Physics 2A: Lecture 10

Today's Agenda

- Impulse and Momentum (or the chapter where physicists run out of letters)
 - Non-constant forces
 - Impulse-momentum thm
- Conservation of Linear momentum
 - External/Internal forces
 - Examples



Linear Momentum

Moving object has linear momentum such that:

$$\vec{p} = m\vec{v}$$

Vector quantity in same direction as velocity

• Units: kg m/s or N s $p_v = mv_v$

What makes change in motion difficult? Momentum gives a sense of how hard it is to stop an object Student, "I really don't understand what exactly momentum is interms of a quantity."

Newton's Second law

Newton's second law was originally written in terms of momentum

$$\vec{F}_{net} = \frac{d\vec{p}}{dt}$$
 (1)

$$\vec{F}_{net} = \frac{d(mv)}{dt} = m\frac{dv}{dt} = m\bar{a}$$

$$ec{F}_{\scriptscriptstyle net}=mec{a}$$
 (2

Equation (1) and (2) are equivalent if the mass is not allowed to change.

Newton's Second Law

We can rearrange Newton's second law

 $ec{p}_{ ext{f}}$

$$\vec{F}_{net} = \frac{d\vec{p}}{dt} \qquad J_x = \Delta p$$

$$d\vec{p} = \vec{F}_{net} dt \qquad J_y = \Delta p$$

$$\int_{\vec{p}_i}^{\vec{p}_f} d\vec{p} = \int_{t_i}^{t_f} \vec{F}_{net} dt$$

$$-\vec{p}_i = \int_{t_i}^{t_f} \vec{F}_{net} dt = \vec{J}$$

X

V

Clicker Question 1:

You drop an egg onto A) the floor B) a thick piece of foam rubber. In both cases, the egg does not bounce (assume the egg hits each surface with the same speed v).

In which case is the magnitude of the impulse caused by the collision with the surface greater?

A) FloorB) FoamC) It's the same

Pre-Class Quiz



Clicker Question 2:

Two identical balls are dropped from the same height onto the floor. In case 1 the ball bounces back up, and in case 2 the ball sticks to the floor without bouncing. In which case is the impulse given to the ball by the floor the biggest?

(a) Case 1

- (b) Case 2
- (c) Both are the same

External/Internal Forces



Conservation of Momentum

Newton's second law for a system

$$\vec{F}_{net}^{ext} = \frac{d\vec{p}}{dt}$$

• The total momentum of an isolated system remains constant

Isolated system = no external forces

Conservation of Linear Momentum

• The total momentum of an isolated system remains constant

 $\vec{p}_{f} = \vec{p}_{i}$ $\sum m\vec{v}_{f} = \sum m\vec{v}_{i}$ $\sum mv_{f} = \sum m\vec{v}_{i}$ $\sum mv_{f} = \sum mv_{i}$ $\sum mv_{f} = \sum mv_{i}$

Clicker Question 3:

- Two balls of equal mass are thrown horizontally with the same initial velocity. They hit identical stationary boxes resting on a frictionless horizontal surface.
- The ball hitting box 1 bounces back, while the ball hitting box 2 gets stuck.
 - Which box ends up moving faster?

(a) Box 1 (b) Box 2 (c) same $2 \rightarrow 2$

Impulse delivered to box 1 is larger

Clicker Question 3:

- Since the total external force in the x-direction is zero, momentum is conserved along the x-axis.
- In both cases the initial momentum is the same (*mv* of ball).
- In case 1 the ball has negative momentum after the collision, hence the box must have more positive momentum if the total is to be conserved.
- The speed of the box in case 1 is greater.



Noether's Thm

- Emmy Noether developed the general connection between symmetry and conservation laws
- Symmetries describe changes that can be made without altering how an object looks or acts. A sphere is perfectly symmetric: Rotate it any direction and it appears the same. Likewise, symmetries pervade the laws of physics: Equations don't change in different places in time or space.
- Noether's theorem proclaims that every such symmetry has an associated conservation law, and vice versa — for every conservation law, there's an associated symmetry.
- *Emmy Noether's Wonderful Theorem,* Dwight E. Neuenschwander



Discrete vs. Continuous Symmetry

• Discrete:

- Continuous:



Clicker Question 4:

A bullet having an initial velocity of 300 m/s in the +x direction penetrates an initially stationary soda can of mass 100 gm and emerges on the other side with a final velocity of 200 m/s in the +x direction. The velocity of the soda can after the collision is 5 m/s, also in the +x direction. Assume the soda can slides on a horizontal frictionless surface. What is the mass of the bullet?

A. 2 gm
B. 5 gm
C. 12 gm
D. 21 gm
E. 25 gm



Clicker Question 4:



 $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$

Clicker Question 6:

The two boxes are sliding along a frictionless surface. They collide and stick together. Afterward, the velocity of two boxes is

- A. 2 m/s to the left.
- B. 1 m/s to the left.
- C. 0 m/s, at rest.
- D. 1 m/s to the right.
- E. 2 m/s to the right.



Clicker Question 5:

A small car and a large truck collide head-on and stick together. Which one feels the larger impulse?

- a) the car
- b) the truck



- c) they both feel the same impulse
- d) can't tell without knowing the final velocities

Collisions and Explosions

- Conservation of momentum is very useful for analyzing collisions and explosions
- In collisions/explosions, forces are very complicated; momentum gives us a useful way to solve these problems (treat colliding/exploding particles as system)
- Momentum conservation is almost always a very good model to use during a collision/explosion (as the external forces are generally small compared to collision/explosion forces)
- This is one reason why momentum is so important

$$F_{avgy}\Delta t = \Delta p$$

Conservation of Linear Momentum

The total momentum of an isolated system remains constant

$$\vec{P}_{i} = \vec{P}_{f}$$

 $\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$

If the motion is along a single axis, the motion is 1-d and we can write the equation about that axis:

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

Example: a 2-D Collision

George is driving south along at 18.0 m/s in a flatbed truck heavily loaded, while John is driving a VW Beatle at 42.0 m/s east.

Because John is texting on his cell phone, he does not see the red light and collides with the front of the truck. During the collision, the vehicles lock together.

If George's truck has a total mass of 8320 kg and John's Beatle has a total mass of 1220 kg, find the velocity of the interlocked vehicles immediately after the collision.



Beatle

Example





Clicker Question 6:

After the accident, which is true about the angle of the velocity of the two cars relative to the eastward direction?

- a) $\theta < 45^{\circ}$
- b) $\theta > 45^{\circ}$
- c) $\theta = 45^{\circ}$



Clicker Question 7:

What is the correct equation for the x-direction momentum?

- $a) \quad m_B v_B = (m_T + m_B) v_{xf}$
- b) $m_T v_T = (m_T + m_B) v_{xf}$
- c) $m_B v_B + m_T v_T = (m_T + m_B) v_{xf}$
- d) $m_B v_B = (m_T + m_B) v_f \sin \theta$



Clicker Question 8:

Two dry ice pucks slide on a horizontal, frictionless surface. Puck A, which is 2 kg, moves at speed 7 m/s in the positive *x* direction and Puck B, which is 1 kg, moves at speed 8 m/s in the negative y direction as shown in the figure. The pucks collide near the star in the figure. After the collision Puck B is moving in the positive x direction, while Puck A is moving in the direction that makes 45° with the positive *x*-axis as illustrated.

What is the speed of Puck A after the collision?

- (a) 1 m/s
- (b) 2 m/s
- (c) $2\sqrt{2}$ m/s
- (d) 4 m/s
- (e) $4\sqrt{2}$ m/s



Two dry ice pucks slide on a horizontal, frictionless surface. Puck A, which is 2 kg, moves at speed 7 m/s in the positive *x* direction and Puck B, which is 1 kg, moves at speed 8 m/s in the negative y direction as shown in the figure. The pucks collide near the star in the figure. After the collision Puck B is moving in the positive x direction, while Puck A is moving in the direction that makes 45° with the positive *x*-axis as illustrated. What is the speed of Puck A after the collision?



Two dry ice pucks slide on a horizontal, frictionless surface. Puck A, which is 2 kg, moves at speed 7 m/s in the positive *x* direction and Puck B, which is 1 kg, moves at speed 8 m/s in the negative y direction as shown in the figure. The pucks collide near the star in the figure. After the collision Puck B is moving in the positive x direction, while Puck A is moving in the direction that makes 45° with the positive *x*-axis as illustrated. What is the speed of Puck A after the collision?



Clicker Question 7:

Consider two less-than-desirable options. In the first you are driving 30 mph and crash head-on into an identical car also going 30 mph. In the second option you are driving 30 mph and crash head-on into a stationary brick wall. In neither case does your car bounce off the thing it hits, and the collision time is the same in both cases. Which of these two situations would result in the greatest impact force?

A) hitting the other car

- B) hitting the brick wall
- C) The force would be the same in both cases.
- D) We cannot answer this question without more information.
- E) None of these is true.