M18/4/PHYSI/HP2/ENG/TZ1/XX

Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Thursday 10 May 2018 (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 **[95 marks]**.

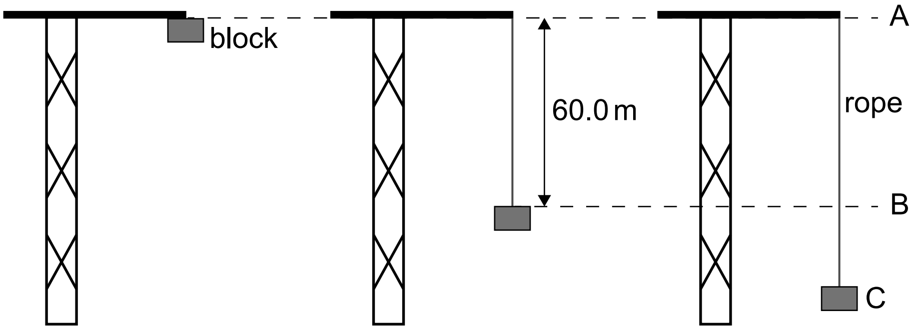
19 pages

2218 – 6508

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

1. An elastic climbing rope is tested by fixing one end of the rope to the top of a crane. The other end of the rope is connected to a block which is initially at position A. The block is released from rest. The mass of the rope is negligible.

diagram not to scale



The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

(a) At position B the rope starts to extend. Calculate the speed of the block at position B. [2]

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(b) At position C the speed of the block reaches zero. The time taken for the block to fall between B and C is 0.759 s. The mass of the block is 80.0 kg.

(i) Determine the magnitude of the average resultant force acting on the block between B and C. [2]

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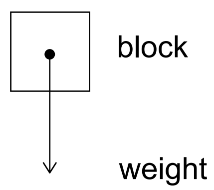
(Question 1 continued)

(ii) Sketch on the diagram the average resultant force acting on the block between B and C. The arrow on the diagram represents the weight of the block. [2]



(iii) Calculate the magnitude of the average force exerted by the rope on the block between B and C. [2]

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(Question 1 continued)

(c) For the rope and block, describe the energy changes that take place

(i) between A and B. [1]

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(ii) between B and C. [1]

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(d) The length reached by the rope at C is 77.4 m. Suggest how energy considerations could be used to determine the elastic constant of the rope. [2]

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(e) In another test, the block hangs in equilibrium at the end of the same elastic rope. The elastic constant of the rope is 400 $N m^{-1}$. The block is pulled 3.50 m vertically below the equilibrium position and is then released from rest.

(i) Calculate the time taken for the block to return to the equilibrium position for the first time. [2]

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(Question 1 continued)

(ii) Calculate the speed of the block as it passes the equilibrium position. [2]

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2. A closed box of fixed volume $0.15\,m^3$ contains 3.0 mol of an ideal monatomic gas. The temperature of the gas is 290 K

(a) Calculate the pressure of the gas. [1]

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(b) When the gas is supplied with 0.86 kJ of energy, its temperature increases by 23 K. The specific heat capacity of the gas is $3.1\,kJ\,kg^{-1}\,K^{-1}$

(i) Calculate, in kg, the mass of the gas. [1]

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(ii) Determine, in kJ, the total kinetic energy of the particles of the gas. [3]

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(c) Explain, with reference to the kinetic model of an ideal gas, how an increase in temperature of the gas leads to an increase in pressure. [3]

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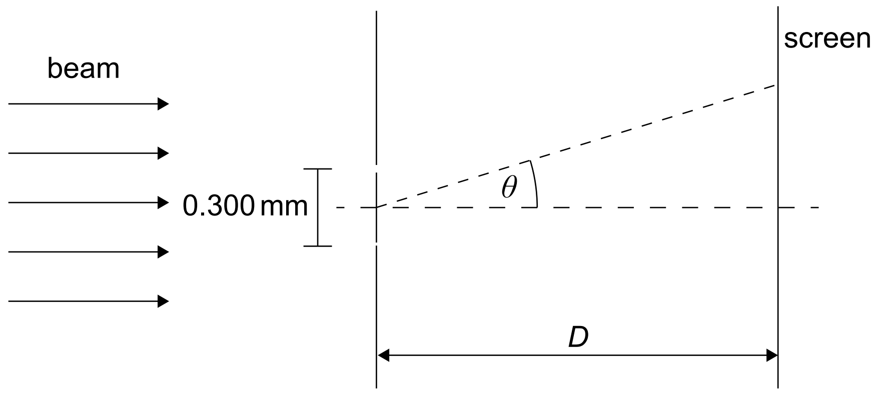
3. A beam of coherent monochromatic light from a distant galaxy is used in an optics experiment on Earth.

(a) The beam is incident normally on a double slit. The distance between the slits is 0.300 mm. A screen is at a distance *D* from the slits. The diffraction angle θ is labelled.



(i) A series of dark and bright fringes appears on the screen. Explain how a dark fringe is formed. [3]

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(ii) Outline why the beam has to be coherent in order for the fringes to be visible. [1]

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(iii) The wavelength of the beam as observed on Earth is 633.0 nm. The separation between a dark and a bright fringe on the screen is 4.50 mm. Calculate *D*. [2]

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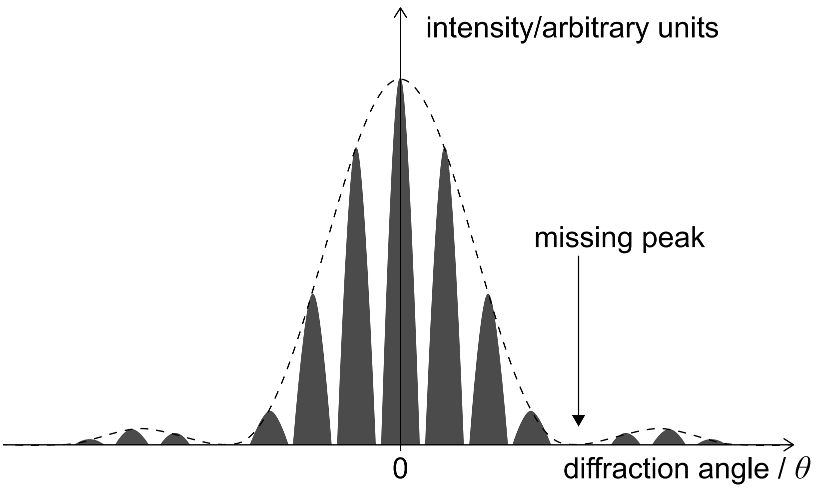
(Question 3 continued)

(b) The graph of variation of intensity with diffraction angle for this experiment is shown.



(i) Calculate the angular separation between the central peak and the missing peak in the double-slit interference intensity pattern. State your answer to an appropriate number of significant figures. [3]

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(ii) Deduce, in mm, the width of one slit. [2]

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(Question 3 continued)

(c) The wavelength of the light in the beam when emitted by the galaxy was 621.4 nm.

Explain, without further calculation, what can be deduced about the relative motion of the galaxy and the Earth. [2]

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(d) The air between the slits and the screen is replaced with water. The refractive index of water is 1.33.

(i) Calculate the wavelength of the light in water. [1]

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(ii) State **two** ways in which the intensity pattern on the screen changes. [2]

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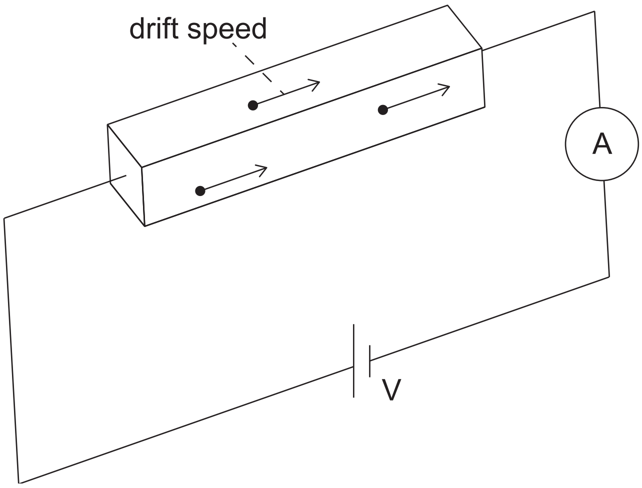
4. An ohmic conductor is connected to an ideal ammeter and to a power supply of output voltage V.



The following data are available for the conductor:

density of free electrons $= 8.5 \times 10^{22}\,\text{cm}^{-3}$
resistivity $\rho = 1.7 \times 10^{-8}\,\Omega\text{m}$
dimensions $\text{w} \times \text{h} \times \text{l} = 0.020\,\text{cm} \times 0.020\,\text{cm} \times 10\,\text{cm}$.

The ammeter reading is 2.0A.

(a) Calculate the resistance of the conductor. [2]

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(b) Calculate the drift speed *v* of the electrons in the conductor in $\text{cm}\,\text{s}^{-1}$. [2]

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(Question 4 continued)

(c) The electric field E inside the sample can be approximated as the uniform electric field between two parallel plates.

(i) Determine the electric field strength E. [2]

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(ii) Show that $\frac{v}{E} = \frac{1}{ne\rho}$. [3]

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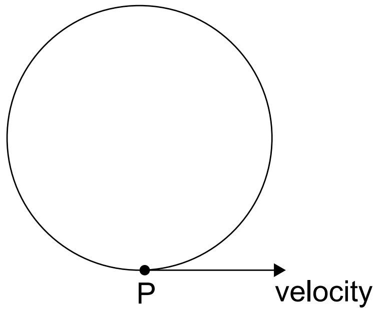
5. An electron moves in circular motion in a uniform magnetic field.



The velocity of the electron at point P is $6.8 \times 10^5\,\text{m}\,\text{s}^{-1}$ in the direction shown.
The magnitude of the magnetic field is 8.5 T.

(a) State the direction of the magnetic field. [1]

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(b) Calculate, in N, the magnitude of the magnetic force acting on the electron. [1]

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(c) Explain why the electron moves

(i) at constant speed. [1]

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(ii) on a circular path. [2]

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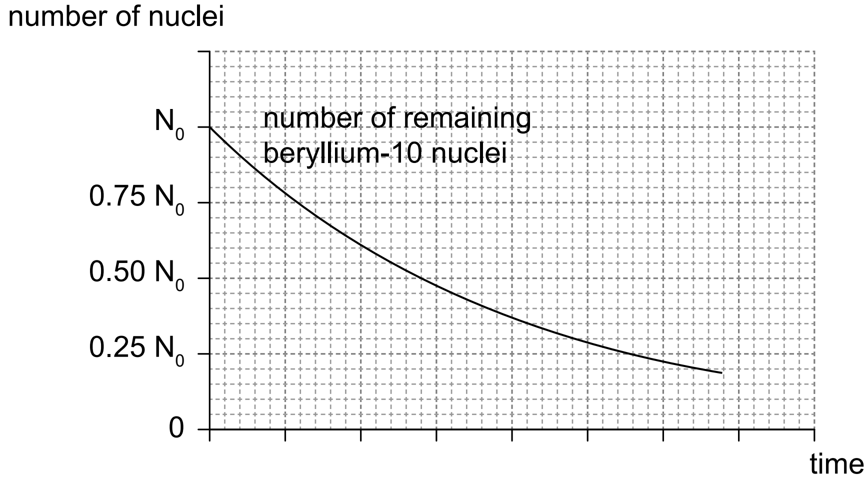
6. The radioactive nuclide beryllium-10 (Be-10) undergoes beta minus ($\beta-$) decay to form a stable boron (B) nuclide.

(a) Identify the missing information for this decay. [2]

$$^{10}_{\square}\text{Be} \rightarrow {}^{\square}_{5}\text{B} + {}^{\square}_{\square}\text{e} + {}^{0}_{0}\square$$

(b) The initial number of nuclei in a pure sample of beryllium-10 is N_0. The graph shows how the number of remaining **beryllium** nuclei in the sample varies with time.



(i) On the graph, sketch how the number of **boron** nuclei in the sample varies with time. [2]

(ii) After 4.3×10^6 years,

$$\frac{\text{number of produced boron nuclei}}{\text{number of remaining beryllium nuclei}} = 7.$$

Show that the half-life of beryllium-10 is 1.4×10^6 years. [3]

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(Question 6 continued)

(iii) Beryllium-10 is used to investigate ice samples from Antarctica. A sample of ice initially contains 7.6×10^{11} atoms of beryllium-10. The present activity of the sample is 8.0×10^{-3} Bq.

Determine, in years, the age of the sample. [3]

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(c) An ice sample is moved to a laboratory for analysis. The temperature of the sample is –20 ˚C.

(i) State what is meant by thermal radiation. [1]

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(ii) Discuss how the frequency of the radiation emitted by a black body can be used to estimate the temperature of the body. [2]

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(Question 6 continued)

(iii) Calculate the peak wavelength in the intensity of the radiation emitted by the ice sample. [2]

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(iv) The temperature in the laboratory is higher than the temperature of the ice sample. Describe **one** other energy transfer that occurs between the ice sample and the laboratory. [2]

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(v) Derive the units of intensity in terms of fundamental SI units. [2]

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7. A capacitor consists of two parallel square plates separated by a vacuum. The plates are 2.5 cm × 2.5 cm squares. The capacitance of the capacitor is 4.3 pF.

(a) Calculate the distance between the plates. [1]

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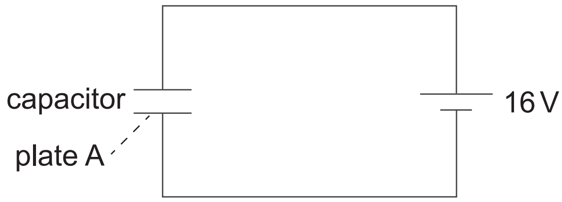
(b) The capacitor is connected to a 16 V cell as shown.

diagram not to scale



Calculate the magnitude and the sign of the charge on plate A when the capacitor is fully charged. [2]

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(c) The capacitor is fully charged and the space between the plates is then filled with a dielectric of permittivity $\varepsilon = 3.0\varepsilon_0$.

Explain whether the magnitude of the charge on plate A increases, decreases or stays constant. [2]

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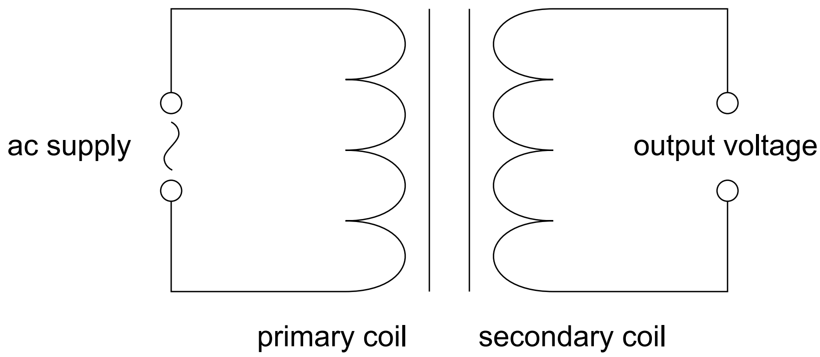
(Question 7 continued)

(d) In a different circuit, a transformer is connected to an alternating current (ac) supply.



The transformer has 100 turns in the primary coil and 1200 turns in the secondary coil. The peak value of the voltage of the ac supply is 220 V. Determine the root mean square (rms) value of the output voltage. [3]

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(e) Describe the use of transformers in electrical power distribution. [3]

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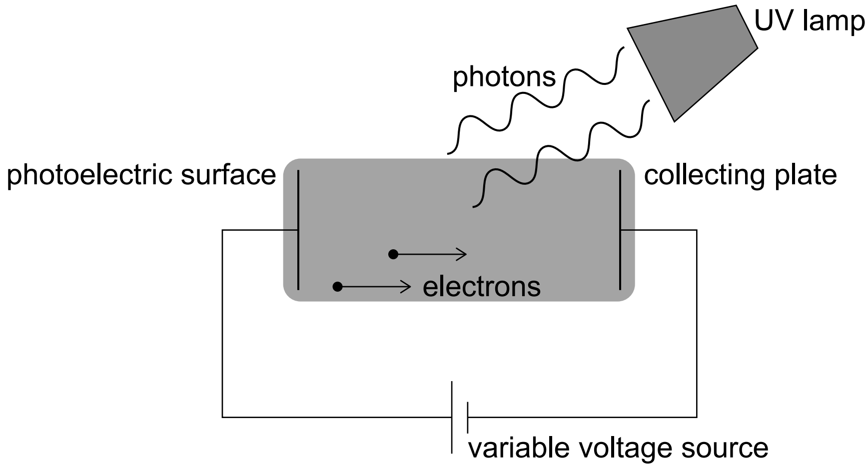
8. Hydrogen atoms in an ultraviolet (UV) lamp make transitions from the first excited state to the ground state. Photons are emitted and are incident on a photoelectric surface as shown.



(a) Show that the energy of photons from the UV lamp is about 10 eV. [2]

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(b) The photons cause the emission of electrons from the photoelectric surface. The work function of the photoelectric surface is 5.1 eV.

(i) Calculate, in J, the maximum kinetic energy of the emitted electrons. [2]

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(ii) Suggest, with reference to conservation of energy, how the variable voltage source can be used to stop all emitted electrons from reaching the collecting plate. [2]

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(Question 8 continued)

(iii) The variable voltage can be adjusted so that no electrons reach the collecting plate. Write down the minimum value of the voltage for which no electrons reach the collecting plate. [1]

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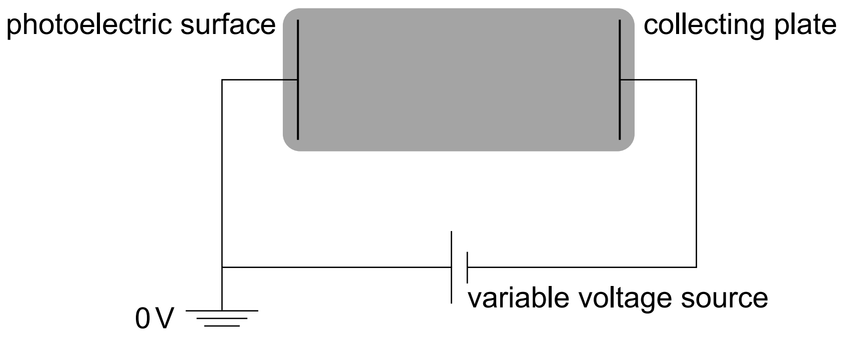
(c) The electric potential of the photoelectric surface is 0 V. The variable voltage is adjusted so that the collecting plate is at –1.2 V.



(i) On the diagram, draw and label the equipotential lines at –0.4 V and –0.8 V. [2]

(ii) An electron is emitted from the photoelectric surface with kinetic energy 2.1 eV. Calculate the speed of the electron at the collecting plate. [2]

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Please **do not** write on this page.

Answers written on this page
will not be marked.