HW 12 Help

34. ORGANIZE AND PLAN When the car stops, its kinetic energy ($K = \frac{1}{2}mv^2$) has to go somewhere. We can assume all of it ends up heating the brakes.

Known: $m = 1120$ kg, $v = 60$ mph.

SOLVE We'll need the velocity in SI units:

$$v = 60 \text{ mph}\left[\frac{1609 \text{ m}}{1 \text{ mi}}\right]\left[\frac{1 \text{ h}}{60 \cdot 60 \text{ s}}\right] = 27 \text{ m/s}$$

The thermal energy in the brakes generated by the stopping is:

$$E_{th} = K = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(1120 \text{ kg})(27 \text{ m/s})^2 = 4.1 \times 10^5 \text{ J}$$

REFLECT That's a fair amount of energy being wasted. Many hybrid electric cars have what's called regenerative braking that tries to recuperate the energy lost during braking and use it to recharge the battery.

39. ORGANIZE AND PLAN During each repetition, you expend energy in increasing the gravitational potential of the barbell ($U_{\text{grav}} = mgh$). We'll assume that you don't expend energy letting the barbell fall back to the starting position.

Known: $m = 75$ kg, $h = 1.9$ m, $N_{\text{reps}} = 20$.

SOLVE The barbell's gravitational potential changes during each rep by:

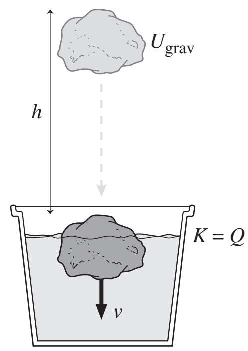
$$U_{\text{grav}} = mgh = (75 \text{ kg})(9.80 \text{ m/s}^2)(1.9 \text{ m}) = 1400 \text{ J}$$

The total energy expended in Joules and Calories:

$$\begin{aligned} E &= U_{\text{grav}} \cdot N_{\text{reps}} = (1400 \text{ J})(20) = 28{,}000 \text{ J} \\ &= 28{,}000 \text{ J}\left[\frac{1 \text{ Cal}}{4186 \text{ J}}\right] = 6.7 \text{ Cal} \end{aligned}$$

REFLECT This matches data on how much energy is burned during 1 minute-worth of weight training.

44. ORGANIZE AND PLAN The rock starts off with gravitational potential energy: $U_{\text{grav}} = m_{\text{rock}}gh.$ This is converted to kinetic energy as it falls to the water; see figure below.



If all this kinetic energy goes into heating the water, we can find the temperature of the water from Equation 13.2: $Q = mc\Delta T,$ where $c = 4186\ \text{J/kg}^\circ\text{C}$ for water.

Known: $m_{\text{rock}} = 0.450\ \text{kg},\ \ h = 10.0\ \text{m},\ \ m_{\text{water}} = 2.5\ \text{kg}$.

SOLVE The heat the water receives is equal to the rock's kinetic energy, which is equal to the gravitational potential energy:

$$Q = K = U_{\text{grav}} = m_{\text{rock}}gh = (0.450\ \text{kg})(9.80\ \text{m/s}^2)(10.0\ \text{m}) = 44.1\ \text{J}$$

This heat causes a rise in the water's temperature:

$$\Delta T = \frac{Q}{m_{\text{water}}c} = \frac{44.1\ \text{J}}{(2.5\ \text{kg})(4186\ \text{J/kg}^\circ\text{C})} = 4.2\times10^{-3}\ {}^\circ\text{C}$$

REFLECT This is an imperceptible temperature change, which agrees with our experience. Dropping a rock into a bucket of water doesn't change the temperature by any noticeable degree.

46. ORGANIZE AND PLAN We will need Equation 2.2: $Q = mc\Delta T,$ along with the density of water: 1.00 kg/L. Note too that a kilowatt-hour (kWh) is a unit of energy, so we'll need to convert J into kWh.

Known: $V = 189\ \text{L},\ \ R = \$0.12/\text{kWh},\ \ \Delta T = 60^\circ\text{C} - 10^\circ\text{C} = 50^\circ\text{C}.$

SOLVE The 189 L is equivalent to 189 kg, so the heat required to raise its temperature by 50 degrees is:

$$Q = mc\Delta T = (189\ \text{kg})(4186\ \text{J/kg}^\circ\text{C})(50^\circ\text{C}) = 3.96\times10^7\ \text{J}$$

To convert this to kWh, recall that $1\ \text{W} = 1\ \text{J/s},$ or equivalently $1\ \text{J} = 1\ \text{W}\cdot\text{s}$:

$$3.96\times10^7\ \text{J}\left[\frac{1\ \text{W}\cdot\text{s}}{1\ \text{J}}\right]\left[\frac{1\ \text{kW}}{1000\ \text{W}}\right]\left[\frac{1\ \text{h}}{60\cdot60\ \text{s}}\right] = 11\ \text{kWh}$$

The cost of this much energy is \$1.32.

REFLECT It takes quite a lot of energy to heat water. Notice that the specific heat of water is the highest of all the substances in Table 13.1. That's why water heaters account for a lot of the energy bill in a house.

55. ORGANIZE AND PLAN This is a straightforward use of Equation 13.2: $Q = mc\Delta T$, where the specific heat of mercury is from Table 13.1: $c = 140\ \text{J/kg}^\circ\text{C}$. The one thing we will need is the density of liquid mercury from Table 10.1: $\rho = 13{,}600\ \text{kg/m}^3$.

Known: $V = 2.30\ \text{mL}$, $\Delta T = 100^\circ\text{C}$.

SOLVE Plugging the mass of mercury $(m = \rho V)$ into Equation 13.2:

$$Q = \rho V c\Delta T = (0.0136\ \text{kg/mL})(2.30\ \text{mL})(140\ \text{J/kg}^\circ\text{C})(100^\circ\text{C}) = 438\ \text{J}$$

REFLECT This heat causes the mercury to expand slightly, which results in the liquid rising inside the thermometer. Because this rise is uniform, we can use it to measure the temperature. In this way, the thermometer works simply by absorbing heat (or losing heat) to the environment.

60. ORGANIZE AND PLAN This will require Equation 13.5: $Q = mL_\text{f}$, with the latent heat of fusion for water from Table 13.3: $L_\text{f} = 3.33\times10^5\ \text{J/kg}$.

Known: $m = 120\ \text{g}$.

SOLVE The energy to melt the ice cube is:

$$Q = mL_\text{f} = (0.120\ \text{kg})(3.33\times10^5\ \text{J/kg}) = 4.00\times10^4\ \text{J}$$

REFLECT When an ice cube melts it takes this energy from the air or the liquid that it is floating in.

66. ORGANIZE AND PLAN Adding ice causes the water's temperature to drop, but once it drops to 0°C, the ice and water are at the same temperature, so there's no more exchange of heat. So what we are looking for is the amount of ice that brings the water just to the freezing point. That means equating the heat taken in by the ice ($Q_{ice} = m_{ice}L_\text{f}$) to the heat lost by the water ($-Q_\text{water} = -m_\text{water}c\Delta T$), where $L_\text{f} = 3.33\times10^5\ \text{J/kg}$ and $c = 4186\ \text{J/kg}^\circ\text{C}$. The water temperature changes by $\Delta T = 0^\circ\text{C} - 12^\circ\text{C} = -12^\circ\text{C}$.

Known: $m_\text{water} = 325\ \text{g}$.

SOLVE Equating the heat gain and loss ($Q_\text{ice} = -Q_\text{water}$) allows us to solve for the ice mass:

$$m_\text{ice} = -\frac{m_\text{water}c\Delta T}{L_f} = -\frac{(0.325\ \text{kg})(4186\ \text{J/kg}^\circ\text{C})(-12^\circ\text{C})}{(3.33\times10^5\ \text{J/kg})} = 0.049\ \text{kg}$$

REFLECT This is probably two ice cubes, which seems about right. Notice that if you put less ice than this, the ice will all melt, but the water will still be above 0°C. If you put more ice than this, the water will reach 0°C, but there will still be ice in the glass. It won't melt because the water is the same temperature. (Of course, the ice will eventually melt because of heat loss out of the glass.)

74. **ORGANIZE AND PLAN** The person loses energy $Q_B = m_B c_B \Delta T_B$, where the specific heat of the body is: $c_B = 3500$ J/kg$^\circ$C. If we assume the person's temperature starts off at 37°C, then the water cools it to 36°C. On the flip side, the water warms from 1°C to 36°C, thereby gaining in energy by $Q_W = m_W c_W \Delta T_W$, where the specific heat of water is: $c_W = 4186$ J/kg$^\circ$C.

Known: $m_B = 62$ kg, $\Delta T_B = -1^\circ$C, $\Delta T_W = 35^\circ$C.

SOLVE Solving for the mass of water:

$$m_W = -\frac{m_B c_B \Delta T_B}{c_W \Delta T_W} = -\frac{(65\text{ kg})(3500\text{ J/kg}^\circ\text{C})(-1^\circ\text{C})}{(4186\text{ J/kg}^\circ\text{C})(35^\circ\text{C})} = 1.6\text{ kg}$$

REFLECT The person needs to drink over a liter and a half of water. Compare this to the previous problem where the amount of sweat needed to drop 1°C is much less. That's the advantage of evaporation: it is very efficient at cooling because it requires a lot of energy to evaporate even a relatively small amount of water.

82. **ORGANIZE AND PLAN** The Stefan-Boltzmann law (Equation 13.8) tells us the rate at which a body radiates energy: $P = e\sigma A T^4$. Saying the Sun is a blackbody means that its emissivity is one, i.e.: $e = 1$. The Stefan-Boltzmann constant is: $\sigma = 5.67\times10^{-8}$ W/m^{2}K^4, and the surface area of a sphere is: $A = 4\pi r^2$.

Known: $r = 6.96\times10^8$ m, $T = 5800$ K.

SOLVE Substituting the values into the Stefan-Boltzmann law:

$$P = e\sigma A T^4 = (1)(5.67\times10^{-8}\text{ W/m}^2\text{K}^4)\left(4\pi(6.96\times10^8\text{ m})^2\right)(5800\text{ K})^4 = 3.91\times10^{26}\text{ W}$$

REFLECT Currently, the world uses somewhere around 15 TW (1.5×10^{13} W) of power. In comparison, the Sun emits over 10 quadrillion times the energy we use.

84. **ORGANIZE AND PLAN** The cylinder radiates energy according to the Stefan-Boltzmann law (Equation 13.8): $P_{\text{out}} = e\sigma A T_{\text{cyl}}^4$. But it also receives energy from the room: $P_{in} = e\sigma A T_{\text{room}}^4$. The net power radiated by the cylinder is then: $P_{\text{net}} = P_{\text{out}} - P_{\text{in}}$. We'll assume the cylinder has an emissivity of one, i.e.: $e = 1$. We'll have to determine the surface area of the cylinder, and convert the temperatures into Kelvin.

Known: $r = 2.0$ cm, $h = 12$ cm, $T_{\text{cyl}} = 450^\circ$C, $T_{\text{room}} = 25^\circ$C, $\sigma = 5.67\times10^{-8}$ W/m^{2}K^4.

SOLVE The surface area of the cylinder is made up of two circles and one rectangle:

$$A = 2\cdot\pi r^2 + 2\pi r h = 2\pi\left((0.02\text{ m})^2 + (0.02\text{ m})(0.12\text{ m})\right) = 0.018\text{ m}^2$$

Substituting this and the other values into the net power equation:

$$P_{\text{net}} = e\sigma A(T_{\text{cyl}}^4 - T_{\text{room}}^4) = (5.67\times10^{-8}\text{ W/m}^2\text{K}^4)(0.018\text{ m}^2)\left((723\text{ K})^4 - (298\text{ K})^4\right) = 271\text{ W}$$

REFLECT Observe that the Stefan-Boltzmann law doesn't work with degrees Celsius. The net power being lost is substantial. Consequently, the cylinder's temperature will rapidly drop, and as it does so will the amount of radiation.