Spring 2013

PHYS-2010

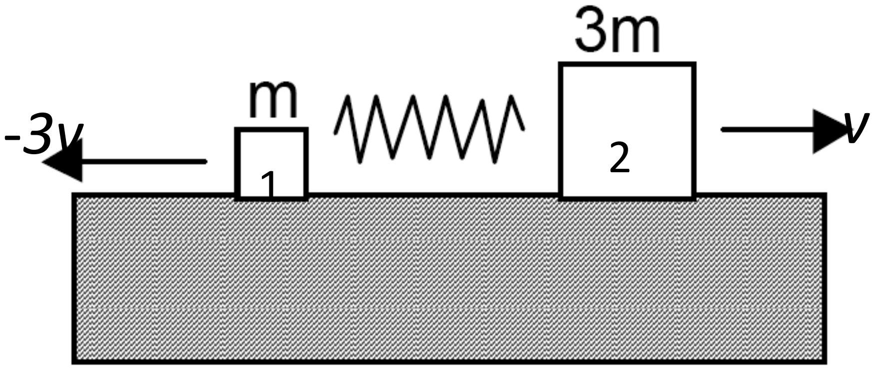
Lecture 26

Clicker Question

Room Frequency BA

Two masses of size **m** and **3m** are at rest on a frictionless table.

A compressed, massless spring between the masses is suddenly allowed to uncompress, pushing the masses apart.



While the spring is in contact with the masses,

how does the magnitude of the force of **m** on **3m** compare to the magnitude of the force of **3m** on **m**?

A) the same as

B) less than

C) greater than

D) unknown

A cannon of mass **M=1000 kg** fires a cannonball of mass **m=10 kg** with velocity $\mathbf{v_B}$=100m/s.
What is the recoil velocity $\mathbf{v_C}$ of the cannon?

Momentum is conserved

$$p_{initial} = p_{final}$$

$$0 = Mv_C + mv_B$$

$$v_C = -\frac{m}{M} v_B$$

$$v_C = -\frac{10kg}{1000kg} 100m/s = -1m/s$$

What happens to keep the cannon from going back at 1m/s?

ANNOUNCEMENTS

- CAPA Set # 9 due tonight, March 15, at 11:59 pm
- CAPA Set #10 now available, due next Friday.
- Written Homework # 6 due Monday, March 18.
- Reading: finish Giancoli Chapter 7 on Momentum
- Reading for next week: Chapter 8 on Rotation

Section Next Week Reminder

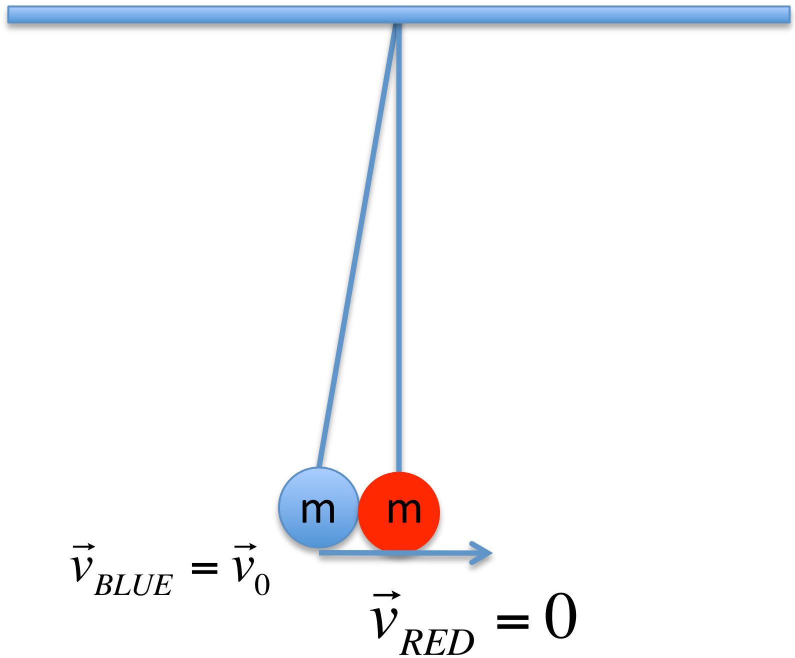
- You must complete at least 5 of the 6 labs to receive a passing grade in this course.
- If you missed a lab, you can make it up during one of two Review/ Lab make-up weeks:
  - **March 19-21 (labs 1-3)**
  - **April 30 – May 2 (labs 4-6)**
- Even if you don't need to make up a lab, you still **must** attend your section those weeks for the Review Recitation.
- To make up a lab, contact your TA **ahead of time**.

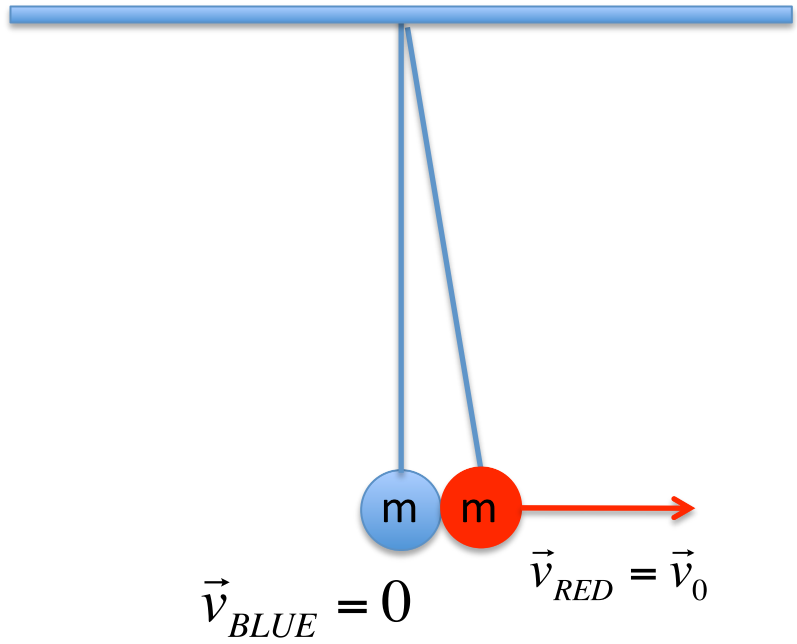
  You will need to arrange attending twice: (1) for lab make-up

  and (2) for the review recitation. You can attend any other section (in addition to your regular section), if you have that section's TA permission in advance.

Clicker Question

Consider a suspended blue sphere that collides **elastically** with a suspended red sphere.

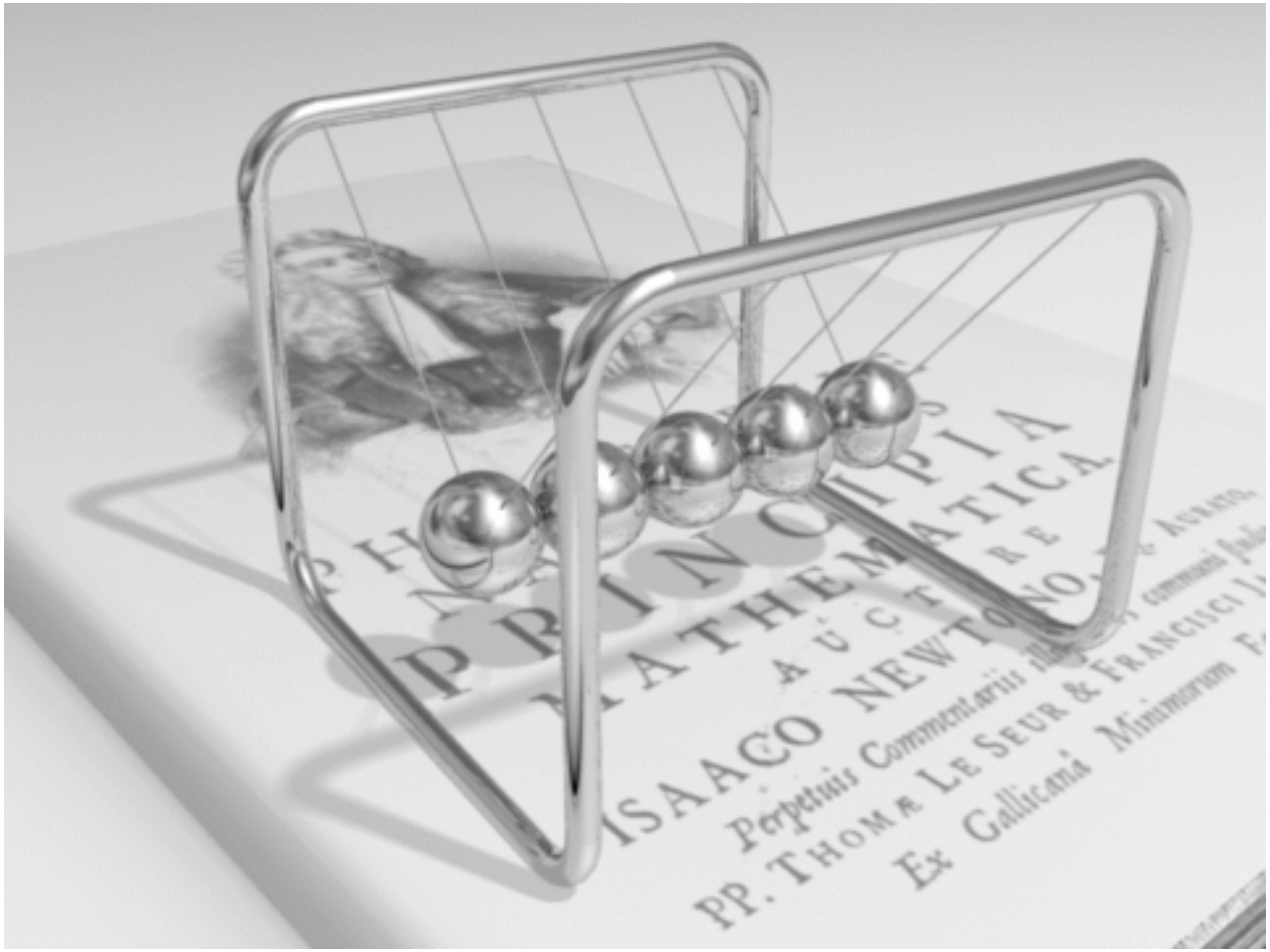




After impact, is the situation at right possible: A) Yes B) No

Exactly as we derived for an elastic collision between two equal mass objects.

Newton's Cradle

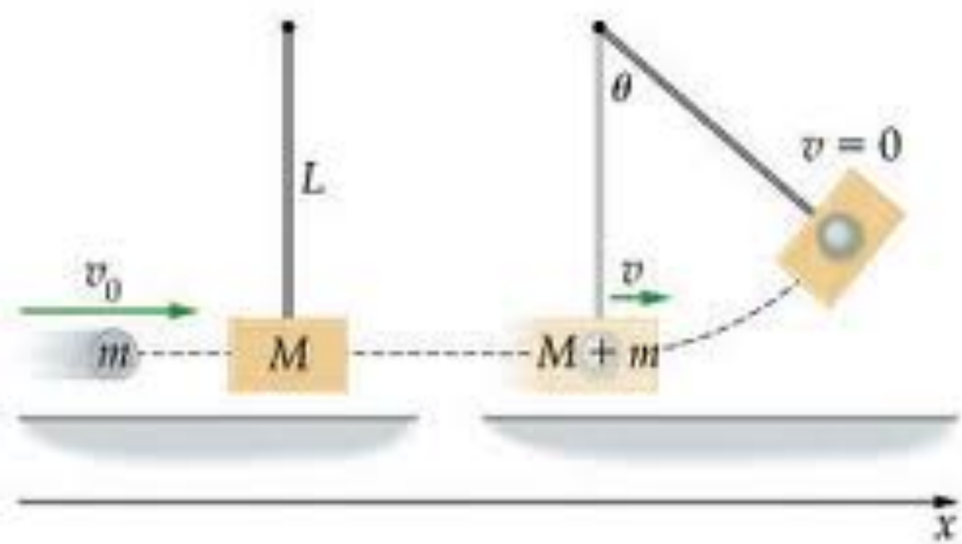


Clicker Question

Room Frequency BA

Ballistic Pendulum

A bullet of mass **m** with initial horizontal velocity $\mathbf{v_0}$ is fired into a large suspended block of mass **M**.



Which of the following is true for the initial collision?

A) Only energy is conserved

B) Only momentum is conserved

C) Only kinetic Energy is conserved

D) Energy and momentum are conserved

E) Kinetic energy and momentum are conserved

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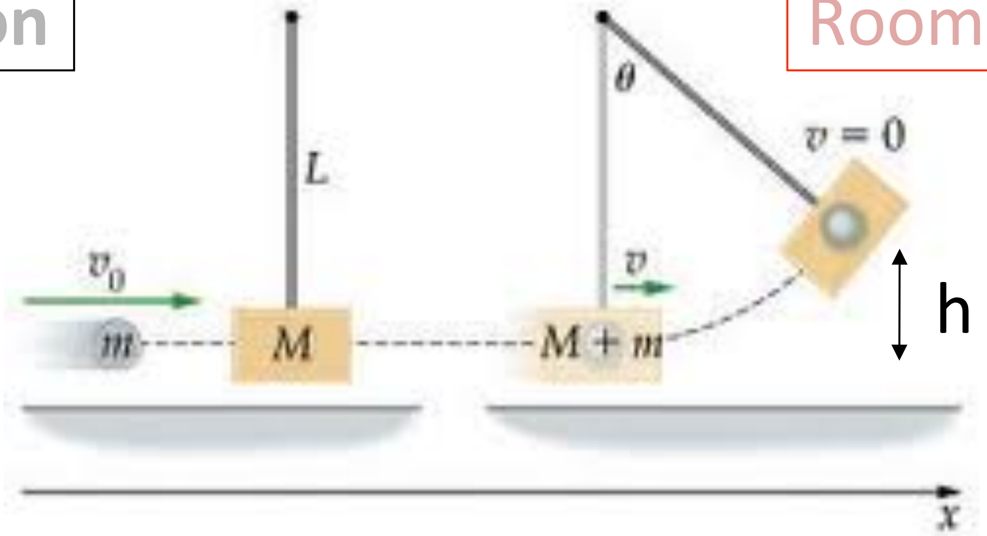
Room Frequency BA



For the initial collision where the bullet hits the pendulum, can there be zero thermal energy generated?

A) Yes

B) No

$$KE_i + PE_i \stackrel{?}{=} KE_f + PE_f$$

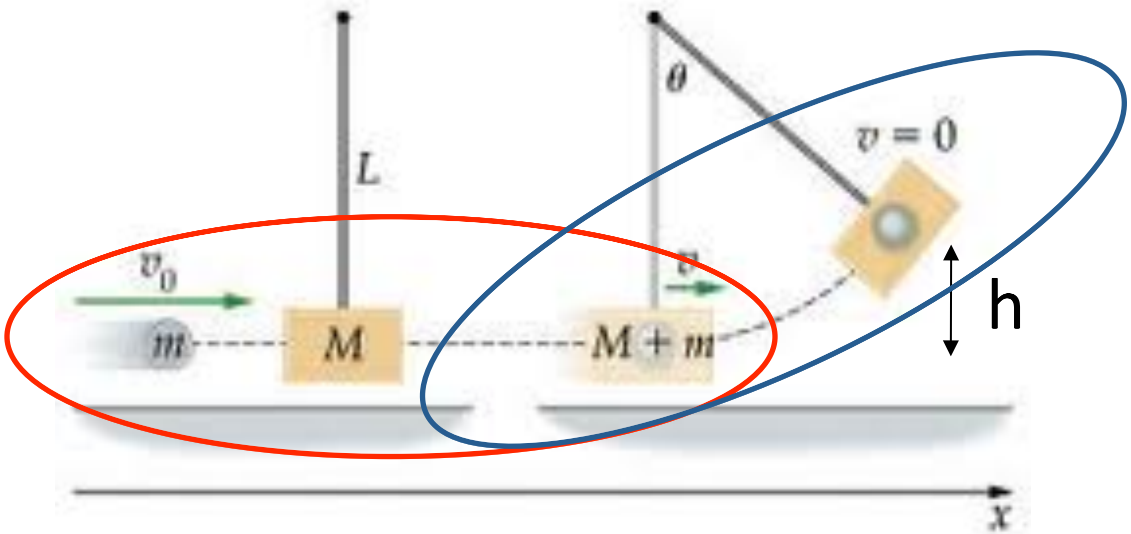
$$\frac{1}{2}mv_0^2 + 0 = \frac{1}{2}(M+m)v^2 + 0 \Rightarrow v = \sqrt{\frac{m}{M+m}}v_0$$

Impossible

$$mv_0 = (M+m)v \Rightarrow v = \frac{m}{M+m}v_0$$

Clicker Question

Room Frequency BA



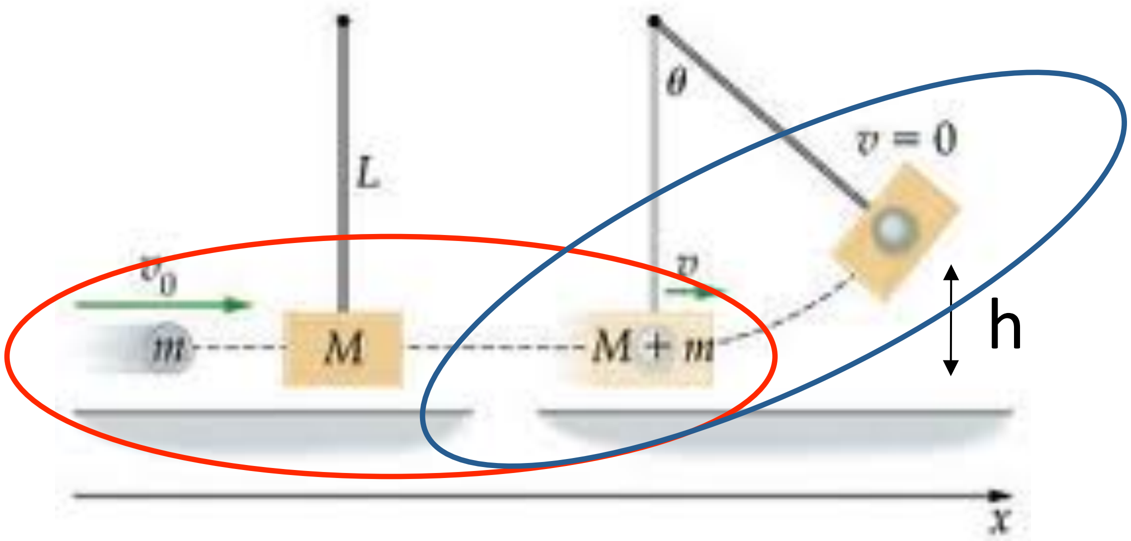
Is the momentum of the system (M+m) conserved for the second part?

A) Yes

B) No

No, because an external net force is acting (gravity)!

We say so often the momentum is conserved, but it clearly cannot be if a net external force is acting on the system.



However, gravity is a conservative force and so mechanical energy is still conserved (neglecting friction, air resistance).

$$KE_i + PE_i = KE_f + PE_f$$

$$\frac{1}{2}(M+m)v^2 + 0 = (M+m)gh$$

$$h = \frac{v^2}{2g}$$

IMPULSE

Momentum is conserved ($\Delta p = 0$) if ***no net force*** operates during the interaction of two objects.

But, what if we only consider a single object or

if F_{net} is non-zero?

$$\vec{F}_{net} = m\vec{a} = m\frac{\Delta\vec{v}}{\Delta t}$$

$$\vec{F}_{net}\Delta t = m\Delta\vec{v} = \Delta(m\vec{v}) = \Delta\vec{p}$$

Impulse: $\vec{I} = \vec{F}_{net}\Delta t = \Delta\vec{p}$

= net force x time = change in momentum

Clicker Question

Room Frequency BA

$$\vec{I} = \Delta\vec{p} = \vec{F}_{net}\Delta t$$

A ball bounces off the floor as shown. The direction of the impulse of the ball, $\Delta\vec{p}$, is

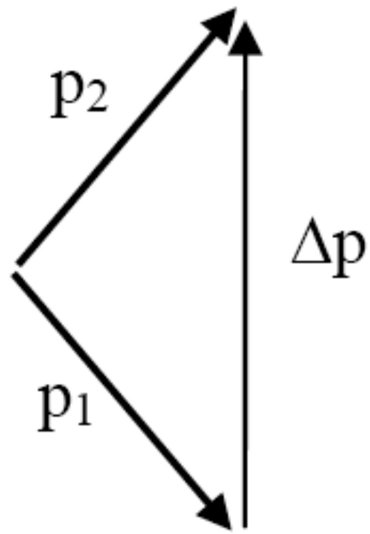
A) Straight up,

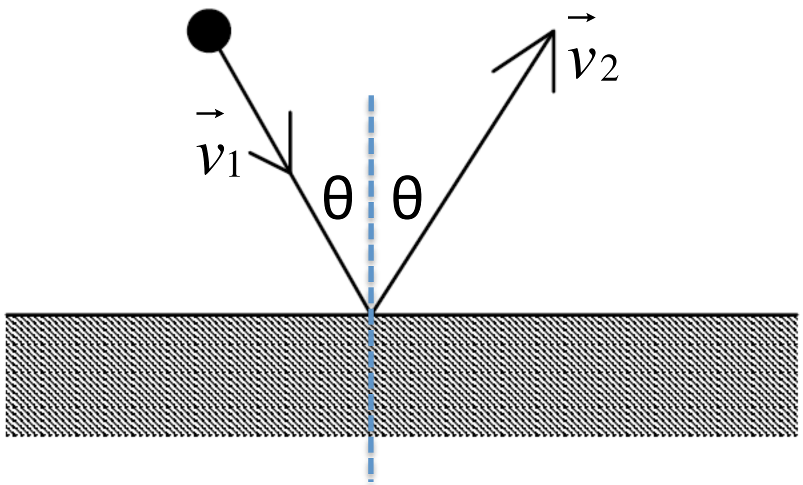
B) Straight down,

C) To the right,

D) To the left,

E) Indeterminate.





Note: the angle of incidence is equal to the angle of reflection.

$$\vec{p}_1 + \Delta\vec{p} = \vec{p}_2$$

$$\vec{p}_1 = (p_x, -p_y)$$

$$\vec{p}_2 = (p_x, p_y)$$

$$\Delta p = \vec{p}_2 - \vec{p}_1 = (p_x, p_y) - (p_x, -p_y)$$

$$= (0, 2p_y)$$

Clicker Question

$$\vec{I} = \Delta\vec{p} = \vec{F}_{net}\Delta t$$

Room Frequency BA

A fast-ball thrown at a batter has a momentum of magnitude $|p_i|$ = (0.3kg)(40m/s) = 12 kg m/s.

The batter hits the ball back in a line drive with momentum of magnitude $|p_f|$ = (0.3kg)(80m/s) = 24 kg m/s.

What is the magnitude of the impulse $|\Delta p|$?

A) 12 kg m/s
B) 24 kg m/s
C) 36 kg m/s
D) 0 kg m/s
E) None of these.

$P_{initial}$ = + 12 kg m/s

P_{final} = - 24 kg m/s

|Impulse|=|ΔP| = |-24 –(+12)|=36 kg m/s

Air Bags and Impulse

About 15 to 20 milliseconds after the collision occurs the crash sensors decide whether or not the collision is serious enough to inflate the airbag (usually 23 km/h = 14 mph).

It takes about 20 milliseconds to inflate the airbag.

At around 60 milliseconds the person has made contact with the airbag and the airbag now starts to deflate.

The passenger continues to be acted on by the airbag as it is in the deflation process which takes about 35 to 40 milliseconds.

A 75kg man is involved in a car accident.
He was traveling at 18 m/s (= 40 mph) when he hit a truck.

If he had no airbag in his car and he came to rest against the steering wheel in 5 milliseconds (0.005 seconds) find the force on his body.

$$\text{Impulse} = F\,\Delta t = \Delta p = m\,\Delta v$$

$$F = (m\,\Delta v) / \Delta t$$

$$F = (75\text{kg})(-18\text{m/s}) / (0.005\text{s})$$

$$F = -\,270{,}000 \text{ Newtons}$$

If he had an airbag that inflated and deflated correctly, bringing him to rest over a time of 50 msec = 0.05 s, find the force on his body.

$$F = (m\,\Delta v) / \Delta t$$

$$F = (75\text{kg})(-18\text{m/s}) / (0.05\text{ s})$$

$$F = -\,27{,}000 \text{ Newtons} \quad (a = 37\text{ g})$$

Which is only about 10% of the force felt without an airbag…
a definite improvement!