Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

8 November 2024

Zone A morning | **Zone B** morning | **Zone C** morning

Candidate session number

2 hours 15 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer 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 **[90 marks]**.

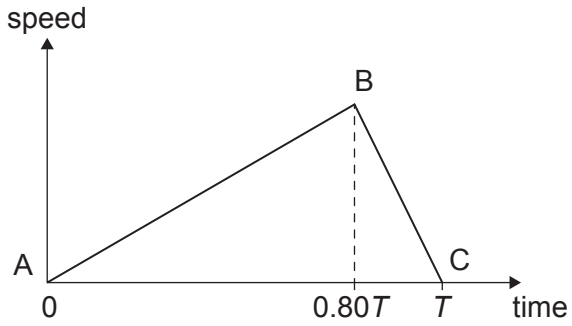
8824 – 9591

25 pages

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A train starting from rest travels from A to B with acceleration $0.20\,m\,s^{-2}$ and then decelerates to rest from B to C. The total distance from A to C is 1800 m. The graph shows the variation with time of the speed of the train.

diagram not to scale



The time of travel from A to C is T and the time from A to B is $0.80\,T$.

(a) Write down the speed of the train when at point B in terms of T. [1]

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(b) Determine T. [2]

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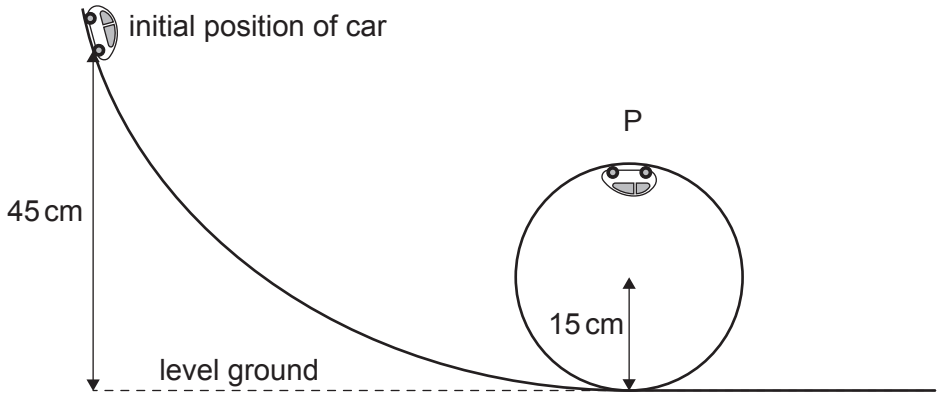
2. (a) In a "loop-the-loop" toy, a car of mass 0.12 kg is released from rest. The initial position of the car is 45 cm above level ground. The radius of the circular loop is 15 cm. The car reaches the top of the loop at position P. Frictional and air resistance forces are negligible.

diagram not to scale



(i) Show that the speed of the car at P is 1.7 m s^{-1}. [2]

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(ii) Determine the normal force exerted by the loop on the car at P. [3]

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(iii) State why the car stays in contact with the loop. [1]

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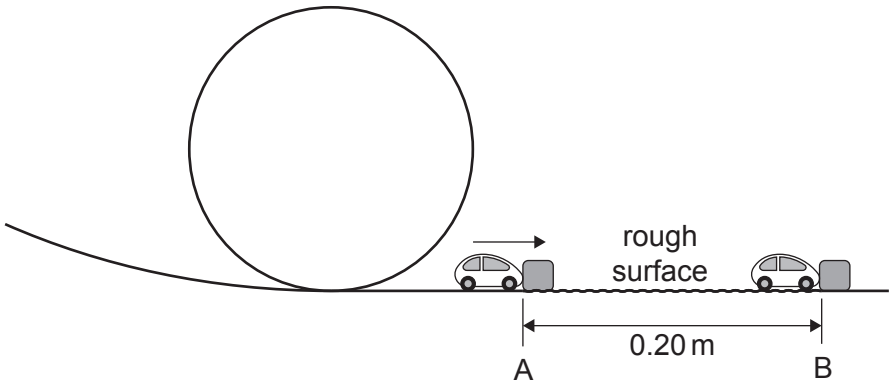
(Question 2 continued)

(b) At point A the car collides with a block of mass 0.18 kg and sticks to it. After the collision, the car and the block move together with speed $1.2\,m\,s^{-1}$.

diagram not to scale



(i) Calculate the speed of the car just before it collides with the block. [2]

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(ii) The surface from A to B is rough and the combined car and block come to rest at B. The distance AB is 0.20 m. Determine the rate of change of momentum of the combined car and block from A to B. [3]

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(Question 2 continued)

(iii) Calculate the dynamic coefficient of friction between the rough surface and the combined car and block. [2]

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3. (a) Outline, by reference to Newton's third law, how a gas in a container exerts pressure on the container walls. [2]

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(b) State **one** difference between an ideal gas and a real gas. [1]

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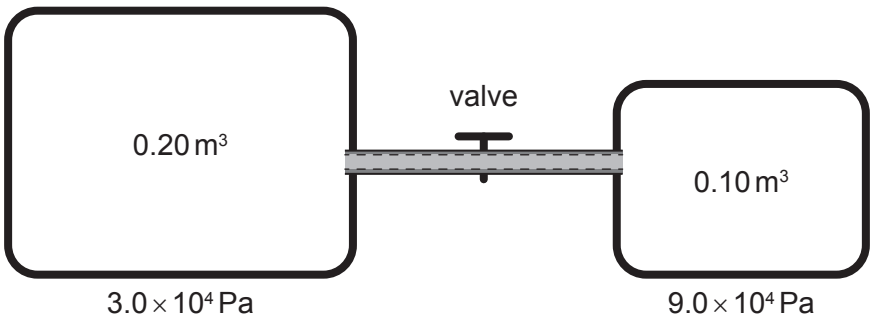
(c) Two containers of volume $0.20\,m^3$ and $0.10\,m^3$ are filled with an ideal gas. The pressure in the larger container is 3.0×10^4 Pa. The pressure in the smaller container is 9.0×10^4 Pa. The temperature of the gas in both containers is the same. A thin tube with a valve joins the containers. The valve is initially closed.



The valve is opened so that gas can move from one container to the other. The temperature remains unchanged.

Determine the new pressure of the gas. [3]

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4. (a) (i) State what is meant by a transverse wave. [1]

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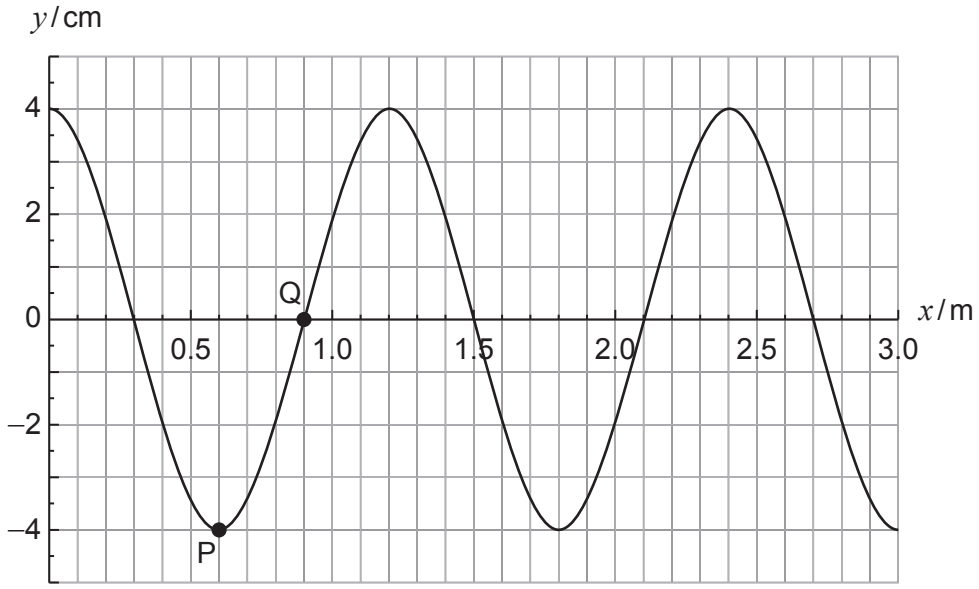
A transverse wave is travelling to the right on a string. The graph shows, at one particular time, the variation of the displacement y with distance x along the string. Two points, P and Q, on the string have been marked.



(ii) Explain whether P or Q has the greater acceleration. [2]

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(Question 4 continued)

(iii) The speed of the wave is $62\,m\,s^{-1}$. Calculate the period of the wave giving your answer to the correct number of significant figures. [2]

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(iv) Calculate the average speed of P during one complete oscillation. [2]

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(b) The string is now stretched between an oscillator and a fixed point. When the oscillator is set to a frequency of 120 Hz the standing wave shown in the diagram is observed on the string.

Draw the standing wave that would be observed on the same string when the oscillator is set to a frequency of 180 Hz. [1]

(c) Physicists and engineers study simple harmonic oscillations even though most oscillations are not simple harmonic. Suggest why this is a useful thing to do. [1]

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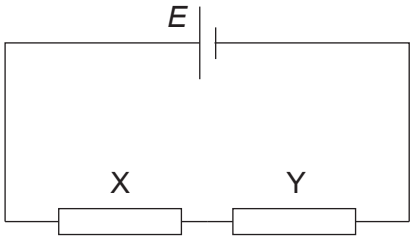
5. (a) Two resistors, X and Y, are connected in series to a cell of emf *E* and negligible internal resistance. The resistances of X and Y are constant.



The power dissipated in X is greater than that in Y.

State and explain how the resistance of X compares with the resistance of Y. [2]

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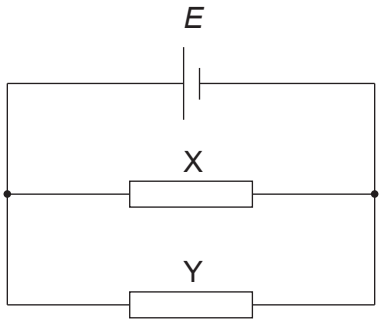
(b) X and Y are now connected in parallel to the same cell.



State and explain which resistor has the greater power dissipation. [2]

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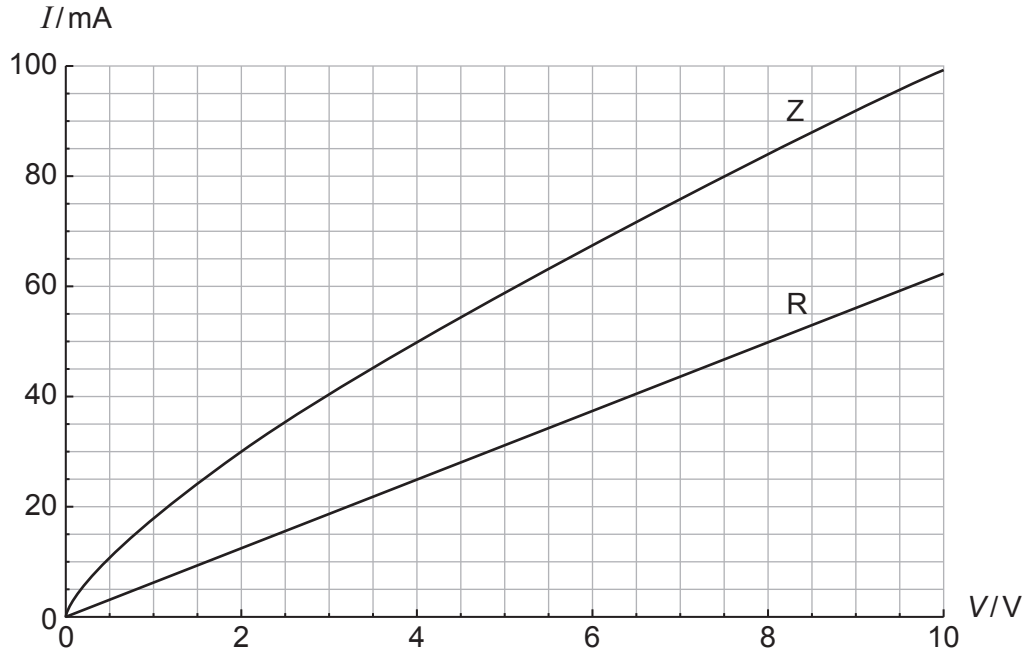
(Question 5 continued)

(c) A lamp Z and a resistor R have the I-V characteristics shown in the graph.



(i) Describe the variation with voltage of the resistance of Z. [2]

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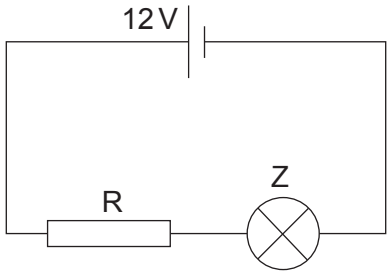
(Question 5 continued)

(ii) R and Z are connected in series to a cell of emf 12 V and negligible internal resistance.



Determine, using the graph, the power dissipated in lamp Z. [3]

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6. The binding energy of the stable nuclide $^{131}_{54}Xe$ is 1.105 GeV.

(a) (i) Outline what is meant by binding energy. [1]

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(ii) Calculate, in GeV c^{-2}, the mass of a nucleus of $^{131}_{54}Xe$. [2]

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(b) $^{133}_{54}Xe$ and $^{131}_{54}Xe$ are two isotopes of xenon.

(i) Outline what is meant by isotopes. [2]

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(ii) $^{133}_{54}Xe$ is radioactive. Suggest how the binding energy per nucleon for $^{131}_{54}Xe$ compares with that of $^{133}_{54}Xe$. [1]

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(This question continues on the following page)

(Question 6 continued)

(iii) Determine the number of up quarks (u quarks) in the nucleus of $^{131}_{54}Xe$. [2]

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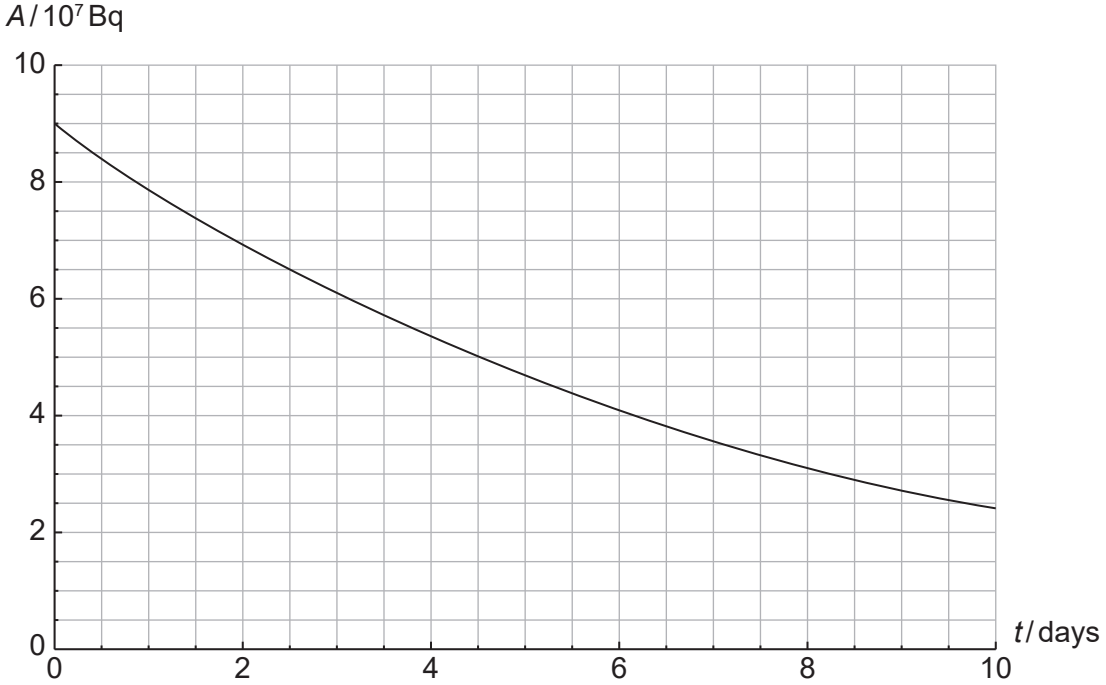
(Question 6 continued)

(c) The graph shows the variation with time of the activity of a pure sample of $^{133}_{54}Xe$.



(i) Estimate the half-life of $^{133}_{54}Xe$. [1]

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(ii) Calculate the activity of the sample after 25 days as a fraction of the initial activity. [3]

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7. (a) Describe the energy transfers taking place in a wind generator. [2]

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(b) The maximum power that can be extracted from a wind generator is given by $P = \frac{1}{2}\rho A v^3$.

State **one** assumption made in deriving this equation. [1]

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(c) The following data are available for a wind generator:

Blade radius	$= 2.5\,\text{m}$
Air density	$= 1.2\,\text{kg m}^{-3}$
Wind speed incident on blades	$= 6.8\,\text{m s}^{-1}$
Wind speed after leaving blades	$= 2.6\,\text{m s}^{-1}$

Determine the maximum power, stating the correct unit, produced by this wind generator. [2]

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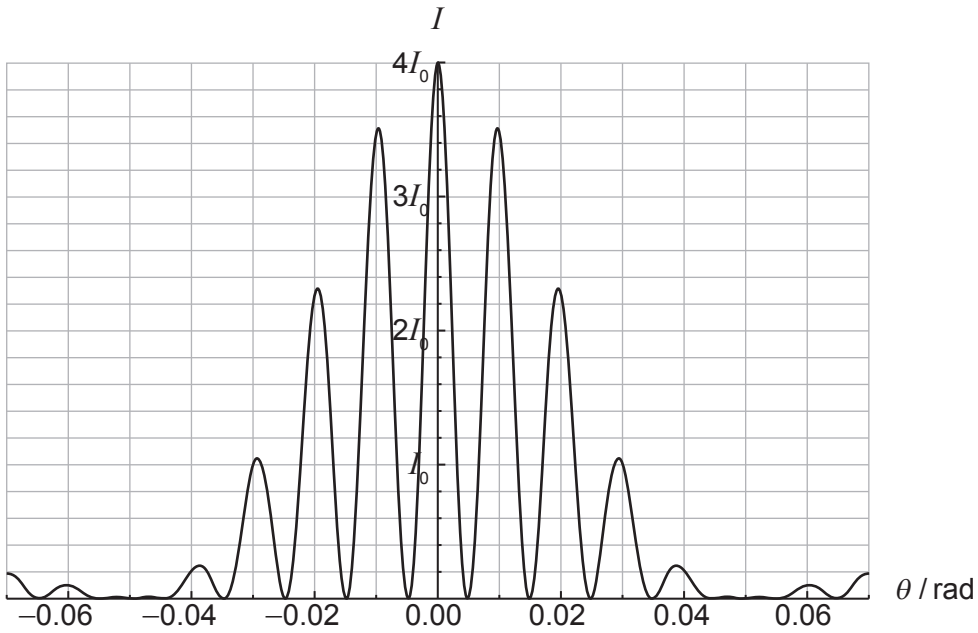
8. (a) Light of wavelength 6.0×10^{-7} m is incident on two parallel slits.

The graph shows the variation with diffraction angle θ of the intensity I of light observed on a screen far from the slits. I_0 is the intensity of light on the screen due to one slit only.



(i) Identify a feature of this graph that suggests that the slit width is not negligible. [1]

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(ii) Estimate the slit width. [2]

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(Question 8 continued)

(iii) Outline how the central maximum is formed. [3]

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(iv) Explain why the intensity of the central maximum is equal to $4I_0$. [2]

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(b) The spectrum of sodium contains two lines at wavelengths 589.0 nm and 589.6 nm.

400 slits of a diffraction grating are illuminated. Determine whether these lines are resolved in the second order. [2]

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9. (a) The gravitational potential due to an isolated point mass is zero at infinity. Explain why the gravitational potential at all other points is negative. [2]

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(b) A probe is launched from the surface of a planet with a speed $0.9\,v_{esc}$ where v_{esc} is the escape speed from the planet.

(i) State what is meant by escape speed. [1]

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(ii) The radius of the planet is R. Determine, in terms of R, the maximum height above the surface the probe can reach. [3]

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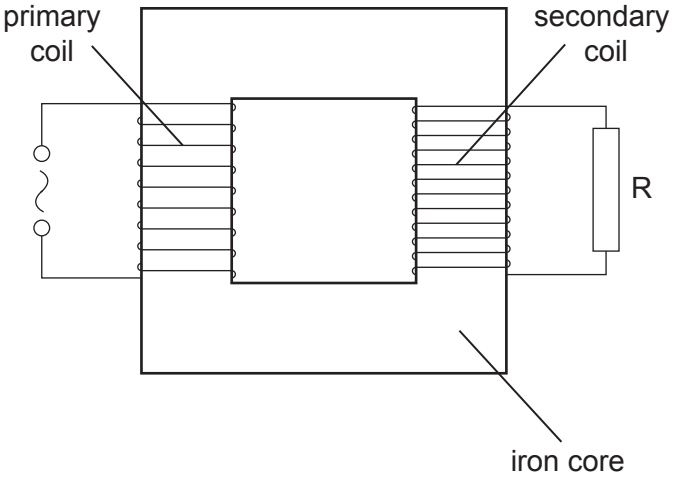
10. The diagram shows an ideal transformer with an iron core. A resistor R is connected to the secondary coil.



(a) Describe the function of the iron core. [1]

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(b) An alternating voltage is applied to the primary coil. Explain, using Faraday's law, why a voltage is induced in the secondary coil. [3]

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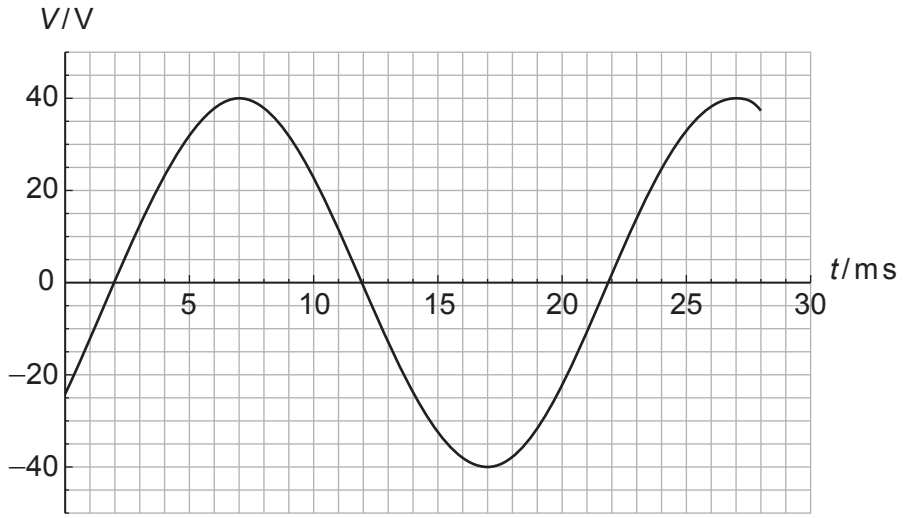
(Question 10 continued)

(c) The graph shows the variation with time t of the voltage V in the primary coil.



The number of turns in the primary coil is 600. The peak value of the voltage in the secondary coil is 120 V.

(i) Calculate the number of turns in the secondary coil. [2]

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(ii) Calculate the frequency of voltage in the secondary coil. [1]

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(This question continues on the following page)

(Question 10 continued)

(d) For the input voltage in (c) the average power dissipated in the resistor R is 2.5 W.

Determine

(i) the root mean square (rms) current in R. [2]

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(ii) the resistance of R. [1]

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11. (a) Electrons are emitted from a metal surface when very low intensity light is incident on it. This emission occurs with no observable time delay.

Outline why this observation is not consistent with the wave theory of light. [2]

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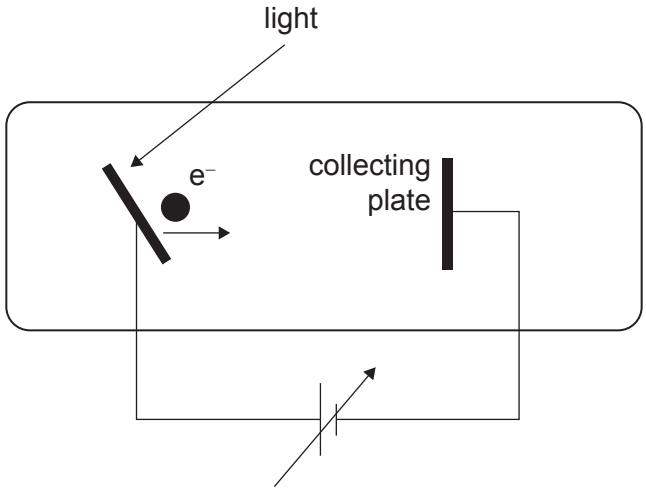
(b) Light of wavelength 5.2×10^{-7} m is incident on a metal surface and causes the emission of electrons of maximum kinetic energy 1.8 eV.



(i) Estimate, in eV, the work function of the metal surface. [2]

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(Question 11 continued)

(ii) The emf of the power supply is set at 0.60 V. Determine the speed of the electrons as they arrive at the collecting plate. [3]

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