DAY 1

Summary of Primary Topics Covered

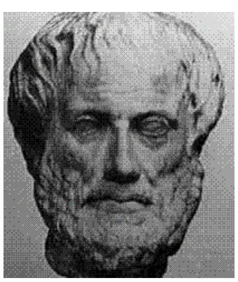
Explaining how the World Works

Physics is a science that attempts to explain how the natural world works. People everywhere like to form explanations for why things happen.

Coatliue, goddess of the earth and creator of man, patron of life and death - in the National Museum of Anthropology in Mexico City. www.bluffton.edu/~sullivanm

A common way of doing this is to invoke supernatural principles. For example: *A rock falls to the ground more rapidly than a leaf because the rock came from the ground. Rock spirits are close kin to the Mother Earth goddess, and Mother Earth draws them in with joy. The leaf comes from the forest spirits who have a less close relationship with Mother Earth, and draw near her with less enthusiasm.*

However, if you believe that supernatural forces run the world, then you must always worry that those forces continue to do that which they have always done. If the rock spirits and the Earth mother have a falling out, rocks could start hopping off the ground and that would be dangerous. You might want to make some sort of offering to make sure the nature forces are happy.



The ancient Greeks broke from this pattern. The most famous of these Greeks was Aristotle, who lived around 350 B.C. Aristotle formed theories for how the world worked that did not involve supernatural forces. He theorized that all things on Earth were made of four elements - Fire, Air, Water, and Earth. These elements had a natural tendency to move toward the center of the Earth - the element Earth having that tendency most strongly, and the element Fire having it least strongly. So a rock falls more rapidly than a leaf because it is pure Earth (it comes from the ground, it won't burn). A leaf contains other elements, like Fire (this can be proven by exposing a dry leaf to a flame - the leaf burns, releasing the Fire inside it). Aristotle's theories dominated physics for nearly

2000 years, even though to today's scientists they have obvious flaws!

The scientific tradition of the ancient Greeks was kept alive in Islamic and European cultures. Aristotle's dominance eventually ended, in part because the flaws in his theories became more apparent as the natural world was studied more, and in part because Aristotle's theories were thought to be in conflict with Christian theology. Aristotle's ideas began to be challenged in medieval European universities during the 1200's.

An important medieval development was the concept of *momentum*. Aristotle had thought that for an object to move, it must have a mover to make it go; if a child stops pulling a wagon, the wagon comes to a halt. In the 1300's the French scholar Jean Buridan proposed that setting an object motion gives it a property (momentum) that tends to keep it in motion without need for an external mover to power it along. That momentum depended on how massive an object was and how fast it moved. Buridan discussed objects like spinning wheels -- grindstones, for example; massive objects that keep turning once they have been set in motion, and which would conceivably keep turning indefinitely if the bearings on which they rotated could be lubricated well enough.

Perhaps the best-known of those who brought down Aristotle's ideas was the scientist Galileo Galilei, who lived in the early 1600's. Galileo did experiments and came up with ideas that laid the groundwork for Isaac Newton (considered by many to be the greatest physicist of all time) to formulate his Three Laws of Motion a few decades after Galileo. These Laws of Motion are one of the fundamental concepts in physics today – one of the basic tools physicists use in understanding how the world works.

Newton's Three Laws of Motion

1 -- *An object at rest will remain at rest until acted on by a net outside force. An object in motion will remain in motion at constant speed in a straight line path until acted on by a net outside force.*

This tendency of objects to resist change in motion is known as inertia. Objects that have a lot of inertia (those that are hard to get moving when they are at rest, and hard to stop once they are moving) are said to be massive. Objects with less inertia are less massive. Stated in terms of momentum, this law says that unless a net outside force acts on an object, its momentum does not change.

A force is simply a push or a pull.

2 -- *If an object is acted on by a net outside force, the object will accelerate. The amount of acceleration is determined by the amount of net outside force applied to the object and the amount of mass/inertia the object possesses:*

$$acceleration = \frac{Force}{Mass}$$

	Small force	**Large force**
Small mass	Middling acceleration	Greatest acceleration
Large mass	Least acceleration	Middling acceleration

Stated in terms of momentum, this law says that a net external force results in a change in momentum, with a greater force resulting in a greater change.

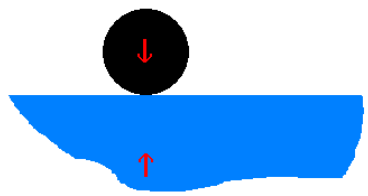
3 -- *If an object exerts a force on a second object, the second object exerts an equal and opposite force back on the first object.*

These "Newton's 3rd Law Pair" forces are equal in type and size. A contact force (like the force of a shoe on the ground) cannot be a 3rd Law Pair force for an "action at a distance force" (also known as a field force) like the pull of gravity or a magnet. If one object is exerting a contact force on a second object, the second object will exert an equal and opposite contact force back on the first. If one object is exerting a contact force and a field force on a second object, the second object will exert an equal and opposite contact force back on the first, and an equal and opposite field force back on the first.

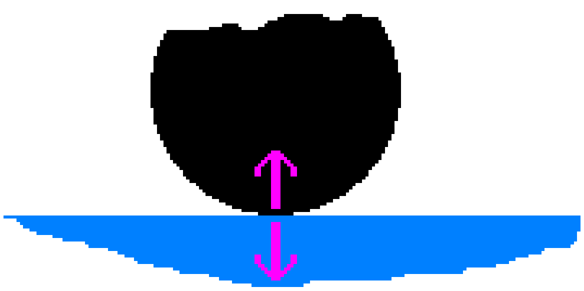
Example Problem #1

A bowling ball sits at rest on thick ice. Identify the forces acting on the ball. What is the net force on the ball?

Solution:



The Earth is pulling on the ball via gravity (a field force – the Earth doesn't have to touch the ball to pull on it via gravity). Therefore, there is a downward gravity force on the ball. According to Newton's 3rd law, that means there is an upward gravity force on the Earth – Earth pulls ball down, ball pulls Earth up. So those are a Newton's 3rd Law Pair, show by the red arrows in the figure above.



However, there is also a force of contact where the ball touches the ice. The ice exerts an upward push on the ball via contact. If the ice were to suddenly melt into water the ball would sink, right? So clearly the ice is doing something to hold it up. So if the ice exerts an upward contact force on the ball, the ball must be exerting a downward contact force on the ice. Those two contact forces, shown by the purple arrows in the figure at left, are another 3rd Law Pair.

Since the ball is at rest, it is not accelerating (acceleration = 0). Since there is no acceleration, there is no net force, either. The downward pull of gravity on the ball, and the upward push of the ice on the ball, must cancel each other out.