2018-2019 Term 2

PHYS1001 Essential Physics

Assignment 5

Due date: 12th March, 2019 by 6:00 pm

(Please leave your homework in the box with the label “PHYS 1001” outside room 213 in Science Centre North Block)

Please answer **all** six questions

1. A small immersion heater rated at 500 W is used to heat a cup of water with mass M.
   (a) The temperature of the water raised from 20°C to 80°C in 6 minutes. Given the specific heat capacity of water is 4186 J/kg/°C, estimate the mass M.

   (b) List two assumptions made in above estimation. Do you think your value of M in part (a) is overestimated or underestimated? Explain your answer.

   Answers:

   (a) $\text{Energy supplied by the heater} = \text{Power} \times \text{time} = 500 \times 360 = 180000\ J$

$$Energy\ supplied\ by\ the\ heater = M \times c \times \Delta T$$
$$180000 = M \times (4186) \times (80 - 20)$$
$$M = 0.72\ \text{kg}$$

   (b) 1. There is no heat loss to environment
   2. Efficiency of the heater is 100%
   The mass M is over-estimated as the actual energy intake to raise the temperature of water is less than the value calculated in (a).

2. Steam with a mass of 20 g and at a temperature of 100 °C is added to 100 g of ice at 0 °C. Calculate the final temperature of the mixture when equilibrium is reached. The specific heat capacity of water is 4186 J/kg/°C. The latent heat of fusion and vaporization of water are 3.33×10^5J/kg and 22.6×10^5J/kg respectively.
   Answers:

$$\text{heat absorbed by the ice=heat released by the stem}$$
$$m_{ice} l_f + m_{ice} c\Delta T = m_{steam} l_v + m_{steam} c\Delta T$$
$$(0.1)(3.33 \times 10^5) + (0.1)(4186)(T - 0) = (0.02)(22.6 \times 10^5 + 4186(100 - T))$$
$$T = 39.3°\text{C}$$

3. A 50 g bullet is initially moving at 200 m/s. It is embedded into a block of ice at 0°C before stopping. Assuming the temperature of the bullet does not have any significant change, calculate

how much ice is melted as a result of this collision. Given the latent heat of fusion of ice is 334 kJ/kg.

Answer:

$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}(0.05)(200)^2 = 1000\ \text{J}$$

Amount of ice melted:

$$Q = ml$$
$$1000 = m(334000)$$
$$m = 3.0 \times 10^{-3}\ \text{kg}$$

4. A car is parked in an outdoor carpark in a sunny day. It is found that the temperature in the car is higher than the outside temperature (i.e. the car behaves like a greenhouse). Applying the concepts of heat transfer (e.g. conduction, convection, radiation) you have learnt in lectures, explain why the temperature in the car is higher than the outside temperature.

Answer:

The transparent window of the car allows sunlight to pass through and heat up the internal compartment of car by radiation. Since the windows of the car are closed, warm air in the car cannot escape by convection. The temperature in the car rises.

5. Dry sand and water with mass m_{sand} and m_{water} respectively are mixed together. The specific heat capacity of the mixture $c_{mixture}$ is measured to be 1200 J/kg/°C. It is known that the specific heat capacity of dry sand c_{sand} and the specific heat capacity of water c_{water} are 900 J/kg/°C and 4186 J/kg/°C respectively.

(a) Show that the mass ratio between water and dry sand is given by:

$$\frac{m_{sand}}{m_{water}} = \frac{c_{mixture} - c_{water}}{c_{sand} - c_{mixture}}$$

(b) What is the mass ratio $m_{sand}: m_{water}$?

Answers:

(a) Imagine a process in which heat is absorbed. We can write down the heat absorbed in the process by two expressions:

$$Q = c_{mixture}(m_{sand} + m_{water})\Delta\text{T}$$
$$Q = c_{sand}m_{sand}\Delta T + c_{water}m_{water}\Delta T$$

This gives us:

$$c_{mixture}(m_{sand} + m_{water})\Delta T = c_{sand}m_{sand}\Delta T + c_{water}m_{water}\Delta T$$
$$\frac{m_{sand}}{m_{water}} = \frac{c_{mixture} - c_{water}}{c_{sand} - c_{mixture}}$$

(b)

$$\frac{m_{sand}}{m_{water}} = \frac{1200-4186}{900-1200}$$

$$\frac{m_{sand}}{m_{water}} = 10$$

6. It is known that the specific heat capacity of water is higher than that of ethanol. If a glass of water at 100°C of mass m is mixed with a glass of ethanol at 0°C of the same mass, will the temperature of the final solution be higher or lower than 50°C? Explain your answer.

   Answers:

   The heat released form the water should be equal to the heat absorbed by the ethanol. Then we have:

$$Q_{water} = c_{water}m(100 - T) = Q_{ethanol} = c_{ethanol}m(T - 0)$$

   Which gives us:

$$c_{water}(100 - T) = c_{ethanol}(T - 0)$$
$$100c_{water} - Tc_{water} = c_{ethanol}T$$
$$T = \left(\frac{c_{water}}{c_{ethanol} + c_{water}}\right)100$$

   Since $c_{water} > c_{ethanol}$, $\frac{c_{water}}{c_{ethanol}+c_{water}} > 0.5$

$$\mathrm{T} > 50°\mathrm{C}$$