Candidate Name	Centre Number	Candidate Number

GCE A level

1325/01

PHYSICS

ASSESSMENT UNIT PH5: ELECTROMAGNETISM, NUCLEI & OPTIONS

P.M. TUESDAY, 29 June 2010

1¾ hours

For Examiner's use only.		
A1.	10	
A2.	10	
A3.	20	
A4.	10	
A5.	10	
B6.	20	
C	20	
Total	100	

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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

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:

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.

Examiner only

SECTION A

A1. *(a)* Calculate the binding energy **per nucleon** of ${}^{14}_{6}C$. [4]

(1u = 931MeV, $m_{neutron}$ = 1.008665u, m_{proton} = 1.007276u, mass of ${}^{14}_{6}C$ nucleus = 13.999950u).

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The following reaction can be regarded as evidence for the existence of neutrinos (or an anti-neutrino in this case).

$${}^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta^{-} + \overline{\nu}_e$$

The mass of the ${}^{14}_{6}C$ nucleus is 13.999950u and the mass of the ${}^{14}_{7}N$ nucleus is 13.999234u. The mass of the β^{-} particle is 0.000549u and the anti-neutrino ($\overline{\nu}_e$) has negligible mass.

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

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The evidence for the existence of the anti-neutrino came from the (unexpected) wide variation of the energies of the β^{-} particles emitted. However, you should now ignore the existence of the anti-neutrino.

(c) Explain briefly, using conservation of momentum, which particle (${}^{14}_{7}N$ or β^{-}) receives most of the energy of the reaction. [3]

Before the reaction (stationary ${}^{14}_{6}C$) After the reaction

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Examiner only

A2. Caesium-137 ($^{137}_{55}Cs$) is a radioactive byproduct from fission nuclear power stations. It has a half life of 30 years and emits β^- radiation.

(a) Complete the following reaction equation by entering the appropriate numbers in the boxes. [2]

$$^{137}_{55}Cs \longrightarrow {}^{\square}_{\square}Ba + {}^{\square}_{\square}\beta^-$$

(b) Show that the decay constant of caesium-137 is approximately $7 \times 10^{-10}\ s^{-1}$. [2]

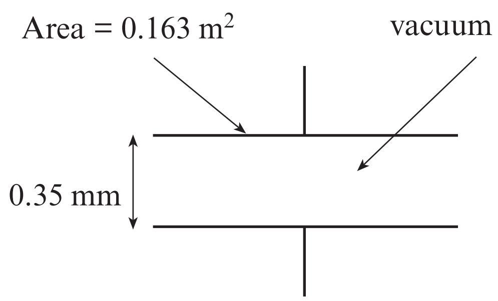
(c) Show that the initial activity of 1.0 kg of caesium-137 is approximately 3×10^{15} Bq. [2]

(d) Explain why 1.0 kg of caesium-137, although it has an activity of 3×10^{15} Bq, would be quite safe in a sealed metal box of thickness 1 cm. [1]

(e) When the activity of 1.0 kg of caesium has dropped to 1000 Bq (comparable to soil) it can be disposed of by mixing with soil and scattering on the ground. Calculate how long it takes for the caesium sample to reduce its activity from 3×10^{15} Bq to 1000 Bq. [3]

Examiner only

A3. *(a)* Calculate the capacitance of the capacitor shown. [2]



(b) The capacitor is charged so that there is a p.d. of 1.2 kV across the plates. Calculate

(i) the charge stored, [1]

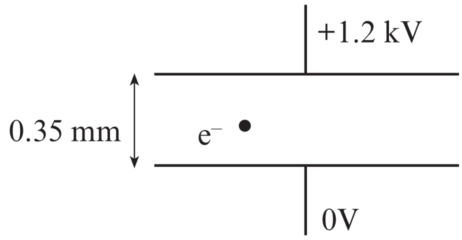
(ii) the energy stored in the capacitor. [1]

(c) The capacitor is discharged through a 670 kΩ resistor. Calculate the time the capacitor takes to lose half its charge. [3]

(d) Explain briefly whether or not the time the capacitor takes to lose half its energy is longer or shorter than your answer to *(c)*. [2]

Examiner only

(e) An electron is located between the plates of the charged capacitor. Show that the acceleration experienced by the electron is approximately $6 \times 10^{17}\ \mathrm{m\,s^{-2}}$. [3]



(f) The electron starts from rest halfway between the plates.

(i) Use the acceleration ($6 \times 10^{17}\ \mathrm{m\,s^{-2}}$) to calculate the speed of the electron when it strikes the upper plate of the capacitor. [2]

(ii) Show that the speed of the electron (when it strikes the upper plate of the capacitor) corresponds to a kinetic energy of 0.6 keV and explain briefly another method for obtaining this answer of K.E. = 0.6 keV. [3]

(iii) Calculate the time the electron takes to travel to the upper plate. [3]

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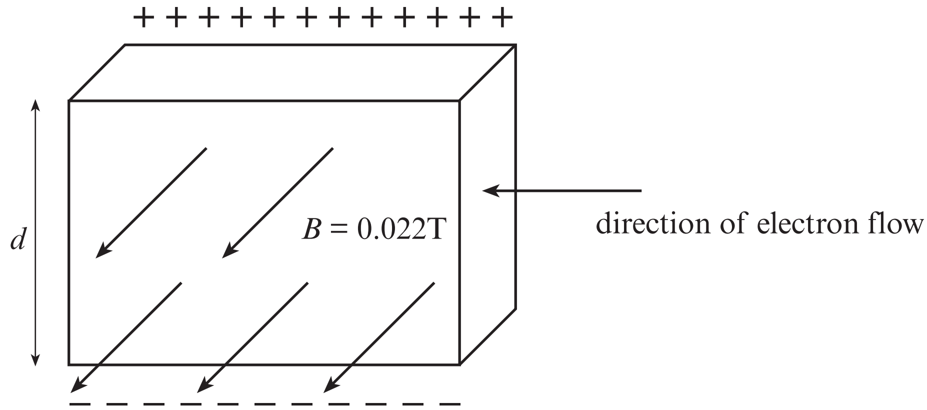
A4. Electrons move through a metallic conductor as shown and experience a force due to the applied magnetic field (*B* perpendicular to the front face as shown).



(a) Explain why charges accumulate on the upper and lower face of the conductor as shown. [2]

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(b) Indicate on the diagram how you would connect a voltmeter in order to measure the Hall voltage (V_H). [1]

(c) By equating the electrical and magnetic forces acting on an electron in the conductor, show that $V_H = Bvd$. [3]

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(d) (i) The magnetic field (B = 0.022 T) is produced by a solenoid of length 2.00 m and with 15000 turns. Calculate the current in the solenoid. [2]

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(ii) Where must the conductor be placed and how should it be orientated in relation to the solenoid to obtain the maximum Hall voltage? [2]

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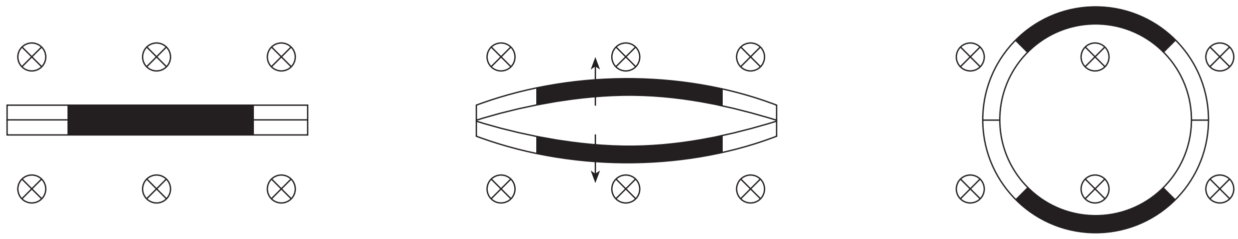
A5. A magician's metallic wand can spring apart into the shape of a circular hoop (see below).

B = 58 m T



(a) The hoop is in a magnetic field. Explain why an emf is induced in the hoop as it expands. [3]

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(b) Explain why the current flows anticlockwise in the diagram. [2]

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(c) The hoop, of radius 31.0 cm, is in a region of uniform magnetic flux density (*B*) of 58 mT and expands from the wand shape to the hoop in a time of 63 ms. Calculate the average current flowing in the hoop as it expands if the resistance of the hoop is 0.44Ω. [5]

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Turn over.

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SECTION B

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

B6. *(a)* Write brief notes about **one** of the following (paragraphs 3-5).

- The Higgs boson
- Grand Unification Theories
- Dark matter and dark energy. [3]

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(b) (i) Calculate the speed of a proton with 50 MeV of energy (paragraph 12). [2]

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(ii) Use the same method to calculate the speed of a 7 TeV proton (paragraph 12). [1]

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(iii) Explain briefly which of your two answers *(b)*(i) or *(b)*(ii) cannot be valid. [2]

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(c) Explain briefly the role of the liquid helium in producing strong magnetic fields (paragraph 10, 15, 24). [2]

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(d) (i) Assuming a typical grain of sand to be a cube, make an estimate for the length of its side and hence its volume in m^3. [2]

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(ii) Use your answer to *(d)*(i) to check whether *1.0 × 10⁻⁹ gram of hydrogen* occupies the volume of a grain of sand at room temperature and pressure (10^5Pa). (paragraph 20). [3]

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(e) Some theoretical physicists believe that the large hadron collider might destroy the planet (paragraph 18) due to the formation of tiny black holes. The event horizon of a black hole is the distance from a black hole within which nothing can escape. This distance for a black hole formed from two protons is around 10^{-54}m. Explain why such a black hole would be unlikely to pull in the whole mass of the Earth rapidly. [2]

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(f) Explain briefly why 'contaminating the proton tubes with soot' would be a problem (paragraph 24). [1]

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(g) In the novel Angels and Demons an anti-matter bomb is produced. Calculate the energy released by an anti-matter reaction where 3.1×10^{-6} kg of anti-matter is annihilated (paragraph 27). [2]

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Turn over.

Examiner only

SECTION C

This section contains questions on the following 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

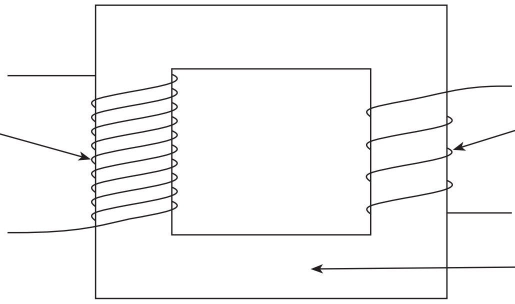
Answer the question on **one topic only**.

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

Examiner only

Option A: Further Electromagnetism and Alternating Currents

C7. *(a)* A diagram of a transformer is shown. Explain how an a.c. voltage is induced in the secondary coil. [4]



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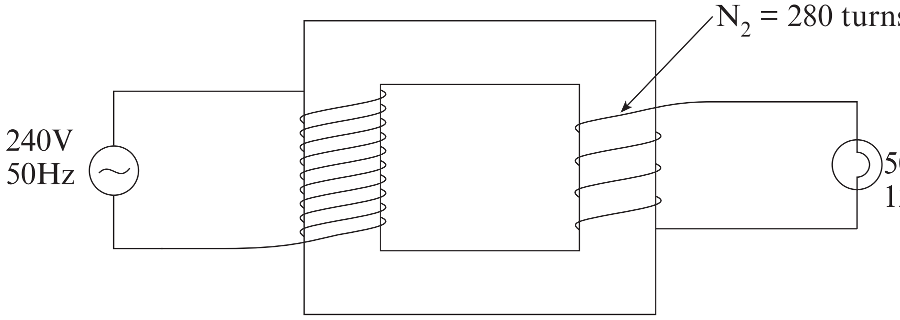
(b) A transformer is used to modify the mains power supply voltage in order to run a light bulb which is rated 50 W at 12 V.



(i) Calculate the number of turns in the primary coil of the transformer. [2]

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(ii) Calculate the current in the primary coil. [3]

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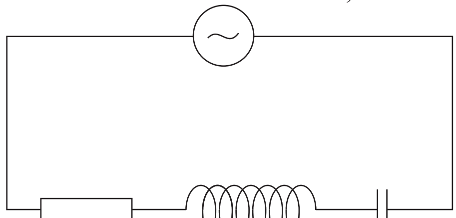
Examiner only

(c)



(i) The resonance frequency of the above circuit is 1000 Hz. Explain why the rms current is just below 0.45 A. [2]

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(ii) Calculate V_L, the rms p.d. across the inductor. [2]

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(iii) Write down V_C, the rms p.d. across the capacitor. .... [1]

(iv) Calculate the Q factor of the circuit. [2]

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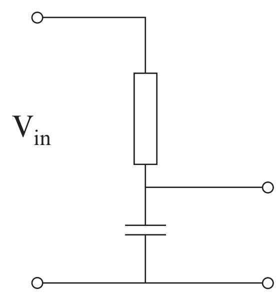
(v) Sketch a phasor diagram showing V_L, V_C and V_R approximately to scale. [2]

(d) Explain briefly whether or not the circuit shown is a high pass or a low pass filter. [2]



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

C8. Here are two short extracts from Thomas Young's description of his *double slits* experiment.
"The bright stripes on each side [of the central bright stripe] are at such distances, that the light coming to them from one of 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 ..."
"From a comparison of various experiments, it appears that the breadth of the undulations constituting the extreme red light must be supposed to be, in air, about one 36 thousandth of an inch, and those of the extreme violet, about one 60 thousandth ..."

(a) Write a sentence to convey the meaning of the first extract in terms of *wavelength* and *path* (or *path length* or *path difference)*. [2]

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(b) Use Young's values from the second extract to calculate the wavelength range of visible light in nanometres. [1 inch = 0.0254 m] [2]

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(c) The experiment – with Young's interpretation of it – is now regarded as the classic demonstration of the wave nature of light. At the time, though, it seems to have been thought unconvincing. It was even ridiculed.
Give two reasons for the poor reception of Young's work. [4]

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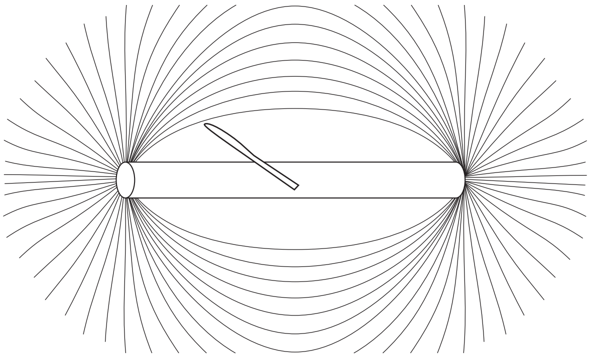

(d) Faraday's diagram shows a knife moving near a magnet.

Explain how the diagram enabled him to describe one of his discoveries. [2]

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(e) Faraday speculated that the propagation of light involved lines of force. How did he think the propagation took place? [2]

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(f) (i) Maxwell imagined all space to be filled with a cellular medium (Maxwell's *vortex ether)* and explored its properties mathematically. Describe what *magnetic lines of force* consisted of, in this ether. [2]

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(ii) Why did **neighbouring** magnetic lines of force pose a problem, and by what device did Maxwell solve it? Feel free to draw diagrams. [2]

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Examiner only

(g) Maxwell's investigation of his vortex ether led him to conclude that light must be an electromagnetic wave, which Hertz confirmed experimentally.
Explain why, despite this triumph, the notion of an ether was abandoned. [4]

Examiner only

Option C: Materials Option

C9. *(a)* (i) By drawing simple diagrams showing positions of atoms, give a detailed description, in terms of dislocations, of plastic deformation in a ductile material such as a pure metal. [4]

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(ii) Describe at the atomic level **one** method of making pure metals stronger and stiffer. [2]

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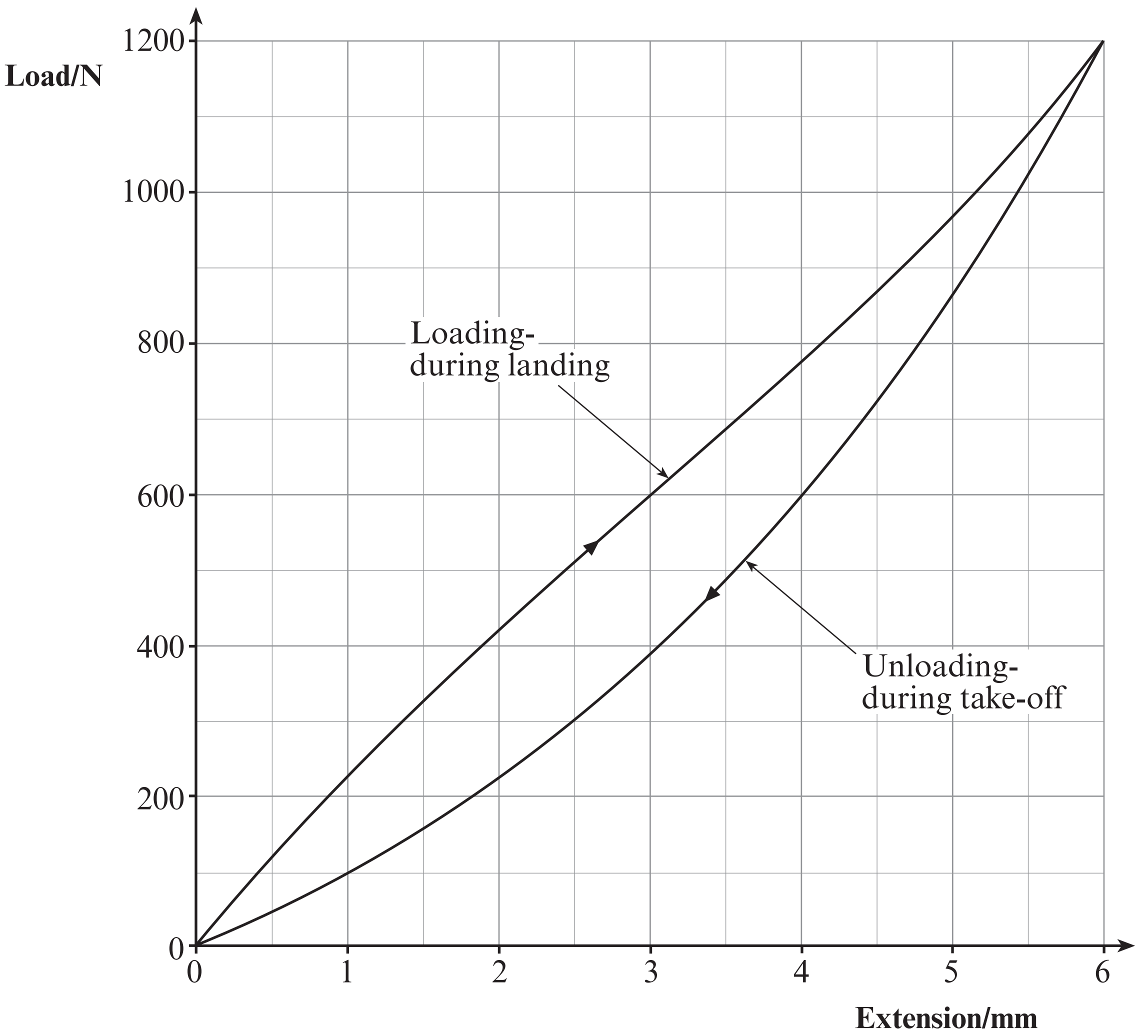
(b) A kangaroo stores much of its kinetic and potential energy in its achilles tendons during ‘hopping’. The achilles tendon is, in fact, well suited to serve as an effective spring (or rubber band) for energy recovery. During one ‘hop’, **most** of the energy that is used to stretch the tendon during ‘landing’ can be recovered elastically to aid ‘take off’ thus helping to offset the work the muscles have to do.

Examiner only

A typical Load-extension graph for a kangaroo achilles tendon is shown for one complete ‘hop’.



(i) The tendon returns to its original length after unloading, but not along the same curve as during loading. What is this effect called? [1]

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(ii) Compare the energy stored in the tendon after loading with that recovered form it after unloading and account for the difference. [No calculations are required here]. [2]

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Turn over.

Examiner only

(iii) Estimate the percentage efficiency of the tendon in re-using the energy stored in it. [3]

(iv) I. If it is assumed that the tendon obeys Hooke's law, show that

$$W = \frac{F^2 l}{2AE}$$

Where W is the energy stored during loading, A is the mean cross-sectional area of the tendon, l is the original length, F is the load on the tendon and E is the Young Modulus. [3]

II. The cross-sectional area of the tendon is 0.55cm^2 and its original length is 30 cm. Hence estimate the Young modulus for the tendon. [3]

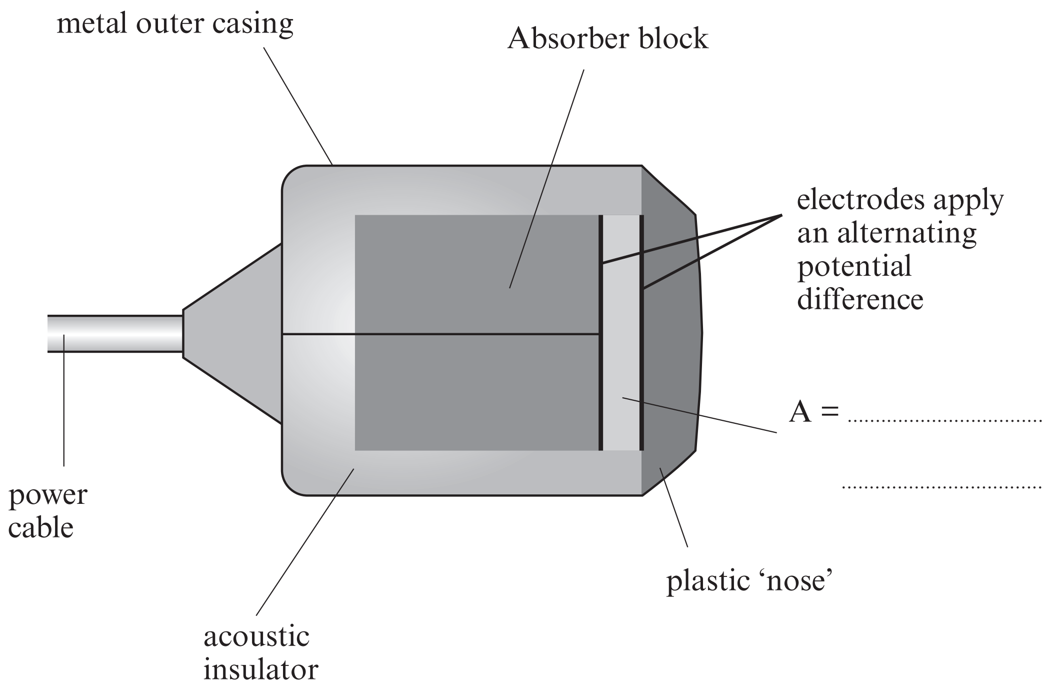
(v) What particular mechanical properties should scientists look for in order to make artificial tendons? [2]

Examiner only

Option D: Biological Measurement and Medical Imaging

C10. *(a)* Below is a simple diagram of an ultrasonic probe,

(i) Label part A. [1]



(ii) Explain why there is a need for an absorber to be placed behind A. [1]

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(iii) The fraction of ultrasound reflected at a boundary is given by the reflection coefficient, R, where

$$R = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2} \text{ and } Z = \text{acoustic impedance}$$

Calculate the reflection coefficient between air and the skin of a patient using the following information. [2]

Medium	Density / kg m^{-3}	Velocity / m s^{-1}
Air	1.30	340
Skin	1075	1600

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Examiner only

(iv) Explain whether or not it is possible for ultrasound scans to be used to study a patient's lungs. [1]

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(b) (i) A radionuclide such as iodine-131 or iodine-123 can be used to investigate kidney function. Give **two** important properties of any radionuclide that is used as a tracer. [2]

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(ii) Following the injection of a tracer, what changes in detected activity will indicate that a kidney is healthy? [1]

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(c) Inside an X-ray tube, electrons are emitted from a heated cathode and accelerated through a very high potential difference towards a target.

(i) What happens to the X-ray output when the heater current is increased? [1]

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(ii) When the X-rays pass through a material, they are absorbed and the beam becomes attenuated. The thickness of material required to reduce the intensity to half its original value is called the half value thickness $X_{\frac{1}{2}}$. Show that $X_{\frac{1}{2}} = \frac{\ln 2}{\mu}$ where μ is the attenuation coefficient. [2]

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(iii) Calculate the attenuation coefficient of lead given that $X_{\frac{1}{2}} = 12\,\text{mm}$. [1]

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(iv) Determine the thickness of lead needed to reduce the intensity of the X-ray beam to 5% of its initial value. [2]

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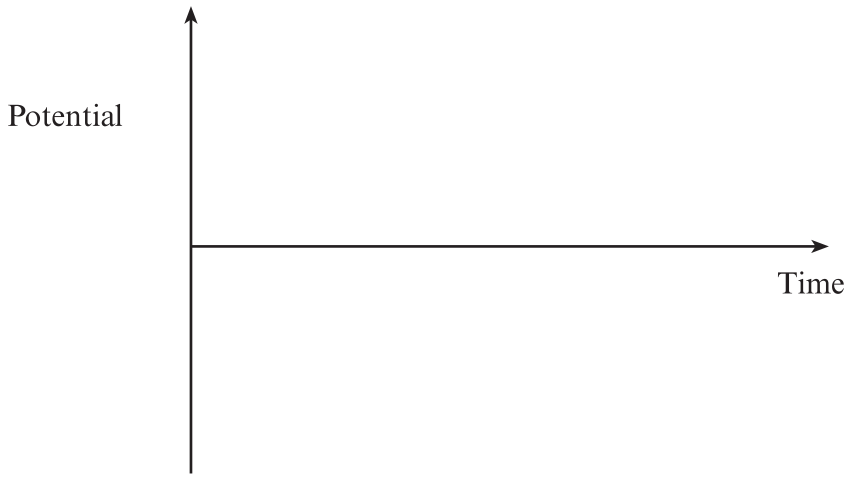
(d) (i) An ECG recorder is used to check a patient's cardiac rhythm. Sketch the expected ECG trace for a healthy heart. Include units on each axis. [3]



(ii) Explain why it is important for an ECG amplifier to have a high input impedance. [1]

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(iii) State **two** other essential characteristics of an ECG amplifier. [2]

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Option E: Energy Matters

C11. *(a)* The traditional petrol-driven car is powered by an internal combustion engine in which a mixture of petrol and air in the cylinders is ignited by a spark. The expanding gases from the resulting explosions force down the pistons which, through linkages and gears, rotate the road wheels and hence propel the car. The following questions relate to a current small family car.

(i) The car has mass 1200 kg and can accelerate from rest to 28 ms^{-1} in 13 s. Assuming constant acceleration, show that this corresponds to a mean power output of 36 kW. [3]

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(ii) Identify **two** specific reasons why the power delivered by the engine needs to be significantly greater than 36 kW. [2]

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(iii) Only part of the chemical energy in the petroleum appears as useful energy. Explain why this is so, referring to the relevant law of thermodynamics. [2]

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(iv) The tank capacity is 42 litres (0.042 m^3) and the average petrol consumption is 5.8 litres for 100 km. Calculate the average range on a full tank. [1]

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(v) Petroleum contains 85% of carbon by weight. In the oxidation (burning) of carbon, one carbon atom (relative atomic mass 12) combines with one molecule of oxygen (relative molecular mass 32) to produce one molecule of carbon dioxide. Calculate the maximum mass of carbon dioxide that a full tank could produce. (Petroleum density = 780 $kg\,m^{-3}$.) [3]

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(vi) The actual carbon dioxide emission for this car is measured to be 137 g/km. Use your answers to (iv) and (v) to calculate the car's theoretical carbon dioxide emission in grams per kilometre and compare these values. [2]

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(vii) State briefly why the carbon dioxide emission figure is important. [1]

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(b) The **annual** UK consumption of electrical energy from the National Grid is 350 TWh.

(i) Express 350 TWh in joules (J). [2]

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(ii) Calculate the mean power in gigawatts (GW). [1]

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(iii) Why does the maximum power capability need to be considerably greater than the mean in (ii)? [1]

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(iv) Outline **one** practical method of storing energy at times of low demand. [2]

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Examiner only