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**International Baccalaureate**
Baccalauréat International
Bachillerato Internacional

**PHYSICS**
**STANDARD LEVEL**
**PAPER 2**

Monday 6 May 2013 (morning)

1 hour 15 minutes

Candidate session number

| 0 | 0 | | | | | | | | |

Examination code

| 2 | 2 | 1 | 3 | – | 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 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]*.

**SECTION A**

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

**A1.**  Data analysis question.

A particular semiconductor device generates an emf, which varies with light intensity. The diagram shows the experimental arrangement which a student used to investigate the variation with distance $d$ of the emf $\varepsilon$.  The power output of the lamp was constant.  (The power supply for the lamp is not shown.)
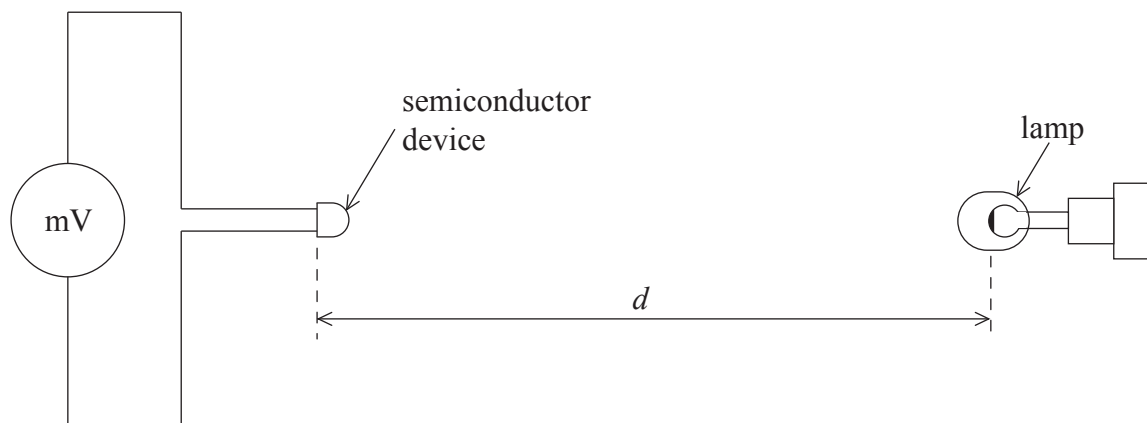


The table shows how $\varepsilon$ varied with $d$.

| $d$ / cm | $\varepsilon$ / mV |
|----------|--------------------|
| 19.1     | 5.5                |
| 18.0     | 6.0                |
| 16.0     | 8.6                |
| 14.0     | 11.9               |
| 12.0     | 19.7               |
| 10.0     | 37.5               |

(a)  Outline why the student has recorded the $\varepsilon$ values to different numbers of significant digits but the same number of decimal places.                                    *[2]*

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*(This question continues on the following page)*

0228

*(Question A1 continued)*

(b)    On looking at the results the student suggests that $\varepsilon$ could be inversely proportional to $d$. He proceeds to multiply each $d$ value by the corresponding value of $\varepsilon$.

    (i)    Explain why this procedure can be used to disprove the student's suggestion but it cannot prove it.    *[2]*

    (ii)    Using the data for $d$ values of 19.1 cm, 16.0 cm and 10.0 cm discuss whether or not $\varepsilon$ is inversely proportional to $d$.    *[3]*

*(This question continues on the following page)*

**Turn over**

*(Question A1 continued)*

(c)     The graph shows some of the data points with the uncertainty in the *d* values.

On the graph

(i)     draw the data point corresponding to the value of $d = 19.1\,\text{cm}$.                    *[1]*

(ii)    assuming that there is a constant absolute uncertainty in measuring all values of *d*, draw the error bar for the data point in (c)(i).                    *[1]*

(iii)   sketch the line of best-fit for all the plotted points.                    *[1]*

*(This question continues on the following page)*

*(Question A1 continued)*

0528

*(Question A1 continued)*

(d)   All values of $\varepsilon$ have a percentage uncertainty of $\pm 3\,\%$.  Calculate the percentage uncertainty in the product $d\varepsilon$ for the value of $d = 18.0\,\text{cm}$.                    *[2]*

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**A2.** This question is about circular motion.

The diagram shows a car moving at a constant speed over a curved bridge. At the position shown, the top surface of the bridge has a radius of curvature of 50 m.

car

top surface of bridge of
radius of curvature 50 m
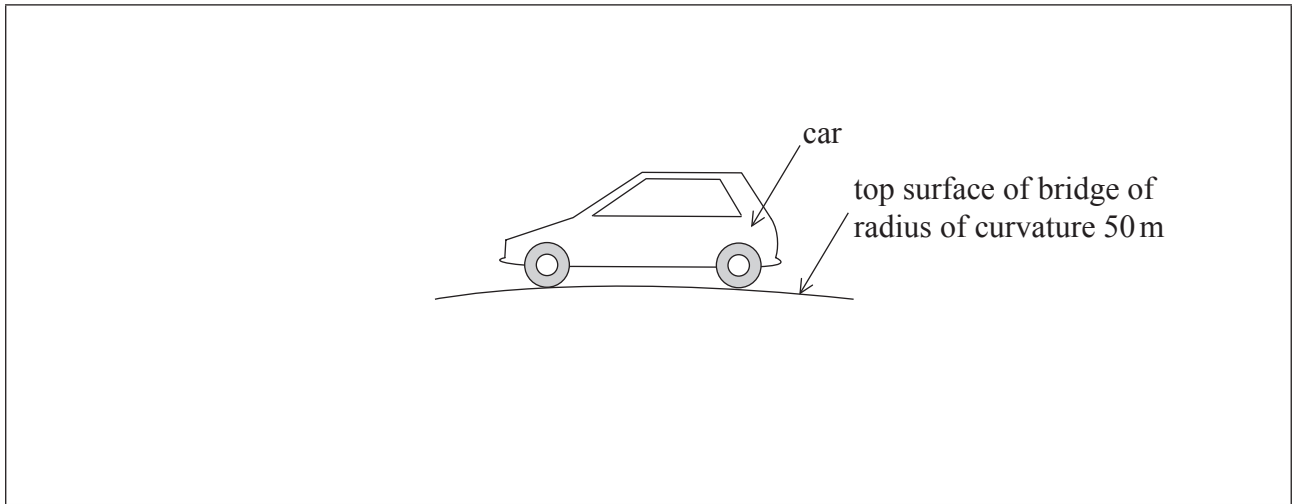
(a) Explain why the car is accelerating even though it is moving with a constant speed. *[2]*

        . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
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(b) On the diagram, draw and label the vertical forces acting on the car in the position shown. *[2]*

(c) Calculate the maximum speed at which the car will stay in contact with the bridge. *[3]*

        . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
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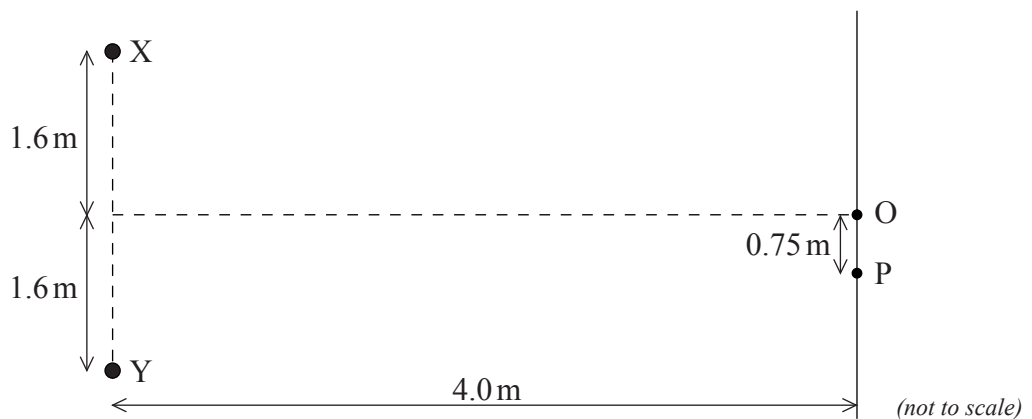
**A3.** This question is about the superposition of waves.

(a) State what is meant by the principle of superposition of waves. *[1]*

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(b) The diagram shows two point sources of sound, X and Y. Each source emits waves of wavelength 1.1 m and amplitude $A$. Over the distances shown, any decrease in amplitude can be neglected. The two sources vibrate in phase.



*(not to scale)*

Points O and P are on a line 4.0 m from the line connecting X and Y. O is opposite the midpoint of XY and P is 0.75 m from O.

(i) Explain why the intensity of the sound at O is $4A^2$. *[2]*

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*(This question continues on the following page)*

*(Question A3 continued)*

(ii)   Deduce that no sound is detected at P.					*[3]*

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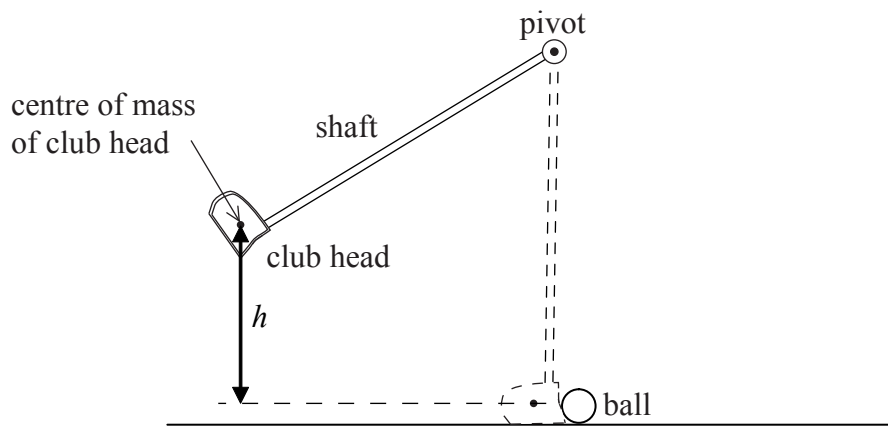
**Turn over**

**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 impulse and momentum. **Part 2** is about nuclear fusion.

**Part 1** Impulse and momentum

The diagram shows an arrangement used to test golf club heads.



The shaft of a club is pivoted and the centre of mass of the club head is raised by a height $h$ before being released. On reaching the vertical position the club head strikes the ball.

(a) (i) Describe the energy changes that take place in the club head from the instant the club is released until the club head and the ball separate. *[2]*

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*(This question continues on the following page)*

*(Question B1, part 1 continued)*

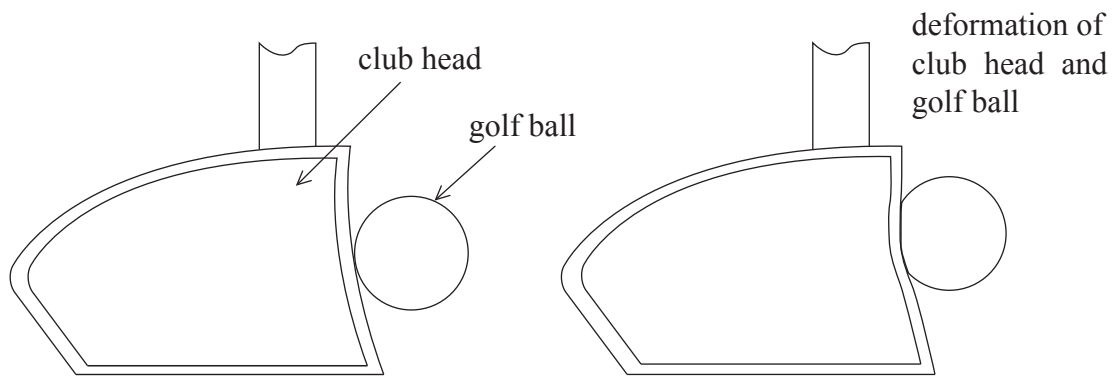    (ii)    Calculate the maximum speed of the club head achievable when $h = 0.85$ m.    *[2]*

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

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(b)    The diagram shows the deformation of a golf ball and club head as they collide during a test.

club head

golf ball

deformation of club head and golf ball

    Explain how increasing the deformation of the club head may be expected to increase the speed at which the ball leaves the club.    *[2]*

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

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*(This question continues on the following page)*

**Turn over**

*(Question B1, part 1 continued)*

(c) In a different experimental arrangement, the club head is in contact with the ball for a time of $220\,\mu s$. The club head has mass $0.17\,kg$ and the ball has mass $0.045\,kg$. At the moment of contact the ball is at rest and the club head is moving with a speed of $38\,m\,s^{-1}$. The ball moves off with an initial speed of $63\,m\,s^{-1}$.

(i) Calculate the average force acting on the ball while the club head is in contact with the ball. *[2]*

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(ii) State the average force acting on the club head while it is in contact with the ball. *[1]*

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(iii) Calculate the speed of the club head at the instant that it loses contact with the ball. *[2]*

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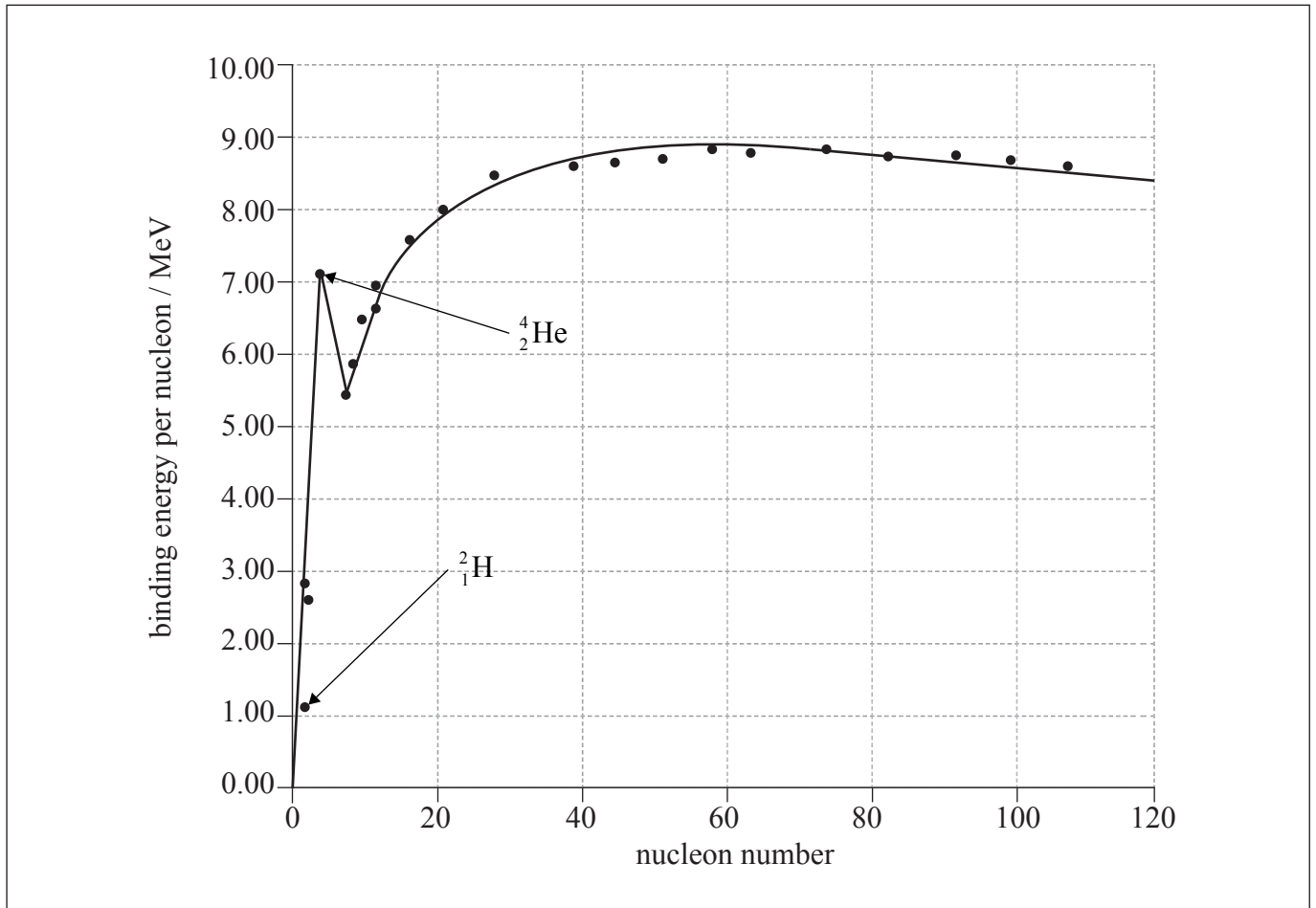
Please **do not** write on this page.

Answers written on this page
will not be marked.

*(Question B1 continued)*

**Part 2** Nuclear fusion

The diagram shows the variation of nuclear binding energy per nucleon with nucleon number for some of the lighter nuclides.



(a) (i) Outline, with reference to mass defect, what is meant by the term nuclear binding energy. *[2]*

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(ii) Label, with the letter **S**, the region on the graph where nuclei are most stable. *[1]*

*(This question continues on the following page)*

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*(Question B1, part 2 continued)*

(iii) Show that the energy released when two $_1^2\text{H}$ nuclei fuse to make a $_2^4\text{He}$ nucleus is approximately 4 pJ. *[4]*

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

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(b) In one nuclear reaction two deuterons (hydrogen-2) fuse to form tritium (hydrogen-3) and another particle. The tritium undergoes $\beta^-$ decay to form an isotope of helium.

(i) Identify the missing particles to complete the equations. *[4]*

$$_1^2\text{H} + _1^2\text{H} \rightarrow _1^3\text{H} + _{...}^{...}......$$

$$_1^3\text{H} \rightarrow _{...}^3\text{He} + _{...}^{...}...... + _{...}^{...}......$$

(ii) Explain which of these reactions is more likely to occur at high temperatures. *[3]*

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**Turn over**

**B2.** This question is in **two** parts. **Part 1** is about simple harmonic motion and forced oscillations. **Part 2** is about electric and magnetic force fields.

   **Part 1**     Simple harmonic motion and forced oscillations

   The graph shows the variation with time of the displacement of an object undergoing simple harmonic motion.
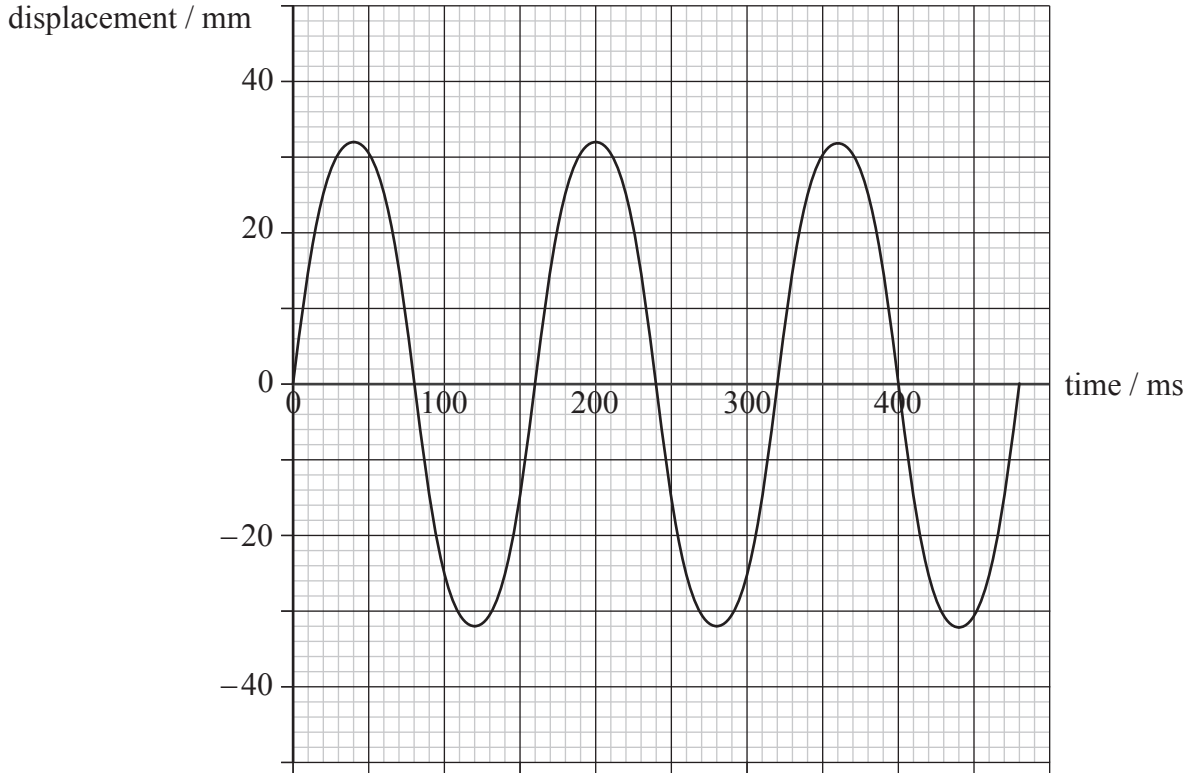


   (a)   (i)   State the amplitude of the oscillation.                                    *[1]*

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   (ii)   Calculate the frequency of the oscillation.                              *[2]*

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*(This question continues on the following page)*

1628

*(Question B2, part 1 continued)*

(b)  (i)  Determine the maximum speed of the object. *[2]*

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(ii)  Determine the acceleration of the object at 140 ms. *[2]*

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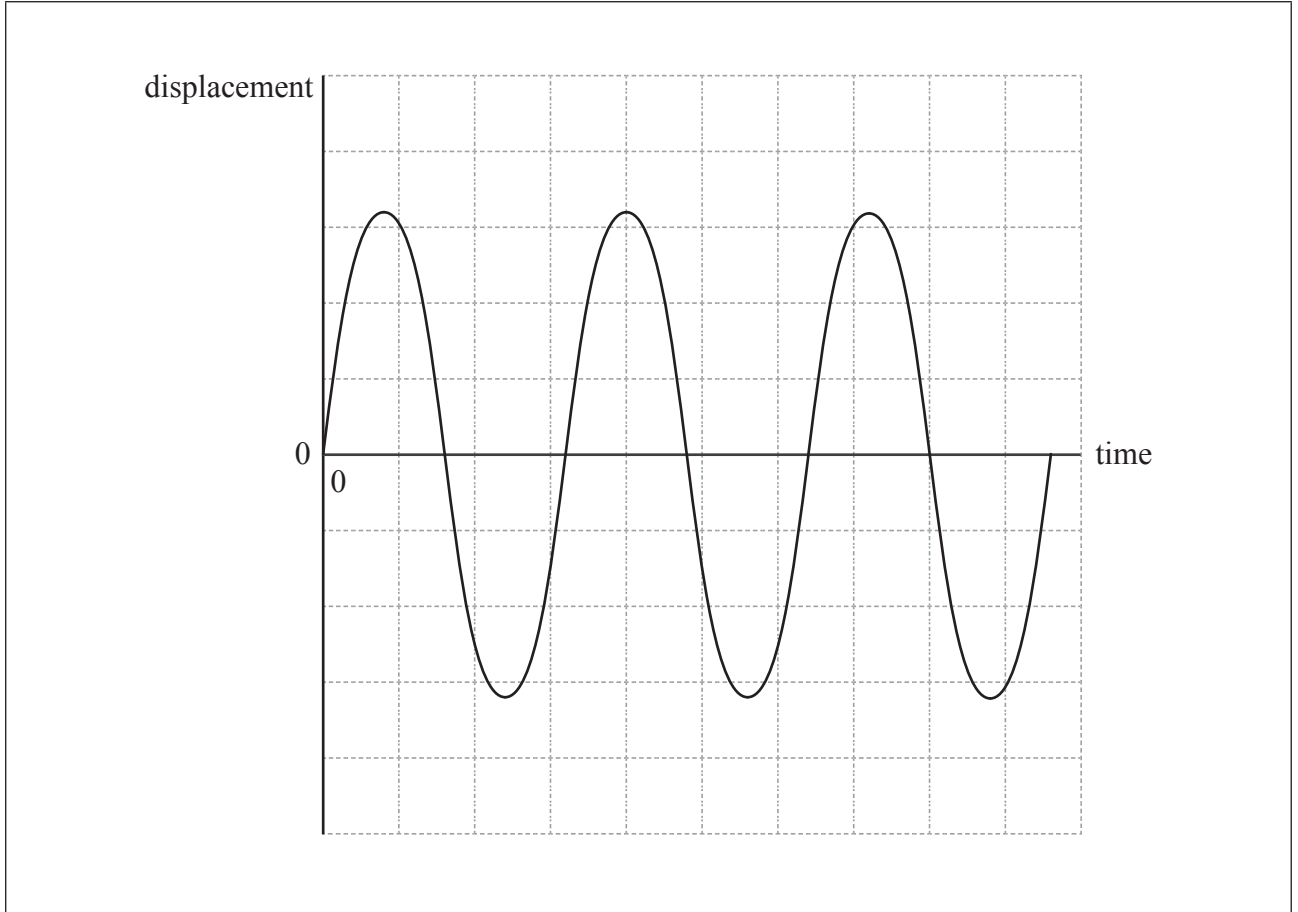
*(This question continues on the following page)*

**Turn over**

*(Question B2, part 1 continued)*

(c)   The graph below shows how the displacement of the object varies with time.  Sketch on the same axes a line indicating how the kinetic energy of the object varies with time. You should ignore the actual values of the kinetic energy.                    *[3]*



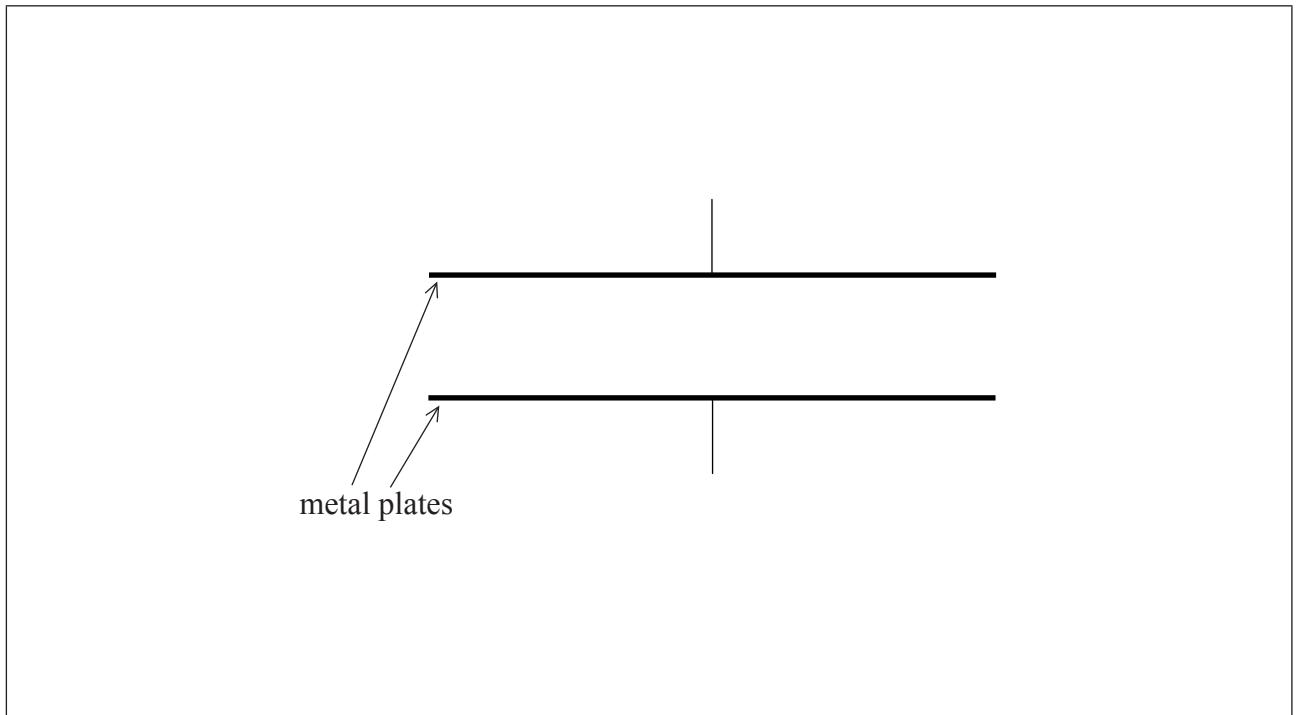*(This question continues on the following page)*

*(Question B2 continued)*

**Part 2** Electric and magnetic force fields

(a) Define *electric field strength*. *[2]*

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(b) The diagram shows a pair of horizontal metal plates. Electrons can be deflected vertically using an electric field between the plates.

metal plates

(i) Label, on the diagram, the polarity of the metal plates which would cause an electron positioned between the plates to accelerate upwards. *[1]*

(ii) Draw the shape and direction of the electric field between the plates on the diagram. *[2]*

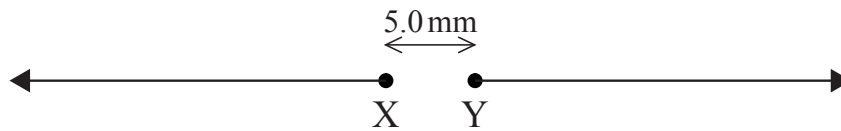*(This question continues on the following page)*

**Turn over**

*(Question B2, part 2 continued)*

(iii) Calculate the force on an electron between the plates when the electric field strength
has a value of $2.5 \times 10^3 \, \text{N C}^{-1}$. *[2]*

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

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(c) The diagram shows two isolated electrons, X and Y, initially at rest in a vacuum.
The initial separation of the electrons is $5.0 \, \text{mm}$. The electrons subsequently move apart
in the directions shown.



(i) Show that the initial electric force acting on each electron due to the other electron
is approximately $9 \times 10^{-24} \, \text{N}$. *[2]*

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

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(ii) Calculate the initial acceleration of one electron due to the force in (c)(i). *[1]*

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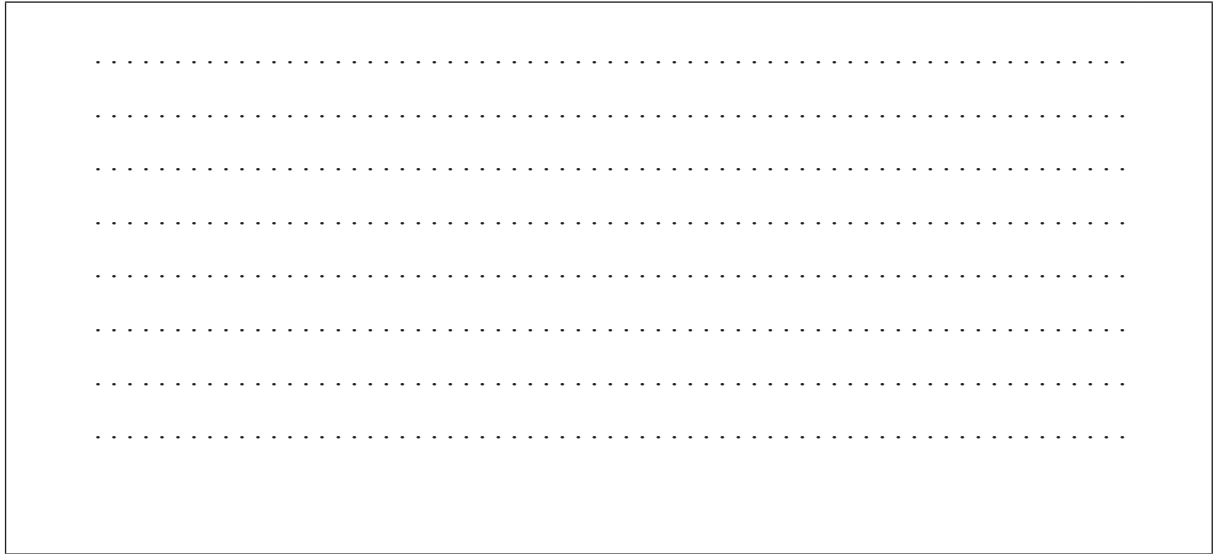
*(This question continues on the following page)*

*(Question B2, part 2 continued)*

(iii) Discuss the motion of one electron after it begins to move. *[3]*

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(iv) The diagram shows Y as seen from X, at one instant. Y is moving into the plane of the paper. For this instant, draw on the diagram the shape and direction of the magnetic field produced by Y. *[2]*

●Y

**Turn over**
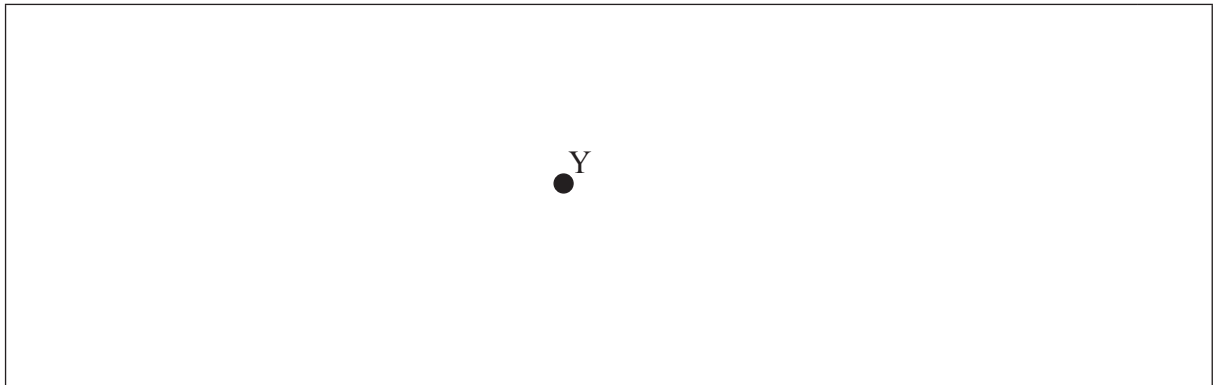
**B3.** This question is about alternative energy supplies.

A small island community requires a peak power of $850\,kW$. Two systems are available for supplying the energy: using wind power or photovoltaic cells.

(a) (i) Outline, with reference to the energy conversions in the machine, the main features of a conventional horizontal-axis wind generator. *[3]*

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(ii) The mean wind speed on the island is $8.0\,m\,s^{-1}$. Show that the maximum power available from a wind generator of blade length $45\,m$ is approximately $2\,MW$. *[2]*

Density of air $= 1.2\,kg\,m^{-3}$

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(iii) The efficiency of the generator is $24\,\%$. Deduce the number of these generators that would be required to provide the islanders with enough power to meet their energy requirements. *[2]*
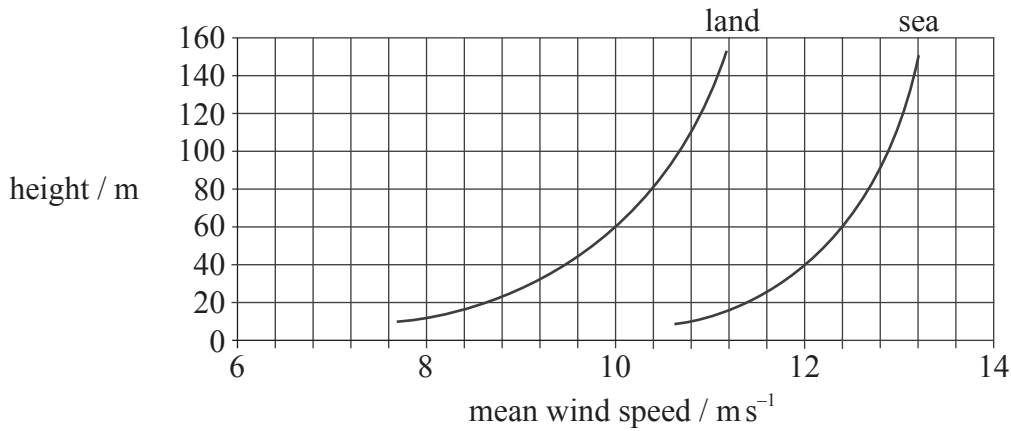
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*(This question continues on the following page)*

*(Question B3 continued)*

(b)    The graph below shows how the wind speed varies with height above the land and above the sea.



(i)    Suggest why, for any given height, the mean wind speed above the sea is greater than the mean wind speed above the land.                                    *[1]*

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(ii)   There is a choice of mounting the wind generators either 60 m above the land or 60 m above the sea.

Calculate the ratio

$$\frac{\text{power available from a land-based generator}}{\text{power available from a sea-based generator}}$$

at a height of 60 m.                                                                *[2]*

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*(This question continues on the following page)*

**Turn over**

*(Question B3 continued)*

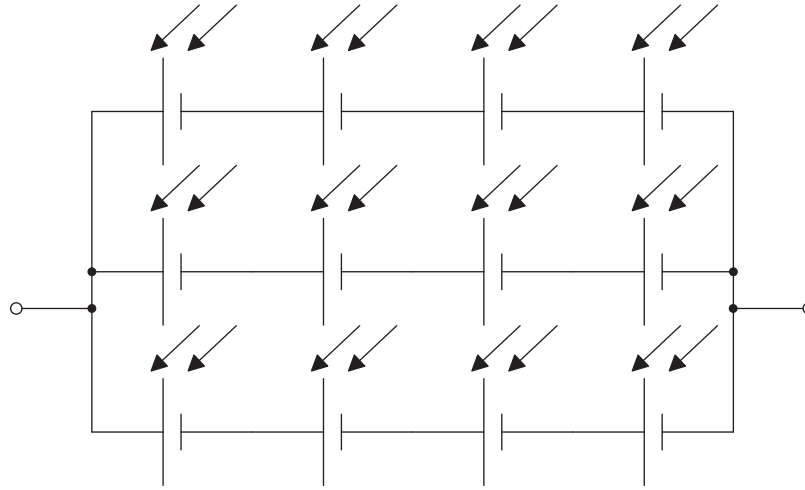(c)    Distinguish between photovoltaic cells and solar heating panels.                    *[2]*

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

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*(This question continues on the following page)*

*(Question B3 continued)*

(d)   The diagram shows 12 photovoltaic cells connected in series and in parallel to form a
module to provide electrical power.

Each cell in the module has an emf of $0.75\,V$ and an internal resistance of $1.8\,\Omega$.

(i)   Calculate the emf of the module.   *[1]*

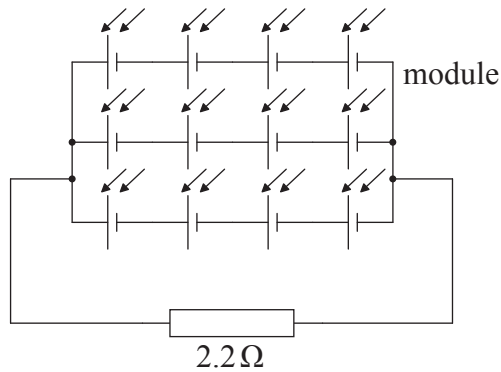(ii)   Determine the internal resistance of the module.   *[3]*

*(This question continues on the following page)*

**Turn over**

*(Question B3 continued)*

(iii) The diagram below shows the module connected to a load resistor of resistance $2.2\,\Omega$.



module

$2.2\,\Omega$

Calculate the power dissipated in the load resistor. *[2]*

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(iv) Discuss the benefits of having cells combined in series and parallel within the module. *[2]*

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

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*(This question continues on the following page)*

*(Question B3 continued)*

(e) The intensity of the Sun's radiation at the position of the Earth's orbit (the solar constant) is approximately $1.4 \times 10^3 \, \text{W m}^{-2}$.

(i) Explain why the average solar power per square metre arriving at the Earth is $3.5 \times 10^2 \, \text{W}$. *[2]*

(ii) State why the solar constant is an approximate value. *[1]*

(iii) Photovoltaic cells are approximately $20\%$ efficient. Estimate the minimum area needed to supply an average power of $850 \, \text{kW}$ over a 24 hour period. *[2]*