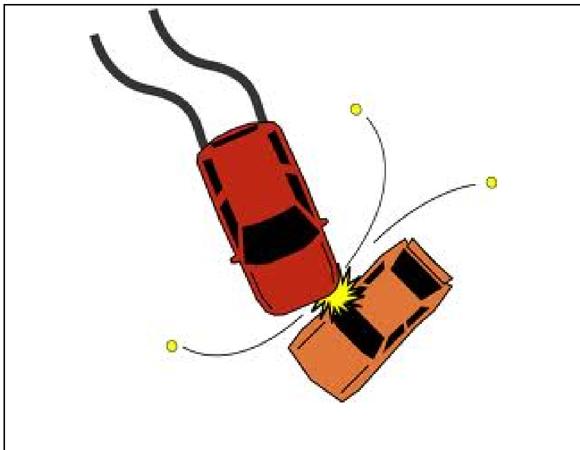
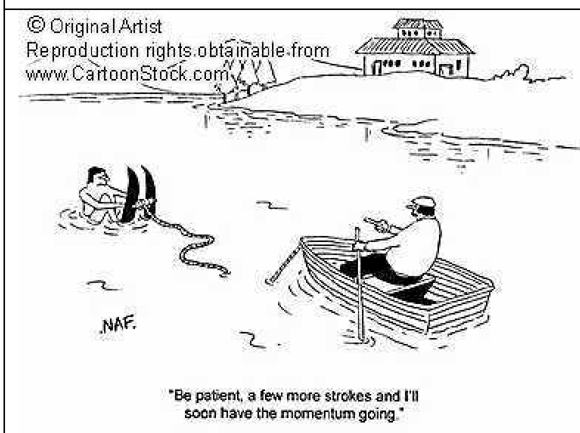
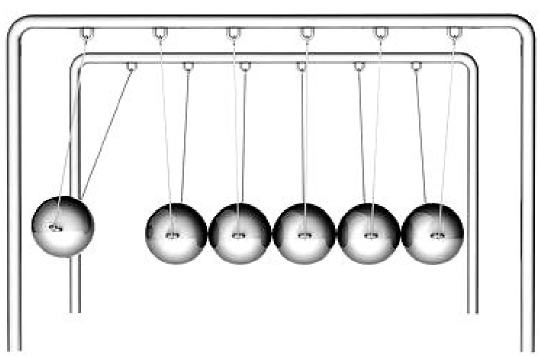
Physics Themed 1617 Williams

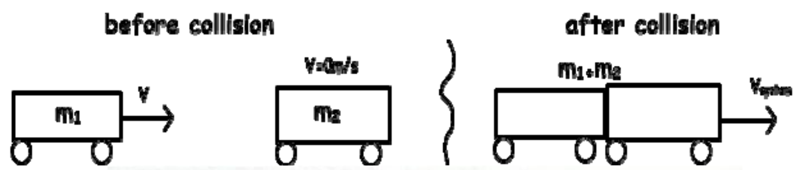
# Impulse & Momentum

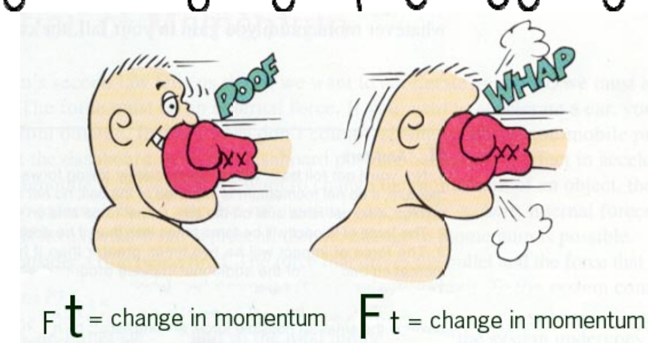


$$F\Delta t = m\Delta v = \Delta p$$



**Momentum Ideas**

1. Momentum is ALWAYS conserved. If it looks like it isn't, it means you aren't considering all objects involved in the collision.
2. If kinetic energy is also conserved, the collision is elastic. This will occur when the object bounces off.
3. If kinetic energy is not conserved, some energy went into other forms. Energy was conserved, just not kinetic energy. This could be either a bouncing collision or a sticking collision.
4. When two object collide, their impulses are the same. This is because $I=F\Delta t$ and F=same (action/reaction) and they are in contact with each other for the same time.
5. There are two main types of impulse situations:
   a. When no matter what, the object ends up stopped. Impulse is the same, so all you can do is alter time or force. By lengthening the time, you reduce the force on the object. An example is landing straight-legged vs bending your knees when you land.
   b. When it is open-ended. The harder the force and the longer the time (preferably both), the greater the impulse and thus the greater the final momentum of the object. An example is hitting a baseball with a bat. The longer and harder you hit, the farther the ball will go because it gets more momentum than when you hit is softer or for less total time.
6. If the problem mentions force, you must use impulse.
7. If the problem mentions time, you must use impulse.
8. Impulse is the change in momentum.
9. If you are only looking at one object in the collision, the object's momentum will increase or decrease if there is an impulse. That means a force acting over time will alter its momentum.
10. The more momentum something has, the harder it is to stop.
11. An object which bounces has a greater impulse than one which just stops. The greater injury will occur with something which bounces because not only does the falling object lose all its momentum, it gains momentum in the opposite direction. It's like getting hit twice.
12. TNEOM still apply. If you have a friction problem, you'll need $f=\mu N$. If you have acceleration, try $F=ma$

**Review for Momentum**

1. How can two objects have the same momentum?
2. How is impulse related to change in momentum?
3. What is the momentum of an 80 kg student walking at 2.0 m/s?
4. What happens to momentum if speed is doubled?
5. What should you do to maximize the momentum of an object?
6. How do momentum and kinetic energy differ?
7. What are the units for momentum?
8. How can an object have a negative momentum?
9. What happens to the momentum of a coaster car if an impulse is applied?
10. Compare and contrast impulse with work
11. What is the momentum reason for using follow through in sports?
12. What is the function of a seatbelt?
13. Why is a bouncing collision more painful than a sticky collision?
14. How do air bags save lives? (use momentum, impulse terms)
15. What happens to the change in momentum if the contact time is doubled?
16. How are inelastic collisions different from elastic collisions?
17. When is the total momentum of a collision not constant?

18. What is the total momentum of two carts, each 0.5 kg, if one cart is moving at 4 m/s to the right and the other is moving at 10 m/s to the left?

19. What happens to the motion of air track carts when they collide and stick together?

20. If a heavier object collides with a lighter object, which object has the greatest change in momentum? How about the greatest change in speed?

21. What impulse is needed to stop a 90 kg football player running at 6.0 m/s?

22. A 20 kg red go-cart moving at 3 m/s hits a stationary blue 25 kg cart. The red cart bounces backwards at 2 m/s.
    a. What was the change in momentum of the red cart?

    b. What was the change in momentum of the blue cart?

    c. What is the velocity of the blue cart after the collision?

23. A 10 g dart is thrown at 20 m/s and sticks into a stationary 200 gram dart board.
    a. What was the change in momentum of the dart?

    b. What was the change in momentum of the dart board?

    c. What is the velocity of the combination dart plus dart board?

24. What force is needed to accelerate a 4000 kg coaster from 0 to 5 m/s in 10 seconds?

25. Which has the most momentum - a fired bullet, person running, falling rain drop, parked car

# 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 $\Delta t$, 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?

## Unit 15 Themed – Vocabulary and Equations – Impulse & Momentum + Year End

$E_i = E_f$ (conservation of energy)
GPE = mgh  KE = $\frac{1}{2}mv^2$
ME = KE + GPE  Wt = mg
W = Fd  P = W/t
AMA = $F_o/F_i$  IMA = $d_i/d_o$
Eff. = $W_o/W_i$  Eff. = $P_o/P_i$
$f = \mu N$  $F_{net} = ma$  $a_c = v^2/r$
$F_c = ma_c$  (circ.) g's = $a_c/9.8$
x = circumference = $2\pi r$
$v = \sqrt{(2g\Delta h)} = \sqrt{(19.6\Delta h)}$

$v = \dfrac{\Delta x}{\Delta t}$  $a = \dfrac{\Delta v}{\Delta t}$
$\Delta x = v_0\,\Delta t + \frac{1}{2}at^2$
$v_f^2 = v_i^2 + 2a\,\Delta x$  $v_f = v_0 + a\,\Delta t$
$\Delta x = v_x\,\Delta t$
$v_{yi} = v\sin\Theta$  $v_x = v\cos\Theta$
$p = mv$  $p_i = p_f$
$(m_1v_1 + m_2v_2)_I = (m_1v_1 + m_2v_2)_f$
$I = \Delta p = m\Delta v = F\Delta t$

| **Equation** | **a** | ***t*** | **$v_{yi}$** | **$v_{yf}$** | **$\Delta y$** |
|---|---|---|---|---|---|
| $v_{yf} = v_{yi} + at$ | √ | √ | √ | √ | ☹ |
| $\Delta y = \dfrac{(v_{yi} + v_{yf})}{2}t$ | ☹ | √ | √ | √ | √ |
| $\Delta y = v_{yi}t + \frac{1}{2}at^2$ | √ | √ | √ | ☹ | √ |
| $v_{yf}^2 = v_{yi}^2 + 2a\Delta y$ | √ | ☹ | √ | √ | √ |

| | | | | | | |
|---|---|---|---|---|---|---|
| *1609 m = 1 mi* | *60 mph = 27 m/s* | *1 hp = 746 W* | *1 lb = 0.4536 kg* | *1 mi = 1609 m* | *1 W-s = 1 J* | *1 ft = 0.3048 m* |

**Symbols:**
p, m, v

**Vocabulary:**
momentum, impulse
elastic collision
bouncy collision
inelastic collision
sticky collision
energy of deformation
conservation of kinetic energy

**Unit Objectives - Williams**

1. I can compute momentum, know it's conserved and can contrast it with impulse
2. Using momentum conservation, I analyze collision problems, finding final velocities
3. I understand what impulse is and can apply it to find applied forces, contact times, etc.
4. I can use principles of impulse and momentum to understand the effects of longer collision times on forces
5. I know equal impulses don't mean equal consequences, like landing on a cushion or a semi-truck crashing into a car
6. I can analyze impulse and momentum equations from graphical information

**Impulse/momentum & Year-end Calendar: 2016-17 (Williams)**

*Bold and underlined means put in journal notes.*

| | | | |
|---|---|---|---|
| 1 | **We:04/26/17** | • Make up quests, Notes **<u>(15-01)</u>**: Impulse & Momentum<br>• Make sextant for tomorrow & go over Six Flags<br>• Discuss junior and senior Final Exams and review assignment for same | • H15-01 |
| 2 | **Th:04/27/17** | • Six Flags Field Trip (alternate in-class assignment for those not going) | • (See tomorrow's assignment!) |
| 3-Prom | **Fr:04/28/17** | • Coaster work time<br>• Moodle time (Final review AND Momentum Q's) | • Have fun while making good, safe decisions |
| 4 | **Mo:05/01/17** | • Short momentum video project:<br>  o Class makes two collisions: Bouncy & Sticky<br>  o Each group video tapes & analyzes on Tracker<br>  o Show conservation (or not) of momentum & KE<br>• Moodle, HW time | • H15-02 |
| 5 | **Tu:05/02/17** | • Finish video project (due tomorrow, start of class) | • Finish video project |
| 6 | **We:05/03/17** | • Collect video project<br>• Roller coaster project time | • H15-03 |
| 7 | **Th:05/04/17** | • Clickers & Moodle time<br>• Momentum pairs quiz | • H15-04 |
| 8 | **Fr:05/05/17** | • Roller coaster project time | • H15-05 |
| 9 | **Mo:05/08/17** | • Possible quiz, Moodle time/HW time | • H15-06 |
| 10 | **Tu:05/09/17** | • Roller coaster project time | • H15-07 |
| 11 | **We:05/10/17** | • Clicker review | • Study for test! |
| 12 | **Th:05/11/17** | • Momentum & Impulse Test | • |
| 13 | **Fr:05/12/17** | • Test make-ups and Roller coaster project time | • Finals Moodle |
| 14-LS | **Mo:05/15/17** | • Coaster project time<br>• Work on Moodle review | • Finals Moodle |
| 15 | **Tu:05/16/17** | • Coaster projects due<br>• Work on Moodle review | • Finals Moodle |
| 16 | **We:05/17/17** | • Q3 review | • Finals Moodle |
| | **Th:05/18/17** | • Q3 review (as much Q4 as class chooses) | • Study for Final! |
| | **Fr:05/19/17** | • Q3 review (as much Q4 as class chooses) | • Study for Final! |
| | **Mo:05/22/17** | • Senior Exams (pt. 1 of JR Final, Q3) | • |
| | **Tu:05/23/17** | • Senior Exams (pt. 1 of JR Final, Q3) | • |
| | **We:05/24/17** | • Senior Exams (pt. 1 of JR Final, Q3) | • |
| | **Th:05/25/17** | • Graduation – Congrats…you will be a great success! | • |
| | **Fr:05/26/17** | • Final Exam (pt. 2 of JR Final) | • |
| | ~~**Mo:05/29/17**~~ | • | • |
| | **Tu:05/30/17** | • Final Exam (pt. 2 of JR Final) | • |
| **Done** | **We:05/31/17** | • Final Exam (pt. 2 of JR Final) | • Have a great summer |