N15/4/PHYSI/HP2/ENG/TZ0/XX

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Monday 9 November 2015 (morning)

2 hours 15 minutes

Candidate session number

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer two questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[95 marks]**.

32 pages

8815 – 6502

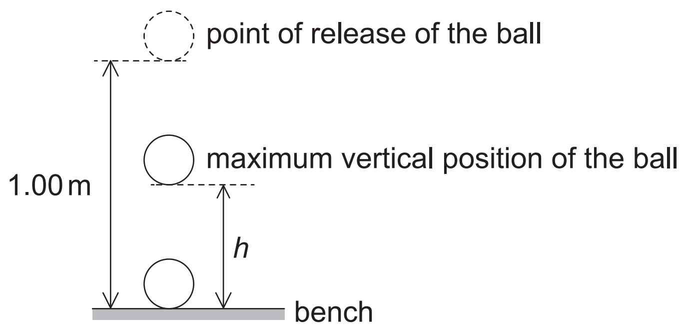
Section A

Answer **all** questions. Write your answers in the boxes provided.

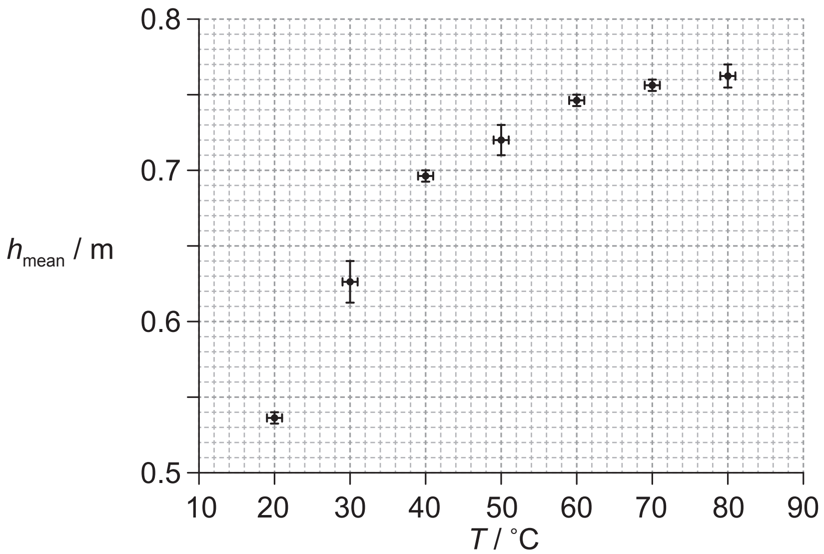
1. Data analysis question.

An experiment is undertaken to investigate the relationship between the temperature of a ball and the height of its first bounce.

A ball is placed in a beaker of water until the ball and the water are at the same temperature. The ball is released from a height of 1.00 m above a bench. The maximum vertical height h from the bottom of the ball above the bench is measured for the first bounce. This procedure is repeated twice and an average h_{mean} is calculated from the three measurements.



The procedure is repeated for a range of temperatures. The graph shows the variation of h_{mean} with temperature T.



(a) Draw the line of best-fit for the data. [1]

(This question continues on the following page)

(Question 1 continued)

(b) A student hypothesizes that h_{mean} is proportional to T^2.

(i) Comment, using **two** points on your line of best-fit, whether or not this is a valid hypothesis. [3]

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(ii) Suggest why using two points cannot confirm that h_{mean} is proportional to T^2. [2]

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(c) (i) State the uncertainty in each value of T. [1]

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(ii) The temperature is measured using a liquid in glass thermometer. Explain why it is likely that the uncertainty in T is constant. [2]

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(Question 1 continued)

(d) Another hypothesis is that $h_{mean} = KT^3$ where K is a constant. Using the graph on page 2, calculate the absolute uncertainty in K corresponding to $T = 50\,^{\circ}C$. [4]

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2. This question is about gravitation and uniform circular motion.

Phobos, a moon of Mars, has an orbital period of 7.7 hours and an orbital radius of 9.4×10^3 km.

(a) Outline why Phobos moves with uniform circular motion. [3]

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(b) Show that the orbital speed of Phobos is about $2\,km\,s^{-1}$. [2]

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(c) Deduce the mass of Mars. [3]

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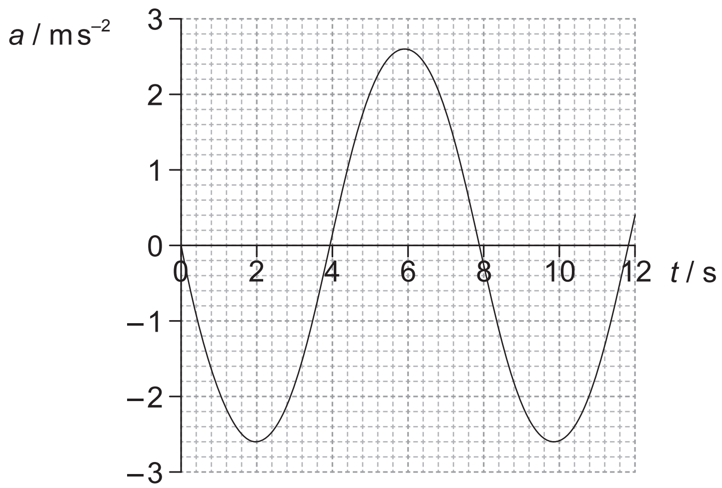
3. This question is about simple harmonic motion (SHM).

The graph shows the variation with time *t* of the acceleration *a* of an object X undergoing simple harmonic motion (SHM).



(a) Define *simple harmonic motion (SHM)*. [2]

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(b) X has a mass of 0.28 kg. Calculate the maximum force acting on X. [1]

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(This question continues on the following page)

(Question 3 continued)

(c) Determine the maximum displacement of X. Give your answer to an appropriate number of significant figures. [4]

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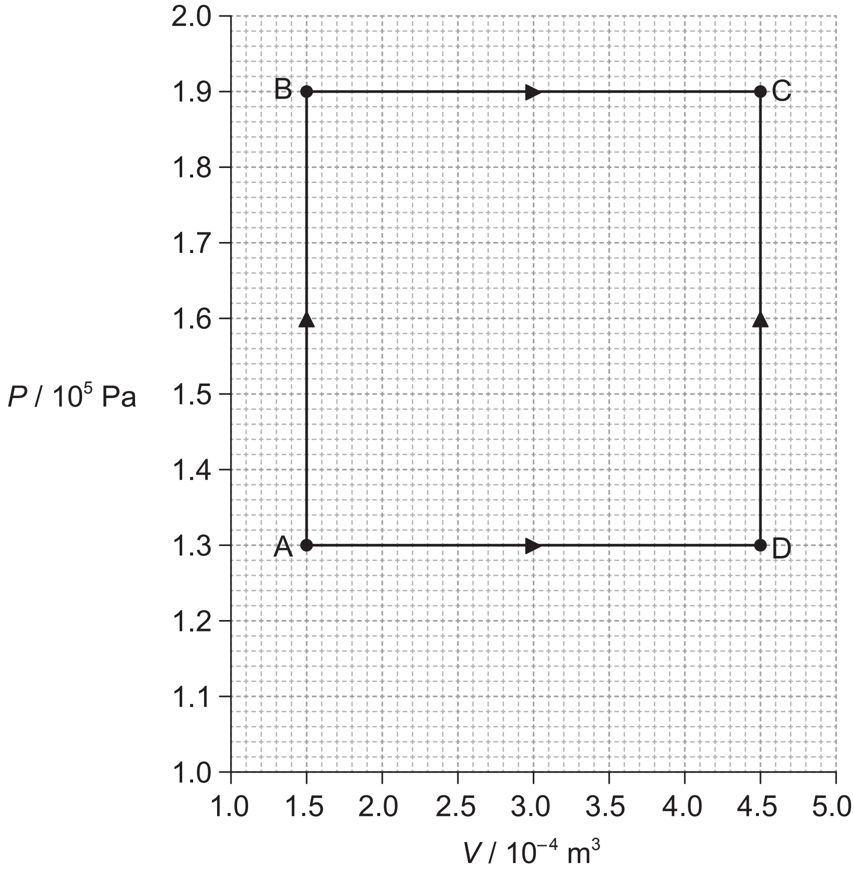
(d) A second object Y oscillates with the same frequency as X but with a phase difference of $\frac{\pi}{4}$. Sketch, using the graph opposite, how the acceleration of object Y varies with *t*. [2]

4. This question is about an ideal gas.

The graph shows how the pressure P of a sample of fixed mass of an ideal gas varies with volume V.



The temperature of the gas at point A is 85 °C. The gas can change its state to that of point C either along route ABC or route ADC.

(a) Calculate the temperature of the gas at point C. [3]

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(This question continues on the following page)

(Question 4 continued)

(b) Compare, without any calculation, the work done and the thermal energy supplied along route ABC **and** route ADC. [3]

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5. This question is about the photoelectric effect.

(a) Outline why the wave model of light cannot account for the photoelectric effect. [3]

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(b) Monochromatic light of wavelength 420 nm is incident on a clean metal surface. The work function of the metal is 2.6×10^{-19} J.

(i) Calculate, in eV, the maximum kinetic energy of the photoelectrons emitted. [3]

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(ii) The intensity of the light is $5.1\,\mu\text{W}\,\text{m}^{-2}$. Determine the number of photoelectrons emitted per second for each mm^2 of the metal surface. Each photon has a 1 in 800 chance of ejecting an electron. [3]

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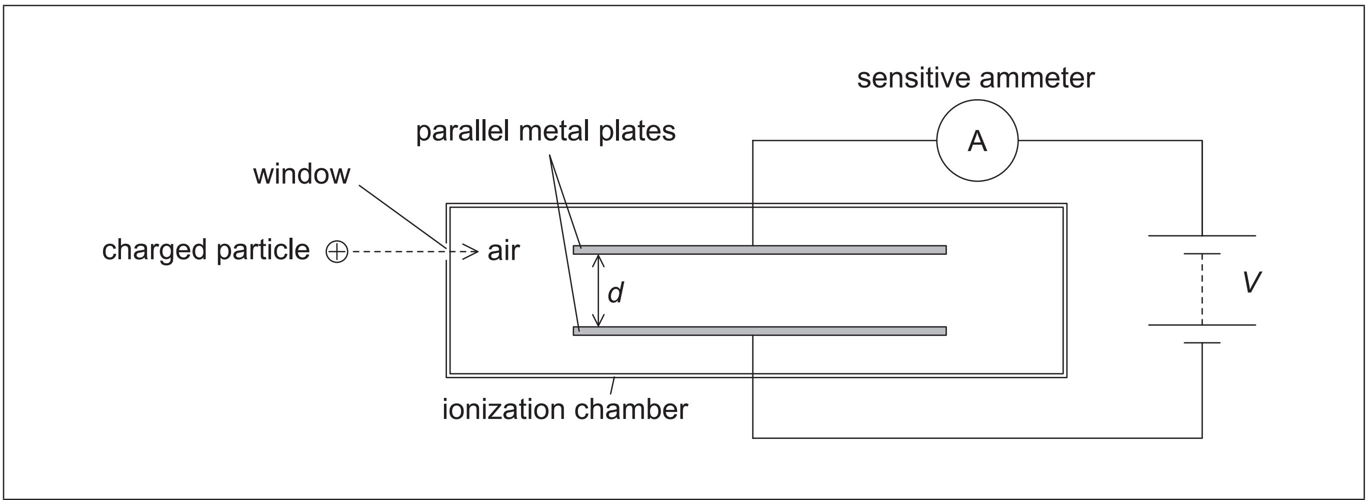
Section B

This section consists of four questions: 6, 7, 8 and 9. Answer **two** questions. Write your answers in the boxes provided.

6. This question is in **two** parts. **Part 1** is about electric fields and radioactive decay. **Part 2** is about waves.

Part 1 Electric fields and radioactive decay

An ionization chamber is a device which can be used to detect charged particles.



The charged particles enter the chamber through a thin window. They then ionize the air between the parallel metal plates. A high potential difference across the plates creates an electric field that causes the ions to move towards the plates. Charge now flows around the circuit and a current is detected by the sensitive ammeter.

(a) On the diagram, draw the shape of the electric field between the plates. [2]

(This question continues on the following page)

(Question 6, part 1 continued)

(b) The separation of the plates *d* is 12 mm and the potential difference *V* between the plates is 5.2 kV. An ionized air molecule M with charge +2*e* is produced when a charged particle collides with an air molecule.

(i) Calculate the electric field strength between the plates. [1]

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(ii) Calculate the force on M. [2]

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(iii) Determine the change in the electric potential energy of M as it moves from the positive to the negative plate. [3]

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(Question 6, part 1 continued)

(c) Radium-226 $\left({}^{226}_{88}\text{Ra}\right)$ decays into an isotope of radon (Rn) by the emission of an alpha particle and a gamma-ray photon. The alpha particle may be detected using the ionization chamber but the gamma-ray photon is unlikely to be detected.

(i) Outline why gamma-ray photons are unlikely to be detected in the ionization chamber. [1]

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(ii) Construct the nuclear equation for the decay of radium-226. [2]

$$^{226}_{88}\text{Ra} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\text{Rn} + {}^{\cdots\cdots}_{\cdots\cdots}\text{He} + {}^{0}_{0}\gamma$$

(iii) Radium-226 has a half-life of 1600 years. Determine the time, in years, it takes for the activity of radium-226 to fall to 5 % of its original activity. [3]

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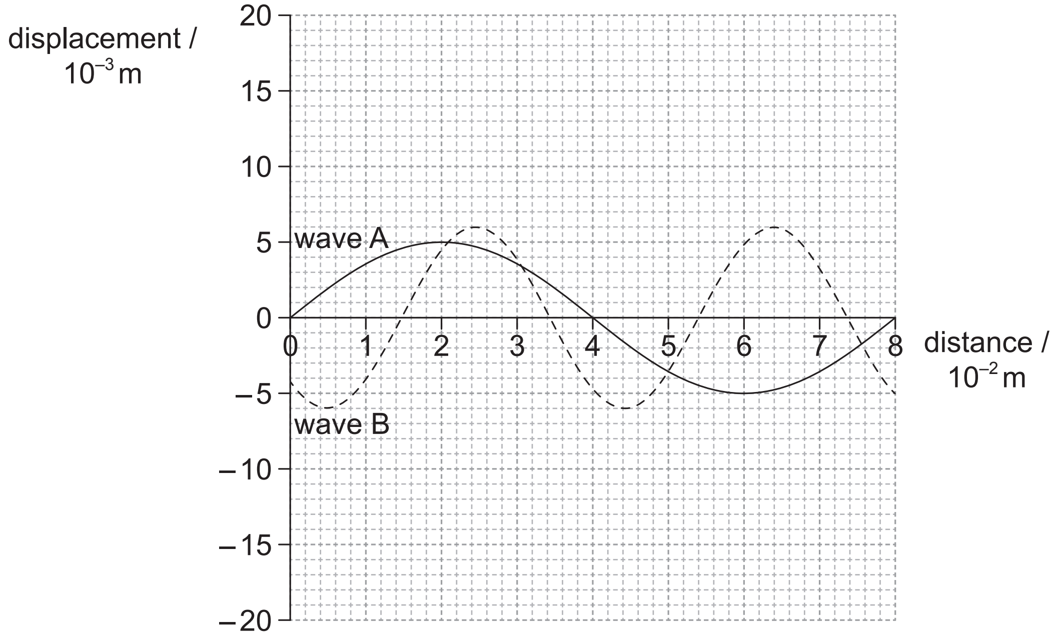
(Question 6 continued from page 14)

Part 2 Waves

Two waves, A and B, are travelling in opposite directions in a tank of water. The graph shows the variation of displacement of the water surface with distance along the wave at a particular instant.



(d) State the amplitude of wave A. [1]

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(Question 6, part 2 continued)

(e) (i) Wave A has a frequency of 9.0 Hz. Calculate the velocity of wave A. [2]

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(ii) Deduce the frequency of wave B. [3]

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(f) (i) State what is meant by the principle of superposition of waves. [2]

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(ii) On the graph opposite, sketch the wave that results from the superposition of wave A and wave B at that instant. [3]

7. This question is in **two** parts. **Part 1** is about energy resources. **Part 2** is about charge-coupled devices (CCDs).

Part 1 Energy resources

Electricity can be generated using nuclear fission, by burning fossil fuels or using pump storage hydroelectric schemes.

(a) Outline which of the three generation methods above is renewable. [2]

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(b) In a nuclear reactor, outline the purpose of the

(i) heat exchanger. [1]

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(ii) moderator. [2]

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(Question 7, part 1 continued)

(c) Fission of one uranium-235 nucleus releases 203 MeV.

(i) Determine the maximum amount of energy, in joule, released by 1.0 g of uranium-235 as a result of fission. [3]

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(ii) Coal has an energy density of $2.8 \times 10^{7}\,\text{J kg}^{-1}$.

Calculate the ratio $\dfrac{\text{energy density of uranium-235}}{\text{energy density of coal}}$. [1]

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(iii) Using your answer to (c)(ii), outline why fossil fuel stations are often built near to the source of the fossil fuel but nuclear power stations are rarely close to the source of the nuclear fuel. [2]

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(Question 7, part 1 continued)

(d) (i) Describe the main principles of the operation of a pump storage hydroelectric scheme. [3]

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(ii) A hydroelectric scheme has an efficiency of 92 %. Water stored in the dam falls through an average height of 57 m. Determine the rate of flow of water, in $kg\,s^{-1}$, required to generate an electrical output power of 4.5 MW. [3]

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(Question 7 continued)

Part 2 Charge-coupled devices (CCDs)

The camera on a smart phone is used to take a photograph of the full Moon. The sensor in the camera consists of an array of square-shaped pixels.

The following data are available.

Pixel area	$= 6.25 \times 10^{-10}\,\text{m}^2$
Area of the disc of the full Moon	$= 9.5 \times 10^{12}\,\text{m}^2$
Area of the image of the full Moon formed on the sensor	$= 1.9 \times 10^{-3}\,\text{m}^2$

(e) The centres of two craters on the Moon are separated by 1.5 km. Deduce whether the images of the centres of the two craters will be resolved. [4]

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(f) Light from the Moon is incident on the pixels for an exposure time of 300 ms. There are 4.7×10^2 photons incident on one pixel each second. Each pixel has a quantum efficiency of 80 % and a capacitance 25 pF.

(i) State what is meant by quantum efficiency. [1]

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(ii) Determine the change in potential difference across each pixel when it is exposed to the light for 300 ms. [3]

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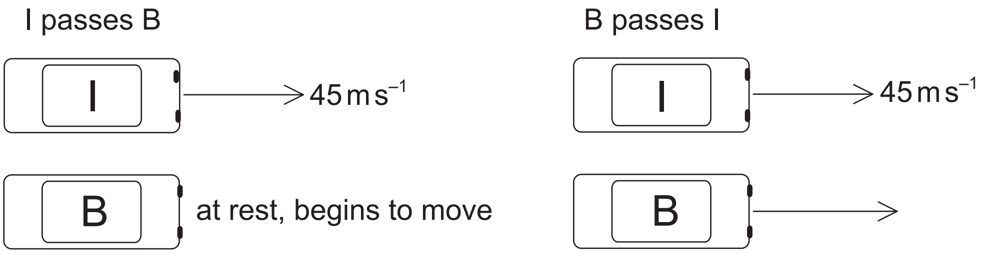
8. This question is in **two** parts. **Part 1** is about kinematics and Newton's laws of motion. **Part 2** is about power transmissions.

Part 1 Kinematics and Newton's laws of motion

Cars I and B are on a straight race track. I is moving at a constant speed of $45\,m\,s^{-1}$ and B is initially at rest. As I passes B, B starts to move with an acceleration of $3.2\,m\,s^{-2}$.



At a later time B passes I. You may assume that both cars are point particles.

(a) (i) Show that the time taken for B to pass I is approximately 28 s. [4]

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(ii) Calculate the distance travelled by B in this time. [2]

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(Question 8, part 1 continued)

(b) B slows down while I remains at a constant speed. The driver in each car wears a seat belt. Using Newton's laws of motion, explain the difference in the tension in the seat belts of the two cars. [3]

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(c) A third car O with mass 930 kg joins the race. O collides with I from behind, moving along the same straight line as I. Before the collision the speed of I is 45 m s^{-1} and its mass is 850 kg. After the collision, I and O stick together and move in a straight line with an initial combined speed of 52 m s^{-1}.

(i) Calculate the speed of O immediately before the collision. [2]

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(ii) The duration of the collision is 0.45 s. Determine the average force acting on O. [2]

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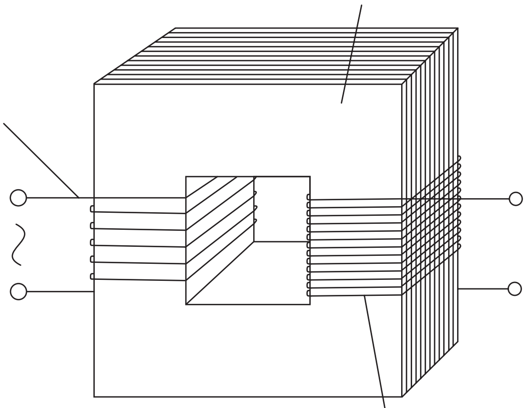
(Question 8 continued)

Part 2 Power transmissions

The diagram shows the main features of an ideal transformer whose primary coil is connected to a source of alternating current (ac) voltage.



(d) Outline, with reference to electromagnetic induction, how a voltage is induced across the secondary coil. [3]

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(e) The primary coil has 25 turns and is connected to an alternating supply with an input voltage of root mean squared (rms) value 12 V. The secondary coil has 80 turns and is not connected to an external circuit. Determine the peak voltage induced across the secondary coil. [2]

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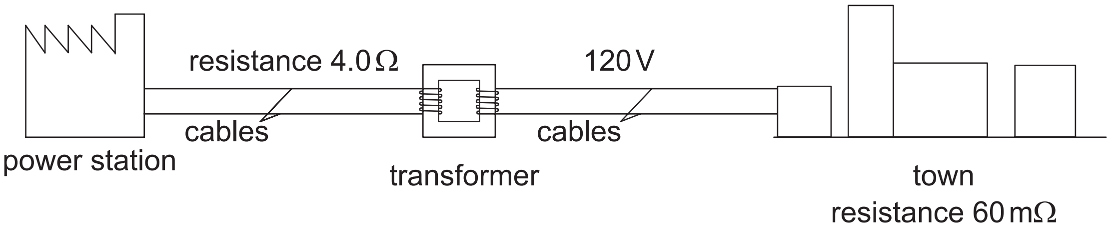
(Question 8, part 2 continued)

(f) A different transformer is used to transmit power to a small town.



The transmission cables from the power station to the transformer have a total resistance of 4.0 Ω. The transformer is 90 % efficient and steps down the voltage to 120 V. At the time of maximum power demand the effective resistance of the town and of the cables from the transformer to the town is 60 mΩ.

(i) Calculate the current in the cables connected to the town. [1]

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(ii) Calculate the power supplied to the transformer. [2]

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(iii) Determine the input voltage to the transformer if the power loss in the cables from the power station is 2.0 kW. [2]

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(Question 8, part 2 continued)

(g) Outline why laminating the core improves the efficiency of a transformer. [2]

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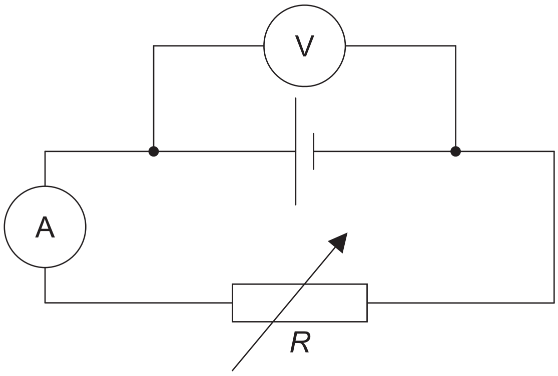
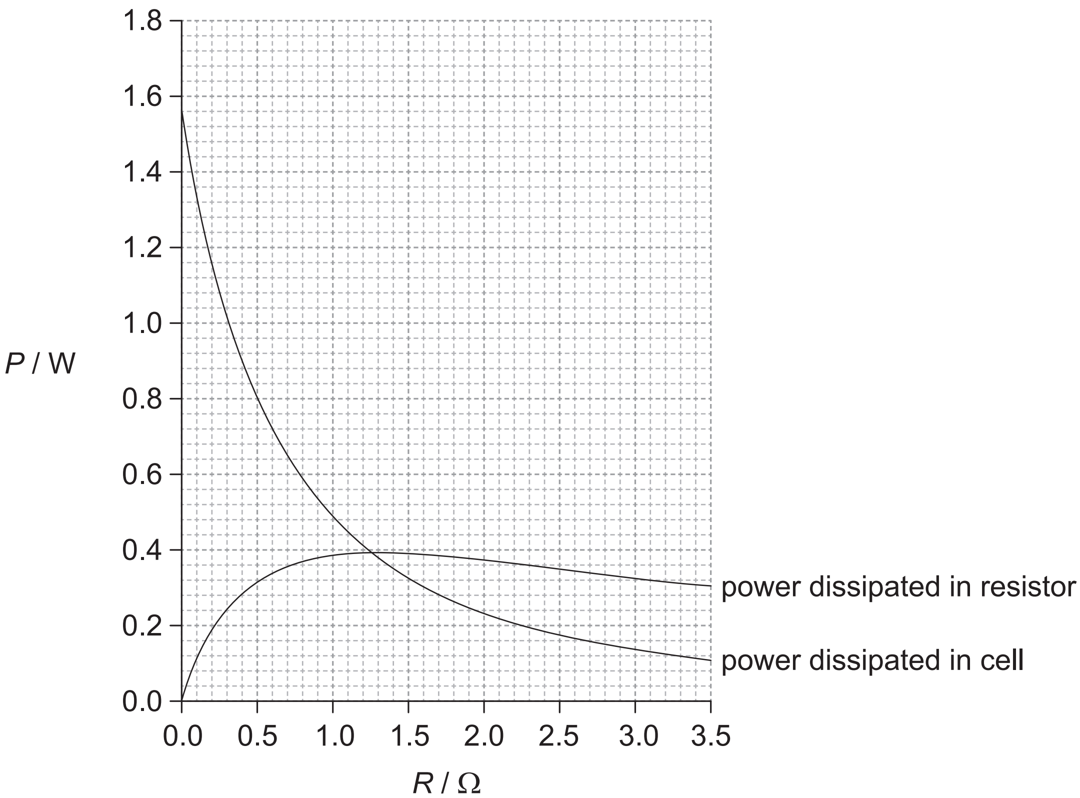
9. This question is in **two** parts. **Part 1** is about electrical circuits. **Part 2** is about magnetic fields.

Part 1 Electrical circuits

The circuit shown is used to investigate how the power developed by a cell varies when the load resistance *R* changes.



The variable resistor is adjusted and a series of current and voltage readings are taken. The graph shows the variation with *R* of the power dissipated in the cell and the power dissipated in the variable resistor.



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(Question 9, part 1 continued)

(a) Show that the current in the circuit is approximately 0.70 A when $R = 0.80\,\Omega$. [3]

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(b) The cell has an internal resistance.

(i) Outline what is meant by the internal resistance of a cell. [2]

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(ii) Determine the internal resistance of the cell. [3]

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(c) Calculate the electromotive force (emf) of the cell. [2]

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(Question 9, part 1 continued)

(d) The cell may be damaged if it dissipates a power greater than 1.2 W. Outline why damage in the cell may occur if the terminals of the cell are short-circuited. [2]

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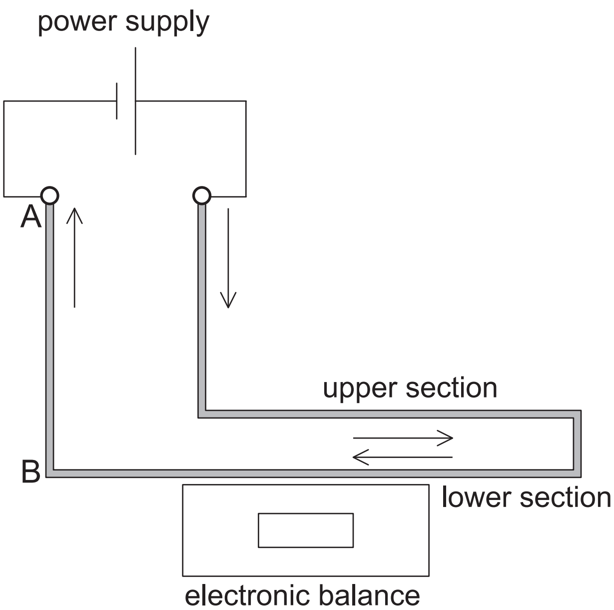
Part 2 Magnetic fields

The diagram shows an arrangement for measuring the force between two parallel sections of the same rigid wire carrying a current as viewed from the front.



The supports for the upper section of the wire and the power supply are not shown.

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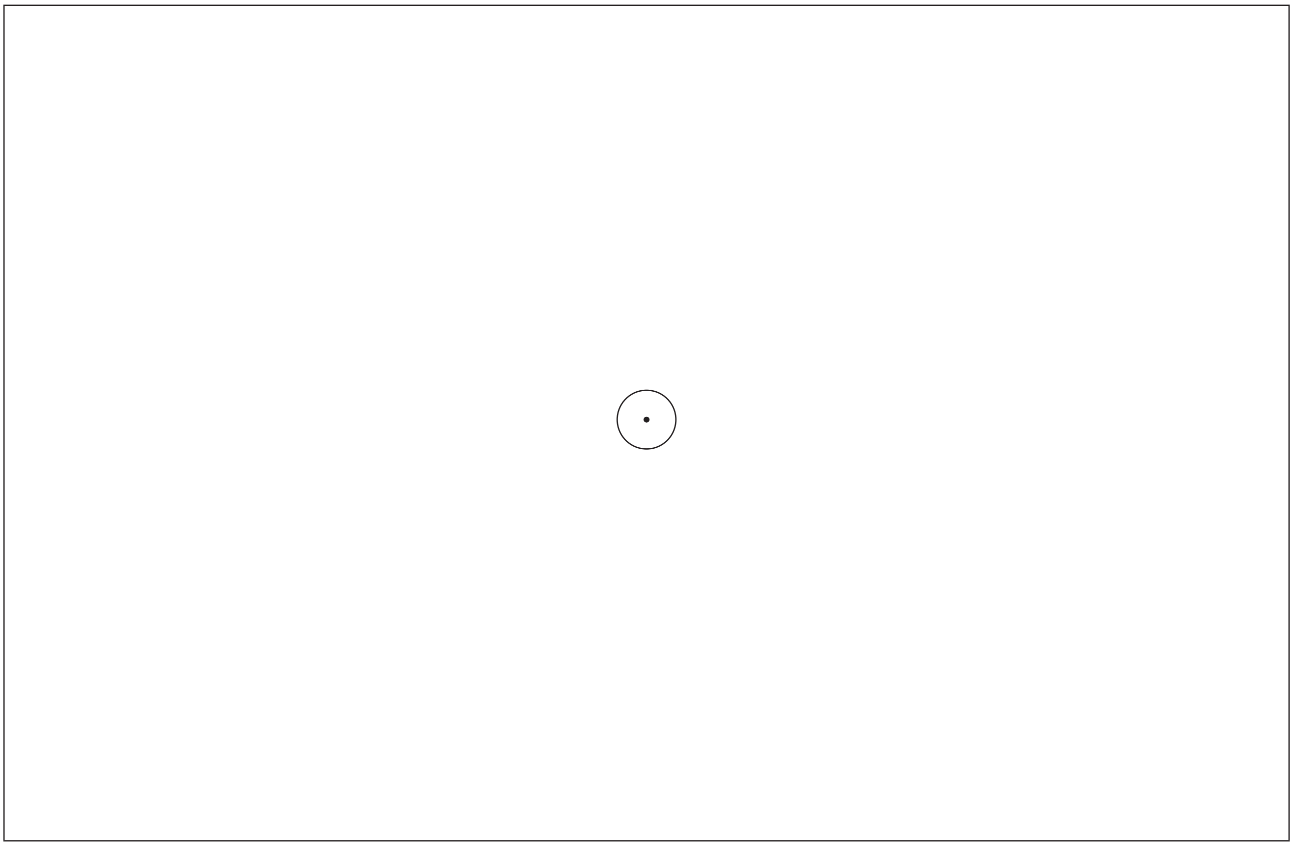
(Question 9, part 2 continued)

(e) The part of the wire from A to B is viewed from above. The direction of the current is out of the plane of the paper.



Using the diagram, draw the magnetic field pattern due to just the current in wire AB. [2]

(f) Deduce what happens to the reading on the electronic balance when the current is switched on. [3]

(This question continues on the following page)

(Question 9, part 2 continued)

(g) When the current in the wire is 0.20 A, the magnetic field strength at the upper section of wire due to the lower section of wire is 1.3×10^{-4} T.

(i) Calculate the magnetic force acting per unit length on the upper section of wire. [1]

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(ii) Each cubic metre of the wire contains approximately 8.5×10^{28} free electrons. The diameter of the wire is 2.5 mm and the length of wire within the magnetic field is 0.15 m. Using the force per unit length calculated in (g)(i), deduce the speed of the electrons in the wire when the current is 0.20 A. [4]

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(h) The upper section of wire is adjusted to make an angle of 30° with the lower section of wire. Outline how the reading of the balance will change, if at all. [3]

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