Physics 225

Section 2,
Fall 2018

Today: Forces and Motion

- **Take Home Message**
  - Force is a vector, that describes motion through Newton's Laws

Physics!

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Physics

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This a *(disambiguation).*
Not to

Physics is the study of forces!

Physics (
(ἐπιστήμη
nature", fr
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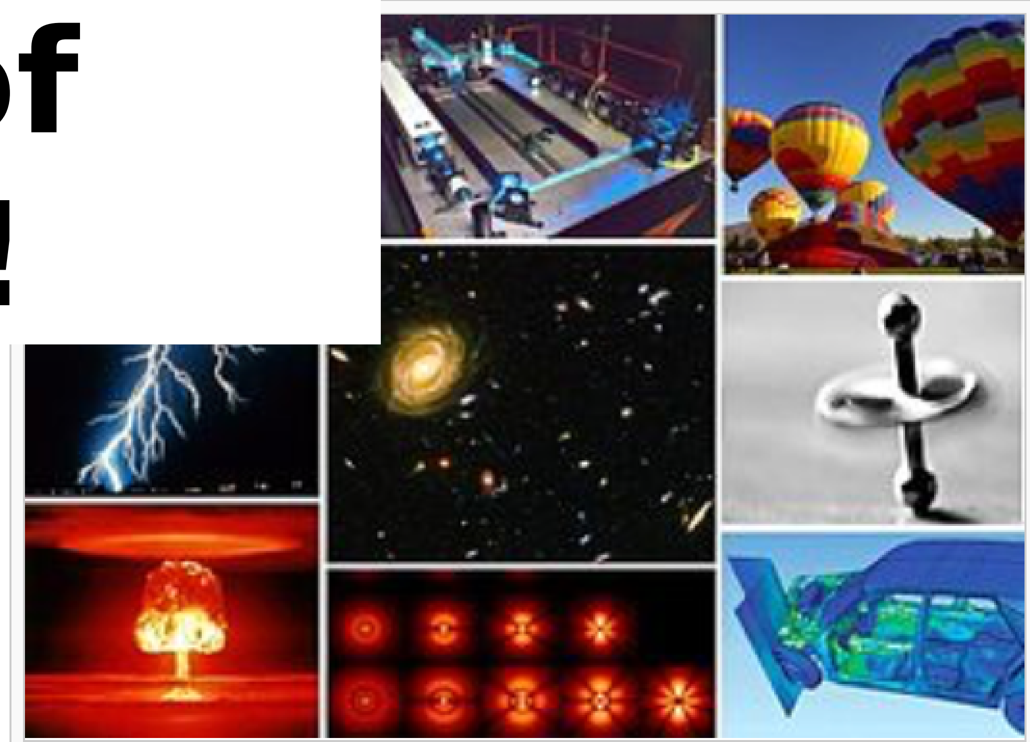
and its mo
related concepts such as energy and force.[5] One of the most fundamental scientific disciplines, the main goal of physics is to understand how the universe behaves.[a][6][7][8]

Physics is one of the oldest academic disciplines, perhaps the oldest through its inclusion of



Various examples of physical phenomena.

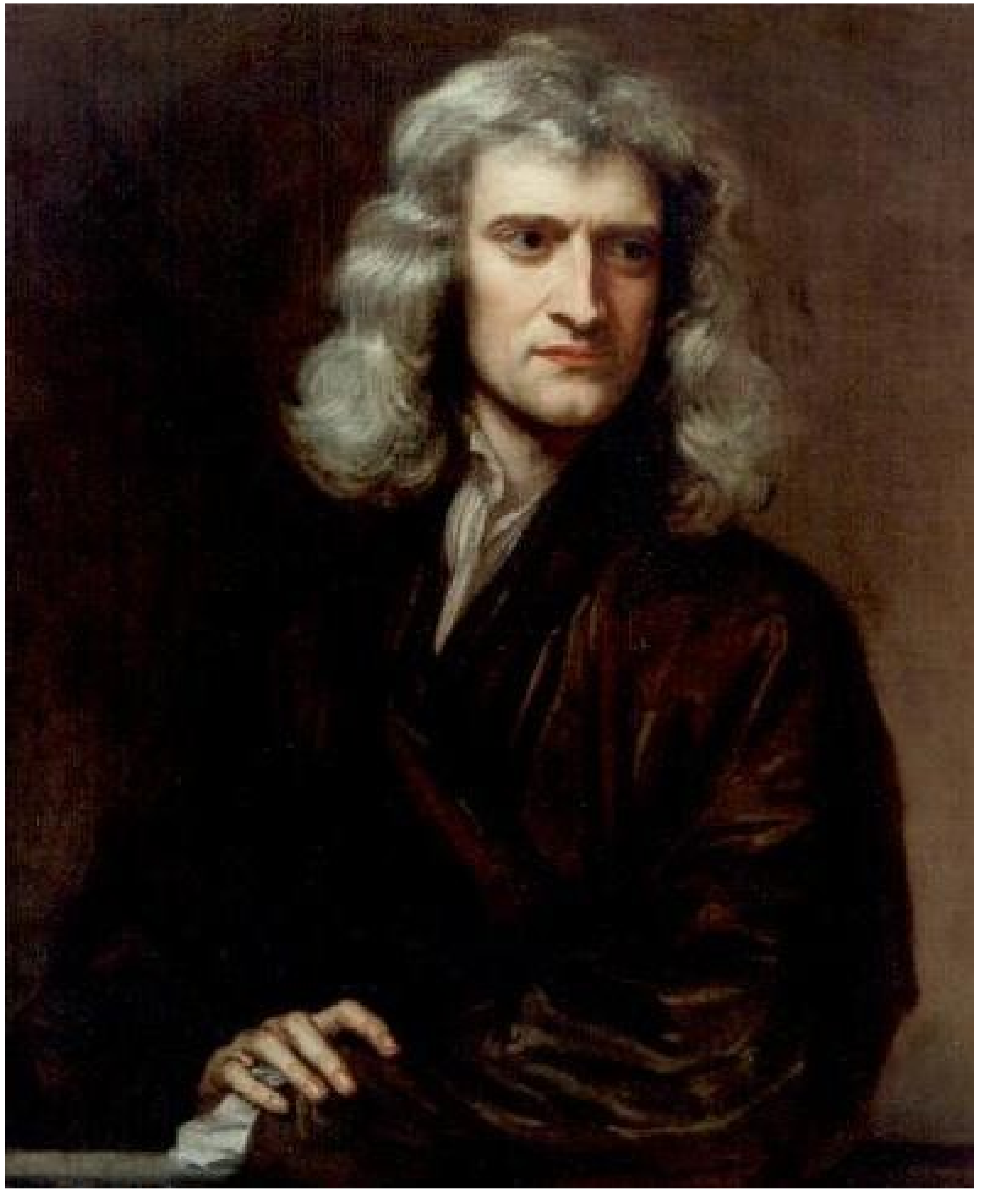
Aristotle

- 384 BC – 322 BC
- Natural and “violent” motion.
- Violent motion is when we interfere with an object
- “It is the nature of all things to be at rest”

$= mV$

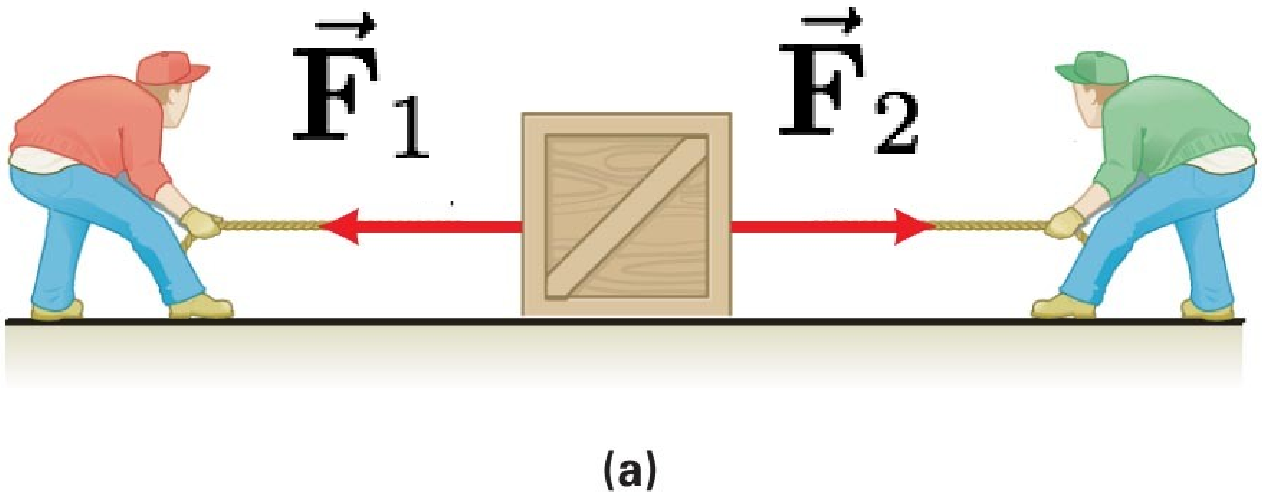
Isaac Newton

- 1643 – 1727
- It is the natural state of an object to travel at constant speed unless acted on by a force.
- Introduced the concept of a “force”



Force

- Force
  - Something capable of *accelerating* an object
    - Contact: push/pull
    - Action-at-a-distance: e.g. gravity
  - Force is a vector



Newton's first law

- Net force: $\vec{\mathbf{F}}_{\mathrm{net}} \equiv \Sigma\vec{\mathbf{F}}_{\mathrm{i}}$
- If the **net force** on an object is zero…
  - If at rest, object remains at rest
  - If moving, moves at a constant velocity
- "Objects move at constant velocity, unless acted on by an external net force"

  (In an inertial frame of reference, i.e. if the origin is not accelerating)

Clicker question #1

Question 4.1b Newton's First Law

A hockey puck slides on ice at constant velocity. What is the *net* force acting on the puck?

A more than its weight

B equal to its weight

C less than its weight but more than zero

D depends on the speed of the puck

zero

Clicker question #2

Question 4.2a **Cart on Track I**

Consider a hockey puck on a horizontal frictionless surface. Once the puck has been given a push and released, what will happen to the puck?

A. slowly come to a stop
B. continue with constant acceleration
C. continue with decreasing acceleration
D. continue with constant velocity
E. immediately come to a stop

Clicker question #3

Question 4.1a Newton's First Law

A book is lying at rest on a table. The book will remain there at rest because:

A there is a net force but the book has too much inertia

B there are no forces acting on it at all

C it does move, but too slowly to be seen

D there is no net force on the book

there is a net force, but the book is too heavy to move

Mass

- Inertia = tendency of an object to remain at rest or to remain in uniform motion (const. velocity)
  - How much an object "resists" accelerating
- Mass = measure of inertia (units kg)
  - Example: computers with same performance

2004
Power Mac G5
18 kg

2012
iPhone 5
0.1 kg

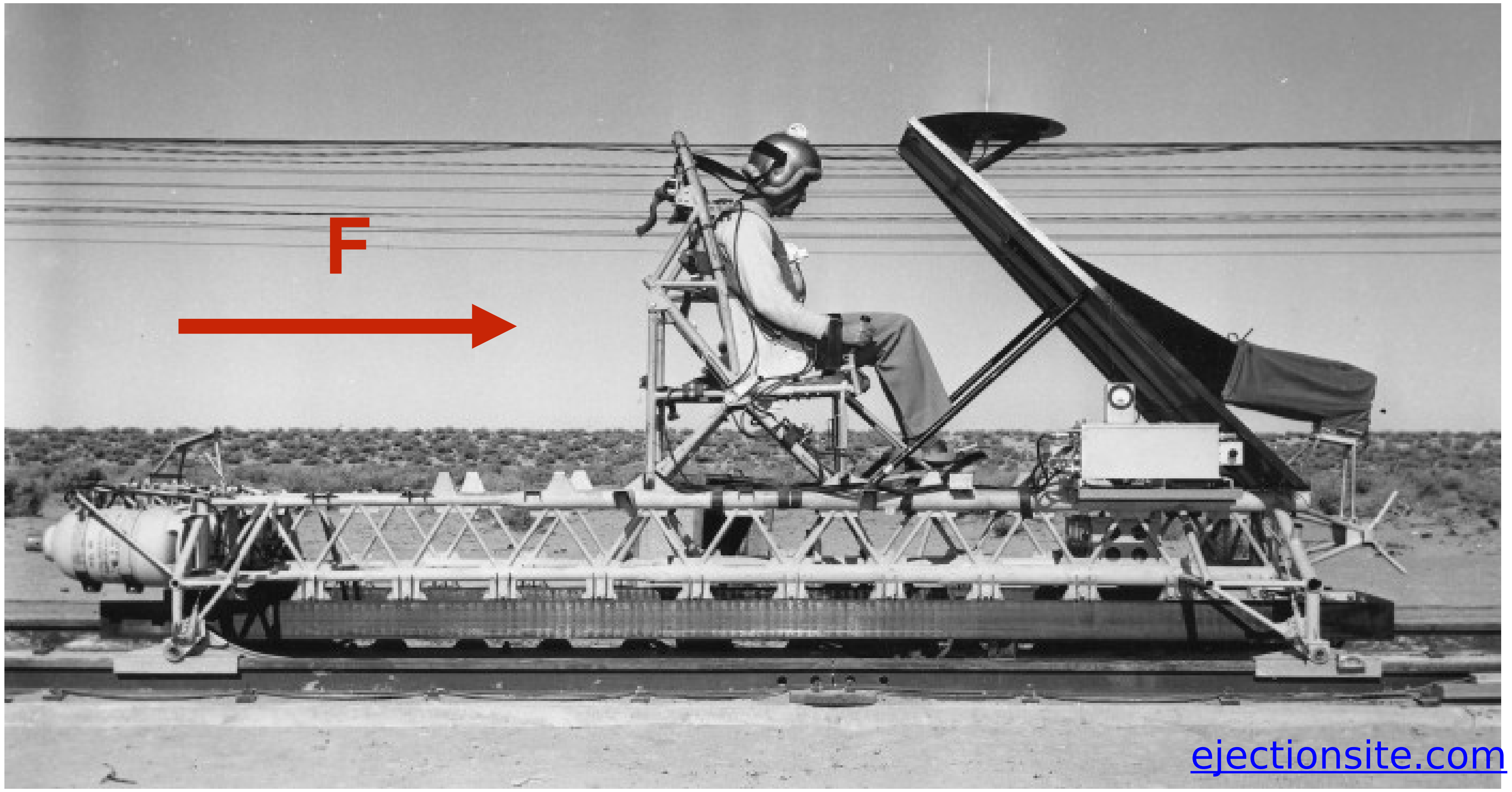
Newton's second law

- If the **net force** on an object of mass *m* is nonzero…

$$\vec{\mathbf{a}} = \frac{\vec{\mathbf{F}}_{\mathrm{net}}}{m}$$

  - Vector equation
  - Applies to entire system or to parts of system

Rocket accelerating

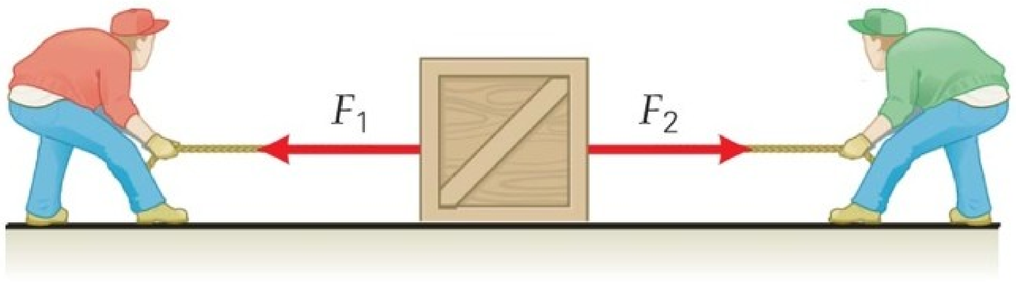


$$\vec{\mathbf{a}} = \frac{\vec{\mathbf{F}}_{\text{net}}}{m}$$ How do we maximize acceleration?

First 2 laws of motion

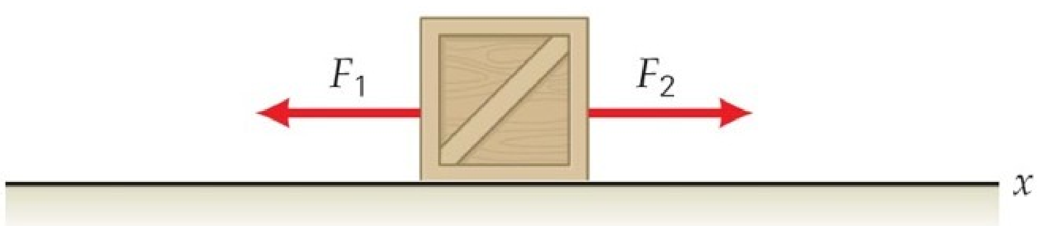
- First law: If $\vec{\mathbf{F}}_{\mathrm{net}} = \mathbf{0}$, then…
  - Object at rest remain at rest
  - Object in motion remains in motion at a constant velocity
- Second law: If $\vec{\mathbf{F}}_{\mathrm{net}} \neq \mathbf{0}$, then…
  - Object of mass *m* accelerates: $\vec{\mathbf{a}} = \dfrac{\vec{\mathbf{F}}_{\mathrm{net}}}{m}$

Net force & acceleration

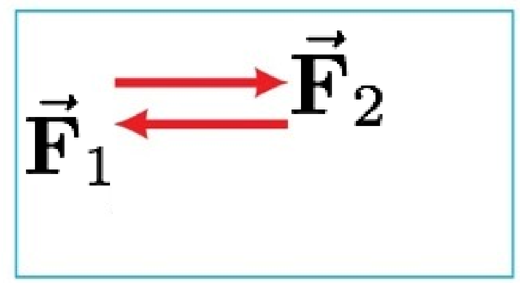


(a)

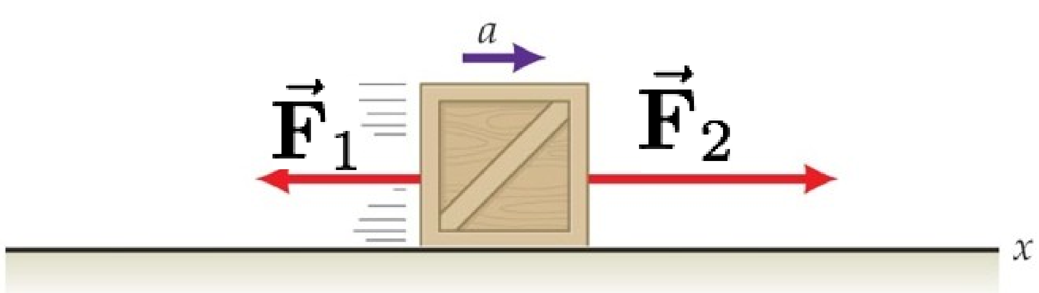
$$\vec{\mathbf{F}}_{\text{net}} = \Sigma\vec{\mathbf{F}}_i = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \cdots$$



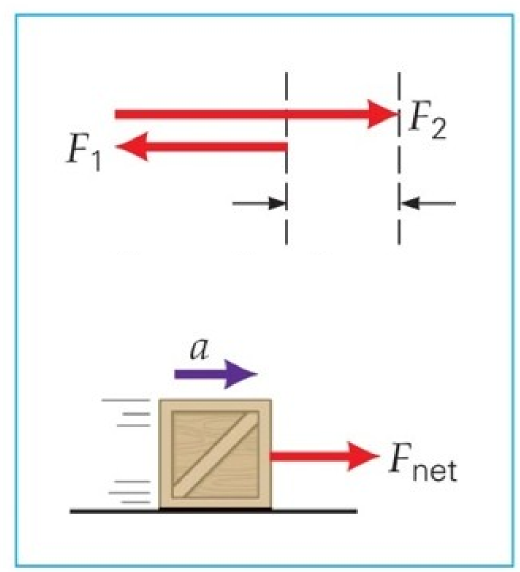
(b) Zero net force (balanced forces)



$$\vec{\mathbf{F}}_{\text{net}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 = 0$$
$$\vec{\mathbf{a}} = 0$$



(c) Nonzero net force (unbalanced forces)



$$\vec{\mathbf{F}}_{\text{net}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 \neq 0$$
$$\vec{\mathbf{a}} \neq 0$$

Force is a vector

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

$$a_x = \frac{F_x^{\text{net}}}{m}$$

$$a_y = \frac{F_y^{\text{net}}}{m}$$

$+y$

$+x$

$$\vec{\mathbf{F}}_x^{\text{net}} = F_x^{\text{net}}\hat{\mathbf{x}}$$

$\vec{\mathbf{F}}^{\text{net}}$

$$\vec{\mathbf{F}}_y^{\text{net}} = F_y^{\text{net}}\hat{\mathbf{y}}$$

Clicker question #4

Question 4.1c Newton's First Law III

You put your book on the bus seat next to you. When the bus stops suddenly, the book slides forward. Why?

A. a net force acted on it
B. no net force acted on it
C. it remained at rest
D. it did not move, but only seemed to
E. gravity briefly stopped acting on it

Clicker question #5

- The net force on a box is in the positive x direction. Which of the following statements best describes the motion of the box?

A Its velocity is parallel to the x axis.

B Its acceleration is parallel to the x axis.

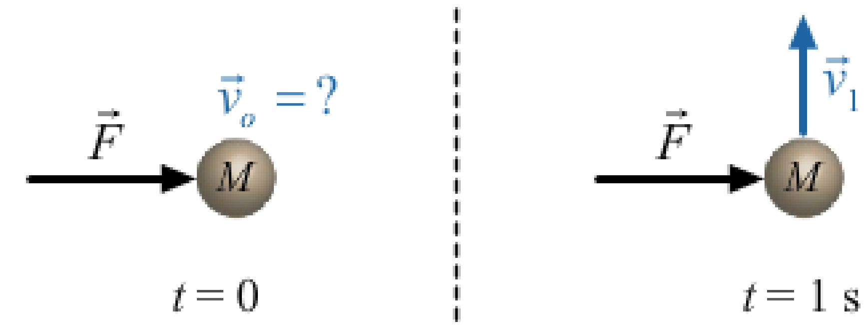
C Both its velocity and its acceleration are parallel to the x axis.

D Neither its velocity nor its acceleration need to be parallel to the x axis.

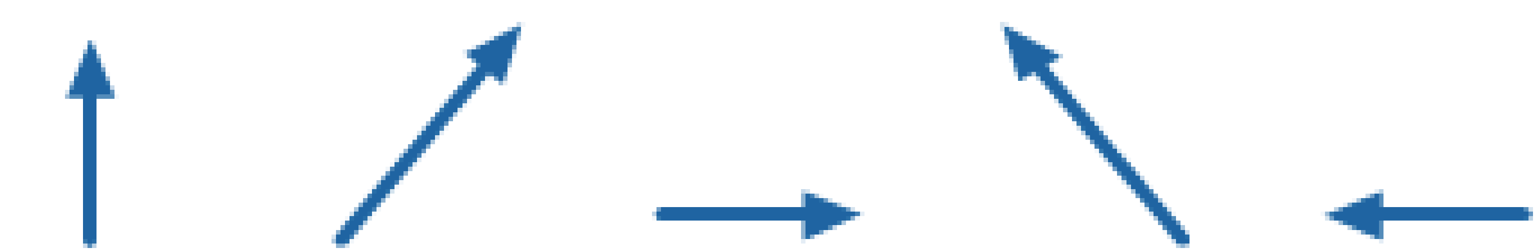
E

Clicker Question #6

- A force **F** acts on a mass **M** during the time period from t = 0 to t = 1 s, the mass moves with velocity $\mathbf{v_1}$ as shown.
  Which arrow represents $\mathbf{v_0}$, the velocity at time t=0 s?



A B C D E



Clicker Question #6

- A force **F** acts on a mass M during the time period from t = 0 to t = 1 s, the mass moves with velocity $\mathbf{v}_1$ as shown.
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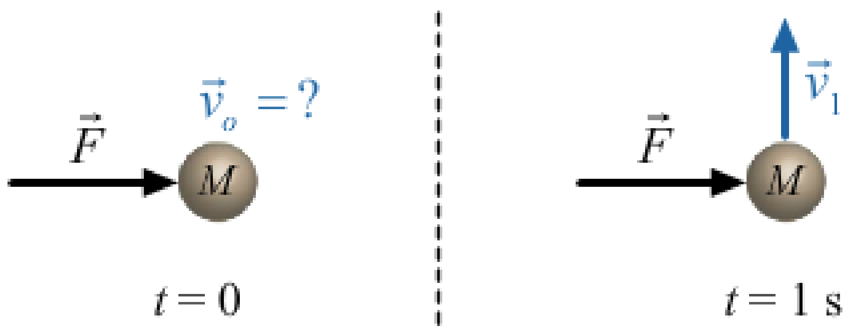
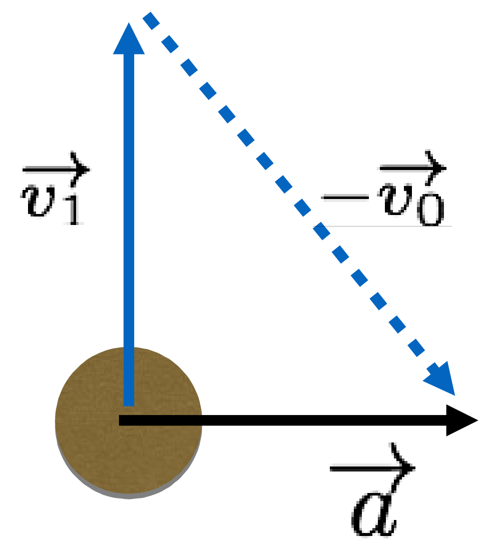
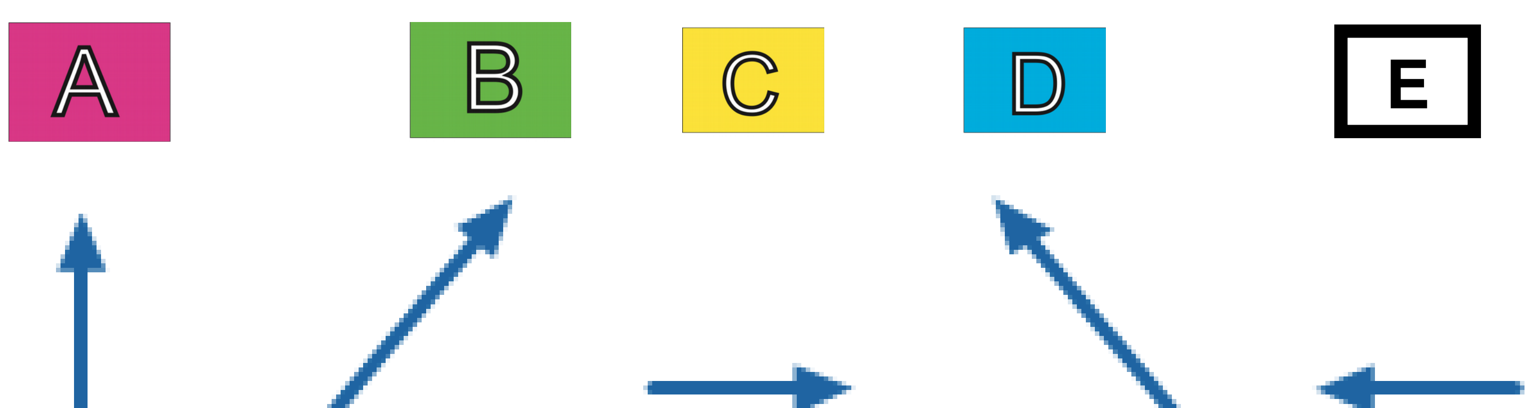


$$\overrightarrow{F} = m\overrightarrow{a}$$

$$\overrightarrow{a} = \frac{\overrightarrow{v_1} - \overrightarrow{v_0}}{t_1 - t_0}$$





how would you measure the angle of $-\overrightarrow{v_0}$?

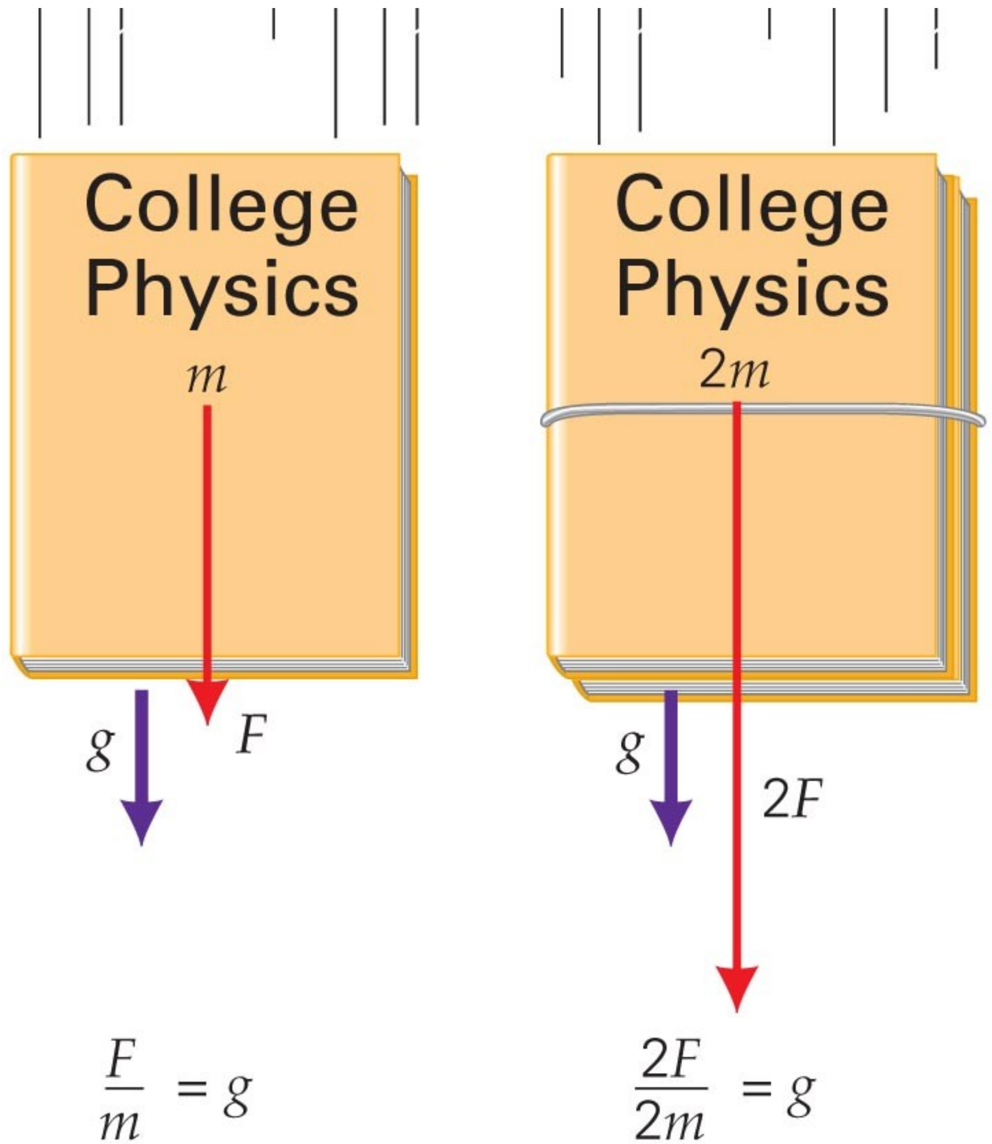
Types of Forces

Weight

- Weight = force of gravity

$+y$

$+x$

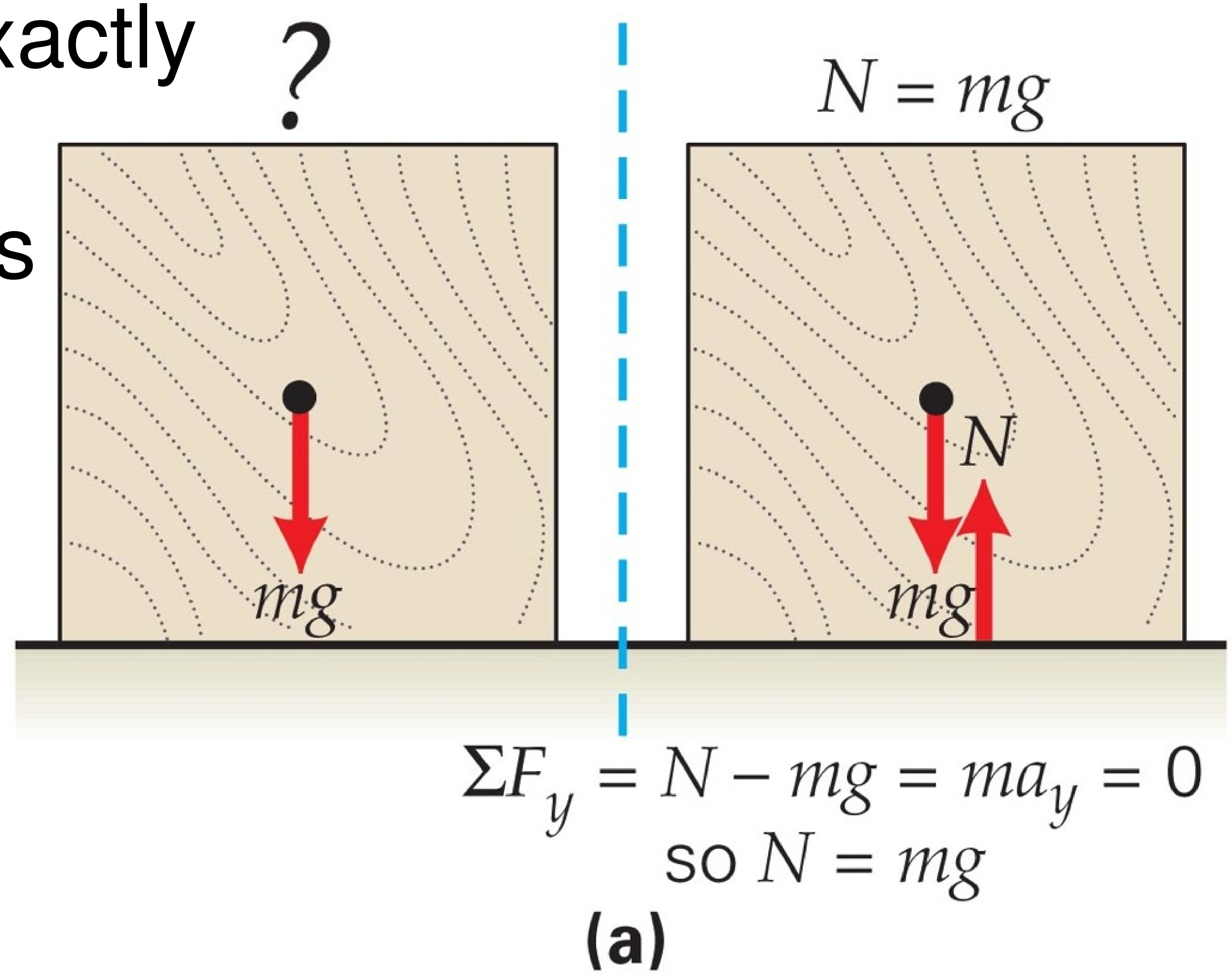


$$\vec{\mathbf{F}}_{\text{grav}} = \vec{W} = m\vec{\mathbf{g}} = -mg\hat{\mathbf{y}}$$

$$a_y = \frac{F_y}{m} = \frac{-mg}{m} = -g$$

Normal force

- Normal force
  - Direction: perpendicular to surface
  - Magnitude: exactly enough so object remains on surface



Normal force

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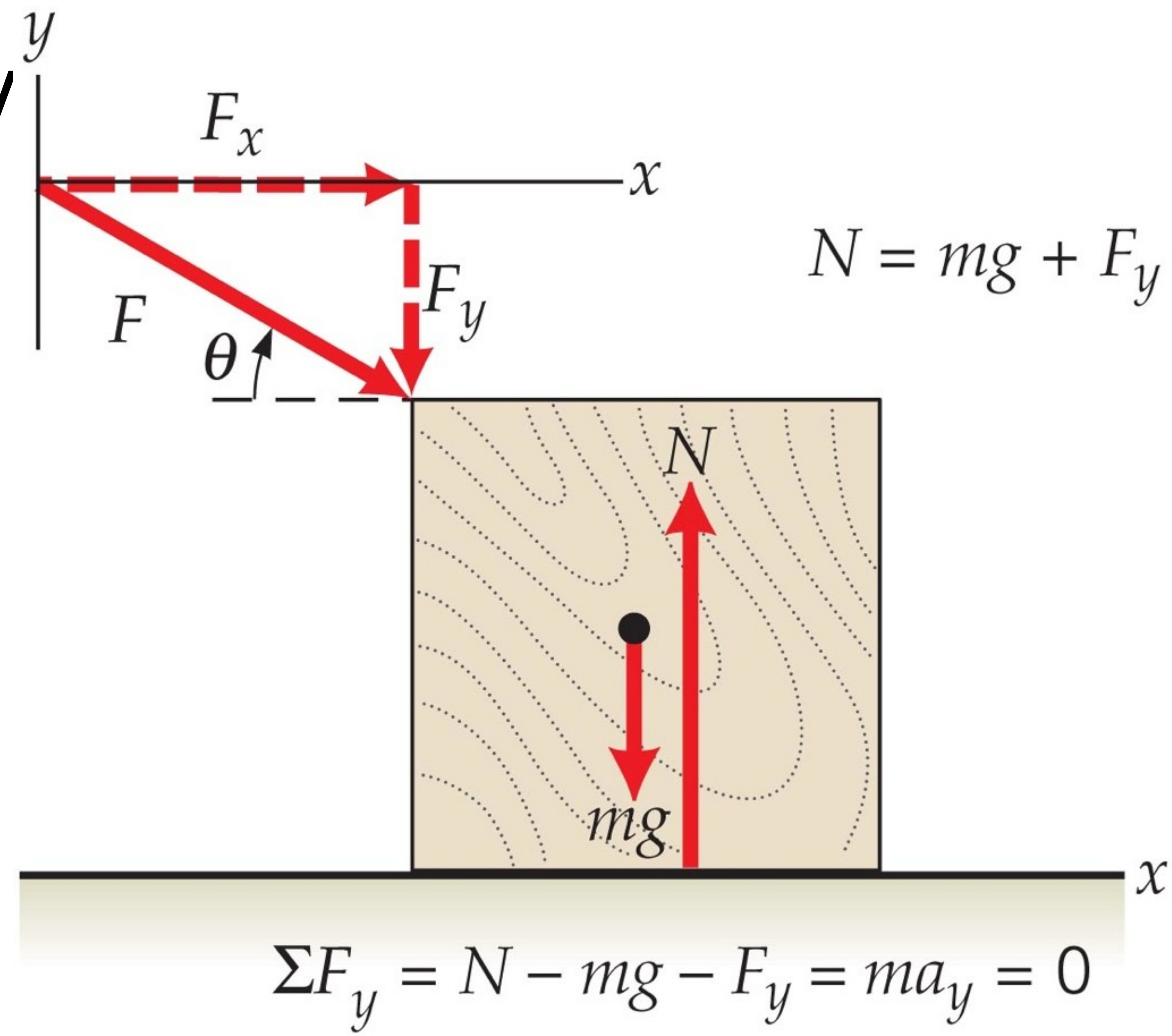
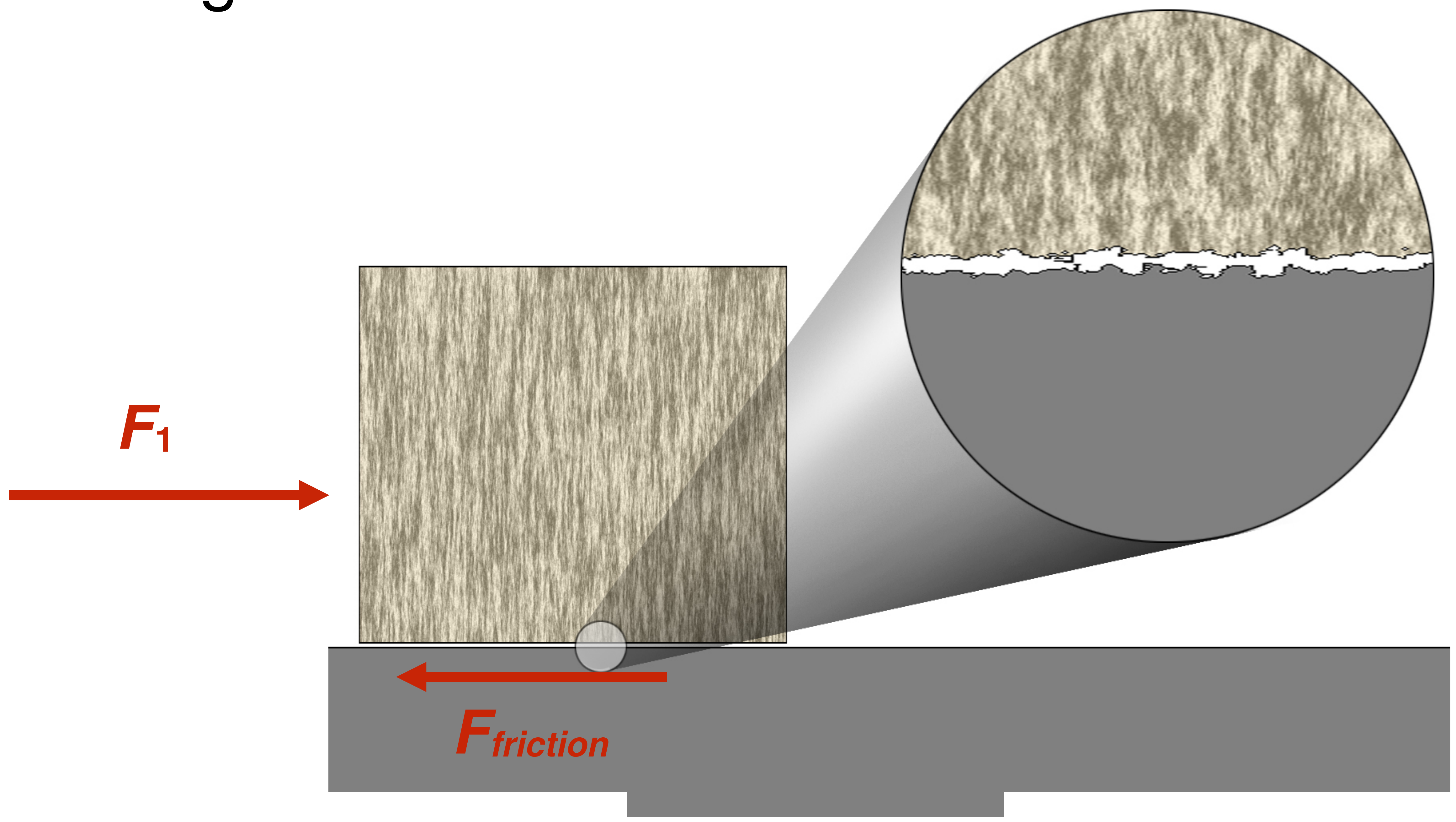


(b)

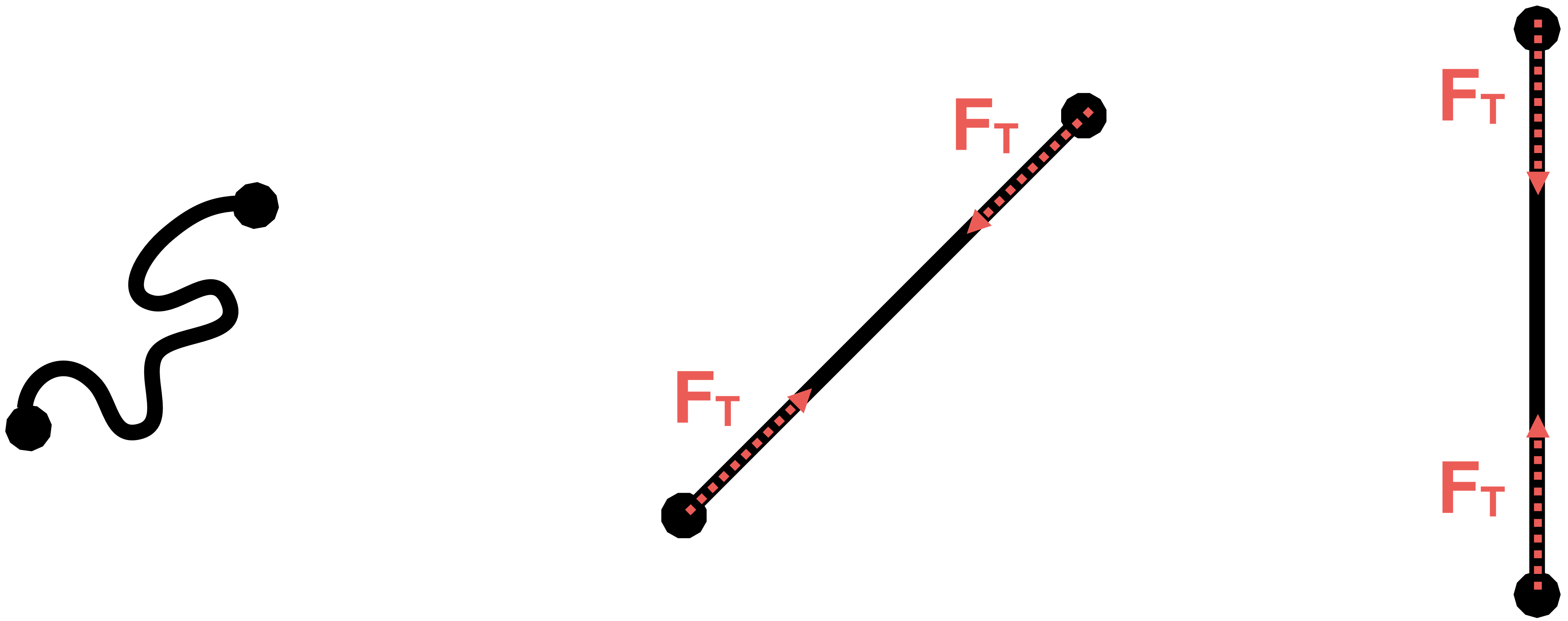
Friction

- friction = resistance that opposes sliding motion
- originates from molecular details



Tension

- Pulling force often transmitted by a taut rope, wire, or cable with a **force at both ends**

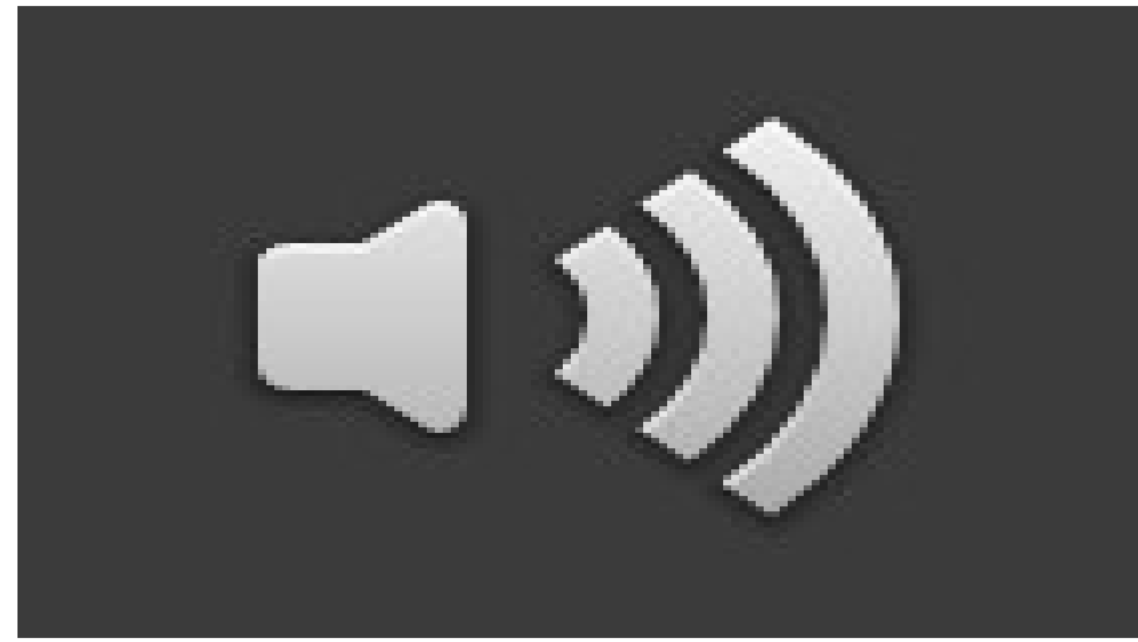


no tension

tension, $\mathbf{F_T}$

tension, $\mathbf{F_T}$

Some examples of tension



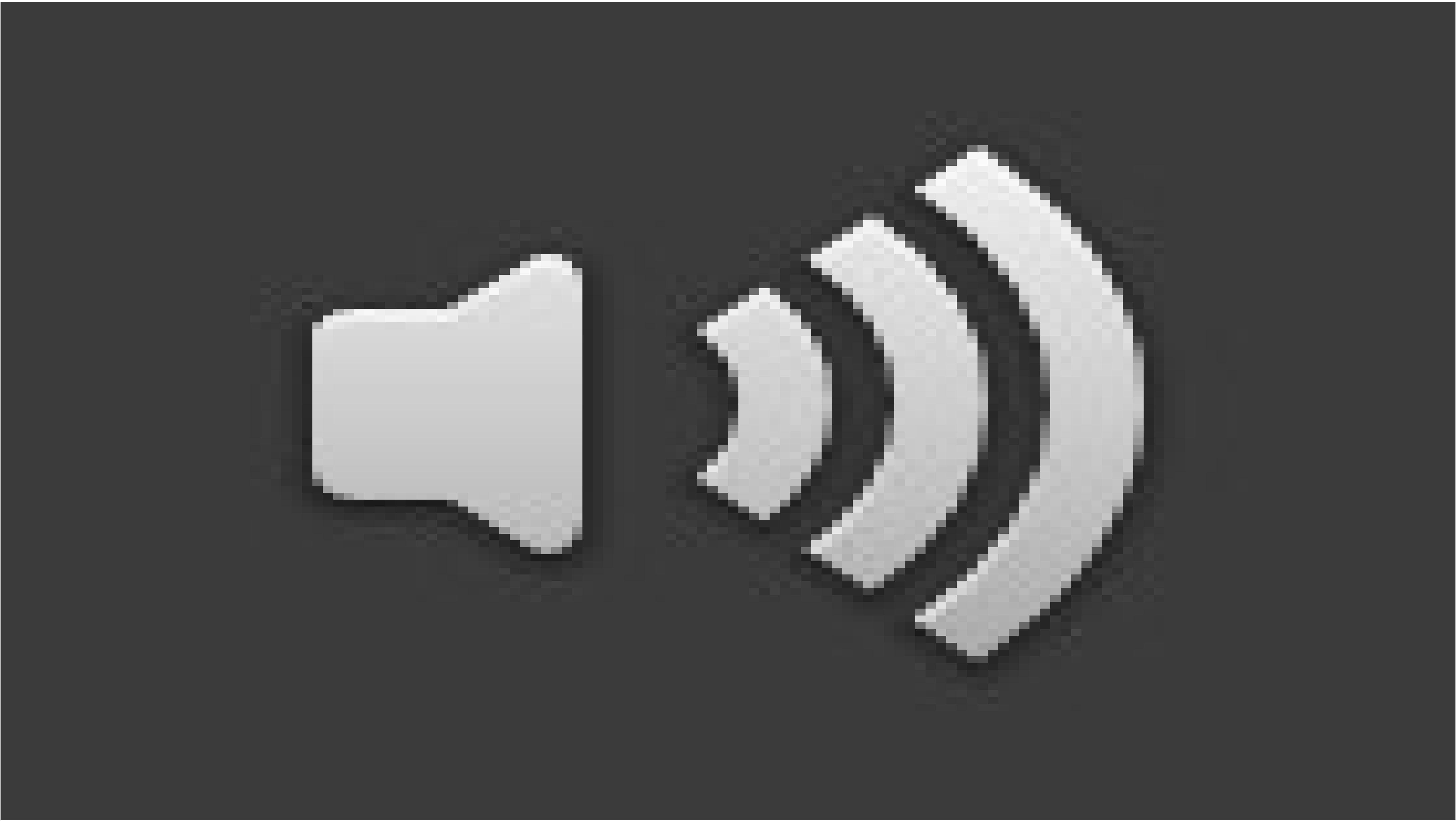
https://www.youtube.com/watch?v=j-zczJXSxnw

https://www.youtube.com/watch?v=4B36Lr0Unp4

- quitous part
  physics!)
- other
  interesting examples!

https://www.youtube.com/watch?v=pfjv9WTCix

Monkey shoot



Bonus example

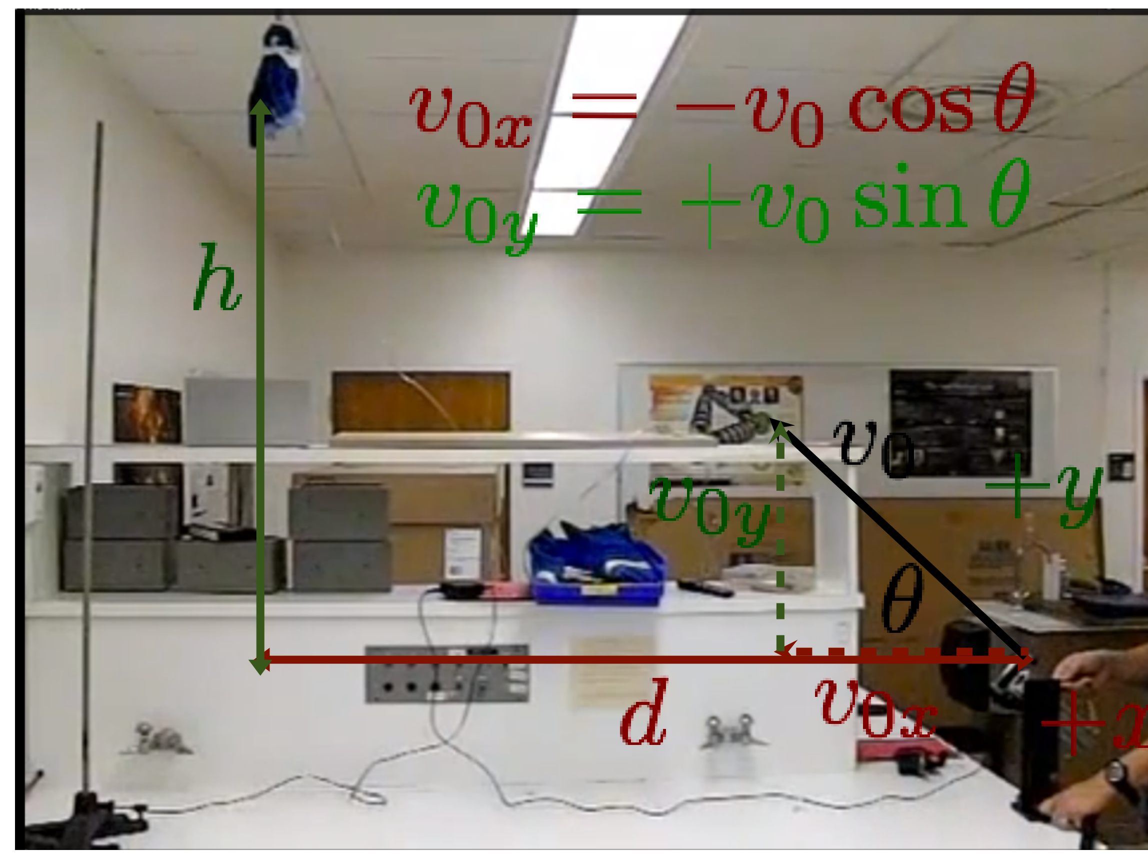
A monkey jumps from a height *h* out of a tree a horizontal distance *d* away at the instant a hunter fires a tranquilizer dart from the ground. At what angle should the hunter aim to hit the monkey?

Given: h d

Goal: θ

Principle: projectile

1. Read the problem
2. Draw a sketch
3. Given? Goal?
4. Brainstorm



Monkey shoot

Given: h d

Goal: θ

Projectile

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2 \qquad y = y_0 + v_{y0}t - \frac{1}{2}gt^2$$

$$v_x = v_{x0} + a_x t \qquad v_y = v_{y0} - gt$$

$$x_M = x_B$$
$$y_M = y_B$$

Monkey

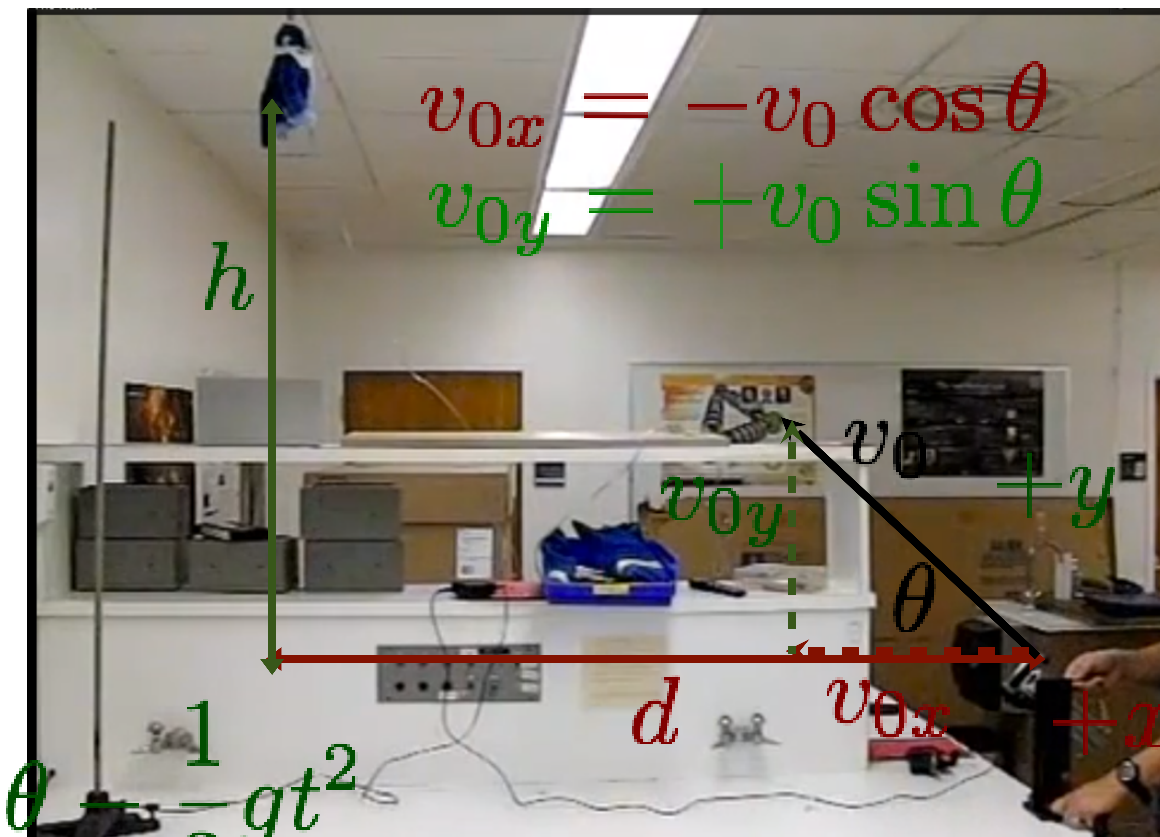
$$x_M = x_{0M} = -d$$

$$y_M = h + \cancel{v_{0yM}}t - \frac{1}{2}gt^2$$

Bullet

$$x_B = \cancel{x_{0B}} - v_{0xB}t = -v_0 t\cos\theta$$

$$y_B = \cancel{y_{0B}} + v_{0yB}t - \frac{1}{2}gt^2 = v_0 t\sin\theta - \frac{1}{2}gt^2$$

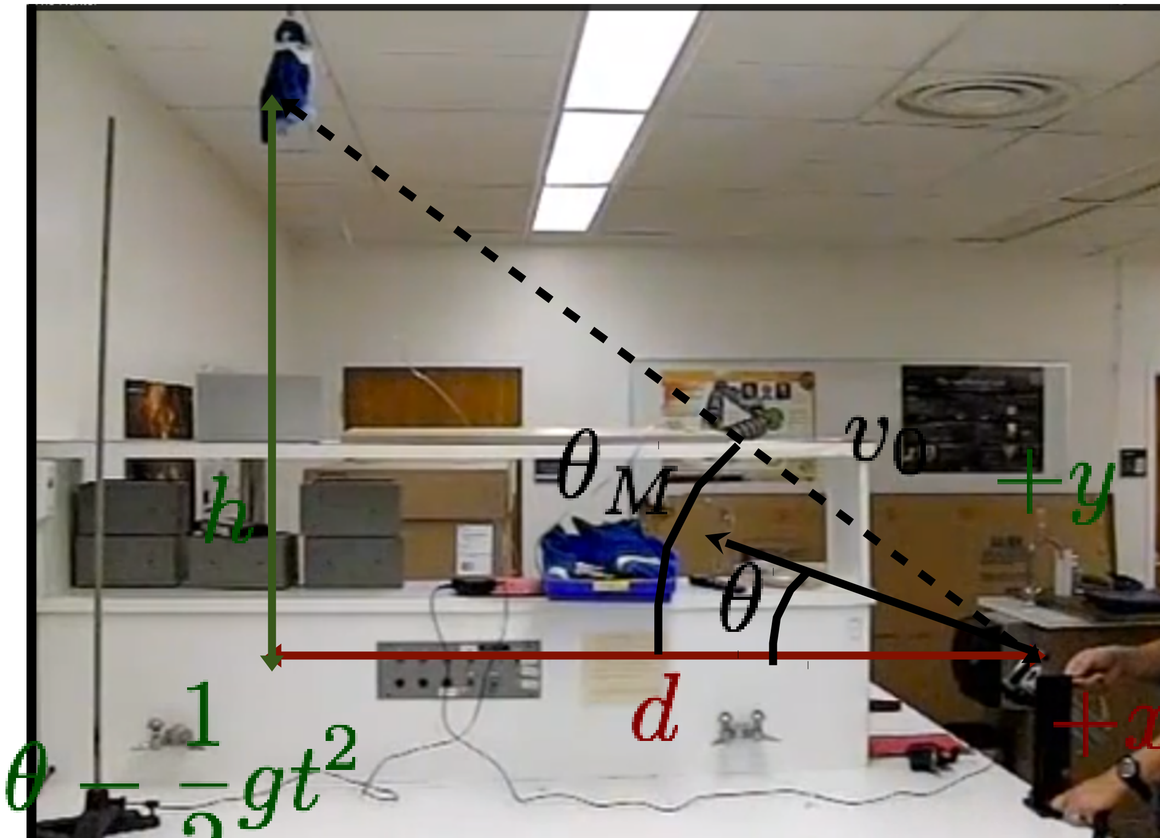


Monkey shoot

Monkey

$$x_M = x_{0M} = -d$$

$$y_M = h + \cancel{v_{0yM}} t - \frac{1}{2} g t^2$$



Bullet

$$x_B = \cancel{x_{0B}} - v_{0xB} t = -v_0 t \cos\theta$$

$$y_B = \cancel{y_{0B}} + v_{0yB} t - \frac{1}{2} g t^2 = v_0 t \sin\theta - \frac{1}{2} g t^2$$

$$\cancel{-}d = \cancel{-}v_0 t \cos\theta$$

$$h - \cancel{\frac{1}{2} g t^2} = v_0 t \sin\theta - \cancel{\frac{1}{2} g t^2}$$

$$\tan\theta = \tan\theta_M = \frac{h}{d} \Rightarrow \theta = \theta_M$$

$$h = v_0 t \sin\theta$$

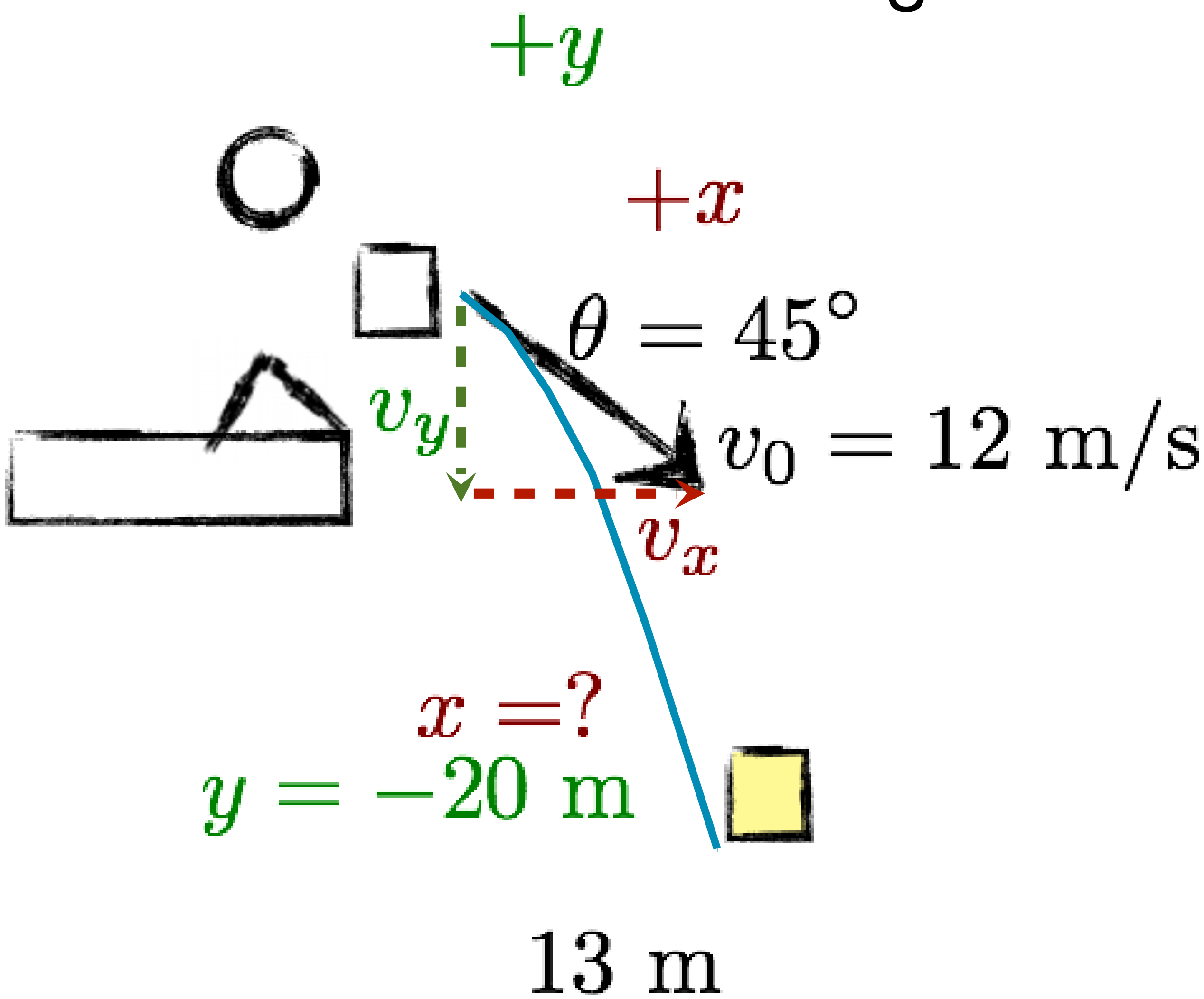
$$d = v_0 t \cos\theta$$

$$\frac{h}{d} = \frac{\cancel{v_0 t}}{\cancel{v_0 t}} \frac{\sin\theta}{\cos\theta} = \tan\theta$$

5. Calculate
6. (Plug in numbers)
7. Reasonable?

Ex. 3.7: stone toss

- A girl on a bridge (height 20 m) throws a stone at 12 m/s, 45° below horizontal. Does the block hit a target on the water that is 13 m from where it goes under the bridge?



Given: $x_0 = y_0 = 0$ $y = -20$ m

$v_0 = 12$ m/s $\theta = 45°$

Goal: $x = ?$

Concept: Projectile

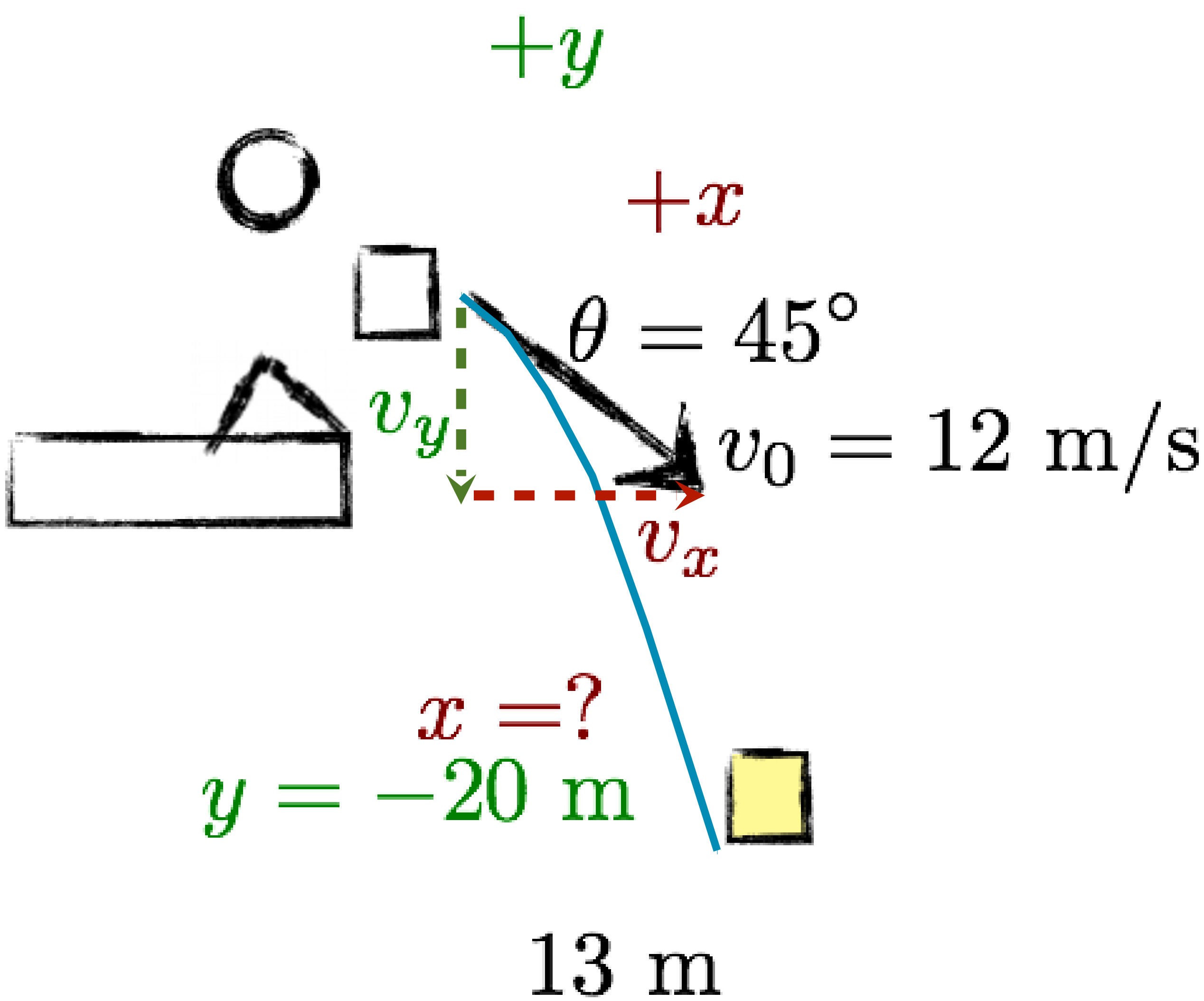
1. Read carefully
2. Draw a sketch
3. Given? Goal?
4. Brainstorm

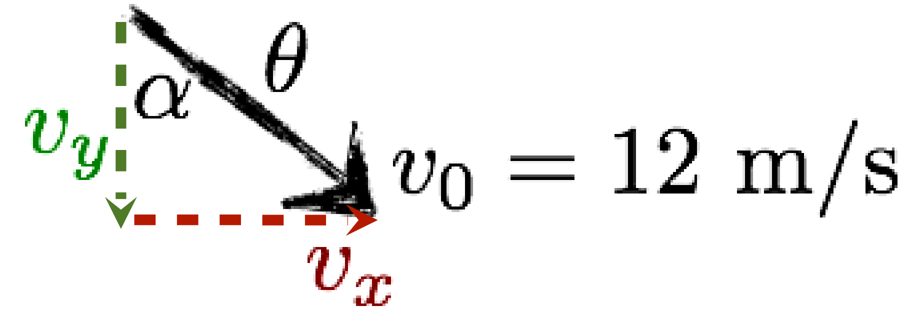
Ex. 3.7

Given: $x_0 = y_0 = 0$ $y = -20\text{ m}$

$v_0 = 12\text{ m/s}$ $\theta = 45°$

Goal: $x = ?$ **Concept:** Projectile





$$|v_{0x}|/|v_0| = \sin\alpha$$

$$|v_{0x}| = |v_0|\sin\alpha$$

$$v_{0x} = +v_0\sin\alpha$$

$$|v_{0y}|/|v_0| = \cos\alpha$$

$$|v_{0y}| = |v_0|\cos\alpha$$

$$v_{0y} = -v_0\cos\alpha$$

1. Read carefully
2. Draw a sketch
3. Given? Goal?
4. Brainstorm
5. Calculate

Ex. 3.7

Given: $x_0 = y_0 = 0$ $\quad y = -20\ \mathrm{m}$ $\quad v_{0x} = +v_0 \sin\alpha$

$v_0 = 12\ \mathrm{m/s}$ $\quad \theta = 45^\circ$ $\quad v_{0y} = -v_0 \cos\alpha$

Goal: $x = ?$ **Concept:** Projectile

$$x = \cancel{x_0} + v_{0x}t \qquad t = \frac{x}{v_{0x}} \qquad t = \frac{x}{v_0 \sin\alpha}$$

$$\sin^2 45^\circ = \cos^2 45^\circ = \frac{1}{2}$$

$$\sin^2\alpha = \cos^2\alpha = \frac{1}{2}$$

$$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$$

$$y = \cancel{y_0} - (\cancel{v_0} \cos\cancel{\alpha})\left(\frac{x}{\cancel{v_0} \sin\cancel{\alpha}}\right) - \frac{\cancel{1}}{2}g\left(\frac{x}{v_0 \sin\cancel{\alpha}}\right)^2$$

$$0 = \left(\frac{g}{v_0^2}\right)x^2 + x + y$$

1. Read carefully
2. Draw a sketch
3. Given? Goal?
4. Brainstorm
5. Calculate

Ex. 3.7

Given: $x_0 = y_0 = 0$ $y = -20\ \mathrm{m}$

$v_0 = 12\ \mathrm{m/s} \quad \theta = 45^\circ$

Goal: $x = ?$ **Concept:** Projectile

$$0 = \left(\frac{g}{v_0^2}\right) x^2 + x + y$$

$$x = \frac{-1 + \sqrt{1 - 4\frac{gy}{v_0^2}}}{2\left(\frac{g}{v_0^2}\right)}$$

$$x = \frac{-1 + \sqrt{1 - 4\left[9.8\ \cancel{\mathrm{m}}/\cancel{\mathrm{s}^2}\right]\left[-20\ \cancel{\mathrm{m}}\right] / \left[12\ \cancel{\mathrm{m}}/\cancel{\mathrm{s}}\right]^2}}{2\left(\left[9.8\ \mathrm{m}/\cancel{\mathrm{s}^2}\right] / \left[12\ \mathrm{m}/\cancel{\mathrm{s}}\right]^2\right)} = 11\ \mathrm{m}$$

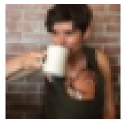
Target at *x* = 13 m. Stone does not hit target.

1. Read carefully
2. Draw a sketch
3. Given? Goal?
4. Brainstorm
5. Calculate
6. Plug in numbers
7. Reasonable?

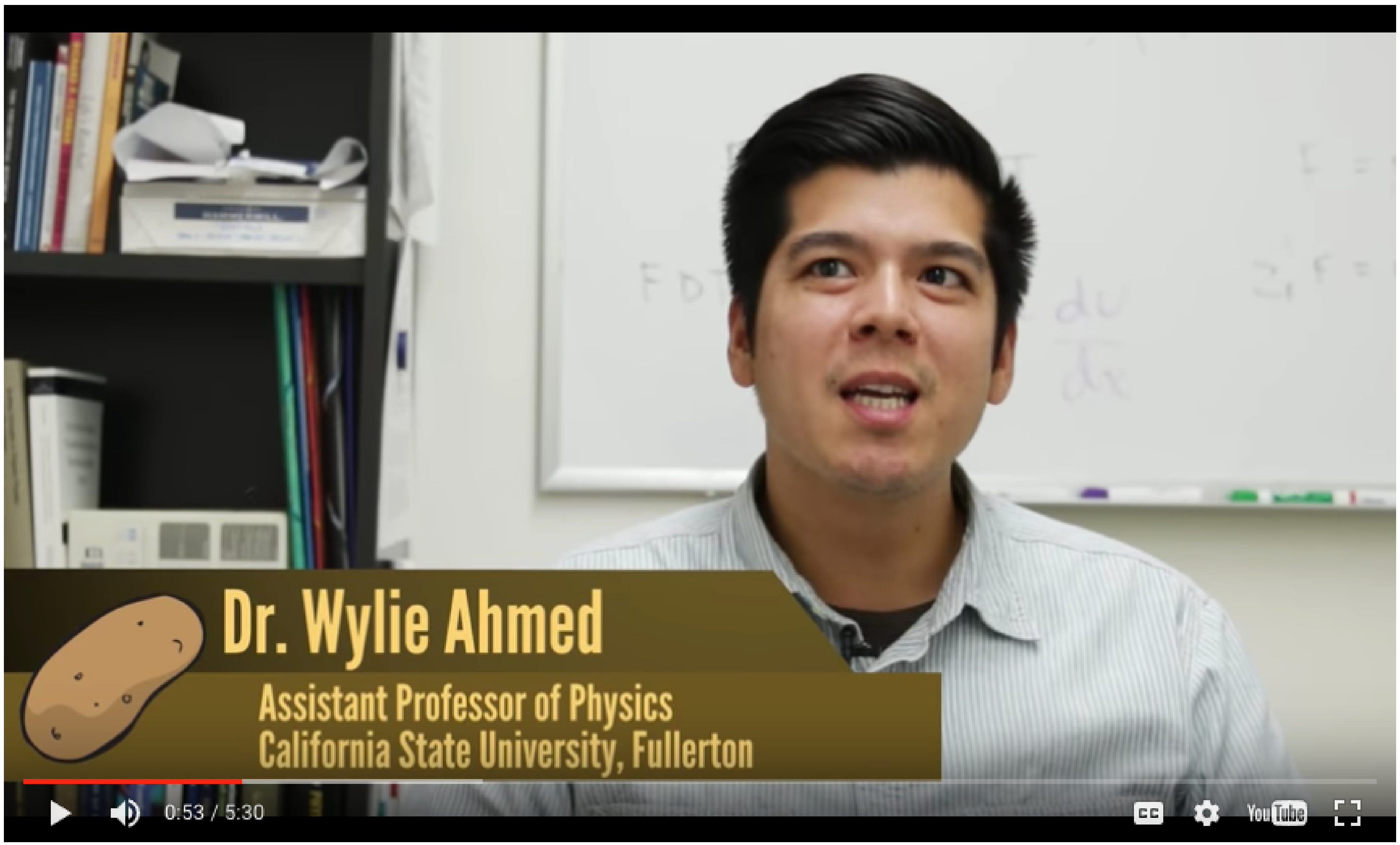
Can You Float On Mashed Potatoes?

We decided to figure out this great mystery.

posted on Feb. 10, 2017, at 3:54 p.m.



Kate Sosa
BuzzFeed Motion Pictures Staff



BuzzFeedBlue / Via youtube.com

https://www.buzzfeed.com/kater11/can-you-float-on-mashed-potatoes?utm_term=.kc7WRz8jP#.pwDK04862