IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

N05/4/PHYSI/HP2/ENG/TZ0/XX+

88056502

PHYSICS
HIGHER LEVEL
PAPER 2

Thursday 17 November 2005 (afternoon)

2 hours 15 minutes

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

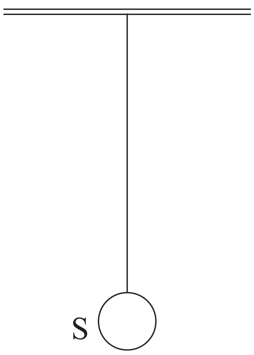
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B in the spaces provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet.

SECTION A

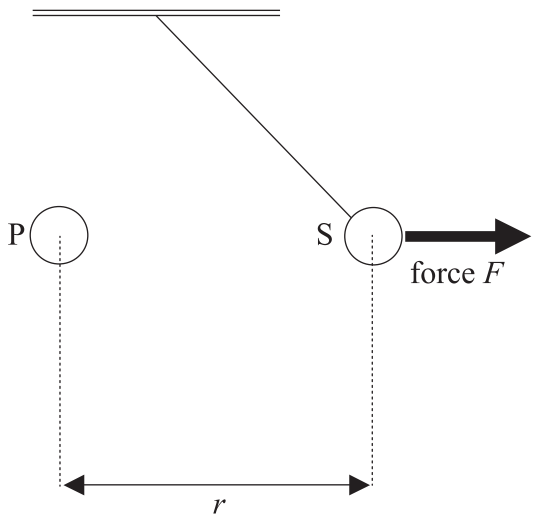
*Answer **all** the questions in the spaces provided.*

A1. This question is about an electrostatics experiment to investigate how the force between two charges varies with the distance between them.

A small charged sphere S hangs vertically from an insulating thread as shown below.



A second identically charged sphere P is brought close to S. S is repelled as shown below.



The magnitude of the electrostatic force on sphere S is F. The separation between the two spheres is r.

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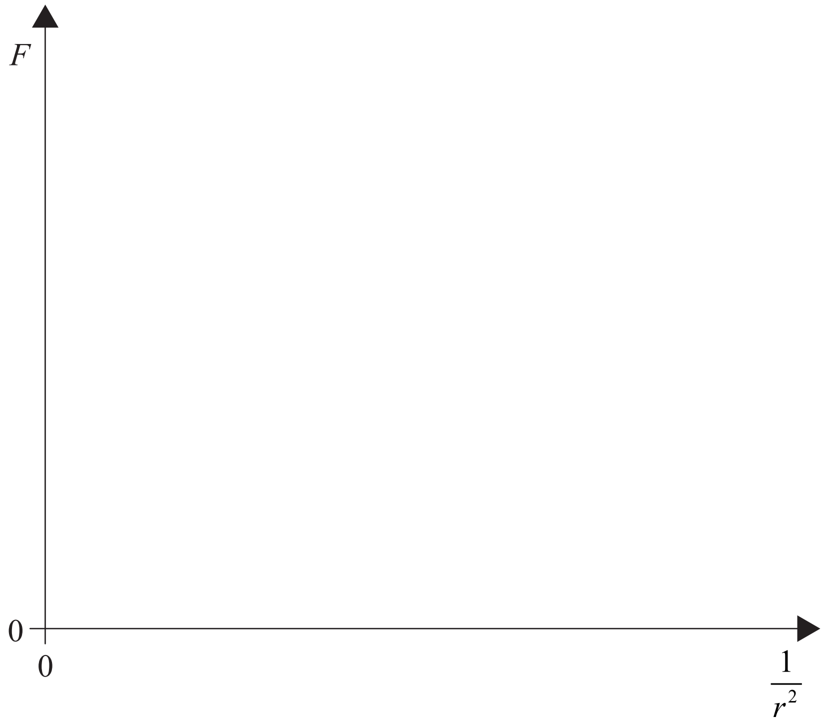
(Question A1 continued)

(a) On the axes below draw a sketch graph to show how, based on Coulomb's law, you would expect F to vary with $\frac{1}{r^2}$. *[2]*



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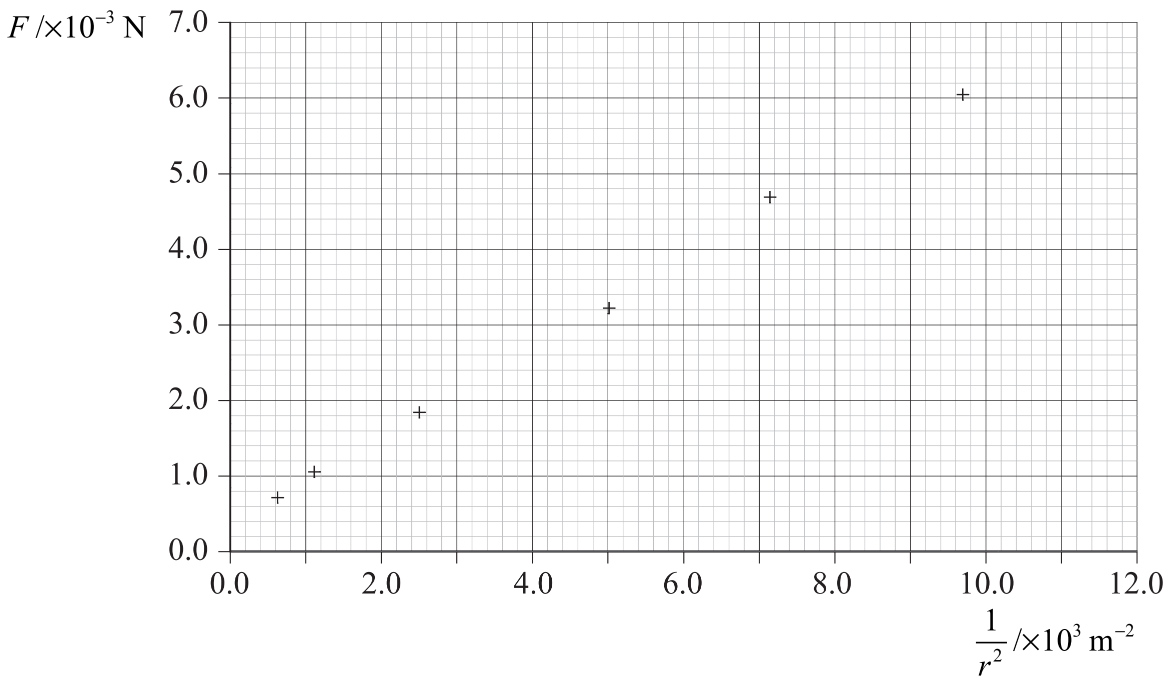
(Question A1 continued)

Values of F are determined for different values of r. The variation with $\frac{1}{r^2}$ of these values is shown below. The estimated uncertainties in these values are negligible.



(b) (i) Draw the best-fit line for these data points. *[2]*

(ii) Use the graph to explain whether, in the experiment, there are random errors, systematic errors or both. *[3]*

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(iii) Calculate the gradient of the line drawn in (b) (i). *[2]*

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(Question A1 continued)

(iv) The magnitude of the charge on each sphere is the same. Use your answer to (b) (iii) to calculate this magnitude. *[4]*

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(c) Explain how a graph showing the variation with lg r of lg F can be used to verify the relation between r and F. *[3]*

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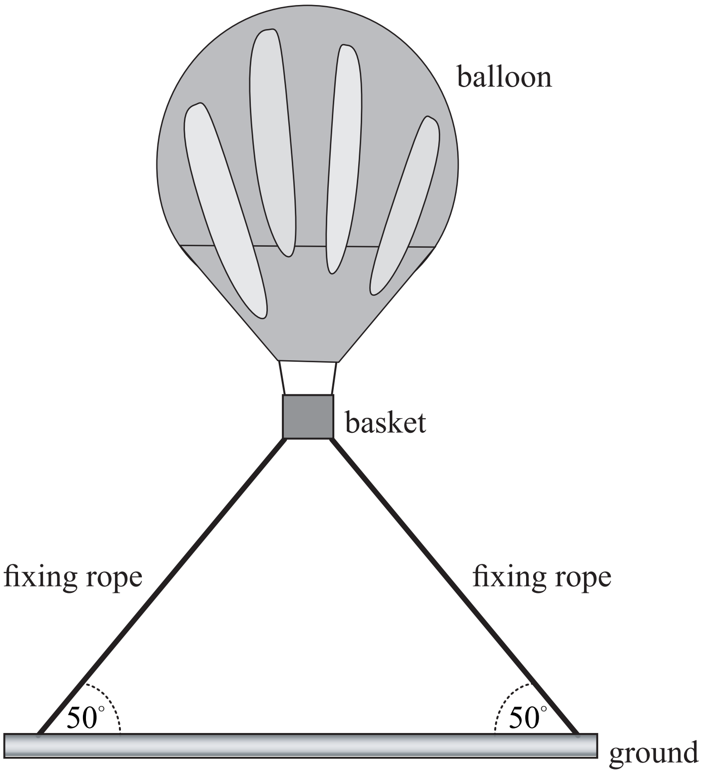
A2. This question is about a balloon used to carry scientific equipment.

The diagram below represents a balloon just before take-off. The balloon's basket is attached to the ground by two fixing ropes.



There is a force F vertically upwards of 2.15×10^3 N on the balloon. The total mass of the balloon and its basket is 1.95×10^2 kg.

(a) State the magnitude of the resultant force on the balloon when it is attached to the ground. *[1]*

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(b) Calculate the tension in **either** of the fixing ropes. *[3]*

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(This question continues on the following page)

(Question A2 continued)

(c) The fixing ropes are released and the balloon accelerates upwards. Calculate the magnitude of this initial acceleration. *[2]*

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(d) The balloon reaches a terminal speed 10 seconds after take-off. The upward force F remains constant. Describe how the magnitude of air friction on the balloon varies during the first 10 seconds of its flight. *[2]*

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A3. This question is about nuclear binding energy and nuclear decay.

(a) State what is meant by a *nucleon*. *[1]*

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(b) Define what is meant by the *binding energy* of a nucleus. *[1]*

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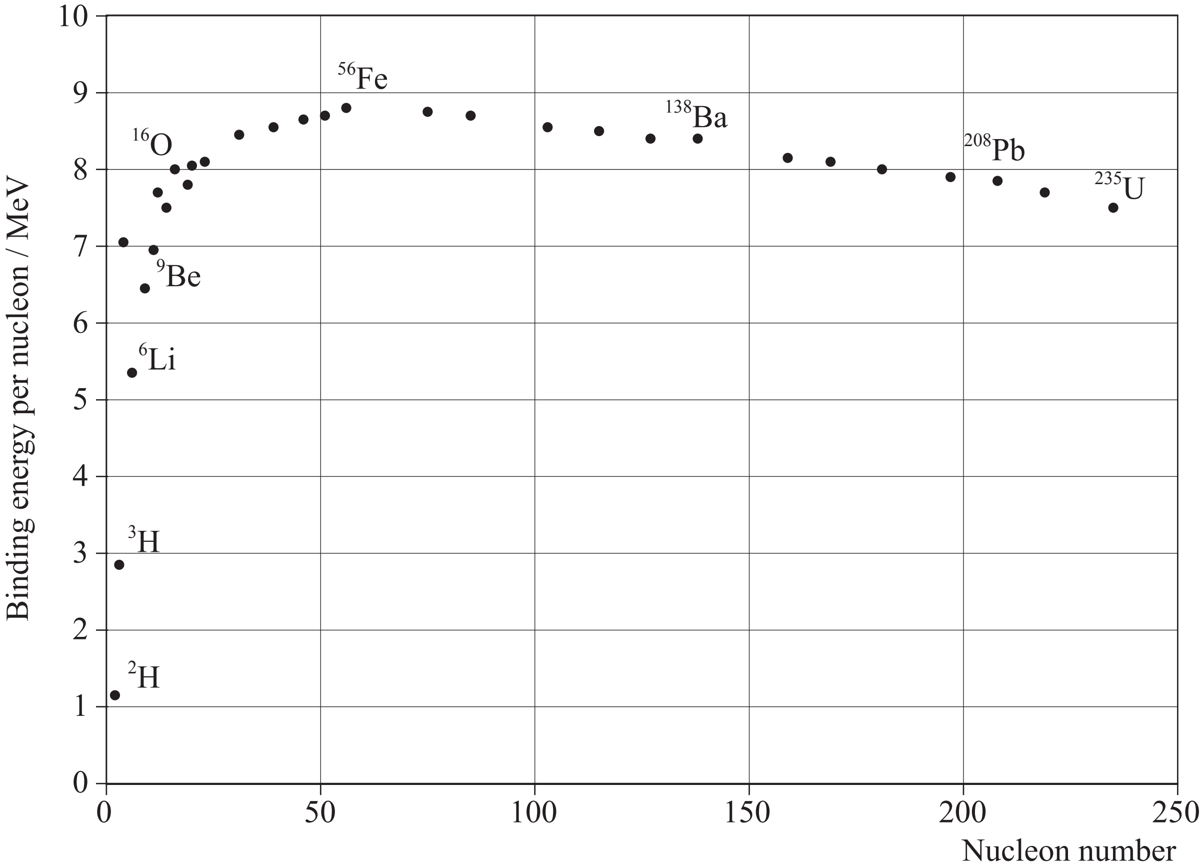
(Question A3 continued)

The graph below shows the variation with nucleon (mass) number of the binding energy per nucleon.



(c) Use the graph to explain why energy can be released in both the fission and the fusion processes. *[3]*

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(Question A3 continued)

(d) Carbon-11, ${}^{11}_{6}C$, undergoes β^+ decay with a half-life of 20.5 minutes to form an isotope of boron.

(i) Write down the nuclear equation for this decay. *[2]*

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(ii) Deduce that a sample of Carbon-11 of mass 1.0×10^{-15} kg contain 5.5×10^{10} atoms. *[2]*

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(iii) Calculate the initial activity of the sample in (d) (ii). *[2]*

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SECTION B

*This section consists of four questions: B1, B2, B3 and B4. Answer **two** questions.*

B1. This question is in **two** parts. **Part 1** is about electrical circuits and **Part 2** is about the physics of cooling.

Part 1 Electrical circuits

Andrew is set the task of measuring the current-voltage (*I-V*) characteristics of a filament lamp. The following equipment and information are available.

	Information
Battery	e.m.f. = 3.0 V, negligible internal resistance
Filament lamp	marked "3 V, 0.2 A"
Voltmeter	resistance = 30 kΩ, reads values between 0.0 and 3.0 V
Ammeter	resistance = 0.1 Ω, reads values between 0.0 and 0.5 A
Potentiometer	resistance = 100 Ω

(a) For the filament lamp operating at normal brightness, calculate

(i) its resistance. *[1]*

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(ii) its power dissipation. *[1]*

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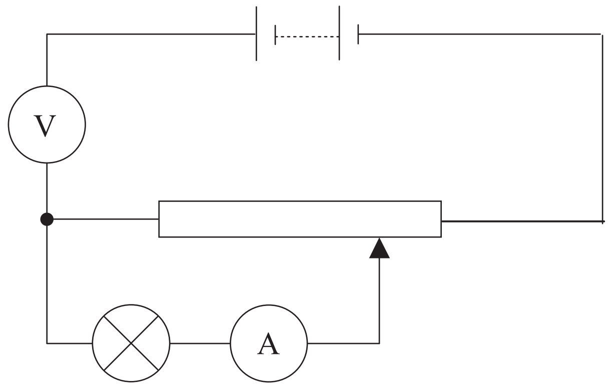
(Question B1, part 1 continued)

Andrew sets up the following **incorrect** circuit.



(b) (i) Explain why the lamp will not light. *[2]*

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(ii) State the approximate reading on the voltmeter. Explain your answer. *[2]*

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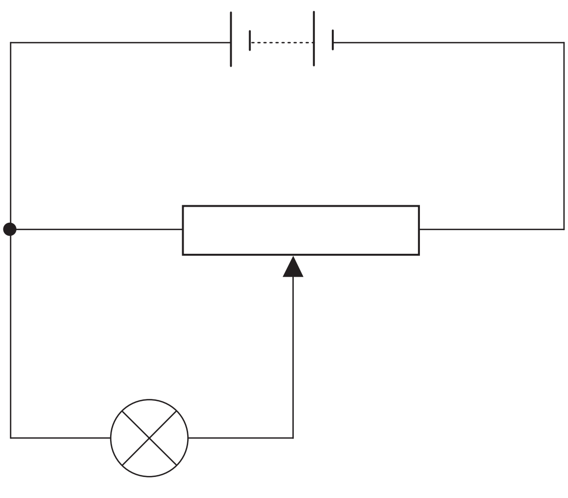
(c) On the circuit diagram below, add circuit symbols to show the correct position of the ammeter and of the voltmeter in order to measure the I-V characteristics of the lamp. *[2]*



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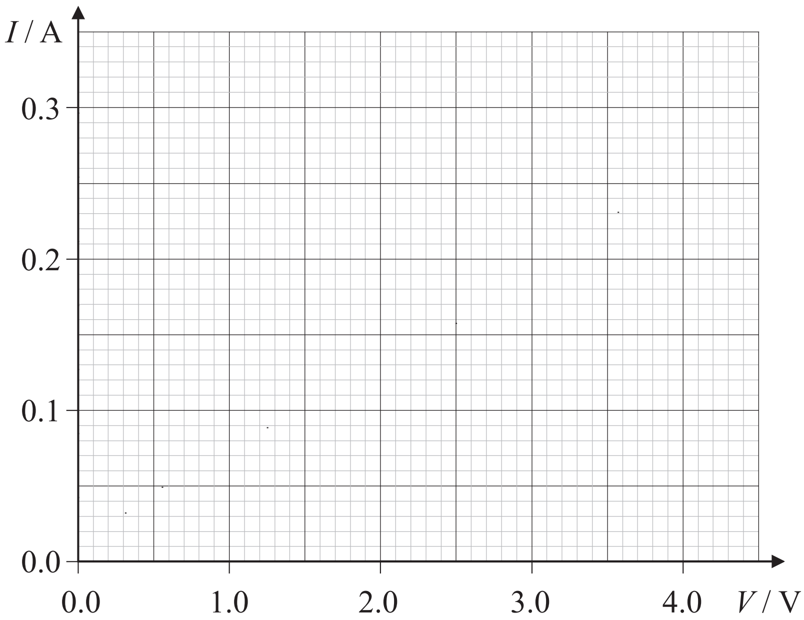
(Question B1, part 1 continued)

(d) On the axes below draw a sketch graph to show the *I-V* characteristics for this filament lamp. *[4]*



(e) Explain the shape of the graph that you have drawn in (d). *[2]*

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(Question B1 continued)

Part 2 The physics of cooling

(a) Explain what is meant by *the temperature of a substance*. *[2]*

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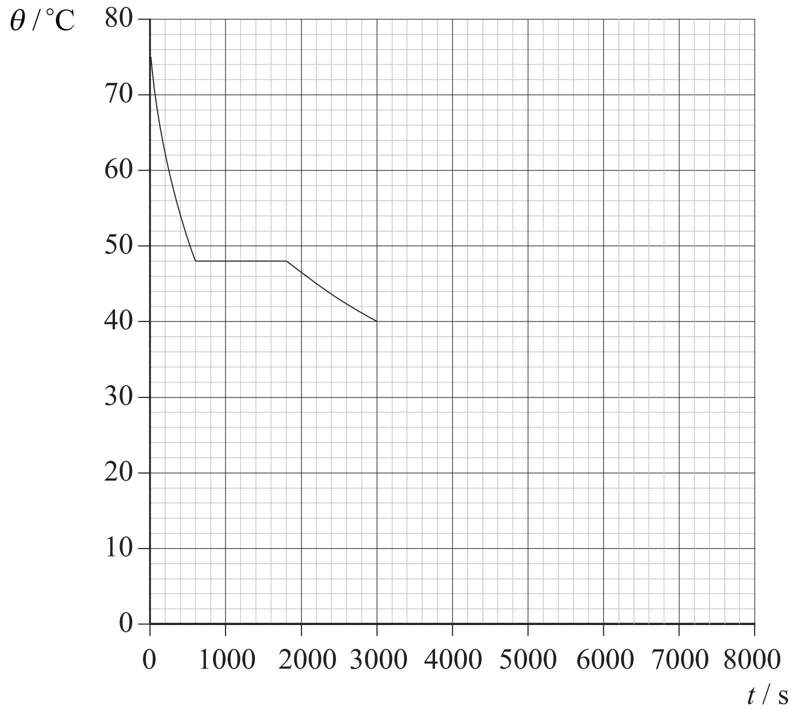
A thermometer is placed in a liquid contained in an open beaker. The reading of the thermometer is recorded at regular intervals. The variation with time t of the temperature θ is shown below.



(b) The temperature of the surroundings is 20 °C. On the graph continue the line to show the variation with time of the temperature for the next 3000 s. *[2]*

(This question continues on the following page)

(Question B1, part 2 continued)

(c) By reference to the graph, state and explain the rate of loss of thermal energy from the substance between

(i) 0 and 600 s. *[2]*

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(ii) 600 and 1800 s. *[4]*

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The mass of the liquid is 0.11 kg and the specific heat capacity of the liquid is 1300 $J\,kg^{-1}\,K^{-1}$.

(d) (i) Use the graph to deduce that the rate of loss of thermal energy at time $t = 600$ s is approximately 4 W. *[3]*

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(ii) Calculate the specific latent heat of fusion of the liquid. *[3]*

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B2. This question is in **two** parts. **Part 1** is about fields and potential. **Part 2** is about the expansion of a gas.

Part 1 Fields and potential

Electric fields and potential

(a) Define *electric potential*. *[2]*

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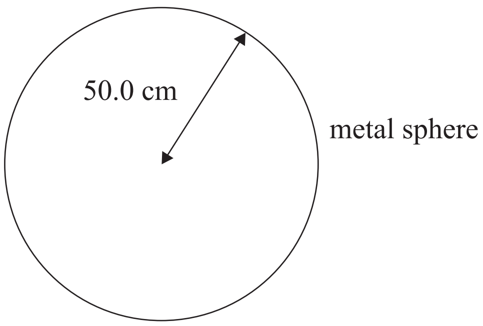
An isolated metal sphere of radius 50.0 cm has a positive charge. The electric potential at the surface of the sphere is 6.0 V.



(b) (i) On the diagram above, draw a line to represent an equipotential surface outside the sphere. *[1]*

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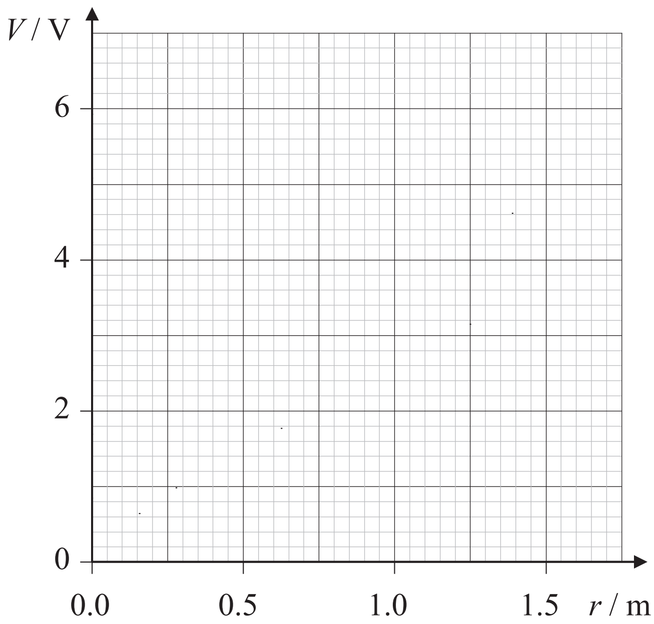
(Question B2, part 1 continued)

(ii) On the axes below, draw a sketch graph to show how the potential V outside the sphere varies with distance r **from the surface of the sphere**. *[4]*



(iii) Explain how the graph drawn in (b) (ii) can be used to determine the magnitude of the electric field strength at the surface of the sphere. *[2]*

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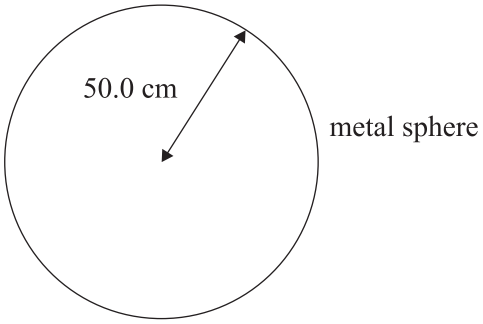
(Question B2, part 1 continued)

(c) On the diagram below draw lines to represent the electric field outside the sphere. *[2]*



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(Question B2, part 1 continued)

Gravitational fields and potential

(d) Derive an expression for the gravitational field strength as a function of distance away from a point mass M. *[3]*

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(e) The radius of the Earth is 6400 km and the gravitational field strength at its surface is 9.8 N kg^{-1}. Calculate a value for the mass of the Earth. *[2]*

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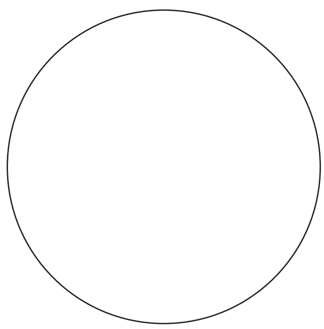
(f) On the diagram below draw lines to represent the gravitational field outside the Earth. *[2]*



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(Question B2, part 1 continued)

(g) A satellite that orbits the Earth is in the gravitational field of the Earth. Discuss why an astronaut inside the satellite feels weightless. *[3]*

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(h) The gravitational potential outside the Earth and the electric potential outside the sphere both vary with distance. Compare these variations. *[2]*

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(Question B2 continued)

Part 2 Expansion of a gas

An ideal gas at an initial pressure of 4.0×10^5 Pa is expanded isothermally from a volume of $3.0\,m^3$ to a volume of $5.0\,m^3$.

(a) Calculate the final pressure of the gas. *[1]*

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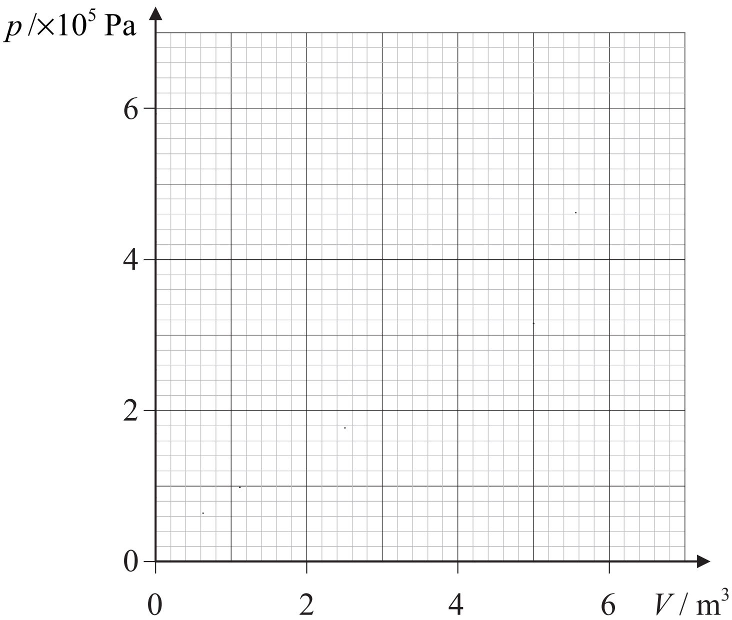
(b) On the axes below draw a sketch graph to show the variation with volume V of the pressure p during this expansion. *[3]*



(c) Use the sketch graph in (b) to

(i) estimate the work done by the gas during this process. *[2]*

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(ii) explain why less work would be done if the gas were to expand adiabatically from the same initial state to the same final volume. *[1]*

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B3. This question is about standing waves and their application to the Schrödinger model of the hydrogen atom.

(a) State the difference between standing waves and travelling waves. *[2]*

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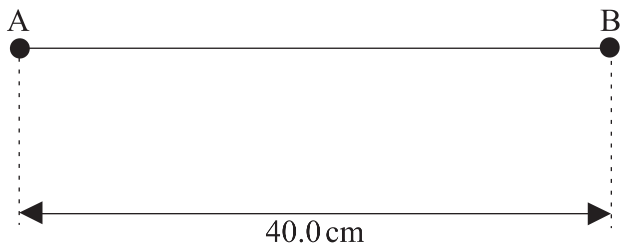
A cord is held under tension between two fixed points A and B. The distance AB is 40.0 cm.



(b) (i) State the wavelength of the fundamental (first harmonic) resonant mode. *[1]*

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(ii) On the diagram above, sketch the shape of the cord when it vibrates in the second harmonic resonant mode. *[1]*

(iii) Explain why it is not possible to have resonant modes of frequencies between the first and second harmonics. *[2]*

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(Question B3 continued)

(iv) The speed of the wave on the string is $200\,\mathrm{m\,s^{-1}}$. Calculate the frequency of the second harmonic. *[2]*

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(v) For a given maximum amplitude the energy of a standing wave is proportional to $(\text{frequency})^2$. Calculate the ratio

$$\frac{\text{energy of the second harmonic}}{\text{energy of the fundamental}},$$

assuming both harmonics have the same maximum amplitude. *[2]*

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(Question B3 continued)

(c) The Schrödinger model of the hydrogen atom incorporates the concept of de Broglie waves.

(i) Describe what is meant by *de Broglie waves*. *[2]*

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(ii) An electron has mass m and kinetic energy E_K. Show that its de Broglie wavelength λ in terms of m, E_K and the Planck constant h, is given by the relationship

$$\lambda = \frac{h}{\sqrt{2mE_K}}.$$ *[2]*

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(iii) Outline an experiment that supports the de Broglie hypothesis. *[5]*

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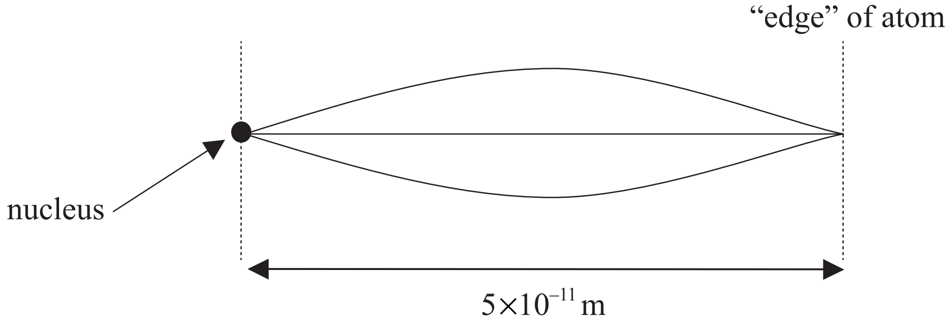
(Question B3 continued)

In a simple model of the hydrogen atom, the “size” of the atom determines the kinetic energy of the electron. Its de Broglie wavelength is equal to the wavelength of the standing wave bounded by the nucleus and the “edge” of the atom, as shown below.



The “edge” of the atom is 5×10^{-11} m from the nucleus.

(d) (i) State the de Broglie wavelength of the electron. *[1]*

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(ii) The “edge” of the hydrogen atom is moved closer to the nucleus. Use your answer in (c) (ii) to describe what changes occur in the kinetic energy of the electron. *[2]*

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(Question B3 continued)

A different model of the hydrogen atom takes into account the fact that the electrical potential energy of the electron depends on its distance from the nucleus.

(e) (i) Explain the variation with the distance from the nucleus of the electrical potential energy of the electron. *[3]*

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(ii) Use your answer to (e) (i) to explain the variation with distance from the nucleus of the kinetic energy of the electron. *[2]*

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(iii) Use your answer to (e) (ii) to suggest how the wavelength of the standing wave of the electron varies with distance away from the nucleus. *[3]*

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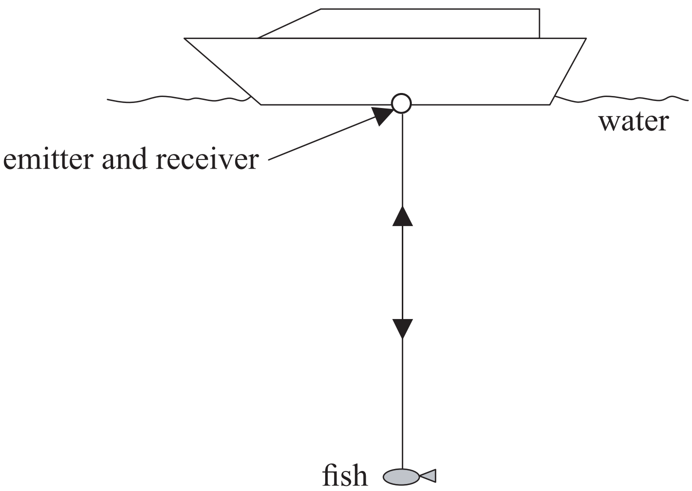
B4. This question is in **two** parts. **Part 1** is about the properties of sound waves and **Part 2** is about kinematics.

Part 1 The properties of sound waves

Reflection and Refraction

One method of finding the position of fish beneath a boat is to send out a pulse of sound waves from the bottom of a boat and time how long the pulse takes to return as shown below. The speed of sound waves in water is $1500\,\text{m}\,\text{s}^{-1}$.



(a) The time between the pulse leaving the emitter and returning to the receiver is 12 ms. Calculate the distance from the bottom of the boat to the fish. *[2]*

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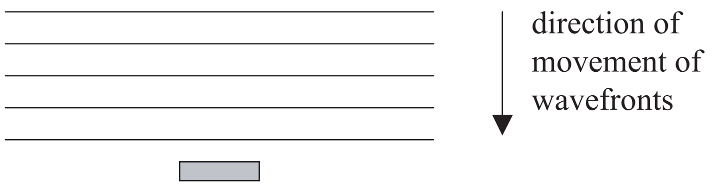
(Question B4, part 1 continued)

In order to find fish using this method, the effects of diffraction at the fish need to be minimised.

(b) (i) The diagram below shows plane wavefronts incident on an obstacle. Complete the diagram to show what is meant by *diffraction of the wavefronts*. *[2]*



(ii) Explain why you would expect the effects of diffraction to be negligible when sound of frequency 60 kHz is incident on a large fish. *[2]*

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(Question B4, part 1 continued)

The Doppler effect can be used to determine the speed of an object.

(c) (i) Explain what is meant by the *Doppler effect*. *[2]*

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(ii) A train approaches and then passes by a stationary observer. The train is moving with constant velocity and emits a sound of constant frequency. The observer hears the frequency change from 490 Hz to 410 Hz. The speed of sound in air is 340 m s^{-1}. Estimate the speed of the train. *[4]*

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(Question B4 continued)

Part 2 Kinematics

(a) State the principle of conservation of energy. *[1]*

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(b) An aircraft accelerates from rest along a horizontal straight runway and then takes-off. Discuss how the principle of conservation of energy applies to the energy changes that take place while the aircraft is accelerating along the runway. *[3]*

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(c) The mass of the aircraft is 8.0×10^{3} kg.

(i) The coefficient of static friction between the axles and the wheels of the aircraft is 3.4×10^{-2}. Estimate the force needed to overcome friction. *[2]*

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(ii) The average resultant force on the aircraft while travelling along the runway is 70 kN. The speed of the aircraft just as it lifts off is $75\,\text{m s}^{-1}$. Estimate the distance travelled along the runway. *[3]*

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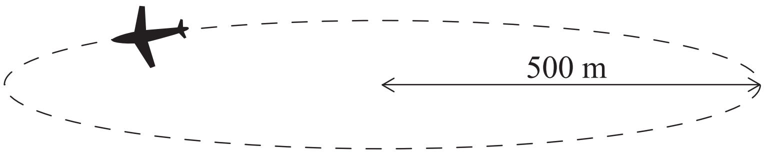
(Question B4, part 2 continued)

When approaching its destination, the pilot puts the aircraft into a holding pattern. This means the aircraft flies at a constant speed of $90\,\mathrm{m\,s^{-1}}$ in a horizontal circle of radius 500 m as shown in the diagram below.



(d) For the aircraft in the holding pattern,

(i) calculate the magnitude of the resultant force on the aircraft. *[2]*

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(ii) state the direction of the resultant force. *[1]*

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(Question B4, part 2 continued)

A package is released from the aircraft in the holding pattern. The height of the aircraft above the ground is 1000 m.

(e) (i) Assuming the frictional forces on the package are negligible, calculate the **velocity** of the package as it hits the ground. *[5]*

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(ii) State the effect of air resistance on the direction, as calculated in (e) (i), with which the package hits the ground. *[1]*

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