# Impulse & Momentum

# 7.1 Momentum

- Can you have inertia sitting in your seat?
- Do you have momentum (relative to the room) sitting in your seat?
- What is momentum?

# 7.1 Momentum

- Which is harder to stop a truck moving 30 mph or a motorcycle moving 40 mph?
- Why?

# 7.1 Momentum

- The truck has more momentum than the motorcycle even though it is moving slower.
- What about a parked truck or a motorcycle moving at 5 mph?

## 7.1 Momentum

$$p = mv$$

- The truck has more inertia but The motorcycle has more momentum.
- Momentum is a product of mass and velocity!
- momentum = mass × velocity
- $p = mv$
- Momentum has both direction and magnitude. It is a *vector quantity.*

# 7.2 Impulse

$$p = mv$$

- What factors affect an object's momentum?
- Mass
- Velocity
- What about Force?

# 7.2 Impulse

$$p = mv$$

- When you push with the same force for twice the time, you impart twice the impulse and produce twice the change in momentum.

# 7.2 Impulse

$$Ft = \Delta(mv)$$

- The quantity *force* × *time interval* is called **impulse.**

$$\textbf{impulse} = F \times t$$

- The greater the impulse exerted on something, the greater will be the change in momentum.
- impulse = change in momentum

$$Ft = \Delta(mv)$$

# 7.2 Impulse

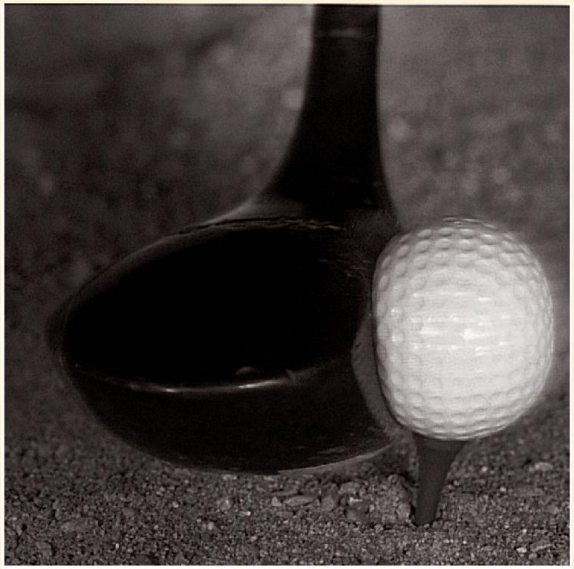
$$Ft = \Delta(mv)$$

- How do you increase momentum then?
- Have you ever heard of follow through when playing a sport?

# 7.2 Impulse

$$Ft = \Delta(mv)$$

- The longer the golf club is in contact with the golf ball means the greater the change in momentum.
- This works with
  - Baseball
  - Tennis
  - Soccer
  - Football
  - Many other sports



# 7.2 Impulse

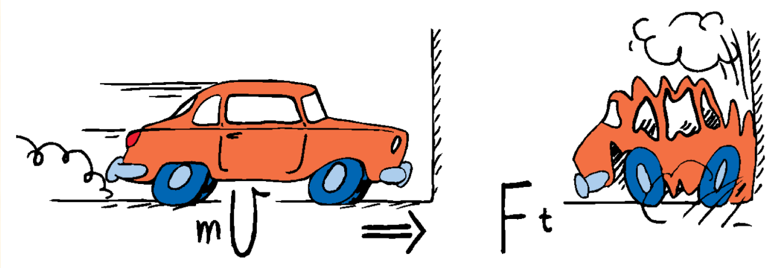
$$Ft = \Delta(mv)$$

- If you had a choice between wrecking into a hay stack or a brick wall which would you choose?
- Why?

# 7.2 Impulse

$$Ft = \Delta(mv)$$

- The change in momentum must be the same for both situations. There is a trade out between force and time. The haystack takes longer to slow the car down so there is less force involved.

# 7.2 Impulse

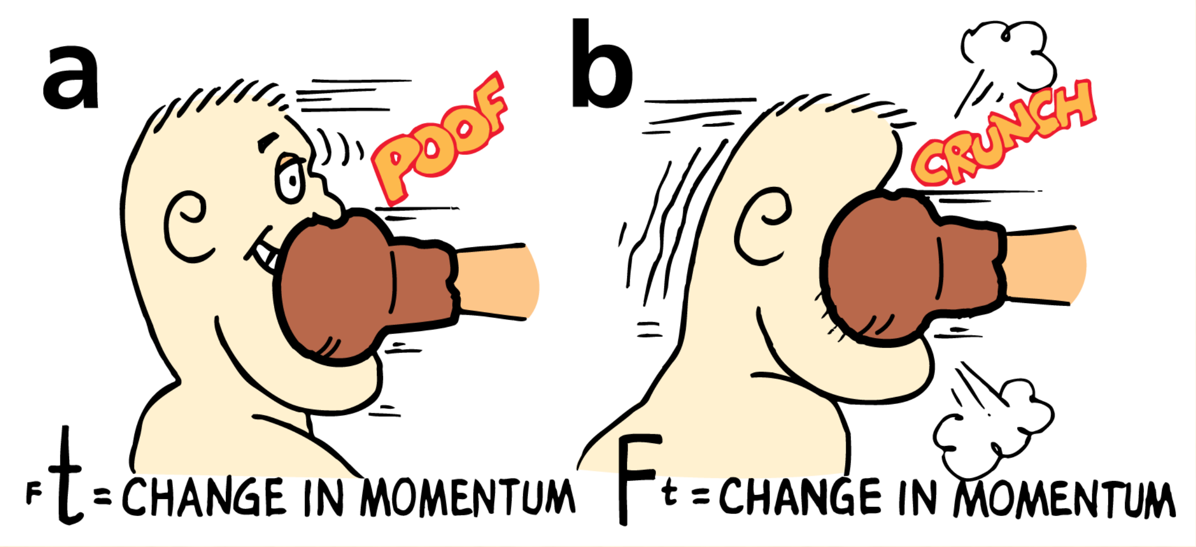
$$Ft = \Delta(mv)$$

- What other applications has this relationship been applied to?

# 7.2 Impulse

$$Ft = \Delta(mv)$$

- If a boxer gets hit in the jaw should they stay firm or move back while the hit is occurring?



# 7.3 Bouncing

$$Ft = \Delta(mv)$$

- Which has a greater change in momentum, catching a falling flower pot or catching it and throwing it back up again?
- Catching it and throwing it up again does! You have the change in velocity to bring it to a stop then a change in velocity to throw it up again.

# 7.3 Bouncing

$$Ft = \Delta(mv)$$

- What hurts more than a flower pot that falls and hits you on the head then breaks and falls on to the ground or the one that hits your head and bounces back up again?
- The one that bounces, it produces as much as twice as much force on your head!

# 7.3 Bouncing

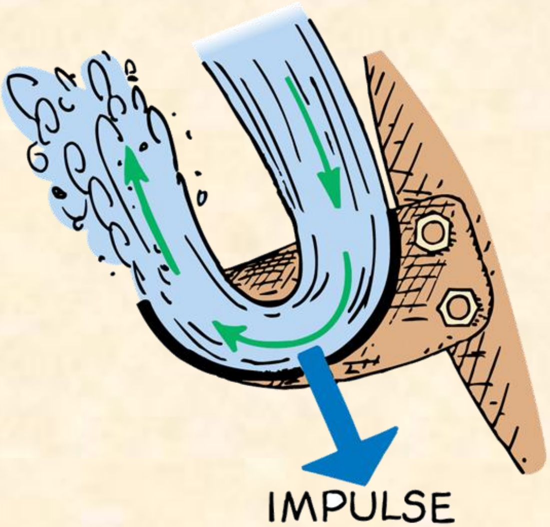
$$Ft = \Delta(mv)$$

- The impulse required to bring an object to a stop and then to “throw it back again” is greater than the impulse required merely to bring the object to a stop.   This is what happens when something “Bounces”.

# 7.3 Bouncing

$$Ft = \Delta(mv)$$

- The curved blades of the Pelton Wheel cause water to bounce and make a U-turn, producing a large impulse that turns the wheel.




$$p_{before} = p_{after}$$

# 7.4 Conservation of Momentum

- The law of conservation of momentum states that, in the absence of an external force, the momentum of a system remains unchanged.

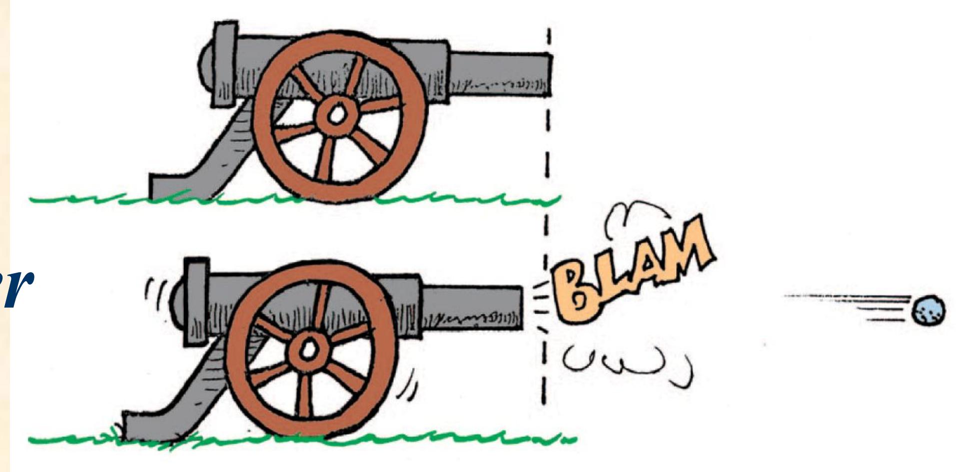
$$p_{before} = p_{after}$$

$$p_{before} = p_{after}$$

# 7.4 Conservation of Momentum

- The momentum before firing a cannon is zero. After firing, the net momentum is still zero because the momentum of the cannon is equal and opposite to the momentum of the cannonball.

$$p_{before} = p_{after}$$



# 7.5 Collisions $mv_{before} = mv_{after}$

- So if the momentum before must equal the momentum after we can expand the equation a bit.

$$p_{before} = p_{after}$$

$$mv_{before} = mv_{after}$$

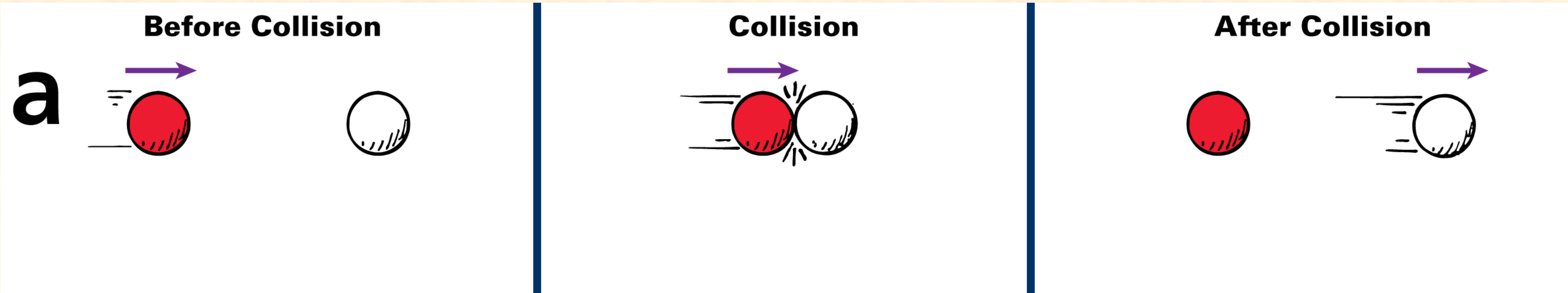
# 7.5 Collisions $mv_{before} = mv_{after}$

- **Elastic Collisions**
  - When objects collide without being permanently deformed and without generating heat, the collision is an elastic collision.
  - Colliding objects bounce perfectly in perfect elastic collisions.
  - The sum of the momentum vectors is the same before and after each collision.

# 7.5 Collisions

$$mv_{before} = mv_{after}$$

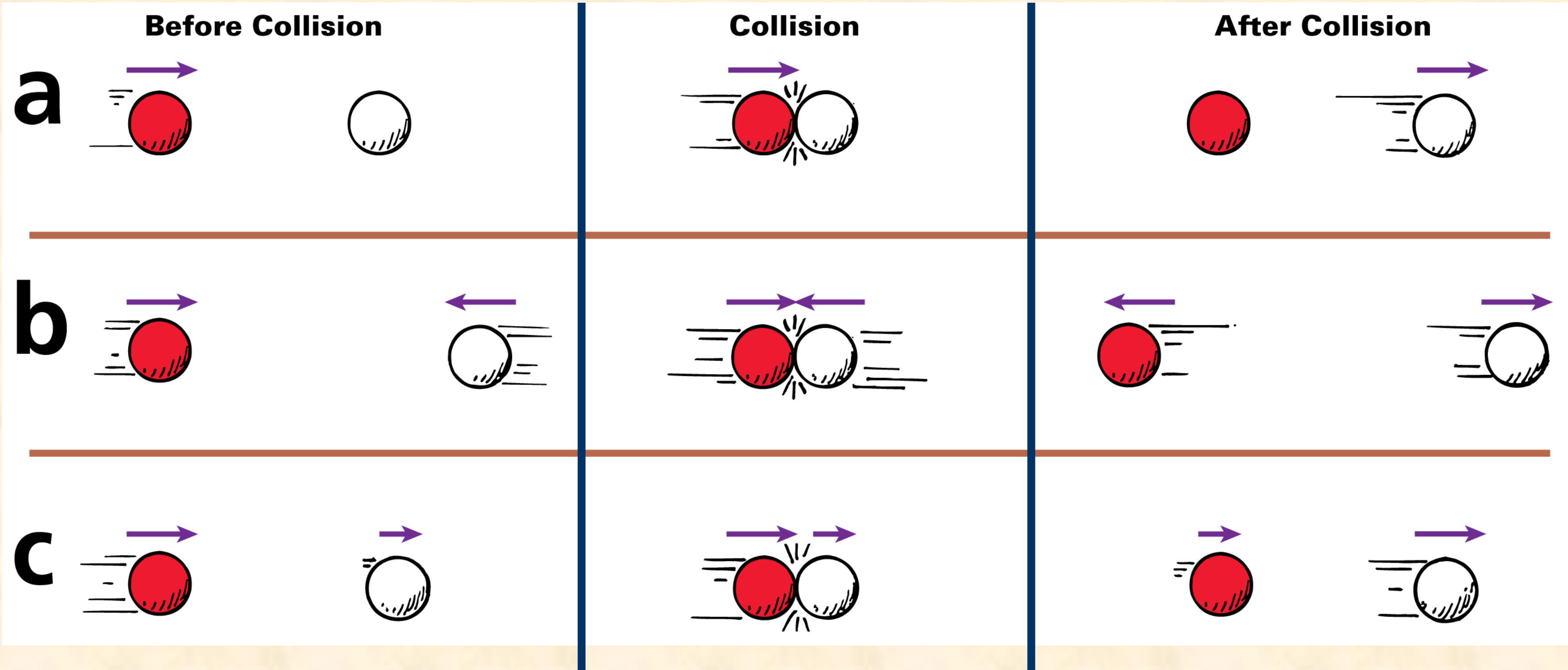
- **Elastic Collisions**
  - When a moving billiard ball collides head-on with a ball at rest, the first ball comes to rest and the second ball moves away with a velocity equal to the initial velocity of the first ball.
  - Momentum is transferred from the first ball to the second ball.



# 7.5 Collisions

$$mv_{before} = mv_{after}$$

- Elastic Collisions



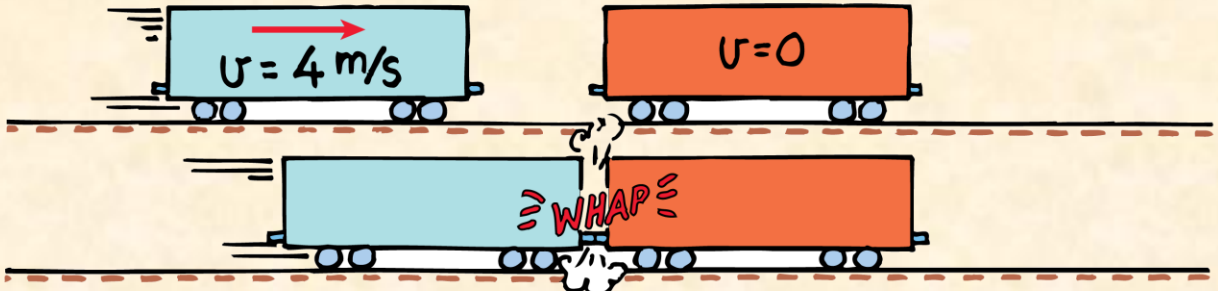
# 7.5 Collisions $mv_{before} = mv_{after}$

- **Inelastic Collisions**
  - A collision in which the colliding objects become distorted and generate heat during the collision is an **inelastic collision.**
  - Momentum conservation holds true even in inelastic collisions.
  - Whenever colliding objects become tangled or couple together, a totally inelastic collision occurs.

# 7.5 Collisions

$$mv_{before} = mv_{after}$$

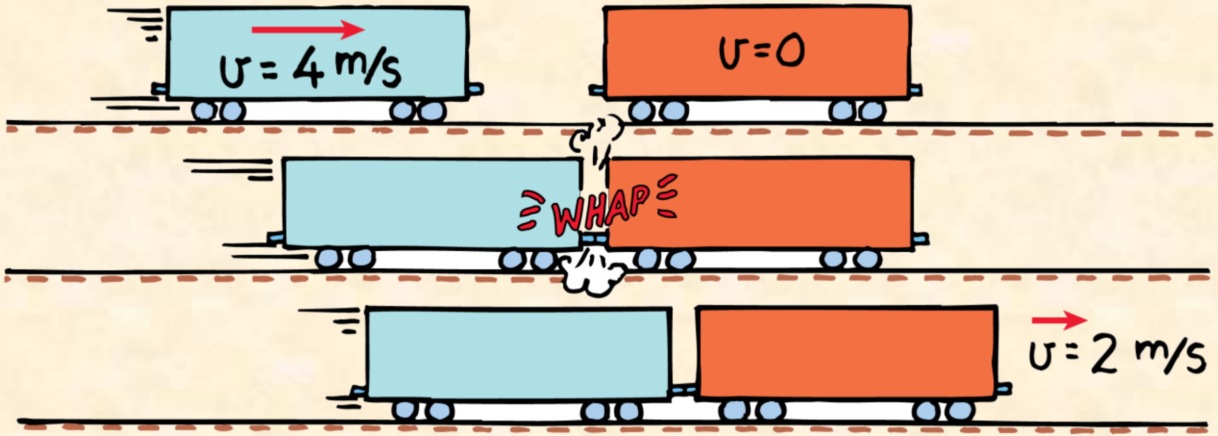
- **Inelastic Collisions**
  - In an inelastic collision between two freight cars of equal mass, the momentum of the freight car on the left is shared with the freight car on the right. What will be the resulting velocity of the two cars?



# 7.5 Collisions

$$mv_{before} = mv_{after}$$

- Inelastic Collisions
  - The freight cars are of equal mass *m,* and one car moves at 4 m/s toward the other car that is at rest.
  - net momentum $_{\text{before collision}}$ = net momentum $_{\text{after collision}}$
  - (net $mv$)$_{\text{before}}$ = (net $mv$)$_{\text{after}}$
  - $(m)(4\text{ m/s}) + (m)(0\text{ m/s}) = (2m)(v_{\text{after}})$



# 7.5 Collisions

$$mv_{before} = mv_{after}$$

- External forces such as friction may have an effect after the collision:
  - Billiard balls encounter friction with the table and the air.
  - After a collision of two trucks, the combined wreck slides along the pavement and friction decreases its momentum.

# 7.5 Collisions

$$mv_{before} = mv_{after}$$

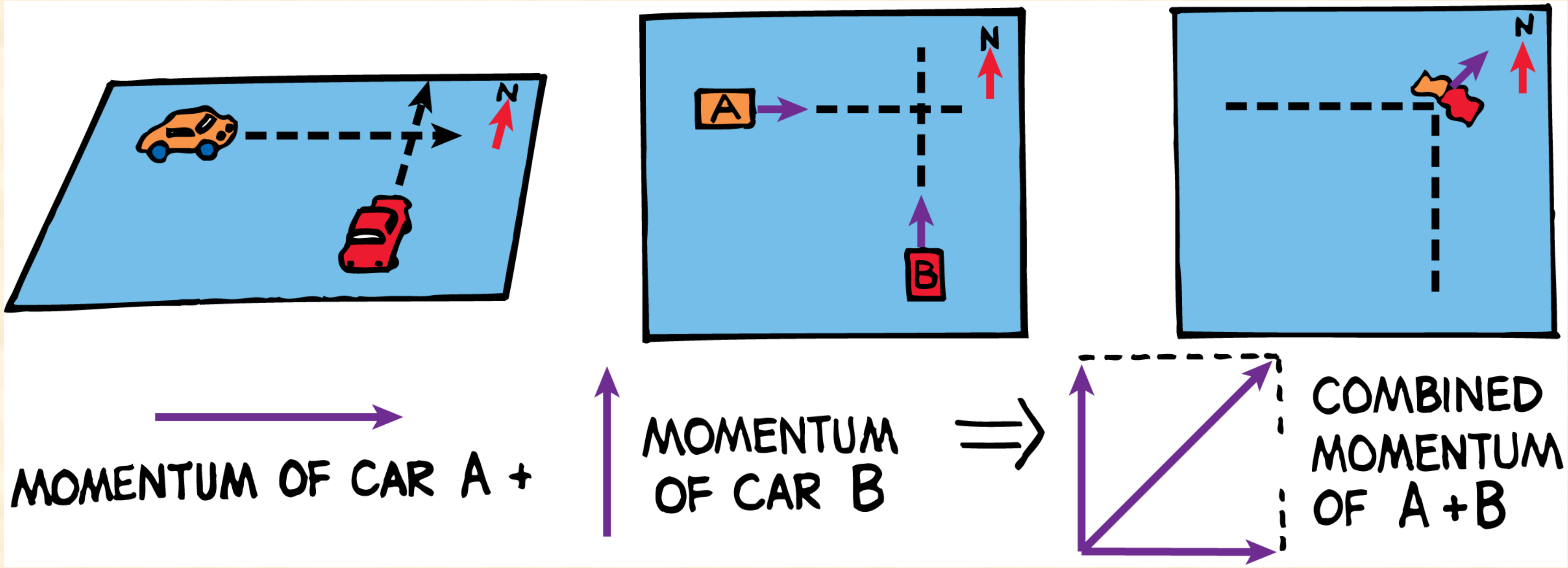
- Do you think perfectly elastic collisions are common in the real world?
- No, if you drop a ball both the ball and where it landed will generate a little heat due to friction.
- At the microscopic level however it is more common such as with electrically charged particles.

## 7.6 Momentum Vectors

- Momentum is conserved even when interacting objects don’t move along the same straight line. To analyze momentum in any direction, we use the vector techniques we’ve previously learned.
- We’ll look at momentum conservation involving angles by considering three examples.

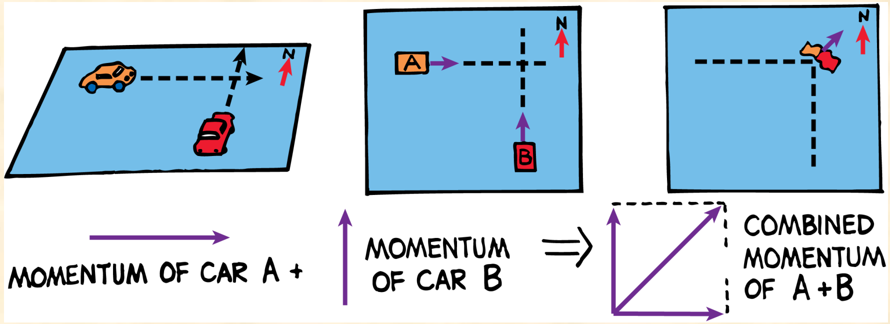
# 7.6 Momentum Vectors

Momentum is a vector quantity. The momentum of the wreck is equal to the vector sum of the momenta of car A and car B before the collision.



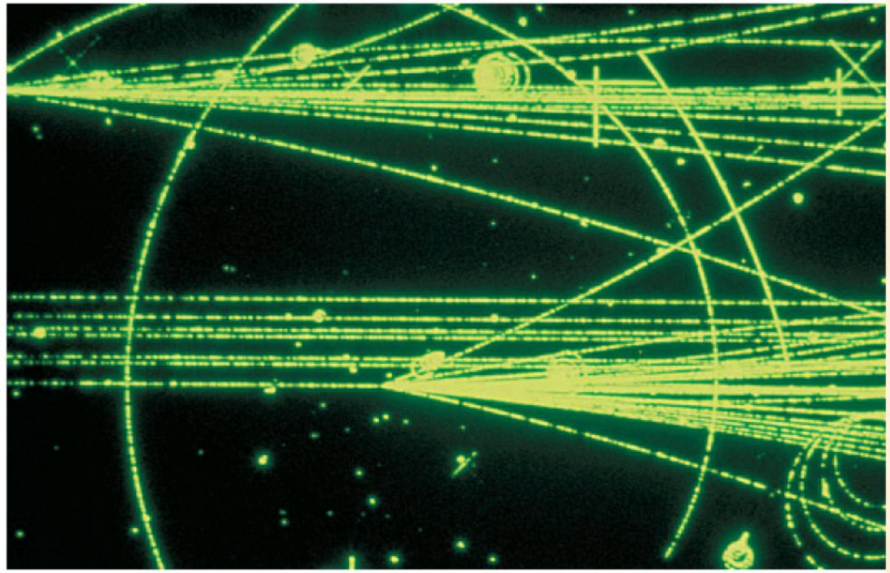
# 7.6 Momentum Vectors

- The momentum of car A is directed due east and that of car B is directed due north.
- If their momenta are equal in magnitude, after colliding their combined momentum will be in a northeast direction with a magnitude $\sqrt{2}$ times the momentum either vehicle had before the collision.

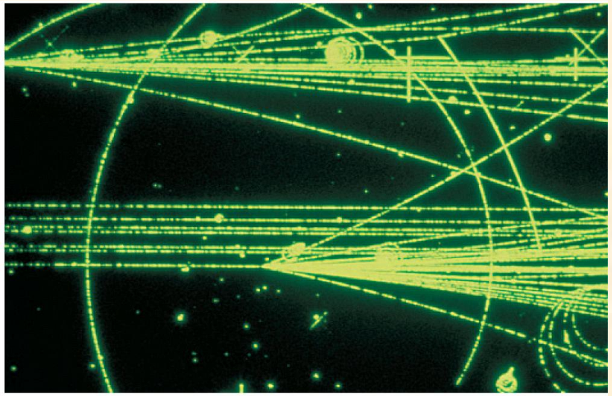


# 7.6 Momentum Vectors

Momentum is conserved for the high-speed elementary particles, as shown by the tracks they leave in a bubble chamber.



# 7.6 Momentum Vectors



- Momentum is conserved for the high-speed elementary particles, as shown by the tracks they leave in a bubble chamber.
  - The mass of these particles can be computed by applying both the conservation of momentum and conservation of energy laws.
  - The conservation laws are extremely useful to experimenters in the atomic and subatomic realms.

# The End...