Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Tuesday 5 November 2019 (afternoon)

Candidate session number

2 hours 15 minutes

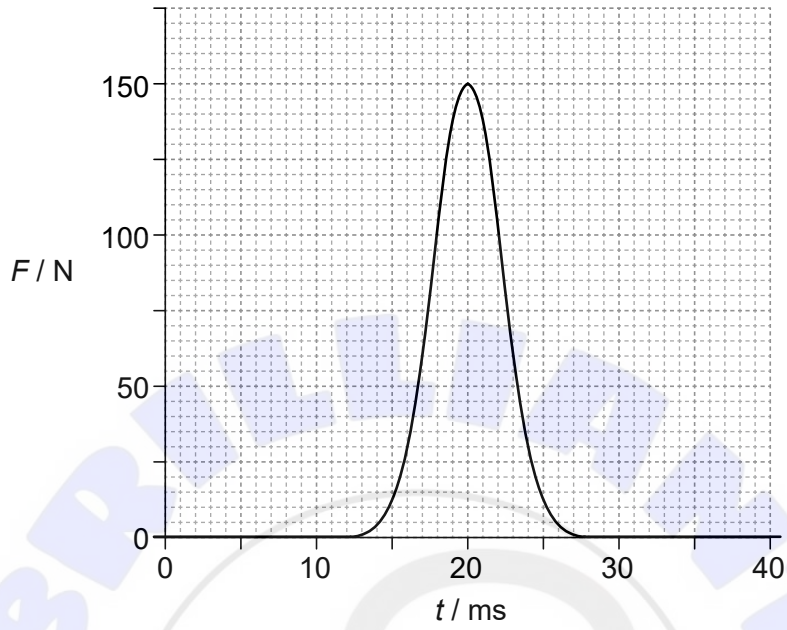
Instructions to candidates

- 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]**.

8819 – 6502

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

1. The graph shows the variation with time t of the horizontal force F exerted on a tennis ball by a racket.



The tennis ball was stationary at the instant when it was hit. The mass of the tennis ball is 5.8×10^{-2} kg. The area under the curve is 0.84 N s.

(a) Calculate the speed of the ball as it leaves the racket. [2]

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(b) Show that the average force exerted on the ball by the racket is about 50 N. [2]

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(Question 1 continued)

(c) Determine, with reference to the work done by the average force, the horizontal distance travelled by the ball while it was in contact with the racket. [3]

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(d) Draw a graph to show the variation with t of the horizontal speed v of the ball while it was in contact with the racket. Numbers are **not** required on the axes. [2]

2. The air in a kitchen has pressure 1.0×10^5 Pa and temperature 22°C. A refrigerator of internal volume 0.36 m^3 is installed in the kitchen.

(a) With the door open the air in the refrigerator is initially at the same temperature and pressure as the air in the kitchen. Calculate the number of molecules of air in the refrigerator. [2]

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(Question 2 continued)

(b) The refrigerator door is closed. The air in the refrigerator is cooled to 5.0°C and the number of air molecules in the refrigerator stays the same.

(i) Determine the pressure of the air inside the refrigerator. [2]

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(ii) The door of the refrigerator has an area of $0.72\,m^2$. Show that the minimum force needed to open the refrigerator door is about 4 kN. [2]

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(iii) Comment on the magnitude of the force in (b)(ii). [2]

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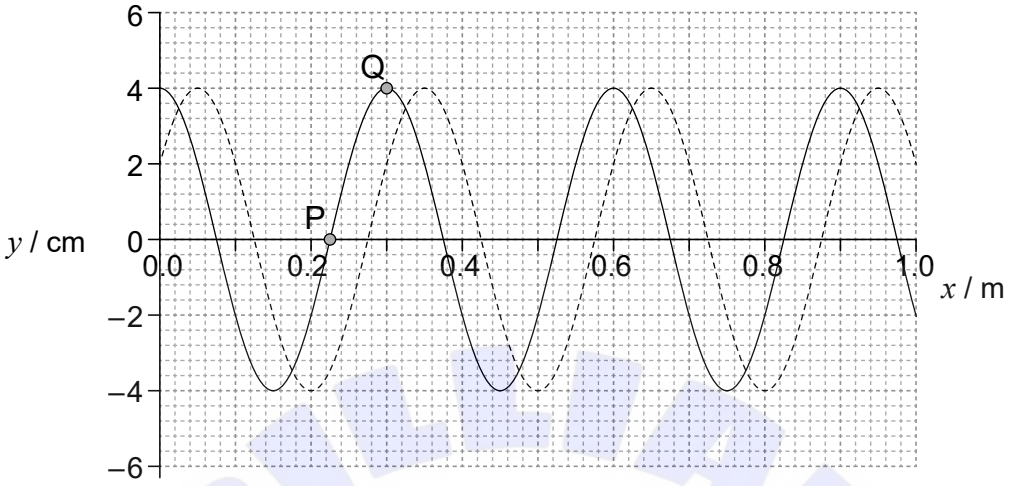
3. The solid line in the graph shows the variation with distance x of the displacement y of a travelling wave at $t = 0$. The dotted line shows the wave 0.20 ms later. The period of the wave is longer than 0.20 ms.



(a) (i) Calculate, in $m\,s^{-1}$, the speed for this wave. [1]

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(ii) Calculate, in Hz, the frequency for this wave. [2]

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(b) The graph also shows the displacement of two particles, P and Q, in the medium at $t = 0$. State and explain which particle has the larger magnitude of acceleration at $t = 0$. [2]

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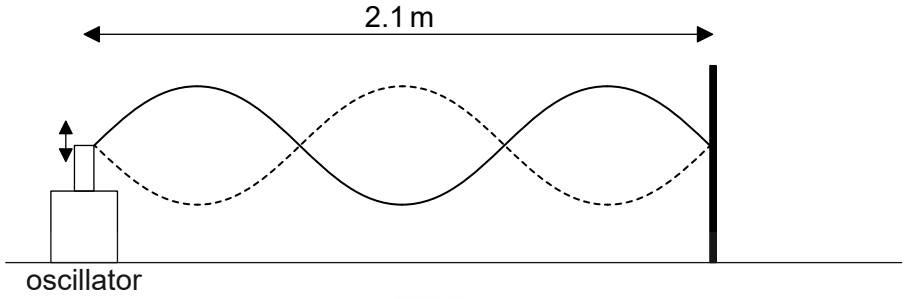
(Question 3 continued)

(c) One end of a string is attached to an oscillator and the other is fixed to a wall. When the frequency of the oscillator is 360 Hz the standing wave shown is formed on the string.



Point X (not shown) is a point on the string at a distance of 10 cm from the oscillator.

(i) State the number of all other points on the string that have the same amplitude and phase as X. [1]

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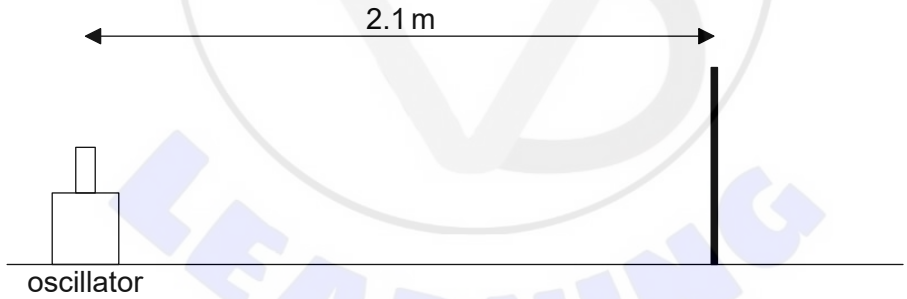
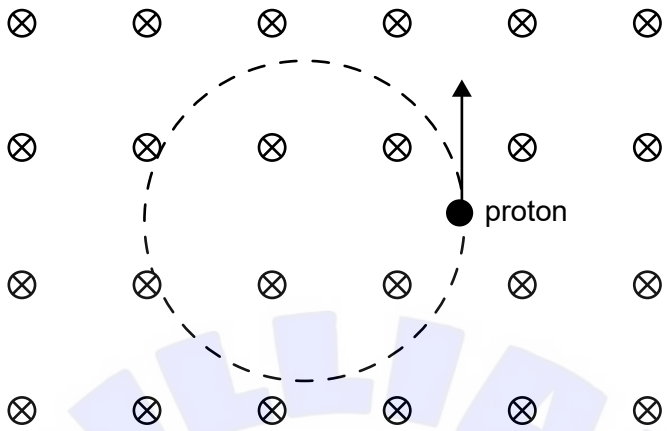
(ii) The frequency of the oscillator is reduced to 120 Hz. On the diagram, draw the standing wave that will be formed on the string. [1]



4. A proton is moving in a region of uniform magnetic field. The magnetic field is directed into the plane of the paper. The arrow shows the velocity of the proton at one instant and the dotted circle gives the path followed by the proton.



(a) Explain why the path of the proton is a circle. [2]

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(b) The speed of the proton is $2.0 \times 10^6\,\text{m s}^{-1}$ and the magnetic field strength B is 0.35 T.

(i) Show that the radius of the path is about 6 cm. [2]

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(Question 4 continued)

(ii) Calculate the time for **one** complete revolution. [2]

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(c) Explain why the kinetic energy of the proton is constant. [2]

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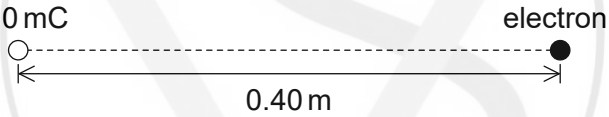
5. An electron is placed at a distance of 0.40 m from a fixed point charge of –6.0 mC.



(a) Show that the electric field strength due to the point charge at the position of the electron is $3.4 \times 10^8\,\text{N C}^{-1}$. [2]

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(b) (i) Calculate the magnitude of the initial acceleration of the electron. [2]

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(Question 5 continued)

(ii) Describe the subsequent motion of the electron. [3]

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6. Wind is incident on the blades of a wind turbine. The radius of the blades is 12 m. The following data are available for the air immediately before and after impact with the blades.

	Before	**After**
Density of air	$1.20\,\text{kg}\,\text{m}^{-3}$	$1.32\,\text{kg}\,\text{m}^{-3}$
Wind speed	$8.0\,\text{m}\,\text{s}^{-1}$	$4.0\,\text{m}\,\text{s}^{-1}$

(a) Determine the maximum power that can be extracted from the wind by this turbine. [3]

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(b) Suggest why the answer in (a) is a maximum. [1]

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7. (a) Radioactive decay is said to be “random” and “spontaneous”. Outline what is meant by each of these terms. [2]

Random: . . . . . .

Spontaneous: . . . . . .

(b) A stationary nucleus of uranium-238 undergoes alpha decay to form thorium-234.

The following data are available.

Energy released in decay	4.27 MeV
Binding energy per nucleon for helium	7.07 MeV
Binding energy per nucleon for thorium	7.60 MeV

(i) Calculate the binding energy per nucleon for uranium-238. [3]

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(ii) Calculate the ratio $\frac{\text{kinetic energy of alpha particle}}{\text{kinetic energy of thorium nucleus}}$. [2]

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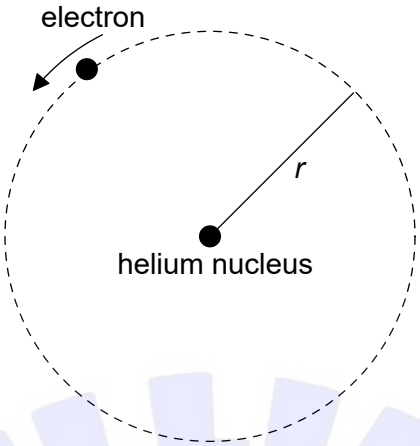
8. (a) In a classical model of the singly-ionized helium atom, a single electron orbits the nucleus in a circular orbit of radius r.



(i) Show that the speed v of the electron with mass m, is given by $v = \sqrt{\frac{2ke^2}{mr}}$. [1]

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(ii) Hence, deduce that the total energy of the electron is given by $E_{TOT} = -\frac{ke^2}{r}$. [2]

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(iii) In this model the electron loses energy by emitting electromagnetic waves. Describe the predicted effect of this emission on the orbital radius of the electron. [2]

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(Question 8 continued)

(b) The Bohr model for hydrogen can be applied to the singly-ionized helium atom. In this model the radius r, in m, of the orbit of the electron is given by $r = 2.7 \times 10^{-11} \times n^2$ where n is a positive integer.

(i) Show that the de Broglie wavelength λ of the electron in the $n = 3$ state is $\lambda = 5.1 \times 10^{-10}$ m.

The formula for the de Broglie wavelength of a particle is $\lambda = \frac{h}{mv}$. [2]

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(ii) Estimate for $n = 3$, the ratio $\frac{\text{circumference of orbit}}{\text{de Broglie wavelength of electron}}$.

State your answer to one significant figure. [1]

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(c) The description of the electron is different in the Schrodinger theory than in the Bohr model. Compare and contrast the description of the electron according to the Bohr model and to the Schrodinger theory. [3]

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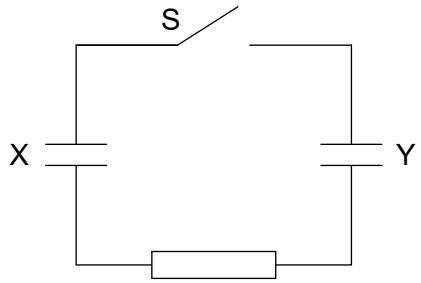
9. X has a capacitance of 18 μF. X is charged so that the one plate has a charge of 48 μC. X is then connected to an uncharged capacitor Y and a resistor via an open switch S.



(a) Calculate, in J, the energy stored in X with the switch S open. [2]

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(b) The capacitance of Y is 12 μF. S is now closed.

(i) Calculate the final charge on X and the final charge on Y. [3]

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(ii) Calculate the final total energy, in J, stored in X and Y. [2]

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(Question 9 continued)

(c) Suggest why the answers to (a) and (b)(ii) are different. [2]

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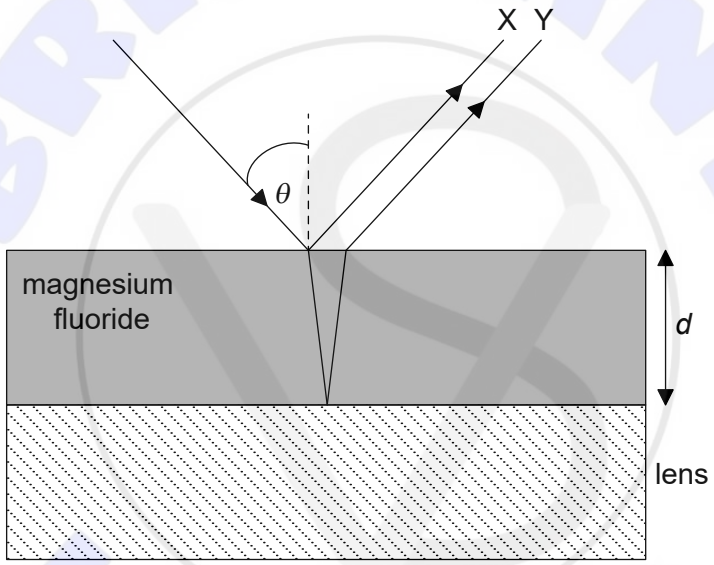
10. The lens of an optical system is coated with a thin film of magnesium fluoride of thickness *d*. Monochromatic light of wavelength 656 nm in air is incident on the lens. The angle of incidence is θ. Two reflected rays, X and Y, are shown.



The following refractive indices are available.

Air	= 1.00
Magnesium fluoride	= 1.38
Lens	= 1.58

(a) Predict whether reflected ray X undergoes a phase change. [2]

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(Question 10 continued)

(b) The thickness of the magnesium fluoride film is d. For the case of normal incidence ($\theta = 0$),

(i) state, in terms of d, the path difference between the reflected rays X and Y. [1]

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(ii) calculate the smallest value of d that will result in destructive interference between ray X and ray Y. [2]

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(iii) discuss a practical advantage of this arrangement. [2]

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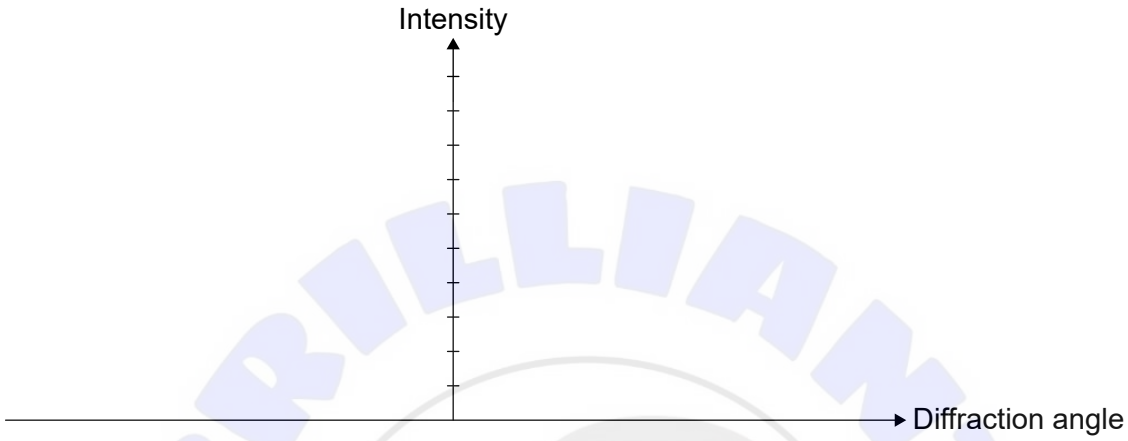
(Question 10 continued)

(c) Light from a point source is incident on the pupil of the eye of an observer. The diameter of the pupil is 2.8 mm.

(i) Draw, on the axes, the variation with diffraction angle of the intensity of light incident on the retina of the observer. [2]



(ii) Estimate, in rad, the smallest angular separation of two distinct point sources of light of wavelength 656 nm that can be resolved by the eye of this observer. [2]

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11. (a) Monochromatic light of very low intensity is incident on a metal surface. The light causes the emission of electrons almost instantaneously. Explain how this observation

(i) does not support the wave nature of light. [2]

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(ii) does support the photon nature of light. [2]

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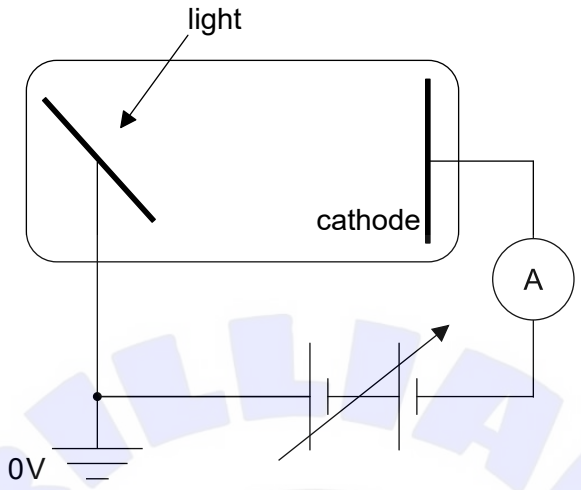
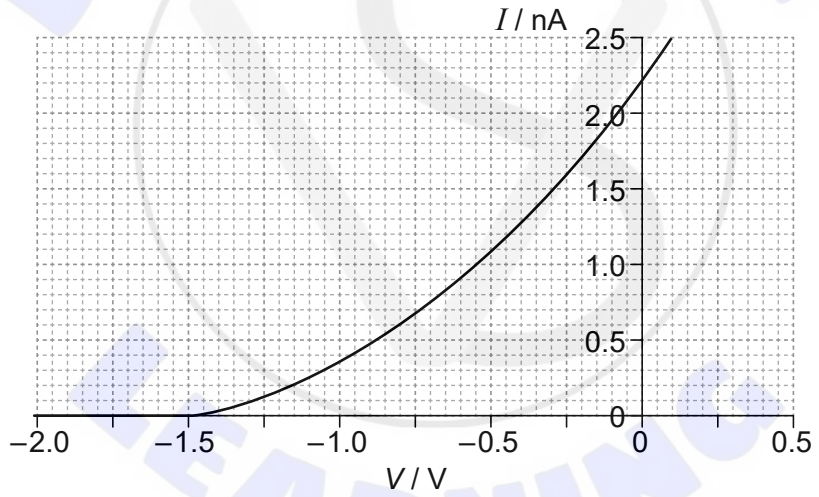
(Question 11 continued)

(b) In an experiment to demonstrate the photoelectric effect, light of wavelength 480 nm is incident on a metal surface.



The graph shows the variation of the current I in the ammeter with the potential V of the cathode.



(i) Calculate, in eV, the work function of the metal surface. [3]

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(Question 11 continued)

(ii) The intensity of the light incident on the surface is reduced by half without changing the wavelength. Draw, on the graph, the variation of the current I with potential V after this change. [2]

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Answers written on this page
will not be marked.