PHYS 100: Lecture 6

NEWTON'S FIRST and THIRD LAWS

First Law:

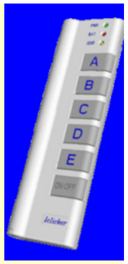
An object subject to no external forces is at rest or moves with constant velocity if viewed from an inertial reference frame.

Third law:

For every action there is an equal and opposite reaction.

$$\vec{F}_{AonB} = -\vec{F}_{BonA}$$

Music



BB

Who is the Artist?

A) The Meters
B) The Neville Brothers
C) Trombone Shorty
D) Michael Franti
E) Radiators

Why?
Didn't get to play Dr John last time…

Nevilles: icons of New Orleans… hope you had a fun Mardi Gras!

THE BIG IDEAS

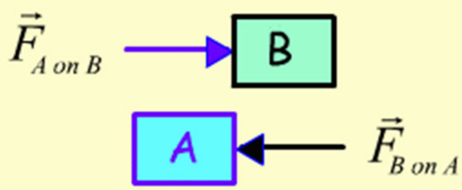
NOTE: THE BIG IDEAS ARE ALWAYS GIVEN IN THE LAST SLIDE

Main Points

First Law:
An object subject to no external forces is at rest or moves with constant velocity if viewed from an inertial reference frame.

Third law:
For every action there is an equal and opposite reaction

$$\vec{F}_{A\ on\ B} = -\vec{F}_{B\ on\ A}$$



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1. Inertial reference frames are those frames in which Newton's Laws always are TRUE.
2. Forces always come in pairs: $\vec{F}_{AonB} = -\vec{F}_{BonA}$

Newton's First Law

Suppose a boy is in an elevator and the cable breaks so that the elevator is in free fall. He decides to do one last experiment and releases two balls as shown.

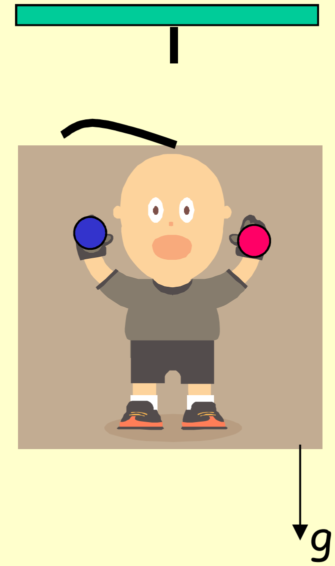
What happens to the balls?

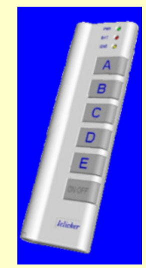
(A) The balls fall to the floor of the elevator with acceleration = g

(B) The balls fall to the floor of the elevator with acceleration > g

(C) The balls fall to the floor of the elevator with acceleration < g

(D) The balls remain at the same height above the floor





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What is the acceleration of the floor of the elevator? $a_{elevator} = g$

What is the acceleration of the balls before release? $a_{before} = g$

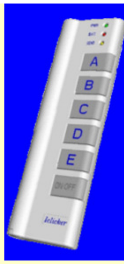
What is the force on the balls after release? $F_{after} = m_{ball}g$

What is the acceleration of the balls after release? $a_{after} = g$

After release, the balls do not move with respect to the elevator.
Therefore, in the elevator frame, $a_{ball} = 0$
But, $F = m_{ball}g$
Therefore, in the elevator frame, F is not equal to ma !!

⇨ Elevator is NOT inertial frame

CheckPoint 2b



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You ask your friend to help you move. He is about to push a box across the floor when he says, "due to Newtons third law the box will push on me with the same force that I push on it, so it's no use to try to push this box."

What is wrong with your friend's reasoning?

I. Newton's Third Law only applies when there is no acceleration. Once the box moves, the forces are not equal.

II. The block can only push back a certain amount of force. Once your friend applies more than that amount of force, the box will move.

(A) Both statements are TRUE

(B) Both statements are FALSE

(C) I is TRUE and II is FALSE

(D) I is FALSE and II is TRUE

I.

Newton's Third Law is ALWAYS TRUE !!
You can use it in ALL situations

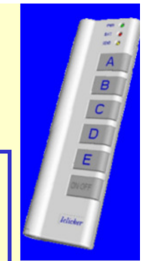
II.

It's true that there is a maximum force that the box can exert on your friend.

But, what would happen if your friend pushes harder than this?

THE BOX WOULD BREAK !

CheckPoint 2b



BB

You ask your friend to help you move. He is about to push a box across the floor when he says, "due to Newtons third law the box will push on me with the same force that I push on it, so it's no use to try to push this box."

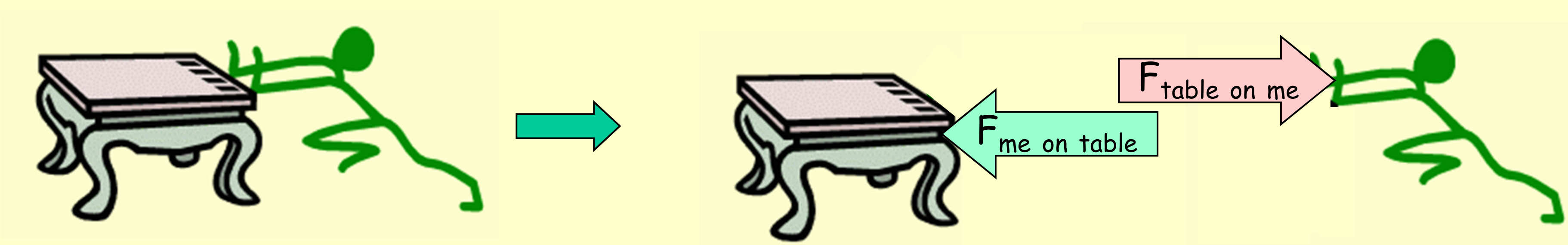
What is wrong with your friend's reasoning?

(A) "Newton's third law only when there is no acceleration. The box will only move if the amount of my friend puts on the box exceeds the amount of force the box puts on me."

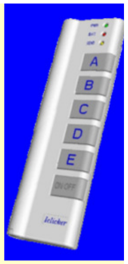
(B) "There is no force acting on the my friend from the box."

(C) "The acceleration of the box is determined by the force on only on the box, not the force done by the box."

(D) "None of the above explain the flaw in your friend's reasoning."



Newton's Third Law Pairs



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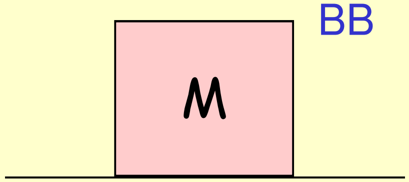
A block of mass M rests on a frictionless floor as shown

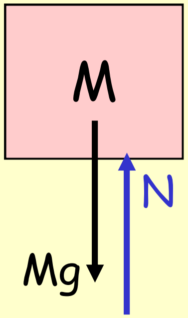
The normal force exerted by the floor on the block and the block's weight are Newton's Third Law pairs (action-reaction forces)

(A) TRUE

(B) FALSE



Let's start with a freebody diagram:



Since the block is at rest, $\Sigma F = 0$

$N = Mg$

WHY ???

- Both of these forces are forces exerted on the block
- Action-Reaction pairs are forces exerted on DIFFERENT OBJECTS
- Action-Reaction pairs do not appear on the same freebody diagram (what would be the point? They would always cancel!)

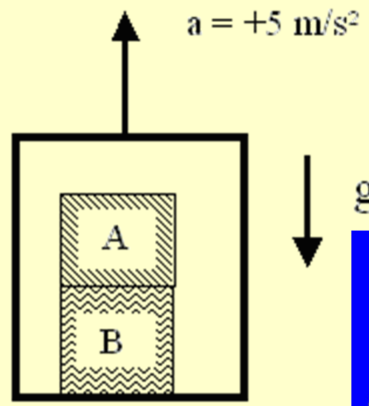
BUT N = Mg DOES NOT MEAN THESE FORCES ARE ACTION-REACTION PAIRS !!

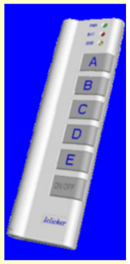
CheckPoint 1a

Block A is stacked on top of Block B in an elevator that is accelerating upwards with $a = +5\ m/s^2$ as shown.

Which is greater, F_{BonA}, the force B exerts on A or F_{AonB}, the force A exerts on B?

(A) $F_{AonB} > F_{BonA}$ (B) They are the same (C) $F_{BonA} > F_{AonB}$





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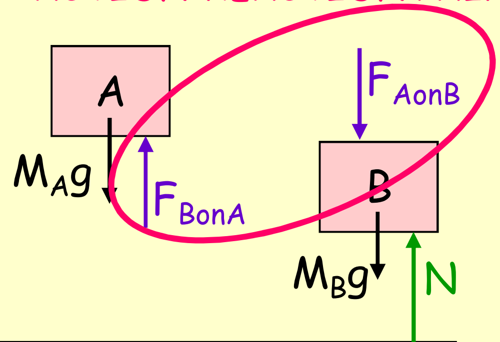
You said:

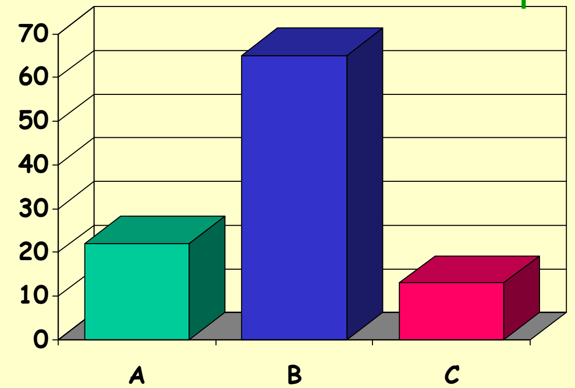
- The force block a exerts on b is greater because both gravity and the force caused by the upward acceleration are pressed down on b, which is characterized only by gravity.

- According to Newton's first law, the forces that they exert on each other must be equal and opposite.

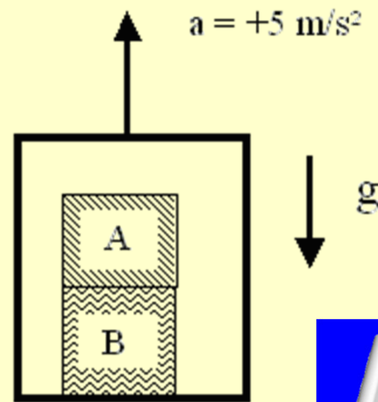
- the acceleration upwards is added to the force of B on A, while it is subtracted from the force of A on B.

Draw freebody diagrams





Follow Up

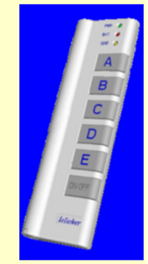


Block A is stacked on top of Block B in an elevator that is accelerating upwards with $a = +5\ m/s^2$ as shown.

What is F_{AonB}, the force A exerts on B?

(A) $F_{AonB} = M_A g$ (B) $F_{AonB} = M_A a$ (C) $F_{AonB} = M_A(a+g)$

(D) $F_{AonB} = M_A(a-g)$ (E) None of these : it depends on M_B



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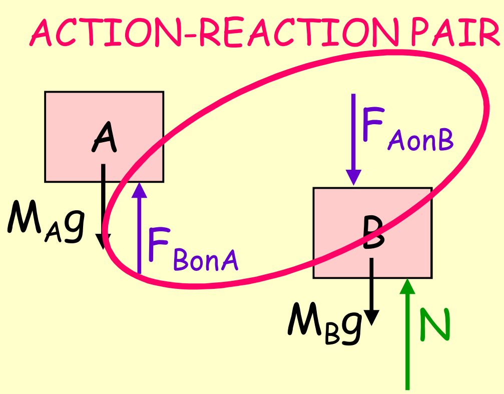
Draw freebody diagrams



magnitudes: $F_{BonA} = F_{AonB}$

QUICKIE:
What is magnitude of acceleration of A?

(A) a (B) a+g (C) a-g (D) 0

What is net force on A? (positive = up) $F_{BonA} - M_A g$

Newton's Second Law

$F_{BonA} - M_A g = M_A a$ → $F_{BonA} = M_A(a + g)$

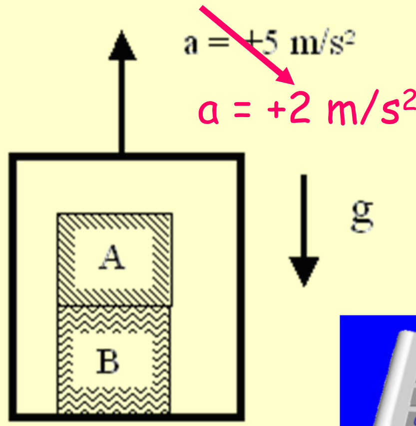
CheckPoint 1b

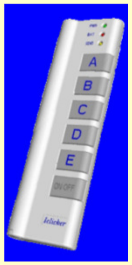
How would F_{AonB}, the force A exerts on B, change if the acceleration is reduced to a = +2 m/s^2?

(A) F_{AonB} increases with decreasing acceleration

(B) F_{AonB} stays the same with decreasing acceleration

(C) F_{AonB} decreases with decreasing acceleration



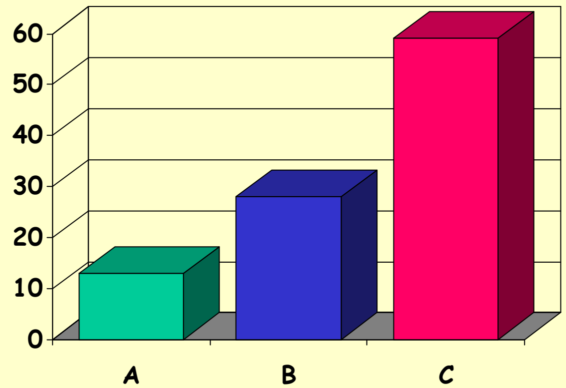


BB

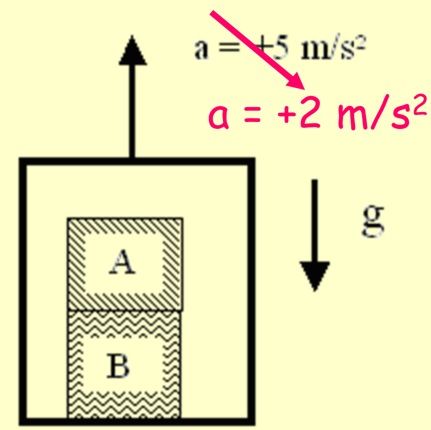
You said:

- From the formula for Newtons Third Law, if Fb on a is decreasing then Fa on b must increase.
- Since the force of A on B only depends on the weight of A (ie, mass of A times acceleration due to gravity), it must not change with the accelration of the elevator.
- Force is equal to Mass multiplied by the acceleration so if the acceleration decreases so will the force.

(C) is correct, but most reasons given for (C) in CheckPoint were not correct !!



CheckPoint 1b



How would F_{AonB}, the force A exerts on B, change if the acceleration is reduced to $a = +2\ m/s^2$?

(A) F_{AonB} increases with decreasing acceleration

(B) F_{AonB} stays the same with decreasing acceleration

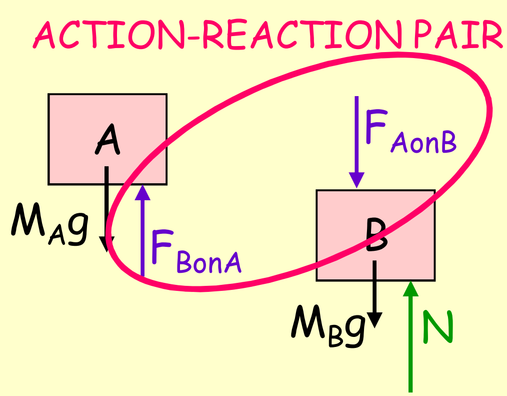
(C) F_{AonB} decreases with decreasing acceleration

(C) is correct, but most reasons given for (C) in Preflight were not correct !!

What is wrong with this explanation ??

"Force is equal to Mass multiplied by the acceleration so if the acceleration decreases so will the force."

Draw freebody diagrams



This argument works for the NET FORCE

Newton's Second Law: NET FORCE = ma

F_{AonB} is NOT the NET FORCE!

B: NET FORCE = $N - M_Bg - F_{AonB}$ ⇨ $N - F_{AonB}$ decreases (no help here)

A: NET FORCE = $F_{BonA} - M_Ag$ ⇨ F_{BonA} decreases

Newton's Third Law ⇩

F_{AonB} decreases

CheckPoint 2a

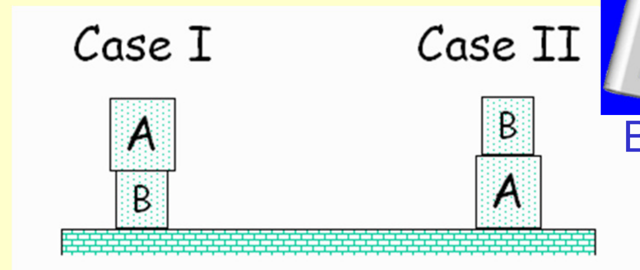
BB

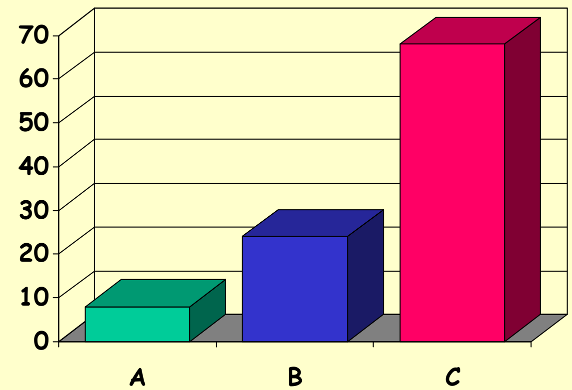
In Case I, Block A rests on block B which rests on the floor. In Case II, the positions are reversed. The mass of block A is twice that of block B

Compare $F_{AonB}(I)$ to $F_{AonB}(II)$:

(A) $F_{AonB}(I) < F_{AonB}(II)$ (B) $F_{AonB}(I) = F_{AonB}(II)$

(C) $F_{AonB}(I) > F_{AonB}(II)$





You said:

- In case 1 the force block A exerts on block B would be smaller because the force is negative and in case 2 the force block A exerts on block B would be positive and therefore larger.

- The forces of the blocks form an action-reaction pair. They stay the same regardless of mass.

- In Case I Block A is exerting a force equal to its own weight on Block B while in Case II Block A is exerting a normal force equal to the weight of Block B on Block B

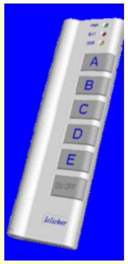
ALSO, must understand WHY this argument is wrong!

Most of the reasons given for (C) in the CheckPoint went something like this:

Because A is heavier it pushes down more in I than B does in II.

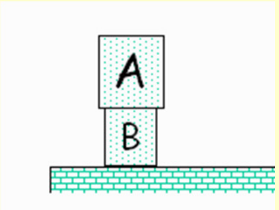
This is kinda OK, but I'd like to make sure you understand in terms of freebody diagrams

Follow Up



BB

Block A rests on block B which rests on the floor. To determine F_{AonB}, You need to draw the freebody diagrams for :

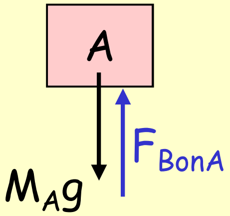


(A) A only (B) B only (C) Both A and B

Knowing Newton's Third Law, We need only draw the freebody diagram for A !!

WHY?

Newton's third law tells us the magnitudes of F_{AonB} and F_{BonA} are the same!



$a = 0$ ⇒ $F_{BonA} = M_A g$

Newton's Third Law ⇒ $F_{BonA} = F_{AonB}$

⇓

$F_{AonB} = M_A g$

Why did I bother to do this freebody diagram thing here?

Your intuition (a block pushes down on another block with its weight) may not work in more complicated situations.. How about 3 blocks??

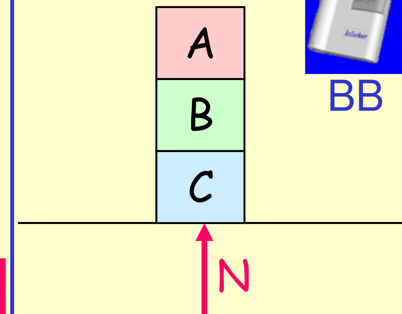
Follow Up

Block A rests on block B which rests on block C which rests on the floor.
You are told:

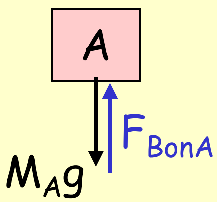
$$F_{BonA} < F_{BonC}$$

Which of the following statements about the masses MUST be TRUE?

(A) $M_A < M_C$ (B) $M_A > M_C$ (C) $M_A > M_B$ (D) We can say nothing about masses.



To find F_{BonA}
Freebody for A

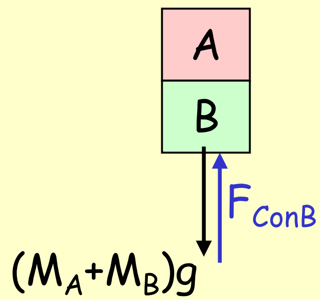


$$F_{BonA} = M_A g$$

To find F_{BonC}
Freebody for AandB

~~Freebody for C~~

Will introduce N !



Newton's Third Law:
$F_{BonC} = F_{ConB}$

Newton's Third Law

$$F_{ConB} = (M_A+M_B)g = F_{BonC}$$

Therefore: $F_{BonA} < F_{BonC}$ for any values of M_A and M_B !!!

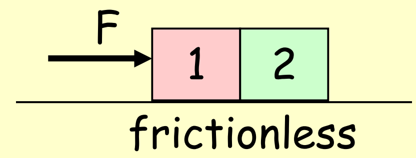
Pushing Blocks

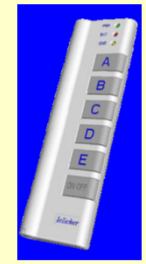
Force F is applied to Block 1 which is in contact with Block 2 as shown. Both blocks move together to the right with acceleration a.

We want to calculate F_{21}, the force Block 2 exerts on Block 1.

First Question: Compare F_{21} and F

(A) $F_{21} < F$ (B) $F_{21} = F$ (C) $F_{21} > F$





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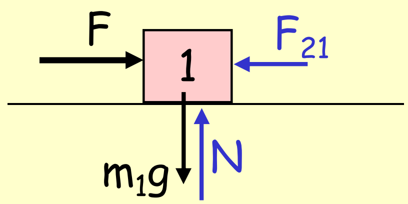
STEP 1: Draw Freebody for Block 1



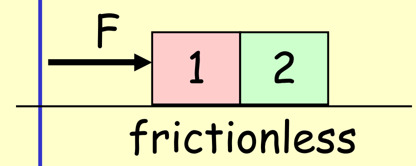
Block 1 accelerates to the right $\Rightarrow$ $F > F_{21}$

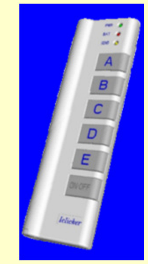
Pushing Blocks

Force F is applied to Block 1 which is in contact with Block 2 as shown. Both blocks move together to the right with acceleration a.

We want to calculate F_{21}, the force Block 2 exerts on Block 1.
Second Question: What is the acceleration?

(A) $a = F/m_1$ (B) $a = F/m_2$ **(C) $a = F/(m_1+m_2)$** (D) need more info





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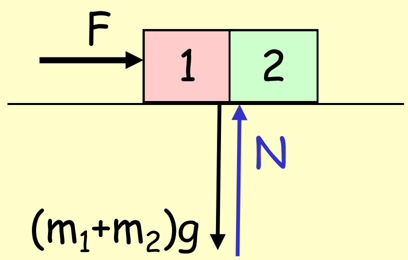
STEP 1: Draw Freebody for Blocks 1and2



Newton's Second Law (Horizontal Direction) → $F = (m_1 + m_2)\,a$ → $a = F/(m_1 + m_2)$

Pushing Blocks

Force F is applied to Block 1 which is in contact with Block 2 as shown. Both blocks move together to the right with acceleration a.

We want to calculate F_{21}, the force Block 2 exerts on Block 1.

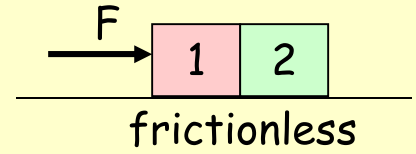
Third Question: What is F_{21}?

(A) $F_{21} = 0$

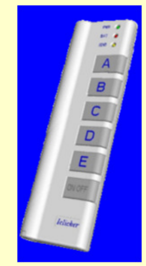
(B) $F_{21} = (m_2-m_1)g$

(C) $F_{21} = Fm_1/(m_2+m_1)$

(D) $F_{21} = Fm_2/(m_2+m_1)$



$a = F/(m_1+m_2)$



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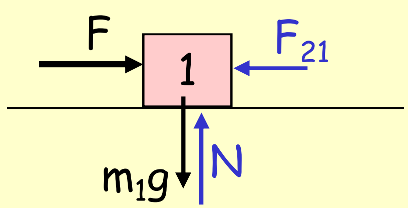
STEP 1: Draw Freebody for Block 1



Newton's Second Law (Horizontal Direction)

$F - F_{21} = m_1a$

$a = F/(m_1+m_2)$

$F_{21} = Fm_2/(m_2+m_1)$

NOTE: Even simpler way is to draw FBD for Block 2 to find F_{12}

Something Similar?

Two blocks connected by a string are pulled across a frictionless floor by force F

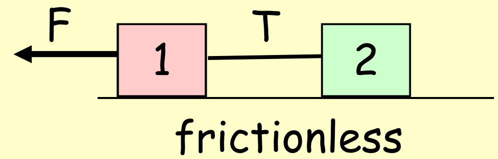
What is the tension in the string connecting the blocks?

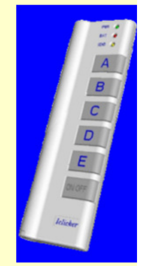
(A) $T = 0$

(B) $T = (m_2 - m_1)g$

(C) $T = Fm_1/(m_2+m_1)$

(D) $T = Fm_2/(m_2+m_1)$





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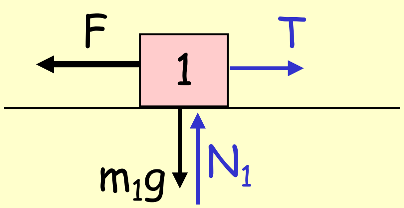
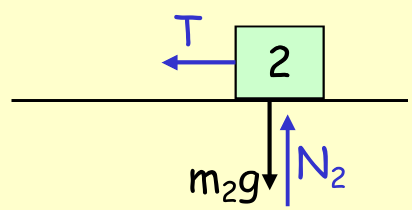
STEP 1: Draw Freebody Diagrams





$a = F/(m_1+m_2)$

Newton's Second Law (Horizontal Direction) → $F - T = m_1a$ $T = m_2a$

$a = F/(m_1+m_2)$ → $T = Fm_2/(m_2+m_1)$ $T = Fm_2/(m_2+m_1)$