Ch 11: Using Energy

Any time Energy is transformed, like $U_g \leftrightarrow K$, some mechanical energy is lost to thermal energy...

→ not all thermal energy can be converted back to mechanical energy (U,K).

Efficiency: a relative measure of how much usable energy there is after a transformation or after work is done on/by a system...

$$\varepsilon = \frac{\text{What you get}}{\text{How much you put in}} \Rightarrow$$

you do work $W = \Delta U_g + E_{th}$

but only U_g is available for future use,

$$\therefore \quad \varepsilon = \frac{\Delta U_g}{\Delta U_g + E_{th}} < 1$$

→ some thermal energy can be used to do work, but not 100%.

So, $\varepsilon < 1$ always!

Chemical Energy

E_{ch} is often measured by the amount of heat (→ thermal Energy) it can generate when burned, using units of calories

→ they use a device called a calorimeter

$$1 \text{ cal of chemical energy} = 4.190 \text{ J}$$

In food, we use Cal = 1000 cal. So,

$$1 \text{ Cal} = 1000 \text{ cal} = 4190 \text{ J}$$

→ energy needed to raise the temperature of 1 g of H_2O by 1°c ($\Delta T =$ 1°c)

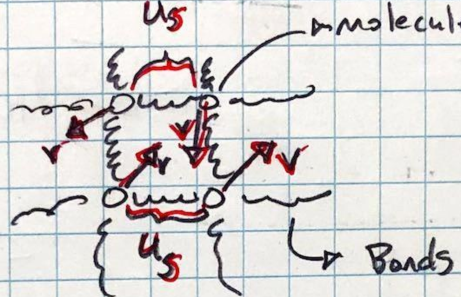
→ the human body generates a lot of heat during motion...! so,

$$\varepsilon = \frac{\Delta U_g + \Delta K}{E_{ch}} \approx 0.25 = 25\%$$

Temperature, Thermal Energy + Heat:

Thermal energy is the **sum** of the kinetic + potential energies of **all** molecules and bonds within a substance,

recall:



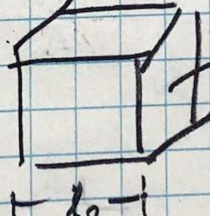
Temperature is an **average** measure of an object's thermal energy

So, a warmer object ($\rightarrow T_1$) can have less thermal energy (than T_2) if its much smaller than the cooler object...

Conceptual:

$\rightarrow T_1$

$\vdash l_1 \dashv$ $\quad V_1 = l_1^3$



$\rightarrow T_2 < T_1$

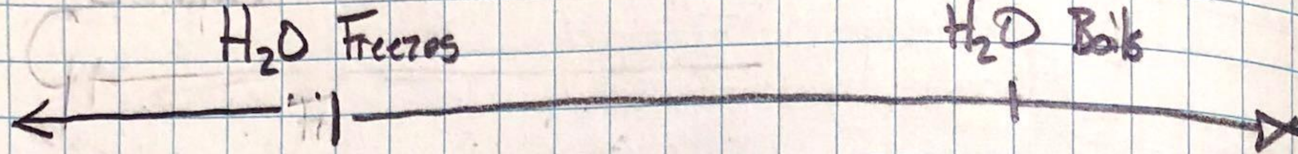
$\vdash l_2 \dashv$ $\quad V_2 = l_2^3 \gg V_1$

Heat $\sim T_1 \cdot V_1$ $\qquad \sim T_2 V_2$

$$H_1 < H_2$$

if
$$\frac{l_1^3}{l_2^3} < \frac{T_1}{T_2}$$

Temperature Scale



Celsius	0°	100°
Fahrenheit	32°	212°

$$\therefore \quad T(°F) = \frac{9}{5} T(°C) + 32$$

$$T(°C) = \frac{5}{9}\left(T(°F) - 32 \right)$$

IF Kinetic energy of all molecules goes to zero... the temperature can not go any lower...

T = Absolute Zero !

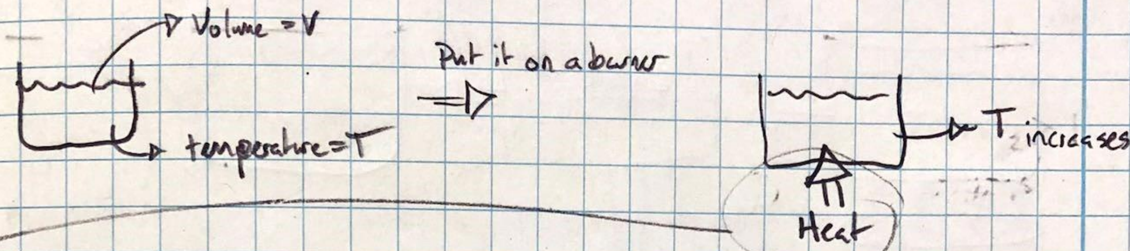
The kelvin scale sets $T(K) = 0$ @ ↑ with the same slope as Celcius

$$\boxed{T(K)} = T(°C) - 273$$

→ **Always** use **Kelvin** for Thermal Energy Problems!

Heat: Measure of total thermal energy in system.

Consider a pot of water:



→ smaller Volumes → T increases faster
Large Vol → T grows slowly
} w/ same input rate $\frac{\Delta E_{th}}{\Delta t}$ = Power

Heat transfers to the water until the water temp = burner temp

→ depends on temp difference $(T_2 - T_1)$

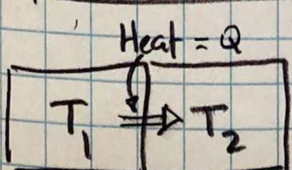
if $(T_2 - T_1) = 0$ ★ Objects are in Thermal Equilibrium!

Q = Heat Energy added to system:

$$\Delta E = W + Q$$

if $\Delta E = \Delta E_{th}$; that is, $\Delta K = 0$, $\Delta E_{chem} = 0$, $\Delta U = 0$ ...

then, $$\boxed{\Delta E_{th} = W + Q}$$ ⟹ 1st Law of Thermodynamics

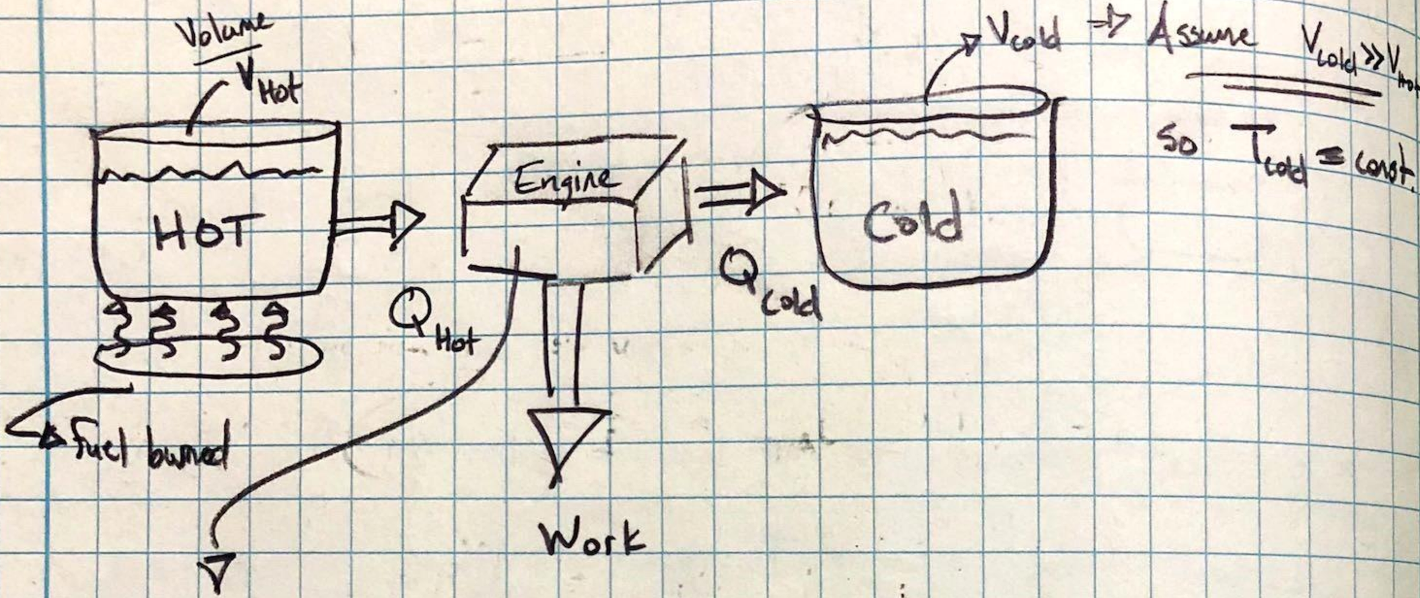


initially $T_1 > T_2$

$\Delta E_{th,2} = Q > 0$, bc $T_1 > T_2$

$\Delta E_{th,1} = -Q < 0$, ∴ Q goes from Hot → Cold

Heat Engine: uses temp difference between two reseviors to do mechanica work...



$$\Delta E_{th} = 0 = Q_{Hot} - W_{out} - Q_{cold}$$

or

$$W_{out} = Q_{Hot} - Q_{cold}$$

In this example, W_{out} is "what you get" and Q_{Hot} is "what it cost"...

$$\therefore \text{Efficiency} = \varepsilon = \frac{Q_{Hot} - Q_{cold}}{Q_{Hot}}$$

$$= 1 - \frac{Q_{Hot}}{Q_{cold}}$$