Thermal Energy

When work is done on an object to accelerate the object, the Kinetic energy of the object increases.

When work is done on an object to change the vertical position of the object, the gravitational potential energy of the object increases.

In the same way, when work is done on an object to overcome friction, the thermal energy of the object increases. When the thermal energy of an object changes, the temperature of the object changes.

Temperature is a measure of how hot or cold an object is in refesence to a thermometer scale. That is, temperature is measured using a thermometer. The temperature of an object is an indication of the amount of thermal energy in the object

Thermal energy is the energy associated with the random motion of molecules and atoms. We know that when the thermal energy of an object increases, the molecular and atomic motion in the object increases. Thermal energy is Kinetic energy at the molecular or atomic level

Thermal Energy of an object can be increased by:

- changing mechanical energy to thermal energy
- transfer of heat from one object to another.

Heat

Heat is the energy that is transferred from a warm object to a cooler one.

Symbol for heat ΔE_h

Because heat and thermal energy are energy, the units of heat and thermal energy are the joule (J). But you may be familar with using calories as a unit of heat.

1.0 cal = 4.184 J

1 Food calorie = 1000 calories

Specific Heat Capacity

Specific Heat Capacity is defined as the amount of heat that a unit mass of substance can gain or lose in order to change its temperature one degree.

Symbol for specific heat capacity: C

Units of specific heat capacity: $\frac{J}{Kg \cdot °C}$

To increase the temperature of a substance, we increase the thermal energy of the substance by allowing heat to flow from a warmer substance.

Different substances have different capacities to hold heat, and therefore different heat capacities

water	$4184 \frac{J}{Kg \cdot °C}$
copper	$390 \frac{J}{Kg \cdot °C}$
lead	$130 \frac{J}{Kg \cdot °C}$

We can see that the heat gained or lost by a substance depends on:

- mass of the substance (m)
- temperature change of the substance (Δt)
- specific heat capacity of the substance (C)

$$\Delta E_h = m \cdot \Delta t \cdot C$$

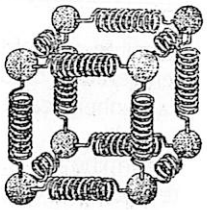
(heat)

VII. HEAT AND THERMAL ENERGY

POINT 1 Thermal Energy and Temperature

A. Thermal energy

a. Matter is made up of molecules which are in continual random motion and so have kinetic energy and potential energy.



Molecular arrangement in a substance

Molecular motion

b. Thermal energy of an object is the sum of the kinetic energy, potential energy, and other kinds of energy of all the molecules in the object. Thermal energy in an object is proportional to the number of molecules in the object.

c. The molecules in a hot object move faster and have a higher thermal energy than the molecules in a cold object.

B. Temperature

a. Temperature is a measure of the average kinetic energy of individual molecules. The SI base unit for temperature is the kelvin (K).

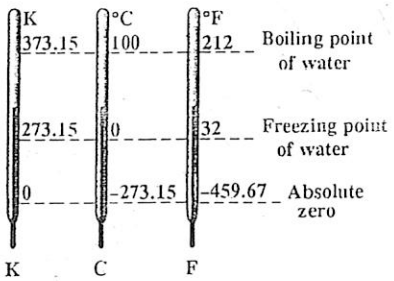
b. The temperature of an object does not depend on the number of molecules in the object.

C. Temperature scales

a. Thermometers are used to measure temperature on the Celsius (°C), Fahrenheit (°F), and Kelvin (K) scales.

b. Two standard points on each scale are the freezing point and the boiling point of water. The freezing point of water is defined as 0°C, 32°F, or 273.15 K, and the boiling point of water is defined as 100°C, 212°F, or 373.15 K.

c. The size of the Celsius degree is larger than that of the Fahrenheit degree by a factor of 9/5. The size of one kelvin is equal to that of one Celsius degree.



$$T_F = \frac{9}{5}T_c + 32 \qquad T = T_C + 273.15 = \frac{5}{9}(T_F - 32) + 273.15$$

d. Absolute zero (0 K) of temperature is the lowest temperature attainable. The kinetic energy of molecules is minimal at absolute zero. Absolute zero is equivalent to −273.15°C or −459.67°F.

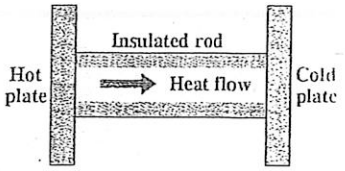
POINT 4 Heat Transfer

A. Heat is transferred from one object to another in three different ways: conduction, convection, and radiation.

B. Conduction

a. Conduction is direct heat transfer through physical contact, and involves energy exchange through molecular collisions.

b. Materials that conduct heat well, such as most metals, are thermal conductors. Materials that conduct heat poorly, such as wood and glass, are thermal insulators.

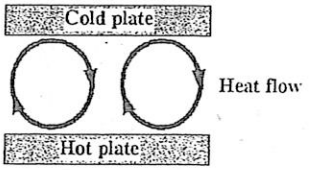


Conduction of heat

C. Convection

a. Convection is heat transfer by the mass movement of molecules of a fluid over considerable distances.

b. Natural convection occurs when the warmer, less dense part of a fluid is pushed upward by the buoyant force provided by the surrounding cooler and denser part. Forced convection occurs when an external device, such as a fan or a pump, causes the fluid to move.

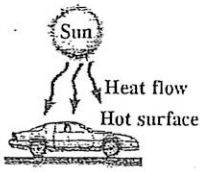


Convection of heat

D. Radiation

a. Radiation is heat transfer by electromagnetic waves that can travel through empty space.

b. All objects, regardless of their temperature, simultaneously absorb and emit electromagnetic waves.



Radiation of heat

PROBLEM 4 Heat Transfer

A student fills two identical cups with the same amount of hot cocoa. One cup has a metal spoon in it and the other does not. After several minutes, which of the two cups contains the cooler cocoa? Explain your answer in terms of heat transfer processes.

Solution

The cup with the metal spoon contains the cooler cocoa. Heat is conducted from the cocoa up through the metal spoon. The heat then radiates and convects into the atmosphere.

RELATED PROBLEMS

24. A woman has a pair of hot pads, and wants to pick up a hot cooking pot on an electric stove. Is it better to soak the hot pads in cold water or to keep them dry in order to pick up the hot pot comfortably? Explain your answer.

25. Does the earth cool off at night more rapidly if the weather is cloudy or clear? Explain your answer.

26. The temperature of the land rises more quickly than that of the water. Use this fact to explain why some breezes from a lake are experienced at the shore of the lake on a sunny day.