Lesson 6 – Thermal Energy and its Transfer

The contents of the following few lessons are based upon the study of thermodynamics, which deals with the concepts of heat and temperature.

Historically, the development of thermodynamics paralleled the development of the atomic theory of matter – both topics helped further the study of the other in many ways. Robert Brown and Albert Einstein were two scientists who played major roles in the development of thermodynamics and their work in both areas forged a connection between the everyday world and the tiny, indivisible building blocks that make it up.

Two crucial discoveries:

Heat –

Kinetic Molecular Theory –

Solid	Liquid	Gas

If the molecules are moving around and have kinetic energy, we know that the kinetic energy must come from somewhere. It turns out that the motion is due in large part to electrostatic potential energy, and so thermal energy must take this into account as well.

Temperature

If all particles in a sample are in constant motion, it is impossible to quantify the actual amount of energy because it is constantly changing. But we can measure the *average* kinetic energy of all the particles in the sample and we call this **temperature**.

When a substance is heated, its volume increases; this is known as **thermal expansion**. Thermal energy increases the kinetic energy of the atoms and molecules in a sample and this causes an increase in the average distance between them. It is on this principle that thermometers operate. A **thermometer** is a device for measuring temperature.

There are three main temperature scales:

Fahrenheit –

Celsius –

Kelvin –

Good to Know

To convert temperatures between different scales use the following formulas:

$$T_C = \tfrac{5}{9}(T_F - 32)$$

$$T_K = T_C + 273.15$$

Here:

T_C – temp in Celsius
T_F – temp in Fahrenheit
T_K – temp in Kelvin

Example 1
On a day when the temperature reaches 50°F, what is the temperature in degrees Celsius and in kelvins?

Thermal Energy Transfer

Recall that heat is the kinetic energy of matter at the atomic level. We are going to turn our attention now to how heat, or thermal energy is transferred from one object to another.

Demonstration

Place your hand on the surface of your desk. Note the warmth of the surface. Now place the same hand on the leg of your chair. Which of the two objects, the desk or the chair leg, is warmer?

Our bodies do not actually measure temperature. All we perceive is the flow of heat in or out of our body. There is no *hot* or *cold*, only an excess or deficit of heat.

We've learned about the conservation of energy – energy is neither created nor destroyed but rather, transferred from one form to another – but until now, we have ignored the conversion of energy to heat. In the mid-1800s, James Joule performed an experiment that showed that energy is conserved when gravitational potential energy is converted to heat energy.

Methods of Heat Energy Transfer

There are three ways heat is transferred from one object to another:

Conduction	Convection	Radiation

Specific Heat Capacity

We would like to be able to quantify heat transfer. The transfer of heat energy to any substance depends on the following three things:

Temperature Difference	Mass of Substance	Type of Substance

Specific heat capacity is the amount of heat energy that is needed to increase the temperature of 1 kg of a particular substance by 1°C.

Each of these three qualities will determine the amount of heat flow in or out of a substance. The mathematical formula for calculating heat transfer is,

$$\Delta E_{\mathrm{H}} = mc\Delta t$$

Where ΔE_{H} is the heat energy transferred in joules (J), m is the mass of the substance in kilograms (kg), Δt is the temperature chance of the substance in °C, and c is the specific heat capacity of the substance in J/kg°C.

Example 2

How much heat energy is required to raise the temperature of a 1 kg piece of copper pipe from 25.0°C to 66.0°C if the specific heat capacity of copper is 3.9×10^2 J/kg°C?

Example 3

A 0.50 kg block of iron at 80.0°C is cooled by removing 2.28×10^4 J of heat energy. What will the final temperature of the metal be if the specific heat capacity of iron is 4.6×10^2 J/kg°C?