Whiteboard: 1/60, f5.6, iso 1000, **WB Use Grey Card**, Manual Audio at level 11, focal length ½ way to ∞. H4n **INPUT @ 95%** gain.

BBB 1/60, f5.6, iso 320, **WB Use Grey Card**, Manual Audio at level 11, focal length ½ way to ∞. H4n **INPUT @ 95%** gain.

BBB Check Horizontal Level & Billy's Lights!! Middle line at bottom 1/3 of desk & remember Billy and Bo chair locations!

Title: Gravitation Field Introduction

Mr.p: Good morning. Bo, what are the two equations we have for the force of gravity acting on an object?

- Bo: [intro] Well, we have force of gravity equals mass times acceleration due to gravity.
- Billy: Which we can use when the acceleration due to gravity is constant, like on the surface of the Earth where the acceleration due to gravity is 9.81 meters per second squared. **{react to Bo not calling it the Big G equation}**

- Bo: Yes, thank you Billy. The other equation is Newton's Universal Law of Gravitation where the force of gravity equals the universal gravitational constant times mass one times mass two all divided by the square of the distance between the centers of mass of the two objects. And we can always use this equation, even if the acceleration due to gravity is not constant.

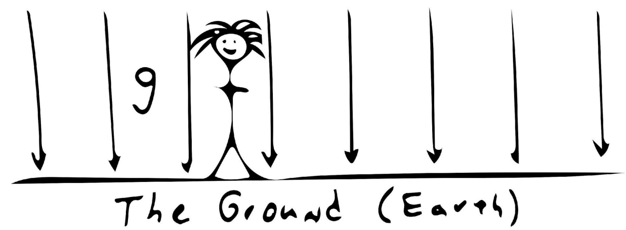
Mr.p: [$F_g = mg$ when g is constant, like on Earth. $F_g = \frac{Gm_1m_2}{r^2}$ always true.] Now we are going to introduce the concept of the gravitational field. Let's start with the simpler equation. [$\Rightarrow g = \frac{F_g}{m}$] If we divide the equation for the force of gravity by mass, we get the acceleration due to gravity equals the force of gravity divided by mass. Billy, what are the units for little g here?

- Billy: That would be force in newtons divided by mass in kilograms, so newtons over kilograms.
- Bo: I thought acceleration was in meters per second squared.
- Bobby: It's the same think because newtons are kilograms times meters per second squared, so if you divide that by kilograms, you get meters per second squared. … I get the units, but I don't know what this is…

Mr.p: [$\Rightarrow \frac{N}{kg} = \frac{\frac{kg \cdot m}{s^2}}{kg} = \frac{m}{s^2}$ & Constant Gravitational Field]

Okay, so first off. Yes, Newton's per kilogram is the same as meters per second squared. Second, the acceleration due to gravity equals the force of gravity divided by mass is the equation for a gravitational field when the gravitational field has a constant value, like it does on planet Earth.

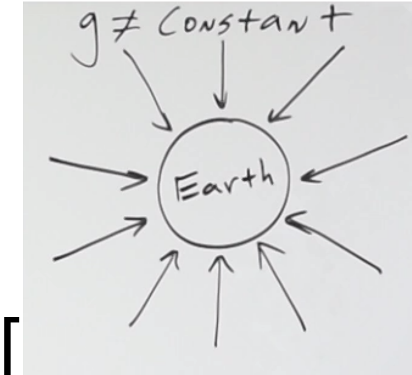
Bo: Did we not recently prove the acceleration due to gravity at the top of Mt. Everest to be 9.77 meters per second squared and therefore show the gravitational field on the surface of the Earth actually is not constant?

Mr.p: [Constant Gravitational Field] Okay, sure, right. It varies ever so slightly, however, for our purposes we can assume the acceleration due to gravity on the surface of the planet is constant and therefore there is a constant gravitational field which exists on the surface of planet Earth. We illustrate it this way. [

] These lines here are called field lines, more specifically, gravitational field lines. The strength of the field is represented by how close the lines are to one another. Because all these lines are parallel and down, the distance between the lines is constant and they illustrate a constant downward gravitational field. In other words, we live our lives in a constant downward gravitational field which has a magnitude of 9.81 meters per second squared. Any object we drop while standing on the surface of this planet will, in the absence of air resistance, increase its velocity by 9.81 meters per second down every second. The concept of a gravitational field essentially removes the mass of the object which has the force of gravity acting on it and identifies that it is irrelevant as far a the acceleration due to gravity is concerned. … Okay, so that is the constant gravitational field which exists on a local level when we look at the planet. However, if we look at the planet from a non-local level, in other words, from outer space, the gravitational field is no longer constant. Bobby, can you derive the equation for the gravitational field there?

Bobby: Uh. Maybe? Let's see. Going back to the beginning here, we need to set our original force of gravity equation, force of gravity equals the mass of the object times the acceleration due to gravity equal to Newton's Universal Law of Gravitation or the universal gravitational constant times the mass of the object times the mass of the Earth all divided by the distance between the centers of mass of the two objects and …

BBB: everybody brought the mass of the object to the party!

Mr.p: [$F_g = m_o g = \frac{G m_o m_E}{r^2} \Rightarrow g = \frac{G m_E}{r^2}$] Correct. We have derived this before, however, realize now we can identify this as the gravitational field which surrounds and is caused by the Earth. And, more generally, if we replace the mass of the Earth in this equation with the mass of any object, you get the gravitational field that surrounds any object. And this is what it looks like. [

] Notice, according to the equation, because the gravitational field is proportional one over r squared, the gravitational field decreases as the we get farther from the planet.

Bobby: That's right. Previously we determined the acceleration due to gravity on the International Space Station was 8.6 meters per second squared.

Mr.p: Correct. The farther apart the gravitational field lines are in the gravitational field drawing, the weaker the gravitational field. As we get farther from the Earth the magnitude of the gravitational field decreases and, therefore, the gravitational field lines in the drawing get farther apart.

Bo: Are those lines real?

Mr.p: Okay. No. These gravitational field likes in the drawing are a way for us to visualize the concept of a gravitational field. Its our way of illustrating what the acceleration of any object would be if it were placed at a location in the gravitational field. But not, it’s not like these lines exist in the real world. They are a visual construct to help us understand the physics. Oh, also notice the equations for gravitational fields we have here are the magnitudes of those fields. For the constant gravitational field, the direction is downward, toward the center of mass of the planet. For the gravitational field which exists around any object, the direction is toward the center of mass of the object. {hear Billy} Right. The direction of the gravitational field is always toward the center of mass of the object creating the gravitational field because the force of gravity is always a pull. … Thank you very much for learning with me today, I enjoyed learning with you.

Billy: (So it is always toward the center of mass of

the object?)