Lesson 28: Mass, Weight, & Fields

Newton's work was all related to one goal he had for himself... to explain gravity.

- Newton realized that to explain the force due to gravity, he would first have to come up with a set of rules to explain forces in general. That's the stuff we've been working on in the last few lessons.
- Newton stated that a gravitational force exists between any two masses.
    - According to his Third Law, this means that when you fall the Earth is pulling you down, while you are pulling the Earth with just as much force up.
    - We don't see the Earth move because it has so much more mass than you that the Earth's inertia (tendency to keep doing what it is already doing) is enormous.

Weight vs Mass

Normally when a person wants to know his or her mass, they will just stand on a scale.

- Since this depends on the **force due to gravity** pulling you down, you are actually measuring your **weight**, a force acting on your body.

$$\textbf{Weight} = F_g = mg$$

- Your **weight** is measured in **Newtons** (just like any other force) and is different in different locations on Earth (since "g" varies from place to place).

Mass is considered to a be constant anywhere in the universe.

- Floating in space, you could hold a car in your hand… it's easy because it has no **weight**.
- Throw it at someone and it hits them with its inertia… it hurts!
    - This is because it still has **mass**, so it will tend to keep doing what it is already doing.
- The amount of material that makes up the car is the same in space as it is on Earth, so they have the same **mass**.
- The **mass** of an object is like asking "how many atoms are in that object?"… this number will always be the same, no matter where you are in the universe.
- **Mass** is always measured in **kilograms.**

Some textbooks make a distinction between **gravitational** mass and **inertial** mass. They are both still a measurement of mass in kilograms. The only difference is really just how it is measured. Gravitational mass is measured by comparing a known mass to an unknown mass. Inertial mass is measured by seeing how much the mass accelerates when a force is applied to it.

The best way to determine the mass of an object is to apply a known force to it and measure its acceleration.

- This is known as the **inertial mass**, since it depends on the inertia of the object.
- Changes in the local acceleration due to gravity would not change this measurement.

Example 1: I have a 5.00kg rock.

a) **Determine** how much it weighs on the Earth and on the Moon.

b) **Determine** its **mass** on the Earth and on the Moon.

a) Weight is measured in Newtons!

On Earth...

$F_g = mg = 5.00\ (-9.81) = -49.1N$

On the Moon, where gravity is $1.67 m/s^2$ (we give that to you)

$F_g = mg = 5.00\ (-1.67) = -8.35N$

b) The mass of the object on the Earth and the moon is 5.00kg! The object has the same matter making it up even if I take it to a different place.

Example 2: An object is accelerated at $3.24 m/s^2$ by a 68.0 N force. **Determine** its inertial mass.

$$F = ma$$

$$m = \frac{F}{a} = \frac{68.0}{3.24} = 20.98765 = 21.0\, kg$$

Gravitational Fields

> **Did You Know?**
> The idea of "fields" is also used in Social Studies classes. The difference is that they call it a "Sphere of Influence." For example, the former USSR had a sphere of influence that extended outwards to many nations that were nearby.

Newton realized that the gravity that keeps you on the Earth is the same gravity that keeps the moon in its orbit around the Earth.

- To explain this **action-at-a-distance** force, physicists often use the idea of **fields**.
- A **field** is an area around an object that has an effect on nearby objects.
- In the case of **gravitational fields**, the field always points in towards the centre of the mass.
- All masses have a **gravitational field**, but only the **gravitational fields** of large objects (like planets) are easily noticeable.

To measure and show the gravitational field around an object, we would place a known **test mass** nearby.

- The test mass is any mass we choose, as long as it is small enough that it does not have a significant gravitational field of its own
  - Theoretically its mass should be $\frac{1}{\infty} kg$ (can also be written as ∞^{-1} kg), which is so close to zero that it doesn't even really matter.
- The test mass will always move towards the centre of the object, so we draw vectors pointing in towards the centre.
- By measuring the force of gravity pulling the test mass towards the object, we have a measurement of the **gravitational field** near the object.

$$g = \frac{F_g}{m}$$

You'll notice that we are actually measuring the acceleration due to gravity at that location.

- We could certainly measure it in m/s^2, or we can choose to use units that have more to do with the experiment we just did, N/kg .
- On many data sheets you'll see that the acceleration due to gravity is also listed as a gravitational field strength.
  - You'll probably see the value listed near Earth's surface as 9.81 **m/s^2** and 9.81 **N/kg**. The two ideas are used pretty interchangeably in most questions.
- The units N/kg make a bit more sense we you are doing something like sitting in a chair.
  - You are certainly not falling and accelerating at 9.81 m/s^2.
  - You actually do experience a pull of 9.81 N downwards for each kilogram of your body… 9.81 N/kg!

It is also reasonable to say that the effect of gravity is greatest when closer to the object.

- As you move further and further away from the centre, the force exerted by gravity becomes weaker (although it never truly disappears).
- Illustration 1 shows this by the way the vectors are further apart from each other when more distant from the object. Closer in the vectors are closer to each other.
  - This means the **gravitational field** is stronger when gravitational field vectors are drawn closer.
- As a relationship, this is shown by...

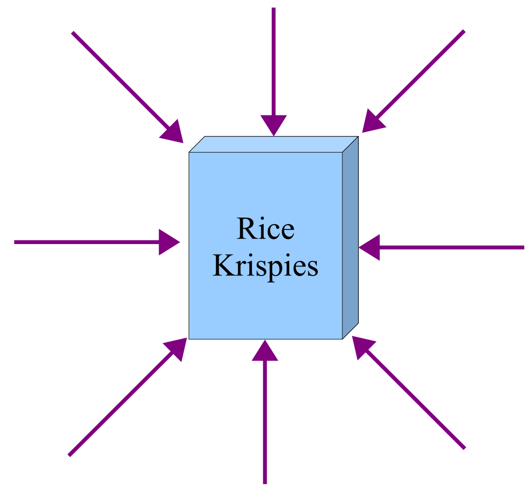

Illustration 1: Although weak, there is a gravitational field around a cereal box.

$$g \propto = \frac{1}{r^2}$$

- This inverse square relationship became the basis of one of Newton's greatest formulas, the ***Law of Universal Gravitation***.

Homework

p202 #1,2,4,5,7,9