Surname	Centre Number	Candidate Number
First name(s)		2

GCE A LEVEL

S25-1420U40-1

1420U40-1

MONDAY, 9 JUNE 2025 – MORNING

PHYSICS – A2 unit 4
Fields and Options

2 hours

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	**12**	
	2.	**22**	
	3.	**6**	
	4.	**14**	
	5.	**7**	
	6.	**19**	
Section B	**Option**	**20**	
	Total	**100**	

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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**: 80 marks. Answer **all** questions. You are advised to spend about 1 hour 35 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 **3**.

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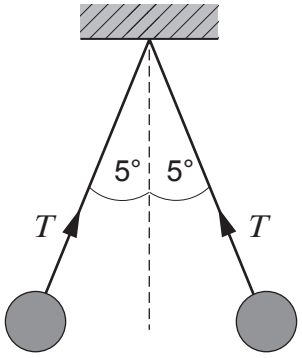
SECTION A

Answer **all** questions.

1. Two identical insulated spheres are suspended by light threads and store an equal amount of charge.



(a) The vertical forces are balanced. Explain why the tension, T, in each thread is almost exactly equal to the weight of the spheres. [1]

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(b) Each sphere has a mass of 2.7 g. Show that the repulsive force between the two spheres is approximately 2 mN. [3]

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Examiner only

(c) Each sphere carries a charge of 125 nC. Calculate the distance between the centres of the spheres assuming that the spheres behave as point charges. [3]

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(d) (i) Define electric potential. [2]

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(ii) Calculate the electric potential at a point which is 7.0 cm from the centre of one sphere and 18.0 cm from the centre of the other sphere. Assume that both spheres can be considered as 125 nC point charges. [3]

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Examiner only

2. (a) The gravitational field strength at a point near a star is 230 N kg^{-1}. Explain the meaning of this statement. [2]

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(b) Draw 4 gravitational field lines **and** 2 equipotentials for the star. [3]

(c) At a distance from the star of 1.20×10^9 m, the gravitational field strength is 230 N kg^{-1}. Show that the mass of the star is approximately 5×10^{30} kg. [3]

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Examiner only

(d) A large planet of mass 7.2×10^{27} kg is a distance of 4.0×10^{10} m from the star. Calculate the position of the centre of mass of the system from the centre of the star. [2]

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(e) (i) Calculate the orbital period of the system. [2]

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(ii) Hence, show that the maximum red shift in the star's hydrogen 656 nm line is approximately 0.3 pm. [3]

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(f) Solomon incorrectly states that this red shift, combined with the Hubble constant, H_0, means that this star is approximately 60×10^{18} m from the solar system. Explain how Solomon has arrived at his conclusion **and** why the conclusion is incorrect. [4]

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(g) Explain, using Hubble's law, why the age of the Universe is approximately $\frac{1}{H_0}$. [3]

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Examiner only

3. State Kepler's three laws of planetary motion. Explain their significance for planets in circular and elliptical orbits. [6 QER]

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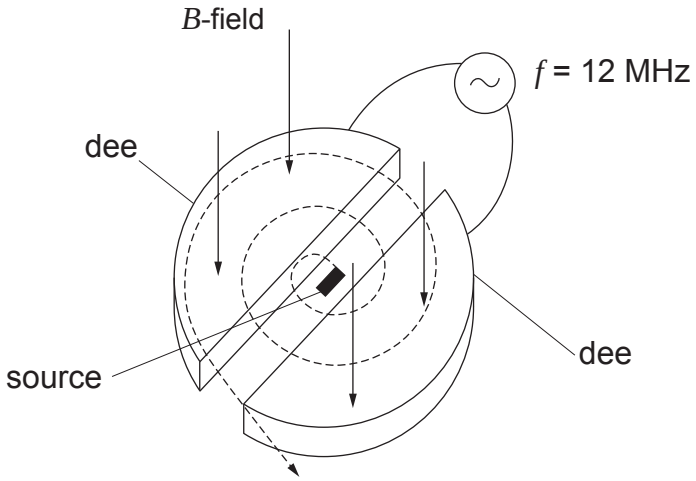
Examiner only

4. A cyclotron consists of two dees in a strong magnetic field. Protons are accelerated between the dees by a varying pd of frequency 12 MHz.



(a) (i) Explain why a valid equation for the motion of the proton while inside a dee is:

$$m\omega^2 r = Bq\omega r$$

where m is the mass of the proton, ω is the angular velocity of the proton, r is the radius of motion of the proton, q is the proton charge and B is the magnetic flux density. [3]

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(ii) Hence or otherwise, calculate the magnetic flux density. [3]

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Examiner only

(b) Each time the proton crosses between the dees, it is accelerated by a pd of 1.2 kV. Calculate the increase in kinetic energy **in J** of the proton each time it crosses between the dees. [2]

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(c) When the proton motion reaches a radius of 0.45 m it exits the cyclotron.

(i) Show that this happens when the proton has a kinetic energy of approximately 1 pJ. [2]

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(ii) The proton is accelerated twice per cycle. Determine whether the proton spends more than a millisecond in the cyclotron if it is accelerated from rest. [2]

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(d) 'All money spent on particle accelerators is wasted!' Discuss this statement briefly. [2]

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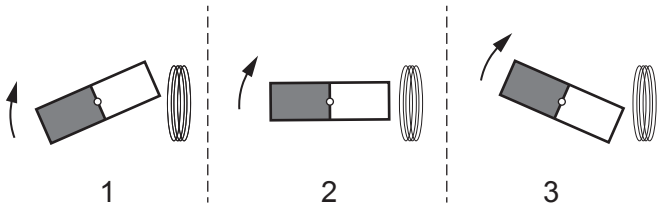
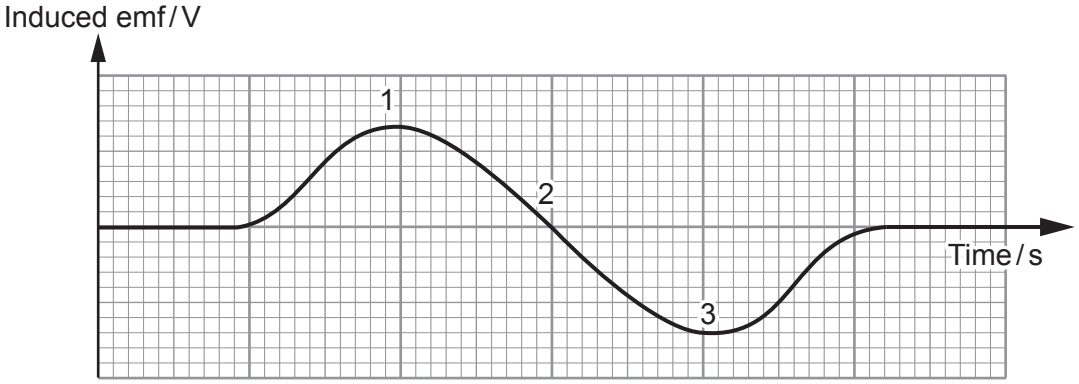
Examiner only

5. A rotating magnet and a stationary coil are used as a generator to produce an emf.





(a) By considering the motion of the magnet between positions 1 and 3, explain why the induced emf in the coil varies as shown in the graph. [4]

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(b) The flux linkages of the coil in positions 1 and 2 are 0.84 Wb turn and 1.47 Wb turn respectively. The magnet takes 13.2 ms to move from position 1 to position 2. Calculate the mean emf induced in the coil between positions 1 and 2. [3]

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Examiner only

6. (a) A capacitor is made using two circular metal plates of radius 28.5 cm, separated by 0.115 mm of air.

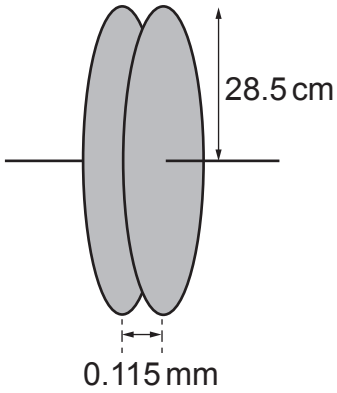

Diagram not to scale

(i) Jezebel states that this capacitor has a capacitance of less than 1 nF. Determine whether Jezebel is correct. [3]

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(ii) Calculate the pd applied to the plates when the electric field between the plates is 77 kN C^{-1}. [2]

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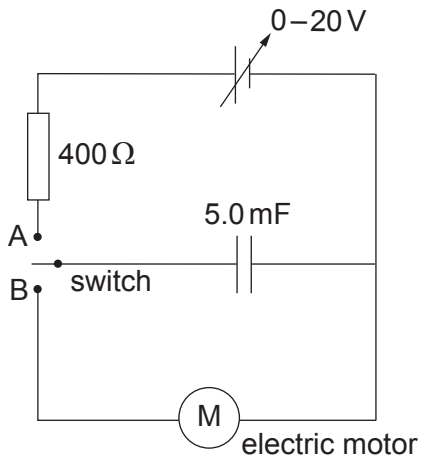
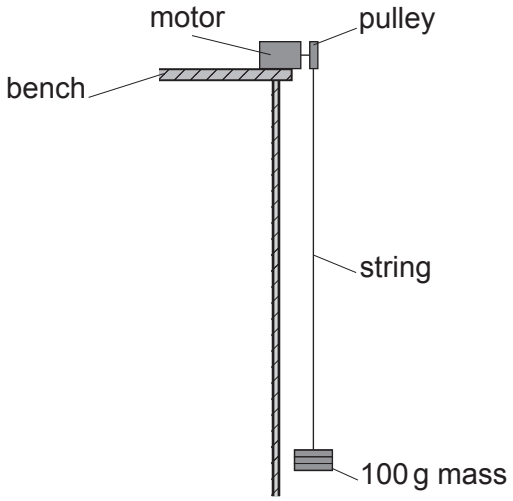
(b) The following circuit is used to investigate the energy stored in a 5.0 mF capacitor. The switch is moved to position A to charge the capacitor. The capacitor is then discharged through an electric motor when the switch is in position B.

The electric motor turns a pulley that lifts a 100 g mass. The pd, V, applied to the capacitor is varied and the maximum height reached by the 100 g mass recorded each time. The maximum height is measured twice for each applied pd and the mean and uncertainty calculated.



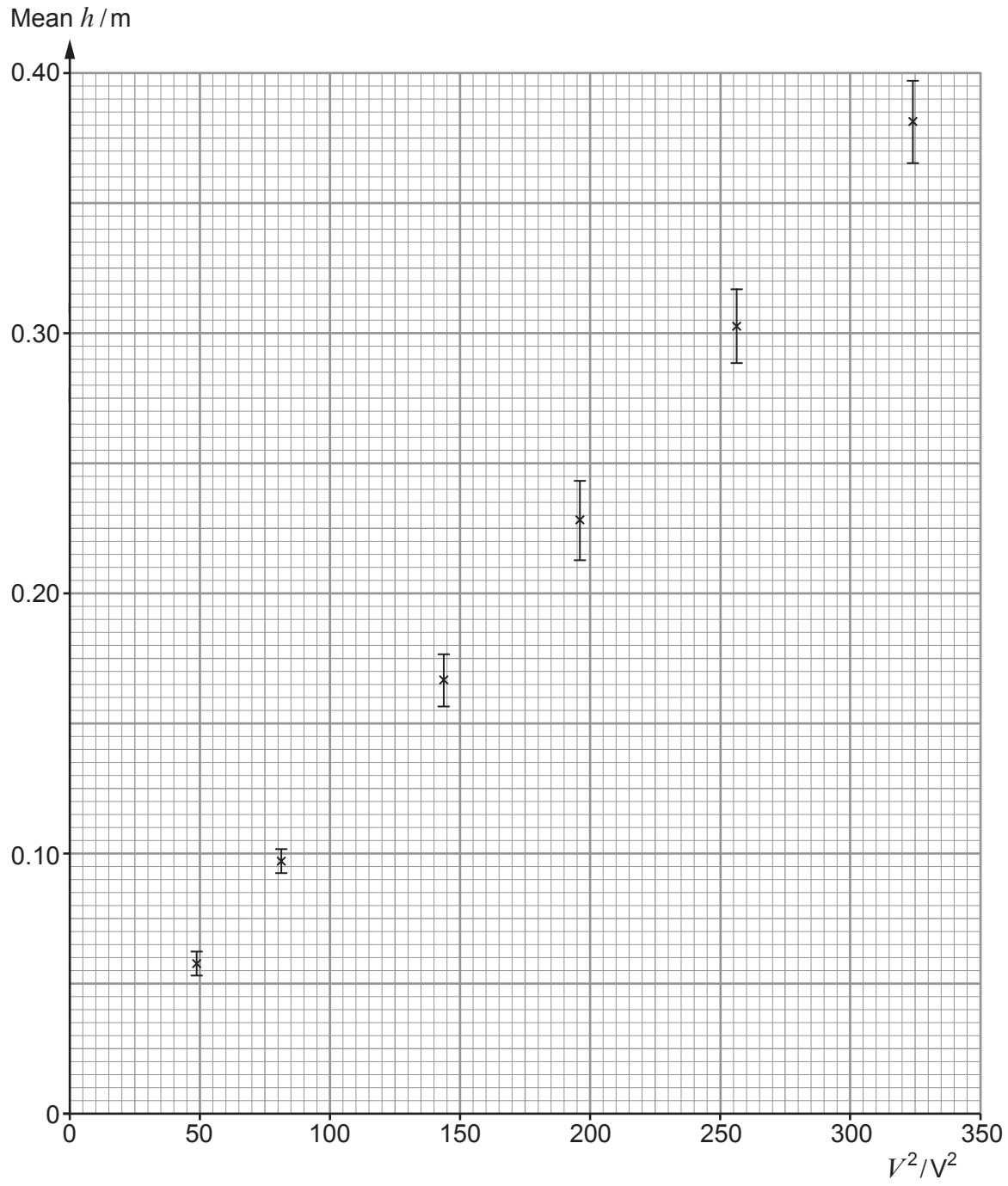


The data points are shown and plotted on the next page.

V / V	V^2 / V^2	Max height, h / m		
		Trial 1	Trial 2	Mean
7.00	49.0	0.063	0.053	0.058 ± 0.005
9.00	81.0	0.093	0.101	0.097 ± 0.004
12.00	144.0	0.176	0.157	0.167 ± 0.010
14.00	196.0	0.242	0.213	0.228 ± 0.015
16.00	256.0	0.317	0.289	0.303 ± 0.014
18.00	324.0	0.397	0.365	0.381 ± 0.016

Examiner only

(i) **Draw** the lines of minimum and maximum gradient through the points. [2]



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(ii) Calculate the mean gradient and its **percentage** uncertainty. [5]

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(iii) Applying the principle of conservation of energy gives:

$$mgh = \eta \times \frac{1}{2}CV^2$$

where η is the overall efficiency of the electric motor.

This means that the gradient of the graph is given by:

$$\text{gradient} = \frac{\eta \times C}{2mg}$$

The 100 g mass has an uncertainty of 2% and the 5.0 mF capacitor has an uncertainty of 10%. Determine whether it is possible for the efficiency, η, to be as high as 50%. [5]

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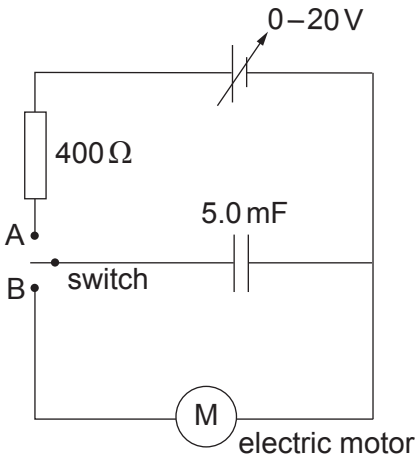
Examiner only

(iv) The experimenter used a charging time of 10 s, that is, the switch was placed in position A for 10 s. Determine whether 10 s is a suitable charging time to ensure that the capacitor was fully charged. [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.

Examiner only

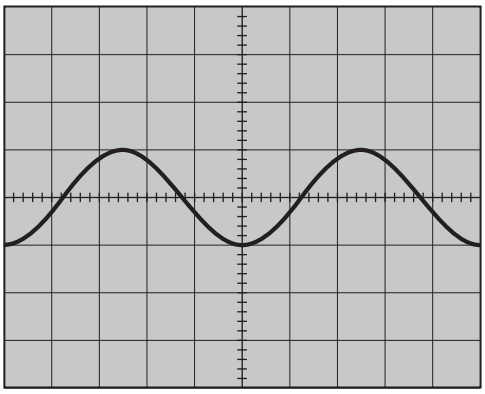
Option A – **Alternating Currents**

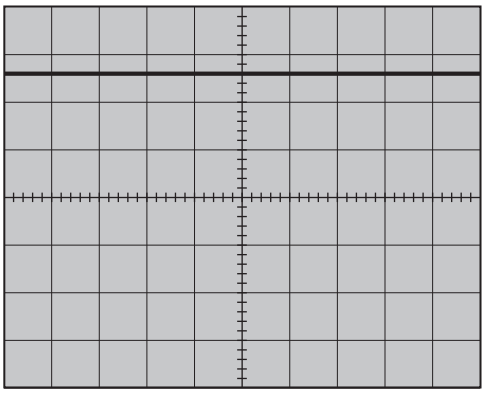
7. (a) Explain how the following oscilloscope traces can be used to measure the:

(i) peak a.c. voltage;

(ii) period of an a.c. supply;

(iii) d.c. voltage. [5]

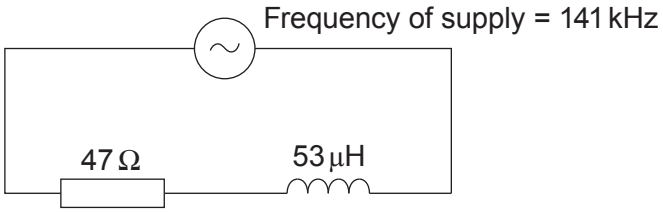




You may add to the diagrams to assist your answer.

Examiner only

(b) (i) Calculate the reactance of the inductor in the following LR circuit. [2]



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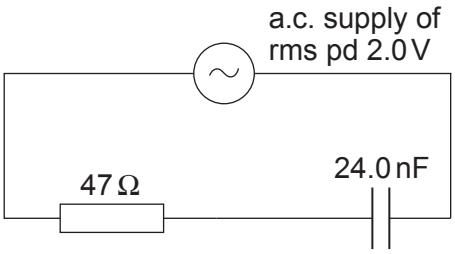
(ii) In the following RC circuit, calculate the frequency at which the reactance of the capacitor is equal to the resistance of the resistor. [2]



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(iii) Calculate the rms pd across the resistor when this occurs. [2]

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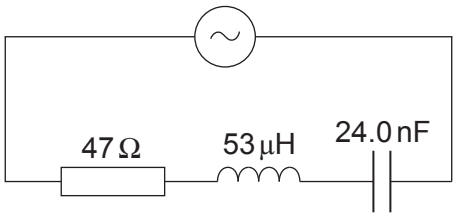
Examiner only

(iv) Hence, or otherwise, determine the resonance frequency **and** Q factor of the following LCR circuit. [2]



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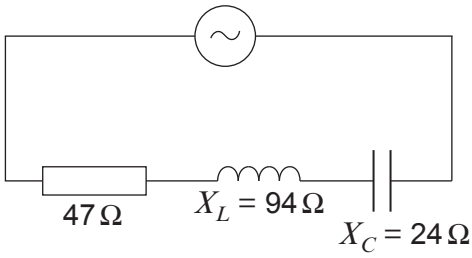
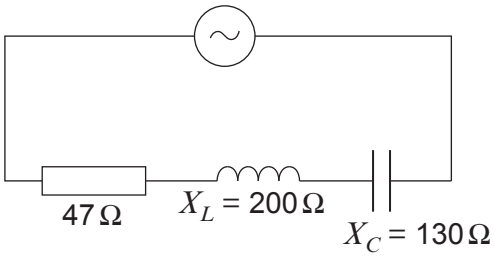
(v) Explain why the following two circuits have the same total impedance. [2]





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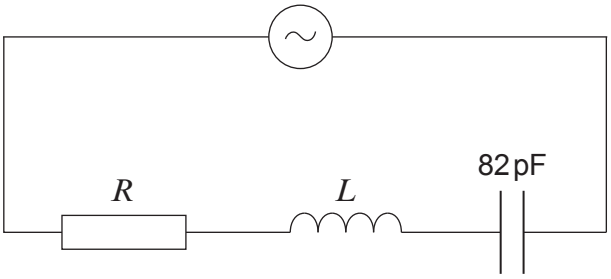
(c) Steve requires the following circuit to have a resonance frequency of 2.70 MHz and a Q factor of 90. Determine the correct values of L and R. [5]



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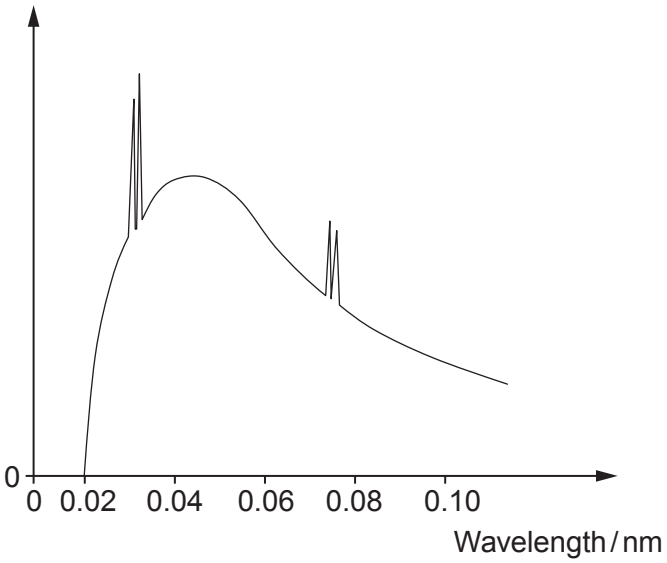
Option B – **Medical Physics**

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



(i) Calculate the operating voltage of the tube. [2]

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(ii) **Draw on the above graph** a spectrum for the same X-ray tube with a **higher** operating voltage. [1]

(iii) State the major difference you would see in the spectrum if the X-ray machine used a different target material. [1]

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(iv) Describe how a CT scan differs from a conventional X-ray and justify why CT scans are **not** offered for the regular checking of patients. [2]

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Examiner only

(b) When using ultrasound to carry out B-scans, a single transducer can be used to send and receive pulses of ultrasound.

(i) Describe how the ultrasound pulses are produced. [2]

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(ii) The following table gives the density and velocity of ultrasound in air and skin.

Medium	Density / $kg\,m^{-3}$	Velocity of ultrasound / $m\,s^{-1}$	Acoustic impedance / $kg\,m^{-2}\,s^{-1}$
air	1.3	340	
skin	1 075.0	1 590	

Use the data in the table to explain why a coupling gel is used when imaging the body with ultrasound. Calculations are needed to justify your answer. [5]

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Examiner only

(c) (i) State and explain **two** essential characteristics of a radioactive isotope used as a tracer in medicine. [2]

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(ii) The total volume of a patient's blood was estimated using an injection of radioactive sodium in solution. The half-life of the radioactive sodium solution was 15 hours and its initial activity was 190 Bq. After 30 hours the activity of 0.5 ml of the patient's blood was found to be 0.0043 Bq. Calculate the total volume of the patient's blood. [3]

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(d) In a magnetic resonance imaging scanner (MRI), large magnetic fields of the order of 1.5 T are used along with short pulses of radio waves. Calculate a suitable wavelength for these radio waves. [2]

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Examiner only

Option C – **The Physics of Sports**

9. (a) (i) Explain what is meant by the moment of inertia of a golf clubhead used as shown in the following image. [3]

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(ii) "The coefficient of restitution between a golf ball and clubhead is 0.83." Explain what is meant by this statement. [2]

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Examiner only

(b) Assume the effects of air resistance can be ignored for this part.
In a competition, a golfer has to hit the ball a minimum distance of 114 m to clear a lake. The golfer is not sure which club to use and decides to use a club called a No.8 iron. Use the data provided in the following table to evaluate whether the club will be suitable to take the shot and clear the lake. [5]

Angle of shot to horizontal	Initial speed of the ball / m s^{-1}
37°	35

(c) The golfer applies backspin to the ball.

(i) Calculate the **total** kinetic energy of the ball at its maximum height if it spins at a rate of 120 revolutions per second and the same club as in part (b) is used to take the shot. Assume that the ball has a mass of 46 g and radius of 21 mm.
(Moment of inertia of a solid sphere $I = \frac{2}{5}mr^2$) [3]

Examiner only

(ii) In reality the effects of air resistance cannot be neglected. Explain how the flight of the ball changes when considering the influence of the air. You may include a diagram to show the extra forces acting on the ball. [4]

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(iii) If the speed of the golf ball relative to the air increases by 42%, determine the factor by which the drag force, F_D, changes. [3]

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Option D – **Energy and the Environment**

10. (a) A wind turbine has a rotor diameter of 128 m and is subject to a mean wind speed of 7.5 m s^{-1}. The transfer of kinetic energy of the incoming air into electrical energy is 46% efficient. State **two** factors that limit this efficiency **and** determine the number of wind turbines required to produce a power output of 50 MW. Density of air = 1.2 kg m^{-3}. [5]

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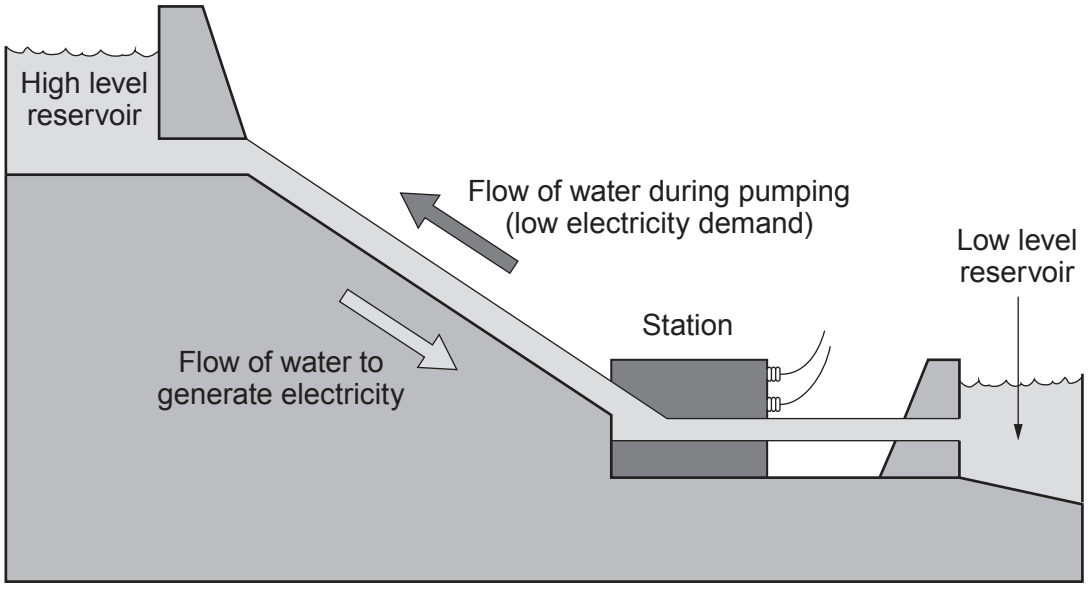
(b) A hydroelectric power station generates an electrical energy output of 90 MWh in 4.5 hours.



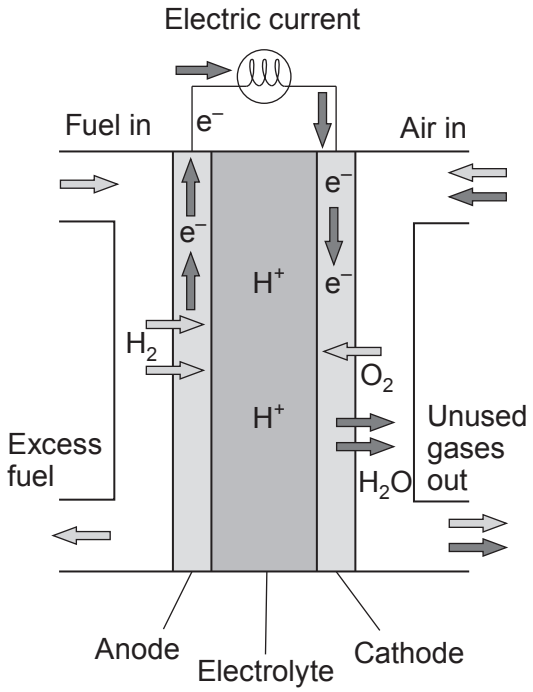
Examiner only

During this time, water passes from a high level reservoir to a low level reservoir with a mean flow rate of $6.8\,m^3\,s^{-1}$. The height difference between the high level reservoir and the low level reservoir is 370 m. Calculate the generating efficiency of the turbines. Density of water = $1\,000\,kg\,m^{-3}$. [4]

(c) Suggest **two** reasons why there are relatively few hydroelectric power stations compared to wind farms in Wales. [2]

Examiner only

(d) The diagram shows a hydrogen fuel cell.



(i) Describe the operation of this fuel cell. [3]

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(ii) It is suggested that these fuel cells have no impact on CO_2 emissions. Discuss whether or not you agree with this suggestion. [2]

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Examiner only

(e) (i) State what is meant by "the U-value of an external wall is 0.18 W m^{-2} K^{-1}". [1]

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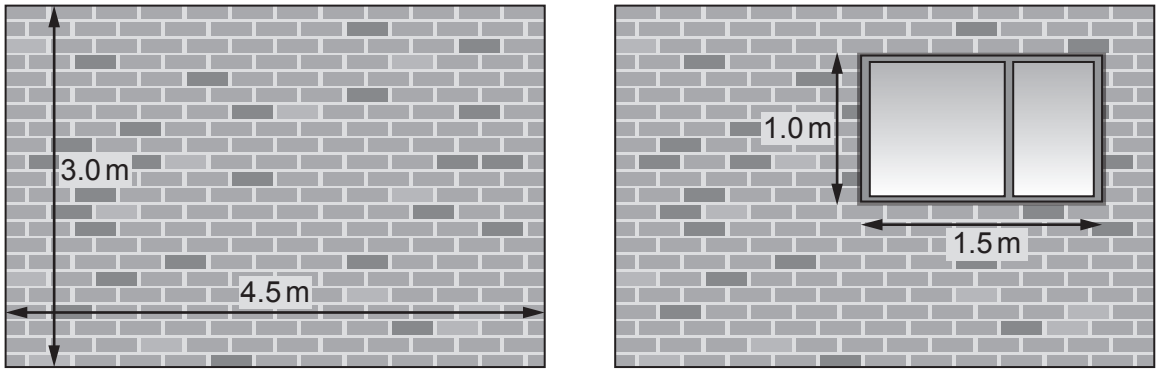
(ii) A homeowner considers replacing part of an external wall with a double-glazed window as shown in the diagram.



An energy saving company claims that introducing the window would double the rate of heat loss from the wall. Evaluate whether the claim is correct. You may assume a temperature difference of 15 °C between the inside and outside of the house. [3]

U-value of an external wall is 0.18 W m^{-2} K^{-1}

U-value of a double-glazed window is 1.26 W m^{-2} K^{-1}

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END OF PAPER

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

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