

Today - Lecture 11

- Begin chapter 10 on collisions, ...
- Hope to finish discussing chapter 10 on Wednesday and make start on chapter 11 (rotations)
- Homework 5 due on Wednesday

Recent News of Note

THE NEW YORK TIMES NATIONAL SATURDAY, OCTOBER 11, 2003

A 'Cosmic Jerk' That Reversed the Universe

By DENNIS OVERBYE

CLEVELAND, Oct. 10 — Astronomers said on Friday that they had determined the time in cosmic history when a mysterious force, "dark energy," began to wrench the universe apart.

Five billion years ago, said Dr. Adam Riess, an astronomer at the Space Telescope Science Institute in Baltimore, the universe experienced a "cosmic jerk." Before then, Dr. Riess said, the combined gravity of the galaxies and everything else in the cosmos was resisting the expansion, slowing it down. Since the jerk, though, the universe has been speeding up.

The results were based on observations by a multinational team of astronomers who used the Hubble Space Telescope to search exploding stars known as Type Ia supernovas, reaching back in time three-quarters of the way to the Big Bang, in which the universe was born. The results should help quell remaining doubts that the expansion of the universe is really accelerating, a strange-sounding notion that has become a pillar of a new and widely accepted model of



Marty Katz for The New York Times

Dr. Adam Riess, who reported yesterday on the speeding and expanding universe, at the Space Telescope Science Institute in Baltimore.

The goal was to measure how much the universe was being slowed down by the gravity of galaxies. Collaborators found Hubble observations of a supernova 10 billion years ago.

Surgery to Part Two

By DENISE GRADY

In an operating room in Dallas this morning, surgeons are to begin the delicate and arduous task of trying to separate Ahmed and Mohamed Ibrahim, 2-year-old twins from Egypt who are joined at the tops of their heads.

The brothers have been in Texas since June 2002, undergoing tests and physical therapy while surgeons from Children's Medical Center and Medical City Dallas Hospital labored to develop a strategy to separate the boys without killing them or causing severe brain damage.

Dr. Dale Swift, one of five neurosurgeons scheduled to operate on the procedure could take 15 to 20 hours. "But who knows?" Dr. Swift added. "It takes what it takes."

One thing that may be true, he said, is that the operating table that the boys are on will not roll them to get to their heads. The skulls in general, boys' bodies are joined at the top of their heads.

Swift said, a "sacred" operation. He said he was so determined to do a 50 percent operation that he accepted that risk.

$$v = \frac{dx}{dt} \quad \text{velocity}$$

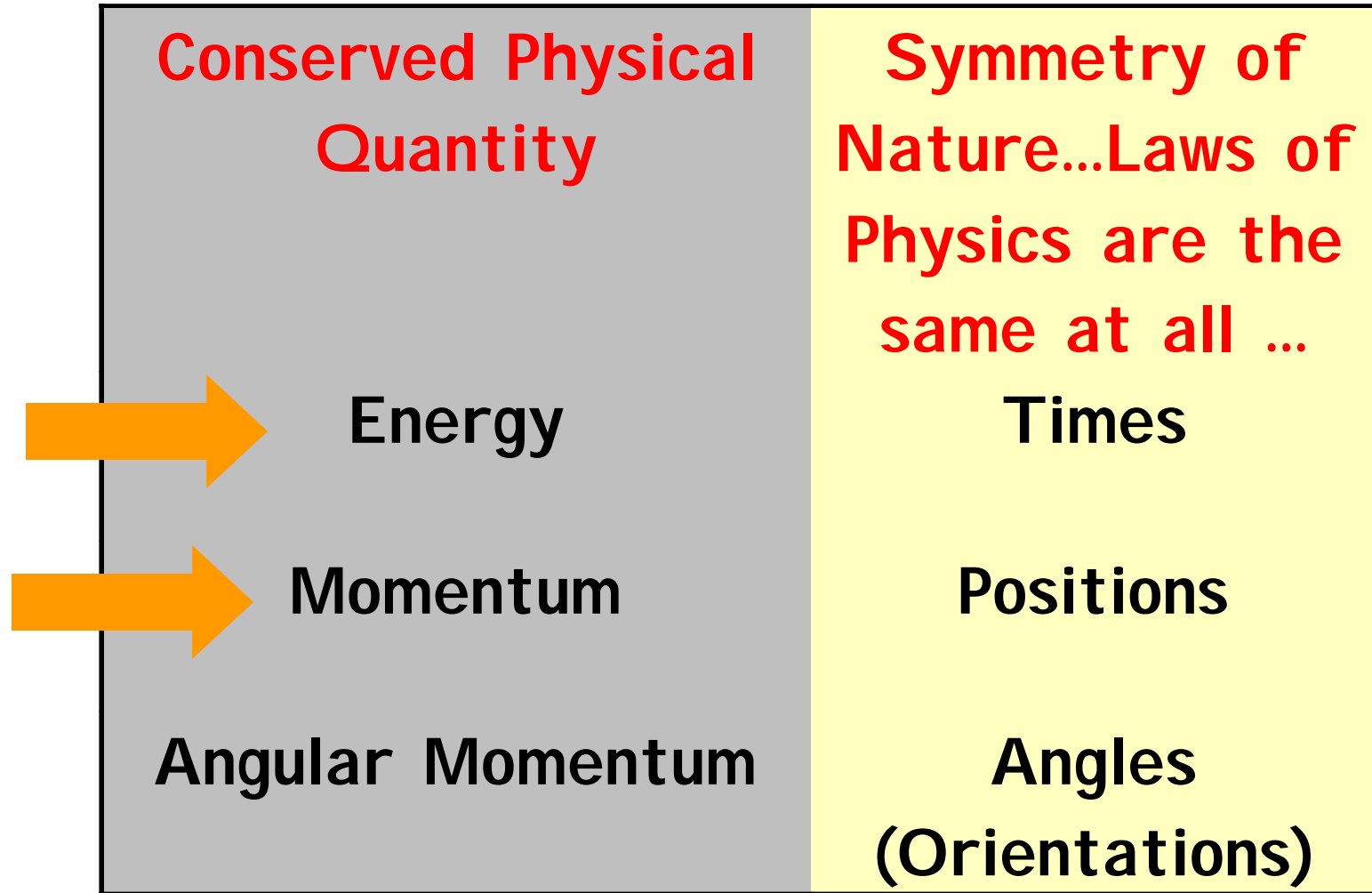
$$a = \frac{dv}{dt} \quad \text{acceleration}$$

$$j = \frac{da}{dt} \quad \text{jerk}$$

- The guy is not the 'jerk'
- He is one of the discoverers
- Example of forefront stuff that relates to concepts of this course ... does not invalidate what you know - part of ongoing process to enhance knowledge

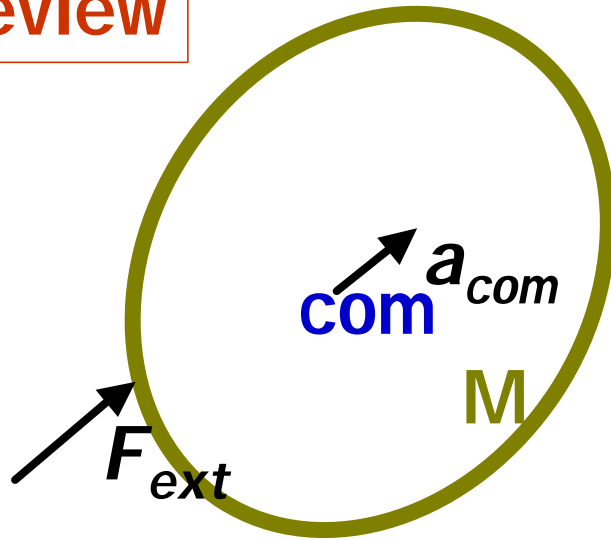
review

Conservation Laws and Symmetry Principles



Momentum and Newton's 2nd Law

review



$$\vec{P}_{com} = M\vec{v}_{com} = \sum_{i=1}^n m_i \vec{v}_i$$

$$\vec{F}_{ext} = \frac{d\vec{P}_{com}}{dt}$$

$$\vec{F} = \frac{d\vec{P}}{dt}$$

more general way of writing Newton's Second Law and more useful than the old way ($F=ma$)

$F = dP/dt$ is more generally correct than $F = ma$!



$$\vec{F} = \frac{d\vec{P}}{dt}$$

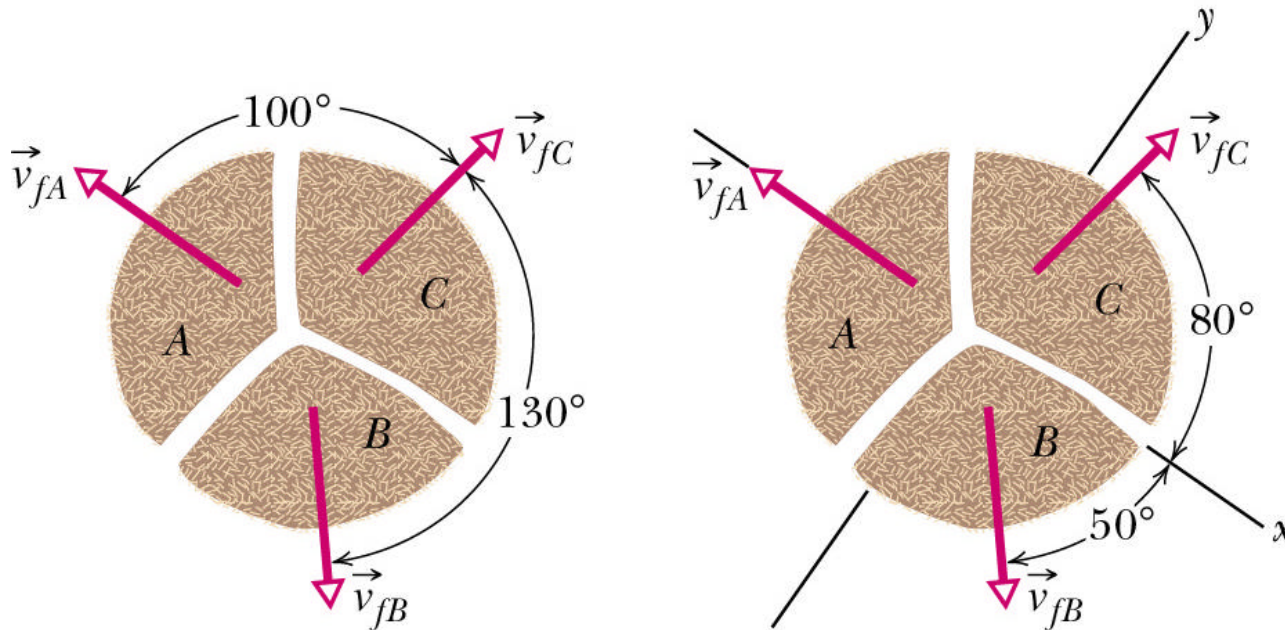
Force on man =
- Force on Hose

$$F = 300 \text{ N}$$

- Suppose water flows at rate of 15.0 kg/s at a speed of 20 m/s .
- You know that the fireman must hold the hose! How much force?
- Net momentum leaving the hose ... means that hose (and contents) exert net force on the water leaving
- Means that water leaving exerts equal and opposite force on the man!
- Someone must hold the hose with this force (or it will move).

Other Examples: $P_{com} = 0$ and fixed

- Sample Problem 9-7 ... cases where $v_{com} = 0$ and position of com stay fixed ... exploding coconut at rest initially ... understand



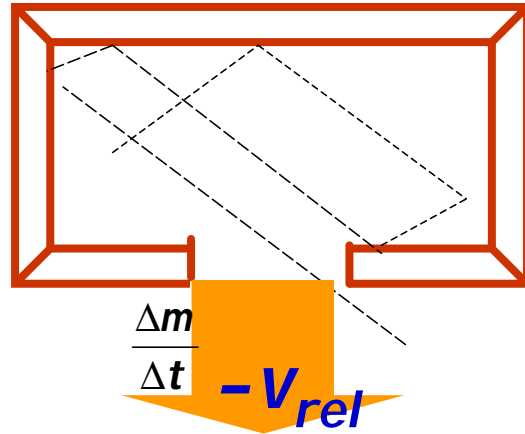
Another case:
pendulum on
glider



cm fixed of pendulum on glider.MOV

$$M_A \vec{v}_A + M_B \vec{v}_B + M_C \vec{v}_C = 0$$

Rockets and Jets



- What happens inside a rocket or jet engine as at left?

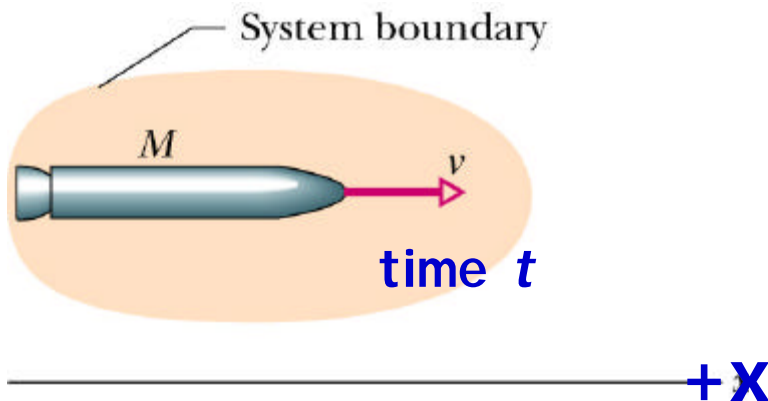
- ◆ Can be thought of as a very hot furnace (combustion chamber) with one opening
- ◆ Hot stuff inside can only get out one way -- through the opening -- rate $R = \frac{1}{2}dM/dt$
- ◆ Call v_{rel} = velocity of rocket relative to exhaust = -velocity of exhaust relative to rocket (det by combustion chamber)
- ◆ Consider over time Dt , the system of rocket + exhaust

- How do rockets work?
- Argued at one time that rockets can't work in space ... nothing to push against --> **WRONG!!**

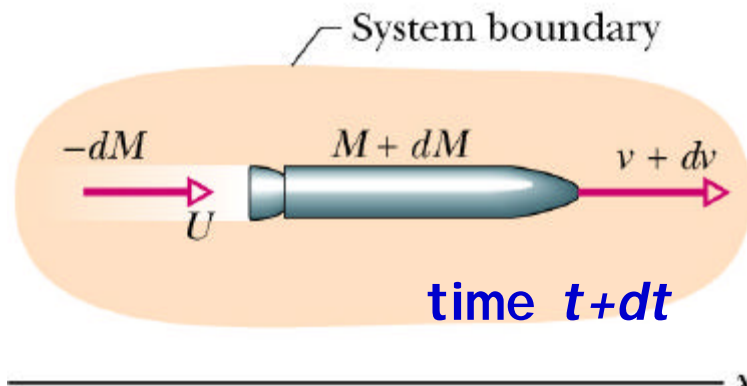


rockets and cons mom.MOV

Analysis of Rockets from Momentum Conservation (See text Section 9-7)



(a)



(b)

- Find P of system at 2 slightly different times: $P(t)$ and $P(t+Dt)$
- Total momentum is conserved for this isolated system: $P(t+Dt)=P(t)$

- Note $dM < 0, v_{rel} > 0$
- $v + dv = v_{rel} + U$

$$[(M + dM)(v + dv) - U dM] - Mv = 0$$

$$Mdv + (v + dv)dM$$

$$- (v + dv - v_{rel})dM = 0$$

$$Mdv = -v_{rel}dM$$

$$M \frac{dv}{dt} = -v_{rel} \frac{dM}{dt}$$

rocket equation

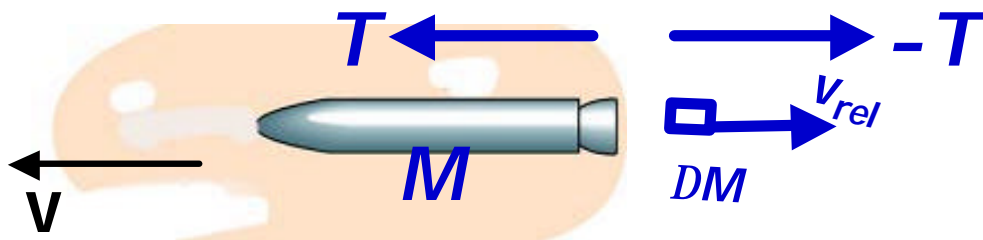
$$\text{THRUST} = v_{rel} R$$

Simple Derivation (already did it)



F on man holding hose is given by

$$F = v_{rel} \frac{dm}{dt}$$



- Force on hose = - Force on expelled mass (water) called the thrust (T)
- Already done in frame where rocket (hose) at rest
- If rocket moving (relative to us) at velocity, v , then force (thrust) on the rocket is

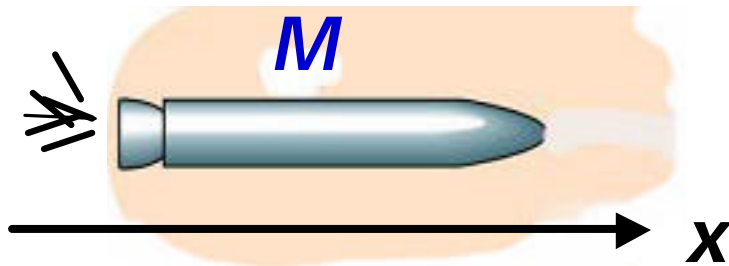
$$T = v_{rel} \frac{dm}{dt} = -v_{rel} \frac{dM}{dt}$$

toward the left in picture

$$-v_{rel} \frac{dM}{dt} = M \frac{dv}{dt}$$

note $\frac{dM}{dt} < 0$

Rockets



$$|Thrust| = M \frac{dv}{dt} = -v_{rel} \frac{dM}{dt}$$

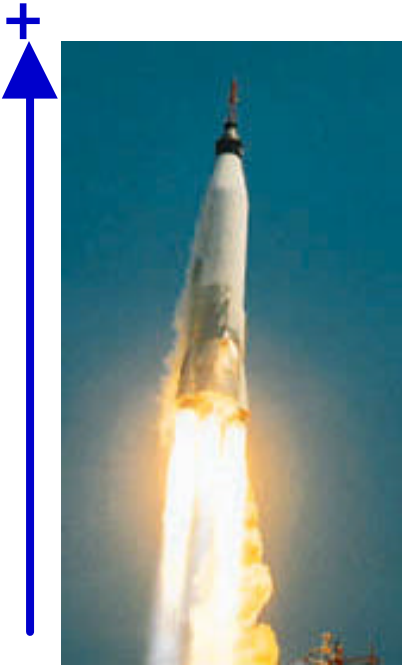
$$M dv = -v_{rel} dM$$

Note v_{rel} and $R = \left| \frac{dM}{dt} \right|$ fixed by conditions (temp, geom) of the combustion chamber; but M and v change.

$$\int_{v_i}^{v_f} dv = -v_{rel} \int_{M_i}^{M_f} \frac{dM}{M}$$

$$v_f = v_i + v_{rel} \ln \frac{M_i}{M_f}$$

Rocket launched from Earth (not in text)



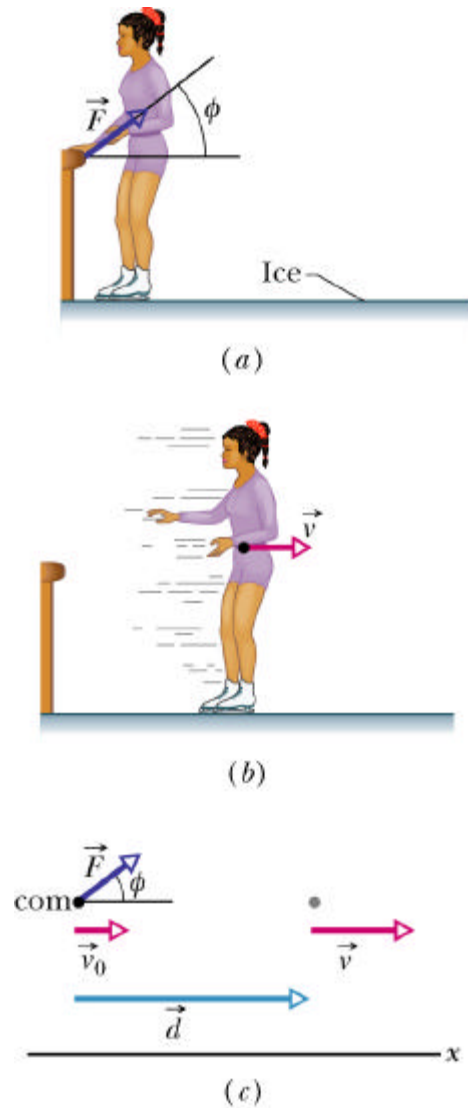
$$M \frac{dv}{dt} = T - Mg$$

$$M \frac{dv}{dt} = -v_{rel} \frac{dM}{dt} - Mg$$

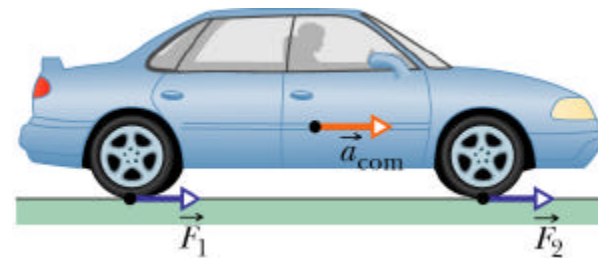
$$v_f = v_i + v_{rel} \ln \frac{M_i}{M_f} - gt \quad \text{with } M_f = M_i - Rt$$

- Biggest payoff is to get rid of the mass FAST ...
 R very large, t small ...
- Be sure to read and understand text discussion of rocket and be able to do rocket problems, in addition to other problems in ch 9 using momentum

Check out section 9-8



- Re-iterates work-energy theorem, but now introduce concept of INTERNAL ENERGY
- Work done by skater increases her kinetic energy ... force on her to accelerate comes from wall
- But wall does no work ... she does ... she uses up some of her Internal Energy to do the work
- Other illustration (car) in text



Impulse and other Momentum Changes: Collisions in Chapter 10

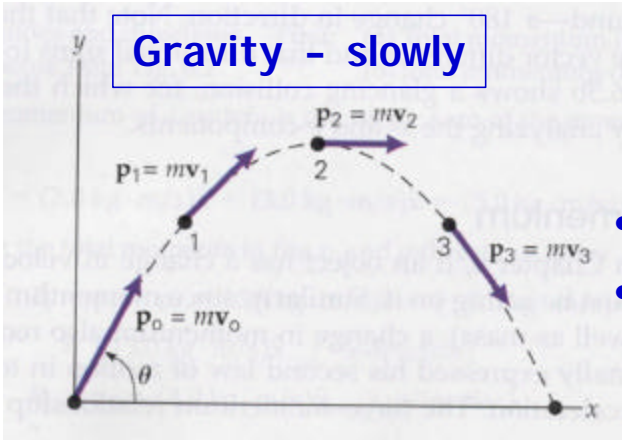


- Cars in collision
- Baseball change in momentum
- Fast picture of football being kicked
- Person in car having life saved



Forces acting over time to change momentum

Gravity - slowly



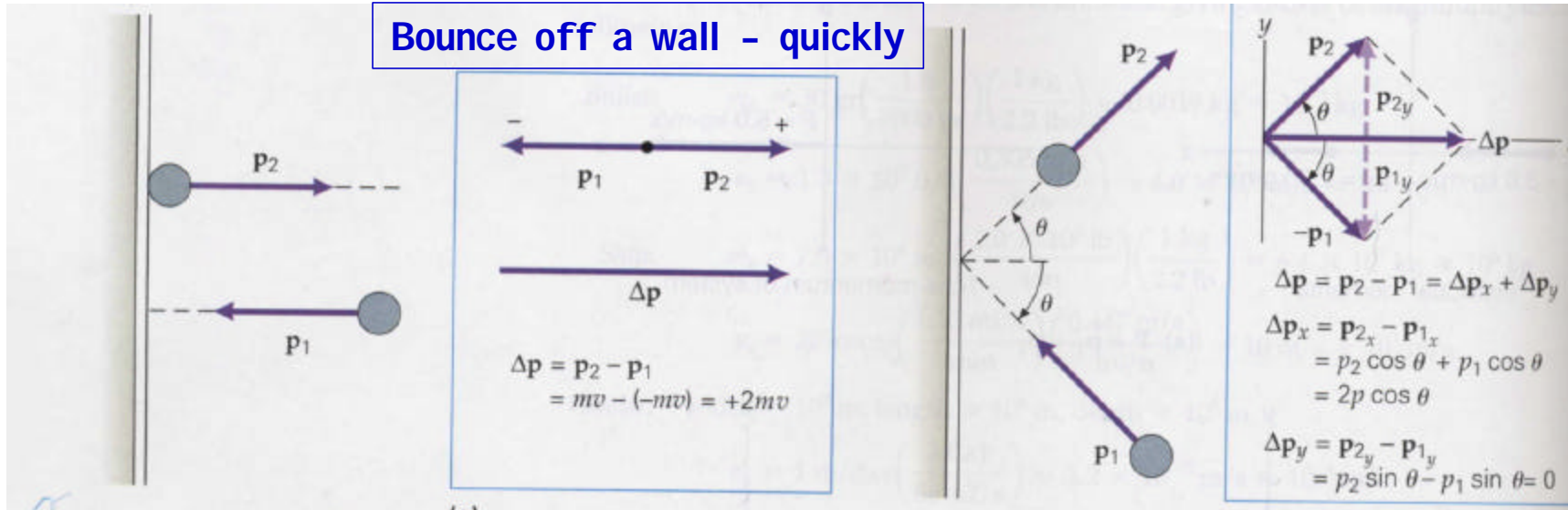
$$F = \frac{\Delta p}{\Delta t}$$

- Examples of real Δp values
- Force bigger, the smaller the time interval, Δt

Stop in a crash - quickly

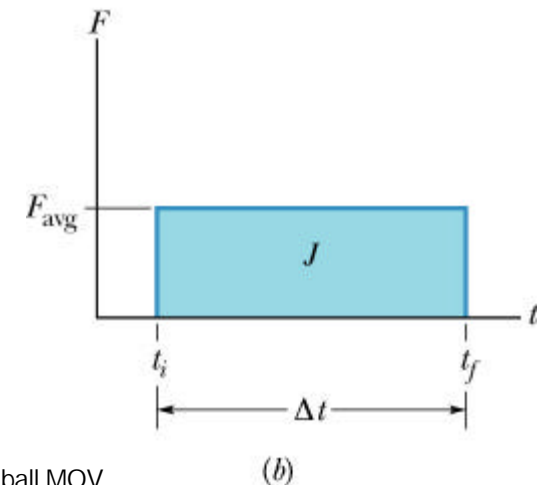
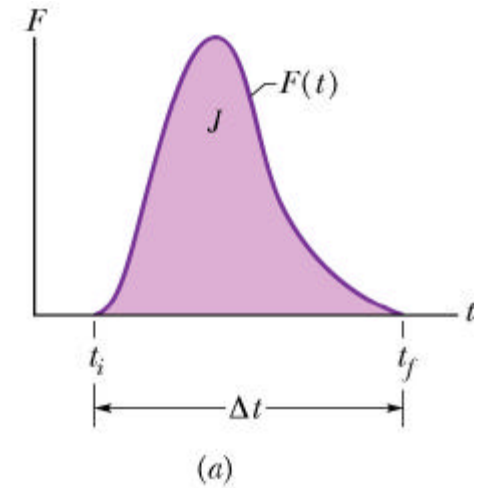
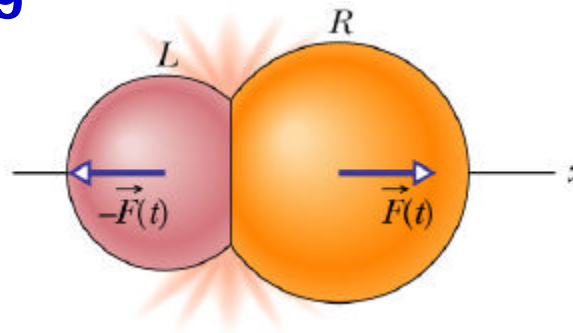


Bounce off a wall - quickly



Impulse=Change in Momentum

- What if just look at one of two colliding bodies?
- Can be big forces, over short time!
- Define impulse, J



$$F = \frac{dp}{dt}$$

$$J \equiv \int_{t_i}^{t_f} F dt = F_{av} \Delta t$$

$$J = \int_{p_i}^{p_f} dp = p_f - p_i = \Delta p$$

 impulse when kick ball.MOV

 impulse when kick ball-impapprox.MOV

Real World Collisions

- Collision forces can be very destructive
- For momentum of each object to change a lot, require large value of impulse
- Bodies, etc survive better if forces small (times long)

$$\mathbf{J} \equiv \int_{t_i}^{t_f} \mathbf{F} dt = \mathbf{F}_{av} \Delta t = \Delta \mathbf{p}$$

$$\mathbf{F}_{av} = \frac{\Delta \mathbf{p}}{\Delta t} \quad \text{Make } \Delta t \text{ large}$$



Lots of examples

Survivability



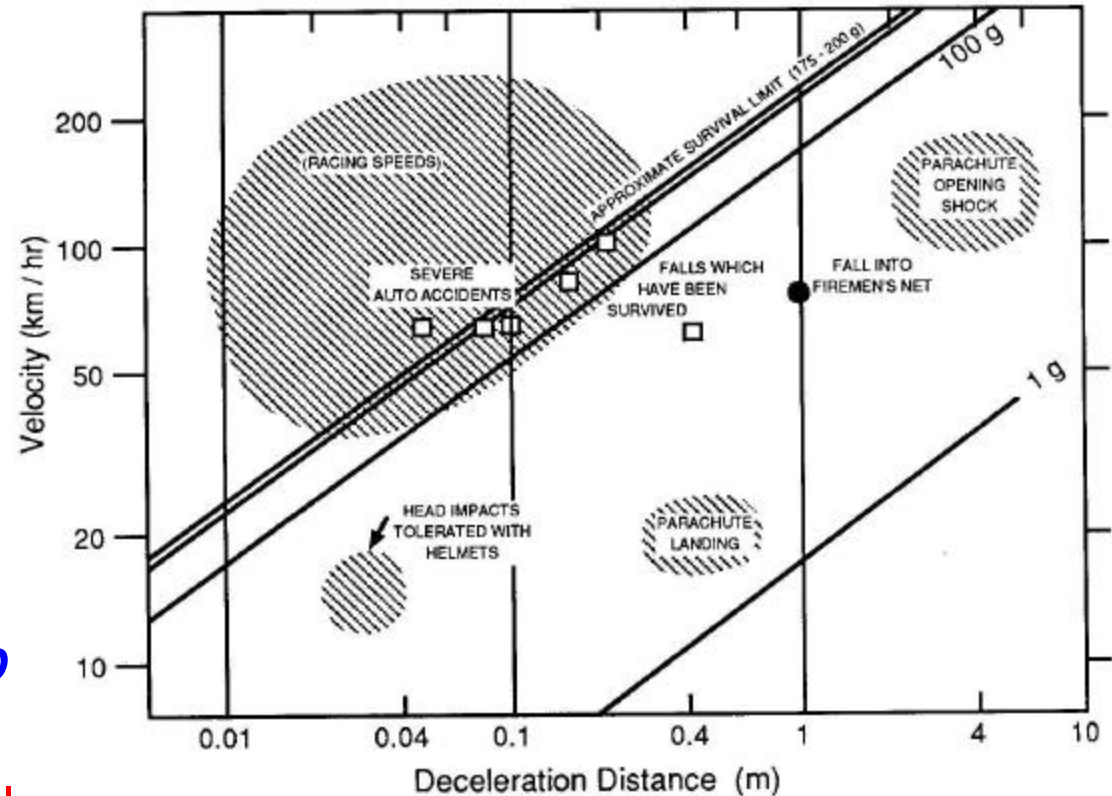
(a)



$$J \equiv \int_{t_i}^{t_f} F dt = F_{av} \Delta t = \Delta p$$

$$F_{av} = \frac{\Delta p}{\Delta t} \quad \text{Make } \Delta t = \frac{\Delta x}{v_{av}} \text{ large}$$

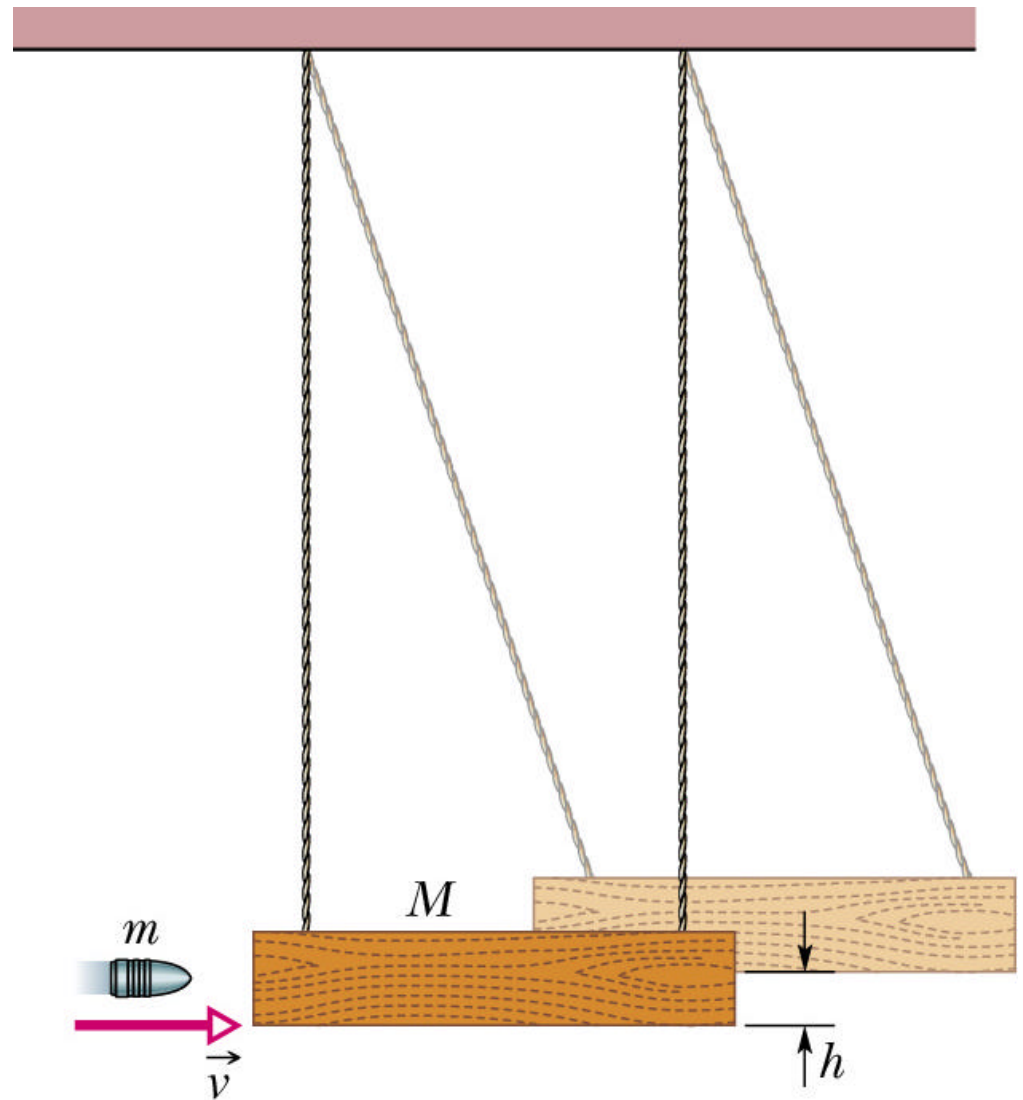
$$\frac{F_{av}}{m} = \frac{v}{\Delta x} v_{av} \approx \frac{1}{2} \frac{v^2}{\Delta x}$$



- Survivability, on average, a consequence of what acceleration is required
- Limits for people average about 175-200 g's, but depend ...

Sample Problem 10-2

- Famous “Ballistic Pendulum” Problem
- Find v from h !
- Illustrates nicely when
 - ◆ momentum conserved
 - ◆ energy conserved
- Illustrates nicely when
 - ◆ momentum not conserved
 - ◆ energy not conserved



Elastic Collisions 1D (sectn 10-5)

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

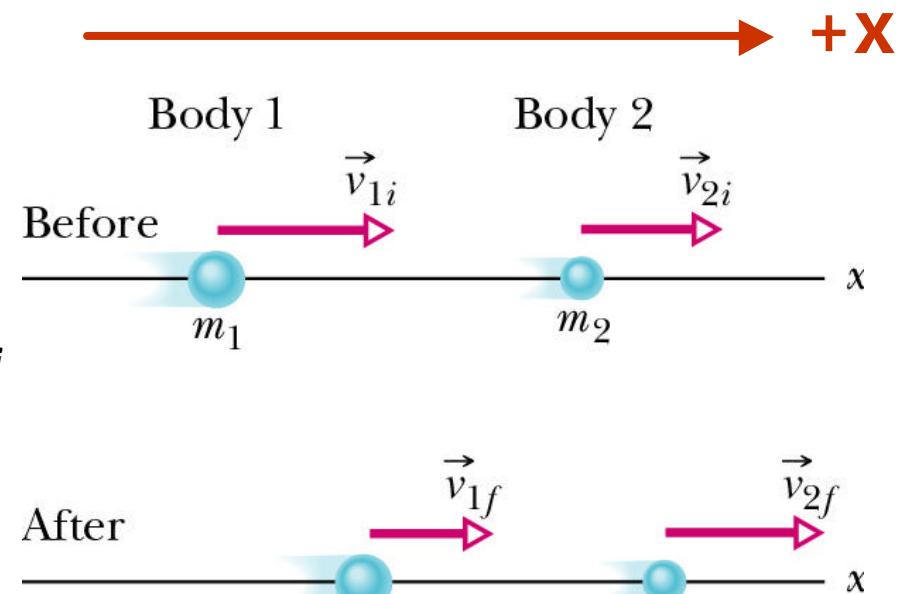
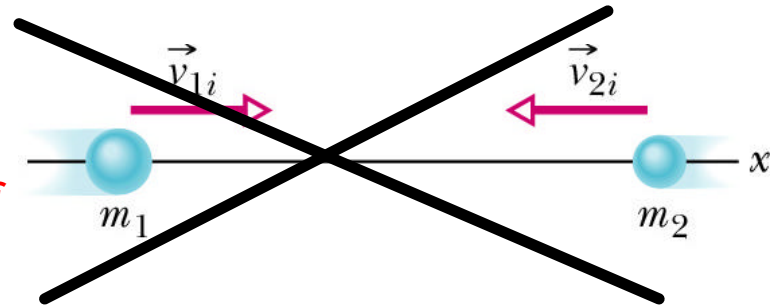
$$\frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2$$

Follow algebra (in text):

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2} v_{1i} + \frac{2m_2}{m_1 + m_2} v_{2i}$$

$$v_{2f} = \frac{2m_1}{m_1 + m_2} v_{1i} + \frac{m_2 - m_1}{m_1 + m_2} v_{2i}$$

Look at consequences
next time



Correct picture...

For convention used

Conclude

- Hope to finish discussing chapter 10 on Wednesday - if time, discuss the **Squirrel vs Sciulli Saga**
- Perhaps begin chapter 11 on rotations
- Homework 5 due on Wednesday