**Unit: Thermal Properties of Matter**

**Task 2: Comprehension and data analysis on thermal change and transfer of thermal energy.**

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| 1.2 | Apply the kinetic theory of matter to explain the effects of heating and changes of state. |
| 1.4 | Analyse the effect of change in temperature in practical situations. |
| 3.1 | Explain the mechanisms of conduction, convection and radiation. |
| 3.2 | Solve problems relating to heat transfer in practical situations. |

**Towing Icebergs**

- Hot desert countries cannot rely on rainfall or rivers for a water supply.
- One solution is to build desalination plants that remove salt from sea water. This is an expensive solution from the point of view of capital outlay and running costs.
- An alternative solution is to obtain the water from Antarctic ice. Icebergs might be cut from the Antarctic ice shelves and then towed to the shores of the desert country where they would be melted and distributed.
- This exercise asks you to assess the two options for providing water.

**Data**

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| Fresh water supply needed | $2 \times 10^6$ $m^3$ per day |
| Distance from Antarctica | $10^4$ km |
| Tug towing force | $5 \times 10^6$ N |
| Towing speed | 0.8 $ms^{-1}$ for an iceberg of volume $10^8$ $m^3$ |
| Total cost to tow an iceberg of $10^8$ $m^3$ | £18 million |
| Total running cost of desalination | £1.50 per $m^3$ of fresh water produced |
| Fuel cost of desalination | 70% of total running costs |
| Cost of electricity | 8p per kW-hour |
| Energy required to melt ice at 0°C | $3.4 \times 10^5$ J $kg^{-1}$ |
| Sun's radiation at the Earth's surface | 600 W $m^{-2}$ |
| Thickness of icebergs | 250 m |
| Number of seconds in a year | $3 \times 10^7$ s |

1. Estimate the volume of ice required per year and the number of icebergs of size $10^8$ $m^3$ that would need to be delivered to the desert country per year.
2. For a $10^8$ $m^3$ iceberg, estimate the fraction of ice originally leaving the Antarctic that would eventually reach the desert country.

3. Use the kinetic theory of matter to explain how the temperature of the ocean and the temperature of the air surrounding the iceberg would affect the rate of melting during the journey. (AC 1.2, 1.4)
4. Compare quantitatively the energy required to melt the $10^8$ $m^3$ iceberg with the energy required to tow it $10^4$ km.
5. Explain how the mechanisms of conduction, convection and radiation would apply if the iceberg was allowed to melt in the sun. (AC 3.1)
6. Discuss, with suitable calculations, the choice between allowing the ice to melt in the sun and melting it using electrical energy. Assume that a 250 MW generating station is available nearby. (AC 3.2)
7. Compare the daily costs of desalination with those of electrical melting (with no energy input from the sun).
8. Discuss how your comparison in Question 7 will be changed if both electrical melting and solar energy melt the ice. What other measures could be employed to reduce solar/electrical costs? (GD2)