SPH3U UNIVERSITY PHYSICS

ENERGY & SOCIETY

- Thermal Energy & Heat (P.148-153)

Thermal Energy & Heat

We are surrounded by the use and effects of heat and thermal energy:

- *thermostats control furnaces*
- *large bodies of water help moderate the climate of certain regions*
- *winds are generated by uneven heating of Earth's surface and atmosphere*
- *the weather influences the clothes we wear*
- *...*

Thermal Energy & Heat

Furthermore, much of the energy we consume is eventually transformed into thermal energy. Thus, thermal energy and heat play a significant role in our lives.

NOTE!

Thermal energy and heat are not exactly the same, and temperature is different from both of them.

Thermal Energy & Heat

Thermal energy *is the total kinetic energy and potential energy of the atoms or molecules of a substance. It depends on the mass, temperature, nature, and state of the substance.* ***Heat****, as stated earlier, is the transfer of thermal energy from a warmer substance to a colder one.*

THERMAL ENERGY

- the total kinetic and potential energy possessed by the particles of a substance

NOTE!

Thermal energy, like all other types of energy, is a scalar quantity and is measured using the SI unit of joules.

Thermal Energy & Heat

Temperature *is a measure of the average kinetic energy of the atoms or molecules of a substance, which increases if the motion of the particles increases.*

TEMPERATURE

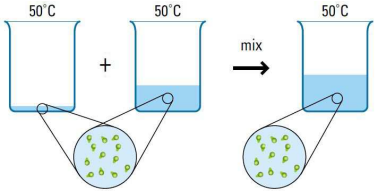
- measure of the average kinetic energy of the particles in a substance
- increases if the motion of the particles increases and vice versa

NOTE!

Temperature is often measured using a mercury or alcohol thermometer.

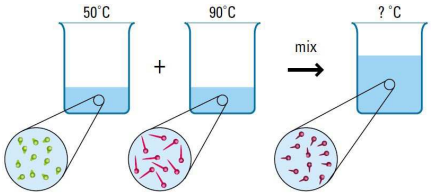
Thermal Energy & Heat

Consider, for example, 100 g of water at 50°C and 500 g of water at 50°C. The samples have the same temperature, but the bigger 500 g sample contains more thermal energy because it has a larger mass. If these samples were mixed, no thermal energy would transfer between them because they are at the same temperature.



Thermal Energy & Heat

Next, consider 500 g of water at 50°C and 500 g of water at 90°C. The warmer sample has more thermal energy because the motion – in other words, the average kinetic energy – of the molecules is greater at a higher temperature. If the two samples were mixed, thermal energy would transfer from the 90°C sample to the 50°C sample.



Thermal Energy & Heat

PRACTICE

1. A parent places a baby bottle containing 150 mL of milk at 7°C into a pot containing 550 mL of water at 85°C.
   (a) Compare the average kinetic energy of the milk molecules and that of the water molecules.

   (a) The water has a greater temperature than the milk.

Thermal Energy & Heat

PRACTICE

1. A parent places a baby bottle containing 150 mL of milk at 7°C into a pot containing 550 mL of water at 85°C.
   (b) Compare the thermal energy of the milk and the water.

   (b) The water has more thermal energy than the milk because the water is hotter and there is more of it.

Thermal Energy & Heat

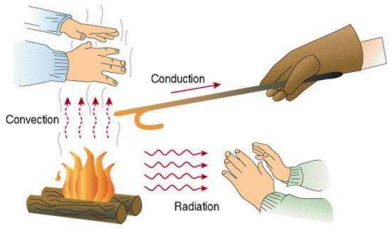
PRACTICE

1. A parent places a baby bottle containing 150 mL of milk at 7°C into a pot containing 550 mL of water at 85°C.
   (c) Will thermal energy stop transferring from the water to the milk at some stage? Explain your answer.

   (c) Thermal energy will stop transferring when both the water and the milk reach the same temperature.

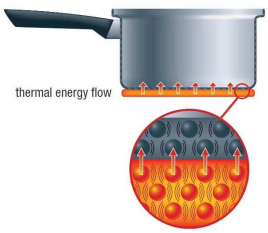
Methods of Heat Transfer

The definition of heat suggests that energy is transferred from a warmer body to a cooler body. This transfer occurs in three possible ways, which you have studied before. They are:



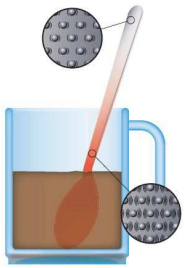
Methods of Heat Transfer – Conduction

Thermal energy can move from a warmer object to a colder object by a process called ***conduction****. Conduction occurs when the fast-moving particles of a warmer object collide with the slower-moving particles of a colder object. These collisions cause the slower-moving particles of the colder object to speed up and the faster-moving particles of the warmer object to slow down.*



Methods of Heat Transfer – Conduction

You might notice this type of thermal energy transfer if you place a cold metal spoon in a cup of hot chocolate.



CONDUCTION

- transfer of thermal energy from a warmer object to a colder object
- occurs through the collision of atoms

NOTE!

Thermal conduction can only occur if the two objects are in physical contact.

Methods of Heat Transfer – Convection

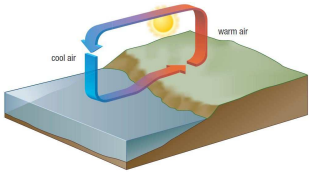
In fluids (liquids and gases), thermal energy can be transferred by convection. ***Convection*** *occurs when colder, denser fluid falls and pushes up warmer, less dense fluid. Consider a pot of water that is being heated on a stovetop. When the water particles nearest to the heat source absorb thermal energy, they move faster and spread farther apart. As a result, the colder, denser water above the warmer water sinks and pushes the warmer, less dense water upward.*

Methods of Heat Transfer – Convection

As the warmer water moves upward and farther away from the heat source, it cools down, increases in density, and falls into the warmer, less dense water below. This process repeats itself, resulting in a continuous ***convection current*** *in which colder water moves downward (toward the heat source) and warmer water moves upward (away from the heat source). In this way, thermal energy spreads throughout the liquid.*

Methods of Heat Transfer – Convection

Convection currents also form in gases, such as air. For example, during the day, ocean breezes are created when cool air above the water falls downward and onto the land, pushing the warmer air over the land upward.

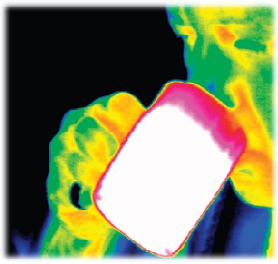


CONVECTION

- transfer of thermal energy through a fluid (liquid or gas)
- occurs when colder, denser fluid falls and pushes up warmer, less dense fluid

Methods of Heat Transfer – Radiation

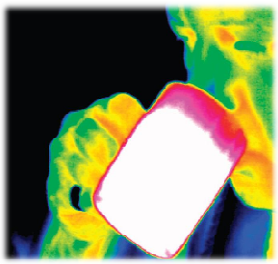
Thermal energy can also be transferred by radiation. ***Radiation*** *is a thermal energy transfer that involves electromagnetic waves being emitted from sources such as lamps, flames, and the Sun. While the Sun is the largest source of radiant energy, all particles that have kinetic energy emit some radiant energy. These waves travel through materials such as air or glass or even through empty space.*



Methods of Heat Transfer – Radiation

RADIATION

- transfer of thermal energy as electromagnetic waves
- does not require the collision or movement of particles

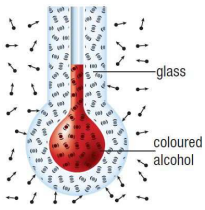


Methods of Heat Transfer

PRACTICE

2. How does a thermometer work?

When a thermometer is placed in a liquid, the particles of the substance bump into the glass of the thermometer. As the temperature of the substance increases, these collisions cause the particles of the glass to vibrate faster.

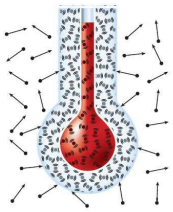


Methods of Heat Transfer

PRACTICE

2. How does a thermometer work?

In turn, the fast-moving particles of the glass collide with the slower-moving particles of the mercury or alcohol inside the tube, making these particles move faster as well. The faster-moving particles of mercury or alcohol begin to spread out and take up more space. This causes the liquid in the thermometer to move higher up the tube and give a higher temperature reading.



Thermal Conductors & Insulators – DYK?

Most metals are good conductors of thermal energy while many non-metals are poor conductors of thermal energy. Metals are called ***thermal conductors*** *because they allow thermal energy to pass through them relatively easily and quickly. So, when your hand touches a metal sink, thermal energy moves easily and quickly from your hand to the metal sink. This makes the metal sink feel cold.*

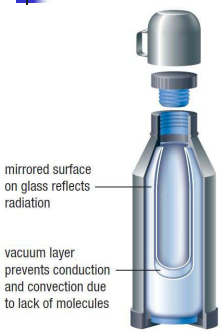
Thermal Conductors & Insulators – DYK?

*Some materials, called **thermal insulators**, do not conduct thermal energy very well. These materials include many types of plastic. You might have noticed that the handles of many pots and pans are made of plastic. The plastic handles prevent thermal energy from moving quickly from the metal pot into your hand. Still air (also called dead air) is also a very good insulator.*

NOTE!

Animals make good use of this form of insulation – hair, fur, and feathers trap air and prevent the transfer of thermal energy.

Thermal Conductors & Insulators – DYK?



The best thermal insulator of all is a vacuum. A vacuum contains no particles or very few particles. So, thermal energy cannot be transferred by conduction or convection. For example, a Thermos bottle uses a vacuum between an inner flask and an outer flask (usually made of glass) to keep hot foods hot and cold foods cold.

NOTE!

The inner flask is usually coated with a shiny, mirror-like layer to reflect any thermal energy that may be transferred by radiation.

Thermal Energy & Heat

PRACTICE

3. Discuss whether this statement is true or false: In conduction, thermal energy is transferred but the particles themselves are not transferred.

   This is true – the particles vibrate, bump into one another, and in the process transfer their energy (of vibration) onto the particles next to them.

Thermal Energy & Heat

PRACTICE

4. If air were a good conductor, you would feel cool even on a day when the air temperature is 25°C. Explain why.

   Since your body temperature is ~ 38°C, thermal energy would transfer from you to the air until you were both at the same temperature.

Thermal Energy & Heat

PRACTICE

5. Would it be better to place an electric room heater near the floor or the ceiling of a room? Explain your answer.

   It would be better to place it near the floor so that a convection current would form.