2025 Sec 4 Assignment 10
Thermal Properties of Matter - Answers

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 law of conservation of energy: 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: minimum m of water when $\Delta\theta_{water}$ is maximum

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 maximum amount of thermal energy released (from part (b)) by the copper ball
(if its temperature falls to zero degree celcius)
is greater than the amount of thermal energy needed by the ice to melt (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 by copper ball to reach T = thermal energy gained by (ice melting + total 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

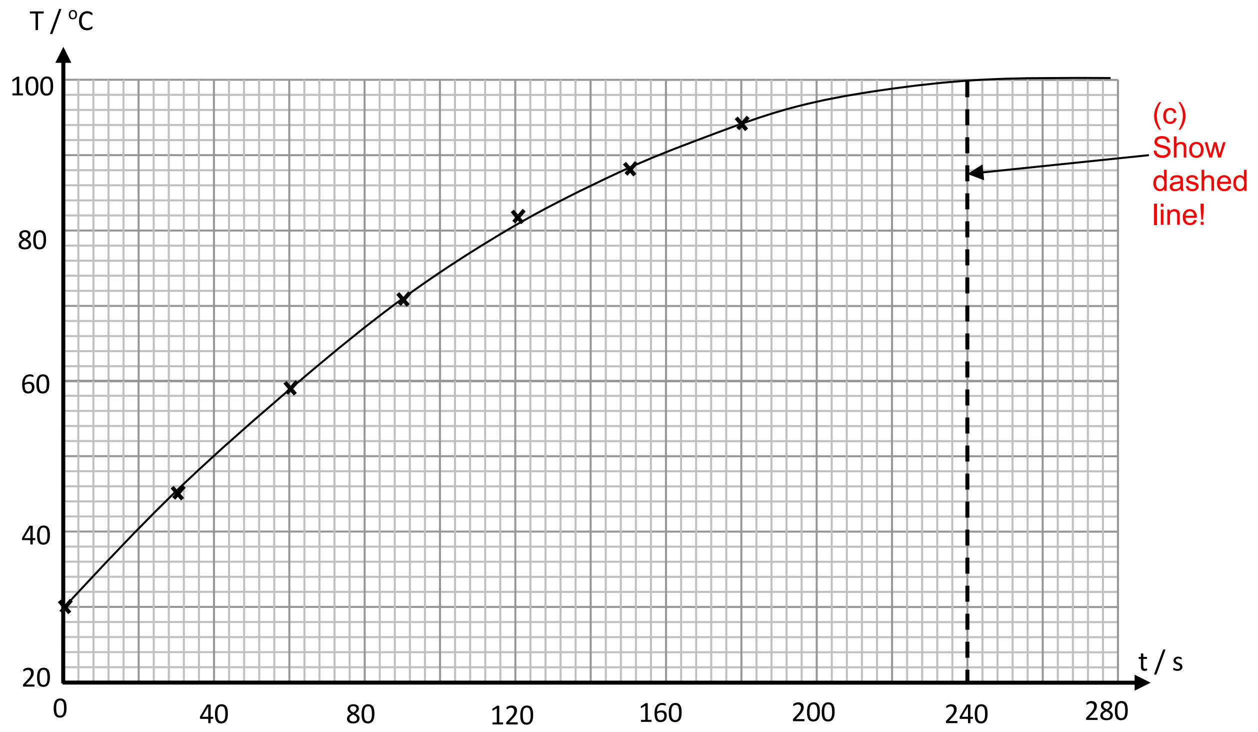
(b) $\Delta\theta$: the rise in body temperature of the person

$Q = mc\Delta\theta$

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

7 (a) All points plotted accurately

A best fit smooth curve.



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

rate of heating of water H	=	rate of thermal energy gained by water G (decreasing)	+ rate of thermal energy loss L (increasing)
(assumed constant)		*(depend on temp. difference Between water & heater)*	*(dep. on temp. diff. between water & surroundings)*
The gradient of the graph (rate of temperature rise) shows the rate of thermal energy gained by water = G = H - L *If rate of heat loss L = 0,* *rate of thermal energy gained G = rate of heating = H = constant → straight line*			

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) From 0 to about 40 s, where the graph is almost straight (or gradient constant).

It means the heat provided by the heater is totally absorbed by the water as there little heat lost to the surroundings initially.

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) x 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) x 24 = 2 hours

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

Energy saved E = P t = 5000 W x (3600 s x 6) = 1.08×10^8 J

OR = 5.0 kW x 6 h = 30 kWh

***Note**: check consistency of units!*