PHYS 107 - Week 3 - Friday

* From kinematics to dynamics

kinematics = treatment of motion without consideration of its causes

↓

dynamics = what causes the motion

"Forces" cause dynamics

Force = intuitive notion of "push" or "pull"
= vector quantity with both direction and magnitude

Historically: Aristotle : - the natural state of an object is at rest.
- any motion requires a force, and an object will come to rest when no force is applied

↓

Galileo (1609) : objects in motion stay in motion unless acted upon by an external force

↓

Newton (1685-16-86) : laws of motion

* Newton's first law: (based on Galileo's work)

$\boxed{\text{Objects have a constant velocity } \vec{v} \text{ unless acted upon by a force } \vec{F}}$

Note: $\vec{v} = 0$ is a perfectly allowed state of motion but not a special case

Moving reference frames with constant velocity → all laws of physics are still valid
→ classical relativity (ball bouncing on a train)

* Newton's second law:

$\boxed{\text{Acceleration of an object that is acted upon by an external force } \vec{F}_{net} \text{ is directly proportional to that force, and inversely proportional to its mass } m.}$

$$\vec{F}_{net} = m\vec{a} \quad \text{or} \quad \vec{a} = \frac{\vec{F}_{net}}{m}$$

$\vec{F}_{net}$ = sum of all external forces (vector sum)
$= \sum_i \vec{F}_i$

$$\underbrace{\vec{F}_{net}}_{\text{dynamics}} = \overbrace{m}^{\text{inertial mass}} \underbrace{\vec{a}}_{\text{kinematics}}$$

Note: first law is a consequence of second law
$\vec{F} = 0 \rightarrow \vec{a} = 0 \rightarrow \vec{v} = \text{constant}$
↳ slope is zero

after units

* Newton's Third law:

$\boxed{\text{If an } \cancel{obj} \text{ object A exerts a force on object B, then object B exerts an } \underbrace{\text{equal}}_{\text{magnitude}} \text{ and } \underbrace{\text{opposite}}_{\text{direction}} \text{ force on object A}}$

$$\vec{F}_{BA} = -\vec{F}_{AB}$$

Examples: - person on floor → floor on person
- gravity on mass → mass on earth

Q Apple-earth

* ~~Units~~: Mass vs. Weight

mass m → units kg
- = measure of inertia of an object (reluctance to change its motion)
- → intrinsic property of an object (number and type of atoms)
- scalar quantity

weight $\vec{W} = -mg$ = force due to gravity
- vector quantity

* Units of force: ~~F~~ units ~~F~~ $m\vec{a} \rightarrow kg\,m/s^2 = N$

$1\,N$ = force of 1 apple in your hand

$(100g)(9.80\,m/s^2) \approx 1\,N$

* Force is a vector: $\vec{F}_{net} = m\vec{a}$ → $\begin{cases} F_x = ma_x \\ F_y = ma_y \\ F_z = ma_z \end{cases}$

Q Forces 3a

* Examples of forces:

- Weight = force due to gravity

$$\vec{F}_g = \vec{W} = m\vec{a} = m\vec{g} \rightarrow -g\text{, downward},\quad |\vec{g}| = 9.80\,m/s^2$$

$$m = 1\,kg \rightarrow \vec{W} = -9.80\,N\text{, downward}$$

On the moon, $\vec{g} = 1.67\,m/s^2$, downward

↳ $\vec{W}' = -1.67\,N$, downward $\approx \frac{1}{6}\vec{W}$

* Person in elevator

{ going at constant velocity
{ standing still $\rightarrow m\vec{a} = 0 = \vec{F}_{net}$

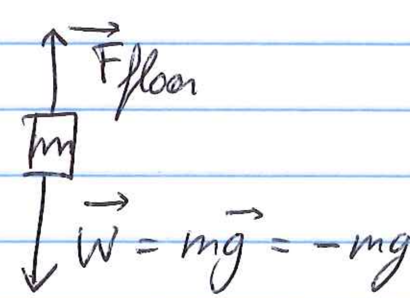
$$\vec{F}_{net} = \underbrace{\vec{F}_{floor}}_{\text{(upward)}} + \underbrace{\vec{W}}_{\text{(downward)}} = 0$$

↓

$$\vec{F}_{floor} = +mg\text{, upwards}$$

Free-body diagram:

diagram with all forces exerting on object (not an accurate picture with details!)



* Falling elevator $\rightarrow$ $\vec{a} = \vec{g}$

↳ $\vec{F}_{net} = m\vec{a} = m\vec{g} = \vec{W} + \vec{F}_{floor}$

↳ $\vec{F}_{floor} = \cancel{\ } m\vec{g} - \vec{W} = 0$

$\longrightarrow$ no force from floor on person

* Rising, accelerating elevator $\rightarrow$ $\vec{a}$ positive, upward

↳ $\vec{F}_{net} = m\vec{a} = \vec{W} + \vec{F}_{floor}$

$\vec{F}_{floor} = m\vec{a} - \underbrace{\vec{W}}_{-mg} = m(a+g)$

↳ feel heavier

* Downward accelerating elevator $\rightarrow$ $\vec{a}$ negative, downward but $|\vec{a}| < |\vec{g}|$

↳ $\vec{F}_{floor} = m\vec{a} - \vec{W} = m(-a+g)$

↳ ~~fle~~ feel lighter