GCE PHYSICS

S21-A420QS

Assessment Resource number 27

Options Resource I

SECTION B: OPTIONAL TOPICS

Option A – **Alternating Currents** ☐

Option B – **Medical Physics** ☐

Option C – **The Physics of Sports** ☐

Option D – **Energy and the Environment** ☐

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

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

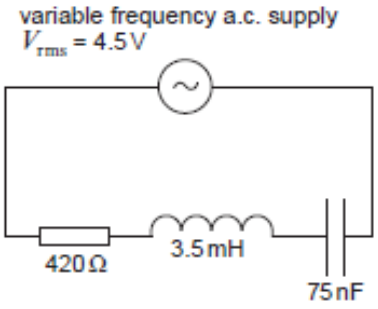
You are advised to spend about 25 minutes on this section.

Option A – Alternating Currents

1 *(a)* With the aid of a phasor diagram, explain why the impedance of an RCL circuit is given by: [3]

$$Z = \sqrt{(X_L - X_C)^2 + R^2}$$

(b) Consider the following RCL circuit.



(i) Show that the combined magnitude of the reactance of the inductor and capacitor is the same (to 3 s.f.) as the resistance of the resistor when the frequency is 4 150 Hz. [3]

(ii) Hence, calculate the rms current in the circuit when the frequency is 4 150 Hz. [3]

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(iii) Calculate (or state) the phase angle between the applied pd and the current when the frequency is 4 150 Hz. [1]

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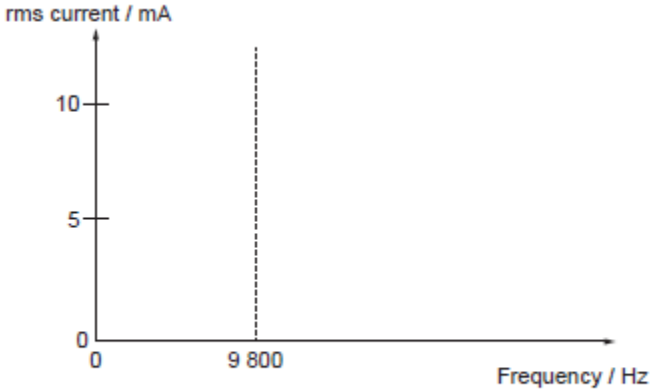
(iv) The resonance frequency of the RCL circuit is approximately 9 800 Hz. By **sketching** a graph of rms current against frequency, explain why there is a second higher frequency that provides the same rms current as your answer to *(b)*(ii). [3]



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(v) This second frequency occurs when the magnitude of the reactances of the inductor and capacitor are reversed from those in part *(b)*(i). Use this information to calculate this second frequency. [2]

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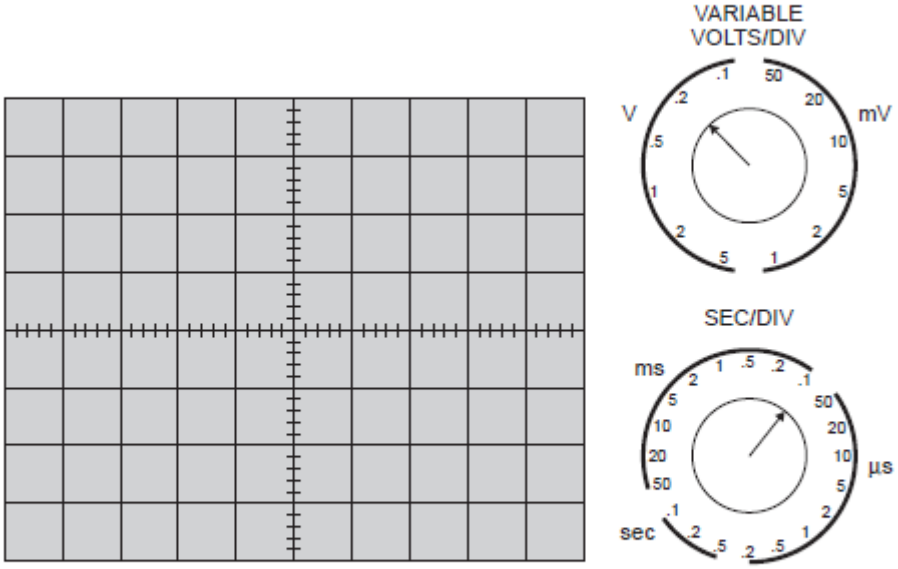
(c) Robyn is required to produce a wave trace on an oscilloscope for an a.c. power supply of frequency 3.0 kHz and rms pd 0.60 V. Deduce whether or not the settings of the oscilloscope shown below are appropriate. [5]



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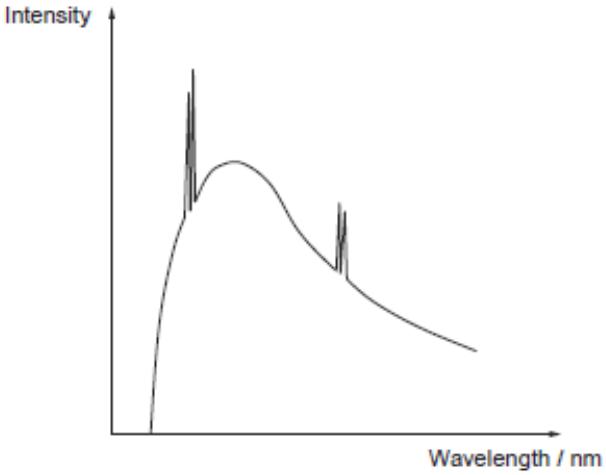
Option B – Medical Physics

(a) The graph below shows the intensity spectrum for an X-ray tube.



(i) **Draw on the above diagram** an intensity spectrum for the same X-ray tube with a **higher** operating voltage. [1]

(ii) If the operating voltage of the tube is 30 000 V, determine the minimum wavelength of the X-rays produced. [2]

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(iii) If the anode current is 120 mA and the X-ray tube has an efficiency of 0.450 % calculate the rate of production of heat at the anode. [2]

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(iv) Explain whether it would be possible to reduce the minimum wavelength to zero. [1]

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(b) (i) An ultrasound probe (A scan) can be used to determine the thickness of a lens in the human eye. Explain how a piezoelectric transducer can be used to produce ultrasound. [2]

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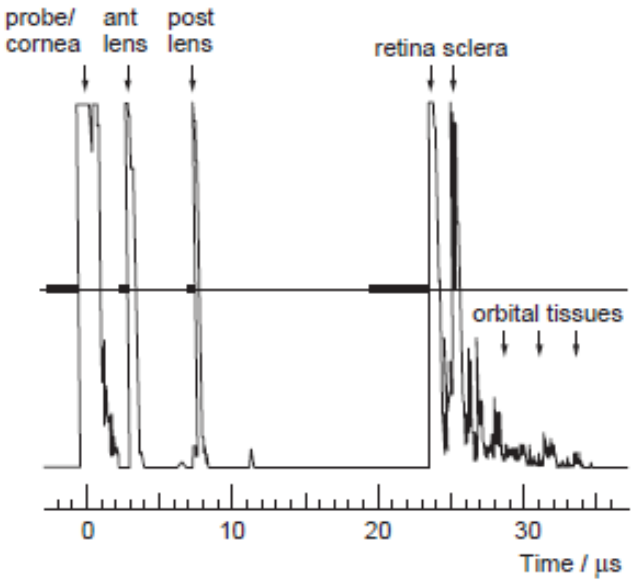
(ii) A typical ultrasound A scan used to determine the thickness of a lens is given in the diagram below. The spike labelled 'ant lens' corresponds to the front of the lens and the spike labelled 'post lens' corresponds to the back of the lens.



Use the information in the diagram to calculate the lens thickness. The speed of ultrasound in the lens is 1640 m s^{-1}. [3]

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

X-ray **ultrasound A scan** **radioactive tracer** **CT scan**

Justifying the reasons for your answer, state which of the above you would use to detect the following:

(i) A cerebral haemorrhage (bleed in the brain). [3]

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(ii) An underactive thyroid gland. [2]

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(d) An MRI (magnetic resonance imaging) scanner has a magnetic field that varies from 0.80 T to 1.40 T along its length. Calculate the wavelength of electromagnetic waves required to scan a slice halfway along its length **and** state which part of the electromagnetic spectrum they belong to. [4]

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Option C – Physics of Sports

(a) (i) Explain what is meant by the term *moment of inertia* of an object. [2]

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(ii) Calculate the moment of inertia of a cricket ball which has a rotational kinetic energy of 1.47 J if it is spinning at a rate of 30 revolutions per second. [3]

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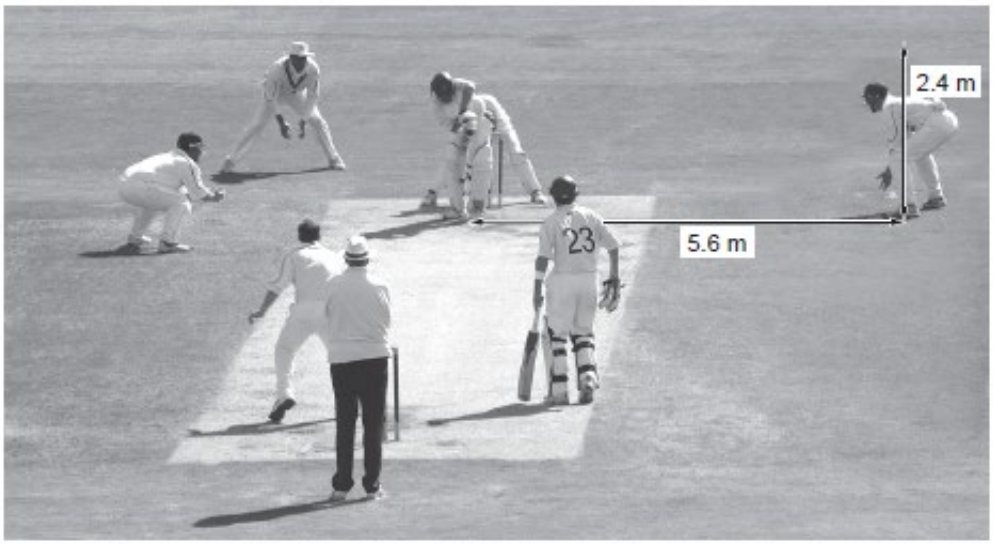
(b) (i) The batsman hits the ball with an initial velocity of 25 m s^{-1} at an angle of 30° to the horizontal. A fielder standing 5.6 m away from the batsman can catch a ball 2.4 m above the ground. Evaluate whether the ball can be caught by the fielder. Assume that air resistance can be ignored and that the ball is hit from ground level. [5]



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(ii) Explain why a fielder will move his hands in the direction of motion of the cricket ball when catching. [2]

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(iii) The coefficient of restitution between the pitch and the ball is 0.37. Determine the bounce height if the ball falls from a height of 2.35 m. [2]

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(c) For this part of the question, the interactions between the ball and the air need to be taken into account.

(i) Explain why a spinning cricket ball will change direction when moving through the air. Your answer should include the forces acting on the ball during the flight and a diagram may be included. [3]

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(ii) Determine the drag force acting on a cricket ball of radius 3.6 cm during flight if the speed of the ball is 24.3 $m\,s^{-1}$ and its drag coefficient is 0.76.
Density of air = 1.3 $kg\,m^{-3}$. [3]

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Option D – Energy and the Environment

(a) (i) The total power emitted by the Sun is 3.8×10^{26} W. Calculate the intensity of radiation received at the upper atmosphere of planet Earth and state the name given to this value. The distance between the Earth and the Sun is 1.5×10^{11} m. [2]

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(ii) A student models the energy balance of planet Earth without its atmosphere. He calculates the theoretical power absorbed by the Earth to be 1.2×10^{17} W. Assuming the Earth to be in thermal equilibrium and to behave as a black body, show that the temperature of the Earth for this model is approximately 250 K. The radius of the Earth is 6.4×10^{6} m. [3]

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(iii) The actual mean surface temperature of the Earth is 287 K. Without calculation, account for this difference in temperature and explain how human activity has further contributed to this. [3]

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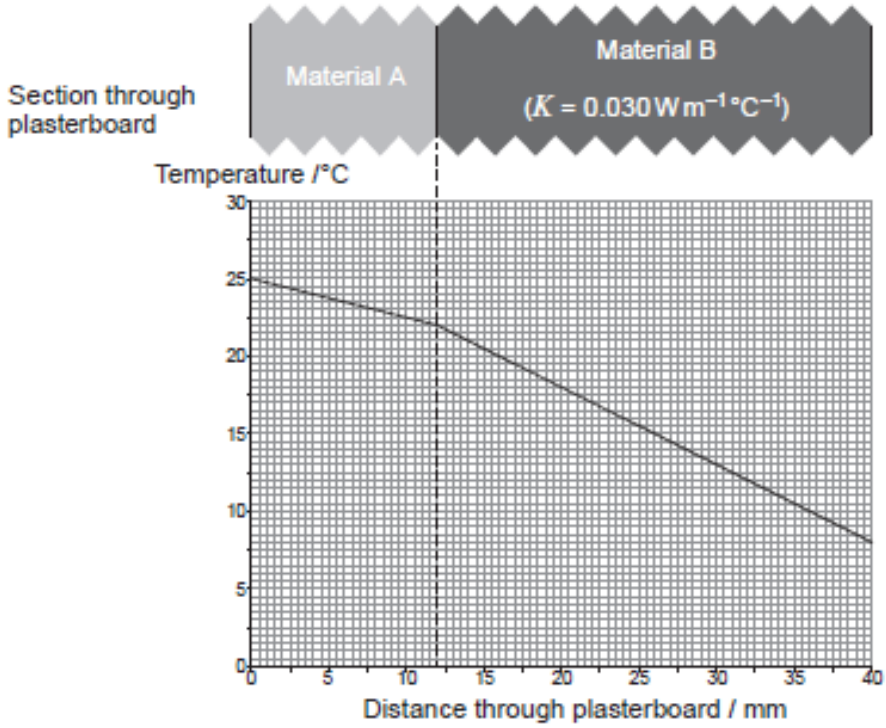
(b) (i) State and explain the three conditions that are simultaneously required to produce a sustainable fusion reaction. [3]

(ii) A fusion test reactor requires a triple product greater than $3.5 \times 10^{28}\,\text{s K m}^{-3}$. The plasma has a volume of $70\,\text{m}^3$ and contains 2.4×10^{22} particles. If a confinement time of 0.9 seconds is achieved, determine the minimum temperature necessary for this reaction. [2]

(c) (i) A company manufactures thermal plasterboards using a composite of two different materials. One of the materials is known to have a *thermal conductivity value of* $0.030\,\text{W m}^{-1}\,^{\circ}\text{C}^{-1}$. Explain what the statement in italics means. [2]

(ii) Jack investigates the thermal properties of a sample of thermal plasterboard. He produces a graph of temperature against distance as shown below.



Jack suggests that material B has twice the thermal conductivity value of material A and that the U-value of the plasterboard is approximately 0.90 W m^{-2} °C^{-1}. Evaluate whether or not Jack's suggestions are correct. [5]

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