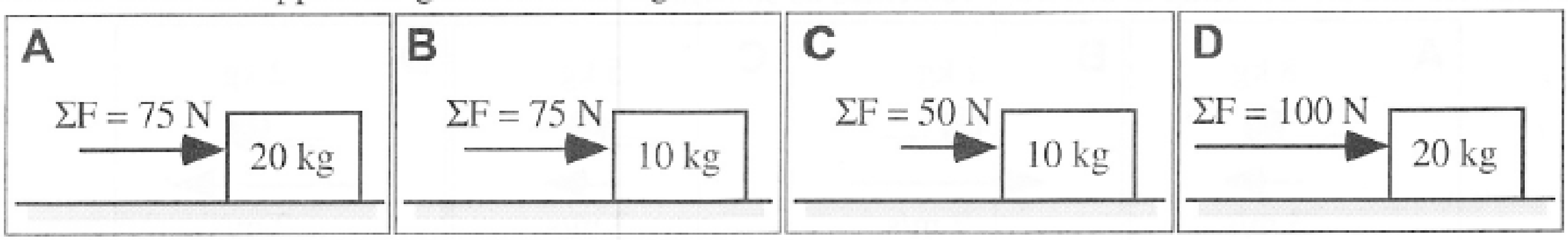
B5-RT02: FORCE PUSHING BOX I—CHANGE IN MOMENTUM

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.

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

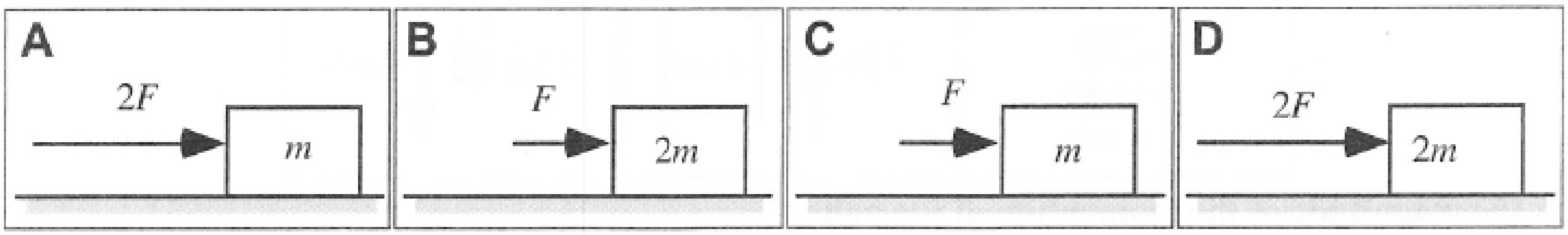
Explain your reasoning.

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-RT04: FORCE PUSHING BOX III—CHANGE IN MOMENTUM

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 change in momentum for each box for the same time interval.

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

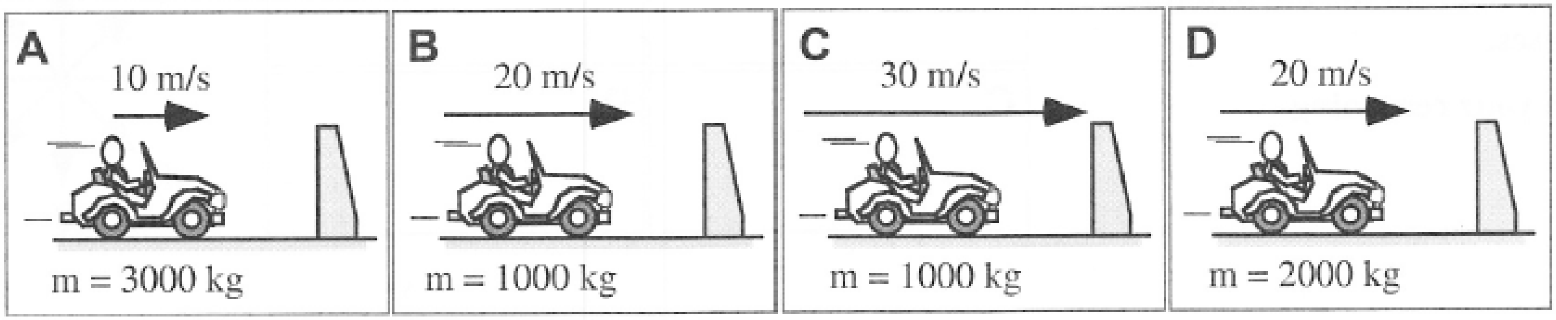
Explain your reasoning.

Answer: A = D > B = C.

*Since change in momentum related to impulse = F*t, so we can rank on F since the time is the same for all four cases.*

B5-RT08: Cars Stopped by Constant Force Barriers—Stopping Time

Cars moving along horizontal roads are about to be stopped when they hit a protective barrier. All of the cars are the same size and shape, but they are moving at different speeds and have different masses. The barriers are all identical and exert the same constant force.



Rank the time that it takes to stop the cars as the barriers apply the same constant force.

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

Explain your reasoning.

Answer: D > A = C > B.

Since the same force is acting on all cars and we are asked about the time interval to bring the cars to rest, the physical quantity involved is the momentum. The barriers are going to exert an impulse on the cars bringing them to rest and that impulse will be equal to the change in momentum for the cars. So the ranking is based on the product of the mass and velocity.

B5-WWT16: Object Changing Velocity III—Impulse

A 2-kg object accelerates as a net external force is applied to it. During the 5-second interval that the force is applied, the object's velocity changes from 3 m/s to the right to 7 m/s to the left.

A student states:

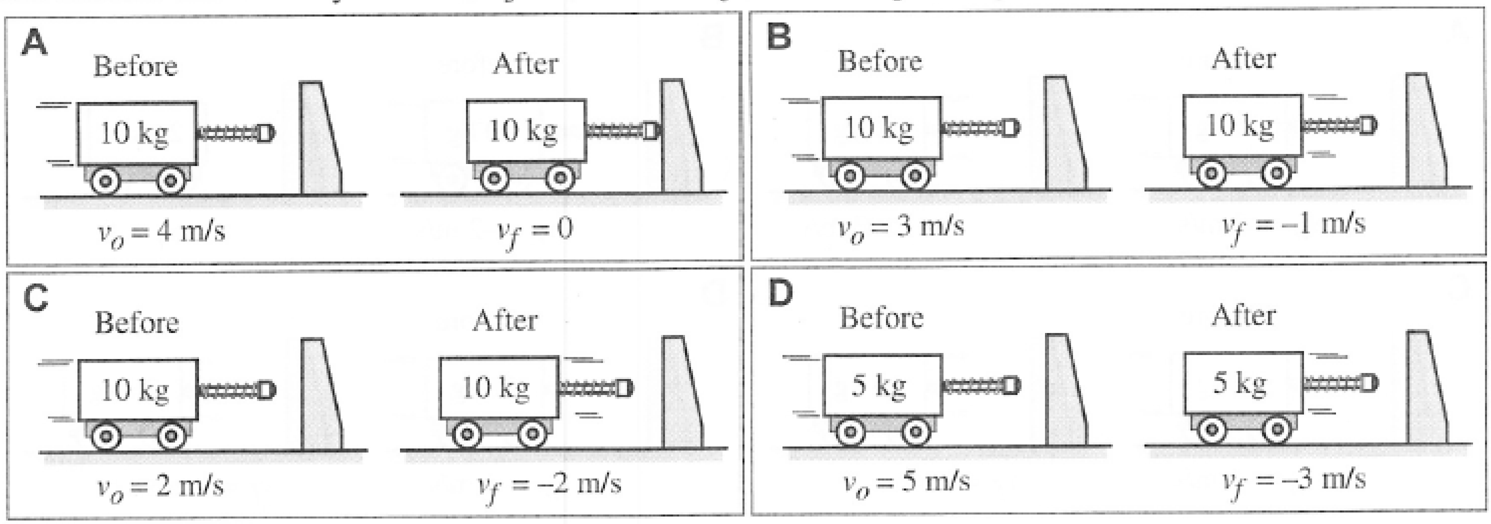
"The change in velocity for this 2 kg object was 4 m/s, so the change in momentum, and also the impulse, was 8 kg·m/s."

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 because momentum is a vector so the change in momentum (taking to the right as the positive direction) is equal to 2 kg (–7 m/s – (+3 m/s)) = –20 kg•m/s, or 20 kg•m/s to the left.

B5-RT10: Bouncing Cart I—Change in Momentum

Carts with spring plungers run into fixed barriers. The carts are identical but are carrying different loads and so have different masses. The velocity of the cart just before and just after impact is given.



Rank the magnitude of the change in momentum of these carts.

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

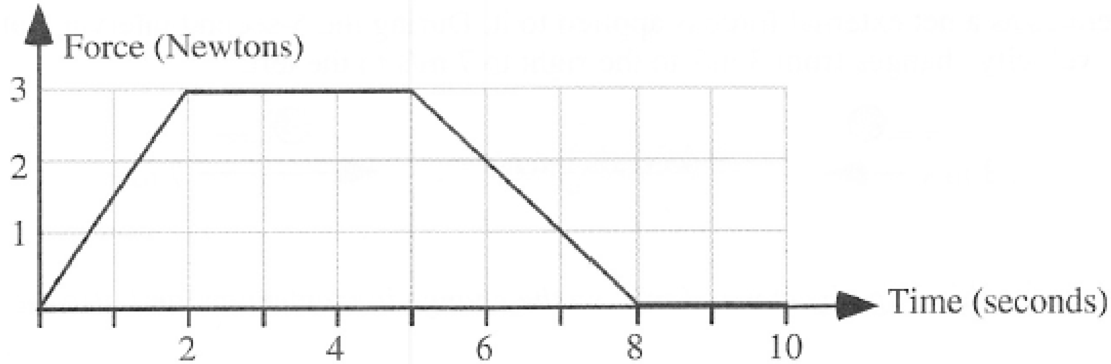
Explain your reasoning.

Answer: All have the same change in momentum, 40 kgm/s to the left.

The change in momentum is the final momentum minus the initial momentum, but in calculating this we have to keep in mind that momentum is a vector quantity. That means our calculations have to use the signs of the velocity, so for example, the change in momentum of case B (with positive directions to the right) is –10 (kg)(m)/s –30 (kg)(m)/s = –40 (kg)(m)/s.

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**

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

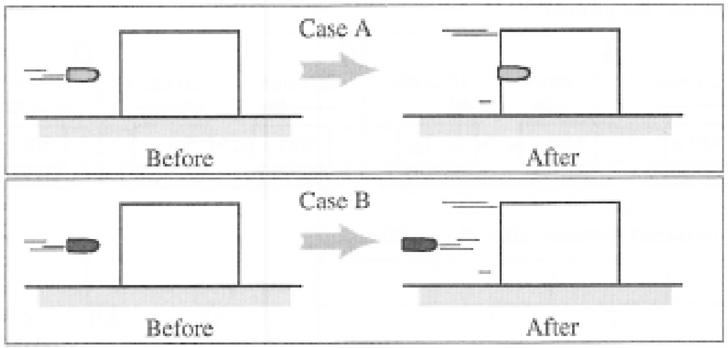
Explain your reasoning.

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-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.

(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? _____

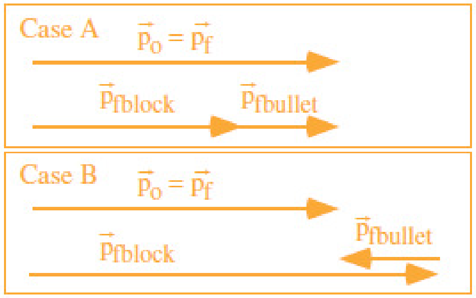
Explain your reasoning.

(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.

(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.

(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.

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

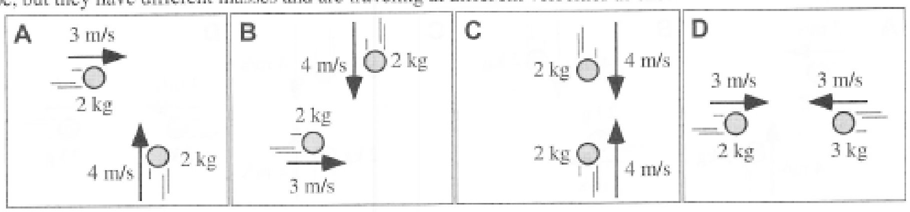
Explain your reasoning.

Answr: A = B > D > C.

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

B5-QRT29: Colliding Ball Systems—Momentum Direction before and after Colliding

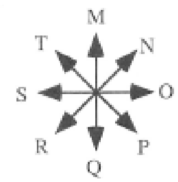
In the figures below, two balls traveling in different directions are about to collide. The balls have the same size and shape, but they have different masses and are traveling at different velocities as shown.



For the questions below, use the directions indicated by the arrows in the direction rosette, or use **J** for no direction, **K** for into the page, or **L** for out of the page.

(a) Identify the closest directional match for the direction of the momentum of the two-ball systems before they collide.

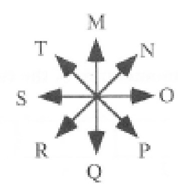
A	B
C	D



Explain your reasoning.

(b) Identify the closest directional match for the direction of the momentum of the two-ball systems after they collide if the balls stick together.

A	B
C	D

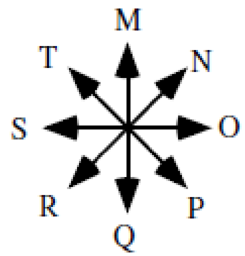


Explain your reasoning.

Answer: A is N, B is P, C is J since the momentum is zero, D is S.
The question is asking about the total momentum of the system which is the vector addition of the two momenta.

(b) Identify the closest directional match for the direction of the momentum of the two-ball systems after they collide if the balls stick together.

A	B
C	D



A is N, B is P, C is J since it is zero, D is S.

Explain your reasoning.

Momentum is conserved so the momentum of the system is the same direction after as before collision in all the cases. The direction of the momentum of the system is the vector sum of the momentum of the two parts.