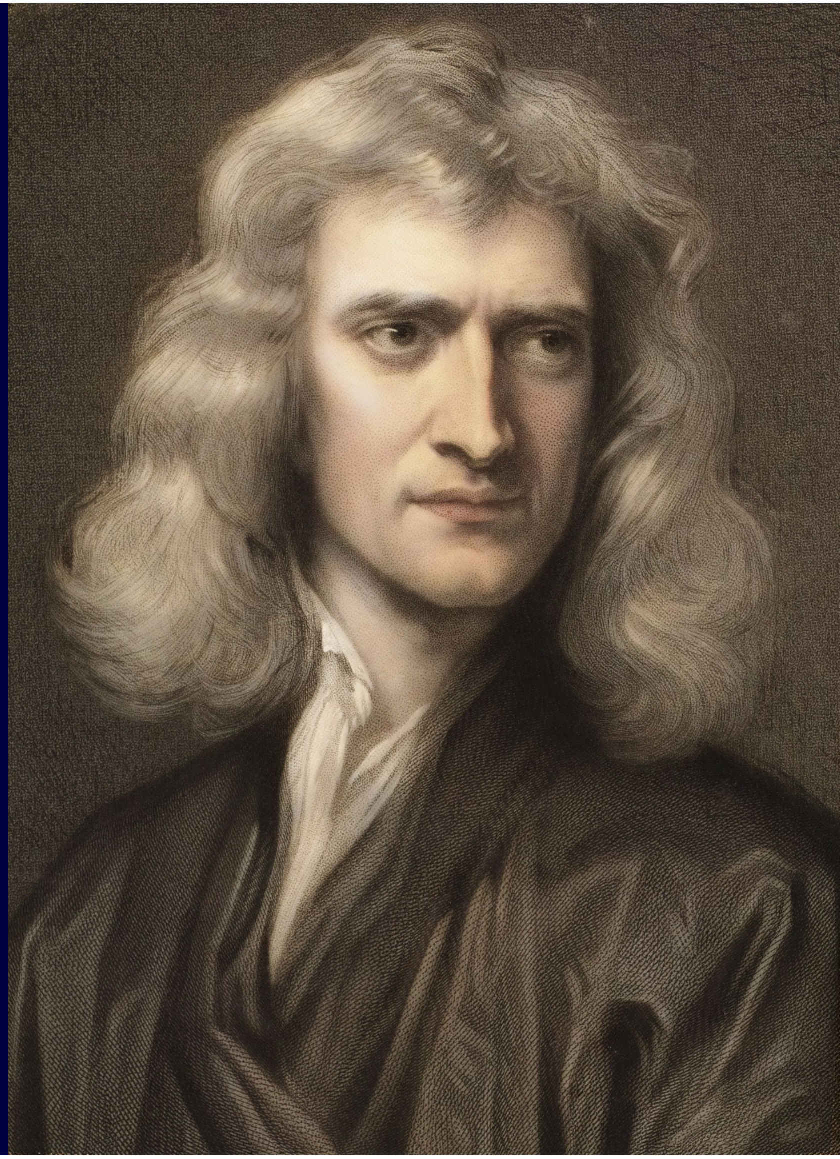
# Physics 2A: Lecture 5
# Today's Agenda

- Newton's 3 laws
  - Dynamics: Why do things move?

- Forces
  - Normal Force
  - Tension Force
  - Gravitational Force

# Start Recording!

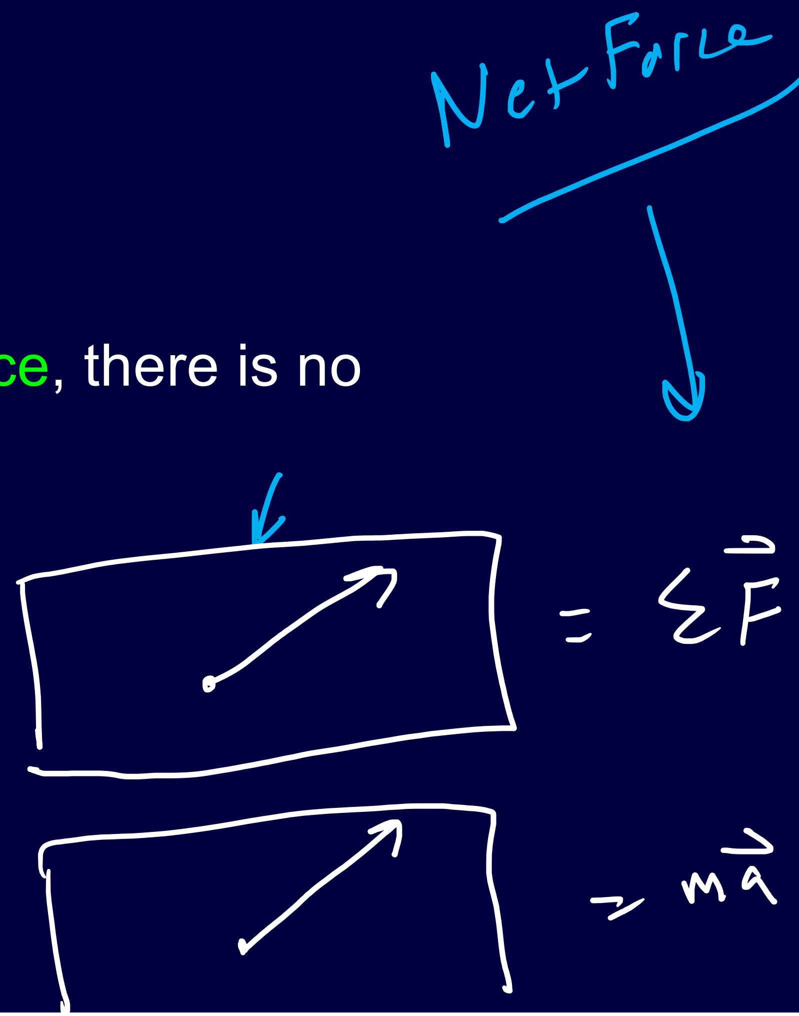


# Today:

- Newton's first two laws

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

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



# 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.

$\Sigma F_X = ma_X$

$\Sigma F_Y = ma_Y$

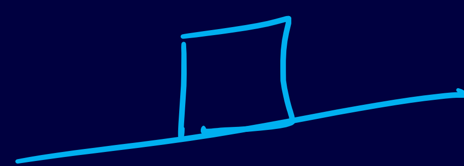
Step 6: Solve for what you need.

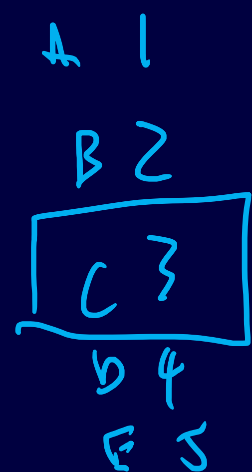
Student: What are the equations needed in order to solve for tension?

# Clicker Question 9:

A 50-kg crate rests on the bed of a truck which is accelerating to the right with $a = 3.9\ m/s^2$. What is the minimum coefficient of static friction between the surface of the truck and the crate such that the crate does not slip?

(a) 0.1
(b) 0.2
(c) 0.3
(d) 0.4
(e) 0.5





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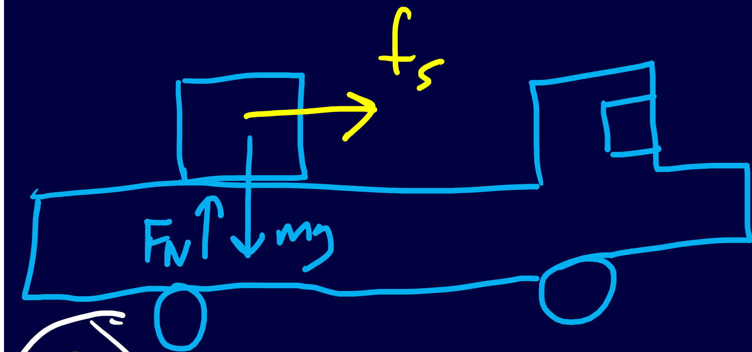



$$f_s^{max} = \mu_s F_N$$

$$\Sigma F_x = ma_x$$

$$f_s = ma$$

$$\Sigma F_y = ma_y = 0$$

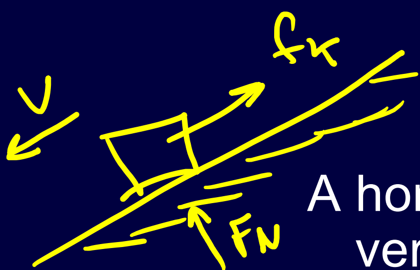
$$F_N - mg = 0$$

$$F_N = mg$$

$$f_s^{max} = \mu_s F_N = ma$$

$$\mu_s mg = ma$$

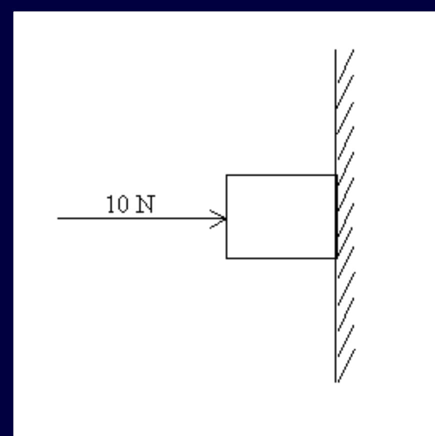
$$\mu_s = \frac{a}{g} = \frac{3.9\ m/s^2}{9.81\ m/s^2} = 0.4$$

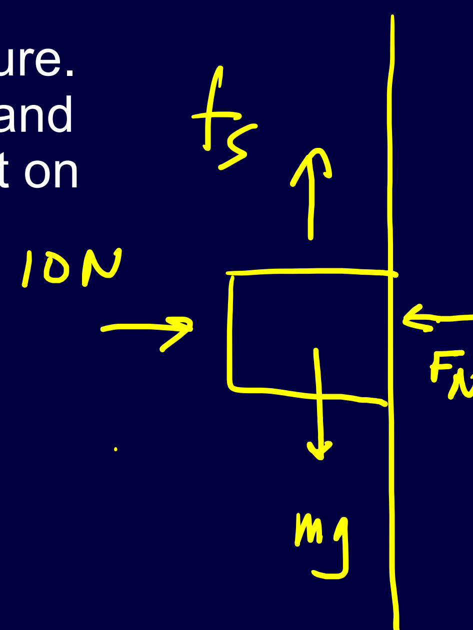


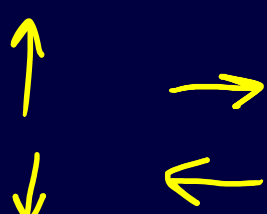

# Clicker Question 10:

A horizontal force of 10 N pushes a block against a vertical wall, holding it in place as shown in the figure. The coefficient of static friction between the block and the wall is $\mu_s = 0.59$. How many different forces act on the block?

(a) 2
(b) 3
(c) 4



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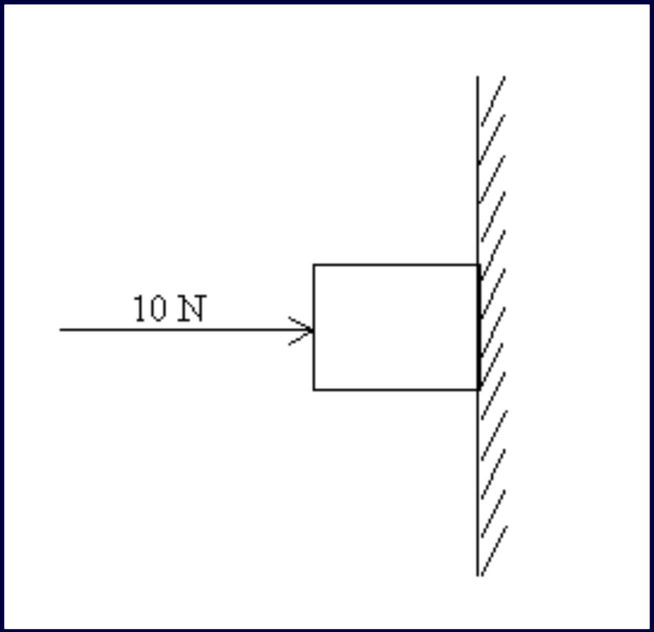
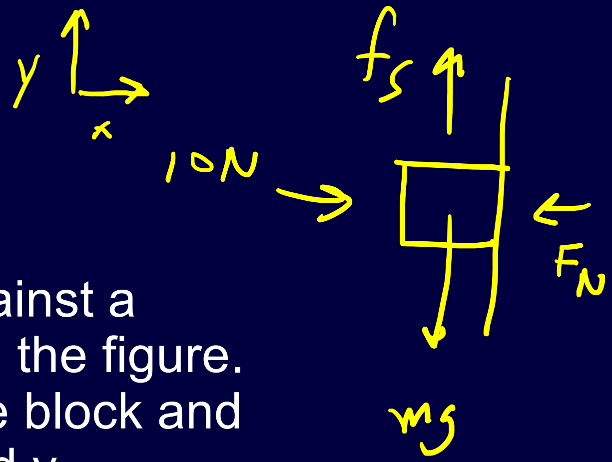
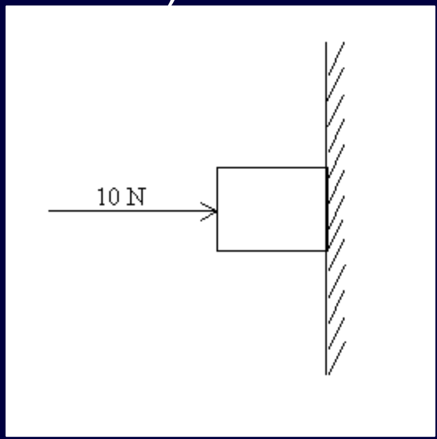


# Clicker Question 11:




A horizontal force of 10 N pushes a block against a vertical wall, holding it in place as shown in the figure. The coefficient of static friction between the block and the wall is $\mu_s = 0.59$. What are correct x and y component equations for this block? ($F_S$ is the static frictional force, and $F_N$ is the normal force)

(a) $F_N = mg$, $F_S = 10$ N
(b) $F_N = 10$ N, $F_S = mg$ ✓
(c) $F_S = 10$ N, $F_N = mg$
(d) $F_S = F_N$, $mg = 10$ N
(e) $F_S = 10$ N - mg, $F_N = 0$



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Static Problems

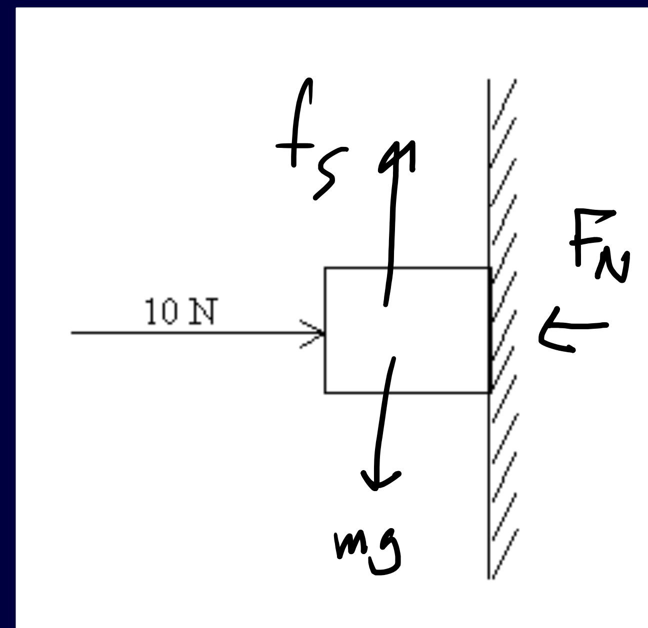
$$\sum F_y = 0 \qquad \sum F_x = 0$$

$$f_s - mg = 0 \qquad 10\,N - F_N = 0$$

$$f_s = mg \qquad 10\,N = F_N$$

$$f_s^{max} = \mu_s F_N = mg$$

$$m = \frac{\mu_s F_N}{g} = \frac{(0.59)\,10\,N}{9.81\,m/s^2} = 0.6\,kg$$



$f_s = mg$

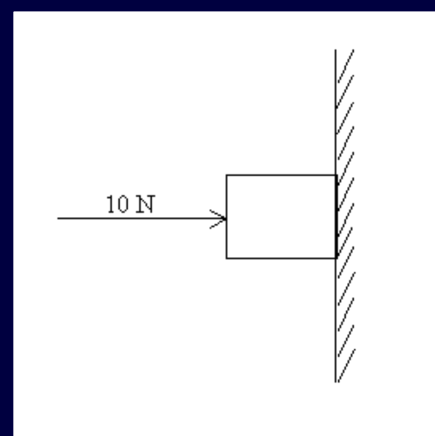
$10 N = F_N$

## Clicker Question 12:

$f_s^{max} = \mu_s F_N$

In the preceding problem, what is the maximum mass of the block such that it does not slip?

(a) 2.4 kg
(b) 9.8 kg
(c) 3.0 kg
(d) 0.6 kg
(e) 10 kg

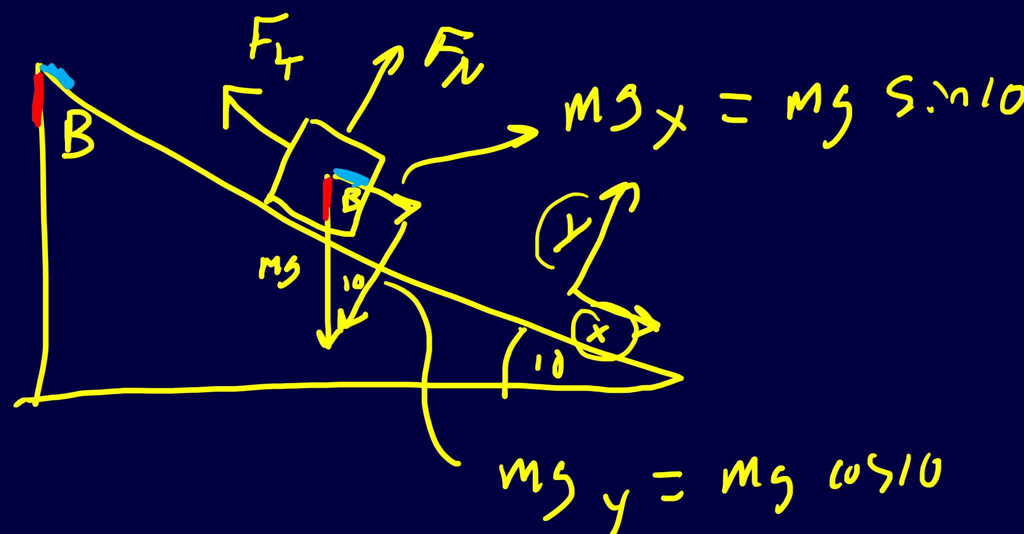


# Clicker Question 1:

1. Forces
2. FBD
3. Coordinates
4. →

A 10 kg box is sliding with constant velocity down a ramp that makes an angle of 10° with the horizontal. What is the magnitude of the frictional force between the ramp and the box?

(a) 7 N
(b) 17 N
(c) 34N
(d) 98 N
(e) 10 3N



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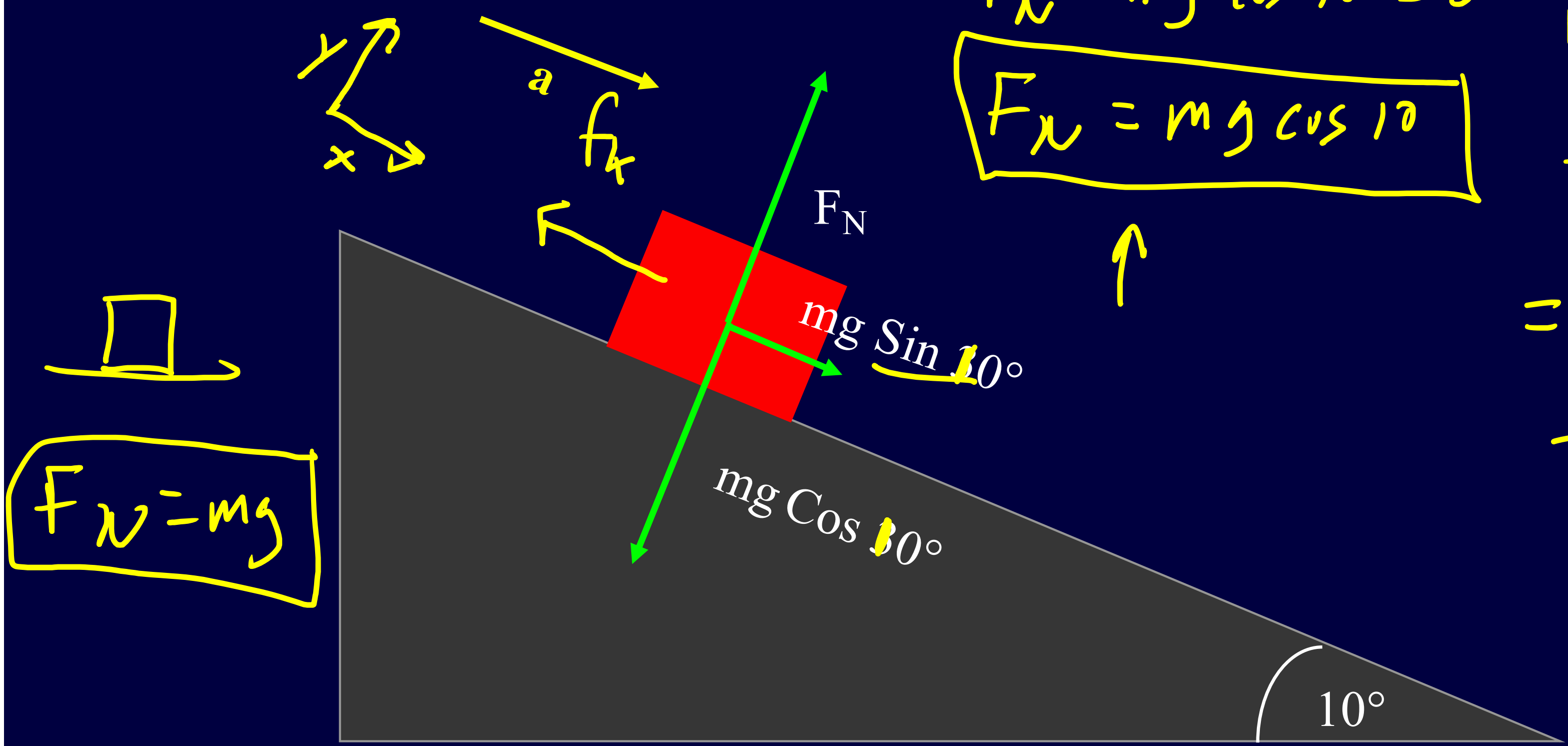



$\sum F_y = 0$

$F_N - mg\cos 10 = 0$

$F_N = mg\cos 10$

$\sum F_x = 0$

$mg\sin 10 - f_k = 0$

$f_k = mg\sin 10$

$= (10\,kg)\,g\,\sin(10)$

$= 17\,N$

## Newton’s Third Law

- Whenever an object exerts a force on a second object, the second object exerts a force on the first that is equal in magnitude and opposite in direction. (Action-Reaction)
- Sometimes this law is misunderstood
- ‘Action-reaction’ pairs are ***always*** equal and opposite

## Clicker Question 2:

A bug hits the windshield of a truck on the highway. Which is a true statement about the magnitude of the force the windshield feels due to the bug, $F_{w,b}$, and the magnitude of the force the bug feels due to the windshield, $F_{b,w}$.

(A) $F_{w,b} > F_{b,w}$

(B) $F_{w,b} = F_{b,w}$

(C) $F_{w,b} < F_{b,w}$

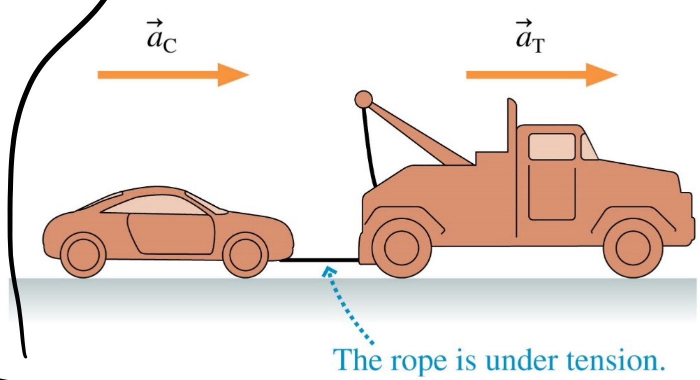
# Student Responses

$\uparrow a = \frac{F}{m} \downarrow$

- Correct: Newton's ~~Second~~ third Law states to every action there's an equal and opposite reaction when two objects are involved. The force exerted on the bug by the windshield and the force exerted on the windshield by the bug are both the same magnitude. The reason way the bug is more effected by the windshield is because the bug has a smaller mass and the car has a larger mass. F = ma, The windshield weighs more, but barely accelerates, the bug barely weighs anything, but has a greater magnitude of acceleration.
- Incorrect: Since the bug weights less than the truck, the force that the truck puts on the bug is larger. So the bug feels more force than the truck does from the bug.
- Incorrect: Since the windshield is stronger and bigger than the bug then the bug would feel more of a force acting on it than the windshield.
- Incorrect: I think that the magnitude of the force that the bug feels from the windshield is greater because the truck keeps moving forward after the collision because the bug was so small that the force it exerted on the windshield barely even affects the trucks motion.

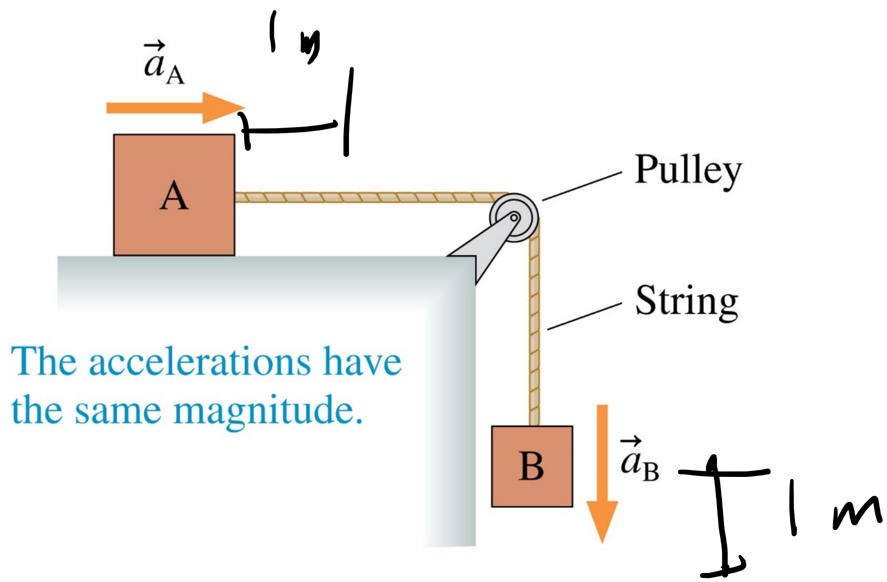
# Acceleration Constraints

- If two objects A and B move together, their accelerations are *constrained* to be equal: $a_A = a_B$
- This equation is called an **acceleration constraint**.
- Consider a car being towed by a truck.
- In this case, the acceleration constraint is $a_{Cx} = a_{Tx} = a_x$ .
- Because the accelerations of both objects are equal, we can drop the subscripts C and T and call both of them $a_x$ .



# Acceleration Constraints

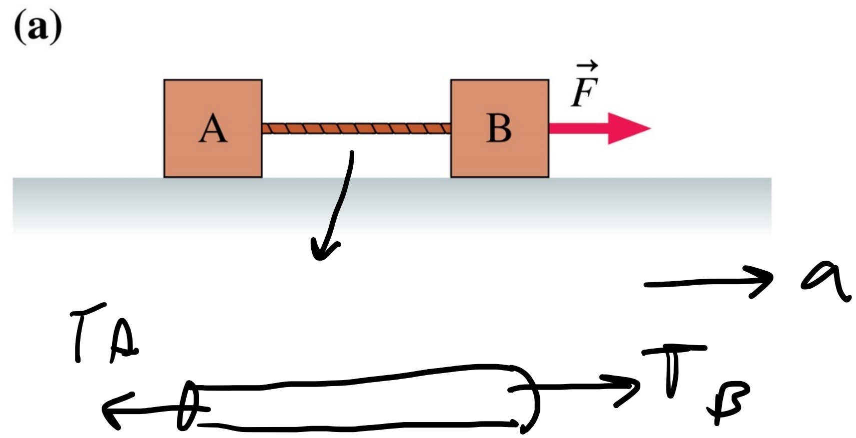
- Sometimes the acceleration of A and B may have different signs.
- Consider the blocks A and B in the figure.
- The string constrains the two objects to accelerate together.




- But, as A moves to the right in the $+x$ direction, B moves down in the $-y$ direction.
- In this case, the acceleration constraint is $a_{Ax} = -a_{By}$.

# The Massless String Approximation

- Often in problems the mass of the string or rope is much less than the masses of the objects that it connects.
- In such cases, we can adopt the following **massless string approximation**:




$$T_{\text{B on S}} = T_{\text{A on S}} \qquad \text{(massless string approximation)}$$

$\Sigma F_x = m a_x$

$T_B - T_A = ma \approx 0$

$T_B = T_A$

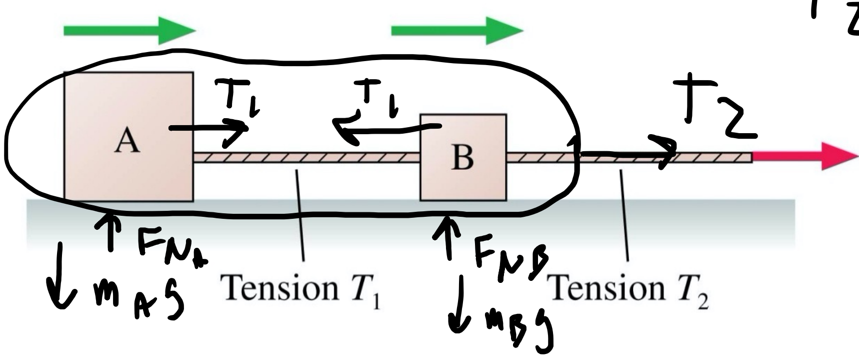
$T_B - T_A = 0.001\ N$

Student: For problem 2, if the mass of the blocks differ in mass will the tension remain the same between all the blocks? I think it will but I wanted to be sure.

# Clicker Question 3:

Boxes A and B are being pulled to the right on a frictionless surface. Box A has a larger mass than B. How do the two tension forces compare?

A. $T_1 > T_2$
B. $T_1 = T_2$
C. $T_1 < T_2$
D. Not enough information to tell.




$\Sigma F_x = ma_x$

$T_1 = m_A a$

$\Sigma F_x = m_{TOT} a$

$T_2 - T_1 + T_1 =$

$T_2 = (m_A + m_B) a$

# Student Responses

- Incorrect: Even though both boxes have different mass, Box A and B would still have the same tension since according to Newton 3rd the forces would exert the same force by the box(objects) being attached. $\Sigma F_x = ma_x$
- Incorrect: I'm not sure but I feel like the tension between the two boxes would be greater since box A is exerting a negative force directly onto T1.
- Correct: Tension two will be greater because it is pulling the mass of both B and A

# Clicker Question 4:

Three blocks each have a mass of 3 kg and are being pulled over a frictionless surface by a force of 20 N.

What acceleration does block A have?

a) Zero $m/s^2$
b) 2.22 $m/s^2$
c) 6.67 $m/s^2$
d) 60 $m/s^2$
e) 180 $m/s^2$