Surname	Centre Number	Candidate Number
Other Names		2

GCE A level

1325/01

PHYSICS

ASSESSMENT UNIT PH5: ELECTROMAGNETISM, NUCLEI & OPTIONS

A.M. MONDAY, 27 June 2011

$1\frac{3}{4}$ hours

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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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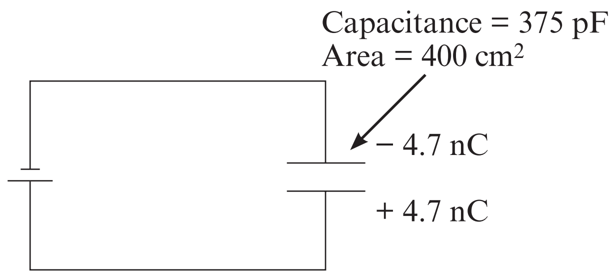
SECTION A

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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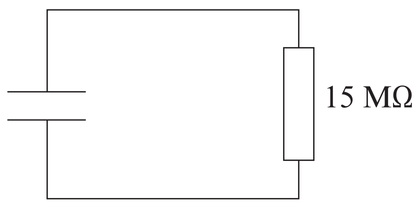
(b) The capacitor is now discharged through a 15 MΩ resistor.

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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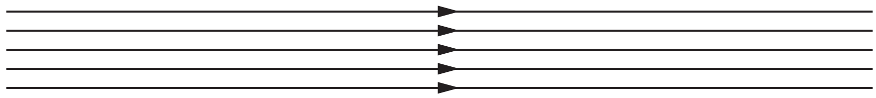
2. Each of five long, straight, parallel wires carries a current of 0.3A.



(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]

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(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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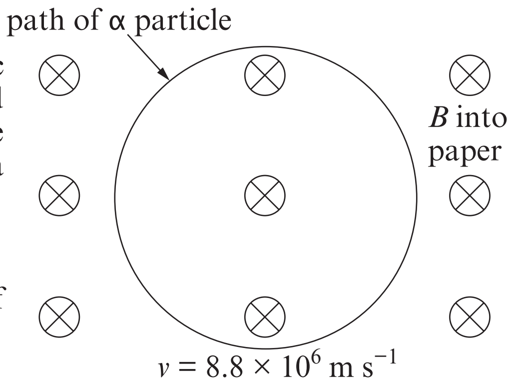
(c) The α particle travels in the Earth's magnetic field. This may be assumed to be uniform and of strength 2.4 μT as shown. The α particle travels in a circular path, as shown, at a constant speed of 8.8×10^6 m s^{-1}.
The mass of the α particle is 4 u.



(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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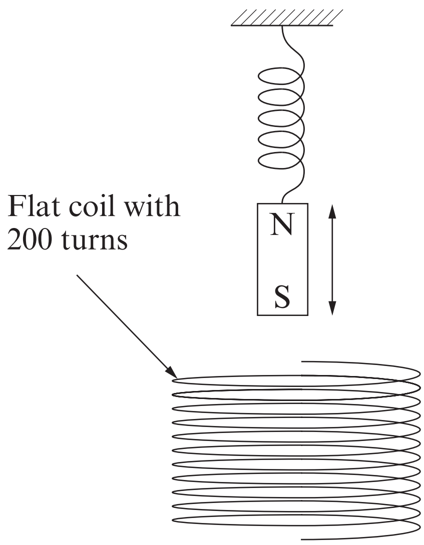
3. A strong magnet is held on a spring and performs simple harmonic motion near a flat coil as shown.



(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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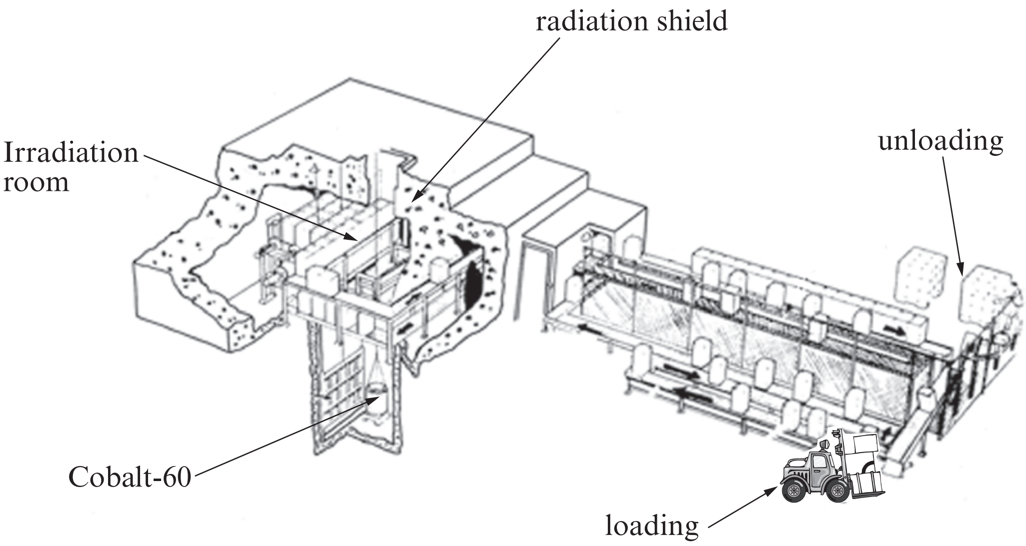
4. Radioactive cobalt-60 ($^{60}_{27}Co$) is used to irradiate and sterilise surgical equipment. Many instruments can be irradiated simultaneously as shown.



(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]

$$^{241}_{95}\text{Am} \longrightarrow \,^{\cdots\cdots}_{\cdots\cdots}\text{Np} + \,^{\cdots\cdots}_{\cdots\cdots}\alpha$$

(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

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(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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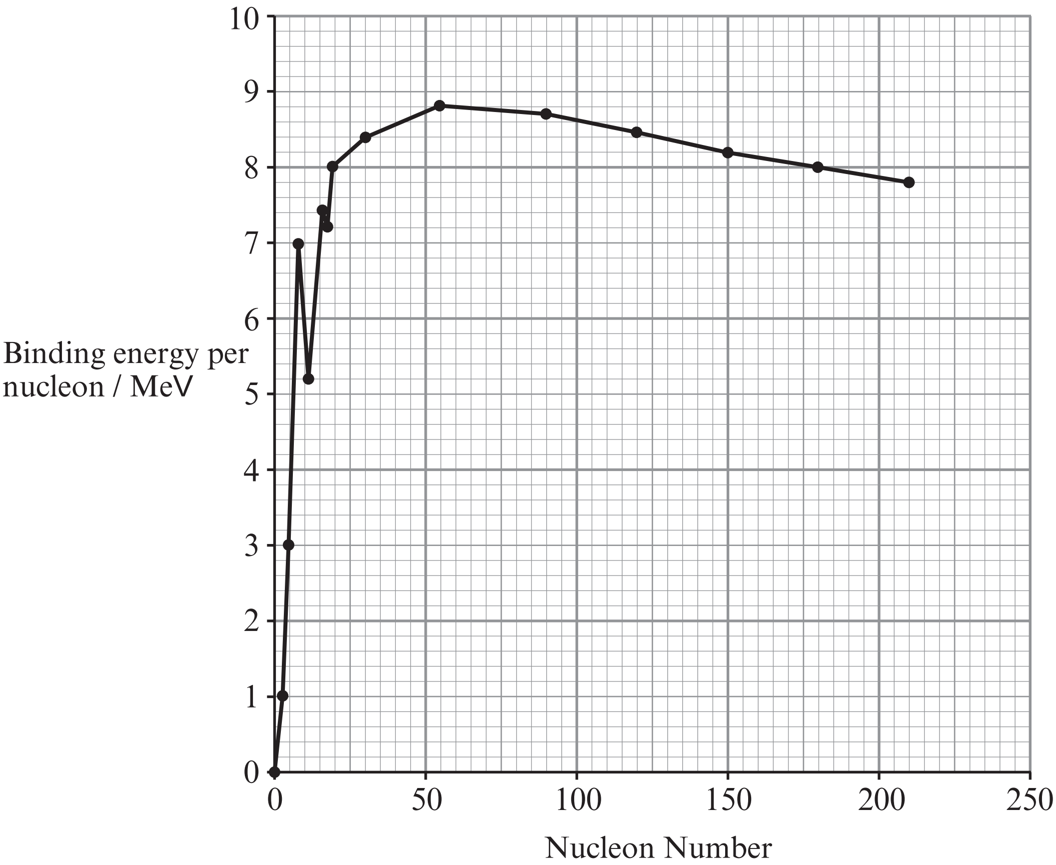
(ii) Plot your answer from *(c)*(i) on the graph below. [1]



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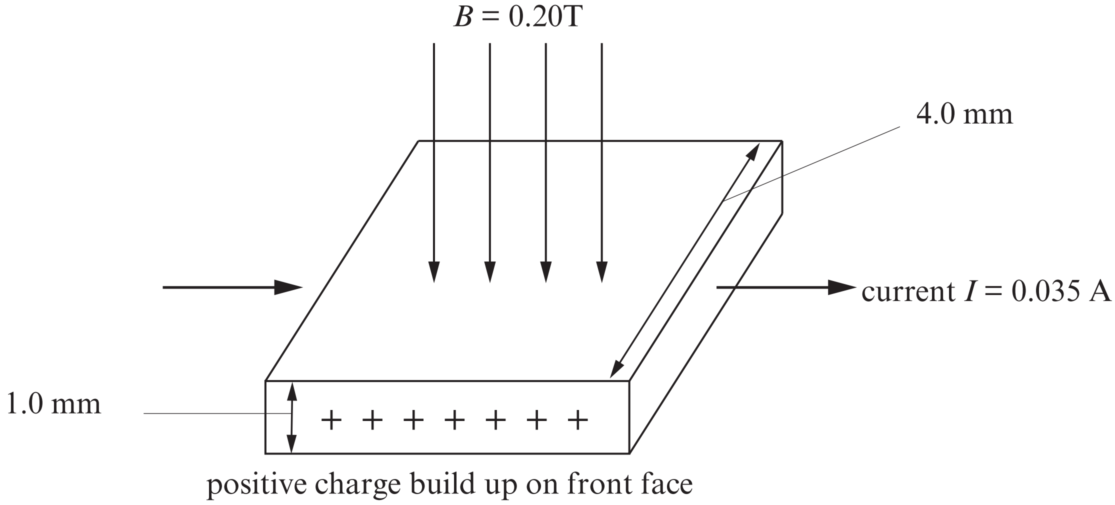
6. The number *n* of free electrons per unit volume in a silicon chip can be found by measuring the Hall voltage across it when placed in a uniform magnetic field as shown.



(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]

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(b) Explain why a pit depth of a quarter wavelength in a CD 'maximises the interference' (paragraph 11). [2]

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(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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Examiner only

(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]

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(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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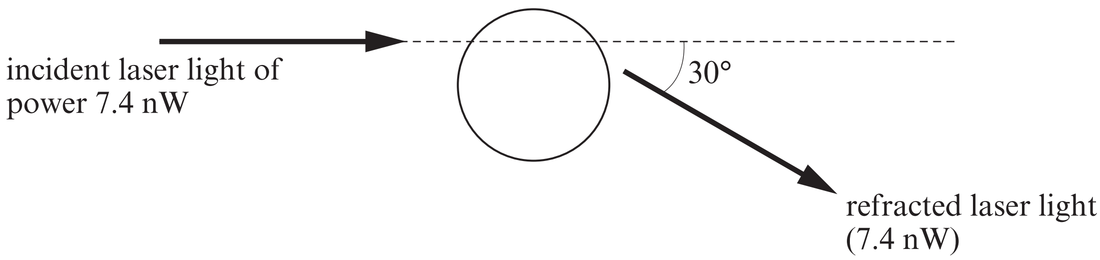
(f) Calculate the net vertical force acting on the spherical particle below due to the change in momentum of the incident light (paragraphs 21&22). [4]
The wavelength of the laser light is 520 nm.



(g) Discuss some advantages and disadvantages of inertial confinement fusion (para 24).[2]

Examiner only

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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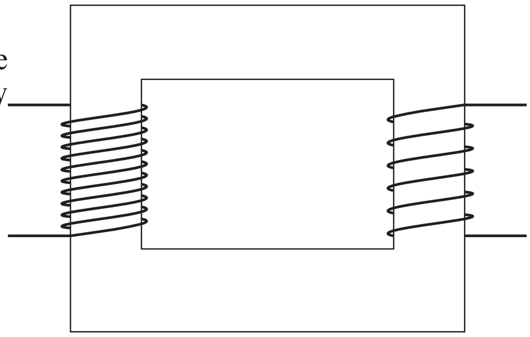
Option A: Further Electromagnetism and Alternating Currents

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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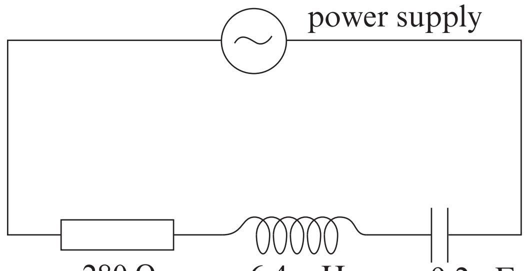
Examiner only

(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]

(ii) Show that the resonance frequency of the LCR circuit is 20.7 kHz. [2]

Turn over.

(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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Examiner only

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

$$t = \frac{1}{\ln 2}\left[\ln \frac{N_0}{N}\right] \times 1.52\ \mu\text{s}$$

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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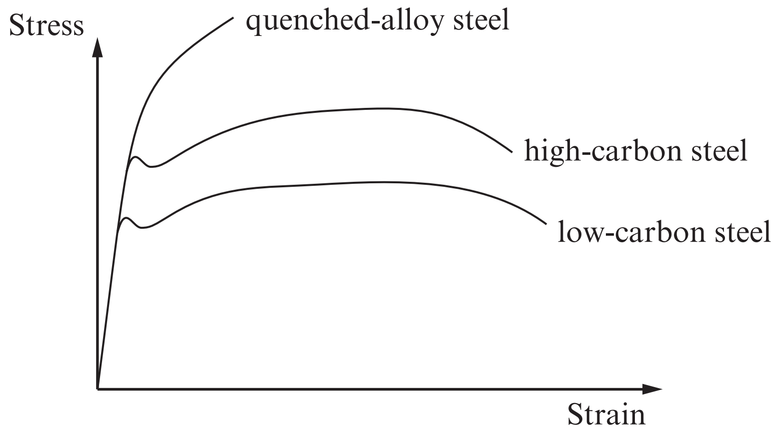
Option C: Materials.

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]

(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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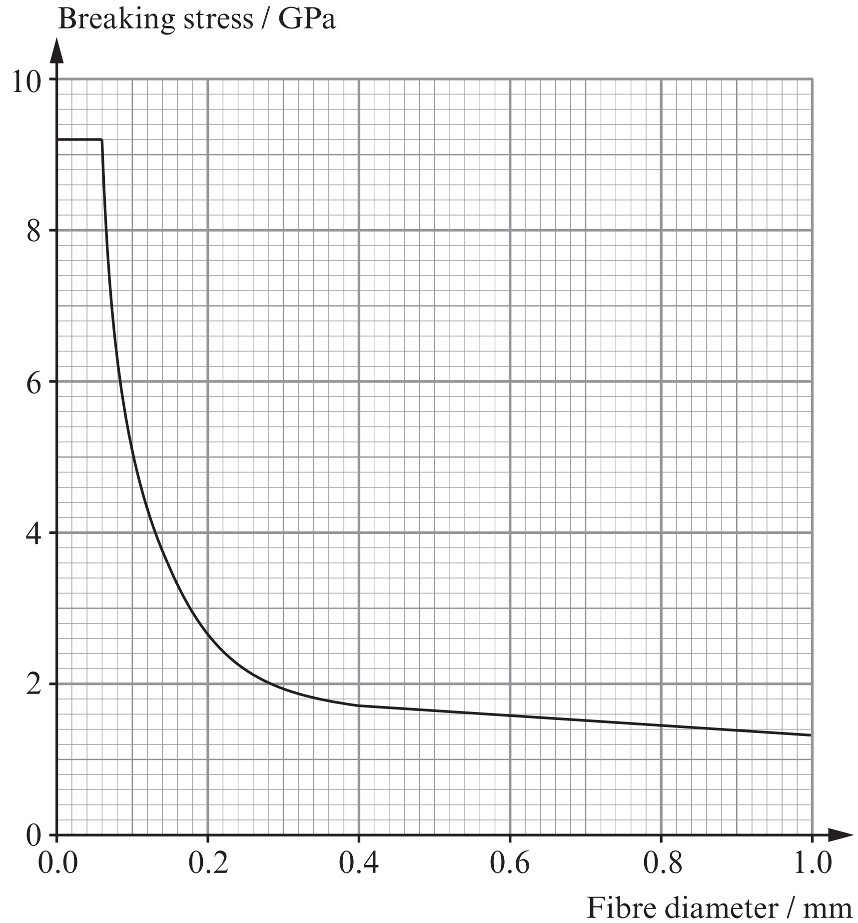
B. Glass is a brittle material. The graph shows how the tensile breaking stress of glass, in the form of thin fibres and rods, varies with the diameter of the fibre.



(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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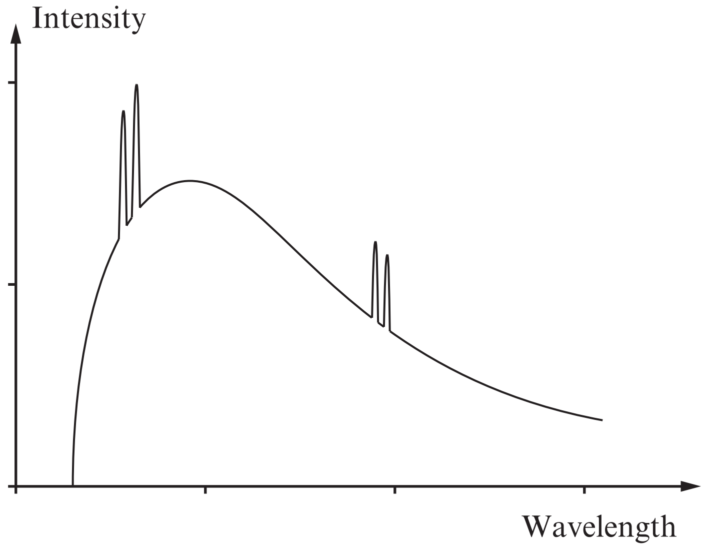
Option D: Biological Measurement and Medical Imaging

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]

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(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]

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(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]

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(ii) The wavelength of ultrasound used is 0.50 mm and it travels through blood at $1500\,\text{m}\,\text{s}^{-1}$. If the wavelength shift is 0.60 μm, calculate the speed of the flow of blood. [2]

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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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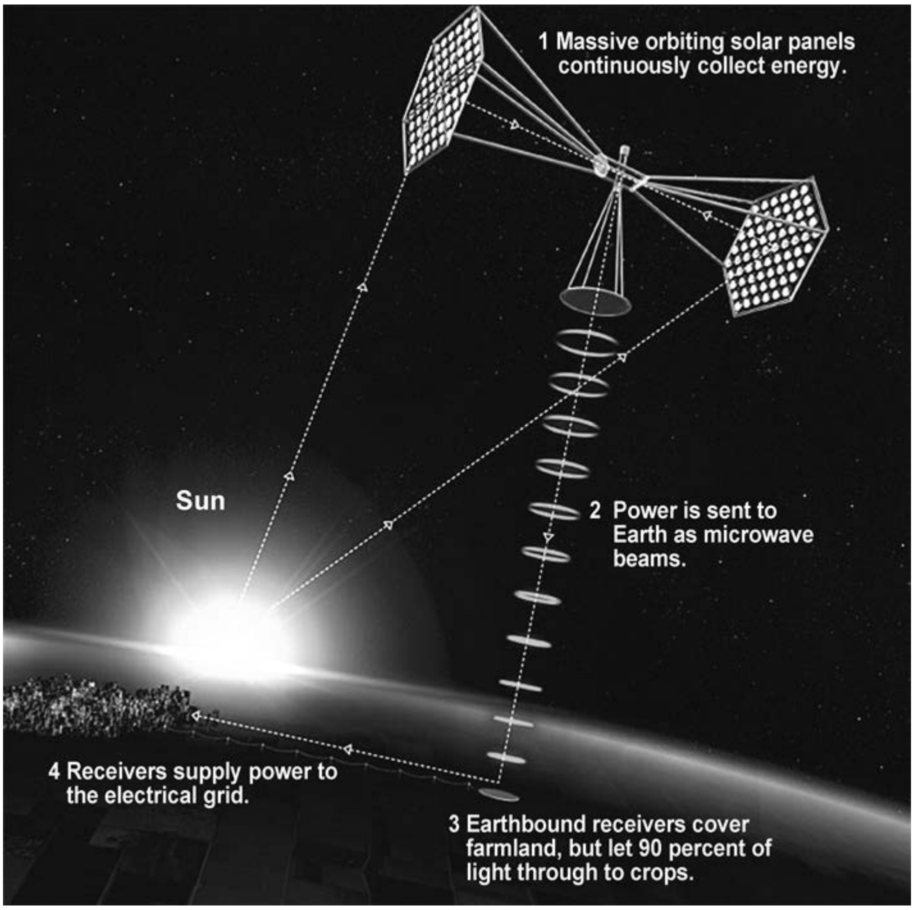
Examiner only

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]

(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]

(f) Discuss briefly whether or not the SBSP system seems feasible and discuss its possible advantages over ground based solar panels. [4]

END OF QUESTION PAPER

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