Course announcement

- Homework set 1 will be posted on eLearn on 9/30 at 8AM and due on next Friday (10/7) at 5PM. No late homework will be accepted.
- Office hours: Office Hours: 12:00~1:00 Monday @ Physics building R520 or by Microsoft Team(same link as online course) https://teams.live.com/meet/9570955571789
- Appointment with TA

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2	9/23(Fri.)	**Kinetics:** motion in 2D and 3D
3	9/27(Tue.)	**Newton's law:** Newton's first and second law I
3	9/30(Fri.)	**Newton's law:** Newton's first and second law II (Homework 1)
4	10/4(Tue.)	**Newton's law:** Newton's third law and Using Newton's law

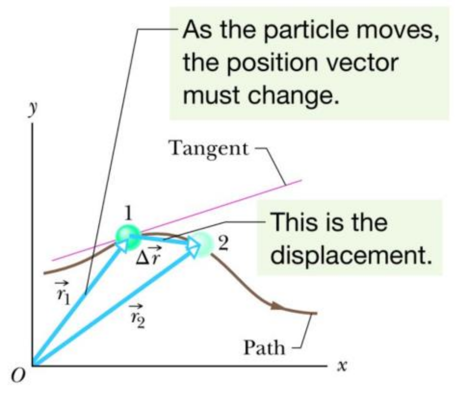
GENERAL PHYSICS B1
NEWTON’S LAW

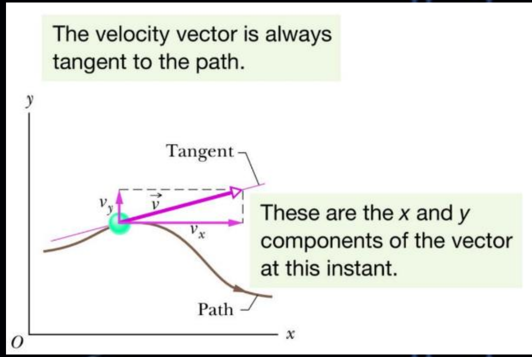
Newton’s First and Second Law I

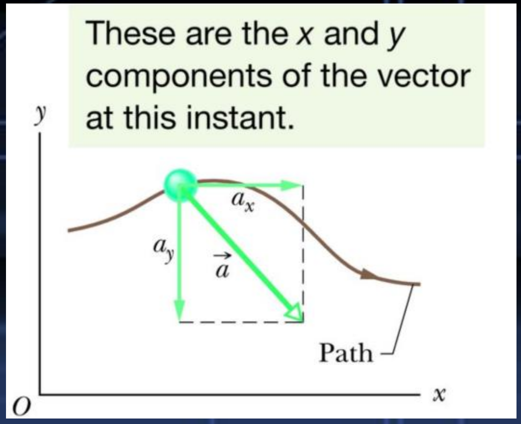
2022/09/27

Motion in two and three dimension

- Position: $\vec{r} = x\hat{\mathrm{i}} + y\hat{\mathrm{j}} + z\hat{\mathrm{k}}$
- Displacement: $\Delta\vec{r} = (x_2 - x_1)\,\hat{\mathrm{i}} + (y_2 - y_1)\,\hat{\mathrm{j}} + (z_2 - z_1)\,\hat{\mathrm{k}}$
- Average velocity: $\vec{v}_{\text{avg}} = \frac{\Delta x\hat{\mathrm{i}} + \Delta y\hat{\mathrm{j}} + \Delta z\hat{\mathrm{k}}}{\Delta t} = \frac{\Delta x}{\Delta t}\,\hat{\mathrm{i}} + \frac{\Delta y}{\Delta t}\,\hat{\mathrm{j}} + \frac{\Delta z}{\Delta t}\,\hat{\mathrm{k}}.$
- Instantaneous velocity: $\vec{v} = \frac{d}{dt}\left(x\hat{\mathrm{i}} + y\hat{\mathrm{j}} + z\hat{\mathrm{k}}\right) = \frac{dx}{dt}\hat{\mathrm{i}} + \frac{dx}{dt}\hat{\mathrm{j}} + \frac{dz}{dt}\hat{\mathrm{k}}$
- Average acceleration: $\vec{a}_{\text{avg}} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} = \frac{\Delta\vec{v}}{\Delta t}$
- Instantaneous acceleration : $\vec{a} = \frac{d}{dt}\left(v_x\,\hat{\mathrm{i}} + v_y\,\hat{\mathrm{j}} + v_z\,\hat{\mathrm{k}}\right) = \frac{dv_x}{dt}\,\hat{\mathrm{i}} + \frac{dv_y}{dt}\,\hat{\mathrm{j}} + \frac{dv_z}{dt}\,\hat{\mathrm{k}}.$

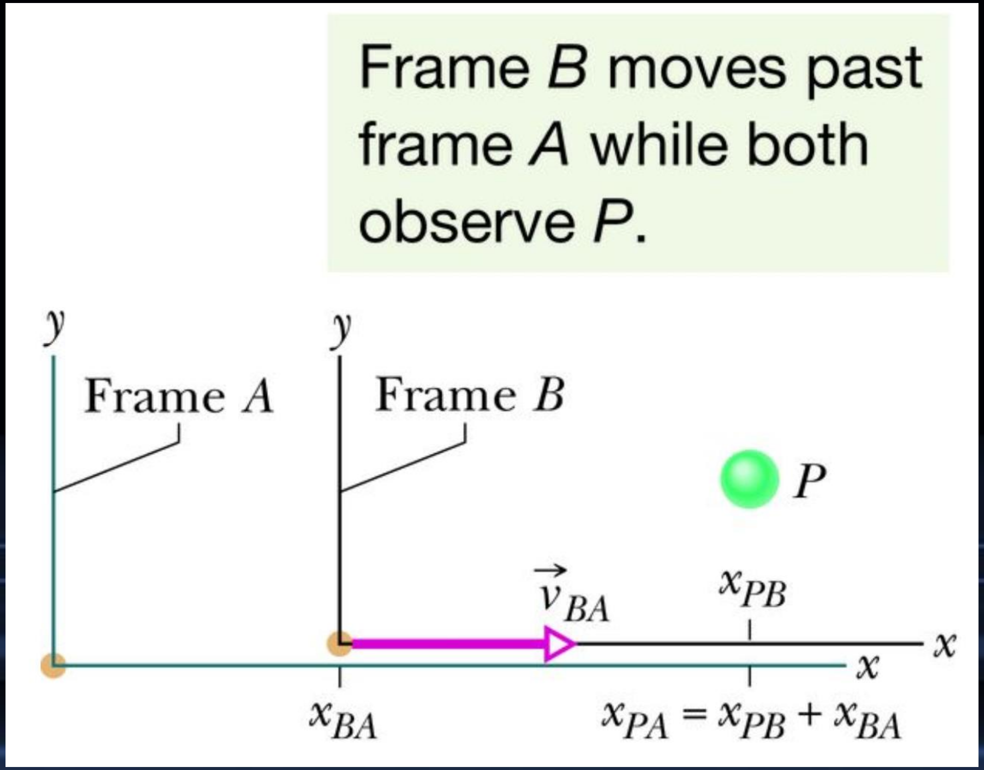






Relative motion in one dimension

- If the observer have a relative constant velocity to the observed object, then:



Relative motion in one dimension (2)

- We can find that:

$$x_{PA} = x_{PB} + x_{BA}$$

- Thus the conversion of velocity between frames:

$$\frac{d}{dt}(x_{PA}) = \frac{d}{dt}(x_{PB}) + \frac{d}{dt}(x_{BA})$$

$$v_{PA} = v_{PB} + v_{BA}$$

Relative motion in one dimension (2)

- For the acceleration:

$$\frac{d}{dt}(v_{PA}) = \frac{d}{dt}(v_{PB}) + \frac{d}{dt}(v_{BA})$$

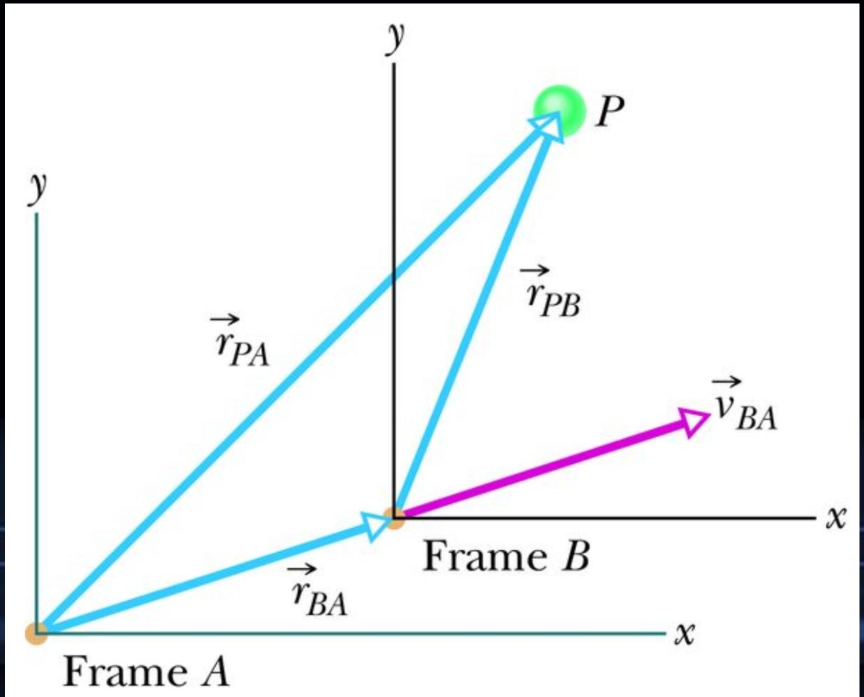
- Frame B moves with constant velocity, we have:

$$a_{PA} = a_{PB}$$

- The velocity changes on different frames but acceleration is a constant if the frame moves with constant velocity.

Relative motion in two dimension

- The relative motion can be generalized in two or even three dimension:

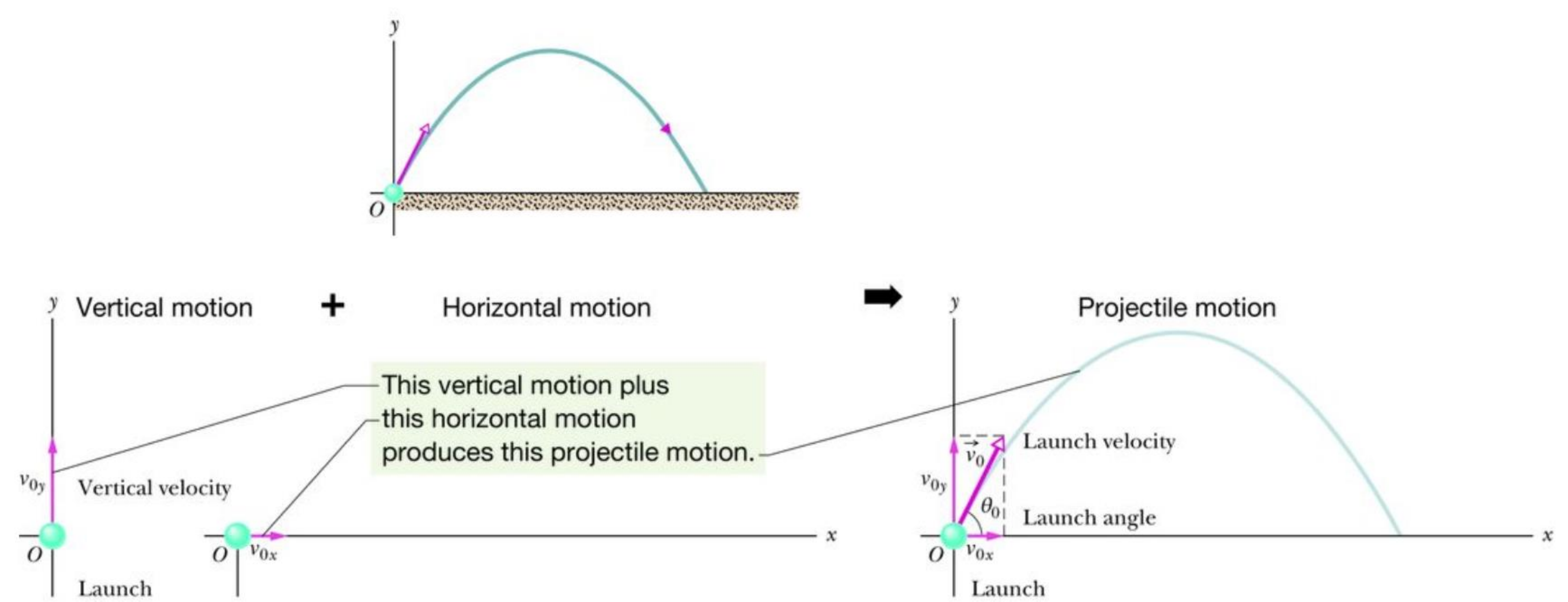


$$\vec{r}_{PA} = \vec{r}_{PB} + \vec{r}_{BA}$$

$$\vec{v}_{PA} = \vec{v}_{PB} + \vec{v}_{BA}$$

$$\vec{a}_{PA} = \vec{a}_{PB}$$

Projectile motion



Projectile motion

- Horizontal motion:

$$x - x_0 = v_{0x}t$$
$$= (v_0 \cos \theta_0)t$$

- Vertical motion:

$$y - y_0 = v_{0y}t - \frac{1}{2}gt^2$$
$$= (v_0 \sin \theta_0)t - \frac{1}{2}gt^2$$

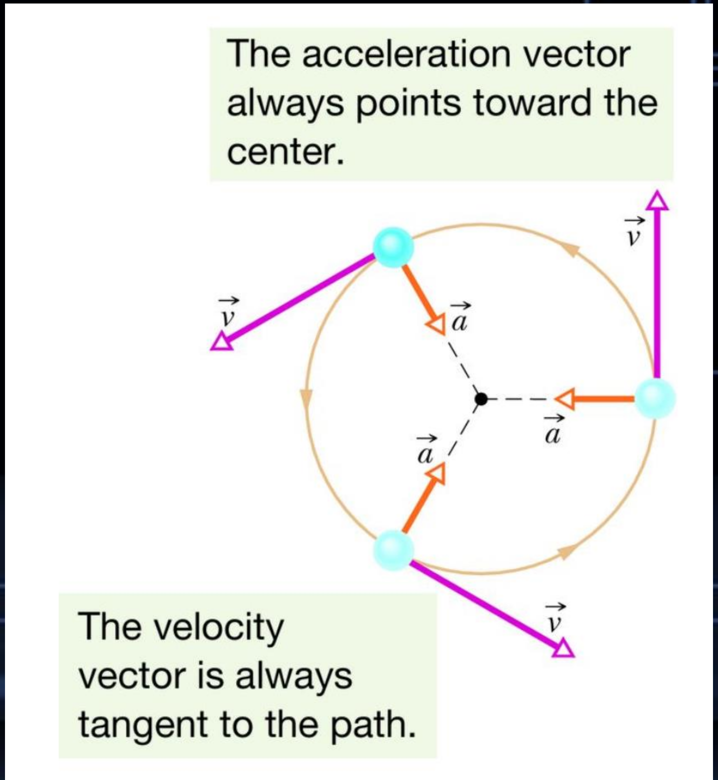
- Equation of the path:

$$y = (\tan \theta_0)x - \frac{gx^2}{2(v_0 \cos \theta_0)^2}$$

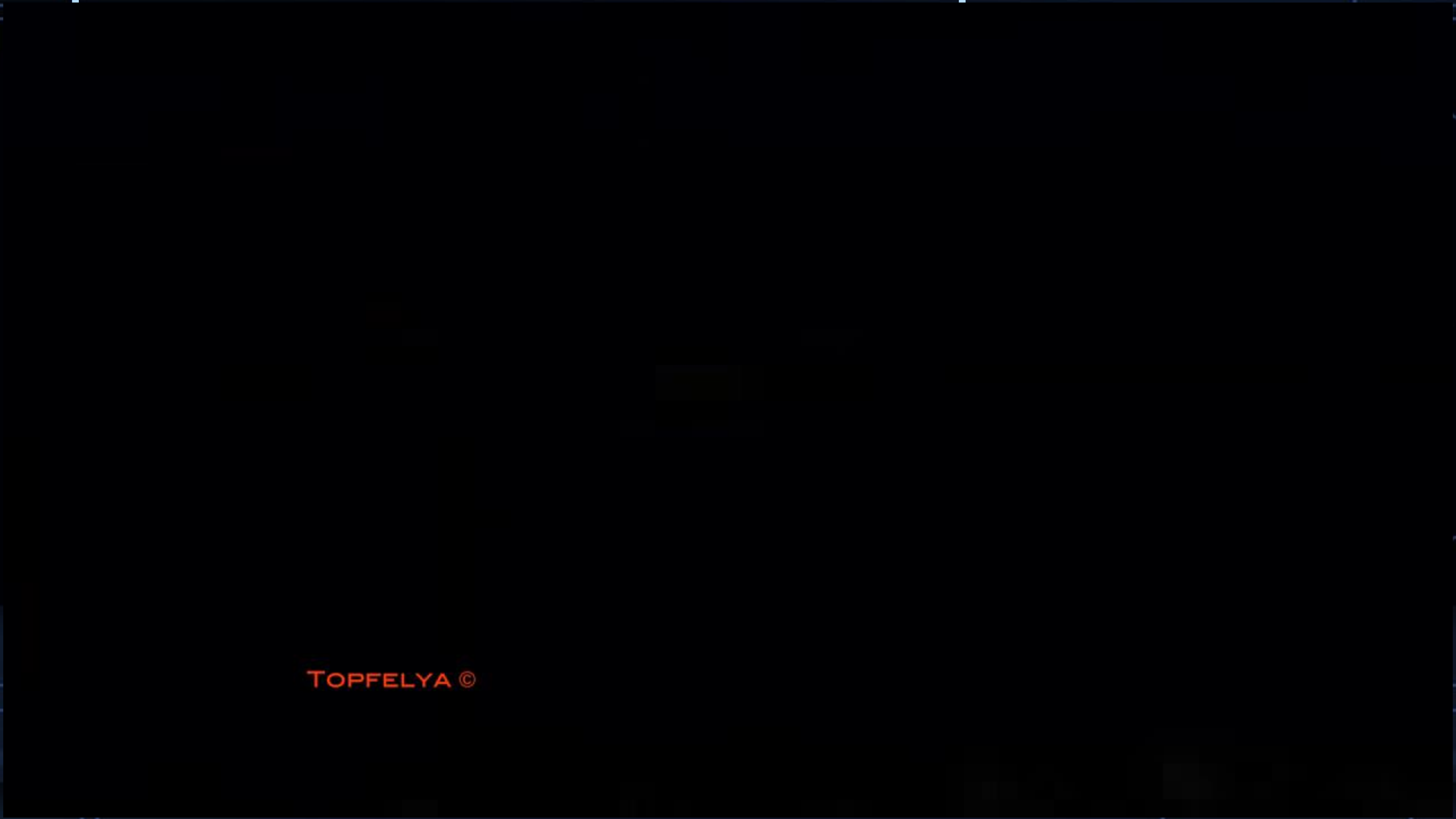
Uniform Circular Motion

- The condition of having uniform circular motion is:

$$a = \sqrt{a_x^2 + a_y^2} = \frac{v^2}{r}\sqrt{(\cos\ \theta)^2 + (\sin\ \theta)^2} = \frac{v^2}{r}\sqrt{1} = \frac{v^2}{r}$$



Example of relative motion: an airplane in crosswind



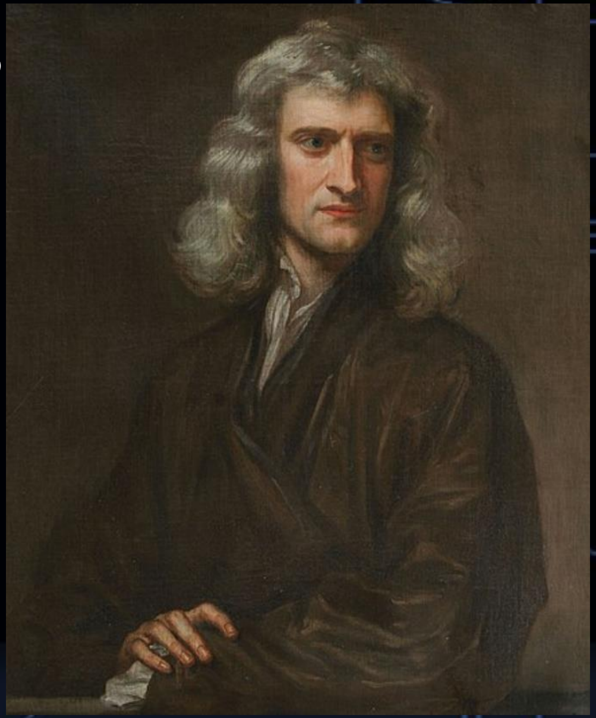
https://www.youtube.com/watch?v=NHw1QDn5mxM

Topic of today’s course

- Newton’s first law and Inertia frame
- Newton’s second law

Newton's Laws of Motion

- The relationship between force and motion is first understood and formulated with mathematical descriptions: Newtonian mechanics.
- There are three primary laws of motion.



Force

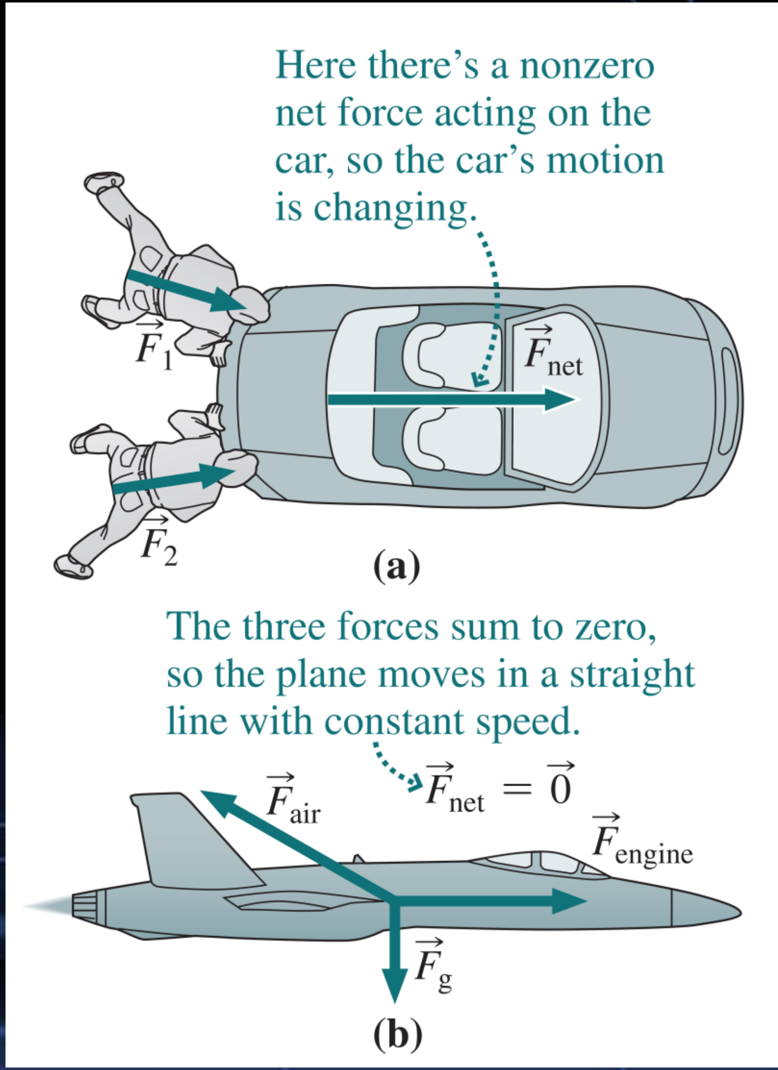
- Force is a vector quantity and thus has not only magnitude but also direction. So, if two or more forces act on a body, we find the net force (or resultant force) by adding them as vectors
- Unit: Newton(N) - the force to put a $1kg$ body on a horizontal, frictionless surface and pull horizontally such that the body has an acceleration of $1m/s^2$.

Newton’s first law of motion

- **Newton’s first law of motion:** A body in uniform motion remains in uniform motion, and a body at rest remains at rest, unless acted on by a nonzero net force ($\overrightarrow{F_{net}} \neq 0$) .

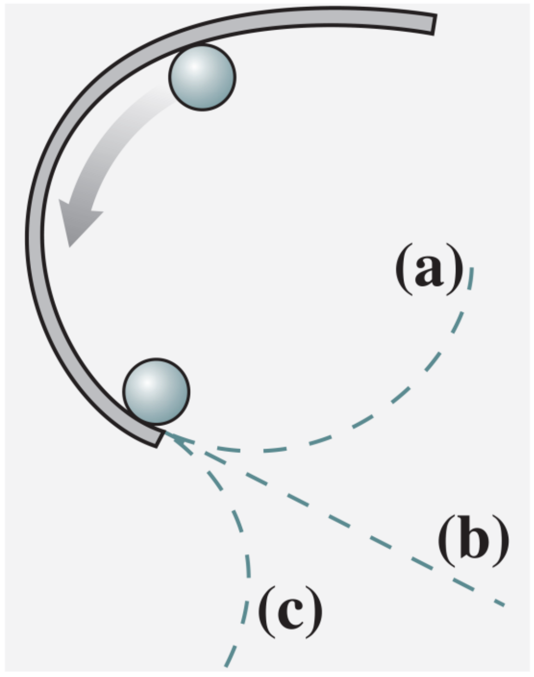
Results of Newton's first law of motion

- Uniform motion is motion at a constant speed in a straight line.
- The first law maintains that uniform motion is a natural state, requiring no explanation.
- Net force is the vector sum of all forces that act on a given object.



Think about it…

A curved barrier lies on a horizontal tabletop, as shown. A ball rolls along the barrier and the barrier exerts a force that guides the ball in its curved path. After the ball leaves the barrier, which path does it follow?

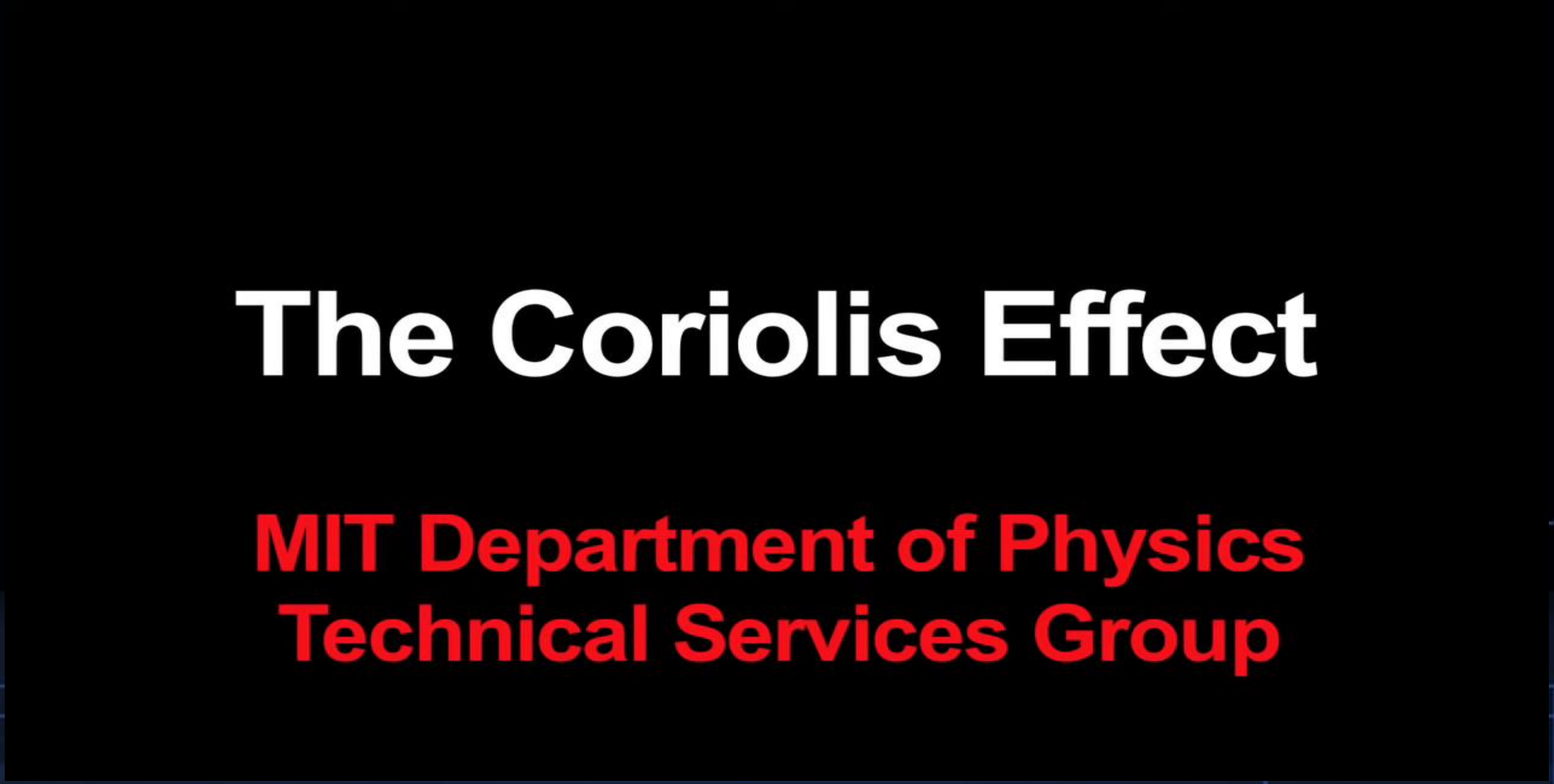


Inertial reference frame

- Newton's first law is NOT true in all reference frames, but we can always find reference frames in which it (as well as the rest of Newtonian mechanics) is true. Such special frames are referred to as inertial reference frames, or simply inertial frames.
- All inertial frames are move to each other with constant relative velocities.

Example of non-inertial frame

- Rotating frame



https://www.youtube.com/watch?v=dt_XJp77-mk

Newton's second law of motion I

- Newton defined "quantity of motion," now called **momentum**, as the product of an object's mass and velocity: $\vec{p} = m\vec{v}$
- **Newton's second law**: The net force on a body is equal to the product of the body's mass and its acceleration.

$$\overrightarrow{F_{net}} = \frac{d\vec{p}}{dt}$$

Newton's second law of motion II

- When mass is constant, Newton's second law becomes:

$$\overrightarrow{F_{net}} = \frac{d\vec{p}}{dt} = m\frac{d\vec{v}}{dt} = m\vec{a}$$

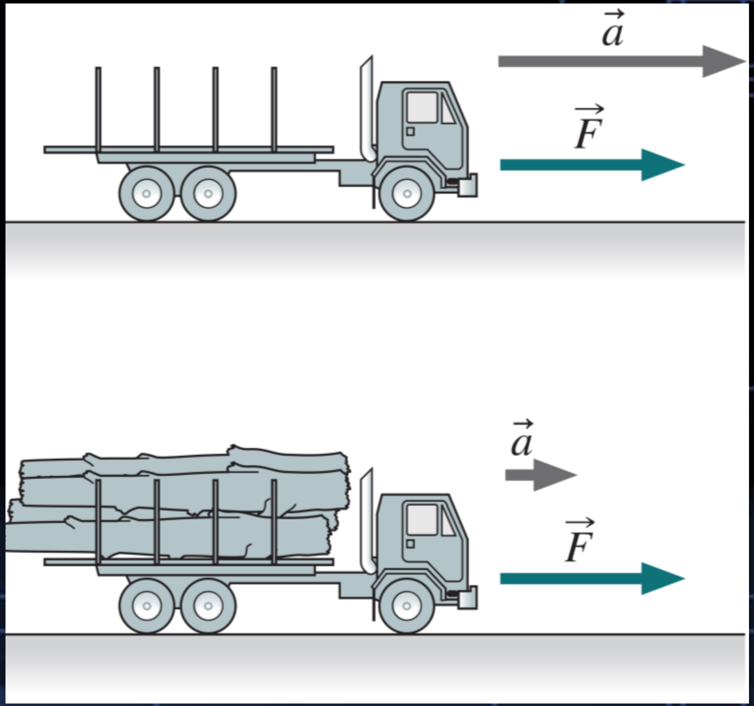
- The acceleration component along a given axis is caused only by the sum of the force components along that same axis, and not by force components along any other axis.

$$F_{net,x} = ma_x, F_{net,y} = ma_y, F_{net,z} = ma_z$$

Mass, Inertia, and Force

- If we solve the second law for the acceleration, we find that : $\vec{a} = \vec{F}/m$

The mass *m* that appears in Newton's laws is thus a measure of an object's **inertia** and determines the object's response to a given force.



$\frac{m_1}{m_2} = \frac{|\vec{a}_1|}{|\vec{a}_2|}$ With the same force $\vec{F}$

Units in Newton's second law

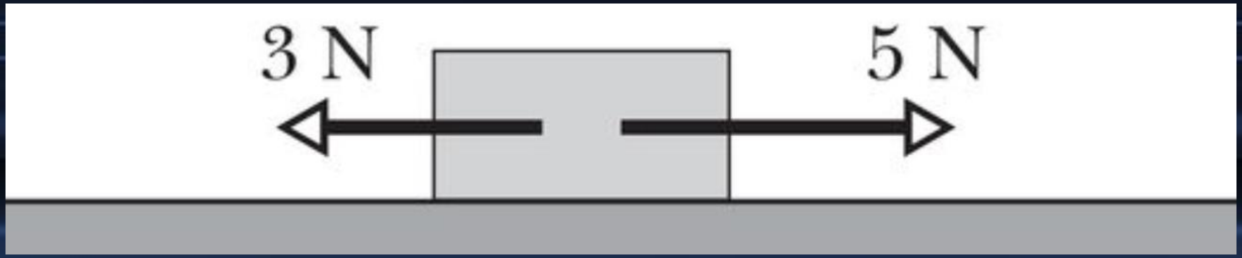
System	Force	Mass	Acceleration
SI	newton (N)	kilogram (kg)	m/s^2
CGS[a]	dyne	gram (g)	cm/s^2
British[b]	pound (lb)	slug	ft/s^2

[a] 1 dyne = $1\ g \cdot cm/s^2$.

[b] 1 lb = $1\ slug \cdot ft/s^2$.

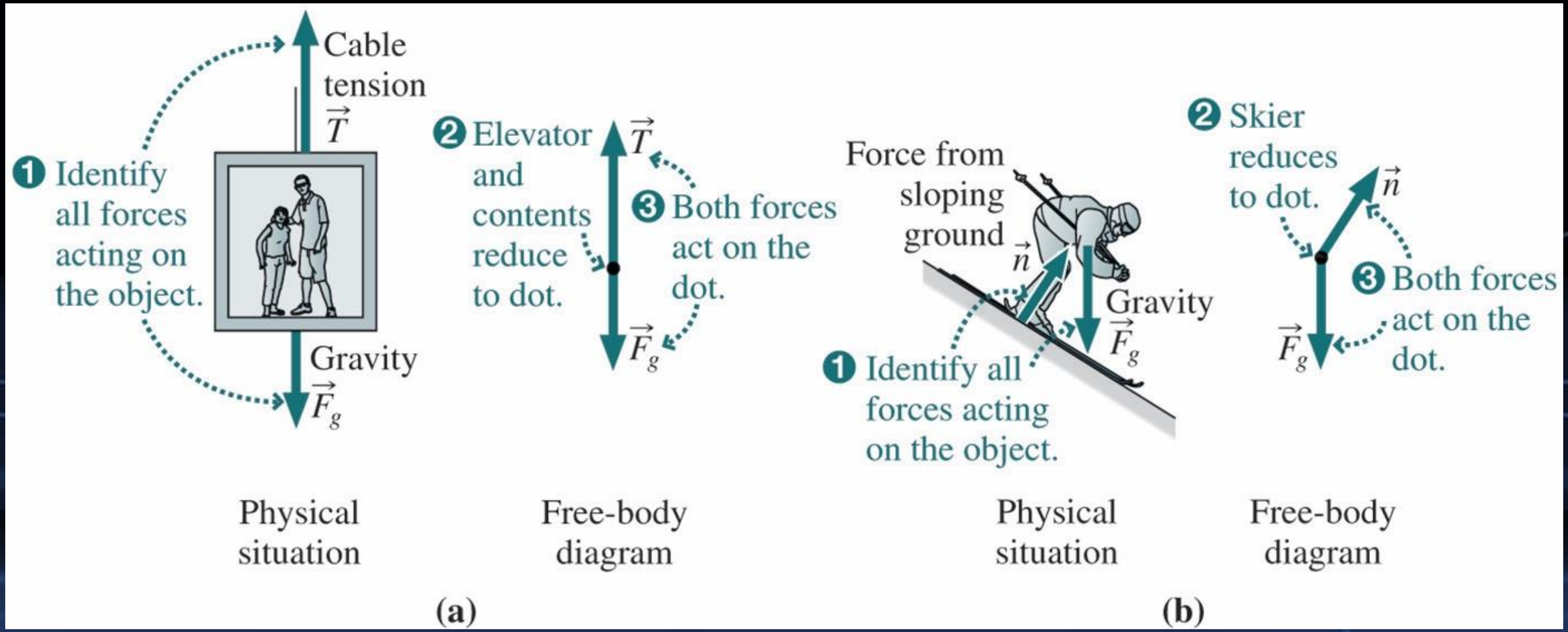
Free body diagram

- To analyze the net force on an object, we often use a free body diagram in which the only body shown is the one for which we are summing forces.
- In a system, only external force will result in acceleration of the system.



Using free body diagram

- Identify the object of interest and the forces acting on it.
- Represent the object as a dot.
- Draw the vectors for only those forces acting on the object, with their tails starting on the dot.



Summary

- **Newton's first law of motion:** A body in uniform motion remains in uniform motion, and a body at rest remains at rest, unless acted on by a nonzero net force ($\overrightarrow{F_{net}} \neq 0$) .
- **Newton's second law**: The net force on a body is equal to the product of the body's mass and its acceleration.

$$\overrightarrow{F_{net}} = \frac{d\vec{p}}{dt}$$

When mass is constant, Newton's second law becomes:

$$\overrightarrow{F_{net}} = m\vec{a}$$

Next

- Some particular forces
- Application of Newton’s second law
- Equation of motion
- Newton’s third law