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Baccalauréat International
Bachillerato Internacional

PHYSICS
STANDARD LEVEL
PAPER 2

Candidate session number

0	0							

Wednesday 11 May 2011 (afternoon)

1 hour 15 minutes

Examination code

2	2	1	1	–	6	5	1	1

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 questions.
- Write your answers in the boxes provided.

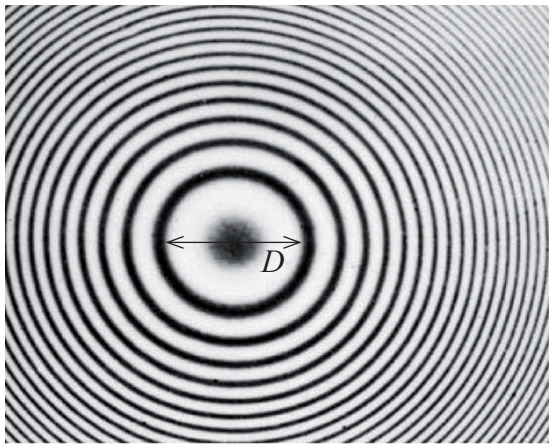
0132

SECTION A

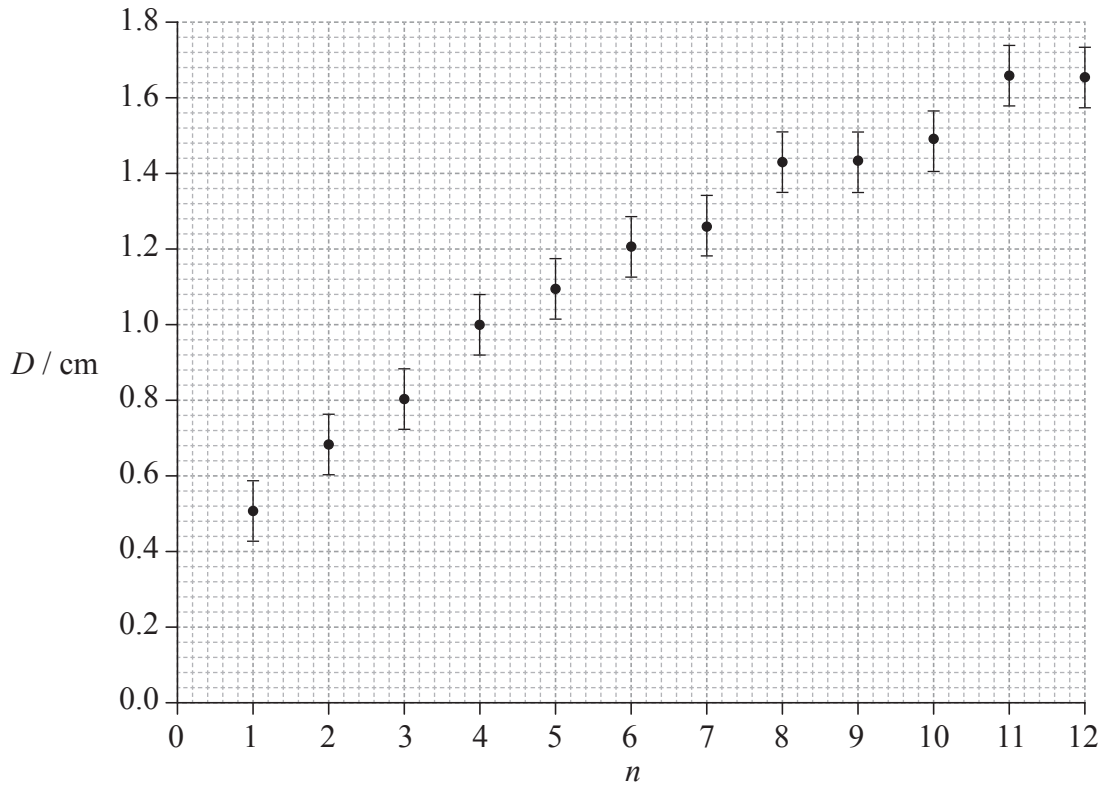
*Answer **all** questions. Write your answers in the boxes provided.*

A1. Data analysis question.

The photograph below shows a magnified image of a dark central disc surrounded by concentric dark rings. These rings were produced as a result of interference of monochromatic light.



The graph below shows how the ring diameter D varies with the ring number n. The innermost ring corresponds to $n=1$. The corresponding diameter is labelled in the photograph. Error bars for the diameter D are shown.



(This question continues on the following page)

(Question A1 continued)

(a) State **one** piece of evidence that shows that D is not proportional to n. *[1]*

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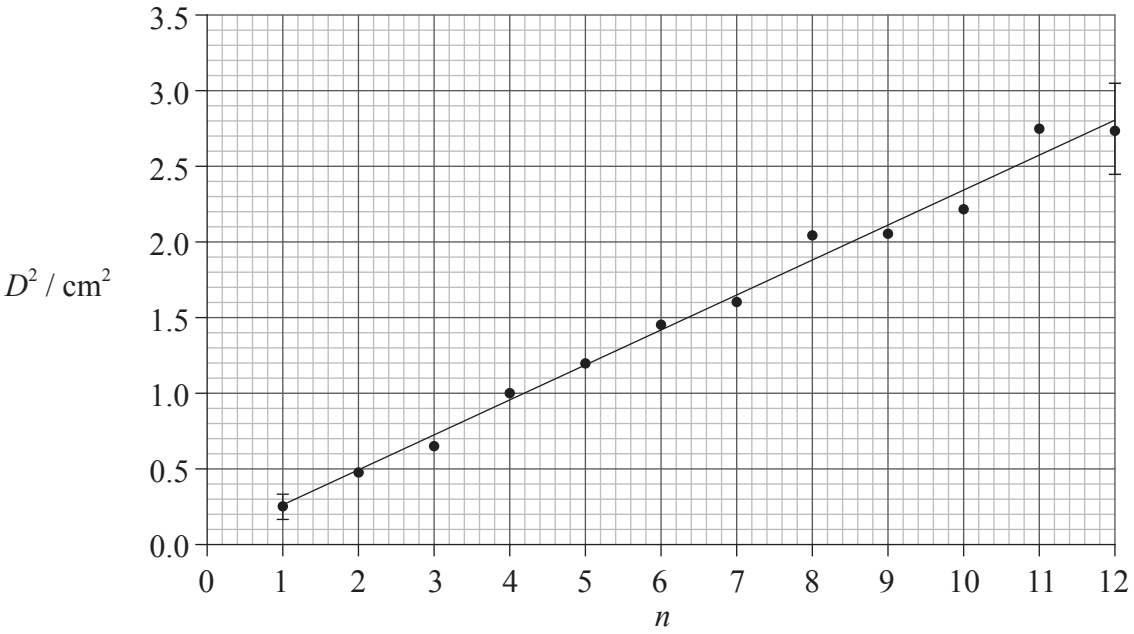
(b) On the graph opposite, draw the line of best-fit for the data points. *[2]*

(This question continues on the following page)

(Question A1 continued)

(c) Theory suggests that $D^2 = kn$.

A graph of D^2 against n is shown below. Error bars are shown for the first and last data points only.



(i) Using the graph on page 2, calculate the percentage uncertainty in D^2, of the ring $n = 7$. *[2]*

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(Question A1 continued)

(ii) Based on the graph opposite, state **one** piece of evidence that supports the relationship $D^2 = kn$. *[1]*

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(iii) Use the graph opposite to determine the value of the constant k, as well as its uncertainty. *[4]*

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(iv) State the unit for the constant k. *[1]*

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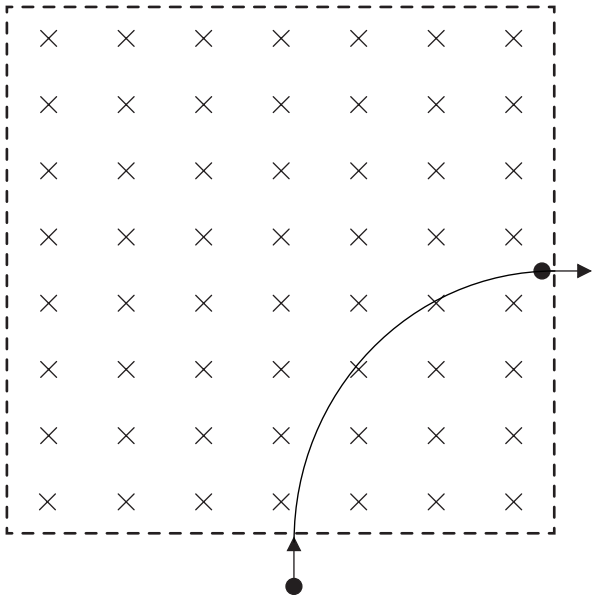
A2. This question is about motion in a magnetic field.

An electron, that has been accelerated from rest by a potential difference of 250 V, enters a region of magnetic field of strength 0.12 T that is directed into the plane of the page.



(a) The electron's path while in the region of magnetic field is a quarter circle. Show that the

(i) speed of the electron after acceleration is $9.4\times10^{6}\,\mathrm{m\,s^{-1}}$. *[2]*

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(ii) radius of the path is $4.5\times10^{-4}\,\mathrm{m}$. *[2]*

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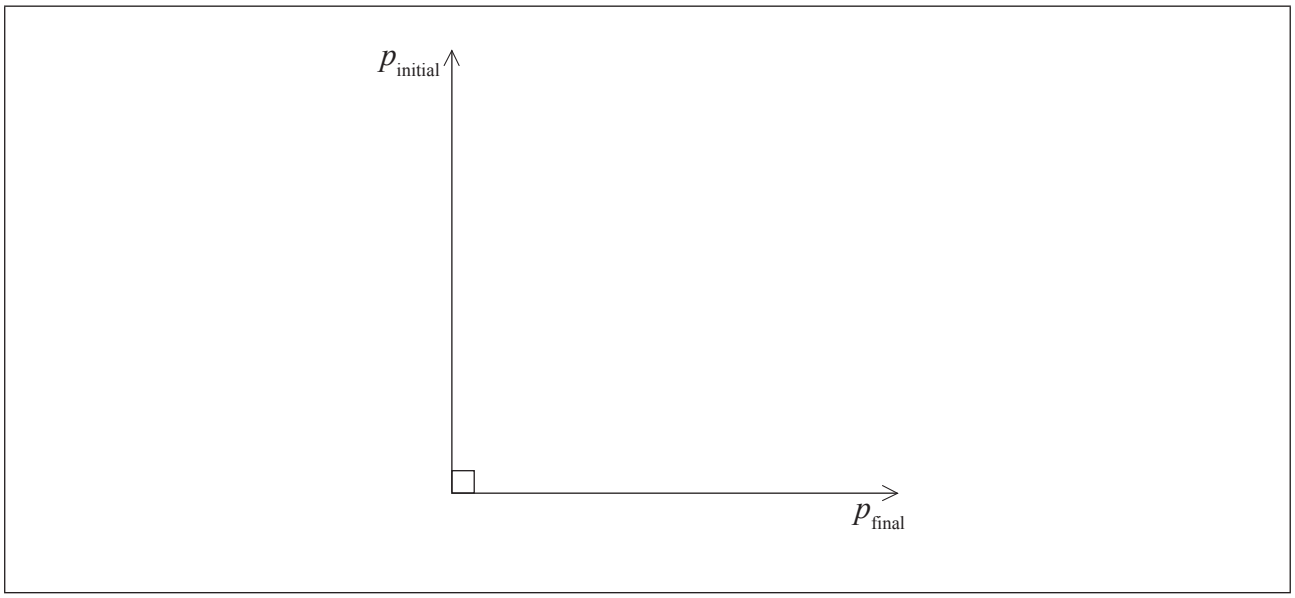
(Question A2 continued)

(b) The diagram below shows the momentum of the electron as it enters and leaves the region of magnetic field. The magnitude of the initial momentum and of the final momentum is 8.6×10^{-24} N s.



(i) On the diagram above, draw an arrow to indicate the vector representing the change in the momentum of the electron. *[1]*

(ii) Show that the magnitude of the change in the momentum of the electron is 1.2×10^{-23} N s. *[1]*

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(iii) The time the electron spends in the region of magnetic field is 7.5×10^{-11} s. Estimate the magnitude of the average force on the electron. *[1]*

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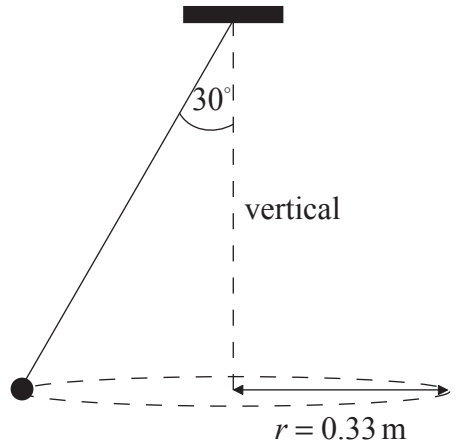
A3. This question is about circular motion.

A ball of mass 0.25 kg is attached to a string and is made to rotate with constant speed v along a horizontal circle of radius $r = 0.33\,\text{m}$. The string is attached to the ceiling and makes an angle of 30° with the vertical.



(a) (i) On the diagram above, draw and label arrows to represent the forces on the ball in the position shown. *[2]*

(ii) State and explain whether the ball is in equilibrium. *[2]*

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(This question continues on the following page)

(Question A3 continued)

(b) Determine the speed of rotation of the ball. *[3]*

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SECTION B

*This section consists of three questions: B1, B2 and B3. Answer **one** question. Write your answers in the boxes provided.*

B1. This question is in **two** parts. **Part 1** is about a nuclear reactor. **Part 2** is about simple harmonic oscillations.

Part 1 Nuclear reactor

(a) Uranium is used as a fuel in a small research nuclear reactor. The concentration of $^{235}_{92}\text{U}$ in a sample of uranium must be increased before it can be used as a fuel.

State the name of the process by which the concentration of $^{235}_{92}\text{U}$ is increased. *[1]*

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(b) The reactor produces 24 MW of power. The efficiency of the reactor is 32 %. In the fission of one uranium-235 nucleus 3.2×10^{-11} J of energy is released.

Determine the mass of uranium-235 that undergoes fission in one year in this reactor. *[4]*

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(Question B1, part 1 continued)

(c) Explain what would happen if the moderator of this reactor were to be removed. *[3]*

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(d) During its normal operation, the following set of reactions takes place in the reactor.

$$^{1}_{0}\text{n} + {}^{238}_{92}\text{U} \rightarrow {}^{239}_{92}\text{U} \qquad \text{(I)}$$

$$^{239}_{92}\text{U} \rightarrow {}^{239}_{93}\text{Np} + {}^{0}_{-1}e + \overline{\nu} \qquad \text{(II)}$$

$$^{239}_{93}\text{Np} \rightarrow {}^{239}_{94}\text{Pu} + {}^{0}_{-1}e + \overline{\nu} \qquad \text{(III)}$$

(i) State the name of the process represented by reaction (II). *[1]*

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(ii) Comment on the international implications of the product of these reactions. *[2]*

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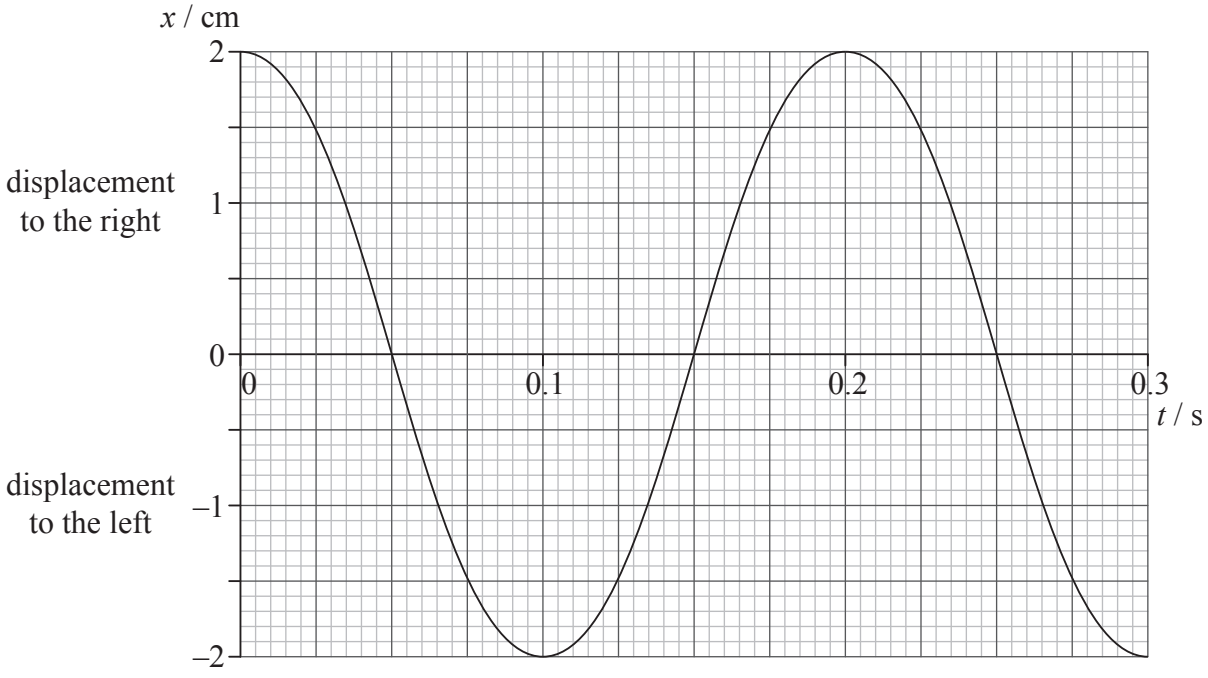
(Question B1 continued)

Part 2 Simple harmonic oscillations

A longitudinal wave travels through a medium from left to right.

Graph 1 shows the variation with time t of the displacement x of a particle P in the medium.

Graph 1



(a) For particle P,

(i) state how graph 1 shows that its oscillations are not damped. *[1]*

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(This question continues on the following page)

(Question B1, part 2 continued)

(ii) calculate the magnitude of its maximum acceleration. *[2]*

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(iii) calculate its speed at $t = 0.12\,\text{s}$. *[2]*

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(iv) state its direction of motion at $t = 0.12\,\text{s}$. *[1]*

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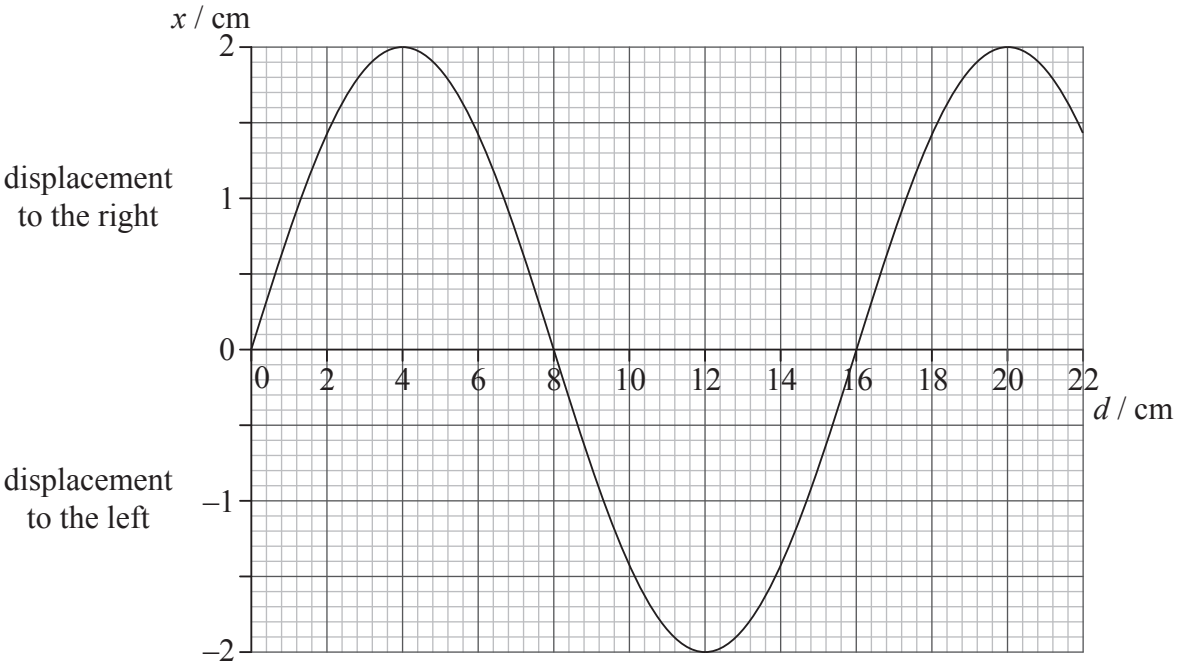
(Question B1, part 2 continued)

(b) Graph 2 shows the variation with position d of the displacement x of particles in the medium at a particular instant of time.

Graph 2



Determine for the longitudinal wave, using graph 1 and graph 2,

(i) the frequency. *[2]*

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(ii) the speed. *[2]*

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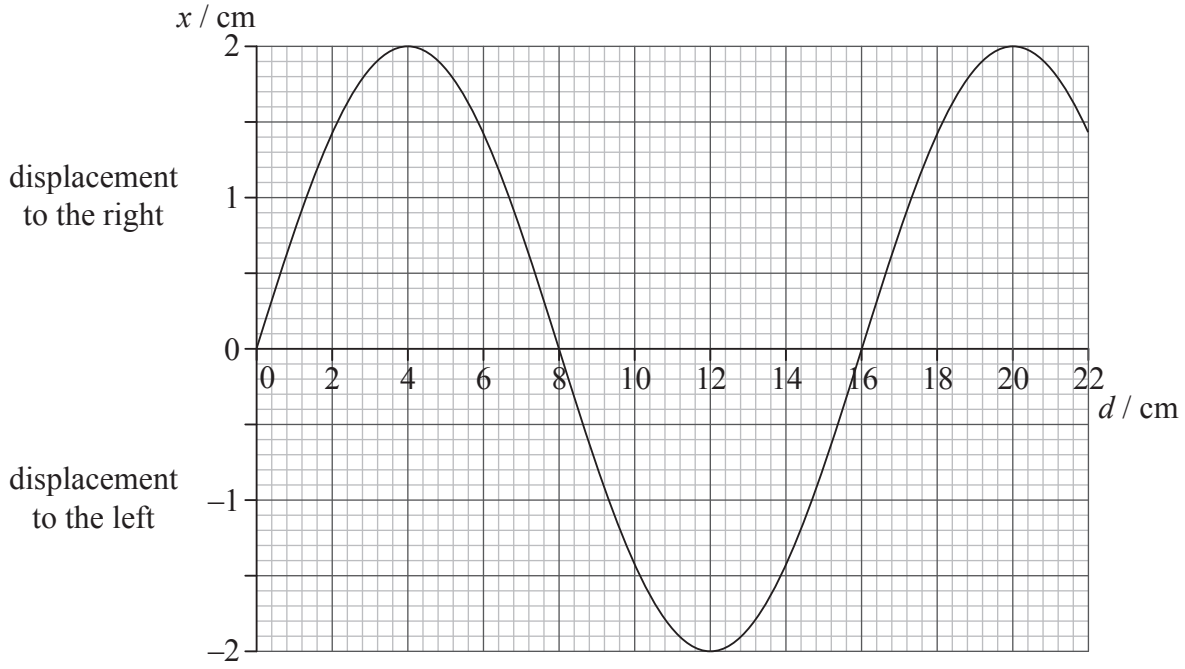
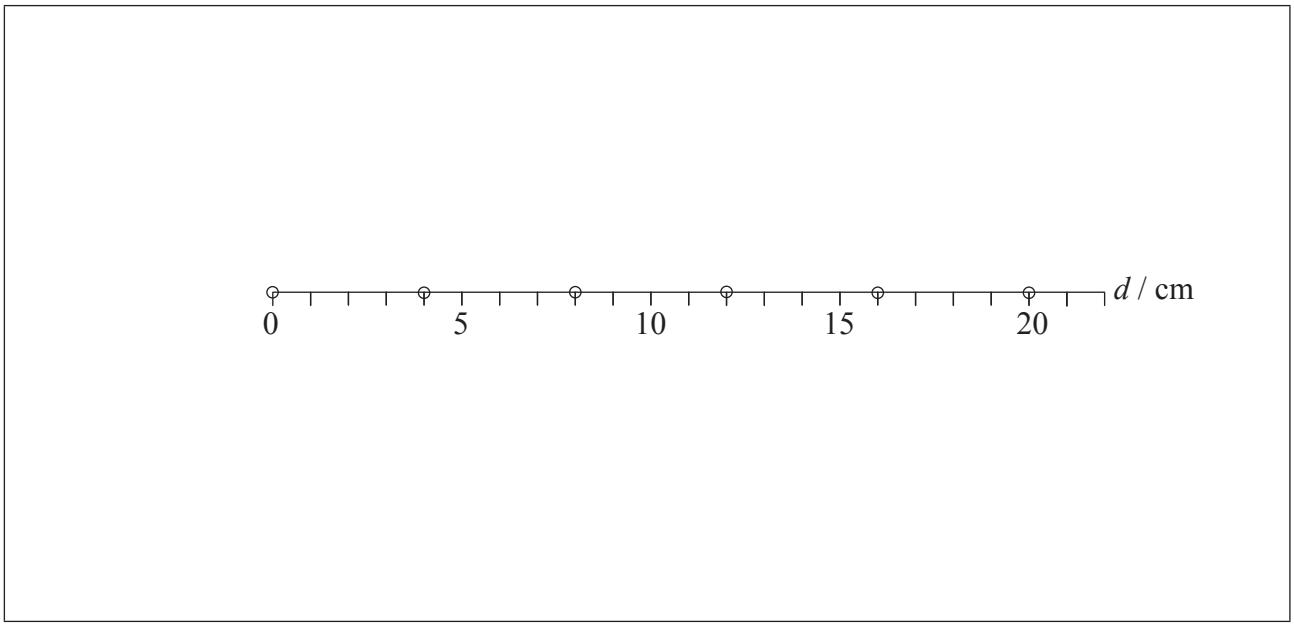
(Question B1, part 2 continued)

Graph 2 – reproduced to assist with answering (c)(i).



(c) The diagram shows the equilibrium positions of six particles in the medium.



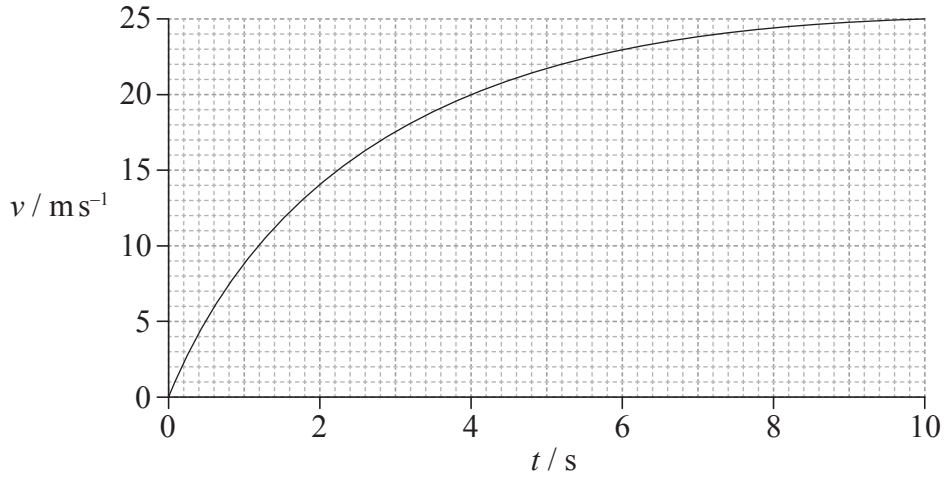
(i) On the diagram above, draw crosses to indicate the positions of these six particles at the instant of time when the displacement is given by graph 2. *[3]*

(ii) On the diagram above, label with the letter C a particle that is at the centre of a compression. *[1]*

B2. This question is in **two** parts. **Part 1** is about mechanics and thermal physics. **Part 2** is about nuclear physics.

Part 1 Mechanics and thermal physics

The graph shows the variation with time t of the speed v of a ball of mass 0.50 kg, that has been released from rest above the Earth's surface.



The force of air resistance is **not** negligible. Assume that the acceleration of free fall is $g = 9.81\,\text{m s}^{-2}$.

(a) State, without any calculations, how the graph could be used to determine the distance fallen. *[1]*

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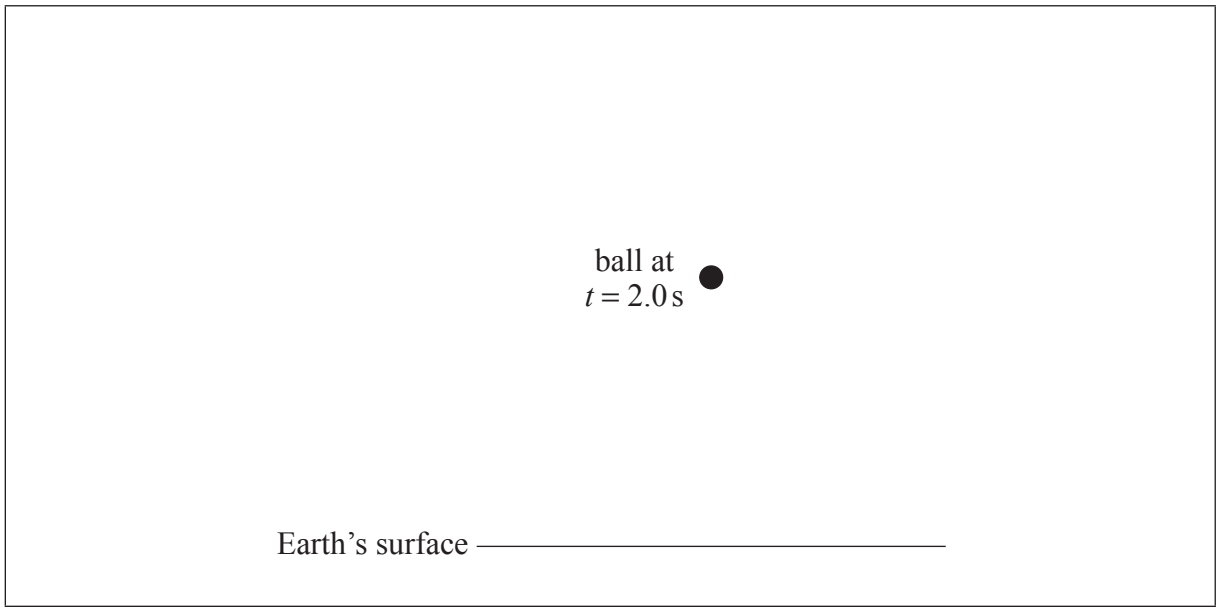
(Question B2, part 1 continued)

(b) (i) In the space below, draw and label arrows to represent the forces on the ball at 2.0 s. *[1]*



(ii) Use the graph opposite to show that the acceleration of the ball at 2.0 s is approximately $4\,\text{m}\,\text{s}^{-2}$. *[2]*

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(iii) Calculate the magnitude of the force of air resistance on the ball at 2.0 s. *[2]*

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(Question B2, part 1 continued)

(iv) State and explain whether the air resistance on the ball at $t = 5.0\,\text{s}$ is smaller than, equal to **or** greater than the air resistance at $t = 2.0\,\text{s}$. *[2]*

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(Question B2, part 1 continued)

(c) After 10 s the ball has fallen 190 m.

(i) Show that the sum of the potential and kinetic energies of the ball has decreased by 780 J. *[3]*

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(ii) The specific heat capacity of the ball is $480\,J\,kg^{-1}\,K^{-1}$. Estimate the increase in the temperature of the ball. *[2]*

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(iii) State an assumption made in the estimate in (c)(ii). *[1]*

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(Question B2 continued)

Part 2 Nuclear physics

(a) (i) Define *binding energy* of a nucleus. *[1]*

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(ii) The mass of a nucleus of plutonium $\left({}^{239}_{94}\mathrm{Pu}\right)$ is 238.990396 u. Deduce that the binding energy per nucleon for plutonium is 7.6 MeV. *[3]*

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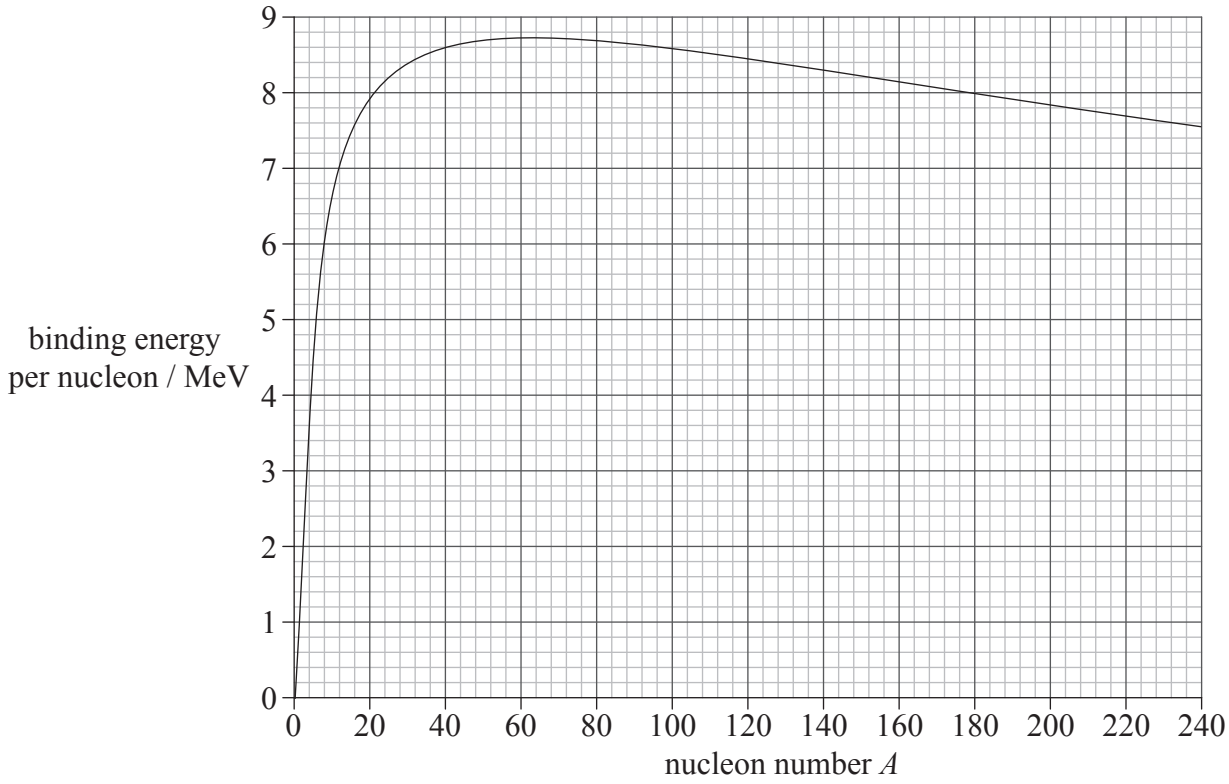
(Question B2, part 2 continued)

(b) The graph shows the variation with nucleon number A of the binding energy per nucleon.



Plutonium $\left({}^{239}_{94}\text{Pu}\right)$ undergoes nuclear fission according to the reaction given below.

$$^{239}_{94}\text{Pu} + {}^{1}_{0}\text{n} \rightarrow {}^{91}_{38}\text{Sr} + {}^{146}_{56}\text{Ba} + x\,{}^{1}_{0}\text{n}$$

(i) Calculate the number x of neutrons produced. *[1]*

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(This question continues on the following page)

(Question B2, part 2 continued)

(ii) Use the graph to estimate the energy released in this reaction. *[2]*

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(c) Stable nuclei with a mass number greater than about 20, contain more neutrons than protons. By reference to the properties of the nuclear force and of the electrostatic force, suggest an explanation for this observation. *[4]*

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B3. This question is in **two** parts. **Part 1** is about electric circuits. **Part 2** is about the energy balance of the Earth.

Part 1 Electric circuits

(a) Define

(i) *electromotive force* (emf) of a battery. *[1]*

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(ii) *electrical resistance* of a conductor. *[1]*

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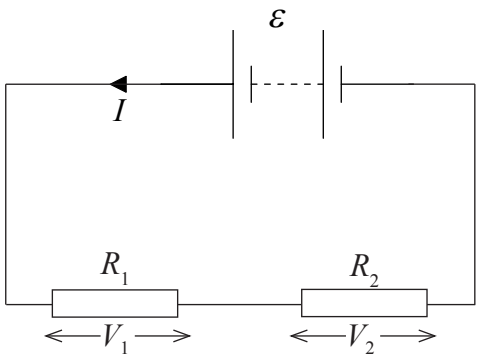
(Question B3, part 1 continued)

(b) A battery of emf ε and negligible internal resistance is connected in series to two resistors. The current in the circuit is I.



(i) State an equation giving the total power delivered by the battery. *[1]*

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(ii) The potential difference across resistor R_1 is V_1 and that across resistor R_2 is V_2. Using the law of the conservation of energy, deduce the equation below. *[2]*

$$\varepsilon = V_1 + V_2$$

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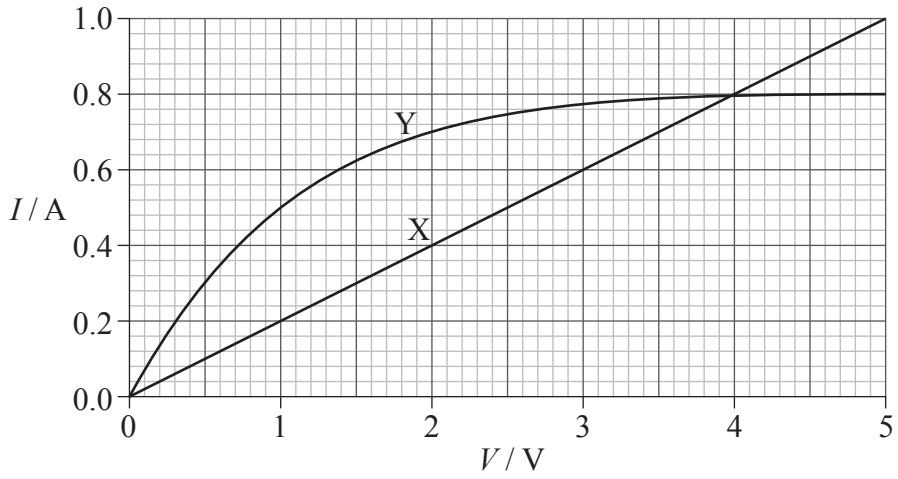
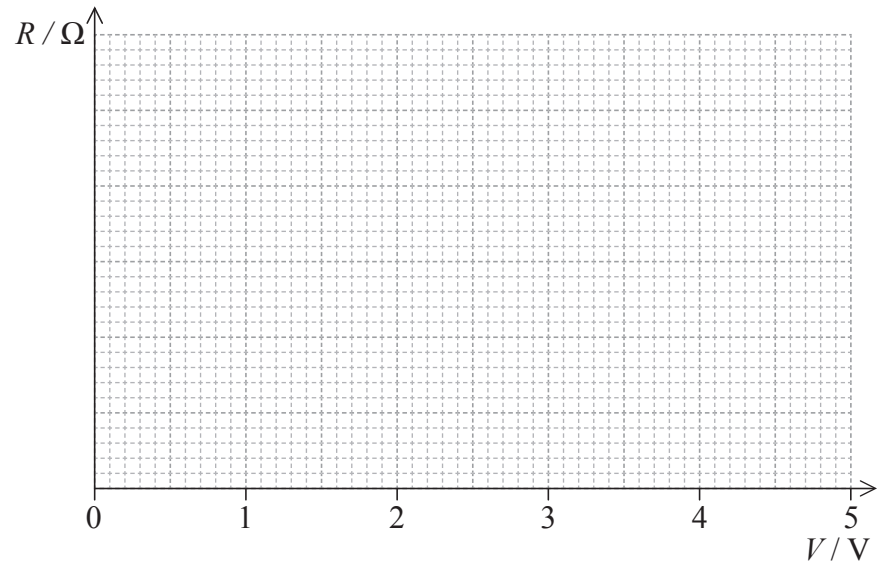
(Question B3, part 1 continued)

(c) The graph shows the *I*-*V* characteristics of two conductors, X and Y.



On the axes below, sketch graphs to show the variation with potential difference *V* of the resistance of conductor X (label this graph X) and conductor Y (label this graph Y). You do not need to put any numbers on the vertical axis. *[3]*



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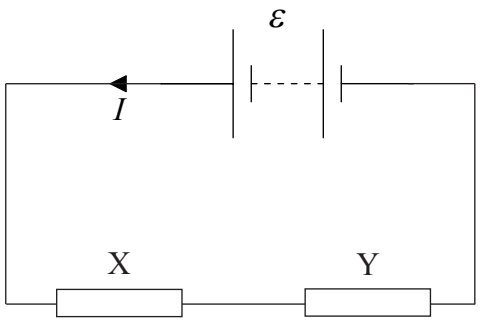
(Question B3, part 1 continued)

(d) The conductors in (c) are connected in series to a battery of emf ε and negligible internal resistance.



The power dissipated in each of the two resistors is the same.

Using the graph given in (c),

(i) determine the emf of the battery. *[2]*

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(ii) calculate the total power dissipated in the circuit. *[2]*

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(Question B3 continued)

Part 2 Energy balance of the Earth

(a) The intensity of the Sun's radiation at the position of the Earth is approximately $1400\,\text{W m}^{-2}$.

Suggest why the average power received per unit area of the Earth is $350\,\text{W m}^{-2}$. *[2]*

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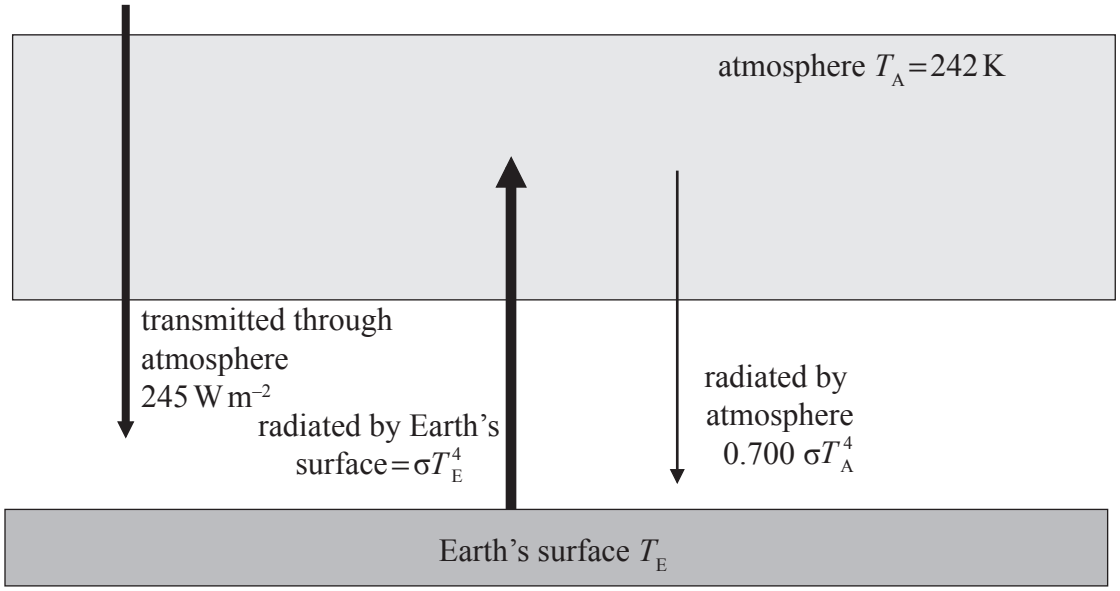
(b) The diagram shows a simplified model of the energy balance of the Earth's surface. The diagram shows radiation entering or leaving the Earth's surface only.



The average equilibrium temperature of the Earth's surface is T_E and that of the atmosphere is $T_A = 242\,\text{K}$.

(i) Using the data from the diagram, state the emissivity of the atmosphere. *[1]*

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(This question continues on the following page)

(Question B3, part 2 continued)

(ii) Show that the intensity of the radiation radiated by the atmosphere towards the Earth's surface is $136\,W\,m^{-2}$. *[1]*

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(iii) By reference to the energy balance of the Earth's surface, calculate T_E. *[2]*

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(Question B3, part 2 continued)

(c) (i) Outline a mechanism by which part of the radiation radiated by the Earth's surface is absorbed by greenhouse gases in the atmosphere. *[3]*

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(ii) Suggest why the incoming solar radiation is not affected by the mechanism you outlined in (c)(i). *[2]*

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(iii) Carbon dioxide (CO_2) is a greenhouse gas. State **one** source and **one** sink (object that removes CO_2) of this gas. *[2]*

Source: . . . . . .

Sink: . . . . . .

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