

Physics 101: Lecture 11

Momentum and Impulse

- Today's lecture will cover Textbook Sections 7.1-7.5



Comments:

- Exam tonight – 7 PM (5:15 PM conflict)

Momentum and Impulse

➤ Momentum $p = mv$

» Momentum is a VECTOR

➤ Impulse $I = F\Delta t$

» Impulse is just the change in momentum: $I = \Delta p$

Key Ideas

- Earlier: **Work-Energy**

- $F_{\text{Net}} = m a$ multiply both sides by d
- $F_{\text{Net}} d = m a d$ (note $a d = \frac{1}{2} \Delta v^2$)
- $F_{\text{Net}} d = \frac{1}{2} m \Delta v^2$
- $W_{\text{Net}} = \Delta KE$ Define Work and Kinetic Energy

- This Time: **Impulse-Momentum**

- $F_{\text{Net}} = m a$
- $F_{\text{Net}} = m \Delta v / \Delta t$ (note $a = \Delta v / \Delta t$)
- $F_{\text{Net}} = \Delta (mv) / \Delta t = \Delta p / \Delta t$
- $I_{\text{Net}} = \Delta p$ Define Impulse and Momentum demo

Checkpoint 1

A magician yanks a tablecloth out from under some dishes. Miraculously, the dishes remain on the table where they were. Briefly explain why the dishes were not given much impulse by the tablecloth.

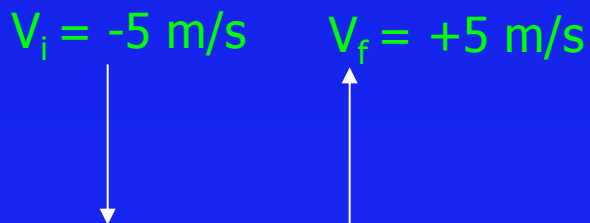
ACT (w/ demo)

Two identical balls are dropped from the same height onto the floor. In each case they have velocity v downward just before hitting 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 magnitude of the impulse given to the ball by the floor the biggest?

A. Case 1 ← correct

B. Case 2

C. The same



Bouncing Ball

$$\begin{aligned} |I| &= |\Delta p| \\ &= |m v_{\text{final}} - m v_{\text{initial}}| \\ &= |m(v_{\text{final}} - v_{\text{initial}})| \\ &= 2 m v \end{aligned}$$

Sticky Ball

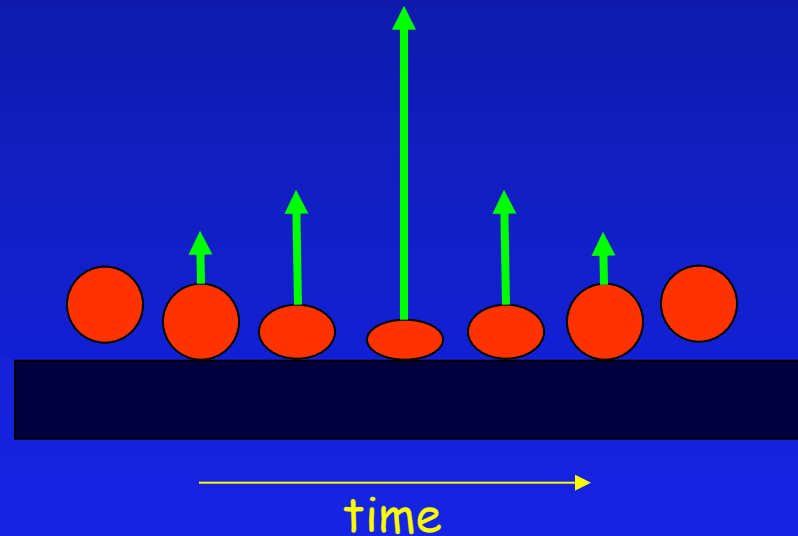
$$\begin{aligned} |I| &= |\Delta p| \\ &= |m v_{\text{final}} - m v_{\text{initial}}| \\ &= |m(0 - v_{\text{initial}})| \\ &= m v \end{aligned}$$

ACT

In both cases of the above question, the direction of the impulse given to the ball by the floor is the same. What is this direction?

A. Upward ← correct

B. Downward



ACTs

You drop an egg onto 1) the floor 2) a thick piece of foam rubber. In both cases, the egg does not bounce (demo).

In which case is the impulse greater?

A) Floor

$$I = \Delta P$$

B) Foam

C) the same

Same change in momentum

In which case is the average force greater

A) Floor

$$\Delta p = F \Delta t$$

B) Foam

$$F = \Delta p / \Delta t$$

C) the same

Smaller $\Delta t = \text{large } F$



Pushing Off...

Fred (75 kg) and Jane (50 kg) are at rest on skates facing each other. Jane then pushes Fred w/ a constant force $F = 45 \text{ N}$ for a time $\Delta t = 3$ seconds. Who will be moving fastest at the end of the push?

A) Fred

B) Same

C) Jane

Fred

$$F = +45 \text{ N} \quad (\text{positive direct.})$$

$$I = +45 (3) \text{ N-s} = 135 \text{ N-s}$$

$$I = \Delta p$$

$$= mv_f - mv_i$$

$$I/m = v_f - v_i = v_f$$

$$v_f = 135 \text{ N-s} / 75 \text{ kg}$$

$$= 1.8 \text{ m/s}$$

Jane

$$F = -45 \text{ N} \quad \text{Newton's 3rd law}$$

$$I = -45 (3) \text{ N-s} = -135 \text{ N-s}$$

$$I = \Delta p$$

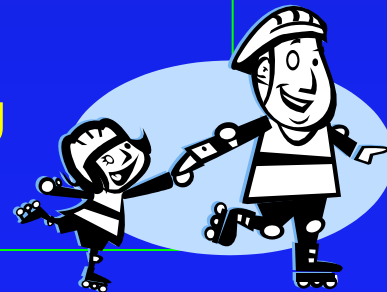
$$= mv_f - mv_i$$

$$I/m = v_f - v_i = v_f$$

$$v_f = -135 \text{ N-s} / 50 \text{ kg}$$

$$= -2.7 \text{ m/s}$$

$$\text{Note: } P_{\text{fred}} + P_{\text{jane}} = (1.8) 75 + (-2.7) 50 = 0!$$



Momentum is Conserved

- Like Energy, Momentum is “Conserved”, meaning it can not be created nor destroyed
 - Can be transferred
- Total Momentum does not change with time.

This is a BIG deal!

Impulse and Momentum Summary

$$F_{\text{Net}}\Delta t = \Delta p$$

- For single object....

- $F_{\text{Net}} = 0 \Rightarrow$ momentum conserved ($\Delta p = 0$)

- For collection of objects ...

- $F_{\text{Net}} = 0 \Rightarrow$ total momentum conserved ($\Delta P_{\text{tot}} = 0$)

- $F_{\text{Net}} = m_{\text{total}} a$

Momentum ACT

A car w/ mass 1200 kg is driving north at 40 m/s, and turns east driving 30 m/s. What is the magnitude of the car's change in momentum?

- A) 0 B) 12,000 C) 36,000 D) 48,000 E) 60,000

$$P_{\text{initial}} = m v_{\text{initial}} = (1200 \text{ Kg}) * 40 \text{ m/s} = 48,000 \text{ kg m/s North}$$

$$P_{\text{final}} = m v_{\text{final}} = (1200 \text{ Kg}) * 30 \text{ m/s} = 36,000 \text{ kg m/s East}$$

North-South:

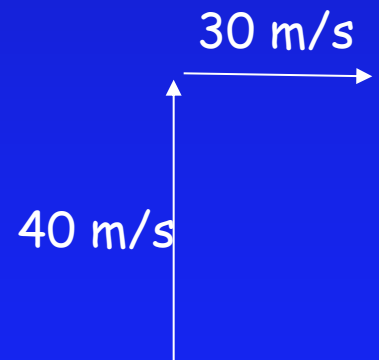
$$P_{\text{final}} - P_{\text{initial}} = (0 - 48000) = -48,000 \text{ kg m/s}$$

East-West:

$$P_{\text{final}} - P_{\text{initial}} = (36000 - 0) = +36,000 \text{ kg m/s}$$

Magnitude :

$$\text{Sqrt}(P_{\text{North}}^2 + P_{\text{East}}^2) = 60,000 \text{ kg m/s}$$



Checkpoint 2 & 3

Is it possible for a system of two objects to have zero total momentum while having a non-zero total kinetic energy?

1. YES

2. NO

demo

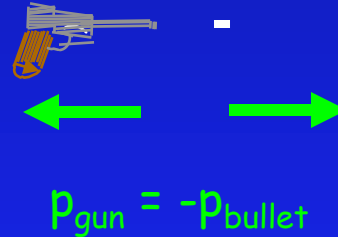
ACT

Movies often show someone firing a gun loaded with blanks. In a blank cartridge the lead bullet is removed and the end of the shell casing is crimped shut to prevent the gunpowder from spilling out. When a gun fires a blank, is the recoil greater than, the same as, or less than when the gun fires a standard bullet?

A. greater than

B. same as

C. less than ← correct



If there is no bullet then $p_{\text{bullet}} = 0$ so $p_{\text{gun}} = 0$

Summary

➤ Impulse $I = F\Delta t$

» Gives change in momentum $I = \Delta p$

➤ Momentum $p = mv$

» Momentum is VECTOR

» Momentum is conserved (when $F_{\text{Net}} = 0$)

■ $\Sigma mv_{\text{initial}} = \Sigma mv_{\text{final}}$