PHYSICS
HIGHER LEVEL
PAPER 2

Candidate number

Tuesday 4 May 2004 (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.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet.

SECTION A

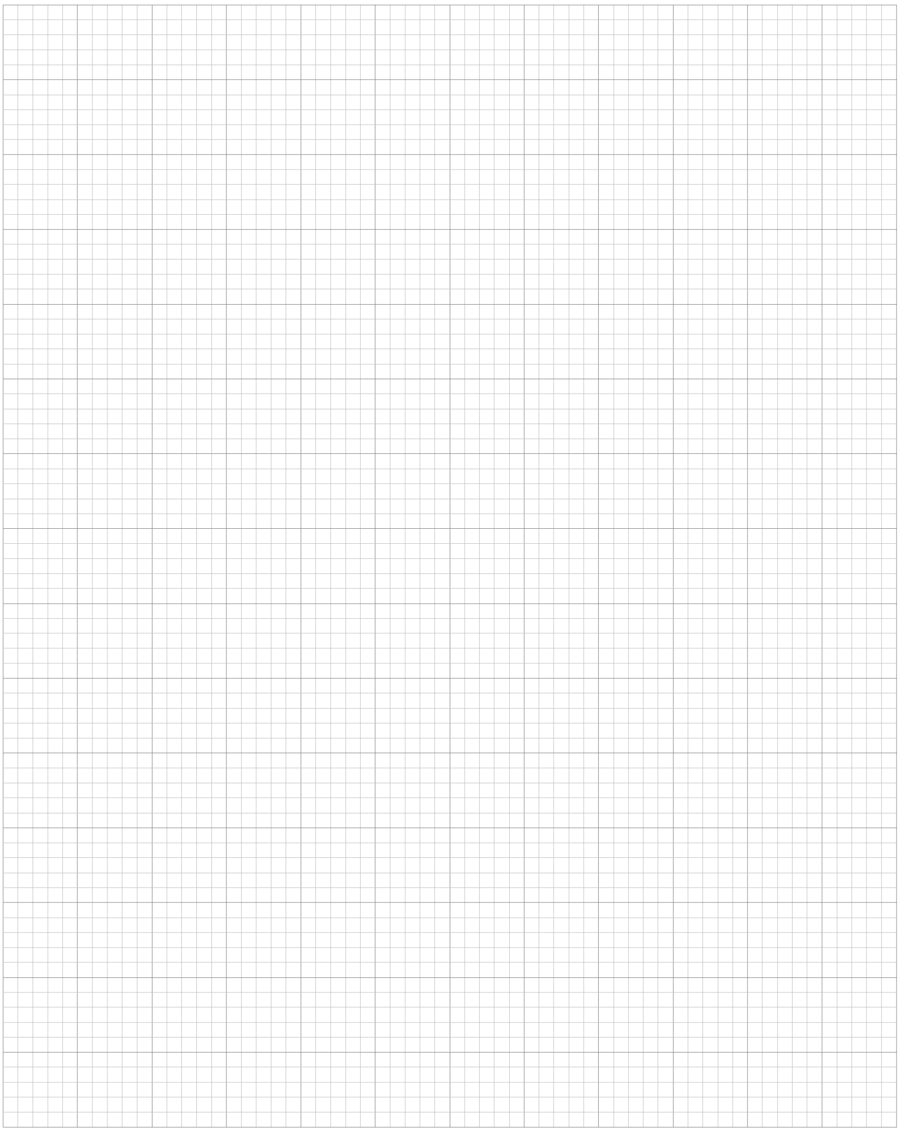
*Answer **all** the questions in the spaces provided.*

A1. Data based question. This question is about change of electrical resistance with temperature.

The table below gives values of the resistance R of an electrical component for different values of its temperature T. (*Uncertainties in measurement are not shown*.)

T/°C	1.2	2.0	3.5	5.2	6.8	8.1	9.6
R/Ω	3590	3480	3250	3060	2880	2770	2650

(a) On the grid below, plot a graph to show the variation with temperature T of the resistance R. Show values on the temperature axis from $T = 0$°C to $T = 10$°C. *[3]*



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(Question A1 continued)

(b) (i) Draw a curve that best fits the points you have plotted. Extend your curve to cover the temperature range from $0^{\circ}C$ to $10^{\circ}C$. *[1]*

(ii) Use your graph to determine the resistance at $0^{\circ}C$ and at $10^{\circ}C$. *[2]*

Resistance at $0^{\circ}C$ = ... Ω

Resistance at $10^{\circ}C$ = ... Ω

(c) On your graph, draw a straight-line between the resistance values at $0^{\circ}C$ and at $10^{\circ}C$. This line shows the variation with temperature (between $0^{\circ}C$ and $10^{\circ}C$) of the resistance, assuming a linear change. *[1]*

(d) (i) Assuming a linear change of resistance with temperature, use your graph to determine the temperature at which the resistance is 3060 Ω. *[1]*

Temperature = ... °C

(ii) Use your answer in (d)(i) to calculate the percentage difference in the temperature for a resistance of 3060 Ω that results from assuming a linear change rather than the non-linear change. *[3]*

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(e) In a particular experiment to measure the variation with temperature of the resistance, each measurement of resistance has an uncertainty of ± 30 Ω and the uncertainty in the temperature measurements is $\pm\ 0.2^{\circ}C$.

(i) On your graph in (a), show the uncertainties in the values of R and of T for temperatures of $1.2^{\circ}C$, $5.2^{\circ}C$ and $9.6^{\circ}C$. *[2]*

(ii) State and explain whether, within the experimental uncertainties, the relationship between resistance and temperature could be linear. *[2]*

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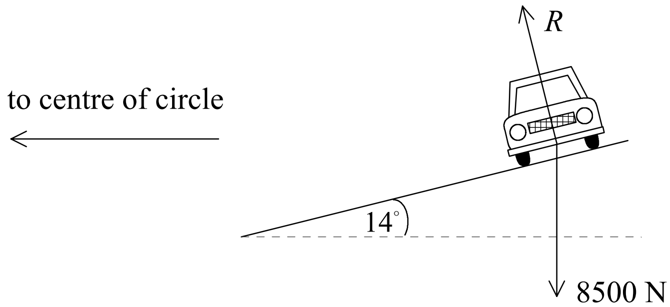
A2. This question is about the motion of a car.

A car of weight 8500 N is travelling at constant speed along a road that is an arc of a circle. In order that the car may travel more easily round the arc, the road is banked at 14° to the horizontal, as shown below.



At one particular speed v of the car, there is no frictional force at 90° to the direction of travel of the car between the tyres and the road surface. The reaction force of the road on the car is R.

(a) Deduce that the horizontal component of the force R is approximately 2100 N. *[2]*

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(b) State the magnitude and direction of the resultant force acting on the car. *[2]*

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(c) Determine the speed v of the car at which it travels round the arc of radius 150 m without tending to slide. *[3]*

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(d) Deduce in which direction the car will tend to slide if it travels round the curve at a speed greater than v. *[2]*

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A3. This question is about entropy changes.

(a) State what is meant by an *increase in entropy* of a system. *[1]*

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(b) State, in terms of entropy, the second law of thermodynamics. *[2]*

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(c) When a chicken develops inside an egg, the entropy of the egg and its contents decreases. Explain how this observation is consistent with the second law of thermodynamics. *[2]*

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A4. This question is about the wave nature of matter.

(a) Explain what is meant by the *de Broglie wavelength* of a particle. *[2]*

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(b) Calculate the de Broglie wavelength of an electron that has been accelerated from rest through a potential difference of 5.0 kV. *[4]*

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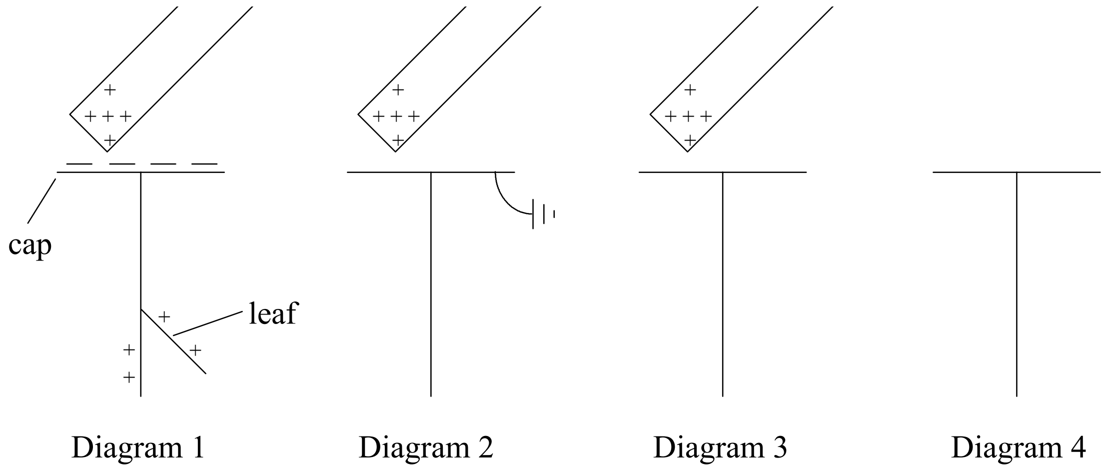
SECTION B

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

B1. This question is about electrical energy and associated phenomena.

Static electricity

A positively charged rod is brought near to the cap of an uncharged gold-leaf electroscope. The distribution of charge on the electroscope is illustrated in diagram 1. Diagrams 2, 3 and 4 are incomplete diagrams of the electroscope.



(a) (i) The cap of the electroscope is then earthed. On diagram 2, show the deflection, if any, of the leaf and the distribution of charge on the electroscope. *[2]*

(ii) The earth connection is now removed. On diagram 3, show the deflection, if any, of the leaf and the distribution of charge on the electroscope. *[1]*

(iii) Finally, the positively charged rod is removed. On diagram 4, show the deflection, if any, of the leaf and the distribution of charge on the electroscope. *[2]*

(b) (i) Define *electric potential difference* between two points. *[2]*

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(ii) Using your answers to (a), explain whether a gold-leaf electroscope measures electric charge **or** electric potential difference. *[3]*

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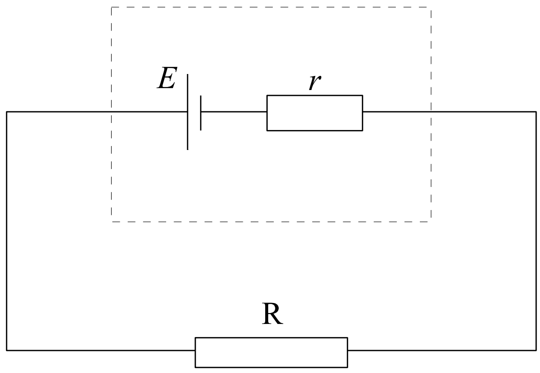
(Question B1 continued)

Current electricity

A cell of electromotive force (e.m.f.) E and internal resistance r is connected in series with a resistor R, as shown below.



The cell supplies 8.1×10^3 J of energy when 5.8×10^3 C of charge moves completely round the circuit. The current in the circuit is constant.

(c) (i) Calculate the e.m.f. E of the cell. *[2]*

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(ii) The resistor R has resistance 6.0 Ω. The potential difference between its terminals is 1.2 V. Determine the internal resistance r of the cell. *[3]*

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(iii) Calculate the total energy transfer in the resistor R. *[2]*

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(Question B1 continued)

(iv) Describe, in terms of a simple model of electrical conduction, the mechanism by which the energy transfer in the resistor R takes place. *[5]*

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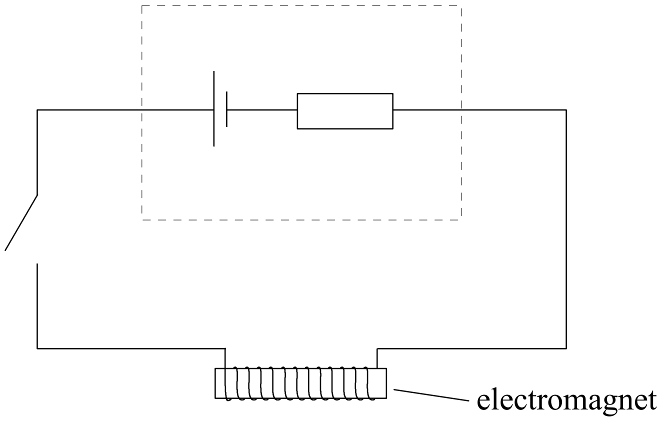
(Question B1 continued)

Electromagnetism

The resistor R is now replaced with an electromagnet and a switch, as shown below.



The current in the circuit is switched on.

(d) (i) State Faraday's law of electromagnetic induction and use the law to explain why an e.m.f. is induced in the coil of the electromagnet. *[3]*

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(ii) State Lenz's law and use the law to predict the direction of the induced e.m.f. in (d)(i). *[3]*

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(iii) Magnetic energy is stored in the electromagnet. State and explain, with reference to the induced e.m.f., the origin of this energy. *[2]*

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B2. This question is about waves and wave motion. **Part 1** deals with earthquake waves and **Part 2** with the Doppler effect.

Part 1 Earthquake waves

(a) (i) Light is emitted from a candle flame. Explain why, in this situation, it is correct to refer to the "speed of the emitted light", rather than its velocity. *[2]*

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(ii) By reference to displacement, describe the difference between a longitudinal wave and a transverse wave. *[3]*

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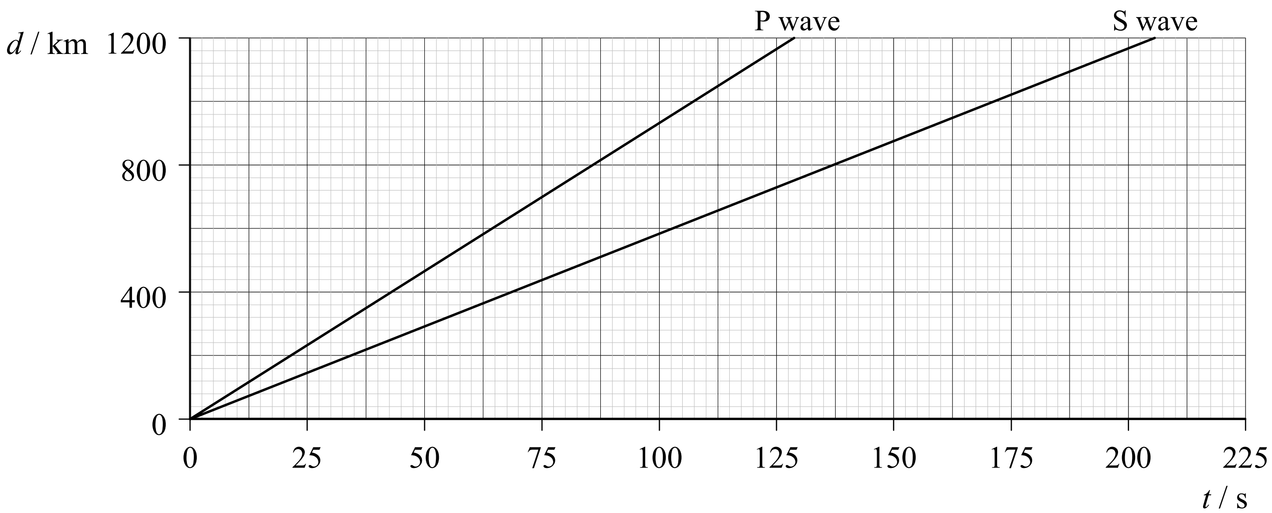
The centre of an earthquake produces both longitudinal waves (P waves) and transverse waves (S waves). The graph below shows the variation with time t of the distance d moved by the two types of wave.



(b) Use the graph to determine the speed of

(i) the P waves. *[1]*

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(Question B2 part 1 continued)

(ii) the S waves. *[1]*

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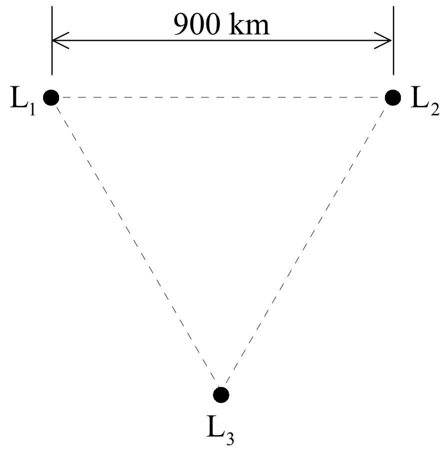
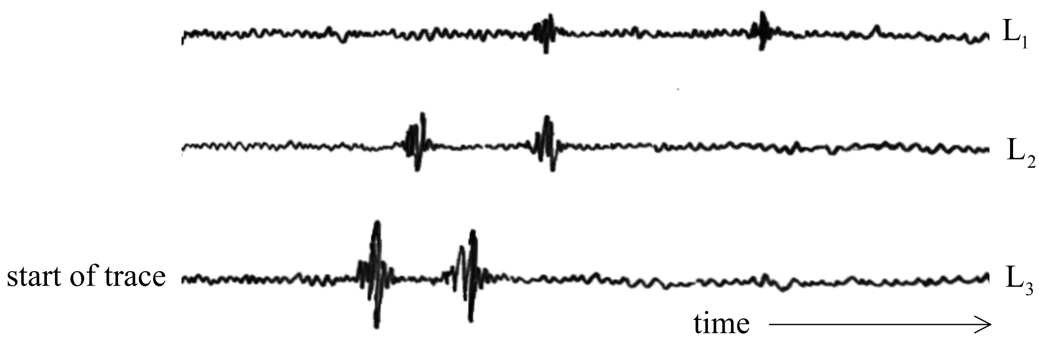
(Question B2 part 1 continued)

The waves from an earthquake close to the Earth's surface are detected at three laboratories L_1, L_2 and L_3. The laboratories are at the corners of a triangle so that each is separated from the others by a distance of 900 km, as shown in the diagram below.



The records of the variation with time of the vibrations produced by the earthquake as detected at the three laboratories are shown below. All three records were started at the same time.



On each record, one pulse is made by the S wave and the other by the P wave. The separation of the two pulses is referred to as the S-P interval.

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(Question B2 part 1 continued)

(c) (i) On the trace produced by laboratory L_2, identify, by reference to your answers in (b), the pulse due to the P wave (label the pulse P). *[1]*

(ii) Using evidence from the records of the earthquake, state which laboratory was closest to the site of the earthquake. *[1]*

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(iii) State **three** separate pieces of evidence for your statement in (c)(ii). *[3]*

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(iv) The S-P intervals are 68 s, 42 s and 27 s for laboratories L_1, L_2 and L_3 respectively. Use the graph, or otherwise, to determine the distance of the earthquake from each laboratory. Explain your working. *[4]*

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Distance from L_1 = ... km

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Distance from L_2 = ... km

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Distance from L_3 = ... km

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(v) Mark on the diagram a possible site of the earthquake. *[1]*

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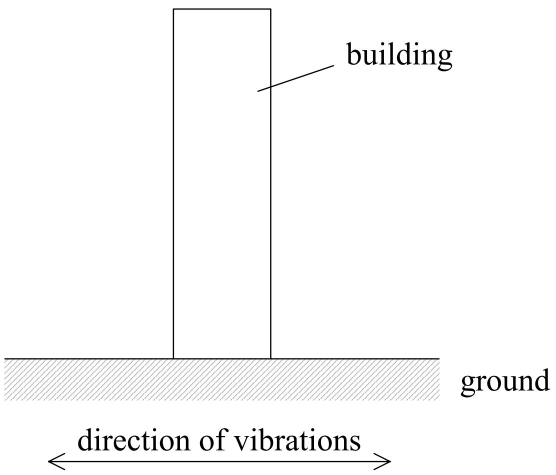
(Question B2 part 1 continued)

There is a tall building near to the site of the earthquake, as illustrated below.



The base of the building vibrates horizontally due to the earthquake.

(d) (i) On the diagram, draw the fundamental mode of vibration of the building caused by these vibrations. *[1]*

The building is of height 280 m and the mean speed of waves in the structure of the building is $3.4\times10^{3}\ \text{m s}^{-1}$.

(ii) Explain quantitatively why earthquake waves of frequency about 6 Hz are likely to be very destructive. *[3]*

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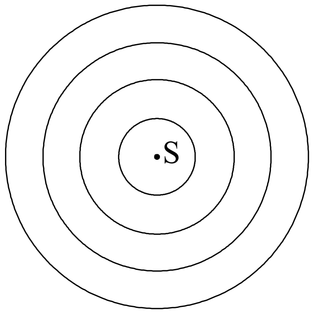
(Question B2 continued)

Part 2 The Doppler effect

The diagram below shows wavefronts produced by a stationary wave source S. The spacing of the wavefronts is equal to the wavelength of the waves. The wavefronts travel with speed V.



(a) The source S now moves to the right with speed $\frac{1}{2}V$. In the space below, draw **four** successive wavefronts to show the pattern of waves produced by the moving source. *[3]*

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(Question B2 part 2 continued)

(b) Derive the Doppler formula for the observed frequency f_0 of a sound source, as heard by a stationary observer, when the source approaches the stationary observer with speed v. The speed of sound is V and the frequency of the sound emitted by the source is f. *[3]*

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The Sun rotates about its centre. The light from one edge of the Sun, as seen by a stationary observer, shows a Doppler shift of 0.004 nm for light of wavelength 600.000 nm.

(c) Assuming that the Doppler formula for sound may be used for light, estimate the linear speed of a point on the surface of the Sun due to its rotation. *[3]*

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B3. This question is about nuclear reactions.

(a) (i) Distinguish between *fission* and *radioactive decay*. *[4]*

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A nucleus of uranium-235 $\left({}^{235}_{92}\mathrm{U}\right)$ may absorb a neutron and then undergo fission to produce nuclei of strontium-90 $\left({}^{90}_{38}\mathrm{Sr}\right)$ and xenon-142 $\left({}^{142}_{54}\mathrm{Xe}\right)$ and some neutrons.

The strontium-90 and the xenon-142 nuclei both undergo radioactive decay with the emission of β^- particles.

(ii) Write down the nuclear equation for this fission reaction. *[2]*

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(iii) State the effect, if any, on the mass number (nucleon number) and on the atomic number (proton number) of a nucleus when the nucleus undergoes β^- decay. *[2]*

Mass number: . . . .

Atomic number: . . . .

The uranium-235 nucleus is stationary at the time that the fission reaction occurs. In this fission reaction, 198 MeV of energy is released. Of this total energy, 102 MeV and 65 MeV are the kinetic energies of the strontium-90 and xenon-142 nuclei respectively.

(b) (i) Suggest what has happened to the remaining 31 MeV of energy. *[2]*

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(ii) Calculate the magnitude of the momentum of the strontium-90 nucleus. *[4]*

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(Question B3 continued)

(iii) Explain why the magnitude of the momentum of the strontium-90 nucleus is not exactly equal in magnitude to that of the xenon-142 nucleus. *[2]*

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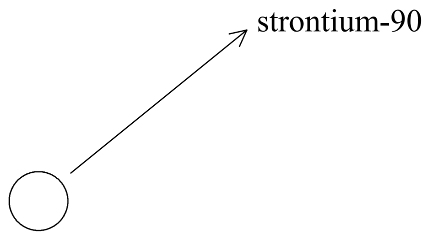
On the diagram below, the circle represents the position of a uranium-235 nucleus before fission. The momentum of the strontium-90 nucleus after fission is represented by the arrow.



(iv) On the diagram above, draw an arrow to represent the momentum of the xenon-142 nucleus after the fission. *[2]*

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(Question B3 continued)

(c) (i) Define the *decay constant* for radioactive decay. *[2]*

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(ii) The half-life of strontium-90 is 28.0 years. Deduce that the decay constant of strontium-90 is $7.85\times10^{-10}\,s^{-1}$. *[1]*

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(d) The decay constant of xenon-142 is $0.462\,s^{-1}$. Initially, a sample of radioactive waste material contains equal numbers of strontium-90 and xenon-142 nuclei.

(i) Use the values of the decay constants in (c) and (d) to calculate the time taken for the ratio

$$\frac{\text{number of strontium-90 nuclei}}{\text{number of xenon-142 nuclei}}$$

to become equal to 1.20×10^{6}. *[3]*

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(ii) Suggest why, in the long-term, strontium-90 presents a greater problem then xenon-142 as radioactive waste. *[2]*

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(Question B3 continued)

(e) (i) Name **one** other particle, apart from an electron, that is emitted from a nucleus that is undergoing β^- decay. *[1]*

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(ii) State the name of the interaction responsible for beta decay. *[1]*

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(iii) Describe what is meant by an *exchange particle* and state the name of the exchange particle involved in the weak interaction. *[2]*

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B4. This question is in **two** parts. **Part 1** is about gases and specific heat capacity and **Part 2** is about gravitation.

Part 1 Gases and specific heat capacity

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

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An ideal gas occupies a volume of $1.2\,\text{m}^3$ at a temperature of $27\,^\circ\text{C}$ and a pressure of 1.0×10^5 Pa. The density of the gas is $1.6\,\text{kg}\,\text{m}^{-3}$. It is found that 1.5×10^4 J of energy is required to raise the temperature of the gas to $52\,^\circ\text{C}$ when the gas is held at constant volume.

(b) Determine the specific heat capacity at constant volume of the gas. *[3]*

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(c) A second sample of the same gas as above is heated from $27\,^\circ\text{C}$ to $52\,^\circ\text{C}$ at constant pressure.

(i) Show that the volume of the gas at $52\,^\circ\text{C}$ is $1.3\,\text{m}^3$. *[2]*

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(ii) Calculate the work done by the gas during the heating process. *[2]*

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(d) The specific heat capacity for the gas kept at constant volume is different to that when the gas is kept at constant pressure. State and explain whether the specific heat capacity for an ideal gas at constant pressure is greater **or** less than the specific heat capacity of the gas at constant volume. *[3]*

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(This question continues on the following page)

(Question B4 continued)

Part 2 Gravitation

A space probe is launched from the equator in the direction of the north pole of the Earth. During the launch, the energy E given to the space probe of mass m is

$$E = \frac{3GMm}{4R_e}$$

where G is the Gravitational constant and M and R_e are, respectively, the mass and radius of the Earth. Work done in overcoming frictional forces is not to be considered.

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

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(ii) Deduce that the space probe will not be able to travel into deep space. *[3]*

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The space probe is launched into a circular polar orbit of radius R.

(b) Derive expressions, in terms of G, M, R_e, m and R for

(i) the change in gravitational potential energy of the space probe as a result of travelling from the Earth's surface to its orbit. *[1]*

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(ii) the kinetic energy of the space probe when in its orbit. *[2]*

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(Question B4 part 2 continued)

(c) Using your answers in (b) and the total energy supplied to the space probe as given in (a), determine the height of the orbit above the Earth's surface. *[4]*

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A space probe in a low orbit round the Earth will experience friction due to the Earth's atmosphere.

(d) (i) Describe how friction with the air reduces the energy of the space probe. *[2]*

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(ii) Suggest why the rate of loss of energy of the space probe depends on the density of the air and also the speed of the space probe. *[2]*

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(iii) State what will happen to the height of the space probe above the Earth's surface and to its speed as air resistance gradually reduces the total energy of the space probe. *[2]*

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