportional to temperature</u> or only tail end of distribution (1) with high enough energy	3

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Question			Marking details	Marks Available
		(ii)	$n = or \geq \frac{3.5\times10^{28}}{0.9\times120000000}$ (1) Multiplying by $2.5 \times 1.67 \times 10^{-27}$ (1) Answer = 1.35×10^{-6} [kg m^{-3}] (1)	3
	(e)		9×10^{16} (1) $\times 2 = 18 \times 10^{16}$ [J] (1)	2
	(f)		Coal - **any 2 of**: acid rain, CO_2, non-renewable, lasts hundreds of years, increase asthma, damage to buildings/trees/etc, global warming (1) Natural gas - **any 2 of:** less acid rain, CO_2, non-renewable lasts tens or hundreds of years, global warming (1) Biomass - **any 2 of:** acid rain, CO_2 neutral (roughly), renewable/lasts millions of years, increase asthma, damage to buildings/trees/etc, (roughly) no global warming, large land area needed (1) Uranium-235 **any 2 of**: no acid rain, no CO_2, lasts thousands of years, no increase asthma, no damage to buildings/trees/etc, (little or) no global warming, leak or explosion risk, disposal of waste, hazardous waste, large energy output per kg of fuel (1) Wind **any 2 of:** no acid rain, no CO_2, renewable/lasts millions of years, no increase asthma, no damage to buildings/trees/etc, no global warming, low power, weather dependent/unreliable, large area (1) (ugly/kills birds/noisy/disrupts TV signals OK but only 1 point max for these) NOTE: No marks for cheap/expensive - eliminated in stem!!	5
			Question 12 Total	**[20]**

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Surname	Centre Number	Candidate Number
Other Names		2

GCE A level

1325/01

PHYSICS – PH5
ASSESSMENT UNIT
Electromagnetism, Nuclei & Options

A.M. THURSDAY, 19 June 2014

1 hour 45 minutes

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010001

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator, a **Case Study Booklet** and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use pencil or gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet. If you run out of space, use the continuation pages at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 3 sections, **A**, **B**, and **C**.

Section A: 60 marks. Answer **all** questions. You are advised to spend about 1 hour on this section.

Section B: 20 marks. The Case Study. Answer **all** questions. You are advised to spend about 20 minutes on this section.

Section C: Options; 20 marks. Answer **one option only.** You are advised to spend about 20 minutes on this section.

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SECTION A

Answer **all** *questions.*

1. *(a)* Carbon fuses with helium to produce oxygen and energy.

$$^{12}_{6}\mathrm{C} + {}^{4}_{2}\mathrm{He} \longrightarrow {}^{16}_{8}\mathrm{O} + 7.16\ \mathrm{MeV}$$

The masses of the helium and carbon nuclei are 4.0015 u and 11.9967 u respectively.

(i) Calculate the binding energy **per nucleon** of the carbon nucleus (1 u = 931 MeV, m_{proton} = 1.0073 u, m_{neutron} = 1.0087 u). [3]

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(ii) Use the energy released in the above reaction to calculate the mass of the oxygen-16 nucleus to 6 significant figures. (1 u = 931 MeV.) [4]

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(b) It is important to choose suitable materials inside a nuclear fission reactor to act as control rods, moderator and coolant. Name **one important property of the materials** used for the:

(i) control rods; ..... [1]

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(ii) moderator; ..... [1]

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(iii) coolant. ..... [1]

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2. *(a)* Radon gas ($^{222}_{86}Ra$) is radioactive and can be a significant health hazard in areas that have a high natural concentration of the gas. Radon decays to a stable form of lead (Pb) via 4 alpha decays and 4 beta decays and radon has a half-life of 3.8 days.

(i) Calculate the mass number and atomic number of this stable isotope of lead (Pb). [2]

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(ii) Give **three** reasons why radon gas is particularly dangerous. [3]

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(b) Calculate the time taken for the number of radon gas particles to decrease to 9.0% of their initial number. [4]

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(c) When radon gas is kept in a lead lined container for 3.8 days, the number of radon gas particles halves. However, the activity inside the container is considerably higher than half the original activity. Suggest a reason why. [1]

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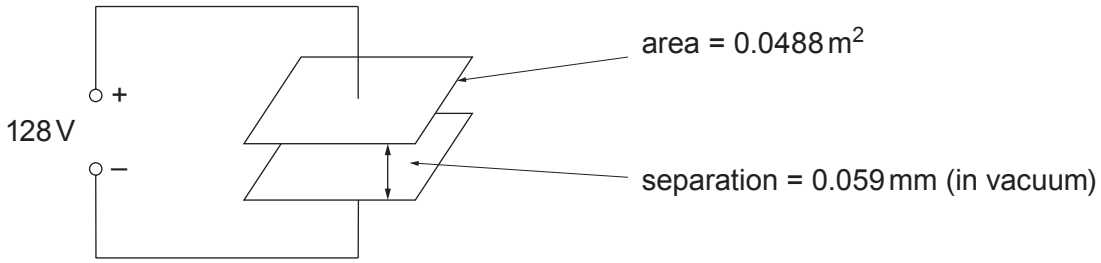
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3. *(a)*



(i) Calculate the charge stored by the capacitor. [3]

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(ii) Use *(a)*(i) to calculate the energy stored by the capacitor. [1]

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(iii) Calculate the electric field strength *(E)* between the plates. [2]

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(b) After the capacitor is charged it is isolated from the power supply so that the charge stored **remains constant**. Then the plates are pulled further apart.

(i) Explain what happens to the capacitance of the capacitor and hence the energy stored by the capacitor. [2]

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(ii) Explain how energy is conserved in this case. [2]

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4. *(a)* A long solenoid of length 1.45 m has 9 560 turns. Calculate the magnetic field strength *(B)* inside the solenoid when it carries a current of 320 mA. [2]

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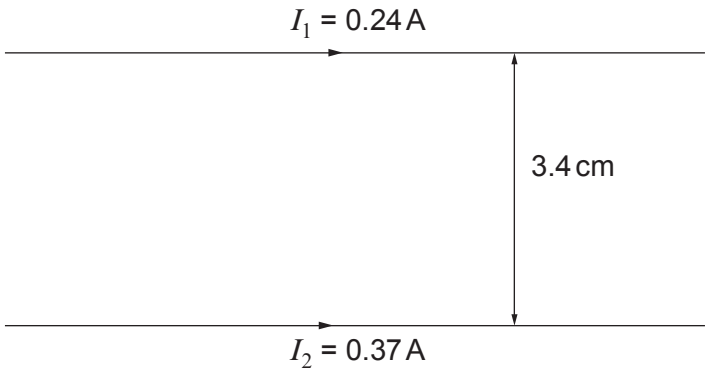
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(b) Calculate the resultant magnetic field strength *(B)* half way between the two long wires shown and **state its direction**. [4]



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(c) Calculate the position between the two wires where the magnetic field strength is zero. [3]

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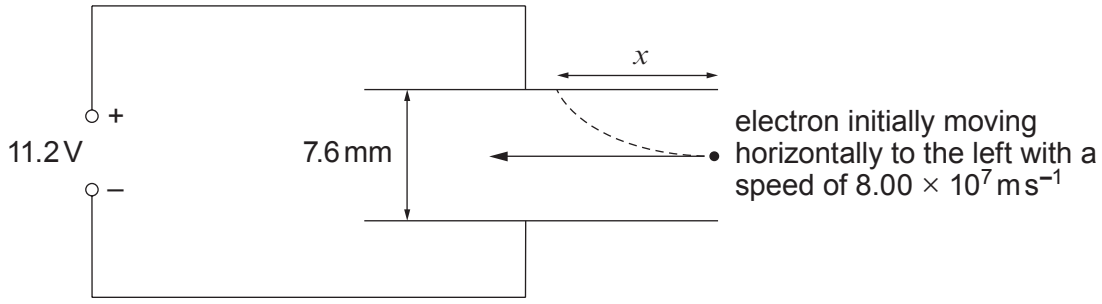
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5. An electron enters the uniform electric field **half way** between the plates of a capacitor as shown. The electron is travelling in a vacuum.



(a) Show that the vertical acceleration of the electron is approximately $2.6 \times 10^{14}\,m\,s^{-2}$. [4]

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(b) (i) Explain why the **horizontal speed** of the electron remains constant. [1]

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(ii) Explain why the vertical **acceleration** of the electron is constant. [1]

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(c) The electron enters the plates and travels a horizontal distance x before hitting the top plate (see diagram). Calculate x. [3]

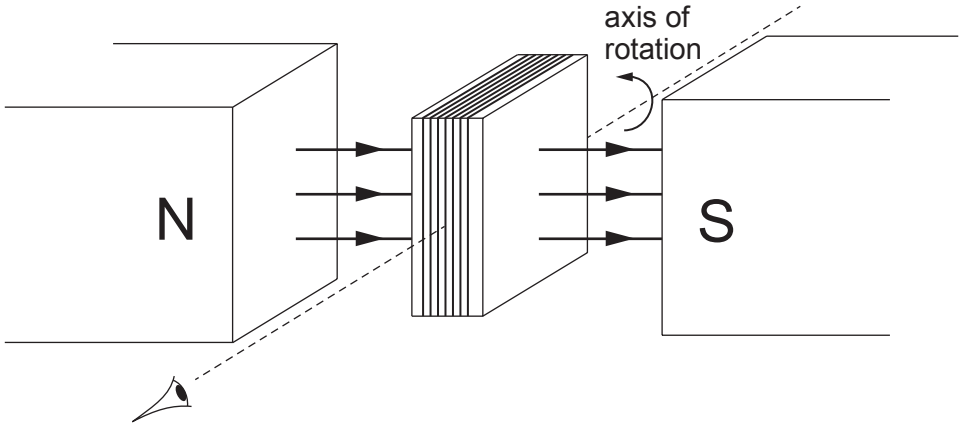
(d) Calculate the **extra** kinetic energy gained by the electron before striking the plate. [2]

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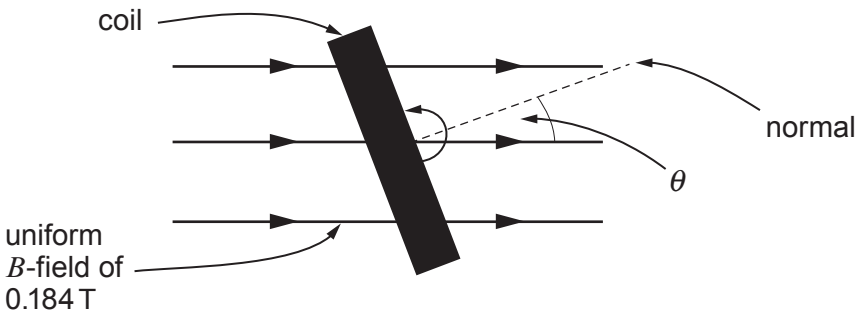
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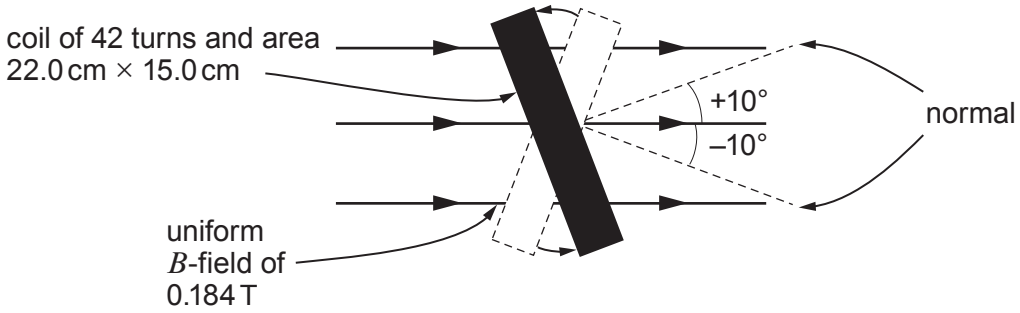
6. A rectangular coil rotates at a constant angular velocity within a uniform magnetic field. The coil has 42 turns and area 22.0 cm × 15.0 cm. The diagram below is a simplified 3D diagram of the coil when the magnetic field is perpendicular to the coil.



The second diagram is a 2D representation of the coil looking along the axis of rotation.



(a) (i) Calculate the flux **linkage** of the coil for the angles $\theta = -10°$ and $\theta = +10°$. [2]



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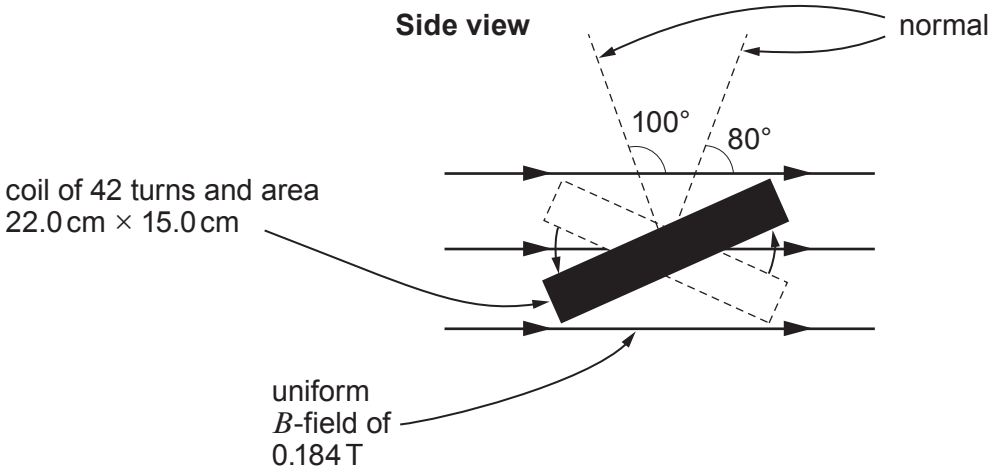
(ii) Explain why the mean induced emf is zero as the coil moves between $\theta = -10°$ and $\theta = +10°$. [1]

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(b) Calculate the mean induced emf in the coil when the angle θ changes from 80° to 100° if the period of rotation of the coil is 0.100 s. [4]



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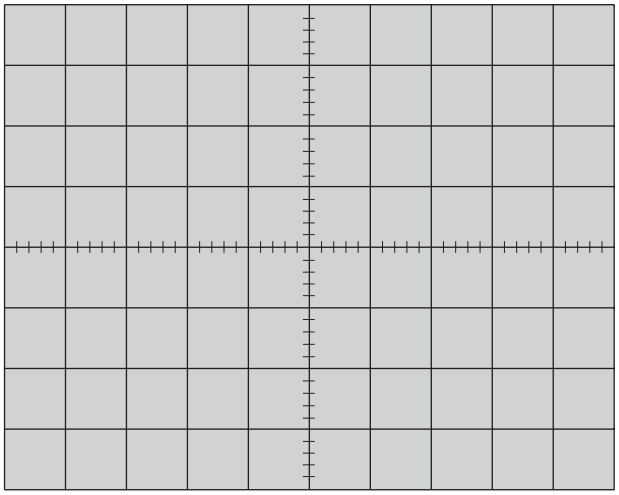
(c) An oscilloscope is used to display the sinusoidal emf in a different coil rotating at a frequency of 12.5 Hz and producing an **rms** pd of 12.0 V. The oscilloscope settings are 5 V per division (vertically) and 20 ms per division (horizontally). Sketch a trace that might be seen on the oscilloscope. (Space is provided for your workings.) [3]

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SECTION B

Answer **all** *questions.*

The questions refer to the case study.
Direct quotes from the original passage will not be awarded marks.

7. *(a)* Explain briefly how parallax is used to measure the distances of stars from the Earth. (See paragraph 1.) [2]

(b) The parallax angle for a certain star is measured as 0.25 arcseconds. Calculate the distance of the star in light years. (See paragraph 4.) [2]

(c) Consider two stars of equal absolute magnitude the first at a distance of 1 parsec and the second at a distance of 10 parsec. Use the equation $M = m + 5(1 + \log_{10} p)$ to confirm that *'a difference of 5 magnitudes is defined as being equivalent to a factor of 100 in brightness'.* (See paragraphs 7 and 8.) [3]

(d) What percentage of the Universe is not hydrogen or helium? (See paragraph 10.) [1]

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(e) In your own words, explain why absorption corresponding to the Paschen series does not occur in relatively cold stars. (See paragraphs 11 and 12.) [3]

(f) Calculate a value for the constant, b, in the equation $L = br^2T^4$ and give its unit. (See paragraph 15.) [3]

(g) (i) Show that the equation $(M + m)T^2 = a^3$ is valid for the orbit of the Earth around the Sun. (See paragraph 16.) [1]

(ii) A small planet orbits a star that has a mass 0.32 M_{Sun} and its period of orbit is found to be 0.46 year. Estimate the planet's distance from its star stating any approximation that you make. [2]

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(h) Explain the intensity variation with respect to time shown in the diagram for the eclipsing binary star. (See paragraph 21.) [3]

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SECTION C: OPTIONAL TOPICS

Option A: **Further Electromagnetism and Alternating Currents** ☐

Option B: **Revolutions in Physics – Electromagnetism and Space–Time** ☐

Option C: **Materials** ☐

Option D: **Biological Measurement and Medical Imaging** ☐

Option E: **Energy Matters** ☐

Answer the question on **one topic only.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

You are advised to spend about 20 minutes on this section.

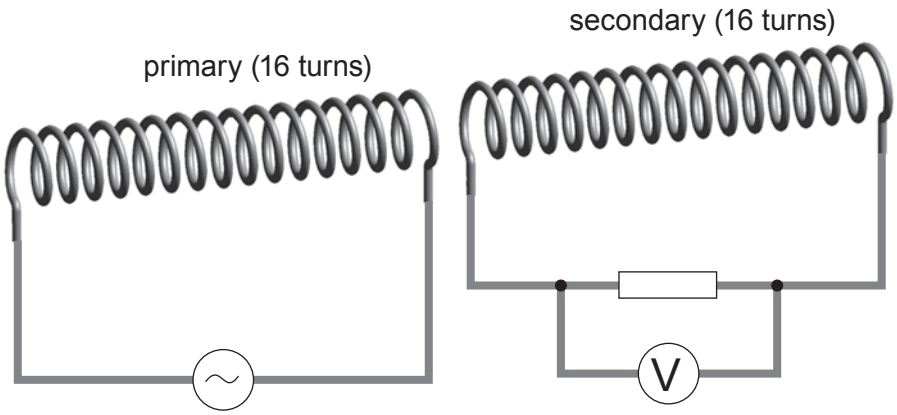
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Option A: Further Electromagnetism and Alternating Currents

8. *(a)* A sinusoidal pd of 6 V (rms) and frequency 0.9 Hz is supplied to the primary solenoid.



(i) State how the reading on the voltmeter varies and explain what causes the voltmeter reading to vary. [4]

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(ii) Give a reason why the rms pd measured by the voltmeter will be much lower than 6 V. [1]

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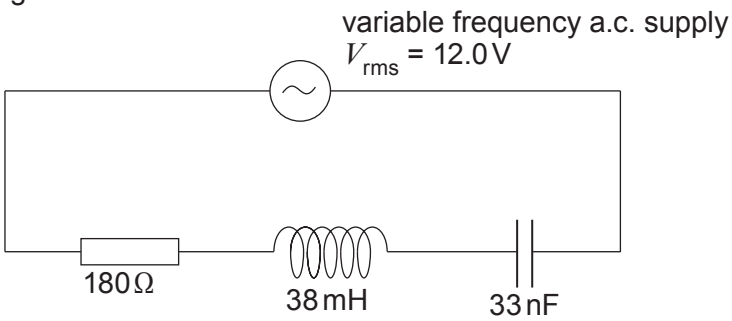
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(b) For the following circuit:



(i) calculate the resonance frequency; [2]

(ii) calculate the rms pd across each component at resonance. [4]

(c) The frequency of the a.c. supply is now set to 5.8 kHz.

(i) Calculate the rms current. [3]

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(ii) Calculate the phase angle between the current and the applied pd (a phasor diagram may assist your calculation). [3]

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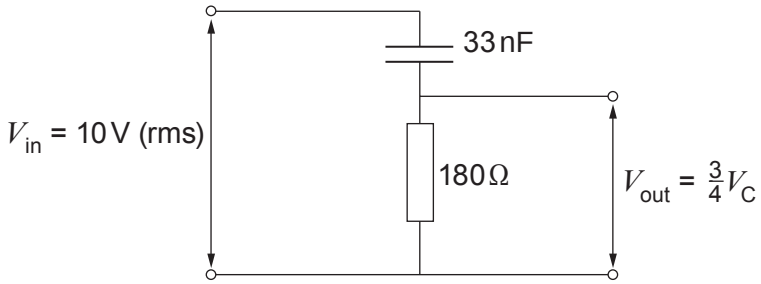
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(d) In the high pass filter shown the rms output pd is $\frac{3}{4}$ of the rms pd across the capacitor.



Calculate the frequency of the input pd. [3]

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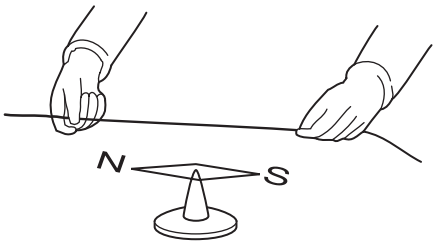
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Option B: Revolutions in Physics – Electromagnetism and Space–Time

9. A sketch is given of the apparatus used in a famous experiment of 1820, showing the magnetic effects of an electric current.



(a) (i) Who performed the experiment? [1]

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(ii) Part of the apparatus (not shown) was a voltaic pile. What is the modern name for a voltaic pile? [1]

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(iii) Describe what was done in the experiment, what was observed and what conclusion was reached about the magnetic field due to the current. [3]

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(iv) The experiment and its results inspired Faraday to start a search which led to his discovery of electromagnetic induction. What was Faraday searching for? [1]

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(b) (i) Explain how a magnetic field is represented in Maxwell's vortex ether. Include a labelled diagram of a region containing four vortices. [3]

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(ii) Maxwell wrote about his vortex ether:

> "The conception of a particle having its motion connected with that of a vortex by perfect rolling contact may appear somewhat awkward. I do not bring it forward as a mode of connexion existing in nature, or even as that which I would willingly assent to as an electrical hypothesis. It is, however, a mode of connexion which is mechanically conceivable, and easily investigated, and it serves to bring out the actual mechanical connexions between the known electro-magnetic phenomena [...]."

Discuss briefly whether or not the vortex ether served its purpose, even though few physicists – if any – would argue for its existence. [2]

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(c) Describe briefly how Hertz:

(i) produced electromagnetic waves and how he detected them; [2]

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(ii) confirmed the transverse nature of the waves; [1]

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(iii) measured the wavelength. [2]

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(d) (i) State what is meant by a *proper time interval* between two events. [1]

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(ii) A spacecraft travels between two space stations, A and B, at a speed of $0.140\,c$ (that is $4.20 \times 10^7\,\text{m s}^{-1}$). A clock on board the spacecraft records the journey time from A to B as 50.0 s.

Synchronised clocks in the space stations A and B record the spacecraft passing them at times t_A and t_B. Calculate the time interval $(t_B - t_A)$. [Assume A and B to be in fixed positions in an inertial frame.] [3]

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Option C: Materials

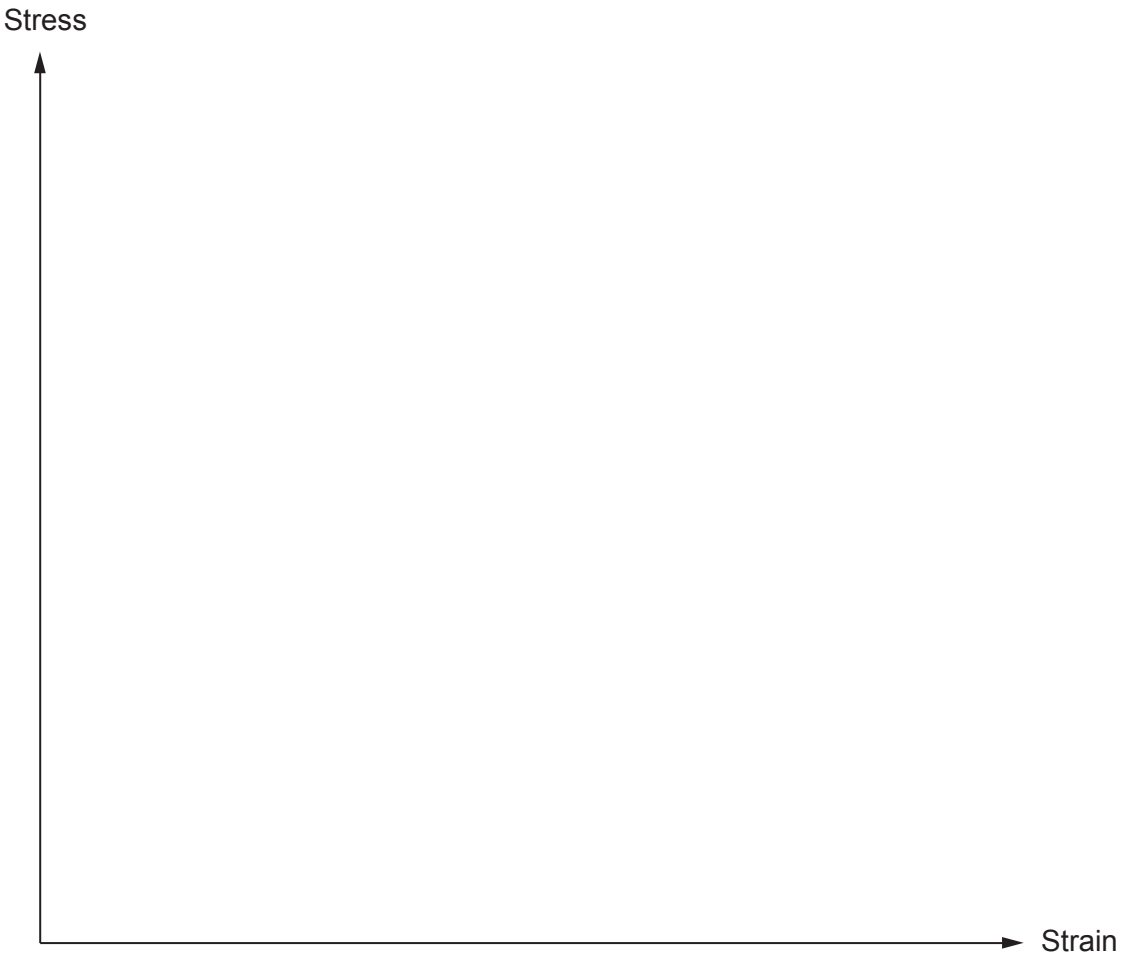
10. *(a)* Sketch a typical stress-strain graph for the stretching to breaking point of a ductile metal such as copper. Label on your graph:

(i) the elastic limit;

(ii) the yield point;

(iii) the region of plastic deformation;

(iv) the breaking point. [6]

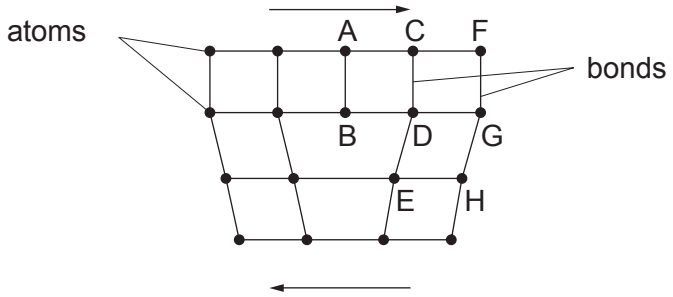


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(b) The diagram shows the arrangement of atoms in a metal crystal in the region of a dislocation.



(i) Using the letters in the diagram, explain how plastic deformation takes place in ductile metals when forces are applied as shown by the arrows. Space is provided so that you can illustrate your answer if you wish to do so (or you may add to the existing diagram). [3]

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(ii) 'Superalloys' in the form of single crystals have recently been developed to withstand extreme conditions of temperature and pressure. **In terms of atomic structure**, give one reason why superalloys can withstand higher temperatures and pressures than conventional multi-crystal alloys. [1]

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(iii) State one application of 'superalloys'. [1]

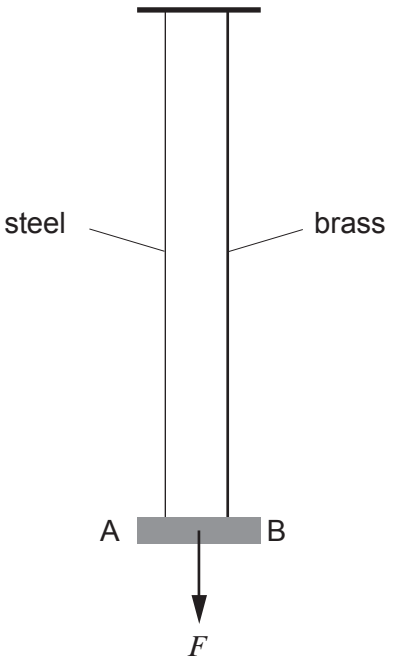
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(c) A light bar (AB) is suspended horizontally from two vertical wires, one of steel and one of brass as shown in the diagram. Each wire is of the same length, though their cross-sectional areas (A_{brass} and A_{steel}) are different. When a force F is applied to the **centre** of AB the wires **extend by an equal amount** and the bar remains horizontal.



(i) Given that the Young modulus of steel is $2.0 \times 10^{11}\,N\,m^{-2}$, and that of brass is $1.0 \times 10^{11}\,N\,m^{-2}$, show clearly that $A_{brass} = 2A_{steel}$. [2]

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(ii) Determine the tension in each wire when $F = 100\,N$. [1]

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(iii) Hence calculate the extension in the steel wire when $F = 100\,N$. The initial length of wire is 2.0 m and its cross-sectional area is $2.8 \times 10^{-7}\,m^2$. [2]

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(iv) Calculate the energy stored in the steel wire when $F = 100\,N$. [2]

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(v) Without further calculation, comment on the energy stored in the brass wire when $F = 100\,N$ and justify your answer. [2]

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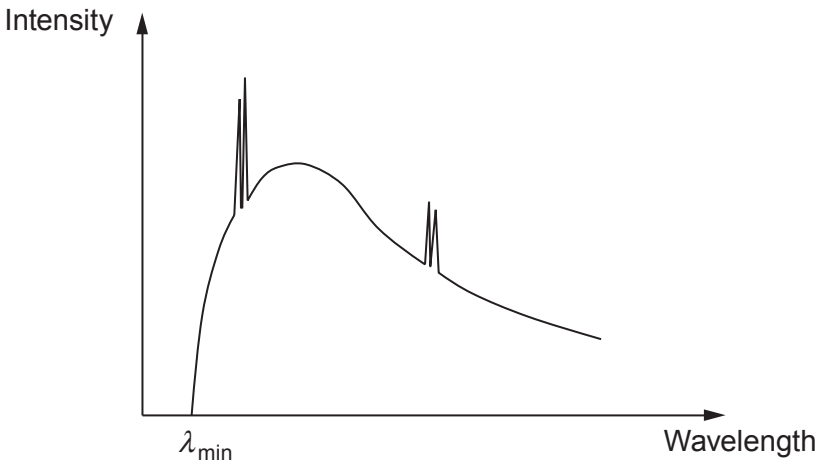
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Option D: Biological Measurement and Medical Imaging

11. The diagram below shows a typical intensity spectrum for the output of an X-ray tube using a tungsten target.

(a) (i) Label the **background spectrum** and the **line spectrum**. [1]



(ii) Explain clearly how each of the two spectra is produced; [4]

(I) line spectrum;

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(II) background spectrum.

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(iii) If the X-ray tube is operated at an accelerating pd of 60 kV calculate the minimum wavelength of an X-ray photon emitted from the tube. [2]

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(b) You have the choice of the following forms of medical imaging:

X-ray **ultrasound A-scan** **ultrasound B-scan** **MRI scan** **CT scan**

Which of the above would be the most suitable to image the following? Give a reason for each answer. [6]

(i) The development of an unborn baby.

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(ii) A lung tumour in a patient who wears a pacemaker (metal container).

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(iii) A brain tumour in an adult patient.

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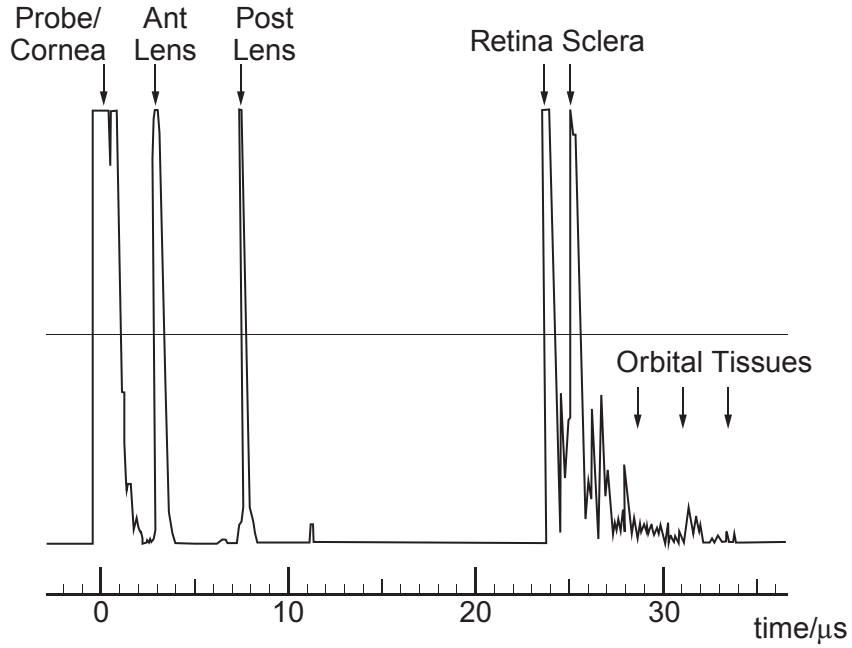
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(c) Ultrasound A-scans can be used on the human eye in order to obtain accurate measurements of the thickness of the lens. Below is a copy of such a scan.



Use the information in the diagram to calculate the lens thickness. The spike labelled 'Ant Lens' corresponds to the front of the lens and the spike labelled 'Post Lens' corresponds to the back of the lens. The velocity of ultrasound in the lens is 1640 m s^{-1}. [3]

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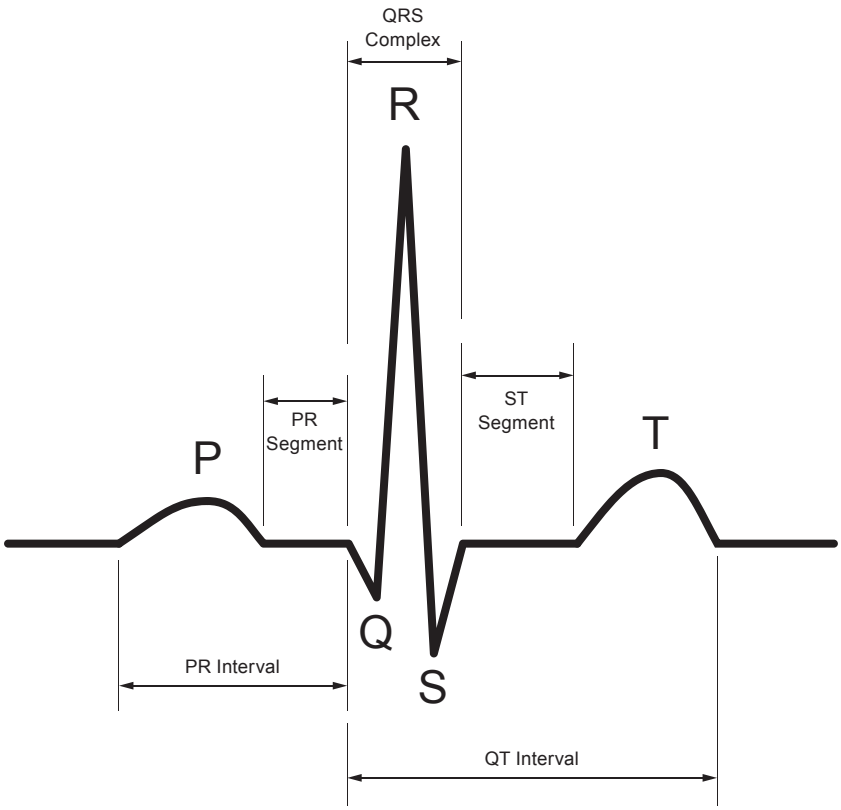
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(d) The diagram below shows an ECG trace for a healthy person.



What changes would you expect to the above pattern if:

(i) a person had high blood pressure due to the ventricles working too hard; [2]

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(ii) the atrium was not contracting properly; [1]

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(iii) the ECG trace was taken for a person who had recently had a mild heart attack (myocardial infarction MI)? [1]

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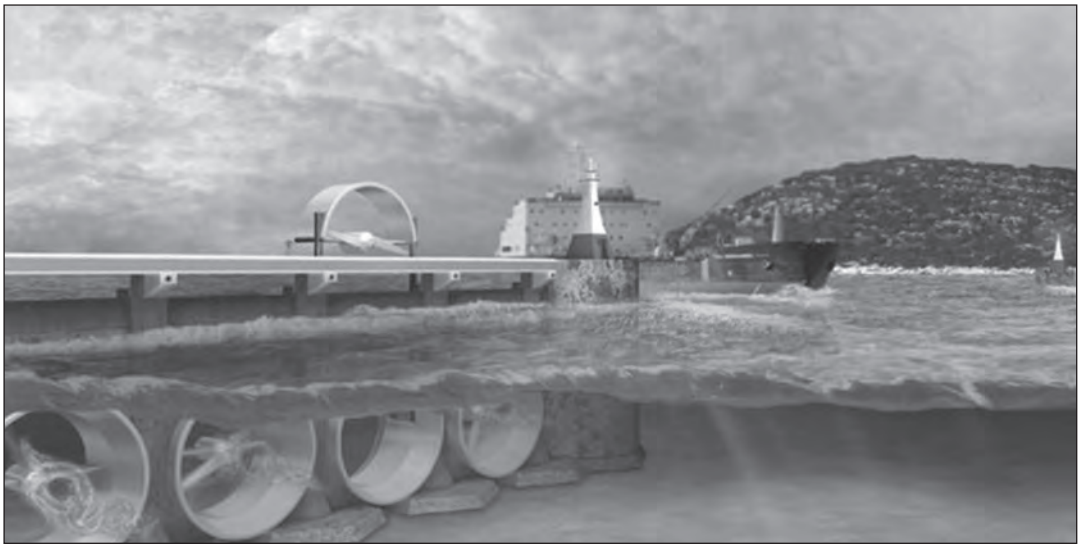
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Option E: Energy matters

12. One possible scheme to decrease CO_2 emissions for the UK is to build a Severn barrage and to use the twice daily motion of tidal water in the Bristol channel for electricity production.



(a) Discuss briefly two points:

(i) in favour of this scheme (note that merely stating: 'to decrease CO_2 emissions' will not be enough for a mark); [2]

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(ii) against this scheme. [2]

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(b) Write down the two energy **conversions** associated with this scheme. [2]

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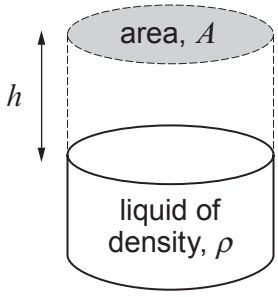
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(c) A column of liquid of density, ρ, has an area, A. The column is increased in height by a distance, h (see diagram). Show that the increased potential energy is given by:

$$\text{PE} = \tfrac{1}{2} A\rho g h^2$$

where g is the acceleration due to gravity. [3]



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(d) The mean tidal height *(h)* in the Severn estuary is 14 m, the area of water the proposed scheme covers is 140 km^2, the density of sea water is 1 025 $kg\,m^{-3}$ and there are approximately 2 high tides every day. Estimate the average power output of the scheme assuming an efficiency of 75%. [4]

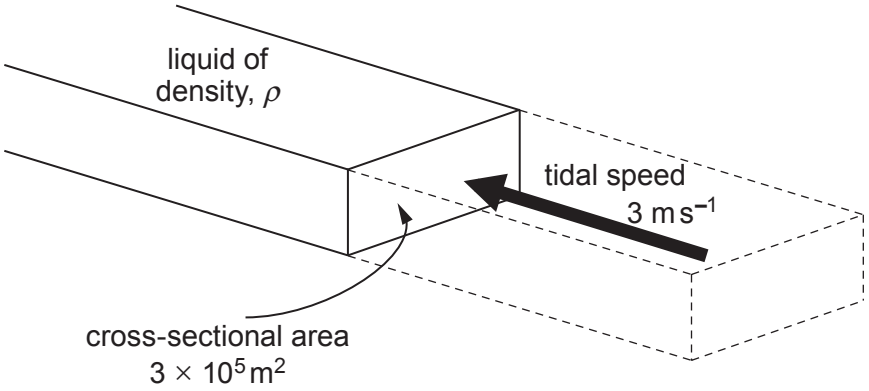
(e) (i) Another scheme has been proposed without the need to trap the water at high tide. This would employ turbines rotating almost continually as the tide flows in both directions. State the **two** main advantages of this type of scheme. [2]

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(ii) The mean cross-sectional area of the Severn estuary is approximately $3 \times 10^5 \text{ m}^2$ and its mean tidal speed is approximately 3 m s^{-1}. By considering the mass and energy of the water passing this cross-section per second, estimate the mean power obtainable by this alternative method (density = $1\,025 \text{ kg m}^{-3}$ and efficiency = 75%). [4]



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(iii) Explain briefly why the **mean** tidal speed included in the calculation above is an underestimate of the value that should actually be used. [1]

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GCE A level

1325/01-B

PHYSICS – PH5
ASSESSMENT UNIT

A.M. THURSDAY, 19 June 2014

CASE STUDY FOR USE WITH SECTION B

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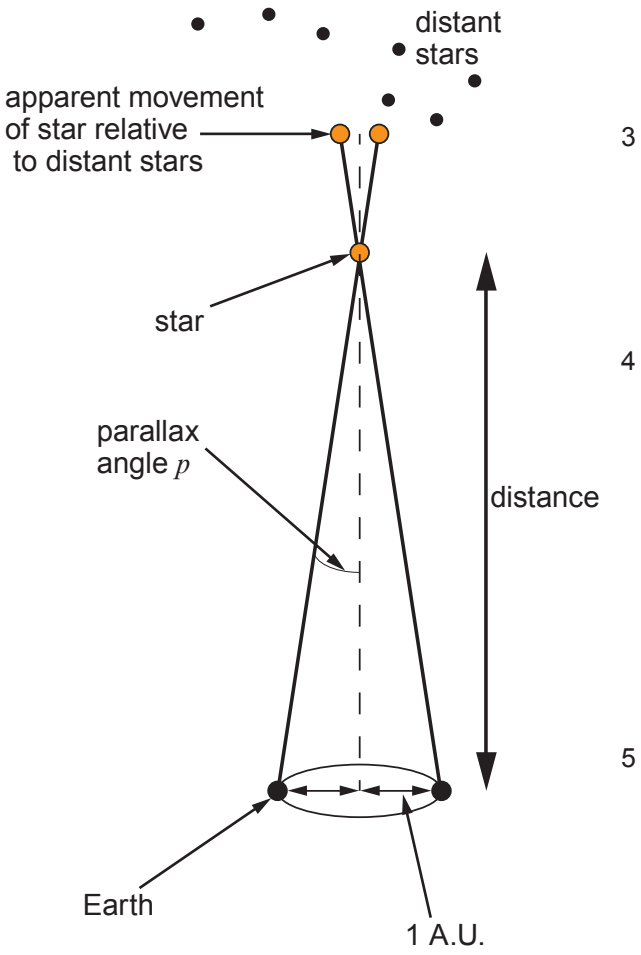
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Paragraph

How do we measure the properties of stars?
(freely adapted from Elementary Astronomy lecture course given at Pennsylvania State University, original notes written by Professor Robin Ciardullo).

Parallax is rather a useful effect when studying stars, it can tell us how close the nearest stars are. The motion of the Earth around the Sun provides the parallax and we can measure the parallax angle. For the nearest stars, this angle is about one arcsecond, that is, $\frac{1}{60}$ of $\frac{1}{60}$ of one degree ($\frac{1}{3600}$ of a degree). For comparison, the angular size of the Moon is $\frac{1}{2}$ of a degree. Thus, if you divide the Moon into 1800 pieces, you'll get 1 arcsecond. 1

Through the trigonometry of the extremely skinny triangle on the right, we can then measure a distance. 2



Astronomers always try to make things as easy as possible for themselves. They define a new unit of distance, called the **parsec**. 3

One parsec is **the distance a star would have if it had a parallax angle of 1 arcsecond.** (For those who insist on numbers, it's about 206 265 Astronomical Units, or 3×10^{13} km or 3.25 light years.) Note that by defining a parsec in this way, the relationship between the measured parallax angle and the implied distance is trivial. If a star has a parallax of 1 arcsec, its distance is 1 parsec. If it has a parallax of $\frac{1}{2}$ arcsec its distance is 2 parsec. If it has a parallax of $\frac{1}{10}$ arcsec, its distance is 10 parsecs. And so on. 4

If we measure the distance to a star, and we measure how bright a star appears in the sky, we can then figure out the star's intrinsic brightness i.e. how bright the star really is. (Is the star a matchstick in front of our eyes, or a searchlight far away?) This is done using the inverse square law of light, which relates the intrinsic luminosity, L to its apparent luminosity I by: 5

$$I = \frac{L}{r^2}$$ where r is the distance.

Astronomers don't measure brightness in terms of watts (or even gigawatts). Sometimes they use **solar luminosities,** which is how bright a star is compared with the Sun. (For reference, the Sun is equivalent to a 4×10^{26} W light bulb!) More often (unfortunately), they use **absolute magnitude.** 6

Apparent magnitude describes how bright a star appears in the sky. Vega's apparent magnitude is defined as zero. Deneb's apparent magnitude is close to 1; Polaris (the North Star) is close to 2. The faintest star you can generally see has an apparent magnitude of around 3 or 4. The faintest star you can see out in the desert far from the lights of a city has an apparent magnitude of 6. Note that the magnitude scale goes backward – big numbers represent faint stars. Also note that magnitude scale works the way the human eye does, 7

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Paragraph

which is logarithmically. This means that each magnitude is 2.5 times fainter than the previous magnitude. A star with apparent magnitude m = **1** is 2.5 times fainter than a star with m = **0**. A star with m = **2** is 2.5 × 2.5 = 6.25 times fainter than one with m = **0**. And so on. In fact, a difference of 5 magnitudes is defined as being equivalent to a factor of 100 in brightness.

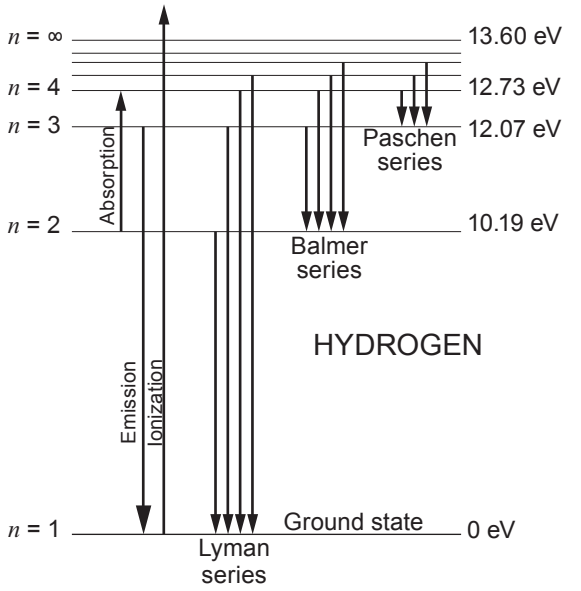
The apparent magnitude of a star describes how bright the star appears. The absolute magnitude of a star describes the star's intrinsic brightness, Absolute magnitude is defined in this way – **a star's absolute magnitude is the apparent magnitude the star WOULD have IF it were at a distance of 10 parsec.** The Sun has an apparent magnitude of –26. However, if the Sun were 10 parsecs away from the Earth, it would be much fainter; its apparent magnitude would be about 5 (you wouldn't normally be able to see it). So the Sun's absolute magnitude is 5. For stars other than the Sun, the formula that relates apparent magnitude, absolute magnitude and parallax angle is: 8

$$M = m + 5(1 + log_{10}p)$$

where M is the absolute magnitude, m is the apparent magnitude and p is the star's parallax angle in arcseconds.

Stellar surface temperatures are relatively easy to estimate. One way to do this is to estimate the star's colour. The redder the star, the cooler it is; the bluer the star, the hotter it is. But there's another way to measure a star's temperature, which works even when (for one reason or another), the colour method doesn't work well. The method involves looking at the star's spectrum. 9

Stars are made mostly of hydrogen and helium. Nine out of ten atoms in the universe are hydrogen atoms. Nine out of ten of what's left is helium. So, when we observe the spectrum of a star, we should see mostly hydrogen and helium. We don't, and the reason comes from the atomic physics of the individual elements. 10



To understand this, let's consider the hydrogen atom as an example. Like all atoms, hydrogen has multiple levels for its electron. It turns out that for hydrogen, the distance between the first level and the second level is huge – it's equivalent to a far ultraviolet photon. Optical absorptions for hydrogen only occur when an electron in the second level grabs a photon and goes up to a higher level. This atomic structure has an interesting consequence. 11

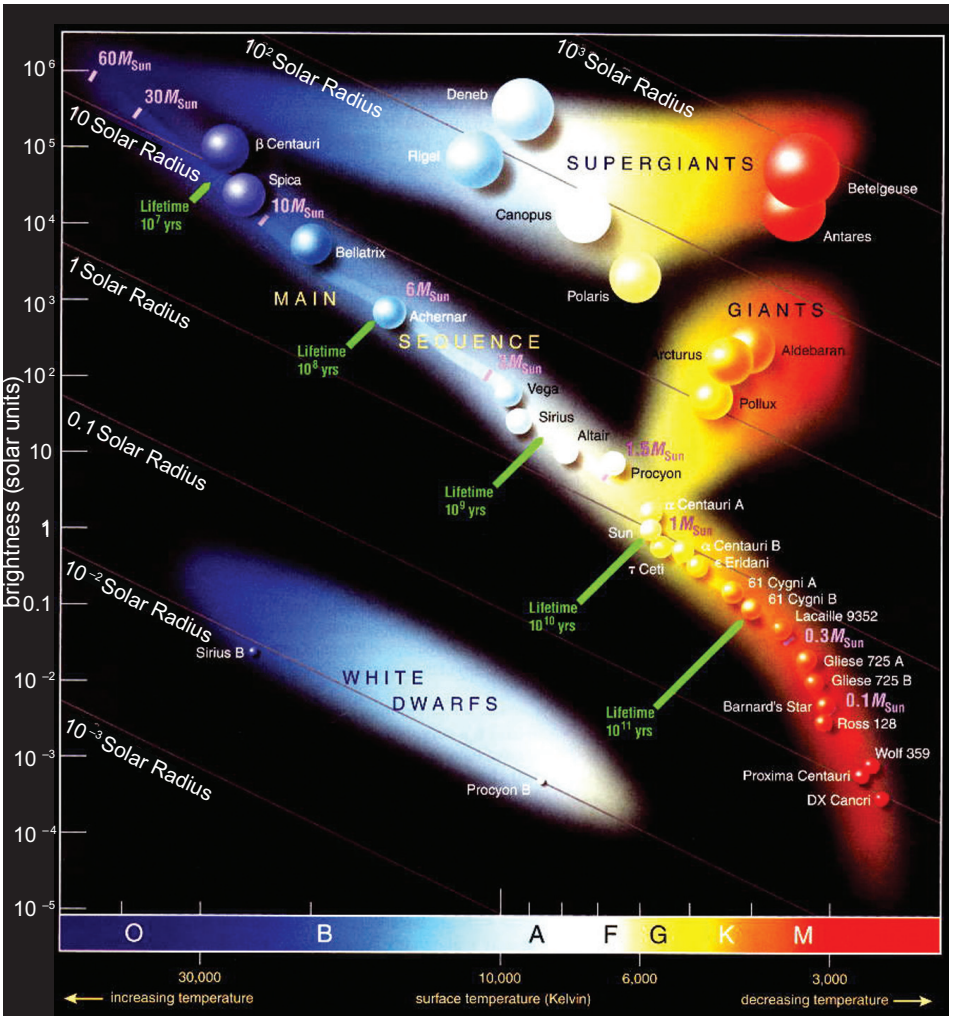
Consider hydrogen in the atmosphere of a cool, red star. Virtually all the hydrogen will have its electrons in the ground (lowest) state. In order for one of these electrons to be in the second level, where it can grab an optical photon, it either has to *(a)* absorb an ultraviolet photon of the proper energy, or *(b)* be hit by something that has enough energy to push it up. But, in the case of a cool star, there are hardly any ultraviolet photons to absorb, and the atoms are moving so slowly that none of the collisions are hard enough to move an electron to a higher energy level. As a result, in cool stars, there are no hydrogen atoms that have their electrons in the second level, and therefore there are no **optical** absorption lines from hydrogen. 12

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Paragraph

Now consider a very hot star. This hot star emits many high energy photons, and many of these are energetic enough to kick a hydrogen electron completely out of the atom (i.e. to ionize the atom). If all the hydrogen atoms have lost their electrons, then there won't be any hydrogen electrons in the second energy level, and again, there will be no optical absorption from hydrogen. So hot stars, like cool stars, will show no hydrogen absorption lines in the visible range. Thus, if one sees strong hydrogen absorption, the star must be of intermediate temperature (it is strongest at about 10 000 degrees). 13



So far, we have discussed how to derive the intrinsic luminosity of a star and the star's temperature. When astronomers find out two properties of an object (such as a star), the first thing they usually do is plot one versus the other. This is the **Hertzprung-Russell diagram,** otherwise known as the HR diagram. The x-axis of the HR diagram gives the stars' temperatures (or, equivalently their colour, or spectral type). Because astronomers like to do things backwards, hot blue, O-stars are plotted on the left, and cool, red, M-stars are plotted on the right. The y-axis of the HR diagram gives the stars intrinsic luminosity (or absolute magnitude). Bright stars are at the top of the diagram, cool stars are near the bottom. An overwhelming majority of stars (more than 90%) fall in a band across the diagram, going from cool and faint to hot and bright. This band is called the **main sequence** and it makes sense. Recall that from the blackbody law, hot objects radiate a lot more energy than cool objects (by temperature to the fourth power). So, it is reasonable that cool stars are faint and hot stars are bright. However, there are some peculiar stars that do not fall on the main sequence. In particular, some stars are both very red and very bright, while others are very blue and very faint. Let's consider the red stars first. Each square metre of these stars must be relatively faint, since cool objects do not radiate much light. The only way that these stars can be bright is to be enormous (i.e. they must have a lot of square metres). We will call these **red giant stars**. Conversely, the only way very hot stars can be faint is to be exceedingly small. These are **white dwarf** stars (though a better name would be blue dwarf stars). 14

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Paragraph

Note that in reality, the brightness of a star depends on two factors: its temperature and how much surface area the star has. In other words:

$$L = br^2T^4 \quad (15)$$

where L is the absolute luminosity of the star, r is the star's radius, T is the star's surface temperature, and b is a number to make the units come out all right. Note also that the radius of the star is plotted with a dashed line in the HR diagram – the lower left (blue) of the diagram is small, while the upper right (red) end of the diagram is large.

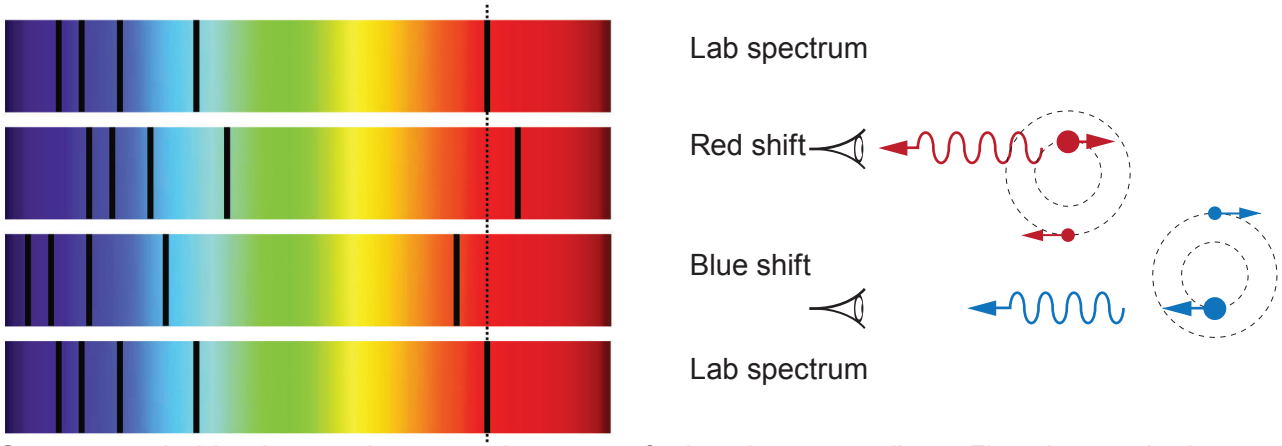
Another important property to understand is stellar mass. Stars can be 'weighed' using the laws of Kepler and Newton. Recall that Newton's modification to Kepler's 3rd law is:

$$(M + m)T^2 = a^3 \quad (16)$$

where T is the orbital period (in years), a the semi-major axis of the orbit (in astronomical units), and M and m the masses of the two objects (in solar masses). If we could identify **binary stars** that orbit around each other, and if we could measure their period and their semi-major axis, we could measure their total mass.

The universe is kind to us. Perhaps $\frac{1}{2}$ of all stars are binary stars. Astronomers have different names for these stars, which depend on how we identify and perceive their binary nature. Here's a list of terminology; note that the same stars can occasionally fall into more than one category. (17)

Spectroscopic Binary. This is an extremely important type of binary star. For spectroscopic binaries, the two stars are so close together that an astronomer only sees one object (usually only the brighter of the two stars). However, over time, the astronomer will see that the Doppler shift changes. First, the star will be moving towards us; then away from us; then towards us again. Spectroscopic binaries can have periods of months, days, hours, or even minutes! (18)



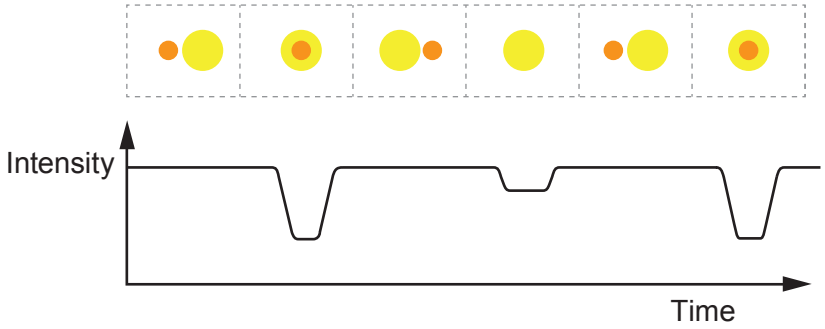
Spectroscopic binaries are important because of what they can tell us. First, by monitoring the Doppler shift, one can time how long it takes to complete one forward-backward-forward cycle. That's the star's period. Next, again, from the Doppler shift, one can determine the star's velocity. Velocity times time equals distance, so this gives you the size of the star's orbit, and, with a minimal amount of mathematics, the orbit's semi-major axis. The law of gravity then gives you the total mass of the two stars. (19)

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Paragraph

If one star is very bright, while the other is very faint, then you will only see the absorption lines of the bright star. In this case, the star is a **single-line spectroscopic binary** and you can't do any more with it. However, if both stars are about equal brightness, then you may see absorption lines from both stars. While one star is moving towards you, the other will be moving away from you. The relative speeds of the stars tell you the relative mass: the more massive star will be moving slowly, while the less massive star will be moving rapidly. In this **double-line spectroscopic binary** case, you can not only measure the total mass of both stars together, but the mass ratio of the stars. You thus have individual masses. 20



Eclipsing Binary. Eclipsing binaries are like spectroscopic binaries in that the astronomer only sees one object. However, in this case, one star occasionally gets in the way of the other, i.e. one star eclipses the other. When this happens, the light from the system decreases. By following the object's **light curve,** one can measure the star's period. Eclipsing binaries are important because for these stars, you know the orientation; the plane of the orbit is along your line-of-sight. 21

If you measure the absorption lines of an eclipsing binary, you'll find it to be a spectroscopic binary. Since the inclination of the stars is known, then there is no ambiguity about the mass determination from the Doppler shift. Moreover, by timing how long it takes for the stars to move into and out of eclipse, and by noting how fast the stars are moving, it is possible to use these systems to measure not only a star's mass but also its size. 22

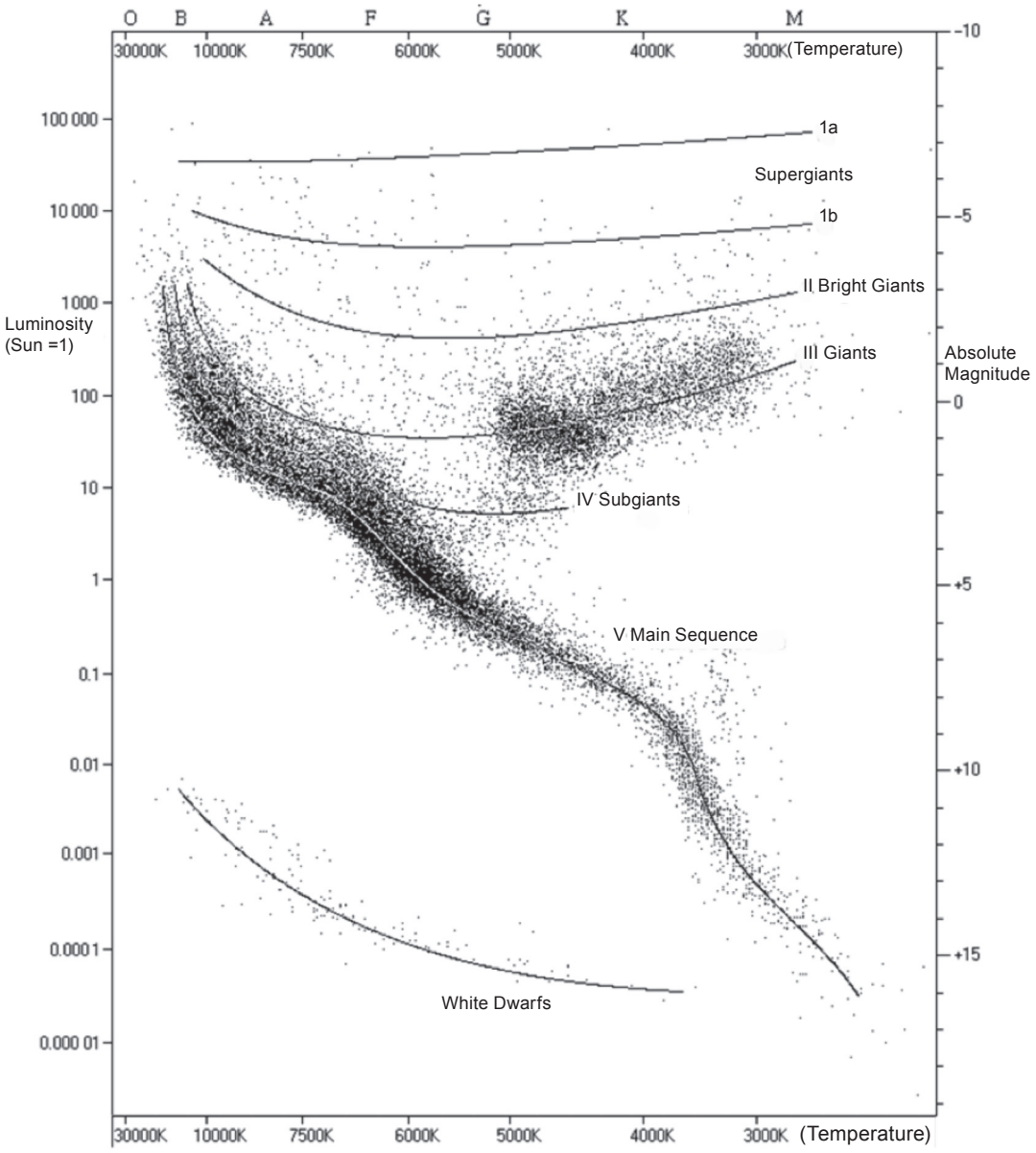
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Paragraph

Incredible though it may seem, each dot on the Hertzsprung-Russell diagram represents a nearby star. All this information on thousands of stars has been gathered using little more than the theories discussed in this article. The equipment used were basic mirrors, prisms (or gratings) and light detectors. However, let it not be forgotten the amount of work required to collate this quantity of data and the intelligence of the few with the insight to develop these theories in the first place. 23

Spectral Class



END OF PAPER

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GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2014

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INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2014 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

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PH2	6
PH3	10
PH4	13
PH5	20
PH6	36

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Question			Marking details	Marks Available
1	*(a)*	(i)	Attempt at 6n + 6p - mass of carbon nucleus (1) × 931 and ÷12 **or** $E = mc^2$ and ÷12 (1) Correct answer = 7.7 [MeV/nucleon] **or** 1.23×10^{-12} [J] (1)	3
		(ii)	Conversion of 7.16 MeV to mass = 0.00769 [u] (1) Conservation of mass-energy 4.0015 + 11.9967 - 0.00769 (1) Answer approx correct e.g. 15.99 u accept (16.07 ± 0.08) [u] **or** $(2.67 \pm 0.02) \times 10^{-26}$ [kg] (1) 15.9905 (accuracy mark, also available for 16.0059 and without unit) (1)	4
	(b)	(i)	Neutron absorber **or** high melting point (**or** other valid response)	1
		(ii)	Light nucleus **or** poor neutron absorber **or** slows down neutrons (**or** other valid response)	1
		(iii)	High heat capacity **or** poor neutron absorber **or** doesn't become radioactive (**or** other valid response) Don't accept must be a fluid **or** good ability to conduct heat away	1
			Question 1 Total	**[10]**

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Question			Marking details	Marks Available
2	*(a)*	(i)	Mass number = 206 (1) Atomic number = 82 (1)	2
		(ii)	Gas can be <u>inhaled</u> (1) (Don't accept if state both ingest and inhale) **Any 2 (×1) from:** • Dense gas **or** stays in basements • Alpha <u>highly</u> ionising • Multiple emissions i.e. more than 1 alpha (do not accept emits alpha and beta by itself) • Short half-life • Contaminates wells • Enters through cracks Don't accept high activity **or** contaminates water supply **or** alpha particles are breathed in **or** causing cancer	3
	(b)		Use of $\lambda = \frac{ln2}{T_{1/2}}$ e.g. $\lambda = 0.182$ [day^{-1}] (2.11×10^{-6} s^{-1}) **or** $t = nT_{1/2}$ (1) Logs taken correctly e.g. $\ln A = \ln A_0 - \lambda t$ **or** $\ln A = \ln A_0 - n\ln 2$ (1) Algebra correct e.g. $t = \frac{1}{\lambda}\ln\frac{A_0}{A}$ **or** $n = \frac{1}{\ln 2}\ln\frac{A_0}{A}$ **or** implied (1) Correct answer 13.2 [days] (1.14×10^6 [s]) (1)	4
	(c)		Daughter nuclei give added activity	1
			Question 2 Total	**[10]**

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Question			Marking details	Marks Available
3	*(a)*	(i)	Values substituted into $C = \frac{\varepsilon_0 A}{d}$ (= 7.32×10^{-9} F) (1)	3
			$Q = CV$ (**or** implied) note $C = \frac{Q}{V}$ not good enough (1)	
			Answer = 9.37×10^{-7} [C] (1)	
		(ii)	Answer = 6.0×10^{-5} [J] (**ecf**)	1
		(iii)	$E = \frac{V}{d}$ (1)	2
			Answer = 2 170 000 [V m^{-1}] (1)	
	(b)	(i)	Capacitance decreases (1)	2
			Energy stored increases (1)	
		(ii)	Work done by separating plates **or** work done against field **or** increase in potential energy (1) (accept energy used instead of work done)	2
			Equal to increase in stored energy (1)	
			Question 3 Total	**[10]**

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Question			Marking details	Marks Available
4	*(a)*		$n = \frac{9560}{1.45}$ (1) Correct answer = 2.65×10^{-3} T **UNIT mark** (1)	2
	(b)		$B = \frac{\mu_0 I}{2\pi a}$ used (e.g. 2.82×10^{-6} [T] **or** 4.35×10^{-6} [T] **or** 10^{x} slips) (1) Subtracting **or** adding fields (1) 1.53×10^{-6} [T] no **ecf** (1) Out of paper (1)	4
	(c)		Equating fields e.g. $\frac{\mu_0 \times 0.24}{2\pi \times a} = \frac{\mu_0 \times 0.37}{2\pi \times (0.034 - a)}$ **or** $\frac{\mu_0 \times I_1}{2\pi \times a} = \frac{\mu_0 \times I_2}{2\pi \times b}$ (1) (Accept $\frac{a_1}{a_2} = \frac{0.37}{0.24}$ (= 1.54 or 0.65 reciprocal)) Algebra $\frac{0.24 \times 0.034}{(0.37+0.24)} = a$ **or** $\frac{0.37 \times 0.034}{(0.37+0.24)} = a$ **or** $a = \frac{1.54}{2.54} \times 0.034$ etc (1) Answer = 0.0134 [m] **or** 0.0206 [m] but must be clear from algebra, working **or** statement that the point is nearer the upper wire (1)	3
			Question 4 Total	**[9]**

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Question			Marking details	Marks Available
5	*(a)*		$F = Eq$ (**or** eE) used **or** implied (1) $E = \frac{V}{d}$ **quoted or** implied (1) $a = \frac{F}{m}$ used **or** implied (1) $a = \frac{11.2\text{x}1.6\text{x}10^{-19}}{9.11\text{x}10^{-31}\text{x}7.6\text{x}10^{-3}}$ $[= 2.588 \times 10^{14}]$ (1) N.B. Use of $a = \frac{Eq}{m}$ **or** $F = \frac{Vq}{d}$ **award 2 marks or** $a = \frac{Vq}{md}$ **award 3 marks**	4
	(b)	(i)	No horizontal forces (don't accept no horizontal acceleration **or** because it's in a vacuum)	1
		(ii)	Constant vertical force **or** uniform electric field	1
	(c)		Valid method for obtaining time e.g. $s = ut + \frac{1}{2}at^2$ (1) Time correct = 5.4×10^{-9} [s] (1) Answer = $8.00 \times 10^{7} \times 5.4$ ns = 43 [cm] **(ecf)** (1) (factors of 10 or $\sqrt{10}$ slips only penalised 1 mark)	3
	(d)		Valid method e.g. definition of eV, force × distance, getting resultant velocity and finding change in $\frac{1}{2}mv^2$ (1) Answer = 5.6 [eV] (which can simply be written for full marks) **or** 8.96×10^{-19} [J] **(ecf)** (1) (answer of 11.2 eV gets 1/2 marks)	2
			Question 5 Total	**[11]**

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Question			Marking details	Marks Available
6	*(a)*	(i)	Flux linkage = $NBA\cos\theta$ used (1) 0.251 [Wb] [and 0.251 Wb] (1)	2
		(ii)	No change in flux [linkage] **or** field lines cut in one direction and then the opposite direction Don't accept rate of change of flux is 0	1
	(b)		Flux linkage = 0.0443 **or** -0.0443 (1) Time = $\frac{20}{360} \times 0.1$ (1) Attempt at change of flux (linkage) divided by time (1) Answer = [-] 15.9 [V] (1)	4
	(c)		Peak emf = 17 [V] Sinusoid with peak of 3.4 squares high (**ecf)** (1) Sinusoid with period of 4 squares (1)	3
			Question 6 total	**[10]**

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Question			Marking details	Marks Available
7	(a)		**Any 2 (×1) from:** • Near stars move relative to distant stars [due to Earth orbit] • More movement (or larger angle) means stars nearer (inversely proportional etc.) or accept parsec = 1/arcsec • Parallax (or distance) can be measured from readings 6 months apart (or accept readings where Earth movement is known etc.)	2
	(b)		4 parsec **or** angle = $1.5 \times 10^{11}/d$ (1) $4 \times 3.25 = 13$ [light year] (1)	2
	(c)		10× distance gives <u>100 times</u> less intensity (1) Substituting 1 and 0.1 into equation **accept 1 and 10** (1) $m = M - 5$ and $m = M$ shown (1) **Alternative:** 2.5^5 roughly equal to 100 **award 2 marks**	3
	(d)		1[%] Accept 0.01 but not 0.01 %	1
	(e)		Electrons need to be in the high energy levels (1) They need to be in $n = 3$ (1st mark can be implied in the 2nd mark) (1) Not possible because no ultraviolet to absorb **or** collisions don't have enough KE (1)	3
	(f)		Comparison with $4\pi r^2 \sigma T^4$ **or** $b = 4\pi\sigma$ (1) Answer $b = 7.13 \times 10^{-7}$ (1) Unit = W m^{-2} K^{-4} **or** equivalent (1)	3

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Question			Marking details	Marks Available
	(g)	(i)	T = 1 (year) and a = 1 (AU) and M = 1 Accept because everything = 1	1
		(ii)	Assuming $M + m \approx 0.32\ M_{Sun}$ (1) $a = \sqrt[3]{0.32 \times 0.46^2} = 0.41$ [AU] (1)	2
	(h)		Drop when large eclipses small (1) And small eclipses large (1) Bigger drop when the hotter/brighter star is blocked (1) **Award 3 marks** for bigger drop when small in front of large	3
			Question 7 Total	**[20]**

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Question			Marking details	Marks Available
8	*(a)*	(i)	Sinusoidal reading on voltmeter @ 0.9 Hz (or across resistor) (1) Sinusoidal (or changing) *B*-field in primary (1) Leads to *B*-field cutting secondary **or** flux changing in secondary (1) emf induced in secondary due to Faraday's (1)	4
		(ii)	Lost flux **or** no iron core **or** low frequency **or** low turns	1
	(b)	(i)	$\omega L = \frac{1}{\omega C}$ **or** $f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ (1) Answer = 4 490 [Hz] (1)	2
		(ii)	V_R = 12 [V] (1) I = 0.067 [A] (1) $V_L = \mathrm{I} \times \omega L$ **or** $V_C = \mathrm{I} \times \frac{1}{\omega C}$ (1) V_L = 71.5 [V] **and** V_C = 71.5 [V] **or** implied e.g. V_C = same (1)	4
8	*(c)*	(i)	$Z = \sqrt{(X_L - X_C)^2 + R^2}$ (1) Z = 581 [Ω] or implied (1) Current $= \frac{12}{581}$ = 21 [mA] (1)	3
		(ii)	Phasor diagram (1) $\tan\theta = \frac{X_L - X_C}{R}$ (this step implies vector diagram if omitted) (1) Answer = 72° **(ecf)** (1) (18° and similar slips gain 1/2)	3
	(d)		$\frac{R}{X_C} = \frac{3}{4}$ (1) $X_C = \frac{1}{2\pi fC}$ **or** $X_C = \frac{1}{\omega C}$ and $\omega = 2\pi f$ **used** (1) Answer = 20 [kHz] (1)	3
			Question 8 Total	**[20]**

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Question			Marking details	Marks Available
9	*(a)*	(i)	Ørsted **or** Oersted (accept Orsted)	1
		(ii)	Battery (not cell)	1
		(iii)	**Any 3 (×1) from:** • Current passed through wire **or** pile connected across wire • Compass turned [nearly] at right angles to wire • When compass above wire points in opposite direction • Compass points according to rh grip (or screw) rule • Field lines circle around wire	3
		(iv)	Electric effect arising from magnetism (or from magnet)	1
	(b)	(i)	Vortices shown separated by (smaller) idlers (1) Vortices and/or idlers labelled (1) Rotation shown or stated (1)	3
		(ii)	**Any 2 (×1) from:** • Maxwell used it to predict e-m waves • Maxwell used it to explain magnetic field due to a wire • Maxwell used it to explain [any other e-m effect!] • Its existence is irrelevant / Maxwell didn't suppose it existed	2

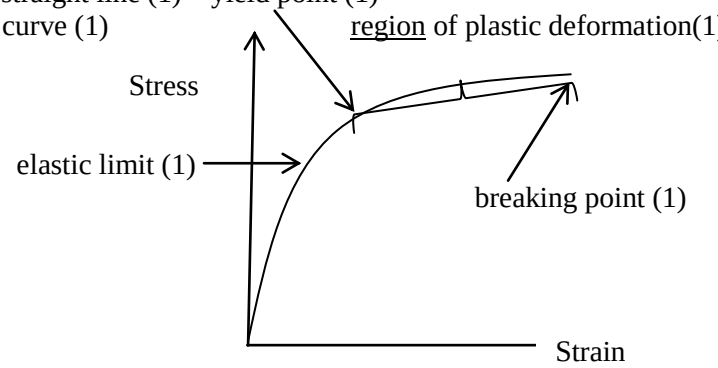
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Question			Marking details	Marks Available
9	*(c)*	(i)	Produced when sparks occurred between [ball-ended] rods [connected to an induction coil or high voltage]. (1) Detected by sparks occurring across spark-gap between rods or across break in ring. (1)	2
		(ii)	He found spark intensity varied according to orientation of detector rods [relative to transmitter rods]. **or** he interposed metal grille between transmitter and detector, finding spark intensity varied with grille orientation.	1
		(iii)	He used metal reflector to produce stationary wave. (1) He measured distance between nodes [and doubled it]. (1)	2
	(d)	(i)	Time between events in a frame in which the events occur at the same place. **or** time between events as measured by a clock present at both events.	1
		(ii)	$\gamma = 1.01$ (1) $t_B - t_A = 0.5000\ \gamma$ (1) despite mistakes in γ $t_B - t_A = 0.5050$ [s] (1) allow **ecf** on γ arising from slips.	3
			Question 9 total	**[20]**

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Question			Marking details	Marks Available
10	*(a)*		Elastic, straight line (1) yield point (1) curve (1) region of plastic deformation(1)  	6
	(b)	(i)	DE broken **or** E bonds with B (1) HG broken **or** H bonds with D (1) Movement of dislocations stated (1) Or all clearly seen from diagrams	3
		(ii)	No dislocations (or equivalent) **or** no grain boundaries Don't accept addition of foreign atoms Don't accept single crystal (stated in question)	1
		(iii)	Any valid use e.g. Turbine blades (don't accept wind turbines), combustion chambers, nuclear reactors, wear resistant materials, rocket engines etc.	1
	(c)	(i)	$\frac{Fl}{2\times10^{11}A_{steel}} = \frac{Fl}{1\times10^{11}A_{brass}}$ (1) Convincing algebra to show $A_{brass} = 2\times A_{steel}$ (1) (**alternative:** force, length and extension all the same 1 mark so brass must have twice the CSA 1 mark only – not fully shown as required)	2
		(ii)	50 [N]	1
		(iii)	$\Delta x = \frac{50\times2}{\left(2.8\times10^{-7}\right)\times2\times10^{11}}$ (1) – substitution (**ecf** on 50 N) Δx = 1.8 [mm] (1) (correct unit required m or mm)	2
		(iv)	E = ½ Fx (1) (accept $\boldsymbol{E = \frac{1}{2}\sigma\varepsilon V}$) E = 0.044 [J] (1) **(ecf** on Δx only)	2
		(v)	Same (1) F and Δx same (1)	2
			Question 10 total	**[20]**

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Question				Marking details	Marks Available
11	*(a)*	(i)		Both background and line spectra labelled clearly	1
		(ii)	I	[Inner] electrons [of target element] knocked out / ionised (1)	4
				Electrons from higher energy levels fall to take their place (1)	
			II	Rapid deceleration of <u>electrons</u> (1)	
				On collision with target element / nucleus (1)	
		(iii)		$\lambda = \frac{hc}{eV}$ (or rearrangement in figures) (1)	2
				$\lambda = 2.07 \times 10^{-11}$ [m] (1) Accept 2.1×10^{-11} [m]	
	(b)	(i)		Ultrasound B-scan (1)	6
				Moving pictures/ see organ development **not** 'give a 2D image' (1)	
		(ii)		CT scan (1)	
				Distinguishes soft tissue well (1)	
				Accept MRI cannot be used because of pacemaker	
		(iii)		MRI scan (1)	
				Gives high quality images of soft tissue (1)	
	(c)			Time taken from scale 5 ± 1 [μs] (1)	3
				Distance = 8.2×10^{-3} [m] (1) **(ecf)**	
				Thickness = $\frac{8.2 \times 10^{-3}}{2} = 4.1 \times 10^{-3}$ [m] (1)	

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Question			Marking details	Marks Available
11	*(d)*	(i)	QRS wave / R / central spike (1) Bigger / higher /more spiked (1)	2
		(ii)	P wave flatter / P wave extended/ prolonged PR interval / no P wave / smaller P wave / P wider / P lower amplitude	1
		(iii)	Deepening of Q wave / T wave inversion / ST elevation / ST depression {Irregular interval / inverted waves / bigger distance P to QRS to T wave} N.B. any incorrect statement negates the mark	1
			Question 11 total	**[20]**

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Question			Marking details	Marks Available
12	*(a)*	(i)	**Any 2 ×(1) from:** • Possible second use as a bridge • Cheap electricity after build • Zero or low CO_2 after built • High output • Predictable output • Sustainable/renewable/reliable energy source that will not run out	2
		(ii)	**Any 2 ×(1) from:** • Only available twice a day (i.e. not a constant output) • Possible huge impact on Severn estuary wildlife • High CO_2 costs to build • Expensive to build (£3k per kW as opposed to £1k per kW coal)	2
	(b)		GPE (PE not good enough) to KE **or** GPE to electrical (1) KE / mechanical to electrical **or** const KE when running (1)	2
	(c)		Mean height increase = 0.5 h must be stated **not** implied (1) Either volume = Ah **or** mass = $Ah\rho$ (1) Correct substitution into mgh **(ecf)** (1)	3
	(d)		Values substituted into equation (1.38×10^{14} J) (1) ×2 (or using time as 12 hrs) and × 0.75 (1) Dividing by time or $P = E/t$ etc. (1) Answer = 2.4 [GW] **(no ecf)** (1)	4

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Question			Marking details	Marks Available
12	(e)	(i)	**Any 2 ×(1) from:** • Continuous electricity not twice a day • Less damage to environment • Less impact on shipping	2
		(ii)	Mass per second = $A\rho v$ (or implied) (1) KE per second = 0.5 $A\rho v\, v^2$ (or good attempt at $0.5mv^2$) (1) × 0.75 (1) Answer = 3.1 [GW] **(no ecf)** (1)	4
		(iii)	Because $\propto \lvert v^3 \rvert$(accept v^2, v^3 *etc.*) and we need $\lvert \overline{v^3} \rvert$ not $\lvert \bar{v} \rvert$ Wordy answers also valid e.g. 'if speed is 1.5 and 4.5 say, 4.5^2 will be far more significant than 1.5^2 or 'the power output for high speeds will be far greater than for low speeds increasing the mean power' etc.	1
			Question 12 total	**[20]**

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Surname	Centre Number	Candidate Number
Other Names		2

GCE A level

1325/01

PHYSICS

ASSESSMENT UNIT PH5:
Electromagnetism, Nuclei & Options

A.M. THURSDAY, 20 June 2013

1¾ hours

1325
010001

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator, a **Case Study Booklet** and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use pencil or gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet. If you run out of space, use the continuation pages at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 3 sections, **A**, **B**, and **C**.

Section A: 60 marks. Answer **all** questions. You are advised to spend about 1 hour on this section.

Section B: 20 marks. The Case Study. Answer **all** questions. You are advised to spend about 20 minutes on this section.

Section C: Options; 20 marks. Answer **one option only.** You are advised to spend about 20 minutes on this section.

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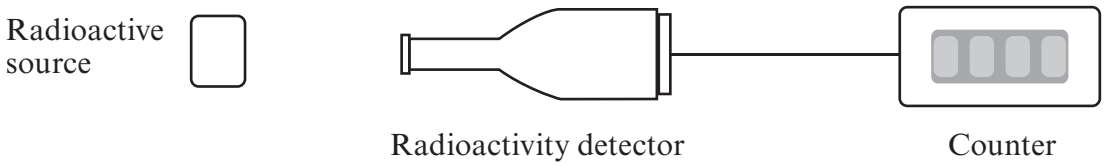
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SECTION A

1. A student is uncertain whether or not a radioactive source emits α, β or γ radiation or a combination of these radiations.

(a) Describe how the student would use a detector and counter along with suitable absorbers to find which radiation(s) are emitted by the radioactive source. [4]



(b) A radioactive isotope has a starting activity of 76.0×10^{15} Bq and a half life of 25.6 days.

(i) Calculate the activity after 51.2 days. ..... [1]

(ii) Calculate the activity after 1 year. [4]

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(iii) Calculate the number of radioactive nuclei present at the start. [2]

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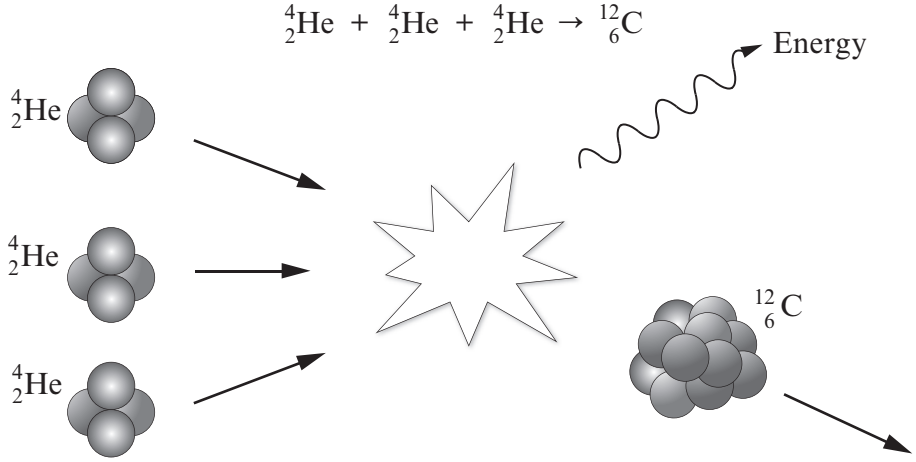
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2. The following fusion reaction can occur inside stars with core temperatures of around 100 million kelvin.

$$^{4}_{2}\text{He} + {}^{4}_{2}\text{He} + {}^{4}_{2}\text{He} \rightarrow {}^{12}_{6}\text{C}$$



(a) Calculate the energy released in the above reaction from the following data. [3]

Mass of $^{4}_{2}$He = 4.0026 u Mass of $^{12}_{6}$C = 12.0000 u 1 u = 931 MeV

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(b) The isotope $^{62}_{28}Ni$ has a binding energy per nucleon of 8.795 MeV/nucleon and this is the highest known binding energy per nucleon.
Calculate the mass of a $^{62}_{28}Ni$ nucleus in unified atomic mass units (u) and give your answer to 5 significant figures. [5]

mass of proton = 1.00728 u, mass of neutron = 1.00866 u, 1u = 931 MeV

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3. *(a)* A 131 nF capacitor is charged using a potential difference of 1.62 V. Calculate the charge stored by the capacitor. [2]

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(b) This 131 nF capacitor is then disconnected from the power supply and a large resistor connected across its terminals. As the capacitor discharges, the pd across it decreases from 1.62 V to 0.47 V in 220 ms. Calculate the resistance of the resistor. [4]

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(c) The plates of this 131 nF capacitor are square and are separated by 0.15 mm. Calculate the length of a side of the capacitor plate. [3]

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(d) In practice, how could the capacitance of this capacitor be increased by a factor of 100? [1]

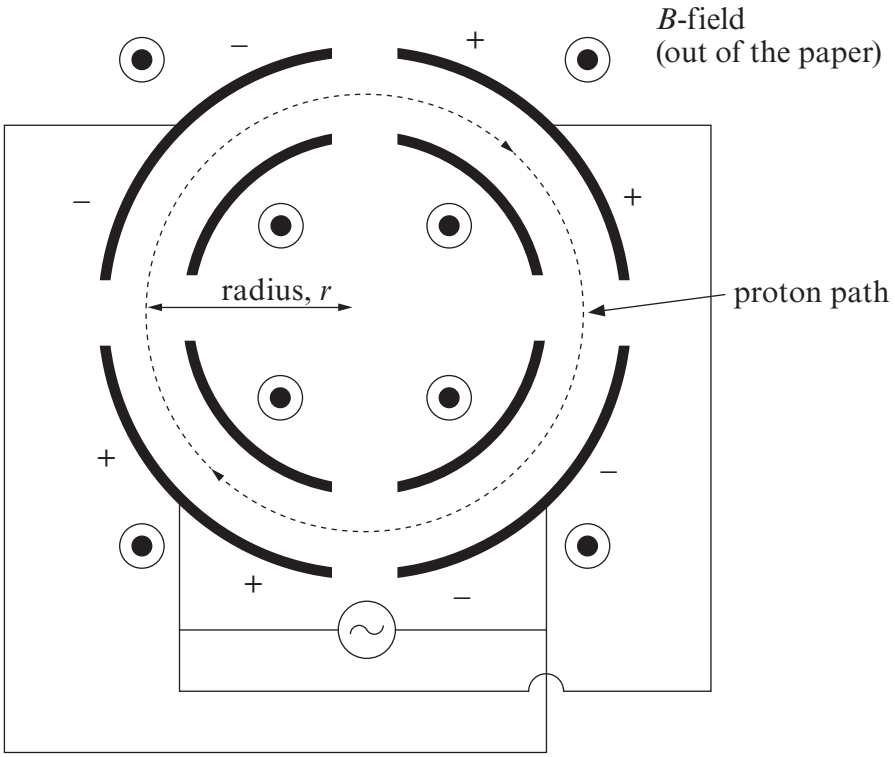
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4. The diagram below is an example of a particle accelerator called a synchrotron. In this synchrotron, protons are accelerated and their path is kept circular by a magnetic field which has to increase as the speed of the protons increases. The protons themselves are accelerated by the alternating potential difference applied to the quarter circle plates (see + and - in the diagram).



(a) Derive the equation $r = \frac{mv}{Be}$ for a particle of mass m and charge e moving with velocity v at right angles to a uniform magnetic field, B. [2]

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(b) Use the equation $r = \frac{mv}{Be}$ to explain why the magnetic field must be increased as the speed of the protons increases. [2]

(c) Protons take 1.78 μs to complete a circuit of a synchrotron of radius 8.50 m. Calculate the strength of the magnetic field, B, required. [$m_{proton} = 1.67 \times 10^{-27}$ kg.] [4]

(d) (i) Modern synchrotrons use magnetic fields up to 10 T which cannot be produced using copper wires at room temperature. Explain why not, using $B = \mu_0 nI$. [2]

(ii) Hence, explain why superconducting magnets are used to produce large magnetic fields in synchrotrons. [1]

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5. *(a)* State the **two** laws of electromagnetic induction (Faraday's law and Lenz's law). [3]

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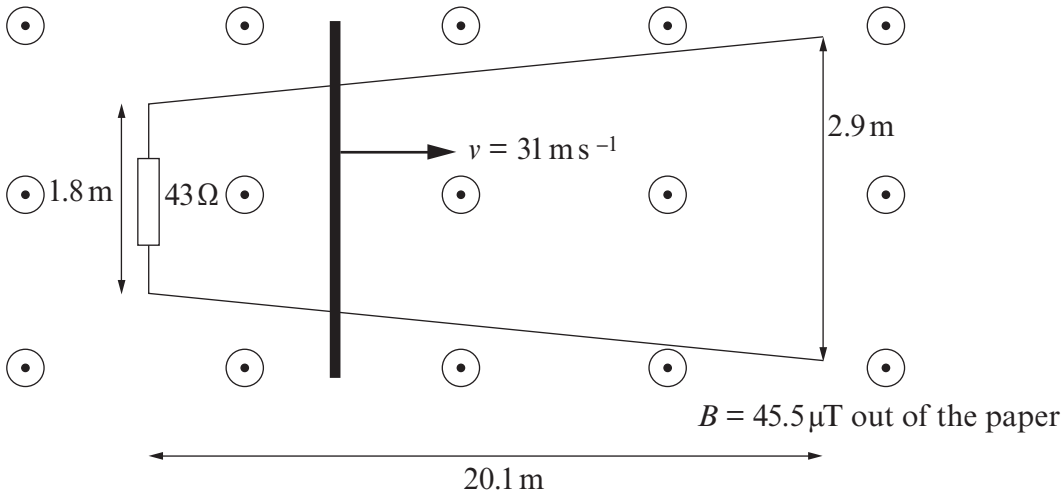
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(b) A thick conducting bar is moved with constant speed over non-parallel conducting rails as shown below. The rails have negligible resistance and the *B*-field is uniform.



(i) Indicate the direction of the induced current on the diagram and explain how you arrived at your answer. [2]

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(ii) The conductor moves at a constant speed of 31 m s^{-1}. Use Faraday's law to explain why the induced emf increases. [2]

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(iii) The conductor starts moving from the end near the 43 Ω resistor. Calculate the mean current in the resistor when the conducting bar has travelled the full 20.1 m length of the track. [4]

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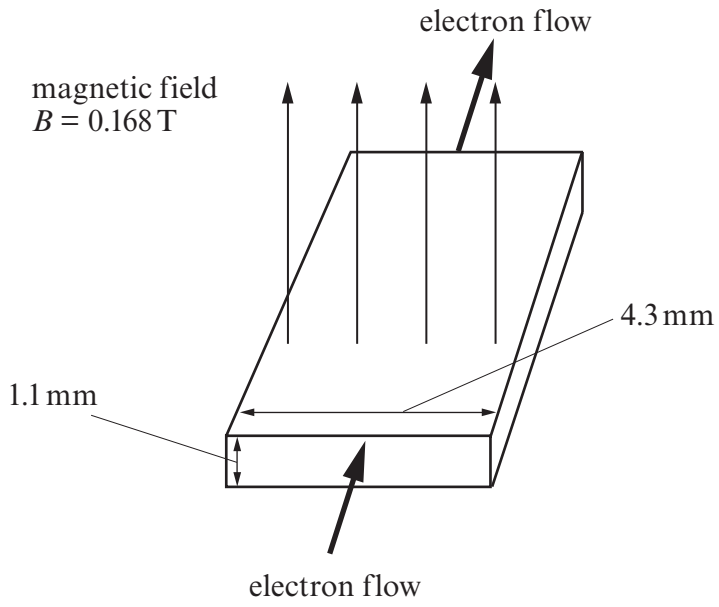
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6. Electrons flow through a silicon wafer which is used as a Hall probe.



(a) Show on the above diagram:

(i) the face of the silicon wafer that becomes positively charged; [1]

(ii) how you would connect a voltmeter to measure the Hall voltage. [1]

(b) Calculate the drift velocity of the electrons given that the Hall voltage is 0.314 mV. [3]

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(c) As electrons move through the wafer, explain why no work is done on them by the electric field, E_H. [1]

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(d) The current flowing in the silicon wafer is 0.38 A. Calculate the number of free electrons per unit volume in the silicon wafer. [3]

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SECTION B

The questions refer to the case study.
Direct quotes from the original passage will not be awarded marks.

7. *(a)* In your own words and referring to diagram 2 in the case study, explain lift in terms of Newton's laws. (See paragraph 3.) [2]

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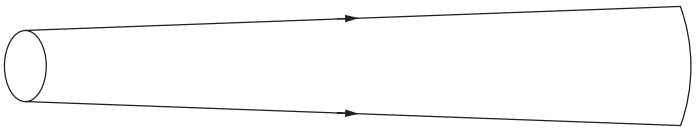
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(b) The streamline diagram shows streamlines getting further apart. Explain why there must be a net force to the left acting on the air in the streamline.
(See paragraphs 6 & 7.) [2]



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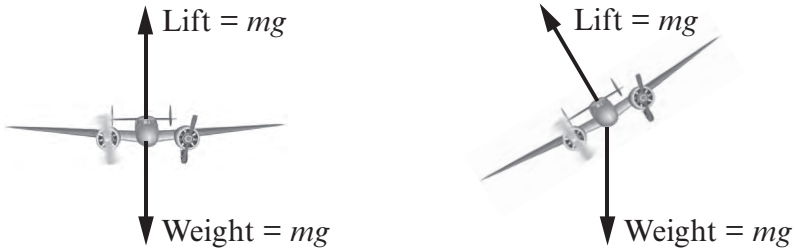
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(c) An aeroplane is initially flying forward at a constant speed horizontally. It then tilts as shown. The magnitude of the lift force remains constant. Explain why the aeroplane must now accelerate downwards and to the left. [2]



(d) Houses can explode when tornados pass nearby. Explain this using Bernoulli's equation. (See paragraphs 7, 8 & 9.) [2]

(e) Check that the figure for lift (130 kN) for a super jumbo wing at $80\,m\,s^{-1}$ is correct if you assume that the speed over the top of the wing is only 2% greater than $80\,m\,s^{-1}$. (See paragraph 13.) [3]

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(f) Show that the lift coefficient has no units. (See paragraph 17.) [3]

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(g) Calculate the lift coefficient for an Airbus super jumbo at take-off. (See paragraph 17.) [2]

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(h) Draw a labelled diagram of the set up that might be employed using a hair dryer, stand, clamp, protractor, digital balance and metal plate to measure lift coefficient against angle of attack. (See paragraphs 18 and 19.) [4]

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SECTION C: OPTIONAL TOPICS

Option A: **Further Electromagnetism and Alternating Currents** ☐

Option B: **Revolutions in Physics - The Newtonian Revolution** ☐

Option C: **Materials** ☐

Option D: **Biological Measurement and Medical Imaging** ☐

Option E: **Energy Matters** ☐

Answer the question on **one topic only.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

You are advised to spend about 20 minutes on this section.

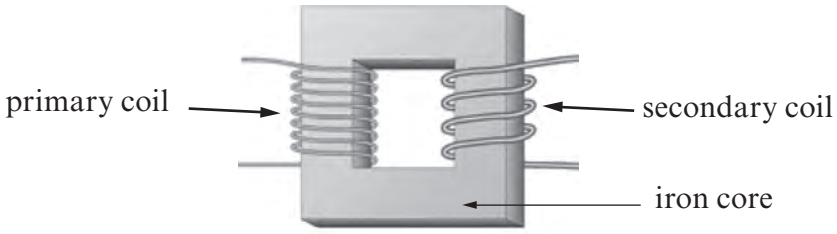
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Option A: Further Electromagnetism and Alternating Currents

8. *(a)* Explain how an alternating current in the primary coil leads to an alternating emf in the secondary coil. [3]



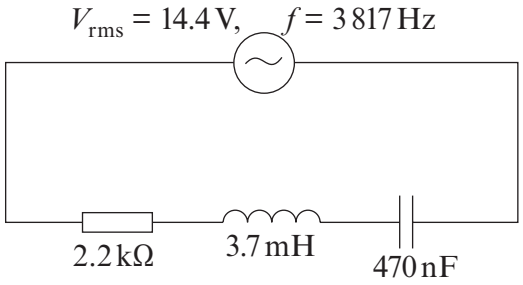
(b) State and explain briefly **three** ways in which the design of a transformer reduces energy losses. [3]

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(c) (i) Calculate the reactances of the capacitor and inductor at the frequency shown. [3]



(ii) How can you tell that this is the resonance frequency of the circuit? [1]

(iii) Calculate the current at the resonance frequency of 3 817 Hz. [1]

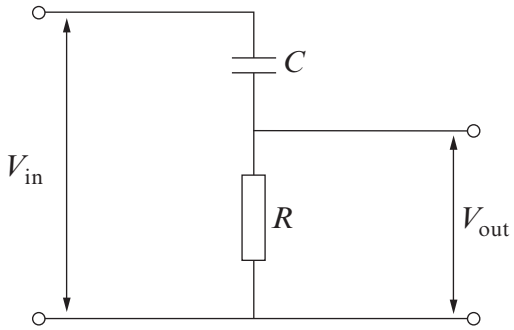
(iv) Calculate the current when the frequency is 38.17 kHz (the rms pd remains 14.4 V). [3]

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(d) (i) Explain why the circuit shown is a high pass filter. [3]



(ii) $C = 470\,\text{nF}$ and $R = 2.2\,\text{k}\Omega$. Using a phasor diagram or otherwise, calculate the frequency when $V_{out} = \frac{1}{\sqrt{2}} V_{in}$. [Hint: $\cos 45° = \frac{1}{\sqrt{2}}$.] [3]

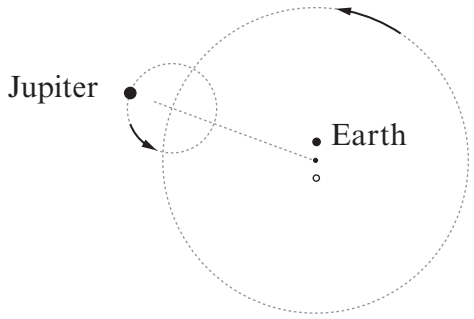
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Option B: Revolutions in Physics - The Newtonian Revolution

9. *(a)* (i) The diagram shows a simplified version of Ptolemy's scheme to account for the observed motion of Jupiter.



(I) **Label on the diagram** the following: *equant, deferent, epicycle.* [2]

(II) Explain whether Jupiter's observed motion is *prograde* or *retrograde* when it is in the position shown. [1]

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(III) Ptolemy's scheme predicts the motions of planets. What other changing feature of planets' appearances does the scheme predict? [1]

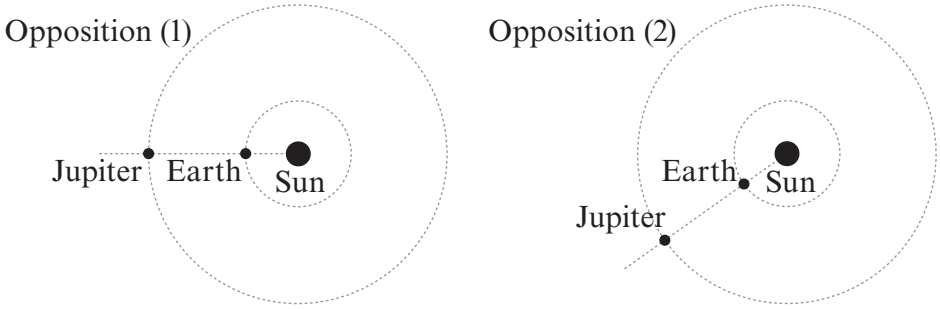
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(ii) The diagrams show two successive *oppositions* of Jupiter and the Sun, as seen on a simplified Copernican scheme. Opposition (2) occurs time Δt after opposition (1).



It can be shown that $\frac{2\pi}{T_E}\Delta t - \frac{2\pi}{T_J}\Delta t = 2\pi$, or equivalently, $\frac{\Delta t}{T_E} - \frac{\Delta t}{T_J} = 1$, in which T_E and T_J are the periodic times of the Earth and Jupiter.

(I) Explain how the equation (either version) arises. [2]

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(II) The time Δt, observed between successive oppositions is found to be 1.092 years. Calculate Jupiter's period of revolution in years. [2]

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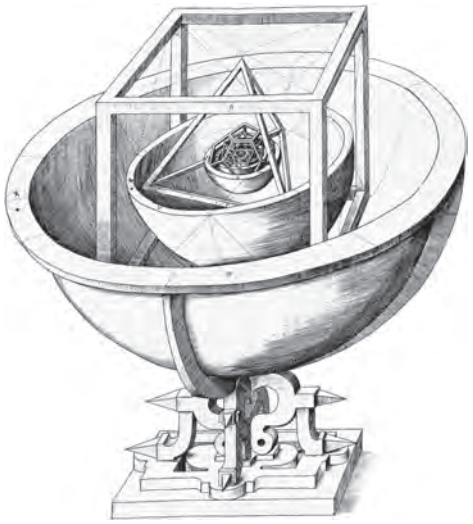
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(b) The diagram shows a model illustrating an early idea of Kepler, involving the five regular solids.



(i) Explain Kepler's idea, and why, eventually, he rejected it. [2]

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(ii) "By trying to make use of the regular solid, Kepler was following an ancient tradition." Discuss this statement briefly. [2]

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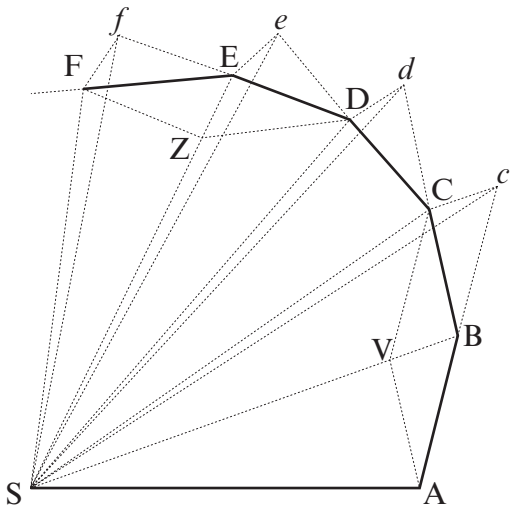
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(c) The diagram is taken from Newton's *Principia* (Proposition I, Theorem I).



(i) Explain what the path ABCDEF represents, and why there are sharp changes of direction at **each** of the points A, B, C, D, E and F. [2]

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(ii) What does Newton show, in Theorem I? [1]

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(d) The Moon's mean orbital radius is 3.84×10^8 m, and its period of revolution is 27.3 days. The Earth's mean radius is 6.37×10^6 m.

(i) Calculate the ratio: $\dfrac{\text{orbital acceleration of the Moon}}{\text{acceleration due to gravity on Earth's surface}}$ [2]

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(ii) Show clearly that this supports an inverse square law of gravitation. [2]

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(iii) What assumption are you making about the Earth's mass distribution? [1]

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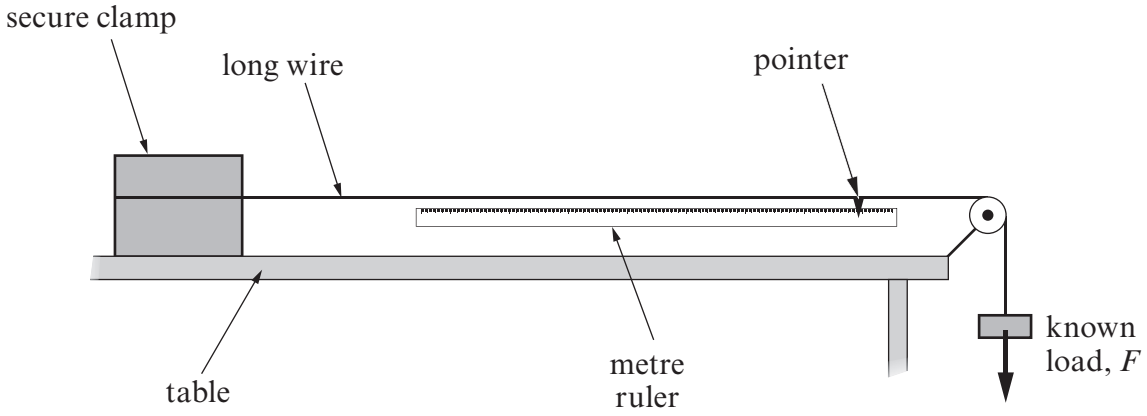
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Option C: Materials

10. *(a)* The diagram shows apparatus that may be used to obtain a value for the Young modulus of a metal in the form of a long wire. A known load, F, is applied to one end of the wire. The extension, Δx, of the wire is measured using the pointer and metre ruler.



(i) To obtain a value for the Young modulus, two other measurements must be made. State what these measurements are and what equipment you would use. [2]

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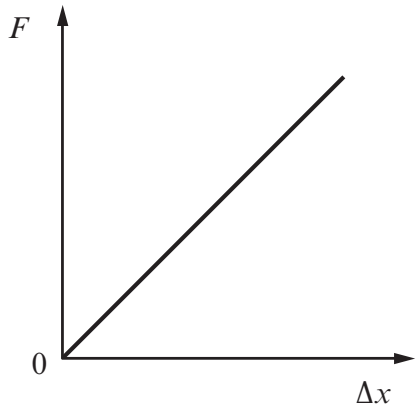
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(ii) A graph of load, F, against extension, Δx, may be obtained from the experiment.



Explain how a value of the Young modulus may be obtained by using the measurements in part *(a)*(i) and information from the graph. [3]

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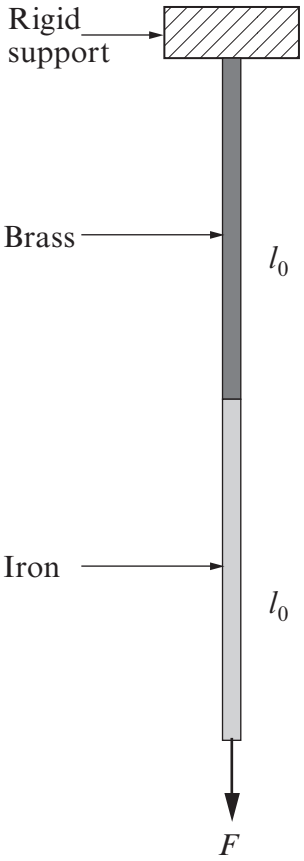
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(b) Two wires, one of brass and one of iron, each of length l_0 and each with the same **diameter** are joined end to end and hung from a rigid support. A force, F, is applied as shown in the diagram.



(i) The extension in the brass wire, Δx_{brass} is given by: $\Delta x = \dfrac{Fl_0}{AE_{brass}}$

where A and E_{brass} represent the cross-sectional area of the wire and the Young modulus of brass respectively. Write down a similar expression for the extension of the iron wire. [1]

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(ii) The strain energy, W, in the wire due to the stretching force F, is given by $\frac{1}{2}F\Delta x$, where Δx represents the total extension in the wire combination. Show that

$$W = \frac{F^2 l_0}{2A}\left(\frac{1}{E_{brass}} + \frac{1}{E_{iron}}\right)$$ [2]

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(iii) Calculate W when $F = 47.0$ N. Assume the diameter of both wires is 1.0 mm and each has an unstretched length, l_0, of 2.0 m. [$E_{brass} = 100$ GPa; $E_{iron} = 200$ GPa.] [3]

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(iv) Hence, or otherwise, determine the overall extension of the combination of wires when $F = 47.0$ N. [1]

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(v) Explain, using the Young moduli given, which of the two wires has undergone the greater extension and hence determine the ratio $\frac{\Delta x_{brass}}{\Delta x_{iron}}$. [4]

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(c) Use the information in the table below:

(i) to **complete** the table to determine whether the polymers given are examples of thermosetting or thermoplastic polymers; [2]

Name	Tensile strength / MPa	Maximum strain / %	Young modulus / GPa	Thermosetting or thermoplastic?
Melamine formaldehyde	65	0.6	12	
Low density polyethylene	17	500	0.3	

(ii) to explain which of the polymers given might be brittle and which of the two is the stiffer. [2]

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Option D: Biological Measurement and Medical Imaging

11. *(a)* An X-ray machine emits X-rays of minimum wavelength 0.030 nm.

(i) Sketch a graph of intensity against wavelength for the resulting X-ray spectrum. **Label** the main features of the spectrum. [3]



(ii) Calculate the accelerating potential difference used to produce a spectrum with a minimum wavelength of 0.030 nm. [2]

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(iii) When diagnosing and treating a child's broken arm, images of the arm are needed. What **two** properties of X-rays make them suitable for this imaging? [2]

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(iv) X-ray imaging is not suitable for revealing brain tumours. Which imaging technique should be used? Give reasons for your choice. [3]

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(b) The fraction, f, of ultrasound reflected back at a boundary between two materials of acoustic impedances Z_1 and Z_2 is given by the equation:

$$f = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

(i) Define acoustic impedance, Z. [1]

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(ii) Using the information given in the table below determine the fraction of ultrasound reflected at an air / skin boundary. [2]

Medium	Density / $\mathrm{kg\,m^{-3}}$	Velocity of ultrasound / $\mathrm{m\,s^{-1}}$
Air	1.300	340
Skin	1 075	1 590

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(iii) Explain the importance of your answer to *(b)*(ii) and state what ultrasound radiographers must do to obtain clear images of the body. [2]

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(c) (i) Explain the difference between radiation exposure and absorbed dose. [2]

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(ii) Explain why, for the same absorbed dose, the dose equivalent would be different for exposure to alpha particles than for gamma rays. [3]

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Option E: Energy Matters

12. A new nuclear reactor has been proposed based on the reaction of lithium-7 and a proton to produce two α-particles.

$$ {}^{1}_{1}\mathrm{p} + {}^{7}_{3}\mathrm{Li} \rightarrow {}^{8}_{4}\mathrm{Be} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He} + 17.1\ \mathrm{MeV} $$

Although this is not a new nuclear reaction (it was the original splitting the atom experiment in 1932), there have been some theoretical developments that suggest this might be a useful reaction.

The above reaction is produced by ionising hydrogen and accelerating the resulting protons in a vacuum to an energy of around 300 keV. Unfortunately, in the past, only one in 30 million protons accelerated to the correct voltage have produced this nuclear reaction.

(a) (i) The above reaction is produced by accelerating ionised hydrogen with 300 kV. Explain **two** possible benefits of the system compared with fission reactors. [4]

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(ii) Calculate the energy required to accelerate 30 million protons to an energy of 300 keV and explain why the above reaction does not seem profitable. [3]

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(iii) There is around 10^{16} kg of $^{7}_{3}$Li in the world's oceans and the mass of $^{7}_{3}$Li can be taken as 7 u. Calculate the number of $^{7}_{3}$Li atoms in the world's oceans. [2]

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(iv) The total annual world energy consumption is around 5×10^{20} J. Assuming that each $^{7}_{3}$Li atom can, ideally, provide an energy of 17.1 MeV, calculate the number of years $^{7}_{3}$Li could supply the world's energy consumption. [3]

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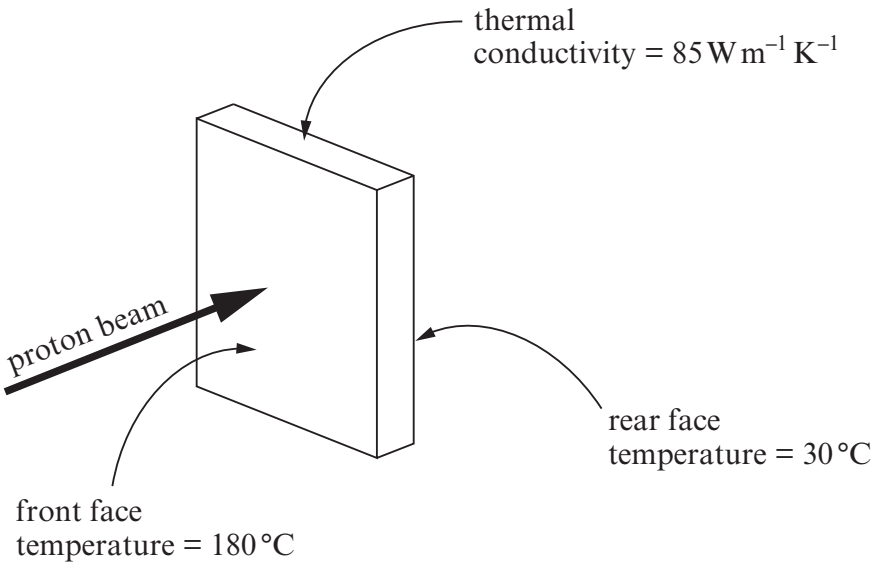
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(b) (i) It has been suggested that lithium wafers of dimension 20 mm × 20 mm × 2.5 mm be used as a target for the proton bombardment, leading to the temperature difference shown. Calculate the heat transferred through the lithium wafer from the data shown. [3]



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(ii) The heat transferred through the lithium wafer is used to raise the temperature of a flowing gas. By sending this gas quickly through a compressor, its temperature can be raised dramatically. Explain why the temperature of the gas increases using the first law of thermodynamics. [2]

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(iii) Eventually, water will be boiled to produce superheated steam to drive turbines and generators. Explain why superheated steam at 500 °C leads to greater efficiencies than steam at 100 °C. [3]

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END OF PAPER

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GCE A level

1325/01-B

PHYSICS

ASSESSMENT UNIT PH5

A.M. THURSDAY, 20 June 2013

CASE STUDY FOR USE WITH SECTION B

Examination copy
To be given out at the start of the examination.
The pre-release copy must not be used.

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Paragraph

From Newton, through Bernoulli to Super Jumbos – an explanation of lift

Let's define some forces first. Air flowing past a body exerts forces on it. **Lift** is the force that is perpendicular to the flow direction and **drag** is the force parallel to the flow direction. Other forces that act are **weight** and **thrust**. The thrust on an aeroplane is provided by the propellers or jets but this force is absent for gliders. 1

Lift is commonly associated with wings but lift is also generated by propellers, kites, helicopter rotors, rudders, sails on sailboats, hydrofoils, wings on racing cars, wind turbines and other objects. While the common meaning of the word "lift" assumes that lift opposes gravity, lift in its technical sense can be in any direction since it is defined with respect to the direction of flow rather than the direction of gravity. When an aircraft is flying straight and level, the lift opposes the weight. However, when an aircraft is climbing, descending, or banking in a turn, for example, the lift is tilted with respect to the vertical. Lift may also be entirely downwards in some aerobatic manoeuvres, or on the spoiler of a racing car. Lift may also be horizontal, for instance on the sail on a sailing boat.

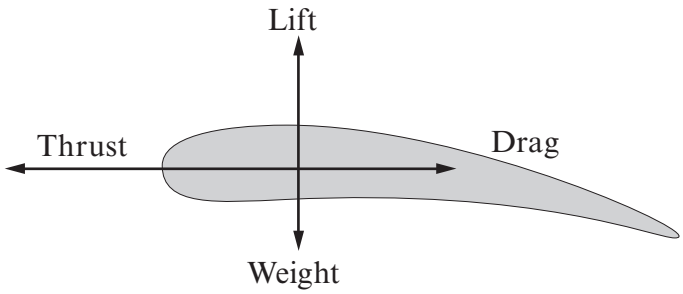


Diagram 1: Forces on an aerofoil 2

Newton's laws: lift and the deflection of the flow

Flow of air around an aerofoil in a wind tunnel. Note the curved streamlines above and below the foil, and the overall downward deflection of the air. One way to understand the generation of lift is to observe that the air is deflected as it passes the aerofoil. Since the foil must exert a force on the air to change its direction, the air must exert a force of equal magnitude but opposite direction on the foil. In the case of an aeroplane wing, the wing exerts a downward force on the air and the air exerts an upward force on the wing. This explanation relies on the second and third of Newton's laws of motion: *The net force on an object is equal to its rate of momentum change*, and: *To every action there is an equal and opposite reaction.*

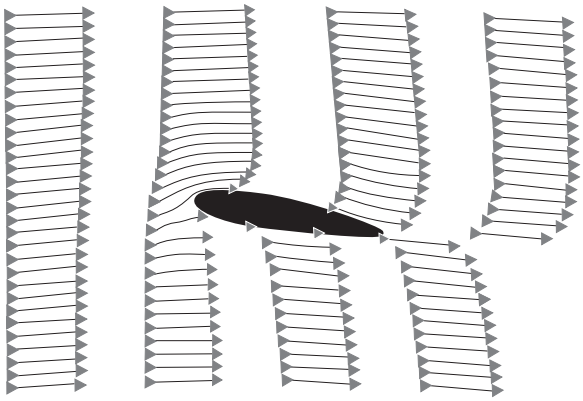


Diagram 2: Vector diagram of flow past an aerofoil 3

Pressure differences

Lift may also be described in terms of air pressure. Wherever there is a net force there is also a pressure difference, thus deflection of the flow indicates the presence of a net force and a pressure difference. This pressure difference implies the average pressure on the upper surface of the wing is lower than the average pressure on the underside. 4

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Bernoulli's Equation

In much the same way as the laws of electricity can be derived from conservation of charge and energy, the theories of aerodynamics can be derived from conservation of mass and energy. Let's consider conservation of mass first but we also have to make a couple of assumptions: 5

1. The density of the air is a constant (it turns out that this is a very good approximation as long as speeds remain below about 250 mph).

2. We consider a steady flow so that the air is moving along in steady streamlines.

Now let's consider streamlines that are getting closer together in this narrowing tube of starting cross-sectional area A_1 and finishing cross-sectional area A_2. 6

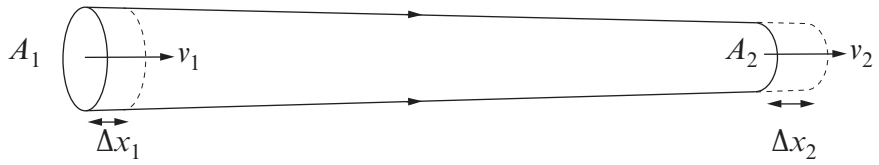


Diagram 3: Air flow in a streamline

The streamlines follow the path of the air so that (by definition) no air crosses the streamlines. The volume of air entering the tube in time Δt is

$$A_1 \Delta x_1 = A_1 v_1 \Delta t$$

and the volume of air leaving the tube in time Δt is

$$A_2 \Delta x_2 = A_2 v_2 \Delta t$$

Because the density is a constant, mass is proportional to volume and conservation of mass now means conservation of volume. So:

$$A_1 v_1 \Delta t = A_2 v_2 \Delta t \qquad \text{or} \qquad A_1 v_1 = A_2 v_2$$

As the area decreases from left to right then the velocity must increase due to conservation of mass.

You can go even further than this, if the velocity is increasing from left to right then we have an acceleration and there must be a net force. The only thing that can supply this net force is a greater pressure on the left side of the tube than on the right. This would suggest that the pressure must be higher on the left side where the speed of the air is lower. Bernoulli's equation can be derived using this concept and the result is this: 7

$$p = p_0 - \tfrac{1}{2}\rho v^2$$

where p is the pressure, p_0 is the pressure of air that isn't moving, ρ is the density of air and v is the speed of the air. Basically, Bernoulli's equation says that the pressure of air that is moving is decreased by an amount $\tfrac{1}{2}\rho v^2$.

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There are many things that can be explained using Bernoulli's equation but here's a little explanation of one of the most annoying aerodynamic effects of all. Consider a person taking a shower with a light shower curtain. Which way does the shower curtain move? 8

To use Bernoulli's equation you need some idea of the speed of the air. Outside the shower, the air should be stationary (unless you live in a draughty house) but inside the shower, the water droplets are causing the air to move slightly. According to Bernoulli's equation, the pressure inside the shower will be lower so that the net force on the shower curtain is inward. There you are - an explanation of why that irritating cold and wet shower curtain always creeps spookily inwards towards you. 9

Explaining lift using Bernoulli

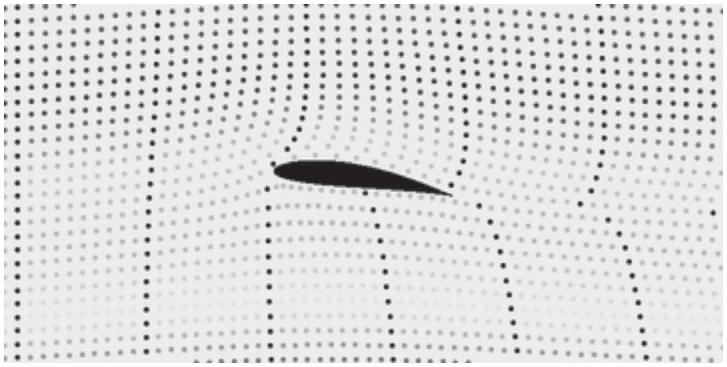


Diagram 4: Flow past an aerofoil showing time intervals

The diagram to the left represents the same flow past a wing as the previous vector diagram (diagram 2). The horizontal gaps between the dots in the diagram represent equal intervals of time. Note that the spaces between the dark dots are much bigger at the upper surface than at the lower surface. This means that the speed of the flow is far greater over the top of the wing than over the bottom. Hence, applying Bernoulli's equation explains why the above wing experiences lift. 10

Diagram 4 is great for explaining lift using Bernoulli's equation but it also debunks the old explanation of lift which went like this: 11

- when the air splits to go above and below the wing, the air passing above the wing takes exactly the same time to reach the back of the wing as the air passing underneath,
- the top side of the wing is designed to be longer than the bottom,
- so air travels quicker over the top of the wing,
- Bernoulli explains why the pressure below is bigger than above and hence lift.

One look at diagram 4 should dismiss the first point of the old argument. Also, if the old explanation was complete: 12

1. how can an aeroplane fly when the top of the wing is only 2% longer than the bottom?
2. how can an aeroplane fly upside down?

To get an idea of the first point, an Airbus super jumbo takes off at a speed of $80\,m\,s^{-1}$ in air of density $1.2\,kg\,m^{-3}$. Its wings are made in Broughton, North Wales and have an enormous area of around $850\,m^2$. If you assume that the speed over the top of the wing is 2% larger, this gives a total lift force of 130 kN. This may sound impressive until you realise that the mass of an empty super jumbo is around 300 tonnes. The truth is that although the top side of the wing is only 2% longer than the bottom, the increase in speed can be more than 50% over the top side of the wing. 13

The second point is answered by considering the angle of attack (θ) of the wing because this is also important in deflecting the airflow. 14

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Lift due to an angle of attack

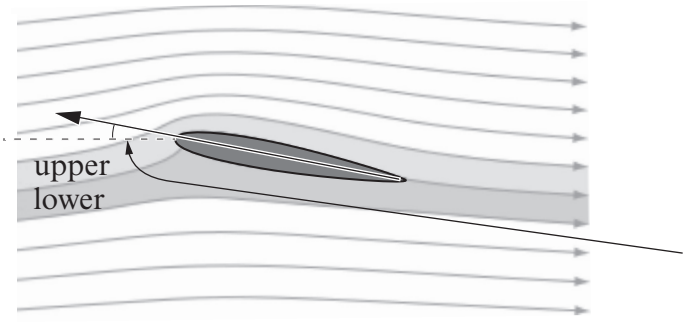


Diagram 5

The aerofoil shown to the left is symmetrical – the top and bottom of the aerofoil are the same (the wings of aerobatic planes are designed to be like this so that they fly equally well upside down). In order to produce lift, the wings have to be tilted to produce the same flow as in diagrams 2 & 4. 15

An aeroplane flying upside down can still have an angle of attack and produce lift. 16



Lift coefficient

The lift force provided by a wing can be calculated as a function of speed with the following equation: 17

$$L = \frac{1}{2}\rho v^2 A C_L$$

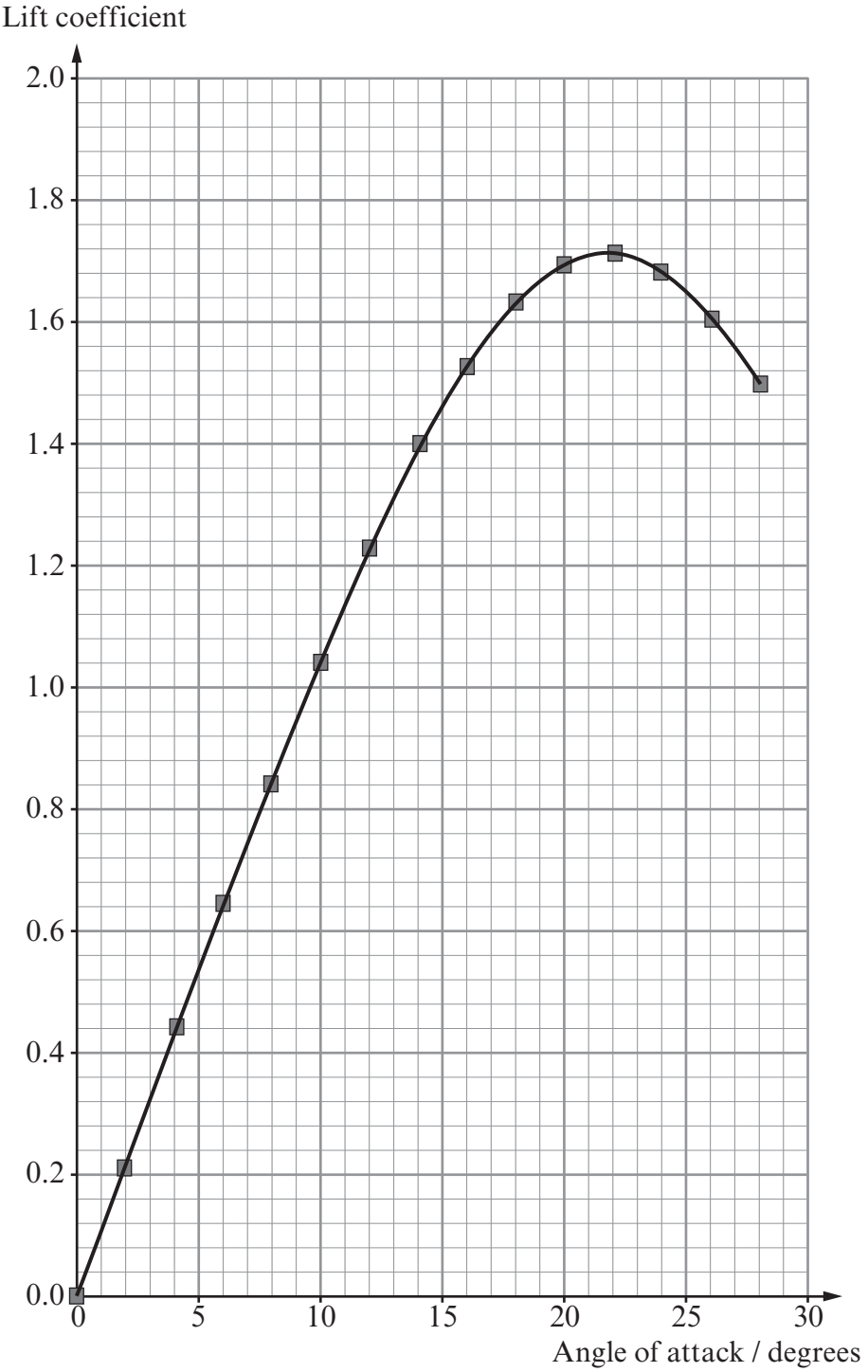
where

- L is lift force,
- ρ is air density,
- v is air speed,
- A is the area of the wing, and
- C_L is the lift coefficient of the wing (dependent on the angle of attack).

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This theory works very well and a standard experiment is to measure the lift coefficient as a function of angle of attack. In practice, real wings would be tested in extremely expensive wind tunnels but you could set up a cheap version of the experiment in a school lab using a thin metal plate as a makeshift aerofoil. You'd also need a hair dryer, stand, clamp, protractor and a digital balance. 18

You won't be able to get such good data with a makeshift set-up because of the accuracy of your protractor and it's unlikely that a cheap hairdryer will produce a particularly uniform airflow. However, you should be able to measure the lift very accurately using the digital scales and the general trend of the graph shown should be measurable.



19

20

Conclusions

There are many aspects of the physics of lift and flight that are accessible to you as A-level physics students. It's surprising how far you can get just with Newton's laws of motion but applying these laws to obtain Bernoulli's equation leads to a far greater understanding of lift and fluid dynamics in general. You should now be able to explain how an aeroplane can fly upside down and even perform a rough experiment to show that your explanation is valid. You can even tell your friends what the likely pressure difference is between the top and bottom surface of an Airbus super jumbo wing.

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GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2013

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INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2013 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

	Page
PH1	1
PH2	5
PH4	10
PH5	17

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Question			Marking details	Marks Available
1.	*(a)*		Correct α or β absorber (1) If drop after α absorber, then α present (1) (Alpha is stopped by paper – award 2 marks) If **further** drop after β absorber then β present (1) If (significant) count after β absorber then γ present or equivalent (1)	4
	(b)	(i)	19×10^{15} [Bq]	1
		(ii)	Use of $\lambda = \frac{ln2}{T_{1/2}}$ (1) e.g. 0.0271 per day or 3.13×10^{-7} s^{-1} (1) Or $A = \frac{A_0}{2^x}$ quoted Or $A = \frac{A_0}{2^x}$ used Substitutions of values (ignore wrong units or factors of ten slips) (1) Or $x = 14.26$ Correct answer 3.85×10^{12} [Bq] (1)	4
		(iii)	Attempt at using $A = \lambda N$ e.g. $76 \times 10^{15} = \lambda N$ (1) $N = 2.4 \times 10^{23}$ (1)	2
			Question 1 Total	**[11]**

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Question			Marking details	Marks Available
2.	*(a)*		Attempt at LHS – RHS (1) (Difference = 0.0078) Attempt at mass-energy conversion x 931 or $E = mc^2$ used (1) Answer = 7.26 MeV (1.16×10^{-12} J) (1)*** **UNIT MARK***	3
	(b)		8.795 x number of nucleons attempted [545.29 MeV] (1) Mass equivalent = 0.5857 [u] (1) 28 protons & 34 neutrons stated or implied (1) Mass of 28p & 34n = 62.49828 (1) Answer = 61.913 [u] (1) must be to 5 significant figures	5
			Question 2 Total	**[8]**

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Question			Marking details	Marks Available
3.	*(a)*		$Q = CV$ (1) 212 [nC] (1)	2
	(b)		Taking logs e.g. $\ln Q = \ln Q_0 - \frac{t}{CR}$ (1) Algebra e.g. $R = -\frac{t}{C \ln \frac{V}{V_0}}$ (1) Substitution of correct values (1) Answer = 1.36 [MΩ] (1)	4
	(c)		$C = \frac{\varepsilon_0 A}{d}$ used e.g. rearranged (1) A = x^2 (or implied) $\rightarrow C = \frac{\varepsilon_0 x^2}{d}$ first two marks (1) Answer =1.49 [m] (1)	3
	(d)		Dielectric between plates	1
			Question 3 total	**[10]**

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Question			Marking details	Marks Available
4.	*(a)*		$Bev = \frac{mv^2}{r}$ (1)	
			Convincing algebra (minimum of showing *v* cancelling then jumping to answer) i.e. $Bev = \frac{mv^2}{r} \rightarrow r = \frac{mv}{Be}$ (1)	2
	(b)		*r* stays constant (1) (accept to stop *r* from increasing)	
			m and *e* can't be changed (accept $B \propto v$ or $\frac{v}{B} = \text{constant}$ or *m* increases and *e* is a constant) (1)	2
	(c)		Method e.g. $v = \frac{2\pi r}{T}$ or $v = \omega r$ and $\omega = 2\pi f$ or $v = 2\pi f r$ (1)	
			$v = 3 \times 10^7$ [m s^{-1}] (1)	
			$B = \frac{mv}{re}$ i.e. rearranged (1)	4
			B = 0.037 [T] (1) **ecf** on *v*	
	(d)	(i)	*nI* needs to be very large (accept needs very large current) (1)	
			Detail e.g. for *B* = 10 [T], *nI* = 8 000 000 (1) (don't accept *n*=1 but accept valid *n* and *I* calculation) or wires would melt before high *B* achieved or *n* needs thin wires but current needs thick wires etc.	2
		(ii)	Huge currents achievable or no heat dissipation (accept larger currents or large currents)	1
			Question 4 Total	**[11]**

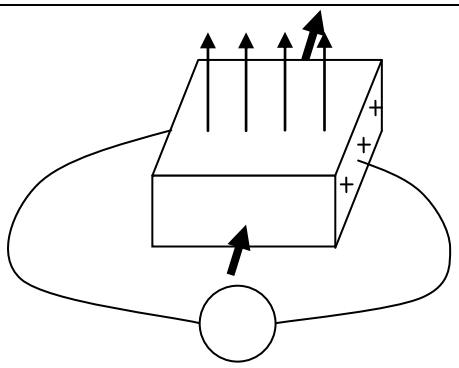
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Question			Marking details	Marks Available
5.	*(a)*		The [induced] emf is proportional [or equal] to the rate of change [or cutting] of flux [linkage] or d*BAN*/d*t* and terms defined Nearly correct statements award 1 out of 2 marks e.g. The emf is equal to the change of flux The current is **proportional** to the rate of change of flux The emf is proportional to the cutting of flux *BAN*/*t* and terms defined Wrong statements get 0 The emf is equal/proportional to the flux linkage The current is **equal** to the rate of change of flux	2
			Lenz - the [induced] emf [or current] opposes [or tends to oppose etc.] the change [to which it is due]	1
	(b)	(i)	Clockwise (1) any 1 of FLHR(must have correct direction), FRHR, right hand grip rule (1)	2
		(ii)	Area increases ✓ at an increasing rate ✓ or cutting of flux ✓ inside the loop ✓ or $E=Blv$ ✓ and l is increasing ✓	2
		(iii)	$V = \frac{BAN}{t}$ and $t = \frac{20.1}{31} (= 0.648\ \text{s})$ or $E = Blv$ used (1) $A = \frac{1.8+2.9}{2} \times 20.1 [= 47.2]$ or mean l = 2.35 [m] (1) $I = \frac{V}{R}$ (1) Correct answer $I = 77\ [\mu\text{A}]$ (1)	4
			Question 5 Total	**[11]**

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Question			Marking details	Marks Available
6.	*(a)*	(i)	+ve correct 	1
		(ii)	voltmeter correct	1
	(b)		$V_H = Bvd$ or implied/$eE = Bev$ (1)	3
			$v = \frac{0.314\times10^{-3}}{0.168\times0.0043}$ (1) = 0.435 m s^{-1} (1)	
			or $E=V/d$ (1) and ans (1)	
	(c)		Force perpendicular to motion	1
			or no motion in direction of E_H	
			or $P = IV$ (or $P = I^2R$) and $I = 0$ in that direction	
	(d)		Use of $I = nAve$ e.g. $n = \frac{I}{Ave}$ or $V = \frac{BI}{nte}$ (1)	3
			Calculation of A or correct substitution (1)	
			Answer $n = 1.16 \times 10^{24}$ m^{-3} *** **UNIT MARK** *** (1) **ecf** on v	
			Question 6 Total	**[9]**

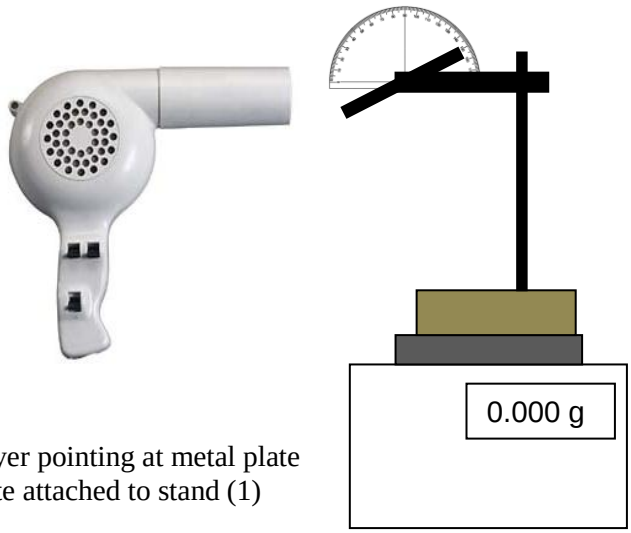
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Question			Marking details	Marks Available
7.	*(a)*		Downward momentum given to air hence a force is applied (1) (N.B. downward can appear next to momentum or force) Newton's 3rd (or implied) force exerted on the plane by the air (1)	2
	(b)		Speed is greater at left side [due to conservation of mass] (1) (accept speed is decreasing) Air is decelerating or acceleration to the left or due to decrease in momentum(1)	2
	(c)		Lift component left is unbalanced (1) i.e. linking to resultant force Vertical component of lift is [slightly] less than weight (1) i.e. linking to direction Alternative: Good vector diagram (award 2 marks) The lift and weight added together give a resultant force acting downwards to the left. (award 1 mark only) Or resultant force is down and left (award 1 mark only) Or lift + weight is down and left (award 1 mark only)	2
	(d)		Air has high speed in tornados (1) (accept moving) This means a much lower pressure outside or much higher pressure inside (1) (N.B. much can also be implied by high speed in the 1st mark)	2
	(e)		Attempt at pressure difference (1) Pressure difference correct i.e. 155 [Pa] (1) Pressure difference 155 **ecf** x 850 [=130 kN] (1) (No marks for using the lift equation)	3

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Question			Marking details	Marks Available
	(f)		All units correct award 2 marks 2 or 3 units correct award 1 mark LHS= kg m s^{-2} **and** kg m^{-3}, m s^{-1} and m^2 on RHS (2) Convincing algebra and method (1)	3
	(g)		Lift = weight or implied (accept 300 x g) (1) C_L = 0.90 (1) **ecf** on incorrect force	2
	(h)		 Hair dryer pointing at metal plate and plate attached to stand (1) Protractor set to measure angle of attack or angle labelled (1) Metal plate & attachment on digital balance (1) Labelling of 4/5 of hair dryer, stand / clamp, protractor, digital balance and metal plate (1)	4
			Question 7 Total	**[20]**

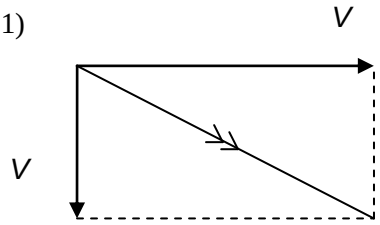
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Question			Marking details	Marks Available
8.	*(a)*		Alternating current means an alternating *B*-field (needs a direct link) (1) [alternating] *B*-field transferred through core to secondary (1) Changing flux inside the secondary coil [gives emf] (1) (accept flux cuts the secondary coil but not flux goes through secondary coil)	3
	(b)		(needs design & loss method) Low resistance wires to reduce heat dissipation from wires (or equivalent) (1) Laminated core to reduce eddy currents (1) Suitable core alloy (or silicon steel etc.) to reduce magnetisation losses (or hysteresis **or to reduce leakage flux**/stray field etc.) (1)	3
	(c)	(i)	$\omega = 2\pi f = 24\,000\ [\mathrm{s}^{-1}]$ (1) $\omega L = 88.7\ [\Omega]$ (1) $\frac{1}{\omega C} = 88.7\ [\Omega]$ (1)	3
		(ii)	Reactances are the same (accept impedances) (this can be stated regardless of a wrong answer to (i))	1
		(iii)	Answer = 6.5 [mA] (allow **ecf** if full method followed through) (i.e. using $Z = \sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2 + R^2}$ etc.)	1

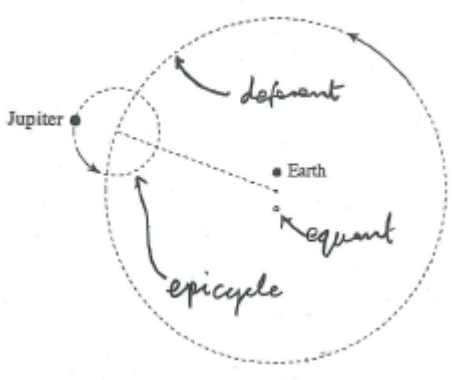
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Question			Marking details	Marks Available
8.		(iv)	Ignore capacitance (or $\omega L - \frac{1}{\omega C}$ attempted) (1) Correct calculation for impedance e.g.. $\sqrt{887^2 + 2\,200^2}$ (1) Answer = $\frac{14.4}{2370}$ = 6.1 [mA] (1)	3
	(d)	(i)	**Attempt** at an explanation at low **and** high frequency (1) Correct variation of X_C with frequency (i.e. large at low frequency **or** low at high frequency) (1) Correct division of pd with respect to frequency (e.g. at high frequency $R>>X_C$ so V_{OUT} is large **or** the opposite at low frequency) (1)	3
		(ii)	Phasor diagram drawn or implied (1)  $X_C = R$ or $V_C = V_R$ either derived or quoted (implies diagram correct) (1) Answer = 154 [Hz] (1)	3
			Question 8 Total	**[20]**

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Question			Marking details	Marks Available
9.	*(a)*	(i)(I)	2 marks : 3 labels 1 mark : 2 labels  	2
		(II)	Prograde and motion on epicycle and deferent in same direction – or equivalent	1
		(III)	Brightness or size	1
		(ii) (I)	Either $\frac{2\pi}{T_{E/J}}\Delta t$ (1) represents angle swept out by Earth/Jupiter in time Δt (1) **OR** $\frac{\Delta t}{T_{E/J}}$ (1) represents fraction of a cycle swept out by Earth/Jupiter in time Δt Earth sweeps out extra angle 2π or one extra revolution (1)	2
		(II)	$\frac{1.092}{1}-\frac{1.092}{T_J}$ = 1 (1) $1.092T_J - 1.092 = 1T_J$ T_J = 11.9 [years] (1)	2
	(b)	(i)	Nesting of: sphere of mercury / solid / sphere of Venus/solid (1) Didn't give quite correct orbital radii (1)	2

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Question			Marking details	Marks Available
		(ii)	Mention of Plato or Pythagoras (1) Nature based on mathematics (or equivalent) (1)	2
	(c)	(i)	Path of body acted on by central force [towards S] Accept path of planet. (1) [Central] force applied at [just] these points (1)	2
		(ii)	Equal areas in equal times **OR** area swept out proportional to time	1
	(d)	(i)	Use of or by implication : (1) $\frac{v^2}{rg_{surf}} or \frac{r\omega^2}{g_{surf}}$ =2.78 x 10^{-4} (1)	2
		(ii)	Attempt to evaluate $\left(\frac{r_E}{r_{MO}}\right)^2$ (1) = 2.75 x 10^{-4} (1)	2
		(iii)	Either: spherically symmetric **OR** behaves as if all at centre	1
			Question total	**[20]**

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Question			Marking details	Marks Available
10.	*(a)*	(i)	Diameter[accept width/thickness do not accept radius/area]→ micrometer/digital calliper [accept vernier calipers but not vernier only] (1)	
			Original [accept natural] length→ metre rule (1)	2
		(ii)	Take (one set of) F and e from graph **or** Measure gradient [or = $F/\Delta x$] Accept gradient = EA/l (1)	
			Use value of $\pi d^2/4$ or πr^2 [explanation of how A is calculated required – can be awarded from (i)] (1)	
			Insert in relevant equations (1) $Y = \frac{Fl_0}{A\Delta x}$ **or** $Y = grad \times \frac{l_0}{A}$ etc.	3
	(b)	(i)	$[e_{iron}] = \frac{Fl_0}{AE_{iron}}$ [must show $\frac{Fl_0}{A}$]	1
		(ii)	Attempt at $e_{brass} + e_{iron}$ (1)	
			Correct manipulation/algebra (1)	2
		(iii)	CSA calculated: 7.9×10^{-7} [m^2] (1)	
			Substitution (**ecf** on CSA) (1)	
			$W = 0.042$ [J] (1) [-1 for slip in power of 10; -1 for use of diameter instead of radius]	3
		(iv)	1.8 mm **UNIT mark**	1

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Question			Marking details	Marks Available
		(v)	Greater extension by brass [or smallest extension by iron] (1) $e \propto 1/E$ (1) [link Young modulus to extension] All other factors same for both wires (1) Ratio 2:1 (1.2 mm:0.6 mm) (1) [Full marks may be obtained by calculation only].	4
	(c)	(i)	Melamine formaldehyde → thermosetting (1) Low density polyethylene → thermoplastic (1)	2
		(ii)	Melamine brittle – low max strain (1) **or** polythene not brittle – high max strain Melamine stiffer – higher Young modulus (1) **or** polythene less stiff – lower Young modulus [or accept low strain for high stress as explanation for stiffness of material]	2
			Question total	**[20]**

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Question			Marking details	Marks Available
11.	*(a)*	(i)	Continuous background spectrum (1) Do not accept: a symmetric shape or touching *x* axis on LHS At least 1 line spectrum (1) Must be part of spectrum not placed on top Minimum wavelength not at 0,0 (1)	3
		(ii)	$eV = \frac{hc}{\lambda}$ (1) $E = \frac{hc}{\lambda}$ not enough Answer V = 41 250 [V] (1) 41 kV ok but do not accept 41 keV	2
		(iii)	Able to penetrate muscle but stopped by denser materials (1) Accept: body/flesh/tissue skin for muscle Accept: bone/harder materials for denser **Both needed** Expose photographic film (1)	2
		(iv)	Any 3x(1) from: –MRI (scan) If X-ray or ultrasound chosen 0 for whole question If PET chosen award maximum of 2 out of 3 marks –[high quality] images of *soft tissue* –Contrast can be controlled –X-rays are absorbed by bone/skull Accept: MRI not absorbed by skull Accept: X-rays cannot penetrate skull	3

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Question			Marking details	Marks Available
	(b)	(i)	Z = Density x velocity [of ultrasound in the material] Must be in words as equation is given Do not accept speed of light for velocity	1
		(ii)	Z_1 = 442 **and** Z_2 = 1 700 x 10^3 (1) f = approx 1 / 0.995 (1)	2
		(iii)	Almost all ultrasound reflected/ none able to enter the body (1)	
			Need for a coupling gel/medium (1)	2
	(c)	(i)	Exposure: amount of radiation incident on the body (1) Do not accept: 'total radiation exposed to' as it is a rewrite of the question.	2
			absorbed dose: <u>energy</u> per unit mass absorbed by body (1)	
		(ii)	Dose equivalent = dose x quality factor (1) Do not accept in terms of units	
			Quality factor depends on ionization or alpha Q = 20 and gamma Q = 1(1) Greater for alpha than gamma (1)	3
			Question total	**[20]**

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Question			Marking details	Marks Available
12.	*(a)*	(i)	Any 2 x (2) from Easily controllable Accept: no chain reaction (1) Because can switch off protons/hydrogen (1) **OR** No radioactive by-products or products are alpha particles (1) Any good relevant detail e.g. no storage costs for thousands of years Or alpha particles easily contained etc. (1) **OR** Fuel cheaper than fuel for fission (1) Detail e.g. per MJ output, H from the sea, no isotope enrichment needed, selling the He would help pay for the fuel (1) **OR** Fuel supplies would last longer than for fission (1) Detail: sensible remarks about U and H (1)	4
		(ii)	30 000 000 x 300 keV (in whatever units) (1) Conversion so that answer and reaction energy in the same units (i.e. 9 million MeV or equivalent e.g. 2.74×10^{-12} and 1.44×10^{-6} J) (1) Comment implying far less energy out than in (1)	3
		(iii)	$7 \times 1.66 \times 10^{-27}$ seen (1) Answer $[10^{16} / 7u] = 8.6 \times 10^{41}$ (1)	2
		(iv)	Answer (iii) x 17.1 MeV (or its J equivalent 2.74×10^{-12}) (1) Tolerate slips in powers of 10; answer mark will be lost. previous answer / 5×10^{20} (regardless of mixed units) (1) Answer = 4.7×10^{9} (1)	3

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Question			Marking details	Marks Available
	(b)	(i)	Area = 20 mm x 20 mm or implied (1) Including side-faces loses the mark. Temperature difference = 150 [^{o}C] (1) Heat = 2 040 [W] (1) **ecf** on *A*, provided not a volume instead of an area	3
		(ii)	Work is done on the gas (1) Internal energy of the gas increases (no heat not required) (1) Freestanding mark i.e. accept if wrongly deduced, but only if link with temperature rise made.	2
		(iii)	Efficiency = $1 - \frac{T_2}{T_1}$ accept $\frac{Q_1 - Q_2}{Q_1}$ or $1 - \frac{Q_2}{Q_1}$ (1) T_1 is larger or $\frac{T_2}{T_1}$ is smaller Q_1 is larger or $\frac{Q_2}{Q_1}$ is smaller but these need an explanation e.g. because temperature is higher. If done by putting temperatures into formula, they must be in K. (1) Efficiency is greater in equation (not an independent mark i.e. valid earlier argument needed, ignoring °C instead of K) (1)	3
			Question total	**[20]**

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Surname	Centre Number	Candidate Number
Other Names		2

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GCE A level

1325/01

PHYSICS

ASSESSMENT UNIT PH5: ELECTROMAGNETISM, NUCLEI & OPTIONS

A.M. MONDAY, 18 June 2012

1¾ hours

1325 010001

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator, a **Case Study Booklet** and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

This paper is in 3 sections, **A**, **B**, and **C**.

Section A: 60 marks. Answer **all** questions. You are advised to spend about 1 hour on this section.

Section B: 20 marks. The Case Study. Answer **all** questions. You are advised to spend about 20 minutes on this section.

Section C: Options; 20 marks. Answer **one option only.** You are advised to spend about 20 minutes on this section.

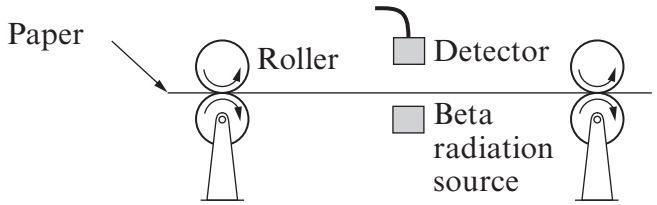
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SECTION A

1. The thickness of paper is measured using a beta radiation source and detector (see below).



(a) Explain why it would be inappropriate to use either alpha radiation or gamma radiation for this task. [2]

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(b) The beta radiation source most commonly used is strontium-90 which decays as shown. Place the correct numbers on the dotted lines. [2]

$$^{90}_{38}\text{Sr} \longrightarrow \;^{\ldots\ldots}_{\ldots\ldots}\text{Y} + \;^{\ldots\ldots}_{\ldots\ldots}\beta$$

(c) The half life of strontium-90 is 28.8 years. Show that its decay constant is $7.6 \times 10^{-10}\ s^{-1}$. [2]

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(d) If the initial activity of the strontium-90 source is 140 GBq, calculate its activity after 10 years. [2]

(e) Calculate the mass of strontium-90 required to produce an activity of 140 GBq. [3]

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2. One of the nuclear reactions that occurs inside a nuclear power station is:

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \longrightarrow ^{92}_{36}\mathrm{Kr} + ^{141}_{56}\mathrm{Ba} + 3\,^{1}_{0}\mathrm{n}$$

The masses of the relevant nuclei are as follows:

Mass of $^{235}_{92}\mathrm{U}$ = 234.9933 u Mass of $^{92}_{36}\mathrm{Kr}$ = 91.9064 u

Mass of $^{141}_{56}\mathrm{Ba}$ = 140.8836 u Mass of $^{1}_{0}\mathrm{n}$ = 1.0087 u

(a) Calculate the energy released in this nuclear reaction (1 u = 931 MeV). [3]

(b) Explain briefly how this reaction can lead to a chain reaction. [2]

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(c) Explain briefly the different purposes of the moderator and control rods in a nuclear reactor. [3]

(d) Discuss briefly the problems associated with disposing of waste products from a nuclear power station. [2]

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Turn over.

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3. *(a)* (i) A capacitor has plates of area 8.2×10^{-4} m^2 and a separation of 0.77 mm. Calculate the capacitance of the capacitor assuming that there is air (or a vacuum) between the plates. [2]

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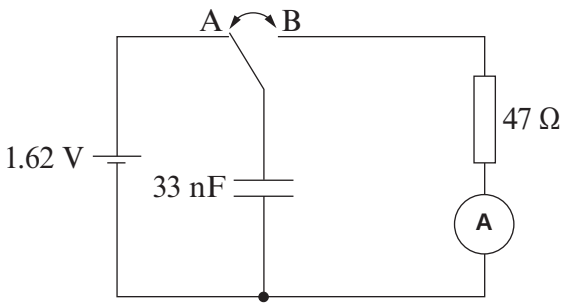
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(ii) Keeping the dimensions of the capacitor the same, how could you increase its capacitance? [1]

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(b) Another capacitor is charged and discharged using the following circuit.



(i) Calculate the charge stored by the capacitor when fully charged. [2]

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(ii) The fully charged capacitor is now discharged through the 47 Ω resistor by moving the switch to B. Calculate the charge still remaining on the capacitor after it has been discharging for 50.0 μs and comment on the magnitude of your answer. [3]

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(iii) The capacitor is charged and discharged a total of 20 000 times per second. Calculate the average current through the ammeter. [2]

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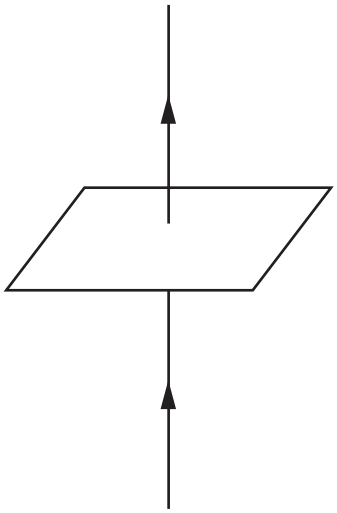
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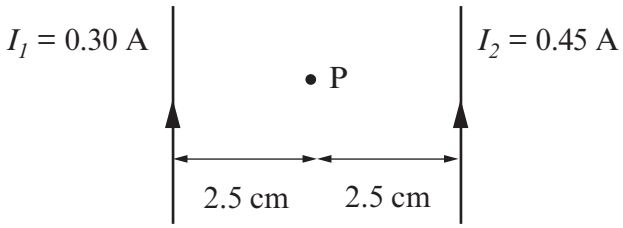
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4. *(a)* Sketch the magnetic field due to the current-carrying wire shown. [2]



(b) Two long, straight wires carry currents as shown.



(i) Calculate the resultant magnetic field strength at point P in the above diagram and **state its direction**. [4]

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(ii) Explain why there is an attractive force between the two long wires in the diagram on the opposite page. [3]

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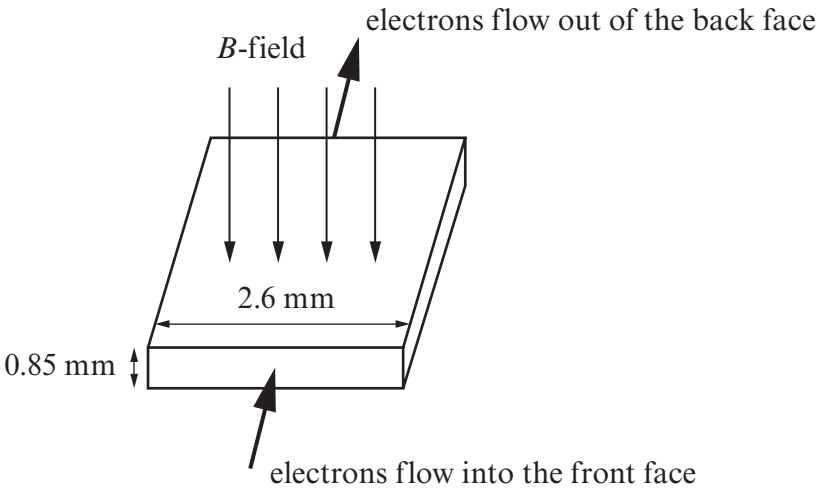
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5. Electrons flow through a gold wafer which is used as a Hall probe.



(a) Explain which face of the wafer becomes negatively charged due to the Hall effect. [3]

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(b) The electric field due to the Hall voltage is 3.2×10^{-6} V m^{-1}. Calculate the Hall voltage. [2]

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(c) The following equation is used in conjunction with the Hall effect: $eE = Bev$. State what the forces eE and Bev are and explain why they are equal. [2]

(d) The current flowing in the wafer is 0.82 A and the concentration of free electrons in gold is 5.9×10^{28} m^{-3}. Calculate the magnetic field strength, B. [Hint: Use $I = nAve$] [3]

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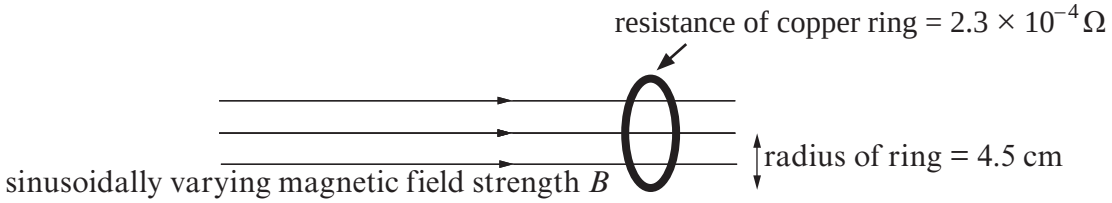
6. *(a)* State Faraday's law of electromagnetic induction. [2]

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(b) A circular copper heating ring works by being placed in a sinusoidally varying magnetic field. A large sinusoidal current is then induced in the ring and the ring becomes hot (see below).



(i) The maximum rate at which the magnetic field strength changes is 72 T s^{-1}. Show that the maximum current flowing in the ring is approximately 2000 A. [4]

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(ii) Calculate the rms value of the induced current. [2]

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(iii) Calculate the mean power dissipated in the heating ring. [2]

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SECTION B

The questions refer to the Case Study.
Direct quotes from the original passage will not be awarded marks.

7. *(a)* Explain briefly why all the Solar System planets appear on the same horizontal line on the graph below. [1]

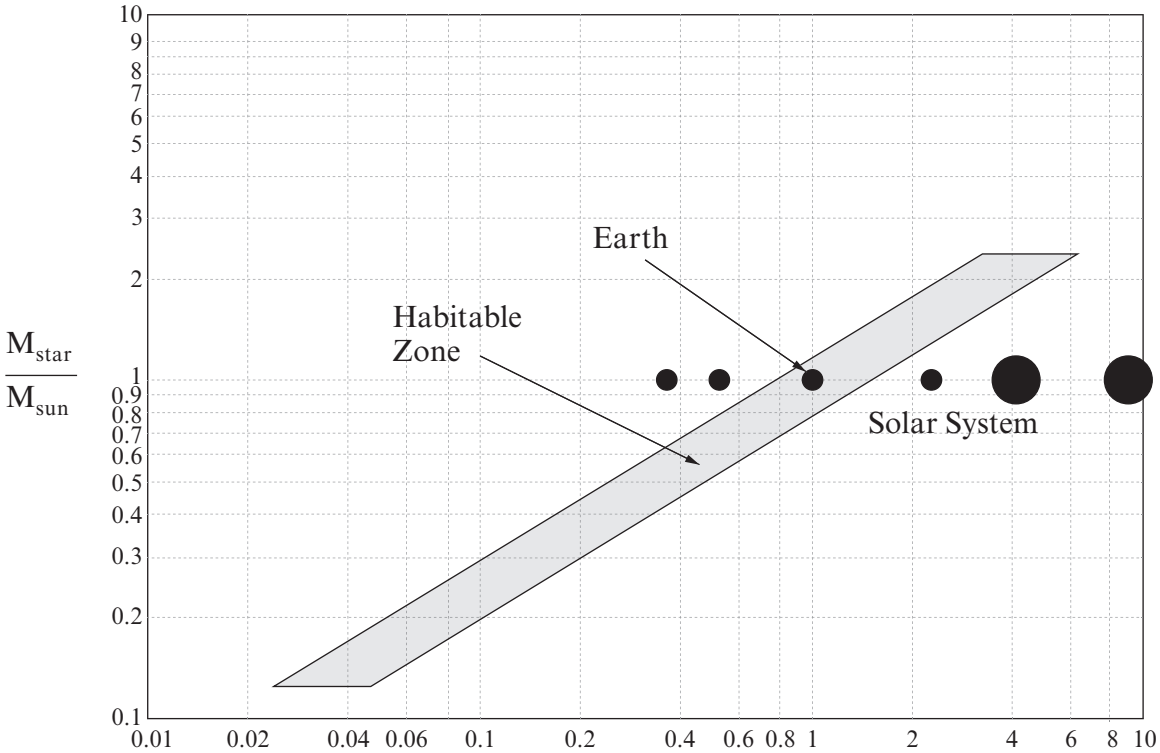
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Graph of Star Mass (relative to our Sun) v Planet Distance from the Star



(b) Place crosses on the graph to represent:

(i) an exoplanet orbiting a star twice the mass of the Sun and at a distance four times the Sun-Earth separation; [1]

(ii) an exoplanet orbiting a star 0.25 times the mass of the Sun and at a distance of 0.04 times the Sun-Earth separation. [1]

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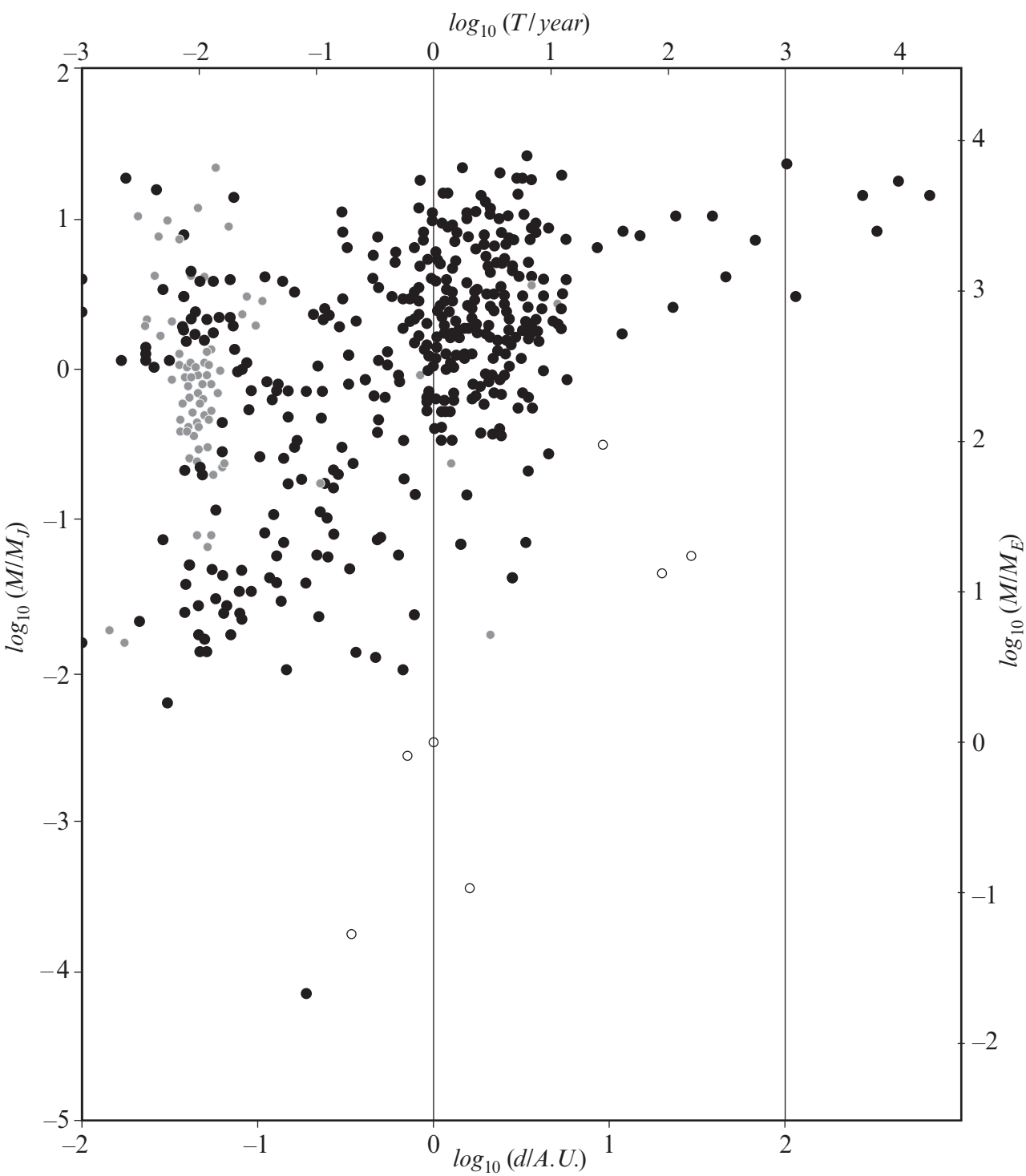
(c) Explain whether or not abundant liquid water could be found on **each** of the planets in part *(b)*. [See also Paragraph 2.] [2]

(d) Derive the equation $v_s = M_p\sqrt{\frac{G}{M_s d}}$ from the equations in the box in Paragraph 8. [2]

(e) Explain how the equation $v_s = M_p\sqrt{\frac{G}{M_s d}}$ agrees with the statement "the Doppler method is most sensitive to large planets which are close to small stars". [Paragraph 8.] [4]

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(f) Explain whether or not the orbital parameters scatter plot (above) confirms the statement "the Doppler method is most sensitive to large planets which are close to small stars."

[2]

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(g) **Place a cross** to show the position of the planet Earth on the orbital parameters scatter plot. [2]

(h) Jupiter's radius is $^{1}/_{20}$ that of the Sun. Calculate the fractional (or percentage) change in the Sun's apparent intensity as Jupiter transits in front of the Sun (as measured by a very distant observer). [Paragraph 9.] [2]

(i) Explain briefly how radial velocity measurements combined with transit measurements lead to the mean density of an exoplanet. [Paragraph 21.] [3]

Source

page 16 – http://en.wikipedia.org/wiki/File:Exoplanet_Period–Mass_Scatter.png

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SECTION C: OPTIONAL TOPICS

Option A: **Further Electromagnetism and Alternating Currents** ☐

Option B: **Revolutions in Physics - Electromagnetism and Space-Time** ☐

Option C: **Materials** ☐

Option D: **Biological Measurement and Medical Imaging** ☐

Option E: **Energy Matters** ☐

Answer the question on **one topic only.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

You are advised to spend about 20 minutes on this section.

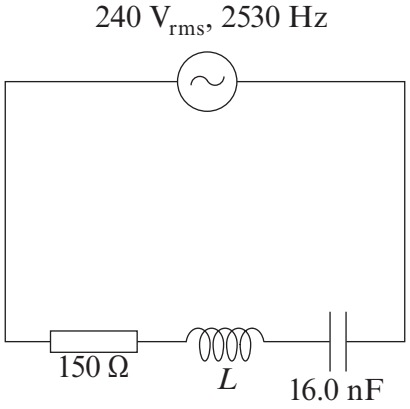
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Option A: Further Electromagnetism and Alternating Currents

C8. *(a)* A long solenoid is used in a LCR circuit.



(i) If the resonance frequency of the circuit is 2530 Hz, calculate L, the inductance of the solenoid. [3]

(ii) Explain why the rms current at resonance is 1.6 A. [2]

(iii) Calculate the rms pd across the capacitor at resonance. [3]

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(iv) Write down the following values at resonance: [4]

- the rms pd across the inductor; .....
- the mean power dissipation in the inductor; .....
- the mean power dissipation in the capacitor; .....
- the phase angle between the applied voltage and the current. .....

(b) The self-inductance of a coil is defined by the equation $E = -L\frac{\Delta I}{\Delta t}$.
Give the meanings of: [2]

E .....

L .....

$\frac{\Delta I}{\Delta t}$ .....

(c) The magnetic field strength, B, at the centre of a long solenoid is given by the equation $B = \mu_0 nI$.
Use Faraday's law to show that the self inductance of a long solenoid is given by

$$L = \mu_0 n^2 lA$$

where l is the length of the solenoid and A is its cross-sectional area. [4]

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(d) A long solenoid is of length 2.70 m, has 3400 turns per unit length and its turns have a radius of 4.50 cm. Calculate its self-inductance. [2]

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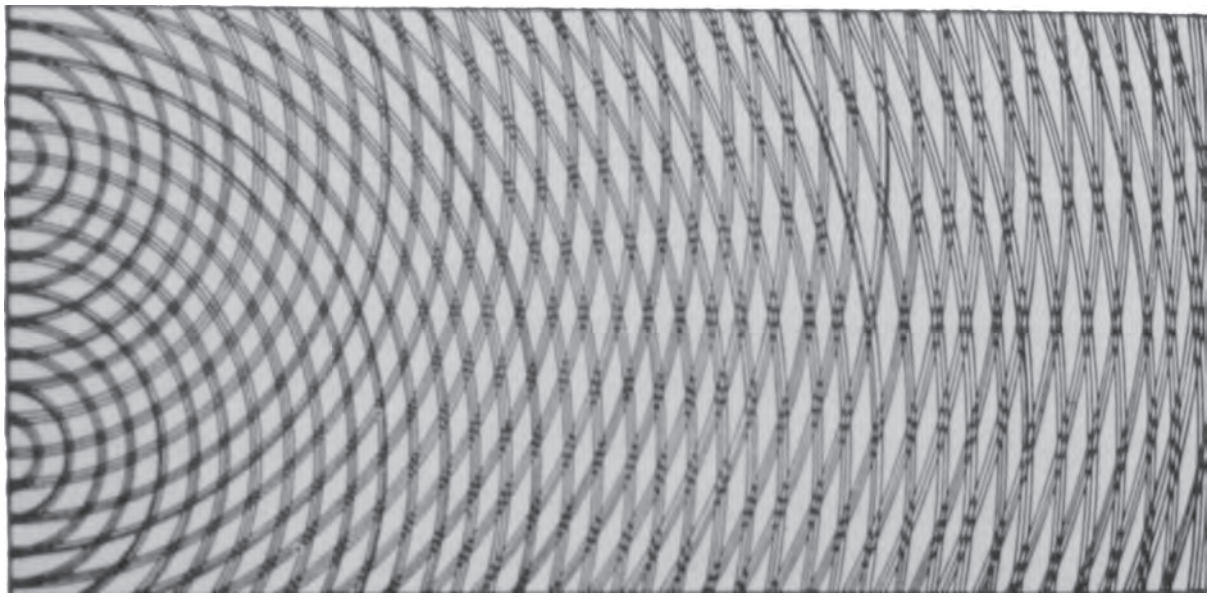
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Option B: Revolutions in Physics

C9. *(a)* The diagram below was used by Thomas Young in connection with the behaviour of waves.



(i) What does the diagram show?
As part of your answer, you should label significant features. [2]

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(ii) Young's experiments, and his interpretation of them, are now seen as the rebirth of the wave theory of light. How did the theories proposed earlier by Newton and by Huygens differ (if at all) from Young's theory? [3]

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(b) (i) Describe the experiment in which Faraday discovered *electromagnetic induction*. Include a sketched labelled diagram. [4]

(ii) What did Faraday mean by *magnetic lines of force*, and what use did he make of them in describing and/or explaining electromagnetic phenomena? [2]

(iii) How did Maxwell represent lines of force in his vortex ether? [2]

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(c) (i) State the two postulates on which Einstein's *Special Theory of Relativity* is based. [2]

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(ii) A charged pion moving in the x-direction at a speed of 0.60 c activates a detector placed at $x = 0$, and decays at $x = 0.36$ m.

(I) Calculate the *proper time* between the events of the pion being detected and the pion decaying. [4]

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(II) What does this *proper time* tell us? [1]

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Option C: Materials

C10. *(a)* Materials can be classified as being *crystalline, amorphous* or *polymeric*. Choose two of the terms in italics and explain their meaning in terms of their microscopic structure and give one example of each of your chosen materials. [3]

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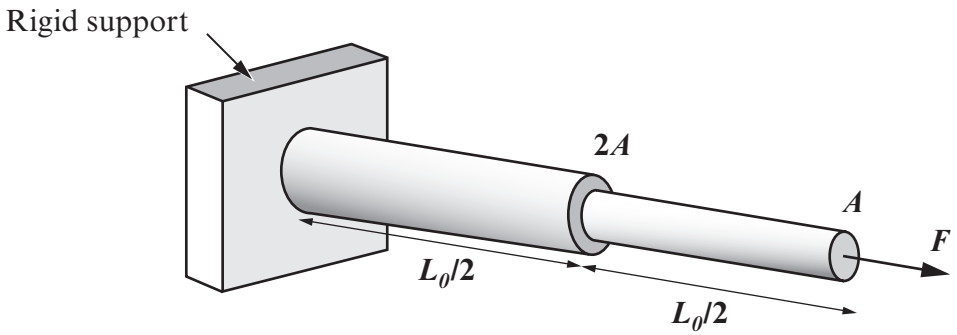
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(b) The bar in the figure below is made from a single piece of material. It consists of two segments of equal length $\boldsymbol{L_0/2}$ and cross-sectional area $\boldsymbol{A}$ **and** $\boldsymbol{2A}$.
The diagram is not drawn to scale



(i) Show that the **total** extension $\Delta \boldsymbol{x}$ of the bar under the action of an applied force F, as shown in the diagram, can be given by

$$\Delta x = \frac{3FL_0}{4AY}$$

where Y represents the Young Modulus of the material in the bar. [3]

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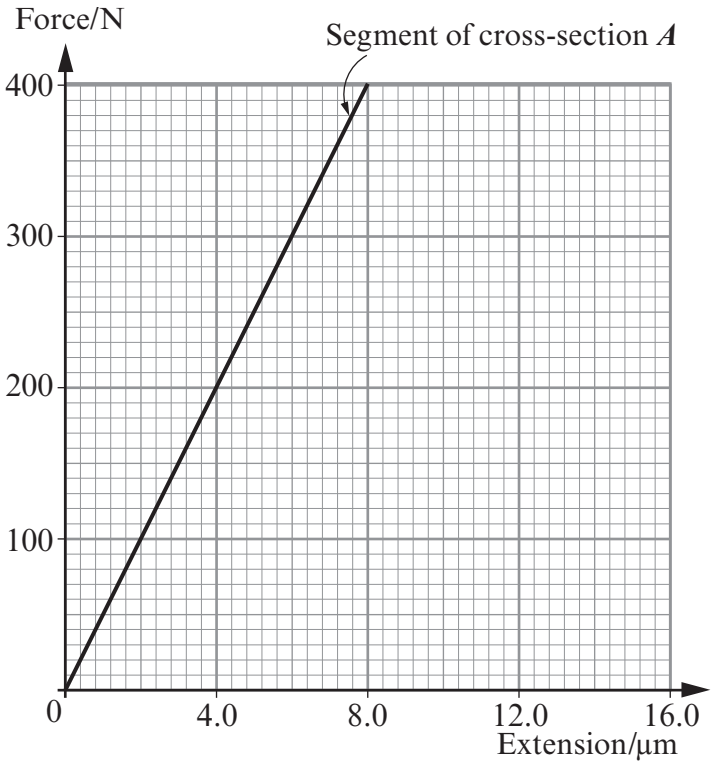
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(ii) The graph shows the variation of extension with applied force for the segment of cross-section ***A***.



(I) Draw (on the same grid) the expected force-extension graph for the segment of cross-section **2*A***. [1]

(II) Determine the Young modulus of the metal in the bar given that $L_0 = 4.0$ m and $A = 5 \times 10^{-4}\,m^2$. [3]

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(III) Calculate the elastic potential energy stored in the bar when $F = 200$ N. [3]

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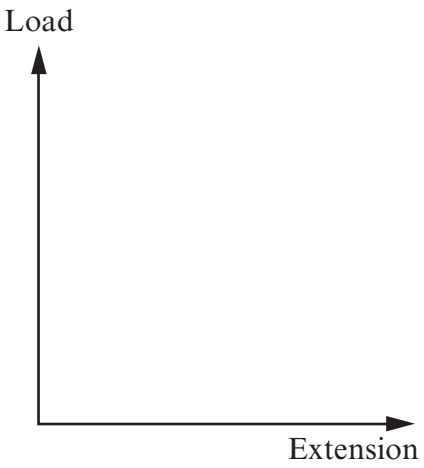
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(c) (i) When a specimen of rubber is gradually loaded and then unloaded it may show *elastic hysteresis* and *permanent set*. Explain the meaning of the terms in italics. Illustrate your answer with a sketch of the load-extension graph which would be obtained. [3]



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(ii) By **referring to the molecular structure** of rubber explain why

(I) rubber has a low value of the Young modulus compared with metals. [2]

(II) the value of the Young modulus increases with a rise in temperature. [2]

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Option D: Biological Measurement and Medical Imaging

C11. *(a)* (i) Ultrasound can be used to carry out two different types of test, an amplitude scan (A-scan) and a brightness scan (B-scan). State the differences in the type of information obtained from an A-scan and a B-scan. [2]

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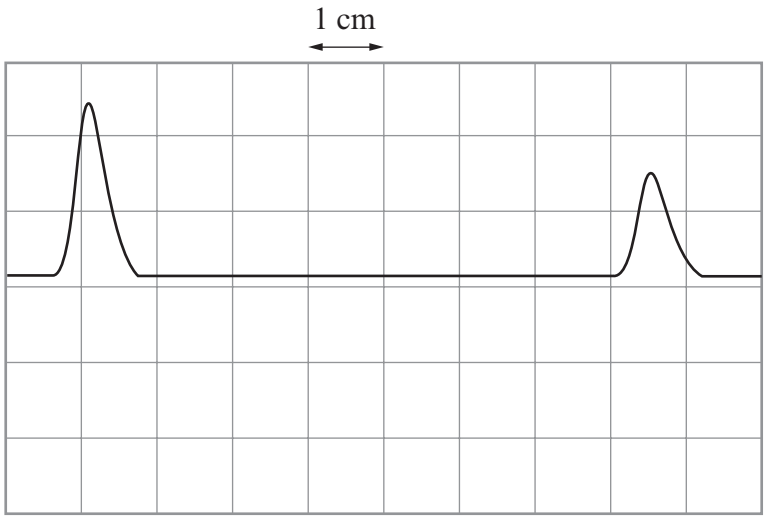
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(ii) Give an example of when a B-scan would be used in medicine. [1]

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(iii) An A-scan is used to determine the thickness of a layer of skin and fat in a patient's body. The grid below shows the interval between the initial pulse and the reflected pulse on a cathode ray oscilloscope (CRO). The time base is set so that 1 cm represents 2 μs.



(I) If the speed of ultrasound in skin and fat is 1.45×10^3 m s^{-1}, calculate the thickness of the layer of skin and fat. [3]

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(II) How would the trace on the opposite page change if no gel was placed between the ultrasonic probe and the patient's skin? [1]

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(b) (i) X-ray tubes use a hot wire to produce electrons. What happens to the X-ray output if the current to the hot wire increases? Explain your answer. [2]

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(ii) An X-ray tube accelerates electrons through a potential difference of 80 kV, giving a **beam** current of 0.45 A. Calculate:

(I) the number of electrons reaching the target every second; [1]

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(II) the maximum photon energy of the X-rays produced. [1]

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(iii) Computerised axial tomography (CT scans) use a rotating X-ray tube to build up high contrast images of slices through the body. Explain why CT scans are **not** offered for regular checking of healthy patients. [1]

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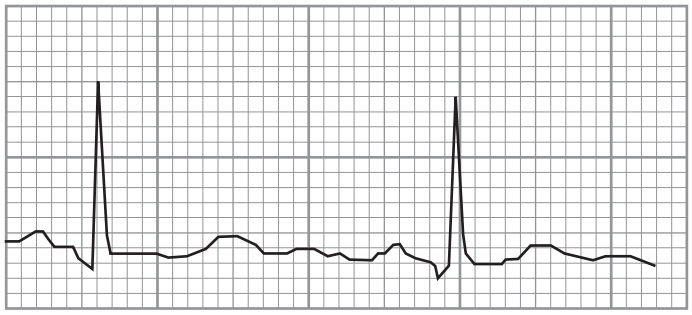
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(c) Electrodes are placed on a healthy patient in order to record the electrical behaviour of the heart. One trace obtained is shown below.



Complete the graph by adding suitable axes, scales and units. [3]

(d) Explain, briefly, how Magnetic Resonance Imaging (MRI) can produce detailed images of slices through the body. [3]

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(e) When using ionising radiation in medicine the different types of radiation are given a Quality, or Q factor. Do beta particles have a higher, lower or the same Q factor as alpha particles? Explain your answer. [2]

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Option E: Energy Matters

C12.



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Suppose that a new power station is required to meet the increased electricity demand in London. It is proposed that the site of the derelict Battersea power station in central London be used. There are two options for the new power station - a coal powered station or a nuclear powered station.

(a) Write down some suitable points for and against both coal and nuclear power and discuss whether or not central London is a suitable location for such power stations. [5]

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(b) Show that the efficiency $\frac{Q_1 - Q_2}{Q_1}$ can be written as $1 - \frac{T_2}{T_1}$ for a Carnot cycle. [2]

(c) Calculate the maximum efficiency of a heat engine operating between 50 °C and 500 °C. [1]

(d) Coal produces 25 GJ of thermal energy per tonne (1000 kg) and a 35% efficient coal power station produces 3.6 GW of electrical power.

(i) Calculate the mass of coal burned per second by the power station. [3]

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(ii) Each GJ of energy produced by the power station releases 2.1 kg of pollutants (other than CO_2) into the atmosphere. Calculate the mass of these other pollutants produced by the power station every day. [2]

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(e) In Combined Heat and Power (CHP) stations the waste heat is transferred to hot water pipes for heating nearby houses. The hot water is at a temperature of 80 °C and is transferred in iron pipes of **diameter** 32.0 cm.

(i) Calculate the total surface area of 90 m of pipes of diameter 32.0 cm. [2]

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(ii) The thermal conductivity of iron is 77 W m^{-1} K^{-1}, the iron is of thickness 2.54 cm and the temperature of the outside of the iron is 35 °C. Use the thermal conductivity equation to estimate the heat lost per second through the iron pipes. [3]

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THE QUESTION CONTINUES ON PAGE 36

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(iii) Explain briefly the most appropriate way of reducing the heat losses from the hot iron pipes. [2]

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GCE A level

1325/01-B

PHYSICS

ASSESSMENT UNIT PH5

A.M. MONDAY, 18 June 2012

CASE STUDY FOR USE WITH SECTION B

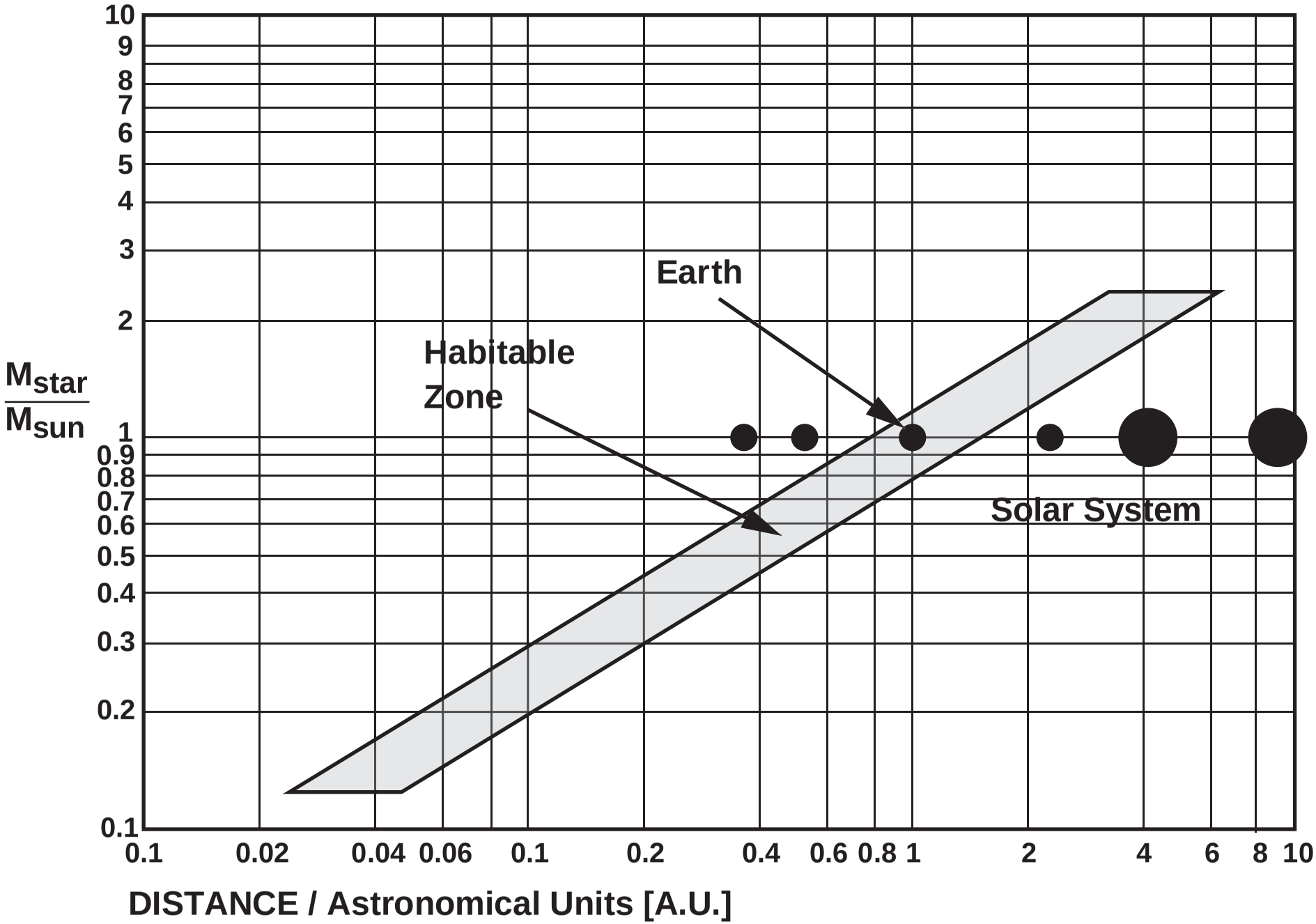
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1. **EXTRASOLAR PLANETS**
   An EXTRASOLAR PLANET, or EXOPLANET, is a planet outside the Solar System. Astronomers have announced the confirmed detection of more than 500 such planets. Most exoplanets have been detected through radial velocity observations and other indirect methods rather than actual imaging and most of these are giant planets thought to resemble Jupiter. It is now known that a substantial fraction of stars have planetary systems, including at least around 10% of sun-like stars (the true proportion may be much higher). It follows that billions of exoplanets must exist in our own galaxy alone. There are over a thousand planet candidates awaiting confirmation by more detailed investigations, including nearly a hundred that may be in the "Habitable Zone" (see opposite).

2. **This planetary habitability chart shows where life might exist on extrasolar planets based on our own solar system and life on Earth. The habitable zone represents the distance from the star where the temperature is not so hot that all the water evaporates and not so cold that all the water freezes.**

Graph of Star Mass (relative to our Sun) v Planet Distance from the Star



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3. **HISTORY OF DETECTION**

Unconfirmed until 1992, extrasolar planets had long been a subject of discussion and speculation. In the sixteenth century the Italian philosopher Giordano Bruno, an early supporter of the Copernican theory that the Earth and other planets orbit the Sun, put forward the view that the fixed stars are similar to the Sun and are likewise accompanied by their own planets. In the eighteenth century the same possibility was mentioned by Isaac Newton in the "General Scholium" that concludes his PRINCIPIA. Making a comparison with the Sun's planets, he wrote "And if the fixed stars are the centres of similar systems, they will all be constructed according to a similar design and subject to the dominion of ONE."

4. **In early 1992, radio astronomers Aleksander Wolszczan and Dale Frail announced the discovery of planets around a pulsar, PSR 1257+12. This discovery was quickly confirmed, and is generally considered to be the first definitive detection of exoplanets. These pulsar planets are believed to have formed from the unusual remnants of the supernova that produced the pulsar, in a second round of planet formation, or else to be the remaining rocky cores of gas giants that survived the supernova and then decayed into their current orbits.**

5. On October 6, 1995, Michel Mayor and Didier Queloz of the University of Geneva announced the first definitive detection of an exoplanet orbiting an ordinary main-sequence star (51 Pegasi). This discovery, made at the Observatoire de Haute-Provence, ushered in the modern era of exoplanetary discovery. Technological advances, most notably in high-resolution spectroscopy, led to the detection of many new exoplanets at a rapid rate.

DETECTION METHODS

6. Planets are extremely faint compared with their parent stars. At visible wavelengths, they usually have less than a millionth of their parent star's brightness. It is extremely difficult to detect such a faint light source, and furthermore the parent star causes a glare that tends to wash it out. For the above reasons, telescopes have directly imaged no more than about ten exoplanets. This has only been possible for planets that are especially large (usually much larger than Jupiter) and widely separated from their parent star. Most of the directly imaged planets have also been very hot, so that they emit intense infrared radiation; the images have then been made at infrared rather than visible wavelengths, in order to reduce the problem of glare from the parent star.

At the moment, however, the vast majority of known extrasolar planets have only been detected through indirect methods. The following are the indirect methods that have proven useful:

7. RADIAL VELOCITY OR DOPPLER METHOD

As a planet orbits a star, the star also moves in its own small orbit around the system's centre of mass. Variations in the star's radial velocity – that is, the speed with which it moves towards or away from Earth – can be detected from displacements in the star's spectral lines due to the Doppler effect. Extremely small radial-velocity variations can be observed, down to roughly 1 m s^{-1}. This has been by far the most productive method of discovering exoplanets. It has the advantage of being applicable to stars with a wide range of characteristics.

The Doppler shift of a spectral line is proportional to the orbital velocity of the star and we can use the equation opposite to approximate the orbital velocity of a star (v_S).

8. where M_p is the mass of the exoplanet, M_S is the mass of the star and d is the distance between them (the approximation is that the mass of the star is far greater than the mass of the planet). This equation explains why the Doppler method is most sensitive to large planets which are close to small stars.

$$v_S = M_p \sqrt{\frac{G}{M_S d}}$$

from, $\frac{M_S v_S^2}{r_S} = \frac{G M_S M_p}{d^2}$

↑

centripetal F = gravitational F

and $M_S r_S = M_p d$

↑

approximation of centre of mass equation

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9. TRANSIT METHOD

If a planet crosses (or transits) in front of its parent star's disk, then the observed brightness of the star drops by a small amount. The amount by which the star dims depends on its cross-sectional area and on the cross-sectional area of the planet. For instance, the Earth has a radius approximately 100 times less than the Sun, so as it passes in front of the Sun an observer would notice a 0.01% drop in the Sun's apparent intensity. This has been the second most productive method of detection, though it suffers from a substantial rate of false positives (due to the small drop in intensities) and confirmation from another method is usually considered necessary.

10. TRANSIT TIMING VARIATION (TTV)

TTV is an extension of the transit method where the variations in transit of one planet can be used to detect another. The first planetary candidate found this way was exoplanet WASP-3c, using WASP-3b in the WASP-3 system by Rozhen Observatory, Jena Observatory, and Torún Centre for Astronomy. The new method can potentially detect Earth sized planets or exomoons.

11. GRAVITATIONAL MICROLENSING

Microlensing occurs when the gravitational field of a star acts like a lens, magnifying the light of a distant background star. Planets orbiting the lensing star can cause detectable anomalies in the magnification as it varies over time. This method has resulted in only a few planetary detections, but it has the advantage of being especially sensitive to planets at large separations from their parent stars.

12. ASTROMETRY

Astrometry consists of precisely measuring a star's position in the sky and observing the changes in that position over time. The motion of a star due to the gravitational influence of a planet may be observable. Because that motion is so small, however, this method has not yet been very productive at detecting exoplanets.

13. PULSAR TIMING

A pulsar (the small, ultradense remnant of a star that has exploded as a supernova) emits radio waves extremely regularly as it rotates. If planets orbit the pulsar, they will cause slight anomalies in the timing of its observed radio pulses. Four planets have been detected in this way, around two different pulsars. The first confirmed discovery of an extrasolar planet was made using this method.

14. TIMING OF ECLIPSING BINARIES

If a planet has a large orbit that carries it around both members of an eclipsing double star system, then the planet can be detected through small variations in the timing of the stars' eclipses of each other. As of December 2009, two planets have been found by this method.

15. CIRCUMSTELLAR DISKS

Disks of space dust surround many stars, and this dust can be detected because it absorbs ordinary starlight and re-emits it as infrared radiation. Features in the disks may suggest the presence of planets.

16. Most extrasolar planet candidates have been found using ground-based telescopes. However, many of the methods can work more effectively with space-based telescopes that avoid atmospheric haze and turbulence. COROT (launched December 2006) and Kepler (launched March 2009) are the two currently active space missions dedicated to searching for extrasolar planets. Hubble Space Telescope and MOST have also found or confirmed a few planets. There are also several planned or proposed space missions geared towards exoplanet observation, such as New Worlds Mission, Darwin, Space Interferometry Mission, Terrestrial Planet Finder and PEGASE.

ORBITAL PARAMETERS

Scatter plot (opposite) showing masses and orbital periods of extrasolar planets discovered.

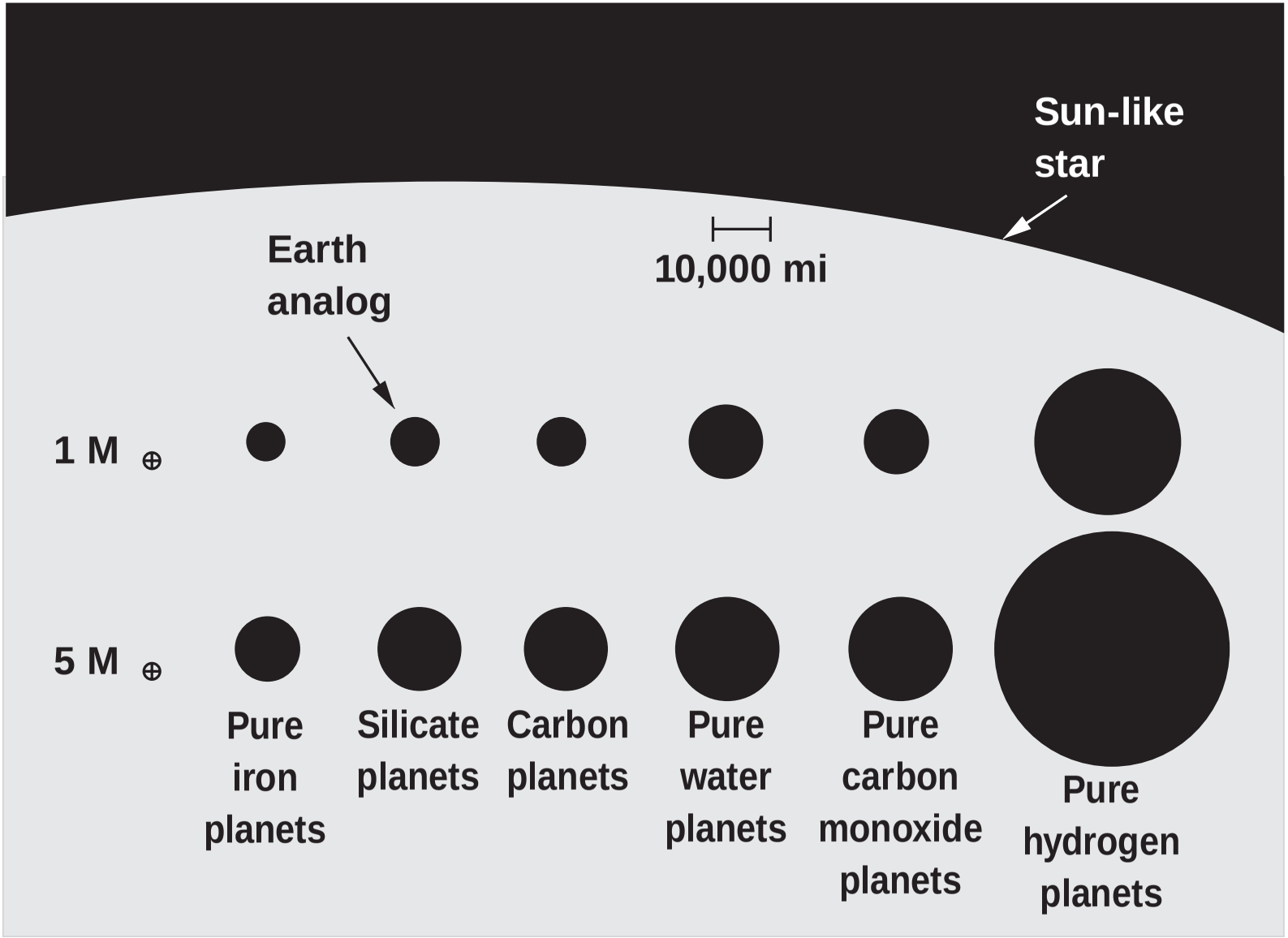
17. **Many exoplanets have orbits with very small radii, and are thus much closer to their parent star than any planet in our own solar system is to the Sun. Astronomers were initially very surprised by these “hot Jupiters”, but it is now clear that most exoplanets (or, at least, most high-mass exoplanets) have much larger orbits, some located in habitable zones - suitable for liquid water and life.**

18. **MASS DISTRIBUTION**
The vast majority of exoplanets detected so far have high masses. Many are considerably more massive than Jupiter, the most massive planet in the Solar System. However, these high masses are in large part due to an observational selection effect: all detection methods are much more likely to discover massive planets. This bias makes statistical analysis difficult, but it appears that lower-mass planets are actually more common than higher-mass ones, at least within a broad mass range that includes all giant planets. In addition, the fact that astronomers have found several planets only a few times more massive than Earth, despite the great difficulty of detecting them, indicates that such planets are fairly common.

19. The results from the first 43 days of the Kepler mission “imply that small candidate planets with periods less than 30 days are much more common than large candidate planets with periods less than 30 days and that the ground-based discoveries are sampling the large-size tail of the size distribution”.

20. TEMPERATURE AND COMPOSITION
It is possible to estimate the temperature of an exoplanet based on the intensity of the light it receives from its parent star. For example, the planet OGLE-2005-BLG-390Lb is estimated to have a surface temperature of roughly -220 °C (roughly 50 K). However, such estimates may be substantially in error because factors such as the greenhouse effect may introduce unknown complications. A few planets have had their temperature measured by observing the variation in infrared radiation as the planet moves around in its orbit and is eclipsed by its parent star. For example, the planet HD 189733b has been found to have an average temperature of 1205±9 K (932±9 °C) on its dayside and 973±33 K (700±33 °C) on its nightside.

Predicted sizes of different kinds of planets



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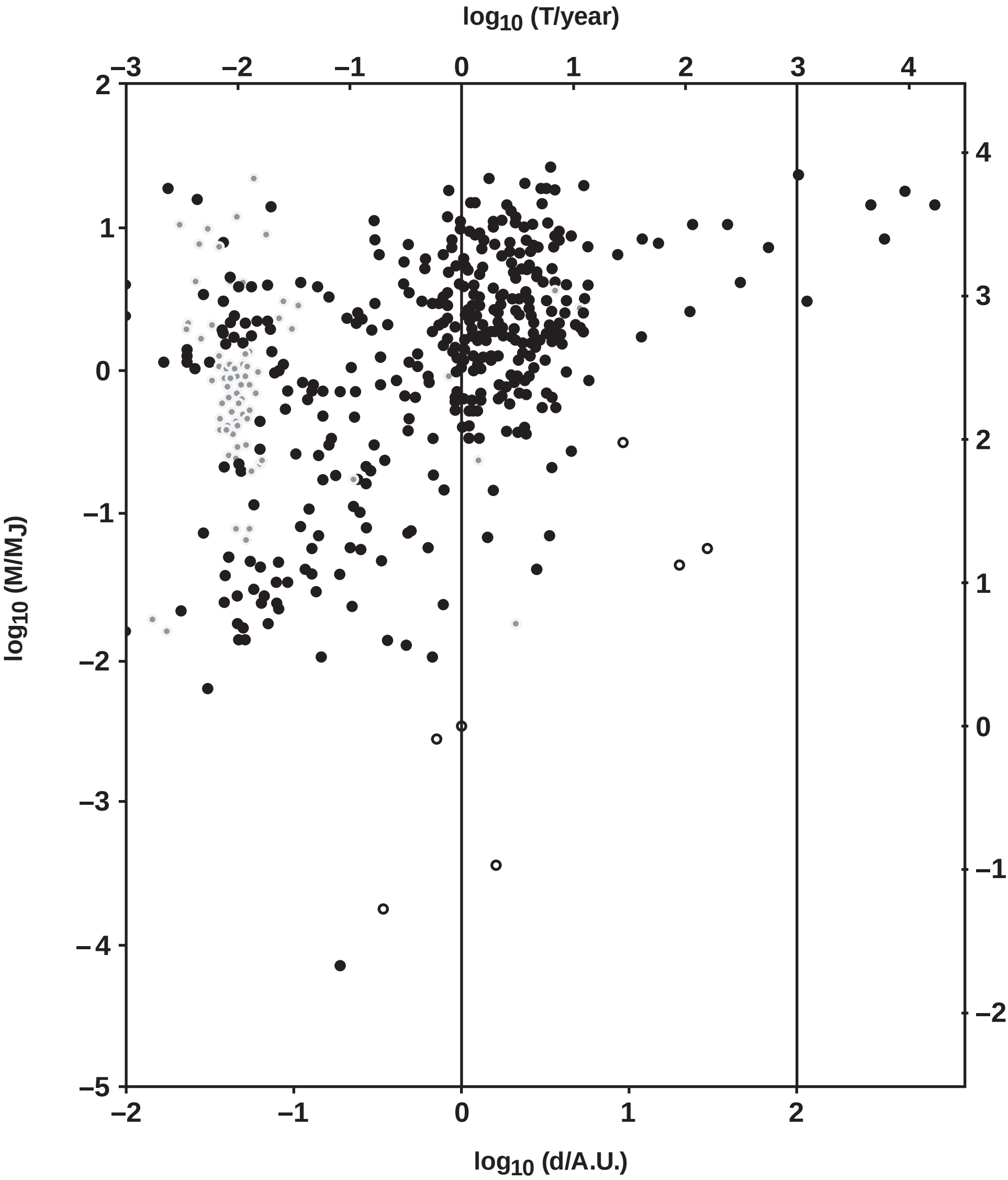
21. If a planet is detectable by both the radial-velocity and the transit methods, then both its true mass and its radius can be found. The planet's density can then be calculated. Planets with low density are inferred to be composed mainly of hydrogen and helium, while planets of intermediate density are inferred to have water as a major constituent. A planet of high density is believed to be rocky, like Earth and the other terrestrial planets of the Solar System.

22. UNANSWERED QUESTIONS
Many unanswered questions remain about the properties of exoplanets. One puzzle is that many transiting exoplanets are much larger than expected given their mass, meaning that they have surprisingly low density. Several theories have been proposed to explain this observation, but none have yet been widely accepted among astronomers. Another question is how likely exoplanets are to possess moons. No such moons have yet been detected, but they may be fairly common.

23. Perhaps the most interesting question about exoplanets is whether they might support life. Several planets do have orbits in their parent star's habitable zone, where it should be possible for liquid water to exist and for Earth-like conditions to prevail. Most of those planets

are giant planets more similar to Jupiter than to Earth; if any of them have large moons, the moons might be a more plausible abode of life. Gliese 581g, thought to be a rocky planet orbiting in the middle of its star's habitable zone, was discovered in September 2010 and, if confirmed, could be the most "Earth-like" planet discovered to date.

24. Various estimates have been made as to how many planets might support simple life or even intelligent life. For example, Dr. Alan Boss of the Carnegie Institution of Science estimates there may be a "hundred billion" terrestrial planets in our Milky Way Galaxy, many with simple life forms. He further believes there could be thousands of civilizations in our galaxy. Recent work by Duncan Forgan of Edinburgh University has also tried to estimate the number of intelligent civilizations in our galaxy. The research suggested there could be thousands of them. Apart from the scenario of an extraterrestrial civilization that is emitting powerful signals, the detection of life at interstellar distances is a tremendously challenging technical task that will not be feasible for many years, even if such life exists.


log10 (T/year)
−3
−2
−1
0
1
2
3
4
2
1
0
−1
−2
−3
−4
−5
log10 (M/MJ)
4
3
2
1
0
−1
−2
log10 (M/ME)
−2
−1
0
1
2
log10 (d/A.U.)

GCE A level

1325/01-B

PHYSICS

ASSESSMENT UNIT PH5

A.M. MONDAY, 18 June 2012

CASE STUDY FOR USE WITH SECTION B

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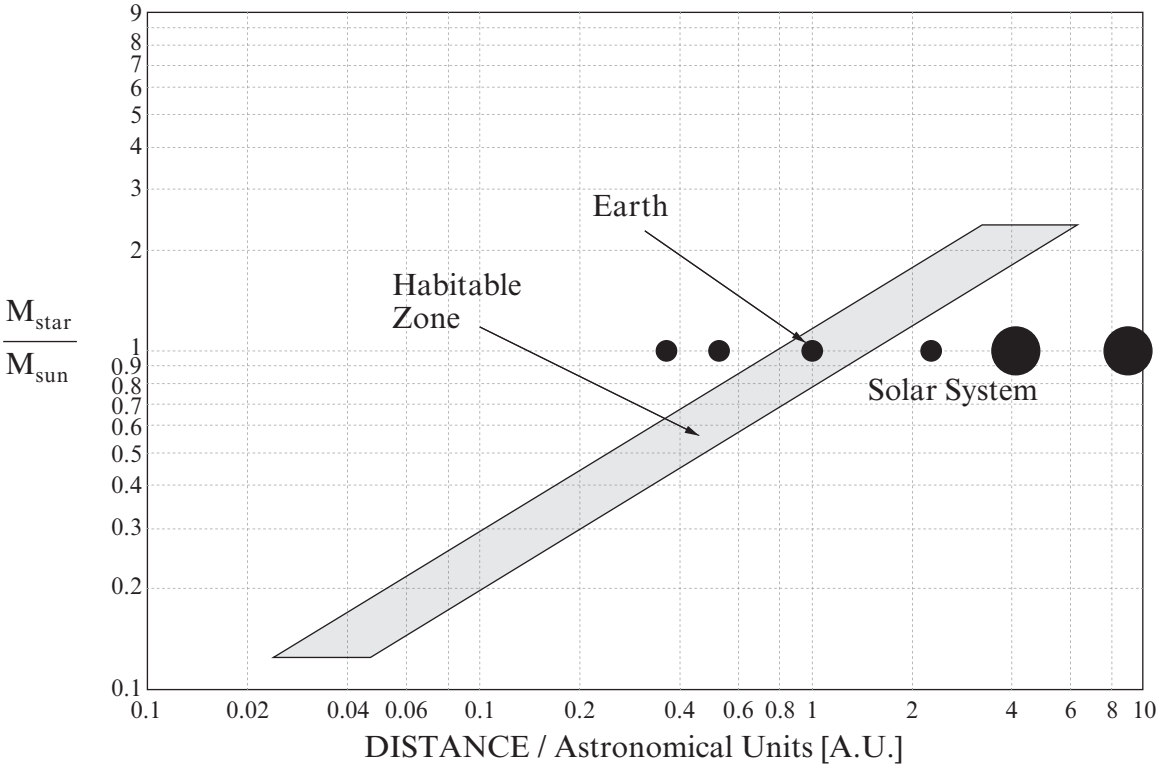
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Paragraph

Extrasolar planets

An **extrasolar planet**, or **exoplanet**, is a planet outside the Solar System. Astronomers have announced the confirmed detection of more than 500 such planets. Most exoplanets have been detected through radial velocity observations and other indirect methods rather than actual imaging and most of these are giant planets thought to resemble Jupiter. It is now known that a substantial fraction of stars 1
have planetary systems, including at least around 10% of sun-like stars (the true proportion may be much higher). It follows that billions of exoplanets must exist in our own galaxy alone. There are over a thousand planet candidates awaiting confirmation by more detailed investigations, including nearly a hundred that may be in the "Habitable Zone" (see below).

Graph of Star Mass (relative to our Sun) v Planet Distance from the Star



This planetary habitability chart shows where life might exist on extrasolar planets based on our own solar system and life on Earth. The habitable zone represents the distance from the star 2
where the temperature is not so hot that all the water evaporates and not so cold that all the water freezes.

History of detection

Unconfirmed until 1992, extrasolar planets had long been a subject of discussion and speculation. In the sixteenth century the Italian philosopher Giordano Bruno, an early supporter of the Copernican theory that the Earth and other planets orbit the Sun, put forward the view that the fixed stars are similar to the Sun and are likewise accompanied by their own planets. In 3
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Detection methods

Planets are extremely faint compared with their parent stars. At visible wavelengths, they usually have less than a millionth of their parent star's brightness. It is extremely difficult to detect such a faint light source, and furthermore the parent star causes a glare that tends to wash it out.

For the above reasons, telescopes have directly imaged no more than about ten exoplanets. This has only been possible for planets that are especially large (usually much larger than Jupiter) and widely separated from their parent star. Most of the directly imaged planets have also been very hot, so that they emit intense infrared radiation; the images have then been made at infrared rather than visible wavelengths, in order to reduce the problem of glare from the parent star. 6

At the moment, however, the vast majority of known extrasolar planets have only been detected through indirect methods. The following are the indirect methods that have proven useful:

1325
01B003

- **Radial velocity or Doppler method**

  As a planet orbits a star, the star also moves in its own small orbit around the system's centre of mass. Variations in the star's radial velocity – that is, the speed with which it moves towards or away from Earth – can be detected from displacements in the star's spectral lines due to the Doppler effect. Extremely small radial-velocity variations can be observed, down to roughly $1\,m\,s^{-1}$. This has been by far the most productive method of discovering exoplanets. It has the advantage of being applicable to stars with a wide range of characteristics. 7

  The Doppler shift of a spectral line is proportional to the orbital velocity of the star and we can use the following equation to approximate the orbital velocity of a star (v_s).

$$v_s = M_p\sqrt{\frac{G}{M_s d}}$$

from, $\frac{M_s v_s^2}{r_s} = \frac{GM_sM_p}{d^2}$ (centripetal F = gravitational F) and $M_s r_s = M_p d$ (approximation of centre of mass equation)

  where M_p is the mass of the exoplanet, M_s is the mass of the star and d is the distance between them (the approximation is that the mass of the star is far greater than the mass of the planet). This equation explains why the Doppler method is most sensitive to large planets which are close to small stars. 8

Turn over.

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Transit method

If a planet crosses (or transits) in front of its parent star's disk, then the observed brightness of the star drops by a small amount. The amount by which the star dims depends on its cross-sectional area and on the cross-sectional area of the planet. For instance, the Earth has a radius approximately 100 times less than the Sun, so as it passes in front of the Sun an observer would notice a 0.01% drop in the Sun's apparent intensity. This has been the second most productive method of detection, though it suffers from a substantial rate of false positives (due to the small drop in intensities) and confirmation from another method is usually considered necessary. 9

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  TTV is an extension of the transit method where the variations in transit of one planet can be used to detect another. The first planetary candidate found this way was exoplanet WASP-3c, using WASP-3b in the WASP-3 system by Rozhen Observatory, Jena Observatory, and Toruń Centre for Astronomy. The new method can potentially detect Earth sized planets or exomoons. 10

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- **Astrometry**
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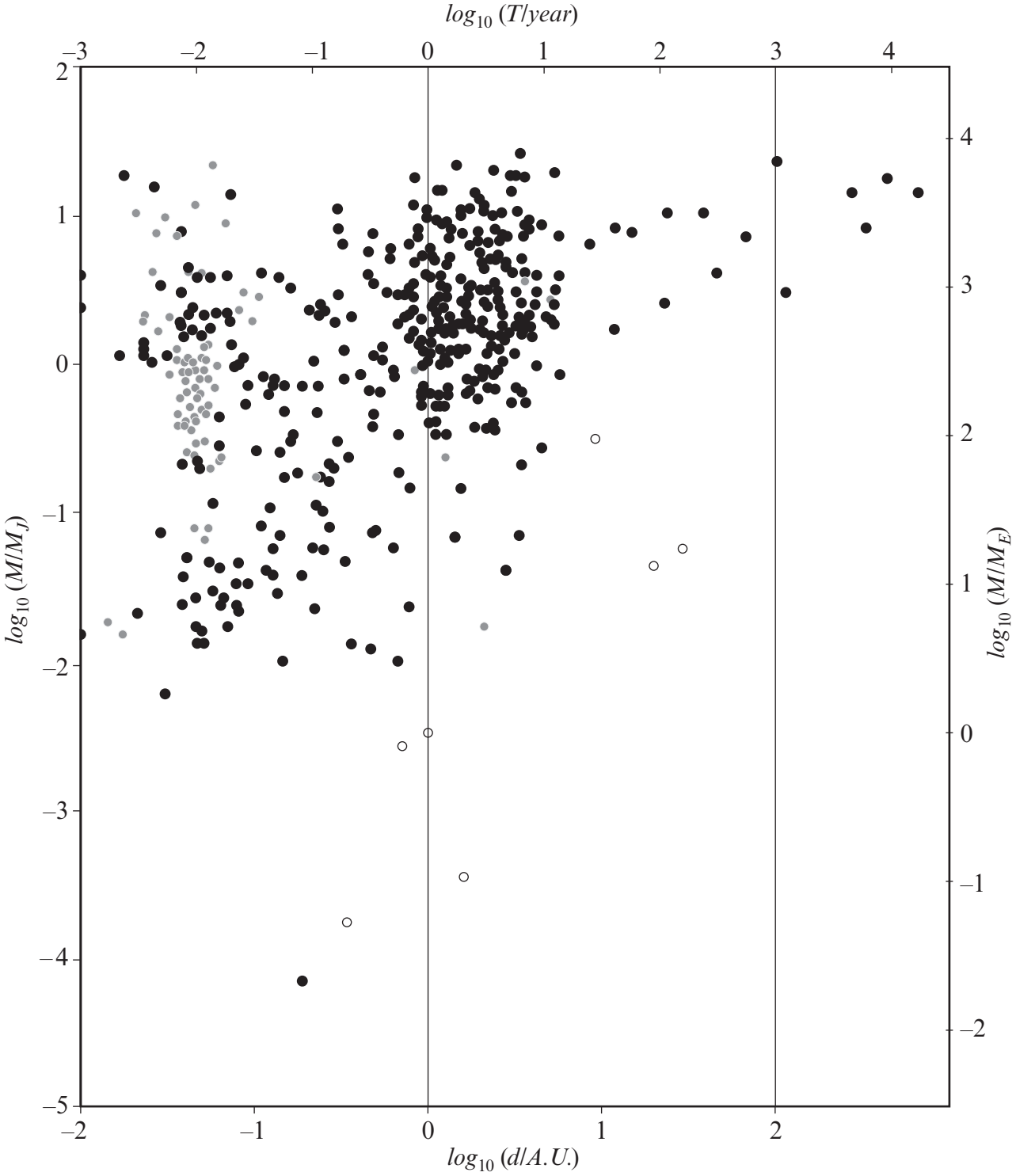
- **Timing of eclipsing binaries**
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- **Circumstellar disks**
  Disks of space dust surround many stars, and this dust can be detected because it absorbs ordinary starlight and re-emits it as infrared radiation. Features in the disks may suggest the presence of planets. 15

Most extrasolar planet candidates have been found using ground-based telescopes. However, many of the methods can work more effectively with space-based telescopes that avoid atmospheric haze and turbulence. COROT (launched December 2006) and Kepler (launched March 2009) are the two currently active space missions dedicated to searching for extrasolar planets. Hubble Space Telescope and MOST have also found or confirmed a few planets. There are also several planned or proposed space missions geared towards exoplanet observation, such as New Worlds Mission, Darwin, Space Interferometry Mission, Terrestrial Planet Finder and PEGASE. 16

Orbital parameters

Scatter plot showing masses and orbital periods of extrasolar planets discovered.



Many exoplanets have orbits with very small radii, and are thus much closer to their parent star than any planet in our own solar system is to the Sun. Astronomers were initially very surprised by these "hot Jupiters", but it is now clear that most exoplanets (or, at least, most high-mass exoplanets) have much larger orbits, some located in habitable zones - suitable for liquid water and life. 17

Turn over.

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Mass distribution

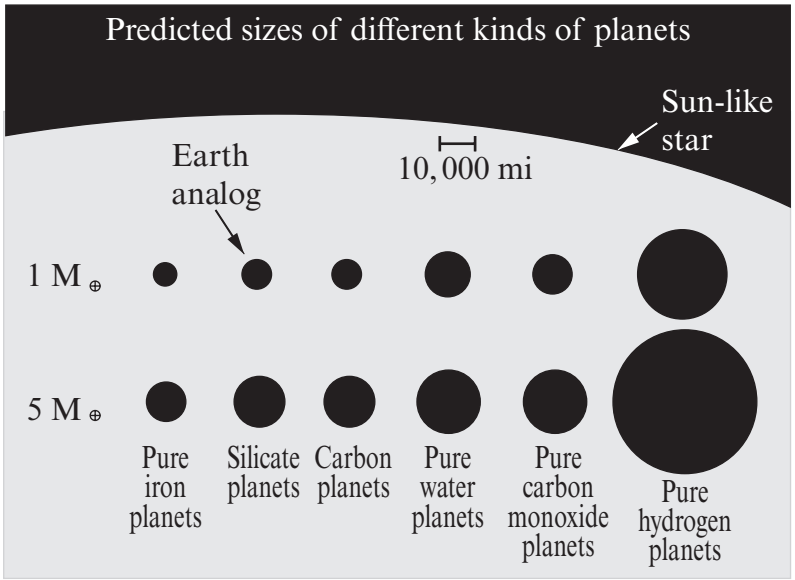
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The results from the first 43 days of the Kepler mission "imply that small candidate planets with periods less than 30 days are much more common than large candidate planets with periods less than 30 days and that the ground-based discoveries are sampling the large-size tail of the size distribution". 19

Temperature and composition

It is possible to estimate the temperature of an exoplanet based on the intensity of the light it receives from its parent star. For example, the planet OGLE-2005-BLG-390Lb is estimated to have a surface temperature of roughly -220 °C (roughly 50 K). However, such estimates may be substantially in error because factors such as the greenhouse effect may introduce unknown complications. A few planets have had their temperature measured by observing the variation in infrared radiation as the planet moves around in its orbit and is eclipsed by its parent star. For example, the planet HD 189733b has been found to have an average temperature of 1205±9 K (932±9 °C) on its dayside and 973±33 K (700±33 °C) on its nightside. 20

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Unanswered questions

Many unanswered questions remain about the properties of exoplanets. One puzzle is that many transiting exoplanets are much larger than expected given their mass, meaning that they have surprisingly low density. Several theories have been proposed to explain this observation, but none have yet been widely accepted among astronomers. Another question is how likely exoplanets are to possess moons. No such moons have yet been detected, but they may be fairly common. 22

Perhaps the most interesting question about exoplanets is whether they might support life. Several planets do have orbits in their parent star's habitable zone, where it should be possible for liquid water to exist and for Earth-like conditions to prevail. Most of those planets are giant planets more similar to Jupiter than to Earth; if any of them have large moons, the moons might be a more plausible abode of life. Gliese 581g, thought to be a rocky planet orbiting in the middle of its star's habitable zone, was discovered in September 2010 and, if confirmed, could be the most "Earth-like" planet discovered to date. 23

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Sources:

page 5 - http://en.wikipedia.org/wiki/File:Exoplanet_Period-Mass_Scatter.png

page 6 - http://en.wikipedia.org/wiki/File:Planet_sizes.svg

GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2012

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INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2012 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

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Question			Marking details	Marks Available
1	*(a)*		All α absorbed / stopped by paper (1)	
			(nearly) all γ passes through (1)	2
	(b)		${}^{0}_{-1}[\beta]$ correct (1)	
			Conservation of A and Z (but not for trivial ${}^{0}_{0}\beta$) (1)	2
	(c)		$\lambda = \frac{ln2}{T_{1/2}}$ used (1)	
			$\frac{ln2}{28.8\times365\times24\times3600}$ $[= 7.63 \times 10^{-10}\ s^{-1}]$ (1)	2
	(d)		Correct equation used i.e. some understanding of $A = A_0 e^{-\lambda t}$ or $A = \frac{A_0}{2^n}$ (1)	
			Answer correct (110 GBq **ecf** on λ) (1)	2
	(e)		$A = \pm\lambda N$ used (e.g. 140 = 7.6 x 10^{-10} N is ok) (1)	
			N = 1.83 x 10^{20} (1)	
			Mass = 90 u x 1.83 x 10^{20} = 27.4 x 10^{-6} kg (27.4 mg) **ecf** on N (1) **UNIT mark**	3
			Question 1 total	**[11]**

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Question			Marking details	Marks Available
2	*(a)*		LHS - RHS attempted (0.1859 u) (1) x 931 or $E=mc^2$ used (must have u to kg conversion) (1) 173.1 [MeV] / 2.78 x 10^{-11} [J](1)	3
	(b)		[more or 3] <u>neutrons</u> are released (1) These can produce fission (or, on average one of these....) (1)	2
	(c)		Control rods stop or absorb neutrons (1) Moderator slows neutrons (1) To increase [probability of] fission (or increase capture X-section) (1)	3
	(d)		[Highly] radioactive for many years / long half life (1) Any sensible **A level standard** comment relating to - storage, leakage, transportation, cost, dirty bombs etc. (1)	2
			Question 2 Total	**[10]**

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Question			Marking details	Marks Available
3	*(a)*	(i)	$C = \frac{\varepsilon_0 A}{d}$ used $(= \frac{8.85\times10^{-12}\times 8.2\times10^{-4}}{0.77\times10^{-3}})$ (1)	
			Answer correct (9.42×10^{-12} F) (1) **UNIT mark**	2
		(ii)	Dielectric accept solid insulator	1
	(b)	(i)	$Q = CV$ (used or implied) (1)	
			Answer correct (5.35×10^{-8} [C]) (1)	2
		(ii)	$Q = Q_0 \exp(\frac{-t}{RC})$ used e.g. $Q_0 \exp(\frac{-50\times10^{-6}}{47\times33\times10^{-9}})$ (1)	
			$= 5.3 \times 10^{-22}$ [C] (1)	
			Comment e.g. v. small or completely discharged etc. (1) **ecf**	3
		(iii)	$I = \frac{Q}{t}$ and $T = \frac{1}{f}$ (or implied) or $I = Q \times 20\,000$ (1)	
			$= 20\,000 \times 5.35 \times 10^{-8} = 1.07 \times 10^{-3}$ [A] (1) **ecf**	2
			Question 3 Total	**[10]**

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Question			Marking details	Marks Available
4	*(a)*		Concentric circle / ellipse with wire @ centre (1) Direction correct and unambiguous (1)	2
	(b)	(i)	$B = \frac{\mu_0 I}{2\pi a}$ used (1) $B_1 = 2.4\text{x}10^{-6}$ [T] **and** $B_2 = 3.6\text{x}10^{-6}$ [T] (1) Answer $B = 1.2\text{x}10^{-6}$ [T] (1) **ecf** Out of paper (1)	4
		(ii)	One wire is in the magnetic field of another (can be implied)(1) Field due to I_2 out of paper at I_1 (1) Force to left due to LHR (1) Other wire is opposite due to N3 or opposite field or equivalent (1) **AWARD a maximum of 3 marks** OR One wire is in the magnetic field of another (can be implied) (1) Field due to I_1 out of paper at I_2 (1) Force to right due to LHR (1) Other wire is opposite due to N3 or opposite field or equivalent (1) **AWARD a maximum of 3 marks**	3
			Question 4 Total	**[9]**

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Question			Marking details	Marks Available
5	*(a)*		The right side (independent mark) (1) **Force [on electrons (can be implied)]** is to the right (1) Due to LHR or current back to front face (1)	3
	(b)		$V = Ed$ *(or $E=V/d$)* (1) Quoted only or implied $= 3.2\text{x}10^{-6}$ x $2.6\text{x}10^{-3}$(**ecf** from a) $= 8.32 \times 10^{-9}$ [V] (1)	2
	(c)		eE = electrical force **and** Bev = magnetic force (1) equilibrium is reached or electrons pass through unaffected etc. (1)	2
	(d)		Substituting $v = \frac{I}{nAe}$ in $eE = Bev$ **or** calculating $v = 3.93 \times 10^{-5}$ m s^{-1}(1) Rearranging i.e. $B = \frac{EnAe}{I}$ (1) Answer = 0.081 T (1) **UNIT mark** **Or** rearranging $V_H = \frac{BI}{nte}$ (1) $\left\{B = \frac{nteV}{I}\right\}$ Correct substitution (including t = 0.85 mm and V = 8.32 nV **ecf**) (1) Answer correct (1)	3
			Question 5 Total	**[10]**

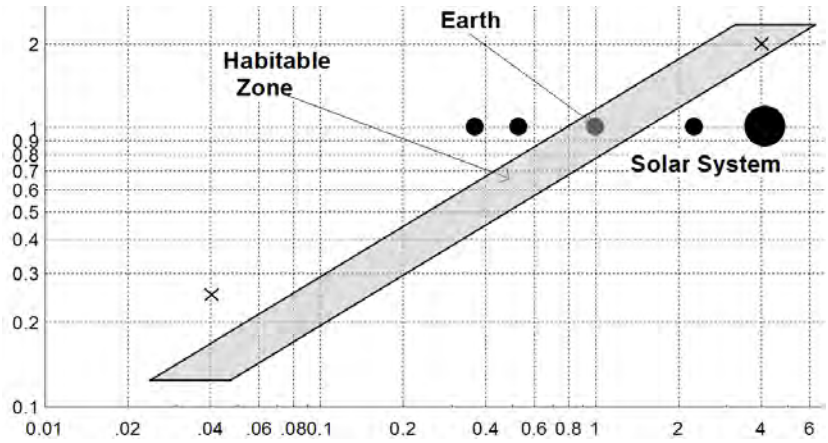
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Question			Marking details	Marks Available
6	*(a)*		Valid complete statement - 2 marks e.g. Induced emf is proportional to (or equal to) the rate of change (or cutting) of flux (linkage). e.g. Accept induced emf = change of flux / time e.g. Accept emf = rate of flux cutting (bod - missing induced) Nearly complete statement - 1 mark e.g. $\mathcal{E} = [-]\frac{[d]\varphi}{[d]t}$ (terms not defined) e.g. Induced emf is proportional to change of flux (missing rate of)	2
	(b)	(i)	$\mathcal{E} = -\frac{d\varphi}{dt}$ or $\frac{\varphi}{t}$ or $\frac{BA}{t}$ or $\frac{BAN}{t}$ (1) $A = \pi r^2$ used (1) Use of $I = \frac{V}{R}$ (1) Correct answer (1)	4
		(ii)	$\div \sqrt{2}$ (1) = 1410 [A] (1)	2
		(iii)	$P = IV$ or I^2R or V^2/R used (1) = 456 [W] (1)	2
			Question 6 Total	**[10]**

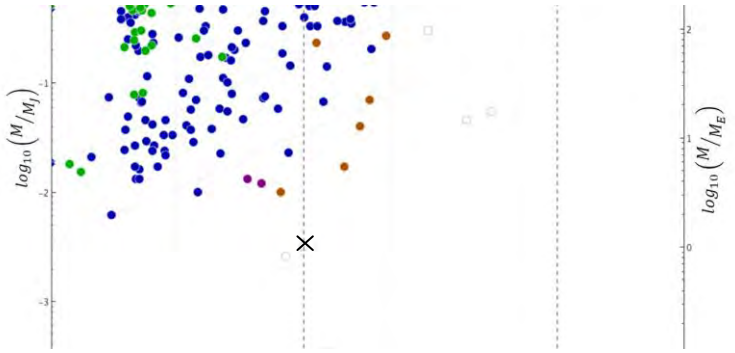
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Question			Marking details	Marks Available
7	*(a)*		Because their star is the Sun **or** they all orbit the Sun **or** $\frac{M_{star}}{M_{Sun}} = 1$ Accept M_{star} is the same	1
	(b)	(i)		1
		(ii)		1
		(c)	(i) yes **because** it's in the habitable zone **ecf** (1) (ii)[no] **because** it is too hot **or** too close to star **ecf** (1)	2
		(d)	Eliminating r_S (1) $\frac{M_S v_S^2}{r_S} = \frac{GM_S M_p}{d^2} \rightarrow \frac{v_S^2}{M_p d / M_S} = \frac{GM_p}{d^2}$ or $M_S v_S^2 = \frac{GM_S r_S M_p}{d^2} = \frac{GM_p d M_p}{d^2}$ Remainder of algebra convincing (1)	2
		(e)	Because Doppler shift $\propto v_S$ (accept depends on) (1) and $v_S \propto M_P$ or v_S increases with M_P (1) and $v_S \propto M_S^{-0.5}$ or v_S decreases with M_S (1) and $v_S \propto d^{-0.5}$ or v_S decreases with d (1)	4

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Question			Marking details	Marks Available
7	*(f)*		Some comment about most planets being large mass e.g. nearly all masses greater than M_E or average/median mass is close to mass of Jupiter etc. (1) Some comment about *d* being quite small on average e.g. mean/median *d* is only about 1 AU (not 0 AU!) or nearly all planets inside 10 AU etc. (1) The graph says nothing about the size of the star (1) **Award a maximum of 2 marks only** Most planets towards top left of graph (by itself) scores 1 mark	2
	(g)		 Accept a circle around the correct planet x correct – 1 mark, y correct – 1 mark	2
	(h)		$\frac{\pi r_1^2}{\pi r_2^2} = \mathbf{20}^2$ (1) Drops by 0.25% or drops **to** 99.75% or drops by $^1/_{400}$ (1) (correct answer implies first step)	2
	(i)		Radial velocity gives mass (1) Transit gives radius **or** area **or** diameter (1) Density = $\frac{mass}{volume}$ and volume from area or diameter or radius (1)	3
			Question 7 Total	**[20]**

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Question			Marking details	Marks Available
8	*(a)*	(i)	$\omega L = \frac{1}{\omega C}$ or $f = \frac{1}{2\pi\sqrt{LC}}$ (1)	
			$\omega = 2\pi f$ or algebra i.e. $L = \frac{1}{4\pi^2 C f^2}$ (1)	
			L = 0.247 H **UNIT mark** (1)	3
		(ii)	$I = \frac{240}{150}$ (1)	
			Because V_L and V_C cancel or because all voltage across R etc. (1)	2
		(iii)	$V = IX_C$ (1)	
			$= I\omega L$ (1)	
			= 6360 [V] (1)	3
		(iv)	6360 [V] (1)	
			0 (1)	
			0 (1)	
			0 (1)	4

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Question			Marking details	Marks Available
8	*(b)*		E - **induced** emf L - (self) inductance (1) For both	
			$\frac{\Delta I}{\Delta t}$ - rate of change of current (1)	2
	(c)		$\mathcal{E} = (-)\frac{d}{dt}(BAN)$ or $\mathcal{E} = (-)\frac{BAN}{t}$ (1)	
			$B = \mu_0 nI$ substituted i.e. $\mathcal{E} = (-)\frac{\mu_0 nIAN}{t}$ (1)	
			$N = nl$ substituted i.e. $\mathcal{E} = (-)\frac{d}{dt}(\mu_0 nIAnl)$ (1)	
			Final arrangement and 'comment' e.g. $\mathcal{E} = (-)\overbrace{\mu_0 n^2 Al}\frac{I}{t}$ (1)	4
	(d)		$L = \mu_0 n^2 \pi r^2 l$ i.e. using πr^2 and $\mu_0 n^2 Al$ (1)	
			Answer [=0.25 H] (1)	2
			Question 8 Total	**[20]**

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Question			Marking details	Marks Available
9	*(a)*	(i)	Either in words or on diagram, for first mark 2 of; for second 3 of: Interference mentioned, 2 sources mentioned or labelled, wavefronts labelled, lines of constructive or destructive interference labelled.	2
		(ii)	**Newton**: Light is moving [or flow of] corpuscles [particles](1) **Huygens**: Light is a wave. (1) But H had no notion of periodic nature of wave (1) [**or** of wavelength **or** of interference]	3
	(b)	(i)	Two coils and iron core shown on diagram. (1) When current switched on or off [accept either] in one coil, (1) Current flowed [or equivalent] in other coil. (1) Detected by deflection of compass needle close to a [long] wire connected across the secondary. (1)	4
		(ii)	Any Two of Lines shown by compass needle or iron filings. Cutting by conductor induces emf [accept current] in conductor **or** emf induced in a circuit if number of lines linking it changes. Lines under tension **or** light/radiation is a wave propagating along the lines.	2

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Question			Marking details	Marks Available
9	*(b)*	(iii)	spinning 'beads' [**or** cells, vortices…] (1)	
			axis of spin along lines of force. (1)	2
	(c)	(i)	Laws of Physics the same in all inertial frames. [Accept: No privileged (special) frame of reference.] (1)	
			Speed of light independent of the motion of its source. [Accept: speed of light always the same.] (1)	2
		(ii)I	time of flight = 0.36 [m] / 0.60 x 3.0 x 10^8 [s] [= 2.0 ns] [or by implication](1)	
			attempt to use this as Δt in time dilation formula (1)	
			Correct evaluation of $\sqrt{(1 - v^2/c^2)}$ or its reciprocal [0.8 or 1.25] [or by implication] (1)	
			= 1.6 [ns] time (1)	4
		II	Time [between events] as found by clock moving with pion **or** by clock present at both events. Accept : time as experienced by pion.	1
			Question 9 Total	**[20]**

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Question			Marking details	Marks Available
10	*(a)*		(2x1) from: crystalline- long range, regular (unit cell repeated) Amorphous- short range, irregular Polymeric- long chain molecules (no order between, only within molecules)	
			2 examples given (1)	3
	(b)	(i)	Equation applied to both sections correctly i.e. $\frac{F\frac{L_0}{2}}{AY}$ and $\frac{F\frac{L_0}{2}}{2AY}$ (1)	
			Extensions added i.e. $\frac{F\frac{L_0}{2}}{AY}+\frac{F\frac{L_0}{2}}{2AY}$ (1)	
			Convincing algebra (1)	3
		(ii)I	Line drawn correctly	1
		II	Re-arrange for ***A*** bar, **2*A*** bar or **combination (1)**	
			Correct force-extension combination for each of above (1)	
			Answer = 2 x 10^{11} [N m^{-2}] (1)	3
		III	Both extensions correct i.e. 2 µm and 4 µm (ecf on line) (1)	
			Correct method of finding energy e.g. $\frac{1}{2}Fx$ or $\frac{1}{2}\sigma\varepsilon\times V$ or area (1)	
			Answer correct E_p = 6 x 10^{-4} [J] (**ecf** on line usually 12x10^{-4} [J]) (1)	3
			Alternative: Areas under graph lines - same method applies	

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Question			Marking details	Marks Available
10	*(c)*	(i)	Hysteresis labelled/described correctly (1)	
			Permanent set labelled/described correctly (1)	
			Correct sketch (1)	3
		(ii)I	Untangling of molecules (rotation about single bonds) (1)	
			Small force causes large extension (1)	2
		II	Increasing temperature increases random rotation about single bond (molecules 'ravel' up and become shorter) (1)	
			(Given) force produces smaller extension (1)	2
			Question 10 Total	**[20]**

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Question			Marking details	Marks Available
11	*(a)*	(i)	A-scan measures distances / depths (1)	
			B-scan provides images (moving) pictures (1)	2
		(ii)	Any valid application e.g. development of foetus, scanning young (born) babies' skulls imaging liver, kidneys, heart locating arteries/veins/nerves locating fluid (puss, blood etc.) inside body (esp abdomen&lungs)	1
		(iii)I	Time = 7.5 x 2 μs (1)	
			Distance = time x 1.45 x 10^3 (=21.8 mm) (1)	
			Thickness = 0.5 x distance (=10.9 mm) (1)	3
		II	Both pulses at start or only the first pulse (accept second pulse very faint)	1
	(b)	(i)	More electrons emitted or hit target (1)	
			Output higher **intensity** (1)	2
		(ii)I	2.8 x 10^{18}	1
		II	80000 x 1.6 x 10^{-19} = 1.28 x 10^{-14} J (accept 80 keV)	1

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Question			Marking details	Marks Available
11	*(b)*	(iii)	High X-ray dose / high exposure / expensive / CT scanner in high demand	1
	(c)		*y*-axis pd or voltage etc. **and** x-axis time (1)	
			y- axis units – mV (1)	
			x-axis unit – s (1)	3
	(d)		Nuclei precess/wobble around field lines (1)	
			Radio waves at resonance frequency change/flip orientation of nuclei (1)	
			Orientation goes back to field direction (while emitting radio waves) (1)	3
	(e)		Lower (1)	
			Alpha are more damaging/ionising (to tissue) (1)	2
			Question 11 Total	**[20]**

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Question			Marking details	Marks Available
12	*(a)*		3 valid points for/against coal & nuclear 3 marks 2 valid points for/against coal & nuclear 2 marks 1 valid point for/against coal & nuclear 1 mark Coal Acid rain, global warming/CO_2 emitting, other specified pollution e.g. smog & carcinogenic particulates, causes asthma, can be very high output power Nuclear Danger of accident/leak in high population area, decommissioning very expensive, waste radioactive for many years **and** must be contained, expensive in general, no CO_2 emission, can be very high output power 2 valid local points 2 marks 1 valid local point 1 mark Local points Large number of local jobs (and plenty of people to fill vacancies), plenty of water available (Thames), less need for long power cables, good rail links, very expensive land prices, causes asthma (but cannot be counted twice), risk of radioactive leak in high population area (but cannot be counted twice), reduces already poor air quality in London etc.	5
	(b)		Substitution of $\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$ (1) Rest of algebra $\frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$ (1)	2
	(c)		$1 - \frac{T_2}{T_1} = 1 - \frac{323}{773} = 0.58$ or 58%	1

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Question			Marking details	Marks Available
12	*(d)*	(i)	$\times \frac{100}{35}$ (i.e. $3.6 \times \frac{100}{35} = 10.3$ GW) (1)	
			$\div 25$ (i.e. $10.3 \div 25$) (1)	
			Answer = 0.411 [tonnes s^{-1}] (1)	3
		(ii)	Method correct i.e. (1) $\times 2.1 \times 24 \times 60 \times 60$ (even if 10.3 GW$\times 2.1 \times 24 \times 60 \times 60$)	
			Answer = 653 tonne (653×10^3 kg) (1)	2
	(e)	(i)	$A = 2\pi rl$ used (allow 1st mark for πdl) (1)	
			Correct answer = 90 [m^2] (1)	2
		(ii)	$\frac{\Delta Q}{\Delta t} = -Ak\frac{\Delta \theta}{\Delta x}$ used (1)	
			Values substituted correctly i.e. $7.24 \times 77 \frac{45}{0.0254}$ (1)	
			Answer correct = 9.87×10^5 [W] (1)	3
		(iii)	Lagging (or description of equivalent) (1)	
			With material of high k (or U) (1) (accept apt material e.g. fibre glass, rockwool etc.)	2
			i.e. wrap fibre glass around the pipe - 2 marks	
			Question 12 Total	**[20]**

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Surname	Centre Number	Candidate Number
Other Names		2

WJEC CBAC

GCE A level

1325/01

PHYSICS

ASSESSMENT UNIT PH5: ELECTROMAGNETISM, NUCLEI & OPTIONS

A.M. MONDAY, 27 June 2011

1¾ hours

1325 010001

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator a **Case Study Booklet** and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

This paper is in 3 sections, **A**, **B**, and **C**.

Section A: 60 marks. Answer **all** questions. You are advised to spend about 1 hour on this section.

Section B: 20 marks. The Case Study. Answer **all** questions. You are advised to spend about 20 minutes on this section.

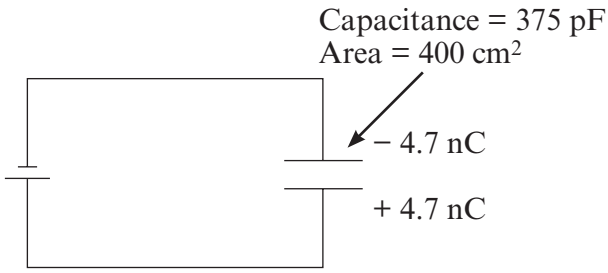
Section C: Options; 20 marks. Answer **one option only.** You are advised to spend about 20 minutes on this section.

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Examiner only

SECTION A

1. A parallel plate capacitor with no dielectric between the plates is charged by a cell as shown in the diagram.



(a) (i) Calculate the emf of the cell. [2]

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.....

(ii) Calculate the separation of the plates of the capacitor. [2]

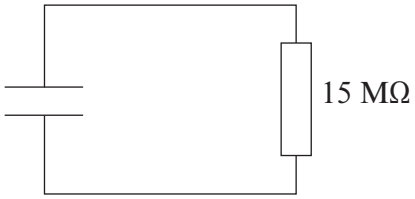
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(b) The capacitor is now discharged through a 15 MΩ resistor.

Calculate the time for the charge on the capacitor to drop from 4.7 nC to 0.7 nC.



[4]

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(c) The capacitor is employed as a fog detector and uses the fact that water is a good dielectric. Explain briefly how the capacitor could detect the presence of fog. [2]

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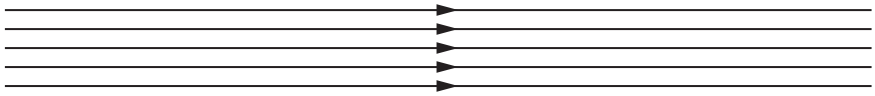
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2. Each of five long, straight, parallel wires carries a current of 0.3A.



(a) The wires are very close together. Show that the magnetic field strength, B, at a distance of 12.5 cm away from them is 2.4 μT. [2]

.....

.....

.....

(b) An α particle travelling with speed 8.8×10^6 m s^{-1} passes through a point where the magnetic field strength is 2.4 μT. Explain briefly in which direction the α particle is travelling when it experiences

(i) no force, [2]

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.....

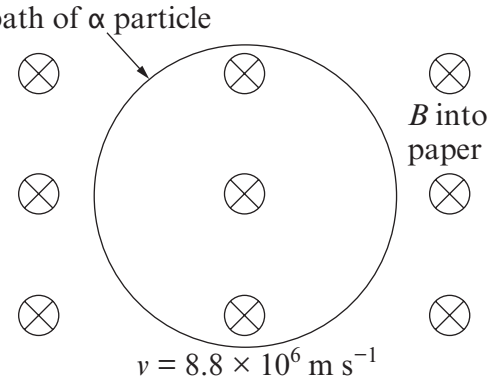
(ii) a force of 3.38×10^{-18} N. [2]

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(c) The α particle travels in the Earth's magnetic field. This may be assumed to be uniform and of strength 2.4 μT as shown. The α particle travels in a circular path, as shown, at a constant speed of 8.8×10^6 m s^{-1}.
The mass of the α particle is 4 u.



(i) **Indicate with an arrow** the direction of motion of the α particle. [1]

(ii) Calculate the radius of the path of the α particle. [3]

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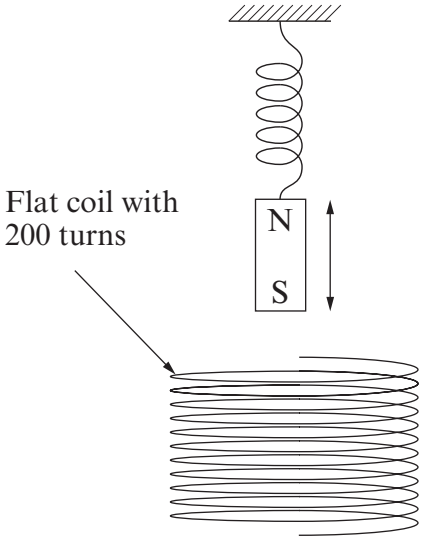
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3. A strong magnet is held on a spring and performs simple harmonic motion near a flat coil as shown.



(a) Explain briefly why an alternating emf is induced in the coil. [3]

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(b) (i) The induced emf varies in magnitude sinusoidally with a peak value of ±0.707 V. Calculate the rms value of the induced emf. [1]

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.....

(ii) State the value of the rate of change of flux through each turn of the coil when the peak value of 0.707 V is obtained and explain how you obtained your answer. [3]

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(c) One end of the coil is connected with the other so that there is an induced current. Explain why the magnet's motion is now damped. [3]

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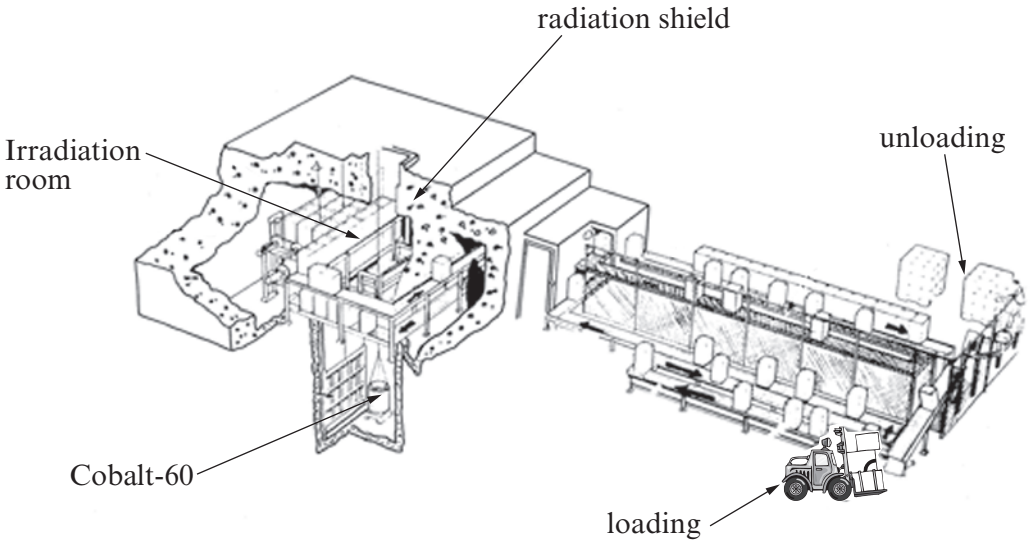
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4. Radioactive cobalt-60 ($^{60}_{27}Co$) is used to irradiate and sterilise surgical equipment. Many instruments can be irradiated simultaneously as shown.



(a) Explain briefly which type of radiation (α, β, or γ) would be most appropriate to irradiate metallic surgical instruments in this way. [2]

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(b) The half life of cobalt-60 is 5.3 years.

(i) Calculate the decay constant of cobalt-60. [2]

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(ii) Calculate the activity of 1 mg of cobalt-60. [3]

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(iii) Calculate the time taken (in years) for the activity of a cobalt-60 source to drop from 4.16×10^{10} Bq to 1.04×10^{10} Bq. [3]

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5. Americium-241($^{241}_{95}$Am) is an artificially made radioactive isotope and is commonly used in smoke detectors. It decays through emission of an α particle to neptunium (Np).

(a) Complete the following reaction equation by entering the appropriate numbers on the dotted lines. [2]

$$^{241}_{95}\text{Am} \longrightarrow \text{.....Np} + \text{.....}\alpha$$

(b) Use the following data to calculate the energy released in the above reaction. [3]

mass of americium 241 nucleus = 241.00471 u mass of α particle = 4.00151 u,
mass of neptunium nucleus = 236.99712 u 1u = 931 MeV

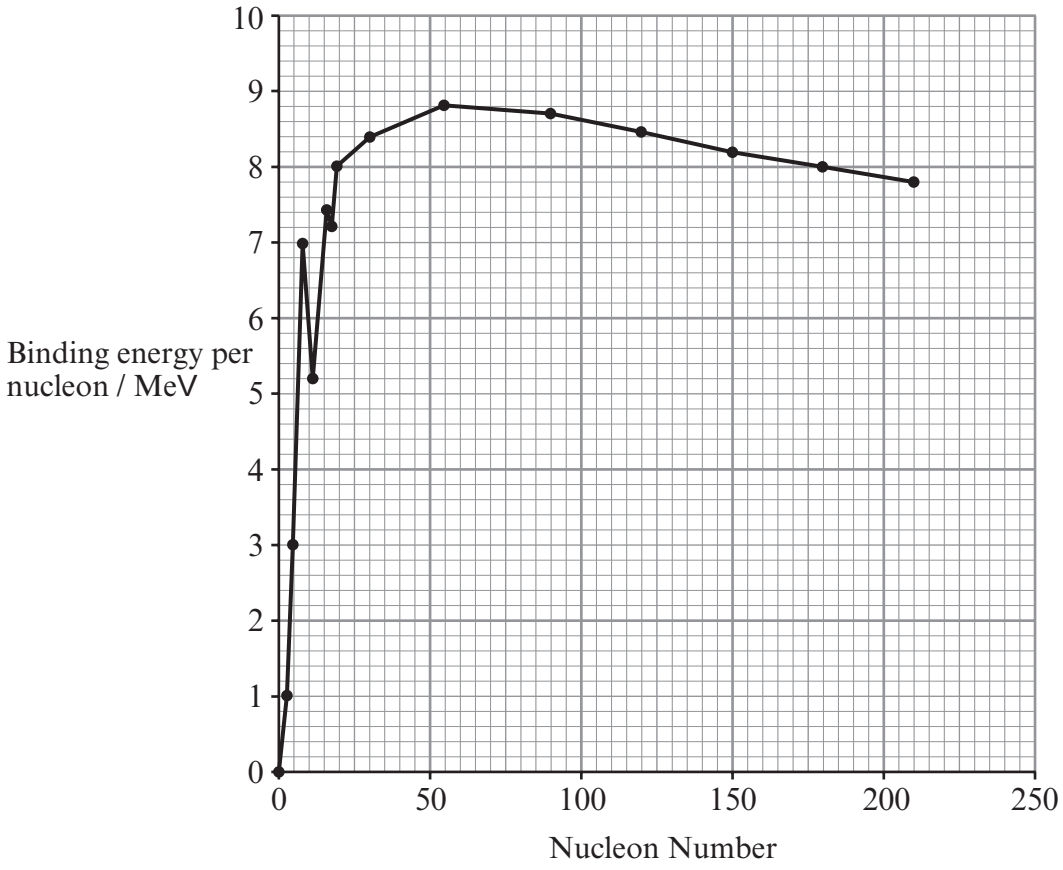
(c) (i) Calculate the binding energy per nucleon of americium-241. [4]

mass of proton = 1.00728 u, mass of americium nucleus = 241.00471 u,
mass of neutron = 1.00866 u, 1u = 931 MeV

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(ii) Plot your answer from *(c)*(i) on the graph below. [1]

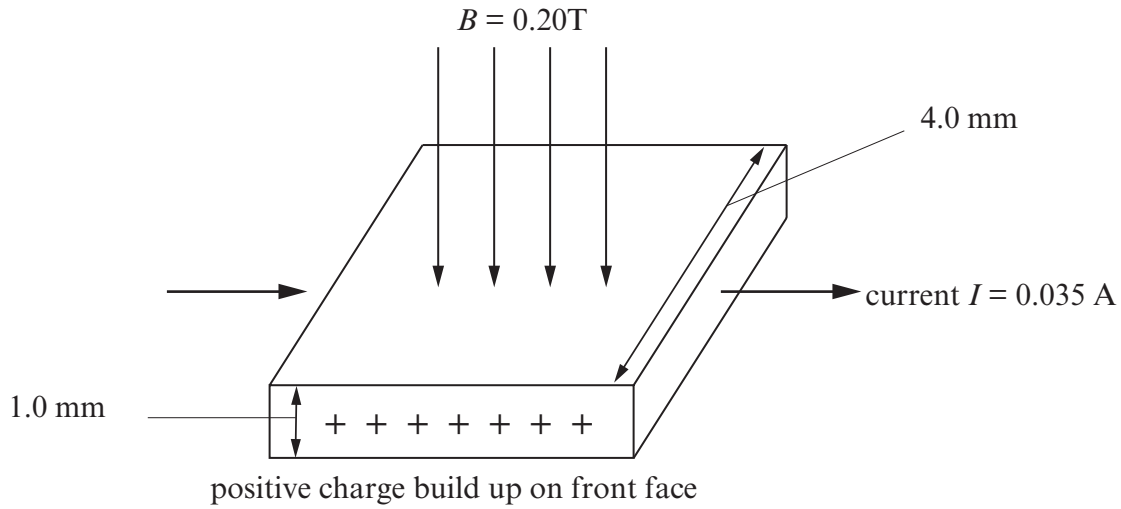


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6. The number n of free electrons per unit volume in a silicon chip can be found by measuring the Hall voltage across it when placed in a uniform magnetic field as shown.



(a) Insert a voltmeter on the above diagram to show how you would measure the Hall voltage. [1]

(b) Explain why a positive charge builds up on the front face. [3]

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(c) There is a uniform electric field between the front and the back faces and the Hall voltage is 8.5 mV. Calculate the value of this electric field. [2]

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(d) Calculate n, by equating the magnetic and electrical force on an electron in the Hall probe and using the relationship $I = nAve$. [4]

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SECTION B

The questions refer to the Case Study.
Direct quotes from the original passage will not be awarded marks.

7. *(a)* The distance between the Earth and the Moon is 400 000 km. Calculate the time taken for laser light to travel from Texas to the Moon and back (paragraph 5). [2]

(b) Explain why a pit depth of a quarter wavelength in a CD 'maximises the interference' (paragraph 11). [2]

(c) Paragraph 12 states that the 7 beams, after passing through the diffraction grating, are evenly spaced. This suggests that the angles between the diffracted beams are equal. By calculating the angles of the beams to the normal, check whether or not this is true. The DVD laser has a wavelength of 640 nm and the diffraction grating has 815 lines per centimetre. [4]

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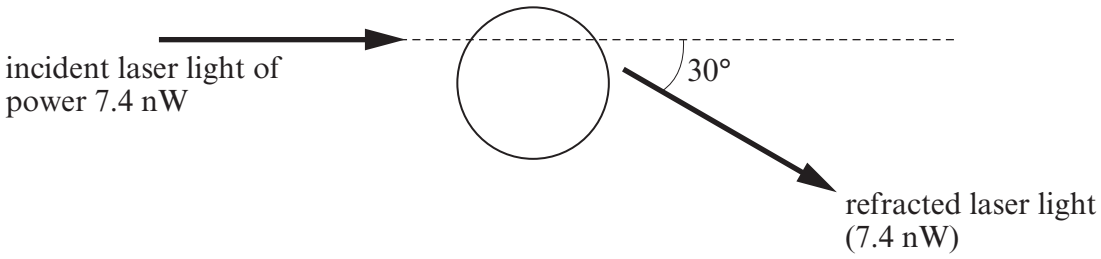
(d) A sodium atom has a mass of 23 u. Use equations relating to kinetic theory to check that a sodium atom's rms velocity is 570 m s^{-1} when the temperature is 300 K (paragraph 15). [3]

(e) Explain, in your own words, why tuning the laser light 0.97 GHz below the sodium line will result in sodium atoms travelling at 570 m s^{-1} being slowed down rather than accelerated (paragraph 16). [3]

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(f) Calculate the net vertical force acting on the spherical particle below due to the change in momentum of the incident light (paragraphs 21&22). [4]
The wavelength of the laser light is 520 nm.



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(g) Discuss some advantages and disadvantages of inertial confinement fusion (para 24).[2]

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SECTION C: OPTIONAL TOPICS

Option A: **Further Electromagnetism and Alternating Currents** ☐

Option B: **Revolutions in Physics - Electromagnetism and Space-Time** ☐

Option C: **Materials** ☐

Option D: **Biological Measurement and Medical Imaging** ☐

Option E: **Energy Matters** ☐

Answer the question on **one topic only.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

You are advised to spend about 20 minutes on this section.

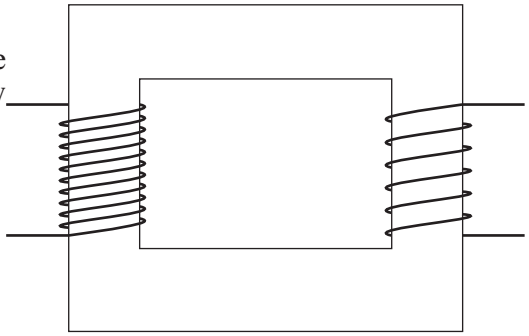
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Option A: Further Electromagnetism and Alternating Currents

C8. *(a)* Explain two ways in which the design of the core of a transformer can reduce its energy dissipation. [4]



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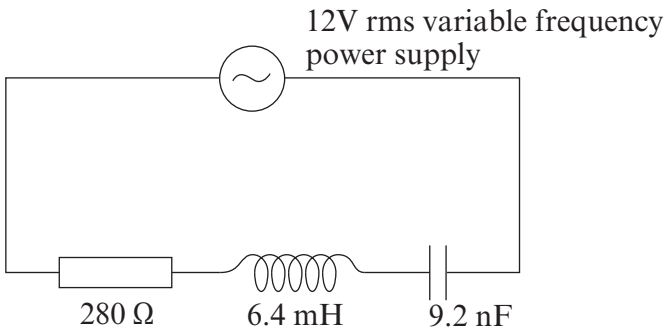
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(b) A series LCR circuit is constructed as shown.



(i) Use a phasor diagram to show that the impedance of an LCR circuit is given by

$$Z = \sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2 + R^2}$$

[3]

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(ii) Show that the resonance frequency of the LCR circuit is 20.7 kHz. [2]

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(iii) Explain why the rms current at resonance is approximately 40 mA. [2]

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(iv) Calculate the Q factor of the circuit. [2]

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(v) Calculate the rms current when the frequency is half the resonance frequency (10.35 kHz). [4]

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(vi) The current has exactly the same value as in (v) when the frequency is **twice** the resonance frequency. Explain briefly why this is so. This can be done without a calculator. [3]

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Option B: Revolutions in Physics - Electromagnetism and Space-Time

C9. *(a)* By 1820 there was considerable evidence that light was a *transverse wave.*

(i) Write two or three sentences about the contributions of

(I) Malus, [2]

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(II) Fresnel. [2]

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(ii) At that time, light waves were believed to propagate as mechanical waves through a material medium. Why was the *transverse* nature of the waves problematic? [2]

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(b) Maxwell used his *vortex ether* to predict the existence of *electromagnetic waves.*

(i) How were magnetic fields and electric fields represented in the *vortex ether*? [2]

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(ii) What two properties of the material of the vortex ether determined the speed at which the waves propagated? [1]

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(iii) How did Maxwell infer from experimental measurements that 'light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena'? [2]

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(iv) Describe an electromagnetic wave in terms of *fields.* [2]

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(c) (i) Maxwell believed his *Equations* applied only in the frame of reference of the ether. Discuss whether this view is consistent with the *Principle of Relativity.* [2]

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(ii) The *time dilation* equation of *Special Relativity* has been tested using particles called *muons* travelling downwards through the atmosphere at very high speeds.

In one experiment muons of speed 0.9952 c travelled to sea level through a measured distance of 1907 m.

(I) Calculate the time taken for this descent, as would be read by clocks in the Earth's frame of reference. [1]

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(II) Use the *time dilation equation* to predict the time for the descent that would be recorded by a clock travelling with the muons. [2]

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(III) A batch of muons can be regarded as its *own* clock. Muons are unstable, decaying with a half-life of 1.52 μs, so we can use their decay to obtain the proper time (from the muon point of view). The proper time, t, for the number of muons to decrease from N_0 to N is given by

$$t = \frac{1}{\ln 2}\left[\ln \frac{N_0}{N}\right] \times 1.52\ \mu s$$

In one experiment, for every 563 muons detected at a height of 1907 m, 408 were detected at sea level.

Calculate t for the descent from these experimental results and comment on whether this gives support for this time dilation formula. [2]

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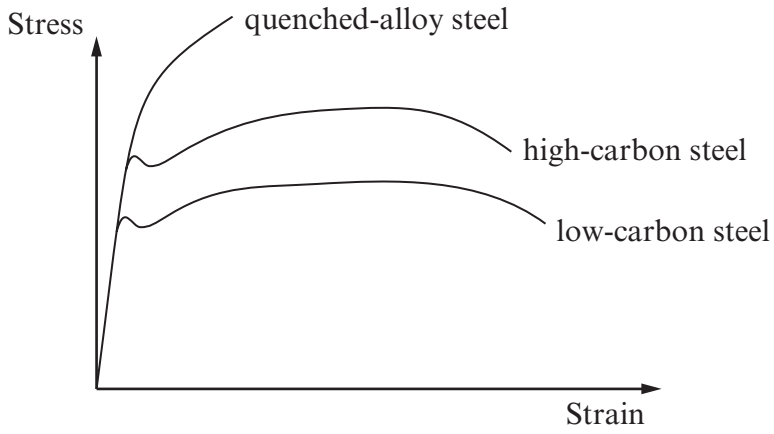
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Option C: Materials.

C10. A. Stress - Strain curves for several kinds of steel are shown.



(a) State, giving reasons, which steel

(i) is the most ductile; [1]

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(ii) has the highest breaking stress. [1]

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(b) What can be said about their Young moduli? [1]

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(c) Compare the physical properties of high-carbon steel with low-carbon steel and explain these properties in terms of molecular structure. [4]

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(d) (i) Long steel wires are used for towing oil platforms out at sea. If a wire were to break, about 25% of the stored elastic energy would be transformed to kinetic energy. Show that the speed, v, of the wire when it breaks can be estimated from

$$v = \frac{1}{2}\sqrt{\frac{\sigma\varepsilon}{\rho}}$$

where ρ is the density of the steel and σ and ε have their usual meanings. [4]

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(ii) Estimate the speed of a quenched-alloy steel wire which breaks given that its breaking stress is 700 MPa and the corresponding strain is 0.2%. Assume $\rho = 8000 \text{ kg m}^{-3}$. [2]

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(iii) Using the graphs on page 22 as guides, explain how you would expect the speed of a breaking wire made of low-carbon steel of the same dimensions (i.e. length and diameter) to compare with your answer to *(d)*(ii). Assume the densities are equal. [2]

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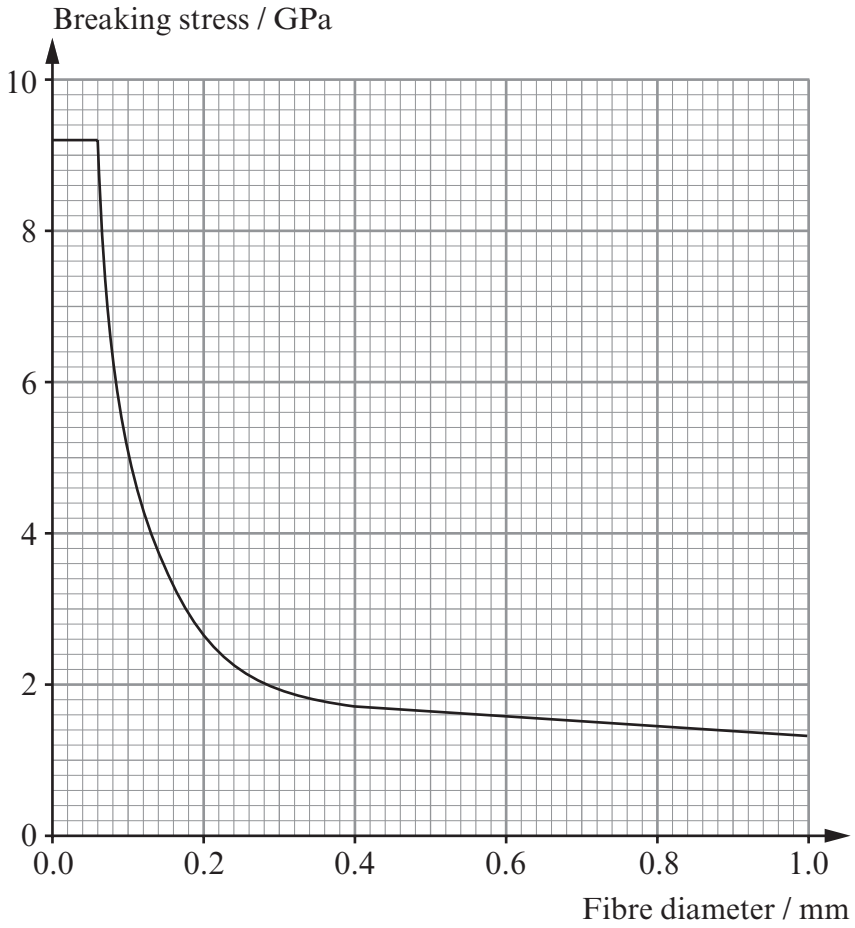
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B. Glass is a brittle material. The graph shows how the tensile breaking stress of glass, in the form of thin fibres and rods, varies with the diameter of the fibre.



(a) Use the graph to estimate the greatest **mass** which can be hung from a glass fibre of diameter 0.20 mm. [2]

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(b) Explain why very thin fibres (or 'whiskers') have a greater breaking stress than thicker ones and suggest why there is a maximum value. [2]

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(c) 'Fibre-glass' is a widely used composite material. State what it consists of. [1]

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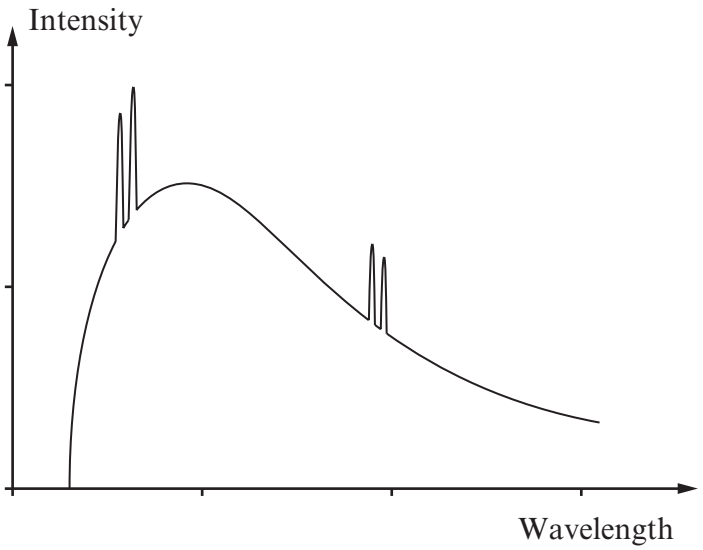
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Option D: Biological Measurement and Medical Imaging

C11. *(a)* The diagram to the right is a typical X-ray emission spectrum for an X-ray tube with a tungsten target



(i) Draw on the graph another curve that would be typical for the tube when operated at a lower potential difference. [2]

(ii) What difference(s) would there be to the graph if the tungsten target were replaced by another metal? [1]

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(iii) The X-ray tube has a working potential difference of 75 000V. Calculate the minimum wavelength of an X-ray photon emitted from the tube. [2]

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(iv) If the anode current is 0.125 A and the X-ray tube has an efficiency of 0.5%, calculate the rate of production of heat at the anode. [2]

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(b) Describe how X-rays are used in CT (computerised axial tomography) scanning. State how a CT scan differs from a conventional X-ray. [3]

(c) MRI (magnetic resonance imaging) can also be used in diagnostic medicine. Both MRI and CT scans use electromagnetic radiation. State the region of the electromagnetic spectrum used in MRI and explain its effect on hydrogen nuclei. [3]

(d) An ultrasound probe is used to study the flow of blood from the heart.

(i) Explain how a piezoelectric transducer can be used to produce ultrasound. [1]

(ii) The wavelength of ultrasound used is 0.50 mm and it travels through blood at $1500\,m\,s^{-1}$. If the wavelength shift is 0.60 μm, calculate the speed of the flow of blood. [2]

QUESTION CONTINUES ON PAGE 28

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(e) (i) Describe the effect on living matter when it is exposed to ionising radiation. [2]

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(ii) Explain what is meant by absorbed dose, and dose equivalent. [2]

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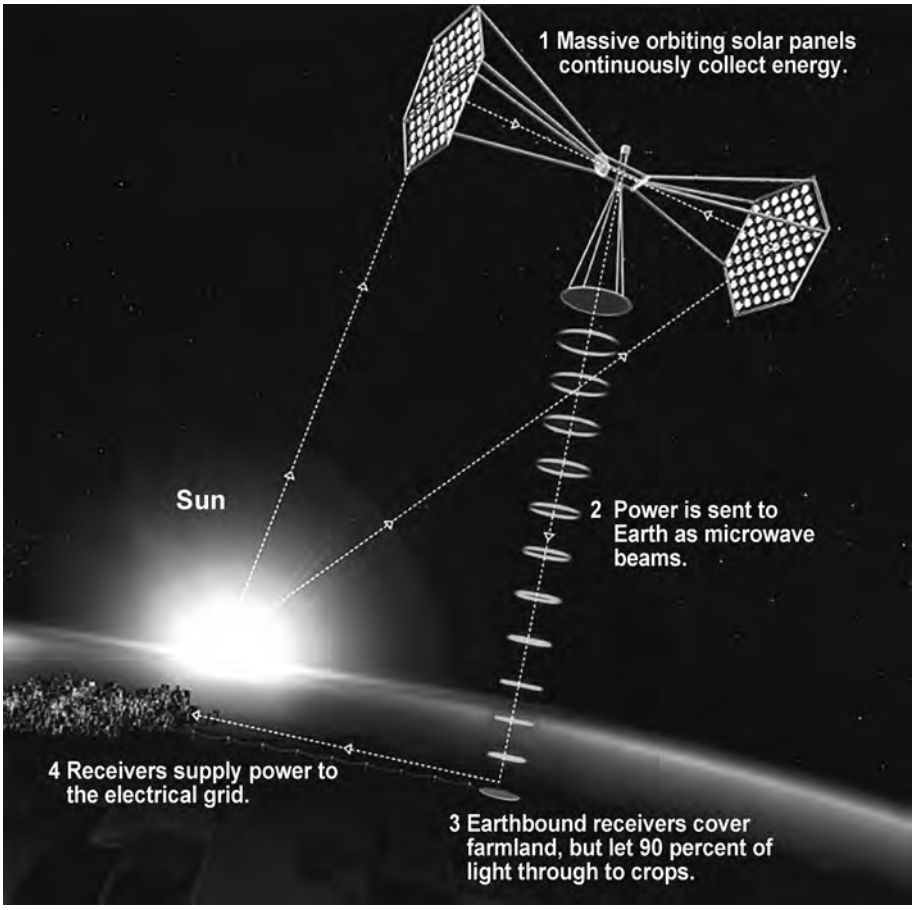
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Option E: Energy Matters

C12. In 1968 an alternative energy source using Space Based Solar Panels (SBSP) was proposed by Peter Glaser. The SBSP system then beams solar energy to the Earth in the form of microwave radiation which is picked up by antennae and converted to electrical energy.



(a) (i) The solar constant is 1.37 kWm^{-2}. Calculate the total solar power incident on 7.8 km^2 of solar panels in orbit around the Earth. [2]

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(ii) Use the following data to confirm that the solar constant is 1.37 kWm^{-2}.
Sun's radius = 6.96×10^8 m, Sun's surface temperature = 5778 K,
Earth's orbital radius = 1.496×10^{11} m. [4]

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(b) Each kWh of electricity is sold for £0.20 and the overall efficiency of the SBSP system is 40%. Calculate the money that the solar panels can make in one year. [3]

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(c) The 7.8 km^2 of solar panels is made of a material 0.26 mm thick and of density 2 440 kg m^{-3}. Calculate the total mass of the solar panels. [3]

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(d) The payload of the space shuttle is approximately 25 000 kg and each round trip for the space shuttle costs around £350 000 000. Calculate the total cost of using the space shuttle to place the solar panels in orbit. [2]

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(e) The SBSP system uses **no** heat engine to produce electricity unlike nearly all other methods of high power electricity production. Explain why this is a great advantage.

[The efficiency of an ideal heat engine is $1 - \frac{T_1}{T_2}$]. [2]

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(f) Discuss briefly whether or not the SBSP system seems feasible and discuss its possible advantages over ground based solar panels. [4]

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END OF QUESTION PAPER

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PHYSICS

ASSESSMENT UNIT PH5

A.M. MONDAY, 27 June 2011

CASE STUDY FOR USE WITH SECTION B

Examination copy
To be given out at the start of the examination.
The pre-release copy must not be used.

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Paragraph

Lasers and their Applications

With over a billion lasers manufactured per year these elegant devices have proved their worth since the first ruby laser started 'lasing' in 1960. At least seven Nobel prizes are attributable to the theory or uses of lasers but, still, their applications seem to increase daily. Some uses of lasers are slightly inelegant in that they just use their high power to vaporise, fuse, melt, blind or destroy but many applications are more subtle - relying on their highly directional nature, their ability to produce ultra short pulses or their monochromatic or coherent nature. Here are some wide-ranging examples encompassing these invaluable properties of lasers. 1

Medical Uses of Lasers

The highly collimated beam of a laser can be further focused to a microscopic dot of extremely high energy density. This makes it useful as a cutting and cauterizing instrument. A focused laser can act as an extremely sharp scalpel for delicate surgery, cauterizing as it cuts. ("Cauterizing" refers to long-standing medical practices of using a hot instrument or a high frequency electrical probe to singe the tissue around an incision, sealing off tiny blood vessels to stop bleeding.) The cauterizing action is particularly important for surgical procedures in blood-rich tissue such as the liver. 2

Lasers have been used to make incisions half a micrometre wide, compared with about 80 μm for the diameter of a human hair. 3

Surveying and Ranging

Helium-neon and semiconductor lasers have become standard parts of the field surveyor's equipment. A fast laser pulse is sent to a corner reflector at the point to be measured and the time of reflection is measured to get the distance. 4

Some such surveying is long distance! The Apollo 11 and Apollo 14 astronauts put corner reflectors on the surface of the Moon for determination of the Earth-Moon distance. A powerful laser pulse from the MacDonald Observatory in Texas had spread to about a 3 km radius by the time it got to the Moon, but the reflection was strong enough to be detected. We now know the range from the Moon to Texas within about 15 cm, a nine significant digit measurement. A pulsed ruby laser was used for this measurement. 5

Laser Sights and Firearms

The laser has in most firearms applications been used as a tool to enhance the targeting of other weapon systems. For example, a *laser sight* is a small, usually visible-light laser placed on a handgun or a rifle and aligned to emit a beam parallel to the barrel. Since a laser beam by definition has low divergence, the laser light appears as a small spot even at long distances; the user places the spot on the desired target and the barrel of the gun is aligned (but does not allow for bullet drop, wind or the target moving while the bullet travels). 6

Another limitation of a laser sight is that light leaving a laser is slightly diverging due to diffraction of the beam as it exits the aperture. The beam divergence is given by equation 1. 7

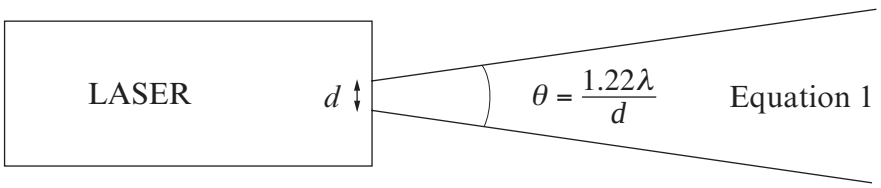


Diagram 1

Typical divergence of a laser beam is around 1 milliradian but this is far less accurate than that obtainable by a good marksman with a large telescopic lens.

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Lasers in Communication

Fibre optic cables are a major mode of communication partly because multiple signals can be sent with high quality and low loss by light propagating along the fibres. The light sources are lasers or LEDs but lasers have significant advantages because they are more nearly monochromatic and this allows the pulse shape to be maintained better over long distances. If a better pulse shape can be maintained, then the communication can be sent at higher rates without overlap of the pulses. 8

Telephone fibre drivers may be solid state lasers the size of a grain of sand and consume a power of only half a milliwatt. Yet they can send 50 million pulses per second into an attached telephone fibre and encode over 600 simultaneous telephone conversations. 9

CD-ROMs and DVD-ROMs

Today, most CD-ROM and DVD-ROM disc drives use a single highly concentrated laser beam to read the digital signal that is encoded onto tracks of an optical disc (CD or DVD). The single laser beam is directed at a single track of information, which forms a continuous spiral on the disc that begins at the disc centre and spirals outward towards the outer edge. Variations (in data pit length) on the disc surface cause variations in the reflected laser beam, which are detected by an optical sensor. 10

The disc drive rotates the disc and the tracks run under the laser beam. The drive system has an optical motor control that allows the laser to exactly focus and follow the spiral path of the pits and lands, to stay focused on the "track". The laser is reflected at different intensities for different amounts of time (the length of a pit or land) as it passes over the spiral track. A zero actually corresponds to high reflected intensity off a flat pit or a flat land section. A one corresponds to low reflected intensity at the edge of a pit and land where destructive interference occurs between the two reflections. In order to maximise the interference between light reflected from 'land' and light reflected from a 'pit', the pit depth is chosen as a quarter of a wavelength. The reflected laser light is then directed to a light sensitive detector that turns the light variations into a stream of serial data, representing the pattern of pits and lands on the disc. This data stream is amplified and sent to a microprocessor for interpretation. The laser, lenses to focus the beam, a mirror to point the reflected beam and the light sensitive detector, combined are known as an "optical pick-up". 11

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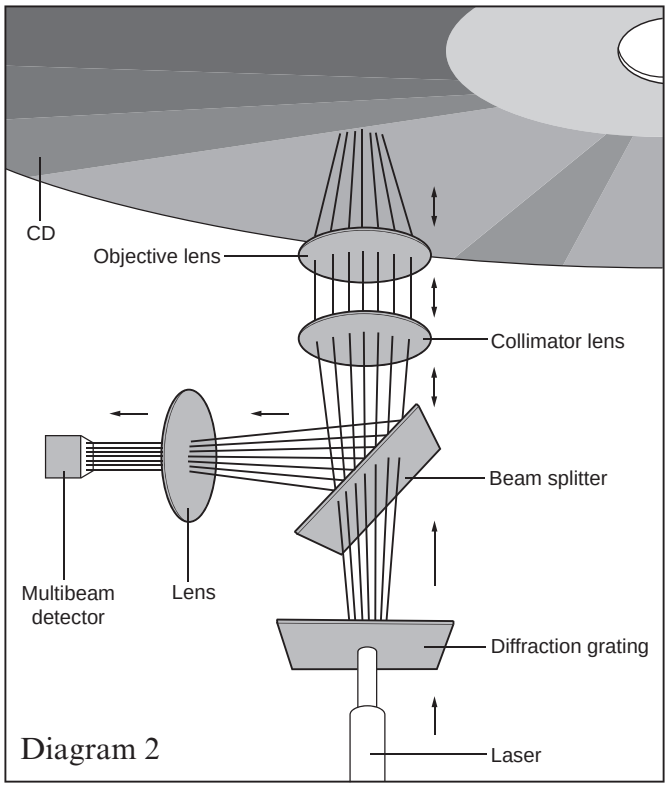


Diagram 2

The Multiple Beam approach to illuminating and detecting multiple tracks (see diagram at left) uses a diffracted laser beam in conjuction with a multiple beam detector array. The laser light from a conventional laser diode is sent through a diffraction grating, which splits the beam into seven discrete beams, spaced evenly to illuminate seven tracks. The seven beams pass through a beam splitting (two-way) mirror to the objective lens and onto the surface of the disc. Focus and tracking are accomplished with conventional detection elements on the central beam. The three beams on either side of the centre beam are readable by a multibeam detector array as long as the centre beam is on track and in focus. 12

Turn over.

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The reflected beams return from the disc via the same path and are directed to the multiple beam detector array by the reflective surface of the beam splitter. The detector contains seven discrete detectors spaced to align with seven reflected tracks. Note that a standard single beam pick-up is very similar. In a single beam pick-up, the diffraction grating would be removed and the detector would have a single data detection point. 13

Laser Cooling

Starting in about 1985, the use of lasers to achieve extremely low temperatures has advanced to the point that temperatures of 10^{-9} K have been reached. If an atom is travelling toward a laser beam and absorbs a photon from the laser, it will be slowed by the fact that the photon has momentum 14

$$p = \frac{E}{c} = \frac{h}{\lambda} \qquad \text{Equation 2}$$

If we take a sodium atom as an example, and assume that a number of sodium atoms are freely moving in a vacuum chamber at 300 K, the rms velocity of a sodium atom from kinetic theory would be about 570 ms^{-1}. Then if a laser is tuned just below a sodium emission line (about 2.1 eV), a sodium atom travelling toward the laser and absorbing a laser photon would have its momentum reduced by the amount of the momentum of the photon. It would take a large number of such absorptions to cool the sodium atoms to near 0 K since one absorption would slow a sodium atom by only about 3 cm/s out of a speed of 570 ms^{-1}. A straight projection requires almost 20,000 photons to reduce the sodium atom momentum to zero. The change in speed from the absorption of one photon can be calculated from 15

$$\Delta v = \frac{p_{\text{photon}}}{m_{\text{sodium}}} \qquad \text{Equation 3}$$

That seems like a lot of photons, but a laser can induce in the order of 10^7 absorptions per second so that an atom could be stopped in a matter of milliseconds.

A conceptual problem is that an absorption can also speed up an atom if it catches it from behind, so it is necessary to have more absorptions from head-on photons if your goal is to slow down the atoms. This is accomplished in practice by tuning the laser slightly below the resonance absorption of a stationary sodium atom. From the atom's perspective, the head on photon is seen as Doppler shifted upward toward its resonant frequency and it is therefore more strongly absorbed than a photon travelling in the opposite direction which is Doppler shifted away from the resonance. In the case of our room temperature sodium atom above, the incoming photon would be Doppler shifted up 0.97 GHz, so to get the head on photon to match the resonance frequency would require that the laser be tuned below the resonant peak by that amount. This method of cooling sodium atoms was proposed by Theodore Hansch and Arthur Schawlow at Stanford University in 1975 and achieved by Chu at AT&T Bell Labs in 1985. Sodium atoms were cooled from a thermal beam at 500 K to about 240 μK. The experimental technique involved directing laser beams from opposite directions upon the sample, polarised at 90° with respect to each other. Six lasers could then provide a pair of beams along each coordinate axis. 16

Continuing to cool the sodium atoms by this method requires the tuning of the laser upward in frequency toward the atomic resonance frequency because the Doppler shift will be smaller. This places a practical limit on how much cooling can be achieved, because the differential cooling rate is reduced and at a certain point the cooling mechanism is foiled by heating due to the random absorption and re-emission of photons. 17

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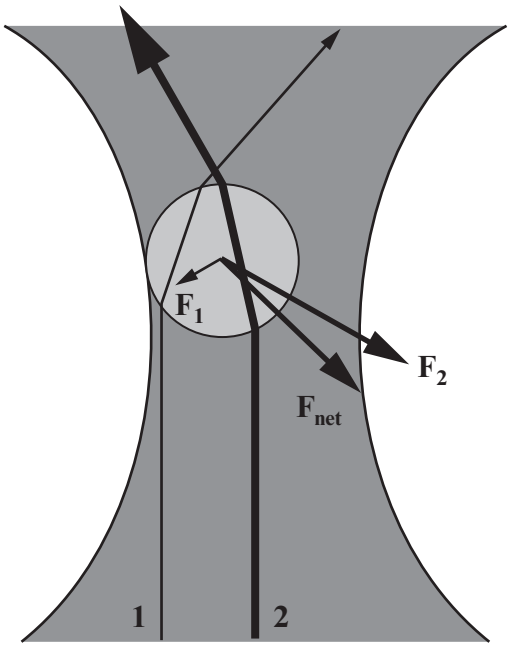
Optical Tweezers

Optical tweezers are capable of manipulating nanometre and micrometre-sized high refractive index particles by exerting extremely small forces via a focused laser beam. The beam is typically focused by sending it through a microscope. The narrowest point of the focused beam, known as the beam waist, contains a very high light intensity gradient. It turns out that particles are attracted along the gradient to the region of strongest light intensity, which is the centre of the beam. This is called an optical trap because it holds the particle in the centre of the beam. This beam can then be moved so that the trap moves the particle and acts like an optical tweezers. The force applied to the particle is actually linear with respect to its displacement from the centre of the trap as long as the displacement is small. In this way, an optical trap can be compared with a simple spring which follows Hooke's Law. 18

Optical traps are very sensitive instruments and are capable of the manipulation and detection of sub-nanometre displacements for sub-micrometre particles. For this reason, they are often used to manipulate DNA. The proteins and enzymes that interact with DNA are also studied in this way. 19

Here's an explanation of how the optical tweezers work based on refractive index (this theory only applies to larger particles where we can use ray theory). 20

In cases where the diameter of a trapped particle is significantly greater than the wavelength of light, the trapping phenomenon can be explained using ray optics. As shown in diagram 3, an individual ray of light emitted from the laser will be refracted as it enters and exits the particle. As a result, the ray will exit in a direction different from which it originated. Since light has a momentum associated with it, this change in direction indicates that its momentum has changed. Due to Newton's third law, there should be an equal and opposite momentum change on the particle. 21



Ray optics explanation.
When the particle is displaced from the beam centre, the larger momentum change of the more intense rays cause a net force to be applied back toward the centre of the trap

Diagram 3

The particle is displaced from the centre of the beam, as in diagram 3, and we consider light rays on both sides of our spherical particle (see rays 1 and 2). Ray 1 veers to the right which means that it exerts a force (F_1) to the left on the particle (due to Newton's third law). Ray 2 veers to the left which means that it exerts a force (F_2) to the right on the particle (again, due to Newton's third law). However, force F_2 is greater than F_1 because of the higher intensity of the beam towards the centre of the beam waist; hence the net force is towards the centre of the beam. 22

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Now all we have to do to move our tiny particle is to move the laser beam and the particle follows in the 'optical trap'. Thus our focused laser beam is acting like optical tweezers. 23

Nuclear fusion

Some of the world's most powerful and complex arrangements of multiple lasers and optical amplifiers are used to produce extremely high intensity pulses of light of extremely short duration. These pulses are arranged such that they impact pellets of deuterium-tritium simultaneously from all directions, hoping that the squeezing effect of the impacts will induce atomic fusion in the pellets. This technique, known as "inertial confinement fusion", so far has not been able to achieve "breakeven", that is, so far the fusion reaction generates less power than is used to power the lasers. However, research continues and the recent introduction of a technique called 'fast ignition' along with improvements in laser efficiency means that inertial confinement fusion might soon be profitable. When you consider that 10 mg of deuterium-tritium mixture contains the same amount of energy as a barrel of oil (6 GJ) and that the sea contains around 10^{16} kilograms of both deuterium and lithium (from which tritium is made), laser nuclear fusion might well be the energy source of the future. 24

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