Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

A420U30-1

S25-A420U30-1

TUESDAY, 17 JUNE 2025 – MORNING

PHYSICS – A level component 3

Light, Nuclei and Options

2 hours 15 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**21**	
	2.	**10**	
	3.	**10**	
	4.	**11**	
	5.	**17**	
	6.	**9**	
	7.	**8**	
	8.	**14**	
Section B	**Option**	**20**	
	Total	**120**	

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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.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) 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 question **7**(a).

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SECTION A

Answer **all** questions.

1. (a) (i) Define the terms 'transverse wave' **and** 'longitudinal wave'. Give an example of each type of wave. [3]

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(ii) Explain why only one of these two types of waves can be polarised **and** the other type cannot be polarised. [3]

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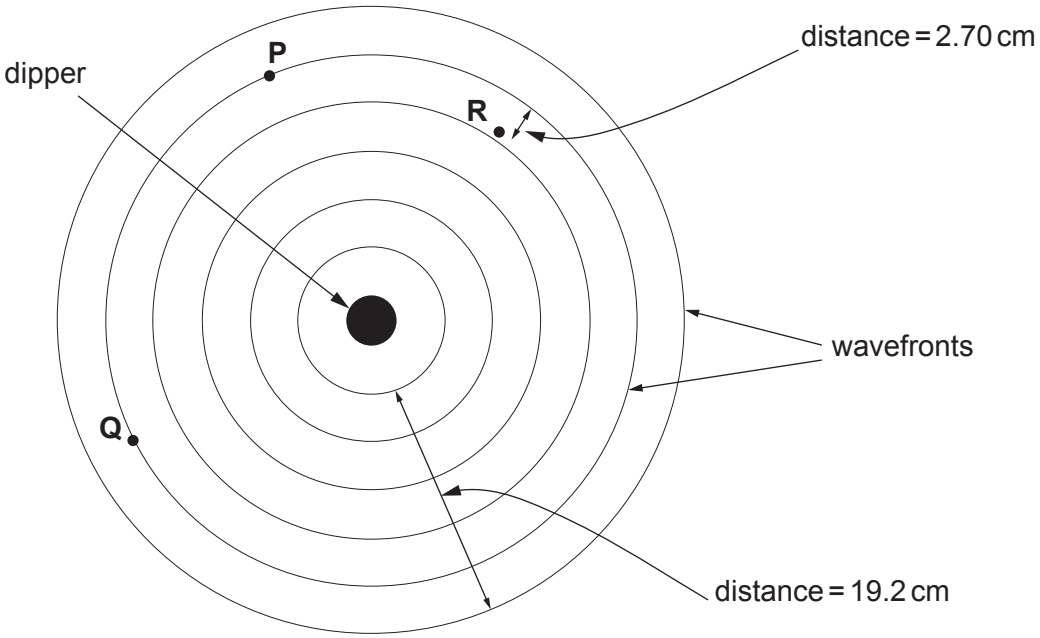
(b) Circular wavefronts are produced in a ripple tank by a dipper oscillating up and down with simple harmonic motion. The wavefronts on the diagram represent peaks on the water.



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(i) Use the information in the diagram to calculate the wavelength of the waves. [2]

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(ii) **Draw an arrow on the diagram** at **Q** to indicate the direction of wave travel. [1]

(iii) State the phase of point **P** relative to point **Q**. [1]

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(iv) Calculate the phase of point **R** relative to point **Q**, giving your answer in radians.[3]

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(c) The displacement, y, (in m) of oscillation of the wave at time, t, (in s) at a radius of 8.0 cm is given by:

$$y = 2.2 \times 10^{-3} \cos 10.7t$$

(i) Calculate the speed of propagation of the wave. [3]

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(ii) Calculate the maximum speed of oscillation of the water surface at this radius. [2]

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(iii) Floella reads in a textbook that the **energy carried by a wave is proportional to its amplitude squared**. She states that, because the waves are spreading in circles, conservation of energy means that the amplitude at double this distance, (i.e. at 16.0 cm) will be approximately 1.6 mm.
Determine whether Floella is correct. [3]

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2. A beam of white light is shone normally on a diffraction grating. The n = 0 order beam produces a bright white dot on a screen but the n = 1 order beam produces a spectrum of light.

(a) (i) Explain why the n = 0 order beam produces a bright white dot. [2]

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(ii) Explain why the n = 1 order beam produces a spectrum. [2]

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(b) (i) Yellow light of wavelength 575 nm is seen in the n = 2 spectrum at an angle of 16.1°. Calculate the number of lines per mm in the diffraction grating. [3]

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(ii) Yousef states that it is impossible for any visible wavelength in the n = 2 spectrum to overlap with the n = 1 visible spectrum. Determine whether Yousef is correct. [3]

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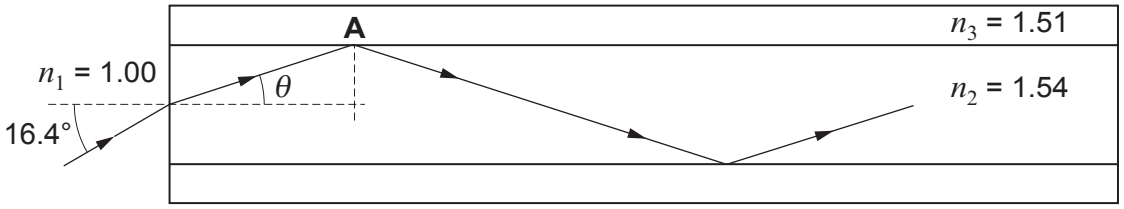
3. Light is incident on an optical fibre as shown.



(a) Calculate the angle labelled θ in the diagram. [2]

(b) Explain why total internal reflection occurs at **A**.
Use calculations to support your answer. [4]

(c) The length of the optical fibre is 16.0 km. Calculate the time lag between pulses travelling along the central axis of the optical fibre and pulses travelling via the zig-zag path shown in the diagram. [4]

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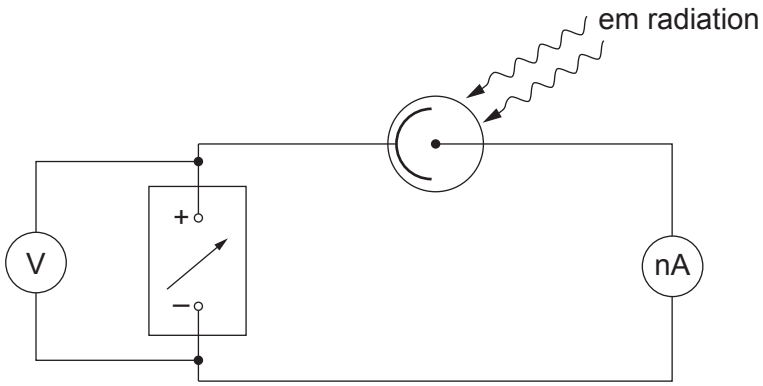
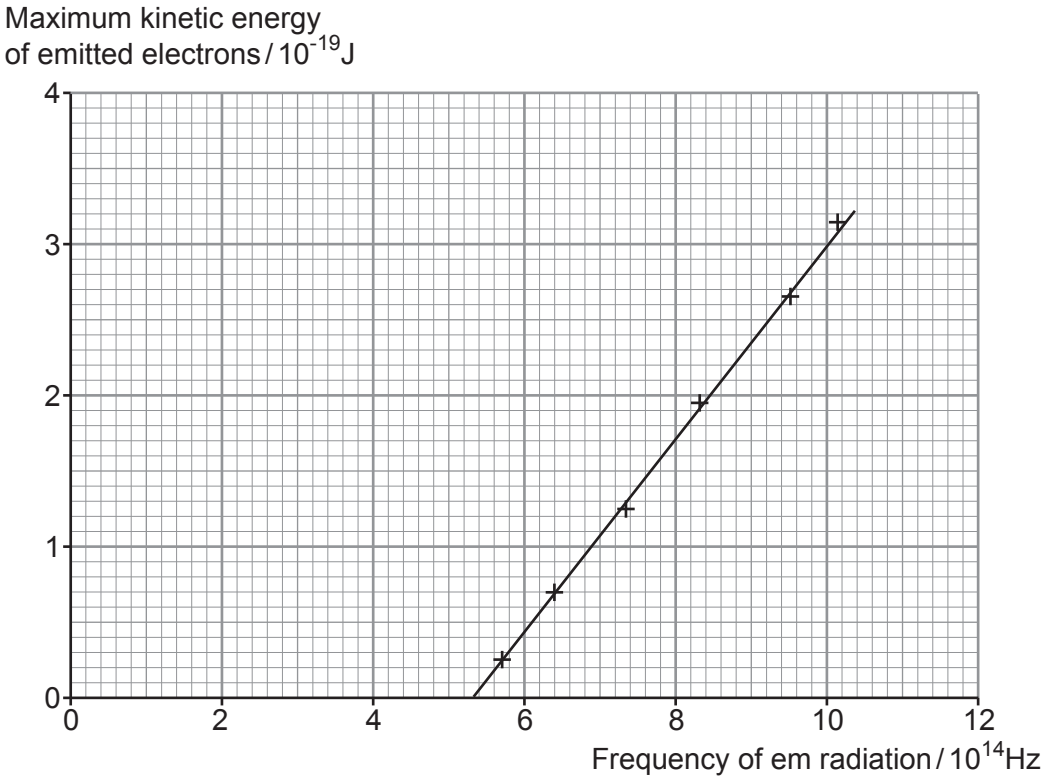
4. The following apparatus is used to investigate the photoelectric effect.



The following results are obtained:



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(a) Explain briefly how these results were obtained. [4]

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(b) Use the graph to calculate a value for the Planck constant. [3]

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(c) Determine which of the following metals could have been used for the surface of the photocell. [4]

Metal	Work function, ϕ/eV
Cs	2.14
K	2.30
Na	2.75
Ca	3.20
Mo	4.17
Pb	4.25

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5. (a) The activity of a radioactive sample is measured in becquerel.

(i) Explain what is meant by activity. [1]

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(ii) Define the becquerel (Bq). [1]

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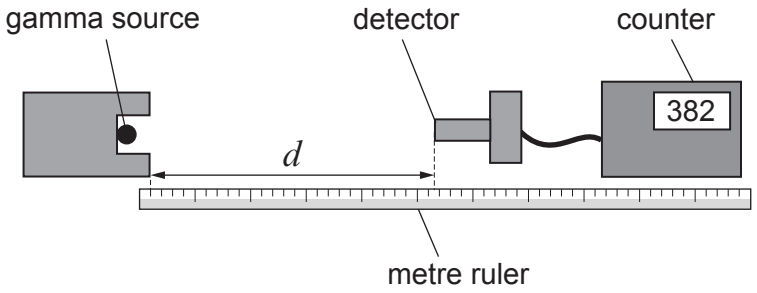
(b) Anong carries out an experiment to confirm the inverse square law for gamma radiation. She uses the following set-up.



She varies the distance, d, between the gamma source and the detector and records the number of counts detected over a time of 60 s.

Her results are shown in the table.

Distance, d / cm	Number of counts in 60 s	Corrected count, C, in 60 s	$\frac{1}{\sqrt{C}}$
5.0	11 115	11 087	9.5×10^{-3}
10.0	2505	2477	20.1×10^{-3}
15.0	1086	1058	30.8×10^{-3}
20.0	.....	576	41.7×10^{-3}
25.0	382	354	53.1×10^{-3}
30.0	274	246	.....
35.0	212	184	73.6×10^{-3}

(i) Use the table to calculate the background radiation in counts in 60 s. [1]

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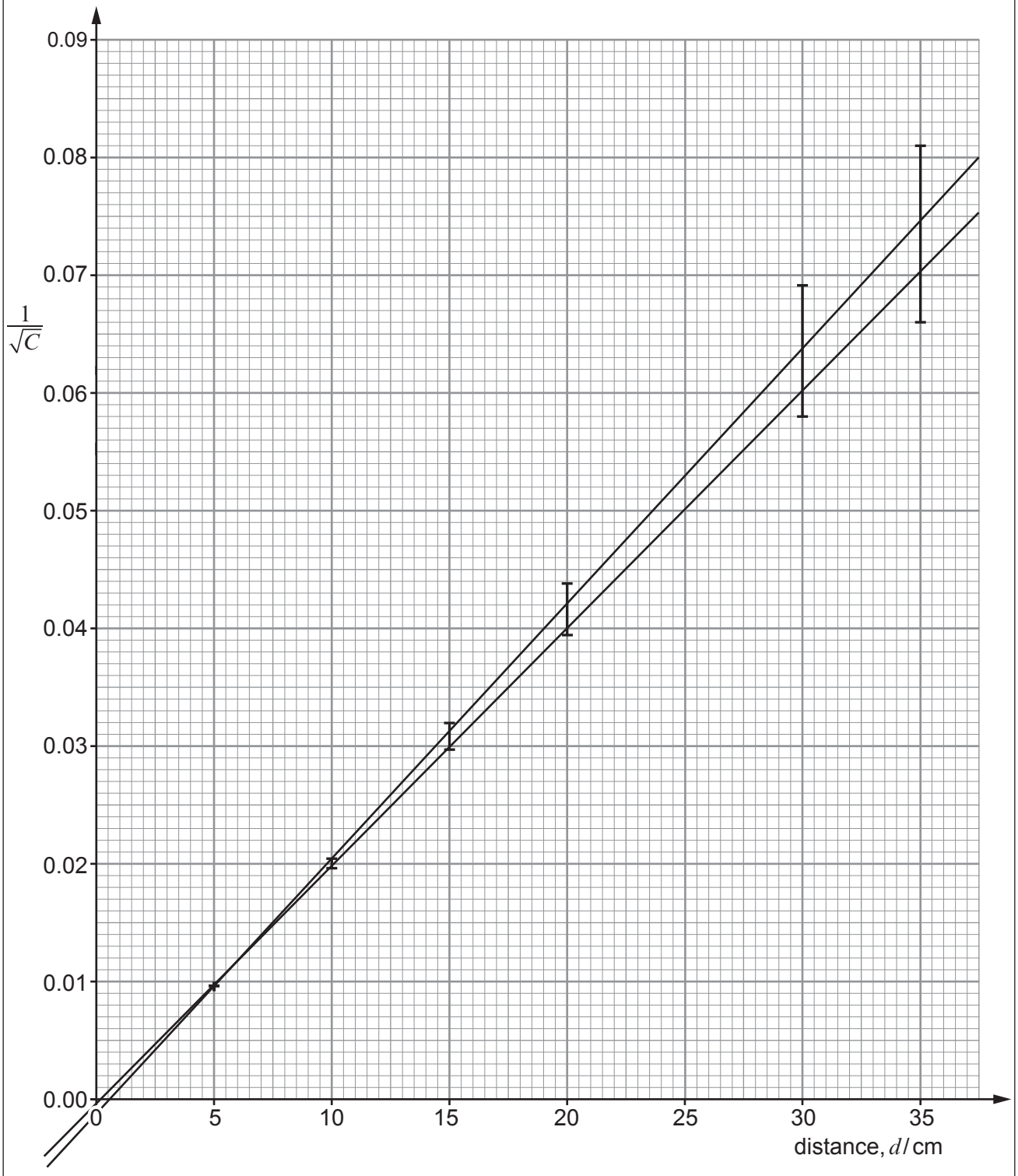
(ii) **Complete** the table. [2]

Examiner only

(iii) **Complete** the graph by plotting the point and error bar for the distance of 25 cm. Note that the uncertainties in distance, d, are too small to plot and that the uncertainty in $\frac{1}{\sqrt{C}}$ for the 25 cm point is ± 0.0035. The lines of maximum and minimum gradient have been drawn for you. [2]



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(c) The relationship between C and d should be of the form:

$$C = \frac{k}{d^2}$$

where k is a constant.

(i) Explain why this relationship is expected to give a straight line through the origin for the graph in part (b)(iii). [2]

(ii) Explain to what extent the graph in part (b)(iii) agrees with this theory. Where the graph disagrees with the theory, suggest a reason for this. [4]

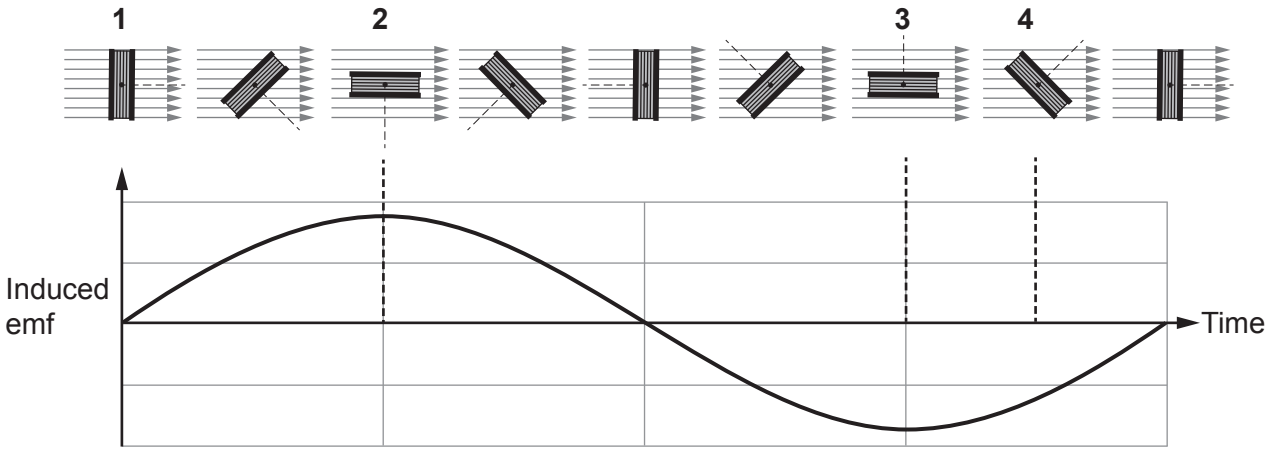
(d) Anong calculates the area of the window of the detector as 1.27 cm^2. She concludes that the activity of the gamma source must be around 18 000 Bq. Explaining your reasoning carefully, determine whether she is correct. [4]

17

Examiner only

6. (a) State the **two** laws of electromagnetic induction: the laws of Faraday and Lenz. [3]

(b) A square coil rotates clockwise at a constant rate in a uniform magnetic field. The position of the rotating coil and the induced emf are shown below.



(i) Use the laws of electromagnetic induction to explain the induced emf in each of positions **1, 2, 3** and **4**. [4]

(ii) Use the laws of electromagnetic induction to explain how the graph would change if the rotation rate were doubled. [2]

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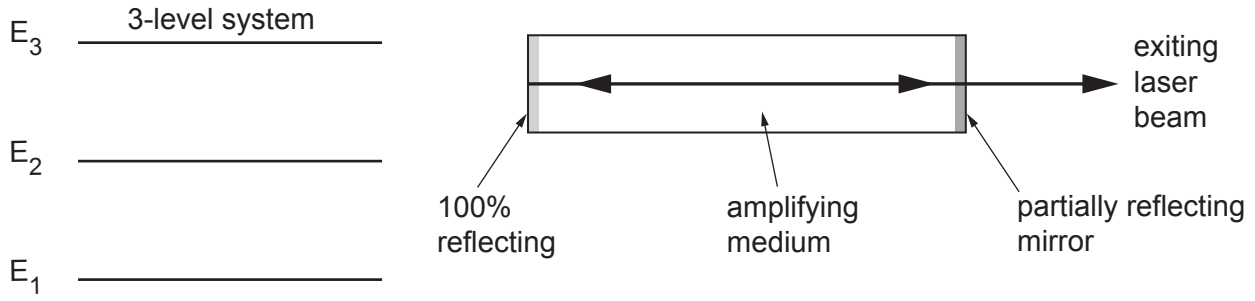
Examiner only

7. (a) Explain how a 3-level laser system works. Include an explanation of the role of the amplifying medium. [6 QER]



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(b) Semiconductor lasers are used in many applications because they are far more efficient than gas lasers. State **one** use and another advantage of semiconductor lasers. [2]

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Examiner only

8. A delta minus, Δ^-, particle is a 1st generation baryon and decays into a neutron, n, and an unidentified 1st generation particle, X.

$$\Delta^- \rightarrow \mathrm{n} + \mathrm{X}$$

(a) Identify particle X, using conservation of charge, baryon number and lepton number. Show your reasoning clearly. [4]

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(b) Show that the quark make-up of the Δ^- is ddd. [1]

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(c) Determine whether up and down quark numbers are conserved in this decay. [2]

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Examiner only

(d) The mass of the Δ^- particle is 1.323 u, the mass of a neutron is 1.009 u, and the mass of particle X is 0.150 u. From Einstein's Theory of Relativity, nothing can travel faster than light. Determine whether Einstein's Theory of Relativity should be considered when calculating the speed of particle X after this decay.
You may assume that particle X has far greater kinetic energy than the neutron. [5]

(e) On 10 August 2023, it was announced in a seminar that the magnetic moment of muons does not fit the standard model of particles. The magnetic moment of a muon should be exactly 2 but it has been measured as 2.002331841.
Explain briefly how the scientific community should proceed. [2]

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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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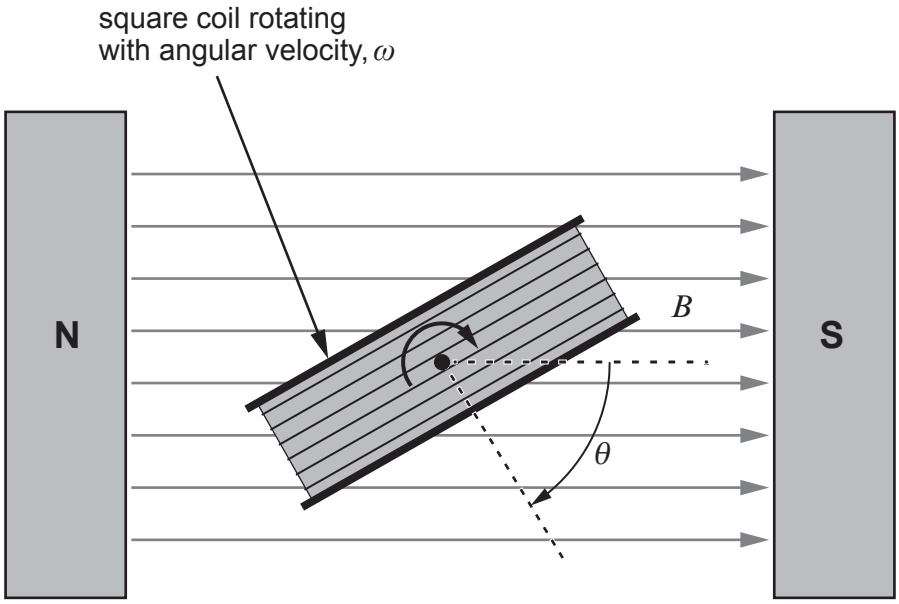
Option A **– Alternating Currents**

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



(i) State **two** changes that could be made to the design of the coil in order to increase the peak emf (for the same angular velocity and magnetic field). [2]

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(ii) Write an equation for the peak emf induced in a rotating coil. [1]

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(iii) The sinusoidal emf produced by the coil rotating in the uniform magnetic field has **rms** value of 4.2 V and a frequency of 50.0 Hz.
The coil is connected to the input of an oscilloscope. The oscilloscope settings are shown opposite.
Sketch the expected trace on the oscilloscope screen. [5]
Space for calculations.

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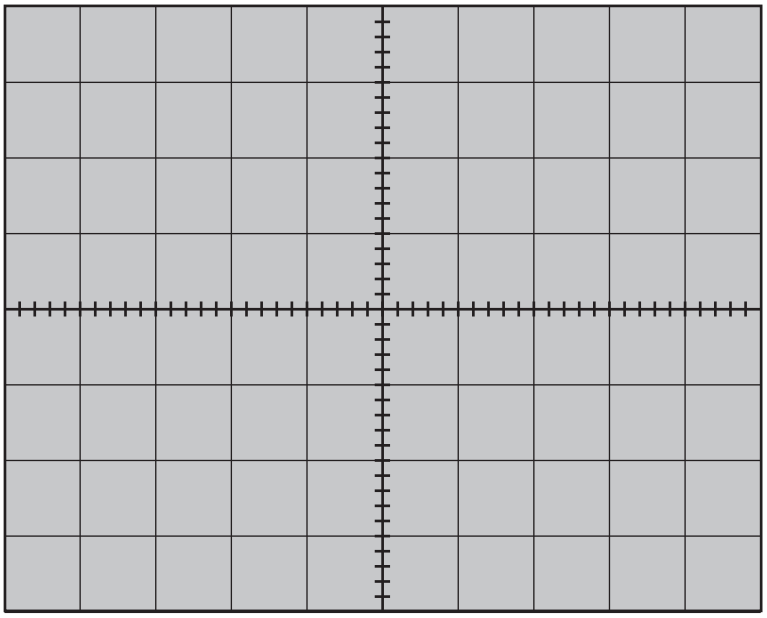
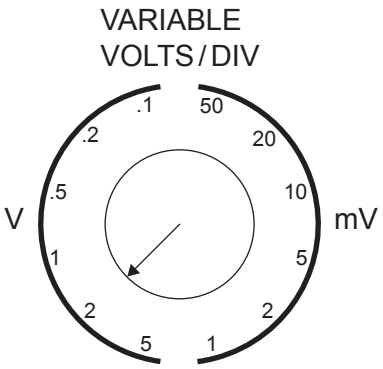
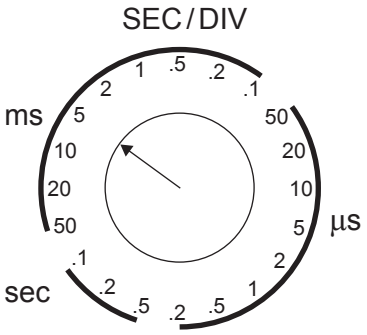
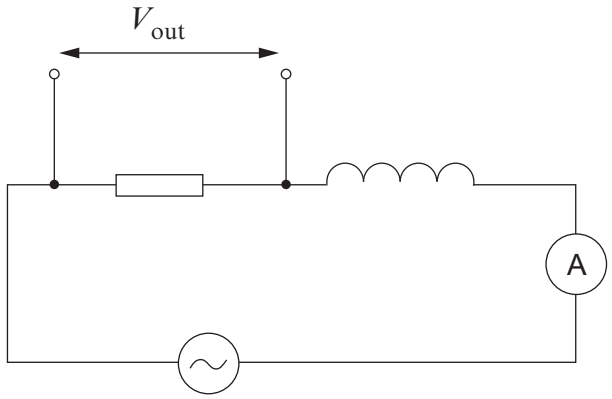






(b) Sophie builds the following circuit. She claims that the rms voltage output, V_{out}, will be smaller at higher frequencies. Evaluate Sophie's claim and state whether you agree with her. [3]



V_{in} = V(rms)
(variable frequency)

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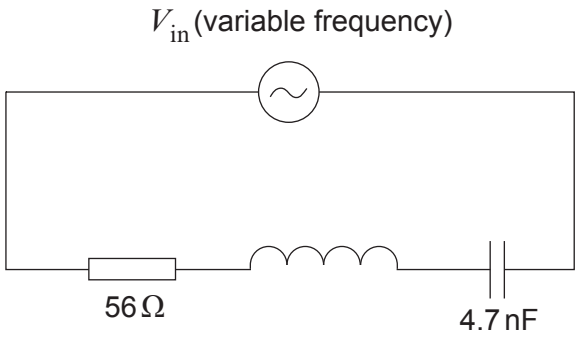
(c) Dan builds the following circuit to determine the inductance of an inductor.



(i) State the mean power dissipated in the inductor. [1]

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(ii) When the frequency of V_{in} is equal to 15 kHz, the rms current is at its maximum. Determine the value of the inductance of the inductor. [4]

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(iii) Calculate the Q factor of the circuit. [3]

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(iv) State the effect of increasing the Q factor on the resonance curve. [1]

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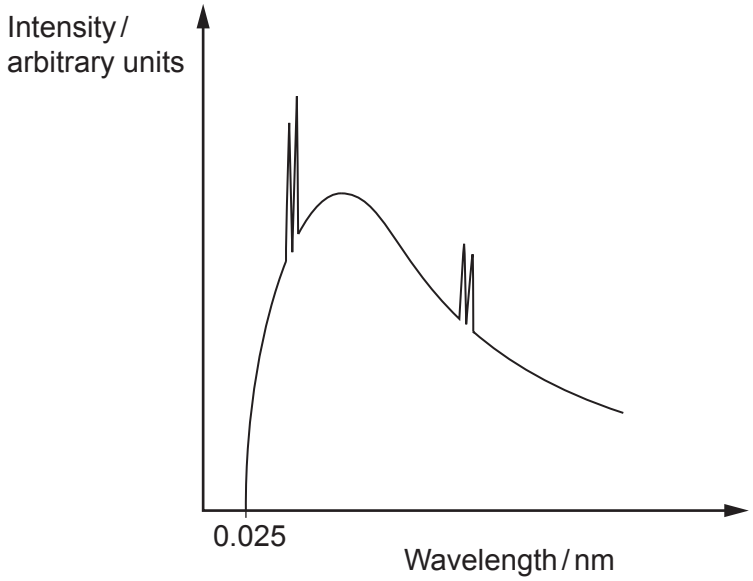
Examiner only

Option B **– Medical Physics**

10. (a) The diagram below is a typical X-ray emission spectrum for an X-ray tube with a tungsten target.



(i) I. Determine the working voltage of the X-ray tube. [2]

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II. **Draw on the diagram** above the emission spectrum for an X–ray tube operating at a lower working voltage **and** using a different metal target. [2]

(ii) I. When a beam of X-rays passes through bone, the X-rays are absorbed and the beam becomes attenuated. The thickness of bone needed to reduce the original intensity by 50% is known as 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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II. A beam of X-rays is used to detect a fracture in a piece of bone. If the half-value thickness for these X-rays is 1.4 cm, calculate the thickness of bone that reduces the incident intensity to 65% of its original value. [3]

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(b) Doctors are concerned about a head injury sustained by a rugby player and in particular whether there is an internal bleed in the brain. They have the choice of the following imaging techniques.

X-ray **MRI** **ultrasound B-scan** **radioactive tracers** **CT scan**

Evaluate the suitability of **all five** types of imaging techniques for diagnosing the player. [5]

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(c) (i) Explain how a gamma camera detects the gamma rays given off by a technetium-99m source. [3]

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(ii) During a positron emission tomography (PET) scan, a positron of kinetic energy 2.2 MeV collides with a stationary electron and both are annihilated in the collision. As a consequence, two identical gamma rays are produced. Calculate the energy of **each** of the gamma rays produced **in joules**. [3]

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Option C **– The Physics of Sports**

11. A golfer hits a golf ball which is initially at rest. The ball has a mass of 0.046 kg and a diameter of 43 mm. The moment of inertia of a sphere = $\frac{2}{5}mr^2$.

(a) (i) Explain how the way the golfer stands to hit the ball gives her stability. [2]

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(ii) Explain what is meant by the statement that "the coefficient of restitution between the club and the ball is 0.830". [2]

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(iii) After being hit, the ball spins with an angular velocity of 280 rad s^{-1}. Calculate the torque exerted on the golf ball by the club if it is in contact with the ball for a time of 0.26 ms. [3]

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(iv) Discuss whether the principle of conservation of angular momentum can be applied to the system of the ball and the club when the golfer hits the ball. [2]

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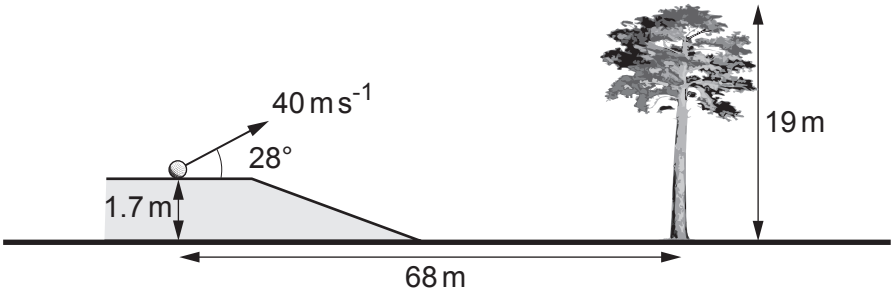
(b) The golfer takes another shot intending the ball to pass over the top of a tree during its flight. Ignore the effects of air resistance for this part.



(i) The golfer hits the ball at an angle of 28° with an initial speed of 40 m s^{-1}. Explain why the ball does not hit the tree. [4]

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Examiner only

(ii) The ball spins with an angular velocity of 195 rad s^{-1} when travelling through the air. Evaluate whether the rotational kinetic energy can be considered negligible compared to the linear kinetic energy of the ball when the ball is at its maximum height. [3]

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(c) Modern golf equipment leads to golf balls flying further. This means that many old golf courses are now too short. It has been proposed that the design of golf balls be changed to reduce their flight distance. Use physics to explain some changes that can be made to golf ball design to decrease their flight distance. [4]

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Examiner only

Option D **– Energy and the Environment**

12. (a) Solar energy is a renewable energy source. State what is meant by 'renewable energy source'. [1]

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(b) The main energy production mechanism in the Sun is the fusion of protons. The following equation summarises the proton-proton chain, the set of reactions that take place in the Sun.

$$4\,{}^{1}_{1}\mathrm{H} \quad + \quad 2\,{}^{0}_{-1}\mathrm{e} \quad \longrightarrow \quad {}^{4}_{2}\mathrm{He} \quad + \quad 2\nu_{\mathrm{e}}$$

Mass of ${}^{1}_{1}\mathrm{H}$ = 1.007 28 u Mass of ν_{e} = 0.000 00 u

Mass of ${}^{4}_{2}\mathrm{He}$ = 4.001 51 u Mass of ${}^{0}_{-1}\mathrm{e}$ = 0.000 55 u

(i) Calculate the percentage mass loss in this fusion reaction. [2]

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(ii) Define the solar constant **and** calculate its value.

Power emitted by the Sun = 3.83×10^{26} W

Distance from Sun to Earth = 1.50×10^{8} km [3]

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Examiner only

(iii) The UK government has set a target to increase the mean electrical power generated by solar photovoltaic cells to 70 GW by the year 2035. If the mean annual intensity of the solar radiation reaching the Earth's surface is 342 W m^{-2} and the cells are 20% efficient, calculate the area of the cells required. [2]

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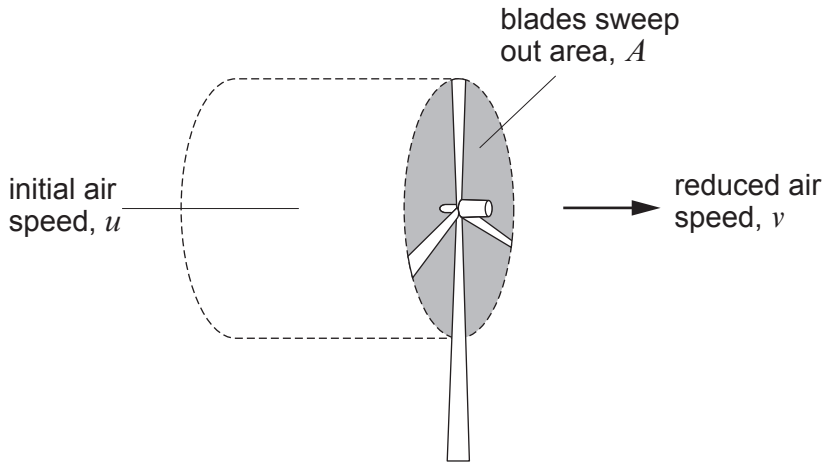
(c) A wind turbine has blades which sweep out an area of radius 70 m at right angles to the wind direction.
The energy transferred to the turbine from the air per second as it passes through the blades is 2.0 MJ.
After passing through the turbine, the reduced air speed, v, is 4.1 m s^{-1}.



(i) Determine the initial speed of the air, u, before it passes through the blades.
Density of air = 1.2 kg m^{-3} [3]

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(ii) An energy company claims that it can build an underwater tidal turbine that can generate the same amount of electrical power as a wind turbine, but with blades that are $\frac{1}{100}$ of the length. Evaluate this claim, stating any assumptions made. [3]

Density of sea water = $1025\,kg\,m^{-3}$

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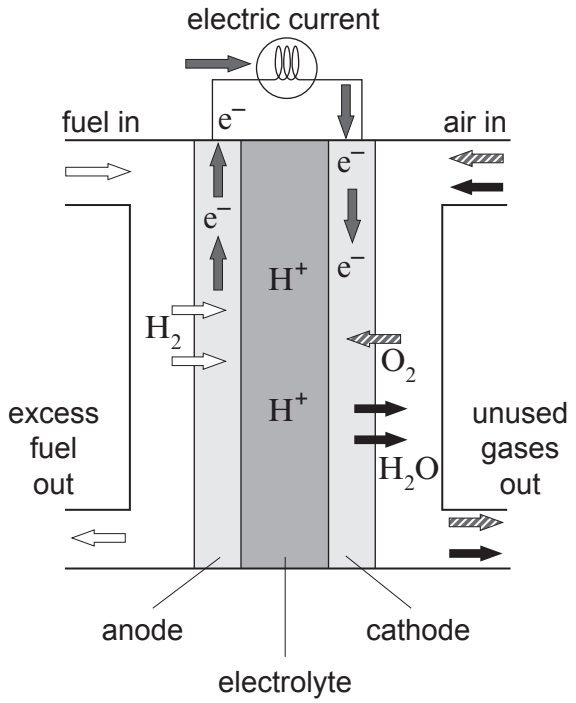
(d) Hydrogen fuel cell technology is considered by some to be the future of transport and some car manufacturers already produce hydrogen fuel cell electric cars. The basic layout for a hydrogen fuel cell is shown in the diagram below.



(i) State the main energy transfer in a fuel cell. [1]

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(ii) Explain the purpose of the electrolyte. [1]

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(iii) State the waste product. [1]

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(iv) Some car manufacturers claim that the use of hydrogen fuel cells will not contribute any CO_2 to the atmosphere. Evaluate this claim. [3]

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END OF PAPER

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Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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