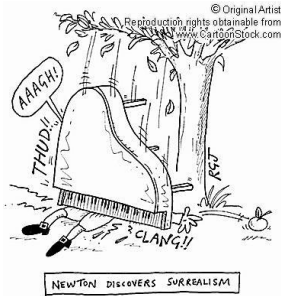


## Newton's Laws

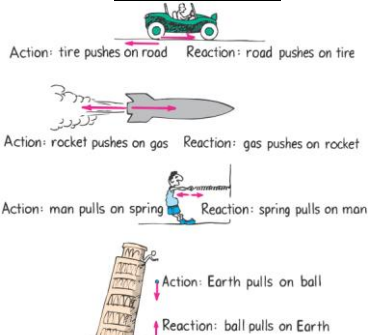


<http://cartoonstock.com/directory/N/Newton.asp>

## Summary of Newton's Laws

- Second Law:  $\Sigma \vec{F}_i = m\vec{a}$
- First Law:  $\vec{a} = 0$
- Third Law: For every action force, there is an equal and opposite reaction force.

## Third Law



## Bus and the bug

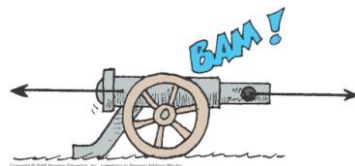
Consider a high speed bus colliding head-on with an innocent bug. The force of impact splatters the unfortunate bug all over the windshield. Which is greater, then force on the bug (by the bus) or the force on the bus (by the bug)?

## Bus and the bug

Consider a high speed bus colliding head-on with an innocent bug. The force of impact splatters the unfortunate bug all over the windshield. Which is greater, then force on the bug (by the bus) or the force on the bus (by the bug)?

**The forces are the same in strength.**

## Action and reaction on different masses



### Third Law

- If forces occur in pairs and each pair is equal and opposite, how do objects move in the first place? What's up? Don't these forces cancel?
- Only forces on an object can "cancel". Action and reaction forces act on different objects.
- Only forces on YOU accelerate YOU.

### Third Law

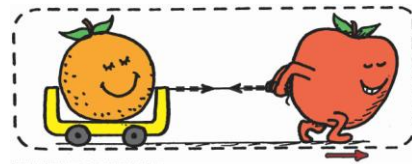
If a cart starts at rest and pulls back on you with a force equal to the force you pull on it, as required by Newton's third law, how is it possible for you to make the wagon start to move?

### Third Law

Which team wins in a tug-of-war---the team that pulls harder on the rope, or the team that pushes harder against the ground?

### Defining your "system"

- Forces *internal* to the system cancel
- Forces *external* to the system determine the system's acceleration



### A Newton's Laws problem

A boxer punches a sheet of paper in midair, and thereby brings it from rest up to a speed of 25 m/s in 0.05 seconds. The mass of the paper is 0.003 kg. What is the force of the punch on the paper?

### Inertial Ball



What can we learn from this demo?

## Forces are vectors

- What are *vectors*? A vector is a geometric object that has both a magnitude (or length) and a direction. It can be represented as an arrow.
- Adding vectors graphically.
- Resolving a vector into components is another way to add vectors.