Examiner only

4. *(a)* The diagram shows a positively charged particle at rest. Draw and label the electric field on the diagram – include electric field lines and equipotential surfaces.

[2]

(b) (i) An alpha particle (helium nucleus) of charge 3.2×10^{-19} C and mass 6.6×10^{-27} kg travels with a speed of $5.0 \times 10^{6}\,\text{m s}^{-1}$. Calculate its kinetic energy.

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[1]

(ii) If the alpha particle travels head-on towards a stationary copper nucleus of charge 4.6×10^{-18} C in thin copper foil, find their distance of closest approach.

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[4]

(iii) Describe in terms of energy what happens to the alpha particle after it has reached the point of closest approach.

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[2]

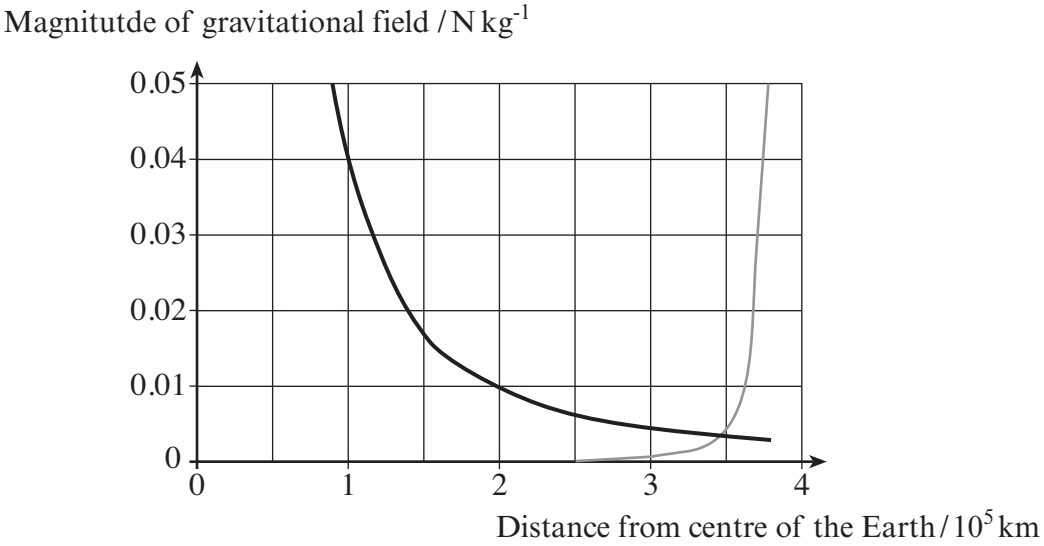
Examiner only

(iv) Complete the sketch below by showing the path of the alpha particle (α) if it was not travelling head-on towards the copper nucleus (Cu).

[1]

Examiner only

6. The graph below shows the **magnitudes** of the gravitational fields of the Earth (thick curve) and of the Moon (thin curve) along the line connecting the centre of the Earth to the centre of the Moon. Fields in excess of $0.05\,N\,kg^{-1}$ are beyond the scale of the graph and are not plotted.



(a) Show by calculation that the gravitational field due to the Earth at a distance 1.0×10^5 km agrees with the graph. (Mass of the Earth = 6.0×10^{24} kg).

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[3]

(b) Explain why the Moon's gravitational field near the Earth is significantly less than the Earth's field near the Moon.

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[1]

Examiner only

(c) Estimate the distance of the point of intersection of the two curves from the centre of the Earth. Explain the significance of this point of intersection.

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[2]

(d) A spacecraft is launched directly **towards the Earth** from the equator of the Moon. Discuss the forces due to gravity that it experiences during its journey to Earth, mentioning their relative magnitudes.

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[3]

(e) A second spacecraft is launched on the far-side of the Moon so that it travels directly away from the Earth. Would it require more or less energy than the first spacecraft to escape from the Moon? Explain your answer.

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[2]

Examiner only

7. A star of mass 2.2×10^{30} kg has a companion planet. The star and planet orbit a common centre of mass with an orbital period of 1090 days.

(a) If the star's orbital speed is $45.5\,\text{m}\,\text{s}^{-1}$, determine the radius of the star's orbit.

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[3]

(b) (i) Show that the distance from the planet to the star is approximately 3.2×10^{11} m. The mass of the planet is very much smaller than the mass of the star.

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[4]

(ii) Hence, estimate the mass of the planet.

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[2]

Examiner only

(c) Suggest how the orbital speed of the star may have been measured.

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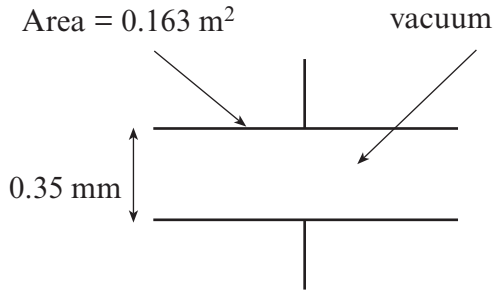
[2]

Examiner only

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



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(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]

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

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

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(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]

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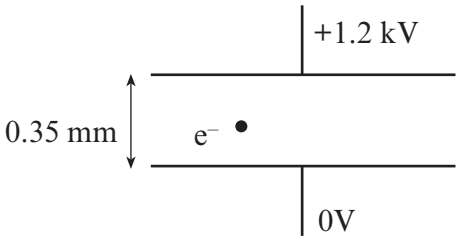
(e) An electron is located between the plates of the charged capacitor. Show that the acceleration experienced by the electron is approximately $6 \times 10^{17}\ m\,s^{-2}$. [3]



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

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

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(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]

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

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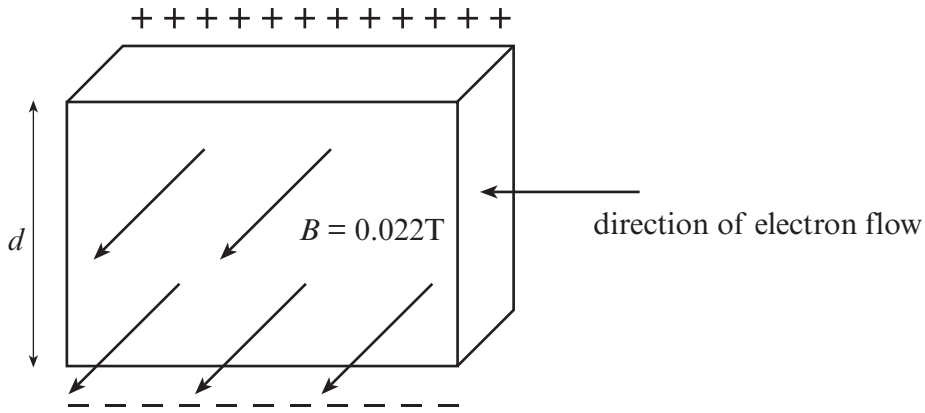
Examiner only

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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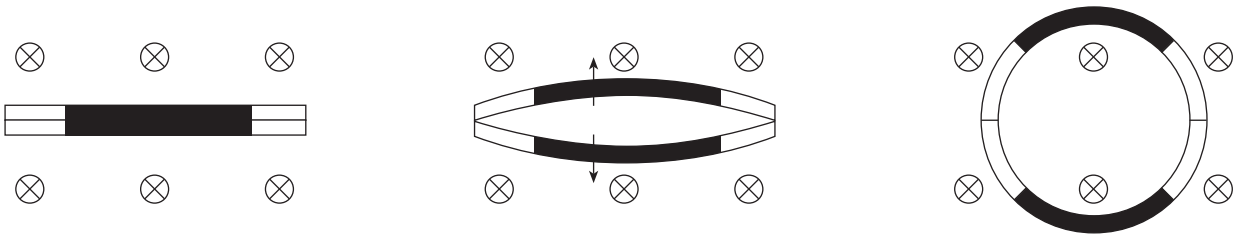
Examiner only

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 0.44 Ω. [5]

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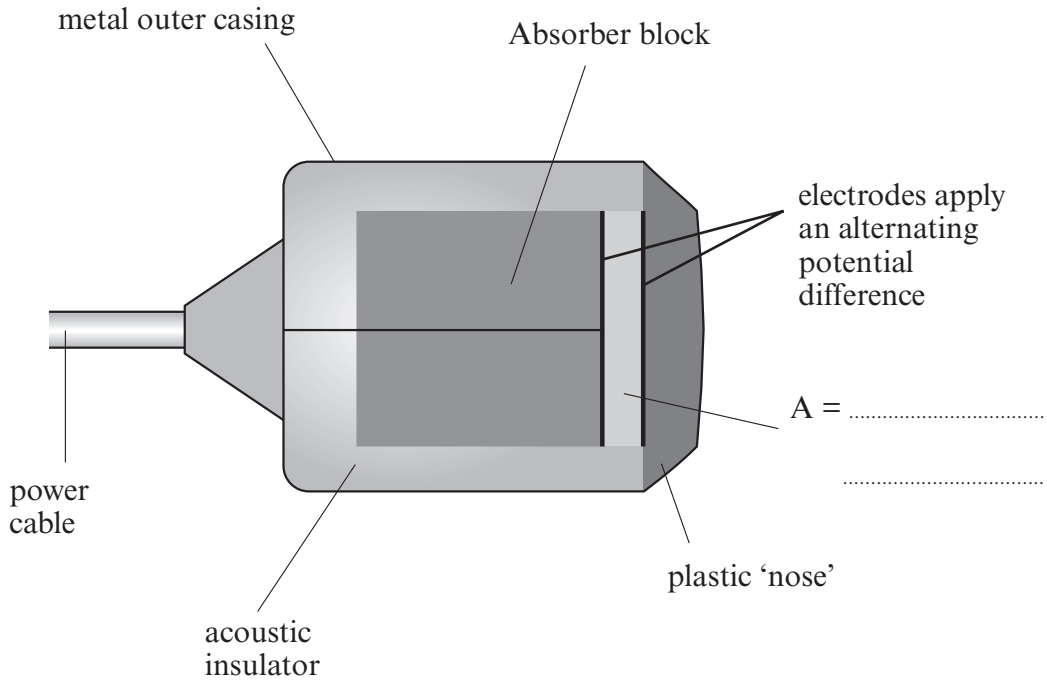
Examiner only

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

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

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

Medium	Density / $kg\,m^{-3}$	Velocity / ms^{-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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Examiner only

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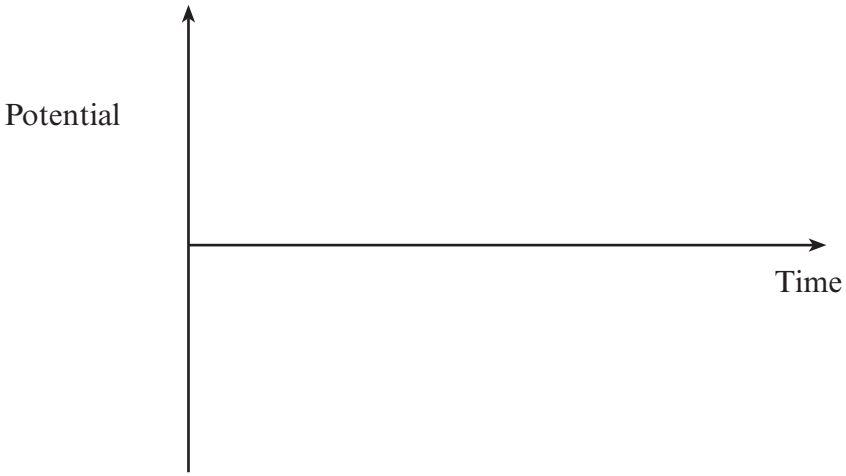
(d) (i) An ECG recorder is used to check a patient's cardiac rhythm. Sketch the expected ECG trace for a healthy heart. Include units on each axis. [3]



(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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