Physics ATAR - Year 11

Thermal Physics
Unit Test
2017

Name: SOLUTIONS

Mark: / 55

= %

Time Allowed: 50.0 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 Data

Triple point of water = 273.16 K

Thermometer Calibration: $\frac{\theta}{100} = \frac{X_\theta - X_0}{X_{100} - X_0}$

c_{glass} = 670 J kg^{-1} K^{-1}
c_{argon} = 520 J kg^{-1} K^{-1}
$c_{concrete}$ = 2.09 x 10^3 J kg^{-1} K^{-1}

First Law of Thermodynamics $\Delta U = Q - W$
$L_{f\ butter}$ = 60.0 x 10^3 J kg^{-1}

1. An electric hot plate heats a 145 g stick of butter from its melting point at 42.0°C until it is completely melted.

(a) Calculate the amount of energy the butter has absorbed to completely change phase.

(3 marks)

Converts 145 g to 0.145 kg (0.5)

$Q = m_{Butter} L_{f\ Butter}$ (0.5)

$Q = (0.145)(60.0 \text{ x } 10^3)$ (1)

$Q = 8700\ J$ (1)

(b) If the hot place consumes 13.7 kJ of energy during the melting process, calculate the efficiency of the heating process.

(3 marks)

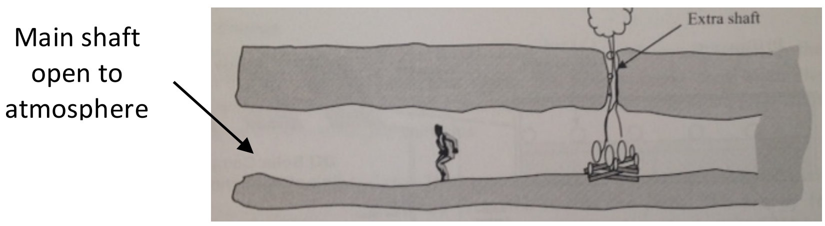
$\eta = \frac{Useful\ Energy}{Total\ Energy} \times 100$ (1)

$\eta = \frac{8700}{13.7 \times 10^3} \times 100$ (1)

$\eta = 63.5\ \%$ (1)

2. In the 18th Century, mines were often ventilated with air by drilling a small extra shaft and lighting a fire beneath it. Explain how the fire helps to ventilate the mine with reference to the kinetic theory.

(4 marks)



- Kinetic energy from the hot air in the fire is transferred to the cooler air above the fire.
- As the speed of the particles is proportional to their kinetic energy, the particles above the fire move fast and spread further apart making the air less dense.
- The less dense (hot) air rises and is replaced by cold (fresh) air brought in from the outside.
- Forming a natural convection current.

3. A cylinder filled with 0.130 kg of argon (which behaves as an ideal gas), is sealed with a piston that is free to move up and down. The gas is initially at 3.00 x 10^2 K. The cylinder is heated from below. After a few minutes, 171 J of heat has been added to the system. The gas expands and as a result, does work on the piston, exerting an upwards force of 2.50 x 10^2 N over a distance of 0.0200 m.

(a) Assuming no loss to the surroundings, calculate the increase in internal energy of the argon. (4 marks)

Work done on piston:
W = Fs (0.5)
= (250)(0.02) (0.5)
= 5 Nm (1)
As work done is done *by* the system W = + 5 Nm

Q = + 171 J

ΔU = Q – W (1)
ΔU = 171 - 5 (0.5) (0 marks if incorrect signs used)
= 166 J (0.5)

(b) Calculate the expected final temperature of the argon. State and justify any assumptions made. (6 marks)

- One assumption of an ideal gas is that there is no stored potential within particles (no forces exerted) (1 mark justification)
- Therefore all of the extra energy results in a temperature increase (Q = 166 J) (1 mark stating assumption)

$Q = mc\Delta T$ (1 mark)

$\Delta T = \frac{Q}{mc} =$ 166 / (0.130 * 520) (1 mark)
= 2.46 K (1 mark)

$T_f = T_i + \Delta T = 300 + 2.46 = 302\ K$ (1 mark)

4. Some storage heating systems use the energy from the sun to heat a house. A large block of concrete is used to absorb energy during the day and then release this energy back in to the house at night. Over the course of a hot day, a concrete slab reaches a temperature of 32.0°C.

A house owner discovers, around sundown, that the night is going to be very hot and she wishes to cool the slab of concrete. She uses water from the hose, initially at 15.0°C to cool the block. After she has applied 1.00 x 10^3 kg water, the slab and water reach an equilibrium temperature of 26.0°C.

Assuming no losses to the surroundings, calculate the mass of the concrete slab.

(4 marks)

$Q_1 + Q_2 = 0$ (0.5)

$m_c = ?;\quad c_c = 2.09 \text{ x } 10^3 \text{ J kg}^{-1} \text{ K}^{-1};\quad \Delta T_c = -6℃$

$m_w = 1000\ kg;\ c_w = 4180\ \text{ J kg}^{-1} \text{ K}^{-1};\ \Delta T_w = 11℃$

$m_c c_c \Delta T_c + m_w c_w \Delta T_w = 0$ (0.5)

$$m_c = \frac{-m_w c_w \Delta T_w}{c_c \Delta T_c}$$

$m_c = \frac{-(1000)(4180)(11)}{(2090)(-6)}$ (2 working total)

$m_c = 3670\ kg$ (1)

5. A 2.30 kW hair dryer is used to vaporise 0.430 kg of water, initially at 22.3 °C, from a woman's hair.

(a) Calculate the heat input required for water to reach its boiling point.

(3 marks)

$Q = mc\Delta T$
= (0.430)(4180)(100-22.3)
= 1.40×10^5 J

(b) Calculate the time you would expect this to take using the power rating of the hair dryer.

(3 marks)

P = 2.30×10^3 W (0.5)

$P = \frac{E}{t}$ (0.5)

$t = \frac{E}{P} = \frac{1.40 \times 10^5}{2.30 \times 10^3}$ (1)

t= 60.9 s (1)

(c) In reality, this process actually takes close to 180 s. Provide two reasons why this might be the case.

(2 marks)

- Heat is lost to the surrounding air and hair
- Electrical energy is also converted to other forms such as sound and kinetic

6. A student makes a crude thermometer in order to measure the soil temperature in his vegetable patch. He only has a few pieces of equipment to work with. These are; some resistance wire, a multimeter from his father's tool box which measures resistance plus the usual household appliances such as a fridge and a kettle.

(a) State what is required in order to calibrate the thermometer?

(2 marks)

- Record 2 reference points of known temperature (e.g. boiling and melting point of water.
- Divide the interval into 100 segments (for Celsius) (provide a scale)

The resistance of the wire at various temperatures is shown below.
Resistance at the M.P. of ice = 29.8Ω
Resistance at the B.P. of water = 41.5Ω
Resistance in the soil = 31.6Ω

(b) Calculate the temperature of the soil.

(3 Marks)

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

$\frac{\theta}{100} = \frac{31.6 - 29.8}{41.5 - 29.8}$ (1)

$\theta = 15.3$ °C (1)

(c) The soil is wet and he notices that the temperature of the surface of the soil drops considerably when it is very windy. State the reasons for this explaining your answer using the kinetic theory of matter?

(3 marks)

- Water molecules near the surface of the soil can escape into the gaseous phase **(evaporate)** if they have **sufficient kinetic energy** to overcome the attraction of neighboring molecules.
- Escape of the higher kinetic energy molecules **leaves** a collection of **lower kinetic energy** molecules and consequently a **lower temperature,** reducing the temperature of the soil.
- **Wind** constantly removes the higher humidity air from near the soil, **reducing the atmospheric pressure** above the soil, making it easier for particles to gain sufficient energy and **increasing the rate of evaporation.**

(1 mark each bullet point. Not verbatim but concepts in bold should be addressed)

7. A mass of ice with a temperature of -5.00 ^{O}C is added to a glass of tap water at a temperature of 25.0 ^{O}C. The water has a mass of 185 g while the glass has a mass of 120 g. If thermal equilibrium occurs at 3.60 ^{O}C, calculate the mass of ice that was added (Ignore any losses to the surroundings).

(6 marks)

Changes occurring:

1) Ice: -5.00 ^{O}C → 0 ^{O}C ΔT_i = 5 ^{O}C, $m_i = ?$
2) Ice: 0 ^{O}C → 0 ^{O}C Water $m_i = ?$
3) Water: 0 ^{O}C → 3.6 ^{O}C ΔT_{w1} = 3.6 ^{O}C, $m_i = ?$
4) Water: 25.0 ^{O}C → 3.6 ^{O}C ΔT_{w2} = 3.6 – 25 = -21.4 ^{O}C, $m_w = 0.185\ kg$
5) Glass: 25.0 ^{O}C → 3.6 ^{O}C ΔT_g = -21.4 ^{O}C, $m_g = 0.120\ kg$

(Correctly assigning variables: 3 marks. -1 for each mistake)

$Q_1 + Q_2 + Q_3 + Q_4 + Q_5 = 0$

$m_i c_i \Delta T_i + m_i L_f + m_i c_w \Delta T_{w1} + m_w c_w \Delta T_{w2} + m_g c_g \Delta T_g = 0$ (1)

$m_i(c_i \Delta T_i + L_f + c_w \Delta T_{w1}) + m_w c_w \Delta T_{w2} + m_g c_g \Delta T_g = 0$

$m_i = \frac{-m_w c_w \Delta T_{w2} - m_g c_g \Delta T_g}{(c_i \Delta T_i + L_f + c_w \Delta T_{w1})}$

$$m_i = \frac{-(0.185)(4180)(-21.4) - (0.120)(670)(-21.4)}{(2100)(5) + \left(3.34 \times 10^5\right) + (4180)(3.6)} = \frac{18269.18}{359548} \qquad (2)$$

$$m_i = 0.0508 = 5.08 \times 10^{-2}\ kg \qquad (1)$$

8. Sam is a very frugal driver. In an effort to save money, he does not like to turn the refrigerated air conditioning on inside his car during summer. On the other hand, he has no problem using the heating system whenever he feels like during winter.

The air conditioning system uses a refrigerant circuit. The refrigerant undergoes a constant cycle of vaporisation and condensation. Warm air is blown over the liquid refrigerant, causing the air to become cooled. The cooled air is driven into the passenger compartment with a fan.

a) For the air conditioning system, explain where the energy from the warm air goes and the impact this has on the refrigerant circuit.

(2 marks)

- The energy is absorbed by the refrigerant
- Giving the refrigerant the energy to evaporate (latent heat of vaporisation)

b) Explain why the heating system is fundamentally more efficient than the cooling system.

(2 marks)

- The refrigerant circuit requires **constant energy input from a compressor / pump**
- The heating circuit does not require additional energy input, it uses **excess heat generated from the car's engine**

OR

- The heating circuit moves heat from a **HOT area to a COLD area. This is a natural process** as stated in the 2nd law of thermodynamics.
- The cooling circuit causes heat to flow from **COLD to HOT areas which requires an input of WORK.**

9. On a hot summer's day, the temperature of a rough black leather steering wheel inside a car becomes much higher than the temperature of the air inside the car.

A common interpretation of the second law of thermodynamics is that in natural conditions "Heat always flows from Hot to Cold". At first inspection, the above observation appears to disobey this law.

a) Nominate the primary source of energy and heat transfer mechanism that results in the steering wheel being heated. Explain why the steering wheel becomes hotter than the surrounding air.

(3 marks)

- The sun is the source
- Heat is transmitted via radiation
- Matte Black absorbs more radiant heat due to a high emissivity value **OR** air particles are less dense and therefore absorb less over a given area.

b) State whether the above heat transfer mechanism obeys the second law of thermodynamics and justify your response.

(2 marks)

- Yes
- The sun is hotter than the steering wheel

END OF TEST