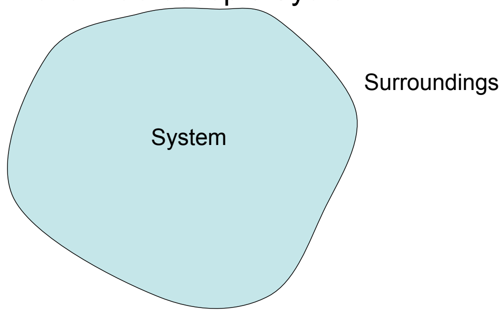
Chapter 6--Kinetic and Potential Energy of a Macroscopic System



Thermal Energy

Thermal energy is the total kinetic and potential energy of a macroscopic system. Temperature is related to thermal energy. Higher temperature indicates more thermal energy.

Thermal energy of a solid: movie

Thermal energy of a gas: model

Thermal energy of a bouncing ball: model

Example – a bouncing ball.

A 0.01 kg superball is dropped from a height of 1 m. After bouncing once, it reaches a maximum height of 0.6 m. What is the change in the thermal energy of the ball?

After a long time, the ball is eventually at rest. What is the change in thermal energy of the ball?

Thermal Energy

Thermal energy is the total kinetic and potential energy of a macroscopic system. Temperature is related to thermal energy. Higher temperature indicates more thermal energy. (movie)

$$\Delta E_{therm} = mc\Delta T$$

as long as the system does not change phase.

Temperature Scales

Kelvin: 0 is absolute zero; 273 K is melting point of ice (freezing point of water).

Celsius: -273 °C is absolute zero; 0°C is melting point of ice; 100°C is boiling point of water.

Note: a **change** in temperature of 1 K is equivalent to a **change** in temperature of 1°C.

Specific Heat

High c means it takes a lot of energy to increase its temperature 1 K.

Substance	specific heat c (J/kg/K)
Aluminum	910
Copper	390
Iron	470
Ice (near 0 ◦ C)	2100
Mercury	138
Water	4190
Ethanol	2428

Poll

In one pot, you have 2.0 kg of water. In another identical pot, you have 1.0 kg of water. Which mass of water will have a higher specific heat?

1. 1 kg of water
2. 2 kg of water
3. Neither, because they have the same specific heat.

Poll

In one pot, you have 2.0 kg of water. In another identical pot, you have 1.0 kg of water. Which mass of water requires **more** energy to increase its temperature 1 K?

1. 1 kg of water
2. 2 kg of water
3. Neither, because they require the same amount of energy to increase the temperature 1 K.

Poll

In one pot, you have 1.0 kg of water at a temperature of 5°C and in another pot you have 1.0 kg of water at a temperature of 30°C. Which pot of water requires more energy to raise its temperature 1 K?

1. 1 kg of water at 5°C
2. 1 kg of water at 30°C
3. Neither, because they require the same amount of energy to increase temperature 1 K.

Poll

In one pot, you have 1.0 kg of water at a temperature of 5°C and in another pot you have 1.0 kg of water at a temperature of 30°C. Which pot of water requires more energy to raise its temperature to a final temperature of 50°C?

1. 1 kg of water at 5°C
2. 1 kg of water at 30°C
3. Neither, because they require the same amount of energy to increase temperature to 50°C.

Poll

1.5 kg of water and 1.5 kg of aluminum absorb the same amount of energy via a transfer of thermal energy. Which one's temperature will change the most? (Assume that no phase change occurs during the process.) The specific heat capacity of Al is 910 J/kg/K

1. 1.5 kg of water
2. 1.5 kg of aluminum
3. Neither, because their temperature changes the same amount.

Example

A superball has a mass of 20 g and a specific heat capacity of 2.0 J/kg/K. If you drop it from rest from a height of 1 m above th floor and if it is eventually comes to rest on the floor, what is its change in temperature?

Calorimetry

Two or more bodies of different temperature come to equilibrium. Assume the system is insulated.

Example

A 0.010 kg aluminum strip at room temperature (20°C) is brought into contact with a 0.010 kg iron strip at 60 °C. The specific heat capacity of Al is 0.910 J/K/g. The specific heat capacity of iron is 0.470 J/K/g. What will be the equilibrium temperature of the strips? What assumptions did you make regarding the systems when doing your calculation?

Poll

A hot piece of copper of mass 400 grams and temperature 130°C is placed into 400 grams of water at 20°C. Will the final temperature of the system be **closer** to 20°C or 130°C?

1. Closer to 20°C
2. Closer to 130°C
3. Neither, it will be exactly equal to the arithmetic average which is 75°C.

Change in Phase

Energy needed to melt or freeze

$$\Delta E_{therm} = \pm m L_f$$

Energy needed to evaporate or condense

$$\Delta E_{therm} = \pm m L_v$$

Latent Heat of Fusion

Table 3: Latent Heat of Fusion

Substance	Melting point (K)	Melting point (°C)	Heat of fusion (10^3 J/kg)
Helium	3.5	-269.65	5.23
Hydrogen	13.84	-259.31	58.6
Nitrogen	63.18	-209.97	25.5
Oxygen	54.36	-218.79	13.8
Ethyl alcohol	159	-114	104.2
Mercury	234	-39	11.8
Water	273.15	0.00	334
Sulfur	392	119	38.1
Lead	600.5	327.3	24.5
Antimony	903.65	630.50	165
Silver	1233.95	960.80	88.3
Gold	1336.15	1063.00	64.5
Copper	1356	1083	134

Latent Heat of Vaporization

Table 2: Latent Heat of Vaporization

Substance	Boiling point (K)	Boiling point (°C)	Heat of vaporization (10^3 J/kg)
Helium	4.216	-268.93	20.9
Hydrogen	20.26	-252.89	452
Nitrogen	77.34	-195.81	201
Oxygen	90.18	-182.97	213
Ethyl alcohol	351	78	854
Mercury	630	357	272
Water	373.15	100.00	2256
Sulfur	717.75	444.60	326
Lead	2023	1750	871
Antimony	1713	1440	561
Silver	2466	2193	2336
Gold	2933	2660	1578
Copper	2840	2567	5069

Poll

Which requires more energy, to melt 1 kg of ice or to evaporate 1 kg of water?

1. Melt 1 kg of ice
2. Evaporate 1 kg of water
3. Neither, because they require the same amount of energy.

Heat Transfer, Q

If the temperature of the system is different than the temperature of the surroundings AND if the system is NOT insulated, then energy is transferred thermally to the system from the surroundings (or vice versa).

Note: the thermal energy of the system may not necessarily change (or change the same amount) as a result of Q being added or removed from the system.

$$Q \neq \Delta E_{therm}$$

Methods of Heat Transfer between System and Surroundings

Conduction

Convection

Radiation

Conservation of Energy

$$\Delta E_{sys} = W + Q$$

$$E_i + (W + Q) = E_f$$

Energy Dissipation

Air resistance and friction cause the thermal energy of a system and surroundings to increase (even if there is no heat transfer, Q).

Example

A 0.002 kg coffee filter is released from rest from a height 2 m. If there is no air resistance, what will be its speed when it hits the floor? Suppose that it reaches a terminal speed of 0.25 m/s. What is the change in thermal energy of the coffee filter and surrounding air due to air resistance?