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PHYSICS
HIGHER LEVEL
PAPER 2

Candidate session number

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Wednesday 9 November 2011 (afternoon)

2 hours 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 two questions.
- Write your answers in the boxes provided.

0140

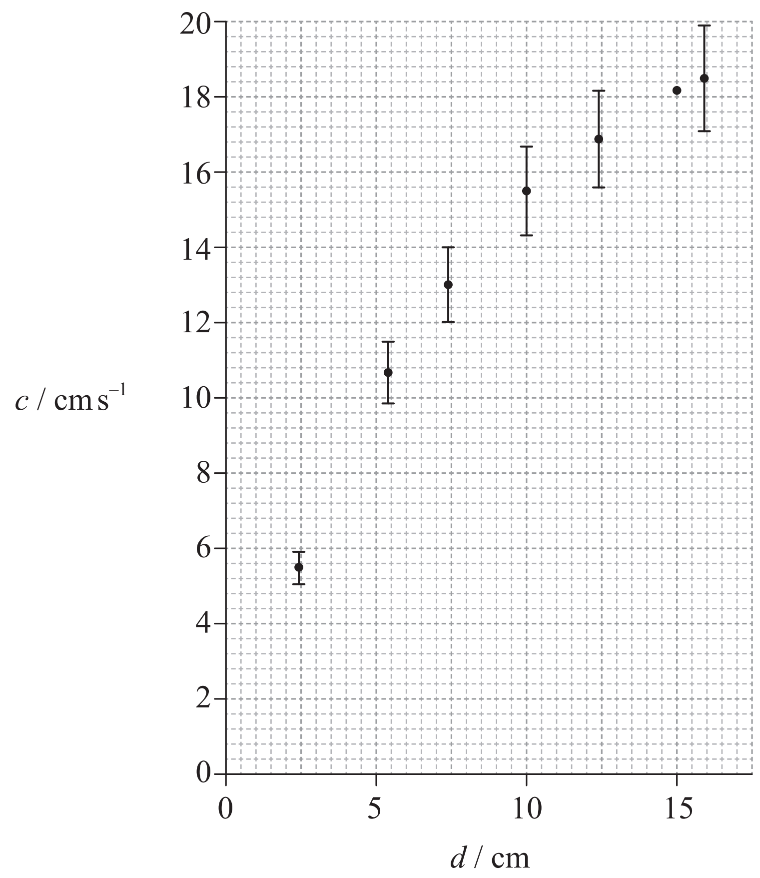
38 pages

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 $d = 15$ 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 $1.3\,\text{cm}\,\text{s}^{-1}$. *[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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(This question continues on the following page)

(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 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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A3. This question is about nuclear processes.

(a) Describe what is meant by

(i) radioactive decay. *[2]*

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(ii) nuclear fusion. *[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 taken for 90 % of a sample of tritium to decay. *[3]*

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(Question A3 continued)

(c) A nuclide of deuterium $\left({}^{2}_{1}\mathrm{H}\right)$ and a nuclide of tritium $\left({}^{3}_{1}\mathrm{H}\right)$ undergo nuclear fusion. The reaction equation for this process is

$$ {}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + \mathrm{X} $$

(i) Identify X. *[1]*

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(ii) Each fusion reaction releases $2.8\ \ 10^{-12}$ 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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(iii) State **two** problems associated with sustaining this fusion reaction in order to produce energy on a commercial scale. *[2]*

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A4. This question is about escape speed and gravitational effects.

(a) Explain what is meant by escape speed. *[2]*

(b) Titania is a moon that orbits the planet Uranus. The mass of Titania is $3.5 \;\; 10^{21}$ kg. The radius of Titania is 800 km.

(i) Use the data to calculate the gravitational potential at the surface of Titania. *[2]*

(ii) Use your answer to (b)(i) to determine the escape speed for Titania. *[3]*

(This question continues on the following page)

(Question A4 continued)

(c) An astronaut visiting Titania throws an object away from him with an initial horizontal velocity of $1.8\,\text{m}\,\text{s}^{-1}$. The object is $1.5\,\text{m}$ above the moon's surface when it is thrown. The gravitational field strength at the surface of Titania is $0.37\,\text{N}\,\text{kg}^{-1}$.

Calculate the distance from the astronaut at which the object first strikes the surface. *[3]*

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A5. This question is about charge-coupled devices (CCDs).

(a) Define *quantum efficiency*. *[1]*

(b) The CCD of a digital camera is composed of square pixels each of area $2.2\ \ 10^{-5}\,\text{mm}^2$. The image of a square window of length 1.2 m is formed on the sensor. The magnification of the CCD is $5.0\ \ 10^{-3}$.

Determine the number of pixels that are used to form the image of the window on the CCD. *[3]*

(c) State **two** advantages that digital cameras have over film cameras. *[2]*

1.

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SECTION B

*This section consists of four questions: B1, B2, B3 and B4. Answer **two** questions. Write your answers in the boxes provided.*

B1. This question is in **two** parts. **Part 1** is about the greenhouse effect. **Part 2** is about electromagnetic induction.

Part 1 Greenhouse effect

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

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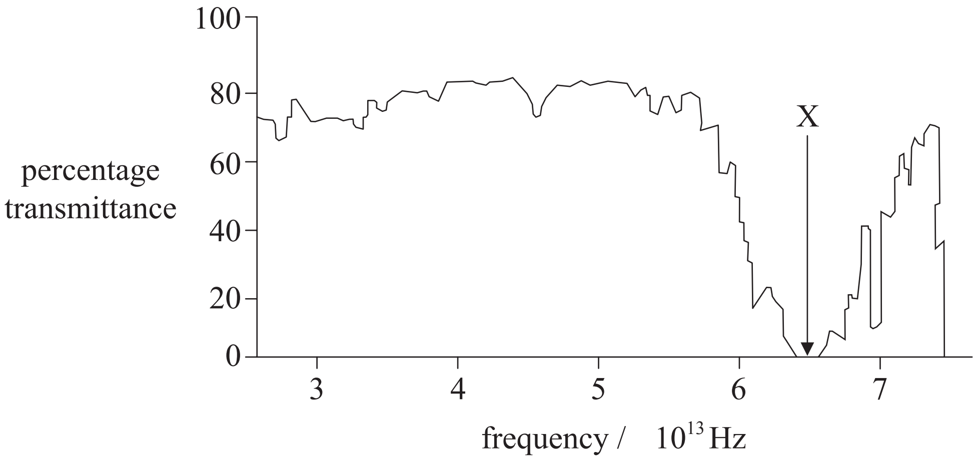
(Question B1, part 1 continued)

(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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(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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(Question B1, part 1 continued)

(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 B1, 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 $= 2.4\ \ 10^{5}\ \text{km}^{2}$

Total water volume of Great Lakes system $= 2.3\ \ 10^{3}\ \text{km}^{3}$

Coefficient of volume expansion of water $= 2.1\ \ 10^{-4}\ \text{K}^{-1}$

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]*

(This question continues on page 16)

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Answers written on this page
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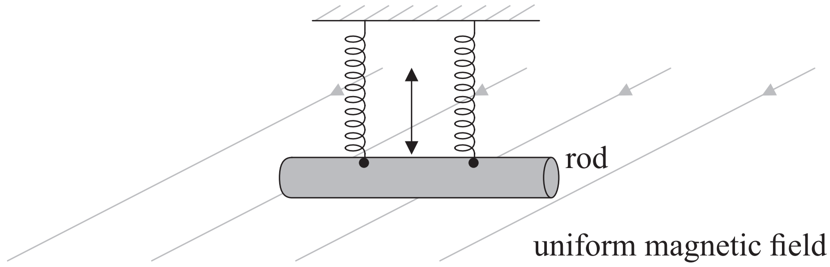
(Question B1 continued from page 14)

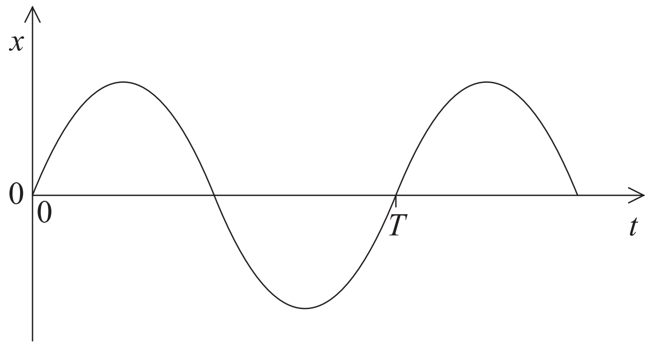
Part 2 Electromagnetic induction

The diagram shows a horizontal metal rod suspended by two vertical insulated springs.



The rod moves vertically up and down with simple harmonic motion with a time period T at right angles to a uniform magnetic field.

The diagram shows the variation with time t of the vertical displacement x of the rod.



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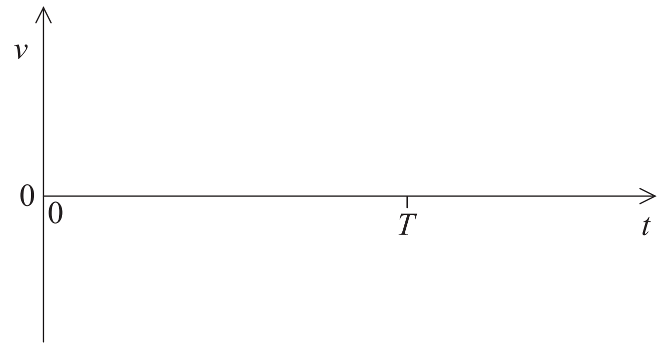
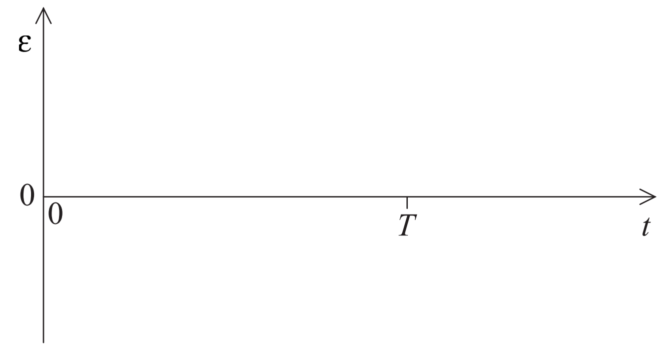
(Question B1, part 2 continued)

(a) On the axes provided, draw a graph to show

(i) the variation with time t of the vertical velocity v of the rod. *[2]*



(ii) the variation with time t of the emf ε generated between the ends of the rod. *[1]*



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(Question B1, part 2 continued)

(b) The length of the rod is 0.18 m and the magnitude of the magnetic field is 58 μT. The frequency of the simple harmonic motion is 2.5 Hz. The amplitude of the motion is 8.2 10^{-2} m.

Determine the magnitude of the maximum emf ε_{max} between the ends of the rod. *[3]*

(c) The frequency of the motion is doubled without any change in the amplitude of the motion.

State and explain the changes to the variation with time *t* of the emf ε generated as a result of this change in frequency. *[4]*

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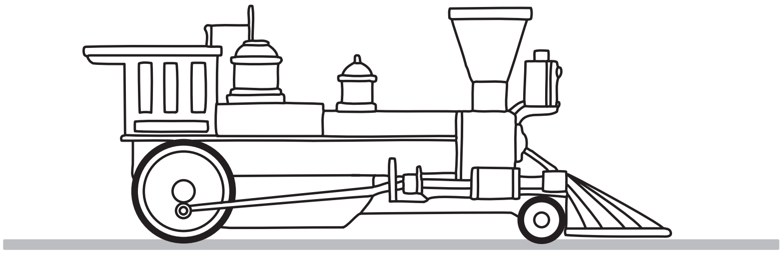
will not be marked.

B2. This question is in **two** parts. **Part 1** is about forces. **Part 2** is about resolution.

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 B2, part 1 continued)

(c) The constant horizontal velocity of the railway engine is $16\,\text{m s}^{-1}$. 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 $16\,\text{m s}^{-1}$, 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 B2, 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 $16\,\text{m}\,\text{s}^{-1}$. *[1]*

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(ii) Determine the **total** horizontal resistive force when the railway engine is travelling at $8.0\,\text{m}\,\text{s}^{-1}$. *[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 B2 continued)

Part 2 Resolution

(a) (i) State the wave phenomenon that limits the resolution of the eye. *[1]*

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(ii) State the Rayleigh criterion for determining if the images of two objects are just resolved. *[2]*

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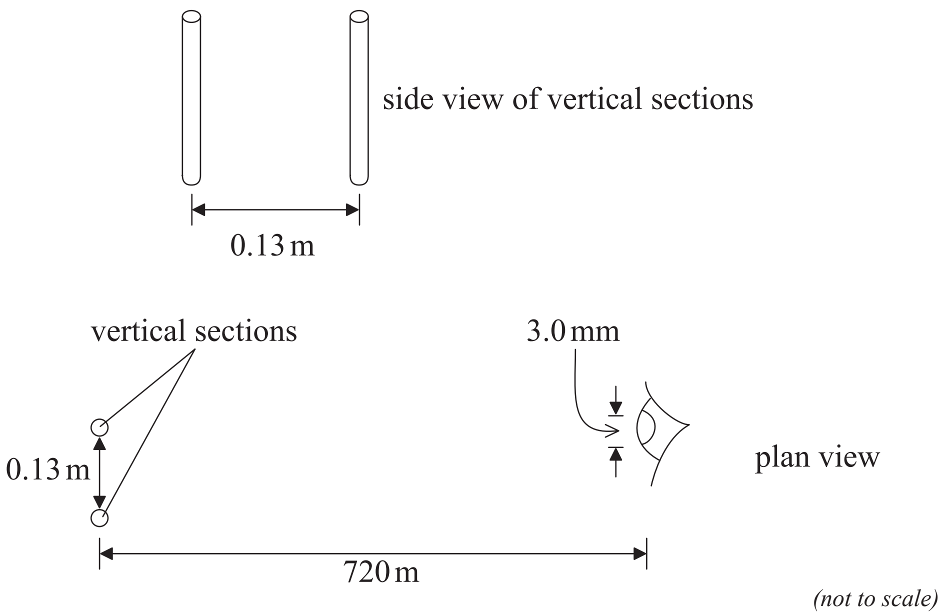
(Question B2, part 2 continued)

(b) An advertising sign contains two straight vertical sections that emit light.



The vertical sections are separated by a horizontal distance of 0.13 m. An observer views them from a distance of 720 m. The wavelength of the emitted light is 510 nm and the diameter of the aperture of the observer's eye is 3.0 mm.

(i) Determine if the images formed on the retina of the observer will be resolved. *[3]*

(This question continues on the following page)

(Question B2, part 2 continued)

(ii) One of the vertical sections is switched off. The observer looks at the illuminated vertical section. The diameter of the aperture of the observer's eye is now 2.5 mm.

Calculate the angular width of the central maximum of the diffraction pattern formed on the observer's retina. *[2]*

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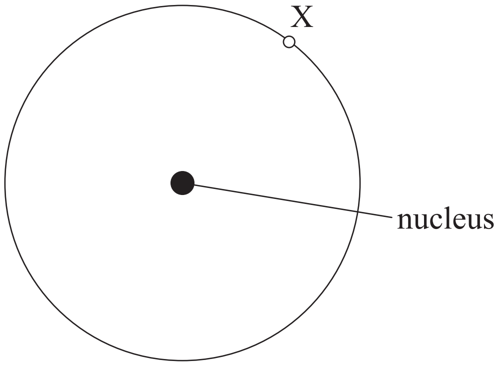
B3. This question is in **two** parts. **Part 1** is about the properties of tungsten. **Part 2** is about the properties of a gas.

Part 1 Properties of tungsten

An isolated nucleus of an atom of the metal tungsten contains 74 protons.



Point X is 140 pm from the nucleus.

(a) (i) On the diagram above, draw an arrow to show the direction of the electric field at point X. *[1]*

(ii) Assuming the nucleus acts as a point charge, determine the magnitude of the electric field strength at point X. *[2]*

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(Question B3, part 1 continued)

(b) 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]*

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

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

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

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

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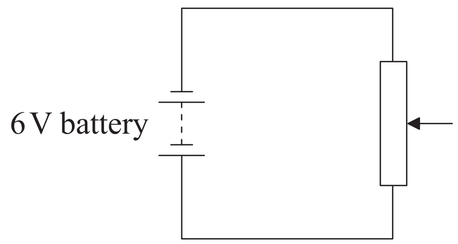
(Question B3, part 1 continued)

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



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

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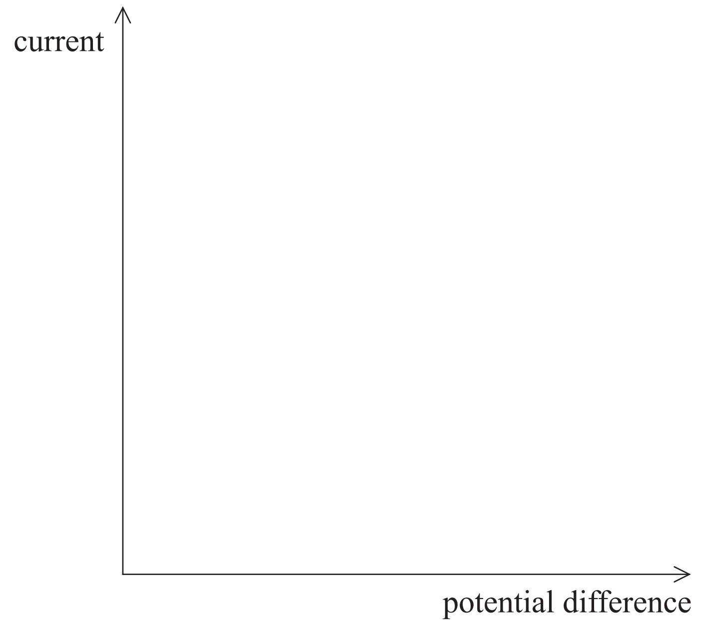
(Question B3, part 1 continued)

(ii) On the axes provided, sketch a graph to show how the current in the bulb varies with the potential difference. *[2]*



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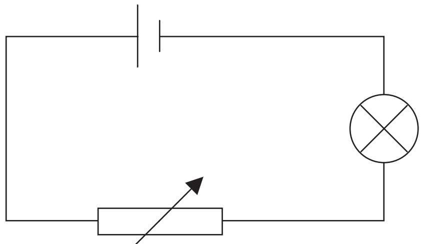
(Question B3, part 1 continued)

(e) A student sets up a different circuit to measure the *I–V* graph. The cell has an emf of 6.0 V and negligible internal resistance. The variable resistor has a minimum resistance of zero and a maximum resistance of 5.0 Ω.



Explain, with a calculation, why this circuit will not allow for a full range of potential difference from 0 V to 6 V across the bulb. Assume that the resistance of the lamp remains constant at a value of 2.4 Ω. *[3]*

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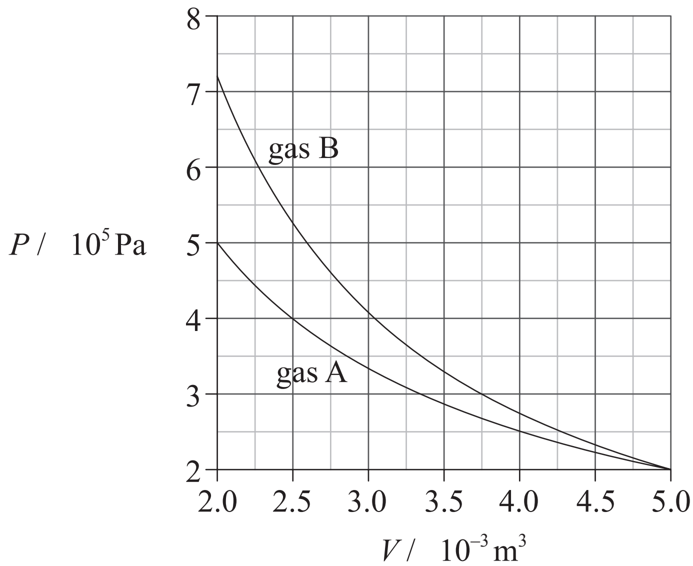
(Question B3 continued from page 30)

Part 2 Properties of a gas

A fixed mass of an ideal gas is at an initial volume of $2.0 \times 10^{-3}\,m^3$. It undergoes an adiabatic expansion to a volume of $5.0 \times 10^{-3}\,m^3$. An identical ideal gas undergoes the same change of volume but this time isothermally.

The graph shows the variation with volume V of the pressure P of the two gases.



(a) Using data from the graph above, identify which gas, A **or** B, undergoes the isothermal expansion. *[2]*

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(Question B3, part 2 continued)

(b) Using the graph opposite, estimate the difference in work done by each gas. *[4]*

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(c) Explain, with reference to the first law of thermodynamics, and without further calculation, the change in temperature of the gas undergoing the adiabatic change. *[4]*

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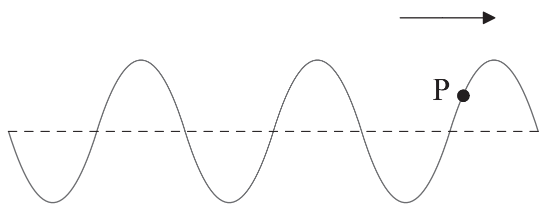
B4. This question is in **two** parts. **Part 1** is about wave motion. **Part 2** is about atomic spectra.

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 B4, 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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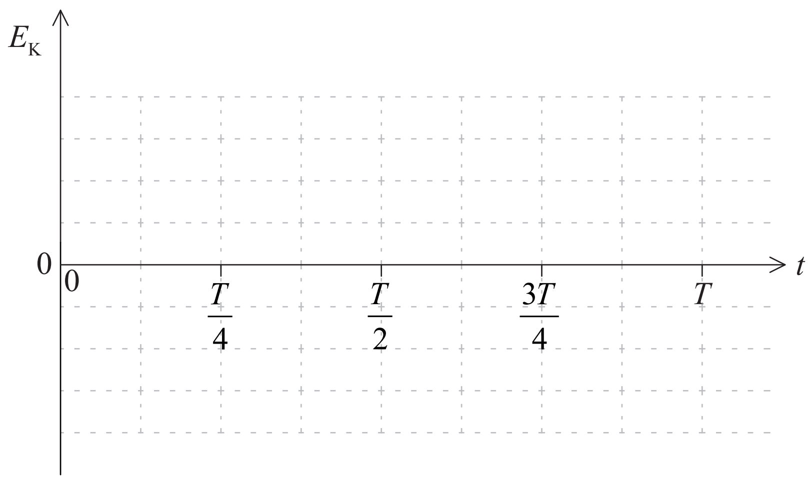
(ii) Sketch a graph to show how the kinetic energy E_K of marker P varies with time t from $t=0$ to $t=T$, where T is the time period of the oscillation calculated in (b). Annotate the axes of the graph with numerical values. *[3]*



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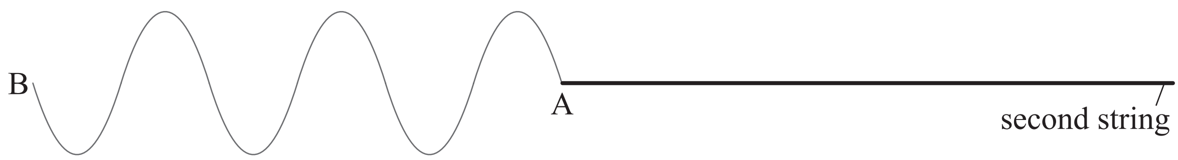
(Question B4, part 1 continued)

(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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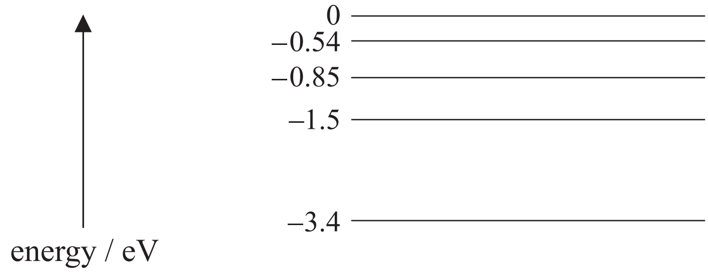
(Question B4 continued)

Part 2 Atomic spectra

The diagram shows some of the principal energy levels of atomic hydrogen.



The emission line spectrum of atomic hydrogen contains a blue line of wavelength 490 nm.

(a) (i) Calculate, in eV, the energy of a photon of wavelength 490 nm. *[2]*

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(ii) On the diagram above, identify with an arrow, the electron transition that gives rise to the emission line of wavelength 490 nm. *[2]*

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(Question B4, part 2 continued)

(b) Explain how the electron in a box model of the hydrogen atom

(i) gives rise to quantized energy levels. *[3]*

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(ii) links with the Schrödinger model. *[3]*

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