Themed: 15-01

Impulse & Momentum

Collision Science

Momentum

- Momentum is the “vector product of mass and velocity”
- What the heck does that mean?
  - Momentum is mass x velocity
  - The symbol we use is “p”…p = mv
  - It’s a vector because velocity is a vector
  - Use “dimensional analysis” to find the correct units (kg m/s, SI units for mass x SI units for vel.)

Momentum

- Momentum is often used to understand collisions because MOMENTUM is CONSERVED
- $(mv)_{before} = (mv)_{after}$ (momentum before collision = momentum after collision)
- Example: A 20 kg cart moving 5 m/s strikes a 12 kg cart and they stick together.
  - How fast does the combined cart go?
- When KE is not "conserved", this is a "perfectly inelastic collision" ("Sticky collision")
- Some of the KE goes into energy of deformation (smashing of the colliding objects)
- When energy is conserved, no "crashing" takes place, this is an "elastic collision" ("bouncy")

Momentum

- Bouncy collision example:
- Maya and Max are in bumper cars. Max's car stops working and Maya decides to take revenge. Maya + car have a mass of 70 kg and Max + car have a mass of 150 kg. If Maya is moving forward with 5 m/s of speed and Max's post-collision speed is 3.183 m/s forward, then:

1. What is Maya's velocity after the collision? (her speed is 1.82 m/s, but that's not her velocity!)
2. Who is more likely to be sore as a result of the collision? (who has the greater change in velocity to their body?)
3. How does this relate to a collision between a big truck and a small car?

Isolated systems

- Often add the caveat: Momentum is conserved in an “isolated system”
- Isolated: nothing external adding or absorbing momentum (no mystery momentum unaccounted for)
- Collisions not required: momentum conserved for field forces too (gravity for example)

Impulse

- Impulse is the change of momentum:
  - $\Delta p = m\Delta v$ (divide by Δt, set $a = \Delta v/\Delta t$, $F = ma$)
  - $m\Delta v = F\Delta t$
- Impulse explains forces during collisions
- Impulse shows us how short contact times result in HUGE forces (stuntman landing on concrete vs. landing on a cushion)
- Example: A 120 kg football player running 8 m/s hits padding with a 500 lb force (2200 N). How much contact time does the collision take? If a 2,000 lb force is required to break a bone, what must the maximum contact time be? What is the purpose of the padding?

Change of momentum

- Did I mention impulse is the change of momentum already?
- A huge truck crashes with a tiny car
  - Which has the greater impulse?
  - Which has the greater change in speed?
  - Which passenger experiences the greater acceleration change? ($a = \Delta v / \Delta t$)

Momentum and vectors

- Momentum is conserved in x, y and z direction
- We will only worry about linear momentum (like linear motion, +/- or left/right, etc. will do)….Whew!

Did we already talk about impulse being the SAME thing as momentum change? Just checking!

Impulse and forces

- $\Delta p = m\Delta v = F\Delta t$
- Notice the relationship between momentum change and force?
- Which has a bigger momentum change: crashing into a brick wall or a pile of hay?
- Which would you rather crash into and how does the equation explain why?