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).

\[ \vec{v}_1 = [-63.5 \hat{i} - 63.5 \hat{j} - 5.2 \hat{k}] \text{ mph} \]
\[ \vec{v}_2 = [82.5 \hat{i} + 47.6 \hat{j} + 55 \hat{k}] \text{ mph} \]

Major league baseball weighs 5 1/8 ounce.

Time of impact = 0.001 second
\( \vec{v}_1 = [ -63.5 \hat{i} - 63.5 \hat{j} - 5.2 \hat{k} ] \) 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

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

\[ m = 0.00948 \text{ slug} \approx \left( \frac{1}{100} \right) \text{ slug} \]

**Impulse of the bat onto the ball:**

\[
\int \vec{F} dt = m\vec{v}_2 - m\vec{v}_1 = m( \vec{v}_2 - \vec{v}_1 )
\]

\[ = 0.00948 \text{ slug} \left[ [82.5, 47.6, 55] - [-63.5, -63.5, -5.2] \right] \left[ \frac{88 \text{ fps}}{60 \text{ mph}} \right] \]

\[ \int \vec{F} dt = [2.130 \hat{i} + 1.621 \hat{j} + 0.8783 \hat{k}] \text{ lb-sec} \]

**Bat onto ball**

Impulse is a vector!

**Write the I-M Eqn for the BALL**

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

\[
\int \vec{F} dt = -[2.130 \hat{i} + 1.621 \hat{j} + 0.8783 \hat{k}] \text{ lb-sec}
\]

**Ball onto bat**
\[ \int F \, dt = [2.13 \hat{i} + 1.621 \hat{j} + 0.8783 \hat{k}] \text{ lb-sec} \]

Bat onto ball

Magnitude of this impulse:

\[ \left| \int F \, dt \right| = \sqrt{2.13^2 + 1.62^2 + 0.878^2} = 2.817 \text{ lb-sec} \]

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: \( F_{\text{avg}} \Delta t = 2.817 \text{ lb-sec} \)

If \( \Delta t = 0.001 \text{ sec} \), then...

\[ F_{\text{avg}} = \frac{2.817 \text{ lb-sec}}{0.001 \text{ sec}} = 2817 \text{ lb} ! \]
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?

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**Force During this Bat-Ball Impact:**

- **Actual Force**
  - Peak Force = 5000+ lb?
  - \( F \)
  - \( \Delta t = 0.001 \text{ sec} \)

- **Modeled as**
  - Often
  - \( F_{\text{AVG}} = 2817 \text{ lb} \)
  - \( \Delta t = 0.001 \text{ sec} \)

**Impulse = Area under curve...**

\[
\int F \, dt = \bar{F}_{\text{AVG}} \Delta t
\]