2021 Sec 4 Assignment 20 [30 marks]
Thermal Properties of Matter - Answers

1 $Q = m\,c\,\Delta\theta$ = 0.0850 x 880 x (90.0 – 20.0) [1]
= 5236 J ≈ 5240 J (3 s.f.) [1]

2 $P = Q / t = (m\,c\,\Delta\theta) / t$ = (0.300 x 4200 x 35.0)/ (3.20 x 60) [1]
= 229.7 ≈ 230 W [1]

3 *Apply law of conservation of energy: word equation before actual formulae!*
Word equation: Heat lost by water = heat 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 x 3.34 x 10^5) /4200 x (60.0 – 0.0) [1]

= 0.0205 kg ≈ 21 g [1]

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 x 3.34 x 10^5 = 3340 J [1]

(b) $Q = mc\Delta\theta$ = 0.200 x 400 x (100.0 – 0.0) [1]
= 8000 J [1]

(c) Yes, it is possible to melt all the ice as
the maximum amount of heat released (from part (b)) by the copper ball (if its temperature falls to zero degree celcius)
is greater than the amount of heat needed by the ice to melt (from part (a)). [1]

(d) Let the final temperature be T

Word equation:
Energy released by copper ball = energy gained by (ice melting + total amount of water to reach T + calorimeter) to reach T

Actual formulae:
$m_{ball}\, c_{copper} \Delta\theta_{ball} = m_{ice}\, l_f + m_w\, c_w\, \Delta\theta_w + m_{cal}\, c_{copper}\, \Delta\theta_{cal}$ [1]

0.200(400)(100–T) = 3340 + (0.060+0.010)(4200)(T – 0) + (0.050)(400)(T – 0)
80 x100 – 80T = 3340 + 294T + 20T [1]
4660 = 394T

T = 11.8 °C ≈ 12 °C [1]

5(a) Infra-red radiation [1]

(b)(i) Mass of air in the room $= 3.00\ m^3 \times 3.00\ m \times 3.00\ m \times 1.29\ kg\ m^{-3}$
$= 34.8\ kg$ [1]

(ii) power = heat energy/t or $P = E / t \rightarrow E = Pt$
Energy supplied by heater, $E = 1500 \times 60 \times 60 = 5.4 \times 10^6\ J$ [1]
Heat gained by air = Energy supplied by heater
$Q = m\,c\,\Delta\theta = 5.4 \times 10^6$
$34.8 \times 1000 \times \Delta\theta = 5.4 \times 10^6$
$\Delta\theta = 155.2 \approx 160\ °C$ [1]

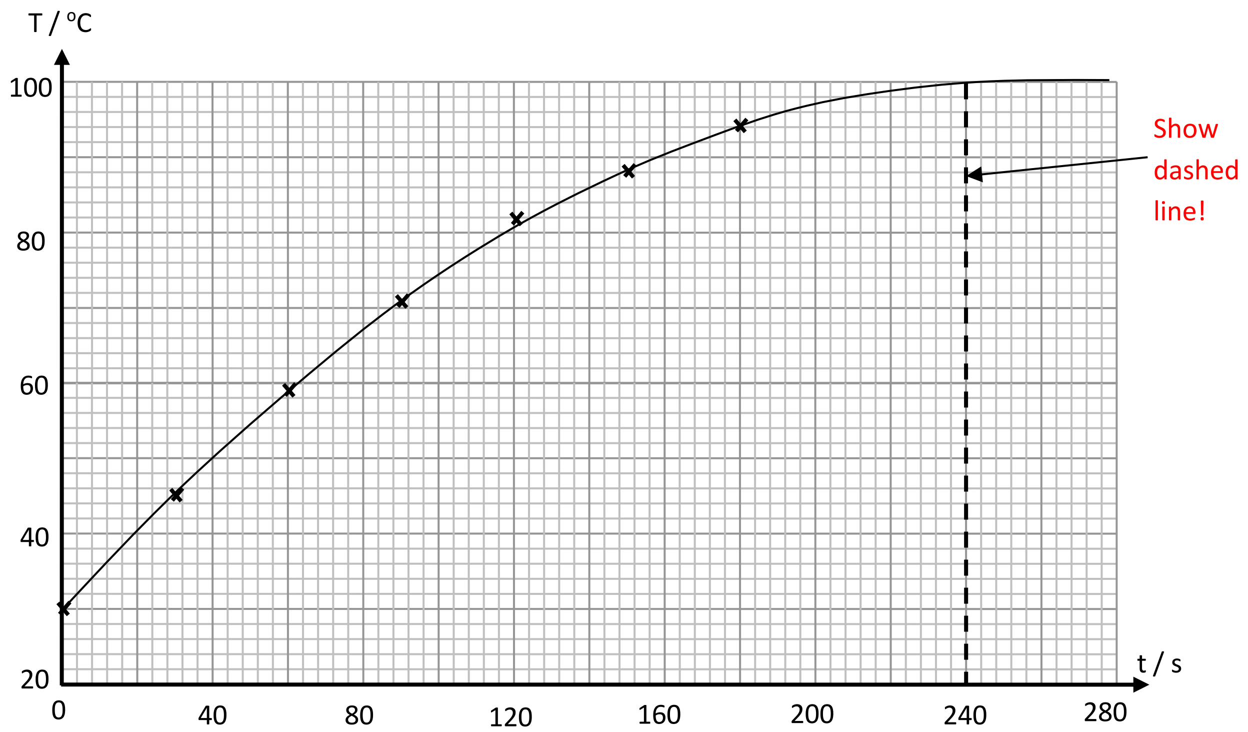
(iii) There is much energy loss to surroundings (by conduction through walls, windows, ceiling, etc)
Heated air expands (volume increase) and may escape from the room.
The heater is less than 100% efficient.
Any one of the above. [1]

6 (a) Energy required to evaporate 2 kg of water
$Q = ml_v = 2 \times 2.26 \times 10^6 = 4.52 \times 10^6 \approx 4.5 \times 10^6\ J$ [1]

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

$$\Delta\theta = \frac{Q}{mc} = \frac{4.52 \times 10^6}{60 \times 3500} = 21.5\ °C$$ [1]

7 (a) All points plotted accurately [1]
A best fit smooth curve. [1]



Note: Apply law of conservation of energy

rate of heating H	= rate of heat gained by water G +	rate of heat loss L
(constant)	(decreasing)	(increasing)
		Depends on temperature difference

The gradient of the graph (rate of temperature rise) shows the rate of heat gained by water.

If rate of heat loss = 0, rate of heat gained = rate of heating = 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 heat gained by water decreases.

Hence, rate of temperature rise also decreases, causing the gradient to decrease. [1]

(c) 240 s. (Refer to the graph) [1]

- 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). [1]

It means the heat provided by the heater is totally absorbed by the water as there little heat lost to the surroundings initially. [1]

8(a) Graph A shows the cooling-heating cycle for the unlagged tank. [1]

- Rate of heat loss is greater, so gradient is steeper.

(b) For the unlagged tank: 120 min or 2 hour cycles

Total time = 40 min x (24 / 2) = 40 x 12 = 480 min [1]

= 480/60 = 8 hours

For the lagged tank: 240 min or 4 hour cycles

Total time = 20 min x (24 / 4) = 20 x 6 = 120 min or 2 hours [1]

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

Energy saved E = P t = 5000 x (3600 x 6) = 1.08×10^8 J [1]

OR = 5.0 kW x 6 h = 30 kWh