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

PHYSICS
HIGHER LEVEL
PAPER 2

Candidate number

Monday 19 May 2003 (afternoon)

2 hours 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your candidate number in the box 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. You may continue your answers on answer sheets. Write your candidate number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

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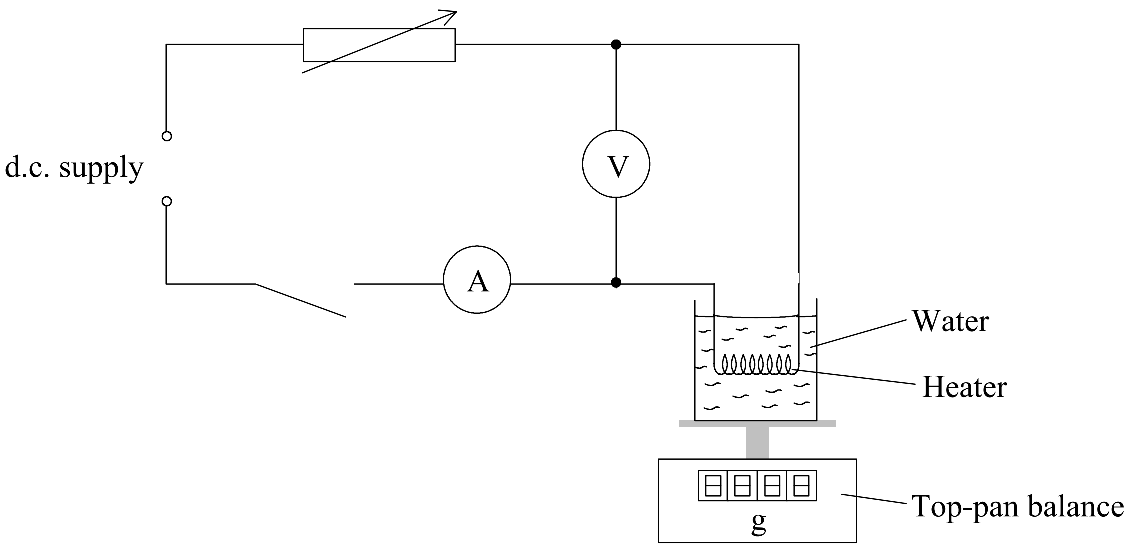
SECTION A

*Candidates must answer **all** questions in the spaces provided.*

A1. Some students were asked to design and carry out an experiment to determine the specific latent heat of vaporization of water. They set up the apparatus shown below.



The current was switched on and maintained constant using the variable resistor. The readings of the voltmeter and the ammeter were noted. When the water was boiling steadily, the reading of the top-pan balance was taken and, simultaneously, a stopwatch was started. The reading of the top-pan balance was taken again after 200 seconds and then after a further 200 seconds.

The change in reading of the top-pan balance during each 200 second interval was calculated and an average found. The power of the heater was calculated by multiplying together the readings of the voltmeter and the ammeter.

(a) Suggest how the students would know when the water was boiling steadily. *[1]*

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(b) Explain why a reading of the mass lost in the first 200 seconds and then a reading of the mass lost in the next 200 second interval were taken, rather than one single reading of the mass lost in 400 seconds. *[2]*

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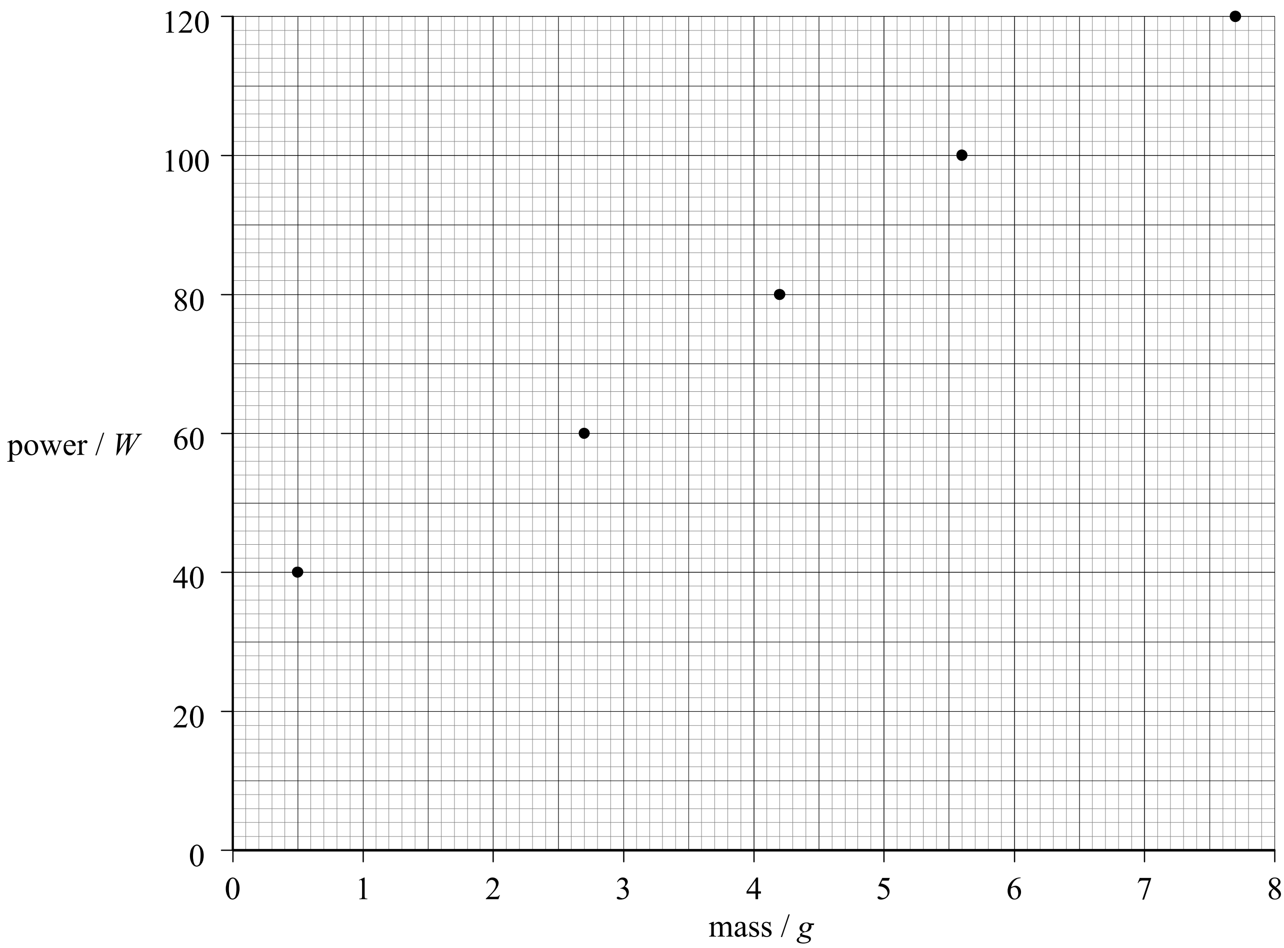
(This question continues on the following page)

(Question A1 continued)

The students repeated the experiment for different powers supplied to the heater. A graph of the power of the heater against the mass of water lost (the change in balance reading) in 200 seconds was plotted. The results are shown below. *(Error bars showing the uncertainties in the measurements are not shown.)*



(c) (i) On the graph above, draw the best-fit straight line for the data points. *[1]*

(ii) Determine the gradient of the line you have drawn. *[3]*

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(This question continues on the following page)

(Question A1 continued)

In order to find a value for the specific latent heat of vaporization L, the students used the equation

$$P = mL\,,$$

where P is the power of the heater and m is the mass of water evaporated **per second**.

(d) Use your answer for the gradient of the graph to determine a value for the specific latent heat of vaporization of water. *[3]*

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(e) The theory of the experiment would suggest that the graph line should pass through the origin. Explain briefly why the graph does not pass through the origin. *[2]*

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A2. (a) State what is meant by an *ideal* gas. *[2]*

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(b) The internal volume of a gas cylinder is $2.0 \times 10^{-2}\,\text{m}^3$. An ideal gas is pumped into the cylinder until the pressure becomes 20 MPa at a temperature of 17 °C.

Determine

(i) the number of moles of gas in the cylinder. *[2]*

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(ii) the number of gas atoms in the cylinder. *[2]*

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(c) (i) Using your answers in (b), determine the average volume occupied by one gas atom. *[1]*

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(ii) Estimate a value for the average separation of the gas atoms. *[2]*

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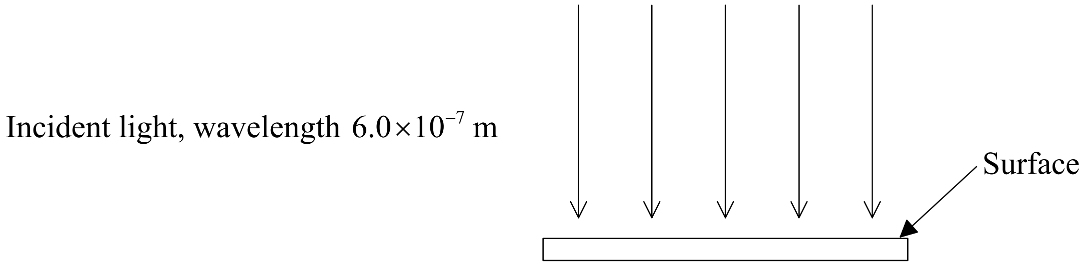
A3. Light of wavelength 6.0×10^{-7} m is incident normally on a plane surface as shown below.



The light photons are absorbed by the surface.

(a) Show that, for one photon of the light,

(i) its energy is 3.3×10^{-19} J . *[2]*

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(ii) its momentum is 1.1×10^{-27} kg m s^{-1}. *[2]*

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(b) The light has intensity 5.0 W m^{-2}. Determine, for an area of 1.0 m^2 of the plane surface,

(i) the number of photons incident per second. *[1]*

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(ii) the change in momentum per second of the photons. *[1]*

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(This question continues on the following page)

(Question A3 continued)

(c) (i) Using your answers in (b), state the pressure exerted by the light on the surface. *[1]*

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(ii) State and explain what would happen to this pressure if the light is reflected rather than absorbed by the surface. *[3]*

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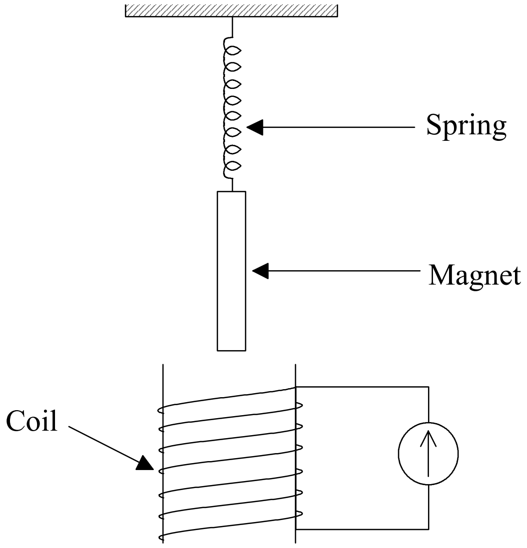
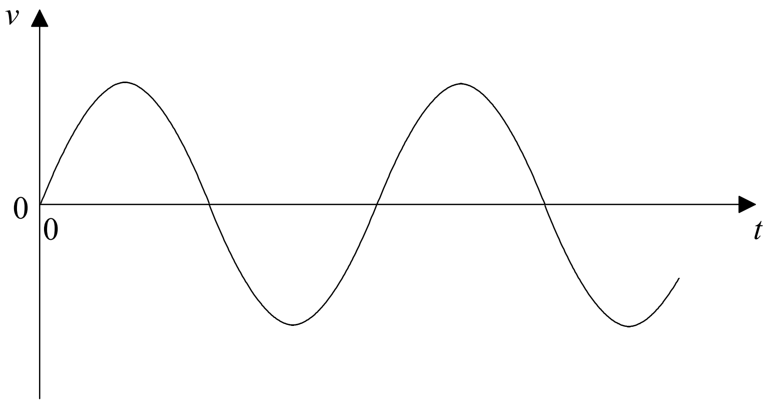
A4. A bar magnet is suspended above a coil of wire by means of a spring, as shown below.



The ends of the coil are connected to a sensitive high resistance voltmeter. The bar magnet is pulled down so that its north pole is level with the top of the coil. The magnet is released and the variation with time t of the velocity v of the magnet is shown below.



(a) On the diagram above,

(i) mark with the letter M, one point in the motion where the reading of the voltmeter is a maximum.

(ii) mark with the letter Z, one point where the reading on the voltmeter is zero. *[2]*

(b) Explain, in terms of changes in flux linkage, why the reading on the voltmeter is alternating. *[2]*

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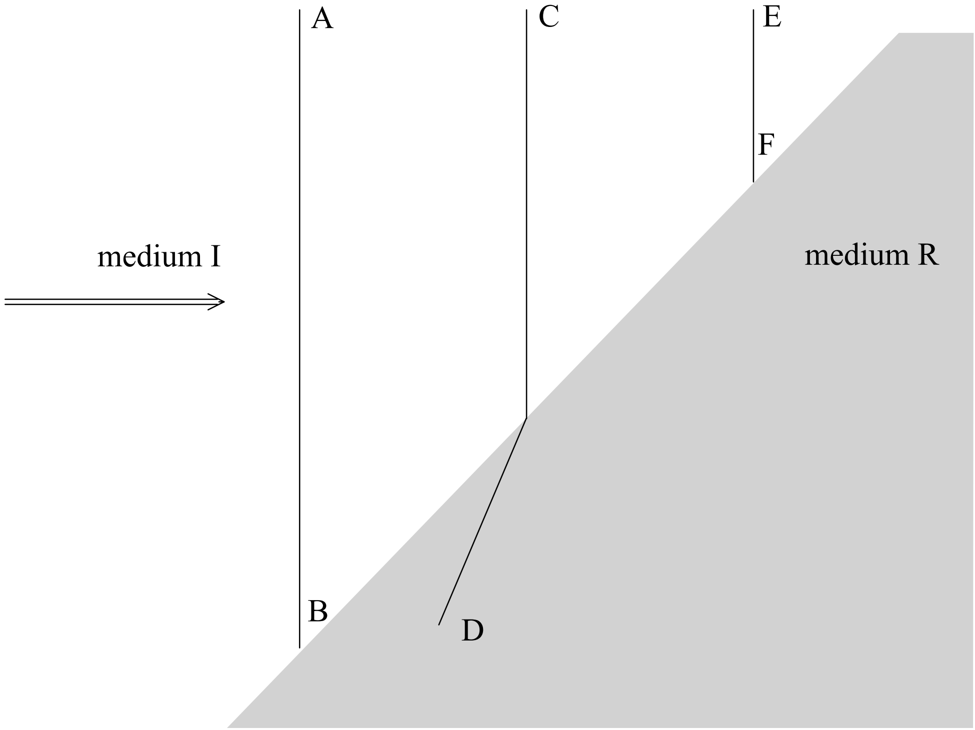
SECTION B

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

B1. This question is about waves and wave properties.

The diagram below shows three wavefronts incident on a boundary between medium I and medium R. Wavefront CD is shown crossing the boundary. Wavefront EF is incomplete.



(a) (i) On the diagram above, draw a line to complete the wavefront EF. *[1]*

(ii) Explain in which medium, I **or** R, the wave has the higher speed. *[3]*

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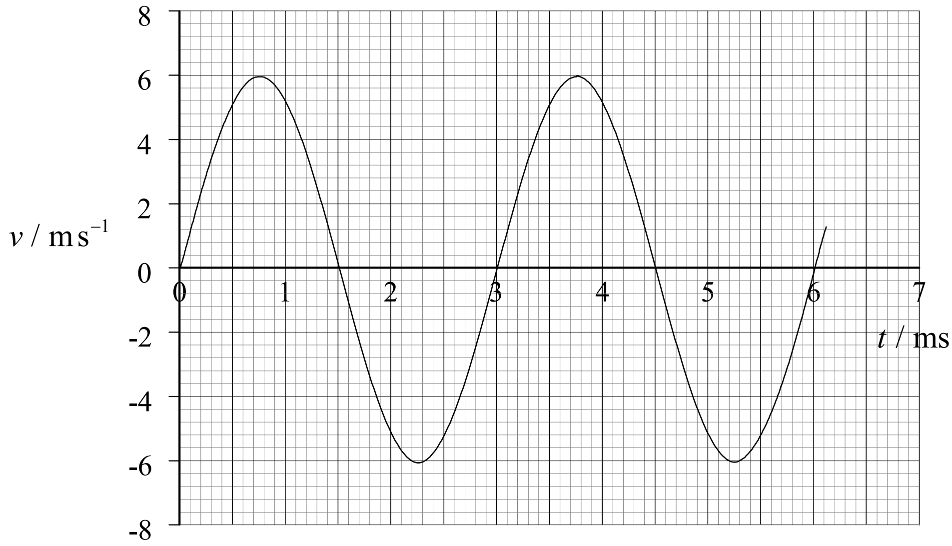
(Question B1 continued)

The graph below shows the variation with time t of the velocity v of one particle of the medium through which the wave is travelling.



(b) (i) Explain how it can be deduced from the graph that the particle is oscillating. *[2]*

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

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(iii) Mark on the graph with the letter M one time at which the particle is at maximum displacement. *[1]*

(iv) Estimate the area between the curve and the x-axis from the time $t = 0$ to the time $t = 1.5$ ms. *[2]*

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(v) Suggest what the area in b (iv) represents. *[1]*

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(c) (i) State the principle of superposition. *[2]*

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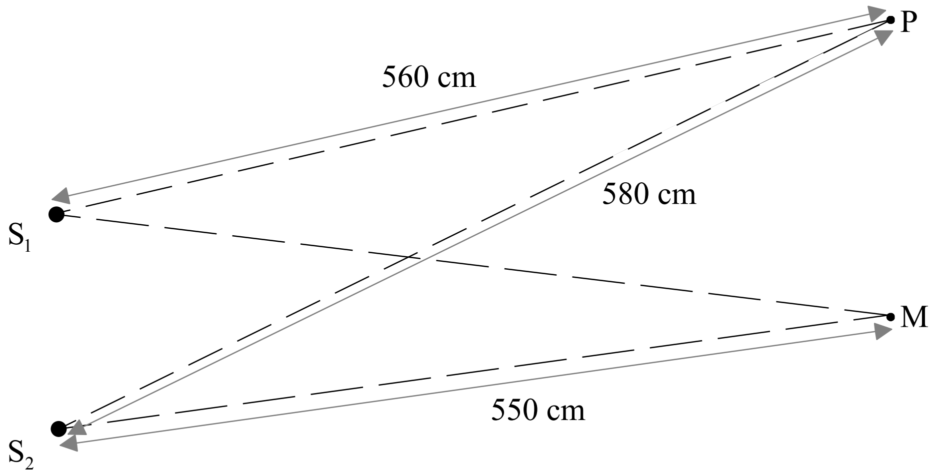
(Question B1 continued)

Two loudspeakers S_1 and S_2 are connected to the same output of a frequency generator and are placed in a large room as shown below.



Sound waves of wavelength 40 cm and amplitude A are emitted by both loudspeakers.

M is a point distance 550 cm from both S_1 and S_2. Point P is a distance 560 cm from S_1 and 580 cm from S_2.

(ii) State and explain what happens to the loudness of the sound detected by a microphone when the microphone is moved from point M to point P. *[4]*

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(iii) Referring to the diagram above, the amplitude of the wave emitted by S_1 is now increased to $2A$. The wave emitted by S_2 is unchanged. Deduce what change, if any, occurs in the loudness of the sound at point M and at point P when this change in amplitude is made. *[4]*

at point M: . . . .

. . . .

at point P: . . . .

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(iv) The loudspeakers are now replaced with two monochromatic light sources. State the reason why bright and dark fringes are not observed along the line PM. *[1]*

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(This question continues on the following page)

(Question B1 continued)

Waves of frequency f and speed c are emitted by a stationary source of sound. An observer moves along a straight line towards the source at a constant speed v.

(d) State, in terms of f, c and v, an expression for

(i) the wavelength of the sound detected by the observer. *[1]*

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(ii) the apparent speed of the wave as measured by the observer. *[1]*

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The observer carries a second source of sound, producing waves of the same actual frequency and speed as the stationary source. Whilst moving, the observer detects a beat frequency of 6.0 Hz for sound waves emitted by the sources of frequency 500 Hz and speed 340 $m\,s^{-1}$.

(e) (i) Describe what is meant by *beats*. *[2]*

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(ii) Calculate the speed v of the observer. *[3]*

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B2. This question is about work, energy and power.

(a) Define the *work done* by a force. *[2]*

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A body of mass m is in a gravitational field of strength g. The body is moved through a distance h at constant speed v in the opposite direction to the field.

(b) Derive an expression in terms of

(i) m, g and h, for the work done on the body. *[2]*

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(ii) m, g and v, for the power required to move the body. *[2]*

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(c) A mass falls near the Earth's surface at constant speed in still air. Discuss the energy changes, if any, that occur in the gravitational potential energy and in the kinetic energy of the mass. *[3]*

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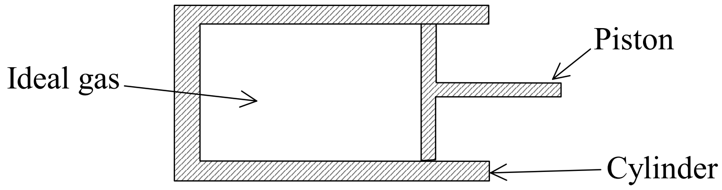
(Question B2 continued)

A sample of an ideal gas is contained in a cylinder fitted with a piston, as shown below.



(d) (i) Explain, in terms of molecules, what is meant by the *internal energy* of the gas. *[2]*

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(ii) The piston is suddenly moved inwards, decreasing the volume of the gas. By considering the speeds of molecules, suggest why the temperature of the gas changes. *[5]*

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(iii) The gas now expands at constant pressure p so that the volume increases by an amount ΔV. Derive an expression for the work done by the gas. *[4]*

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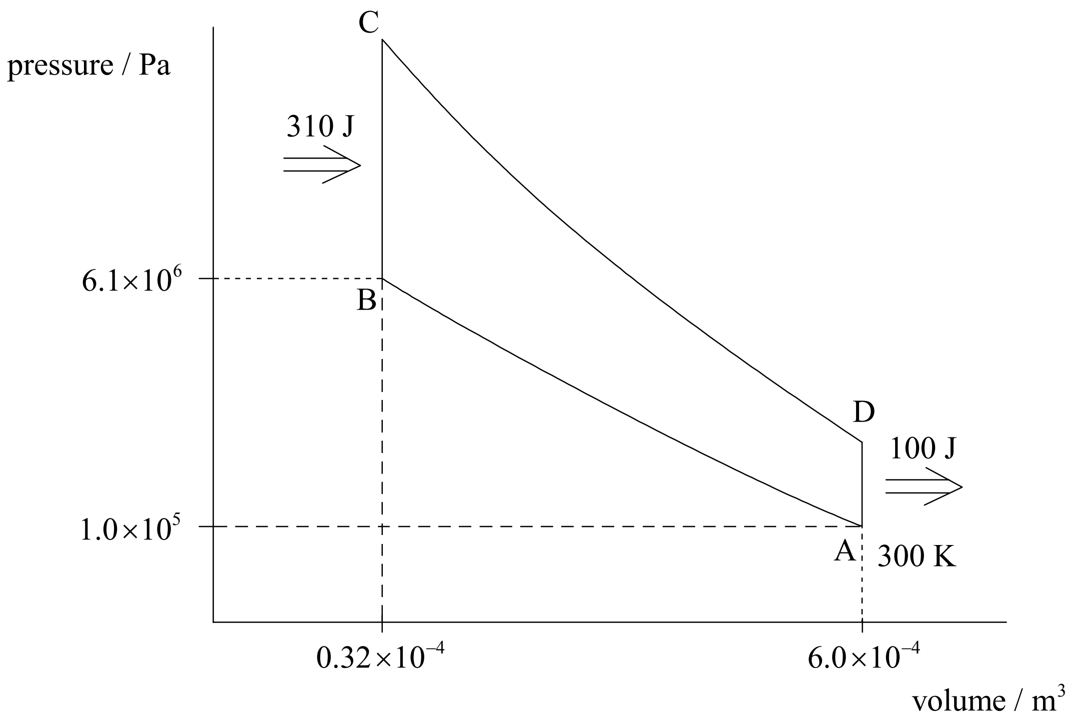
(Question B2 continued)

An engine operates by using an isolated mass of an ideal gas. The gas is compressed adiabatically and then it is heated at constant volume. The gas gains 310 J of energy during the heating process. The gas then expands adiabatically. Finally, the gas is cooled so that it returns to its original state. During the cooling process, 100 J of energy is extracted. The cycle is shown below.



(e) (i) Mark, on the diagram, arrows to show the direction of operation of the stages of the cycle. *[1]*

(ii) Using data for point A, calculate the number of moles of gas. *[2]*

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(iii) Determine the temperature of the gas at point B in the cycle. *[2]*

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(This question continues on the following page)

(Question B2(e) continued)

(iv) State what is represented by the area ABCD on the diagram and give the value of this quantity. *[2]*

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(v) Calculate the efficiency of the engine. *[3]*

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B3. This question is about nuclear reactions.

(a) Complete the table below, by placing a tick (✓) in the relevant columns, to show how an increase in each of the following properties affects the rate of decay of a sample of radioactive material. *[2]*

Property	**Effect on rate of decay**		
	increase	decrease	stays the same
temperature of sample			
pressure on sample			
amount of sample			

Radium-226 ($^{226}_{88}$Ra) undergoes natural radioactive decay to disintegrate spontaneously with the emission of an alpha particle (α-particle) to form radon (Rn). The decay constant for this reaction is $4.30 \times 10^{-4}\ \text{yr}^{-1}$. The masses of the particles involved in the reaction are

radium:	226.0254 u
radon:	222.0176 u
α-particle:	4.0026 u

(b) (i) Explain what is meant by the statement that the decay constant is $4.30 \times 10^{-4}\ \text{yr}^{-1}$. *[2]*

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(ii) Calculate the energy released in the reaction. *[3]*

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(c) The radium nucleus was stationary before the reaction.

(i) Explain, in terms of the momentum of the particles, why the radon nucleus and the α-particle move off in opposite directions after the reaction. *[3]*

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(This question continues on the following page)

(Question B3(c) continued)

(ii) The speed of the radon nucleus after the reaction is v_R and that of the α-particle is v_α. Determine the ratio $\frac{v_\alpha}{v_R}$. *[3]*

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A college has been using a sample of radium-226 as an α-particle source for 30 years. Initially, the mass of radium was 15.0 μg.

(d) Determine

(i) the initial number of atoms of radium-226 in the sample.

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(ii) the number of atoms of radium-226 in the sample after 30 years.

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(iii) the average activity of the sample during the 30 year period. *[6]*

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(Question B3 continued)

(e) The α-particle is composed of protons and neutrons. Describe, by reference to the structure of the proton and the neutron, why they are not classed as fundamental particles. *[3]*

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Another type of nuclear reaction is a fusion reaction. This reaction is the main source of the Sun's radiant energy.

(f) (i) State what is meant by a *fusion reaction*. *[3]*

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(ii) Explain why the temperature and pressure of the gases in the Sun's core must both be very high for it to produce its radiant energy. *[5]*

High temperature: . . . .

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High pressure: . . . .

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B4. This question is about forces on charged particles.

(a) A charged particle is situated in a field of force. Deduce the nature of the force-field (magnetic, electric or gravitational) when the force on the particle

(i) is along the direction of the field regardless of its charge and velocity.

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(ii) is independent of the velocity of the particle but depends on its charge.

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(iii) depends on the velocity of the particle and its charge. *[5]*

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(b) An electron is accelerated from rest in a vacuum through a potential difference of 2.1 kV. Deduce that the final speed of the electron is $2.7 \times 10^7 \text{ m s}^{-1}$. *[3]*

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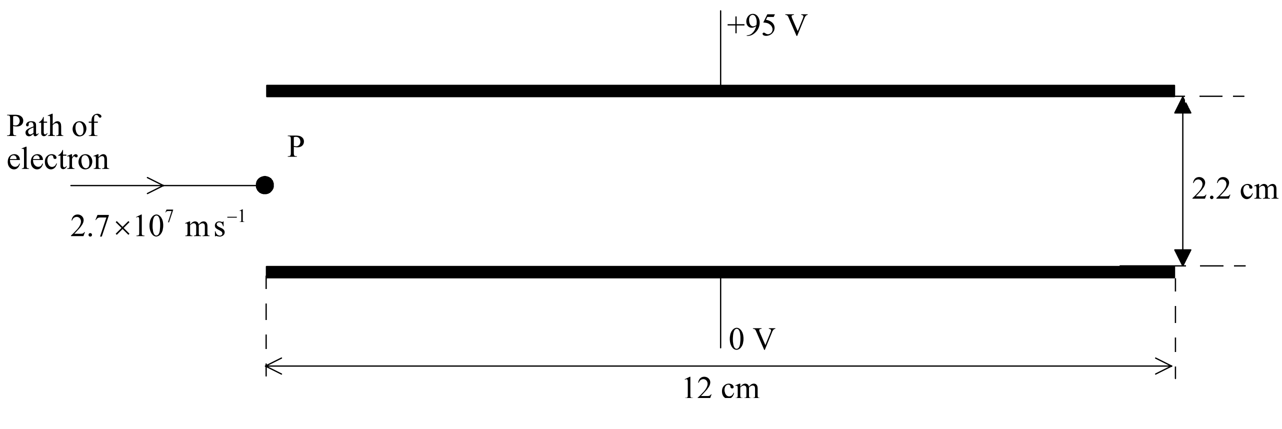
The electron in (b) then enters a region of uniform electric field between two conducting horizontal metal plates as shown below.



The electric field outside the region of the plates may be assumed to be zero.
The potential difference between the plates is 95 V and their separation is 2.2 cm.

As the electron enters the region of the electric field, it is travelling parallel to the plates.

(c) (i) On the diagram above, draw an arrow at P to show the direction of the force due to the electric field acting on the electron. *[1]*

(This question continues on the following page)

(Question B4(c) continued)

(ii) Calculate the force on the electron due to the electric field. *[3]*

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(d) The plates in the diagram opposite are of length 12 cm. Determine

(i) the time of flight between the plates. *[1]*

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(ii) the vertical distance moved by the electron during its passage between the plates. *[3]*

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(e) Suggest why gravitational effects were not considered when calculating the deflection of the electron. *[2]*

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(This question continues on the following page)

(Question B4 continued)

(f) In a mass spectrometer, electric and magnetic fields are used to select charged particles of one particular speed. A uniform magnetic field is applied in the region between the plates, such that the electron passes between the plates without being deviated.

For this magnetic field,

(i) state and explain its direction. *[3]*

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(ii) determine its magnitude. *[2]*

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(g) The electric and magnetic fields in (f) remain unchanged. Giving a brief explanation in each case, compare qualitatively the deflection of the electron in (f) with that of

(i) an electron travelling at a greater initial speed.

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(ii) a proton having the same speed.

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(iii) an alpha particle (α-particle) having the same speed. *[7]*

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