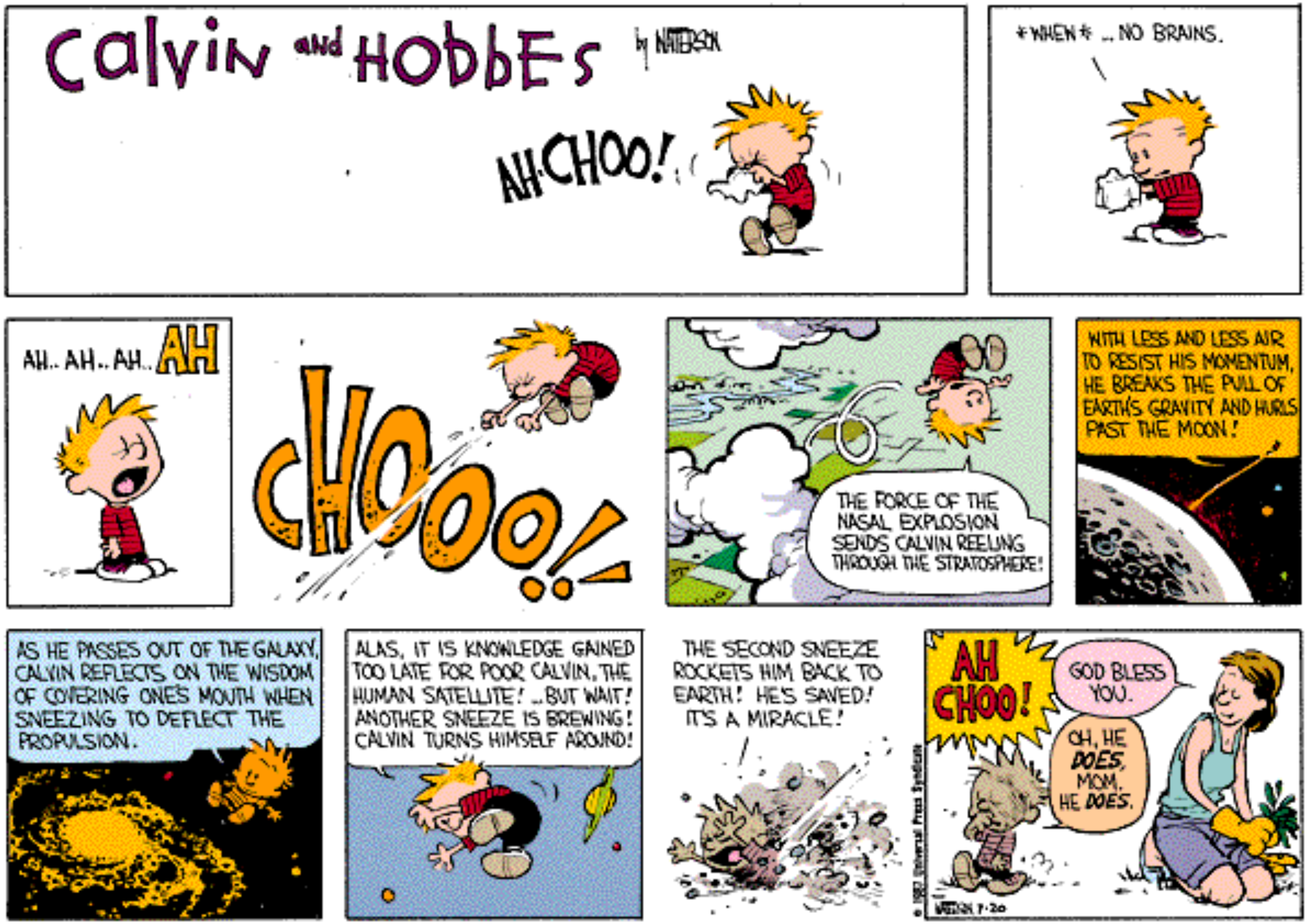
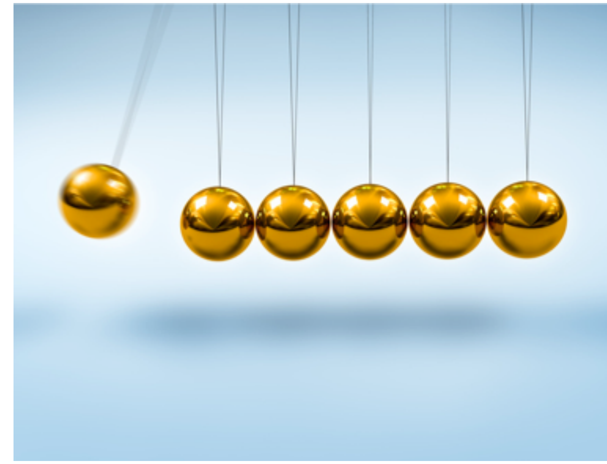
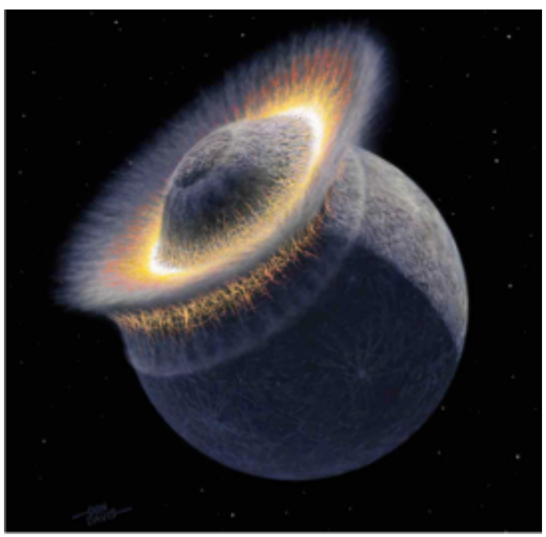
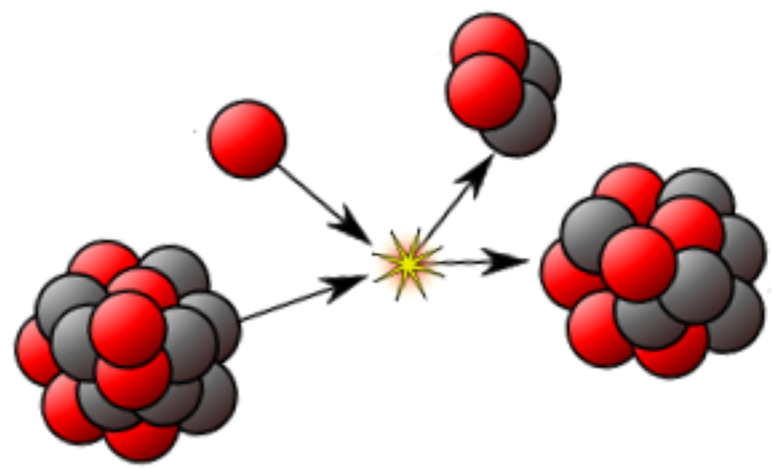

Calvin and HOBBES
by WATTERSON
AH-CHOO!
WHEW ...NO BRAINS.
AH.. AH.. AH.. AH
CHOOO!!
THE FORCE OF THE NASAL EXPLOSION SENDS CALVIN REELING THROUGH THE STRATOSPHERE!
WITH LESS AND LESS AIR TO RESIST HIS MOMENTUM, HE BREAKS THE PULL OF EARTH'S GRAVITY AND HURLS PAST THE MOON!
AS HE PASSES OUT OF THE GALAXY, CALVIN REFLECTS ON THE WISDOM OF COVERING ONE'S MOUTH WHEN SNEEZING TO DEFLECT THE PROPULSION.
ALAS, IT IS KNOWLEDGE GAINED TOO LATE FOR POOR CALVIN, THE HUMAN SATELLITE! ...BUT WAIT! ANOTHER SNEEZE IS BREWING! CALVIN TURNS HIMSELF AROUND!
THE SECOND SNEEZE ROCKETS HIM BACK TO EARTH! HE'S SAVED! IT'S A MIRACLE!
AH CHOO!
GOD BLESS YOU.
OH, HE *DOES*, MOM. HE *DOES*.
WATTERSON 7-20

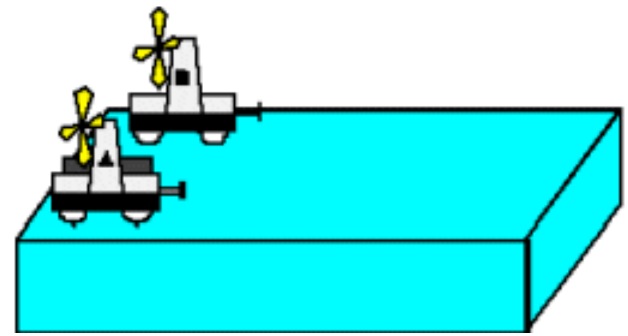


Ch 11- Modeling Multi-Particle Systems





Two fan carts are on opposite sides of a table with their fans pointed in the same direction. Cart A is twice as heavy as cart B. When the fans are on, they cause the air to exert a constant force of the cart independent of its mass. Assume friction can be neglected. The fans are set with a timer so that after they are switched on, **they stay on for a fixed length of time, Δt, and then are turned off**.



Just after the fans are turned off, which is true about the momenta of the two carts?

(A) $\mathbf{p}_A > \mathbf{p}_B$
(B) $\mathbf{p}_A < \mathbf{p}_B$
(C) $\mathbf{p}_A = \mathbf{p}_B$

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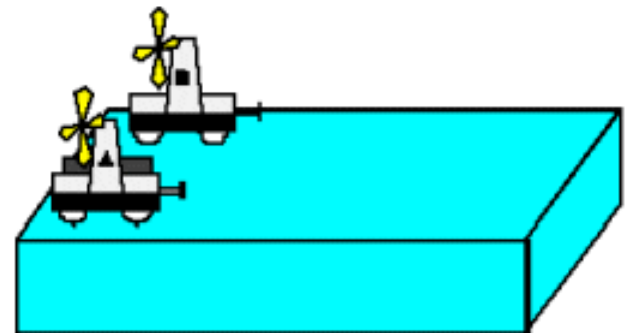

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Since the force applied is the same on the two carts; and the time the force is exerted is the same; the change in momentum must be the same. Since both carts start at rest their initial momenta is equal and thus their final momenta must be equal.

Announcements

- Reading Questions for Ch 12 due tomorrow night at midnight
- First set of Homework on Ch 11 due on Friday at midnight

Momentum of System of Particles

- Momentum: a vector quantity that depends on both mass and velocity of the object of interest

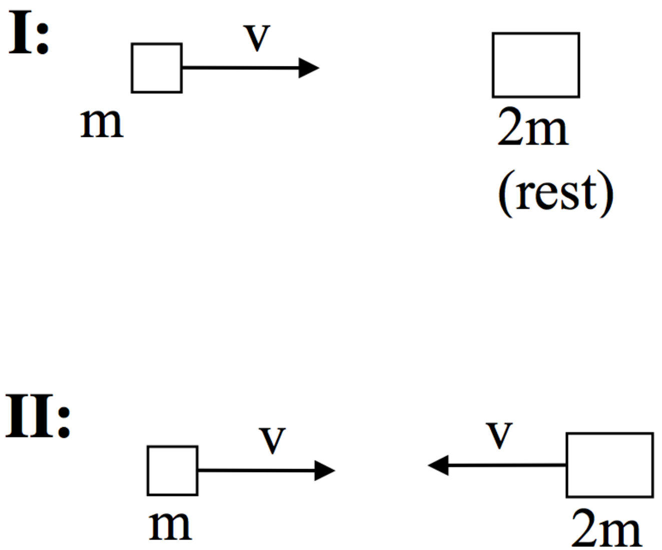
$$\vec{p} = m\vec{v}$$

- A system of particles would have a total momentum that is equal to the sum of the individual momentums

$$\vec{p}_{\ total} = \sum_i \vec{p}_i = \sum_i m_i v_i = m_1 \vec{v}_{\ i} + m_2 \vec{v}_2 + m_3 \vec{v}_3 + \ldots$$

In which situation is the magnitude of the momentum the largest?

A. Situation I has the larger total momentum
B. Situation II has the larger total momentum
C. Same magnitude of total momentum in both cases



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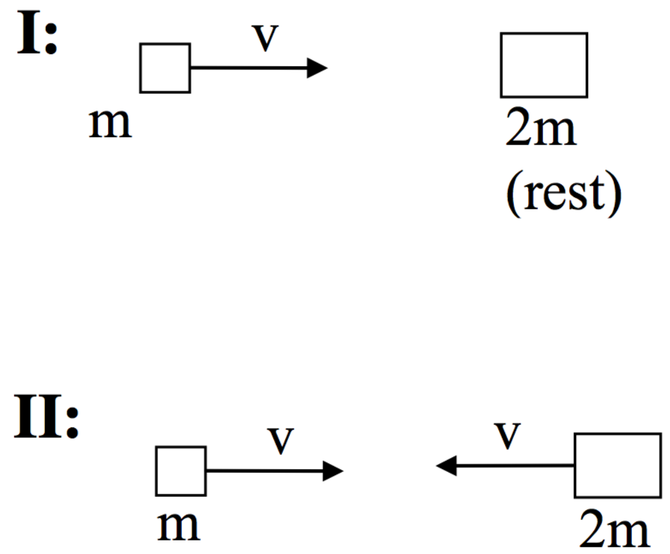


If both blocks are in the system
I: p = mv +0 = mv
II: p = mv -2mv = -mv
So in terms of magnitude they are equal

Newton's 2nd Law AKA: "The Momentum Principle"

- Momentum: a vector quantity that depends on both mass and velocity of the object of interest

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

- Changes in momentum are achieved by exerting a net force on the system

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

- What happens in a system of multiple particles?

$$\frac{d\vec{p}_{tot}}{dt} = ???$$

$$\vec{p}_{total} = \sum_i \vec{p}_i = \vec{p}_1 + \vec{p}_2 + \vec{p}_3 + \ldots$$

$$\frac{d\vec{p}}{dt} = \frac{d(\vec{p}_1 + \vec{p}_2 + \vec{p}_3 + \ldots)}{dt}$$

$$\frac{d\vec{p}}{dt} = \frac{d\vec{p}_1}{dt} + \frac{d\vec{p}_2}{dt} + \frac{d\vec{p}_3}{dt} + \ldots$$

$\vec{F}_{\text{net (on 1)}}$

$$\vec{F}_{net->1} = \vec{F}_{2->1} + \vec{F}_{3->1} + \vec{F}_{external->1} + \ldots.$$

Continued on next slide.

$$\frac{d\vec{p}_{tot}}{dt} = \frac{d\vec{p}_1}{dt} + \frac{d\vec{p}_2}{dt} + \frac{d\vec{p}_3}{dt}$$

$$\hookrightarrow \vec{F}\Delta t = \Delta\vec{p}$$

$$\frac{d\vec{p}_1}{dt} = \vec{F}_{net(1)}$$

$$= \vec{F}_{2\to1} + \vec{F}_{3\to1} + \vec{F}_{ext\to1} + \vec{F}_{1\to2} + \vec{F}_{3\to2} + \vec{F}_{ext\to2}$$

$$+ \vec{F}_{1\to3} + \vec{F}_{2\to3} + \vec{F}_{ext\to3}$$

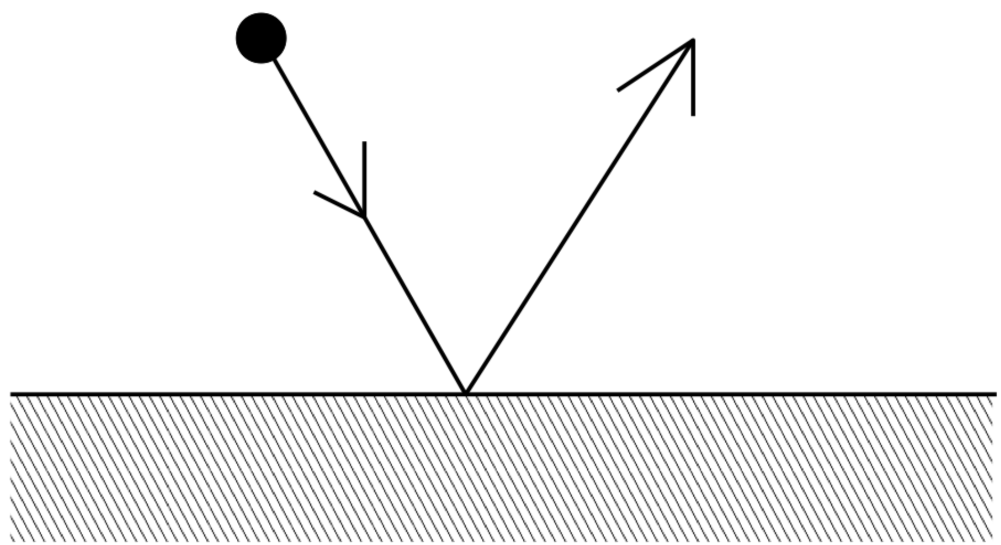
N3 : $\vec{F}_{1\to2} = -\vec{F}_{2\to1}$

$$\frac{d\vec{p}_{tot}}{dt} = \vec{F}_{ext\to1} + \vec{F}_{ext\to2} + \vec{F}_{ext\to3}$$

$$\boxed{\frac{d\vec{p}_{tot}}{dt} = \vec{F}_{ext\to sys}}$$

A ball bounces off the floor elastically, the direction of the change in momentum is …

A. Straight up
B. Straight down
C. To the left
D. To the right
E. Something else



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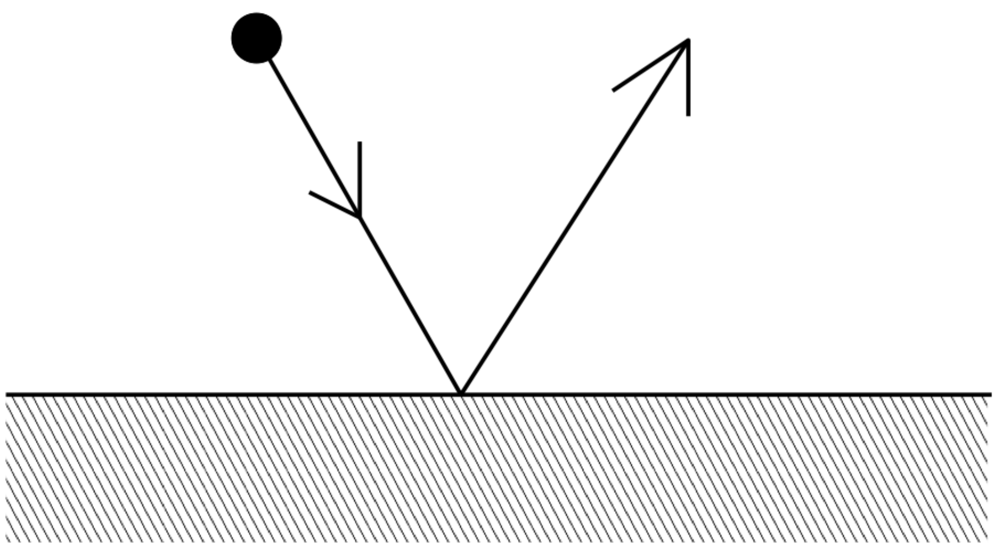
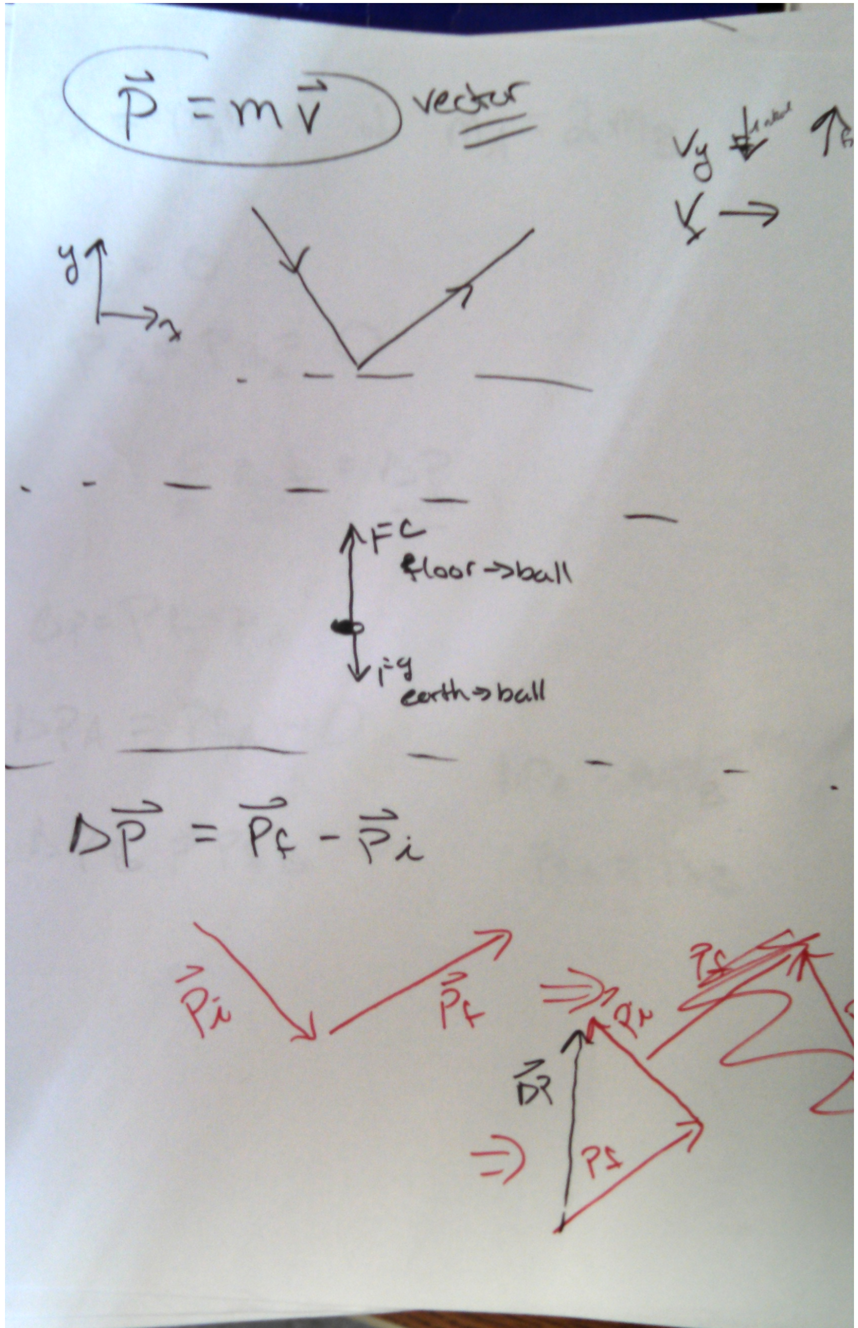


3 different ways to think about this – see next slide.



Change in the velocity vector by components:
x-direction no change
y-direction now going up instead of down.

The force the floor exerts is up and the change in momentum is a result of an external force so change in momentum is up.

Vector addition. The vector sum of $p_f – p_i$ gives you the change in momentum, which is up.

Momentum of System of Particles

- For a *system* of particles, the rate of change of of the total momentum (p_{tot}) is equal to the net external force on the system

$$\frac{d\vec{p}_{sys}}{dt} = \vec{F}_{external}$$

$$\Delta KE = W_{surroundings}$$

- What happens when the external force is zero (or very small compared to the internal interactions)?

$$\frac{d\vec{p}_{sys}}{dt} = 0$$

<u>Momentum is conserved</u>

A 5 kg skateboard is moving across a frictionless floor at 2.0 m/s. A 70 kg boy, riding the skateboard, jumps off so that he hits the floor with zero velocity. What's the velocity of the board after the boy jumps off?

A. 30 m/s
B. 75 m/s
C. 2 m/s
D. 16 m/s
E. Something else

A 5 kg skateboard is moving across a frictionless floor at 2.0 m/s. A 70 kg boy, riding the skateboard, jumps off so that he hits the floor with a velocity of 1.0 m/s in the opposite direction. What's the velocity of the board after the boy jumps off?

A. 30 m/s
B. 75 m/s
C. 2 m/s
D. 16 m/s
E. Something else