# Conceptual Physics I
## Classical Mechanics

Lesson 5A - Newton’s Third Law

# Review of Newton’s 1st and 2nd Laws

First Law – An object at rest tends to stay at rest and an object in motion tends to stay in motion (constant velocity) unless acted upon by an unbalanced force.

Second Law – An unbalanced force causes a mass to accelerate in the direction of the unbalanced force.  The acceleration is directly proportional to the force and inversely proportional to the mass

When a person pushes on a wall, there is a mutual interaction going on between the person and the wall.

- The person pushes on the wall
- The wall pushes back on the person


This reasoning led Newton to devise his third law: the law of action and reaction

## Newton’s Third Law:

Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object.

One force is called the *action force*. The other force is called the *reaction force*.

The action force and the reaction force are equal in force and opposite in direction.

Newton’s Third Law could be stated:

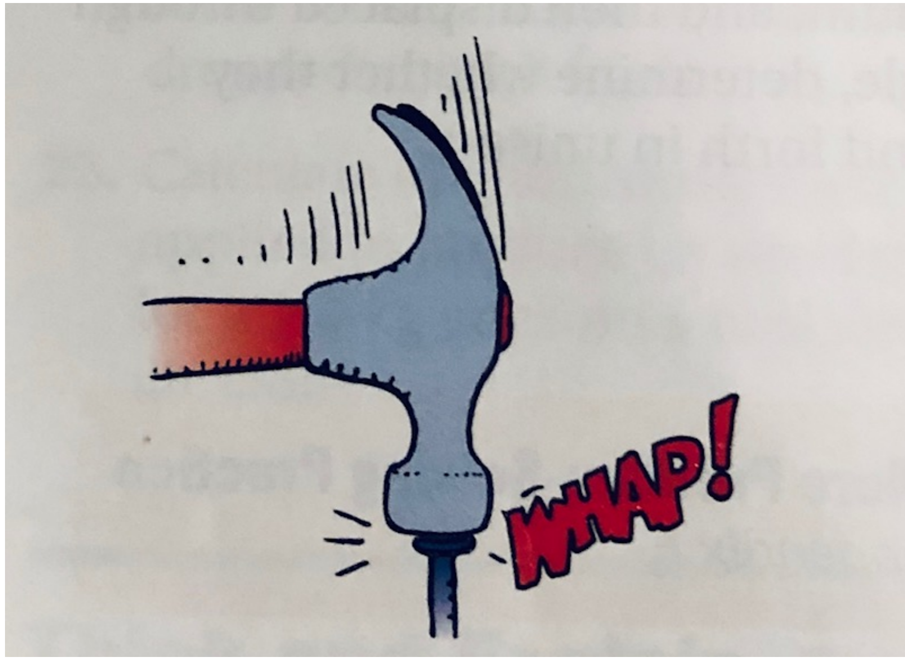
“To every action there is always an equal opposing reaction.”

# Lesson 5A - Newton's Third Law

Hammer hits the nail

Nail hits the hammer

Equal forces



# Lesson 5A - Newton's Third Law

Girl pushes on boat

Boat pushes on girl

Equal forces

What happens to the boat when she jumps to shore?

The boat moves away from her.

Questions:

1) Does a stick of dynamite contain force?

No.  An object doesn't contain force.  A force is something that acts on it.  It turns out that the thing a stick of dynamite possesses that causes it to explode is energy.

## Questions:

2) A car accelerates along a road. Thinking about Newton’s Third Law, what is the force that moves the car?

The road pushing on the car. According to Newton’s Third Law, the road pushes on the car with an equal and opposite force of the car pushing on the road. Does this mean the car is causing the earth to rotate backwards? Yes, although very slightly due to the large mass of the earth.

## Questions:

3) Does the dog wag the tail or does the tail wag the dog? Or both? Both

Sometimes the pair of action and reaction forces in an interaction is not immediately obvious.

For example, what are the action/reaction forces in the case of a falling boulder?

Action:  Earth pulling on the boulder.

Reaction?  Boulder pulling on the earth

In general, one should think about the action and reaction forces like this:

Action:  Object A exerts a force on object B.

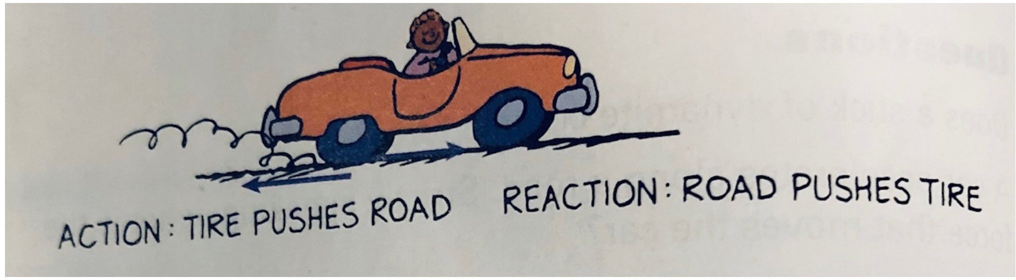
Reaction:  Object B exerts a force on object A.

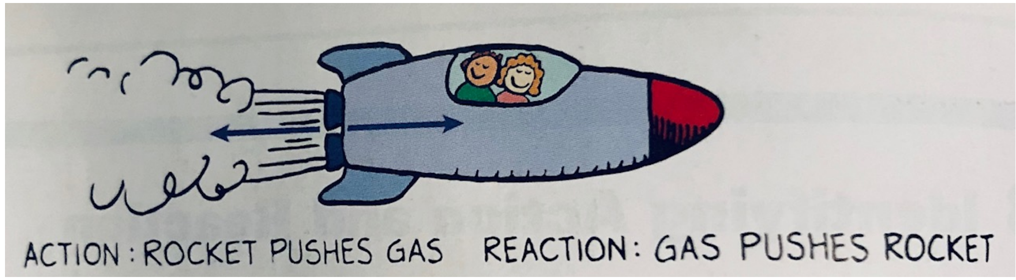
Question:  We know that the Earth pulls on the Moon. Does the Moon also pull on the Earth?  Yes

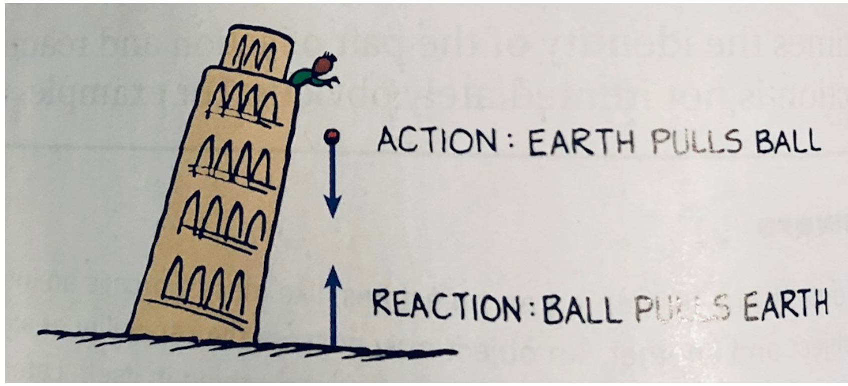
Which pull is stronger?  The pulls are the same.

# Lesson 5A - Newton's Third Law

## Some examples of action/reaction forces



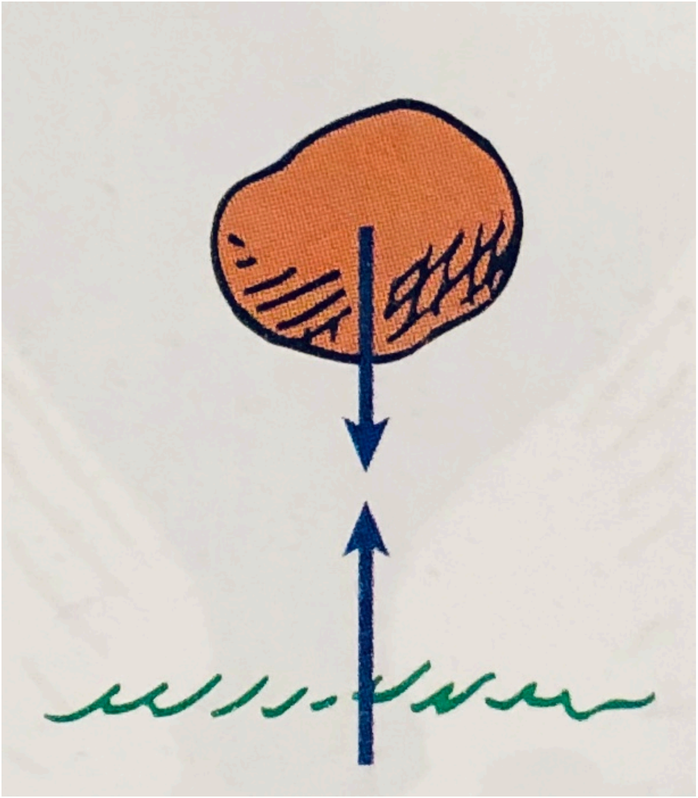



So Newton's Third Law says that the Earth is pulled up by a falling boulder with just as much force as the boulder is pulled down by the Earth.

So why do we not see (or feel) the Earth rushing up towards the boulder?

Because of the difference in the masses.



# Lesson 5A - Newton's Third Law

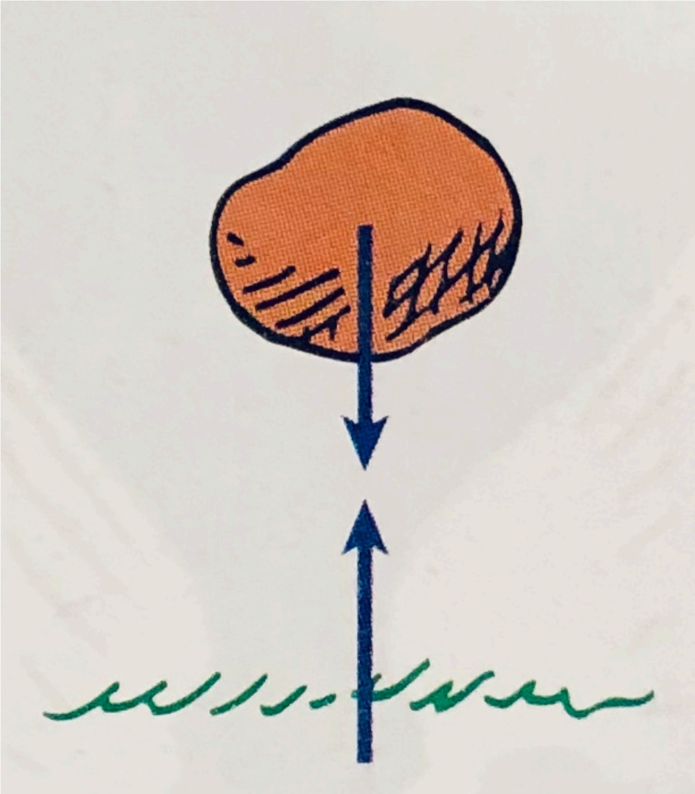
Newton’s Third Law can be written as:

$$F_{A\ on\ B} = F_{B\ on\ A}$$

Using Newton’s Second Law (F=ma), we can rewrite this as

$$m_A a_A = m_B a_B$$

If the mass of A is smaller than the mass of B, it will have a larger acceleration than that of B.

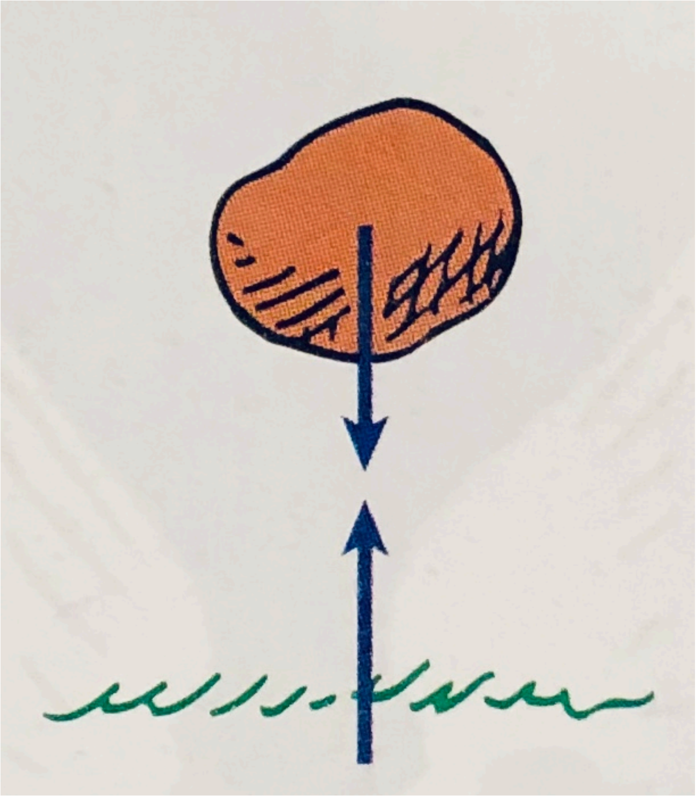


So we can write:

$m_{rock} a_{rock} = m_{earth} a_{earth}$

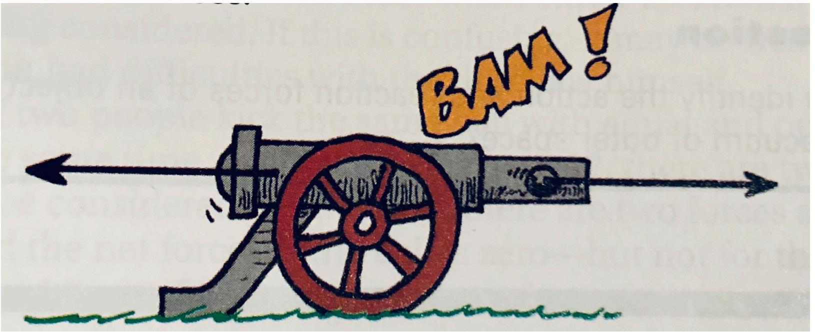
*Smaller rock means larger acceleration.*

*Larger earth means smaller acceleration*



# Lesson 5A - Newton's Third Law

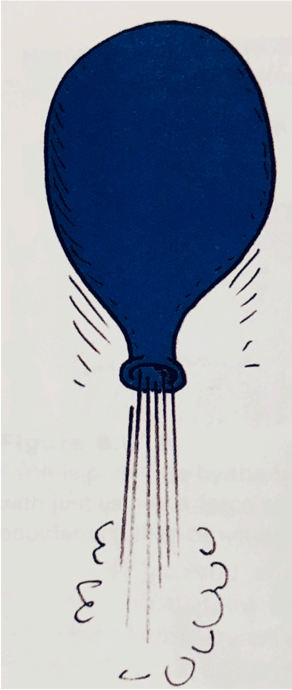
Consider a cannon firing a cannonball. The force that the cannon exerts on the cannonball is exactly equal and opposite to the force the cannonball exerts on the cannon. Thus, the “kick” of the cannon upon firing.




Why doesn’t the cannon kick more than it does? The difference in masses. The larger mass accelerates less.

What about a balloon soaring into the air as air escapes?

The balloon pushes on the escaping air molecules, and the escaping air molecules push on the balloon



## Questions:

1) In the interaction between a hammer and the nail it hits, is a force exerted on the nail? Yes. On the hammer? Yes. How many forces occur in this interaction? Two.

2) When you walk along a floor, what pushes you along? The floor pushing on your feet.

## Questions:

3) When swimming, you push the water backward as the action force. What is the reaction force? The water pushing back on you.

4) If the action is a bowstring acting on an arrow, what is the reaction force? The arrow acting back on the bowstring.

## Questions:

5) When you jump up, the world really does recoil downward. Why can't this motion of the world be noticed? Because the world is much more massive than a person.

6) How can a rocket be propelled above the atmosphere where there is no air to "push against"? The action/reaction pair that is causing the motion is the exhaust pushing against the rocket and the rocket pushing against the exhaust. Nothing to do with the air.

## Questions:

7) Your weight is the result of the gravitational force of Earth on your body. What is the corresponding reaction force? The gravitational force of your body on the Earth.
8) Would it be correct to say the the action/reaction pair of a book lying on a table is the weight force and the normal force? No, because both the weight force and the normal force act on the book. The action/reaction pair would be the book pushing on the table/the table pushing on the book. Equal and opposite.

## Questions:

9) When a high jumper leaves the ground, what is the source of the upward force that accelerates her? She is accelerated by the force of the ground pushing on her feet.

What force acts after her feet are no longer in contact with the ground? The gravitational force, just like in projectile motion.

## Questions:

10) A speeding bus makes contact with a bug that splatters onto the windshield. Because of the sudden force, the unfortunate bug undergoes a sudden deceleration. Is the corresponding force that the bug exerts against the windshield greater, less, or the same?

The force is the same. Is the resulting deceleration of the bus greater than, less than, or the same as that of the bug? The bus decelerates much less than the bug.