Christ Church Grammar School

Science Department
Year 11 2021

ATAR PHYSICS
UNIT 1: THERMAL PHYSICS
TOPIC TEST 2021

SOLUTIONS

Teacher: CJO HKR JRM
(Please circle)

Time allowed for this paper
Working time for paper: 50 minutes.

Instructions to candidates:

- You must include **all** working to be awarded full marks for a question.
- Answers should be expressed to 3 significant figures unless otherwise indicated.
- Marks may be deducted if diagrams are not drawn neatly with a ruler and to scale (if specified).
- Marks will be deducted for incorrect or absent units.
- **No** graphics calculators are permitted – scientific calculators only.

Mark: / 48

= %

Question 1 **(7 marks)**

Students are investigating steam. They allow a sample of 85.0 g of steam at a temperature of 115 °C to condense onto a cold stainless steel plate, where its final temperature is measured to be 72.0 °C.

(a) Calculate the heat released during the experiment.

(3 marks)

Description	Marks
$Q = mc\Delta T$ $Q = mL_V$ $Q_{TOTAL} = Q_1 + Q_2 + Q_3$	1
Q_{TOTAL}= (0.085)(2000)(100-115) + -(0.085)(2.26 x 10^6) + (0.085)(4180)(72-100) Q_{TOTAL}= -2550 – 192,100 – 9950	1
Q_{TOTAL}= - 204,600 J = 205,000 J released	1
Total	3

The stainless steel plate had a mass of 4.62 kg and experienced a temperature rise of 81.0 °C.

($c_{stainless\ steel}$= 490 J kg^{-1} K^{-1})

(b) Calculate the percentage of the total energy that was transferred to the surroundings. (If you could not solve part (a), use heat released = 3.00 x 10^5 J)

(4 marks)

Description	Marks
Energy absorbed by steel $Q = mc\Delta T$ = (4.62)(490)(81)	1
= 183 kJ	1
Heat to surroundings = 205,000 – 183,000 = 22,000 J	1
22,000 / 205,000 = 10.7% (alternative answer 39.0%)	1
Total	4

Question 2 **(6 marks)**

Marie is convinced that the temperature display on her oven is not accurate and devises a test to investigate. She places a 320 g copper tray in the oven on a setting of 200 °C for several minutes until thermal equilibrium is reached. She then immerses the tray into an insulated esky containing 1.90 kg of water at 15.0 °C. After a few minutes, the temperature of the water and tray was uniform at 17.6 °C.

(c_{cu}= 390 J kg^{-1} K^{-1})

(a) Calculate the temperature of the oven according to Marie's experimental results, and state whether her oven "runs cool" (lower than the temperature that is set), or "runs hot".

(4 marks)

Description	Marks
$Q = mc\Delta T$ $Q_1 + Q_2 = 0$	1
$(mc\Delta T)_{water} + (mc\Delta T)_{copper} = 0$ 1.90 (4180) (17.6-15.0) + 0.320 (390) (17.6-T_{i-}) = 0	1
2196.5-124.8 T_i+ 20649.2 = 0	1
T_i = 183 °C Therefore oven runs cool	1
Total	4

(b) Explain whether your calculated value for part (a) is likely to be an over or underestimate of the true temperature.

(2 marks)

Description	Marks
Underestimate	1
Not all energy would be transferred to the water, as some would be transferred to the environment/air.	1
Total	2

Question 3 **(3 marks)**

Explain, with reference to the kinetic theory, how an alcohol in glass thermometer is able to indicate temperature when it is immersed in a hotter substance.

Description	Marks
When immersed in a hotter substance, energy will be conducted into the alcohol from the substance it is measuring	1
This increase the average kinetic energy of the particles, hence particles will increase in speed and collide more with their neighbours, increasing in volume. The volume expansion is proportional to temperature.	1
This causes the alcohol to rise through the capillary and indicate temperature on the calibrated scale	1
Total	3

Question 4 **(3 marks)**

A 42.0 g sample of iron is suspended in a 320 g sample of water and the mixture is left to reach thermal equilibrium at 25.0 °C, before being heated to 100 °C. Calculate the amount of energy required to heat the mixture.

(c_{iron} = 450 J kg^{-1} K^{-1})

Description	Marks
$Q = mc\Delta T$ $Q_{total} = Q_{Fe} + Q_{water}$	1
$Q_{total} = (mc\Delta T)_{Fe} + (mc\Delta T)_{water}$ = (0.0420)(450)(100-25) + (0.320)(4180)(100-25)	1
= 1.02×10^5 J	1
Total	3

Question 5 **(4 marks)**

Explain why evaporation of a substance can occur at any temperature and why the rate of evaporation increases as temperature increases.

Description	Marks
• Evaporation occurs when particles at the surface of a liquid have sufficient energy to break free from the bonds of the surrounding molecules and turn into a gas	1
• At any temperature, there is a distribution of speeds / energies of the particles in a substance, hence some particles will have sufficiently high energy to change phase.	1
• Temperature is proportional to mean translational kinetic energy (or velocity), hence as temperature increases, so too does the average energy of the particles.	1
• This increases the proportion of particles that have sufficient energy to change phase, hence increasing the rate of evaporation.	1
Total	4

Question 6 **(3 marks)**

A common thought experiment is whether it would be possible to cook a raw chicken by slapping it. The idea behind it is that you input energy by slapping the chicken and this will raise the temperature of the chicken and create the chemical change required to cook it.

Explain this experiment with reference to the 1st Law of Thermodynamics.

Description	Marks
First Law of Thermodynamics states that the change in an object's internal energy is equal to the heat transferred to it minus the work it does on its surroundings ($\Delta U = Q - W$)	1
Slapping the chicken does mechanical work on the system by exerting a force over a distance, increasing its internal energy.	1
As internal energy is the sum of Ep and Ek, and temperature is a measure of the mean translational kinetic energy, a portion of this energy will go to increasing the chicken's Ek and hence temperature will increase.	1
Total	3

Question 7 **(5 marks)**

In preparing your insulated water cooler for a hot and long day's work, you fill it up with 3.00 L of water at room temperature (22.0 °C). Calculate the mass of ice at -20.0 °C you should add to the thermos in order to create a nice refreshing 12.0 °C drink.

(Assume for water 1 L = 1 kg)

Description	Marks
$Q = mc\Delta T$ $Q = mL_V$ $Q_1 + Q_2 + Q_3 + Q_4 = 0$	1
1. Water 22 °C→ Water 12 °C (LOSE -) 2. Ice -10 °C → Ice 0 °C (GAIN +) 3. Ice 0°C → Water 0°C (GAIN +) 4. Water 0 °C → Water 12 °C (GAIN+)	
$(mc\Delta T)_{water} + (mc\Delta T)_{ice} + mL_f + (mc\Delta T)_{ice\ water} = 0$	1
3(4180)(12-22) + m(2100)(0- -20) + m(334,000) + m(4180)(12- 0) = 0	1
-125,400 + 42,000 m + 334,000 m + 50,160 m = 0	1
m = 125400 / 42620 = 0.294 kg	1
Total	5

Question 8 **(4 marks)**

In a cold laboratory, two items, A and B, are in thermal equilibrium with each other. When the laboratory assistant touches these items with her hands, she claims that Item A is far colder than Item B. Explain whether this statement is true and what could explain it.

Description	Marks
Statement is false	1
If A and B are in thermal equilibrium then they must be at the same temperature	1
Item A has a higher thermal conductivity than B, and hence will conduct heat away from her hand at a faster rate	1
This results in the temperature of her hand reducing more quickly, leading her to feel as though the item is colder.	1
Total	4

Question 9 **(7 marks)**

A microwave oven is used to heat up a 250 g mass of water from 20.0 °C to 60.0 °C in 75.0 s, with an efficiency of 68.0%

The house is powered by solar panels, each measuring 1500 x 1000 mm. Each panel can produce a total of 275 W averaged over a sunny day.

(a) Calculate the total area of panels that would need to be dedicated to the microwave's operation. (5 marks)

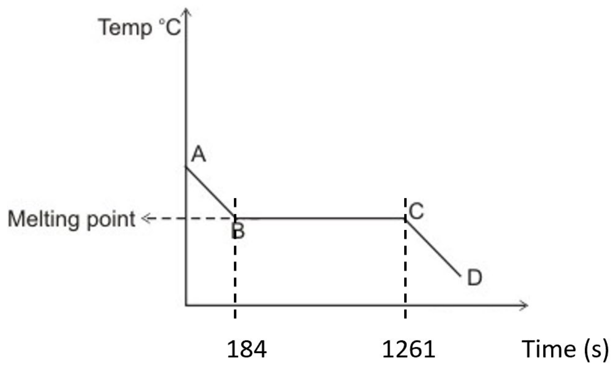
Description	Marks
$Q = mc\Delta T \quad \mathrm{P} = \frac{Q}{t}$	1
$P = \frac{mc\Delta T}{t} = \frac{(0.250)(4180)(60-20)}{75}$ = 557.3 W used	1
$Efficiency = \frac{P_{useful}}{P_{total}} \quad P_{total} = \frac{557.3}{0.68}$ = 819.6 W	1
For each solar panel, power per unit area: 275 / (1.5 x 1) = 183.3 W / m^2	1
$\frac{819.6\ W}{183.3\ W/m^2}$ = 4.47 m^2 of panels (~ 3 panels)	1
Total	5

(b) State two ways that designers could maximise the amount of energy absorbed by the solar panels. (2 marks)

Description	Marks
Increase surface area (more area to absorb sun's energy)	1
Matte black surface (increasing emissivity)	1
Locate panels in area of maximum sunlight (North facing) Change angle of panels to track sun (increasing time of exposure or maximising surface area)	1
Keep well ventilated to reduce ΔT (reducing losses)	1
(Idea only, explanation not required)	
Total	2

Question 10 **(6 marks)**

A student would like to estimate the energy required to completely melt 5.75 kg of a particular substance, but he does not know the latent heat of fusion for this substance. Instead he takes a 3.00 g liquid sample of the substance and experimentally obtains this cooling curve by immersing the substance in an ice bath.



He knows from analysing the ice bath that heat is removed as a rate of 0.638 W uniformly throughout the experiment. Using his results, calculate the energy required to melt the 5.75 kg of substance, assuming it starts at its melting point.

Description	Marks
$\mathrm{P} = \frac{Q}{t} \quad \mathrm{Q} = \mathrm{Pt}$	1
Q = (0.635)(1261-184)= 687.1 J	1
$Q = mL_F \quad L_F = \frac{Q}{m} = \frac{687.1}{0.003}$	1
L_F= 229,000 J kg^{-1}	1
$Q = mL_F$ = (5.75)(229,000)	1
= 1.32 x 10^6 J	1
Total	6

END OF TEST