Physics ATAR - Year 11

Thermal Physics Test 2019

Name: SOLUTIONS

Mark: / 51

= %

Teacher: CJO JRM PCW

Time Allowed: 50 Minutes

Notes to Students:

1. You must include **all** working to be awarded full marks for a question.
2. Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
3. **No** graphics calculators are permitted – scientific calculators only.

ADDITIONAL FORMULAE AND DATA

First Law of Thermodynamics: $\Delta U = Q - W$

Temperature Conversion: K = C + 273

2Question 1 **(9 marks)**

During an exercise routine, a 65.0 kg person may give off 7.50 x 10^2 kJ of heat in 35.0 minutes by evaporation of sweat from the skin.

(a) Calculate the mass of water that has been lost by evaporation of sweat.

(3 marks)

$Q = mL_V \quad m = \frac{Q}{L_V}$ 1

$= \frac{7.50\times10^5}{2.26\times10^6}$ 1

= 0.332 kg 1

(b) Although the energy removed draws heat from mass of the person, explain why their overall body temperature remains at a constant 37.0 °C.

(3 marks)

- extra heat is produced by cellular repiration
- At the same rate that it is removed
- To maintain thermal equilibrium/regulation of temperature/constant body temp

The person notices that on a particularly humid day, the same exercise routine is a lot more exhausting and uncomfortable than when it is a dry day.

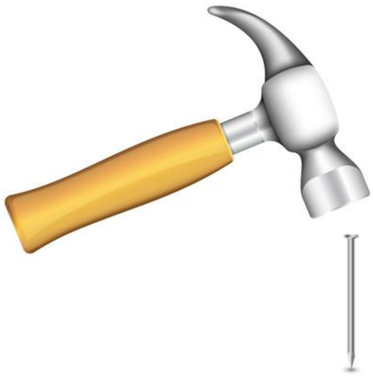
(c) Explain, making reference to relevant modes of heat transfer why this is the case.

(3 marks)

- Humidity is a factor the affects the rate of evaporation, (as vapor falls back to the surface returning Lv)
- During the a humid day, less sweat is able to evaporate
- Meaning less heat is removed in a given time

Question 2 **(8 marks)**

A 1.40 kg hammer is travelling at a speed of 1.80 ms^{-1} as it strikes a nail at room temperature (25.0 °C) and is brought to rest.



(a) Calculate the temperature rise of a 8.00 g iron nail if the nail is struck 10 times in quick succession.

(4 marks)

(c_{Fe} = 4.50x10^2 Jkg^{-1}K^{-1})

Ek = ½mv^2 x10 ½

= ½(1.40)(1.80^2) x10 1

= 22.7 J

$Q = mc\Delta T$ ½

$\Delta T = \frac{Q}{mc} = \frac{22.7}{(0.008 \times 450)}$ 1

= 6.31 K 1

(if Tf is solved for directly as 31.6 °C, allow full marks)

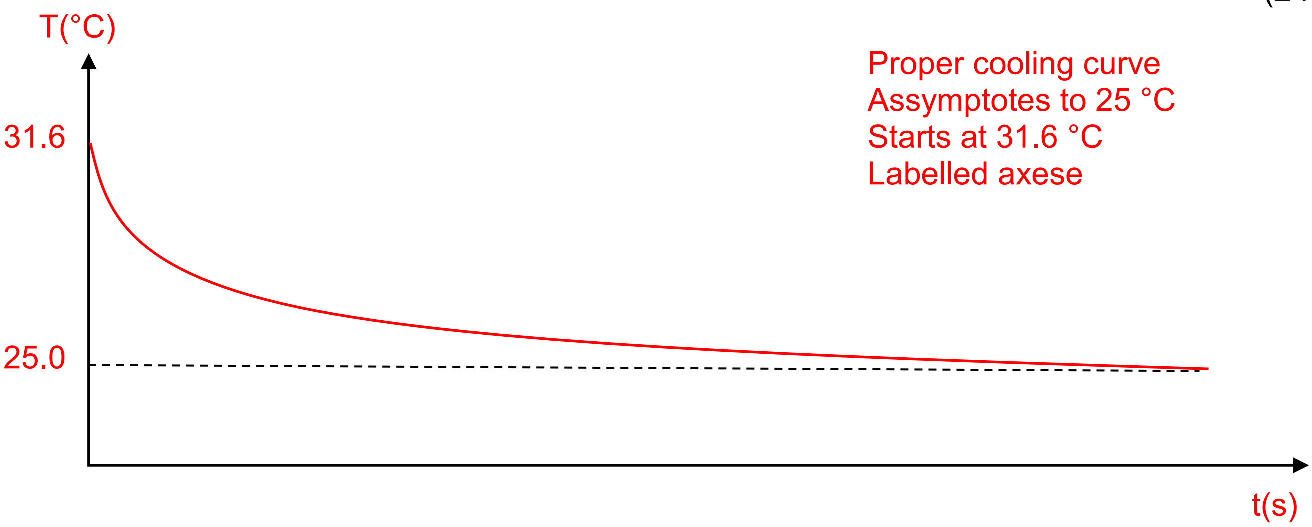
(b) State two assumptions made in the calculations for part (a)

(2 marks)

- Hammer gains no Ek (no increase in temperature) or All the heat is transferred to nail
- No energy transferred to environment
- All Ek is converted soley to heat (no sound or mechanical energy)

(c) Sketch a labelled temperature time curve of the nail if it is allowed to sit for an indefinite period of time.

(2 marks)



Proper cooling curve
Assymptotes to 25 °C
Starts at 31.6 °C
Labelled axese

Question 3 **(8 marks)**

A mass of ice at -15.0 °C is placed into an insulated copper calorimeter of mass 0.350 kg containing 0.240 kg of water, both initially at 28.0 °C. The resulting temperature is recorded to be 17.0 °C.

(a) Calculate the mass minimum mass of ice required to produce this temperature change.

(5 marks)

(c_{cu} = 3.90×10^2 $Jkg^{-1}K^{-1}$)

$Q_{gain} + Q_{lost} = 0$ ½

$Q = mc(T_f - T_i)$

$\Delta T_{ice} = +15$

$\Delta T_{icewater} = +17$

$\Delta T_{water} = \Delta T_{Cu} = -11.0$

$Q_{ice} + Q_{melting} + Q_{ice\ water} + Q_{Cu} + Q_{water} = 0$ ½

$m(2100 \times 15.0) + m(3.34 \times 10^5) + m(4180 \times 17.0) + (0.350 \times 390 \times -11.0) + (0.240 \times 4180 \times -11.0) = 0$ 1

$31500m + 334000m + 71100m - 1500 - 11000 = 0$ 1

$437000m - 12500 = 0$ 1

$m = 0.0286$ kg 1

If

$Q = mL_f$ omitted:	m = 0.122 kg
$c_{melted\ water} = 2100$:	m = 0.0313 kg
$Q_{icewater}$ omitted	m = 0.034 kg

(b) Explain why the mass of ice calculated in (a) is described as "minimum mass".

(3 marks)

- In reality, energy would be gained from surroundings environment
- This extra energy could be used to melt more ice or increase ΔT_{water} and ΔT_{Cu}
- Hence a larger mass of ice would be reuired to absorb this extra energy.

OR

- In reality, energy lost would also include the energy removed from the calorimeter
- This would require more ice to be present to absorb the additional energy.
- Hence a larger mass of ice would be reuired to absorb this extra energy.

Question 4 **(8 marks)**

The equation for heat flow through a substance via conduction is given as: $\frac{Q}{t} = \frac{kA\Delta T}{L}$.

Where k = thermal conductivity

A = cross sectional area (m^2)

L = thickness of material (m)

ΔT = temperature difference (K)

(a) Using dimensional analysis, determine the units of thermal conductivity.

(2 marks)

$k = \frac{QL}{tA\Delta T} = \frac{[J][m]}{[s][m^2][K]} = [Js^{-1}m^{-1}K^{-1}]$ or $[Wm^{-1}K^{-1}]$

½ ½ 1

A major source of heat loss from a house is through windows. Consider a glass window 5.00 mm thick and 2.50 m by 1.60 m in area. The inside temperature is 23.00 °C and the outside temperature is 22.60 °C.

(b) If the thermal conductivity of the glass is 0.820, calculate the rate of heat flow through the glass.

(3 marks)

$\frac{Q}{t} = \frac{kA\Delta T}{L}$ 1

$= \frac{0.820(2.50\times1.60)(23.00-22.60)}{5\times10^{-3}}$ 1

= 260 J/s (2.sig.fig) due to ΔT 1 (No mark deduction for 3.sig.fig)

(c) State and explain, making reference a relevant mode of heat transfer, one modification that can be made **to the window** that will reduce the rate of heat transfer.

(3 marks)

- Double glazing or heavy curtains
- Traps a pocket of still air which acts as an insulator
- Reducing rate of heat transfer via conduction

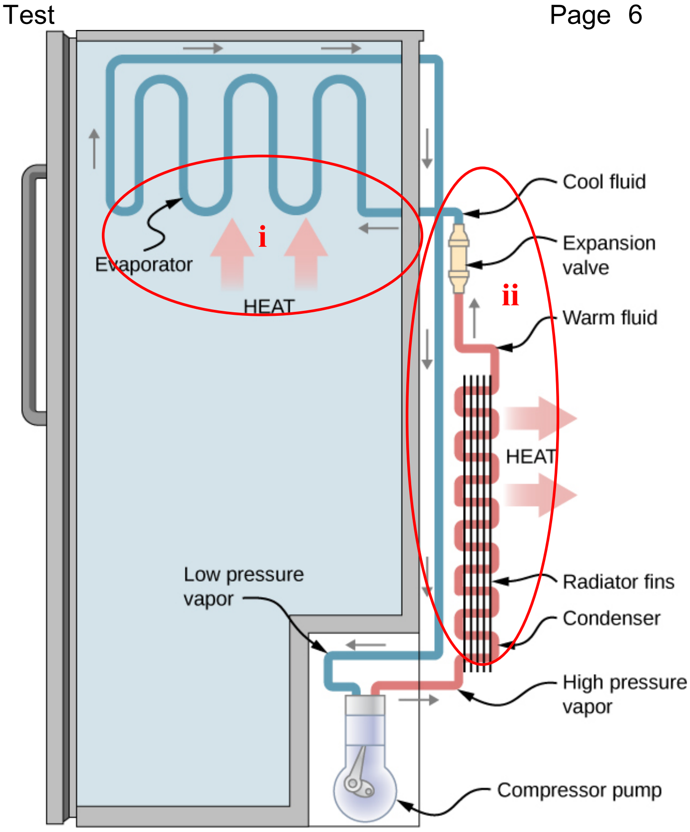
- Increase L
- As $\frac{Q}{t}$ is inversely proportional to L,
- this would decrease rate of heat transfer via conduction

- Decrease k, or A
- As $\frac{Q}{t}$ is proportional to k and A,
- this would decrease rate of heat transfer via conduction

- tint with silver tinting
- shiny silver has a low emissivity
- and would reduce rate of heat transfer via radiation

Question 5 **(12 marks)**

The diagram provided shows the movement of refrigerant through a refrigeration cycle. In order for heat to be successfully removed from the inside of the refrigerator, a compressor must do work on the system by compressing the vapour as it cycles to the rear of the refrigerator.



(a) Describe the effect that compressing the vapour has on its temperature, making reference to the kinetic theory of matter or relevant scientific laws.

(3 marks)

- As the compressor does work the internal energy of the refrigerant (Ek only) increases
- As temperature is a measure of the mean translational velocities of particles in a substance,
- The temperature of the refrigerant increases.

- Gay-Lussac's Law states that pressure and temperature are proportional to each other.
- The compressor increases the pressure of the system
- Resulting in an increase in temperature of the particles.

The compressor does 7550 J of work on 0.0550 kg of refrigerant vapour initially at 12.0 °C in a given time period.

(b) Providing there is no phase change at the location, calulate increase in internal energy of the refrigerant and the final temperature of the refrigerant.

(4 marks)

$C_{refrigerant}$ = 2740 Jkg^{-1}K^{-1}

No heat transfer

$\Delta U = \cancel{Q} - W$

$= -7550$ J

Q = 7550

$\Delta T = T_f - T_i = \frac{Q}{mc}$

1

$T_f = \frac{Q}{mc} + T_i$

$= \frac{7550}{(0.0550)(2740)} + 12.0$

= 62.1 °C

(c) On the diagram of the refrigerator on the previous page:

i. circle the region where the refrigerant is drawing heat from its surroundings in order to evaporate.

(1 mark)

ii. the region where the refrigerant is doing work on its surroundings.

(1 mark)

The radiator fins at the rear of the refrigerator play an important role of removing heat at the greatest rate possible.

(e) State and explain one feature of the radiator fins that maximises this heat transfer.

(3 marks)

- Black matte surface
- Increases emissivity 'e'
- Since Q/t $\propto$ 'e' this increases rate of heat transfer via radiation

- Fins increase surface area
- This increases A
- Since Q/t $\propto$ 'A' this increases rate of heat transfer via conduction from metal to air

- Made of metal
- This increases the conductivity constant 'k'
- Since Q/t $\propto$ 'k' this increases rate of heat transfer via conduction

Question 6 **(2 marks)**

Provide one similarity and difference between conduction and convection.

Similarity: both involve the net transfer of heat from one region to another.
Both involve elastic collisions that impart Ek

Difference: Convection involves the net transfer of matter, conduction does not
Convection cannot occur in solids, conduction can.

Question 7 **(4 marks)**

A student wishes to determine the initial temperature of a 0.352 kg piece of copper. He heats the copper in an oven and then places the piece in an insulated foam container containing 0.750 kg of Water at 20.00 °C. The final temperature of the mixture is measured to be 24.50 °C. Calulate the initial temperature of the copper.

$C_{copper} = 3.90 \times 10^2 \ Jkg^{-1}K^{-1}$

$Q_{gain} + Q_{lost} = 0$ ½ $Q = mc(T_f - T_i)$ ½ $\Delta T_{water} = 4.50$

$\Delta T_{Cu} = 24.50 - Ti$

$Q_{Water} + Q_{copper} = 0$

$(0.750 \times 4180 \times 4.50) + (0.352 \times 390 \times 24.50) - (0.352 \times 390 \times Ti) = 0$ 1

$14100 + 3360 - 137\ Ti = 0$ 1

$Ti = 127\ °C$ 1

END OF TEST