1. **Reading Assignment**


2. **similar to Serway 19.42**

A bubble of air from a scuba diver’s tank is emitted near the bottom of a lake 30 m deep, where the water temperature is 5°C. How does its volume change as it rises to the surface, where the water temperature is 20°C? (Pressure increases by 1 atm for each 10 m of depth.)

**SOLUTION:** From the ideal gas law: \( PV = nRT \)

so \( \frac{PV}{T} \) = constant. Since the depth is 30 m, the pressure is 4 atm (1 atm from the surface and 3 from the water.) So:

\[
\frac{4V_i}{5 + 273} = \frac{V_f}{20 + 273},
\]

\[
V_f = 4.2V_i.
\]

3. **Serway 20.12 plus**

A student inhales 22°C air and exhales 37°C air. The average volume of air in one breath is 200 cm³. The density of air is approximately 1.25 kg/m³, and its specific heat is 1000 J/kg°C.

a) Neglecting evaporation of water into the air, estimate the amount of heat lost by the student to the air in one day. Express your answer first in Joules. Then compute how many food Calories must be consumed by the student to supply this thermal energy.

b) Estimate how much thermal energy is radiated during one day by a naked student in a room at 75°F. (Take \( e = 1 \) for the student.)

**SOLUTION:**

a) The amount of heat lost in one breath is

\[
Q = mc\Delta T
= (2 \times 10^{-4} \text{ m}^3 \cdot 1.25 \text{ kg/m}^3)(10^3 \text{ J/kg} \cdot \text{°C})(37 - 22 \text{ °C})
= 3.75 \text{J}.
\]

Assume a student takes 30 breaths a minute, so in one day:

\[
Q_{Tot} = (30)(60)(24)(3.75) \text{ J} = 1.6 \times 10^5 \text{ J}
= 39 \text{ Cal.}
\]

b) We want to estimate the number of calories the student burns just keeping warm. This will be on the order of the amount of heat radiated away by a student at body temperature (37°C=310K) minus the amount of heat absorbed from the 75°F ≈ 300K room. The total energy radiated from or absorbed by the student in a day is \( Q = Pt \) where \( t \approx 9 \times 10^4 s \) is the number of seconds in a day, and the power \( P \) is given by Stephan’s Law (with \( e = 1 \)) by

\[
P = \sigma AT^4.
\]

Estimating the surface area of the student at \( A \approx 2 \text{m}^2 \) gives

\[
Q = t\sigma A(T_{body}^4 - T_{room}^4) = (9 \times 10^4)(5.7 \times 10^{-8})(2)[(310)^4 - (300)^4]
\approx 10^7 \text{ J} \approx 2000 \text{ Cal}.
\]
4. Serway 20.16
A 1 kg block of copper at 20°C is dropped into a large vessel of liquid nitrogen which is at 77 K. How many kilograms of nitrogen boil away by the time the copper reaches 77 K? (The specific heat of copper is 0.092 cal/g°C. The latent heat of vaporization of nitrogen is 48 cal/g.)

**SOLUTION:** First, how much heat is given off by the block?

\[ Q = mc\Delta T \]
\[ = (1 \text{ kg})(92 \text{ cal/kg}°\text{C})(20 + 273 - 77)°\text{C} \]
\[ = 2.0 \times 10^4 \text{ cal.} \]

How much liquid nitrogen will boil?

\[ m = \frac{Q}{L} = \frac{2.0 \times 10^4 \text{ cal}}{48 \text{ cal/g}} = 4.1 \times 10^2 \text{ g.} \]

5. Serway 20.60
A Styrofoam box has a surface area of 0.8 m² and a wall thickness of 2 cm. The temperature inside is 5°C, and that outside is 25°C. If it takes 8.0 h for 5 kg of ice to melt in the container, determine the thermal conductivity of the Styrofoam.

**SOLUTION:** The amount of heat needed to melt the ice is:

\[ Q = mL = (5 \text{ kg})(3.3 \times 10^5 \text{ J/kg}) = 1.7 \times 10^6 \text{ J.} \]

The rate of heat transfer is given by:

\[ H = \frac{Q}{t} = kA\frac{(T_H - T_C)}{L}, \quad \text{or} \]
\[ k = \frac{QL}{At(T_H - T_C)} = \frac{(1.7 \times 10^6 \text{ J}) \cdot (0.02 \text{ m})}{(0.8 \text{ m}^2) \cdot (8 \cdot 60 \cdot 60 \text{ sec}) \cdot (25 - 5 \text{ K})} \]
\[ = 0.074 \text{ W/m} \cdot \text{K.} \]

6. Electromagnetic radiation from the sun has an intensity of 1000 W/m² at the earth. Use this number and Stefan’s law (with \( e = 1 \)) to estimate the temperature at the surface of the sun.

**SOLUTION:** The total power radiated from the sun is given by the intensity at the earth’s distance from the sun, \( d \), times the area of a sphere of radius \( d \),

\[ P = I_{\text{earth}}4\pi d^2. \]

The intensity at the sun’s surface is then that power divided by the area of a sphere of the sun’s radius, \( r \),

\[ I = \frac{P}{4\pi r^2} = I_{\text{earth}} \left( \frac{d}{r} \right)^2. \]

Using \( d = 1.5 \times 10^{11} \text{ m} \) and \( r = 7.0 \times 10^8 \text{ m} \) gives

\[ I = (1000 \text{ W/m}^2) \left( \frac{1.5 \times 10^{11}}{7.0 \times 10^8} \right)^2 = 4.6 \times 10^7 \text{ W/m}^2. \]

So, using Stefan’s Law with \( e = 1 \) gives

\[ T = \left( \frac{I}{\sigma} \right)^{1/4} = \left( \frac{4.6 \times 10^7}{5.7 \times 10^{-8}} \right)^{1/4} = 5.3 \times 10^3 \text{ K.} \]
A pond of water at 0°C is covered with a layer of ice 4 cm thick. If the air temperature stays constant at −10°C, how long will it be before the ice thickness is 8 cm? (Hint: To solve this problem, utilize Equation 20.14 from your text in the form
\[
\frac{dQ}{dt} = kA \frac{ΔT}{x}
\] (7.1)
and note that the incremental heat \(dQ\) extracted from the water through the thickness \(x\) of ice is the amount required to freeze an extra thickness \(dx\) of ice. That is \(dQ = LρAdx\), where \(ρ\) is the density of the ice, \(A\) is the area, and \(L\) is the latent heat of freezing.)

SOLUTION: Using the suggested hint, equation (7.1) becomes
\[
LρA \frac{dx}{dt} = kA \frac{ΔT}{x}, \quad \text{or}
\]
\[
dt = \frac{Lρ}{kΔT} x dx.
\]
Integrating from \(t = 0\) to \(t = t\) during which the thickness \(x\) grows from \(x = 4\) cm to 8 cm gives
\[
\int_0^t dt = \frac{Lρ}{kΔT} \int_{0.04}^{0.08} x dx, \quad \text{so}
\]
\[
t = \left( \frac{9.2 \times 10^2}{(10)(2.0)} \right) \frac{3.3 \times 10^5}{2} \left[ (0.08)^2 - (0.04)^2 \right]
\]
\[
= 3.6 \times 10^3 \text{ seconds} = 10 \text{ hours}
\]
where we have used \(ρ = 9.2 \times 10^2 \text{ kg/m}^3\), \(L = 3.3 \times 10^5 \text{ J/kg}\), \(k = 2.0 \text{ W/m°C}\), and \(ΔT = 10°C\).