Thermal energy is dissipated &
hard to transform into other types
so we want to avoid creating too
much if we can

e.g. electrical energy is hard to
store unless converted into other forms

& charge a battery —
convert electrical into
chemical energy

no energy conversion is perfect —
some thermal energy is always created
(at the macroscopic level)

efficiency $e = \frac{\text{what you get}}{\text{what you pay}}$

$= \frac{80J}{100J} = 0.8 = 80\%$

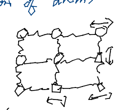
Two reasons for inefficiency
1) the process may be flawed,
or may prioritize other things
e.g. rusty engine
powerful car
– power is obtained at
the expense of efficiency

humans usually convert
chemical energy to kinetic/potential energy
at $e = 25\%$

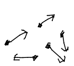
2) fundamental limitations from
physical law
2nd Law of Thermodynamics

What is thermal energy?
— total energy of the random
motion of atoms in an object

• solid
Kinetic Energy &
Spring energy of
vibrating atoms



• fluid
particles
are moving around



thermal energy doesn't
include the bulk
KE

because energy is spread out over
so many particles, difficult
to coordinate it & convert it
into other types of energy

Temperature is a measure of average energy per particle

Usually $E_{th} = \frac{f}{2} N k T$

f: just a constant depending on type of molecules/atoms you have

Boltzmann constant $k = 1.38 \times 10^{-23}$ J/K

N: # of particles

T: temperature ... in Kelvin

Temperature Scales

Celsius & Fahrenheit have an arbitrary 0

0°C: freezing T of water
but not a real zero —
not a lack of anything

in Kelvin, 0K is absolute zero
- no thermal energy
- molecules stop

absolute temperature scale

any time T shows up in an equation, it must be an absolute temperature.

$\underbrace{1\,K = 1\,C^\circ}_{\text{changes in T}}$ but $\underbrace{1\,K = -272^\circ C}_{\text{temperature}}$

ΔT

absolute zero is $-273^\circ C$

water freezes at 0°C 273 K
fall weather 10°C 283 K

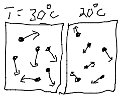
$\Delta T = 10^\circ C - 0^\circ C = 10 C^\circ$
$283K - 273K = 10K$

$300K \rightarrow 27^\circ C \rightarrow 81^\circ F$
"room temperature"

0°C: freezing
10°C: fall
20°C: room temp.
30°C: hot day
40°C: high fever

two objects at different T

T = 30°C 20°C



T↓ T↑

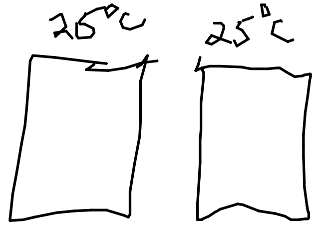
fast molecules will speed up slower molecules & vice versa

flow of energy from hot to cold
This flow is called heat (Q).

Objects don't have heat.
heat is a flow

Heat will flow from hot to cold
high T low T

Heat flows until temperatures are the same



<u>thermal</u> <u>equilibrium</u>

Three types of heat

1) conduction: objects touch
molecules transfer energy
between objects
but molecules don't
change objects

2) convection: hot and cold particles
move around & mix
in a fluid

3) radiation: works across a vacuum
e.g. Sun