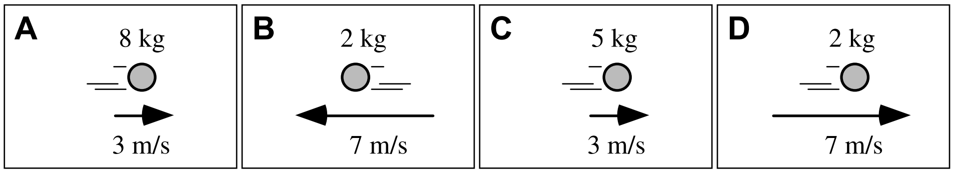
B5 MOMENTUM AND IMPULSE

B5-RT01: MOVING BALL I—MOMENTUM AND KINETIC ENERGY

In the figures below, balls are traveling in different directions. The balls have the same size and shape, but they have different masses and are traveling at different velocities as shown.



(a) Rank the magnitude of the momentum of the balls.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Answer: A > C > B = D.

*Based on magnitude of the momentum = mass*instantaneous speed.*

(b) Rank the kinetic energy of the balls.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

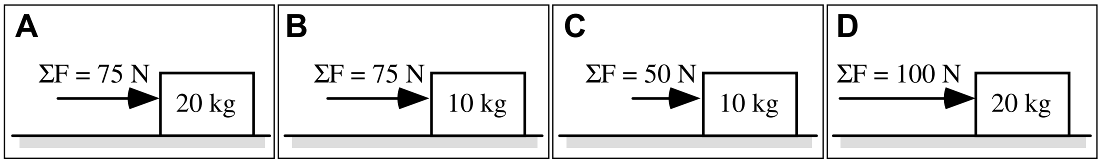
Explain your reasoning.

Answr: B = D > A > C.

*Based on definition of kinetic energas one-half the mass*velocity*^{2}*.*

B5-RT02: Force Pushing Box I—Change in Momentum

Identical boxes that are filled with different objects are initially at rest. A horizontal force is applied for 10 seconds, and the boxes move across the floor. The mass of the box with its contents and the *net* force acting on the box while the horizontal force are applied is given in each figure.



Rank the magnitude of the change in momentum during a 10-second interval for each box.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

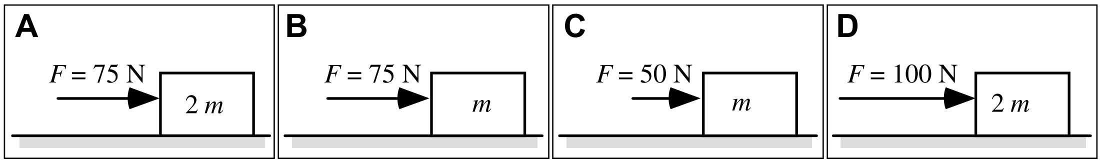
Explain your reasoning.

Answer: D > A = B > C.

The time interval is the same for all four cases, so the magnitudes of the momentum changes, which are equal to the impulses applied to the boxes, will be proportional to the net forces acting.

B5-RT03: Force Pushing Box II—Impulse

Identical boxes that are filled with different amounts of sand are initially at rest. A horizontal force is applied, and the boxes move across the floor. The mass of the box with its contents and the *net* force acting on the box while the horizontal force is applied are given in each figure.



Rank the magnitude of the impulse on each box for a 2-second time interval.

___	___	___	___	OR	___	___	___
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

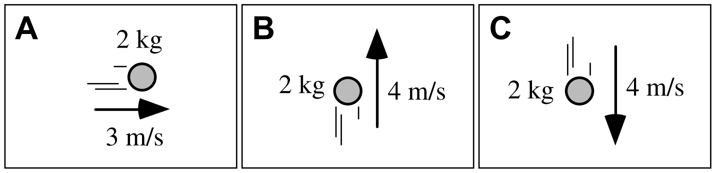
Explain your reasoning.

Answer: A = D > B = C. **WRONG!!!!!**

Impulse is defined as F*t, so here we can rank on F since the time is the same for all four.

B5-RT06: Moving Ball II—Momentum and Kinetic Energy

In the figures below, balls are traveling in different directions. The balls have the same size, mass and shape, but they are traveling with different velocities as shown.



(a) Rank the magnitude of the momentum of the balls.

1 Greatest	2	3 Least	OR	All the same	All zero	Cannot determine

Explain your reasoning.

Answr: B = C > A.

*Ranked on velocity based on magnitude of the momentum = mass*velocity which is proportional to velocity only since the mass is the same.*

(b) Rank the kinetic energy of the balls.

1 Greatest	2	3 Least	OR	All the same	All zero	Cannot determine

Explain your reasoning.

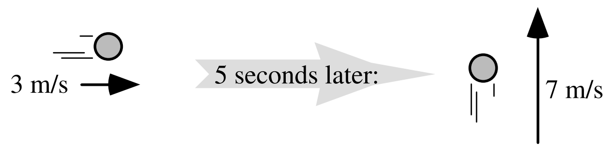
Answer: B = C > A.

Ranked on velocity based on kinitic energy is proportional to mass$velocity^2$ which is proportional to velocity only since the mass is the same.*

B5-WWT17: OBJECT CHANGING VELOCITY IV—IMPULSE

A student proposes the following description for the impulse on a 2-kg object that changes direction and speed as shown:

"The object goes from moving at 3 m/s in the positive x-direction to 7 m/s in the positive y-direction in 5 seconds. So the impulse given to it is 8 kg·m/s, since the impulse equals the change in momentum. The 5 seconds does not enter into the calculation of this impulse."

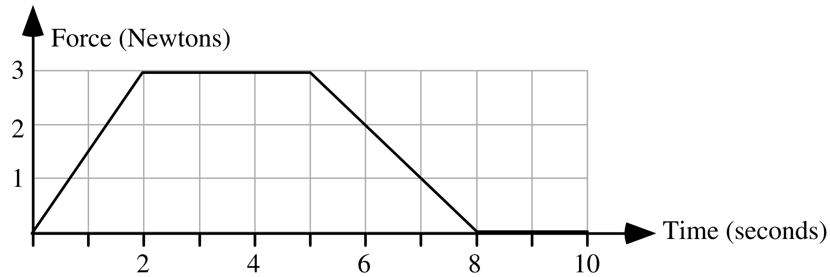


What, if anything, is wrong with this statement? If anything is wrong, identify it and explain how to correct it. If this statement is correct, explain why.

Answer: The 8 kg•m/s is incorrect since the impulse and the change in momentum are vector quantities and this description does not treat them as such. Using a coordinate axis with positive x to the right and positive y toward the top of the page, the final momentum of the object is zero in the x-direction, so the change in momentum in the x-direction is –6 kg•m/s. The initial momentum of the object in the y-direction is zero, so the change in momentum in the y-direction is 14 kg•m/s. We can use the Pythagorean theorem to find the magnitude of the change in momentum, which is 15.2 k•m/s. The direction of the change in momentum is 23.2 degrees to the left of the positive-y axis.

B5-RT18: Force-Time Graph I—Impulse Applied to Box

A 10-kg box, initially at rest, moves along a frictionless horizontal surface. A horizontal force to the right is applied to the box. The magnitude of the force changes as a function of time as shown.



Rank the impulse applied to the box by this force during each 2-second interval indicated below.

A. 0 to 2 s **B. 2 to 4 s** **C. 4 to 6 s** **D. 6 to 8 s** **E. 8 to 10 s**

					OR			
1 Greatest	2	3	4	5 Least		All the same	All zero	Cannot determine

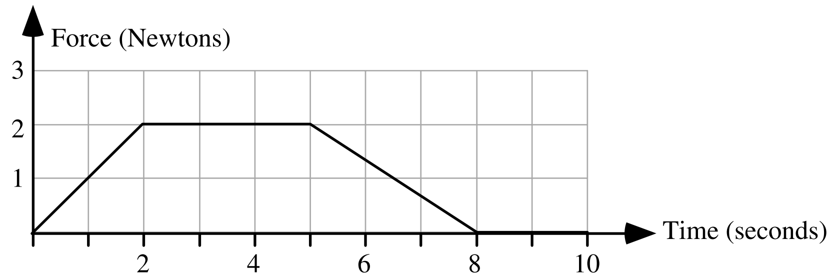
Explain your reasoning.

Answer: B > C > A > D > E.

The impulse for each time interval is equal to the area under the graph during that time interval. From zero to 2 seconds this is 2 kg m/s; from 2 to 4 seconds it is 4 kg m/s; from 4 to 6 seconds it is 3.67 kg m/s; from 6 to 8 seconds it is 1.33 kg m/s; and from 8 to 10 seconds it is zero. (Note that you don't really need to calculate values as a visual inspection will enable one to rank the areas.)

B5-WWT19: FORCE-TIME GRAPH II—IMPULSE APPLIED TO BOX

A 10-kg box, initially at rest, moves along a frictionless horizontal surface. A horizontal force to the right is applied to the box. The magnitude of the force changes as a function of time as shown.



A student calculates that the impulse applied by the force during the first 2 seconds is 4 N·s and that the impulse applied during the following 3 seconds is 6 N·s.

What, if anything, is wrong with these calculations? If something is wrong, identify it and explain how to correct it. If these calculations are correct, explain why.

Answer: The student's calculations are wrong.

The impulse is given by the area under the curve which for the first two seconds is 2 N·s since (1/2)·2 s·2 N= 2 N·s. The student's calculation for the next three seconds is correct.

B5-WWT20: TWO SKATERS PUSHING OFF EACH OTHER—FORCE

Two skaters, a large girl and a small boy, are initially standing face-to-face but then push off each other. After they are no longer touching, the boy has more kinetic energy than the girl. A physics student who is watching makes the following contention about the forces that the boy and girl exerted on each other:

"Since the boy has more kinetic energy, he also has more momentum, so the girl had to have pushed harder on him than he pushed on her."

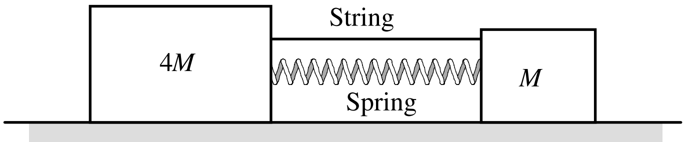
What, if anything, is wrong with this contention? If something is wrong, identify all problems and explain how to correct them. If this contention is correct, explain why.

Answer: The boy does not have a larger momentum than the girl after they push off each other; their momenta are equal.

Newton's Third Law requires that the forces the two exerted on each other had to have been equal in magnitude and oppositely directed, and since those forces acted for the same time intervals, the change in momentum had to be equal in magnitude but oppositely directed for the two skaters. Consequently, since they both started from rest, their final momenta are equal in magnitude.

B5-CT21: TWO BOXES ON A FRICTIONLESS SURFACE—MOMENTUM AND SPEED

Two boxes are tied together by a string and are sitting at rest on a frictionless surface. Between the two boxes is a massless compressed spring. The string tying the two boxes together is cut and the spring expands, pushing the boxes apart. The box on the left has four times the mass of the box on the right.



(a) After the string is cut and the boxes lose contact with the spring, will the magnitude of the momentum of the box on the left be (i) *greater than*, (ii) *less than*, or (iii) *equal to* the magnitude of the momentum of the box on the right? _____

Explain your reasoning.

Answer: (iii) Equal.

The same force—as required by Newton's third law—acts on both boxes for the same time interval, so they both experience the same impulse.

(b) At the instant (after the string is cut) that the boxes lose contact with the spring, will the speed of the box on the left be (i) *greater than*, (ii) *less than*, or (iii) *equal to* the speed of the box on the right? _____

Explain your reasoning.

Answer: (ii) less than.

The box on the left will have one-fourth the speed of the box on the right. Before the string is cut, the momentum of the system is zero. Momentum will be conserved, so the boxes will have equal but opposite momenta after they lose contact with the spring. So the box with the larger mass will have a lower speed.

B5-WWT22: BALL HITTING A WALL—MOMENTUM

A student observing a rubber ball hitting a wall and rebounding states:

"The change in momentum for the ball is equal and opposite to the change in momentum for the wall, because in this situation momentum has to be conserved."

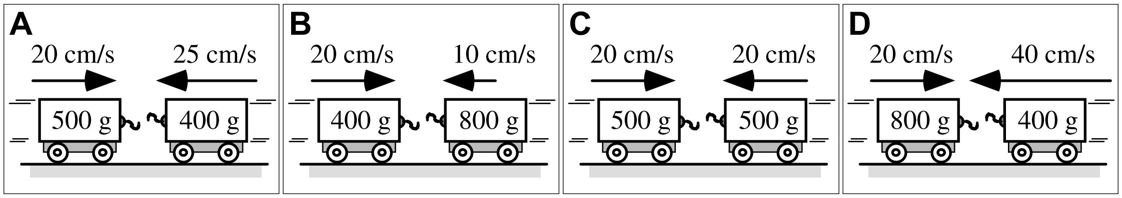
What, if anything, is wrong with this statement? If something is wrong, identify it and explain how to correct it. If this statement is correct, explain why.

Answer: This statement is incorrect.

Momentum is conserved for a system if there is no net impulse acting on that system. If we consider the ball and the wall as a single system, during the collision the ground will exert a horizontal force on the wall and there will be a net impulse on the system. Momentum is not conserved for the system of the ball and wall.

B5-RT23: Colliding Carts Sticking Together—Final Speed

Two carts traveling in opposite directions are about to collide. The carts are all identical in size and shape, but they carry different loads and are traveling at different speeds. The carts stick together after the collision. There is no friction between the carts and the ground.



Rank the speed of the two-cart systems after the collision.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

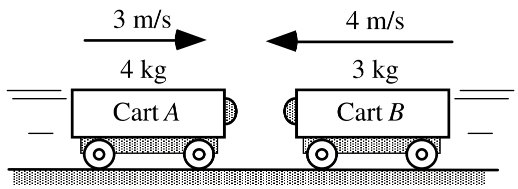
Explain your reasoning.

Answer: The final speed is zero for all of the cart systems.

The total initial momentum of the system of two carts is zero for all cases, so after the collision the two carts, which are stuck together, will be at rest.

B5-SCT24: TWO MOVING CARTS—RESULT OF COLLISION

Carts A and B are shown just before they collide. Four students discussing this situation make the following contentions:



Alma: *"After the collision, the carts will stick together and move off to the left. Cart B has more speed, and its speed is going to determine which cart dominates in the collision."*

Baxter: *"I think they'll stick together and move off to the right because Cart A is heavier. It's like when a heavy truck hits a car: The truck is going to win no matter which one's going fastest, just because it's heavier."*

Callie: *"I think the speed and the mass compensate, and the carts are going to be at rest after the collision."*

Dante: *"The carts must have the same momentum after the collision as before the collision, and the only way this is going to happen is if they keep the same speeds. All the collision does is change their directions, so that Cart A will be moving to the left at 3 m/s and Cart B will be moving to the right at 4 m/s."*

With which, if any, of these students do you agree?

Alma _____ Baxter _____ Callie _____ Dante _____ None of them_____

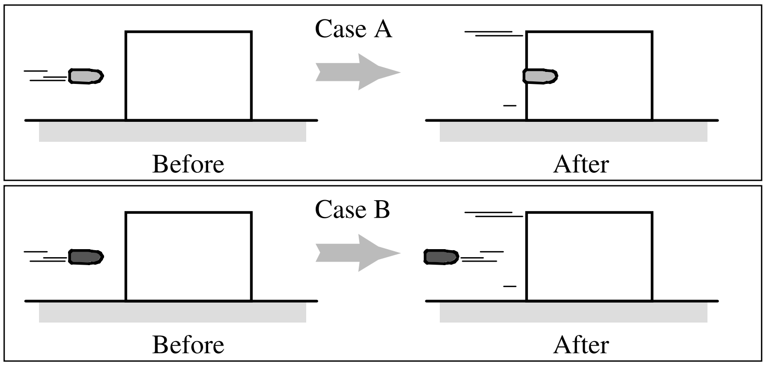
Explain your reasoning.

Answer: None of these contentions is correct.

We do not have enough information to determine the velocity of either cart after the collision. Momentum will be conserved for the collision, but this could happen in a number of ways, such as the carts sticking together and remaining at rest, or the carts bouncing off one another. What actually happens depends on the construction of the carts and on the material of the surfaces that come into contact (rubber, clay, Velcro, etc.).

B5-CT25: Bullet Strikes a Wooden Block—Block and Bullet Speed After Impact

In Case A, a metal bullet penetrates a wooden block. In Case B, a rubber bullet with the same initial speed and mass bounces off of an identical wooden block.

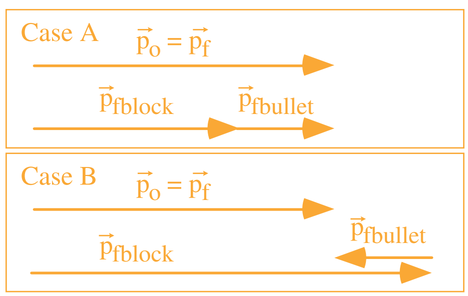


(a) Will the speed of the wooden block after the collision be (i) *greater* in Case A, (ii) *greater* in Case B, or (iii) *the same* in both cases? _____

Explain your reasoning.

Answer: (ii) Greater in case B.

The initial momentum in both cases is the same and points to the right. The final momentum of the bullet points to the right in case A and to the left in case B. Since the final momentum of the system consisting of the bullet and the block is the same as the initial momentum, and this final momentum is the vector sum of the momentum of the bullet and the momentum of the block, the momentum of the block must be greater in case B.



(b) In Case B, will the speed of the bullet after the collision be (i) *greater than*, (ii) *less than*, or (iii) *the same as* the speed of the bullet just before the collision? _____

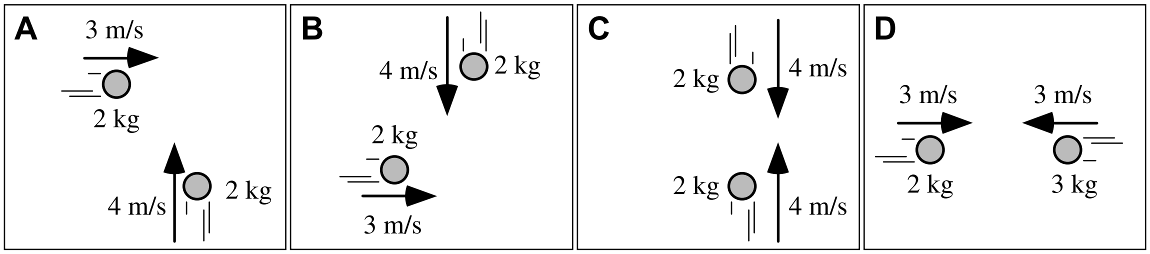
Explain your reasoning.

Answer: (ii) Less than.

The energy of the system containing both block and bullet cannot be greater after the collision than before. The initial energy is the kinetic energy of the bullet, and the final energy is the sum of the kinetic energies of the bullet and the block. Since the block has a non-zero final kinetic energy, the final kinetic energy of the bullet must be less than the initial kinetic energy of the bullet.

B5-RT28: COLLIDING BALL SYSTEMS—MOMENTUM BEFORE AND AFTER COLLIDING

In the figures below, two balls traveling in different directions are about to collide. The balls are identical in size and shape, but they have different masses and are traveling at different velocities as shown.



(a) Rank the magnitude of the momentum of the two-ball systems before they collide.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Answr: A = B > D > C.

Since we add these vectorially giving 10 (kg)(m)/s at an angle for A and B, C is zero, and D is 3 (kg)(m)/s.

(b) Rank the magnitude of the momentum of the two-ball systems after they collide if the balls stick together.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Answr: A = B > D > C.

Same as (a) since momentum of the system is conserved.

(c) Rank the magnitude of the momentum of the two-ball systems after they collide elastically (energy conserved).

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

Answr: A = B > D > C.

Same as (a) since momentum of the system is conserved