IDX G9 Physics H
Study Guide S1 Midterms
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3.8 Relative Velocity

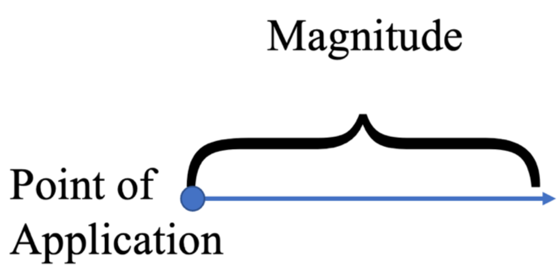
- **Relative Velocity: the velocity of one body relative to another**
- Symbol: $\vec{V}_{A/B}$ = velocity of A relative to B
- 2 main formulas:
    - $\vec{V}_{A/C} = \vec{V}_{A/B} + \vec{V}_{B/C}$
    - $\vec{V}_{A/B} = -\vec{V}_{B/A}$ (same in magnitude, opposite in direction)
- Remember to define +x and/or +y directions before solving relative velocity problems.

4.1 Force & 4.6 Weight

Force:

- **Def: push/pull exerted by one object on another, a vector**
- **Unit: Newton/N =** $\boldsymbol{kgm/s^2}$

- Interaction between 2 objects:
    - **System:** to whom force is exerted
    - **Agent:** by whom force is exerted
- Measured with a spring scale – spring is stretched
- 3 factors of forces:
    - **Magnitude**
    - **Direction**
    - **Point of Application** – location force is exerted
- Graphical Representation



Different Types of Forces:

Four Fundamental Forces: Gravity, Electromagnetic, Strong, and Weak force

Contact Forces: object from external world **touches** a system and exerts a force

- Ex**:** friction, tension, spring, normal force
- All are consequences of fundamental forces

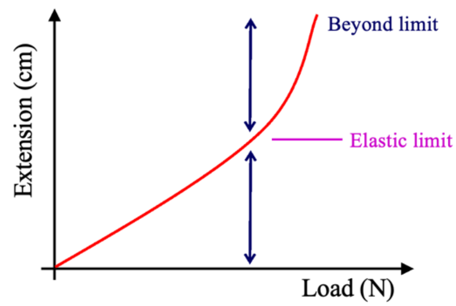
Field Forces: force exerted **without contact**

- Ex: gravitational, electric, magnetic force

Spring Force:

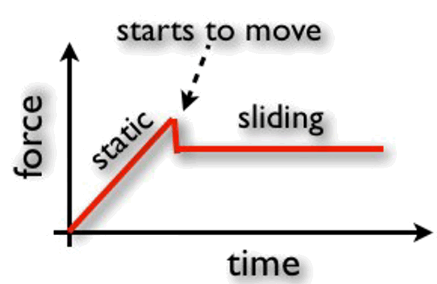
- **Hooke's Law:** magnitude of force is **directly proportional** to amount of **stretch/compression** within **limit** of spring
- **Formula:** $F_{sp} = -kx$
    - F_{sp} – the force exerted by spring on attached object (N)
    - x – the displacement of the spring end from its equilibrium position (cm)

- o k – spring stiffness constant (N/cm)
- o "-"—F is opposite to x
- o **Elastic limit:** point beyond which spring will **no longer return to its original shape** after force is removed



Friction

- Types of friction:
  - **Sliding Friction: occurs when 2 solid surfaces slide over each other**
    - **Static friction (F_{fs}):** Caused by **tendency** of relative motion. (**no** relative motion)
    - **Kinetic friction (F_{fk}):** Caused by **relative motion**
  - **Rolling Friction:** occurs when an object **rolls over a surface** (< sliding friction)
  - **Fluid Friction:** occurs when an object moves **through a fluid**
    - Ex: air or water resistance, oil
- Magnitude of Friction
  - Static Friction: $\boldsymbol{F_{fs} = F_{cause}}$
  - **Maximum Static Friction:** $\boldsymbol{F_{fsmax} = \mu_s \times F_N}$
    - $\boldsymbol{\mu_s}$—coefficient of static friction; depends on roughness of surface
    - $\boldsymbol{F_N}$—normal force between 2 surfaces
    - Range: $\boldsymbol{0 < F_f \le F_{fsmax}}$
  - kinetic friction:
  - $\boldsymbol{F_{fk} \le F_{fsmax}}$
  - $F_{fk} = \mu_k F_N$
    - μ_k – coefficient of kinetic friction
    - F_{fk} does not change with the F_{cause}
    - Note: $\mu_s \ge \mu_k$
  - Factors of Air Resistance:



        - Shape of object – streamlined shape reduces air resistance
        - Size – Surface area ↑ F_{air} ↑
        - Speed ↑ F_{air} ↑
        - Fluid type: Viscosity ↑ F_{air} ↑

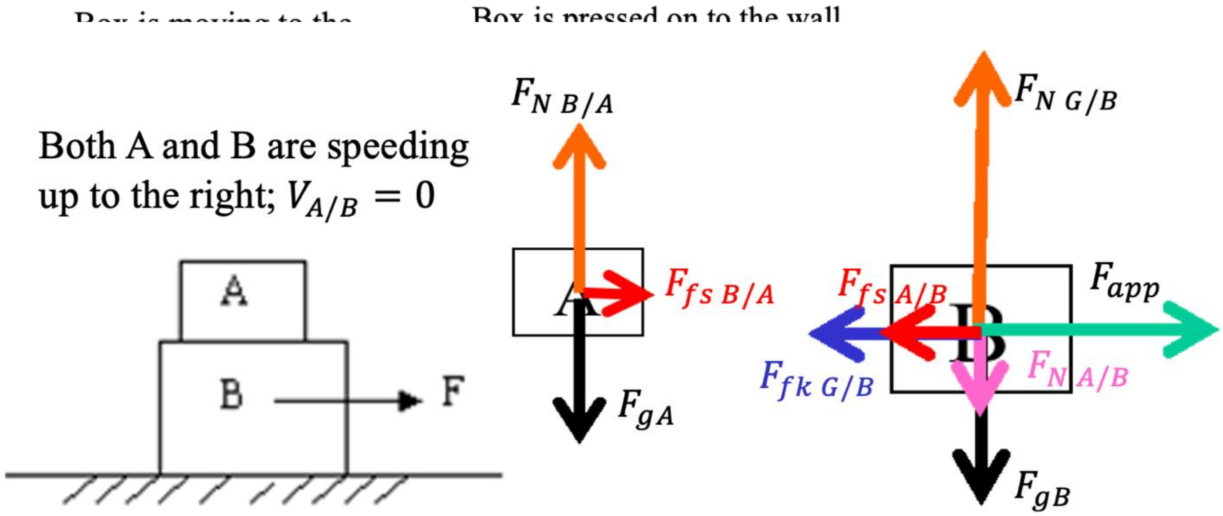
Balanced Forces

- Equilibrant forces:
    - Act on same object and point of application
    - Same magnitude and opposite direction
- Equilibrium: state when object experience balanced forces
    - Either at rest or uniform motion ($a = 0, F_{net} = 0$)
- Unbalanced forces ($F_{net} \neq 0$)
    - Start/stop moving
    - Change direction
    - Change motion
- If 3 force vectors can form a triangle, then the 3 forces can be balanced (and vice versa)

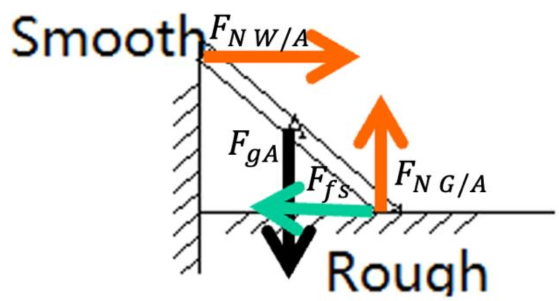
Free Body Diagram

- **Def: physical model that represents all forces on a system**
- Steps of drawing:
    - Represent system as dot at **center of mass**
- Draw all force vectors (see Graphical Representation)
    - common ones include F_{app}; F_g; $F_N, F_T, F_{sp}; F_{\frac{fs}{k}}, F_{air}$

- **Examples:**



- Note: $F_{N\ W/A}$ is not equilibrant of F_{fs}; applied on different points

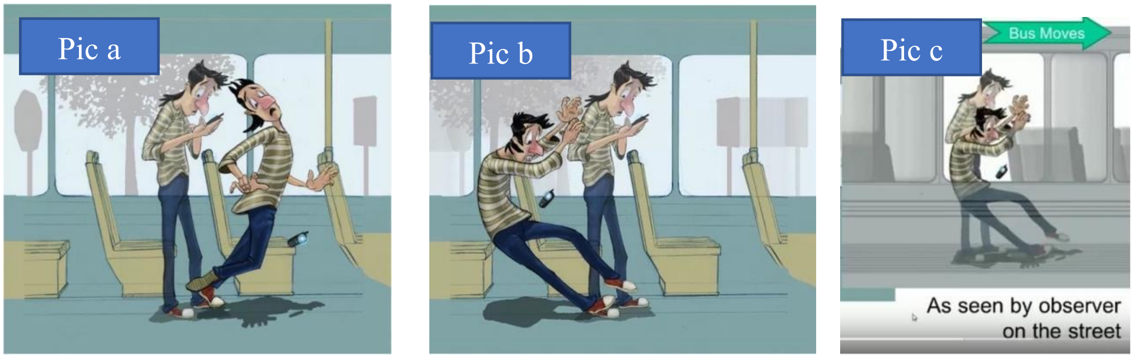


4.2 Newton's 1st Law of Motion

Newton's First Law:

- Statement: Every object continues in its state of **rest**, or of **uniform velocity** in a straight line, as long as **no net force** acts on it
- Also called **the Law of Inertia**
  - **Inertia:** tendency of object to **maintain** its state of **rest / uniform motion** in straight line
    - **Not a force**, no interactions between 2 objects

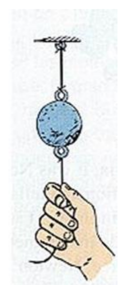
- Depends on **mass**



- Pic a: accelerate backwards
- Pic b: accelerate forwards
- Frame of reference: the Bus, seems like person is experiencing a force
- Pic c: Change frame of reference to street -> continues state of motion **due to inertia**

Inertial Reference Frames (IRF):

- **Inertial Reference Frames:** reference frames in which **Newton's 1st law does hold**
    - Ex: Earth frame of reference≈ IRF, a RF with constant V relative with another IRF is also an IRF
- **Noninertial Reference Frames**: reference frames where **Newton's 1st law does not** hold
    - Ex: reference frame in pic a and b
- Ex question: Why is it that a slow continuous increase in the downward force breaks the string above the massive ball, but a sudden increase breaks the lower string?



    - Answer: Massive ball has great inertia, so it doesn't move/ move little at first; if you pull fast, the upper string won't be affected

4.3 Mass

- Newton: mass is a quantity of matter -> not well defined
- **Inertial Mass:** mass = the ratio of the F_{net} exerted on an object to its acceleration
    - a measure of inertia of an object & resistance to any type of force
- **Gravitational mass:** used in the **law of universal gravitation**, determines the size of the gravitational force between 2 objects

- **The principle of equivalence:** inertial & gravitational mass are equal in magnitude
    - All experiments conducted so far have supported this

4.4 Newton's 2nd Law of Motion

- Statement: acceleration of an object is **directly proportional** to the F_{net} acting on it and is **inversely proportional** to its mass. The direction of acceleration is in the direction of the F_{net} acting on object
    - Formula: $F = ma$
    - Unit: Newton(N)
- **Apparent Weight:** force exerted by the **(spring) scale, weight≠mass**
- Suppose you are standing on a scale in an elevator:
    - when elevator in equilibrium: $F_{sp} = F_g$
    - when elevator accelerates upward uniformly: $F_{sp} > F_g$
    - when elevator accelerates downward uniformly: $F_{sp} < F_g$
    - free fall: $F_{sp} = 0$, **weightlessness** occurs when there are no contact forces

4.5 Newton's 3rd Law of Motion

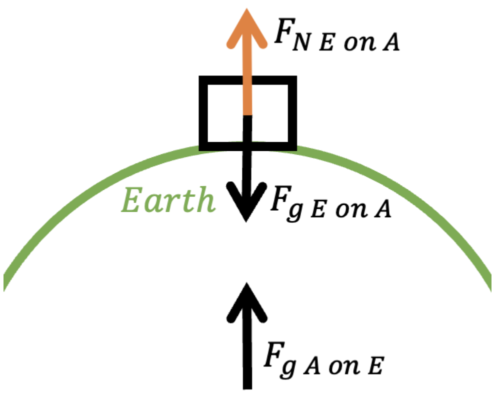
Interaction pair:

- forces always come in pairs - $\boldsymbol{F_{A\ on\ B}}$ **and** $\boldsymbol{F_{B\ on\ A}}$
- opposite directions, equal magnitude, different systems, and same type
- also called **action-reaction pair**

Newton's 3rd Law:

- Whenever one object exerts a force on a second object, the second exerts an equal force in the opposite direction on the first

- Ex: $F_{g\ A\ on\ E}$ and $F_{g\ E\ on\ A}$ are action-reaction forces; $F_{g\ E\ on\ A}$ and $F_{N\ E\ on\ A}$ are balance forces



	Balance force	Action-reaction
Similarities	Equal in magnitude, opposite in direction	
Differences	Same system, can cancel each other	Different system, can not cancel each other
	Not always occur at the same time	Occur at the same time
	Not always change at the same time	Change at the same time
	Not always same type	Same type of force
	Does not change motion	May change motion