Physics ATAR - Year 11

Thermal Physics Test 2018

Name:	Mark: / 53
	= %

Teacher: SFZ JRM

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

$$\frac{T_\theta}{100} = \frac{X_\theta - X_0}{X_{100} - X_0}$$

c_{ice} = 2100 $Jkg^{-1}K^{-1}$

$c_{aluminium}$ = 900 $Jkg^{-1}K^{-1}$

$L_{f\ water}$ = 3.34 x 10^5 Jkg^{-1}

c_{water} = 4180 $Jkg^{-1}K^{-1}$

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

K = C + 273.15

Question 1 **(4 marks)**

A bi-metallic strip is made of two different metals, which expand at different rates as they are heated. This causes the strip to bend as the temperature changes. When placed in boiling water it is found to bend **upwards** 23.5 mm from its unexpanded position. When the strip was placed in a mixture of ice and water the strip bent **downwards** by 14.0 mm from its unexpanded position. The bi metallic strip is then left in a room that has a temperature of 25.1˚C. Determine how far the strip would bend from its unexpanded position.

Let unexpanded position = 0 mm
At 100˚C position = 23.5 mm up
At 0.00˚C position = 14.0 mm down

$$\frac{T_\theta}{100} = \frac{X_\theta - X_0}{X_{100} - X_0} \quad (1)$$

$$X_\theta - X_0 = \frac{T_\theta}{100} \times (X_{100} - X_0)$$

$$X_\theta - X_0 = \frac{25.1}{100} \times (23.5 - (-14.0)) \quad (1)$$

$$X_\theta - X_0 = 0.251 \text{ x } (37.5) = 9.4125 \text{ mm} \quad (1)$$

$$X_\theta = 9.4125 - 14.0 = -4.5875 \text{ mm}$$

= 4.59 mm down (1)

Question 2 **(4 marks)**

In an experiment, students heated 400 copper pellets, each with a mass of 1.00 g, to 95.0˚C before immediately placing them into an insulated calorimeter (with negligible specific heat) containing 0.500 kg of 21.0˚C water. They measured the equilibrium temperature as 26.2˚C using a probe. Determine the experimental value the students determined for the specific heat of copper.

mass of pellets = 400 x 1.00 = 400g, T_i pellets = 95.0˚C,
mass of water = 0.500 kg, T_i water = 21.0˚C, T_f copper and water = 26.2˚C

$Q = mc(T_f - T_i)$ (½)

$Q_{water} + Q_{Cu} = 0$ (½)

$m_{water}c_{water}(T_f - T_i) + m_{Cu}c_{Cu}(T_f - T_i) = 0$

0.500 x 4180 x (26.2 - 21.0) + 0.400 x c_{Cu} x (26.2 - 95.0) = 0 (2)

10868 + (-27.52 c_{Cu}) = 0 c_{Cu} = 10868/27.52

= 395 $Jkg^{-1}K^{-1}$ (1)

-1/2 if do not show working of ΔT as $(T_f - T_i)$

Question 3 **(10 marks)**

An electric hot plate is rated at 2.00kW. A 2.40 kg aluminium pan containing 1.00 L of water at 25.0˚C is placed on top of the hot plate.

(a) Calculate how long it would take, in minutes, to bring the aluminium and the water to the boiling point of water.

(5 marks)

$Q_{total} = Q_{water} + Q_{Al}$ (½)

$Q_{total} = m_{water}c_{water}(T_f - T_i) + m_{Al}c_{Al}(T_f - T_i)$

$Q_{total} = 1.00 \times 4180\ (100 - 25) + 2.40 \times 900 \times (100 - 25)$ (1)

$Q_{total} = 313500 + 162000$

$Q_{total} = 475500$ J (1)

$t = E/P$ (½) $t = Q_{total}/P$

$t = 475500/2000$

$t = 237.75$ s (1)

$t = 3.96$ min (1)

(b) Would the time calculated in (a) above be realistic? Justify your answer.

(2 marks)

* The time is not realistic, it would take longer
• As energy would be transferred to the surroundings from the pan and water, it would take a longer time as more energy would be required to achieve boiling point.

(c) It is measured to take a time of 5.50 minutes for the water to come to boil. Calculate the efficiency of the heating process.

(3 marks)

$$\eta = \frac{\text{Energy output}}{\text{Energy input}} \times \frac{100}{1}$$ (1)

$$\eta = \frac{475500}{660000} \times \frac{100}{1}$$

or

$$\eta = \frac{3.96}{5.50} \times \frac{100}{1}$$ (1)

$\eta = 72.0\%$ (1)

Question 4 **(3 marks)**

In an accident, one boy suffers a steam burn from 0.125 kg of steam at 100˚C, while another is burned by 0.250 kg of boiling water. Explain why the steam burn is more severe than that of the boiling water.

- A scald with hot water gives out energy equivalent only to the specifc heat capacity of water for the temperature change of the water
- When steam condenses it gives out energy equivalent to both the latent heat of vaporisation and specific heat to the environment to the boys skin/flesh
- imparting significantly more energy and causing much more serious burns.

can not get full marks unless there is mention of latent heat of vaporisation and specific heat capacity

Question 5 **(5 marks)**

A 0.100 kg aluminium container containing 0.180 kg of water sits in the sun until it reaches an equilibrium temperature of 40.0°C. Then 50.0 g of ice at -10.0°C is added to the water. Assuming all of the ice melts, determine the final equilibrium temperature.

$Q_{loss} + Q_{gain} = 0$ (½) $Q = mc(T_f - T_i)$ Ti = 40.0 ˚C, Tf =? Ti ice = -10.0 ˚C

$Q_{water} + Q_{Al} + Q_{ice} = 0$ (½)

$(0.18 \times 4180 \times (Tf - 40.0)) + (0.1 \times 900 \times (Tf - 40.0)) + (0.050 \times 4180\ (Tf - 0)) + (0.05 \times 3.34 \times 10^5) + (0.05 \times 2100\ (0 - -10)) = 0$

$752.4Tf - 30096 + 90.0\ Tf - 3600 + 209Tf + 16700 + 1050 = 0$ (2)

$1051.4Tf - 15946 = 0$ (1)

$Tf = 15946/1051.4$

$Tf = 15.16˚C = 15.2\ ˚C$ (1)

Question 6 **(4 marks)**

When using a hand-held pump to pump up a football, the pump suddenly feels much warmer when the piston is pushed. Explain, making reference to the first law of thermodynamics why the pump gets warmer as the piston is pushed into the cylinder.

- As you push the piston in the pump you are doing work on the gas by compressing it
- As the gas is compressed you are increasing the internal energy of the gas.
- The first Law of Thermodynamics indicates that the change in internal energy is equal to the work being done on the gas by the piston ($\Delta U = Q + W$)
- This increases the mean kinetic energy of the gas particles, and as temperature is proportional to this energy, there will be an increase in the temperature of the piston

Question 7 **(10 marks)**

Refrigerators are designed such that there are always pipes on the outside of the cooling compartment, either under or at the back of the refrigerator. When the refrigerator is operating, this piping becomes quite hot.

(a) By making reference to the process of refrigeration, explain why the piping becomes hot. (4 marks)

- The compressor compresses the coolant gas into a liquid
- Releasing energy equivalent to the latent heat of vaporisation of the coolant gas
- This heat energy is transferred to the metal pipes by conduction
- Increasing the temperature of the metal pipes making them feel hot

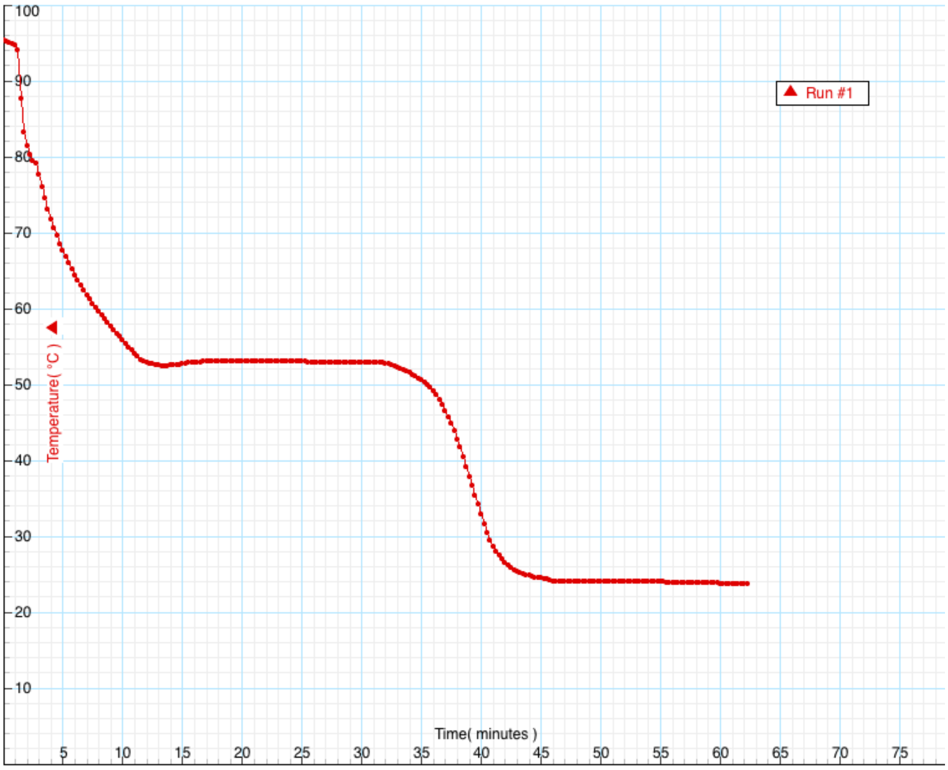
(b) Describe and explain 3 features of the pipes (e.g. colour, material of construction and shape) that make them efficient at energy transfer. (6 marks)

Any 3 of the following:

- The pipes are made of metal as this is the best material to use to conduct heat away from the coolant because it has a high value of thermal conductivity that increases the rate of heat transfer
- The pipes are usually painted matt black as this is the best 'colour' to absorb and emit radiant energy from the pipes to the air that surrounds the pipes
- The pipes are coiled (and usually joined to a lattice of metal also painted black), increasing the surface area that increases the rate of heat transfer via radiation.
- The pipes are thin as this increases the rate of conduction of heat through the pipe
- The pipe is usually a conductive material with a low value tof specific heat capacity that increases the rate of heat loss by conduction

Question 8 **(13 marks)**

The following graph is a **cooling curve** for 1,4-dichlorobenzene. It shows temperature (°C) plotted against time (minutes) for a 240g sample that was placed in a glass beaker and heated to 95°C to become a liquid, and **then allowed to cool** in room temperature air. After 32 minutes the sample had completely solidified and continued to cool until it reached a steady temperature after 45 minutes.



(a) Define the concept of *Heat* and outline one example where this is apparent in this situation. (3 marks)

- Heat is the energy transferred between objects or materials that have a difference in temperature (hot objects transfers heat energy to colder objects.
- An example would be the transfer of energy from the "heater" to the glass beaker to melt the 1,4-diclorobenzene, or the transfer of heat from the hotter glass/liquid 1,4-dichlorobenzene to its surroundings (must explain the transfer of energy from a hotter to a colder substance to get full marks).

(b) Between 12 minutes and 32 minutes the temperature remains constant even though heat was still being transferred out of the sample. Use this context to define and explain the difference between *Internal Energy*, *Temperature.*

(i) Internal Energy (2 marks)

- Internal energy is the sum of the potential and kinetic energy of the particles that make up a substance/material.
- During the time indicated the substance is reducing its particles potential energy to change state from a liquid to a solid.

(ii) Temperature (2 marks)

- Temperature is defined as the mean translational kinetic energy of the particles that make up a substance/material.
- As the substance is not changing temperature there is no change to the particles kinetic energy

(c) After 45 minutes the temperature remains constant, but the net transfer of energy stops. Explain why this happens. (2 marks)

- The 1,4-dichlorobenzene has achieved thermal equilibrium (the same temperauture) with the surroundings,
- indicating there is no net transfer of heat energy between it and its surroundings.

(d) During the period from 12 minutes to 32 minutes it is measured that energy is transferred at a rate of 1.42 kJ per minute out of the 0.240 kg sample of 1,4-dichlorobenzene. Use this information to calculate the *Latent Heat of Fusion* for 1,4-dichlorobenzene.

(4 marks)

t = 20 minutes

Q = P x t (½)

Q = 1.42 kJ x 20 = 28.4 kJ (1)

Q = m x L_v (½) so L_v = Q/m

L_v = $(28.4 \times 10^3)/0.240$ (1)

L_v = 118 $kJkg^{-1}$ (1)

END OF TEST