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PHYSICS
STANDARD LEVEL
PAPER 2

Candidate session number

Thursday 6 November 2014 (morning)

1 hour 15 minutes

Examination code

8	8	1	4	–	6	5	0	5

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 one question.
- 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 *[50 marks]*.

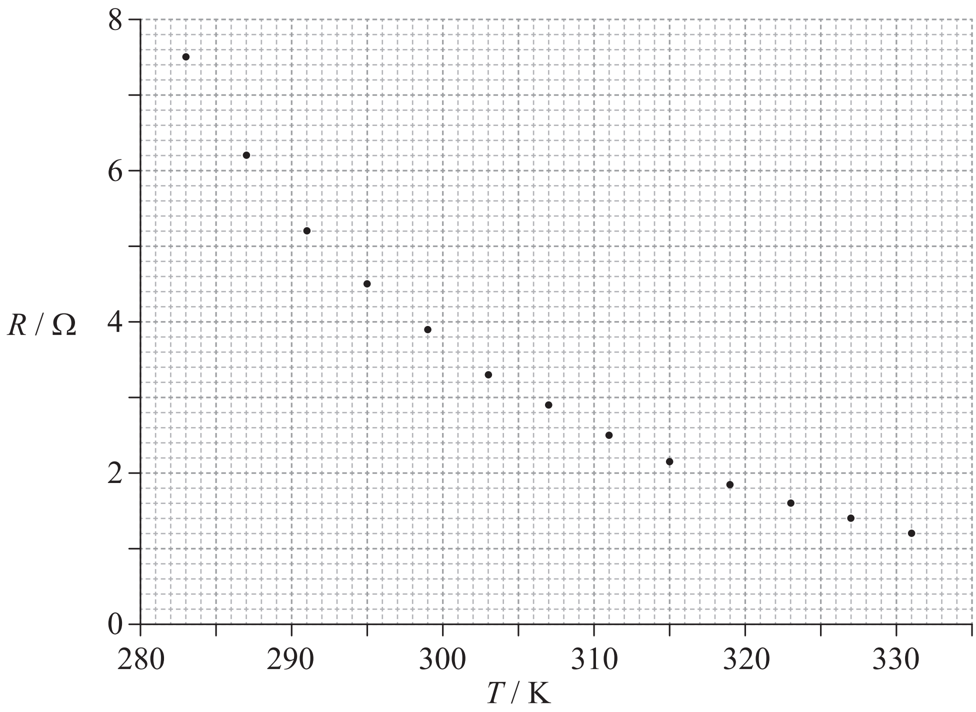
28 pages

SECTION A

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

1. Data analysis question.

A student sets up a circuit to study the variation of resistance *R* of a negative temperature coefficient (NTC) thermistor with temperature *T*. The data are shown plotted on the graph.



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

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(Question 1 continued)

(b) (i) Calculate the gradient of the graph when $T = 291\,K$. *[3]*

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(ii) State the unit for your answer to (b)(i). *[1]*

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(c) The uncertainty in the resistance value is 5%. The uncertainty in the temperature is negligible. On the graph, draw error bars for the data point at $T = 283\,K$ and for the data point at $T = 319\,K$. *[2]*

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Turn over

(Question 1 continued)

(d) The electric current through the thermistor for $T = 283\,\text{K}$ is 0.78 mA. The uncertainty in the electric current is 0.01 mA.

(i) Calculate the power dissipated by the thermistor at $T = 283\text{K}$. *[1]*

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(ii) Determine the uncertainty in the power dissipated by the thermistor at $T = 283\,\text{K}$. *[3]*

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2. This question is about the internal resistance of a cell.

(a) Define *electromotive force (emf)*. *[1]*

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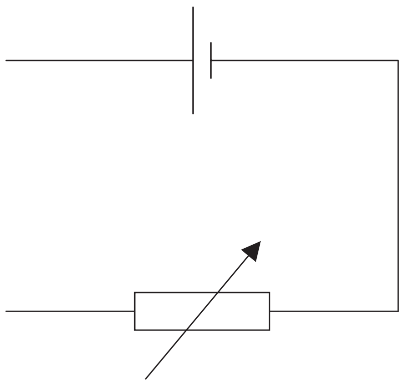
(b) A circuit is used to determine the internal resistance and emf of a cell. It consists of the cell, a variable resistor, an ideal ammeter and an ideal voltmeter. The diagram shows part of the circuit with the ammeter and voltmeter missing.



The variable resistor is set to 1.5 Ω. When the cell converts 7.2 mJ of energy, 5.8 mC of charge moves completely around the circuit. The potential difference across the variable resistor is 0.55 V.

(i) Draw on the diagram the positions of the ammeter and voltmeter. *[1]*

(ii) Show that the emf of the cell is 1.25 V. *[1]*

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(Question 2 continued)

(iii) Determine the internal resistance of the cell. *[2]*

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(iv) Calculate the energy dissipated per second in the variable resistor. *[2]*

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3. This question is about radioactive decay.

A nucleus of an iodine isotope, I-131, undergoes radioactive decay to form a nucleus of the nuclide xenon-131. Xe-131 is stable.

(a) Explain what is meant by an isotope. *[2]*

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(b) Identify the missing entries to complete the nuclear reaction for the decay of I-131. *[1]*

$${}^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{\dots\dots}\mathrm{Xe} + \beta^{-} + \dots\dots\dots\dots\dots$$

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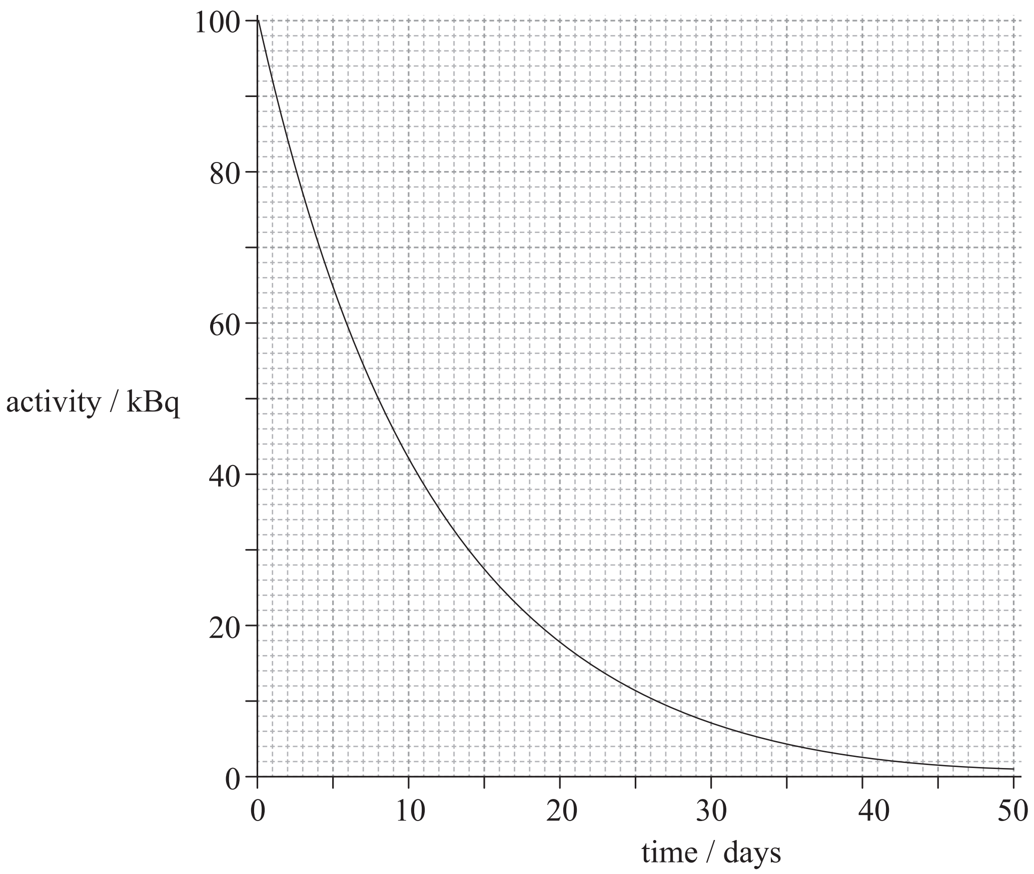
(Question 3 continued)

(c) The initial activity of a sample of I-131 is 100 kBq. The subsequent variation of the activity of the sample with time is shown in the graph.



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(Question 3 continued)

(i) The I-131 can be used for a medical application but only when the activity lies within the range of (20 ± 10) kBq. Determine an estimate for the time during which the iodine can be used. *[2]*

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(ii) A different isotope has half the initial activity and double the half-life of I-131. On the graph in (c), sketch the variation of activity with time for this isotope. *[2]*

SECTION B

*This section consists of three questions: 4, 5 and 6. Answer **one** question. Write your answers in the boxes provided.*

4. This question is in **two** parts. **Part 1** is about the motion of a ship. **Part 2** is about melting ice.

Part 1 Motion of a ship

(a) Outline the meaning of work. *[2]*

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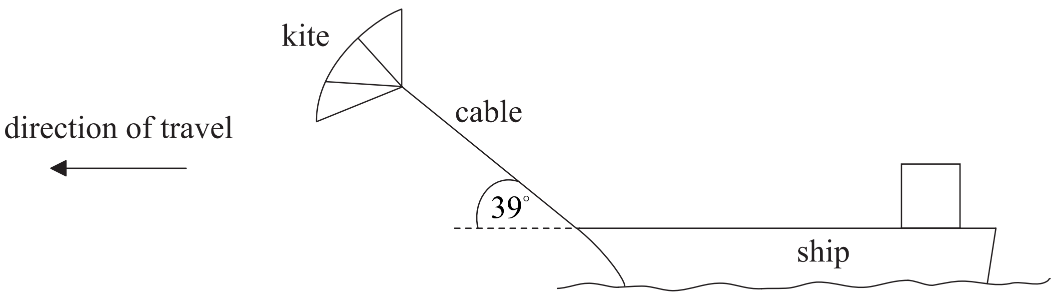
(b) Some cargo ships use kites working together with the ship's engines to move the vessel.



The tension in the cable that connects the kite to the ship is 250 kN. The kite is pulling the ship at an angle of 39° to the horizontal. The ship travels at a steady speed of $8.5\ \text{m s}^{-1}$ when the ship's engines operate with a power output of 2.7 MW.

(i) Calculate the work done on the ship by the kite when the ship travels a distance of 1.0 km. *[2]*

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(This question continues on the following page)

(Question 4, part 1 continued)

(ii) Show that, when the ship is travelling at a speed of $8.5\,\text{m s}^{-1}$, the kite provides about 40 % of the total power required by the ship. *[4]*

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(c) The kite is taken down and no longer produces a force on the ship. The resistive force F that opposes the motion of the ship is related to the speed v of the ship by

$$F = kv^2$$

where k is a constant.

Show that, if the power output of the engines remains at 2.7 MW, the speed of the ship will decrease to about $7\,\text{m s}^{-1}$. Assume that k is independent of whether the kite is in use or not. *[3]*

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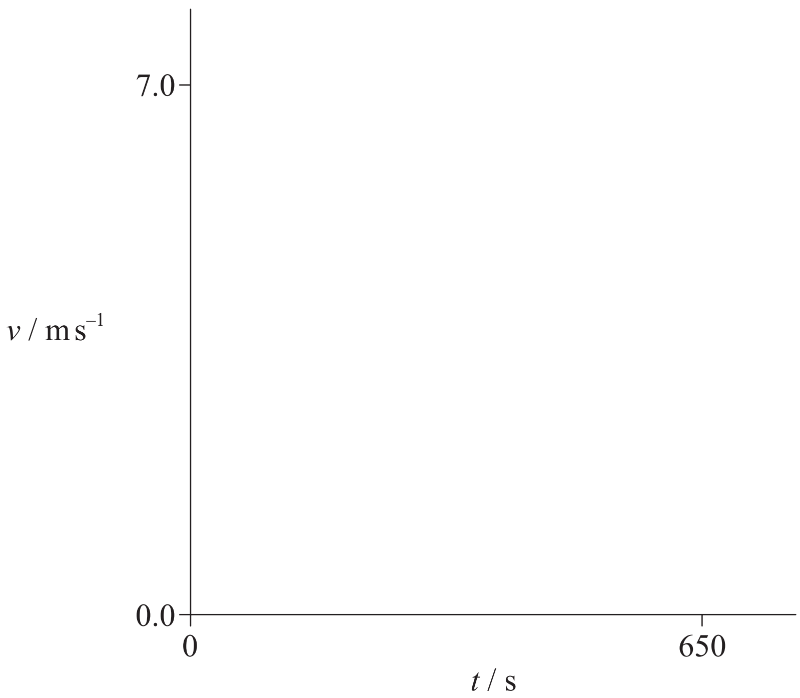
(Question 4, part 1 continued)

(d) The ship's engines are switched off and the ship comes to rest from a speed of 7 m s^{-1} in a time of 650 s.

(i) Estimate the distance that the ship takes to stop. Assume that the acceleration is uniform. *[2]*

(ii) It is unlikely that the acceleration of the ship will be uniform given that the resistive force acting on the ship depends on the speed of the ship. Using the axes, sketch a graph to show how the speed *v* varies with time *t* after the ship's engines are switched off. *[2]*



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(Question 4 continued)

Part 2 Melting ice

(e) Describe, with reference to molecular behaviour, the process of melting ice. *[2]*

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(This question continues on the following page)

(Question 4, part 2 continued)

(f) A container of negligible mass, isolated from its surroundings, contains 0.150 kg of ice at a temperature of –18.7 °C. An electric heater supplies energy at a rate of 125 W.

(i) After a time interval of 45.0 s all of the ice has reached a temperature of 0 °C without any melting. Calculate the specific heat capacity of ice. *[2]*

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(ii) The following data are available.

Specific heat capacity of water $= 4200\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$
Specific latent heat of fusion of ice $= 3.30 \times 10^{5}\,\text{J}\,\text{kg}^{-1}$

Determine the final temperature of the water when the heater supplies energy for a further 600 s. *[3]*

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(This question continues on the following page)

(Question 4, part 2 continued)

(g) The whole of the experiment in (f)(i) and (f)(ii) is repeated with a container of negligible mass that is not isolated from the surroundings. The temperature of the surroundings is 18 °C. Comment on the final temperature of the water in (f)(ii). *[3]*

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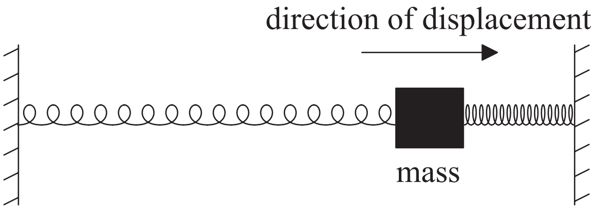
5. This question is in **two** parts. **Part 1** is about the oscillation of a mass. **Part 2** is about nuclear fission.

Part 1 Oscillation of a mass

A mass of 0.80 kg rests on a frictionless surface and is connected to two identical springs both of which are fixed at their other ends. A force of 0.030 N is required to extend or compress each spring by 1.0 mm. When the mass is at rest in the centre of the arrangement, the springs are not extended.

(a) The mass is displaced to the right by 60 mm and released.



(not to scale)

(i) Determine the acceleration of the mass at the moment of release. *[3]*

(ii) Outline why the mass subsequently performs simple harmonic motion (SHM). *[2]*

(This question continues on the following page)

(Question 5, part 1 continued)

(iii) Calculate the period of oscillation of the mass. *[2]*

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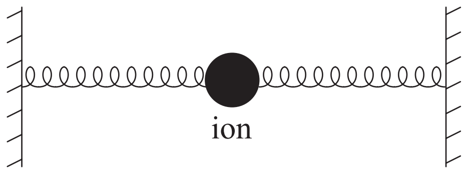
(Question 5, part 1 continued)

(b) The motion of an ion in a crystal lattice can be modelled using the mass–spring arrangement. The inter-atomic forces may be modelled as forces due to springs as in the arrangement shown.



The frequency of vibration of a particular ion is 7×10^{12} Hz and the mass of the ion is 5×10^{-26} kg. The amplitude of vibration of the ion is 1×10^{-11} m.

(i) Estimate the maximum kinetic energy of the ion. *[2]*

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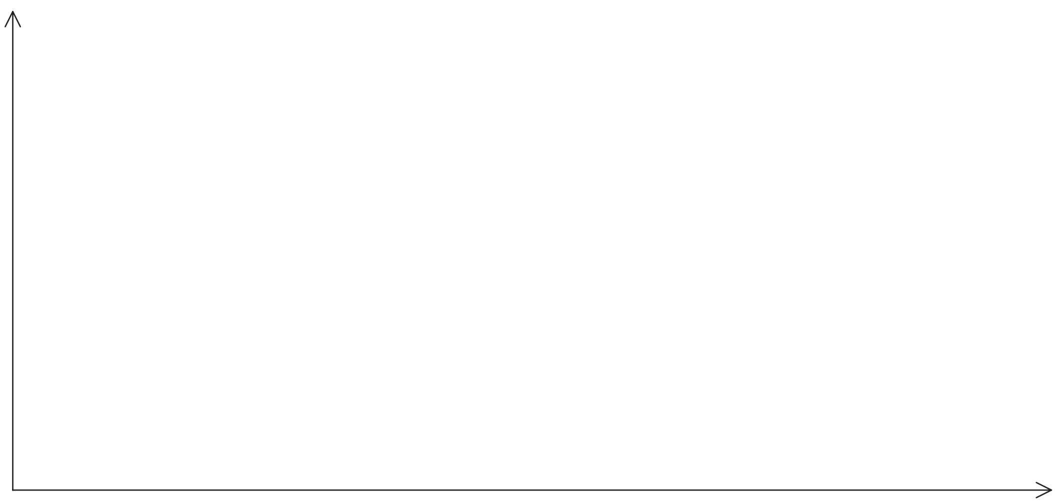
(ii) On the axes, draw a graph to show the variation with time of the kinetic energy of mass and the elastic potential energy stored in the springs. You should add appropriate values to the axes, showing the variation over one period. *[3]*



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(Question 5, part 1 continued)

(c) (i) Calculate the wavelength of an infrared wave with a frequency equal to that of the model in (b). *[1]*

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(ii) Explain how the model in (b) predicts how the lattice will absorb a certain wavelength of electromagnetic infrared radiation. *[2]*

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(Question 5 continued)

Part 2 Nuclear fission

(d) A reaction that takes place in the core of a particular nuclear reactor is as shown.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{89}_{36}Kr + 3^{1}_{0}n$$

In the nuclear reactor, 9.5×10^{19} fissions take place every second. Each fission gives rise to 200 MeV of energy that is available for conversion to electrical energy. The overall efficiency of the nuclear power station is 32 %.

(i) Determine the mass of U-235 that undergoes fission in the reactor every day. *[3]*

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(ii) Calculate the power output of the nuclear power station. *[2]*

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(Question 5, part 2 continued)

(e) In addition to the U-235, the nuclear reactor contains a moderator and control rods. Explain the function of the

(i) moderator. *[3]*

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(ii) control rods. *[2]*

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6. This question is in **two** parts. **Part 1** is about energy resources. **Part 2** is about electric fields.

Part 1 Energy resources

(a) The Sun is a renewable energy source whereas a fossil fuel is a non-renewable energy source. Outline the difference between renewable and non-renewable energy sources. *[2]*

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(b) With reference to the energy transformations and the operation of the devices, distinguish between a photovoltaic cell and a solar heating panel. *[2]*

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(Question 6, part 1 continued)

(c) A photovoltaic panel is made up of a collection (array) of photovoltaic cells. The panel has a total area of $1.3\,m^2$ and is mounted on the roof of a house. The maximum intensity of solar radiation at the location of the panel is $750\,W\,m^{-2}$. The panel produces a power output of $210\,W$ when the solar radiation is at its maximum intensity.

(i) Determine the efficiency of the photovoltaic panel. *[2]*

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(ii) State **two** reasons why the intensity of solar radiation at the location of the panel is not constant. *[2]*

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(Question 6, part 1 continued)

(d) The owner of the house chooses between photovoltaic panels and solar heating panels to provide 4.2 kW of power to heat water. The solar heating panels have an efficiency of 70 %. The maximum intensity of solar radiation at the location remains at $750\,W\,m^{-2}$.

(i) Calculate the minimum area of solar heating panel required to provide this power. *[2]*

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(ii) Comment on whether it is better to use a solar heating panel rather than an array of photovoltaic panels for the house. Do not consider the installation cost of the panels in your answer. *[2]*

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(e) The use of solar energy is a way by which nations can fulfil their obligations under the Kyoto Protocol. Identify **one** aim of the Kyoto Protocol and outline the steps a nation might take to meet its commitments under the protocol. *[3]*

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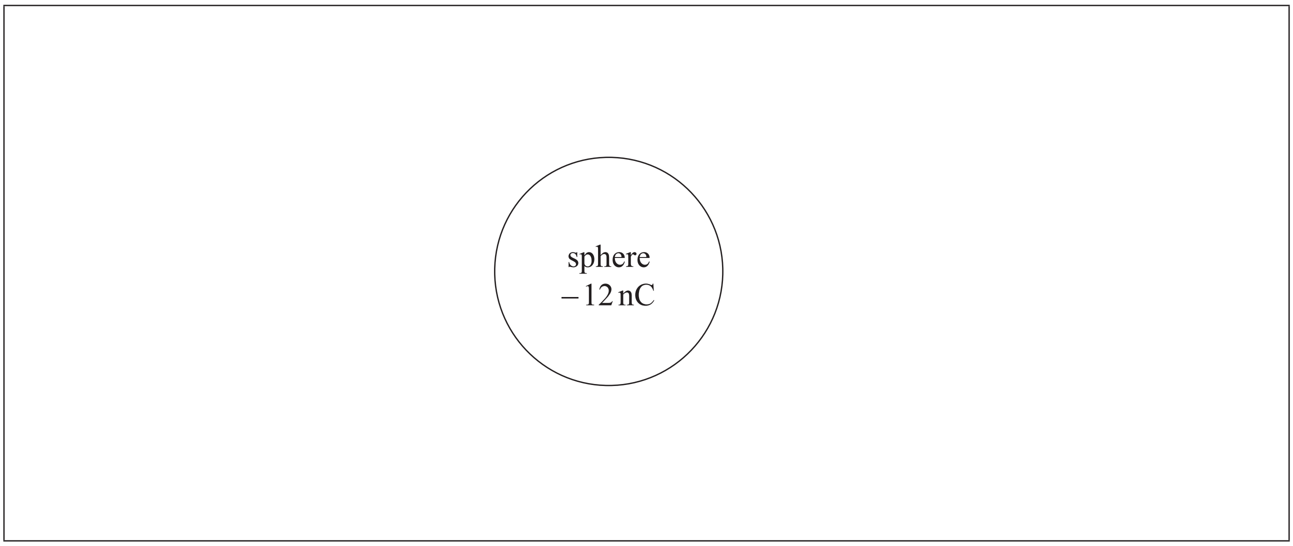
(Question 6 continued)

Part 2 Electric fields

An isolated metal sphere is placed in a vacuum. The sphere has a negative charge of magnitude 12 nC.



(f) Using the diagram, draw the electric field pattern due to the charged sphere. *[2]*

(g) Outside the sphere, the electric field strength is equivalent to that of a point negative charge of magnitude 12 nC placed at the centre of the sphere. The radius *r* of the sphere is 25 mm.

(i) Show that the magnitude of the electric field strength at the surface of the sphere is about $2 \times 10^{5}\,\mathrm{N\,C^{-1}}$. *[2]*

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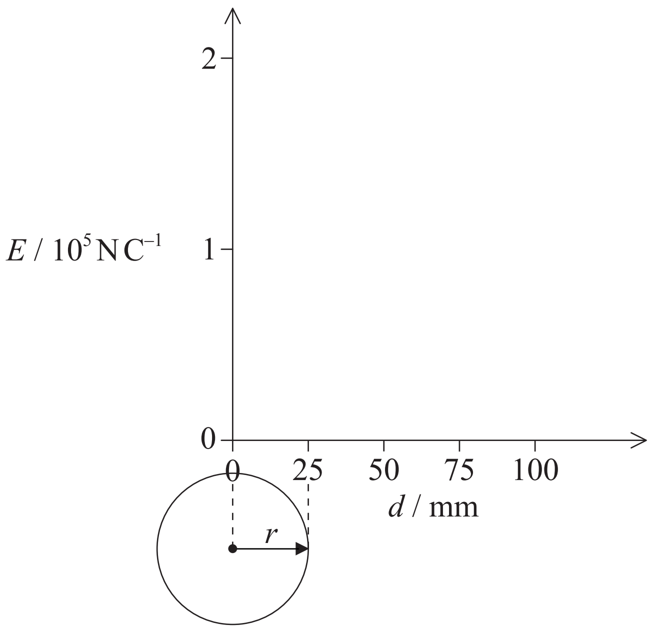
(Question 6, part 2 continued)

(ii) On the axes, draw a graph to show the variation of the electric field strength E with distance d from the centre of the sphere. *[2]*



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(Question 6, part 2 continued)

(h) An electron is initially at rest on the surface of the sphere.

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

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(ii) Discuss the subsequent motion of the electron. *[2]*

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