Physics 200 (Stapleton) Name: Key
Chapter 8: Momentum/Impulse/Collisions

Notes - 8.1 Linear Momentum and Force

1. Write the symbol and equation for momentum. $p = mv$

2. Why is the symbol for momentum a lowercase p?
at one time, momentum was called "impetus," which comes from the latin, "petere", which means "to go."

3. What are the units for momentum? $\frac{kg\,m}{s}$

4. Calculate the momentum of a 110-kg football player running at 8.00 m/s.

$p = mv = 110\,kg\,(8\,m/s) = 880\,kg\,m/s$

Notes - 8.2 Impulse

5. Use Newton's 2nd Law and the momentum formula to write an equation for Δp in terms of Force and time.

$F_{Net} = ma \quad F_{Net} = \frac{m\Delta V}{\Delta t} = \frac{\Delta p}{\Delta t} \Rightarrow F_{Net}\Delta t = \Delta p$

$a = \frac{\Delta V}{\Delta t}$

6. $F_{net}\,\Delta t$ (more commonly written as Ft) is called impulse.

7. Impulse is equivalent to a change in momentum.

8. Imagine a ball falling to the floor and then bouncing upward to a height of 40cm. Now imagine someone throwing the same ball upward a height of 40cm. In which case is a greater impulse applied to the ball? Why? ~~In which case is a greater force applied to the ball? Why?~~

Impulse is greater with the bounce, because the ball's momentum changes more, going from negative to positive.
The thrower's impulse only changes momentum from zero to positive.

9. The effect of a force on an object depends on duration, ~~as well as how great the~~ and magnitude is. A very large force acting for a short time will have a great effect on the momentum of a tennis ball. A small force could cause the same change in momentum, but it would have to act for a longer time. Quantitatively, the effect we are talking about is the change in momentum.

10. Use the impulse formula to show how the same change in momentum can be accomplished by a variety of forces and times.

$$\Delta p = Ft = F t = F t$$

11. Suppose a 60kg human is falling from the sky at a rate of 20m/s. If the human hits the bare ground, the average force applied to the person during impact is 24,000N. ~~If the person lands on a trampoline, the average force of impact is 3,600N. Use the impulse formula to provide a quantitative explanation of why the impact forces are different.~~ Find the impact duration

$$Ft = \Delta p = \Delta mv = mv_{final} - mv_{initial}$$

$$24{,}000N(t) = 0\,kgm/s - (60kg)(-20m/s)$$

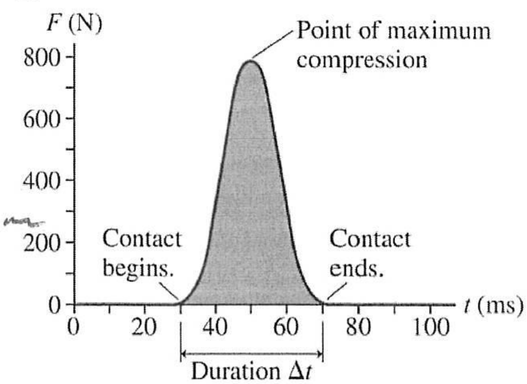
$$\boxed{t = 0.05\,s}$$

12. Name a few ways in which an understanding of impulse can save lives:

Lengthening impact time and reducing impact force...

Helmets, crash pads, airbags, crumple zones

13. What does the area under a force-time graph represent?



$\bar{F}t$ = impulse = change in momentum

Average Force

time

Notes - 8.3 Conservation of Momentum

14. Conservation of momentum formula for 2 objects in an isolated (closed) system...

$m_{1i}V_{1i} + m_{2i}V_{2i} = m_{1f}V_{1f} + m_{2f}V_{2f}$

15. An isolated system is defined to be one in which the net force acting on the system = 0.

16. For an entire isolated system, since $F_{net}\,\Delta t = \Delta p$, when $F_{net} = 0$ then Δp_{Tot} = 0 (i.e. the total momentum is constant).

17. **Example Problem:** A 3kg object has a velocity of 2m/s before it crashes into a second object that has been traveling with a velocity of -5m/s. After the collision, the 3kg object has a velocity of 1m/s, and the other object has a velocity of 2m/s. What is the mass of the second object?

$(3kg)(2m/s) + m_2(-5m/s) = (3kg)(1m/s) + m_2(2m/s)$

$6kg - 5m_2 = 3kg + 2m_2$

$3kg = 7m_2 \Rightarrow \boxed{m_2 = 0.43kg}$

Notes - 8.4 & 8.5 Elastic and Inelastic Collisions

18. How are elastic and inelastic collisions defined?

Total KE remains constant

KE not conserved (KE is lost)

19. When a collision is **inelastic** (not elastic), where does the "lost" kinetic energy go?

Heat, sound, light, potential energy...

20. Give some examples of nearly elastic collisions between macroscopic objects.

Billiard balls,

Newton's cradle

Gas molecules

21. When collisions are perfectly elastic, both momentum and KE are conserved, so one can use a system of 2 equations to find two unknowns when two objects collide (e.g. when objects with known masses, and initial velocities collide, we can find both final velocities). One equation comes from conservation of momentum. The other comes from conservation of KE. However, the math can get ugly. An alternative is to solve problems using the coefficient of restitution…

Coefficient of Restitution: a number from zero to one that tells how elastic a collision is; a ratio of the separation speed of objects after a collision to their approach (or "closing") speed before the collision.

Coefficient of Restitution = $\frac{Separation\ Speed}{Closing\ speed}$

When e =1…

- objects separate as fast as they came together
- collision is **perfectly elastic.**
- No kinetic energy is lost.
- Example: A perfectly bouncy ball approaches the ground at 2m/s (closing speed) and then bounces back up with a speed of 2m/s (separation speed). e = 2/2 = 1

When e=0…

- objects do not separate
- the collision is **perfectly inelastic.**
- Kinetic energy is lost to friction.
- Example: a bullet approaches a ballistic pendulum at 500m/s (closing speed) and the bullet and pendulum then swing upward together (separation speed = 0; no separation). e =0/2

When 1>e>0, objects separate, but not as fast as they came together. Some energy is lost to friction.

Coefficient of Restitution Formula = $e = \frac{V_b' - V_a'}{V_a - V_b}$ …where Va = initial velocity of object A, Vb = initial velocity of object B, and Va′ and Vb′ = their final velocities.

When e=1, $V_b' - V_a' = V_a - V_b$

22. Example Problem: (system of 2 equations)

Equation 1

Cart A has a mass of 4kg and an initial velocity of -2m/s. Cart B has a mass of 3kg and an initial velocity of 0m/s. If the carts collide with perfect elasticity (e=1), what are the carts' velocities after the collision?

$e = 1 \Rightarrow V_B' - V_a' = V_a - V_B \Rightarrow V_B' - V_A' = -2m/s - 0m/s$

$V_B' = V_A' - 2m/s$

Eq. 2 Cons. of Momentum

$(4kg)(-2m/s) + 3kg(0m/s) = 4kg(V_A') + 3kg(V_B')$

$-8kgm/s = 4kgV_A' + 3kg(V_A' - 2m/s)$

$-8kgm/s = 4kgV_A' + 3kgV_A' - 6kgm/s$

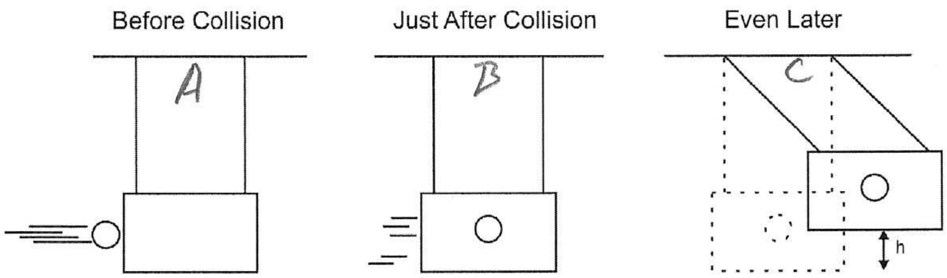
$-2kgm/s = 7kgV_A'$

$\boxed{V_A' = -0.29m/s}$

$\boxed{V_B' = -0.29m/s - 2m/s = -2.29m/s}$

Ballistic Pendulums

Consider the system below, which includes a ballistic pendulum (target/box) and a projectile (circle). Assume that the string supports of the pendulum have negligible friction, that air resistance is also negligible, and that the projectile does not drop significantly before it hits the pendulum…



…when is momentum conserved? Why?

Between A + B. No net force is exerted on the system. * Actually, in figure A, gravity exerts an unbalanced force on the ball, so the ball can gain momentum, but this state lasts a negligible amount of time.

…when is momentum not conserved? Why?

Between B + C. Gravity exerts an outside force. Also, mv changes as velocity decreases

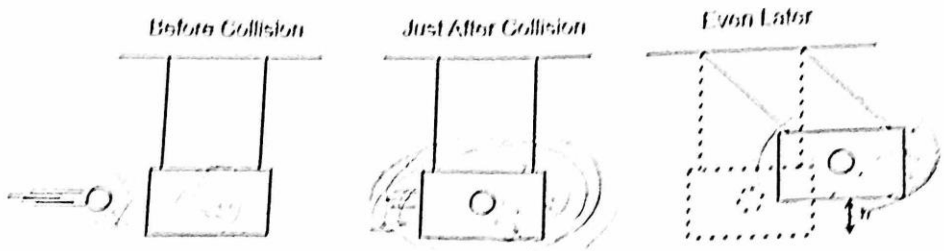
…when is ~~KE~~ Energy conserved? Why?

Between B + C, there is no friction. No non-conservative work.

…when is ~~KE~~ Energy not conserved? Why?

Between A + B.
There is friction during the collision.

also, when objects stick together in a collision, the collision is perfectly inelastic, so KE is lost. PE is constant.



	Launch 1	Launch 2	Your Launch
Projectile Mass (kg)	0.01	0.5	
Pendulum Mass (kg)	1	0.02	
Swing Height, "h" (m)	0.5	0.4	
Projectile Initial Velocity (m/s)	316 m/s		

As a class, answers the following questions using "launch 1" data. Complete the rest on your own.

1. What is the total potential energy of the ball and pendulum in the "even later" picture?

$PE = (1.01\,kg)(9.8\,m/s^2)(0.5\,m) = 4.95\,J$

2. What was the total kinetic energy of the ball and pendulum in the "just after" picture?

$KE = 4.95\,J$

3. What was the shared velocity of the ball and pendulum in the "just after" picture?

$KE = \frac{1}{2}(1.01\,kg)V^2 = 4.95\,J \quad V = 3.13\,m/s$

4. What was the net momentum of the ball and pendulum in the "just after" picture?

$p = mv = (1.01\,kg)(3.13\,m/s) = 3.16\,kg\,m/s$

5. What was the momentum of the ball before the collision?

$p = 3.16\,kg\,m/s$

6. What was the velocity of the ball before the collision?

$p = (0.01\,kg)(V) = 3.16\,kg\,m/s \quad V = 316\,m/s$

7. Is this an elastic or inelastic collision? How can you tell?

$KE_i = \frac{1}{2}(0.01\,kg)(316\,m/s)^2 = 500\,J$

495 J KE is lost