College Physics I: 1511 Mechanics & Thermodynamics

Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

Announcements

- HW grades in ICON today
- Lab grades in ICON this weekend

- Please fill out evaluations!
  - Completion rate 27% as of 12/9
  - Deadline Saturday 12/10

- Final 8:00-10:00 pm in LR1 on Monday 12/12

The Five Most Important Concepts

1. Kinematics
   A. Translational
   B. Rotational

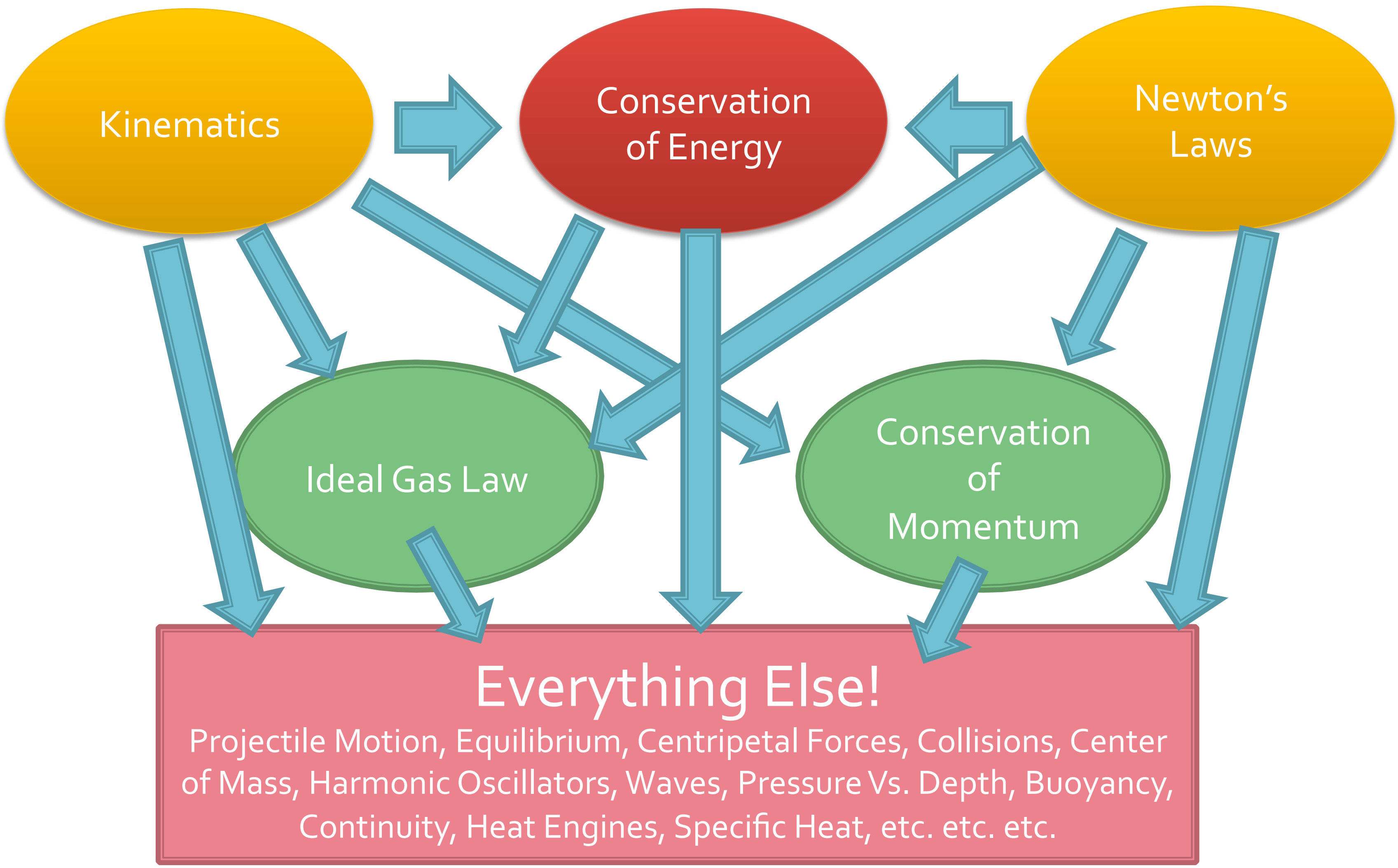
2. Newton's Laws

3. Conservation of Energy
   A. Kinetic Energy
   B. Potential Energy
   C. Work
   D. Heat
   E. Temperature

4. Conservation of Momentum

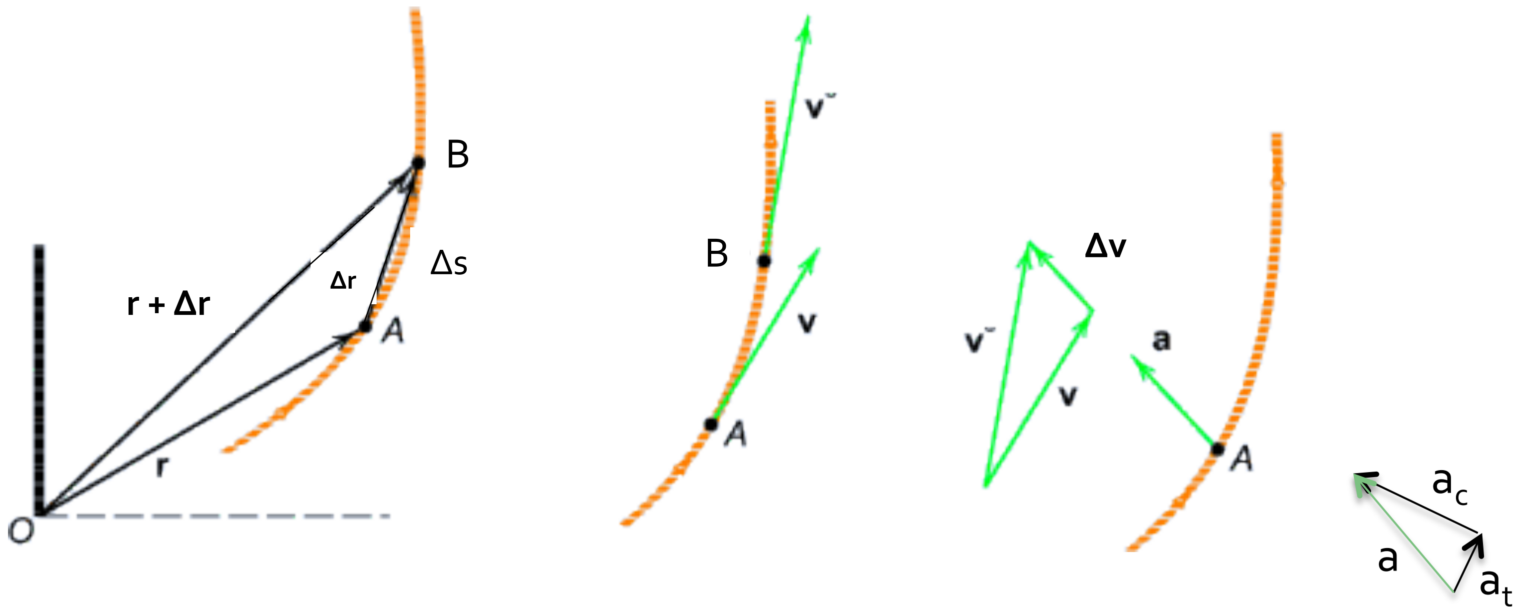
5. Ideal Gas Law and Processes

Physics Concept Flow Chart



Kinematics is the Start

- Kinematic Variables



$$\langle \vec{v} \rangle = \frac{\Delta \vec{r}}{\Delta t} \qquad \langle \vec{a} \rangle = \frac{\Delta \vec{v}}{\Delta t}$$

$$\theta = s/r \qquad \langle \omega \rangle = \frac{\langle v_t \rangle}{r} = \frac{\Delta \theta}{\Delta t} \qquad \langle \alpha \rangle = \frac{\langle a_t \rangle}{r} = \frac{\Delta \omega}{\Delta t} \qquad a_c = v^2/r$$

Kinematics is the Start

- Kinematic Equations

Translational	Rotational
$v = v_0 + at$	$\omega = \omega_0 + \alpha t$
$\Delta x = v_0 t + \frac{1}{2} a t^2$	$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
$v^2 = v_0^2 + 2a\Delta x$	$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

Newton's Laws

Newton's Laws

1. A body will remain at rest, or moving at a constant velocity, unless it is acted on by an unbalanced force.

2. The force experienced by an object is proportional to its mass times the acceleration it experiences:

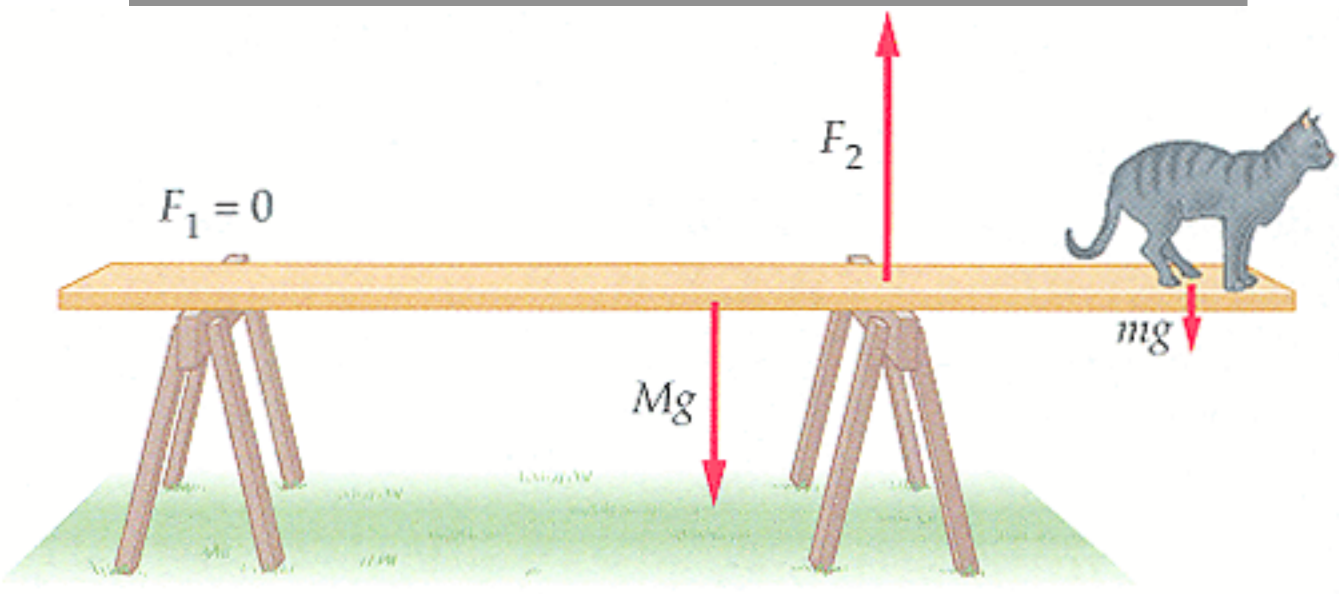
$$\vec{F} = m\vec{a}$$

3. If two bodies exert a force on one another, the forces are equal in magnitude, but opposite in direction:

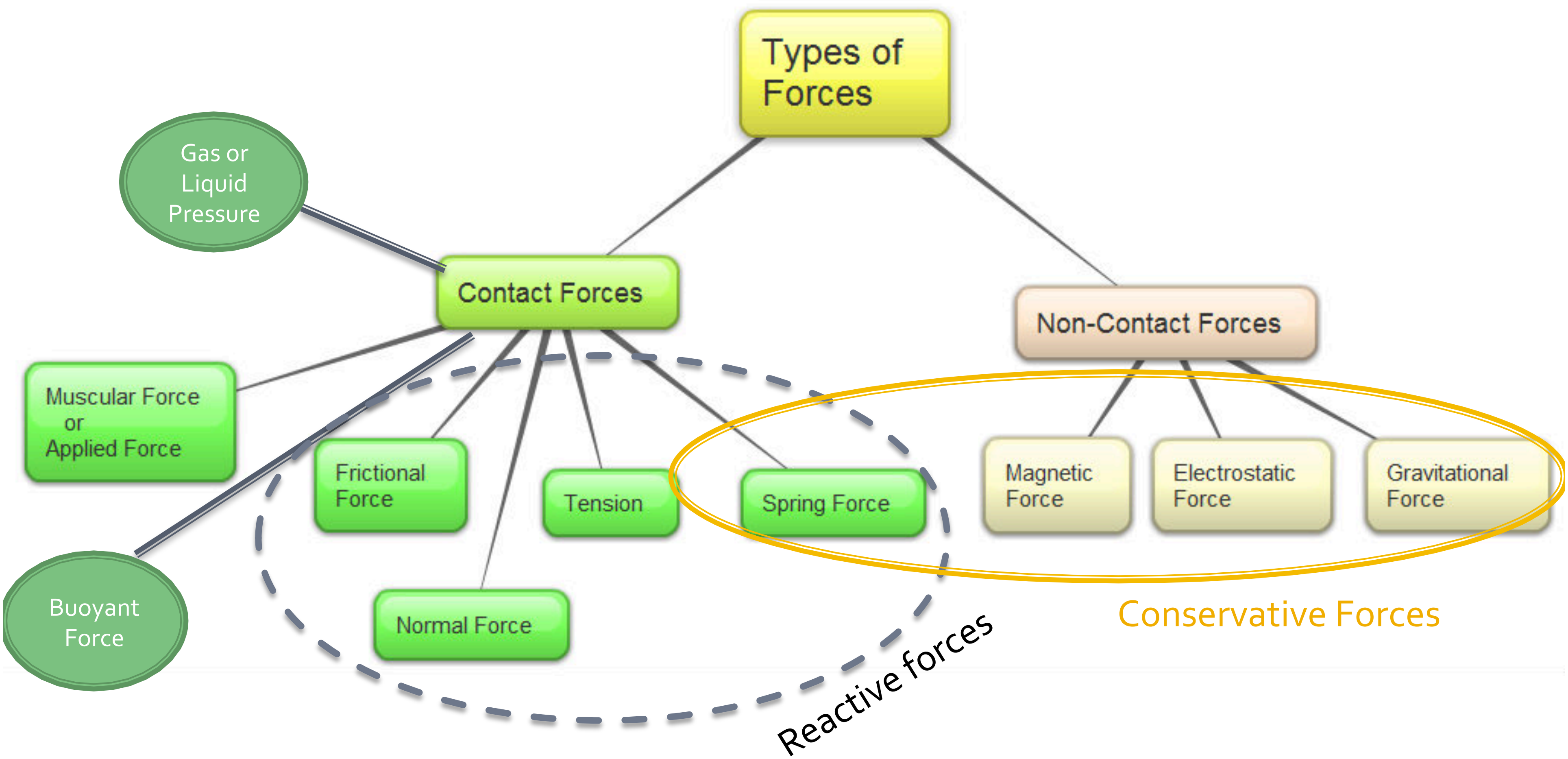
$$\vec{F}_{12} = -\vec{F}_{21}$$

Equilibrium

- Static Equilibrium
  - sum of forces on the body = 0
    - $\Sigma F = 0$
  - sum of torques on the body = 0
    - $\Sigma T = 0$



Forces


Types of Forces
Contact Forces
Non-Contact Forces
Gas or Liquid Pressure
Muscular Force or Applied Force
Buoyant Force
Frictional Force
Tension
Spring Force
Normal Force
Magnetic Force
Electrostatic Force
Gravitational Force
Conservative Forces
Reactive forces

Newton + Kinematics -> Work-Energy Theorem

$$W_{net} = F_{net}\Delta x$$

$$W_{net} = ma\Delta x$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$a\Delta x = \frac{v_f^2 - v_i^2}{2}$$

$$W_{net} = m\left(\frac{v_f^2 - v_i^2}{2}\right)$$

$$W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$\boxed{W_{net} = \Delta KE}$$

Also works for rotational kinematics, but $W = \tau\,\Delta\theta$ and $KE = 1/2\, I\, \omega^2$

Work and Potential Energy

- Work done **on** a body by a conservative force comes from the potential energy PE associated with that force:
  - W and ΔPE are equal and opposite if conservative

Gravitational P.E.

$$W_{gravity} = -mg(\Delta y) = -mg(\Delta h)$$

$$PE_g = -W_{gravity} = mgy = mgh$$

$h = 0$ *is arbitrarily set by you*

E.g. decrease in height

⇒loss in PE

⇒positive W by gravity

⇒increase in KE

Conservation of Mechanical Energy

$$\underbrace{E}_{\substack{\text{Total}\\\text{mechanical}\\\text{energy}}} = \underbrace{\frac{1}{2}mv^2}_{\substack{\text{Translational}\\\text{kinetic}\\\text{energy}}} + \underbrace{\frac{1}{2}I\omega^2}_{\substack{\text{Rotational}\\\text{kinetic}\\\text{energy}}} + \underbrace{mgh}_{\substack{\text{Gravitational}\\\text{potential}\\\text{energy}}} + \underbrace{\frac{1}{2}kx^2}_{\substack{\text{Elastic}\\\text{potential}\\\text{energy}}}$$

Mechanical energy can only change if a non-conservative force acts

A "non-conservative" process is code for a process in which some of the mechanical energy is lost to heat or deformation of the body

$$\Delta E = W_{nc}$$

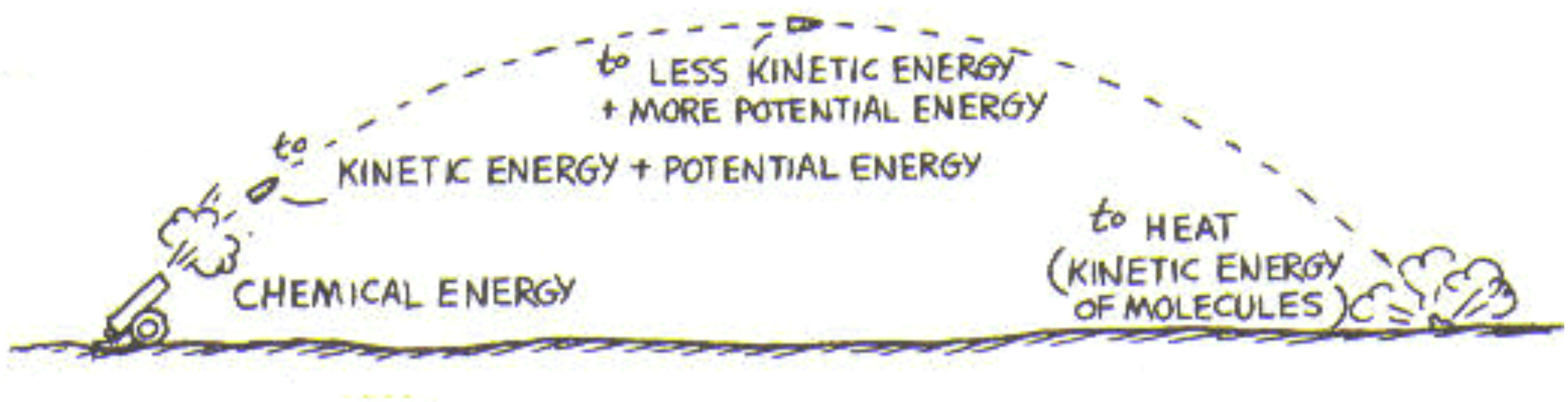
← Nonconservative work done **on** body

Conservation of Total Energy

$$\Delta U \;=\; Q \;(-)\; W$$

ΔU	Q		W
Energy stored or Energy stores Lost	Energy added *to*		Energy used *by*

Nonconservative work done **by** body

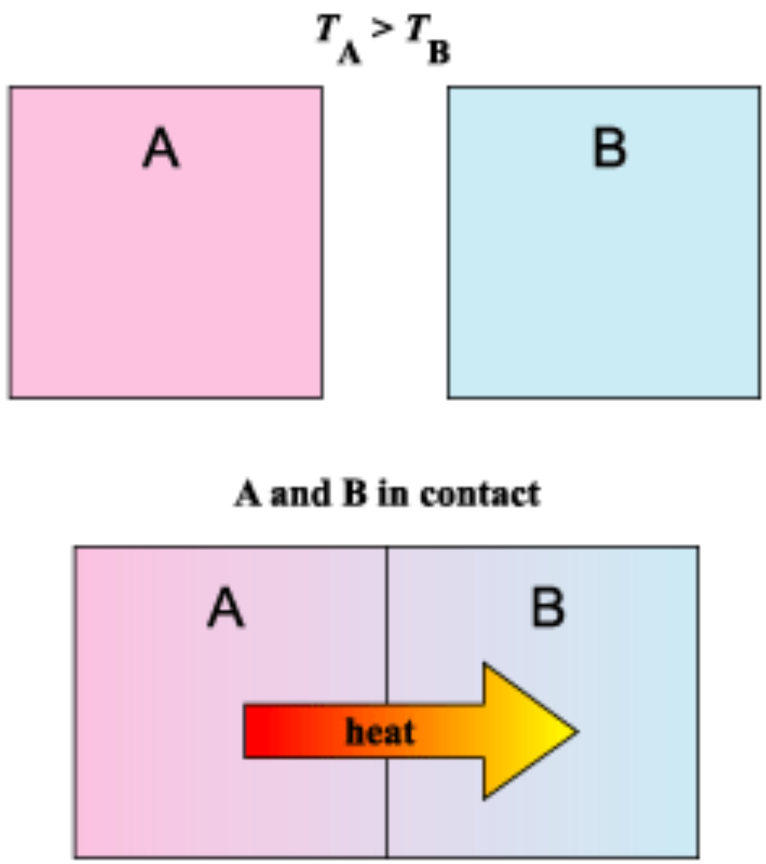


Energy Cannot Be Created or Destroyed

(It just changes forms)

Heat, Internal Energy, Temperature

T_A is proportional to the internal energy U_A in box A



T_B is proportional to the internal energy U_B in box B

$$Q = mc\Delta T$$
$$Q = nC\Delta T$$

Heat will flow (transferring energy) until $T_A = T_B$

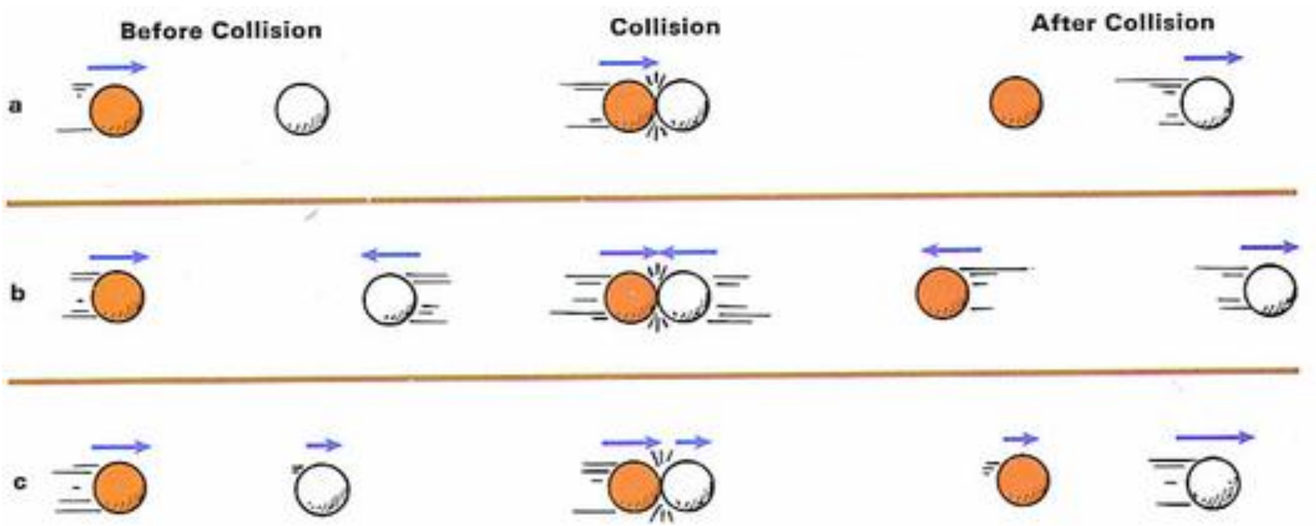
Kinematics + Newton -> Conservation of Momentum

$$p = mv$$

$$F = ma$$

$$F = ma = \frac{m\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$$

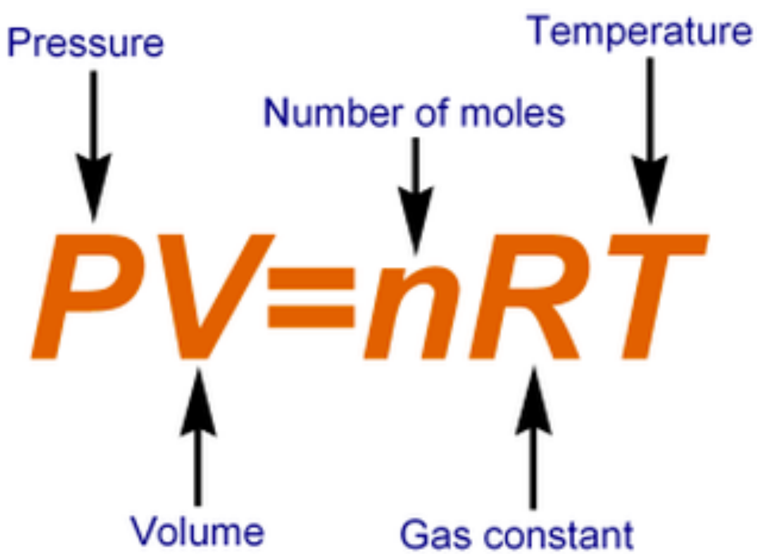
The average force on a constant mass system is seen to be equal to the rate of change of momentum.

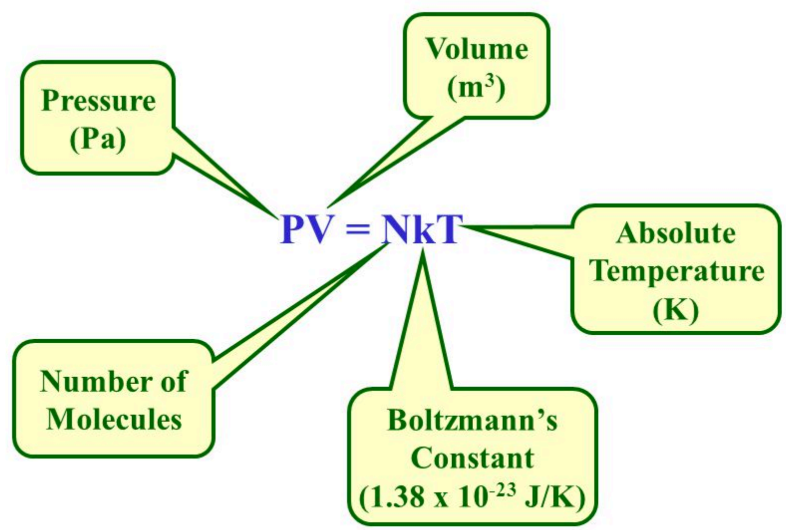


If no external forces : $m_1\vec{v}_{1i} + m_2\vec{v}_{2i} + \ldots + m_n\vec{v}_{ni}$

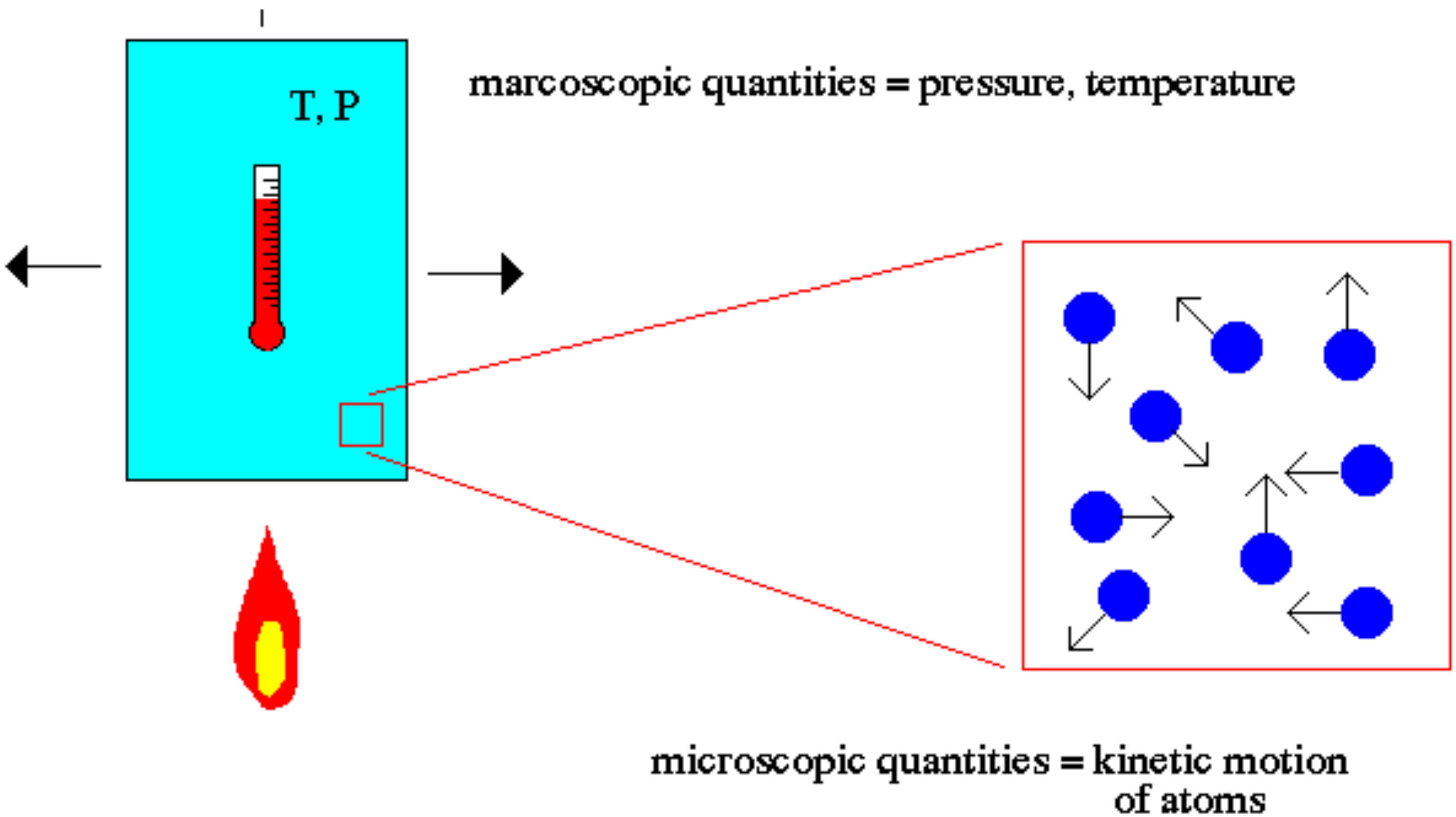
$$= m_1\vec{v}_{1f} + m_2\vec{v}_{2f} + \ldots + m_n\vec{v}_{nf}$$

Ideal Gas Law: An Experimental Fact



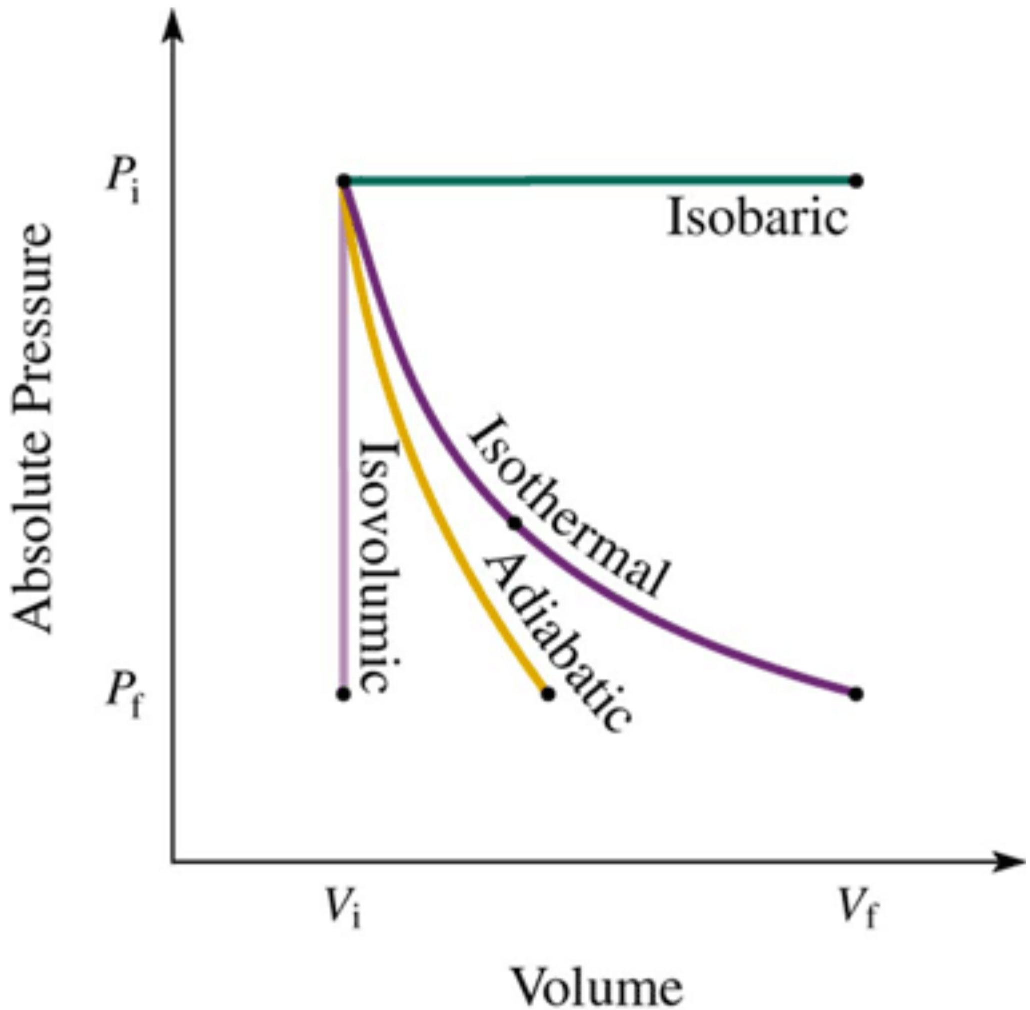


Kinematics + Newton -> Ideal Gas Law



$$PV = nRT \quad \Longleftrightarrow \quad PV = \frac{2}{3} N \left[\overline{\frac{1}{2} m v^2} \right]$$

PV Diagrams



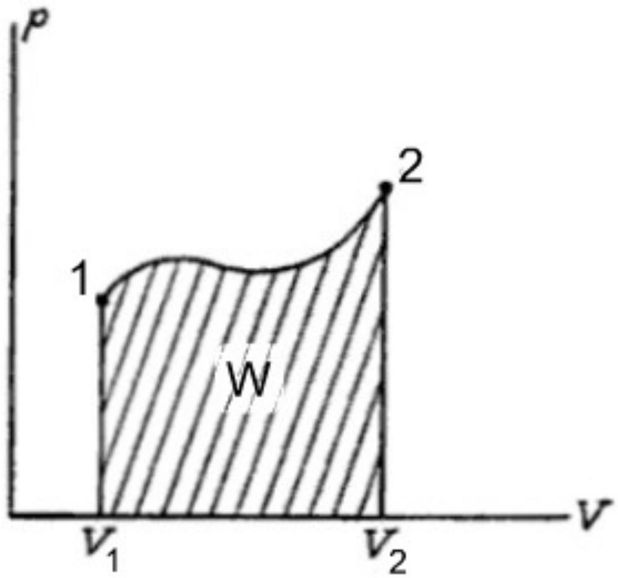
Absolute Pressure
P_i
P_f
Isobaric
Isothermal
Adiabatic
Isovolumic
V_i
V_f
Volume

Ideal Gas Processes

ΔU same for all, just depends on ΔT

Process	ΔU	Q	W
Constant Volume	3/2 nR ΔT (monatomic)	3/2 nR ΔT (monatomic)	0 Lower specific heat All Q goes to U
Constant Pressure	3/2 nR ΔT (monatomic)	5/2 nR ΔT (monatomic)	$P\Delta V = nR\Delta T$ Higher specific heat Some Q goes to W
Constant Temperature	0	nRT ln (V_f/V_i)	nRT ln (V_f/V_i)
Adiabatic (pV^γ = constant)	3/2 nR ΔT (monatomic)	0	-3/2 nR ΔT (monatomic)

PV Diagrams

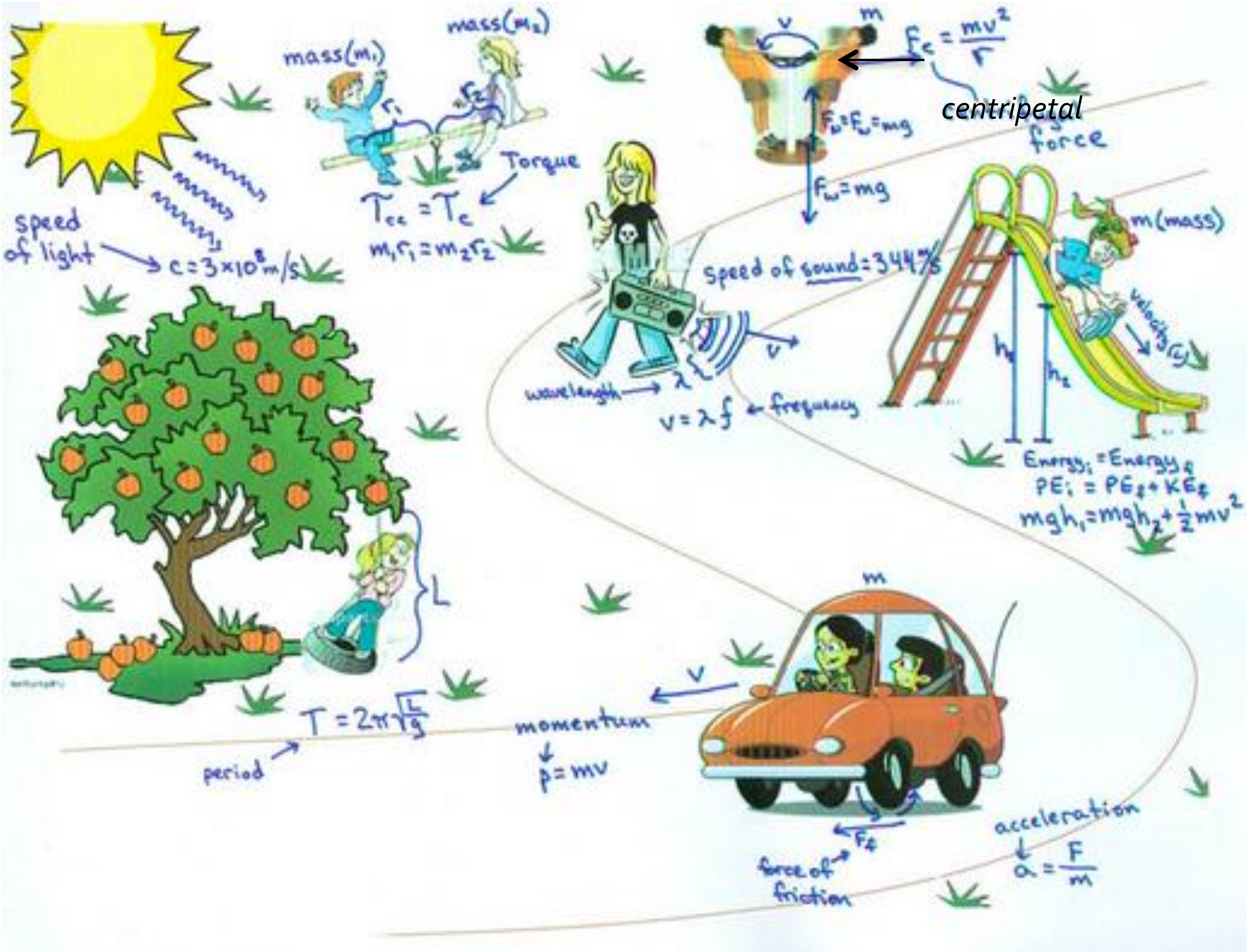


Work W done by gas = area under curve
Increase in volume -> positive work +W by gas
Decrease in volume -> negative work –W by gas

Internal energy U can be read from this diagram as well:
Internal energy U is proportional to temperature T
Temperature T is related to P & V through ideal gas law

From internal energy U and work W, we can get heat Q

Physics in Everyday Life



Conserve Energy

Goodbye!

- You've been a great class!
- You are the future of our world – use your knowledge well
- My door is always open to my former students