Chapter 9A - Impulse and Momentum

- A PowerPoint Presentation by
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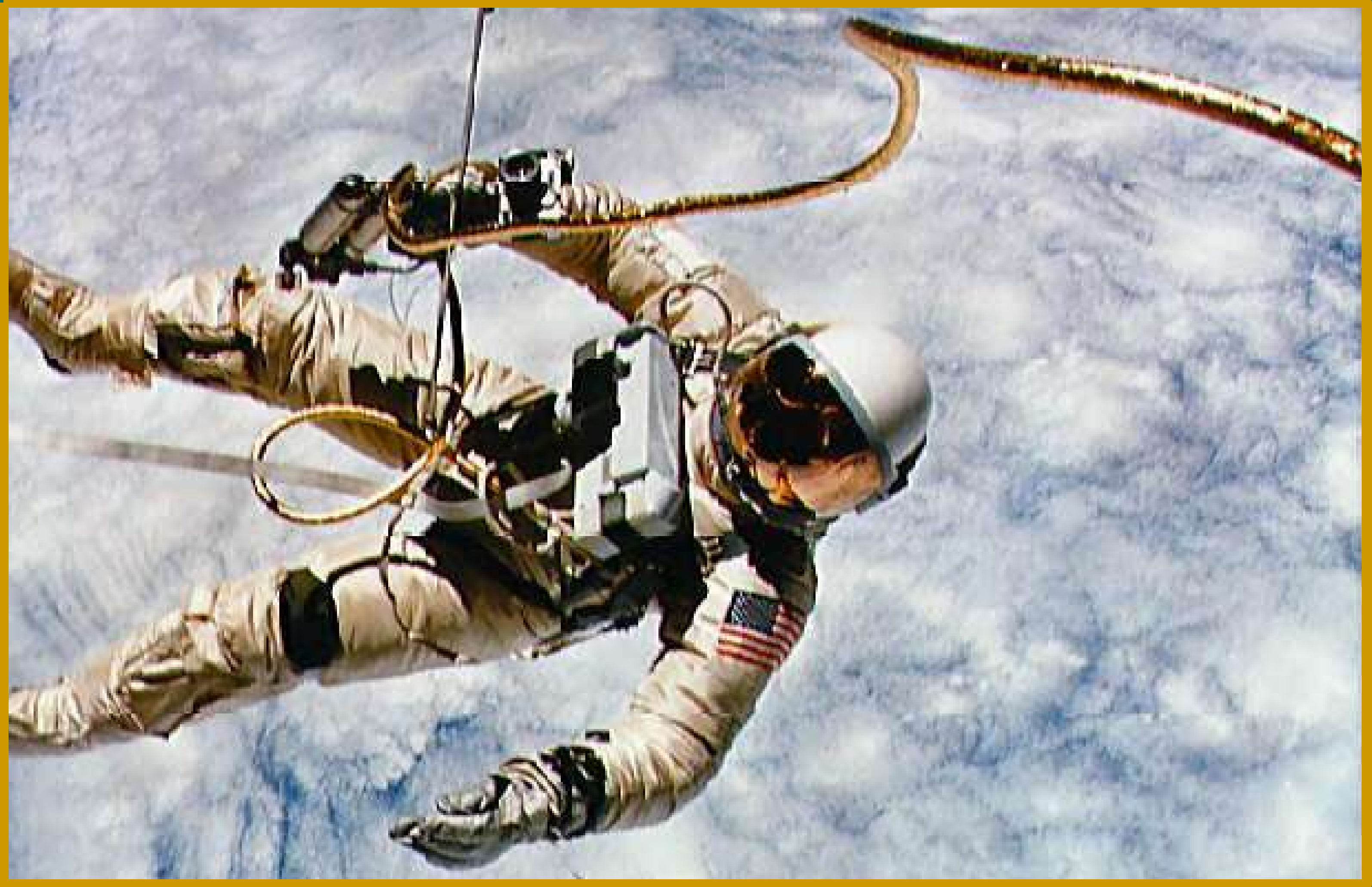
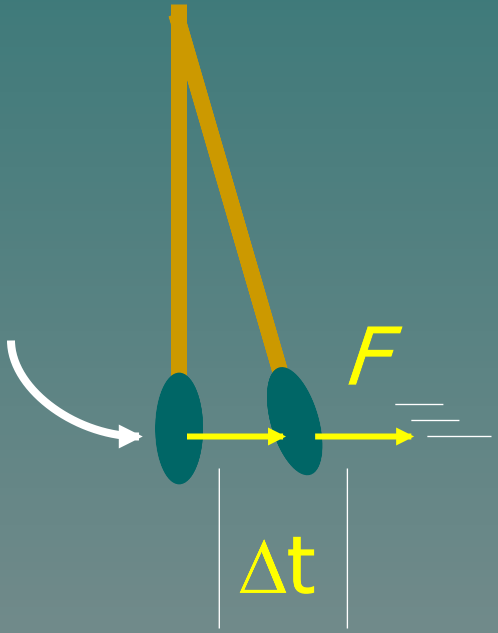


ASTRONAUT Edward H. White II floats in the zero gravity of space. By firing the gas-powered gun, he gains momentum and maneuverability. Credit: NASA

Objectives: After Completing This Module, You Should Be Able To:

- Define and give examples of impulse and momentum along with appropriate units.
- Write and apply a relationship between impulse and momentum in one dimension.
- Write and apply a relationship between impulse and momentum in two dimensions.

IMPULSE



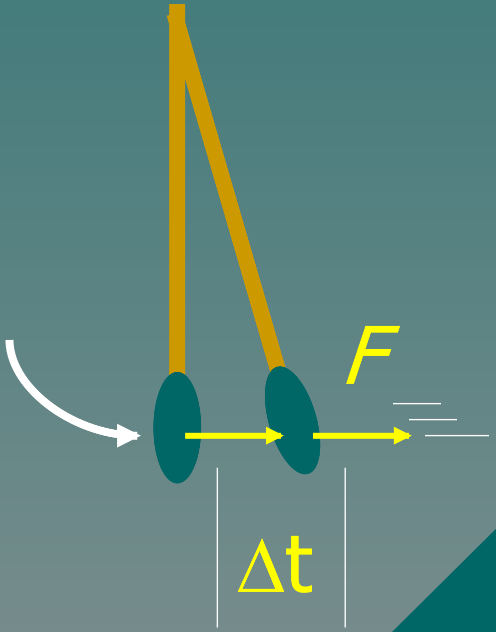
Impulse J is a force F acting for a small time interval Δt.

Impulse:

$$J = F \Delta t$$

Example 1: The face of a golf club exerts an average force of 4000 N for 0.002 s. What is the impulse imparted to the ball?

Impulse: $\boxed{J = F \Delta t}$



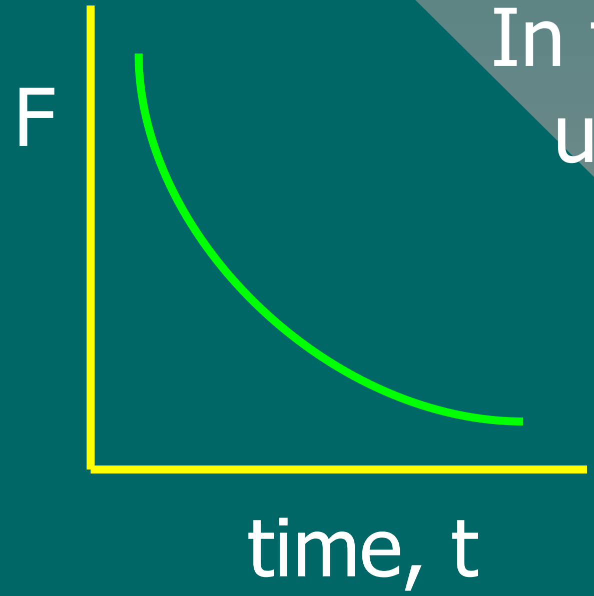
$J = (4000\ N)(0.002\ s)$

$\boxed{J = 8.00\ N{\cdot}s}$

The unit for impulse is the Newton-second (N s)

Impulse from a Varying Force

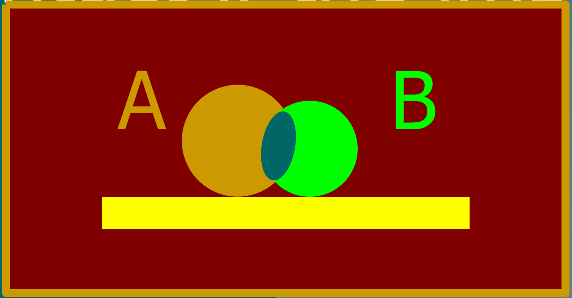
Normally, a force acting for a short interval is not constant. It may be large initially and then play off to zero as shown in the graph.



In the absence of calculus, we use the average force F_{avg}.

$$\boxed{J = F_{avg}\Delta t}$$

Example 2: Two flexible balls collide. The ball B exerts an average force of 1200 N on ball A. How long were the balls in contact if the impulse is 5 N s?



$$J = F_{avg} \Delta t$$

$$\Delta t = \frac{J}{F_{avg}} = \frac{\text{-5 N s}}{\text{-1200 N}}$$

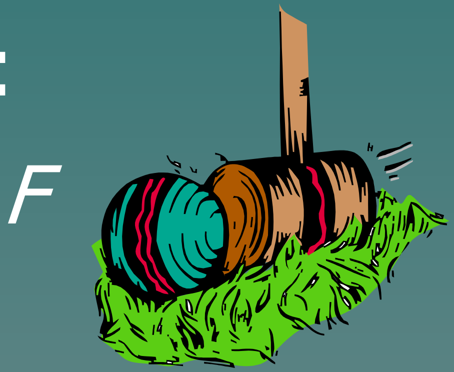
Δt = 0.00420 s

The impulse is negative; the force on ball A is to the left. Unless told otherwise, treat forces as average forces.

Impulse Changes Velocity

Consider a mallet hitting a ball:

$$F = ma; \quad a = \frac{v_f - v_o}{\Delta t}$$



$$F = m\left(\frac{v_f - v_0}{\Delta t}\right)$$

$$F\Delta t = mv_f - mv_o$$

Impulse = Change in "mv"

Momentum Defined

Momentum *p* is defined as the product of mass and velocity, mv. *Units:* kg m/s

$$p = mv$$

Momentum

m = 1000 kg

v = 16 m/s

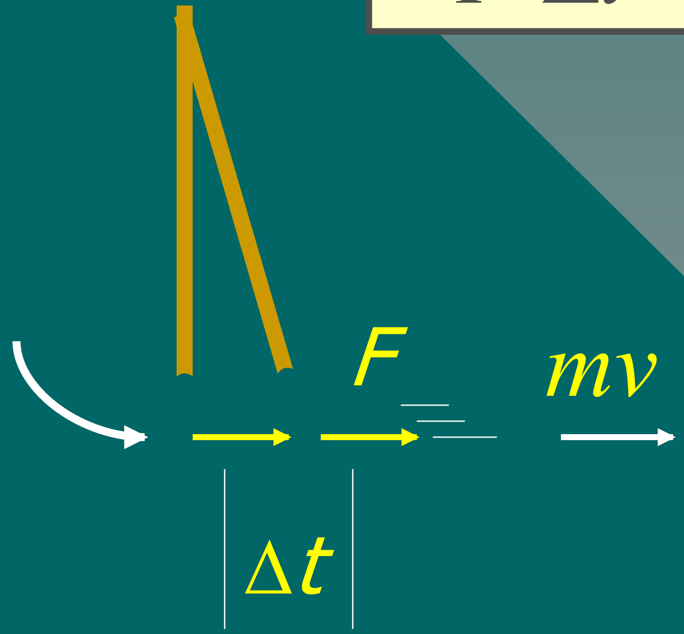
p = (1000 kg)(16 m/s)

p = 16,000 kg m/s

Impulse and Momentum

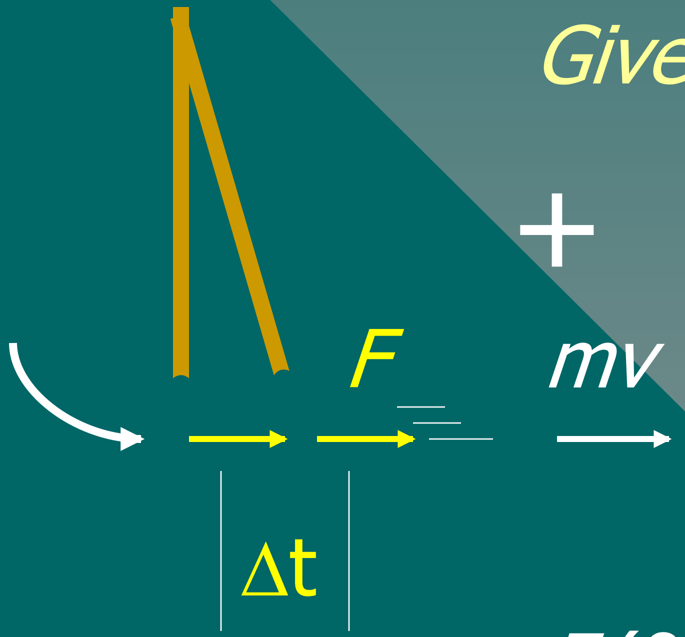
Impulse = Change in momentum

$$\boxed{F\,\Delta t = mv_f - mv_o}$$



A force F acting on a ball for a time Δt increases its momentum mv.

Example 3: A 50-g golf ball leaves the face of the club at 20 m/s. If the club is in contact for 0.002 s, what average force acted on the ball?



Given: $m = 0.05$ kg; $v_o = 0$;

$\Delta t = 0.002$ s; $v_f = 20$ m/s

Choose right as positive.

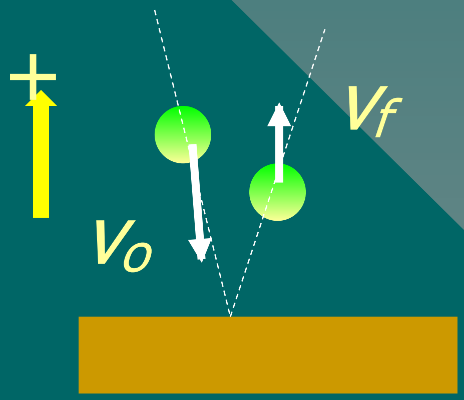
$$F\,\Delta t = mv_f - \cancelto{0}{mv_o}$$

$$F(0.002\text{ s}) = (0.05\text{ kg})(20\text{ m/s})$$

Average Force: $\boxed{F = 500\text{ N}}$

Vector Nature of Momentum

Consider the change in momentum of a ball that is dropped onto a rigid plate:



A 2-kg ball strikes the plate with a speed of 20 m/s and rebounds with a speed of 15 m/s. What is the change in momentum?

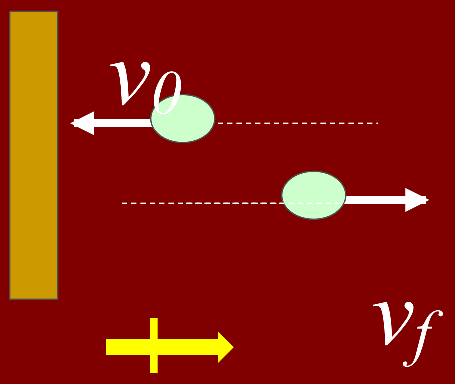
$$\Delta p = mv_f - mv_o = (2\text{ kg})(15\text{ m/s}) - (2\text{ kg})(-20\text{ m/s})$$

$$\Delta p = 30\text{ kg m/s} + 40\text{ kg m/s}$$

$$\boxed{\Delta p = 70\text{ kg m/s}}$$

Directions Are Essential

1. Choose and label a positive direction.



$v_f = +10$ m/s

$v_0 = -30$ m/s

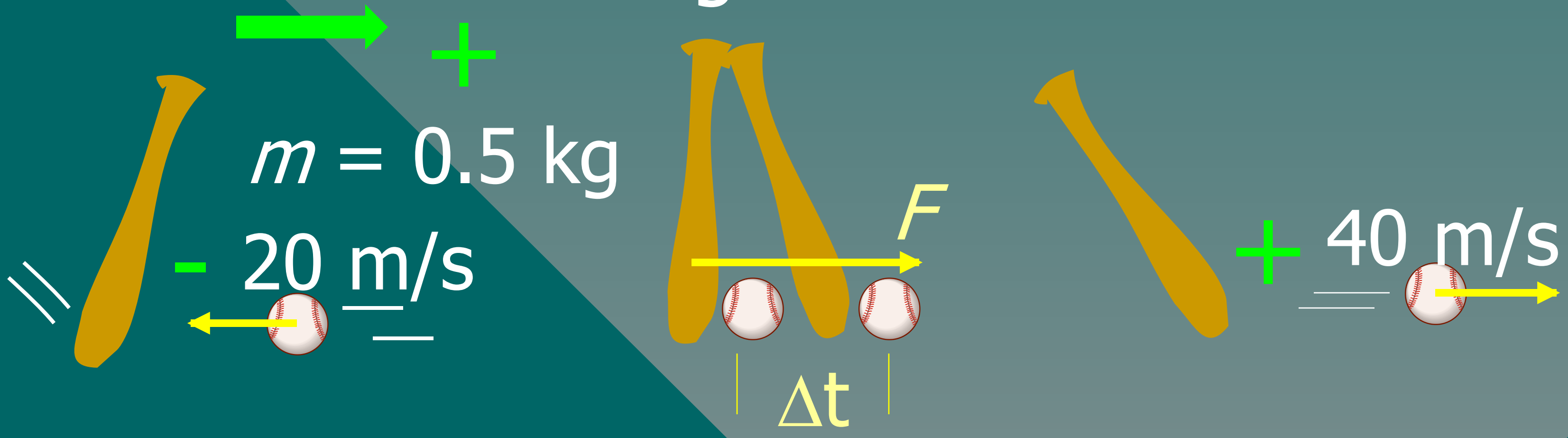
2. A velocity is positive when with this direction and negative when against it.

Assume v_0 is 30 m/s to the left and v_f is 10 m/s to the right. *What is the change in velocity* Δv*?*

$v_f - v_0 =$ (10 m/s) – (-30 m/s)

$$\boxed{\Delta v = 40 \text{ m/s}}$$

Example 4: A 500-g baseball moves to the left at 20 m/s striking a bat. The bat is in contact with the ball for 0.002 s, and it leaves in the opposite direction at 40 m/s. What was average force on ball?

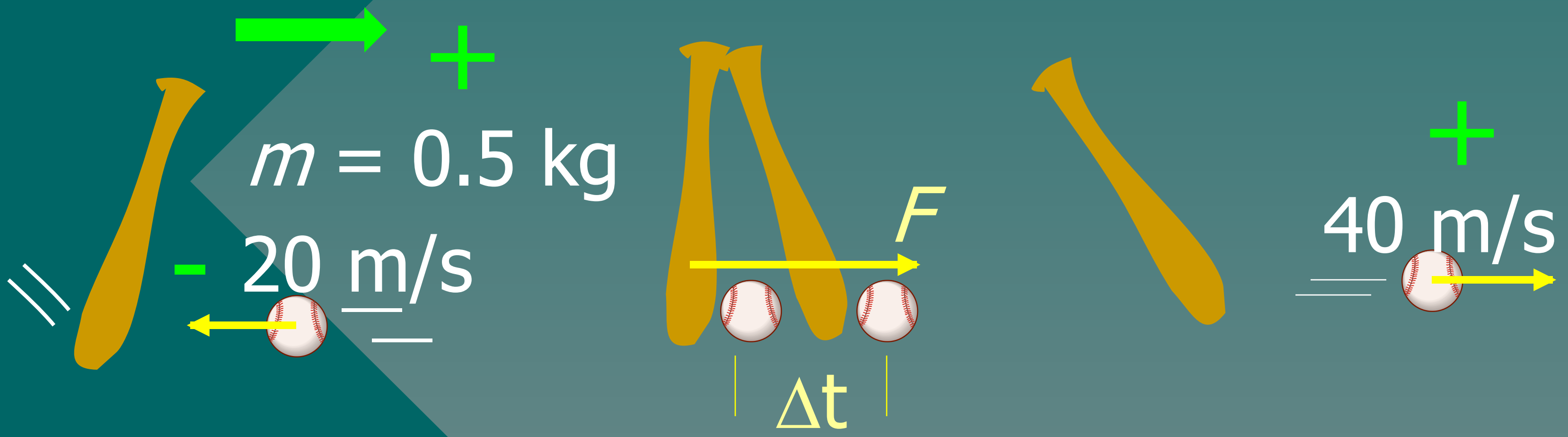


$F\,\Delta t = mv_f - mv_o$ $\quad v_o = -20$ m/s; $\ v_f = 40$ m/s

F(0.002 s) = (0.5 kg)(40 m/s) - (0.5 kg)(-20 m/s)

Continued . . .

Example Continued:



$$F \Delta t = mv_f - mv_o$$

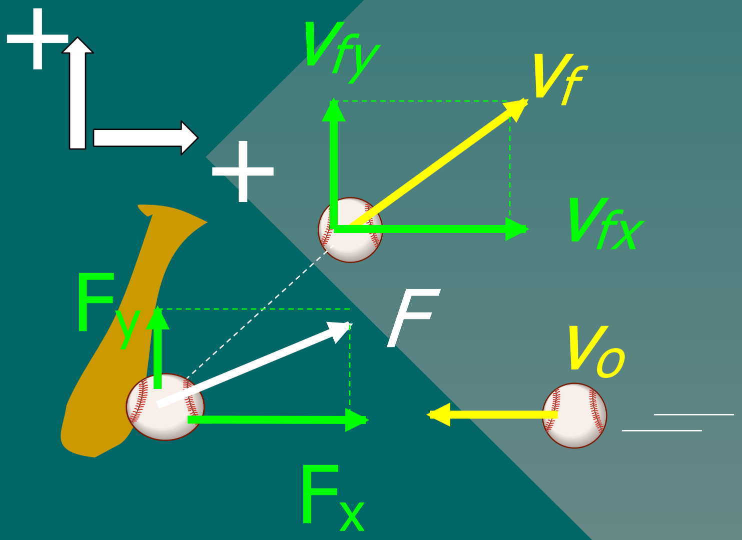
F(0.002 s) = (0.5 kg)(40 m/s) - (0.5 kg)(-20 m/s)

F(0.002 s) = (20 kg m/s) + (10 kg m/s)

F(0.002 s) = 30 kg m/s

F = 15,000 N

Impulse in Two Dimensions



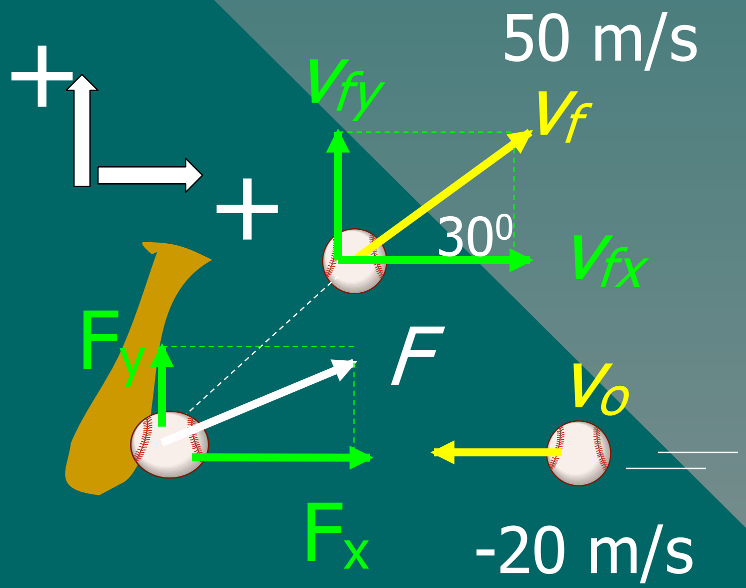
A baseball with an initial velocity v_o hits a bat and leaves with v_f at an angle.

Horizontal and vertical impulse are independent.

$$F = F_x\,\mathbf{i} + F_y\,\mathbf{j} \qquad v_o = v_{ox}\,\mathbf{i} + v_{oy}\,\mathbf{j} \qquad v_f = v_x\mathbf{i} + v_y\,\mathbf{j}$$

$$F_x\,\Delta t = mv_{fx} - mv_{ox} \qquad F_y\,\Delta t = mv_{fy} - mv_{oy}$$

Example 5: A 500-g baseball travelling at 20 m/s leaves a bat with a velocity of 50 m/s at an angle of 30^0. If Δt = 0.002 s, what was the average force F?



v_{ox} = -20 m/s; $v_{oy} = 0$

$v_{fx} = 50 \text{ Cos } 30^0 = 43.3$ m/s

$v_{fy} = 50 \text{ Sin } 30^0 = 25$ m/s

First consider horizontal:

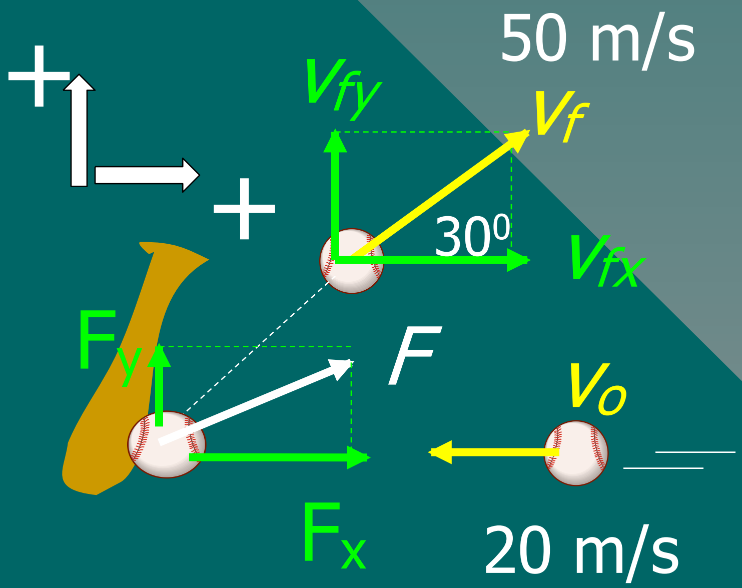
$$F_x \Delta t = mv_{fx} - mv_{ox}$$

$$F_x(.002 \text{ s}) = (0.5 \text{ kg})(43.3 \text{ m/s}) - (0.5 \text{ kg})(-20 \text{ m/s})$$

Example Continued . . .

$$F_x(.002\text{ s}) = (0.5\text{ kg})(43.3\text{ m/s}) - (0.5\text{ kg})(-20\text{ m/s})$$

$$F_x(.002\text{ s}) = 21.7\text{ kg m/s} + 10\text{ kg m/s})$$



$$\boxed{F_x = 15.8\text{ kN}}$$

Now apply to vertical:

$$F_y\,\Delta t = mv_{fy} - \cancelto{0}{mv_{oy}}$$

$$F_y(.002\text{ s}) = (0.5\text{ kg})(25\text{ m/s})$$

$$\boxed{F_y = 6.25\text{ kN}}$$ and $$\boxed{F = 17.0\text{ kN}, 21.5^0}$$

Summary of Formulas:

Impulse

$J = F_{avg}\Delta t$

Momentum

$p = mv$

Impulse = Change in momentum

$F\,\Delta t = mv_f - mv_o$

CONCLUSION: Chapter 9A
Impulse and Momentum