INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

M99/430/H(2)

PHYSICS

Higher Level

Friday 14 May 1999 (afternoon)

Paper 2

2 hours 15 minutes

A

Candidate name:	Candidate category & number:

This examination paper consists of 2 sections, Section A and Section B.
The maximum mark for Section A is 35.
The maximum mark for Section B is 60.
The maximum mark for this paper is 95.

INSTRUCTIONS TO CANDIDATES

Write your candidate name and 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, complete box B below stating the two questions answered in Section B.

B

QUESTIONS ANSWERED
A/ ALL
B/
B/

C

EXAMINER	TEAM LEADER
/35	/35
/30	/30
/30	/30
TOTAL /95	TOTAL /95

D

IBCA
/35
/30
/30
TOTAL /95

EXAMINATION MATERIALS

Required:
Calculator
Physics HL Data Booklet

Allowed:
A simple translating dictionary for candidates not working in their own language

SECTION A

Answer ALL questions in this section.

A1. This question is about determining the acceleration of an aeroplane on a runway.

A jet aeroplane accelerates along the runway before takeoff at night. The regular flashes from the wing light on the moving aeroplane are photographed by a camera. There are also two fixed lights A and B alongside the runway, 30 m apart. The situation is shown in Figure 1.

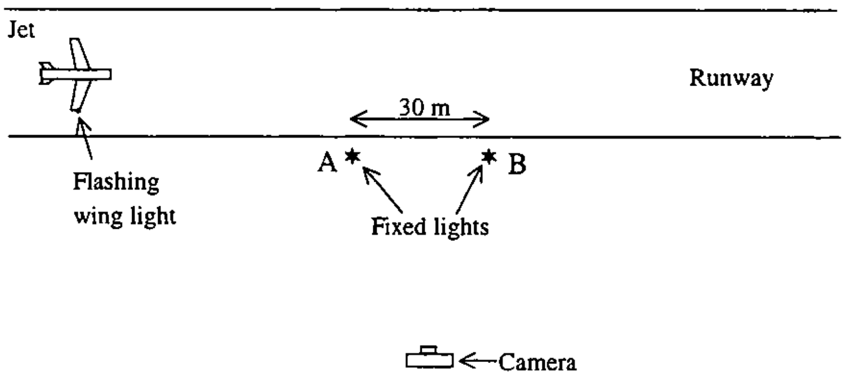

Figure 1: Plan view (not to scale)

The moving wing light appears as a succession of spots R, S, T, U and V on the photographic film, as shown in Figure 2 below. The aeroplane is already moving by the time the first image R is recorded. The wing light flashes every 2.0 seconds. The photograph also records the images of the two fixed lights A and B.

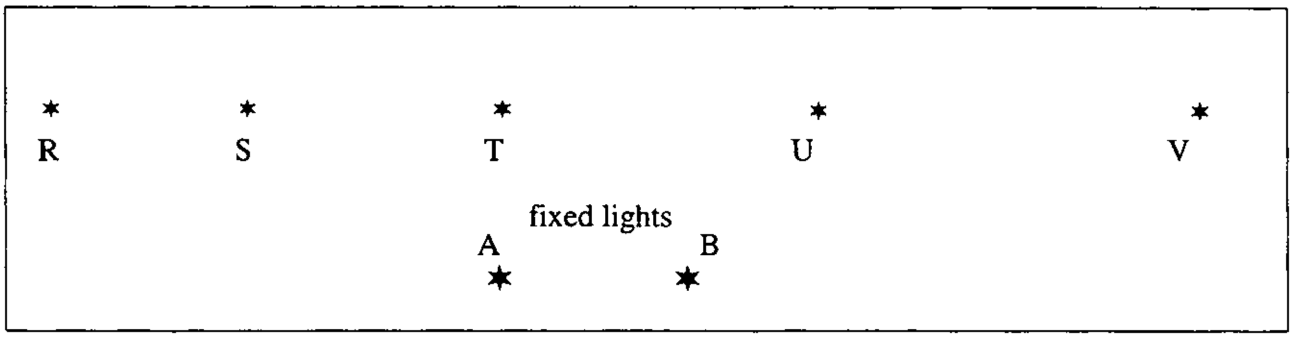

Figure 2: Photographic film record.

By making appropriate measurements on the photograph above, determine:

(a) the distance on the runway represented by 1 mm on the film. *[2]*

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(This question continues on the following page)

(Question A1 continued)

(b) the average velocity of the aeroplane between:

(i) points R and S.

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(ii) points U and V. *[3]*

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(c) the average acceleration of the aeroplane along the runway. *[3]*

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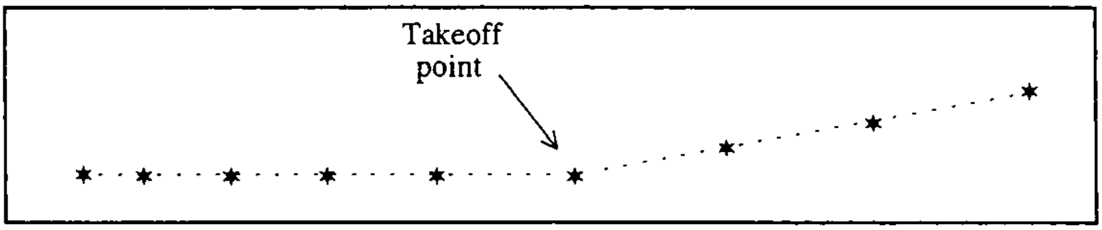
The figure below shows a film record of a jet aeroplane obtained over a longer period of time, so that images are recorded both before and after takeoff.



The film shows that in the first few seconds after takeoff the speed remains approximately constant, although the aeroplane maintains the same engine thrust as before.

(d) Explain why the same thrust can cause the aeroplane to accelerate while on the runway but travel at constant speed while ascending. *[3]*

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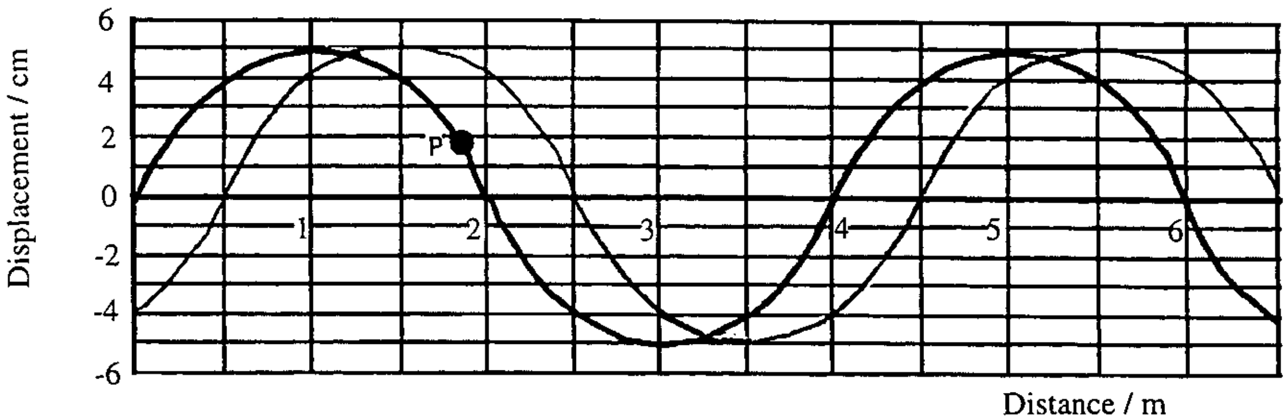
A2. This question is about a transverse wave on a stretched spring.

The thicker line in the figure below shows part of a wave on a spring at time t = 0, while the thinner line shows the wave one tenth of a second later at time t = 0.1 s.



(a) For the wave, determine:

(i) the direction of wave travel. *[1]*

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(ii) the wavelength. *[1]*

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(iii) the wave amplitude. *[1]*

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(iv) the wave speed. *[1]*

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(v) the wave frequency. *[1]*

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(This question continues on the following page)

(Question A2 continued)

(b) Consider the motion of an individual particle of the spring, labelled P on the diagram.

(i) Draw an arrow on the diagram to indicate the direction of motion of particle P at time $t = 0$. *[1]*

(ii) Determine the average speed of particle P between times $t = 0$ and $t = 0.1$ s. *[2]*

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(iii) What is the period of oscillation of particle P? *[1]*

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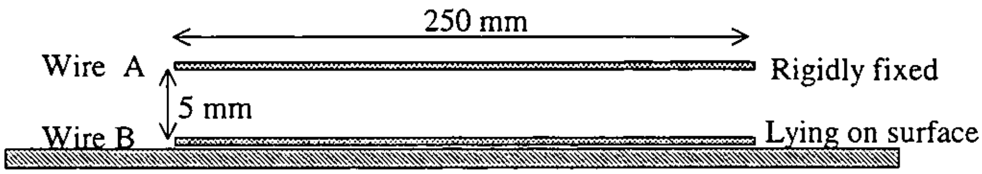
A3. The diagram shows two horizontal parallel wires A and B each 250 mm long. Wire A is rigidly fixed a distance 5 mm vertically above wire B. Wire B lies on a surface with light flexible connecting wires attached to it.



A fixed current of 8A flows in wire A. The current in wire B is gradually increased until B just starts to lift off the surface, and is then kept constant.

(a) For wire B to lift, must the currents in A and B be in the same or opposite directions? *[1]*

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(b) If the mass of wire B is 0.4 g, determine the minimum current required to lift it off the surface. *[5]*

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(c) After wire B has just lifted off the surface, it *accelerates* towards wire A, even though the current is not further increased. Explain why it accelerates, rather than staying just above the surface or rising at constant speed, and state whether the acceleration is constant or not. *[2]*

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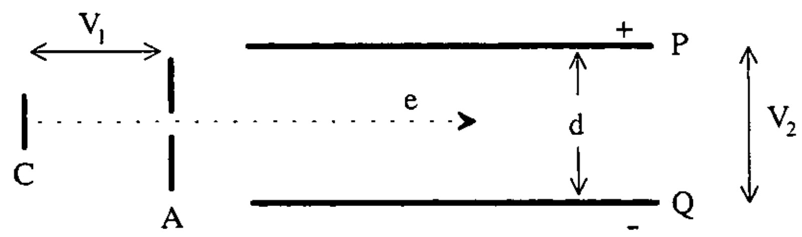
A4. This question is about electrons in electric and magnetic fields.

Electrons of mass m and charge e are accelerated from rest through a potential difference V_1 between cathode C and anode A as shown. They then enter the space between two parallel charged plates P and Q, which are a distance d apart and have a potential difference V_2 between them. The apparatus is in a vacuum.



(a) Draw in electric field lines between plates P and Q. *[1]*

Normally the electrons would be deflected by the electric field between P and Q. However, a magnetic field B is also applied, of such a magnitude and direction as to oppose the electric force on the electrons, so that the path of the electron beam is straight under the combined action of both fields.

(b) What must be the direction of the magnetic field B? Represent the field B appropriately on the diagram above. *[2]*

(c) Derive an expression for the required magnetic field B such that the electron beam is undeflected, in terms of V_1, V_2, d, e, and m. *[4]*

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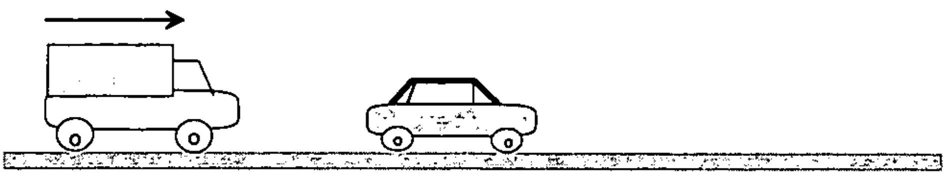
SECTION B

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

B1. 1. This question is about the application of physics principles to a traffic accident.

In the accident, a moving van ran into the back of a car which was stationary with its handbrake on. The vehicles then moved straight onwards, remaining in contact, but came to rest after a certain distance.



Suppose you are brought in as a scientific consultant to determine the speed at which the van must have been travelling when it hit the car. You gather the following information.

- There are skid marks on the road, 15 m long, made by the car's rear tyres after the collision, but no skid marks for the van.
- The car's handbrake acts only on the rear wheels, which support $\frac{3}{8}$ of the car's weight.
- The coefficient of sliding friction between the rear tyres and the road is 0.8.
- The masses of the van and car are 1200 kg and 800 kg respectively.

(a) Using this information and principles of physics, determine the speed of the van just before it hit the car. You may take $g = 10 \text{ m s}^{-2} = 10 \text{ N kg}^{-1}$. *[12]*

(Hint: there are two stages to consider, namely the collision and skidding to a halt after the collision.)

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(Question B1 continued)

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(b) The driver sitting in the car was wearing a safety belt and had a headrest behind her head. Explain whether or not the safety belt and/or headrest could serve a protective function in this particular accident. Refer to the sequence of events and to principles of physics in your answers.

Safety belt: *[3]*

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Headrest: *[3]*

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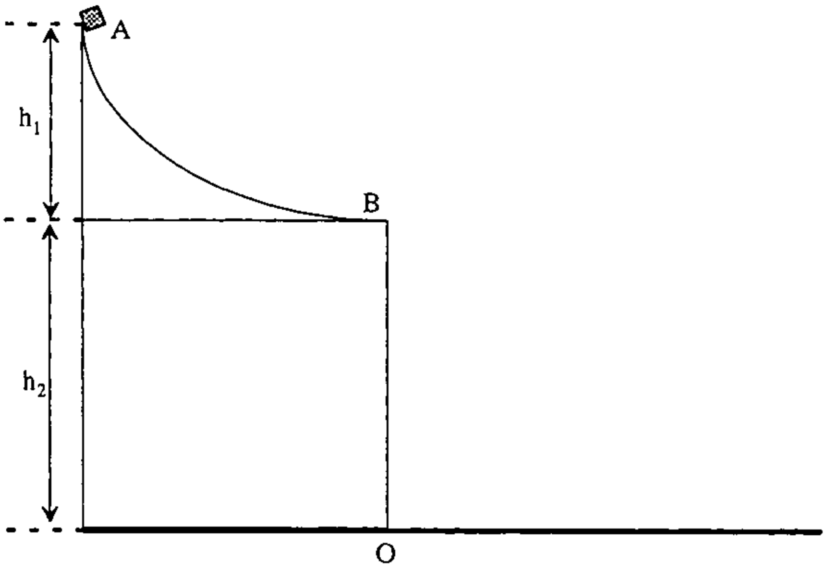
B1. 2. A body slides with negligible friction from point A down a smooth curved ramp, starting from rest. The end of the ramp is horizontal at point B. The end of the ramp is a height h_1 below A and a height h_2 above the floor, as shown in the diagram.



(a) On the diagram above sketch in the shape of the path taken by the body after it leaves the ramp. *[1]*

(b) Show that the body will hit the floor at a distance d from point O given by $d = 2\sqrt{h_1 h_2}$. *[6]*

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(c) Show that the body will hit the floor at an angle θ to the horizontal given by $\tan\theta = \sqrt{h_2 / h_1}$. *[5]*

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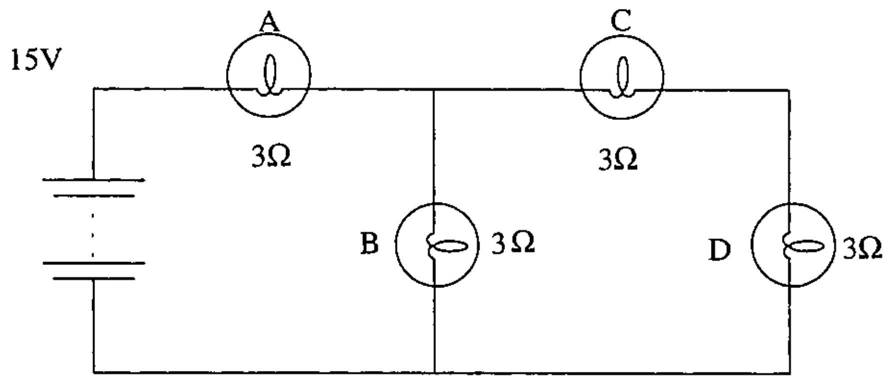
B2. 1. Four bulb circuit

Four identical light bulbs and a 15 V battery are connected in the circuit shown below. The battery has negligible internal resistance. Assume initially that the bulbs are *ohmic* and each has resistance 3Ω.



(a) What is meant by *ohmic* behaviour for a conductor? *[1]*

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(b) How will the brightnesses of the four bulbs compare with each other? Explain, giving qualitative physical reasoning without any calculations. *[3]*

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(Question B2 continued)

(c) For bulb D calculate:

(i) the current
(ii) the potential difference
(iii) the power. *[6]*

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(d) Because the bulb filaments get hot, the bulbs will *not* in fact have ohmic behaviour as assumed above. In terms of a simple microscopic model of electric conduction in a metal, explain why a light bulb filament becomes hot when electric current flows through it. *[3]*

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(This question continues on the following page)

(Question B2 continued)

(e) A consequence of non-ohmic behaviour is that the resistances of the bulbs will not in fact be identical when used in this circuit. As a result, would you expect the actual potential difference across bulb D to be greater than, less than or equal to the value you have calculated in part (c) above? Explain your reasoning. *[3]*

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(f) Sketch in on the original diagram how an ammeter and a voltmeter should be connected in order to measure the actual current and potential difference for bulb D. *[2]*

(g) Suppose bulb D burns out (its filament breaks) while the voltmeter is connected across its socket. Will the voltmeter reading become zero, increase, decrease or remain unchanged? Explain. *[2]*

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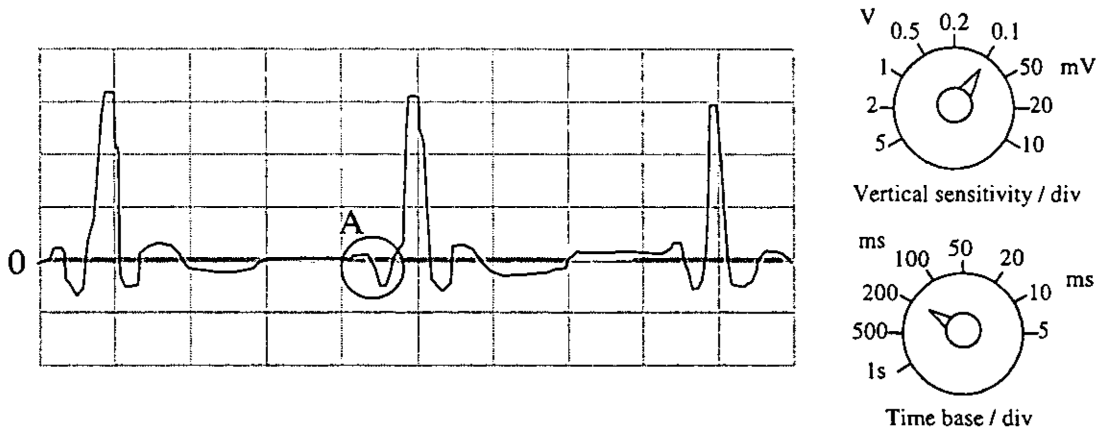
B2. 2. Cathode Ray Oscilloscope

A resting patient's heartbeat is monitored electrically using a Cathode Ray Oscilloscope (CRO), giving a trace on the CRO screen as shown in the figure. The settings of the vertical sensitivity and time-base controls on the CRO are also shown.



(a) Determine the maximum amplitude of the detected electrical signal above the 0 V baseline. *[1]*

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(b) Determine the patient's resting pulse rate in beats per minute. *[3]*

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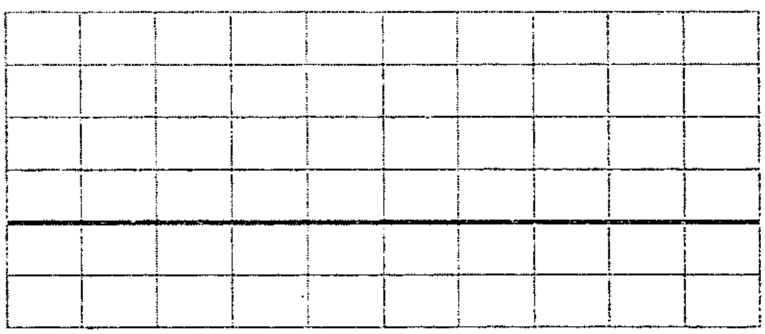
(c) Sketch on the grid below the trace you would expect if the patient's heartbeat was monitored during *exercise* so that the pulse rate doubled. *[2]*



(This question continues on the following page)

(Question B2 continued)

(d) The circle labelled A shows a small signal which occurs prior to each heartbeat. Suppose you wished to examine it in more detail. What settings would you choose for the time-base and vertical sensitivity controls of the CRO to make the signal appear conveniently large on the screen? Explain your choices briefly. *[4]*

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B3. 1. This question is about determining the specific latent heat of fusion of ice.

A student determines the specific latent heat of fusion of ice at home as follows. She takes ice from the freezer, measures its mass and mixes it with a known mass of water in an insulating jug. She stirs until all the ice has melted and measures the final temperature of the mixture. She also measured the temperature in the freezer and the initial temperature of the water.

She records her measurements as follows:

Mass of ice used	m_i	0.12 kg
Initial temperature of ice	T_i	-12 °C
Initial mass of water	m_w	0.40 kg
Initial temperature of water	T_w	22 °C
Final temperature of mixture	T_f	15 °C

The heat capacities of water and ice are c_w= 4.2 kJ kg^{-1} °C^{-1} and c_i= 2.1 kJ kg^{-1} °C^{-1} respectively.

(a) Set up the appropriate equation, representing energy transfers during the process of coming to thermal equilibrium, that will enable her to solve for the specific latent heat L_i of ice. Insert values into the equation from the data above, **but do not solve the equation.** *[5]*

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(This question continues on the following page)

(Question B3 continued)

(b) Explain the physical meaning of each *energy transfer term* in your equation (but not each symbol). *[4]*

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(c) State an assumption you have made about the experiment, in setting up your equation in (a). *[1]*

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(d) Explain from the microscopic point of view, in terms of molecular behaviour, why the temperature of the ice does not increase while it is melting. *[4]*

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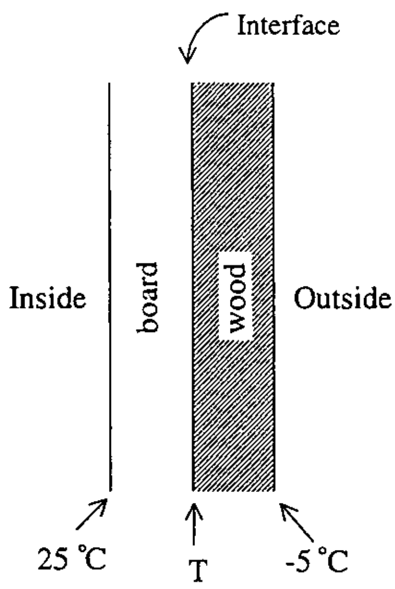
B3. 2. Two-layer cottage wall

The wall of a heated cottage is made of two layers of **equal thickness**, insulating board on the inside and wood on the outside, as shown below. The thermal conductivity of the board is **half** that of wood. In the steady state, with energy flowing steadily from inside to outside, the inside surface temperature of the board is 25 °C and the outside surface temperature of the wood is -5 °C.



(a) Will the rate of energy transfer be greatest through the wood layer, the board layer, or the same for both? Explain your reasoning. *[2]*

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(b) Calculate the temperature T at the interface between board and wood. *[5]*

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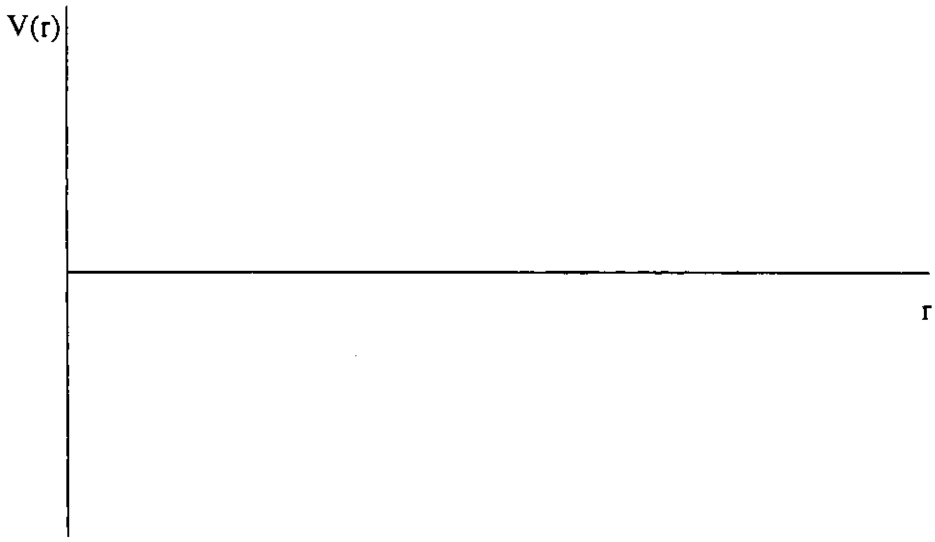
B3. 3. This question is about solids and their expansion with temperature.

(a) For two atoms in a solid, sketch a graph of interatomic potential energy V(r) as a function of distance r between two atoms, on the axes below. *[2]*



(b) Refer to characteristics of the graph and the thermal vibrations of atoms, to explain why solids expand with increasing temperature. *[4]*

(c) Solid expansion is relatively small; show that an iron rod will only expand in length by about 0.1% if its temperature increases by 100 °C. The coefficient of linear expansion of iron is 1.2×10^{-5} °C^{-1}. *[3]*

B4. This question is about a nuclear fission reactor for providing electrical power.

In a nuclear reactor, power is to be generated by the fission of uranium -235. The absorption of a neutron by ^{235}U results in the splitting of the nucleus into two smaller nuclei plus a number of neutrons and the release of energy. The splitting can occur in many ways; for example:

$$n + {}^{235}_{92}U \rightarrow {}^{90}_{38}Sr + {}^{143}_{54}Xe + \text{neutrons} + \text{energy}$$

(a) *The nuclear fission reaction*

(i) How many neutrons are produced in this reaction? *[1]*

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(ii) Explain why the release of several neutrons in each reaction is crucial for the operation of a fission reactor. *[2]*

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(iii) The sum of the rest masses of the uranium plus neutron before the reaction is 0.22 u greater than the sum of the rest masses of the fission products. What becomes of this 'missing mass'? *[1]*

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(iv) Show that the energy released in the above fission reaction is about 200 MeV. *[2]*

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(This question continues on the following page)

(Question B4 continued)

(b) *A nuclear fission power station*

(i) Suppose a nuclear fission power station generates electrical power at 550 MW. Estimate the minimum number of fission reactions occurring each second in the reactor, stating any assumption you have made about efficiency. *[4]*

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(ii) In a reactor, some energy is lost as heat carried away by water. Determine the power lost in this way if 30 tonnes (30×10^3 kg) of water pass through the system every second, rising in temperature by 9 °C in doing so. The specific heat capacity of water is 4.2 kJ kg^{-1} $°C^{-1}$. *[2]*

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(iii) Suppose one had an optimum design of reactor and perfectly efficient generators in the power station. In this case could *all* the energy produced from the fission process be converted to electrical energy, with none lost as waste heat? Explain why or why not. *[2]*

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(Question B4 continued)

(iv) Show that this reactor will use a mass of approximately 20 mg of U-235 as 'fuel' in one second. Take into account both the electrical power output and the power loss to the water. *[6]*

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(c) *After the station shuts down*

At the end of its working life, the reactor is shut down ('decommissioned'). One of the fission products that will remain hazardous is the strontium-90, which is radioactive with a half-life of 29 years.

(i) Calculate how many years it will be before the activity of the strontium-90 drops to one per cent of its initial value. *[4]*

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(This question continues on the following page)

(Question B4 continued)

(ii) Explain why, if the probability of decay of any individual strontium nucleus is constant, the overall activity of a strontium sample decreases with time. *[2]*

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(d) *Comparing with fossil-fuel station*

Instead of a nuclear power station, a fossil-fuel power station (burning coal or oil) could be used.

(i) State **two** advantages of a fossil fuel station compared to a nuclear station. *[2]*

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(ii) State **two** disadvantages of a fossil fuel station compared to a nuclear station. *[2]*

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