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PHYSICS
STANDARD LEVEL
PAPER 2

Candidate session number

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Wednesday 9 November 2011 (afternoon)

1 hour 15 minutes

Examination code

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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.

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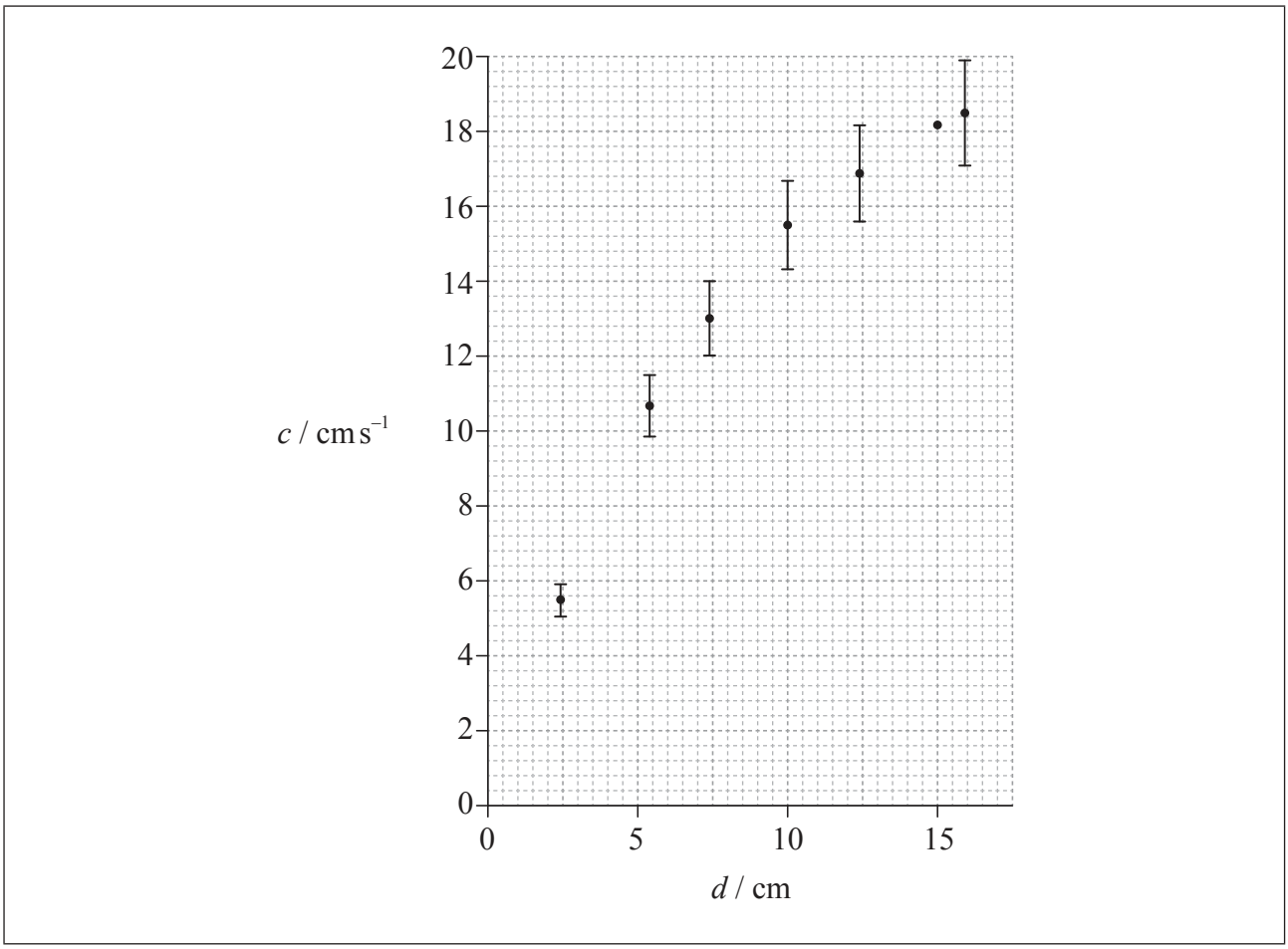
SECTION A

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

A1. Data analysis question.

Caroline carried out an experiment to measure the variation with water depth d of the wave speed c of a surface water wave. Her data are shown plotted below.



The uncertainty in the water depth d is too small to be shown. Uncertainties in the measurement of the wave speed c are shown as error bars on the graph except for the data point corresponding to $d = 15\,\text{cm}$.

(This question continues on the following page)

(Question A1 continued)

(a) Caroline calculated the wave speed by measuring the time t for the wave to travel 150 cm. The uncertainty in this distance is 2 cm. For the reading at a water depth of 15 cm, the time t is 8.3 s with an uncertainty 0.5 s.

(i) Show that the absolute uncertainty in the wave speed at this time is 1.3 cm s^{-1}. *[3]*

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(ii) On the graph opposite, draw the error bar for the data point corresponding to $d = 15$ cm. *[1]*

(b) Caroline hypothesized that the wave speed c is directly proportional to the water depth d.

(i) On the graph opposite, draw a line of best-fit for the data. *[1]*

(ii) Suggest if the data support this hypothesis. *[2]*

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(Question A1 continued)

(c) Another student proposes that c is proportional to $d^{0.5}$.

State a suitable graph that can be plotted to test this proposal. *[1]*

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(d) There is a systematic error in Caroline's determination of the depth.

(i) State what is meant by a systematic error. *[1]*

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(ii) State how the graph in (c) would indicate that there is a systematic error. *[1]*

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A2. This question is about the properties of tungsten.

(a) Tungsten is a conductor used as the filament of an electric lamp. The filament of the lamp is surrounded by glass which is an insulator.

Outline, in terms of their atomic structure, the difference between the electrical properties of tungsten and of glass. *[2]*

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(b) A tungsten filament lamp is marked 6.0 V, 15 W.

(i) Show that the resistance of the lamp at its working voltage is 2.4 Ω. *[1]*

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(ii) The length of the filament is 0.35 m and the resistivity of tungsten is 5.6 10^{-7} Ω m at its working voltage.

Calculate the cross-sectional area of the tungsten filament. *[2]*

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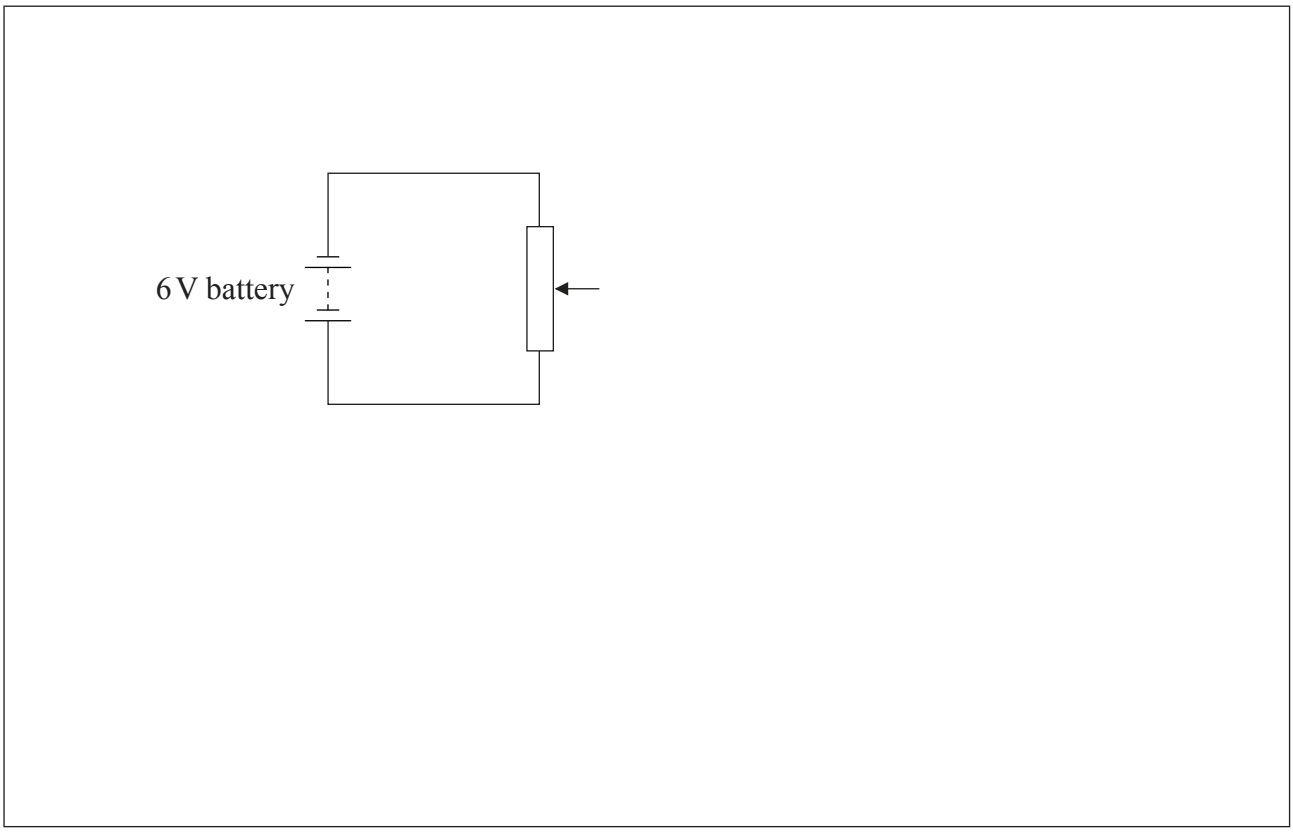
(Question A2 continued)

(c) The diagram shows part of a potential divider circuit used to measure the current-potential difference (*I–V*) characteristic of the bulb.



Draw the complete circuit showing the correct position of the bulb, ammeter and voltmeter. *[2]*

A3. (a) A nuclide of deuterium $\left({}^{2}_{1}\mathrm{H}\right)$ and a nuclide of tritium $\left({}^{3}_{1}\mathrm{H}\right)$ undergo nuclear fusion.

(i) Each fusion reaction releases $2.8\ \ 10^{-12}\,\mathrm{J}$ of energy. Calculate the rate, in $\mathrm{kg\,s^{-1}}$, at which tritium must be fused to produce a power output of 250 MW. *[3]*

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(ii) State **two** problems associated with sustaining this fusion reaction in order to produce energy on a commercial scale. *[2]*

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(b) Tritium is a radioactive nuclide with a half-life of 4500 days. It decays to an isotope of helium.

Determine the time at which 12.5 % of the tritium remains undecayed. *[3]*

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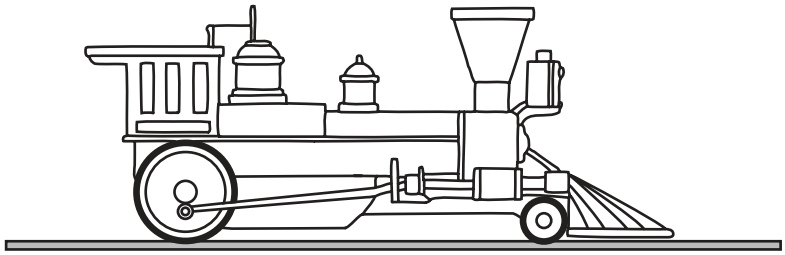
SECTION B

*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 forces. **Part 2** is about internal energy.

Part 1 Forces

A railway engine is travelling along a horizontal track at a constant velocity.



(a) On the diagram above, draw labelled arrows to represent the vertical forces that act on the railway engine. *[3]*

(b) Explain, with reference to Newton's laws of motion, why the velocity of the railway engine is constant. *[2]*

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(Question B1, part 1 continued)

(c) The constant horizontal velocity of the railway engine is $16\,m\,s^{-1}$. A total horizontal resistive force of 76 kN acts on the railway engine.

Calculate the useful power output of the railway engine. *[2]*

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(d) The power driving the railway engine is switched off. The railway engine stops, from its speed of $16\,m\,s^{-1}$, without braking in a distance of 1.1 km. A student hypothesizes that the horizontal resistive force is constant.

Based on this hypothesis, calculate the mass of the railway engine. *[2]*

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(Question B1, part 1 continued)

(e) Another hypothesis is that the horizontal force in (c) consists of two components. One component is a constant frictional force of 19 kN. The other component is a resistive force F that varies with speed v where F is proportional to v^3.

(i) State the value of the magnitude of F when the railway engine is travelling at $16\,m\,s^{-1}$. *[1]*

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(ii) Determine the **total** horizontal resistive force when the railway engine is travelling at $8.0\,m\,s^{-1}$. *[4]*

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(f) On its journey, the railway engine now travels around a curved track at constant speed. Explain whether or not the railway engine is accelerating. *[3]*

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(Question B1 continued)

Part 2 Internal energy

Humans generate internal energy when moving, while their core temperature remains approximately constant.

(a) Distinguish between the concepts of internal energy and temperature. *[3]*

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(b) Explain, in terms of molecular behaviour, how the evaporation of sweat enables humans to maintain a constant temperature. *[3]*

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(Question B1, part 2 continued)

(c) An athlete loses 1.8 kg of water from her body through sweating during a training session that lasts one hour.

Estimate the rate of energy loss by the athlete due to sweating. The specific latent heat of evaporation of water is $2.3 \quad 10^6 \, J \, kg^{-1}$. *[2]*

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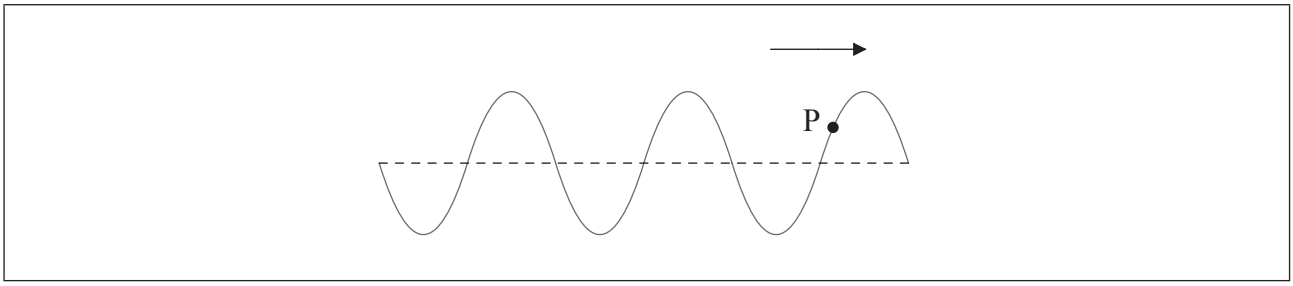
B2. This question is in **two** parts. **Part 1** is about wave motion. **Part 2** is about renewable energy sources.

Part 1 Wave motion

The diagram shows a wave that is travelling to the right along a stretched string at a particular instant.



The dotted line shows the position of the stretched string when it is undisturbed. P is a small marker attached to the string.

(a) On the diagram above, identify

(i) with an arrow, the direction of movement of marker P at the instant in time shown. *[1]*

(ii) the wavelength of the wave. *[1]*

(b) The wavelength of the wave is 25 mm and its speed is 18 mm s^{-1}.

(i) Calculate the time period T of the oscillation of the wave. *[2]*

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(ii) On the diagram above, draw the displacement of the string at a time $\frac{T}{3}$ later than that shown in the diagram. *[1]*

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(Question B2, part 1 continued)

(c) Marker P undergoes simple harmonic motion. The amplitude of the wave is 1.7 10^{-2} m and the mass of marker P is 3.5×10^{-3} kg.

(i) Calculate the maximum kinetic energy of marker P. *[2]*

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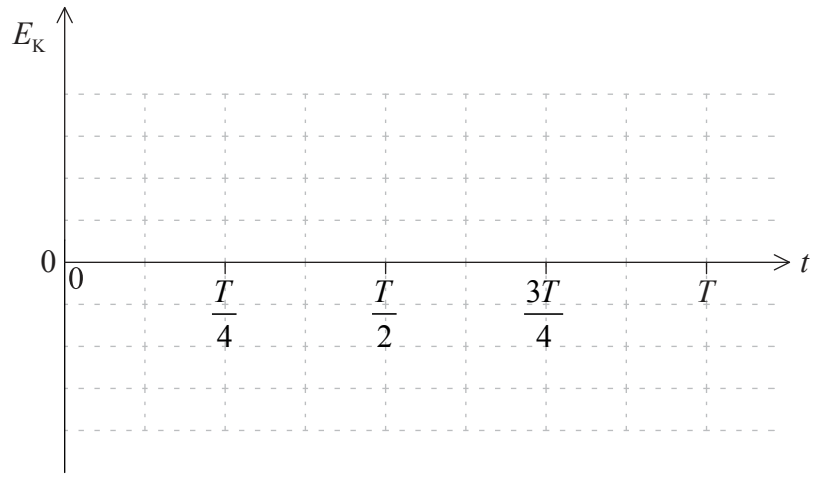
(ii) Sketch a graph to show how the kinetic energy E_K of marker P varies with time t from $t=0$ to $t=T$, where T is the time period of the oscillation calculated in (b). Annotate the axes of the graph with numerical values. *[3]*



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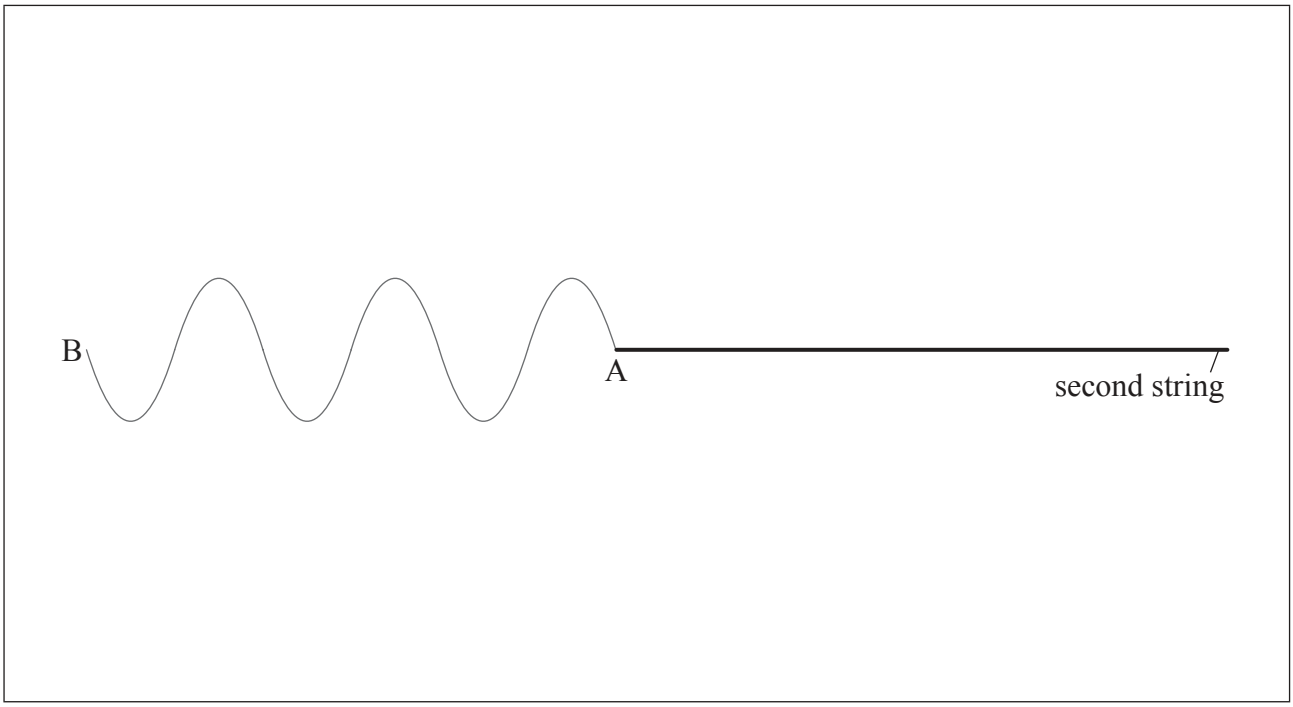
(Question B2, part 1 continued)

(d) The right-hand edge of the wave AB reaches a point where the string is securely attached to a second string in which the speed of waves is smaller than that of the first string.



(i) On the diagram above, draw the shape of the second string after the complete wave AB is travelling in it. *[2]*

(ii) Explain the shape you have drawn in your answer to (d)(i). *[3]*

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(Question B2 continued)

Part 2 Renewable energy sources

(a) The inhabitants of a remote island decide to install a tidal water storage scheme to provide electricity. This scheme is based on the storage of sea water in a tidal lagoon with the controlled release of the water between tides.

(i) State **one** other type of hydroelectric power production. *[1]*

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(ii) Explain the principle of operation of the production method you stated in (a)(i). *[2]*

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(b) A lagoon is to be constructed to hold back the tide. The tide fills the lagoon twice a day.

Surface area of lagoon	$= 1.2 \times 10^5\ \text{m}^2$
Average difference between high and low tide water levels	$= 2.6\ \text{m}$
Density of sea water	$= 1100\ \text{kg m}^{-3}$
Overall efficiency of tidal storage scheme	$= 23\ \%$

(i) Using the data provided, show that the mass of water released from the lagoon each day is $6.9 \times 10^8\ \text{kg}$. *[2]*

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(Question B2, part 2 continued)

(ii) Calculate the total electrical energy that the tidal water storage scheme will output every day. *[3]*

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(c) Another option that the islanders consider is the use of wind power. Suggest **two** possible disadvantages of using wind power as opposed to tidal power. *[2]*

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B3. This question is in **two** parts. **Part 1** is about the greenhouse effect. **Part 2** is about an electric motor.

Part 1 Greenhouse effect

(a) Describe what is meant by the greenhouse effect in the Earth's atmosphere. *[3]*

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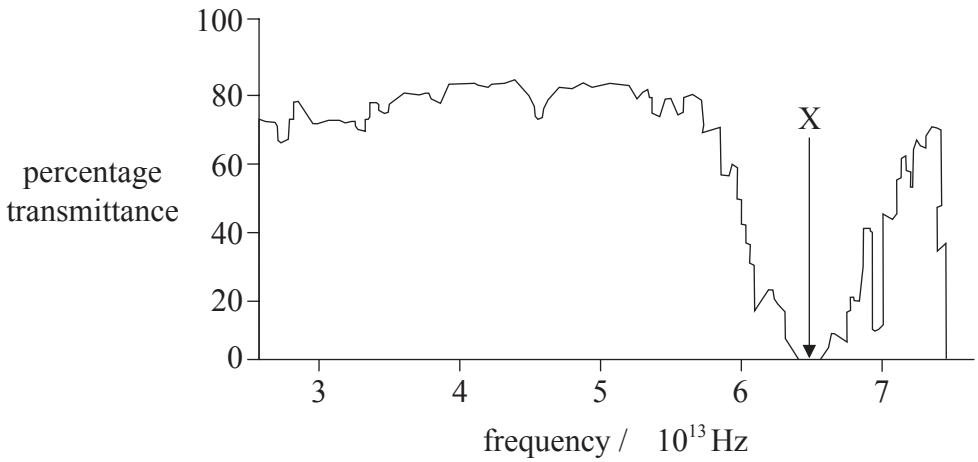
(b) The graph shows the variation with frequency of the percentage transmittance of electromagnetic waves through water vapour in the atmosphere.



(i) Show that the reduction in percentage transmittance labelled X occurs at a wavelength equal to approximately 5 μm. *[1]*

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(Question B3, part 1 continued)

(ii) Suggest, with reference to resonance, the possible reasons for the sharp reduction in percentage transmittance at a wavelength of 5 μm. *[3]*

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(iii) Explain how the reduction in percentage transmittance, labelled X on the graph opposite, accounts for the greenhouse effect. *[2]*

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(iv) Outline how an increase in the concentration of greenhouse gases in the atmosphere may lead to global warming. *[3]*

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(Question B3, part 1 continued)

(c) One source of atmospheric water vapour is evaporation from the Great Lakes system in North America. As a result of evaporation it has been estimated that on a hot day the overall level of the lakes falls by about 1 mm. It has also been estimated that the temperature of the lake area might increase by 0.5 °C if global warming continues at its present rate.

Surface area of Great Lakes system	$=2.4\times10^{5}\,\text{km}^{2}$
Total water volume of Great Lakes system	$=2.3\times10^{3}\,\text{km}^{3}$
Coefficient of volume expansion of water	$=2.1\times10^{-4}\,\text{K}^{-1}$

Use the above data, to show that any increase in water level due to global warming is similar to the loss in water level due to evaporation. *[3]*

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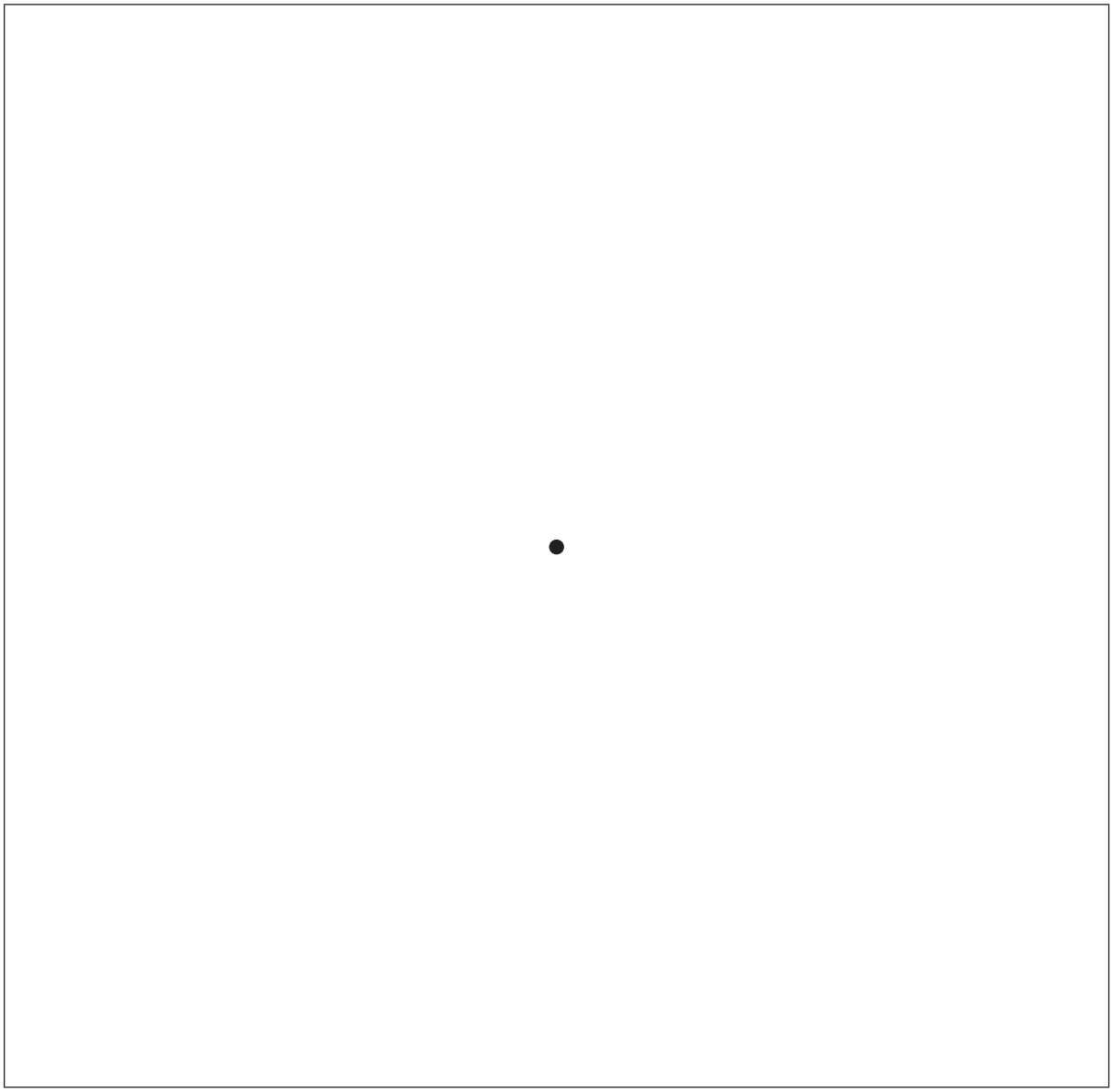
(Question B3 continued)

Part 2 Electric motor

An electric motor is used to raise a load.

(a) Whilst being raised, the load accelerates uniformly upwards. The weight of the cable is negligible compared to the weight of the load.

(i) Draw a labelled free-body force diagram of the forces acting on the accelerating load. The dot below represents the load. *[2]*



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(Question B3, part 2 continued)

(ii) The load has a mass of 350 kg and it takes 6.5 s to raise it from rest through a height of 8.0 m.

Determine the tension in the cable as the load is being raised. *[4]*

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(b) The electric motor can be adjusted such that, after an initial acceleration, the load moves at constant speed. The motor is connected to a 450 V supply and with the load moving at constant speed, it takes the motor 15 s to raise the load through 7.0 m.

(i) Calculate the power delivered to the load by the motor. *[2]*

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(ii) The current in the motor is 30 A. Estimate the efficiency of the motor. *[2]*

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