Physics 1250 H

Room 1138 Smith
Tues, 3-3:55 PM.

Prof. N. Trivedi
- she will be back on Wed, Sep. 26

I am Prof. M. Randeria

Today we start **Unit N**

N for NEWTON

Isaac Newton (1642 - 1727)

biography by James Gleick (2003)
1st paragraph p. 3

Alexander Pope's couplet p. 183.

Newton: ~~Natural~~ Philosophy → ~~modern~~ Science
- Quantitative
- Predictive

(co)invented differential & integral calculus
(also Leibniz).

Central theme of Unit N	⇒	The Laws of Physics are Universal

Chapter N1

Dynamics = description of motion

* Pre-Newtonian point of view
Aristotle (~ 350 B.C.)

	Terrestrial (Earth)	v/s.	Celestial (Heavens)
"Natural state of bodies"	at rest		in motion (in circles)
"motion"	heavy objects move toward the center of the earth		objects stay in the heavens
	external cause needed to make things move		external cause may cause deviation from a perfect circle.

Ptolemy, Copernicus, Kepler, Galileo
⇒ refined the view of celestial motion
e.g. heliocentric: planets move around sun
circle ⟶ ellipse

After 1680's:

Newton's magnum opus in Latin "Mathematical Principles of Natural Philosophy" (1661 → published in 1679).

The Same Laws of Physics govern both terrestrial and celestial phenomena — i.e. all phenomena

Newton's Laws of Motion

In Unit C → conservation laws of
- momentum
- energy
- angular momentum.

→ we could use these to describe & predict motion of various objects in many circumstances.

Unit N → completely general description of dynamics (motion) with greater applicability than conservation laws alone

In fact, we'll see that conservation laws can be deduced from Newton's laws of motion. Historically also "N" came first

Newton's 1st Law

In the absence of external interactions, an object's (or system's) center-of-mass moves at a constant velocity

Newton: Everything's "natural" state is to continue with the

const. velocity! ≡ same speed in a straight line

both for terrestrial & celestial objects.

- Completely different from Aristotle.
- for the motion of planets there must be an "external interaction" or else they wouldn't move in ellipses.

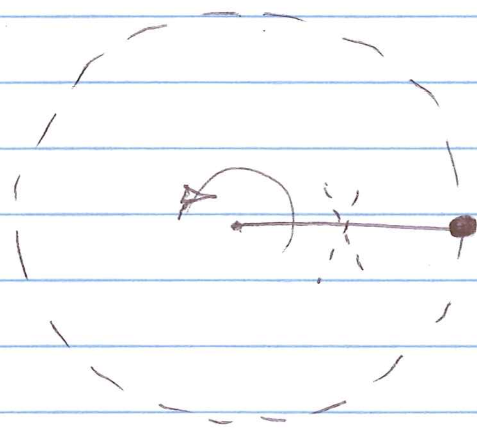
  Much more on that (gravitation) later!
- Newton's 1st law is central to the definition of an intertial reference frame

  which also we will come back to

1st law ≡ equivalent to Consv. of Momentum but important to state it this way for historical reasons! cf. Aristotle

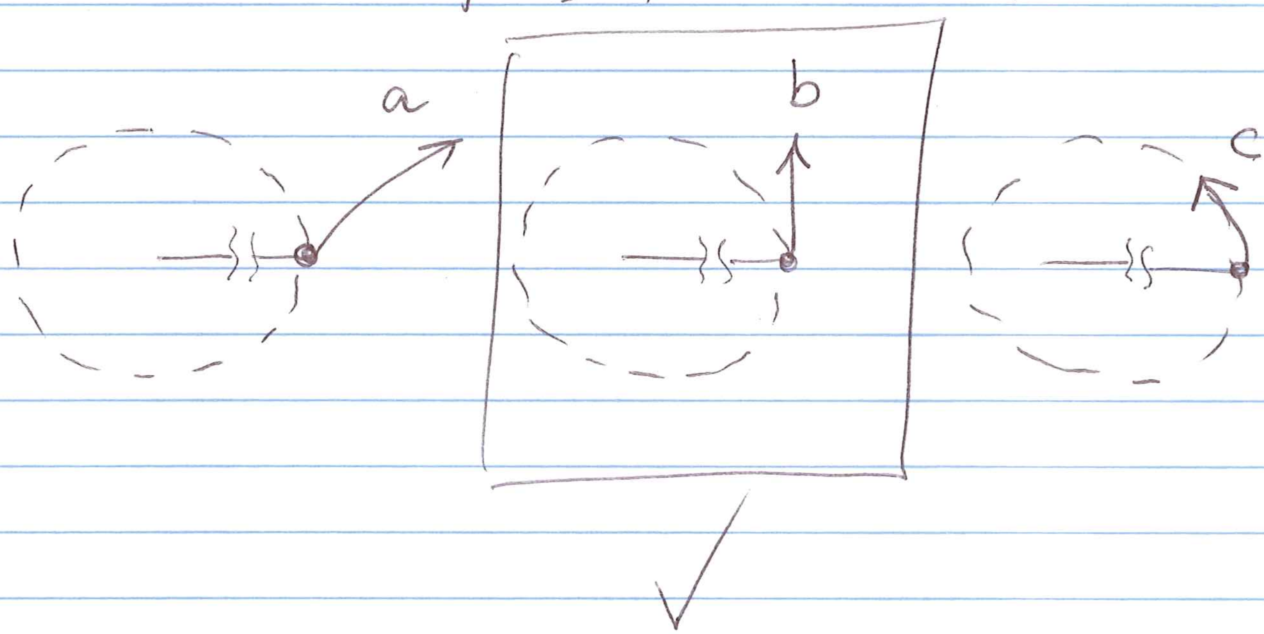
Conceptual qs. on 1st Law:

Circular motion in a plane
(say horizontal — ignore gravity for now)
— stone attached to a string



Cut the string!

What is the trajectory of the stone after that?



Following Moore's text book Do 3rd before 2nd !

Newton's 3rd Law

> When objects A & B interact, the force the interaction exerts on A is equal (in magnitude) and opposite (in direction) to the force that it exerts on B.

"action = reaction"

From Unit C: this is a direct consequence of the momentum transfer model of interactions.

interaction between A & B leads to a transfer of impulse $[d\vec{p}]$ flowing out of A into B. This is equivalent to $[-d\vec{p}]$ flowing from B to A, so that the total change in momentum = 0 (conserved).

$$\therefore \vec{F}_B = \frac{[d\vec{p}]_B}{dt} = \frac{[d\vec{p}]}{dt}$$

(force on B)

$$= -\frac{[-d\vec{p}]}{dt} = -\frac{[dp]_A}{dt}$$

$$= -\vec{F}_A$$

(force on A)

Many people find this confusing

e.g. the force exerted by a baseball on a bat
is equal and opposite to that exerted by the bat on the baseball.
Or they hitting a wall!

Why then does the bat move a little and the ball a lot?

∵ as we shall see next: massive objects respond much to the same force than less massive ones!

The most celebrated of them all:
Newton's 2nd Law of motion

> A net force on a body causes the rate of change of momentum of the center-of-mass.

$$\vec{F} = \frac{d\vec{p}}{dt}$$

actually 3 equations: $F_x = \frac{dp_x}{dt}$, $F_y = \frac{dp_y}{dt}$, $F_z = \frac{dp_z}{dt}$

$\vec{F}$ = net (external) force = $\vec{F}_A + \vec{F}_B + \vec{F}_C + \dots$

vector sum of all the external forces acting on the body.

If the mass of the object is constant in time
(note: it need not be, e.g., rocket burning fuel).

$$\vec{p} = m\vec{v}$$

$$\frac{d\vec{p}}{dt} = \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt}$$

(m = const. in time)

define **acceleration** $\vec{a} = \frac{d\vec{v}}{dt}$

$$\frac{d\vec{p}}{dt} = m\vec{a} \Rightarrow \boxed{\vec{F} = m\vec{a}}$$

2nd Law (cont'd)

note:

(1) External Force causes acceleration $\frac{d\vec{v}}{dt}$

→ does not cause motion, i.e., velocity

(2) Internal interactions are not important, when you consider a system of particles.

internal forces "cancel out" as it were (3rd law).

only external forces count.

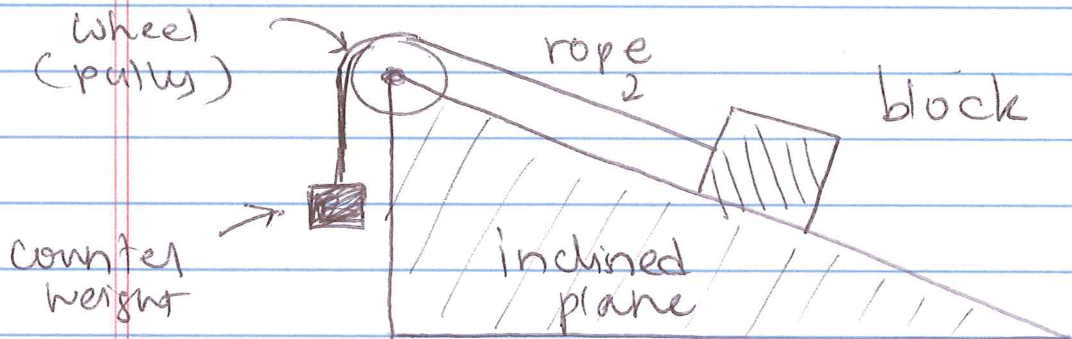
(3) The net external force = vector sum of all external forces enters in the LHS of the 2nd law

The rest of Unit N will be understanding in detail Newton's laws & their consequences by applying them to various specific problems

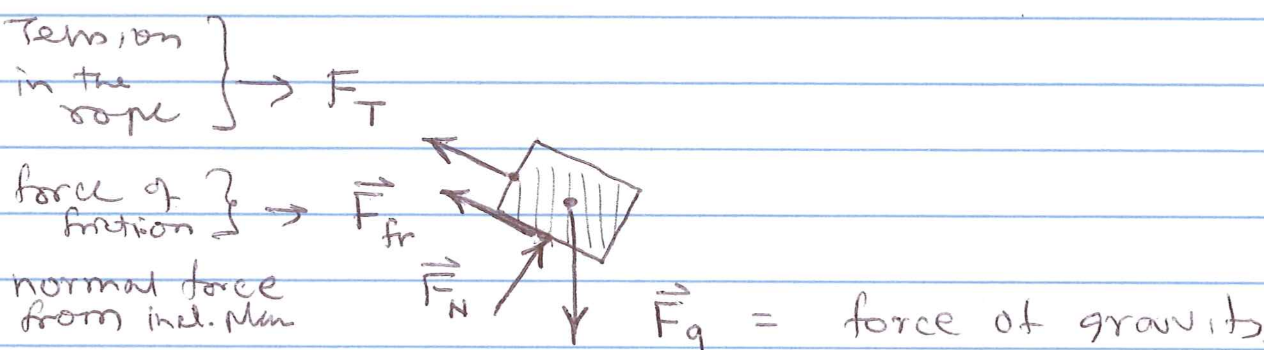
Let us begin by looking at

FREE BODY DIAGRAMS

This is the best way to "isolate" a body and look at <u>all the external forces acting on it</u>



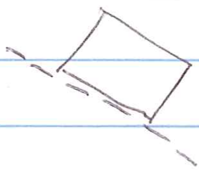
Free body diagram of <u>block</u>



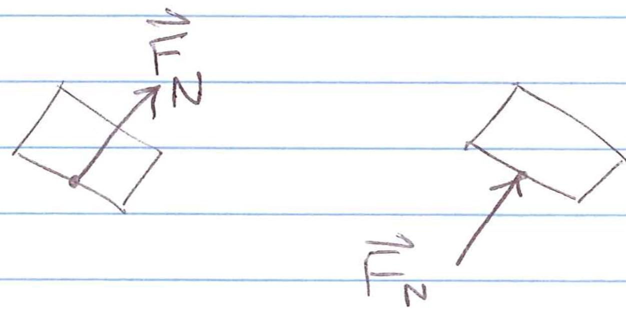
① <u>Focus only on the object</u>

② put a dot on c-of-mass and draw the force of gravity "weight" $\vec{F}_g$ downward.

(3) look at any surfaces with which the object is in contact



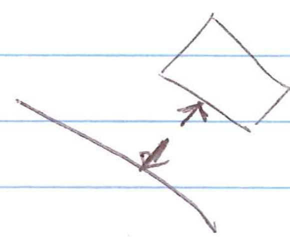
Draw a <u>normal</u> force at the point (or mid point) of contact



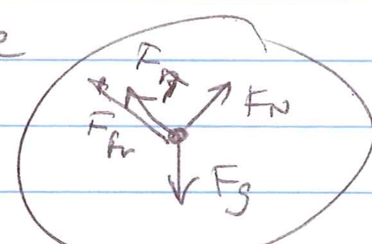
both are OK.

"normal" → perpindicular to surface of contact

direction : "pushing" outward
equal and opp. to push of block <u>on</u> surface



(*) Make a big picture so no confusion!



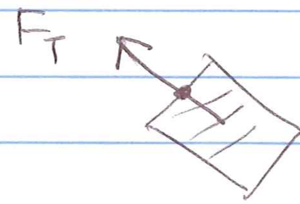
X

LAST

(5) look for other forces

Is someone pushing or pulling the box?

there is the tension in the string!



(6) Finally friction!

another contact force but this is always parallel to surface of contact and opposite to direction of motion

(here we're drawing it as if box is moving down the plane)

(7) magnitudes of these forces

→ we'll see lots of examples of how to compute those for a given problem

→ right now focusing on which external forces act on a body and along what directions

Free Body Diagrams

- Do's and Don'ts:
  - Do **not** draw any arrows indicating quantities which are not forces:
    - don't draw the direction of motion
    - don't draw the velocity vector
    - don't draw the acceleration vector.
  - Draw only the forces that act directly on the object.
    - don't draw forces that act on other objects
    - don't draw forces that your object exerts on other objects.
  - Every force should be identified with a specific interaction.
    - don't draw the net force (that's from a combination of interactions)
    - don't draw "alleged" forces.
- Conceptual Problem (N1X.7)

Which should not be included?