GCE PHYSICS

S21-A420QS

Assessment Resource number 21

Options Resource C

SECTION B: OPTIONAL TOPICS

Option A – **Alternating Currents** ☐

Option B – **Medical Physics** ☐

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

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

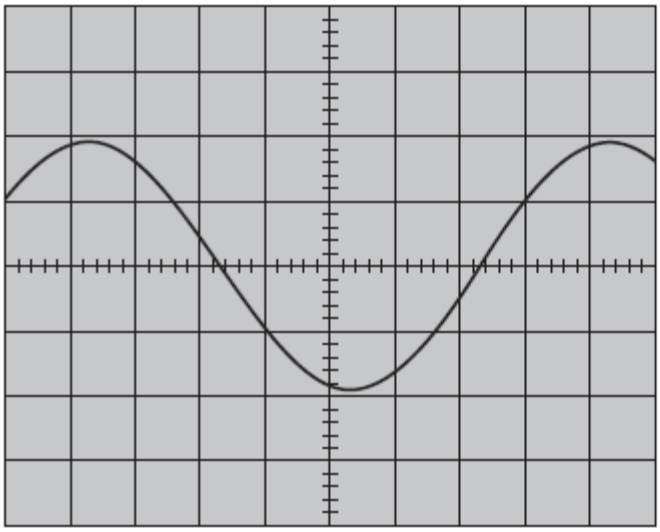
Answer the question on **one topic only.**

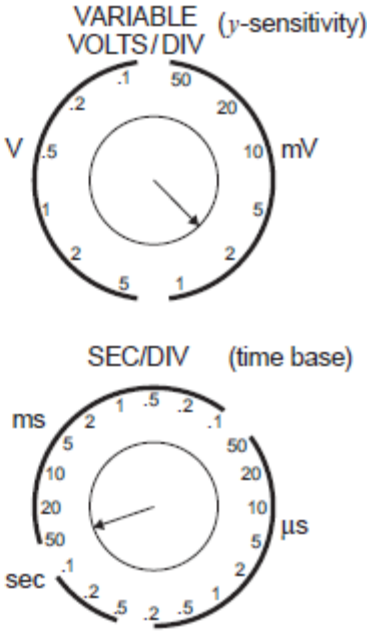
Place a tick (✓) in **one** of the boxes above, to show which topic you are answering.

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

Option A – Alternating Currents

1 An oscilloscope trace is shown along with the settings of the y-sensitivity and the time base.





(a) (i) Calculate the **rms** pd of the oscilloscope trace shown. [2]

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(ii) Calculate the frequency of the oscilloscope trace shown. [2]

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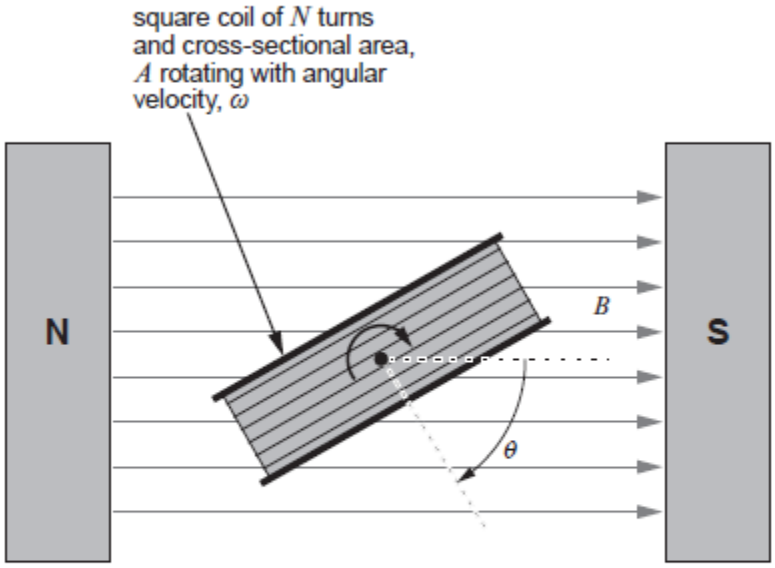
(b) A coil rotates in a magnetic field as shown.



(i) Use Faraday's Law to explain why the peak emf induced in the coil is proportional to the angular velocity of rotation of the coil. [2]

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(ii) Use Faraday's Law to explain why the emf induced in the coil depends on the angle, θ. [2]

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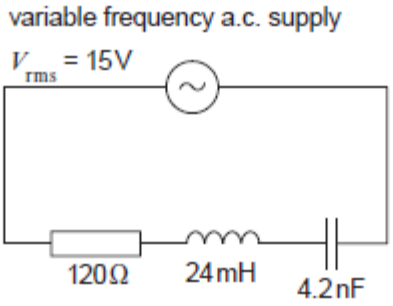
(c) (i) In the following LCR circuit, explain why the rms resonance current is 125 mA. [2]



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(ii) Calculate the resonance frequency of the circuit. [2]

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(iii) Show that the rms current is 42 mA when the frequency of the supply is 17 kHz. [3]

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(iv) Alistair claims that the mean power dissipation in the circuit at 17 kHz is:

$$P = I_{rms} V_{rms} = 0.042 \times 15 = 0.63\,\text{W}$$

Another student Michonne states that the correct value of power is 0.21 W.
Deduce which, if either, of the students is correct. [5]

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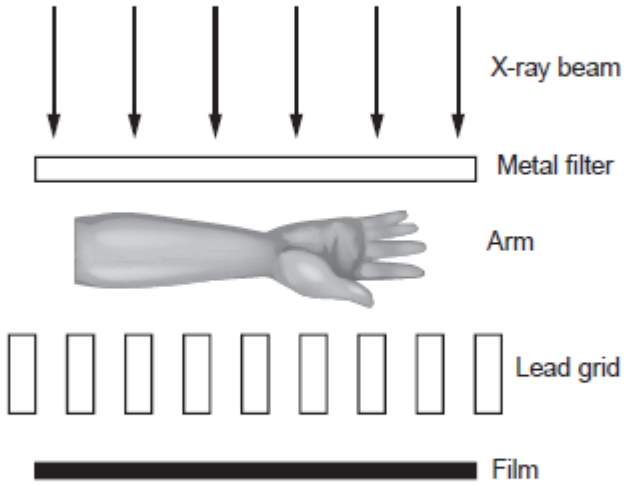
Option B – Medical Physics

(a) When taking an X-ray image of a person's arm a metal filter is placed between the X-ray tube and the arm, and a lead grid between the arm and the film as shown.



Explain the purpose of both the metal filter and the lead grid. [4]

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(b) An X-ray tube operates at a pd of 30 kV producing a tube current of 15 mA.

(i) Calculate the number of electrons that strike the target element every second. [2]

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(ii) Calculate the force exerted by the electron beam on the target. [3]

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

MRI scan **PET scan** **ultrasound B-scan** **CT scan**

Evaluate the effectiveness of each type of imaging in detecting a cancerous tumour on a person's lung. [5]

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(d) (i) Radioactive tracers can be used to measure the volume of blood in a patient. Describe one other use of radioactive tracers naming the part of the body they are diagnosing. [1]

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(ii) An isotope of sodium, Na-24, has a half-life of 15 hours and an initial activity of 160 Bq when injected into a patient. Seven hours later a sample of 5 cm^3 of blood was taken and found to have an activity of 0.12 Bq. Estimate the volume of blood in the patient. [3]

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(iii) Ultrasound of frequency 3.0 MHz was used to measure the rate of flow of blood. A shift of 0.50 kHz was detected. The measurement was taken at an angle of 30° to the direction of flow and the speed of ultrasound through the blood is 1500 ms^{-1}. Calculate the speed of blood flow. [2]

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The following photograph shows a cyclist crossing the finish line at the end of a race.

(a) State why the net moment acting on the cyclist is zero. [1]

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(b) (i) State what is meant by the moment of inertia of an object. [2]

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(ii) A diver of mass 60 kg and height 1.68 m has an angular momentum of 92.1 kg m^2 s^{-1} at the start of her dive. Her moment of inertia, I, at the start of the dive is

$$I = \frac{1}{12} mh^2$$

where m is her mass and h is her height. Calculate her angular velocity. [3]

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(iii) During the dive, the diver tucks in her arms and legs and reduces the moment of inertia to 2.7 kg m^2. Calculate the final angular velocity of the diver. [3]

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(c) The wheel of a Formula 1 car has a moment of inertia of $1.10\,kg\,m^2$. As the car approaches a corner and brakes, its angular velocity decreases from $220\,rad\,s^{-1}$ to $170\,rad\,s^{-1}$ in a time of 0.310 s.

(i) Calculate the resultant torque on the wheel of the car during the braking process. [3]

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(ii) Determine the total rotational kinetic energy lost by the wheels of the car during the above braking process assuming all the wheels have the same moment of inertia. [3]

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(d) During a Grand Prix a driver loses control of the car when approaching a bend and crashes but escapes with minor injuries. The speed reduces from $213\,km\,hr^{-1}$ to zero in a time of 0.651 s. The mass of the car is 640 kg and the driver's mass is 70 kg. Use the given data to evaluate why Grand Prix race circuits have large areas of grass or loose stone chippings around certain corners. [5]

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Option D – Energy and the Environment

(a) (i) State the principle of Archimedes. [1]

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(ii) The Greenland ice sheet is estimated to have an area of 1.5×10^6 km^2 and a mean thickness of 2.1 km.

I. Show that the mass of the Greenland ice sheet is approximately 3×10^{18} kg. [Density of ice = 920 kg m^{-3}] [2]

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II. Scientists predict that sea levels would rise by about 8 metres if all the Greenland ice sheet were to melt. Use the following information to justify their prediction. [2]
[Density of water = 1000 kg m^{-3};
Surface area of ocean on Earth = 3.6×10^8 km^2]

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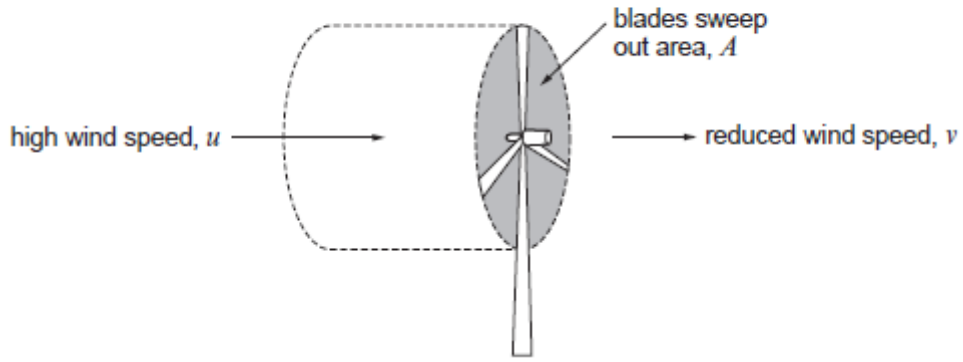
(b) Wind turbines convert as much as possible of the kinetic energy of the air that moves through the area swept out by the blades into electrical energy.



(i) Show that the kinetic energy per second (the power, P) arriving at the blades per second can be given by:

$$P = \frac{1}{2} A \rho u^3$$

where ρ is the density of the air. [2]

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(ii) Use the above equation to determine whether doubling the length of the blades or doubling the wind speed would have the greater effect on the power available to be converted into electrical energy. [2]

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(iii) A wind turbine has blades of length 30 m. Wind of speed $8.0\,m\,s^{-1}$ arrives at the blades, which is reduced to $5.0\,m\,s^{-1}$ after passing through the blades. Calculate the maximum possible efficiency of this wind turbine. [Density of air = $1.2\,kg\,m^{-3}$]. [3]

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(iv) Explain why the actual efficiency of the turbine is less than your answer to *(b)*(iii). [1]

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(c) (i) Use an appropriate equation to show that the unit of the coefficient of thermal conductivity, K, is $Wm^{-1}K^{-1}$. [2]

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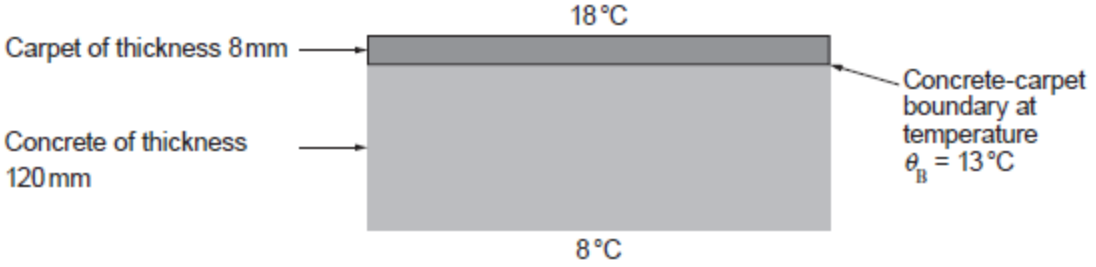
(ii) One room in a house has a floor made of concrete of thickness 120 mm covered by a carpet of thickness 8 mm. The temperature at the upper surface of the carpet is 18 °C and that of the lower surface of the concrete is 8 °C. Show that, under these conditions, the temperature (θ_B), at the concrete-carpet boundary is 13 °C.
[Assume $K_{concrete} = 0.9 Wm^{-1}K^{-1}$ and $K_{carpet} = 0.06\ Wm^{-1}K^{-1}$]. [3]



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(iii) Without the carpet, thermal energy is conducted through the concrete floor (of dimensions 6 m × 8 m) at a rate of 3.6 kW. The carpet manufacturer claims that fitting the carpet would reduce the rate at which energy is transferred by about 50%. Use the above conditions to test their claim. [2]

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