1. Walker3 16.P.006. One day you notice that the outside temperature increased by 24°F between your early morning jog and your lunch at noon. What is the corresponding change in temperature in each of the following scales?

(a) Celsius 13°C
(b) Kelvin 13 K

**Picture the Problem:** A temperature difference is given in Fahrenheit degrees and needs to be converted to Celsius degrees and to kelvins.

**Strategy:** Write the temperature difference in Fahrenheit as a final temperature minus the initial temperature. Use equation 16-1 to write an equation to relate the temperature difference in Fahrenheit with the corresponding temperature difference in Celsius. Do the same with equation 16-3 to find the conversion between Celsius and Kelvin.

**Solution:**
(a) Find the temperature difference in Celsius:

\[ \Delta T_C = T_{c2} - T_{c1} = \frac{9}{5}(T_{f2} - 32°F) - \frac{9}{5}(T_{f1} - 32°F) \]

\[ = \frac{9}{5}(24°F) = 13°C \]

(b) Find the temperature difference in Kelvin:

\[ \Delta T_K = T_{k2} - T_{k1} \]

\[ = \left( T_{c2} + 273.15 \right) - \left( T_{c1} + 273.15 \right) \]

\[ = T_{c2} - T_{c1} = \Delta T_C = 13 K \]

**Insight:** Since the Celsius degree and the Kelvin degree have the same size, a change in Celsius has the same magnitude as the same change in Kelvin.

Here when they say save size they mean same size of steps. Temperature difference in Kelvin is the same as temperature difference in Celsius. While the “step size” of Celsius is 9/5 times of step size of Fahrenheit.

2. Walker3 16.P.005. [565713] The temperature at a particular spot on the surface of the Sun is 6000 K.

(a) Convert this temperature to the Celsius scale.

\[ 5727°C \]

(b) Convert this temperature to the Fahrenheit scale.

\[ 10340°F \]

**Picture the Problem:** The temperature of the surface of the Sun is given in Kelvin and needs to be converted to Celsius and Fahrenheit.

**Strategy:** Use equation 16-3 to convert the temperature to Celsius. Then insert the result into equation 16-1 to calculate the temperature in Fahrenheit.

**Solution:**
1. (a) Convert from Kelvin to Celsius:

\[ T_C = T - 273.15 \text{ K} = 6000 \text{ K} - 273.15 \text{ K} = 5727°C \]

2. (b) Insert \( T_C \) into equation 16-1:

\[ T_F = \frac{9}{5}(5727°C) + 32°F = 10340°F \]

**Insight:** The surface of the Sun is greater than 10,000°F!

3. Walker3 16.P.013. [565953] A steel suspension-bridge is 3910 m long. How much longer is the bridge on a warm summer day (30°C) than on a cold winter day (-5.00°C)?

\[ 1.6m \]
4. Walker3 16.P.017. [565938] Early in the morning, when the temperature is 5.0°C, gasoline is pumped into a car's 51 L steel gas tank until it is filled to the top. Later in the day the temperature rises to 25°C. Since the volume of gasoline increases more for a given temperature increase than the volume of the steel tank, gasoline will spill out of the tank. How much gasoline spills out in this case?

0.93 L

Picture the Problem: A steel gasoline tank is completely filled with gasoline, such that the gasoline and the tank have the same initial volumes. When the gas and tank are heated, the gas expands more than the tank, causing some of the gas to spill out of the tank.

Strategy: Since the initial volumes of the gas and tank are equal, the amount that will spill out is the difference in the increase in volume of the gas and tank, namely: The volume of spilled gasoline \( V_{\text{spill}} = \Delta V_{\text{gas}} - \Delta V_{\text{tank}} \). Use equation 16-6 to calculate the changes in volume for the gas and tank. The coefficient of volume expansion for steel is 3 times the coefficient of linear expansion, which is given in Table 16-1. The coefficient of volume expansion for gas is given in table 16-1.

Solution: 1. Write the volume difference in terms of equation 16-6:
\[ V_{\text{spill}} = \Delta V_{\text{gas}} - \Delta V_{\text{tank}} = (\beta_{\text{gas}} V_{\text{gas}} - 3\alpha_{\text{tank}} V_{\text{tank}}) \Delta T = (\beta_{\text{gas}} - 3\alpha_{\text{tank}}) V_{\text{gas}} \Delta T \]

2. Insert the given data:
\[ V_{\text{spill}} = (9.5 \times 10^{-4} - 3 \times 1.2 \times 10^{-5}) (15 \text{ L}) (25 - 5)^\circ \text{C} = 0.93 \text{ L} \]

Insight: 0.93 L is about a quarter of a gallon. Most commercial gas pumps shut off before your car's tank is completely filled to prevent spillover due to the expansion of gas.

5. Walker3 16.P.024. [565886] During a workout, a person repeatedly lifts a 18.2 lb barbell through a distance of 1.5 ft. How many "reps" of this lift are required to burn off 150 Cal?

25467

Picture the Problem: A person is lifting weights during a workout. The person does work against gravity each time the weight is lifted.

Strategy: Calculate the amount of work done each time the weight is lifted and convert the results to calories. Divide the total work done by the work per lift to calculate the number of lifts necessary to expend the specified amount of calories.

Solution: 1. Multiply force by distance to calculate work done in each repetition:
\[ W = F \Delta y = (13 \text{ lb})(1.4 \text{ ft}) = 18.2 \text{ ft-lb} \]

2. Convert from ft-lbs to Calories:
\[ W = (18.2 \text{ lb-ft})(\frac{1 \text{ m}}{3.281 \text{ ft}}) \left( \frac{4.448 \text{ N}}{1 \text{ lb}} \right) \left( \frac{1 \text{ Cal}}{4186 \text{ N-m}} \right) = 5.89 \times 10^{-3} \text{ Cal} \]

3. Divide the total energy by the energy per repetition:
\[ \text{repetitions} = \frac{150 \text{ Cal}}{5.89 \times 10^{-3} \text{ Cal}} = 2.5 \times 10^4 \]

Insight: Note that there are about 150 Calories in one-half of a standard size Snicker's Bar®.
6. Walker 3 16.P.036. [565880] A blacksmith drops a 0.50 kg iron horseshoe into a bucket containing 25 kg of water.
(a) If the initial temperature of the horseshoe is 450°C, and the initial temperature of the water is 23°C, what is the equilibrium temperature of the system? Assume no heat is exchanged with the surroundings.

Picture the Problem: Heat transfers from a hot horseshoe to the cold water. This decreases the temperature of the horseshoe and increases the temperature of the water until the water and horseshoe are at the same equilibrium temperature.

Strategy: Since only two objects are transferring heat, use equation 16-15 to calculate the equilibrium temperature. To determine which object would cause a larger final temperature, you should compare the heat capacities of the two objects. The object with the higher heat capacity will have more heat to transfer to the water, causing the final temperature to be greater.

c_{\text{water}} = 4186 \text{(J/(kg*K))}

Initial $T_{\text{water}}$ and $T_{\text{hs}}$ are known

The final temperature $T$ has to be more than $T_{\text{water}}$ and less than $T_{\text{hs}}$.

In this case, water absorbs heat and iron gives off heat.

Amount of heat absorbed by water = $|Q_{\text{water}}| = c_{\text{w}} \cdot m_{\text{w}} \cdot (T - T_{\text{water}})$

Amount of heat given off from hs = $|Q_{\text{hs}}| = c_{\text{hs}} \cdot m_{\text{hs}} \cdot (T_{\text{hs}} - T)$

$|Q_{\text{w}}| = |Q_{\text{hs}}|$; because the system doesn’t exchange heat with outside.

Above we considered the absolute value and made sure to use the higher Temp to minus the lower T. Actually, by definition, $Q = c \cdot m \cdot (T_f - T_i)$. $Q(w)$ must be positive and $Q(hs)$ is negative. Since the system doesn’t exchange heat with outside, we have $Q(w) + Q(hs) = 0$; It is the same equation as $|Q_{\text{w}}| = |Q_{\text{hs}}|$, when you use absolute value.

The heat given off by iron horseshoes is equal to the heat absorbed by water.

Ok, so we have

$c_{\text{w}} \cdot m_{\text{w}} \cdot (T - T_{\text{hs}}) + c_{\text{hs}} \cdot m_{\text{hs}} \cdot (T - T_{\text{hs}}) = 0$

Or

$c_{\text{w}} \cdot m_{\text{w}} \cdot (T - T_{\text{i(w)})} = c_{\text{hs}} \cdot m_{\text{hs}} \cdot (T_{\text{hs}} - T)$

You can start to plug in numbers and solve T.

$4186 \cdot 25 \cdot (T - 23) + 448 \cdot (0.5) \cdot (T - 450) = 0$

$T = (448 \cdot 0.5 \cdot 450 + 4186 \cdot 25 \cdot 23)/(448 \cdot 0.5 + 4186 \cdot 25) = 24 \degree \text{C}$

(notice that this kind of result: $Q(w) + Q(hs) = 0$; or $|Q(w)| = |Q(hs)|$;

Then, you are able to write: $c_{\text{w}} \cdot m_{\text{w}} \cdot (T - T_{\text{i(w)})} + c_{\text{hs}} \cdot m_{\text{hs}} \cdot (T - T_{\text{i(hs)}}) = 0$, or even when there are more than 2 objects.

Also please notice, when calculate the exchanged heat, only the temperatures difference between initial and final state were used. And from question 1, you know that 1 degree of Celsius difference is equal to 1 Kevin of difference. It is Ok to use both Celsius or Kelvin scale in this question. But when Temperature $T$ itself is used, instead of temperature change is used, you have to convert Celsius into Kelvin.

You need to understand and really learn that

$Q(w) + Q(hs) = 0$; or $|Q(w)| = |Q(hs)|$;

and conclusions and will not be given in exams. )

You need to understand and really learn that

$Q(w) + Q(hs) = 0$; or $|Q(w)| = |Q(hs)|$;

Then, you are able to write: $c_{\text{w}} \cdot m_{\text{w}} \cdot (T - T_{\text{i(w)})} + c_{\text{hs}} \cdot m_{\text{hs}} \cdot (T - T_{\text{i(hs)}}) = 0$, or even when there are more than 2 objects.

Also please notice, when calculate the exchanged heat, only the temperatures difference between initial and final state were used. And from question 1, you know that 1 degree of Celsius difference is equal to 1 Kevin of difference. It is Ok to use both Celsius or Kelvin scale in this question. But when Temperature $T$ itself is used, instead of temperature change is used, you have to convert Celsius into Kelvin.

You need to understand and really learn that

$Q(w) + Q(hs) = 0$; or $|Q(w)| = |Q(hs)|$;
(b) Suppose the 0.45 kg iron horseshoe had been a 1.0 kg lead horseshoe instead. Would the equilibrium temperature in this case be greater than, less than, or the same as in part (a)?

---Select---

less

The more mass or the higher specific heat the harder to change its temperature, the larger the heat capacity is. When specific heat of the high temperature block is the same, the one with more mass will contribute more to water’s temperature raise. When mass is the same the material with more specific heat can contribute more to the temperature raise. When both mass and specific heat are not the same, we compare their product, the heat capacity.

Heat capacity is the combined effects of the object’s mass and specific heat.

Heat capacity = mass * specific heat

2. (b) Write the heat capacities of the lead and iron:

\[ C_{\text{lb}} = \left[ 1 \text{ kg} \times 128 \text{ J/(kg \cdot K)} \right] = 128 \text{ J/K} \]

\[ C_{\text{re}} = \left[ 0.50 \text{ kg} \times 448 \text{ J/(kg \cdot K)} \right] = 224 \text{ J/K} \]

3. Compare the heat capacities:

Since the heat capacity of the lead is less than the heat capacity of the iron, the final temperature will be less than 24°C.

7. Walker3 16.P.035. [566083] To determine the specific heat of an object, a student heats it to 100°C in boiling water. She then places the 38.0 g object in a 155 g aluminum calorimeter containing 103 g of water. The aluminum and water are initially at a temperature of 20.0°C, and are thermally insulated from their surroundings. If the final temperature is 22.0°C, what is the specific heat of the object?

385 J/(kg \cdot °C)

Picture the Problem: A hot object is immersed in water in a calorimeter cup. Heat transfers from the hot object to the cold water and cup, causing the temperature of the object to decrease and the temperature of the water and cup to increase.

Strategy: Since the heat only transfers between the water, cup, and object, we can use conservation of energy to calculate the heat given off by the object by summing the heats absorbed by the water and cup. Use the heat given off by the object and its change in temperature to calculate its specific heat.

Solution: 1. Let \( \sum Q = 0 \) and solve for \( Q_{\text{ob}} \):

\[ 0 = Q_{\text{ob}} + Q_w + Q_{\text{al}} \]

\[ Q_{\text{ob}} = -(Q_w + Q_{\text{al}}) = -\left( m_w c_w + m_{\text{al}} c_{\text{al}} \right) \Delta T_w \]

Referring to Table 16-2 in your text, identify the material in the object.

2. Solve for the specific heat using equation 16-13:

\[ c_{\text{ob}} = \frac{Q_{\text{ob}}}{m_{\text{ob}} (T - T_{\text{ob}})} \]

\[ c_{\text{ob}} = \frac{(m_w c_w + m_{\text{al}} c_{\text{al}})(T_w - T)}{m_{\text{ob}} (T - T_{\text{ob}})} \]

\[ = \frac{0.103 \text{ kg} [4186 \text{ J/(kg \cdot K)}] + 0.155 \text{ kg} [900 \text{ J/(kg \cdot K)}]}{0.0380 \text{ kg} (22.0 - 100)} \]

\[ = 385 \text{ J/(kg \cdot °C)} = \frac{385 \text{ J/(kg \cdot K)}}{0.0380 \text{ kg}(22.0 - 100)} \]

3. Look up the specific heat in Table 16-2:

The object is made of copper.
8. Walker3 16.P.040. [565737] Assuming your skin temperature is 37.2°C and the temperature of your surroundings is 21.8°C, determine the length of time required for you to radiate away the energy gained by eating a 306 Calorie ice cream cone. Let the emissivity of your skin be 0.915 and its area be 1.22 m².

\[ \text{3.96 hours} \]

**Picture the Problem:** A person, in a cool room, radiates energy at a rate faster than he absorbs energy. This energy can be supplied to the person in the form of calories from an ice cream cone.

**Strategy:** We wish to calculate how long it takes the person to radiate the energy from a single ice cream cone. Set the heat radiated per unit time equal to the net power radiated (equation 16-19) and solve for time. Use the mechanical equivalent of heat (equation 16-8) to write the caloric value of the ice cream cone in terms of Joules.

**Solution:** 1. Set the radiated power equal to the heat loss rate:

\[ P_{\text{rad}} = e\sigma A(T^4 - T_s^4) = \frac{\Delta Q}{\Delta t} \]

2. Solve for the time:

\[ \Delta t = \frac{\Delta Q}{e\sigma A(T^4 - T_s^4)} = \frac{(306 \text{ C} \times 4186 \text{ J/C})}{(0.915)(5.67 \times 10^{-8} \text{ W/(m}^2 \cdot \text{K}^4))[(1.22 \text{ m}^2)][(310.35 \text{ K})^4 - (294.95 \text{ K})^4]} \]

\[ \Delta t = \frac{3.29 \text{ h}}{} \]

**Insight:** In this problem, as with all radiation problems, the temperatures must be converted to Kelvin. Even though the difference of temperatures is the same in Celsius and Kelvin, the difference of the temperatures raised to the fourth power is not the same; \((T_1 - T_2)^4 \neq T_1^4 - T_2^4\)

9. Walker3 16.P.042. [565738] Consider a double-paned window consisting of two panes of glass, each with a thickness of 0.500 cm and an area of 0.725 m², separated by a layer of air with a thickness of 1.75 cm. The temperature on one side of the window is 0.00°C; the temperature on the other side is 20.0°C. In addition, note that the thermal conductivity of glass is roughly 36 times greater than that of air.

(a) Approximate the heat transfer through this window by ignoring the glass. That is, calculate the heat flow per second through the 1.75 cm of air with a temperature difference of 20.0°C. (The exact result for the complete window is 23.4 J/s.) Express your answer with three significant digits. \[ 19.4 \text{ J/s} \]

(b) Use the approximate heat flow found in part (a) to find an approximate temperature difference across each pane of glass. (The exact result is 0.157°C.) Express your answer with three significant digits. \[ 0.164 \text{ °C} \]

**Picture the Problem:** A double-paned window, as shown in the figure, consists of two panes of glass separated by a thin space of air.

**Strategy:** Since the thermal conductivity of air is much smaller than the thermal conductivity of the glass, most of the temperature difference between the inside and outside will occur across the air. Assuming the full temperature difference is across the air, calculate the heat flow through the window using equation 16-16. From that heat flow, and the thermal conductivity of the glass, calculate the temperature difference across the glass. The necessary thermal conductivities are found in Table 16-3.

**Solution:** 1. (a) Apply equation 16-16:

\[ \frac{Q}{t} = kA \left( \frac{\Delta T}{L} \right) = [0.0234 \text{ W/(m} \cdot \text{K})](0.725 \text{ m}^2) \left( \frac{20.0 \text{ °C}}{0.0175 \text{ m}} \right) = 19.4 \text{ J/s} \]
Because we know it was mainly the air which separated the hot and cold T. Part A assumes the Temperature distribution is like the left figure. Based on that you can find Q/t of the total heat flow rate.

In part B, they ask us to use the Q/t heat flow rate we just found in part A to calculate the temperature difference crossing each of the glass panes, under such a heat flow rate. In part B, the Temperature distribution looks like the right figure. As we will find later, that the delta T across a glass pane is around 0.2 C which is much less than 20C. As a result the assumption we used in part be was pretty accurate.

Notice that because the thermal conductivity of air is really small, the heat flow per second is not too much, and we are able to use such a heat flow rate, (19.4 J/s) keep the temperature difference across the air layer to be 20 C deference, which is 36 Fahrenheit deference. But thermal conductivity of glass is much higher (about 35 times higher), in order to keep the temperature difference using a single layer of glass with same thickness, the heat flow per second will be 35 times more. We will have to use a huge heater to maintain such a heat flow in order to keep the room much warmer than outside. The glasses were used to trap the insulating air layer, so that there is no convection.

Suppose we don’t have a huge heater, but use double layer window, and the heat flow through the window will just be the same as we just calculated before, 19.4 J per second. We can now calculate the temperature difference across one single glass layer, at such a low heat lose rate.

\[ \Delta T = \left( \frac{Q}{t} \right) \left( \frac{L}{kA} \right) = (19.4 \text{ J/s}) \left( \frac{0.0050 \text{ m}}{0.84 \text{ W/(m·K)}} \right) (0.725 \text{ m}^2) = 0.16 \text{ C}^\circ \]

**Insight:** Our approximate answer is close to the exact result of 0.157 C°. We could refine our result by recalculating the heat transfer in part (a) using the temperature difference of \( \Delta T = 19.68 \text{ C}^\circ \), which is the temperature across the window minus the temperature difference across each glass pane. And we found that the temperature difference across the glass layer is really small.

1. This means our assumption in A was good enough.
2. This means if we do not have a powerful heater and we can only supply small heat losing rate: 19.4 J per second, and we only have one layer of glass on the window (no insulating air layer), the Temperature of both side of the window will be very close. Too cold.....