Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Tuesday 31 October 2017 (afternoon)

Candidate session number

2 hours 15 minutes

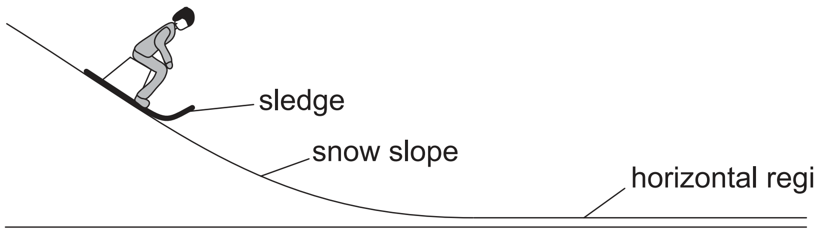
Instructions to candidates

- 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]**.

8817 – 6502

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

1. A girl on a sledge is moving down a snow slope at a uniform speed.



(a) Draw the free-body diagram for the sledge at the position shown on the snow slope. [2]

(b) After leaving the snow slope, the girl on the sledge moves over a horizontal region of snow. Explain, with reference to the physical origin of the forces, why the vertical forces on the girl must be in equilibrium as she moves over the horizontal region. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question 1 continued)

(c) When the sledge is moving on the horizontal region of the snow, the girl jumps off the sledge. The girl has no horizontal velocity after the jump. The velocity of the sledge immediately after the girl jumps off is $4.2\ m\ s^{-1}$. The mass of the girl is 55 kg and the mass of the sledge is 5.5 kg. Calculate the speed of the sledge immediately before the girl jumps from it. [2]

. . . .

. . . .

. . . .

. . . .

(d) The girl chooses to jump so that she lands on loosely-packed snow rather than frozen ice. Outline why she chooses to land on the snow. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question 1 continued)

(e) The sledge, without the girl on it, now travels up a snow slope that makes an angle of 6.5° to the horizontal. At the start of the slope, the speed of the sledge is $4.2\ m\ s^{-1}$. The coefficient of dynamic friction of the sledge on the snow is 0.11.

(i) Show that the acceleration of the sledge is about $-2\ m\ s^{-2}$. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(ii) Calculate the distance along the slope at which the sledge stops moving. Assume that the coefficient of dynamic friction is constant. [2]

. . . .

. . . .

. . . .

. . . .

(f) The coefficient of static friction between the sledge and the snow is 0.14. Outline, with a calculation, the subsequent motion of the sledge. [2]

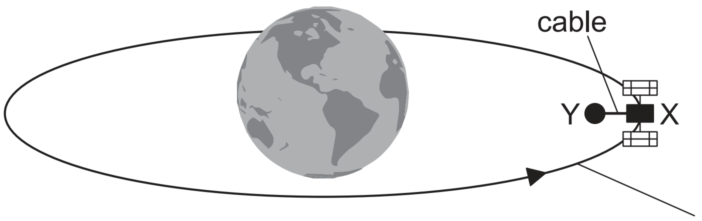
. . . .

. . . .

. . . .

. . . .

2. There is a proposal to power a space satellite X as it orbits the Earth. In this model, X is connected by an electronically-conducting cable to another smaller satellite Y.



(a) Satellite X orbits 6600 km from the centre of the Earth.

Mass of the Earth $= 6.0 \times 10^{24}$ kg

Show that the orbital speed of satellite X is about 8 km s^{-1}. [2]

. . . .

. . . .

. . . .

. . . .

(b) Satellite Y orbits closer to the centre of Earth than satellite X. Outline why

(i) the orbital times for X and Y are different. [1]

. . . .

. . . .

(ii) satellite Y requires a propulsion system. [2]

. . . .

. . . .

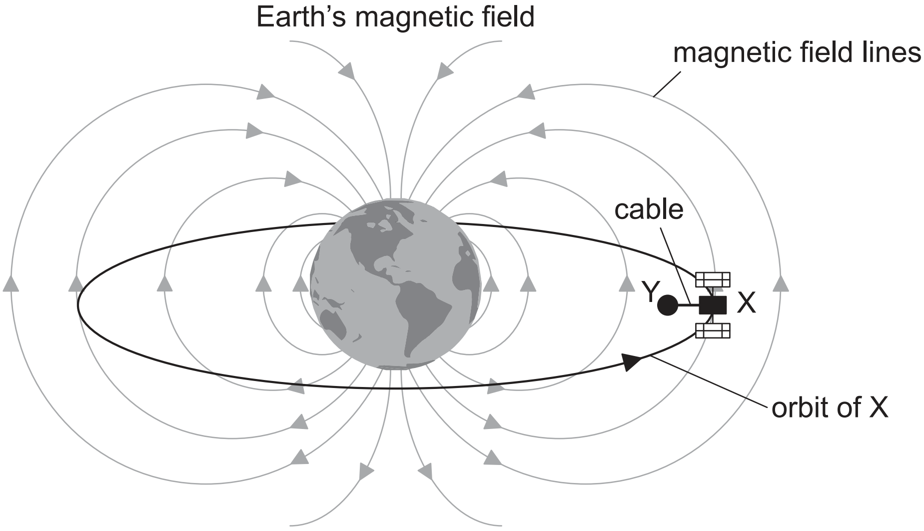
. . . .

. . . .

(This question continues on the following page)

(Question 2 continued)

(c) The cable between the satellites cuts the magnetic field lines of the Earth at right angles.



not to scale

Explain why satellite X becomes positively charged. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(d) Satellite X must release ions into the space between the satellites. Explain why the current in the cable will become zero unless there is a method for transferring charge from X to Y. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question 2 continued)

(e) The magnetic field strength of the Earth is 31 μT at the orbital radius of the satellites. The cable is 15 km in length. Calculate the emf induced in the cable. [2]

. . . .

. . . .

. . . .

. . . .

(f) The cable acts as a spring. Satellite Y has a mass *m* of 3.5×10^2 kg. Under certain circumstances, satellite Y will perform simple harmonic motion (SHM) with a period *T* of 5.2 s.

(i) Estimate the value of *k* in the following expression.

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Give an appropriate unit for your answer. Ignore the mass of the cable and any oscillation of satellite X. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(ii) Describe the energy changes in the satellite Y-cable system during one cycle of the oscillation. [2]

. . . .

. . . .

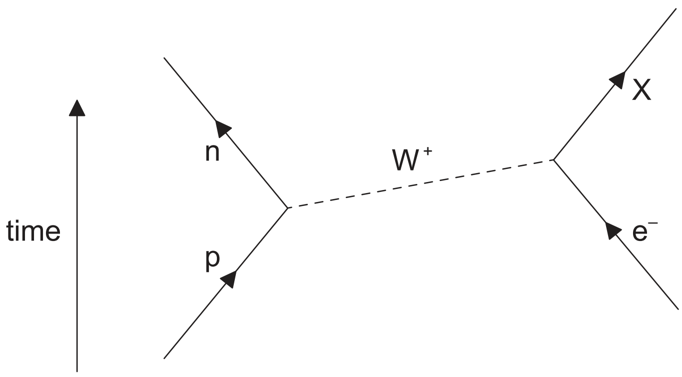
. . . .

. . . .

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

Answers written on this page
will not be marked.

3. (a) The Feynman diagram shows electron capture.



(i) State and explain the nature of the particle labelled X. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(ii) Distinguish between hadrons and leptons. [2]

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question 3 continued)

(b) Particles can be used in scattering experiments to estimate nuclear sizes.

(i) Outline how these experiments are carried out. [2]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(ii) Outline why the particles must be accelerated to high energies in scattering experiments. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(c) State and explain **one** example of a scientific analogy. [2]

. . . .

. . . .

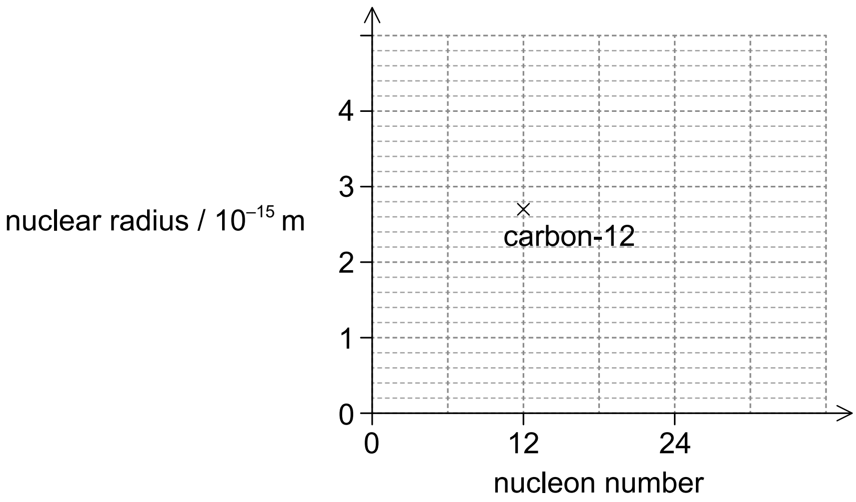
. . . .

. . . .

(This question continues on the following page)

(Question 3 continued)

(d) Electron diffraction experiments indicate that the nuclear radius of carbon-12 $\left({}^{12}_{6}\text{C}\right)$ is 2.7×10^{-15} m. The graph shows the variation of nuclear radius with nucleon number. The nuclear radius of the carbon-12 is shown on the graph.



(i) Determine the radius of the magnesium-24 $\left({}^{24}_{12}\text{Mg}\right)$ nucleus. [2]

. . . .

. . . .

. . . .

. . . .

. . . .

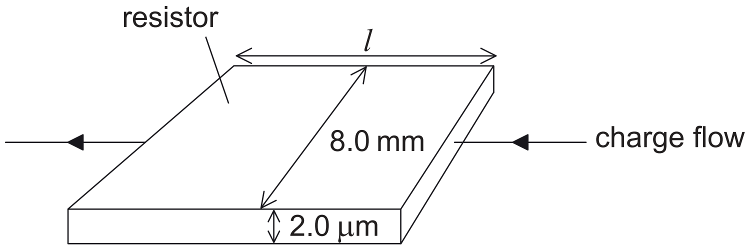
. . . .

(ii) Plot the position of magnesium-24 on the graph. [1]

(iii) Draw a line on the graph, to show the variation of nuclear radius with nucleon number. [2]

4. Electrical resistors can be made by forming a thin film of carbon on a layer of an insulating material.

(a) A carbon film resistor is made from a film of width 8.0 mm and of thickness 2.0 μm. The diagram shows the direction of charge flow through the resistor.



not to scale

(i) The resistance of the carbon film is 82 Ω. The resistivity of carbon is $4.1\times10^{-5}\,\Omega\,\text{m}$. Calculate the length l of the film. [1]

. . . .

. . . .

. . . .

. . . .

(ii) The film must dissipate a power less than 1500 W from each square metre of its surface to avoid damage. Calculate the maximum allowable current for the resistor. [2]

. . . .

. . . .

. . . .

. . . .

(iii) State why knowledge of quantities such as resistivity is useful to scientists. [1]

. . . .

. . . .

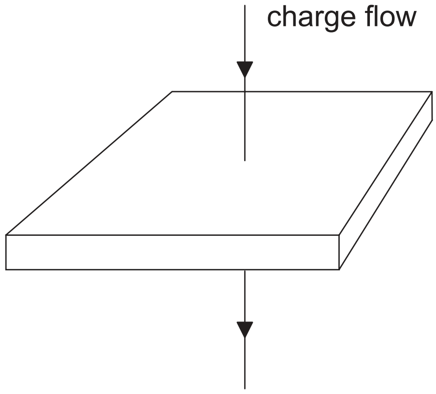
. . . .

. . . .

(This question continues on the following page)

(Question 4 continued)

(b) The current direction is now changed so that charge flows vertically through the film.



not to scale

Deduce, without calculation, the change in the resistance. [2]

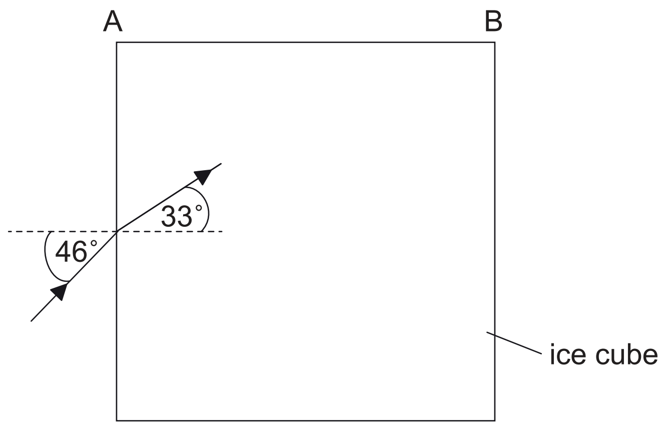
. . . .

. . . .

. . . .

. . . .

5. (a) A large cube is formed from ice. A light ray is incident from a vacuum at an angle of 46˚ to the normal on one surface of the cube. The light ray is parallel to the plane of one of the sides of the cube. The angle of refraction inside the cube is 33˚.



(i) Calculate the speed of light inside the ice cube. [2]

. . . .
. . . .
. . . .
. . . .

(ii) Show that no light emerges from side AB. [3]

. . . .
. . . .
. . . .
. . . .
. . . .
. . . .

(iii) Sketch, on the diagram, the subsequent path of the light ray. [2]

(This question continues on the following page)

(Question 5 continued)

(b) Each side of the ice cube is 0.75 m in length. The initial temperature of the ice cube is –20 °C.

(i) Determine the energy required to melt all of the ice from –20 °C to water at a temperature of 0 °C. [4]

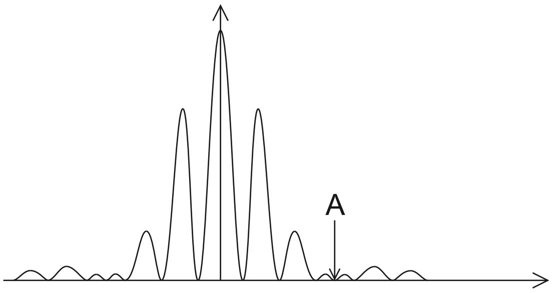
Specific latent heat of fusion of ice $= 330\ \text{kJ kg}^{-1}$
Specific heat capacity of ice $= 2.1\ \text{kJ kg}^{-1}\ \text{K}^{-1}$
Density of ice $= 920\ \text{kg m}^{-3}$

. . . .
. . . .
. . . .
. . . .
. . . .
. . . .
. . . .
. . . .

(ii) Outline the difference between the molecular structure of a solid and a liquid. [1]

. . . .
. . . .
. . . .
. . . .

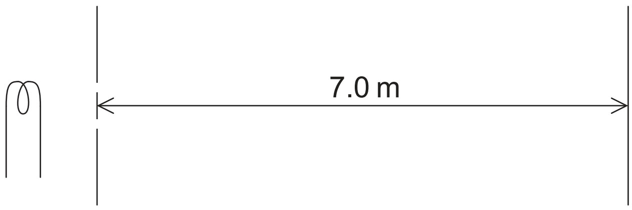
6. (a) Yellow light from a sodium lamp of wavelength 590 nm is incident at normal incidence on a double slit. The resulting interference pattern is observed on a screen. The intensity of the pattern on the screen is shown.



(i) Explain why zero intensity is observed at position A. [2]

. . . .
. . . .
. . . .
. . . .

(ii) The distance from the centre of the pattern to A is 4.1×10^{-2} m. The distance from the screen to the slits is 7.0 m.



Calculate the width of each slit. [2]

. . . .
. . . .
. . . .
. . . .

(This question continues on the following page)

(Question 6 continued)

(iii) Calculate the separation of the two slits. [2]

. . . .

. . . .

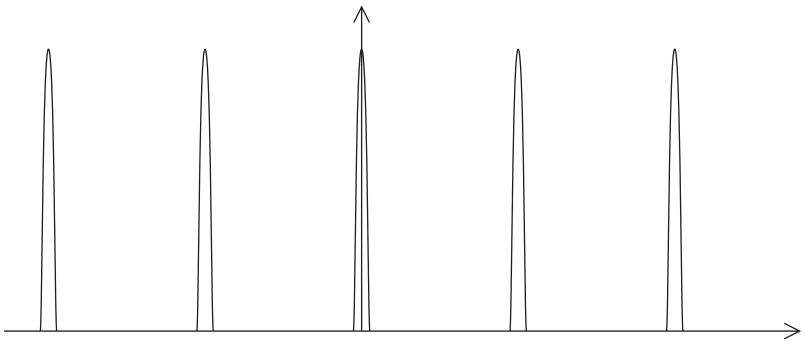
. . . .

. . . .

(This question continues on the following page)

(Question 6 continued)

(b) The double slit is replaced by a diffraction grating that has 600 lines per millimetre. The resulting pattern on the screen is shown.



(i) State and explain the differences between the pattern on the screen due to the grating and the pattern due to the double slit. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(ii) The yellow light is made from two very similar wavelengths that produce two lines in the spectrum of sodium. The wavelengths are 588.995 nm and 589.592 nm. These two lines can just be resolved in the second-order spectrum of this diffraction grating. Determine the beam width of the light incident on the diffraction grating. [3]

. . . .

. . . .

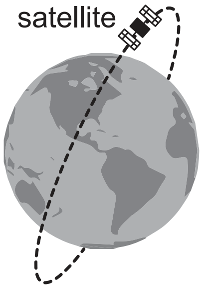
. . . .

. . . .

. . . .

. . . .

7. A satellite is orbiting the Earth in a polar orbit.



(a) The satellite carries an experiment that measures the peak wavelength emitted by different objects. The Sun emits radiation that has a peak wavelength λ_S of 509 nm. The peak wavelength λ_E of the radiation emitted by the Earth is 10.1 μm.

(i) Determine the mean temperature of the Earth. [2]

. . . .

. . . .

. . . .

. . . .

(ii) Suggest how the difference between λ_S and λ_E helps to account for the greenhouse effect. [3]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(b) Not all scientists agree that global warming is caused by the activities of man. Outline how scientists try to ensure agreement on a scientific issue. [1]

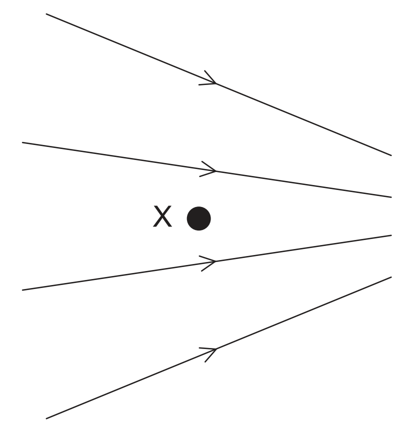
. . . .

. . . .

. . . .

. . . .

8. A non-uniform electric field, with field lines as shown, exists in a region where there is no gravitational field. X is a point in the electric field. The field lines and X lie in the plane of the paper.



(a) Outline what is meant by electric field strength. [2]

. . . .

. . . .

. . . .

. . . .

(b) An electron is placed at X and released from rest. Draw, on the diagram, the direction of the force acting on the electron due to the field. [1]

(This question continues on the following page)

(Question 8 continued)

(c) The electron is replaced by a proton which is also released from rest at X. Compare, without calculation, the motion of the electron with the motion of the proton after release. You may assume that no frictional forces act on the electron or the proton. [4]

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

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

Answers written on this page
will not be marked.

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

Answers written on this page
will not be marked.

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

Answers written on this page
will not be marked.