Gravity and Energy Lab Guide Experiment A04

Part A: Acceleration Due to Gravity

DATA TABLE 1 (25 points): Here you are going to be dropping the HEAVIER ball.

1.) The first step is to find the height from the floor (where your pressure pad sensor is) to the dropping mechanism (where your ball will start out). The part that always tricks up students is that the sticks in the ODU astronomy labs are 2 meters long, i.e., they are not traditional meter sticks! Thus, you have to make sure you read the measurements on the stick very carefully! *HINT:* you'll probably have a height larger than 1 meter, so your height should not be less than 1!
2.) The most tedious part of this experiment is trying to drop your ball right on the pressure pad and having it properly record your **time** – it will probably take a few attempts just to get one correct trial. However, the "correctness" of this whole section will depend on these trials so working to do it right will be rewarding in the long run. You will need to record the time in 5 separate trials.
3.) In the third column, you are asked to just do a simple equation – square the time you got in the second column (the last step) and then divide by 2.
4.) See that the value you found in the previous column is the entire denominator here in this new expression. So here all you need to do is take the height to the ball (that you measured in step 1) and divide it by the number you got in column 3. This, then, is your calculated **acceleration due to gravity**. Is it close to 9.8 m/s^2? If you are around 8 or 10 you are still close, but if you are way off (especially around 4.5 or 15) you may want to make sure your height is correct, or your pressure pad is correctly displaying the time in your trials!
5.) You've found a value for the acceleration of gravity in each of the 5 trials you did. You now need to find the **average acceleration**. Add up all 5 of the accelerations you found and then divide by 5 – this is your average!
6.) Now you need to use the equation in your lab manual to find the **percent difference.** The accepted value is 9.81 m/s^2 and the calculated value is that which you found for the average acceleration. REMEMBER: the percent difference is an *absolute value*, i.e., it should always be positive!

DATA TABLE 2 (25 points) : You need to do the exact same procedure listed above but now for the lighter ball.

a) **(5 points)** We know what the answer *should* be immediately – we know all objects falling from the same height with the same acceleration of gravity should fall to the ground at the same exact time (when we aren't concerned with air resistance of course). Does your data support this? If your two plots aren't close then I would recommend redoing one or both of your experiments.

b) **(5 points)** First, we have the following equation:

$$g = \frac{GM}{R^2}$$

We are looking for the mass of the Earth in this question. First, we need to arrange this to get M by itself in terms of all of the other variables we know; g (the acceleration due to gravity), G (Newtons gravitational constant), and R (the radius of the Earth). In this case, for g you will be using the value that YOU calculated in the experiment above. If you followed directions closely then the value you find for M will be almost exactly that found on Google!

c) **(10 points)** Let's look at the equation above; if you plugged in the mass of the moon (which is *smaller* than the Earth) and the radius of the moon (which is *smaller* than the Earth), would you get the same g?

Part B: Conservation of Energy

Let's go over some physics so we will have an easier time answering the questions here. At any point in a planets orbit, its TOTAL ENERGY is just the sum of its KINETIC ENERGY and POTENTIAL ENERGY. This TOTAL ENRGY always stays the same – i.e., energy is neither created nor destroyed. *Kinetic Energy* (KE) is the energy associated with the movement of an object through space – thus the *faster* an object moves, the *greater* its KE. In our case the potential energy (PE) here is specifically *gravitational potential energy*, meaning that an object will have some amount of energy (its PE) just because it is influenced by another object through gravity.

Let's look at how we can think of gravitational PE. Remember in elementary school when we first learned that PE depended on how high off the ground you lifted an object – the higher you lifted it, the larger its potential energy would be. Dropping the object, all of this PE is converted to KE as it falls. How? Well, we just established that the higher above ground an object is the *larger its potential energy*. As this object falls, it (obviously) will get closer to the ground thus decreasing its PE. However, the TOTAL ENERGY (E = KE + PE) *must* stay the same, and for this to be true a decrease in PE must mean that the KE increases by the same amount. We had previously established that an objects KE increases when the objects speed increases, so as the objects falls and looses height (a decrease in PE), the *speed* of the objects increases due to the necessary increase in its KE.

How can we apply this to planets? Well, Earth is still attracted to the Sun just as the above object is attracted to Earth. So, the *further* away the Earth (or any planet) is away from the sun, the *larger its gravitational PE!* This means that the distance at which the planet is *furthest* from the sun is associated with the point at which the PE is MAXIMUM. However, we still have the requirement that the TOTAL ENERGY be the same at all points, thus as the planet gets further away from the star (its PE *increases*), the planet must move slower (its KE *decreases*). We can then apply this same logic to the case when the planet starts to move closer to the star!

a.) **(2 points)** Remember what we just said about the planets speed – it is directly proportional to the objects KE!
b.) **(2 points)** Same logic as part a!
c.) **(2 points)** The larger the KE the faster the speed, remember?
d.) **(2 points)** Same logic as part b!
e.) **(2 points)** Remember that the planets gravitational PE is associated with how far away the planet is from the sun!
f.) **(2 points)** Same logic as part e!
g.) **(3 points)** Now we are asking about TOTAL ENERGY, what did we mention was so special about the TOTAL ENERGY of the planet as it orbits the sun?

Part C: Other Forms of Energy

1.) In **PART A (5 points),** we know that *temperature* and *thermal energy* must have at least SOMETHING in common because we know what we mean by temperature (how hot/cold something is) and what the word *thermal* means (relating to heat). But what DO we mean when something is hot or cold? What exactly makes something hot/cold to us? Let's take two bottles of air where one is "hotter" than the other. What is the difference between the two at a *molecular* level (the air not the bottle!)? The difference is that the "hotter" air molecules are individually *moving* a lot more / a lot *faster* than the other air molecules. Now some can be moving faster/slower than others, but AS A WHOLE the molecules in the "hotter" bottle are moving faster. Now let's apply what we learned in section B above; what happens when increase the SPEED of an object – its *kinetic energy increases.* Then we could say that *the kinetic energy of the molecules in the "hotter" bottle is greater than those in the "cooler" bottle.* Again, we can't quite say anything about the KE of individual molecules, but we know that the average KE of the molecules in the "hotter" bottle is *greater.* Thus, if we can measure the average kinetic energy of all the molecules of a substance, we would have a way to tell how much "hotter" or "colder" an object is compared to another. This is what we call *TEMPERATURE.*

Thermal Energy is a bit more specific; the thermal energy of one of these bottles would be the *total* amount of energy of all the air molecules together. This *energy* is what is transferred between the "hotter" bottle to your hand in order for you to *feel* that it is hot – "*temperature" is not what is being directly transferred.*

In **PART B (5 points) ,** let's first realize the biggest difference between the oven and pot of water – the oven is full of *air* with is a lot less dense than water – i.e., if you throw your hand into an oven, it will make contact with a lesser number of particles than if you threw your hand into water. This means that even though the air molecules in the oven are moving at greater speeds (it is at a higher temperature), there are less molecules that can transfer their thermal energy to your hand (and the contact with this energy it what severely burns you).

2.) **(5 points)** This problem has two parts, FIRST use $E=mc^2$ to find the total mass-energy (E) in one gram of matter. If you convert this mass into kilograms (kg) and then use the speed of light in m/s^2 ($c = 2.99x10^8$ m/s^2), your resulting value of energy (E) will have units of *Joules*. SECOND, we then find how many years we could run a 100W (watt) light bulb with this much energy.

What are *watts?* A watt is a unit of *power* which is just some amount of energy per some amount of time. More specifically, 1 *watt* is 1 *joule per second.* We know from the first part of this question that a *joule* is a unit of energy, so this should make sense. So, this lightbulb being 100W tells you that it takes 100 *joules per second* to run. With this information (and a total amount of *joules* from the first part of this question), how many total *seconds* could this light bulb be ran for?

I will do an example for you that you can use to answer this question. Say I have 2,000 *joules (J)* at my disposal; how long could I run this 100W lightbulb? First, I would take the total amount of energy I have and then divide it by the rate at which I would use it (i.e., 100W = 100 *joules per second* – the rate at which I would use this energy).

$$\frac{2{,}000\ \mathrm{J}}{100\ \mathrm{W}} = \frac{2{,}000\ \mathrm{J}}{100\ \frac{\mathrm{J}}{\mathrm{s}}} = (2{,}000\ \mathrm{J}) \times \left(\frac{1\ \mathrm{s}}{100\ \mathrm{J}}\right) = 20\ \text{seconds}$$

Notice how this can be solved just like the dimensional analysis problems we worked on in the previous lab. You can use the same method here to solve actual problem in the lab manual, except notice that the only thing that is different is how much energy you start with. However, I would like you to express you answer in *years*; all you have to do is take the total number of seconds you find and divide it by the number of seconds in one year (write out the dimensional analysis problem if you cannot see why). *HINT:* you should be getting a final value larger than 20,000 years!!