Physics 221, January 25

Key Concepts:

- Newton's 1st law
- Newton's 2nd law
- Weight
- Newton's 3rd law

Please find a seat.

Keep all walkways free for safety reasons and to comply with the fire code.

Matter and interactions

In this class we study Classical Physics. It models the macroscopic world around us and works well describing and predicting almost all everyday phenomena. All the laws of classical physics were known by the end of the 19th century.

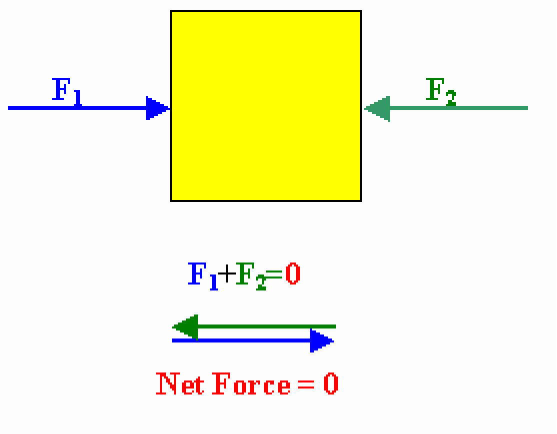
The known properties of matter at the end of the 19th century were mass and charge. The smallest constituents were atoms.

The known interactions were gravity, electromagnetic interactions, and contact force arising from the requirement that "atoms need their space".

Gravity and the electromagnetic interaction act at a distance.

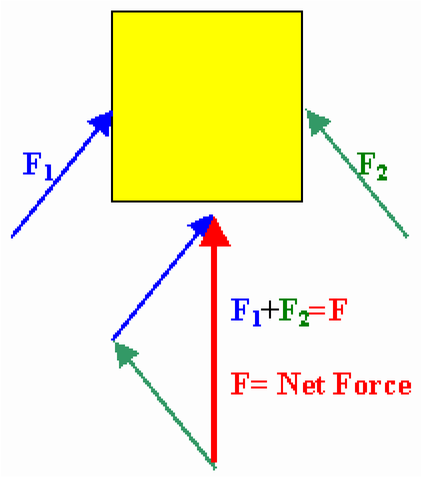
What is a force?

A force is a push or a pull.
It acts on an object due to the interactions of the object with other objects.



Forces are vectors. They have magnitude and direction. Forces add vectorially.

Adding two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ can result in a net force $\mathbf{F}_{net} = \mathbf{F}_1 + \mathbf{F}_2$ that has any magnitude between $F_1 + F_2$ and $|F_1 - F_2|$, depending on the relative directions of the forces.



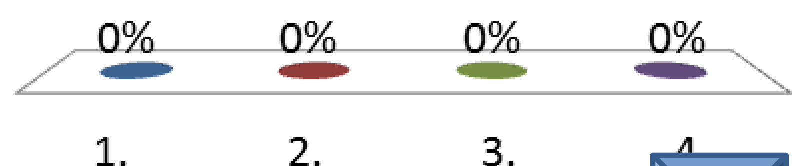
Newton's first law

 Newton's first law, also called the law of inertia, defines a special class of reference frames, called inertial frames. It states that, when viewed in an inertial reference frame, an object at rest remains at rest, and an object in motion continues in motion with constant velocity, unless it is acted on by an external net force.

Note: Newton's second and third laws are valid in all inertial reference frames.

You put your book on the bus seat next to you while the bus is parked at the bus stop. When the bus begins to quickly move away from the bus stop, the book slides towards the back of the seat, without anything pushing it. Why?

1. The back of the seat and the book attract each other.
2. The gravitational force pulls the book backward
3. The motor produces a strong magnetic field.
4. The accelerating bus is not an inertial reference frame.



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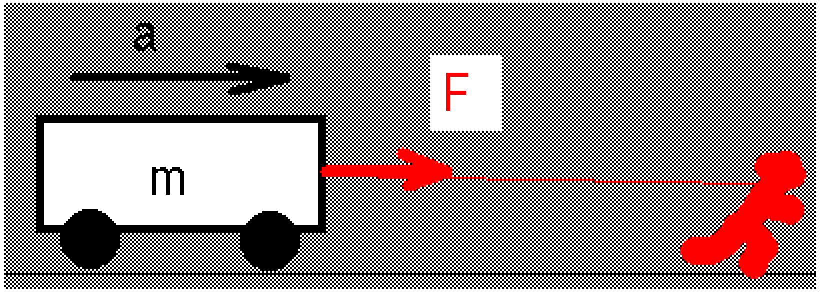
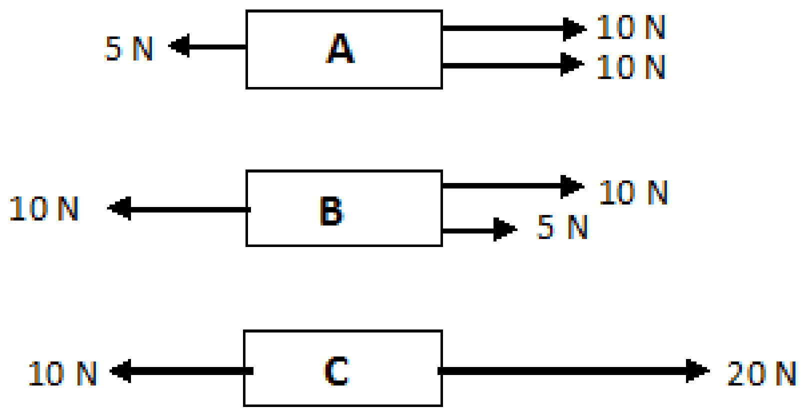
Newton’s second law



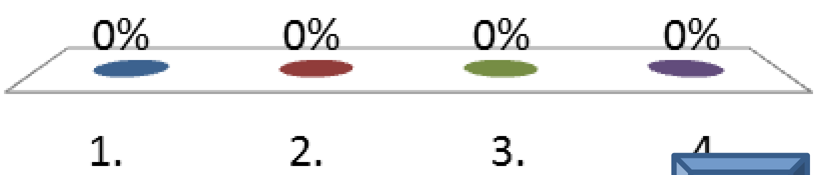
Newton's second law states that the acceleration of an object is directly proportional to the net force acting on it, and inversely proportional to its mass, $\mathbf{F}_{net} = m\mathbf{a}$.

Note: This is a vector equation.
$F_x = ma_x$, $F_y = ma_y$, $F_z = ma_z$.

Rank the following situations (A, B, and C) according to the magnitude of the net force, greatest first.



1. B, C, A
2. C, A, B
3. C, B, A
4. A, C, B



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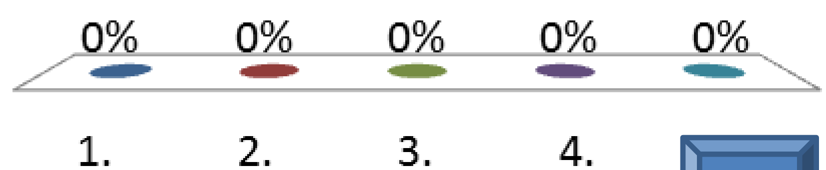
A car has a maximum acceleration of 4.5 m/s^2.   What would be its maximum acceleration while towing a second car twice its mass?

Hint: $F_{max} = ma_{max}$

What is the total mass now?

1. 2.25 m/s^2
2. 2 m/s^2
3. 1.5 m/s^2
4. 1 m/s^2
5. 0.5 m/s^2



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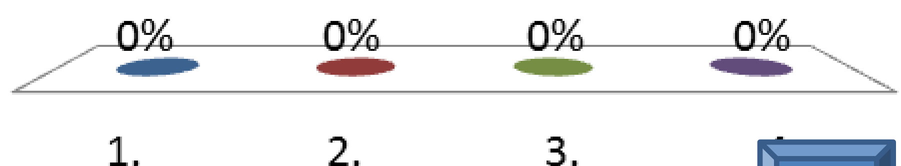
A force of 20 N in the positive x-direction accelerates an object with acceleration a = 2 m/s^2. When the object is moving with velocity v = 10 m/s, an additional force of 10 N in the negative x-direction is applied.
Which statement is true?

Hint:
What is the net force now?

1. The object now accelerates with acceleration a = -1 m/s^2 in the negative x-direction.
2. The object now accelerates with acceleration a = 1 m/s^2 in the positive x-direction.
3. The object now moves with constant velocity.
4. The objects slows down and comes to a stop.



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Weight

The force of gravity , $\mathbf{F}_g$, acting on an object is called its weight.

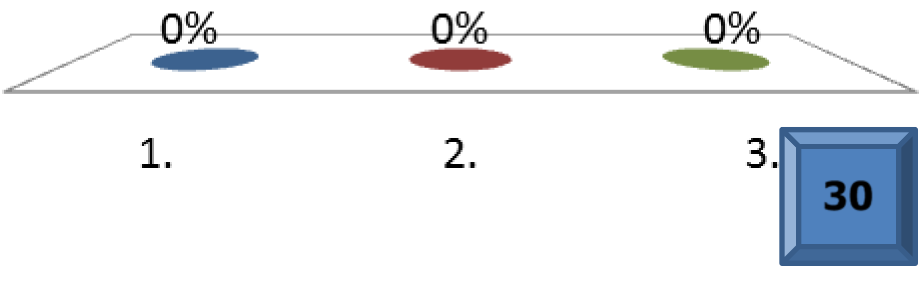
Near the surface of Earth $\mathbf{F}_g = m\mathbf{g}$, pointing downward.

$\mathbf{g} = 9.8 m/s^2$ pointing downward is the gravitational acceleration.

Spring scales measure the force they exert on a object.

A rock is thrown vertically into the air.
At the very top of its trajectory the net force on it is

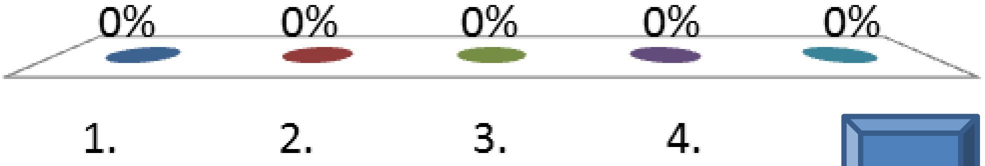
1. less than its weight.
2. more than its weight.
3. equal to its weight.



Suppose you are standing on a bathroom scale while riding in an elevator. For a moment the scale reads 175 lb = 778 N while your actual weight is 155 lb = 689 N. What is your (and the elevator's) acceleration? (Let $g = 10\ m/s^2$.)

1. $-1.14\ m/s^2$
2. $-1.29\ m/s^2$
3. $+1.14\ m/s^2$
4. $+1.29\ m/s^2$
5. $-1.39\ m/s^2$

Hint:
Let the upward direction be the positive direction.
What is your mass?
What is the net force $F_{floor} - mg$ acting on you?
What is your acceleration $a = F_{net}/m$?



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Solution:

Your actual weight: 689 N
Your mass: 68.9 kg

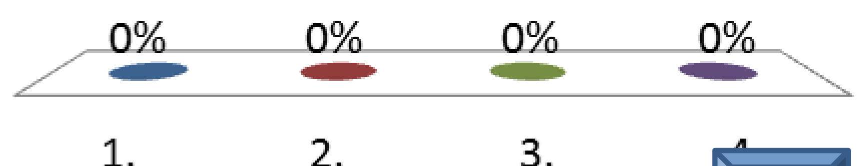
Let the upward direction be the positive direction.

Net force acting on you: $F_{floor} - mg = 778\ N - 689\ N = 89\ N$

$a = F_{net}/m = 89\ N/68.9\ kg = 1.29\ m/s^2$

Suppose an ice skater is moving on the surface of a frozen lake at constant velocity. What is true about the external (outside) forces acting on the skater?

1. There are none.
2. There could be some but they all cancel out.
3. Gravity can be ignored.
4. The all are perfectly horizontal.



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Remember!

constant velocity

$\leftrightarrow$

no acceleration

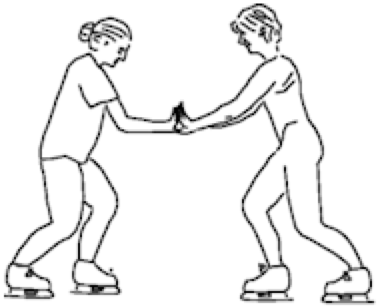
$\leftrightarrow$

no net force

Newton’s third law

Newton's third law is also called the **law of action and reaction**.

For every action force, there exists a reaction force, equal in magnitude and opposite in direction.

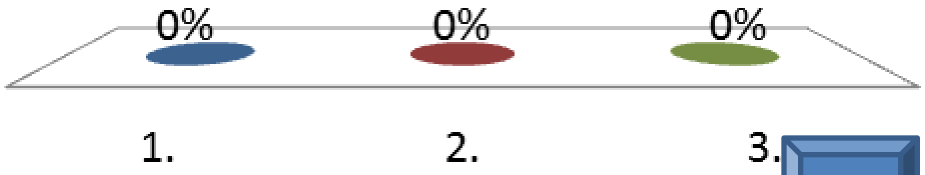


The action and reaction force always act on **different objects.** The objects interact.

A car traveling at 100 km/hr strikes an unfortunate bug and splatters it.

The magnitude of the force of impact is

1. greater on the bug.
2. greater on the car.
3. the same for both.



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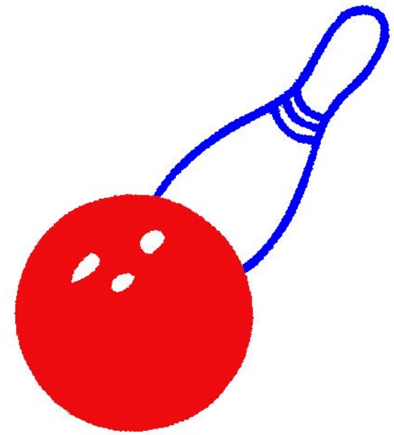
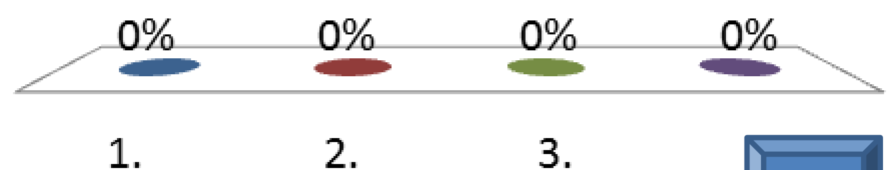
A bowling ball rolls down an alley and hits a bowling pin. Which statement below is true about the magnitudes of the forces exerted during the impact?

1. The bowling pin exerts a larger force on the ball than the ball on the pin.
2. The bowling ball exerts a larger force on the pin than the pin on the ball.
3. The magnitudes of the forces that they exert on each are equal.
4. Any of the above answers could be true. It depends on how fast the bowling ball is moving.





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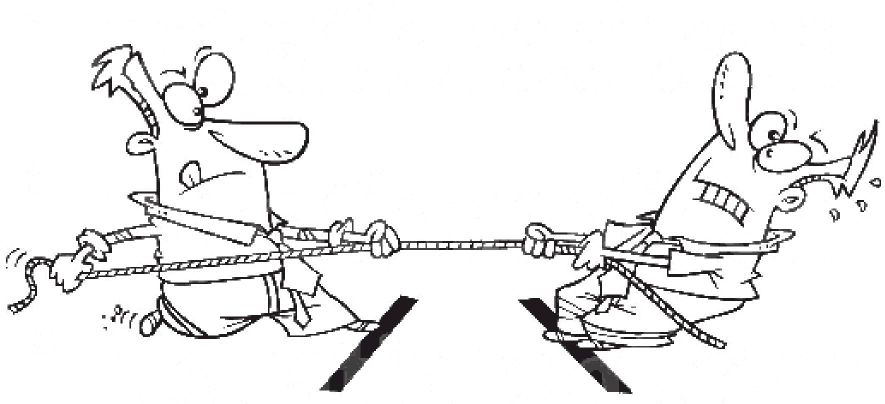
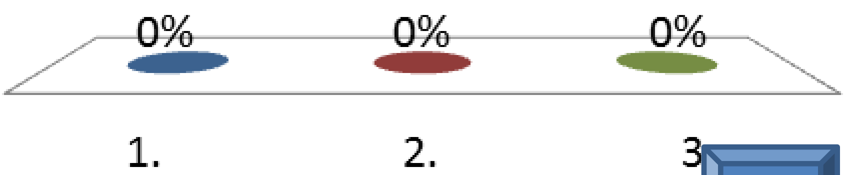
Arnie and Wimpy are playing tug-of-war. They have the same weight, but Arnie wins, pulling Wimpy into the mud puddle. Why did Arnie win?



1. Arnie exerted a greater magnitude force on Wimpy than Wimpy exerted on the Arnie.
2. Arnie exerted a greater magnitude force on the ground than Wimpy exerted on the ground.
3. Arnie gets a gravitational assist.



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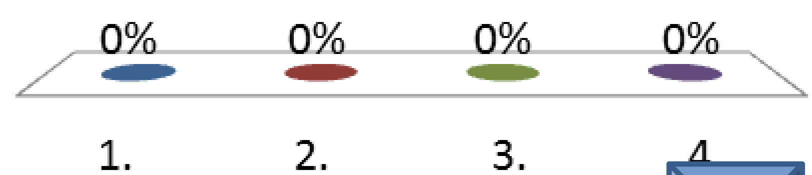
Consider a car at rest. We can conclude that the downward gravitational force Earth exerts on the car and the upward contact force the surface of Earth exerts on the car are equal in magnitude and opposite in direction because

1. the two forces form an action-reaction (interaction) pair.
2. the net force on the car is zero.
3. both of the above.
4. neither of the above.



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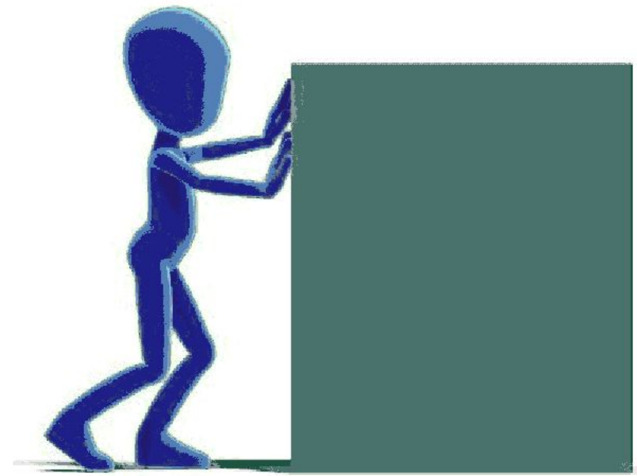
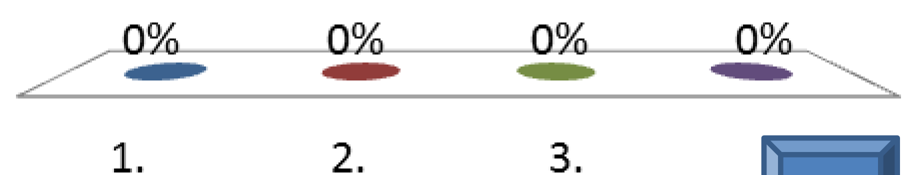
Your hands push on a heavy box to slide it across the floor.
The other force of the action/reaction pair is



1. friction pushing backward on the floor.
2. gravity pulling downward on the box.
3. the box pushing downward against the floor.
4. the box pushing backward against your hands.



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