# HEAT

HEAT $\frac{[M][L]^2}{[T]^2} \equiv Q$

- HEAT IS A MEASURE OF ENERGY TRANSFER
- HEAT REPRESENTS A KIND OF MICROSCOPIC COMPONENT OF ENERGY TRANSFER
- NOTHING POSSESS HEAT

SPECIFIC HEAT $\frac{[L]^2}{[T]^2[K]} \equiv C = \frac{1}{m}\frac{\Delta E}{\Delta T}$ ← RESPONSE FUNCTION

- IF $W=0$ THEN $\Delta E = Q$

$$C = \frac{1}{m}\frac{Q}{\Delta t}$$

- FOR A GIVEN MASS OF A SUBSTANCE, IT IS A MEASURE OF HOW MUCH ENERGY PER TEMPERATURE THE SUBSTANCE CAN ABSORB/EMIT
- IT IS A MATERIAL PROPERTY
- IN GENERAL, IT IS A FUNCTION OF TEMPERATURE, BUT IS ROUGHLY CONSTANT OVER A LIMITED RANGE OF TEMPERATURES

## PHASE TRANSITIONS

- THE TRANSITION FROM A GAS TO A LIQUID, FROM A LIQUID TO A SOLID, etc... IS CALLED A PHASE TRANSITION
- IT TAKES SOME ENERGY (HEAT OF TRANSFORMATION) FOR A SUBSTANCE TO CHANGE ITS PHASE EVEN THOUGH THE TEMPERATURE REMAINS CONSTANT.

$Q_F = \pm m L_F$ ← LATENT HEAT OF FUSION

ADD ± AD HOC BASED ON
SOLID → LIQUID (+)
LIQUID → SOLID (−)

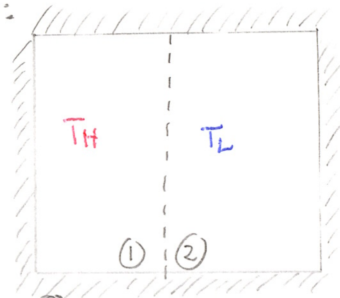
$Q_V = \pm m L_V$ ← LATENT HEAT OF VAPORIZATION

ADD ± AD HOC BASED ON
LIQUID → VAPOR (+)
VAPOR → LIQUID (−)

# CALORIMETRY

- IN AN ISOLATED SYSTEM, CONSISTING OF MULTIPLE BODIES AT DIFFERENT TEMPS, ENERGY WILL BE TRANSFERRED VIA HEAT UNTIL THE SYSTEM IS IN THERMAL EQUILIBRIUM

- EXAMPLE:




INSULATION → ISOLATED:
- NO Q LOSS TO SURROUNDINGS
- NO m LOSS TO SURROUNDINGS

- WITH $Q_{TOTAL} = 0$ AND $W_{TOTAL} = 0$

ALL EQUIVALENT:

$$\sum \Delta E_{TH} = 0$$

$$\Delta E_1 = -\Delta E_2$$

$$Q_1 = -Q_2$$ ~ "HEAT LOST BY 1/2 IS HEAT GAINED BY 2/1"

$$Q_1 + Q_2 = 0$$

$$\sum Q = 0$$

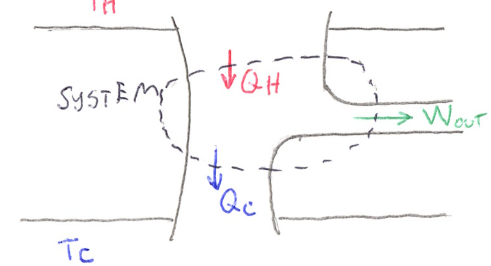
## HEAT TRANSFER MECHANISMS

- CONDUCTION – TRANSFER OF ENERGY VIA CONTACT AND MOMENTUM TRANSFER FROM THERMAL VIBRATIONS
- CONVECTION – TRANSFER OF ENERGY BY A HIGHER ENERGY PARTICLE PHYSICALLY MOVING TO A LOWER ENERGY DENSITY AREA
- RADIATION – TRANSFER OF ENERGY VIA ELECTROMAGNETIC RADIATION

*ALL OBJECTS W/ $T > 0$ RADIATE

# HEAT ENGINES

- USE HEAT TO DO WORK




- 1ST LAW $\Delta E_{TH} = Q + W$ IF $\Delta E_{TH} = 0$ → STEADY STATE

$$\sum Q + \sum W = 0$$

$$Q_H + Q_C + W_{OUT} = 0$$

$$\underbrace{Q_H}_{IN} = -\underbrace{(Q_C + W_{OUT})}_{OUT}$$

↑ USELESS LOST ENERGY

- EFFICIENCY (e)

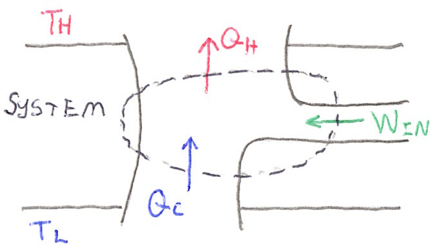
$$e = \frac{GET}{PAY} < 1$$

EXAMPLE: HEAT ENGINE $e = \frac{|W_{OUT}|}{|Q_H|} = \frac{|Q_H| - |Q_C|}{|Q_H|}$

THEORETICAL MAX $e_{MAX} = 1 - \frac{T_C}{T_H}$

## HEAT PUMPS

- DO WORK TO TRANSFER HEAT FROM COLDER AREA TO HOTTER AREA




- 1ST LAW $\Delta E_{TH} = Q + W$ IF $\Delta E_{TH} = 0$ → STEADY STATE

$$Q_H + Q_C + W_{IN} = 0$$

$$\underbrace{-Q_H}_{OUT} = \underbrace{Q_C + W_{IN}}_{IN}$$

- COEFFICIENT OF PERFORMANCE (COP)

$$COP_{HEAT} = \frac{|Q_H|}{W_{IN}} = \frac{|Q_H|}{|Q_H| - |Q_C|} \quad \left(COP_{HEAT\,MAX} = \frac{T_H}{T_H - T_L}\right)$$

$$COP_{COOL} = \frac{|Q_C|}{W_{IN}} = \frac{|Q_C|}{|Q_H| - |Q_C|} \quad \left(COP_{COOL\,MAX} = \frac{T_C}{T_H - T_C}\right)$$