Textbook Reference: Sections 6.3 (Collisions)

Goal/Objectives:
- Understand how momentum and kinetic energy relate to the 3 types of collisions: elastic, inelastic, and perfectly inelastic
- Use projectile equations when an object becomes a horizontal projectile after a collision
- Use energy equations when an object is part of a ballistic pendulum after a collision

Intro:
- try several examples w/ Newton's cradle

(SmartBoard):

2m   m
v   2v

$KE = ½ (2m) (v)^2$ $KE = ½ (m) (2v)^2$

$KE = (m) (v^2)$ $KE = 2 (m) (v^2)$

- analyze the motion of a Newton's cradle
- when 1 marble is started, 1 marble will also rebound from the other side
- when 2 marbles are started, 2 marbles will also rebound from the other side
- how does the Newton's cradle "know" how many marbles should rebound?

- to figure this out, let's see what would happen if it didn't "know" how many marbles should rebound

- look at one possible situation: what if 2 marbles were released from one side and only 1 marble was bounced off of the other side?
- so, the 2 marbles have a mass of 2m . . . the single marble has a velocity of m
- according to conservation of momentum . . . if the 2 marbles have a certain velocity v, what must be the velocity of the single marble?
- it must have a velocity that is twice as big – or a velocity of 2v

- now, what happens when we look at kinetic energy?
- the formula for kinetic energy is ½ mass · velocity squared
- try this equation for the 2 marbles together . . . mass is 2m and velocity is now v^2
- ½ and the 2m cancel out . . . our answer is $m \cdot v^2$

- try this equation for the single marble . . . mass is m and velocity is now (2v) squared
- (2v) squared is $4v^2$
- total KE is $2 \cdot m \cdot v^2$!
- why that is a problem? . . . we have just gained energy, a situation that cannot happen . . . you can't just create energy!

- so, the amount of <u>KE</u> in a collision is important <u>in addition</u> to the amount of <u>momentum</u> in a collision
- how KE & momentum work together in a collision is our topic for today

Homework: C #3, 10
P #28, 29, 30, 54, 58

Videos: Collisions

Equipment: Newton's cradle
Ballistic pendulum

Ballistics powerpoint
golf club collision file ("Hi Speed" file)
ballistics file

- from yesterday, we know that momentum is conserved
- this is true for all types of collisions (we will assume that any friction that acts doesn't kick in until after the collision)

- we know that KE can't be gained (this is why the Newton's cradle example wouldn't work w/ 2 marbles kicking off 1 single marble)
- however, there are some cases where KE is lost
- so, KE does not necessarily have to be conserved
- whether or not KE is conserved determines the type of collision

(B2) Collisions:

- Elastic: p is conserved, KE is conserved — many microscopic, no deforming

- the Newton's cradle is an example of an elastic collision
- (we used this term yesterday . . . we will see today that there are a few more specifics for elastic collisions)
- the true definition of elastic collision is that p and KE are both conserved

- if we release 2 marbles from one side of the Newton's cradle, exactly 2 marbles are bounced off of the other side
- the second pair of marbles has the same mass & velocity as the original pair . . .
- so the second pair of marbles has the same momentum, and the same KE
- (of course we know that since friction exists in real life, very very small amounts of KE have been lost, but basically the KE has been conserved)

- almost all types of "microscopic" collisions are elastic
- for instance, when we study gases and look at the collisions between gas molecules, we will always assume that kinetic energy has been conserved

- large examples of elastic collisions are more difficult to find
- usually colliding objects lose energy to deforming the object
- i.e. car crashes . . . so, car crashes are not even close to being elastic!
- notice that deforming doesn't necessarily mean permanently damaged . . .

(SmartBoard):

- scanned collision photos
- video clip of golf club collision w/ golf ball

- the collision between the volleyball and the force plate involved lost energy b/c the VB "squished," but after the collision it snapped back to its original shape . . . the deforming took energy but was not permanent
- this occurs in most collisions in sports!

- our best examples of macroscopic collisions that are elastic occur when there is very little possibility for something to be deformed
- this is why the Newton's cradle has collisions that are elastic . . . the marbles can't be deformed
- billiard collisions are another example. (remember to bring billiard balls for extra credit on Monday!)

(B2) Collisions:

- Elastic: p is conserved — many microscopic
  KE is conserved — no deforming
  objects same shape & size

(SmartBoard) Elastic Collisions:

Momentum: $m_1 \cdot v_1 + m_2 \cdot v_2 = m_1 \cdot v'_1 + m_2 \cdot v'_2$

KE: $\frac{1}{2} m_1 \cdot v_1^2 + \frac{1}{2} m_2 \cdot v_2^2 = \frac{1}{2} m_1 \cdot v_1'^2 + \frac{1}{2} m_2 \cdot v_2'^2$

$$v_1 + v_1' = v_2 + v_2'$$

- it is also more likely that KE will be conserved if the objects are of similar shape and size, and made from the same types of material
- this again lowers the possibility that energy will be lost to deforming the objects during the collision
- air track carts from yesterday lose very little energy to deformation & are of similar size & material . . . so they are basically elastic collisions

- take a brief look @ the math in elastic collisions . . .
- because we know that KE and p are both conserved, we can actually create two equations for that collision
- one is the conservation of p equation
- the other equation is for the conservation of KE . . . rather long! . . . but it follows the same form as the p equation

- if this applied to a collision like we had yesterday, where the two carts were of unequal mass, our only unknowns would be v_1' and v_2'
- because we have two equations and two unknowns, we could use a system of equations to figure out exactly what the two velocities after the collision were
- so, those velocities that we were predicting yesterday could be calculated out exactly . . . if we know the 2 masses, we can tell exactly how much one of them will slow down when they collide

- bad news is that this is obviously a very complicated system of equations
- good news is first that you won't have to do any calculations with them! . . . (but be aware that there is a method to calculate the velocities that we were estimating yesterday)
- other good news that you may use in other Physics classes . . . these 2 equations can be combined together & simplified (your textbook shows the steps for this)

- the KE equation can be simplified to use velocities only . . . this makes the system much easier to use . . .
- we have the conservation of p equation & the simplified conservation of KE equation
- however, I hate to even put this on the board . . . b/c you won't use it in this class!
- don't confuse yourself w/ the equations we are using!

(B2) Collisions:

- Elastic: p is conserved — many microscopic
  KE is conserved — no deforming
  objects same shape & size

- Inelastic: p is conserved — energy lost in collision
  KE is lost — (to deforming)

- Perfectly Inelastic: p is conserved — objects stick together
  max KE is lost
  (sometimes all KE is lost)

- most macroscopic collisions do involve some sort of energy loss (usually that energy is lost to deformation)
- any type of collision where energy is not conserved is known as inelastic
- for instance, all of the pictures of collisions that you are looking at are inelastic, car crashes are inelastic, etc
- however, <u>inelastic collisions still conserve p</u>!
- this means that conservation of p can always be used to calculate unknown velocities when 2 objects collide
- you can never assume that KE is conserved, but you can always assume that p is conserved!!

- there is a special case of inelastic collisions that you should also be familiar with . . .
- this is known as a "perfectly inelastic collision"
- all inelastic collisions lose energy, but there is one situation where an even greater amount of energy is lost.

- can anyone figure out what situation would result in losing the maximum amount of KE . . . (hint . . . yesterday we looked at a collision where all KE was lost)
- to lose all KE, the carts had to stick together!
- perfectly inelastic collisions is the term given to any type of collision where the objects <u>stick together</u>

- <u>momentum is still conserved</u>
- we do calculate p in a slightly different way . . . remember from yesterday that we write the 2^{nd} side of the equation by using $m_1 + m_2$ as a single mass

- note that perfectly inelastic is a sub-category of inelastic . . . energy is lost in both
- the key w/ perfectly inelastic is that by sticking together . . . the maximum KE for a collision is lost!

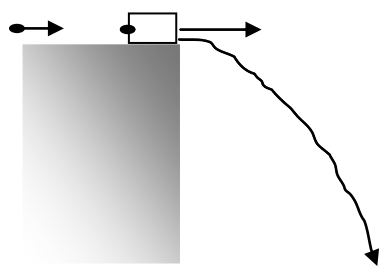
- is it possible to have a collision where 2 objects stick together but don't stop? (sure!)
- so, just b/c a collision is perfectly inelastic doesn't necessarily mean that all KE is lost . . . just the most possible <u>for that situation</u>
- i.e. if you have 2 carts that are equal mass & equal v moving at each other . . . when they stick they will stop
- but . . . if you have 2 carts of unequal mass & equal v moving at each other . . . when they stick they will not stop (they can't, b/c the p of the system is not zero)
- they have lost KE . . . and they have lost the most possible KE for those 2 carts at those 2 velocities, but they haven't lost all KE

(B3) Ballistics:

- p is conserved in collision
- projectiles used after collision

(SmartBoard) Ex:

- Ballistics PowerPoint
- 1st slide runs entire process on mouse-click
- 2nd slide has a pause to click after collision



- many of your homework problems will use momentum in a process called "ballistics"
- this process uses momentum combined with several concepts that we have already studied to determine the velocity of fast moving objects (such as a bullet)

- remember the lab where you fired a dart gun off of the edge of the lab table and used projectile equations in order to find its velocity
- why would this be almost impossible to do w/ a real gun? . . . large amount of space needed!
- however, what if we first fire the bullet into another object, something relatively heavy (often a "block of wood") . . . the bullet would slow down enough for this process to work

- usually the bullet sticks in the block of wood . . . what type of collision is this?
- is p conserved? (yes – always conserved)!

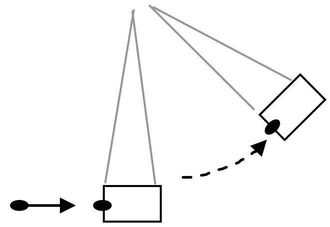
- then, the bullet and the block of wood together become a projectile & we use projectile equations to find dx

- now, usually your unknown is the velocity of the bullet . . . get used to working backwards . . . first use projectiles to find the velocity of the bullet & block of wood when they leave the table . . . then use momentum to find the initial velocity of the bullet

- note that the combination here is conservation of p and projectile equations (we don't ever use energy in the collision b/c it is not conserved all collisions)

(B3) Ballistics:
- p is conserved in collision
- projectiles used after collision
- energy used after collision

(SmartBoard) Ex:
- Ballistics PowerPoint
- 3rd slide runs entire process on mouse-click
- 4th slide has a pause to click after collision



Energy:
$\frac{1}{2} mv^2 \rightarrow mgh$
m = total
v = v'

Momentum:
m_1 = bullet m_2 = block
v_1 = bullet $v_2 = 0$
v' = combination

Demo:
- ballistic pendulum (See Ch6 Demo1 photos)

(SmartBoard):
- video clip of ballistics (volume on!)

- 2nd type of ballistics experiment is known as a "ballistic pendulum"
- same basic purpose is to find the velocity of something moving rather fast . . .

- bullet is also fired into something heavy (ours is a marble shooting into a metal cage, but many HW problems will call it a block of wood)
- but the wood block is part of a pendulum and free to rotate up into the air
- in this case, the velocity of the bullet eventually causes motion upwards instead of projectile motion

- now, what method would we normally use if we have an object that is beginning at the bottom of a path and moving upwards?
- we need to use conservation of energy here . . . but we have to be careful!

- is energy conserved in the collision? . . . no (perfectly inelastic)
- so . . . momentum is used for the collision
- we have 2 separate masses to begin w/ . . . bullet & block
- we have 2 individual velocities <u>before</u> . . . (although block velocity is zero)
- and we have one velocity after . . .
- this is the velocity of the bullet and block of wood together, immediately after they have collided . . . and while they are still at the bottom of the path.

- then, conservation of energy is used to find how far up into the air the block of wood & bullet will move
- usually (there are some exceptions) the bullet is imbedded in the block
- so the mass we use for the movement up is the mass of both together
- the velocity at the bottom is the velocity that they had together right after the collision (v')

- note that conservation of energy is only used <u>after</u> the collision (we must know the velocity of the bullet/block combination <u>before</u> we start using conservation of energy)

- most of you have heard of the field of ballistics . . . it is obviously much more detailed than what we have looked at here!
- here is a little video clip (just for fun) that shows some of the more unique possibilities . . . ☺

Announcements: