

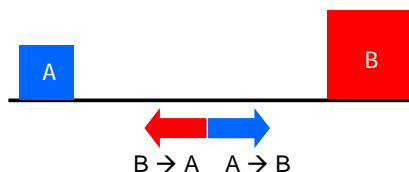
Newton's third law (lecture 7)

For every action there is an equal and opposite reaction.

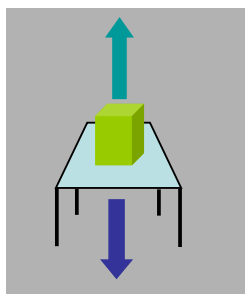
discuss collisions, impulse, momentum and airbags

3rd Law

- If object A exerts a force on object B, then object B exerts an equal force on object A in the opposite direction.



Example



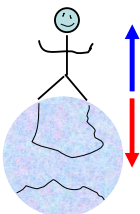
- What keeps the box on the table if gravity is pulling it down?
- The table exerts an equal and opposite force upward that balances the weight of the box
- If the table was flimsy or the box really heavy, it would fall!

The bouncing ball



- Why does the ball bounce?
- It exerts a downward force on ground
- the ground exerts an upward force on it that makes it bounce

You can move the earth!



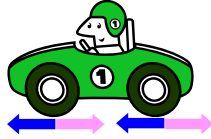
- The earth exerts a force on you
- you exert an *equal* force on the earth
- The resulting accelerations are not the same
- $F_{\text{on earth}} = -F_{\text{on you}}$
- $M_E a_E = m_{\text{you}} a_{\text{you}}$

Action/reaction forces always act on different objects



- A man tries to get the donkey to pull the cart but the donkey has the following argument:
- Why should I even try? No matter how hard I pull on the cart, the cart always pulls back with an equal force, so I can never move it.

Friction is essential to movement



The tires push back on the road and the road pushes the tires forward. If the road is icy, the friction force between the tires and road is reduced.

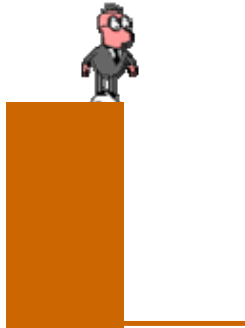
You can't walk without friction



You push on backward on the ground and the ground pushes you forward.

Demonstrations

- Bouncy and non-bounce ball
- Dropping the beakers
- Stunt man jumping off of a building



Impulse

- When two objects collide they exert forces on each other that last only a short time
- We call these short lasting but usually strong forces **IMPULSIVE** forces.
- For example when I hit a nail with a hammer, I give it an impulse.



What is impulse

- If a force F acts for a time t , then the impulse is the **Force \times time = $F \times t$**
- Since force is measured in Newtons and time in seconds, impulse will be measured in Newton-seconds.
- **IMPULSE = $F \times t$**

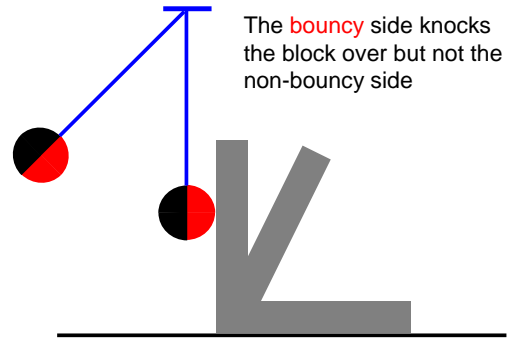
Momentum

- The term momentum is used quite often in everyday conversation about many things.
- For example, you may hear that one team has the momentum, or that a team has lost its momentum.
- Momentum is a physics term that has a very definite meaning. If an object has a mass m and moves with a velocity v , then its momentum is **mass \times velocity = $m \times v$**

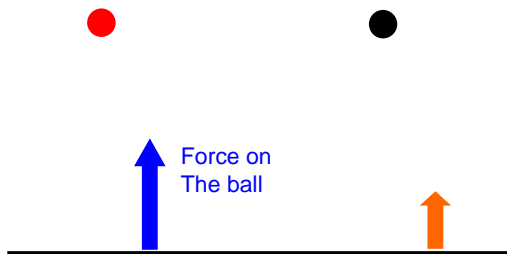
Momentum = $m \times v$

- In physics, if something has momentum, it doesn't lose it easily and if it doesn't have it, it doesn't get it easily – *something has to happen to an object to change its momentum*
- Impulse can change momentum, in fact
Impulse = change in momentum
- **If an object gets an impulse, $F \times t$, then its momentum changes by exactly this amount**

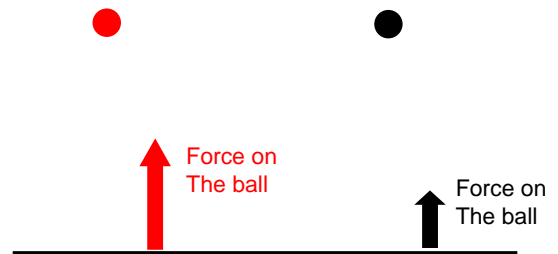
Knock the block over



Elastic and inelastic Collisions (bouncy) (non-bouncy)



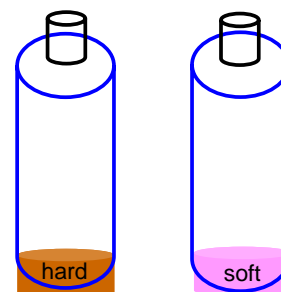
Elastic and inelastic Collisions (bouncy) (non-bouncy)



Bouncing ball

- The force that the ball exerts on the ground is equal to and in the opposite direction as the force of the ground on the ball.
- The ball that bounces back not only must be stopped, but must also be projected back up.
- **The ground exerts more force on the ball that bounces than the ball that stops.**

Physics explains it!



- Beakers dropped from same height so then have the same velocity (and momentum) when they get to the bottom.
- One falls on a hard surface
- The other falls on a cushion.

- Why prevents the beaker that falls on the cushion from breaking?
- First, what causes anything to break?
- If an object experiences a large enough **FORCE** then it might break.
- Why does the beaker that falls on the cushion experience a smaller force?
- Both beakers have the **SAME** change in their momentum – they both hit the bottom with the same speed and both end up with zero velocity.

- The beaker that shatters comes to rest more quickly than the one that gently slows down on the cushion ← this is the key point!
- According to the impulse-momentum relation:
Impulse = Force × time (F × t)
= change in momentum
- $F \times t$ is the same for both. Since the one on the cushion takes longer to slow down the force on it is less, **t is bigger → F smaller**

Air bags

- The same thing is true for airbags
- They protect you by allowing you to come to rest more slowly, then if you hit the steering wheel or the dash board.
- Since you come to rest more slowly, the force on you is less.
- You will hear that “**airbags slow down the force.**” this is not entirely accurate but it is one way of thinking about it.

Read more about it

<http://www.physicsclassroom.com/Class/momentum/U4L1c.html>

<http://www.geocities.com/thesciencefiles/homerun/homerun.html>

<http://www.k12.nf.ca/gc/Science/Physics3204/Projects2003/SlotA/ProjectA2/index1.htm>

Momentum and Collisions

- The concept of momentum is very useful when discussing how 2 objects interact.
- Suppose two objects are on a collision course. **A → ← B**
- We know their masses and speeds before they hit
- The momentum concept helps us to see what can happen after they hit.

Conservation of Momentum

- One consequence of Newton's 3rd law is that if we add the momentum of both objects before the collision it **MUST** be the same as the momentum of the two objects after the collision.
- This is what we mean by **conservation**: when something happens (like a collision) **something doesn't change** – that is very useful to know because collisions can be very complicated!