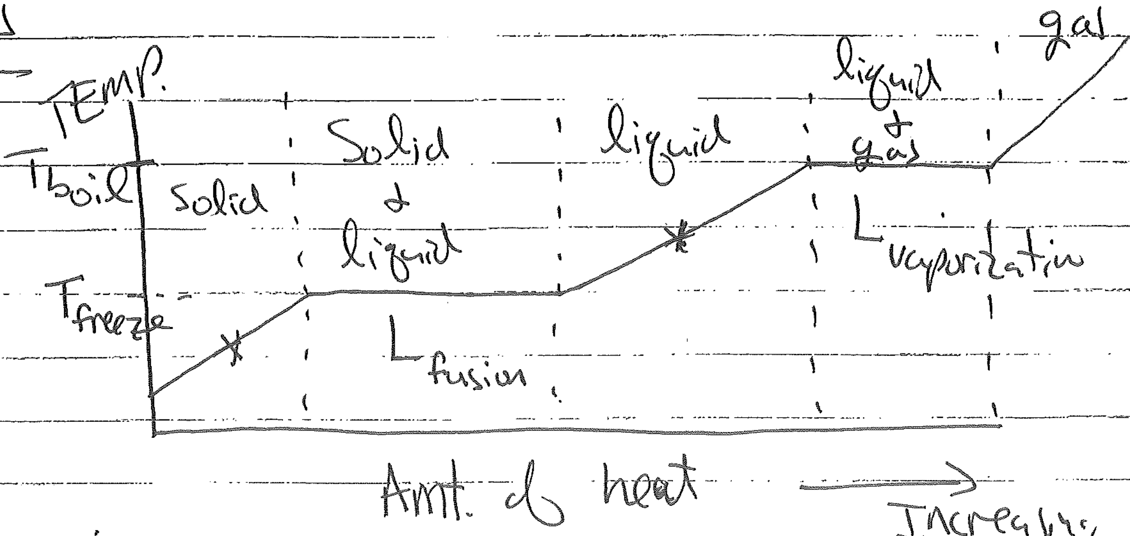
(1400's) **Historical "Heat"** (believed different from Energy) 1800's

Eng. units
- *calorie (cal)
- Food Calorie (Cal) ☺
- *B.T.U.

joules

Empirical RESULTS



Phase transitions: $Q = m L$ *

- Q ← amt. of heat
- m ← mass
- L ← Latent (hidden) heat

Everywhere else: $Q = m c \Delta T$ *

- c ← specific heat

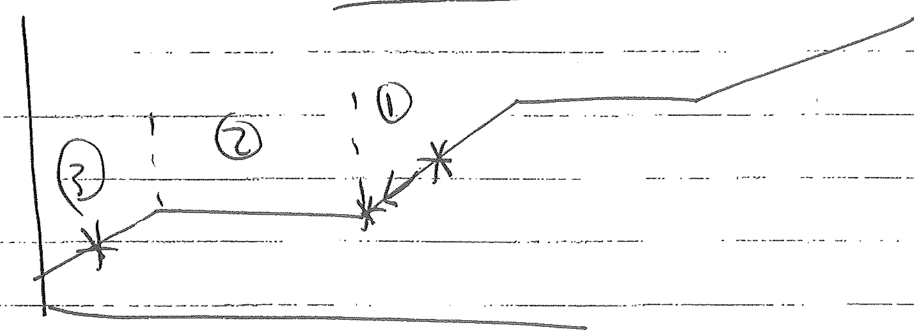
* Match units ☺
Recall ⇒ ΔT is same in Kelvin and Celsius

EX: 10 kg of a material is @ 30°C and is a liquid. How much heat must be removed to turn it into a solid @ 5°C?

$c_{liquid} = 2.04 \ J/kg°C$ $T_{freeze} = 10°C$

$L_{fusion} = 5900 \ J/kg$ $c_{solid} = 2.5 \ J/kg°C$

$$\boxed{-59{,}533 \text{ joules}}$$



(1) $Q = mc\Delta T = 10(2.04)(10-30) = -408 \ J$

(2) $Q = mL = 10(5900) = -59000$

(3) $Q = mc\Delta T = 10(2.5)(5-10) = -125$

$\Delta Q_{TOTAL} = -59533 \ J$

EMPERICAL (☺) (ch. 17)

Thermal Expansion / Contraction

1-d

$$\Delta L = \alpha L_0 \Delta T$$ $\boxed{\text{Eqn. 17.6}}$

ΔL: change in length

α: coeff. of linear expansion

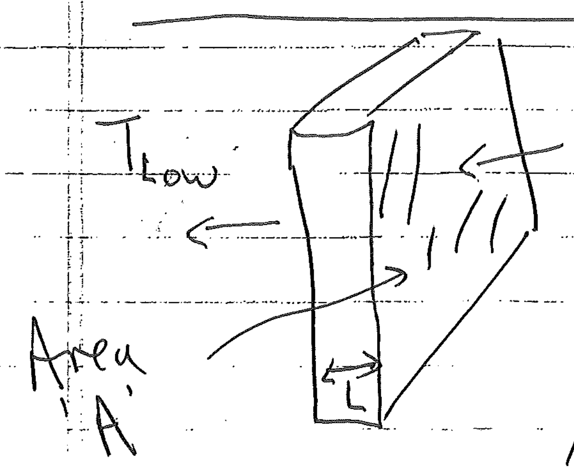
L_0: initial length

"Young's Modulus"

$\boxed{\text{Eqn. 17.12}}$ Couple w/ Stress-Strain relations! ☺

SEE Posted hand out under "Pages"

Heat Transfer Rate $\left(\frac{\Delta Q \text{ or } Q}{\text{time}} \right)$



$$\left(\frac{\Delta Q}{\Delta t}\right) = K \frac{A \, \Delta T}{L}$$

$\left(\frac{\Delta Q}{\Delta t}\right)$: "H" "P"

K: Thermal Conductivity

Joules/sec ⇒ Watt (Power)

Multiple layers:

$$\frac{\Delta Q}{\Delta t} = \frac{A\,\Delta T}{\left(\frac{L_1}{k_1} + \frac{L_2}{k_2} + \cdots\right)} = \frac{A\,\Delta T}{(R_1 + R_2 + \cdots)}$$

↑ "R-value"

RECALL: Conservation of Energy ☆

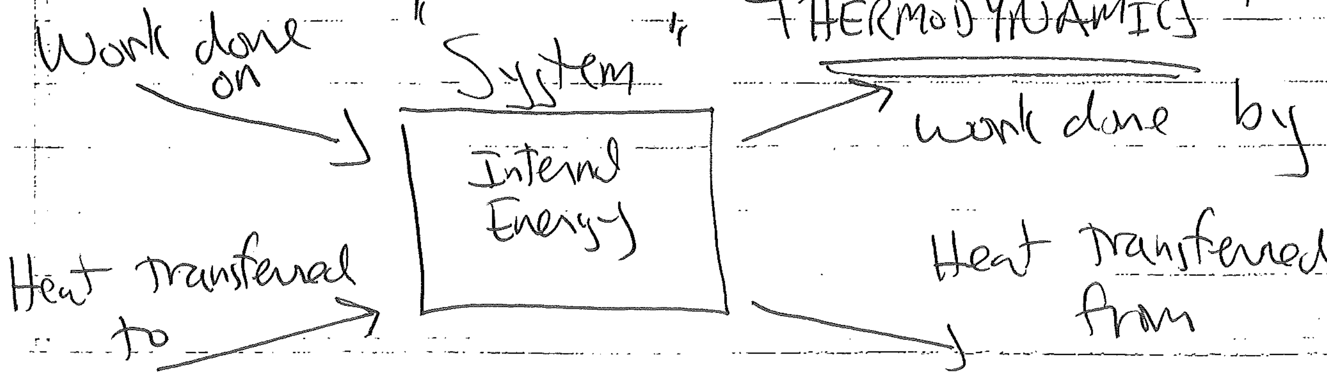
- Forces do work to transform and/or transfer energy.
- Amt. of work done ≡ the amt. of energy transformed/transferred.

☆ Q.) An ice cube is placed on a sunny sidewalk. It melts. What force has done what work??

On microscopic scale ⟹ large #'s of particles. Use statistics to describe behavior.

Force, work ⟹ Temperature, Heat

"THERMODYNAMICS"



"System" ⇒ All things for which you are tracking the energy/energy xfr.

"Internal Energy" ⇒ Σ(microscopic K.E., P.E.)

1st Law of Thermodynamics

$$\Delta E = Q \pm W$$

(ΔU) Change in internal energy of system

Cycle a substance

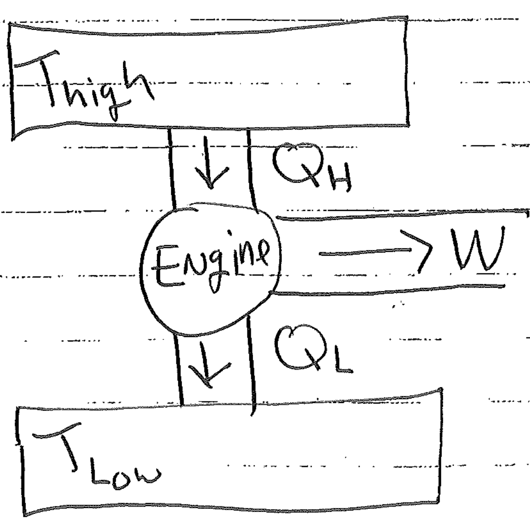
$\Delta E \cong 0$

$\boxed{Q = W}$

HEAT ENGINES: Takes advantage of... Nature's desire to move heat from hot to cold.

DANGER!!!

Q_H, W, Q_L ALL POSITIVE



1st Law

$$Q_H = W + Q_L$$

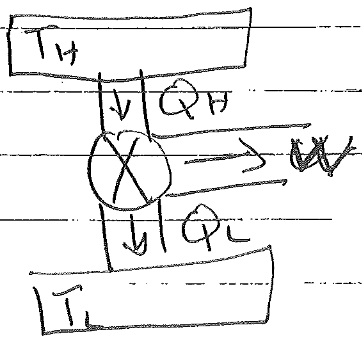
$$\text{Efficiency} = \frac{\text{get}}{\text{pay}}$$

$$\varepsilon = \frac{W}{Q_H}$$

Aside: $\varepsilon = \frac{Q_H - Q_L}{Q_H}$

EX] A heat engine takes in 360 J from a hot reservoir and performs 25 J of work per cycle.

Find the efficiency and the energy expelled to the cold reservoir (per cycle)



$Q_H = 360$ J

$W = 25$ J

1^{st}: $Q_H = W + Q_L$

$\therefore Q_L = Q_H - W = 335$ J

$\varepsilon = \frac{W}{Q_H} = \frac{25}{360} = 0.069$

6.9%

If each cycle takes 0.01 seconds, what is the power output of this engine?

$$\text{Power} = \frac{\text{Energy delivered (work done)}}{\text{time interval}}$$

$$P = \frac{25\text{ J}}{0.01\text{ sec}} = 2500 \text{ watts}$$

At what rate must energy be supplied to the engine from the hot reservoir?

$\frac{360\ J}{0.01\ sec} \Rightarrow 36{,}000\ \frac{joules}{sec}$ must be drawn from hot reservoir.

What is the BEST that can be done?

Sadie Carnot (1796-1832)

1824- "On the Motive Power of Fire"

Modern definition of WORK!!

America → James Watt → 5-7%

"Carnot"/"Ideal" engine has a maximum efficiency: Replace the Q's w\ Kelvin temps.

$$\text{Efficiency} = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{Q_L}{Q_H}$$

$$\varepsilon_{Carnot} = 1 - \frac{T_L}{T_H}$$

(IC is typically ≈ 30%) (?)

Why use electric motors? (instead of Heat Engines)

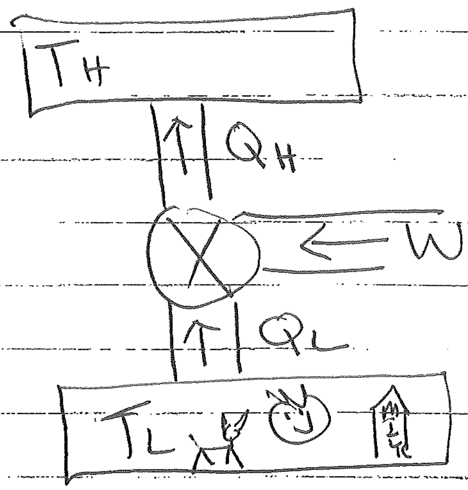
$T_H = 500\ C = 773\ K$

$T_L = 22\ C = 295\ K$

$$\varepsilon_{ideal} = 1 - \frac{295}{773} = 0.62 \quad (Ch. 20.2)$$

62%

Freezers / Fridge / A.C.'s



1st Law: $Q_L + W = Q_H$

"efficiency" = $\frac{\text{get}}{\text{pay}} = \frac{Q_L}{W}$
C.O.P.

If Freezer / Fridge / A.C.

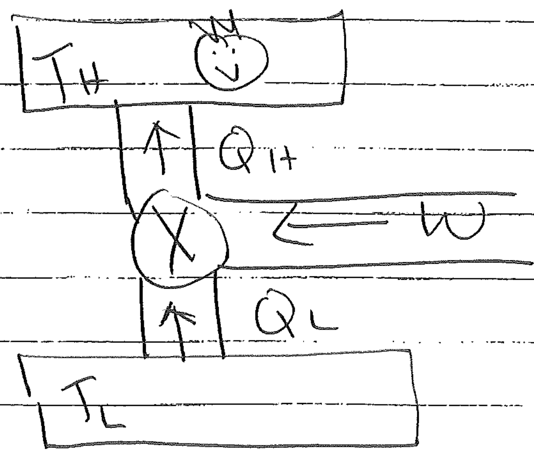
Greater than 1. ☹ ⇒ "Coefficient of Performance"
C.O.P.

$$C.O.P. = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L}$$

Ideal??

$$C.O.P_{Carnot} = \frac{T_L}{T_H - T_L}$$

HEAT PUMPS



1st: $W + Q_L = Q_H$

$$C.O.P. = \frac{\text{get}}{\text{pay}} = \frac{Q_H}{W}$$

$$C.O.P. = \frac{Q_H}{Q_H - Q_L}$$

$$C.O.P._{IDEAL} = \frac{T_H}{T_H - T_L}$$