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Chapter 2 → Energy is Conserved (1st Law)

State variables, functions
System, surrounding, universe
closed vs. open system

Δ Energy ≡ heat and work
Work ⇒ spring, piston, current
Simplest → P.V.

Heat capacities
Phase changes

Enthalpies ΔH

Thermo - heat/<u>energy</u>
dynamics - change, movement (originally - power, strength)

1st LAW - Energy is conserved (really: mass/energy)

2nd LAW - Entropy of an isolated system always increases
3rd LAW - Entropy of any pure, perfect crystal is 0 at 0K (absolute 0).

Entropy → disorder, randomness (will see more later)

This all speaks of <u>bulk</u> properties, what happens with <u>large</u> numbers of particles.

Statistical thermodynamics shows us that this all follows logically from <u>probability</u>.

<u>MECHANISMS</u> OF ENERGY CONSERVATION →

WE HAVE TO BE <u>QUANTITATIVE</u>:

<u>DEFINITIONS</u>:

SYSTEM: WHAT WE'RE INTERESTED IN

SURROUNDINGS: EVERYTHING ELSE

UNIVERSE = SYSTEM + SURROUNDINGS

1^{ST} LAW ⇒ <u>TOTAL</u> <u>ENERGY</u> OF SYSTEM + SURROUNDINGS DOES NOT CHANGE

Energy may be transferred from system ⇆ surroundings and can be interconverted between different <u>kinds</u> of energy, but the <u>total</u> <u>must</u> remain constant.

TRANSFERS OF ENERGY ≡ Heat → thermal
Work → another way to xfer energy

It is <u>changes</u> of energy which interest us, so it is heat and work which interest us.

MORE DEFINITIONS

<u>OPEN SYSTEM</u>	<u>CLOSED SYSTEM</u>	<u>ISOLATED SYSTEM</u>
Can exchange both matter and energy w/ system	Can exchange energy but not matter	No exchange of any kind

Work – xfer of energy

IMPORTANT

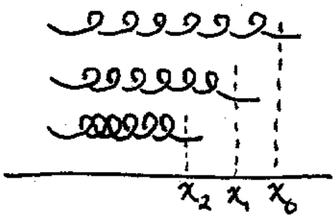
1) Done by the surroundings, on the system (+)
energy of system increases (xferred from surroundings)

2) Done by the systems, on the surroundings (-)
energy of system decreases

Work can be movement against a force

$$\omega = F\Delta x = \int f \partial x$$

Compress a Spring



x_o = relaxed length $(F = 0)$

$$f = k(x - x_o)$$

$\therefore$

$$\omega = \int_{x_1}^{x_2} k(x - x_o)\partial x = k\int_{x_1}^{x_2}(x - x_o)\partial x$$

$$= k\left[\tfrac{1}{2}x^2 - x_o x\right]_{x_1}^{x_2}$$

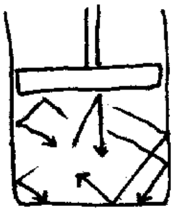
$$= k\left[\tfrac{1}{2}(x_2^2 - x_1^2) - x_o(x_2 - x_1)\right]$$

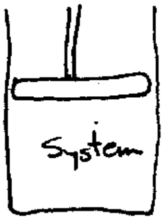
$$= k\left[\frac{(x_2 - x_1)(x_2 + x_1)}{2} - x_o(x_2 - x_1)\right]$$

$$= k(x_2 - x_1)\left[\frac{x_2 + x_1}{2} - x_o\right]$$

Analogy to muscle fibers?

Similarly: $P\Delta V$





Instead of force × displacement in one direction,
we have pressure × ΔVolume
(Force/area)

$$w = -\int_{V_1}^{V_2} P_{op}\,\partial V$$

P_{op}: opposing pressure

Why <u>negative</u>?
Compression ≡ decrease in volume = work done <u>on</u> system
(−) (+)

If P ≈ constant, the integral is <u>easy</u>.

$$w_p = -P_{op}(V_2 - V_1) \Rightarrow \text{Work done ON the system}$$

work <u>at constant pressure</u>
(to simplify integral)

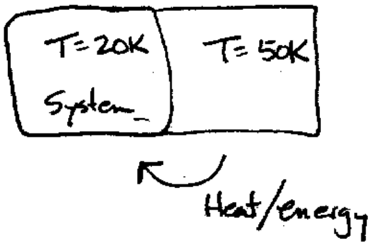
<u>Check</u>: compression ⇒ $V_2 < V_1$

∴ w_p ≡ positive

<u>Exercise</u>:

Work through the examples.
Gravity, electrical, friction

HEAT - Xfer of energy spontaneously



Heat xferred to the system
energy of system increases (E of surroundings decreased)

Heat xferred from the system
Energy of system decreases.

HOW TO DESCRIBE → Heat capacity of the system

$$q = \text{heat (xferred)} = \int_{T_1}^{T_2} C\,\partial T = C\,(T_2 - T_1)$$

↑ if C is temperature-independent

FOR
PURE CHEMICAL SUBSTANCE

MOLAR HEAT CAPACITY = heat capacity per mole
Table 2.1 lists common

VARIABLES OF STATE

We just saw how the energy transferred can be calculated by knowing how one got from state A to state B.

Often (ie. for state variables) you don't need to know how.

State variables describe the state of the system.

Examples P, V, T, E, n

and any simple combination of the above

e.g. $H = \underbrace{E + PV}_{\text{state variables}}$

EQUATIONS OF STATE

Examples $PV = nRT$ ⇐ all are state variables (or constants)

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