Physics of Imagineering **In-class assignment #4**
October 12, 2011 **Gravity**

Goals

1. To be introduced to forces.
2. To learn about the gravitational force.
3. To practice calculations.

Equipment:

Notebook (draw diagrams directly inside), object to drop, meter stick, stopwatch

Force and acceleration

1. When the driver of a car steps on the accelerator, what happens to the car?
2. When the driver steps on the breaks, what happens to the car?
3. When the driver turns the steering wheel, what happens to the car?

These are all examples of forces being placed on the car. Forces cause an object (like the car) to change its speed. This idea is represented by the formula $F = ma$. "a" stands for the acceleration of an object, which is the amount by which it's speed is changing. "m" stands for the mass of the object, which is an intrinsic property of an object (it doesn't really change) measuring how much "stuff" is in the object. "F" is the force that acted on the object to get it to change its speed.

4. Draw an overhead view of a car on a road. Draw an arrow to represent the direction of motion. Draw and label another arrow indicating the direction of the acceleration of the car if the accelerator is pressed. Draw and label arrows indicating the directions of the acceleration for the brakes and the steering wheel.

Gravity

Gravity is a force that can work on an object without touching it. It is one of only four such forces (another is electromagnetism, which we already covered; the other two only operate inside atoms). The force of gravity between two objects depends on the masses of each object (let's call them m and M) and the distance between them (d). This is represented by the formula $F = \frac{GmM}{d^2}$.

5. The gravitational force, like all forces, causes objects to accelerate. It turns out that the acceleration due to gravity depends only on G, the earth's mass, and the earth's radius. Using the given formulas, derive a formula for the acceleration due to gravity. Look up the values of G, the earth's mass, and the earth's radius and calculate the acceleration due to gravity.
6. Asa said that a dropped object's speed is 22 mph after 1 second. Show that this is equivalent to the value you found in #5.

The acceleration of an object is the rate by which the speed changes. If you've taken calculus, you might recognize that rate is a derivative, so that $a = \frac{dv}{dt}$. Furthermore, speed is the rate at which distance changes, so that $v = \frac{dx}{dt}$. Putting these together, we find that $a = \frac{d^2x}{dt^2}$. Using calculus shows that $x = \frac{1}{2}gt^2$. Simpler algebra rearranges this equation to $t = \sqrt{2x/g}$.

7. Pick a partner. Write his or her name in your notebook. While one of you puts your arm straight out, the other should measure the distance from that hand to the ground. Calculate the time it takes for an object to drop that distance influenced only by gravity. Use the stopwatch to measure the time it takes an object to hit the ground when dropped from that height. Does it match your prediction? What about a different object, should it take the same amount of time? Why or why not? Give it a try. Don't forget to write down what objects were dropped.

Equivalence

Forces don't distinguish between gravity and forces that touch. So, you can't tell the difference between standing on the surface of a planet and standing in a spaceship constantly accelerating.

8. You wake up at night in your berth on a rain to find yourself being "pulled" to one side of the train. You naturally assume that the train is rounding a curve, but you are puzzled that you don't hear any sounds of motion. Offer another possible explanation that involves only gravity.

Rides

- California Screamin', Tower of Terror, Matterhorn, Star Tours, Soarin' over California