Lesson 20-Heat and Specific Heat.doc

We learned in Lesson 12 that engines convert internal energy into work. How do engines acquire internal energy to replace that energy lost while performing work? That depends on the type of machine. If the machine is biological, we feed it. However, if the machine is a simple heat machine, we give it energy in the form of heat.

Consider a steam locomotive. The fireman burns coal to liberate the chemical energy stored in the coal. Some of this liberated energy warms the metal in the locomotive. That is heat transfer from the fire to the cooler metal. Some of the liberated energy warms the air, which wafts out of the compartment. That is heat transfer from the fire to the cooler air. We reserve the term heat to refer to the energy transferred from a warm body to a cooler body.

In general, heat is energy in transit between two bodies whose temperatures are different. Another way to state this is to say that heat is any energy transfer that changes the internal energy of the system.

Most importantly for the operation of the locomotive, some of the energy liberated from the coal is transferred from the fire to the water in the boiler and converts that water into steam. Therefore, heat is transferred to the engine, too. Heat transfer from the fire to the engine can only continue as long as the engine is cooler than the fire. The engine reduces its internal energy and its temperature by doing work; moving the locomotive down the tracks. Another way the engine lowers its internal energy is by venting some of the spent steam to the atmosphere at the end of the power stroke of each piston. If, by these various means, the engine cannot lower its internal energy in order to maintain the temperature difference, the engine will eventually stop working.

When energy in the form of sunlight hits the Earth, we can correctly say that heat has been transferred from the warmer Sun to the cooler Earth. The Earth also cools itself. In part the energy from the Sum is re-radiated to the coolness of outer space. In part the Earth cools itself by venting some of its gases from the upper atmosphere. This re-radiation and venting of heat energy is essential to continued life on Earth. If the Earth did not cool itself, the surface of the Earth would eventually reach temperatures comparable to those at the surface of the Sun; around 5,000 ºC.

Specific Heat

When we add heat to an object we also increase the temperature of the object. It is an interesting question to ask how much the temperature will increase. It was learned early in the exploration of heat that the temperature change created by the given quantity of heat depended on the material of the body. For a given body, the change is always proportional to the heat transferred provided no change in state (liquid to gas for example) occurs. Double the heat transferred and you get double the temperature change.

It was learned almost as quickly that the mass of the object was also important. Larger objects required larger infusions of heat to achieve a given temperature change. This is also a proportional relationship. An object with twice the mass requires twice the quantity of heat to achieve a given temperature change.

It was also learned rather quickly that the type of material was also important. Different materials have difference abilities to store heat. For some, only a small amount of heat is required to achieve a given temperature change. Other materials, even when the masses are equal, require more or less heat to achieve the same temperature change.

All of these observations are incorporated into one quantity called the specific heat. Each material has its own unique value of specific heat. The units of specific heat are

$$\text{joules per kilogram per Celsius degree} = \text{J} / (\text{kg}\cdot\text{C}^o)$$

We use it in the following equation to calculate the quantity of heat transferred to an object.

$$\text{Quantity of heat transferred} = \text{mass x specific heat x temperature change}$$

$$Q = m\cdot c\cdot \Delta T$$

$$\text{Joules} = \text{kg} \cdot \text{J} / (\text{kg}\cdot\text{C}^o) \cdot \text{C}^o$$

Examples

I. *4.0 kilograms of copper was heated from 25ºC to 35ºC by immersion in hot water. How much heat was transferred to the copper from the hot water?*

$$Q = m\cdot c\cdot \Delta T = (4.0\text{ kg})\cdot(386\text{ J} / (\text{kg}\cdot\text{C}^o)\ (35 - 25)\ \text{C}^o = (4.0)\cdot(386)\cdot(10)\text{ J}$$

$$= 15{,}440\text{ J} = 15{,}000\text{ J (2 SF)}$$

II. *38 kJ of heat is added to a 7.0 kg piece of aluminum originally at 25ºC. What is the final temperature of the aluminum?*

$$\Delta T = T_F - 25^oC = Q / m\cdot c = 38{,}000 / (7.0\cdot 899) = +6.0385^oC$$

$$T_F = 25^oC + 6.0385^oC = 31.04^oC = 31^oC \text{ (2 SF)}$$

III. *42kJ of heat warm 15.0 kg of a metal from 18.0ºC to 39.7ºC. What metallic element is it?*

$$= Q / (m\cdot\Delta T) = 42{,}000 / (15.0 \cdot (39.7 - 18.0)) = 42{,}000 / (15.0 \cdot 21.7)$$

$$= 129.03\text{ J} / (\text{kg}\cdot\text{C}^o) = 130\text{ J} / (\text{kg}\cdot\text{C}^o)\text{ (2 SF)} \equiv \text{gold or lead}$$