Surname		Centre Number	Candidate Number
Other Names			2

GCE A LEVEL

A420U30-1

S18-A420U30-1

eduqas
Part of WJEC

PHYSICS – A level component 3
Light, Nuclei and Options

THURSDAY, 14 JUNE 2018 – MORNING

2 hours 15 minutes

	For Examiner's use only		
	Question	Maximum Mark	Mark Awarded
Section A	1.	9	
	2.	6	
	3.	12	
	4.	13	
	5.	15	
	6.	13	
	7.	6	
	8.	6	
	9.	9	
	10.	11	
Section B	Option	20	
	Total	120	

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01

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
Do not use gel pen or correction fluid.

Answer **all** questions.

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. If you run out of space, use the continuation page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B.**

Section **A**: 100 marks. Answer **all** questions. You are advised to spend about 1 hour 50 minutes on this section.

Section **B**: 20 marks; Options. Answer **one option only**. You are advised to spend about 25 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in **Q8**.

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SECTION A

Answer **all** *questions.*

1. *(a)* State what is meant by two coherent sources. [1]

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(b) In the 1700s, light was thought to consist of a stream of particles. In the 1800s, it was said to be a wave but since the early 1900s it has been accepted that light behaves both like a wave and like a particle (wave particle duality). Explain briefly the part that Young's double slit experiment played in this history. [2]

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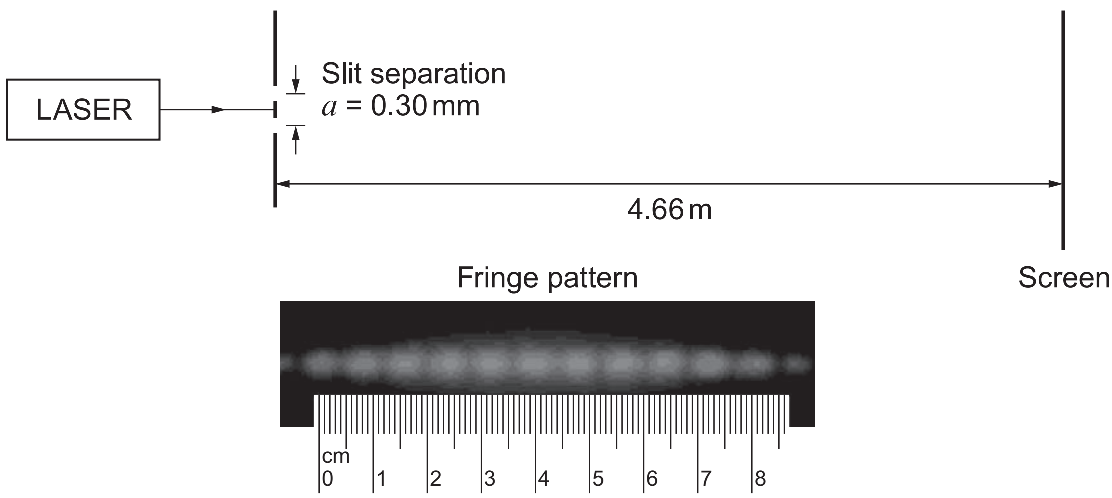
(c) Young's double slit experiment is carried out using laser light.



(i) Calculate the fringe separation from the above diagram. [2]

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(ii) The distance between the slits and the screen is 4.66 m. Calculate the wavelength of the laser light. [2]

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(iii) State one advantage and one disadvantage of using a large slit-to-screen distance. [2]

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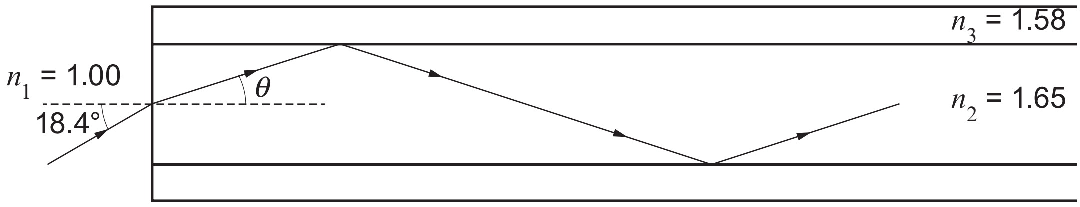
2. A light ray enters an optical fibre as shown.



(a) Show that the angle θ is approximately 10°. [2]

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(b) Deduce whether or not this light will propagate along the length of the optical fibre with total internal reflection as shown. [4]

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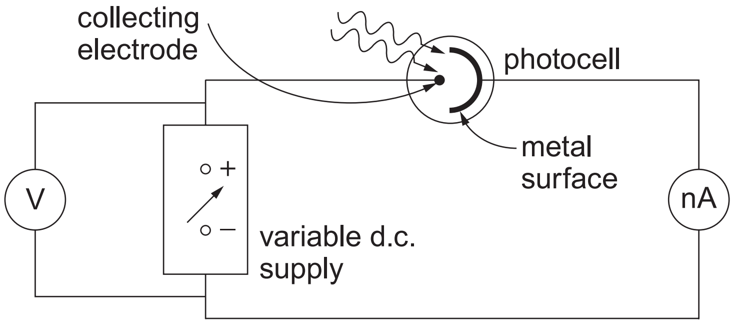
3. Light is incident on a photoelectric cell as shown.



(a) Explain why a current is detected by the ammeter. [3]

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(b) The work function of the metal surface is 2.7 eV and electrons are emitted with a maximum kinetic energy of 1.2 eV.

Calculate the frequency of the incident photons. [3]

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(c) (i) Explain how you would modify and use the circuit opposite to measure the stopping potential. [3]

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(ii) The metal surface of the photocell is radioactive and emits alpha particles some of which arrive at the collecting electrode. Explain briefly what effect this would have on measuring the stopping potential and what could be done to reduce this effect. [3]

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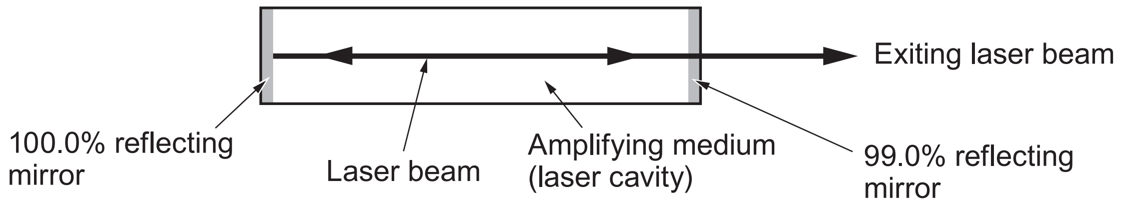
4. A laser has two mirrors either side of the amplifying medium as shown.



(a) Explain the purpose of the 99.0% reflecting mirror and the 100.0% reflecting mirror. [2]

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(b) Explain the purpose of a population inversion in the laser cavity. [3]

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(c) (i) The light intensity inside a powerful laser is 2.0×10^{15} W and its wavelength is $1.05\,\mu$m. Show that this corresponds to approximately 1×10^{34} photons per second. [2]

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(ii) Show that the momentum of a 1.05 μm photon is approximately $6 \times 10^{-28}\,\text{kg m s}^{-1}$. [1]

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(iii) Show that the force exerted on a 100.0% reflecting mirror by a beam of power 2.0×10^{15} W is approximately 1×10^{7} N. [2]

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(iv) Calculate the strain produced in a laser structure if the power of the beam between the mirrors is 2.0×10^{15} W. You may assume that the structure of the laser cavity has a cross-sectional area of $43\,\text{cm}^2$ and is made of a material with Young modulus 2.8×10^{11} Pa. [3]

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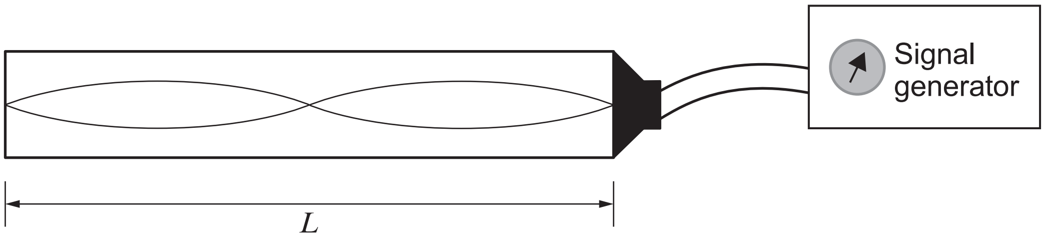
5. An experiment is carried out using stationary waves to measure the speed of sound in air. A loudspeaker is placed at one end of a hollow tube so that both ends are closed. The frequency, f, of the signal generator connected to the loudspeaker is varied and those frequencies corresponding to loud noises recorded.



(a) Describe the differences between a stationary wave and a progressive wave in terms of energy, phase and amplitude. [3]

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(b) Show that the frequencies corresponding to stationary waves are given by:

$$f = \frac{v}{2L}\,n$$

where n is any whole number (n = 2 in the above diagram). [3]

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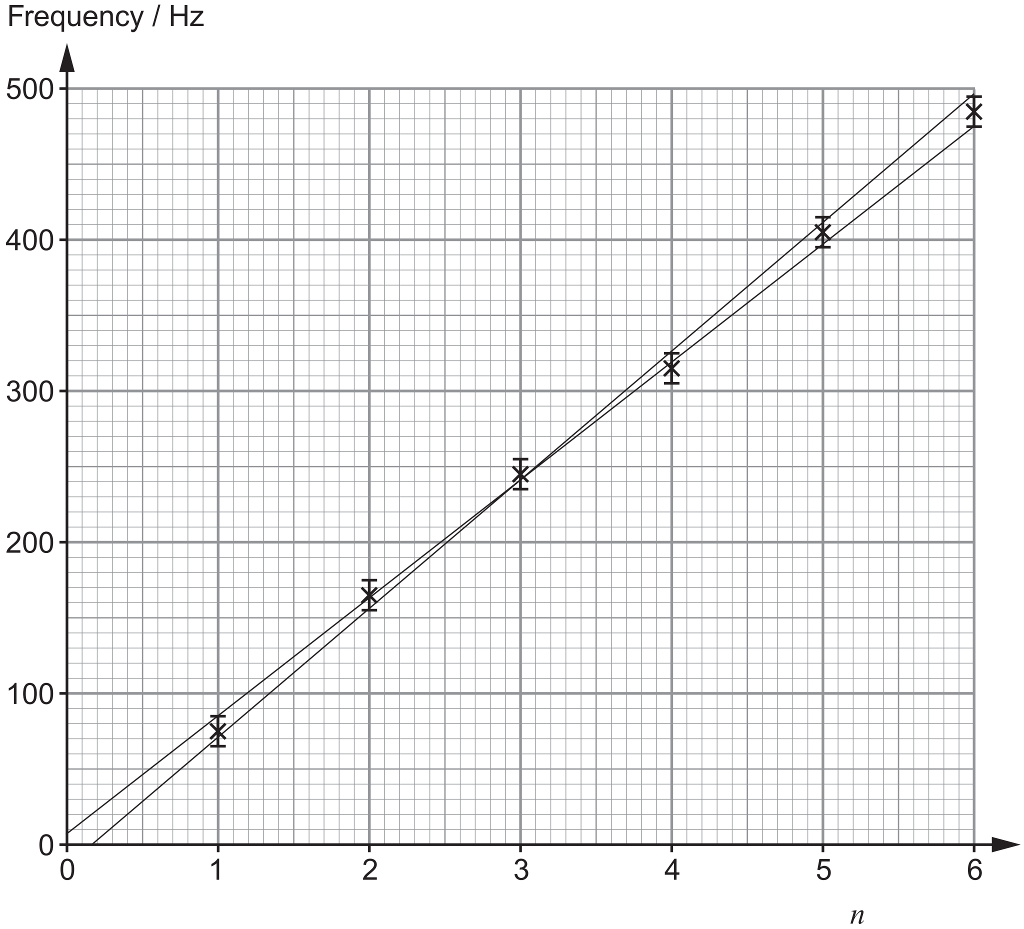
(c) The data obtained are plotted on the grid below.



Explain to what extent the graph agrees with the equation: [3]

$$f = \frac{v}{2L}n$$

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Turn over.

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(d) The experiment is repeated with the tube filled with nitrogen dioxide (NO_2), a gas that is 1.5 times denser than air. The speed of sound in a gas is inversely proportional to the square root of the density, ρ:

$$v \propto \frac{1}{\sqrt{\rho}}$$

Explain what effect this will have on the gradient of the graph. [3]

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(e) A car company is fined £15 billion for excessive NO_2 emissions of its diesel engines. However, there is little or no reliable evidence that NO_2 produces any detrimental health effects at the concentration levels present in the atmosphere. Discuss whether or not the car company or pedestrians have been treated unfairly. [3]

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6. *(a)* A radioactive isotope of thorium decays to a stable lead nucleus ($^{208}_{82}\mathrm{Pb}$) via 6 alpha decays and 4 beta decays. Complete the equation below. [2]

$$^{\cdots\cdots}_{\cdots\cdots}\mathrm{Th} \longrightarrow {}^{208}_{82}\mathrm{Pb} + 6\ {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{He} + 4\ {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{e}^-$$

(b) The half-life of the thorium nucleus is 14.1×10^9 years. Calculate the activity of 5.0×10^{-3} kg of the radioactive thorium (the mass of the thorium atom is approximately 3.9×10^{-25} kg). [5]

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(c) In order to model nuclear decay, 6000 dice are thrown multiple times. All the dice are thrown initially and all dice landing with the number 1 facing upwards are removed. The remaining dice are then thrown and the procedure repeated. The number of remaining dice is recorded each time as well as the number of dice removed (the decay count). The results are recorded in a table and plotted.

Throw number	Number of remaining dice	Number of dice removed
0	6000	
1	4991	1009
2	4200	791
3	3504	696
4	2871	633
5	2391	480
6	2046	345
7	1707	339
8	1435	272
9	1224	211
10	1018	206
11	858	160
12	725	133

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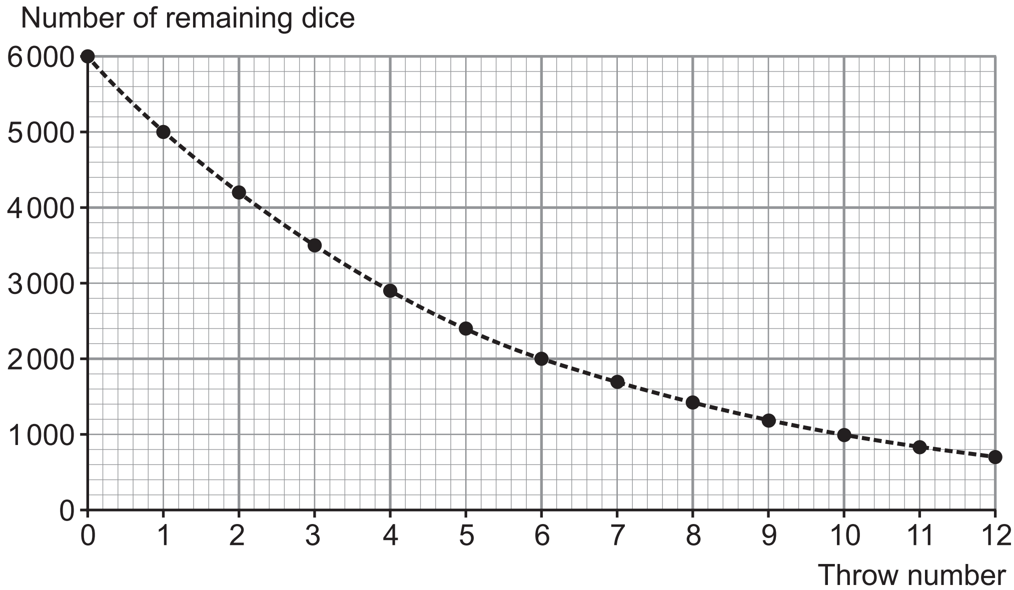
Graph 1



(i) Use the data to deduce whether or not the number of remaining dice decreases exponentially. [4]

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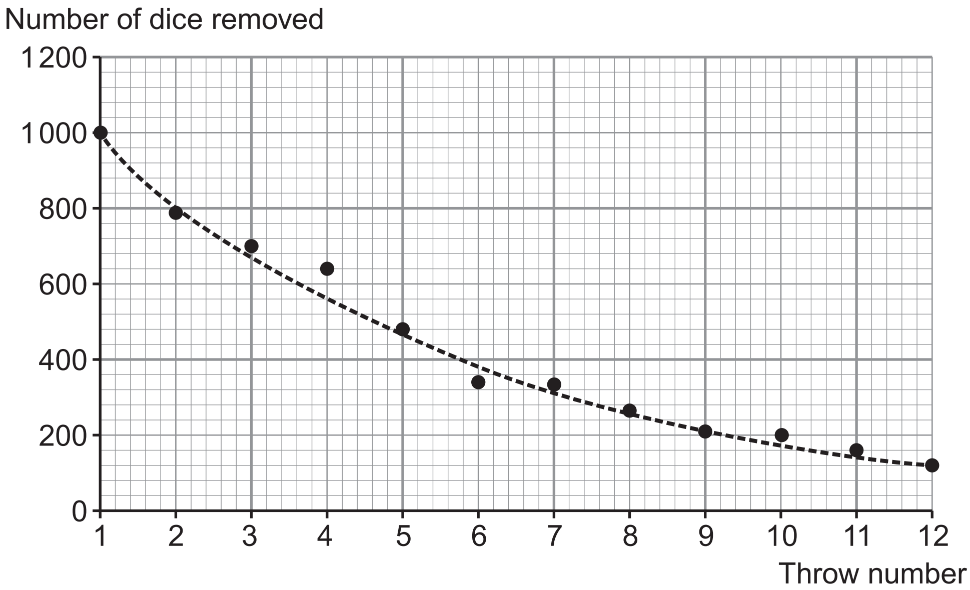
A graph is also plotted of the number of dice removed against the throw number (Graph 2).

Graph 2



(ii) Suggest why there is more scatter in Graph 2 than Graph 1. [2]

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7. *(a)* Explain briefly what is meant by conservation of mass-energy. [2]

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(b) It is suggested that a collision between two protons, each of kinetic energy 3 GeV produces the following interaction:

$$\mathrm{p} + \mathrm{p} \longrightarrow 5\mathrm{p} + 3\overline{\mathrm{p}} + \mathrm{n} + \overline{\mathrm{n}} + 2\pi^{+} + 2\pi^{-} + 4\nu_{\mathrm{e}}$$

Determine which, if any, of the conservation laws are violated (the rest mass-energy of a proton or a neutron ≈ 1 GeV). [4]

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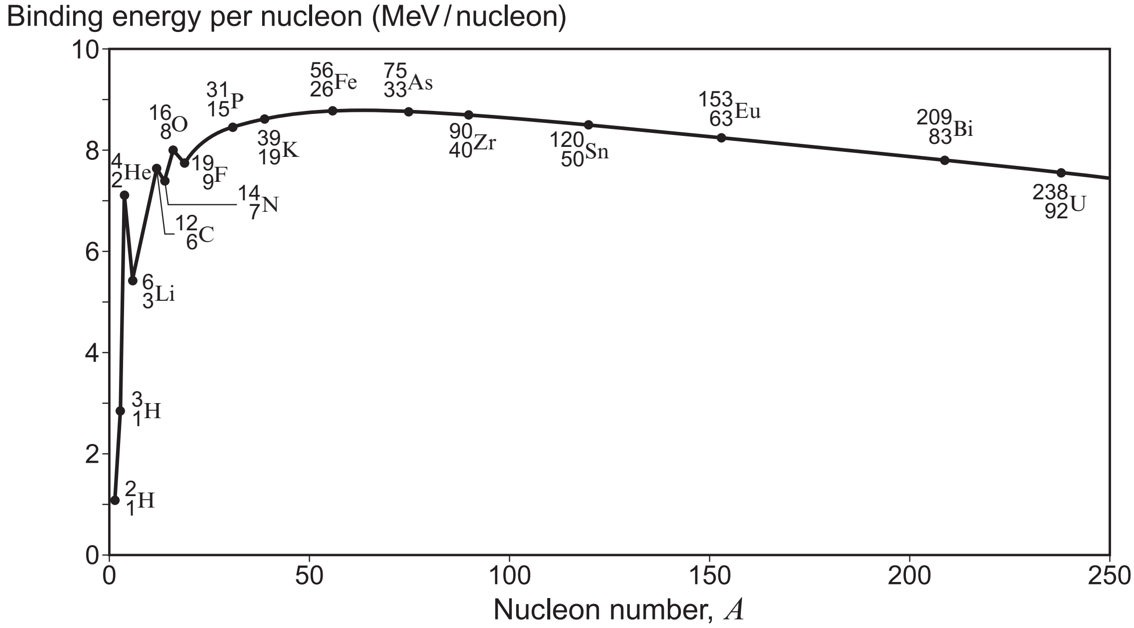
8. Explain the concept of binding energy per nucleon and how it relates to nuclear fission and fusion. [6 QER]



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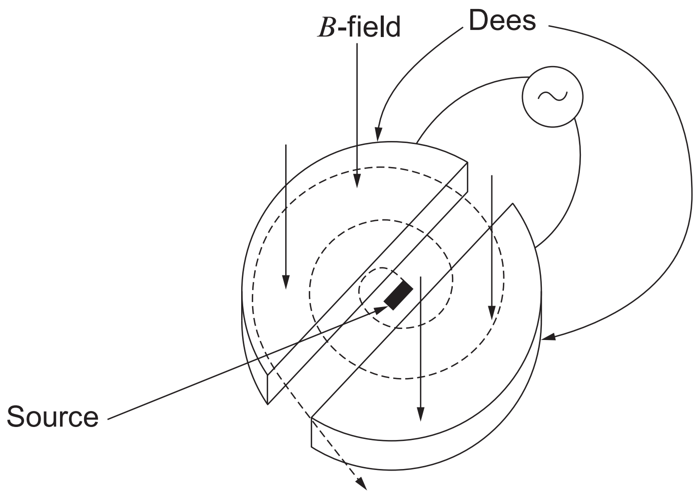
9. A cyclotron is shown and it is used to accelerate helium-4 nuclei from rest. After completing 12 cycles of the cyclotron, a helium nucleus has a kinetic energy of 4.32 MeV.



(a) Calculate the final velocity of a helium-4 nucleus (the mass of a helium-4 nucleus is 4u). [3]

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(b) Calculate the pd between the dees. [3]

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(c) The uniform magnetic flux density is 0.47 T. Calculate the frequency of the alternating pd applied to the dees. [3]

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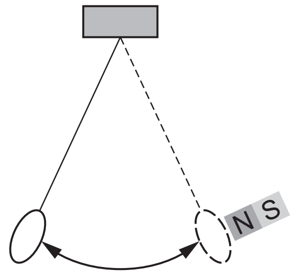
10. A silver ring on a light rod swings as a pendulum with damped simple harmonic motion. The damping is caused by a stationary magnet as shown in the diagram.



(a) Explain why the motion of the pendulum is damped. [4]

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(b) Explain what, if anything, would happen to the motion of the pendulum if the bar magnet were reversed. [2]

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(c) The resistivity of silver is $1.59 \times 10^{-8}\,\Omega\,\text{m}$, the radius of the silver ring is 2.5 cm and the cross-sectional area of the silver wire of the ring is $2.4 \times 10^{-5}\,\text{m}^2$. Show clearly that the resistance of the silver ring is approximately $0.1 \times 10^{-3}\,\Omega$. [2]

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(d) The maximum current induced in the silver ring is 5.5 A. Calculate the maximum rate at which the magnetic flux density inside the ring changes. [3]

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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.

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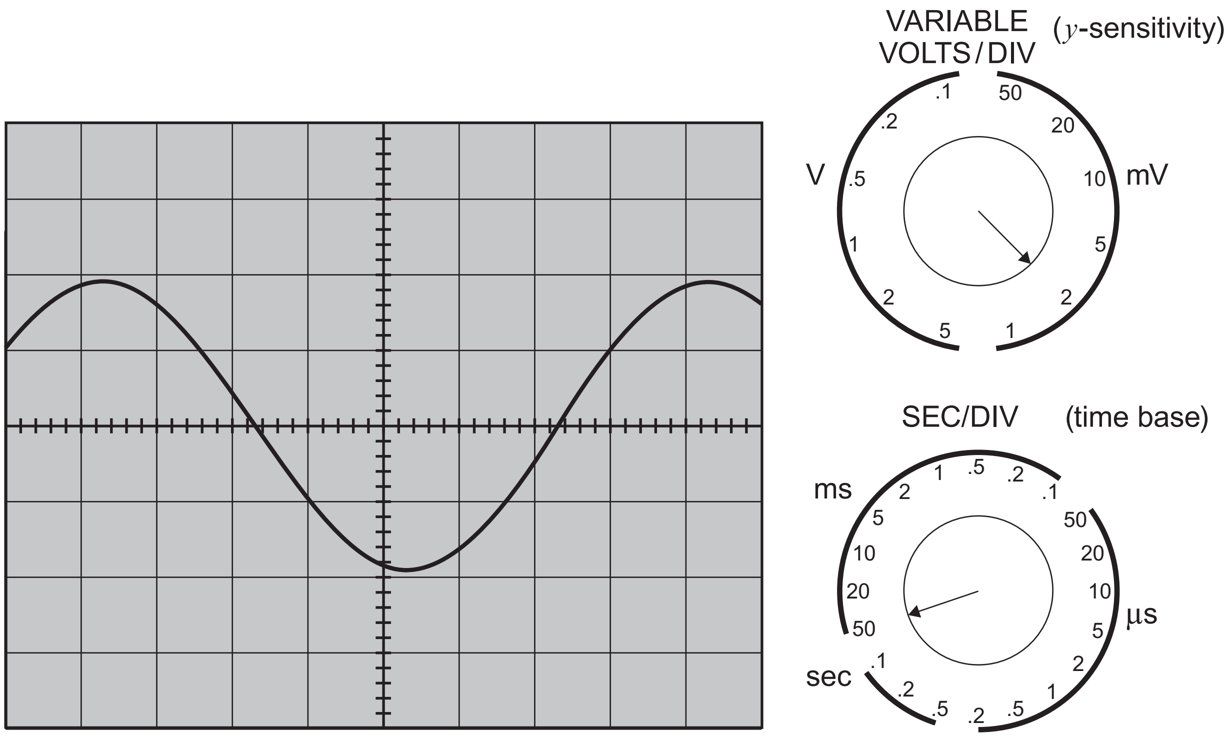
Option A – Alternating Currents

11. 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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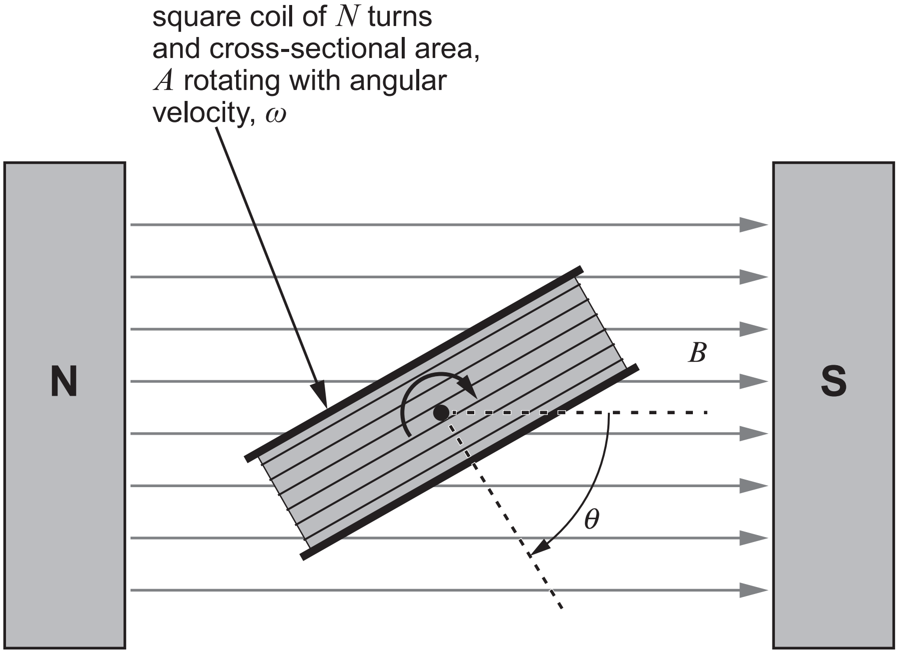
(b) A coil rotates in a magnetic field as shown.



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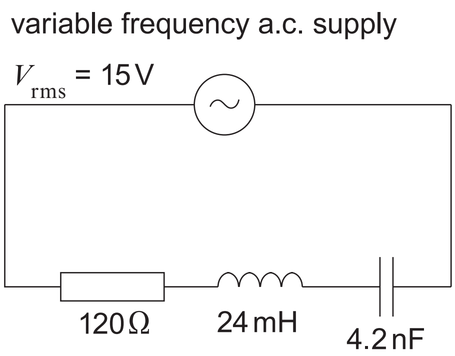
(c) (i) In the following LCR circuit, explain why the rms resonance current is 125 mA. [2]



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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:

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

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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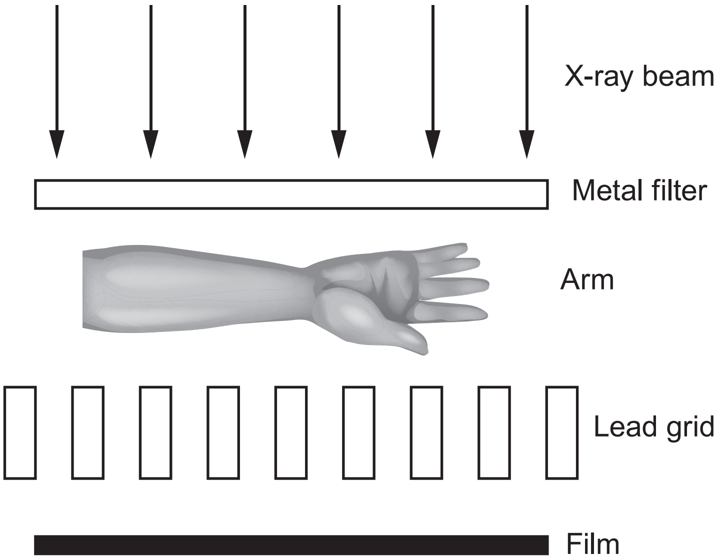
Option B – Medical Physics

12. *(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]

(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]

Examiner only

(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 1 500 $m\,s^{-1}$. Calculate the speed of blood flow. [2]

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Option C – The Physics of Sports

13. 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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Examiner only

(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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Examiner only

(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

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

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(ii) The Greenland ice sheet is estimated to have an area of $1.5 \times 10^6\,km^2$ 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 = $1\,000\,kg\,m^{-3}$;
Surface area of ocean on Earth = $3.6 \times 10^8\,km^2$]

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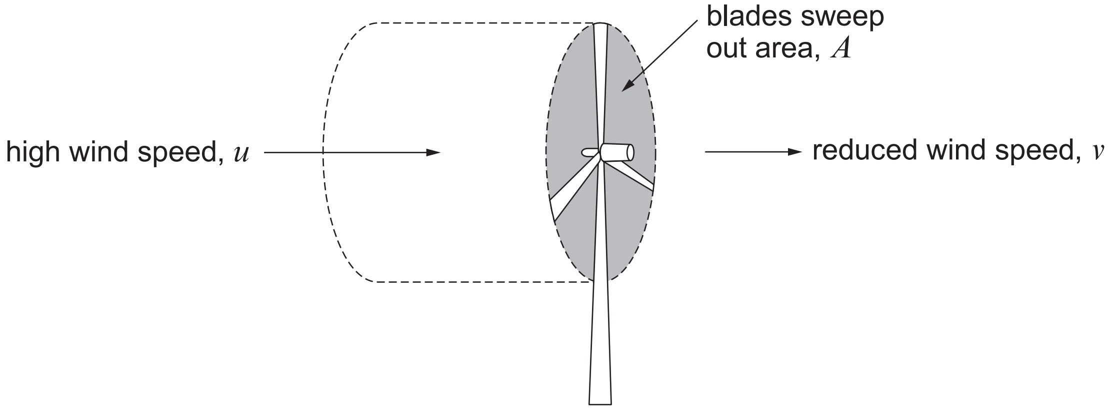
(b) Wind turbines convert as much as possible of the kinetic energy of the air that moves through the area swept out by the blades into electrical energy.



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(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 $8.0\,\mathrm{m\,s^{-1}}$ arrives at the blades, which is reduced to $5.0\,\mathrm{m\,s^{-1}}$ after passing through the blades. Calculate the maximum possible efficiency of this wind turbine. [Density of air = $1.2\,\mathrm{kg\,m^{-3}}$]. [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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Examiner only

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

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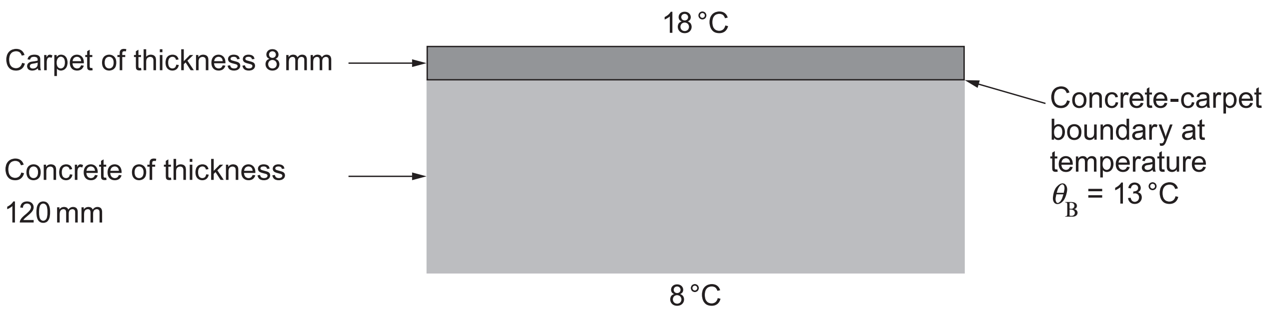
(ii) One room in a house has a floor made of concrete of thickness 120 mm covered by a carpet of thickness 8 mm. The temperature at the upper surface of the carpet is 18 °C and that of the lower surface of the concrete is 8 °C. Show that, under these conditions, the temperature (θ_B), at the concrete-carpet boundary is 13 °C.
[Assume $K_{concrete} = 0.9\,\mathrm{W\,m^{-1}\,K^{-1}}$ and $K_{carpet} = 0.06\,\mathrm{W\,m^{-1}\,K^{-1}}$]. [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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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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