# AP Physics – Intro to Thermodynamics

We have done a lot of work with energy, but the type of energy we’ve dealt with has been mechanical energy. It is time now to look into other types of energy. Thermal energy has to do with the internal energy of a system – the energy of the particles that make a thing up.

***Thermal Energy ≡ The total kinetic energy of the particles in a system***

The particles that make up a system are the molecules, atoms, or ions that make it up. These particles have kinetic energy – they have motion. In a gas, the particles are free to zoom around and bounce off other particles. In a liquid they also flit about, but they also make weak bonds with each other and tend to clump together. In a solid the particles are bound together with chemical bonds. These bonds are not rigid, however, so the particles can move back and forth. Kind of like they’re connected to each other with springs that allow them to vibrate.

***Thermal Definitions:*** Here are some important definitions:

***Thermal Contact ≡ two systems are placed so that they can exchange thermal Energy***

***Heat ≡ thermal energy transferred from one system to another.***

***Temperature ≡ average kinetic energy of the particles in a system.***

***Thermal equilibrium ≡ A static state. Objects in thermal contact reach the same average internal energy state and no longer exchange thermal energy.***

***Temperature:*** Instruments that measure temperature are called thermometers. There are several temperature scales that are in use around the world - the Celsius scale, Fahrenheit scale, Kelvin scale, and the Rankine scale are the major ones.

We will make use of the Celsius scale and the Kelvin scale. The other two scales are only used in the US of A, so we can safely ignore them. (Who cares about a country so backward that they don’t even use the metric system?)

The Celsius scale was originally set up to monitor temperatures on the earth’s surface. The zero point on the scale is fixed at the freezing temperature of water and 100° C is the boiling temperature of the good old H2O (at one atmosphere pressure). The zero on this scale is arbitrary and has no physical meaning as a zero value (zero is supposed to be when you have “nothing”, right?)

Temperatures using the Celsius scale are reported as ***degrees Celsius***. One would say, “Hey, the temperature today is twenty-three degrees Celsius!

The Kelvin scale has a true zero, its zero value represents the lowest possible temperature, which is known as ***absolute zero***. Absolute zero represents the minimum possible energy state for matter.

When reporting a Kelvin temperature, one would say, “Hey it’s three hundred and one Kelvins outside! You don’t use the word “degree” with a Kelvin temperature.

The size of the units for each scale are the same.

Absolute zero, which is zero Kelvins, is –273.15°C. The freezing point of water, 0°C is 273.15 K. Converting between the scales is simple, to convert Celsius to Kelvins you just add 273.15 and to convert Kelvins to Celsius you subtract 273.15.

 

When heat is added to a system, the particles gain kinetic energy. Since their average kinetic energy increases, the temperature increases. Since the particles have increased their kinetic energy, they move faster and further. Each particle takes up more room, so the object as a whole expands.

It expands in all directions.

Engineers and architects have to allow for the expansion of materials with temperature increases when they design things – or else the whole thing could break apart on a cold or hot day. Long structures like bridges have expansion joints to allow for the expansion of the structure with changing temperatures.

Many devices make use of the expansion of materials. Bimetallic strips are used to control the operation of cooling or heating devices. A bimetallic strip is made of two metals that are bonded together. Each metal expands a different amount, so one of the metals expands more than the other. This causes the strip to curve when the temperature changes. This can be used to switch electrical circuits on and off, controlling an air conditioner or a heater.

***Heat Flow:*** Heat can flow from one system to another only if there is a temperature difference between the two systems. The greater the difference in temperature, the faster heat will flow.





The direction of heat flow is from a high temperature system to a low temperature system. Heat can only flow in this direction. There is no logical reason for this; after all, isn’t it reasonable to think that in the winter heat ***could*** flow from the cold outside into the warm inside of your house? It would cut your energy bill. Unfortunately, that will never happen.

***Heat flows from the high temperature system to the low temperature system.***

When an object absorbs heat, its particles must somehow gain kinetic energy. They do this by absorbing heat. There are three ways that heat can be transferred between systems: ***conduction***, ***radiation***, and ***convection***. This is the kind of stuff that you do in elementary science classes.

***Conduction*** is heat transfer by direct contact between two systems. When you sit on a really hot car seat and burn your hide, you have gained heat via conduction. Heat will flow from the hot system to the cold system until thermal equilibrium is reached. At that point heat will no longer flow.

What happens in conduction is that the particles in the hot object, placed against the cold object, have collisions with the particles in the cooler system. In these collisions, the particles in the high temperature system lose energy and the particles in the low temperature system gain energy. The thermal energy transfers through the cool system via collisions between the particles until the particles in the two systems have the same average kinetic energy. We say that the systems have reached thermal equilibrium when this happens.

***Radiation*** is heat transfer via electromagnetic waves. A great deal of the energy from the sun reaches the earth in the form of electromagnetic waves. They travel through space. When you go outside on a warm spring day and bask in the warmth of the sun, you are absorbing heat that has radiated from the sun. Electric space heaters that have those glowing red heat elements provide most of their heat via radiation in the same way. Most of the heat that you get from a fireplace (or a camp fire for that matter) arrives via radiation.

The electromagnetic waves travel through space and are absorbed by the system, the absorbed energy is converted into the kinetic energy of the particles – makes them move back and forth.

***Convection*** is heat transfer via fluid flow. A fluid absorbs heat at one location and then flows to another place where it transfers the heat it absorbed to some other system. Convection is used to heat homes via forced air furnaces. A large fan blows warm air into the rooms of the house through ducts. Cooler air is drawn in through grates and returned to the furnace for heating.

Ovens do most of their heating via conduction. An element in the bottom of the oven heats air. The heated air then circulates around and around in the oven transferring heat to the food you want to cook.

It is quite common to have multiple forms of heat transfer in a system. Burning gasoline in a car engine heats the engine block by conduction. Water is circulated through water channels in the engine block absorbing heat via conduction. It then carries the heat to the radiator – this is convection. The heat is then transferred from the water to the radiator via conduction. Air circulates through the radiator removing heat via conduction (when the air is in direct contact with the metal fins of the radiator). The heated air then departs, removing the heat from the radiator via convection.