Foundations of Physics: Thermal Physics

Week 8 Questions

Name: _____

Date: _____

1 Measuring temperature

We have three different scales for measuring temperature,

(1) Celsius
0°C: freezing point of water, 100°C: boiling point of water.

(2) Kelvin
0K = −273.15°C (Absolute zero, lowest possible temperature)

(3) Fahrenheit
$T_F = \frac{9}{5}T_C + 32$

2 Thermal Expansion

2.1 Linear Expansion

$$\Delta L = \alpha L_0 \Delta T \tag{1}$$

$$L = L_0 + \Delta L = L_0 + \alpha L_0 \Delta T \tag{2}$$

2.2 Volume Expansion

$$\Delta V = \beta V_0 \Delta T \tag{3}$$

3 Gases

Gas Laws:

(1) Boyle: $V \propto \frac{1}{P}$ (Constant T)

(2) Charles: $V \propto T$ (Constant P)

(3) Gay-Lussac: $P \propto V$ (Constant V)

We can combine these 3 laws to form the ideal gas law. With $PV \propto T$ encompassing all relations, we have the following equation,

$$PV = nRT \tag{4}$$

4 Specific heat and latent heat

The amount of heat required to change the temperature of a material is proportional to the mass and to the temperature change: $Q \propto m\Delta T$.

To turn this relationship into an equation, we introduce the specific heat constant, c. This constant is characteristic of the material.
It is defined as the heat needed to increase the temperature of 1 kg of a substance by 1K.

$$Q = mc\Delta T \tag{5}$$

Where Q, the heat energy is measured in units J.

Latent heat (or heat of transformation) is energy released or absorbed, by a body during a constant-temperature process—usually a first-order phase transition, like melting or condensation.
In this context, the heat energy is proportional to the mass of the object: $Q \propto m$, and again to make this into an equation we introduce the quantity L, the specific latent heat for the substance undergoing its transformation[1].

$$Q = mL \tag{6}$$

5 Questions

1. What does it mean for an object to have a high specific heat constant c?

2. One mole of an ideal gas has a temperature of 25°C. If the volume is held constant and the pressure is doubled, what is the final temperature?

[1] Can be vaporisation, fusion, etc.

3. The length of a steel beam increases by 0.73 mm when its temperature is raised from 72°F to 95°F. What is the length of the beam at its original temperature?

4. What is the change in volume when a 1L glass flask is heated by 50°C? (given that $\beta_{\text{glass}} = 27 \times 10^{-6}\ \ ^{\circ}\text{C}^{-1}$)

5. What is the change in diameter of a 20c coin (20°C) when it is held by someone's hand (34°C)? Given that $\alpha_{\text{coin}} = 15 \times 10^{-6}\ \ ^{\circ}\text{C}^{-1}$. Is this change significant?

6. Consider two equal volumes of gas at a given temperature and pressure. One gas, oxygen has molecular mass 32, and the other gas nitrogen has molecular mass 28. What is the ratio of the number of oxygen molecules to the number of nitrogen molecules?

7. Objects A, B are brought into close thermal contact with each other, but they are isolated from their surroundings. Initially, $T_A = 0°\text{C}$, and $T_B = 100°\text{C}$. The specific heat of A is less than the specific heat of B.
   The two objects will soon reach a final temperature T_F. Which is the correct relationship for T_F?

   A. $T_F > 50°\text{C}$

   B. $T_F = 50°\text{C}$

   C. $T_F < 50°\text{C}$

8. Oxygen gas has a temperature of 35°C. What is the rms speed of an oxygen molecule? Mass of one molecule of $O_2 = 32\text{u}$.

9. A puddle contains 2.5kg of water. How much heat energy has it absorbed if the temperature of the water rises from 288 K to 305 K during the day?

10. What is the mass of water at 10°C that must be added to 300kg of water at 50°C to lower its temperature to 40°

11. How much energy does a freezer need to remove from 1.5 kg of water at 20°C to make ice at −12°C?

12. Provide an explanation as to why metal objects feel colder than wooden objects in a room at uniformly comfortable temperature.