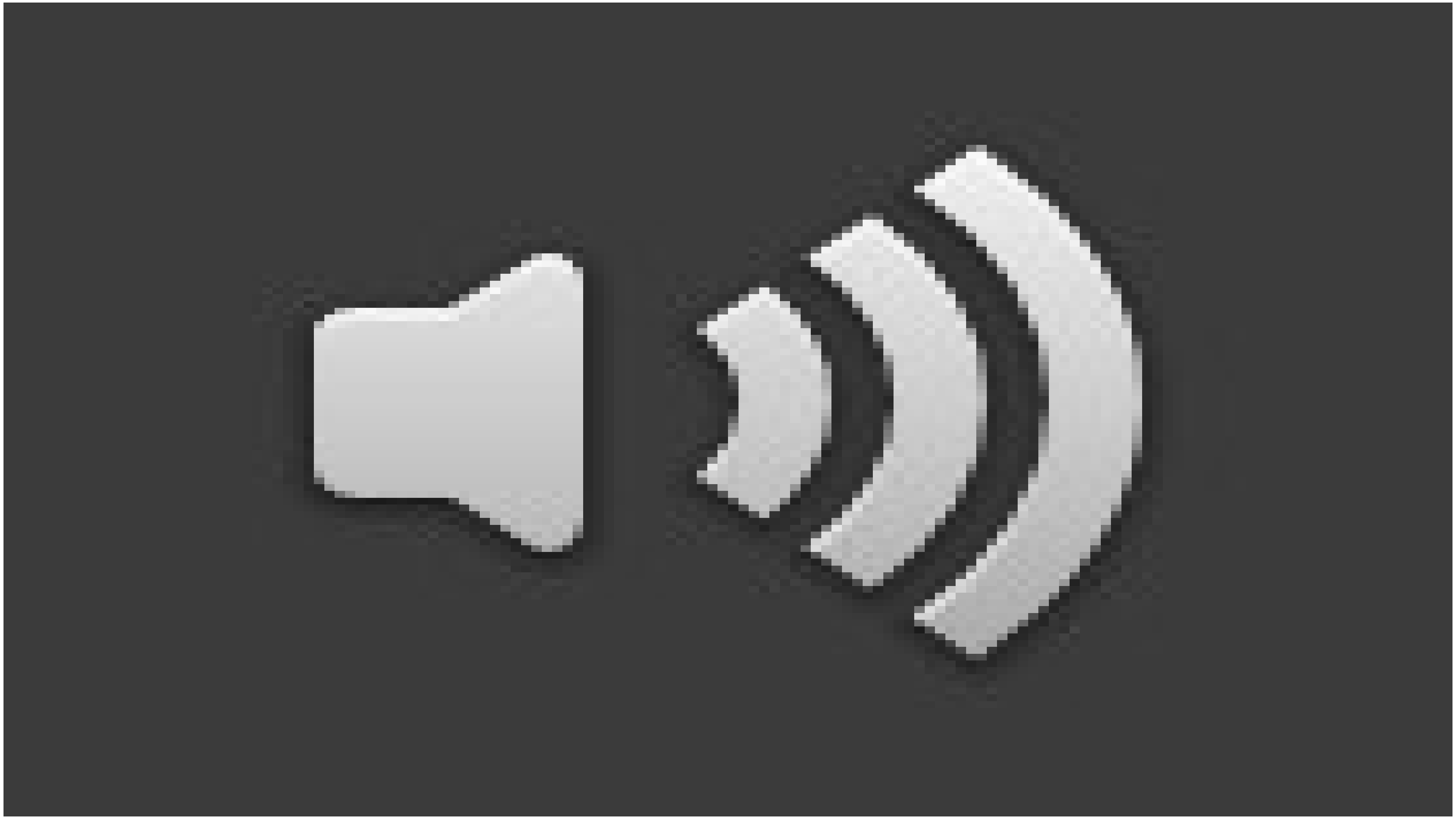
Physics 225

Section 2,
Fall 2018

Last Time: Newtons Laws and Particular Forces



- **Remember**
  - Forces are everywhere!
  - There are many different kinds of forces

Today: Newton's 3rd Law, FBDs, and Friction

- **Take Home Message**
  - Third-law force pairs
  - FBDs are a tool to help solve problems
  - Break everything into components

First 2 laws of motion

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

What are the units of force? Newtons!

What's a Newton?

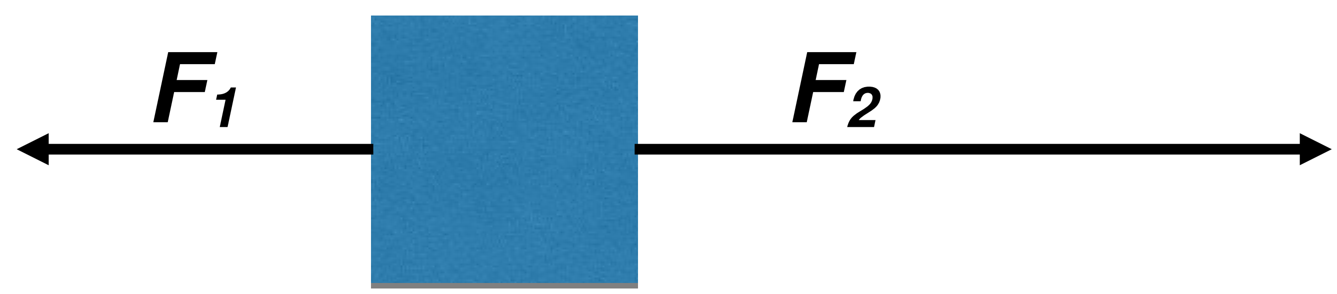
$$\overrightarrow{F_{net}} = m\,\overrightarrow{a} \rightarrow [kg] \cdot [m/s^2]$$

Free Body Diagrams

A block is sliding along a frictionless surface

$+y$

$+x$



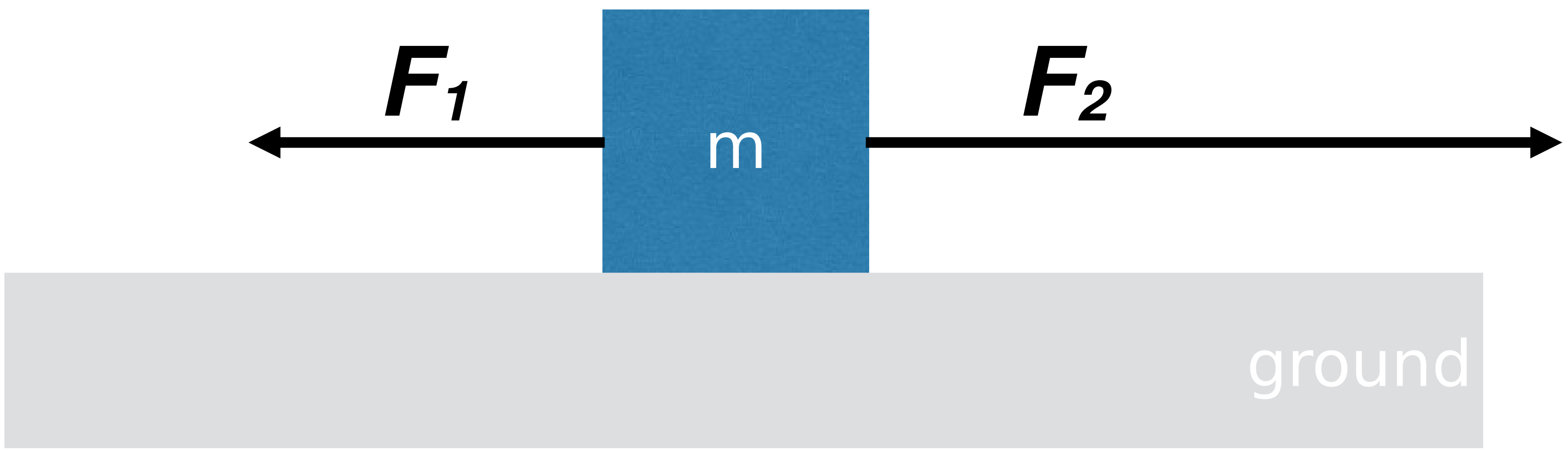
- FBDs are a graphical illustration of applied forces
- Each force is drawn as a vector indicating direction
- Net external force is related to system acceleration (F=ma)

Free Body Diagrams

A block is sliding along a frictionless surface

$+y$

$+x$



m = 1 kg
F_1 = 2 N
F_2 = 8 N

- How do we draw the free body diagram?
  - The x-direction is basically done…

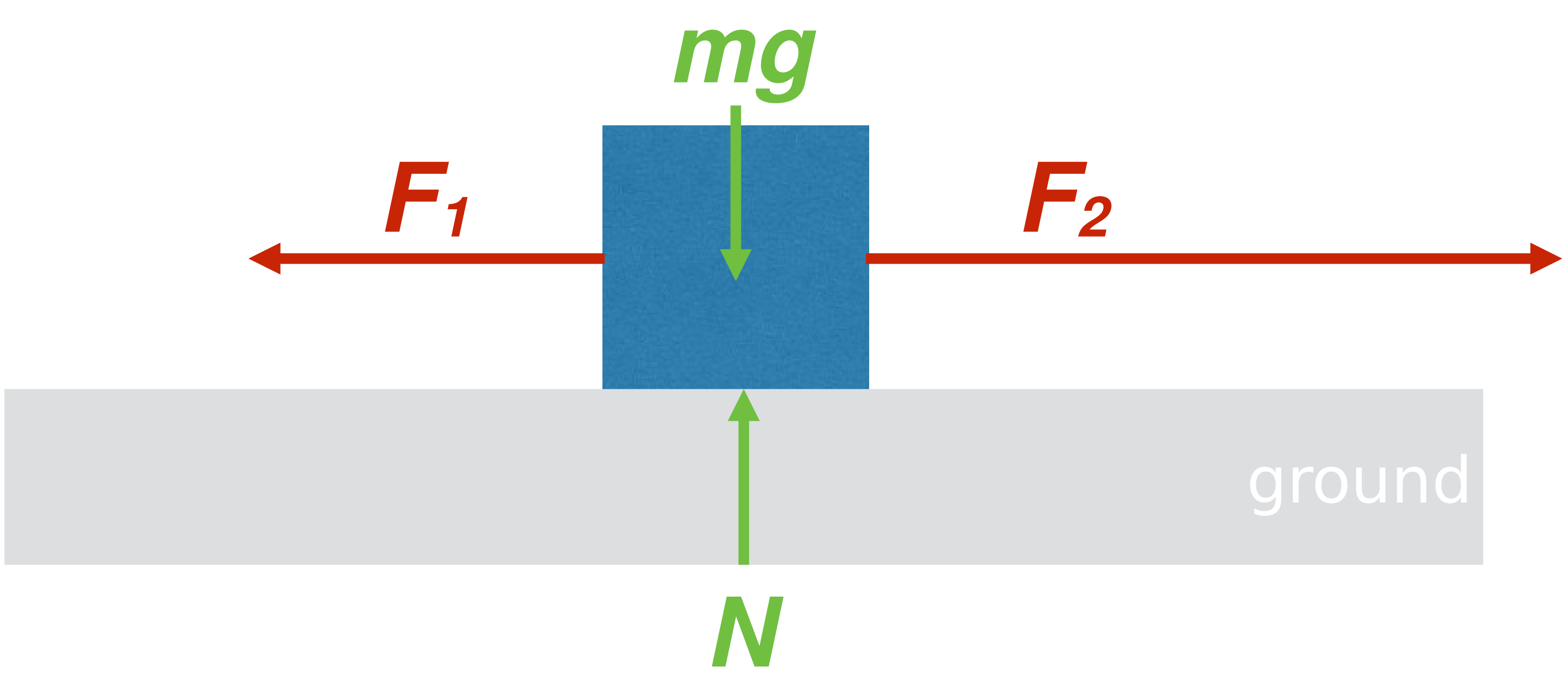
- What about the y-direction?

Free Body Diagrams

A block is sliding along a frictionless surface

$+y$

$+x$



m = 1 kg
F_1 = 2 N
F_2 = 8 N

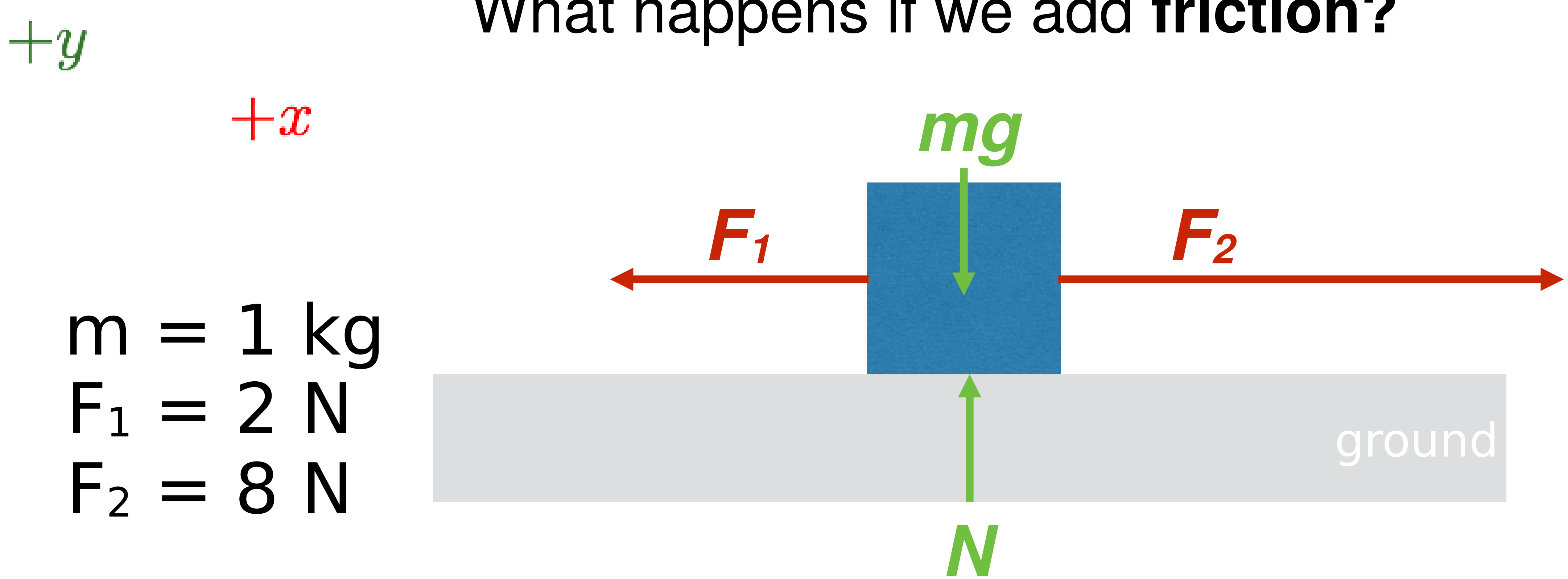
- How do we draw the free body diagram?
  - The x-direction is basically done…

$$\sum F_x = -F_1 + F_2 = ma_x \longrightarrow a_x = \frac{F_2 - F_1}{m} = \frac{(8-2)\ \mathrm{N}}{1\mathrm{kg}} = 6\ \mathrm{m/s^2}$$

$$\sum F_y = -mg + N = m\underbrace{\cancel{a_y}}_{0} \longrightarrow N = mg = (1\mathrm{kg})(9.8\ \mathrm{m/s^2}) = 9.8\ \mathrm{N}$$

Clicker Question #2a

What happens if we add **friction?**



$m = 1$ kg
$F_1 = 2$ N
$F_2 = 8$ N

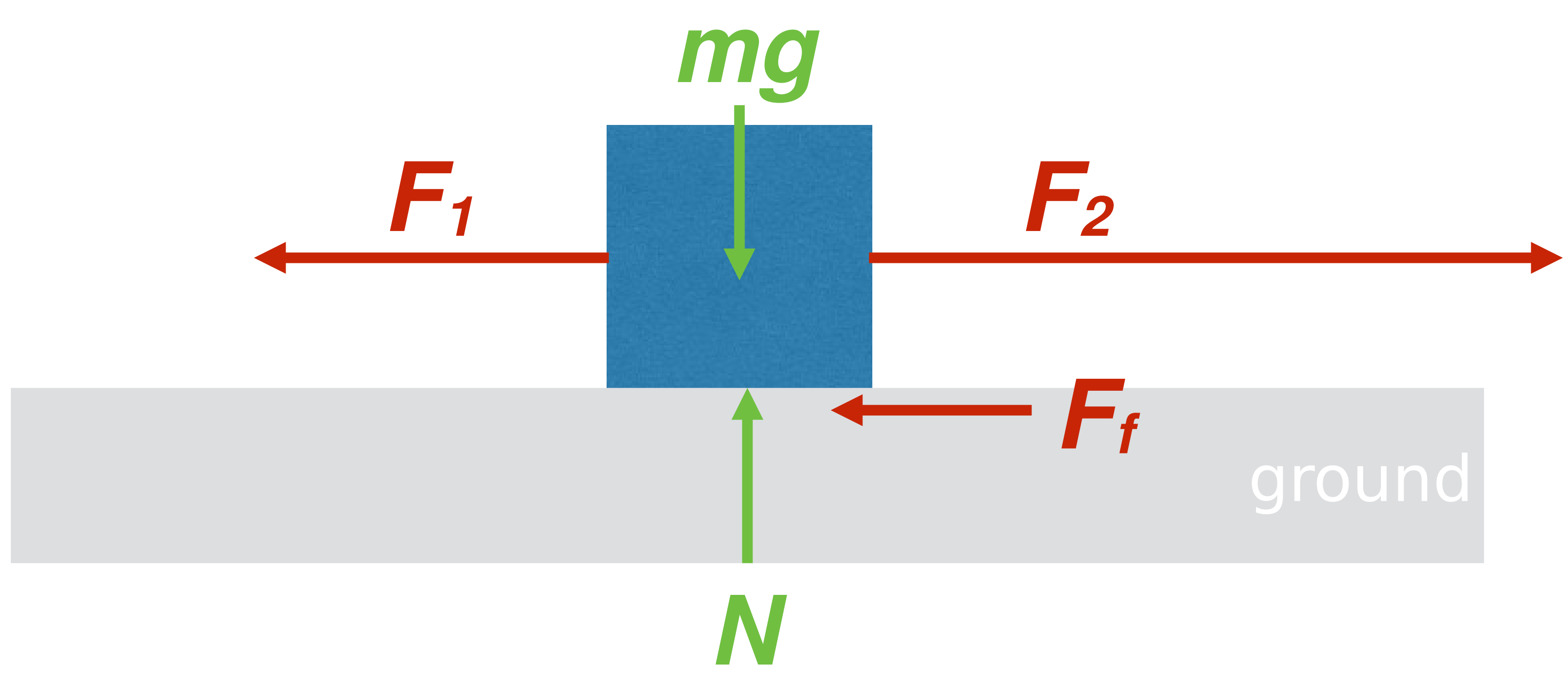
- A Adding a friction force will make the block accelerate more
- B Adding a friction force will slow the block down
- C Adding a friction force will not affect the acceleration
- D Adding a friction force will not affect the net force

Free Body Diagrams

Now what if we add friction?

$+y$

$+x$



m = 1 kg
F_1 = 2 N
F_2 = 8 N
$\mu = 0.2$

- How do we account for friction between the surfaces?

$$\sum F_x = -F_1 + F_2 - F_f = ma_x$$

$$F_f = \mu N$$

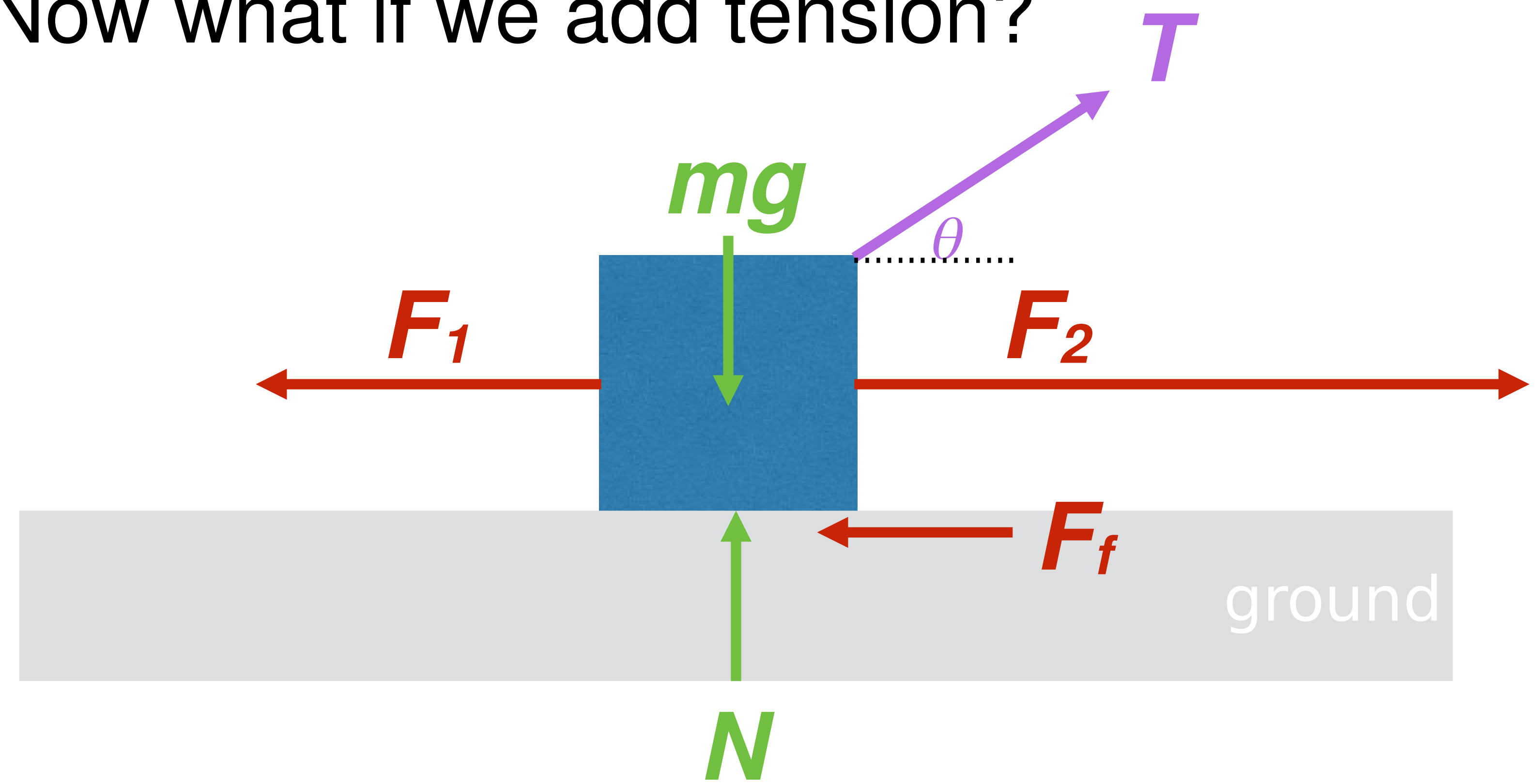
$$a_x = \frac{-F_1+F_2-\mu N}{m} = \frac{(-2+8-(0.2\cdot 9.8))}{1} = 4.04\ \mathrm{m/s}^2$$

Free Body Diagrams

Now what if we add tension?

$+y$

$+x$



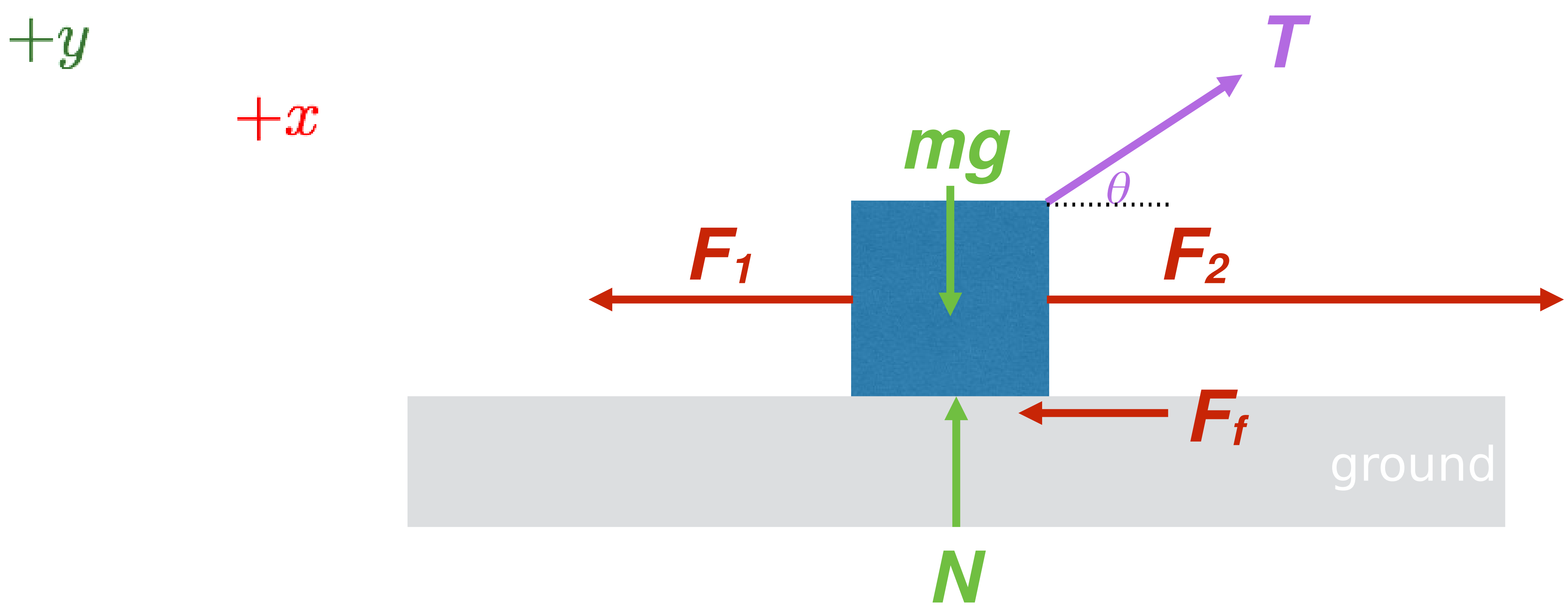
m = 1 kg
F_1 = 2 N
F_2 = 8 N
$\mu = 0.2$
θ=30°

- How do we account for the rope tension pulling on the block?

Clicker Question #2b

m = 1 kg
F_1 = 2 N
F_2 = 8 N
$\mu = 0.2$
θ=30°

How do we account for tension?



A Include ***T*** in the sum of forces in the **x-direction**

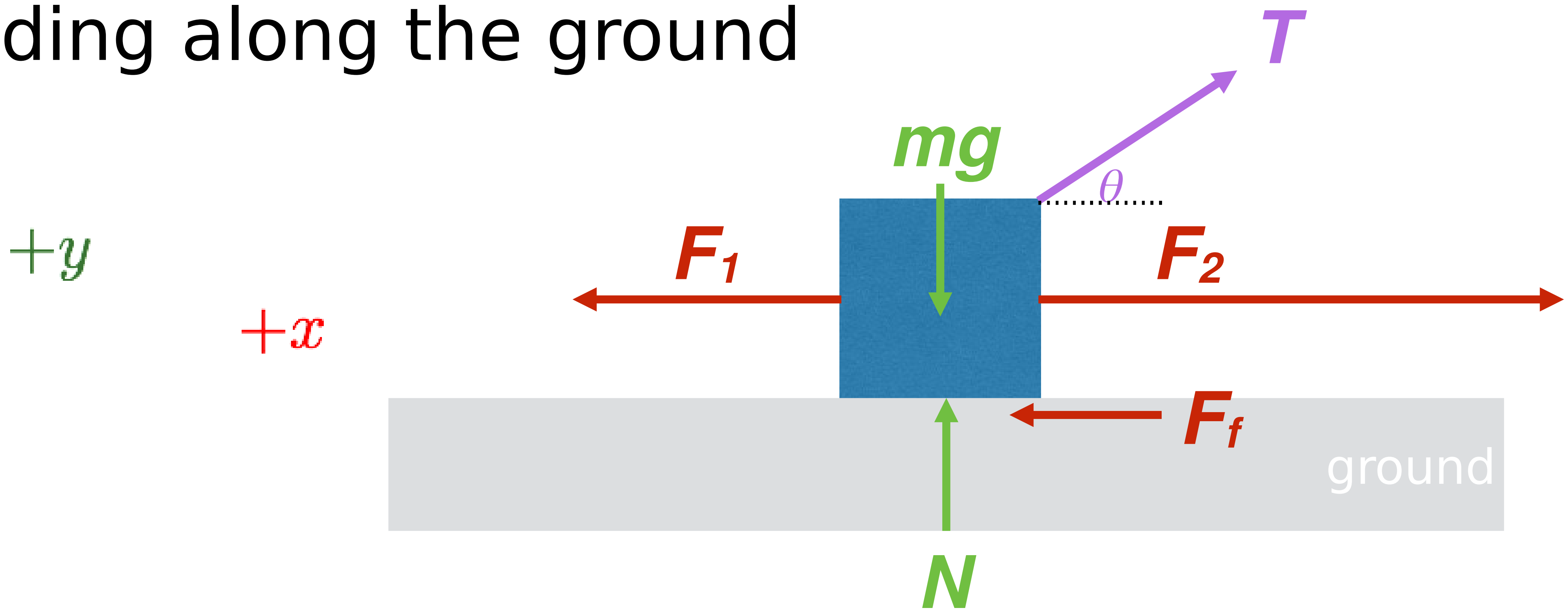
B Include ***T*** in the sum of forces in the **y-direction**

C Include ***T*** in the sum of forces in both **x and y**-directions

D Do not include ***T*** because it is not an external force

In-class activity Name________________________

Calculate the acceleration of the block sliding along the ground



$m = 1$ kg

$F_1 = 2$ N

$F_2 = 8$ N

$\mu = 0.2$

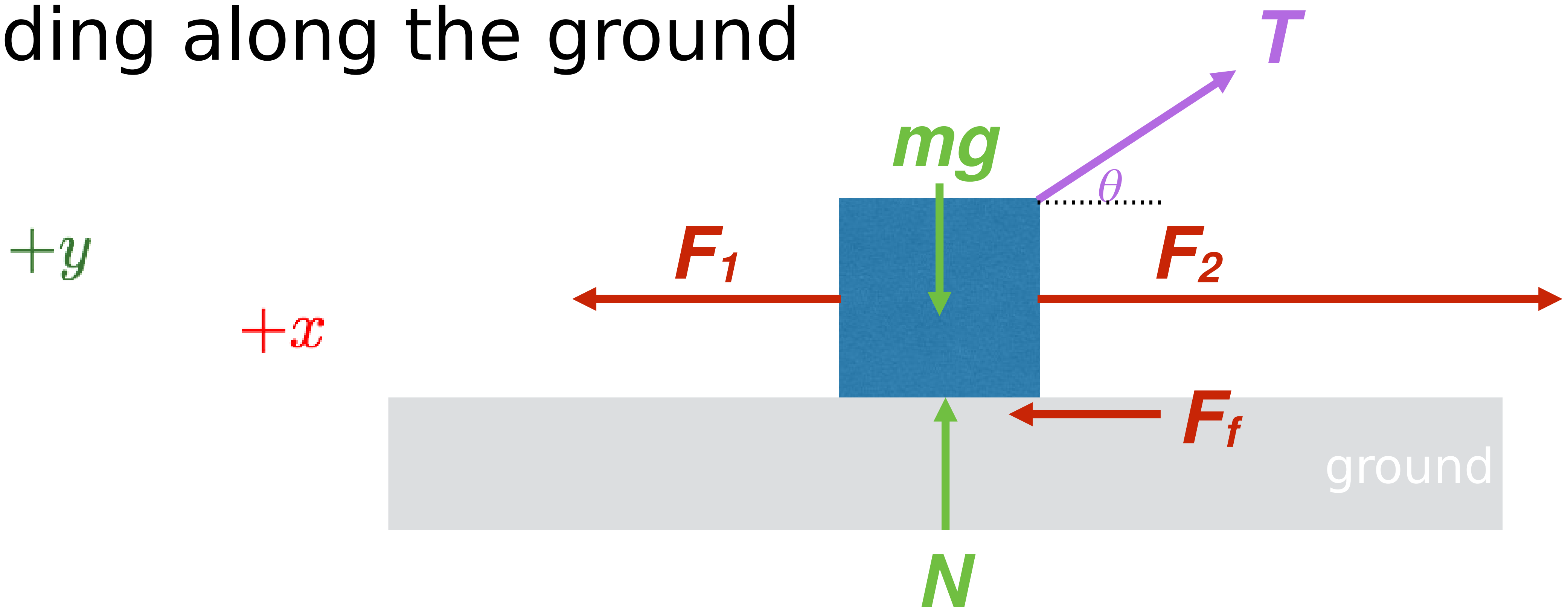
$\theta = 30°$

$T = 5$ N

In-class activity Name________________________

Calculate the acceleration of the block sliding along the ground

m = 1 kg
F_1 = 2 N
F_2 = 8 N
$\mu = 0.2$
θ=30°
T = 5 N



$$\sum F_y = -mg + N + T\sin\theta = ma_y$$

$$a_y = 0 \rightarrow \boxed{N = mg - T\sin\theta} = (9.8 - 5\sin(30°)) = 7.3 \text{ N}$$

$$\sum F_x = -F_1 + F_2 - \mu N + T\cos\theta = ma_x$$

$$\boxed{a_x = \frac{-F_1+F_2-\mu N+T\cos\theta}{m} = 8.87 \text{ m/s}^2}$$

Clicker Question #3

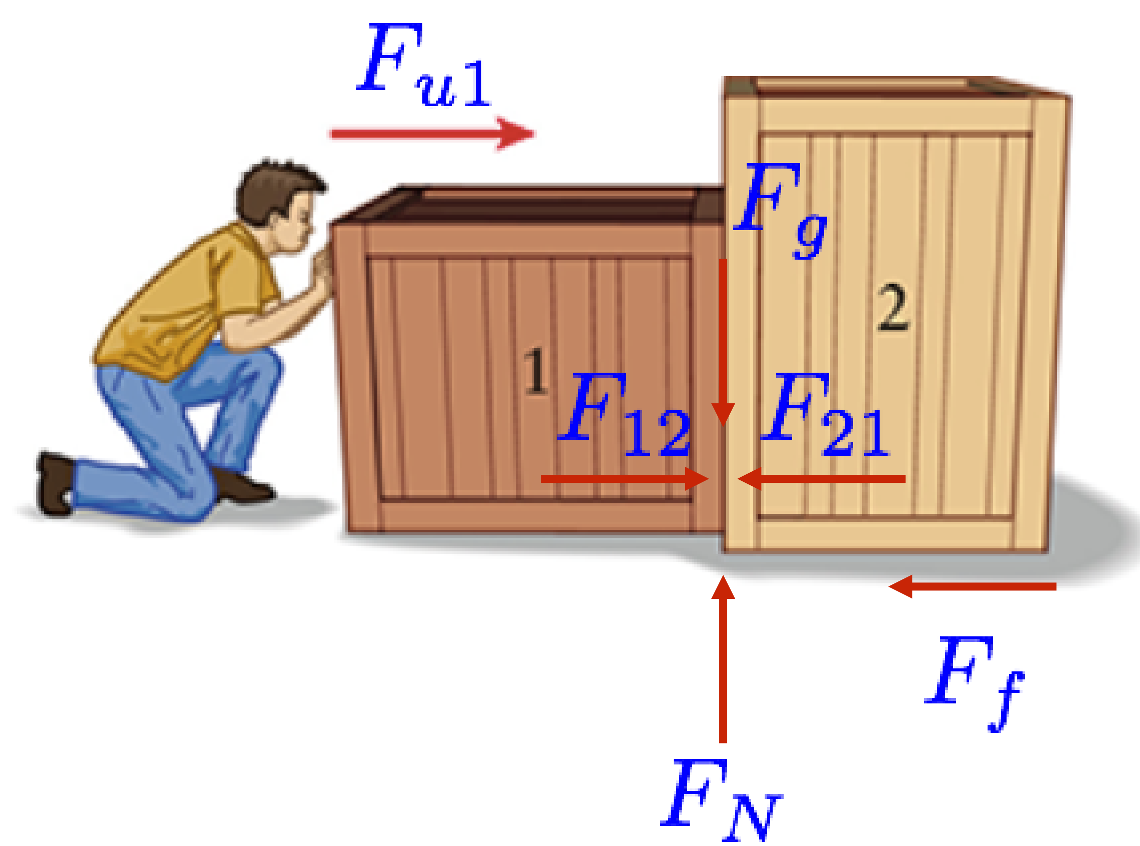
Two crates are at rest, one touching the other, on a horizontal surface. You push horizontally on crate 1 as shown by the red arrow in the figure. Which forces are included in the FBD of the whole two crate system?

A $F_{u1}, F_{12}, F_{21}, F_f$

B F_{u1}, F_{12}

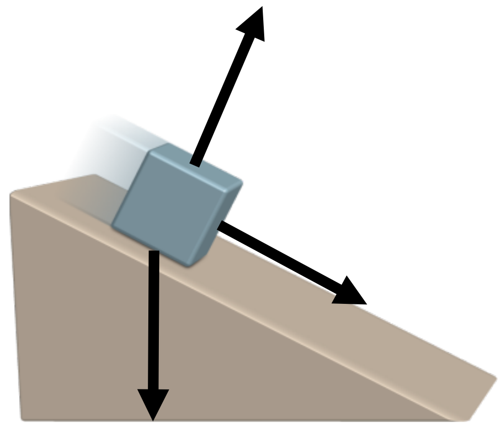
C $F_{u1}, F_{12}, F_{21}, F_f, F_g, F_N$

D F_{u1}, F_f, F_g, F_N

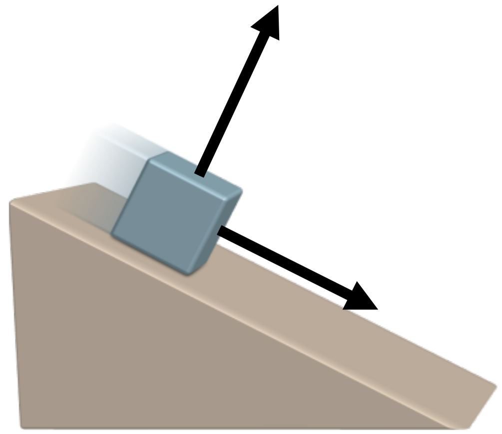


Clicker Question #4

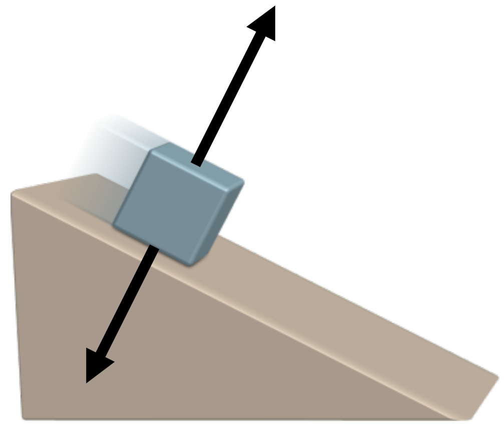
A block slides down a frictionless inclined plane. Which of the following sketches most closely resembles the correct free body diagram for all forces acting on the block? Each arrow represents a force.



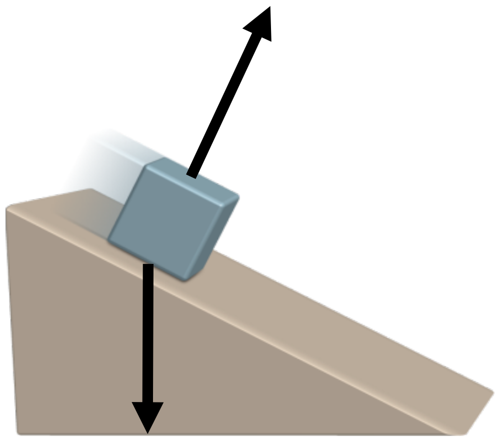
A



B



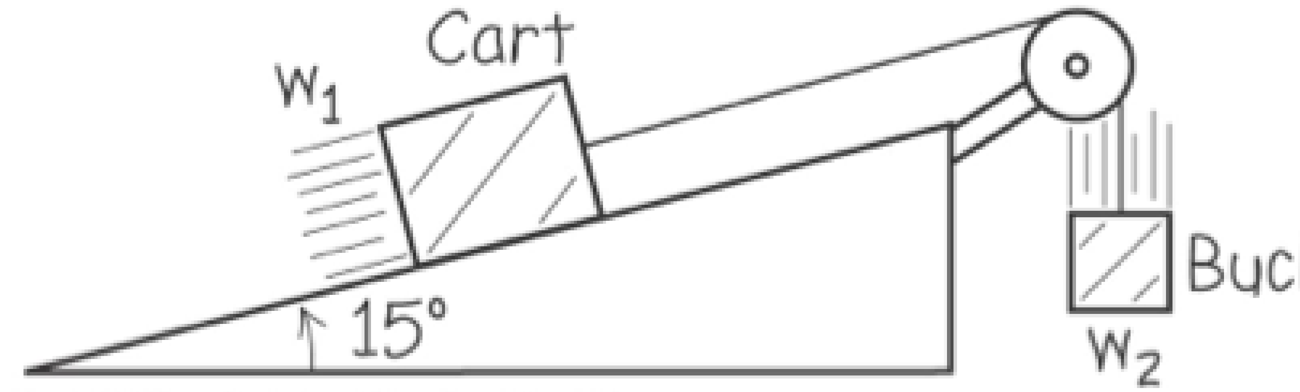
C



D

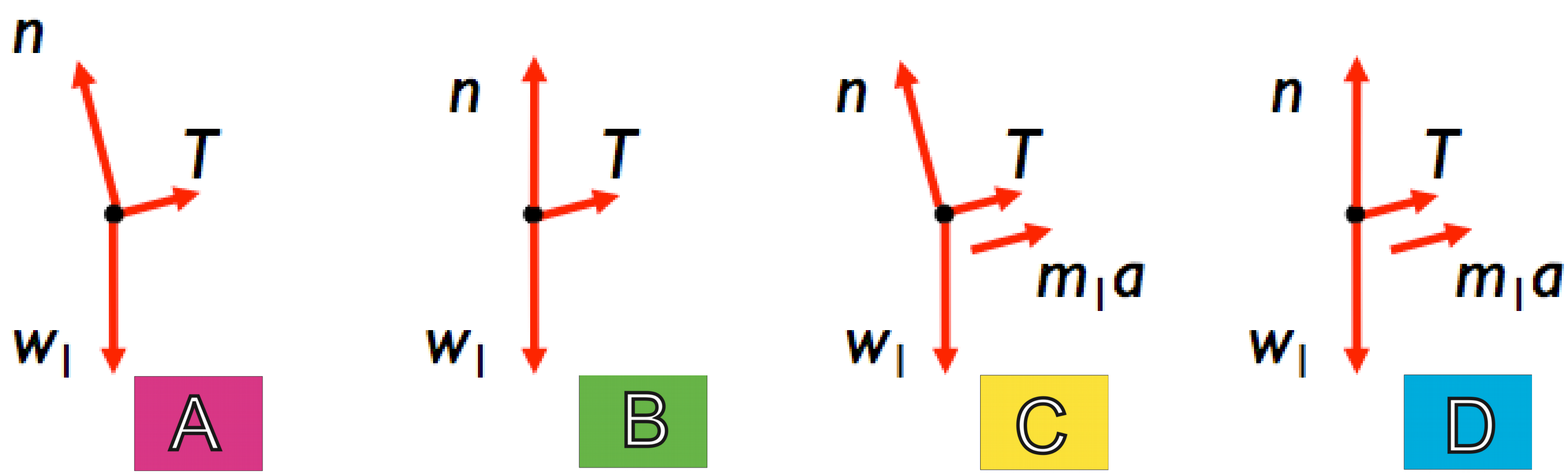
Clicker question #5

A cart (weight w_1) is attached by a lightweight cable to a bucket (weight w_2) as shown. The ramp is frictionless.



When released, the cart accelerates up the ramp.

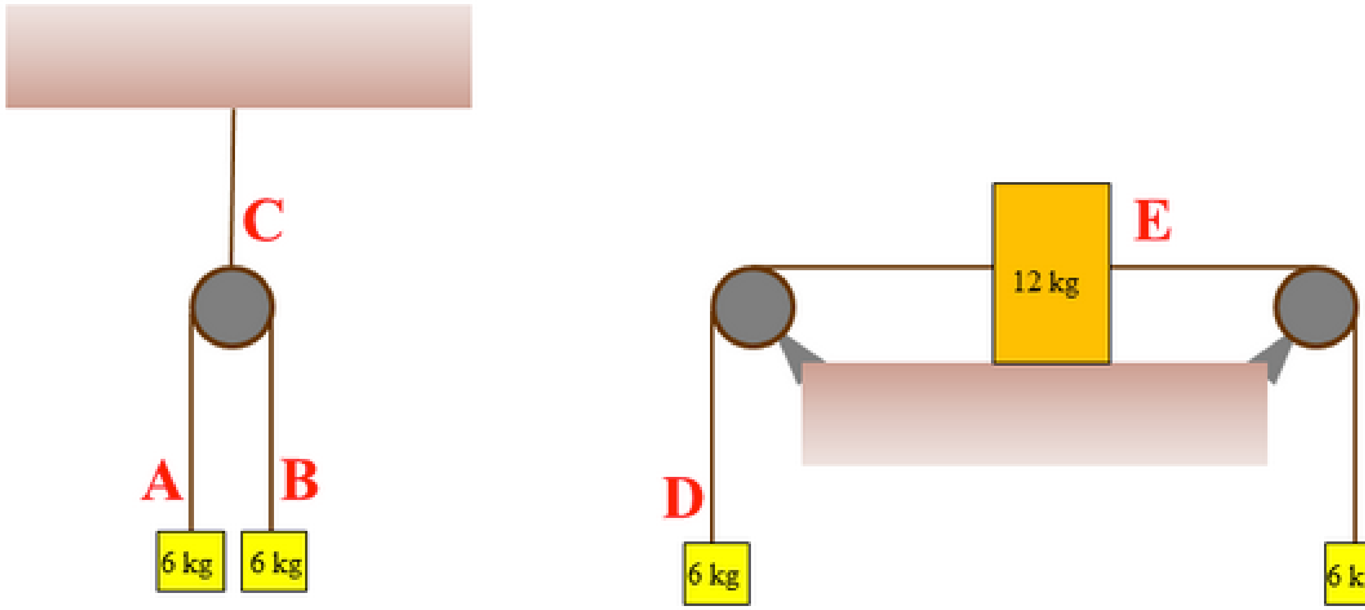
Which of the following is a *correct* free-body diagram for the *cart?*



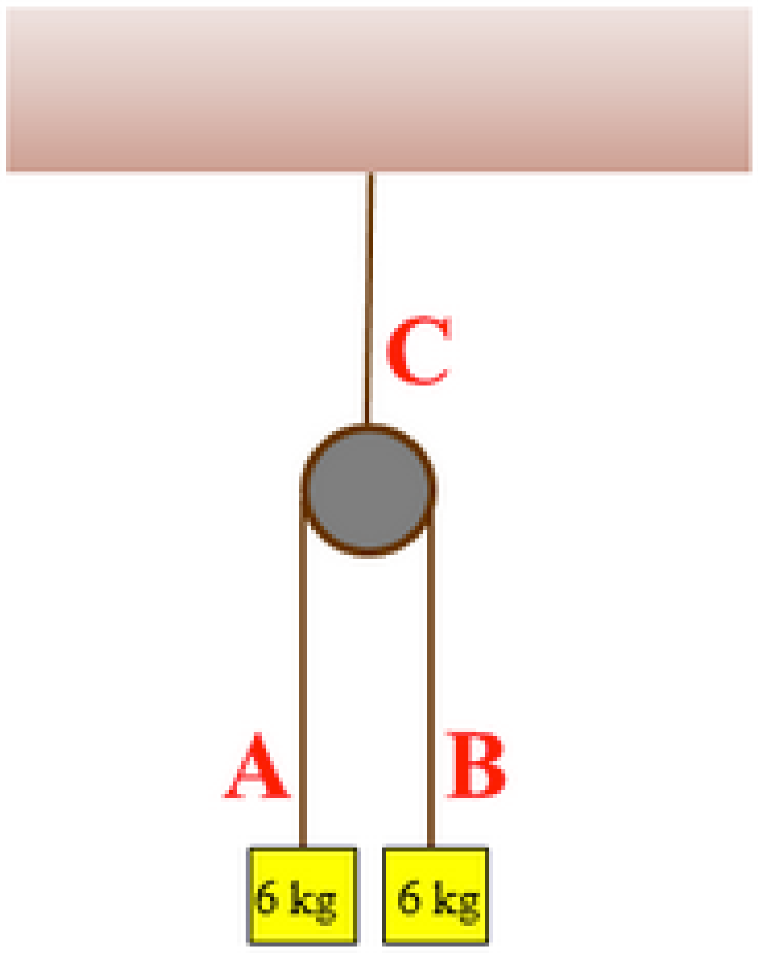
Clicker Question #6

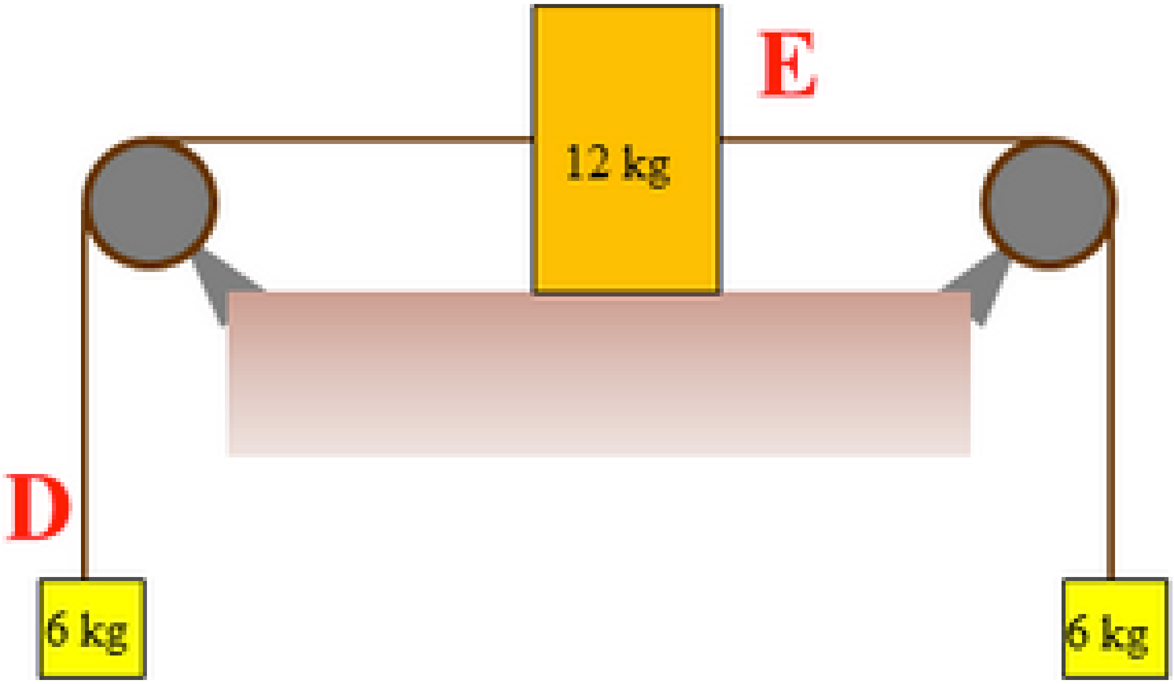
1. In the following setups, all masses are at rest, the ropes and pulleys are massless, and the pulleys and surfaces are frictionless.

- **A** $T_A = T_B = T_D < T_C < T_E$
- **B** $T_D = T_A < T_B < T_C = T_E$
- **C** $T_A = T_B = T_C = T_D = T_E$
- **D** $T_A = T_B = T_D = T_E < T_C$



Lets draw some FBDs

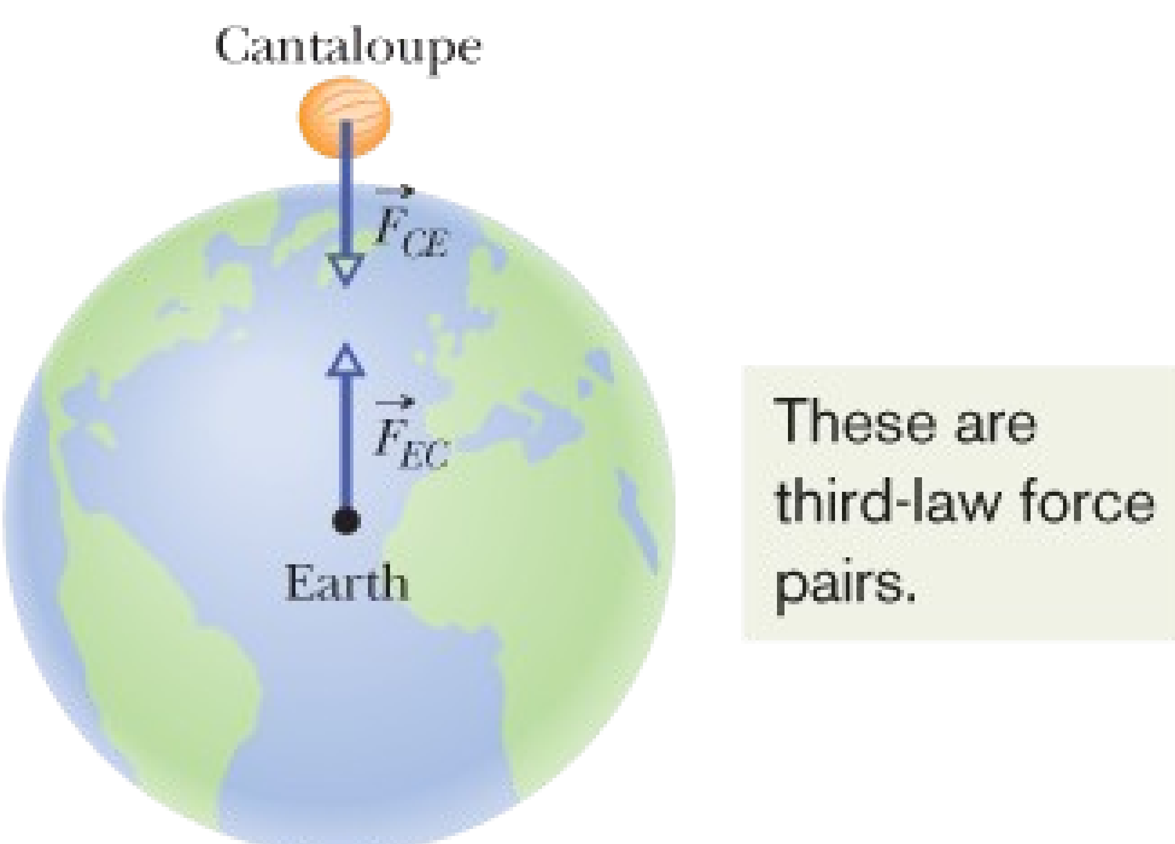




Whats a good coordinate system to use?

Newton's third law

- When two bodies interact, they push or pull on each other, with equal and opposite forces
- "For every action, there is an equal and opposite reaction"



Newton's third law

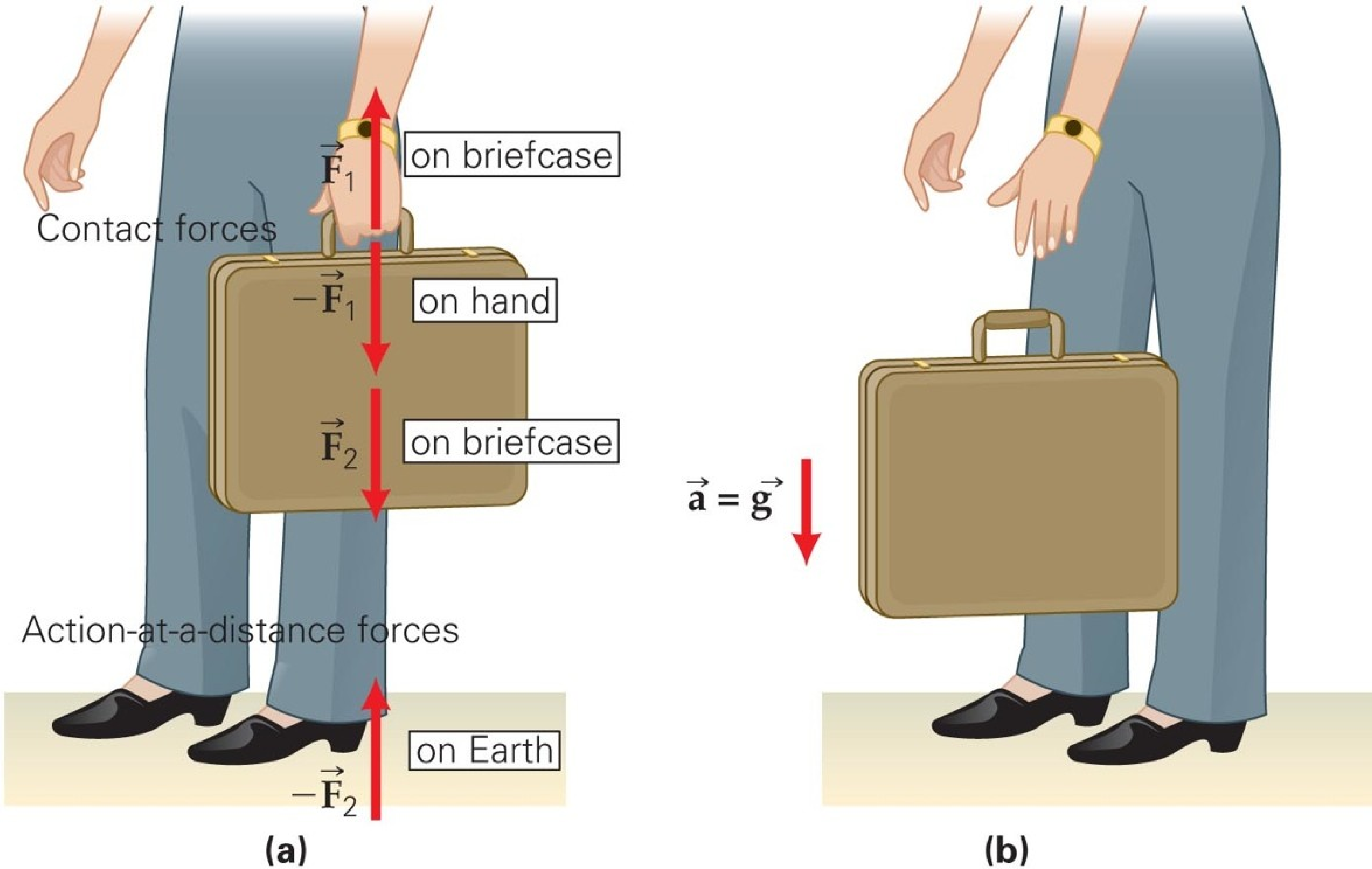
- If force $\vec{\mathbf{F}}_{\mathrm{AB}}$ *on* A *by* B, then…
  - Force *on* B *by* A is $\vec{\mathbf{F}}_{\mathrm{BA}} = -\vec{\mathbf{F}}_{\mathrm{AB}}$
  - Relates forces acting on *different* objects

- Video: fire extinguisher

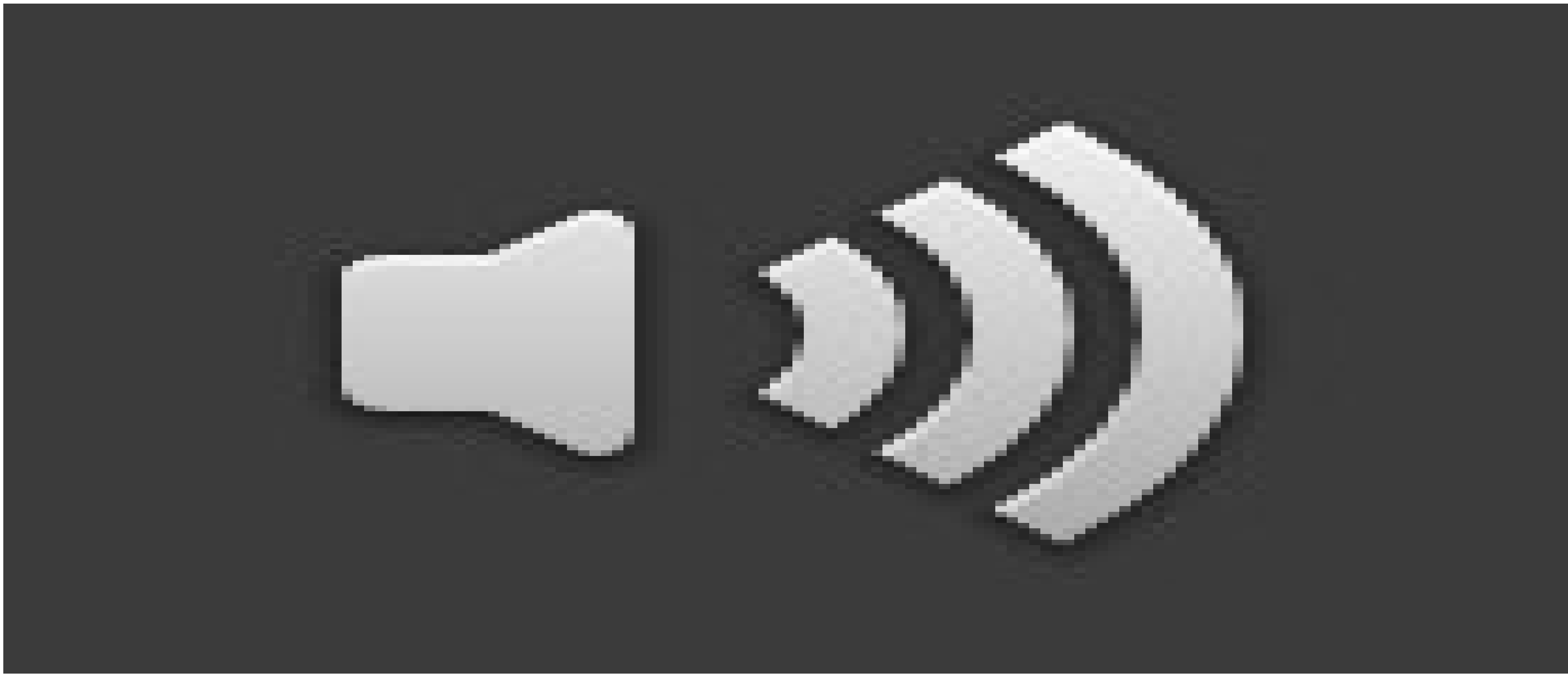
http://www.youtube.com/watch?v=kioIcgnQqpY
http://www.youtube.com/watch?v=pVRgfDSAGO
http://www.youtube.com/watch?v=hHXx8AmBwX

Newton's third law

- Ex. 4.5 in textbook: find all force pairs



- WALL-E shows some good physics!



(EVE doesn't… .)

Clicker question #1a

- WALL-E is moving rightward and wants to slow down. Which way should he aim?

A →

B ←

C Not enough info

D Not sure

http://www.youtube.com/watch?v=hHXx8AmBwXg

Clicker question #1b

- WALL-E is moving rightward and wants to slow down. Which arrow is his desired acceleration?

A →

B ←

C Not enough info

D Not sure

Clicker question #1c

- WALL-E wants to accelerate left. Which direction is the force **on** Wall-E?

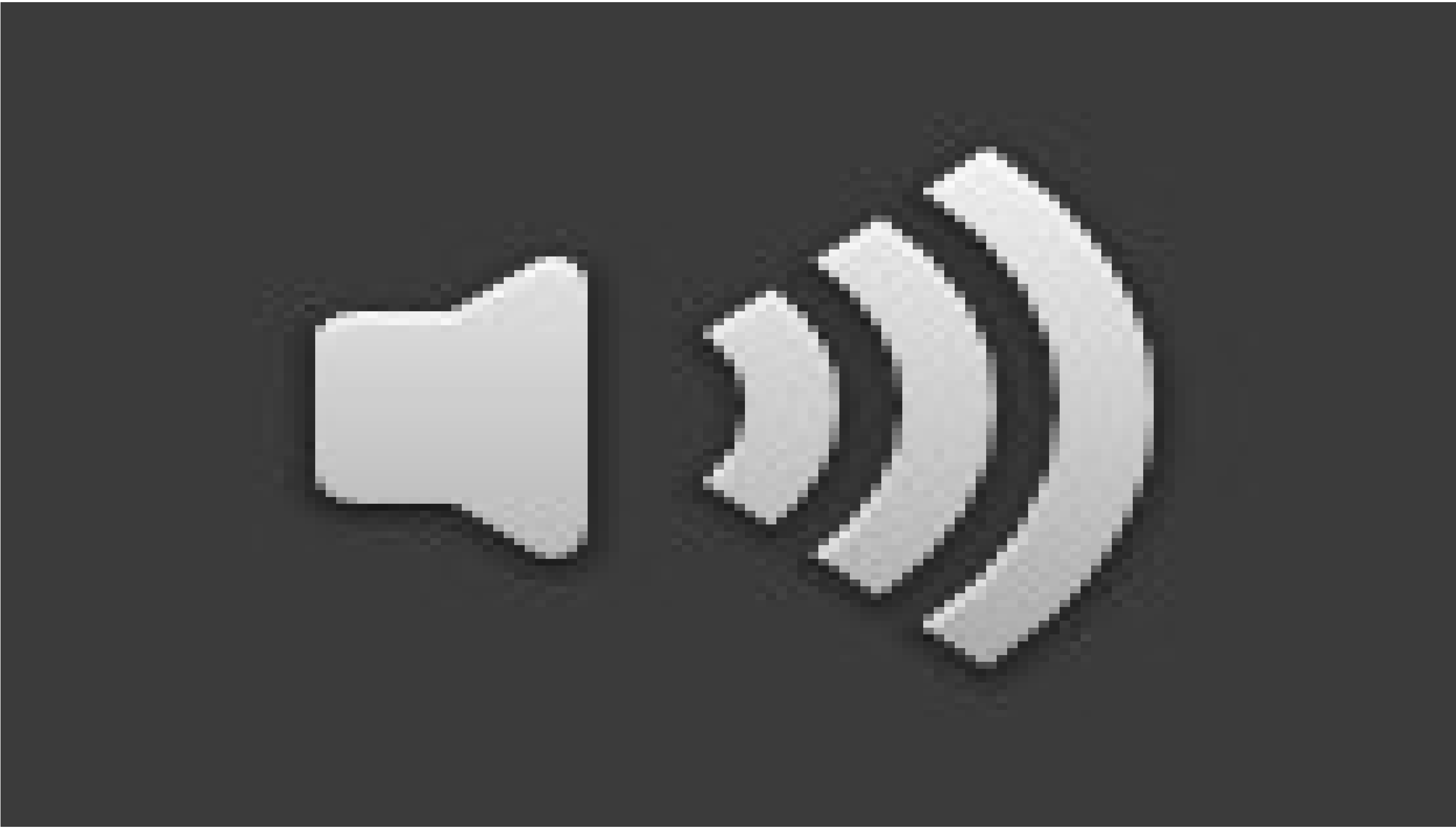
A →

B ←

C Not enough info

D Not sure

Demo: Newton's Third Law



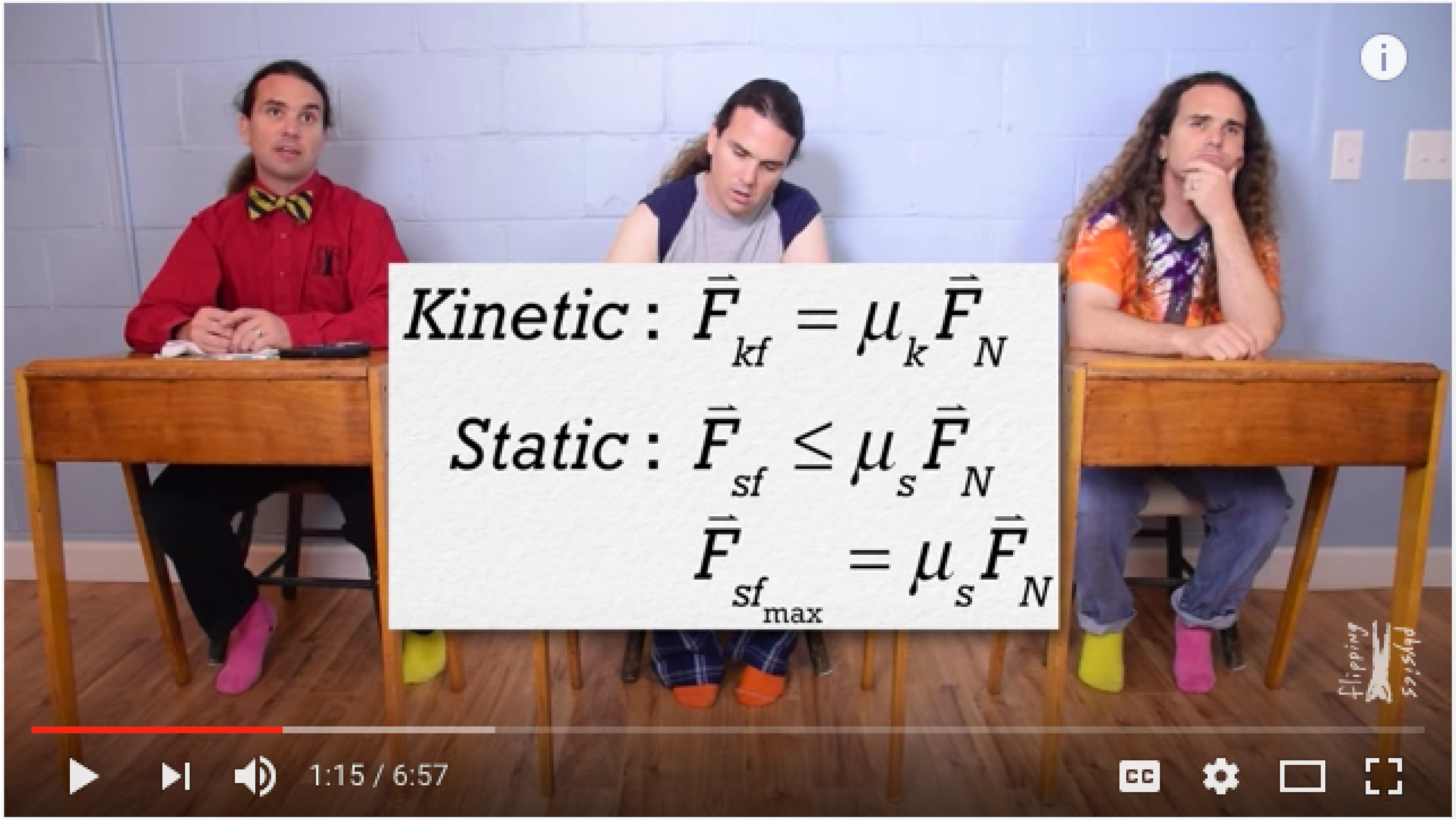
Next time…

- More forces

Due dates

- **Assignments**
  - Finish reading Ch. 6
  - HW4 due Sunday

Next: Two kinds of Friction

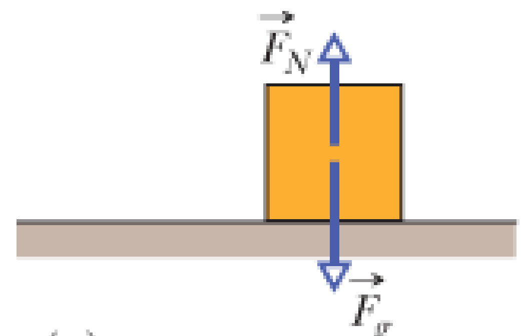


https://www.youtube.com/watch?v=quBTyhdVqQE

- **Take home message**
  - FBD's take practice!
  - Kinetic friction is a constant value
  - Static friction can take on many values

Static and kinetic friction

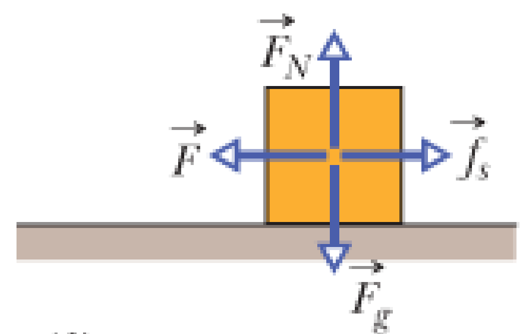
There is no attempt at sliding. Thus, no friction and no motion.



(a)

Frictional force = 0

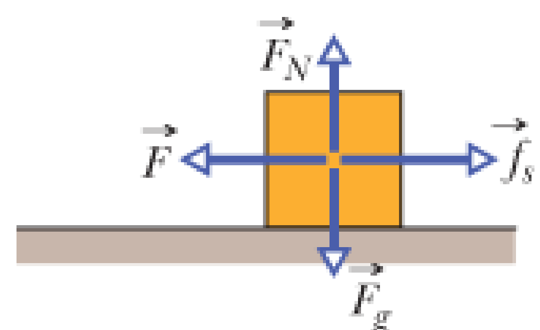
Force $\vec{F}$ attempts sliding but is balanced by the frictional force. No motion.



(b)

Frictional force = F

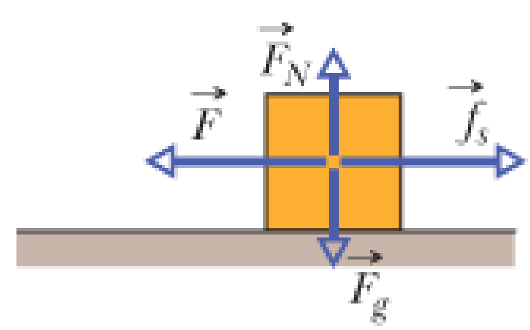
Force $\vec{F}$ is now stronger but is still balanced by the frictional force. No motion.



(c)

Frictional force = F

Force $\vec{F}$ is now even stronger but is still balanced by the frictional force. No motion.

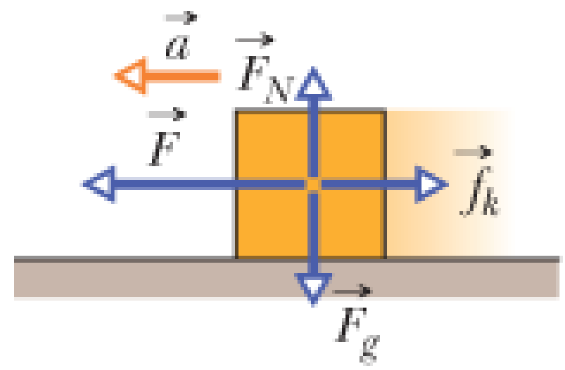


(d)

Frictional force = F

Static and kinetic friction

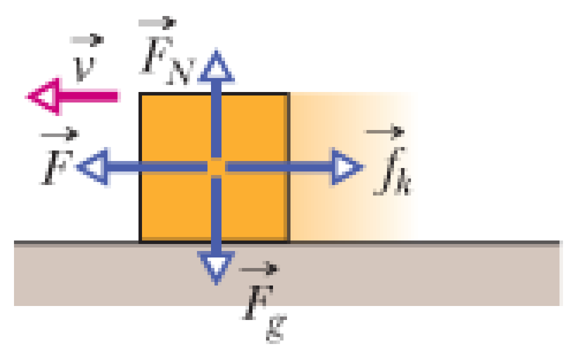
Finally, the applied force has overwhelmed the static frictional force. Block slides and accelerates.



(e)

Weak kinetic frictional force

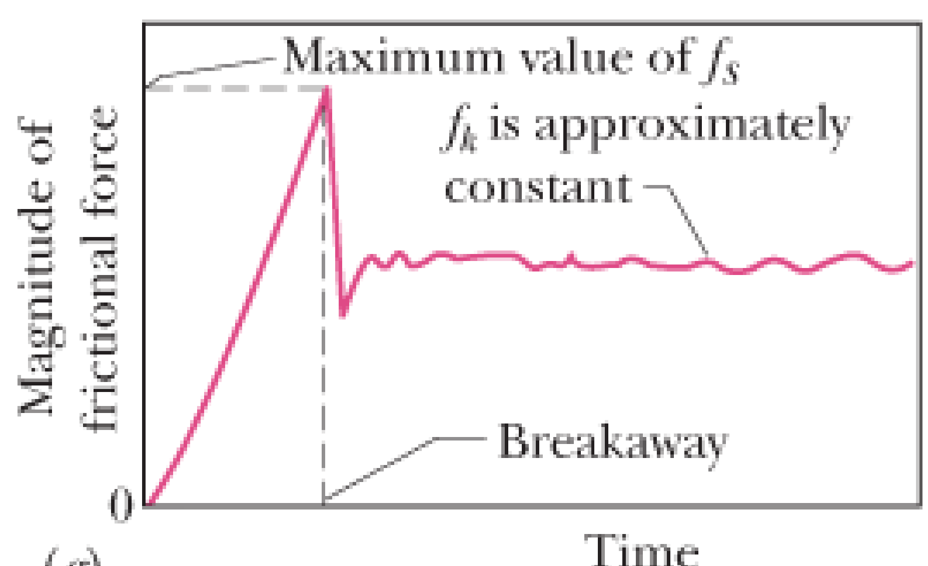
To maintain the speed, weaken force $\vec{F}$ to match the weak frictional force.



(f)

Same weak kinetic frictional force

Static frictional force can only match growing applied force.

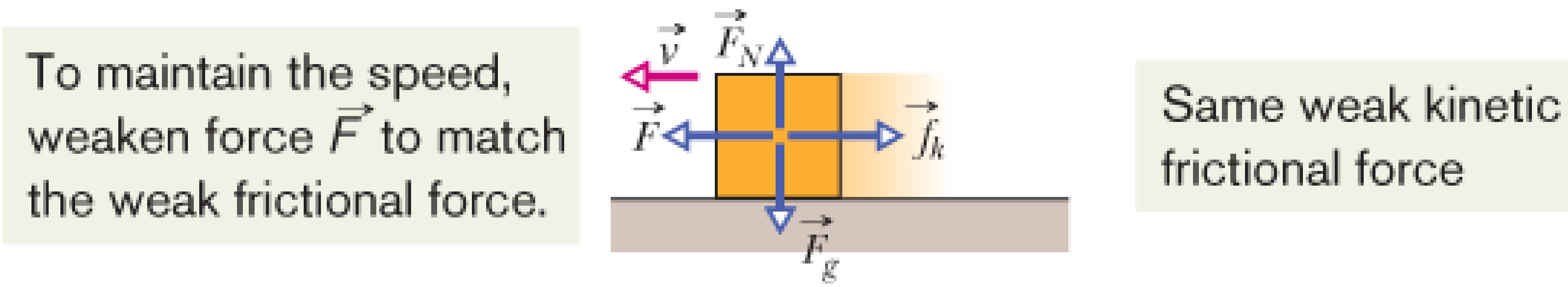


(g)

Kinetic frictional force has only one value (no matching).

Clicker Question #7

What is the net Force on the box?



A F_{net} = the kinetic friction force

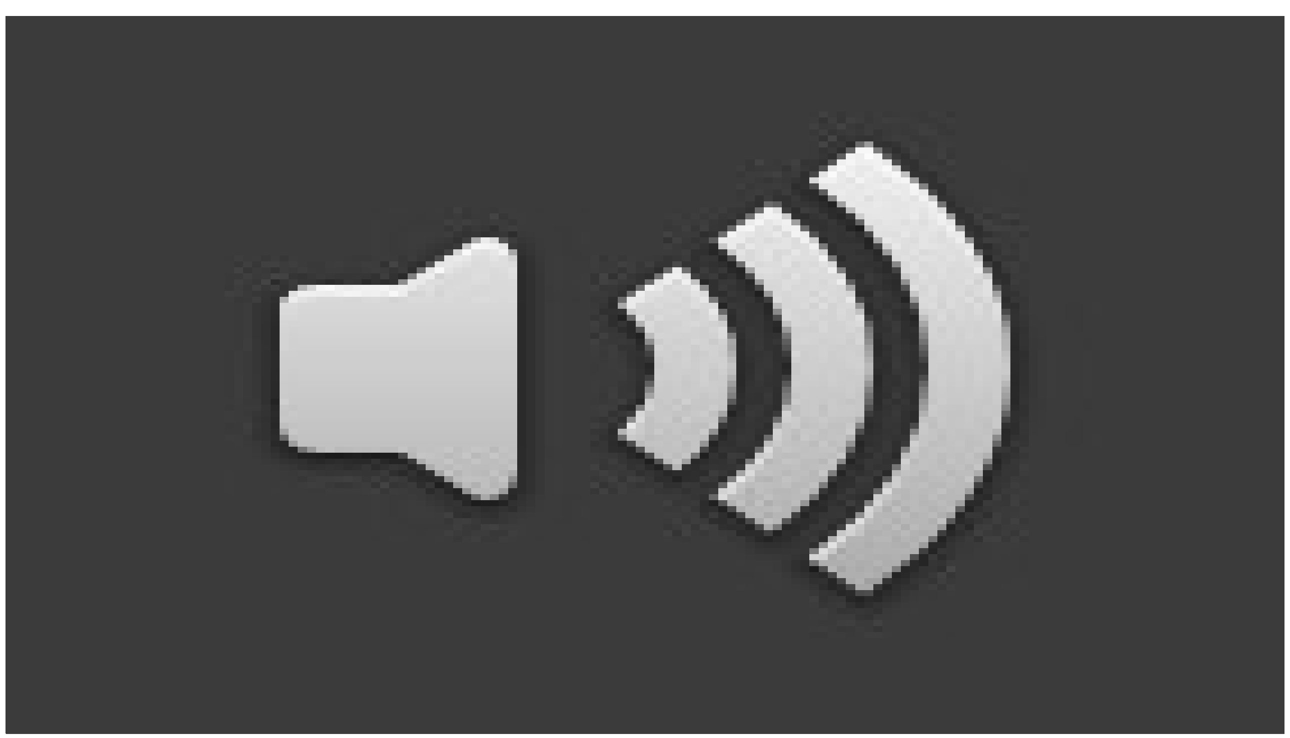
B F_{net} = the applied force, F

C $F_{net} = 0$

D F_{net} = the force of gravity

Static vs. kinetic friction

Static



Kinetic

Is this related to ABS?

- **Yes!** Static friction to stop the car quicker
- Locked up wheels cause sliding (kinetic friction) which is not as effective for braking

Extra Problem

A worker pushes horizontally on a 37.0 kg crate with a force of magnitude 111 N. The coefficient of static friction between the crate and the floor is 0.380. (a) What is the value of $f_{s,max}$ under the circumstances? (b) Does the crate move? ("yes" or "no") (c) What is the frictional force f_r on the crate from the floor? (d) Suppose, next, that a second worker pulls directly upward on the crate to help out. What is the least vertical pull f_{pv} that will allow the first worker's 111 N push to move the crate?