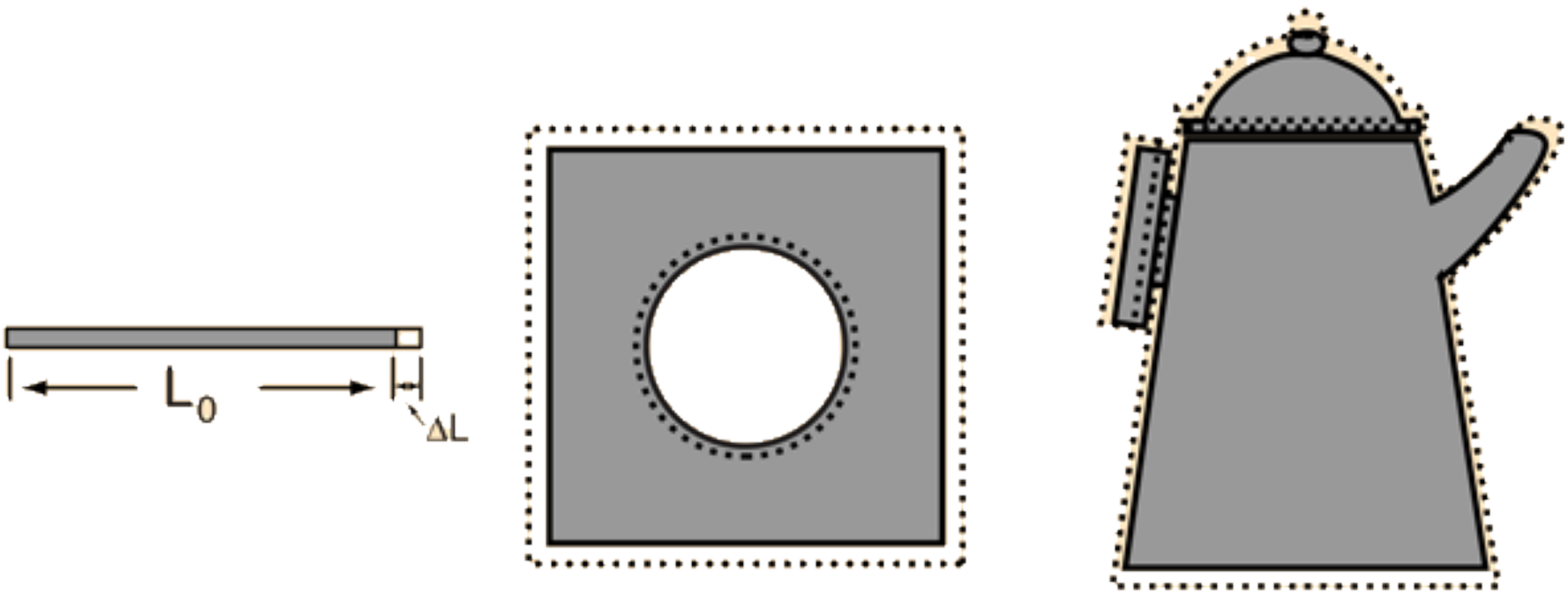
College Physics I: 1511 Mechanics & Thermodynamics

Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

Announcements

- All students have now taken exam 2
- The exam and solutions are posted on the "Notes" page
- Let me know if any questions

Thermal Expansion (or Contraction)



Linear expansion

$$\frac{\Delta L}{L_0} = \alpha \Delta T$$

Area expansion

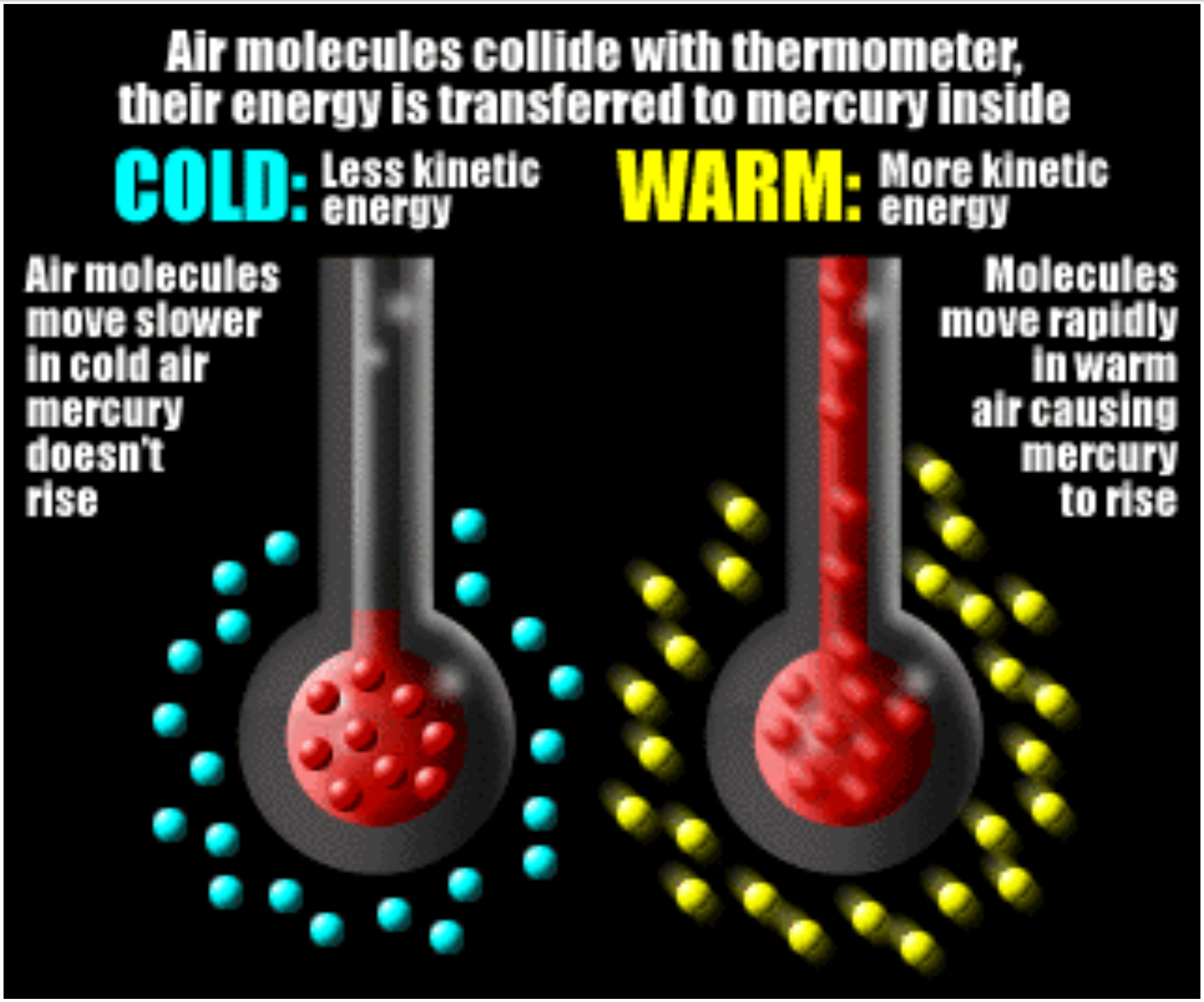
$$\frac{\Delta A}{A_0} = 2\alpha \Delta T$$

Volume expansion

$$\frac{\Delta V}{V_0} = 3\alpha \Delta T$$

$$= \beta \, \Delta T$$

Thermometers



Definition: Heat

- Heat is thermal energy in transit (flowing from hot to cold) from one body or substance to another
- The symbol usually used for heat is Q
- Units of heat are Joules

Heat Vs. Temperature

- Temperature is a measure of the average thermal energy of a substance
- Heat is the transfer of thermal energy
  - At least, this is the physics definition!
- This seems strange, but actually makes sense
  - You cannot feel the thermal energy of a substance unless it is transferred to you!

Heat is Energy

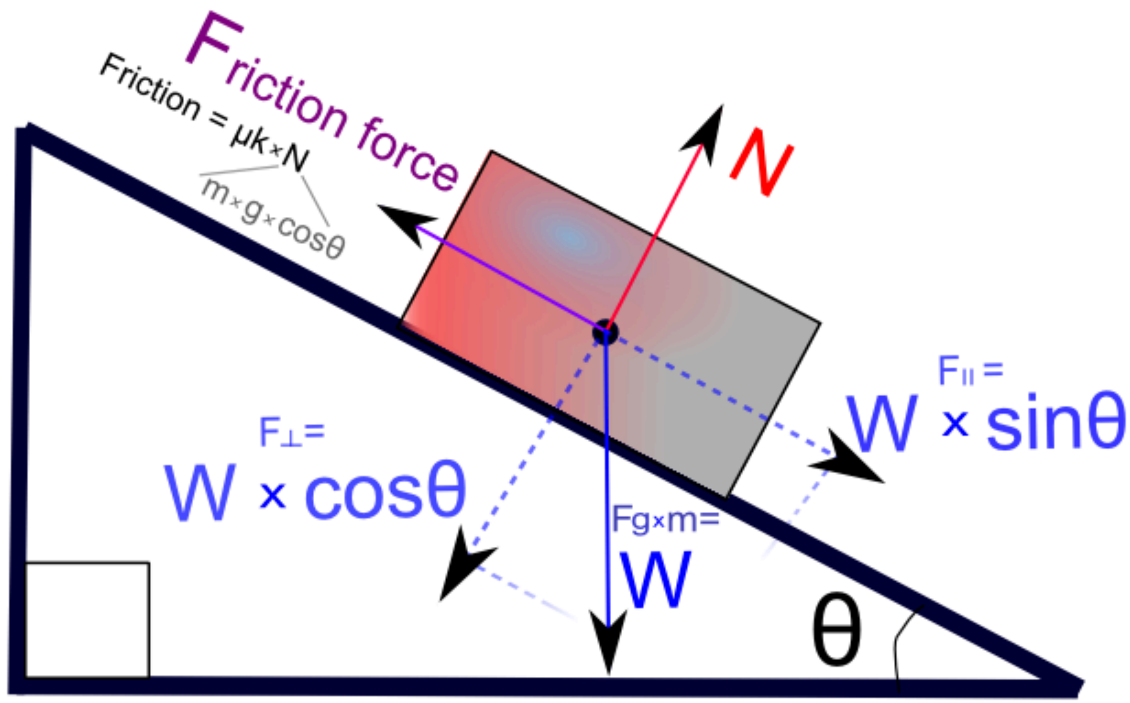
$$\underbrace{E}_{\substack{\text{Total}\\\text{mechanical}\\\text{energy}}} = \underbrace{\tfrac{1}{2}mv^2}_{\substack{\text{Translational}\\\text{kinetic}\\\text{energy}}} + \underbrace{\tfrac{1}{2}I\omega^2}_{\substack{\text{Rotational}\\\text{kinetic}\\\text{energy}}} + \underbrace{mgh}_{\substack{\text{Gravitational}\\\text{potential}\\\text{energy}}} + \underbrace{\tfrac{1}{2}kx^2}_{\substack{\text{Elastic}\\\text{potential}\\\text{energy}}}$$

When mechanical energy is not conserved, where does the excess energy go??

Often it goes into heat!

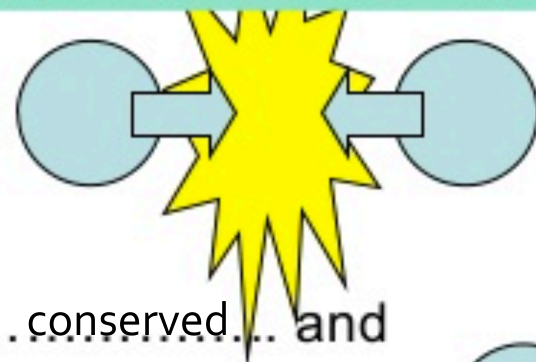
Non-Conservative Forces

- $\Delta E = W_{NC}$



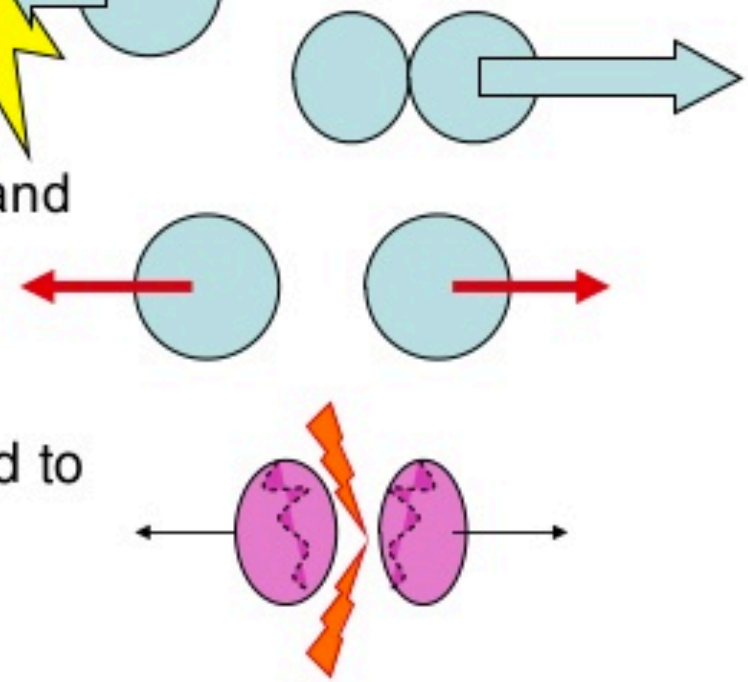
Inelastic Collisions

Elastic & Non-elastic Collisions



Collisions can either be:

a. **Elastic** (…KE.. is …conserved… and no energy lost)



b. ***Inelastic*** (……KE……… is ……lost…… - some is converted to heat, sound etcJ

Heat and Temperature

- Question: What happens to the temperature of an object or substance when you transfer heat to it?
- The answer depends on the phase of the material and its structure

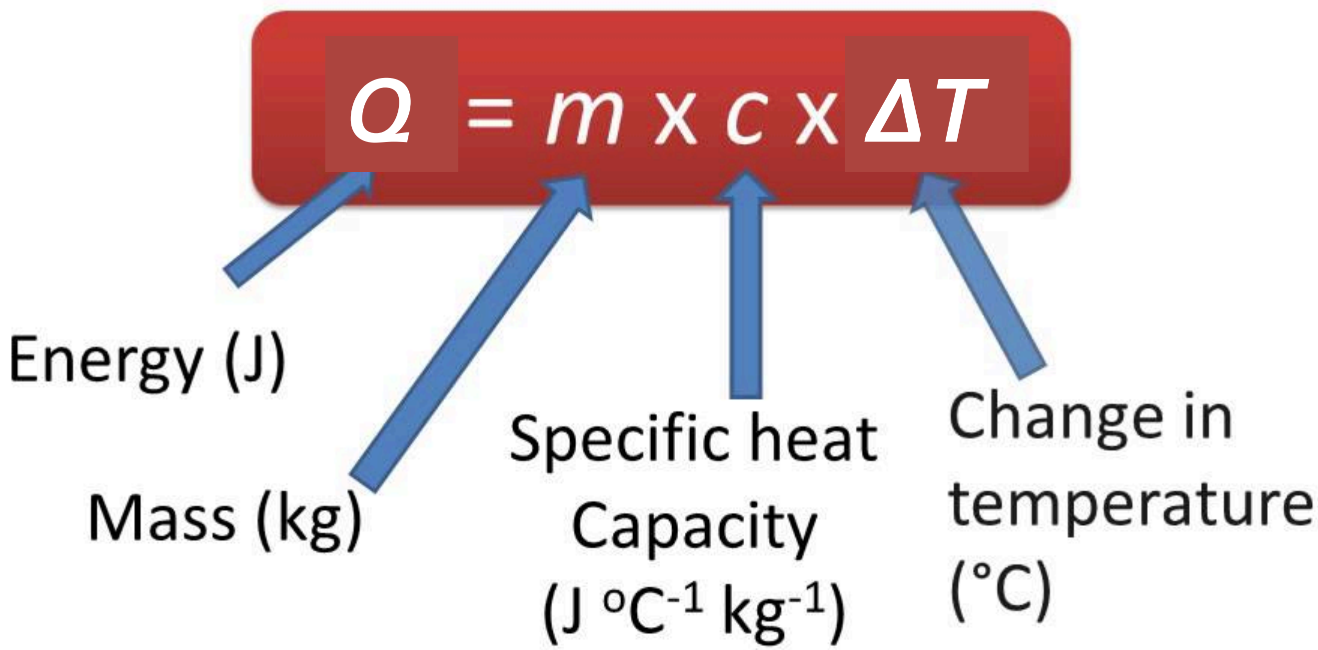
Definition: Specific Heat Capacity

- The specific heat capacity c is the ratio between the heat added and the product of the object's mass and the resulting temperature change
- $c = Q/(m\Delta T)$
- Units of c are J/(kg °C)

Specific Heat Equation

Specific heat capacity

- This is the amount of energy needed to raise the temperature of 1kg of a material by 1°C



Specific Heat Capacity

Material	Specific Heat Capacity [J/kg°C]
Water	4200
Alcohol	2500
Ice	2100
Aluminium	900
Concrete	800
Glass	700
Steel	500
Copper	400

Don't use these values in homework problems – only use values given in book!

Concept Check

- I heat up two beakers, one which has only water, and one which has a block of lead in it (and less water). Which one will show a faster rise in temperature?

A. Beaker with water
B. Beaker with lead
C. Both will rise at the same rate

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$$Q = mc\Delta T$$

$$\Rightarrow \Delta T = Q/(mc)$$

- bigger c means smaller ΔT
- takes more heat to change temperature if c is big

Heat Capacity

Material has a high specific heat capacity	Material has a low specific heat capacity
It takes a longer time to be heated.	It becomes hot very quickly.
It does not lose heat easily.	It lose heat easily.
It is a heat insulator.	It is a good heat conductor.
Smaller rise in temperature	Greater rise in temperature

Thermal Properties of Matter

Cooking Tips

- Metal = great for cooking
  - Heats up quickly, transfers energy to food being cooked
- Ceramics = better for baking
  - Heat up slowly, distribute heat evenly
- Ceramics = better for serving plates, cups, etc.
  - Don’t get hot to the touch as easily, don’t leach heat away from your food, keep liquids warm longer

Heat Capacity of Water

- The specific heat capacity of water is ~4186 J/(kg °C)
- Water has a very high heat capacity due to the strength of multiple hydrogen-oxygen bonds between water molecules

Other Units of Heat

- One kilocalorie = 4186 J
- A kilocalorie is more commonly known as a "food calorie"
  - When you see # of calories on an item of food (in the US, at least), they are actually kilocalories
- One kilocalorie is the amount of heat needed to raise one kg of water by 1 Celsius degree

Concept Check

- If you put a hot 1 kg bar of metal (c = 500 J/(kg °C)) into 1 kg of cold water (c ~4200 J/(kg °C)), how does the final temperature of the metal+ water compare to the initial temperatures?

A. Final temperature halfway between initial temperatures of water and metal
B. Final temperature closer to initial temperature of water
C. Final temperature closer to initial temperature of metal
D. Final temperature equal to initial temperature of water

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Say $T_{m_0} = 100$ C

$T_{w_0} = 40$ C

T_f = final temperature

$$\Delta T_w = T_f - T_{w_0}$$

$$\Delta T_m = T_f - T_{m_0}$$

$$Q_w = m_w c_w \Delta T_w$$
$$Q_m = m_m c_m \Delta T_m$$

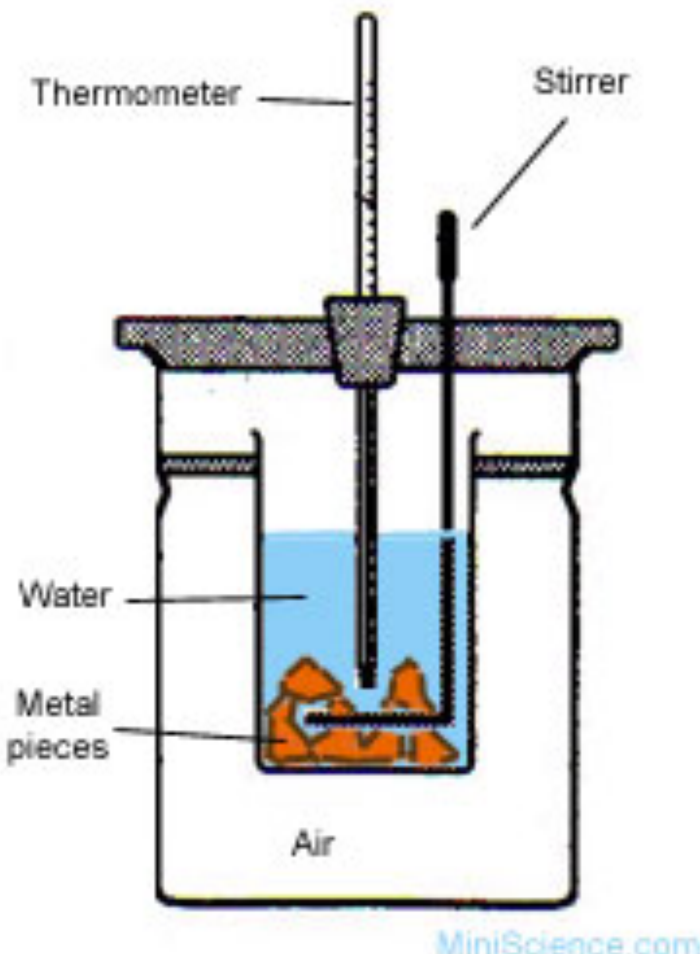
$$Q_w = -Q_m$$

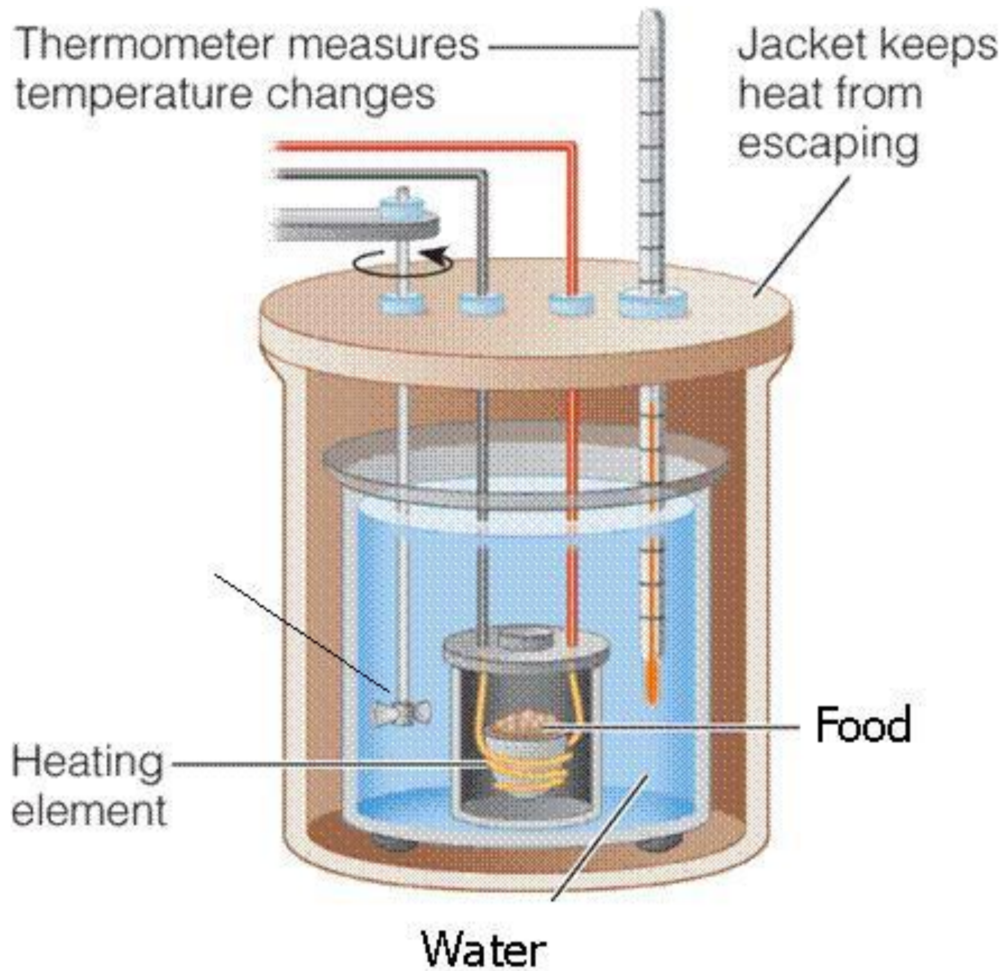
$$m_w c_w \Delta T_w = -m_m c_m \Delta T_m$$

$$1 \cdot 4200 \cdot (T_f - 40) = 1 \cdot 500 \cdot (100 - T_f)$$

$$4200 T_f - 4200 \cdot 40 = 500 \cdot 100 - 500 T_f$$
$$4700 T_f = 500 \cdot 100 + 4200 \cdot 40$$
$$= 218{,}000$$
$$\Rightarrow T_f = \boxed{46.4°C}$$ Much closer to water

Calorimetry





Advance Warning

- Specific heat capacity depends on the phase of a material
- For a gas, it also depends on whether you hold the gas at constant volume or at constant pressure

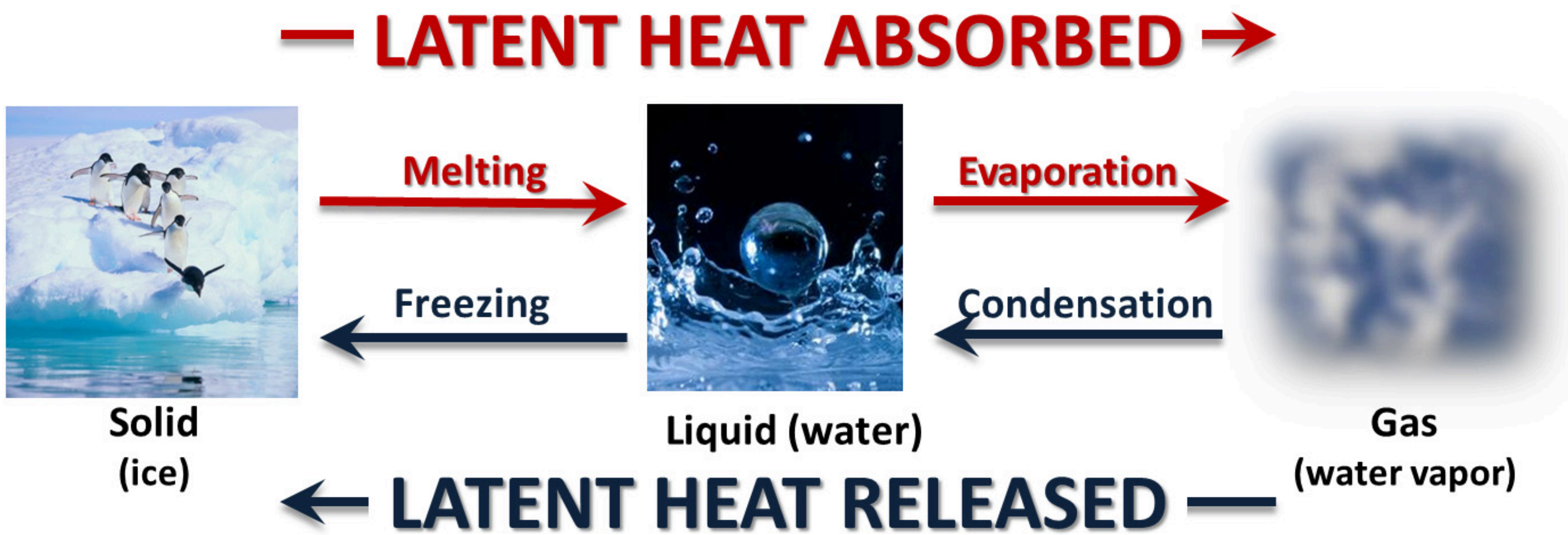
Latent Heat

- In addition to the heat needed to change the temperature of a substance, it also takes heat to change the phase of a substance

$$Q = mL$$

Q = Heat Change	(J or Nm)
m = mass	(kg)
L = specific latent heat	($J\ kg^{-1}$)

Latent Heat Flow



Heating/Cooling Profile