Question 14 **(8 marks)**

An experimental technique in the field of radiography in treating aggressive brain tumours is that of Boron Neutron Capture Therapy. This technique uses the fact that when Boron-10 is injected into the body of a patient, the Boron-10 collects in the brain tumours.

The patient is then bombarded with neutrons which are strongly absorbed by the Boron-10, becoming fissile (radioactive) Boron-11 which produces Lithium-7 and high-energy alpha particles which then kill the cancer cells. On average, each neutron has an energy of 0.650 eV.

(a) Write two nuclear equations describing the above two processes. (2 marks)

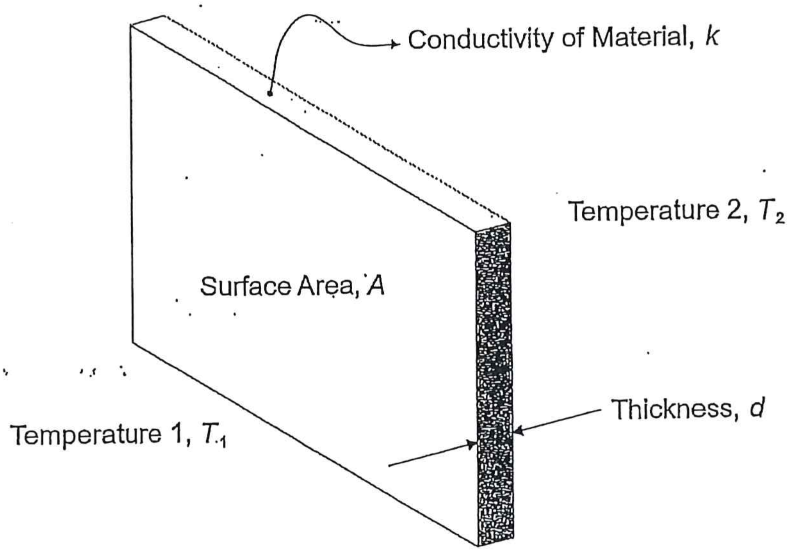
(b) Given that the amount of Boron-10 (10.013 u) required to treat a 2.20 g brain tumour is 25.0 μg per gram of tumour, determine the absorbed dose administered to a 45.0 kg patient. (5 marks)

(c) Suggest a possible reason why an alpha source (the fission of Boron-11) is used in this context rather than a beta source. (1 mark)

Question 15 **(21 marks)**

The following question involves heat transfer through materials and heating an office space.

The rate at which heat is conducted through a material depends on several quantities relating to the physical environment and the shape and size of the material, as shown in the diagram below.



The rate at which heat is conducted through a material depends on temperature (K) on both sides of the material (T_1 and T_2), the surface area A (m^2) exposed, the thickness of the material d (m) and the property of the material known as conductivity k.

The rate of heat transfer through the material is power P (units of J s^{-1}) and is given by:

$$P = \frac{Q}{t} = \frac{kA(T_2 - T_1)}{d}$$

(a) Correctly determine the units of conductivity k. (1 mark)

(b) A single 1.20 m high by 2.30 m wide by 6.00 mm thick glass window separates a 28.0 °C exterior from the 18.0 °C interior office space. The window is letting heat in at a rate of 3.59 kW.

i) Determine the conductivity k of the glass window. (3 marks)

Question 15 (b) continued

ii) Calculate the **theoretical** rise in temperature of 215 kg of air within the office over a period of 15 minutes (the specific heat capacity of air is 1.10×10^3 J kg^{-1} K^{-1}). (3 marks)

iii) Explain why the answer to part b) ii) is impossible. Use relevant physics concept to justify your response. (2 marks)

(c) The owner of the office decides to replace the window mentioned in part b with a double-glazed window in order to reduce heat transfer. The double-glazed window has identical dimensions to the single pane window (1.20 m by 2.30 m) but is 30.00 mm thick and consists of two panes of glass separated by a sealed section containing air.

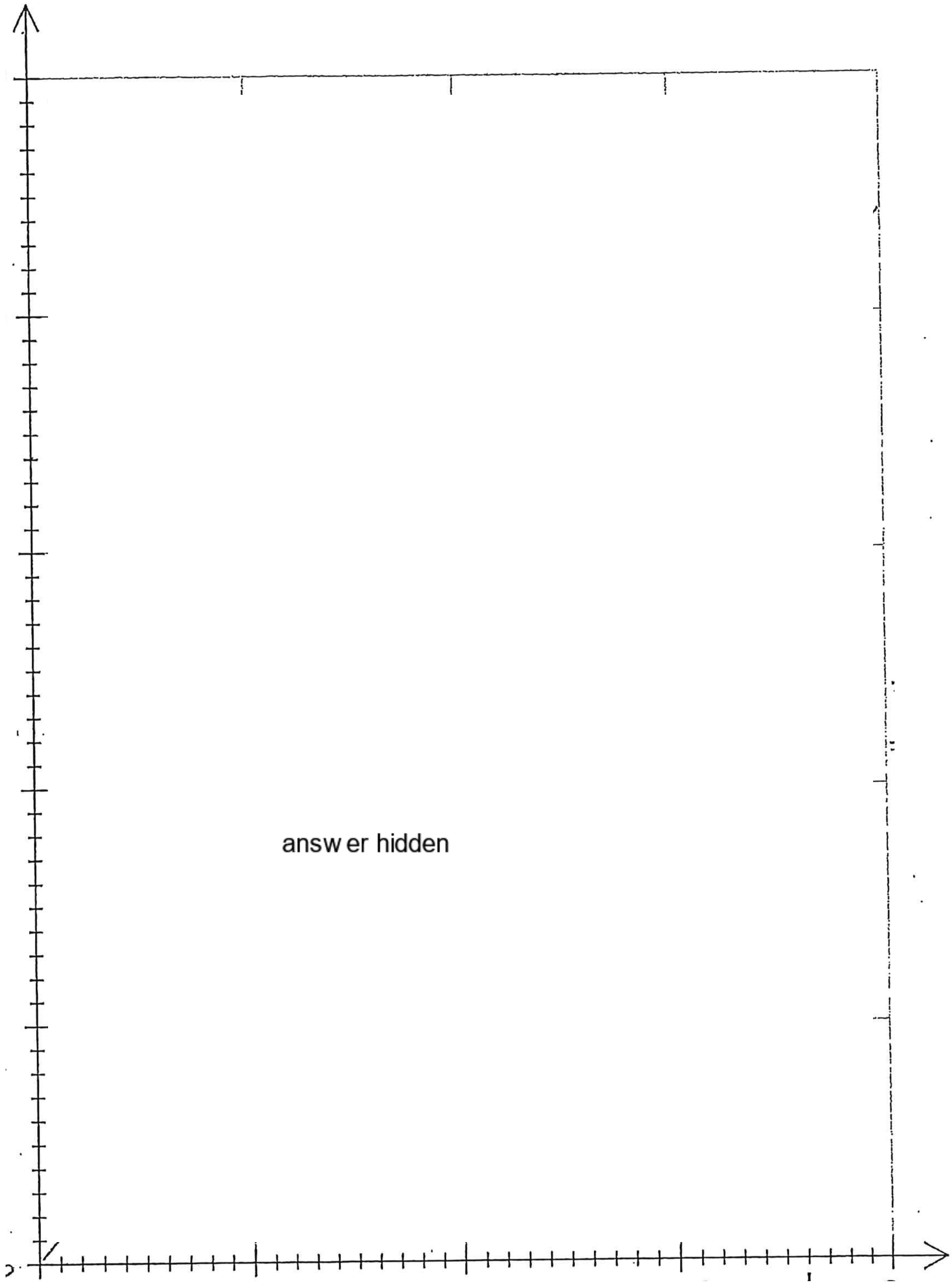
In order to test this double-glazed window, the amount of energy conducted per second through the window and the difference in temperature across the window is recorded for eight trials in the table below.

Trial	1	2	3	4	5	6	7	8
Temp Difference ΔT (K)	2	3	6	9	12	14	17	19
Energy Rate Q/t (J s^{-1})	24	30	72	100	125	155	192	212

i) State why the sealed section containing air reduces heat transfer. (1 mark)

ii) Use the data in the table above to construct a graph by plotting Energy Rate Q/t on the vertical axis and Temp Difference ΔT on the horizontal axis. Include title, axes labels, units and a line of best fit. (5 marks)

(Question 15 continued)



(Question 15 continued)

iii) Calculate the gradient of the line of best fit. (**Show construction lines** on the graph. (3 marks)

iv) Use the value of the gradient of the line of best fit, and information given in the question, to determine a value for the conductivity k of the double-glazed window. **Note**: if you didn't determine a value for the gradient, you may use a gradient of 11.0 J s^{-1} K^{-1}. (3 marks)

Question 16 **(13 marks)**

An electric kettle contains 450 mL of water at an initial temperature of 18.0 °C. The kettle operates on mains voltage (240.0 V) and draws a current of 6.25 A when switched on. The kettle is 90.0 % efficient at converting electrical energy into thermal energy in the water only.

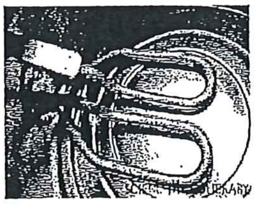
(a) Calculate the amount of heat that the kettle supplies to the water every second after it is switched on. (2 marks)

(b) How much heat is supplied by the kettle to heat the water to reach boiling point (100°C)? (3 marks)

(c) How long will it take for the water to reach boiling point? (3 marks)

(d) How much more energy is required if the 1.20kg stainless steel kettle was included in the heat calculation? Note: The specific heat capacity for stainless steel is 468 J $kg^{-1}K^{-1}$ (3 marks)

(e) The manufacturer of the electric kettle placed the heating element very close to the bottom of the kettle in order to maximise its efficiency. Briefly explain the benefit of this design. Include a well labelled sketch to aid your explanation. (2 marks)



END OF SECTION TWO

Figure 2 below shows the energy flow of 100 J of solar energy incident on the PV-MD device. The solar panel is 15% efficient (converting 15 J out of every 100 J into electrical energy), 25 J is reflected as light, and of the remaining 60 J absorbed as heat, 36 J of heat is used to create clean drinking water with 24 J of heat lost to the surrounding environment.

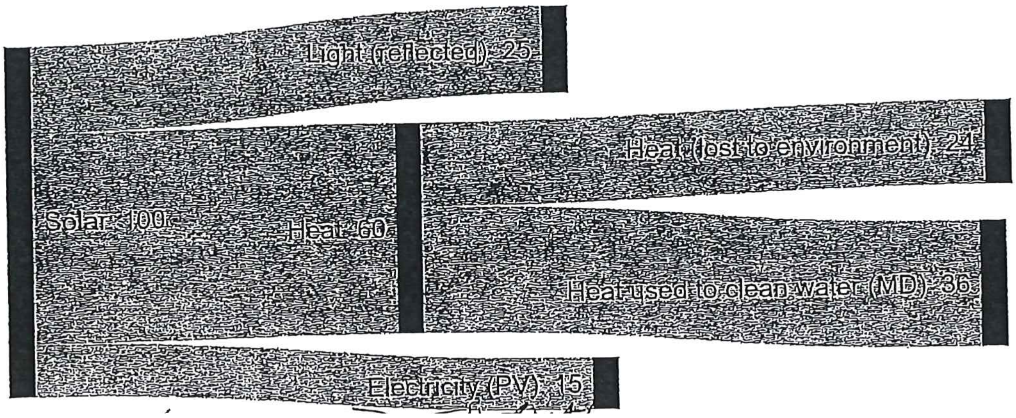


Figure 2 Energy flow diagram for 100 J of incoming solar energy

(a) State one energy transformation taking place in a typical PV–MD device. (1 mark)

(b) With reference to the design of a typical PV-MD device and the kinetic particle model, explain why the hot vapour condenses as it nears the clean water outlet. (3 marks)

(c) Using data from Figure 2, explain how a PV-MD device makes better use of solar energy than a conventional solar panel. As part of your explanation determine an overall efficiency of the PV-MD device described in Figure 2. (3 marks)

(d) The prototype used in the lab experiments consisted of a solar panel measuring 12.0 cm by 12.0 cm, placed under a lamp of intensity 1.00 kW m^{-2} (like that of the Sun) for one hour, during which time the solar panel produced 1296 C of charge. Given that the efficiency of the solar panel used is 15.0%:

i) determine the radiant energy incident on the solar panel in one hour. (3 marks)

ii) determine the electrical energy produced by the panel in one hour. (1 mark)

iii) determine the output current and voltage of the panel. (2 marks)

iv) Confirm by calculations below that the amount of clean water produced by the prototype is **approximately** 0.50 kg per hour per square metre. State your assumptions clearly.

Note: If you could not calculate a value for part (i) you may use a value of 5.0×10^4 J of solar energy incident (falling on) on the solar panel in one hour. (5 marks)