**Portland State University**
**General Physics Workshop**
**Problem Set 7 Pressure, Temperature, thermal expansion, and heat transfer**

**Equations and Relations:**

Fahrenheit to Celsius: $T_C = \frac{5}{9}\left(T_F - 32^\circ\right)$

Celsius to Fahrenheit: $T_F = \frac{9}{5}T_C + 32^\circ$

Celsius to Kelvin: $T = T_C + 273.15$

Linear expansion: $\Delta L = \alpha L_0 \Delta T$

Area expansion: $\Delta A = 2\alpha A_0 \Delta T$

Specific heat $c$: $Q = mc\Delta T$

Volume expansion: $\Delta V = \beta V_0 \Delta T$, $\beta = 3\alpha$

Latent heat $L$: $Q = Lm$

Thermal conduction: $Q = k\frac{Area \cdot \Delta T \cdot t}{length}$

$k$, thermal conductivity

Pressure: $p = \frac{F}{A}$, $p = \rho g h$

1. The weather outside is frightful. The temperature is -26 °F. What is the corresponding temperature in the Celsius and Kelvin scale?
   At what temperature are the Celsius temperature and the Fahrenheit temperature the same?

2. The coefficient of linear expansion of lead is $29 \times 10^{-6}\text{K}^{-1}$. What change in temperature will cause a 5-m long lead bar to change in length by 3.0 mm?

3. An aluminum can is filled to the brim with a liquid. The can and the liquid are heated so their temperatures change by the same amount. The can's initial volume at 15 ºC is $4.5\times10^{-4}$ m$^3$. The coefficient of volume expansion for aluminum is $69\times10^{-6}$ ºC$^{-1}$. When the can and the liquid are heated to 75 ºC, $2.9\times10^{-6}$ m$^3$ of liquid spills over. What is the coefficient of volume expansion of the liquid?

4. If the cost of electricity is 8¢ per kW·h, what does it cost to heat 160 L of water for a bath from 9.5°C (the temperature of the water entering the house) to 70°C?
   *Hint*: 1 L of water has a mass of 1 kg.
   *Hint*: 1 kW·h = 1000 J/s × 3600 s.

5. Suppose you have two solid objects, *A* and *B*, made from different materials. They have the same mass, and each solid is at its melting temperature. You then add heat to melt them.

- *It takes less heat to melt A than B. Which has the larger latent heat of fusion? Why?*

- *The mass of each is doubled. Does it require twice as much heat to melt them? Justify your response.*

(a) Objects $A$ and $B$ have the same mass of 4.0 kg. They melt when $4.0\times10^4$ J of heat is added to $A$ and $8.0\times10^4$ J is added to $B$. Determine the latent heats of fusion.

(b) Find the heat required to melt object A when its mass is 6.0 kg.

6. If 0.10 kg (~0.1 L) of coffee at 90°C is poured into cup with 0.10 kg of coffee at 20°C, and we assume that no heat is transferred to or from the outside, what is the final temperature of the coffee?

7. What is the minimum amount of ice at -10°C that must be added to 0.50 kg of water at 20°C in order to bring the temperature of the water down to 0°C? ($c_{ice}$=2090 J/KgK, $c_{water}$=4186 J/KgK, $L_f$=33.5*$10^4$ J/Kg)

    - *When cooking pasta, why do you turn the heat down once the pasta is in and the water boiling?*

    - *Would it cook faster if you kept the heat up high?*

    - *How does perspiration give the body a means of cooling itself?*

8. A major source of heat loss from a house is by conduction loss through the windows. Calculate the rate of heat flow through a glass window 2.0 m x 1.5 m in area and 3.2 mm thick, if the temperatures at the inner and outer surfaces are 15.0°C and 14.0°C, respectively. The thermal conductivity of glass $k$ is 0.84 J/s·m·C°.

9. The weight of your 1500-kg car is supported equally by its four tires, each inflated to a gauge pressure of 35 lb/in$^2$
(a) What is the area of contact each tire makes with the road?
(b) If the gauge pressure is increased, does the area of contact increase, decrease, or stay the same?

10. A person floats in a boat in a small swimming pool. Inside the boat with the person are several blocks of wood. Suppose the person now throws the blocks of wood into the pool.
(a) Does the boat float higher, lower, or at the same level relative to the water?
(b) Does the water level in the pool increase, decrease, or stay the same?
(c) How would your answers change if the blocks would have been brick blocks?

11. A solid block is attached to a spring scale. When the block is suspended in air, the scale reads 20.0 N; when it is completely immersed in water, the scale reads 17.7 N. What is

**(a)** the volume and
**(b)** the density of the block?

- *As a stunt, you want to sip some soda through a very long, vertical straw. (a) First, explain why the liquid moves upward, against gravity, into your mouth when you sip. (b) What is the tallest straw that you could, in principle, drink from?*

**Additional Questions:**

1. The body temperature of a healthy human is 98.6°F. Express this in degrees Celsius.
2. Rubber has a negative coefficient of linear expansion. What happens to the size of a piece of rubber as it is warmed?
3. A bimetallic strip, consisting of metal G on the top and metal H on the bottom, is rigidly attached to a wall at the left. The coefficient of linear thermal expansion for metal G is greater than that of metal H. What happens to the strip when it is heated uniformly?
4. Why are several layers of clothing warmer than one coat of equal weight?
5. A metal plant stand on a wooden deck feels colder than the wood around it. Is it actually colder? Explain your reasoning.
6. What is the purpose of having fins on an automobile or motorcycle radiator?
7. Why does the surface of a bridge develop ice before the road leading to it?