Thermodynamics

Auburn Mountainview: Physics

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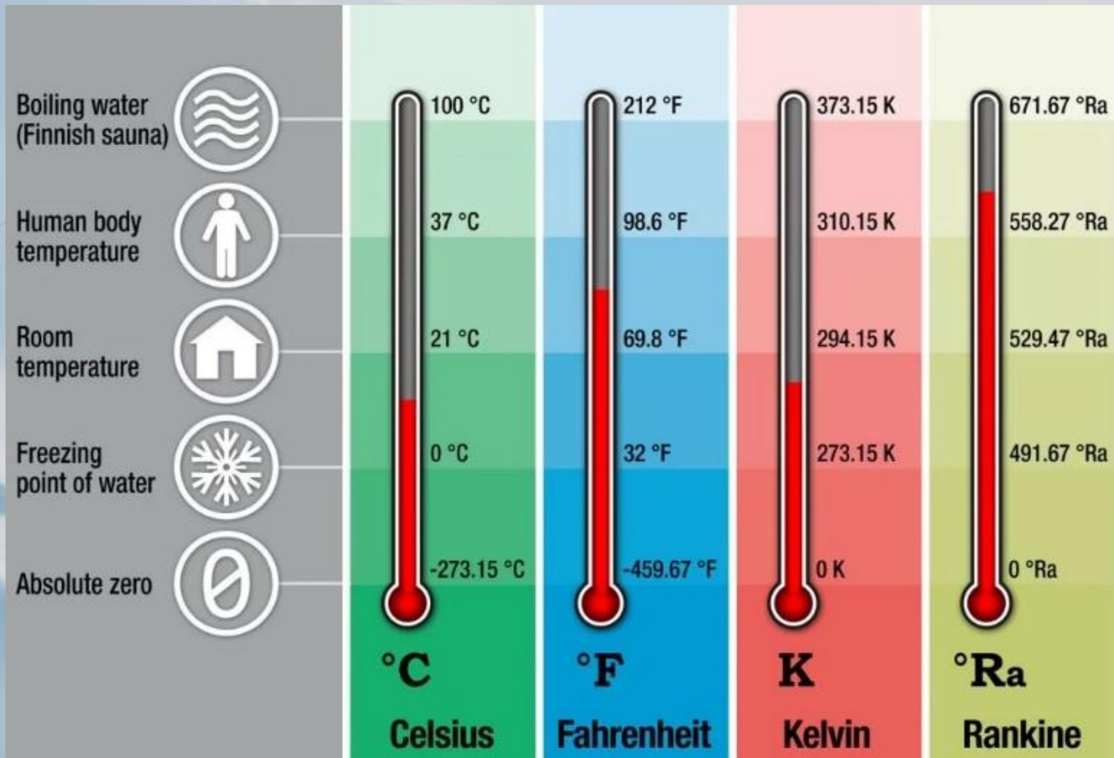
Temperature

- There are many temperature scales.
- Two of them are absolutes (H_2O fusion/condense):
  - Kelvin-K (273.15/373.15)
    - Celsius (Centigrade)-ºC (0/100)
  - Rankine-ºR (491/671)
    - Fahrenheit-ºF (32/212)
- F→C: $T_F = (9/5)T_C + 32$
- C→K: $T_K = T_C + 273.15$

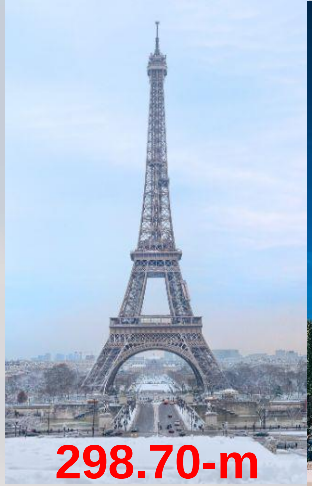


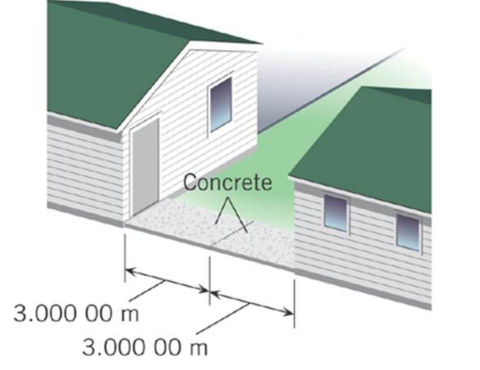
Linear Expansion

- **When heated up a solid will expand.**
  - **The expansion in any one dimension is called Linear Thermal Expansion.**

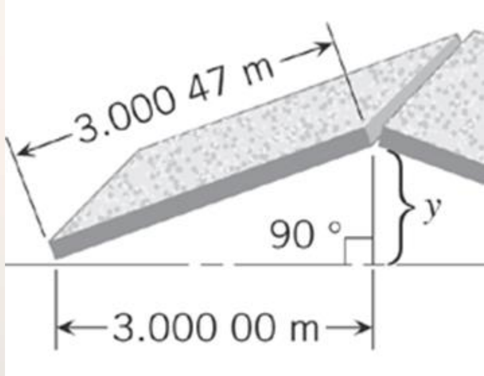
$$\Delta L = \alpha L_o \Delta T$$

  - **The expansion in all dimensions is called Volumetric Thermal Expansion.**
    - $\Delta V = \beta V_o \Delta T$





Example 1



Two 3.00-m concrete sidewalk slabs (α=12 x 10^{-6}-$^oC^{-1}$) at 25.00-^{o}C is between two buildings. When the temperature raises to 38.00-^{o}C calculate how high the slabs buckle.

$$\Delta L = \alpha L_o \Delta T$$

$$\Delta L = 12x10^{-6} - \frac{1}{℃} \cdot 3 - m \cdot 13 - ℃$$

$$\Delta L = 4.68x10^{-4} - m$$

ΔL=

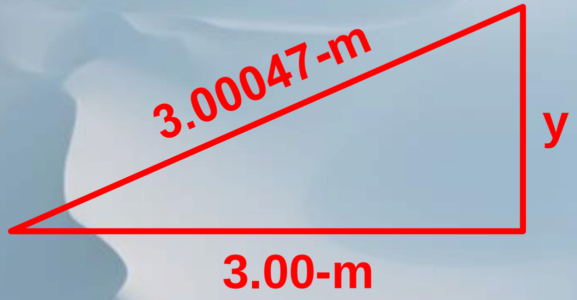
α= 12 x 10^{-6}-$^oC^{-1}$

L_o= 3.00-m

ΔT= (38-25)-^{o}C

Example 1 Cont.

Using the original length as the base and new length as a hypotenuse, solve for the height (y).



$$a^2 + b^2 = c^2$$

$$(3 - m)^2 + y^2 = (3.000468 - m)^2$$

$$y^2 = .002820 - m^2$$

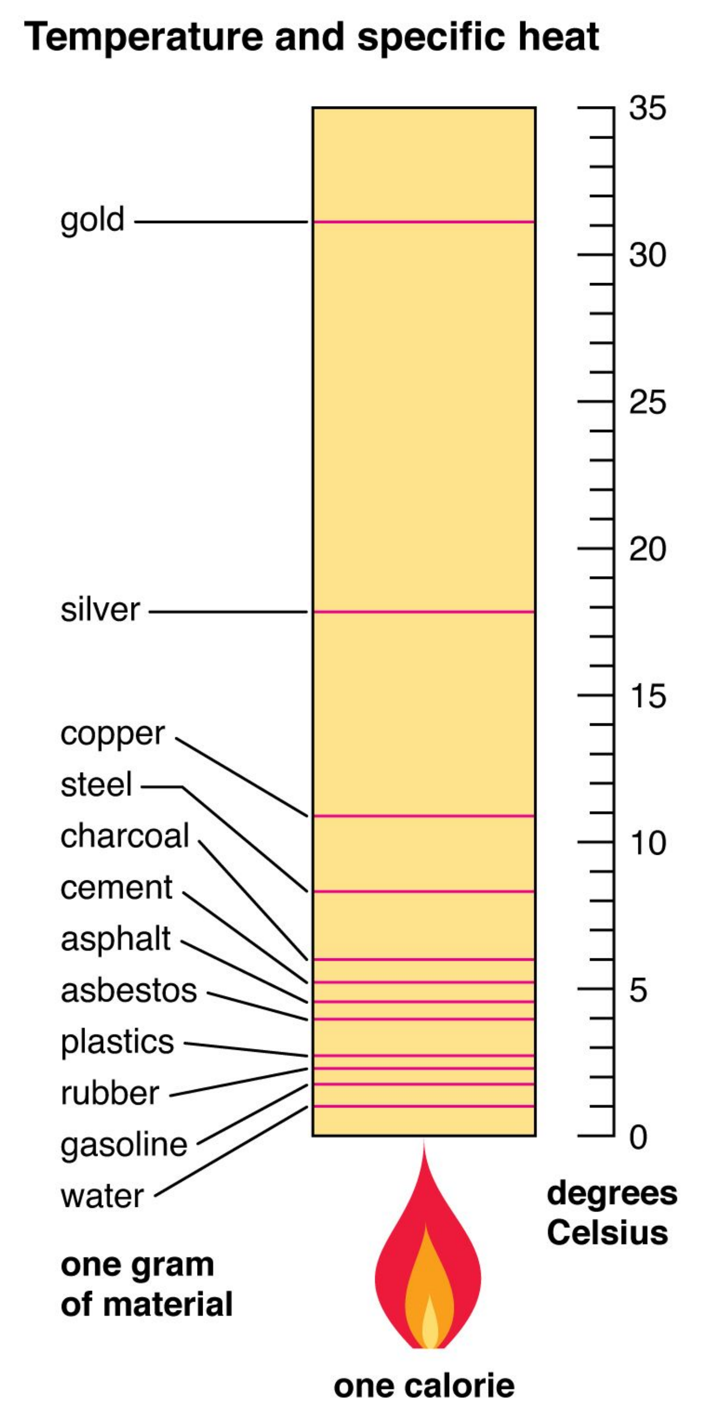
$$y = .0531 - m$$

$$y = 5.31x10^{-2} - m$$

Heat

- **Heat is the amount of energy (J) that flows from a high temp source to a low one.**
- **Solids and Liquids hold heat differently, so they have specific heats; c.**
- **The heat (Q) needed to increase an objects temperature is defined by;**

$$Q = cm\Delta T$$



Example 2

An 8-minute shower uses 17-kg. Water enters a heater at 10.00-ºC. How much heat is needed to raise the water to 50.00-ºC?

PSE charges 14-¢ per kW•hr, how much does this cost?

$$Q = cm\Delta T$$

$$Q = 4186 - \frac{J}{kg℃} \cdot 17 - kg \cdot 40 - ℃$$

$$Q = 2846480 - J$$

Q =
c = 4186-J/Kg•ºC
m = 17-kg
ΔT = 50-10-ºC

$$Q = 2.84x10^6 - J$$

Example 2 Cont.

How much does this cost?

$$Cost = \frac{14\text{-}¢}{kW \cdot hr}$$

$$Q = 2.84x10^6 - J \cdot \frac{1 - W}{1 - \frac{\quad}{s}}$$

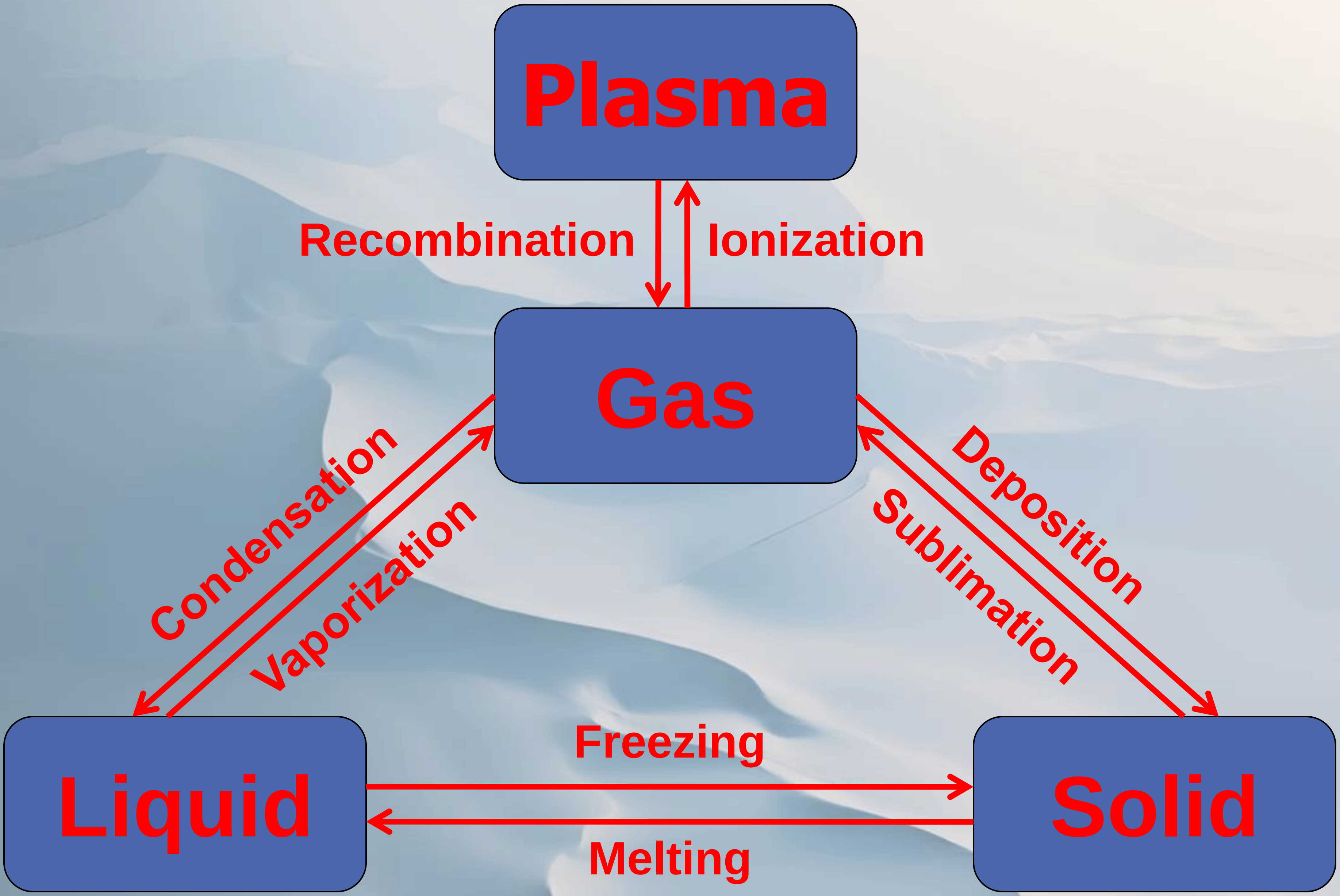
790.688889

$$Q = 2.84x10^6 - Ws \cdot \frac{1 - hr}{3600 - s}$$

$$Q = 790.69 - Whr \cdot \frac{1 - k}{1000}$$

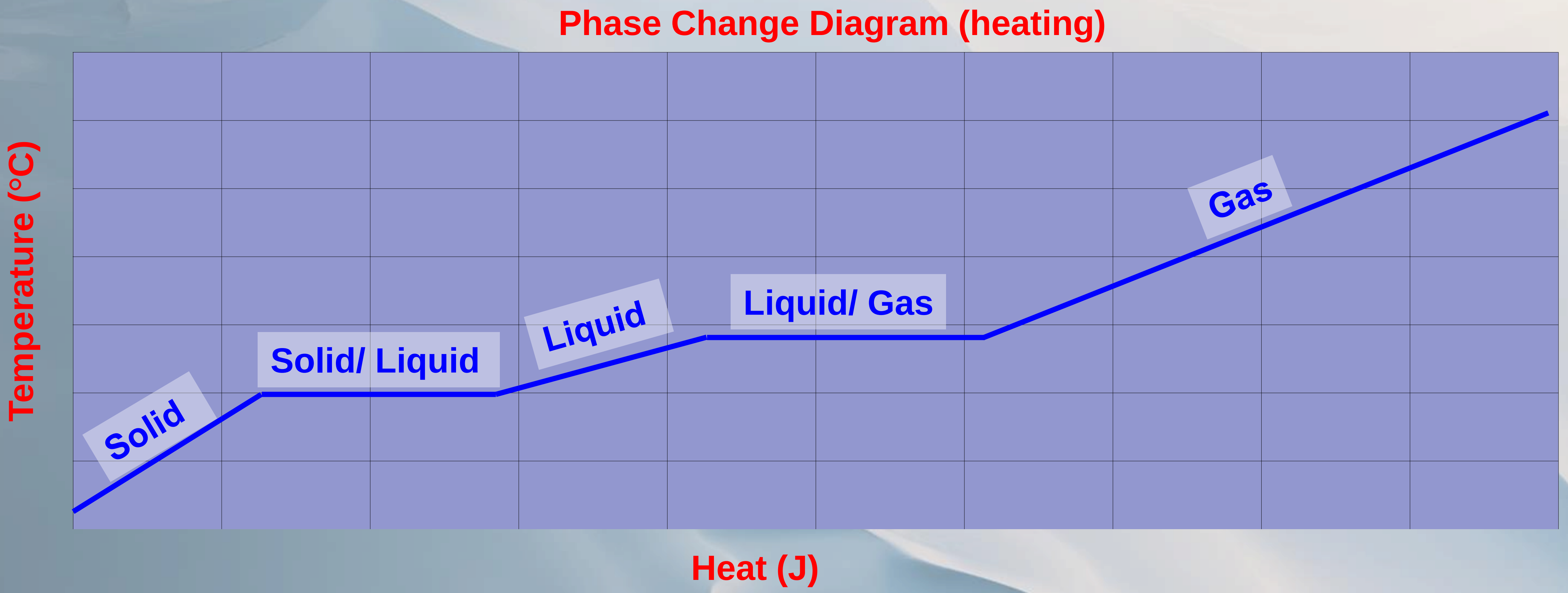
$$Cost = .79069 - kWhr \cdot \frac{14\text{-}¢}{kW \cdot hr}$$

$$Q = 11.06 - ¢$$


Plasma
Recombination
Ionization
Gas
Condensation
Vaporization
Deposition
Sublimation
Liquid
Freezing
Melting
Solid

Phase Changes

- Look at the below graph of a typical material.



Cooling graphs will have negative slopes.

Critical Points

- While changing phases: solid ↔ liquid or liquid ↔ gas the temperature does not change.
  - All heat is used to form/break bonds.
  - Solid ↔ Liquid: Freezing or Melting
  - Liquid ↔ Gas: Condensing or Evaporating
- For changing a phase state, every material has its own amount of Heat (J) per kilogram needed to convert all the material to the new phase.

Latent Heat

- The heat needed to be added or removed for each substance to change phases is called the Latent Heat.

$$Q = mL$$

  - For Solid $\leftrightarrow$ Liquid: Latent Heat of Fusion L_F (J/kg).
  - For Liquid $\leftrightarrow$ Gas: Latent Heat of Vaporization L_V (J/kg).

- Remember while either solid, liquid, or gas the heat needed to reach the next phase state is: $Q = cm\Delta T$.

Example 3

To make a ring 20.00-g of silver needs to be heated 1200.00-ºC. Assuming the silver starts at room temperature (20.00-ºC), how much heat is needed?

Substance	Melting Point (ºC)	Latent Heat of Fusion (J/kg)	Boiling Point (ºC)	Specific Heat Capacity (J/Kg•ºC)
Silver	961.78	10.46×10^4	2162.00	235.00

Example: Three parts (1+3)

1. Heating the Solid Silver (20.00-ºC→961.78-ºC)
2. Melting the Silver (Heat Latent Fusion)
3. Heating the Liquid Silver (961.78-ºC→1200.00-ºC)

– As 1. + 3. use the same ‘c’ they may be combined.

$$Q_{1+3} = cm\Delta T$$

$$Q_{1+3} = 235 - \frac{J}{kg°C} \cdot .02 - kg \cdot 1180 - °C$$

$$Q_{1+3} = 5546 - J$$

Q =
c = 235-J/kg•ºC
m = 20-g
ΔT = 1200-20-ºC

Example: Three parts (2)

1. Heating the Solid Silver (20.00-ºC→961.78-ºC)
2. Melting the Silver (Heat Latent Fusion)
3. Heating the Liquid Silver (961.78-ºC→1200.00-ºC)

– As 1. + 3. use the same ‘c’ they may be combined.

$$Q_2 = mL$$

$$Q_2 = 10.46x10^4 - \frac{J}{kg} \cdot .02 - kg$$

$$Q_2 = 2092 - J$$

$$\Sigma Q = Q_{1+3} + Q_2 = 5546 - J + 2092 - J$$

Q =
m = 20-g
L = 10.46 x 10^4-J/kg

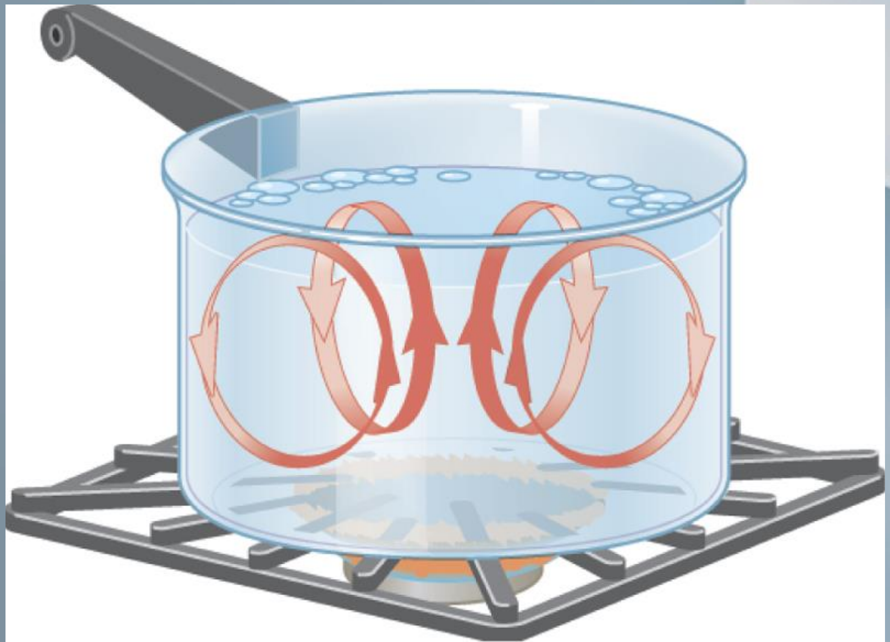
$$\Sigma Q = 7638.00 - J$$

Transferring Heat

- There are three ways to transfer heat.
  - Convection: Transfer due to the bulk movement of a fluid.
  - Conduction: Transfer directly through a material.
  - Radiation: Transfer by electromagnetic radiation.

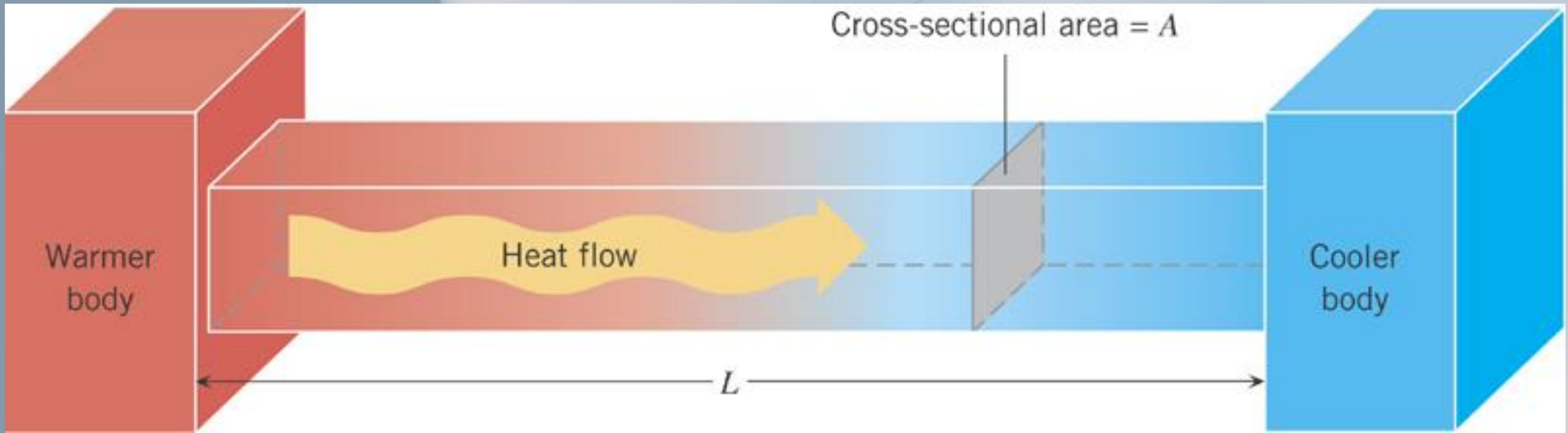
Convection

- Water is a key example:
  - Heat at bottom; Hot water rises and cold sinks. This allows the colder water to get to the bottom and continue the cycle.
  - The opposite also occurs on a lake (top cooled).



Conduction

- **Heat is a fluid.**
  - **Due to gravity, a liquid will flow from high to low.**
  - **Heat too flows from a higher to lower energy source.**
- **Conduction occurs when a material is touching a source with more heat.**



Radiation

- **Energy given off by electromagnetic rays.**
  - **Black objects absorb radiation, White objects reflect it.**