2026 Sec 4 Assignment 10
Thermal Properties of Matter - Answer**s**

1    $Q = m\,c\,\Delta\theta$ $= 0.0850\ \text{kg} \times 880\ \text{J kg}^{-1}\ \text{K}^{-1} \times (90.0 - 20.0)\ \text{K}$
                  $= 5236\ \text{J} \approx 5240\ \text{J}$ (3 s.f.)

2    $P = Q\,/\,t = (m\,c\,\Delta\theta)\,/\,t$ $= (0.300 \times 4200 \times 35.0)/\,(3.20 \times 60)$
                              $= 229.7 \approx 230\ \text{W}$

3   *Apply <u>law of conservation of energy</u>: word equation before actual formulae!*
     Word equation: Therma energy lost by water = thermal energy gained by ice to melt
     Actual formulae: $m_{water}\ c_{water}\Delta\theta_{water} = m_{ice}\ l_f$

     m_{water} $= (m_{ice}\ l_f\ )\,/\,(c_{water}\ \Delta\theta_{water})$
              $= (0.0155 \times 3.34 \times 10^5)\,/4200 \times (60.0 - 0.0)$
              $= 0.0205\ \text{kg} \approx 21\ \text{g}$

     Note: <u>minimum</u> m of water when $\Delta\theta_{water}$ is <u>maximum</u>

4   ***Suggestion***: *Sketch a diagram to track all materials and processes!*

(a) $Q = m_{ice}\ l_f = 0.0100\ \text{kg} \times 3.34 \times 10^5\ \text{J kg}^{-1} = 3340\ \text{J}$

(b) $Q = mc\Delta\theta$ $= 0.200\ \text{kg} \times 400\ \text{J kg}^{-1}\ \text{K}^{-1} \times (100.0 - 0.0)\ \text{K}$

                      $= 8000\ \text{J}$

(c) Yes, it is possible to melt all the ice as
     the <mark>maximum amount of thermal energy released</mark> (from part (b)) by the copper ball
     (if its temperature falls to zero degree celcius)
     is <u><mark>greater</mark></u> than the <mark>amount of thermal energy needed by the ice to melt</mark> (from part (a)).

(d)   ***Note***: *Consider all processes involved! May sketch a diagram to visualize these.*

Let the final temperature be T (> 0 °C)

Word equation:
Thermal energy released =   thermal energy gained by
by copper ball to reach T   (ice melting + <u>total</u> amount of water + calorimeter) to reach T

Actual formulae:
$m_{ball}\ c_{copper}\Delta\theta_{ball}$ $= m_{ice}\ l_f$ $+ m_w\ c_w\ \Delta\theta_w$ $+ m_{cal}\ c_{copper}\ \Delta\theta_{cal}$

$0.200(400)(100-T)$ $= 3340$ $+ (0.060+0.010)(4200)(T - 0) + (0.050)(400)(T - 0)$
$80 \times 100 - 80T$ $= 3340 + 294T + 20T$
          4660 $= 394T$

                  T $= 11.8\ °\text{C}$ $\approx 12\ °\text{C}$

5(a)   Infra-red radiation

(b)(i)   Mass of air in the room = volume x density   = 3.00 m^3 $\times$ 3.00 m $\times$ 3.00 m $\times$ 1.29 kg m^{-3}
                                                                            = 34.8 kg

(ii)   power = heat energy / time   or   P = E / t $\rightarrow$ E = Pt
        Thermal energy supplied by heater, E = 1500 $\times$ 60 $\times$ 60 = 5.4 $\times$ 10^6 J
        Thermal energy gained by air   =   thermal energy supplied by heater
                            Q = m c $\Delta\theta$ =   5.4 $\times$ 10^6
                    34.8 $\times$ 1000 $\times$ $\Delta\theta$ =   5.4 $\times$ 10^6
                            $\Delta\theta$ = 155.2 $\approx$ 160 °C

(iii)   *Note: Consider materials and processes.*

Any one of these:
- There is much thermal energy loss to surroundings (by conduction through walls, windows, ceiling, etc)
- Heated air expands (volume increase) and may escape from the room.
- The heater is less than 100% efficient.

6   (a)   Thermal energy required to evaporate 2 kg of water
                Q   = ml_v = 2 $\times$ 2.26 $\times$ 10^6 = 4.52 $\times$ 10^6 $\approx$ 4.5 $\times$ 10^6 J

        (b) $\Delta\theta$: the rise in body temperature of the person
                Q   = mc$\Delta\theta$

                $$\Delta\theta = \frac{Q}{mc} = \frac{4.52 \times 10^6}{60 \times 3500} = 21.5\,°C \quad \approx 22\,°C$$

7 (a) All points plotted accurately
        A best fit smooth curve.

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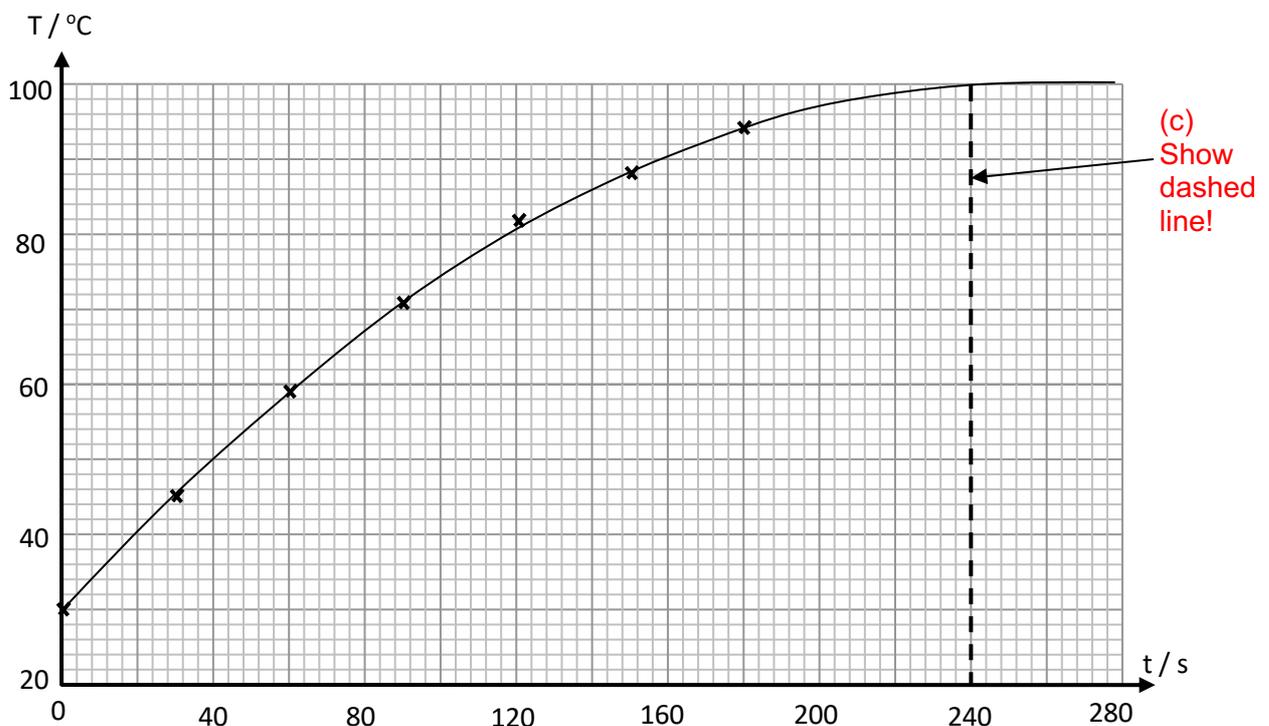
Note: *Apply law of conservation of energy to analyse the processes involved for this graph!*

Heater supplies energy (heat) to the water at a constant rate – this would produce a constant rate of temperature rise if no heat was lost.

Heat lost to the surroundings increases as the temperature difference between the water and the surroundings increases.

Thus, as the water increases in temperature its net gain of heat will reduce and thus the rate of temperature increase will decrease.

It is a misconception to think that the reduced rate of heating is caused by the temperature difference between the water and the heating element becoming smaller. In reality, the temperature of the heating element itself will increase such that the rate of heat transfer from the heating element to the water remains constant (as is stated in the question).

7(b)   As temperature increases, the temperature difference between the hot water and the surrounding increases. Hence, the rate of heat lost from the hot water to the surrounding increases and the rate of thermal energy gained by water decreases.

Hence, rate of temperature rise also decreases, causing the gradient to decrease.

(c)   240 s *(refer to the graph)*
- Extrapolate the curve till it reaches 100 °C, draw a dashed vertical line with to reach time axis and label the value (± 20 s)

(d)   The first part of the graph (From 0 s to about 40 s where the graph is almost straight / gradient constant).

As the water is initially at the same temperature as the surroundings, there will be no temperature difference between the water and the surroundings, and thus no heat loss to the surroundings. It means that all the heat produced by the heater goes into the water causing its temperature to rise.

8(a)   Graph A shows the cooling-heating cycle for the unlagged tank (without insulation).

- Rate of heat loss is greater, so gradient is steeper (temperature dropping)

(b)   **Graph A: unlagged tank** has 120 min or 2 hour cooling-heating cycles.

Total time **unlagged tank** is switched on   = (40 min / 120 min) $\times$ 24 = 8 hours
(temperature rising)

Graph B: lagged tank has 240 min or 4 hour cooling-heating cycles.

Total time **lagged tank** is switched on   = (20 min / 240 min) $\times$ 24 = 2 hours

(c)   Difference in heating time for a 24 hour period = 8 - 2 = 6 hours

Energy saved E   = P t = 5000 W $\times$ (3600 s $\times$ 6) = 1.08 $\times$ 10^8 J

OR   = 5.0 kW $\times$ 6 h = 30 kWh

Note*: check consistency of units!*