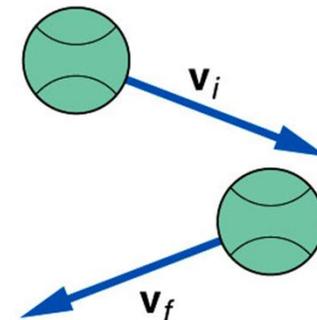


Elastic and Inelastic Collisions

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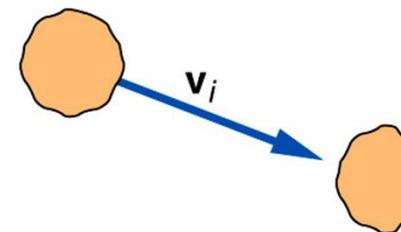
- Different kinds of collisions produce different results.
 - Sometimes the objects stick together.
 - Sometimes the objects bounce apart.
- What is the difference between these types of collisions?
- Is energy conserved as well as momentum?

Elastic



$$v_f = v_i$$

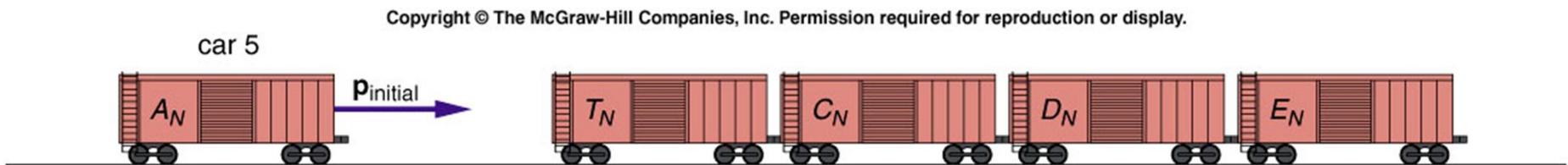
Perfectly inelastic



$$v_f = 0$$

Elastic and Inelastic Collisions

- A collision in which the objects stick together after collision is called a ***perfectly inelastic collision***.
 - The objects do not bounce at all.
 - If we know the total momentum before the collision, we can calculate the final momentum and velocity of the now-joined objects.
- For example:
 - The football players who stay together after colliding.
 - Coupling railroad cars.

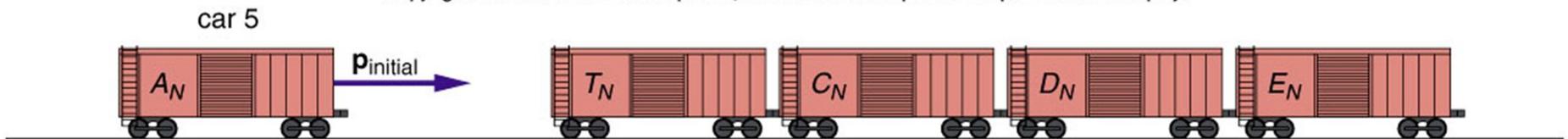


Four railroad cars, all with the same mass of 20,000 kg, sit on a track. A fifth car of identical mass approaches them with a velocity of 15 m/s. This car collides and couples with the other four cars. What is the initial momentum of the system?

- a) 200,000 kg·m/s
- b) 300,000 kg·m/s
- c) 600,000 kg·m/s
- d) 1,200,000 kg·m/s

$$\begin{aligned}m_5 &= 20,000 \text{ kg} \\v_5 &= 15 \text{ m/s} \\p_{\text{initial}} &= m_5 v_5 \\&= (20,000 \text{ kg})(15 \text{ m/s}) \\&= 300,000 \text{ kg}\cdot\text{m/s}\end{aligned}$$

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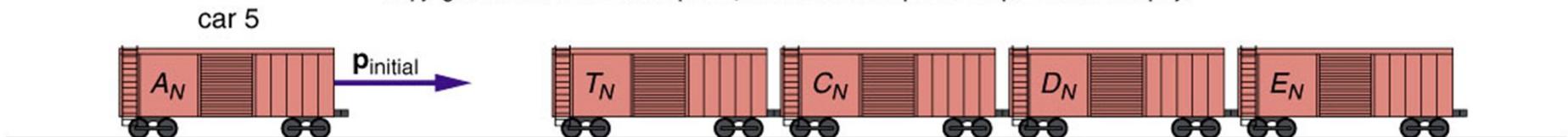


What is the velocity of the five coupled cars after the collision?

- a) 1 m/s
- b) 3 m/s
- c) 5 m/s
- d) 10 m/s

$$\begin{aligned} m_{\text{total}} &= 100,000 \text{ kg} \\ p_{\text{final}} &= p_{\text{initial}} \\ v_{\text{final}} &= p_{\text{final}} / m_{\text{total}} \\ &= (300,000 \text{ kg}\cdot\text{m/s}) / (100,000 \text{ kg}) \\ &= 3 \text{ m/s} \end{aligned}$$

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Is the kinetic energy after the railroad cars collide equal to the original kinetic energy of car 5?

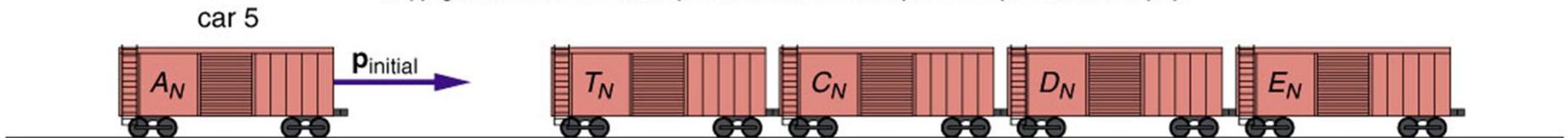
- a) yes
- b) no
- c) It depends.

$$\begin{aligned} KE_{\text{initial}} &= 1/2 m_5 v_5^2 \\ &= 1/2 (20,000 \text{ kg})(15 \text{ m/s})^2 \\ &= 2250 \text{ kJ} \end{aligned}$$

$$\begin{aligned} KE_{\text{final}} &= 1/2 m_{\text{total}} v_{\text{final}}^2 \\ &= 1/2 (100,000 \text{ kg})(3 \text{ m/s})^2 \\ &= 450 \text{ kJ} \end{aligned}$$

$$KE_{\text{final}} \neq KE_{\text{initial}}$$

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Elastic and Inelastic Collisions

- Energy is not conserved in a *perfectly inelastic collision*.
- If the objects bounce apart instead of sticking together, the collision is either *elastic* or *partially inelastic*.
 - An *elastic collision* is one in which *no energy is lost*.
 - A *partially inelastic collision* is one in which *some energy is lost*, but the objects do not stick together.
 - The *greatest portion of energy is lost* in the *perfectly inelastic collision*, when the objects stick.

- A ball bouncing off a floor or wall with no decrease in the magnitude of its velocity is an *elastic collision*.
 - The kinetic energy does not decrease.
 - No energy has been lost.
- A ball sticking to the wall is a *perfectly inelastic collision*.
 - The velocity of the ball after the collision is zero.
 - Its kinetic energy is then zero.
 - All of the kinetic energy has been lost.
 - Does the total momentum become zero?
 - A). Yes
 - B). No.

- A ball bouncing off a floor or wall with no decrease in the magnitude of its velocity is an *elastic collision*.
 - The kinetic energy does not decrease.
 - No energy has been lost.
- A ball sticking to the wall is a *perfectly inelastic collision*.
 - The velocity of the ball after the collision is zero.
 - Its kinetic energy is then zero.
 - All of the kinetic energy has been lost.
 - Does the total momentum become zero?
- Most collisions involve some energy loss, even if the objects do not stick, because the collisions are not perfectly elastic.
 - Heat is generated, the objects may be deformed, and sound waves are created.
 - These would be *partially inelastic collisions*.

1N-02 Collision of Two Large Balls

What happens when two large balls of equal mass collide right one is at rest at the other has velocity v_1 ?



- A). Velocity of right ball is v_1 , left one is 0
- B). Velocity of left ball is v_1 , right one is 0
- C). Velocity of left and right are the same but less than v_1
- D). Depends on how they collide.

1N-02 Collision of Two Large Balls

What happens when two large balls of equal mass collide one is at rest at the other has velocity v_1 ?



Conservation of momentum

$$mv_1 + mv_2 = mv_{1A} + mv_{2A}$$

$$\rightarrow v_1 = v_{1A} + v_{2A}$$

Conservation of Energy (*Elastic*)

$$\frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2 = \frac{1}{2}mv_{1A}^2 + \frac{1}{2}mv_{2A}^2$$

$$\rightarrow v_1^2 = v_{1A}^2 + v_{2A}^2 \quad v_{1A} = 0 \text{ \& } v_{2A} = v_1$$

Completely *Inelastic* collision (stick together)

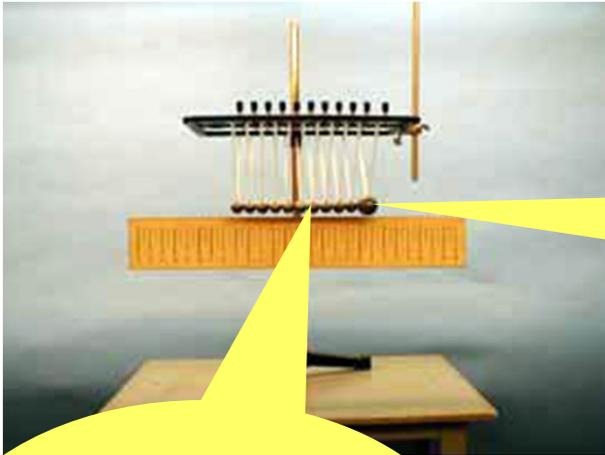
$$mv_1 + mv_2 = (m + m)v_A \quad (v_2 = 0)$$

$$\rightarrow v_1 = 2v_A \quad v_A = \frac{1}{2}v_1$$

• In practice some energy is always lost. You can hear the noise when they hit and there will be some heat generated at impact

1N-12 Fun Balls

An enlarged version of the Classic Toy - The Array of Steel Balls



First case pull back one ball and release

What happens if we use more than one ball?

What happens when more of the balls are pulled back than are left at rest?

The collision is nearly elastic so we can use both momentum conservation and kinetic energy conservation

•NO MATTER HOW MANY BALLS ARE PULLED BACK, THE SAME NUMBER RECOIL AT THE SAME SPEED.

Ch 7 E 10

M_1 and M_2 collide head on

a) Find initial momentum of M_1 and M_2

b) What is the total momentum of the system before collision?



a) $p_1 = -100 \times 3.5 = 350\text{kgm/s}$ $p_2 = 80 \times 6 = 480\text{kgm/s}$

b) Total momentum = $480 - 350 = 130\text{kgm/s}$ east

Ch 7 E 10

c) Ignore external forces, if they stick together after collision, which way do the masses travel?



$$p_1 = -100 \times 3.5 = 350\text{kgm/s} \quad p_2 = 80 \times 6 = 480\text{kgm/s}$$

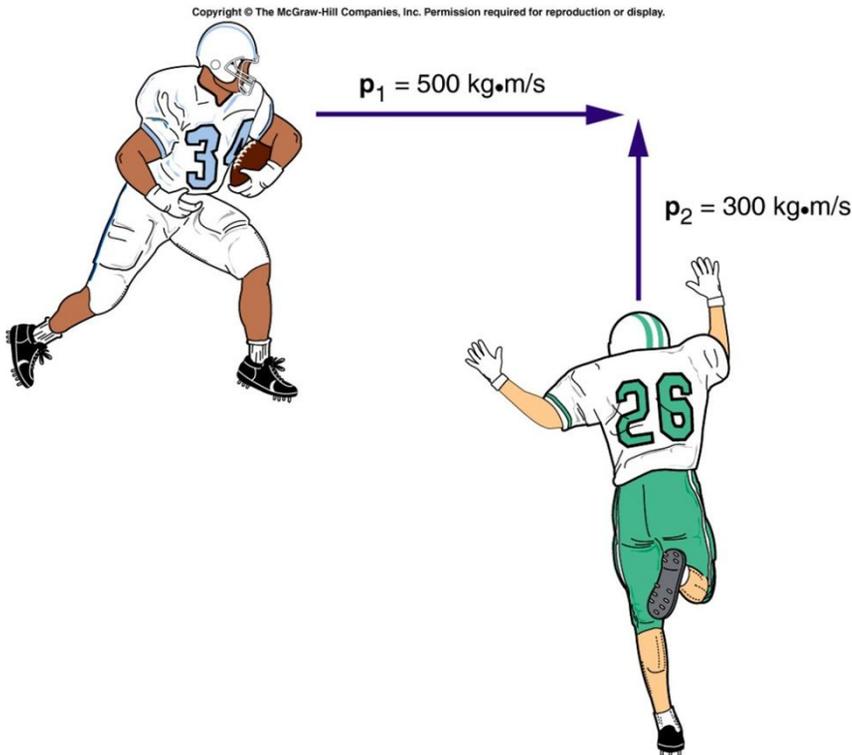
$$\text{Total momentum} = 480 - 350 = 130\text{kgm/s east}$$

- A. West
- B. East
- C. they will all stop

c) The masses will travel **east with $p = 130\text{kgm/sec}$**

Collisions at an Angle

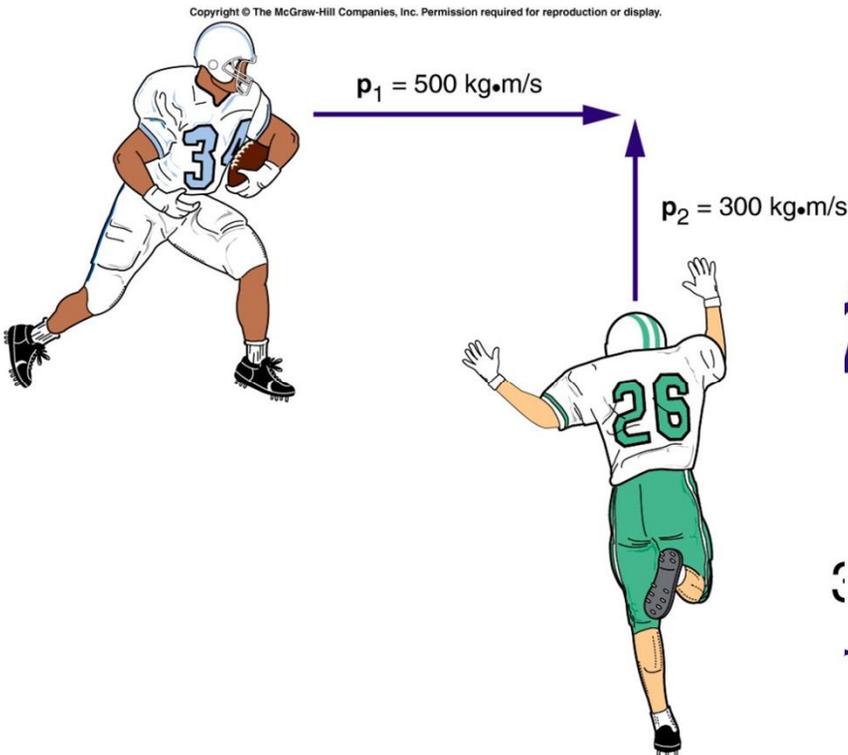
- Two football players traveling at right angles to one another collide and stick together.
 - What will be their direction of motion after the collision?



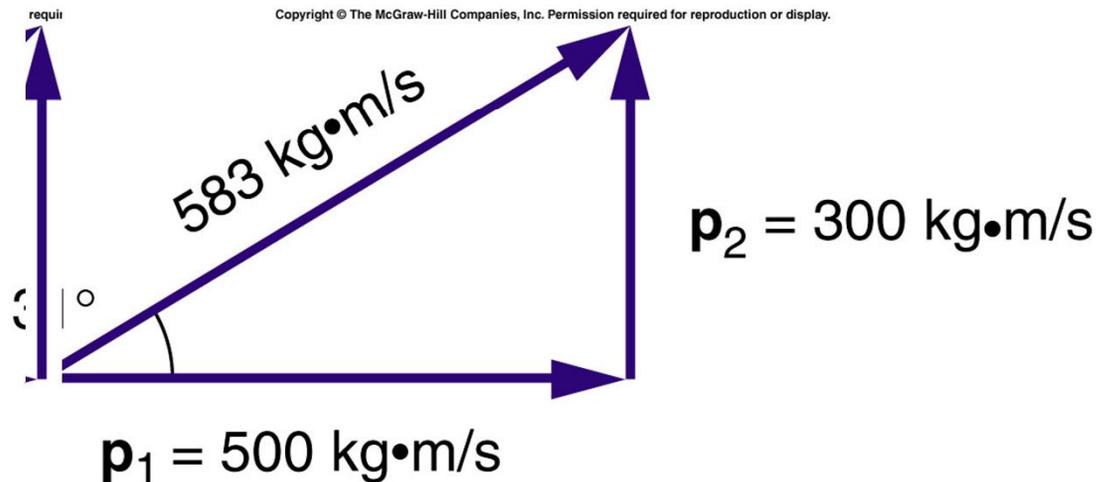
- Add the individual momentum vectors to get the total momentum of the system before the collision.
- The final momentum of the two players stuck together is equal to the total initial momentum.

Collisions at an Angle

- The total momentum of the two football players prior to the collision is the vector sum of their individual momentums.



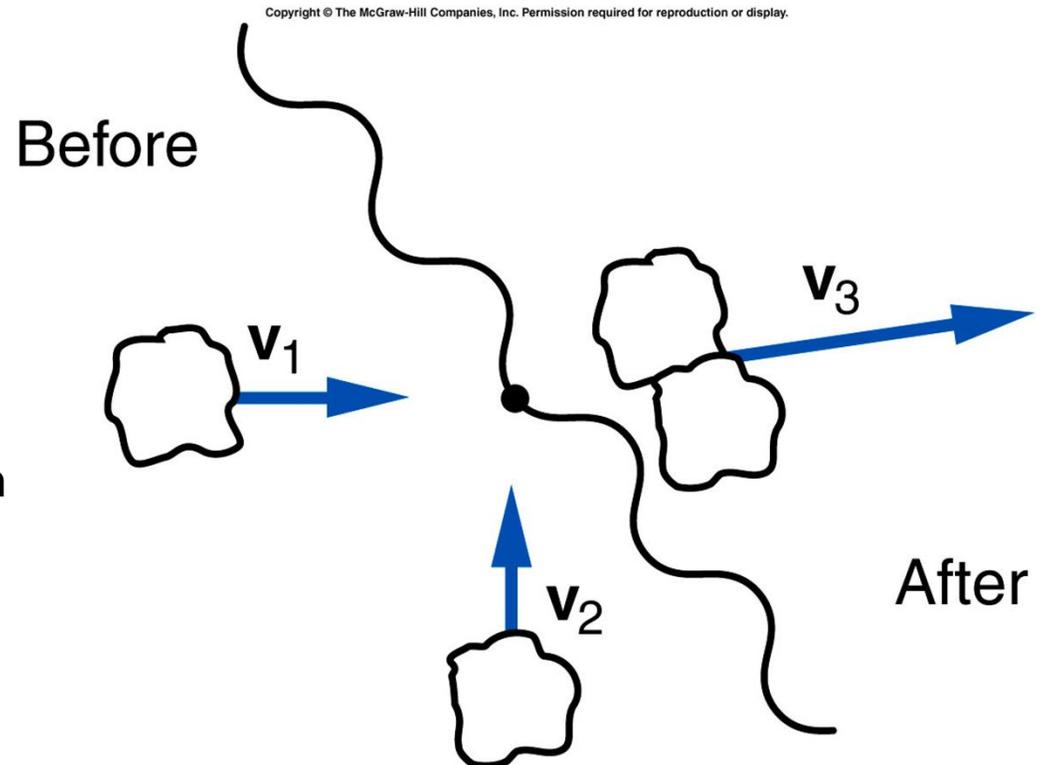
The larger initial momentum has a larger effect on the direction of motion.



Two lumps of clay of equal mass are traveling at right angles with equal speeds as shown, when they collide and stick together. Is it possible that their final velocity vector is in the direction shown?

- a) yes
- b) no
- c) unable to tell from this graph

No. The final momentum will be in a direction making a 45° degree angle with respect to each of the initial momentum vectors.



Ch 7 E 18

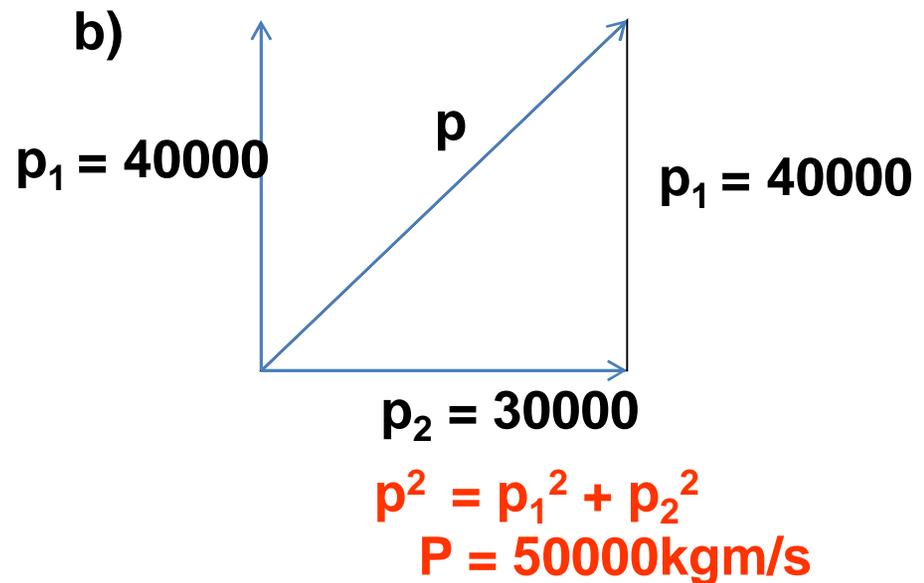
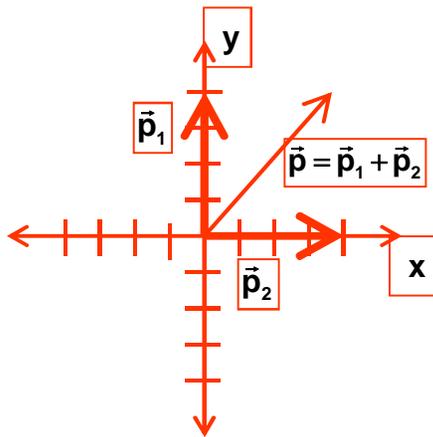
A truck of mass 4000kg and speed 10m/s collides at right angles with a car of mass 1500kg and a speed of 20m/s. What's the total momentum of system before collision?

- A. 70000 kg m/s
- B. 10000 kg m/s
- C. 50000 kg m/s
- D. 40000 kg m/s
- E. 30000 kg m/s

Ch 7 E 18

A truck of mass 4000kg and speed 10m/s collides at right angles with a car of mass 1500kg and a speed of 20m/s. What's the total momentum of system before collision?

a) $p_1 = 40000\text{kgm/s} + y$
 $p_2 = 30000\text{kgm/s} + x$



Ch 7 CP 2

A bullet is fired into block sitting on ice. The bullet travels at 500 m/s with mass 0.005 kg. The wooden block is at rest with a mass of 1.2 kg. Afterwards the bullet is embedded in the block. Find the velocity of the block and bullet after the impact (ignore all frictions).

- A. 3.02 m/s
- B. 2.07 m/s
- C. 500.3 m/s
- D. 250.6 m/s
- E. 12.02 m/s

a) $p_{\text{final}} = p_{\text{initial}} = (0.005 \text{ kg})(500 \text{ m/s})$
 $p_{\text{final}} = (M_{\text{bullet}} + M_{\text{wood}})v = 2.5 \text{ kg m/s}$
 $v = (2.5 \text{ kg m/s}) / (1.205 \text{ kg}) = 2.07 \text{ m/s}$

Ch 7 CP 2

A bullet is fired into wood block sitting on ice. The bullet travels at 500 m/s with mass 0.005 kg. The wooden block is at rest with a mass of 1.2 kg. Afterwards the bullet is embedded in the block. Find the magnitude of the impulse on the block of wood.

- A. 2.07 kg m/s
- B. 1.2 kg m/s
- C. 0.0005 kg m/s
- D. 2.5 kg m/s
- E. 0

$$\begin{aligned} \text{b) Impulse} &= \Delta p = p_{\text{final}} - p_{\text{initial}} \\ &= (1.2 \text{ kg})(2.07 \text{ m/s}) - 0 = \mathbf{2.50} \\ &\quad \mathbf{\text{kg m/s}} \end{aligned}$$

Ch 7 CP 2

A bullet is fired into block sitting on ice. The bullet travels at 500 m/s with mass 0.005 kg. The wooden block is at rest with a mass of 1.2 kg. Afterwards the bullet is embedded in the block. Does the change in momentum of the bullet equal that of wood and how much are the changes?

A. yes. 2.50 kg m/s

B. No. Wood changes 2.50 kg m/s. Bullet changes less than that.

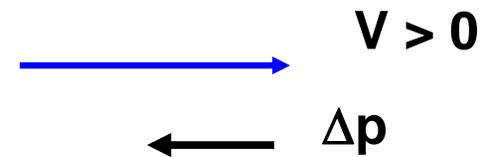
$$\begin{aligned} \text{c) } \Delta p \text{ for bullet} &= (0.005 \text{ kg})(500 \text{ m/s}) - (0.005 \text{ kg})(2.07 \text{ m/s}) \\ &= 2.50 \text{ kg m/s} \end{aligned}$$

Momentum is conserved, so momentum lost by bullet is gained by wood.

Ch 7 CP 4

**Car travels 18 m/s and hits concrete wall. $M_{\text{driver}} = 90 \text{ kg}$.
Find change in momentum of driver.**

- A. 1620 kg m/s
- B. 0 kg m/s
- C. 90 kg m/s
- D. -1620 kg m/s



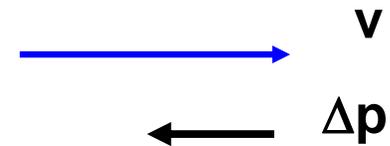
a) When driver comes to a stop his $p = 0$.

$$\Delta p = 0 - (18 \text{ m/s})(90 \text{ kg}) = -1620 \text{ kg m/s}$$

Ch 7 CP 4

Car travels 18 m/s and hits concrete wall. $M_{\text{driver}} = 90 \text{ kg}$.
What impulse produces this change in momentum?

- A. 1620 kg m/s
- B. 0 kg m/s
- C. 90 kg m/s
- D. -1620 kg m/s



Impulse = $\Delta p = -1620 \text{ kg m/s}$

Quiz: Two cars of equal mass collide at right angles to one another in an intersection. Their direction of motion after the collision is as shown. Which car had the greater velocity before the collision?

- a) Car A
- b) Car B
- c) Their velocities were equal in magnitude.
- d) It is impossible to tell from this graph.

Since the angle with respect to the original direction of A is smaller than 45° , car A must have had a larger momentum and thus was traveling faster.

