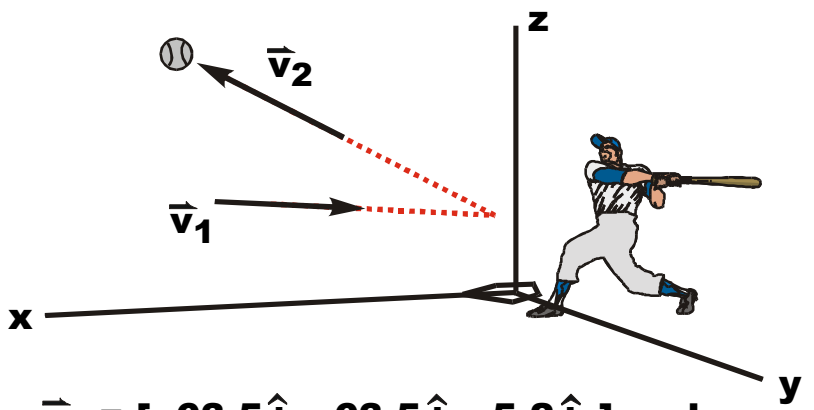
Particle Impulse-Momentum: Example Problem 1

A pitcher throws a 90 mph fastball to a hitter who strikes the ball solidly with the bat, stroking a 110 mph line drive into right center field. A major league baseball weighs 5 1/8 ounce. The velocities, as vectors, are given below. Please determine:

(a) The impulse of the bat onto the ball.

(b) The impulse of the ball onto the bat.

(c) The average bat-ball force during the impact (assume F is constant during impact and that the contact time is 1/1000 sec).



$\vec{v}_1 = [\, -63.5\,\hat{i} \; - 63.5\,\hat{j} \; - 5.2\,\hat{k} \,]$ mph

$\vec{v}_2 = [\, 82.5\,\hat{i} \; + 47.6\,\hat{j} \; + 55\,\hat{k} \,]$ mph

Major league baseball weighs $5\frac{1}{8}$ ounce.

Time of impact = 0.001 second

Ball's Mass

$$m = \left(5\tfrac{1}{8}\ \text{oz}\right)\left[\frac{1\ \text{lb}}{16\ \text{oz}}\right]\left[\frac{\text{slug}}{32.2\ \text{lb}}\right]$$

$$m = .009948\ \text{slug} \cong \left(\frac{1}{100}\right)\ \text{slug}$$

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Impulse of the bat onto the ball:

Write the I-M Eqn for the BALL

$$\int \vec{F}\,dt = m\vec{v}_2 - m\vec{v}_1 = m(\,\vec{v}_2 - \vec{v}_1\,)$$

$$= .009948\text{ slug}\left[[82.5, 47.6, 55] - [-63.5, -63.5, -5.2]\right]\left[\frac{88\text{ fps}}{60\text{ mph}}\right]$$

$$\int_{\text{Bat onto ball}} \vec{F}\,dt = [\,2.130\,\hat{i} + 1.621\,\hat{j} + .8783\,\hat{k}\,]\text{ lb-sec}$$

Impulse is a vector!

Impulse of the ball onto the bat is equal and opposite:

$$\int_{\text{Ball onto bat}} \vec{F}\,dt = -[\,2.130\,\hat{i} + 1.621\,\hat{j} + .8783\,\hat{k}\,]\text{ lb-sec}$$

$$\int_{\text{Bat onto ball}} \vec{F}\,dt = [\,2.130\,\hat{i} + 1.621\,\hat{j} + .8783\,\hat{k}\,] \text{ lb-sec}$$

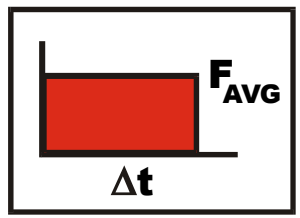
Magnitude of this impulse:

$$\left| \int \vec{F}\,dt \right| = \sqrt{2.13^2 + 1.62^2 + .878^2} = \boxed{2.817 \text{ lb-sec}}$$

This seems small, almost inconsequential, doesn't it?

Calculate the force acting during the bat-ball impact:

Assume the force is constant...



The impulse is: $F_{AVG}\,\Delta t = 2.817$ lb-sec

If $\Delta t = 0.001$ sec, then...

$$F_{AVG} = \frac{2.817 \text{ lb-sec}}{0.001 \text{ sec}} = 2817 \text{ lb } !$$

For lots of interesting information about the game of baseball, including bats striking balls, see the book, The Physics of Baseball, by Robert K. Adair.

On page 52 he notes that impulsive forces up to 8000 lb can occur between a bat and a baseball!

In our example, if the force is not assumed constant over time, the peak force would be much higher—probably 5000-6000 lb?