Heat/Thermal Energy

by

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P4.3A Identify the form of energy in given situations (e.g., moving objects, stretched springs, rocks on cliffs, energy in food).

P4.11b Calculate the final temperature of two liquids (same or different materials) at the same or different temperatures and masses that are combined.

Items;

1- Heat Energy

2- Specific Heat Capacity

3- Conservation of Heat Energy

Heat/Thermal Energy and Temperature

Rub your hands together quickly and they will become warm.

Apply the brakes on a speeding car and they will soon heat up.

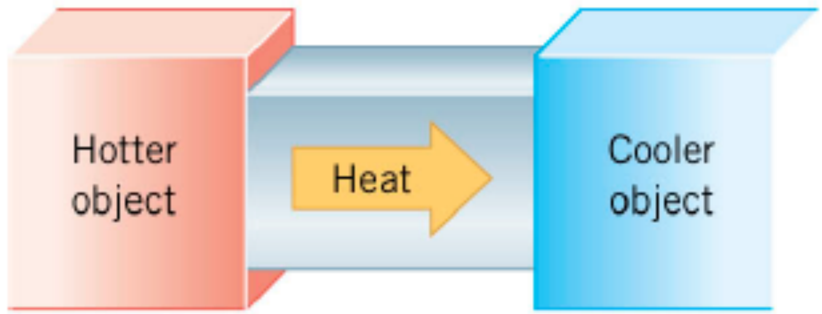
These and other examples suggest that energy of motion, or kinetic energy, can be converted into heat, or Thermal Energy.

Temperature is actually the measure of the average kinetic energy of the atoms and molecules in a substance.

The instrument used to measure temperature is the thermometer.

Heat energy (HE) is defined as the thermal energy that flows from one object to another due to a difference in their temperature.

When two substances at different temperatures are mixed together, the warmer substance loses heat to the cooler substance.



When a substance loses heat, then HE is negative.

When a substance gains heat, then HE is positive.

Heat energy (HE) can be calculated using the formula below in the table.

Heat Energy (HE)
$HE = m \times c \times \Delta T$ $HE = m \times c \times (T_{final} - T_{initial})$

HE: is the heat energy gained or lost in joules (J).

m: is the mass in kilogram (kg).

T: is the temperature.

c: is the specific heat capacity. Its unit is joules per kilogram degree Celsius ($J/kg.^oC$).

Specific Heat Capacity (c)

Specific heat capacity (c) is defined as the quantity of heat required to raise the temperature of 1 kilogram (kg) of substance by 1^{o}C (degree Celsius).

Its unit is joules per kilogram degree Celsius (J/kg.^{o}C).

Below is a table listing the specific heat capacity of various materials.

Substance	*Specific Heat Capacity (c) in* (J/kg.^{o}C)
Aluminum	9.0 x10^{2}
Brass	3.8 x10^{2}
Copper	3.9 x10^{2}
Iron	4.5 x10^{2}
Water (liquid)	4.2 x10^{3}
Air	1.0 x10^{3}

Notice that the specific heat of iron is 4.5 x10^{2} , whereas of water is 4.2 x10^{3}. That means that almost ten times more heat is needed for 1 ^{o}C. rise of temperature of 1Kg of water than for 1 Kg of Iron.

Example 1. *Heating Copper;*

How much heat energy (HE) is required to **heat** 2.0 kg of copper from an initial temperature $T_{initial}$ = 30°C to a final temperature T_{final} = 80°C ? The specific heat capacity of copper (c) = 3.9 x10^2 J/kg.°C.

Data Table				
$T_{initial}$	T_{final}	m	c	HE_{gained}
30°C	80°C	2.0 kg	3.9 x10^2 J/kg.°C	?

$$HE = m \times c \times (T_{final} - T_{initial})$$

$$= 20 \times 3.9 \times 10^2 \times (80-30)$$

$$= 20 \times 3.9 \times 10^2 \times 50$$

$= 3.9 \times 10^4$ J. The answer is a positive number because the system gained heat to warm up from 30°C to 80°C.

Example 2: *Cooling Iron;*

How much heat energy (HE) is **lost** when 0.054 kg of iron is cooled from an initial temperature $T_{initial}$ = 90^oC to a final temperature T_{final} = 10^oC ? The specific heat capacity of iron (c) = 4.5 x 10^2 J/kg.^oC.

Data Table				
$T_{initial}$	T_{final}	m	c	HE_{lost}
90^oC	10^oC	0.054 kg	4.5 x 10^2 J/kg.^oC	?

$$HE = m \times c \times (T_{final} - T_{initial})$$

$$= 0.054 \times 4.5 \times 10^2 \times (10-90)$$

$$= 0.054 \times 4.5 \times 10^2 \times (-80)$$

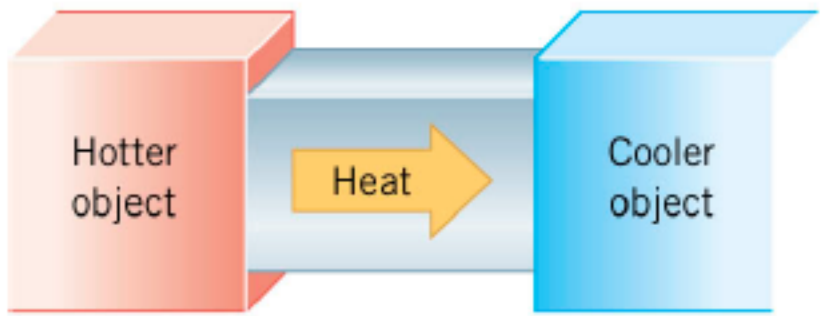
$$= -1.9 \times 10^3 \text{ J}$$

The answer is a negative number because the system lost heat and cooled down from 90^oC to 10^oC.

Law of Conservation of Energy

The law of conservation of energy states that: Energy can not be created nor destroyed, but it can transformed from one type to another. The total amount of energy remains the same.

When two substances at different temperatures are mixed together, the warmer substance loses heat to the cooler substance. This is true provided that no heat energy is lost or gained to the space around the substances.



Law of Conservation of Heat Energy Formula

Law of Conservation of Heat Energy formula
Heat Energy gained = - Heat Energy lost HE gained = - HE lost

When a substance loses heat, then HE is negative.

When a substance gains heat, then HE is positive.

***Example 3:** Mixing Hot and Cold Water;*

A mass of hot water (m_{hot} = ?) at a temperature of $T_{initial/hot}$ =100°C was added to cold water of mass m_{cold} = 1.0 kg and a temperature of $T_{initial/cold}$ = 10°C. The final temperature of the mixture is $T_{final/mixture}$ = 37°C. Calculate the mass of hot water.

The specific heat for hot water: $C_{hot} = 4.2 \times 10^3$ J/kg.°C,

The specific heat for cold water: $C_{cold} = 4.2 \times 10^3$ J/kg.°C

Data Table				
	$T_{initial}$	T_{final}	m	c
Hot Water	100°C	37°C	?	4.2×10^3 J/kg.°C
Cold Water	10°C	37°C	1.0 kg	4.2×10^3 J/kg.°C

According to the law of conservation of energy: When two substances at different temperatures are mixed together, the warmer substance loses heat to the cooler substance.

HE gained by the cold water = - HE lost by the hot water

Write the formula and insert the values from the Data Table

$$m_{\text{cold water}} \times c_{\text{cold water}} (T_{\text{final}} - T_{\text{initial}})_{\text{cold water}} = - m_{\text{hot water}} \times c_{\text{hot water}} (T_{\text{final}} - T_{\text{initial}})_{\text{hot}}$$

$$1 \times 4.2 \times 10^3 \times (37-10) = - m_{\text{hot water}} \times 4.2 \times 10^3 \times (37-100)$$

$$4.2 \times 10^3 \times 27 = - m_{\text{hot water}} \times 4.2 \times 10^3 \times (-63)$$

$$27 = - m_{\text{hot water}} (-63) = 63\, m_{\text{hot water}}$$

$$m_{\text{hot water}} = 27/63 = 0.43 \text{ kg}$$

So, we need to add 0.43 kg of hot water.

So when we add 0.43 kg of hot water at a temperature of 100 ^oC to 1.0 Kg of cold water at a temperature of 10 ^oC, the final mixture will be 1.43 Kg of water at 37 ^oC.

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The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

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