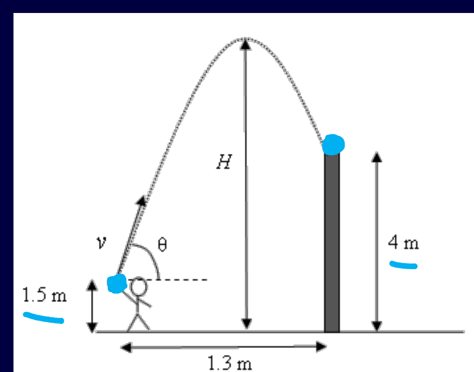
# Physics 2A: Lecture 4
# Today's Agenda

- Newton's 3 laws
  - Dynamics: Why do things move?
- Forces
  - Normal Force
  - Tension Force
  - Gravitational Force

# Clicker Question 10:

Eddy throws a little sand bag so that it lands on the top of a vertical post that is 4 m high. The post is 1.3 m away from Eddy. He releases the bag from a height of 1.5 m above the ground, as shown in the figure. The initial speed of the bag is *v* = 7.5 m/s, the angle, *θ*, between the velocity and the horizontal is *θ* = 80°. You can neglect the friction due to the air. How long does the sand bag stay in the air?

(a) t = 0.7 s
(b) t = 1.0 s
(c) t = 2.5 s




$x_0 = y_0 = 0\ m$

$v_{0x} = 1.3\ m/s$

$v_{0y} = 7.38\ \frac{m}{s}$

$a_x = 0\ m/s^2$

$a_y = -g$

↑ +y

7.5 m/s, 80

$7.5 \sin 80 = 7.38\ m/s$

$7.5 \cos 80 = 1.3\ m/s$

$x_F = 1.3\ m$

$y_F = 4m - 1.5m = 2.5m$

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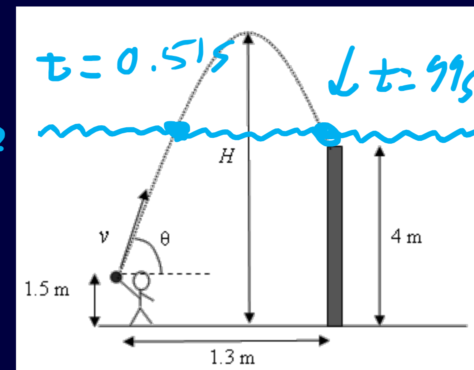



$g = 9.81\ m/s^2$

$y = y_0 + v_{1y} + \frac{1}{2} g t^2$

$2.5\ m = 0 + 7.38\ m/s\ t - \frac{1}{2} g t^2$

$\frac{1}{2} g t^2 - 7.38\ m/s\ t + 2.5\ m = 0$

$a = \frac{1}{2} g = 4.905\ m/s^2$

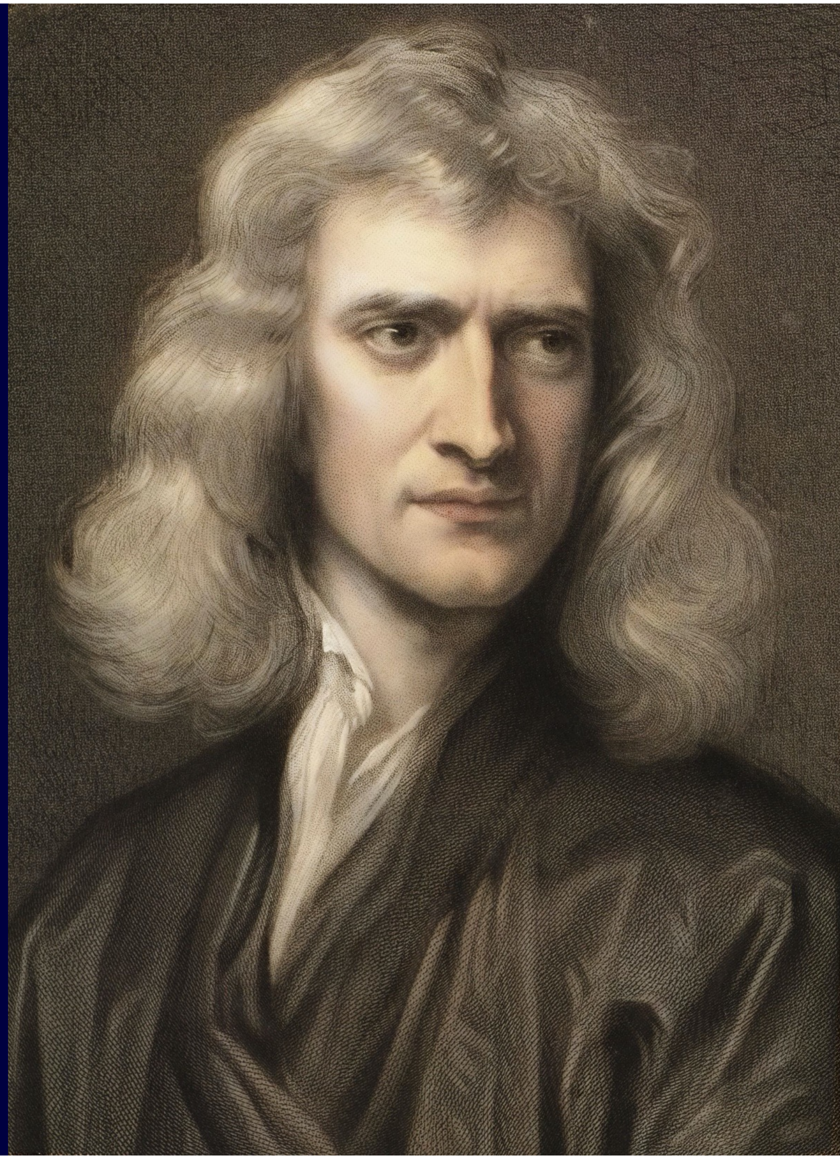
$b = -7.38\ m/s$

$c = 2.5\ m$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{7.38\ m/s \pm \sqrt{(7.38\ m/s)^2 - 4(\frac{1}{2}g)2.5\ m}}{g} = \frac{7.38\ m/s \pm 2.32\ m/s}{g} = \boxed{0.99\ s}$$

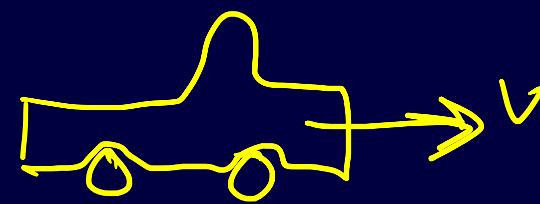
~~0.51 s~~

$x = 1.3\ m/s\ t$



v is constant

# Today:




acceleration? = 0

- Newton's first two laws

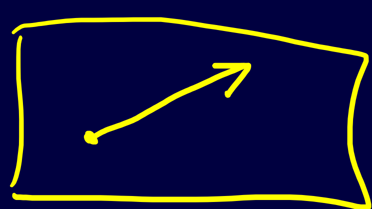
  - First law: If there is no net force, there is no acceleration.

$$\sum \vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots$$

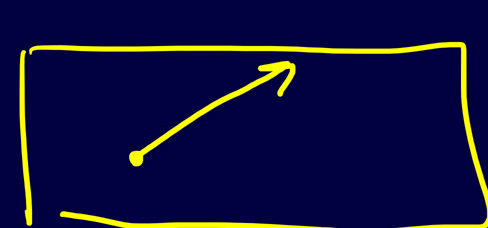
$\sum F$

  - Second law: $\Sigma \vec{F} = m\vec{a}$

=> net force



$m\vec{a}$



# Solving Force Problems

Step 1: What forces are acting on our object?

Step 2: Draw a Free Body Diagram for each object.

Step 3: Select coordinate system.

Try to get as many forces in x-y direction

Step 4: Break all forces into x-y components

Step 5: Apply Newton's Second law.

$\Sigma F_X = ma_X$

$\Sigma F_Y = ma_Y$

Step 6: Solve for what you need.

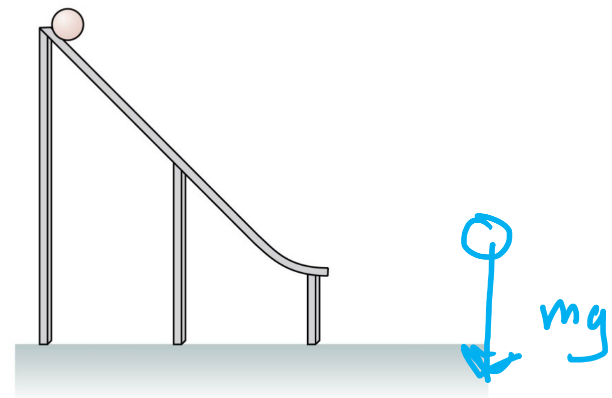
# The Free Body Diagram

- Newton's 2nd Law says that for an object $\Sigma \boldsymbol{F} = m\boldsymbol{a}$.
- Key phrase here is ***for an object.***
- So before we can apply $\Sigma \boldsymbol{F} = m\boldsymbol{a}$ to any given object, we isolate the forces acting on this object:

FREE-BODY-DIAGRAM

# Clicker Question 1

A ball rolls down an incline and off a horizontal ramp. Ignoring air resistance, what force or forces act on the ball as it moves through the air just after leaving the horizontal ramp?




A. The weight of the ball acting vertically down.

B. A horizontal force that maintains the motion.

C. A force whose direction changes as the direction of motion changes.

D. The weight of the ball and a horizontal force.

E. The weight of the ball and a force in the direction of motion.

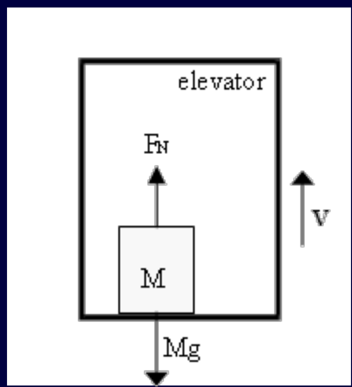
## Clicker Question 2:

Suppose a box having a mass M sits on the floor of an elevator that is moving upward but is slowing down. Compare the weight of the box (Mg) to the magnitude of the normal force exerted by the elevator floor on the box ($F_N$).

(a) $F_N < Mg$

(b) $F_N = Mg$

(c) $F_N > Mg$



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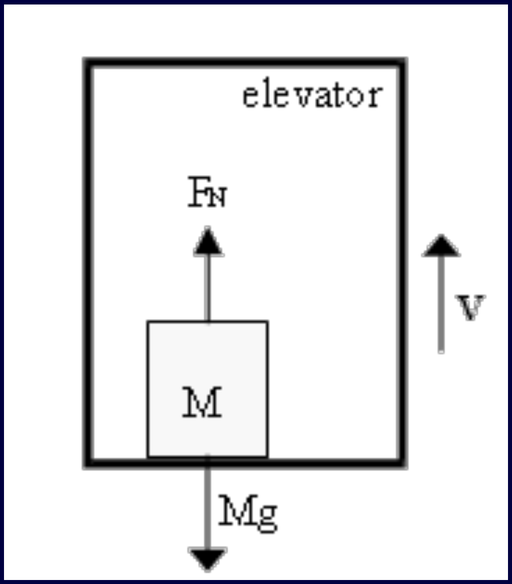


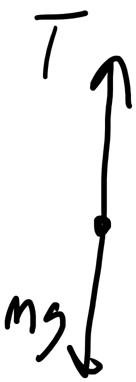

Student: In what cases will the normal force NOT be equal to mg?

## Student Responses

- Incorrect: Elevator is moving up. The normal force exerted on the box is greater than the weight.
- Correct: Fn would be less than Mg because the problem states that the box is currently moving up, but is slowing down. This means that it's accelerating in the negative direction, meaning that its net force is pointing downwards. This means that Mg is greater than Fn because if they were equal the box would have constant velocity and if it was less than Fn it would be moving upwards/getting faster.
- Correct: In order for it to be slowing down, the weight of the box must be greater than the normal force. if they were equal, the movement would be constant and if the normal force is greater than the weight, it would accelerate upward.

# Clicker 3

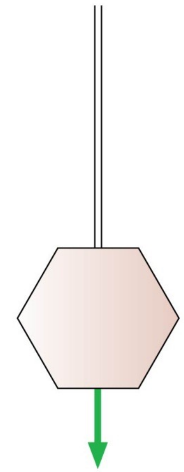
An object on a rope is lowered at constant speed. Which is true?

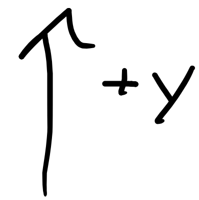



$$\Sigma F_y = ma_y$$

$$T - mg = 0$$

$$\boxed{T = mg}$$






A. The rope tension is greater than the object's weight.

B. The rope tension equals the object's weight.

C. The rope tension is less than the object's weight.

D. The rope tension can't be compared to the object's weight.

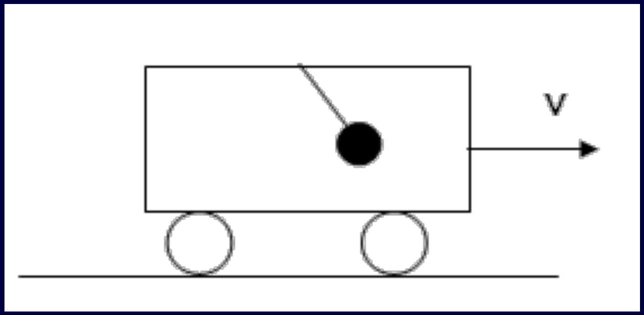
## Clicker Question 4:

A car is moving to the right. A pendulum is suspended from the ceiling and hangs as shown in the figure. What can we say about the speed of the car?

(a) The car has a constant speed.

(b) The car's speed is increasing.

(c) The car's speed is decreasing.

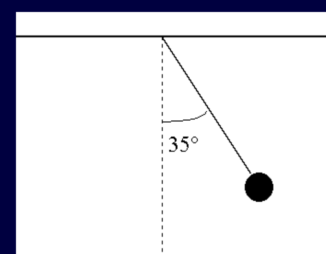


# Clicker Question 5:

A pendulum of mass 45 kg hangs from the roof of a car that is accelerating to the left as shown. Under these circumstances the pendulum hangs as shown. Find the acceleration of the car. What is true about the pendulum?

$a_x =$

$a_y = 0$




(a) $a_x = 0$, $a_y$ = acceleration of the car

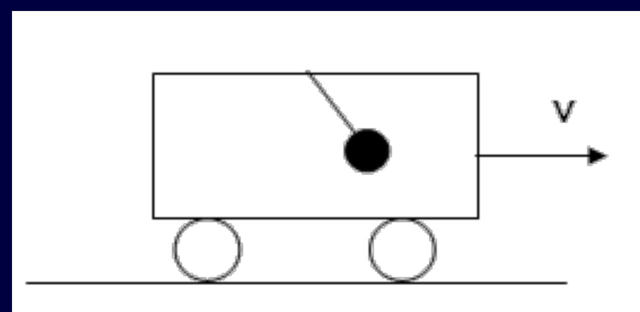
(b) $a_x$ = acceleration of the car, $a_y = 0$

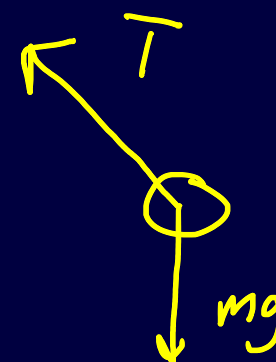
(c) There will be acceleration in both directions

(d) The pendulum does not accelerate.

# Clicker Question 6:

A car is moving to the right. A pendulum is suspended from the ceiling and hangs as shown in the figure. How many forces act on the pendulum?




(a) 1

(b) 2

(c) 3

(d) 4

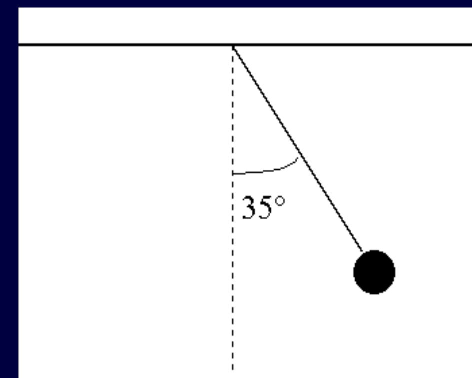
(e) 5

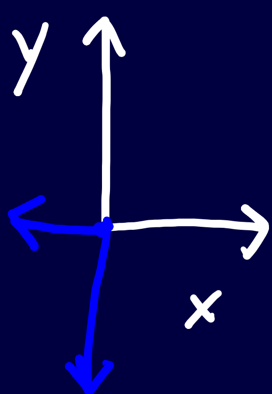
## Student Responses

- Incorrect: force of acceleration and force of gravity.
- Incorrect: Gravity, the force of the string, and the force of the car.
- Correct: There is the force of gravity acting upon it and the tension created from it hanging on the rope.

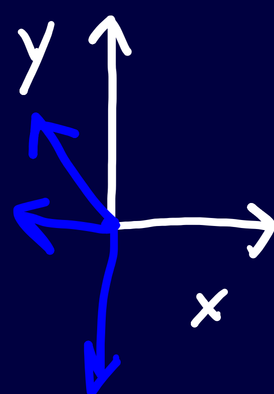
# Clicker Question 7:

A pendulum of mass 45 kg hangs from the roof of a car that is accelerating to the left as shown. Under these circumstances the pendulum hangs as shown. Which is the correct free-body diagram?

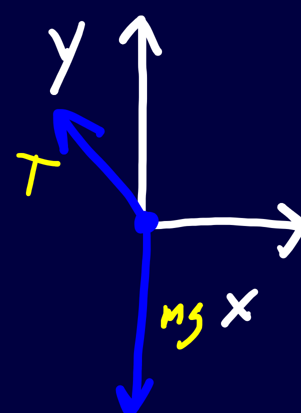


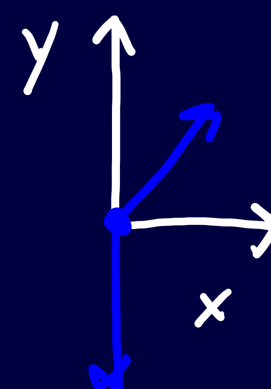

(A)




(B)

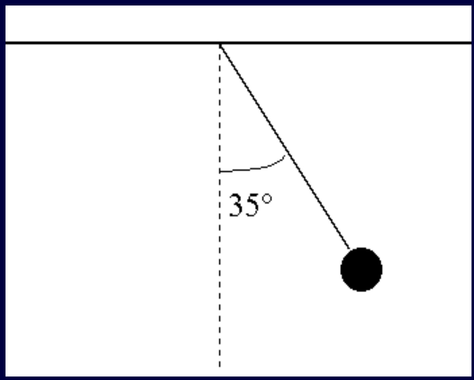



(C)




(D)

A car is moving to the right. A pendulum of mass 45 kg is suspended from the ceiling and hangs as shown in the figure.




$a_x = ?$

$T$, $T\cos\theta$, $T\sin\theta$, $mg$

(1) $\sum F_y = ma_y = 0$

$T\cos 35 - mg = 0$

$T\cos 35 = mg$

$T = \frac{mg}{\cos 35}$

(2) $\sum F_x = ma_x$

$-T\sin 35 = ma_x$

$-\frac{mg}{\cos 35}\sin 35 = ma_x$

$a_x = -g\frac{\sin 35}{\cos 35}$

$= -6.86\ m/s^2$

y, x

$F$, $a_x$

$a_y = 0$

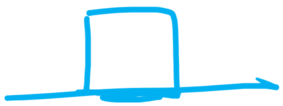
# Static Friction

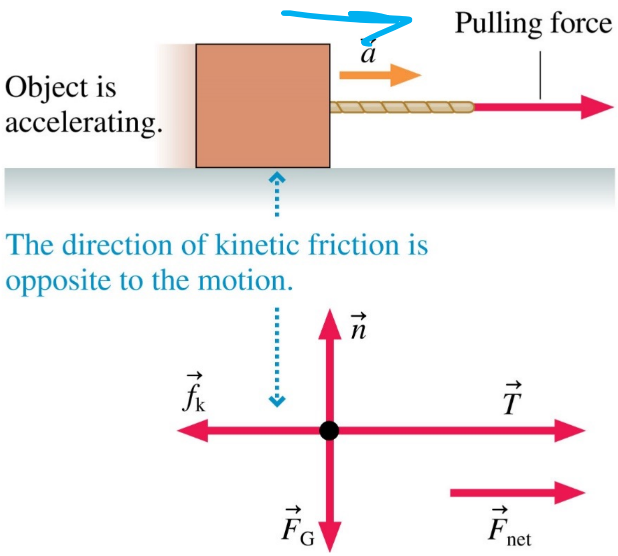
- Static friction force has a *maximum* possible size $f_{s\,max}$.
- An object remains at rest as long as $f_s < f_{s\,max}$.
- The object just begins to slip when $f_s = f_{s\,max}$.
- A static friction force $f_s > f_{s\,max}$ is not physically possible:

$$f_{s\,max} = \mu_s n$$

where the proportionality constant $\mu_s$ is called the **coefficient of static friction**.

# Kinetic Friction






- The **kinetic friction** force is proportional to the magnitude of the normal force:

$$f_k = \mu_k n$$

where the proportionality constant $\mu_k$ is called the **coefficient of kinetic friction.**

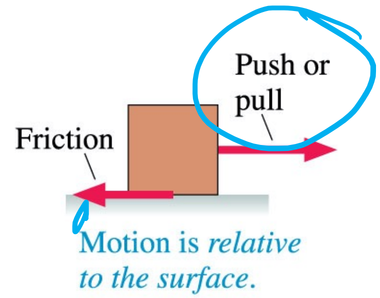
- The kinetic friction direction is opposite to the velocity of the object relative to the surface.
- For any particular pair of surfaces, $\mu_k < \mu_s$.

# A Model of Friction

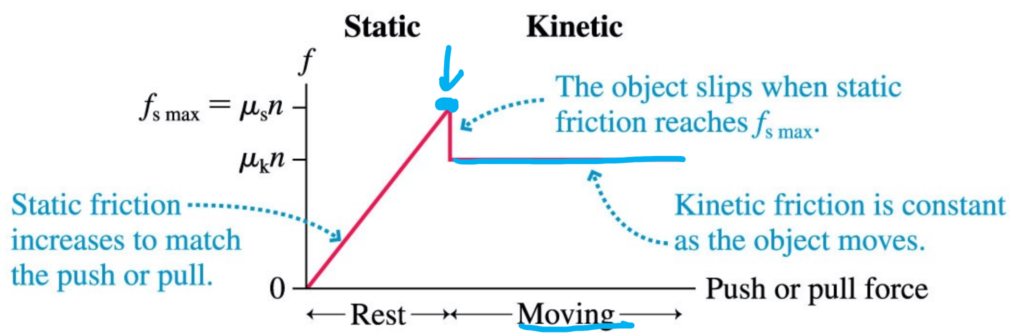
**MODEL 6.3**

## Friction

The friction force is *parallel* to the surface.



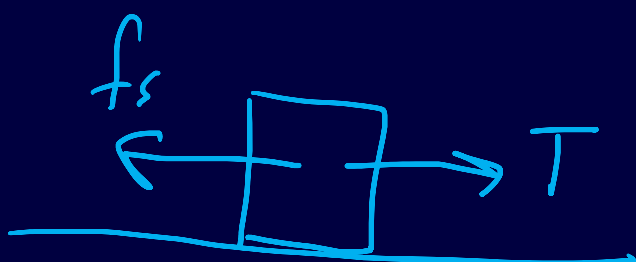

- Static friction: Acts as needed to prevent motion. Can have *any* magnitude up to $f_{s\,max} = \mu_s n$.
- Kinetic friction: Opposes motion with $f_k = \mu_k n$.
- Rolling friction: Opposes motion with $f_r = \mu_r n$.
- Graphically:

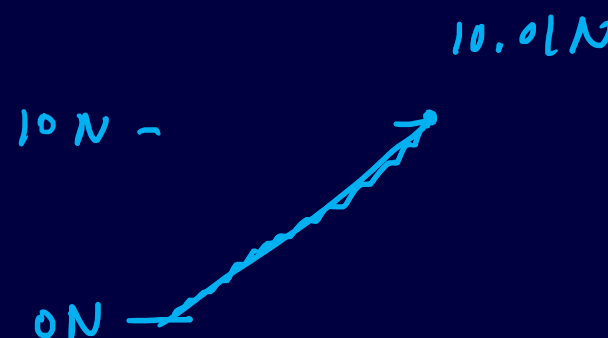


# Student Question

- I don't quite understand how an object begins to slip when static friction = max static friction. How does this reflect Newton's first law stipulating that an object should remain at rest as long as there is no net force? If you have a tension equal and opposite the max static friction, why does the object begin to move?

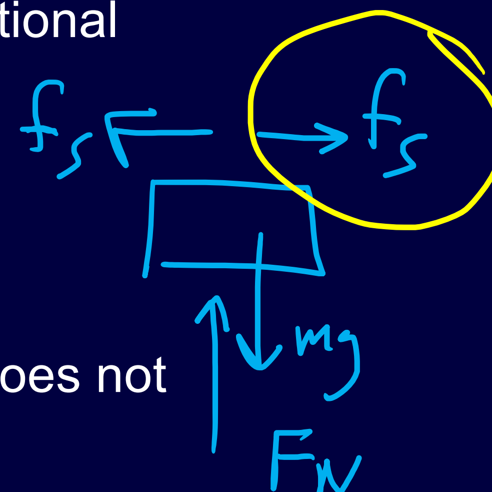
$f_{s\,max} = 10\,N$



# Clicker Question 8:

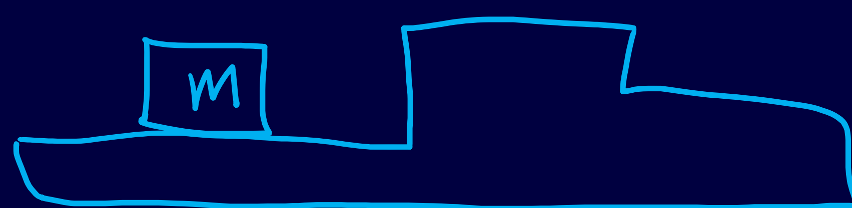

A truck accelerates with a heavy box on its trailer. The box does not slip; which direction does the frictional force point during the acceleration?




(a) In the same direction as the acceleration

(b) In the direction opposite the acceleration

(c) There is no frictional force because the box does not slip



## Student Responses

- Incorrect: Frictional force always goes opposite to the direction of velocity. In this case, the truck is speeding up, which indicates that acceleration and velocity have same direction. Therefore, frictional force points the opposite direction of the acceleration.
- Correct: When the truck accelerates, it applies a force on the heavy box in the forward direction. However, if there were no frictional force acting in the opposite direction, the box would slip or slide backward relative to the trailer
- Correct: The box must have some friction, and it shall move in the same direction of the acceleration in order for the box to accelerate with the truck, otherwise, the box would simply stay in place and not move with the truck.