Lab #1

Conventional Energy Sources

Introduction

We encourage you in this lab to work with a partner when looking up information in the reading or online. Please discuss and compare your answers and ask your TA for help if needed!

In class this semester, we are discussing global warming and energy. In today's lab, we will learn about some conventional energy sources currently used or planned for use in the near future, once we either run out of fossil fuels or stop using them voluntarily.

Please read through the following passage. Where a paragraph contains information asked about in the worksheet, an indicator as to the worksheet question number will appear at the end of the paragraph (though the entire text should be read in order to provide definitions and context for your answers).

Fossil Fuels

There is currently some dispute over "Peak Oil," a concept first introduced by geoscientist M. King Hubbert when he was working for the Shell Oil Company in the 1950's The amount of oil in the Earth's crust that we are able to recover is finite. Experts from oil companies and oil-producing countries have attempted to forecast the supply and demand for oil in the coming decades, but there is a great deal of uncertainty in their predictions. (**Q1**)

Starting from the supply side of the problem, we have several types of oil to consider:

Proven Oil Reserves

This includes oil already extracted from the ground as well as oil that is very likely (95% or better) to be extracted from known reservoirs underground.

Likely Oil Reserves

This includes oil that has about a 50% chance of being extracted, and that uncertainty is either due to uncertainty about the size of the reservoir or uncertainty about our ability to extract the oil from the reservoir. Oil fields such as the

Arctic National Wildlife Refuge and many deep sea fields fall into this category.

Speculative Oil Reserves

This includes oil that has less than 10% chance of being extracted in the future, and it is not generally considered as part of the analysis of total supply.

Unconventional Oil Reserves

This includes oil that could be extracted from oil sands or shales or through conversion of natural gas or coal. Oil shales in Canada and the Rocky Mountain West in the United States fall into this category.

Though in theory, the amount of oil in proven and likely oil reserves should be easy to calculate based on data that could be provided by the companies and/or countries extracting oil from each location, in practice, reliable information is difficult to come by.

Oil companies may want to underestimate the amount of their reserves in order to make oil seem scarce and thus drive up the price. On the other hand, some companies may have incentive to overestimate their resources in order to look more attractive to potential buyers or to drive up their stock price on global exchanges. Governments also have an incentive to overstate reserves in order to promote economic stability or (for producer countries) to increase their perceived worth and bargaining power in international negotiations. (**Q2**, **Q3**)

At this time, reliable estimates of proven and likely oil reserves are somewhere between 800 and 1200 billion barrels.

Unconventional sources of oil could potentially produce four to ten times as much oil as currently exists in our conventional oil reserves, but this oil is much more difficult to extract. Usually, wells have to be dug deeper or the oil has to be separated or purified, both of which are energy-intensive processes. At the limit, imagine the amount of energy it takes to extract one barrel of oil, purify it, clean up the waste products and transport it to its desired destination.

What if the amount of energy to do this is equal to a barrel of oil or more? Then it isn't worth the trouble from an economic standpoint and so while the oil may be there in the ground, it doesn't "count" as part of our oil reserves since it is too much trouble to extract. (**Q4**)

On the demand side, the data is much easier to come by since such figures are routinely reported by various economic agencies with no incentive to mislead (and, in fact, great incentive to be accurate). The oil consumption of the United States is currently around 8 billion barrels per year and while high, it is not growing very quickly (about 1% per year on average). The oil consumption of developing nations like China is smaller, currently around 2.6 billion barrels per year, but it is growing quickly (about 7% per year on average).

If we project these numbers forward, it is fairly easy to figure out, based on various assumptions, how long the oil will last. Just divide the total reserves by the average rate of consumption, which is currently 33 billion barrels per year. The answer you get is somewhere in the neighborhood of 20 to 40 years if you just go by proven and likely reserves, depending upon how much demand is projected to grow (or shrink) in that time.

There has been some debate politically over whether or not the United States should extract oil from the Arctic National Wildlife Refuge (ANWR). At this time, our best estimate of recoverable oil from the ANWR is around 10 billion barrels, which amounts to about 10% of the total estimated amount of undiscovered oil reserves in the United States. The actual amount of oil present there could be as much as 50% higher or lower depending upon various assumptions about the geology of the formation.

If we assume the optimistic case, and if we begin the extraction process now, the field would be open for production in about 10 years, peaking around the year 2030, and at that time, its production would amount to around 2% of our annual consumption of oil in the United States. These numbers tell us that whether we drill or refuse to drill in the ANWR, the impact on "peak oil" will be minimal. (**Q5**)

The term "peak oil" comes from the fact that of the 800-1200 billion barrels of recoverable oil in the world, it won't all come out of the ground in the same way. As oil reservoirs dry up, it becomes substantially more difficult to extract oil from a given well and so while the oil is there, it comes out of the ground more slowly. So there may be 1200 billion barrels of oil in the ground, but as that number shrinks, the amount of oil we can get out of the ground will shrink each successive year.

What offsets the shrinking rate of production is new discoveries and new fields open that will extract oil at high rates. As the number of discoveries tapers off (and there is debate over how quickly that will happen or has happened), the amount of oil produced in a year will peak and then start a slow decline as it becomes more and more difficult to extract remaining reserves from their underground reservoirs.

Regardless of when this may happen, there is near-universal agreement that it will happen, if not this decade then in 20-30 years or perhaps even a few hundred years if we can make the unconventional oil sources feasible. So there is great incentive to explore alternative energy sources, whether you agree with aggressive oil exploration to expand reserves or not.

Based on this introductory passage on “Peak Oil,”, please answer the associated questions on your worksheet before proceeding.

Nuclear Fission

In the discussion above about oil production and consumption, we ignored the concept of global climate change as well as other problems (such as oil spills off the coast of Alaska or in the Gulf of Mexico). As we are discussing in lecture this semester, consumption of fossil fuels like oil, coal and natural gas is a major source of Carbon Dioxide in our atmosphere, not to mention other pollutants. Many scientists feel that fossil fuel usage should be curtailed for this reason alone. So whether you feel that fossil fuel usage should end sooner because of the threat of global warming or later because of dwindling reserves, if we are going to continue using energy, we need to find other sources.

To introduce you to the basics of Nuclear Fission, I will ask you to read through a brief summary of the subject on Wikipedia, accessible in your browser at the following address: http://en.wikipedia.org/wiki/Nuclear_power As you read this article, please answer the associated questions on your worksheet, which are asked in the same order they are covered in the article. (**Q6 through Q13**)

Nuclear Fusion

Fusion reactors work by using light nuclei, such as Hydrogen (or isotopes of Hydrogen, which are Deuterium and Tritium), and combining the nuclei at very high temperatures so they form more complex nuclei like Helium or Lithium. The end result is a nucleus with less mass than the initial components in the reaction, and the lost mass is converted into energy, usually at a much higher rate than what is found in a typical fission reaction.

Hydrogen has a single proton for a nucleus. Deuterium is an isotope of Hydrogen with a proton and a neutron in its nucleus. Tritium is an isotope of Hydrogen with a proton and two neutrons in its nucleus, and Tritium is unstable, with a radioactive half-life of about 12 years. In order for nuclei such as these to fuse together, a fusion reactor must have extremely high temperatures. This is because fusion can only occur if the original nuclei can be forced very close together. (**Q14**)

Normally, two positively charged nuclei will repel each other due to the electric force, and this repulsion increases dramatically as the nuclei get closer together. However, if temperatures are high enough, the nuclei will be moving so quickly that they will approach to very close distances before the electric force can bring them to a stop. (**Q15**)

When this happens, the attractive (but short range) nuclear strong force will bind them together to make a new, larger nucleus. Often, this new nucleus has less total mass than the original nuclei it was constructed from, and this mass that is lost is converted into energy during the reaction. That energy comes off either as light (photons) or as kinetic energy of the resultant particles. This energy is eventually converted into thermal energy which can heat water to power a boiler or steam turbine and so on.

The most common reaction used today in experimental fusion reactors is the combination of Deuterium and Tritium, or the D-T reaction:

$^{2}D + {}^{3}T \dashrightarrow {}^{4}He + n$

Deuterium and Tritium have an advantage for us that they are easier to fuse than ordinary Hydrogen, thanks to the presence of the additional neutrons in the nuclei. The neutrons provide more attractive strong force but no extra positive charge for the repulsive electric force. In this reaction that total mass of the input (^{2}D and ^{3}T) is a little greater than the mass of the output (^{4}He and a neutron), and that mass difference is converted into energy. (**Q16**)

To put the released energy into context, suppose we have one gallon of gasoline. The amount of energy released chemically by burning the gasoline is around 1 billion Joules. That's roughly the amount of energy used by an average household during a day. Suppose we fill a 1-gallon milk jug with a enough of a mix of Deuterium and Hydrogen so that it weighs the same as the gallon of gas. The amount of energy this mix would produce in a fusion reactor is about one million times greater, enough to power an average household for 3000 years!

Because of the essentially limitless abundance of Hydrogen fuel on the Earth (in water) and the enormous amounts of energy available via nuclear fusion, there is a great deal of interest in the scientific community in making commercial fusion reactors viable. First, there are a few problems we will need to overcome.

Confinement

Because of the extremely high temperatures required for fusion to work, ordinary containers are not practical. Any solid we try to use to confine the D-T mixture as it heats up would quickly melt, allowing the plasma to escape. One way around this is called inertial confinement. In this method, the D-T mixture is machined into a solid fuel pellet, and this pellet is then placed on a target at the center of a device that can fire many high energy laser beams into the pellet.

The pellet heats up quickly and explodes outward, but for a tiny fraction of a second, it has the necessary temperature and density for some fusion to occur. This is a similar sort of technology used in a Hydrogen bomb but on a much smaller scale. In a reactor, we would cycle pellets into an ignition chamber many times each second to get a series of controlled bursts and a constant supply of energy. This type of process is similar to using a fuel injector to spray gasoline into a piston chamber, then igniting it with a spark plug, creating a series of tiny explosions to power a car's engine. (**Q17**)

I recommend you read more about the National Ignition Facility at http://lasers.llnl.gov . (**Q18**)

Another method is magnetic confinement. Since the D-T mixture must be heated to extremely high temperatures, the electrons will be stripped from the atoms, creating a gas of positively charged nuclei and negatively charged free electrons. Charged particles cannot cross magnetic field lines easily, a fact that enables the Earth's magnetic field to protect us from the solar wind, a constant stream of high energy charged particles coming from the Sun.

Using a hollow donut-shaped device called a tokamak, we can generate a magnetic field in a continuous ring and confine the plasma within this ring as we heat it up. Thus, the plasma does not actually come into contact with the walls of the chamber. Unfortunately, once fusion begins occuring within the plasma, the plasma will heat up thanks to the extra energy, and that creates instabilities which may allow the plasma to escape confinement. (**Q19**)

For more information and some images/videos of this kind of reactor, visit the website of ITER (International Thermonuclear Experimental Reactor) at http://www.iter.org. (**Q20**, **Q21**)

Energy Accounting

Another problem that must be overcome is inefficiency. When designing a fusion reactor, we must consider both the amount of energy put into the process to make the reaction occur and also the amount of energy that we can successfully extract from the plasma once the fusion has occurred. The ratio of output energy divided by input energy is called the Q-value. (**Q22**)

For the input energy, we consider first the amount of energy it takes to construct the reactor. If the reactor can handle billions of reactions, then this may not be a big deal in the long run, but if the reactor or parts of it must be replaced every so often, then the amount of energy invested in construction materials for every reaction can become significant.

Next, we must consider the amount of energy it takes to acquire the fuel. Perhaps we get the Hydrogen or the D-T mixture from splitting apart water molecules, and that takes energy. Then we must consider the energy to heat up the gas, keep the magnetic fields powered and keep the plasma confined (or to fire the lasers and manufacture the pellet in an inertial confinement reactor).

For the output energy, we hope to harvest as much of it as we can, but there is always some energy lost due to inefficiencies. So in practice, while a gallon of D-T mixture could theoretically provide enough energy to power a household for 3000 years, we might only be able to extract 10% of that energy from each reaction with the rest being lost as waste heat or other means.

In order for a fusion reactor to be commercially viable, the fusion process must have a Q-value greater than 1; otherwise, there is no point going through the fusion process. The purpose of our experimental reactors is, in part, to find an efficient process for manufacturing the fuel, igniting fusion and extracting energy from the process. If we can get a Q-value of 20 or more in an experimental reactor, then we should be able to build viable commercial reactors using the same process. The two experimental reactors mentioned previously (ITER and NIF) are both expected to achieve Q-values of at least 1 for the D-T fusion process. (**Q23**)

Nuclear Waste

Looking again at the D-T reaction, notice that the output products are Helium and a neutron. The Helium nucleus is not harmful and is not considered nuclear waste, but the neutron is potentially harmful. First of all, whether we use inertial confinement or magnetic confinement, the neutron has no charge and so cannot be contained. Thus, while fusion reactions are going on, the walls of the chamber will be bombarded with neutrons.

When ordinary atoms like Carbon or Silicon or Iron are bombarded with neutrons, these neutrons are absorbed into the nuclei, often converting them into highly radioactive and dangerous isotopes. This causes the structure to break down, resulting in replacement costs and radioactive waste. It is possible in theory to blanket the fusion reaction with Lithium, which when bombarded will break apart into Tritium and Helium. Then the Tritium (which is expensive to manufacture due to its short half-life) can be used for another reaction, eliminating the fuel cost. (**Q24**)

Such reactors are expensive and require a lot of energy to maintain operations, so the energy must be extracted from the reactions efficiently. An alternative is to use a fusion reaction that doesn't produce neutrons, such as a combination of simple Hydrogen with Boron-11, which produces 3 Helium-4 nuclei as output, along with energy, but it requires higher temperatures.

And higher temperatures mean a less efficient process. So we must choose whether to deal with the problem of excess neutrons at low temperatures or the inefficiency associated with high temperature reactions. With each generation of experimental reactor, we are approaching a level of efficiency that will make nuclear fusion feasible, but most experts project that the soonest possible date for a commercial reactor is the year 2050 based on current research trends.

Nuclear fusion does hold promise for the future as a way out of our dependence on Carbon-based fossil fuels, but it is still not a reality. In the meantime, if the goal is to reduce or eliminate fossil fuel usage, we will have to consider other alternative sources of energy.

Worksheet

Please turn now to the worksheet for this lab and answer the questions there about nuclear fusion based on the introductory reading you have just completed.

Conclusion

This week's lab is qualitative. The purpose is to give you a chance to go deeper into topics we only have time to touch on in lecture. In qualitative labs, there will be no essay assignment included. When you have finished answering the questions on your worksheet, you are finished with the lab.

Lab #1 Worksheet

Name:
Home TA:

Part 1 (Peak Oil)

From the introductory passage on Peak Oil, answer the following questions in the space provided.

1. Who first modeled the future of oil production and introduced the concept of peak oil?

____

2. Briefly explain one reason why some oil reserves may be underestimated.

3. Briefly explain two reasons why some oil reserves may be overestimated.

4. Explain why, even though a barrel of oil may be present in an unconventional source such as oil shales in the Western United States, we would not count it as part of our overall oil reserves?

5. Explain why the decision on whether or not to extract oil from the Arctic National Wildlife Refuge (ANWR) has very little impact on the overall issue of peak oil.

Part 2 (Nuclear Fission)

From the Wikipedia article on Nuclear Power, answer the following questions:

6. Currently, nuclear power (from fission reactors) provides what percentage of the electricity consumed in the United States? See section 2 - Industry.

________%

7. Based on the pie chart in the right hand column next to the table of contents, what are the five main sources of fuel the world uses for energy?

____________________, ____________________, ____________________,

____________________, ____________________

8. Skip down to section 3 entitled “Nuclear Power Plant” and answer: Describe how electrical energy is generated in a nuclear fission power plant (this is the very first part).

9. From section 4 on “Life Cycle”, the authors perform a calculation for the lifetime of Uranium as an energy source. At current consumption rates, the amount of Uranium in our reserves is enough to last us for at least how many years?

____

10. From section 4.2 on “Solid Waste,” and in particular 4.2.4 “Waste Disposal,” describe where most nuclear waste is stored from nuclear power plant operations.

11. What are the two reasons cited in the next section (4.3 “Reprocessing”) why reprocessing of nuclear waste into usable fuel is not currently a common practice?

12. Moving on to section 10, “The Debate on Nuclear Power”, list five reasons proponents favor the expansion of nuclear fission power?

1. ______________________________

____

2. ______________________________

____

3. ______________________________

____

4. ______________________________

____

5. ______________________________

____

13. List five reasons critics oppose the expansion of nuclear fission power.

1. ______________________________

____

2. ______________________________

____

3. ______________________________

____

4. ______________________________

____

5. ______________________________

____

Part 3 (Nuclear Fusion)

From the introductory passage on Nuclear Fusion, answer the following questions in the space provided.

14. Explain what Deuterium and Tritium are.

15. Explain why high temperatures are necessary in order to achieve nuclear fusion.

16. Explain why it is easier to fuse Deuterium and Tritium as opposed to simple Hydrogen.

17. In your own words, briefly describe the inertial confinement method for nuclear fusion.

18. At the website for the National Ignition Facility (http://lasers.llnl.gov, look under Education —> How Lasers Work and read this short article. Next, the video to watch is now on youtube rather than the NIF website, so navigate to http://www.youtube.com and search for “How NIF works”. Watch the five-minute video and draw a simple sketch of how fusion in the target is ignited by lasers. Use appropriate labels.

19. In your own words, briefly describe the magnetic confinement method for nuclear fusion.

20. Visit the website for the experimental magnetically confined fusion reaction at http://www.iter.org. On the top toolbar, there is a Science menu. On that menu, select “What is Fusion” and briefly explain how fusion generates energy:

21. Under the Science menu at http://www.iter.org, select “ITER Goals” and answer: The current record Q-value for a fusion is 0.67. If the ITER works as envisioned, what will be its Q-value?

____

22. Explain what is the Q-value for a fusion reactor?

23. Suppose a reactor has a Q-value of 20. If 1 million Joules of energy are used to create a fusion reaction, how much energy would be output from the reactor in the form of useful energy such as electricity?

____

24. Explain how nuclear fusion reactions may generate radioactive nuclear waste.

Lab #2

Alternative Energy Sources

Introduction

In Lab 1, we studied fossil fuels and nuclear power. This week, we will explore several alternative sources of energy, many of them renewable, that may augment or even ultimately replace our current energy infrastructure.

Part 1 (Types of Energy)

For this first part of this lab, I will ask several different groups in the lab to explore alternative sources of energy. Your TA will assign each group one source from the following list:

Solar
Wind
Tides
Hydroelectric
Biomass
Biogas
Geothermal

For each energy source, you will be on your own to find credible sources on the web. Wikipedia and Google are good places to start, but again, look for objective, credible sources and use your judgement.

Once you have answered the questions about your specific energy source on your worksheet and once every group in the class has had a chance to research their particular energy source, a representative from each group will present their findings to the class. Based on the presentations, you can then answer a question about each energy source on your worksheet to complete the first part of the lab.

Part 2 (Solar Energy)

In the first part of the lab, we have learned about solar energy, and we will experiment with that today using a photovoltaic cell. This panel converts light (photo) into electricity (volts). The amount of power that reaches the top of the Earth's atmosphere from sunlight is approximately 1300 Watts per square meter. On any given day, the typical amount of power consumer by all humans on the Earth is approximately 20 trillion Watts.

Simple division tells us that if we could collect 1300 Watts of power per square meter with solar energy panels (photovoltaic cells), then we would need about 15 billion square meters of collecting area. This is 15,000 square kilometers or 6,000 square miles, which is about the total area of the state of Connecticut, the 48th largest state in the United States. Unfortunately, it isn't that easy. If it were easy to collect this much energy from such a small area, we would already be doing it.

In today's lab, we will use our photovoltaic cell (PV cell) to explore some of the difficulties we face when trying to harvest solar energy.

The Photoelectric Effect

PV cells convert light energy into electrical energy via the photoelectric effect. Within conducting metals are free electrons. The free electrons move about inside the metal, but in order to leave the metal, they must absorb some minimum amount of energy. Photons (particles of light with a specific energy and wavelength) are one possible source of that energy. If an electron absorbs a photon that has too little energy, then the electron will not escape the metal.

If an electron absorbs a photon with enough energy, the electron will escape the metal. Light (a stream of photons) strikes the PV cell, and some of the photons are energetic enough for electrons in the metal to escape. These electrons are funneled through a conducting material as a current (from which we draw electricity for our devices), and then they are redirected back into the metal.

Efficiency

Even under ideal laboratory conditions, not all of the light energy that strikes a PV cell is converted into electrical energy (or electric current). Many of the photons are not energetic enough, and they have no effect. Some photons have much more energy that what is needed to free the electrons from the metal, and that excess energy is wasted as heat by the electrons after they escape the metal.

The bulbs in your electric lamps emit the equivalent power of a 40 Watt light bulb. The amount of electrical power (in Watts) generated by your solar cell is equal to the current squared multiplied by 50.

Experiment #1

1. Make sure your PV cell and multimeter are properly connected. Your TA can help you with this. **Do not remove any of the connecting wires during this lab as there is a risk of electrical shock.**

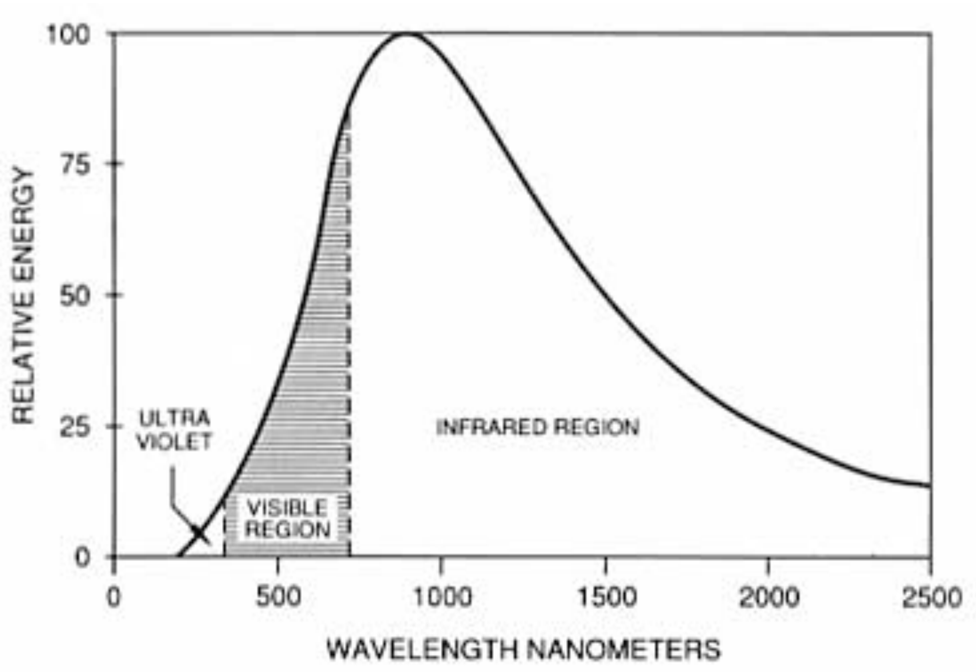
2. Turn on the multimeter by rotating the switch counter-clockwise to the 200 mA position.

3. Plug in your lamp and hold it directly over your PV cell at several different heights (indicated in the first table on your worksheet). Record the current running through the PV cell and the power generated by the cell on your worksheet.

Spectral Response

Not all light is equal when it comes to generating current with a PV cell. Short wavelength (blue light) is more energetic and can more easily allow electrons to escape the metal. However, the extra energy of these photons is wasted, and there aren’t as many of these photons in a typical spectrum for an incandescent light bulb. Long wavelength (red light) is often best if it has enough energy to allow electrons to escape, and there are a lot more of these types of photons in a typical spectrum.

Most of the light emitted by a typical light bulb is in the long wavelength, low energy, infrared part of the spectrum (See figure on next page). These photons are not energetic enough to allow electrons to escape the metal, so their energy is wasted.



The spectral energy distribution of a typical light bulb. Note that less than 20% of the energy is in the visible part of the spectrum, which is the part that is useful for generating current in a PV cell.

Experiment #2

Hold your light source 30 cm away from the PV cell directly overhead and then compared the current and power generated by the PV cell when there is no filter, blue filter, yellow filter and red filter. Record your results on your worksheet.

Atmospheric Effects

Another reason PV cells do not convert all sunlight into energy is that some of the sunlight is absorbed by our atmosphere before it reaches the detector. Sure, 1300 Watts per square meter strikes the top of the atmosphere, but how many watts per square meter make it to your solar energy panel at ground level? That depends largely on the altitude of the Sun.

If the Sun is directly overhead, then the altitude is 90 degrees, and your PV cell will work with maximum efficiency. On the other hand, if the sunlight is coming in at an angle, then that energy will be spread out over a larger area. In addition, it will have to travel through a much longer path in the atmosphere to reach the detector, meaning more light is lost.

As you will see, because the sun has a higher altitude in the sky at different places on Earth, some latitudes are more favorable for collecting solar energy.

Experiment #3

Using your meterstick and protractor, hold your light source exactly 30 cm away from the detector at several different angles. Record the resulting current and power generated by the PV cell on your worksheet.

We are only measuring the loss of power caused by the spreading of the light in this experiment. To account for the additional loss of power due to the longer path length of sunlight in the atmosphere, we would have to greatly increase these effects.

Solar paths

Navigate to **http://personal.tcu.edu/dingram/solar.html** and find two diagrams showing the Sun's daily path through the sky at different times of the year as seen from different locations on the Earth. About how many hours per day at each location and each time of the year is the Sun more than 30 degrees above the horizon? Look at the diagrams to determine your answers, and fill in this information on your worksheet.

Conclusion

Now study each of your data tables. In each table, as you changed the height, color or angle of light, the amount of power generated by the solar cell changed in response. Which variable (height, color or angle) had the largest impact? Explain on your worksheet.

Like last week, there will be no essay associated with this mostly qualitative, information-gathering lab.

Lab #2 Worksheet

Name:
Home TA:

Part 1 (Types of Energy)

12. Which alternative source of energy was assigned to your group?

____

13. Based on your research into this alternative source of energy, briefly describe how this process generates energy.

14. Explain why the alternative energy source you have studied is not currently in more widespread use.

15. Explain what potentially limits this process from producing energy at the level required to satisfy the entire world’s energy needs in the future.

The following questions should be answered based upon either your group’s work or the in-class presentations given by other groups about alternative energy sources.

16. Briefly explain why solar energy is not currently in more widespread use.

17. Briefly explain what potentially limits wind energy from producing enough energy to satisfy the entire world’s future energy needs.

18. Explain what is preventing tidal energy from more widespread use currently.

19. Explain what is preventing hydroelectric energy from more widespread use currently.

20. Describe how the biomass process works as an alternative source of energy.

21. Describe how the biogas process works as an alternative source of energy.

22. Explain what is preventing geothermal energy from more widespread use currently.

Part 2 (Solar Energy)

Experiment #1

Height	Current (mA)	Current (Amps)	Power (Watts)

Experiment #2

Filter	Current (mA)	Current (Amps)	Power (Watts)

Experiment #3

Angle	Current (mA)	Current (Amps)	Power (Watts)

Solar Paths

In Fort Worth, the number of hours per day the Sun is above 30° altitude is…

Summer ___________, Spring/Fall __________, Winter _________

In Honolulu, the number of hours per day the Sun is above 30° altitude is…

Summer ___________, Spring/Fall __________, Winter __________

Conclusion

Which experiment showed the biggest impact (due to height, color or angle) on the amount of solar energy collected as conditions changed? Explain.

Lab #3

The Precautionary Principle

Introduction

Our discussions of global warming in lecture have touched on the difficulty of making long-term forecasts of the Earth's climate. For example, suppose the Carbon content in our atmosphere triples (or more) during the next 100 years. What will then happen to our weather? The answer is almost impossible to determine because it depends upon a number of known (and unknown) positive and negative feedback mechanisms.

For example, what if the increase Carbon Dioxide in our atmosphere warms the Earth to a point where much of the ice on the surface melts? The surface of the Earth would get darker, meaning it would absorb (rather than reflect) more energy from the Sun. This would make the Earth warmer and is an example of a positive feedback effect, meaning that some effect (melting ice) amplifies the original cause (warming), resulting in more warming.

Extra water vapor in our atmosphere as a result of higher temperatures may act as an additional greenhouse gas if it forms into high clouds. That's because high clouds tend to allow visible light from the Sun to reach the ground during the daytime, but they do not allow infrared light from the Earth to escape at night. That's another example of a potentially positive feedback effect.

Or perhaps the extra water vapor in our atmosphere from the warming would instead form into low, thick, reflective clouds. This would tend to cool us off, canceling out some or maybe all of the initial warming. This is an example of a negative feedback effect in which the effect (low, thick clouds) cancels out the original cause (warming).

Our problem is that we cannot easily predict which feedbacks will be the most important. If we assume the positive feedbacks are the most important, then our models of future climate forecast an increase in average temperature of 10 or more degrees, which could cause many environmental and societal problems. If the negative feedbacks are most important, then the average temperature in the future may only be a degree or two warmer, which is unlikely to make a significant impact on the Earth.

In this lab exercise, we will explore what to do in the face of this uncertainty, which is unlikely to go away any time soon. We are going to study the Precautionary Principle as it applies to global warming.

The Precautionary Principle

A widely accepted definition of this principle reads: "In order to protect the environment, the precautionary approach shall be widely accepted by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Applied to global warming, Precautionary Principle (PP) proponents would argue that, though we do not know the ultimate outcome of fossil fuel burning in terms of the global climate, we should, as a precaution, stop burning fossil fuels anyway until scientists have certainty about the long-term effects that fossil fuel burning has on the climate.

In the most rigorous interpretation, PP supporters would say that until there is scientific certainty that no harm to the climate will occur, we should stop burning fossil fuels. The most common interpretation of the PP, however, would be more practical: if there is good reason to believe (but not certainty) that harm will come to the climate, we should stop burning fossil fuels.

This sort of logic has some history, found in common sayings such as "Better safe than sorry," or in medicine, "First, do no harm." There is much debate in governments of countries around the world over how and whether to codify this thinking into legal practice.

Making Your Case

Your TA will assign your group to one side of the debate: either the “pro” or “con” side with regard to the Precautionary Principle. You will have about 45 minutes to build your case. Because resources on the web tend to change locations and new resources often appear, I will ask you to visit a web page that I keep updated with links to both sides of the debate.

http://personal.tcu.edu/dingram/pp.html

Use these links to research and build your case. For the longer articles, you may want to assign each part to a different person in your group. On your lab worksheet, provide an 8-12 sentence argument that justifies your team’s position.

Debate

Next, your TA will moderate a short debate, in which a representative from each side of the debate will present their supporting evidence. After the debate, finish the remaining questions on your worksheet.

Lab #3 Worksheet

Name:

Home TA:

Part 1

In the space below, state your group's assigned position on the Precautionary Principle, then justify it in 8-12 sentences:

Part 2

In the space below, provide a 3-5 sentence summary of the opposing position on the Precautionary Principle:

In the space below, write a 3-5 sentence statement of which side makes the most convincing argument and why.

Name:

Home TA:

Lab #4

Citizen Science: Disk Detective

Introduction

This lab is the first of several "Citizen Science" labs we will do together this semester as part of the zooniverse.org project family. The concept of Citizen Science is that some Astronomical databases are so large and the data so complex that computer algorithms cannot accurately or reliably sort through all of the data to find the kinds of interesting things that astronomers are looking for.

For example, consider NASA's Wide-field Infrared Survey Explorer (WISE) mission: this is a space based telescope that surveyed the entire sky for the first time ever in the infrared part of the spectrum. As a result, we now have a catalog of infrared images of around 700 million astronomical objects. These objects could be asteroids, galaxies, planets, stars, nebulae, or any number of strange objects.

That's where scientific analysis comes in. We must examine the images closely along with other data (in this case, images of the same objects taken at different wavelengths by other surveys) in order to classify the objects we have found. What we are looking for specifically in this case are circumstellar dusty disks that indicate the possible presence of a planetary system.

These kinds of objects are extremely difficult for automated programs to spot. Sure, a very smart computer program might be able to find some dusty disks if you give it some basic guidelines of what to look for, but inevitably, some objects in the sky are outside of the boundaries of whatever definition you provide to your computer algorithm. The human eye, it turns out, is far better at basic pattern recognition that any computer algorithm, and so astronomers have turned to crowdsourcing to find dusty disks buried in their immense ocean of data that computers have missed.

In this lab, you will be looking at pictures of many objects taken by different telescopes in different parts of the spectrum. Visible light ranges from 0.4 (blue) to 0.7 (red) microns. You will be looking at some images near the red end of the visible light range, but most of the images are in the infrared part of the spectrum, from 0.7 microns all the way out to 22 microns. By examining how these objects look at all of these different wavelengths, you will be able to deduce whether they are good candidates to be dusty disks that may harbor planetary systems, good candidates for detailed follow-up observations.

The Zooniverse site does not expect you to be perfect. There are going to be some candidates you see that you are not sure how to classify, and so in some borderline cases, you will find yourself essentially guessing whether or not an object is a real candidate, and you may guess wrong. That's okay. Zooniverse is going to be showing the same objects to dozens of other people as well, hoping to use crowdsourcing to achieve some kind of consensus on which objects are the most likely candidates. Any object that a certain percentage of people say is a good candidate will then be followed up. So you don't have to be perfect, but your best effort is most appreciated.

Before you classify anything, you will be asked to create a login to the Zooniverse site. Please write down your username and password somewhere safe, because you will likely be using the same account for other Citizen Science labs later this semester. If you discover a good candidate, and follow-up confirms and discovers something interesting, then you will get credit for assisting in the discovery of this new, previously unknown object when the scientific papers are published.

Step 1

First, go to **diskdetective.org**, which is a part of the Zooniverse family of web sites. Create a login and password that will work for all of the Zooniverse websites. Before you start classifying, you will read through some introductory material so that you better understand what you are looking at, and you will answer the associated questions below.

At the top of the page on **diskdetective.org** is a menu button. Click there and then click on the “About” page. Read through this initial information and watch the four-minute introductory video (I recommend viewing the video at high resolution and full screen), then answer the following:

From the video, you will see that when you click on the “talk” button above an image on the classifying page, this takes you to a more detailed version of the image with more information. In the video, the narrator clicks on the “SED” button.

What does SED stand for?

____

For this lab, we will ignore the information from the SIMBAD database, even though the video discusses it.

If you think the object is a good candidate, which button will you click on to indicate that?

____

Now click again on the menu button at the top of the page, then click on the “Science” page. Read through this information and answer the following questions:

What does YSO stand for?

____

If viewed from a distance, would our solar system more closely resemble a YSO or a debris disk?

____

Step 2

Before you answer any more questions about circumstellar disks and this project, it would be helpful if you would get a little bit of classifying experience under your belt. So from the main menu, select “Classify” and get started. You should check out the brief tutorial for helpful hints, and you should look at some of the examples shown. You can access these using the circular icons above and to the left of the image you are trying to classify.

Above and to the right of each image is an icon that will open up a new tab for discussion of the object you are classifying. You should experiment with this as you are classifying 10 objects in order to answer questions below for this section of the lab.

<u>Some tips for classifying</u>: If you see multiple objects within the red ring even in just one of the many images, then you can eliminate that object as a candidate (you still have to cycle through all of the images before you can click any boxes), so there are many classifications you can do in just a few seconds. In order to eliminate a candidate for the reason “Object Moves Off the Crosshairs,” the object has to appear to move so that no part of the object is touching the crosshairs any more. Objects that appear non-circular in the first few frames are also fairly common and make the classification decision quick and easy.

For one of the objects that you are classifying that you have concluded is a good candidate to be a circumstellar disk, click on the “Discuss on Talk” circular button above and to the right of the image you are analyzing. This will open up a new tab in your browser. From this screen, answer the following:

What is the ID of the image? ___________________________________

In the space below, sketch the SED graph for this object (just mark the relative locations of each of the 7-10 data points and draw a smooth curve through them). If you aren't sure what to draw here, you may wish to finish part 3 first and then come back to this part.

Once you have classified 10 objects, proceed to part 3. You can tell how many objects you have classified by clicking on the "Menu" button above the upper right part of the image.

Step 3

Now that you have classified some objects and can see what this project involves, you will now need to read some additional articles so that you can better understand what you are seeing and doing.

For more detailed information about this project, you will need to visit the blog associated with the Disk Detective site. From the menu button at the top of the page, access the blog. You may have to scroll down a bit or even go into the archives to find these entries from near the beginning of the project's lifetime.

From February 20, 2014, “That’s No Moon”. The direct link to this blog entry is **http://blog.diskdetective.org/2014/02/20/thats-no-moon/**, answer the following:

How big (in arcseconds) is the image you are analyzing in this project?

____

Disks around stars like Beta Pictoris are much too faint to see against the brightness of the central star in a normal image. How do astronomers take pictures of these disks?

____

____

Most dusty disks seen by the WISE telescope will appear as simple round blobs in the images you are analyzing. Explain why the WISE image of a star like Fomalhaut (very nearby and with a dusty disk) will look very different from an image of the same star taken with the Herschel observatory.

____

____

____

Aside from the four famous dusty disks mentioned in the blog, virtually every other dusty disk we may find in this project will simply appear as a circular dot (rather than an oval or disk-shape) in the WISE images. Explain why.

____

____

Now skip down to the February 4, 2014 blog entry, titled “Why Do the Stars Seem to Grow at Longer Wavelengths?” (the direct link is **http://blog.diskdetective.org/2014/02/04/why-do-the-stars-seem-to-grow-at-longer-wavelengths/**) and answer the following:

Explain why the objects in the longer wavelength images in your analysis typically appear larger than the same objects observed in shorter wavelengths of light.

____

____

____

Finally, skip down to the February 1, 2014 blog entry, titled “Spectral Energy Distributions (SEDs)” (the direct link is **http://blog.diskdetective.org/2014/02/01/spectral-energy-distributions-seds/**) and answer the following:

A regular star without a disk should have a blackbody SED. Describe how the SED will change for a star that has a dusty disk. You may either write a description or sketch a description below with appropriate labels and a brief description.

Step 4

If you didn’t answer the question about the Spectral Energy Distribution sketch in part 2, you may want to go back and do that one now. Now complete 50 additional classifications so that you end up with a total of 60. Once you have completed 60 classifications, alert your TA, who will initial in the space below to indicate that you have successfully completed the last part of the lab. When you click on the menu button, you will be able to see how many classifications you have completed.

____

There will be no concluding essays for Citizen Science labs, in order to make sure you have plenty of time to actually participate in the scientific project.

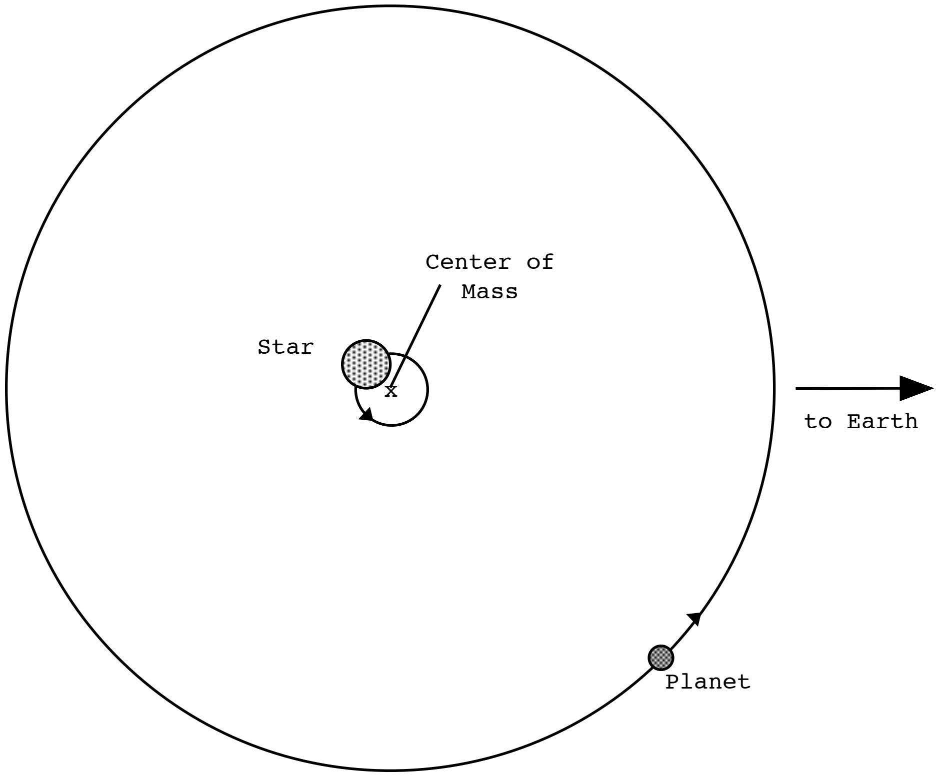
Lab #5

Searching for Extrasolar Planets

Introduction

Since the beginning of recorded history, humans have wondered whether we are alone in the Universe. Recently, Astronomers have begun to make significant progress toward answering this question. For the first time in history, we have detected planets around other stars ("extrasolar planets"). Surveys conducted by several teams of Astronomers have turned up evidence of planets around hundreds of other star systems.

Finding extrasolar planets hasn't been achieved in the past simply because we haven't had the technological know-how to do it. Even using current technology, the kinds of observations needed to reveal the tiny, telltale motions of stars with orbiting planets is almost impossible, requiring extremely high precision and long hours of painstaking research. To help us understand how this technique works, we will first look at a typical extrasolar planetary system (shown below).



Although we cannot observe any of the properties of the orbiting planet directly, we can watch the central star "wobble" back and forth (toward and away from us) in response to the gravity of its companion planet and thus infer many properties about the orbiting planet. The central star and the orbiting planet revolve around a common center of mass. In our own solar system, the center of mass is offset a little bit from the center of our Sun because of the mass of Jupiter; the other planets have a much smaller effect on the location of the center of mass. Some alien astronomer analyzing the motions of our own Sun would see it appear to wobble in a tiny circle about the solar system's center of mass.

This wobbling motion is revealed by the Doppler shift of starlight. As a star moves radially back and forth relative to Earth, its light waves become stretched (redshifted) and compressed (blueshifted) periodically. From that cyclical shifting, astronomers can reconstruct the motion of the star. Then, using simple Physics (like Kepler's Law and Newton's Laws of Motion), we can compute the masses and orbital distances of orbiting companion planets. To detect planets around other stars with this technique requires amazingly precise instruments that can measure wavelength changes of 1 part in 100 million.

NASA has plans to launch a space-based telescope that uses the principles of interferometry to create a Planet Finder telescope. This mission will actually take photographs of Earth-like planets orbiting other stars. Even better, such a telescope could analyze the spectra of such planets to determine if they have atmospheres (and evidence of life).

First things first, though. Let's see how these planets are found to begin with before we start worrying about aliens. To determine the properties of planets around other stars, we must first make two important assumptions and perform two astronomical observations:

<u>Assumption #1</u>: The system is being observed edge-on

We must make this assumption first in order to apply the equations we'll use below. That's because we'll be using the Doppler shift of the star as the equivalent of the star's orbital velocity. If the system is not edge-on, then the Doppler shift will be smaller than the star's true orbital velocity, and our final answer will be incorrect. We'll return to this point later.

Assumption #2: The star that the planet is orbiting has the same mass as our Sun.

One of the quantities we'll need to figure out the properties of the orbiting planet is the mass of the central star. Most survey teams limit their observational samples to Sun-like stars, meaning stars that have all of the same properties (mass, size, composition, temperature) as our own Sun, so this assumption is a safe one to make. We're also assuming that all planetary orbits are perfect circles, which is probably close to the truth in most cases.

Observation #1: The Doppler shift of the star.

We must first observe how the wavelengths of light from the wobbling star shift to the blue (shorter wavelength) and to the red (longer wavelength) of their rest wavelength. These shifts are directly proportional to the star's radial velocity, according to the Doppler shift equation:

$$\frac{\text{Change in wavelength}}{\text{Wavelength}} = \frac{\text{Radial velocity of star}}{\text{Speed of light}}$$

Observation #2: The Period of the orbit

We must also observe how the star's Doppler shift varies over time. Presumably, if we watch the star for a long enough time, the pattern of Doppler shifting will repeat every time the star makes an orbit around the center of mass point of the system. This period will be the same as the period of the orbiting planet!

Step 1

On the data sheet included with this lab is a graph of radial velocity vs time for three different stars, 47 Ursae Majoris (47 UMa), HD 40979, and 51 Pegasi (51 Peg). Remember, we have no way of detecting the radial velocity of an orbiting planet directly. Those orbiting planets (if they exist) are much too faint to detect directly (i.e. with a photograph) with current technology.

To find the orbital velocity of each star about the center of mass of its system, we need to measure the difference between the maximum and minimum shift values. That way, we're getting the shift on each side of the orbit. If we take the difference between these two shifts and divide by two, then we will have found the orbital velocity of the star.

For each star, determine the maximum and minimum values of the radial velocity, the difference between the two (divided by 2) and fill in these values on your worksheet (use two significant figures). We'll do the first calculation for 47 UMa together in class to help you get started.

Step 2

Next we need to determine the Period of the orbit. The period is just the time (in days) that it takes for the star to complete an orbital "cycle".

47 UMa: You can actually see three entire cycles stretching from 1988 to about 1997.

- Estimate to the nearest tenth of a year the times of the first and last minima.

- Take the difference between the two and divide by 3 (since you are adding up 3 periods) to find the period of this star's orbital wobble.

- Convert this time (in years) to seconds by multiplying by the conversion factor 3.2×10^7 seconds per year.

- State your answer in scientific notation with two significant figures.

HD 40979: For this star, you can see seven complete cycles. The x-axis measures time in years.

- Estimate to the nearest tenth of a year the time of the first and last minima and write these values on your worksheet.

- Take the difference between these two times and divided by 7 (since you are adding up 7 periods).

- Finally, convert this time (in years) to seconds by multiplying by the same conversion factor used above.

- State your answer in scientific notation with two significant figures.

51 Peg - For this star, you can see seven complete cycles. Note the x-axis measures the time in days.

- Estimate to the nearest tenth of a day the time of the first and last minima.

- Take the difference between these two times and divide by seven to get the period (in days).

- Finally, convert this time (in days) to seconds by multiplying by the conversion factor of 86,400 seconds per day.

- State your answer in scientific notation with two significant figures.

Step 3

Now that we've found the velocity of the star and the orbital period of the star and planet, we have to do some calculations to discover the mass and the orbital distance of the companion planet. We will start with two equations that govern orbits:

$$v_{orbit} = \sqrt{\frac{GM}{r_{orbit}}}$$

v_{orbit} = orbital velocity of the planet
G = gravitational constant, 6.67×10^{-11}
M = mass of central star, 2.0×10^{30}
r_{orbit} = orbital distance from star to planet

$$2\pi r_{orbit} = v_{orbit} * Period$$

The first equation is simply the equation of orbital velocity that comes from the definition of an orbit: a path taken by an object that balances centrifugal force with gravitational force. The second equation is just a different way of writing "distance = velocity * time".

In this case it is, "Circumference of the orbit = orbital velocity * time it takes to complete an orbit".

These two equations combine to create Kepler's 3rd Law of Planetary orbits, relating the orbital distance of a planet to its orbital period:

$$r^3_{orbit} = \frac{GM(Period)^2}{4\pi^2}$$

For each system, use the Period (in seconds) from step 2, and values for G and M given in the orbital velocity formula on the previous page, in order to calculate r_{orbit}. Write down the answer on your worksheet in scientific notation with two significant figures. Check your work with your partner or another group to be sure you have done this calculation correctly.

The Earth's orbital distance from the Sun is 1.0 Astronomical Units (or 1.0 AU), which is 1.5 x 10^{11} meters. Divide your answer for orbit by the conversion factor 1.5 x 10^{11} to determine the distance from the planet to its parent star in AU.

Step 4

Now let's determine each planet's orbital velocity and, from this, each planet's mass. Finding the orbital velocity is easy...just solve the second orbit equation like this:

$$v_{planet} = \frac{2\pi r_{orbit}}{Period}$$

For each system, determine the orbital velocity of the companion planet in meters/sec. In the equation above, be sure to use r_{orbit} in meters and P in seconds.

Finally, Newton's Laws tell us that there is a very simple (approximate) relationship between the masses of two orbiting bodies and the velocities of two orbiting bodies:

$$M_{planet} = \frac{v_{star} \xleftarrow{\text{from step 1}}}{v_{planet} \xleftarrow{\text{from step 4}}} M_{star} \xleftarrow{\text{use 1000 here}}$$

Assumption #2 tells us that we can assume that the mass of the parent star is the same as the mass of our own Sun, which we know to be **1000 Jupiter-masses.** Using this information and the equation above for each system, solve for the mass of the orbiting planet in Jupiter-masses. Answer with two significant figures.

Step 5 - Errors

The main source of error in this experiment is assumption #1 (that we are observing the systems edge-on). Remember that if our assumption is wrong then the true stellar velocity will be larger than the value we used in this experiment. Fill in the following statement: "If our edge-on assumption is wrong, then the true mass of the planet will be (larger/smaller) than the mass we determined in this experiment." Explain your reasoning. A diagram may help with this part.

Finally, given the planet masses below calculated in published papers by the research teams, using the edge-on assumption (shown below), calculate your percent error for each case.

47 UMa: 2.4 M_{Jup} // HD 40979: 3.3 M_{Jup} // 51 Peg: .47M_{Jup}

Essay

In the first paragraph of your essay, use one sentence each to state your results (planetary mass and orbital distance in AU) for each of the three planetary systems. In the second paragraph, discuss whether, if we were to visit these solar systems, they would look anything like our own. Finally, discuss the implications of these discoveries on our own "solar nebula" theory of solar system formation that says all Jupiter-sized planets (and larger) should be formed in the outer reaches of the solar system.

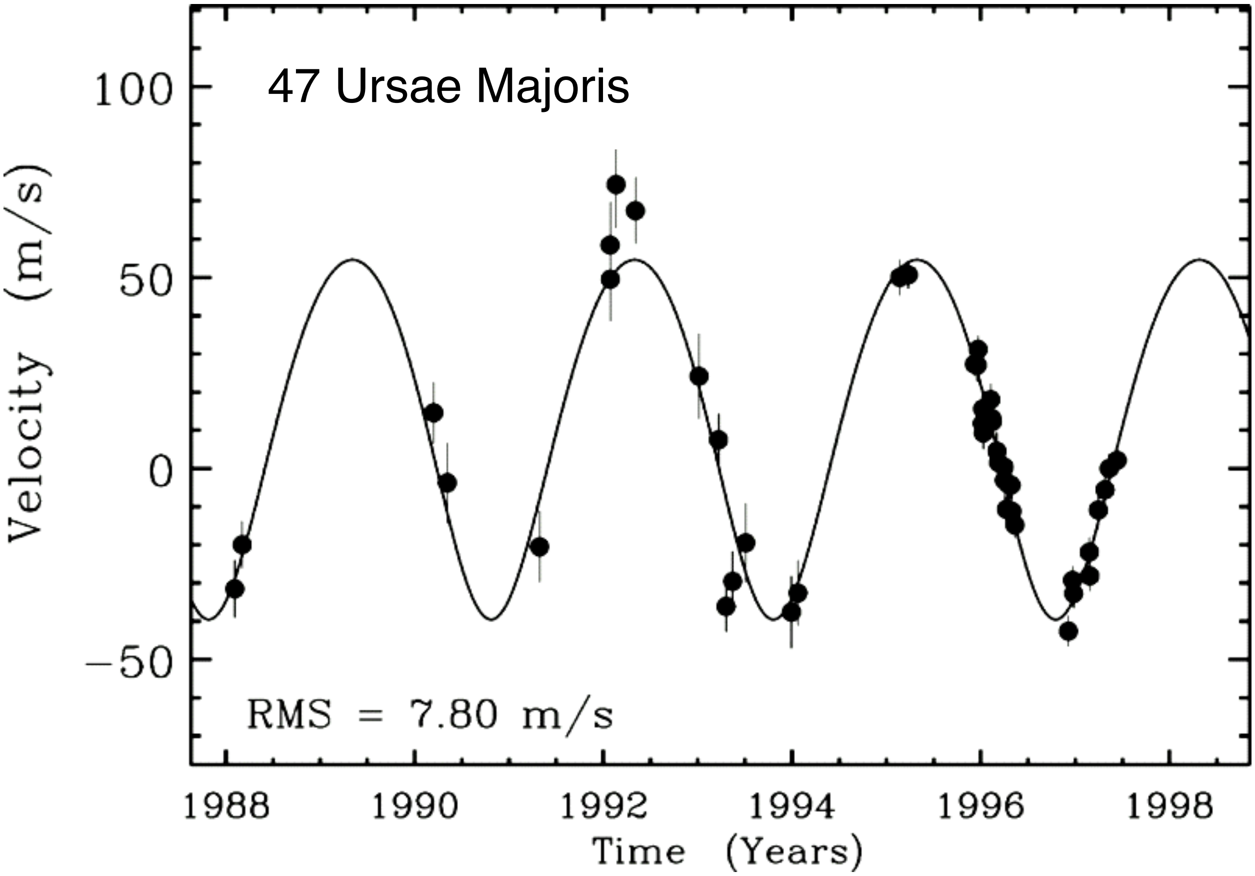
Sources

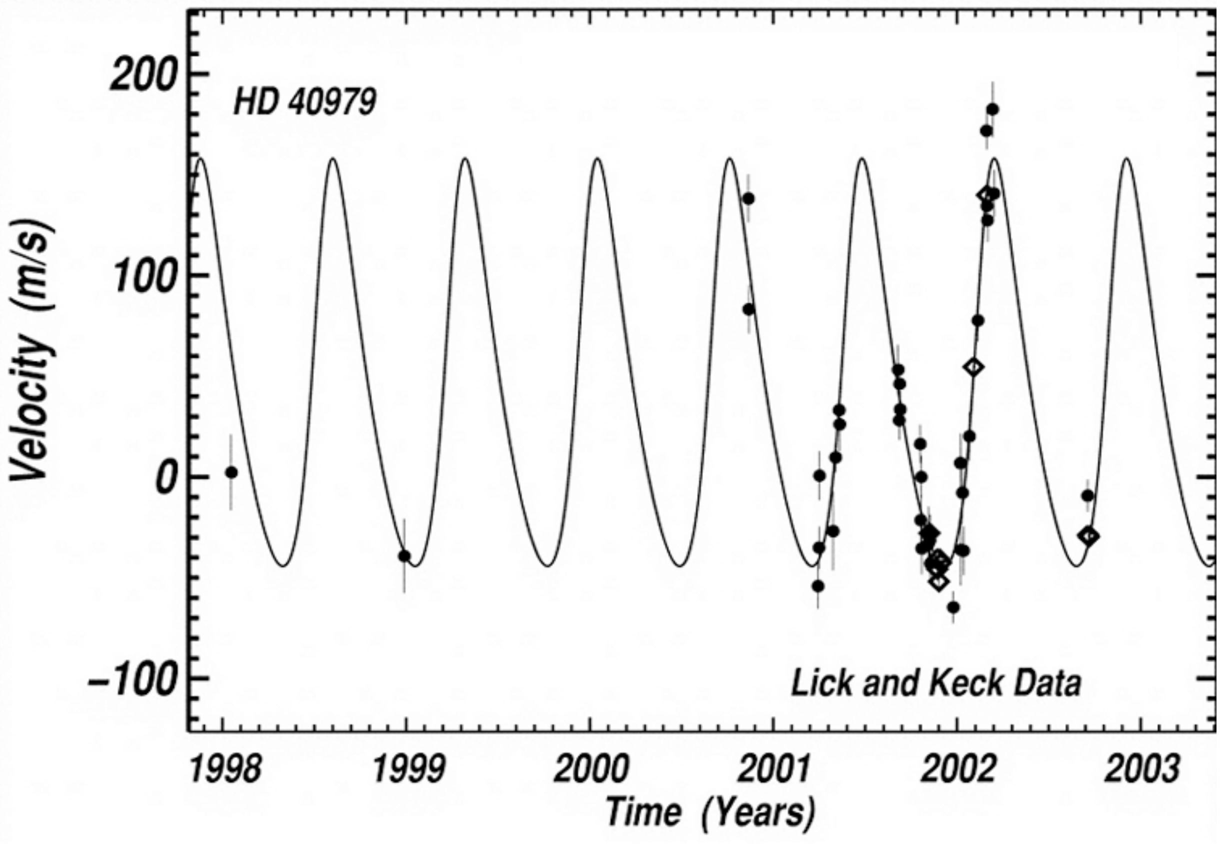
47 UMa: www.public.iastate.edu/~astro.505/firstwk.html

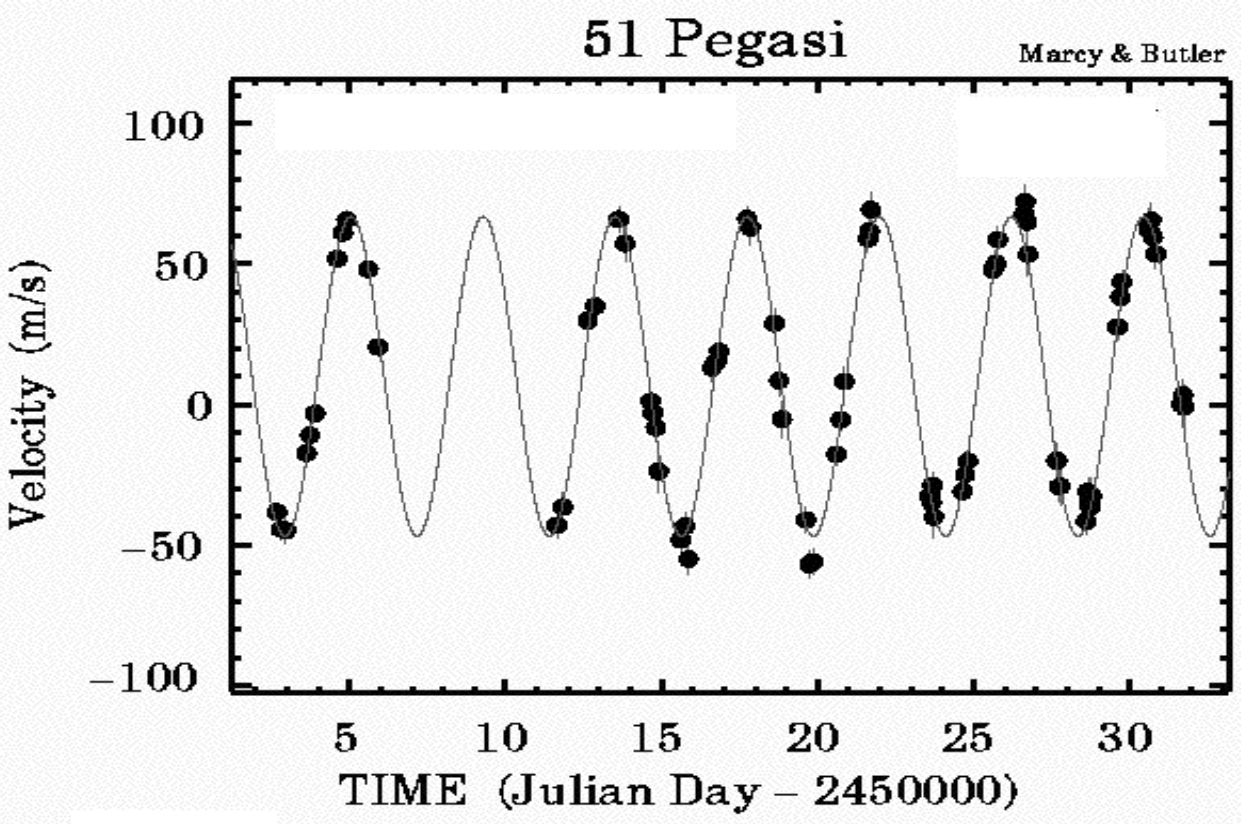
HD 40979: www.markelowitz.com/exobiology.htm

51 Peg: www.astro.lsa.umich.edu/undergrad/labs/extrasolar_planets/pn_51Peg_vt.gif

Data




HD 40979
Velocity (m/s)
200
100
0
−100
Lick and Keck Data
1998
1999
2000
2001
2002
2003
Time (Years)


51 Pegasi
Marcy & Butler
Velocity (m/s)
100
50
0
−50
−100
5
10
15
20
25
30
TIME (Julian Day – 2450000)

Lab #5 Worksheet

Name:
Home TA:

Step 1

47 UMa:

Maximum velocity: ______________ m/s.

Minimum velocity: _______________ m/s.

(Max velocity - Min velocity)/2 = v_{star} = ________________ m/s.

HD 40979:

Maximum velocity: ______________ m/s.

Minimum velocity: _______________ m/s.

(Max velocity - Min velocity)/2 = v_{star} = ________________ m/s.

51 Peg:

Maximum velocity: ______________ m/s.

Minimum velocity: _______________ m/s.

(Max velocity - Min velocity)/2 = v_{star} = ________________ m/s.

Step 2

47 UMa:

First minimum: ____________ Last minimum: ______________

(Last time - first time)/3 = P = ____________ years.

P * 3.2×10^7 = ______________ sec. (**Use this in step 4.**)

HD 40979:

First minimum: ____________ Last minimum: ______________

(Last time - first time)/7 = P = ____________ years.

P * 3.2×10^7 = ______________ seconds. (**Use this in step 4.**)

51 Peg:

First minimum: __________ Last minimum: ____________

(Last time - first time)/7 = P = __________ days.

P * 86,400 = ____________ seconds. (**Use this in step 4.**)

Step 3

47 Uma:

r^3_{planet} = ________________ m^3. r_{planet} = ______________ m.

^^^ Use this in step 4! ^^^

r_{planet} / 1.5 x 10^{11} = _____________ AU.

HD 40979:

r^3_{planet} = ________________ m^3. r_{planet} = ______________ m.

^^^ Use this in step 4! ^^^

r_{planet} / 1.5 x 10^{11} = _____________ AU.

51 Peg:

r^3_{planet} = ________________ m^3. r_{planet} = ______________ m.

^^^ Use this in step 4! ^^^

r_{planet} / 1.5 x 10^{11} = _____________ AU.

Step 4

47 Uma:

v_{planet} = _____________ m/s. M_{planet} = _____________ M_{Jup}

HD 40979:

v_{planet} = _____________ m/s. M_{planet} = _____________ M_{Jup}

51 Peg:

v_{planet} = _____________ m/s. M_{planet} = _____________ M_{Jup}

Step 5

If our edge-on assumption is wrong, the true planet masses will be __________________ than the masses we just calculated. Briefly explain your answer in the space below.

% Error for 47 UMa planet: _________________%

% Error for HD 40979 planet: __________________%

% Error for 51 Peg planet: _________________%

Essay (on reverse side)

Lab #6

Citizen Science: Planet Hunting and the Kepler Mission

Introduction

In today's lab, we are doing another example of Citizen Science, studying an actual scientific database that you can analyze and therefore contribute to our overall body of knowledge about planetary systems. To do this, we will use the website http://planethunters.org.

Visit that website and create an account for your group (if you established a username and password from the "Disk Detective" lab during week 4, then that will work for this lab as well). Once you are done with that, you will need to learn some introductory material to provide the context necessary to understand what you will be doing.

Part 1

On the top row menu of the web page, select "Science". Read the short introduction and answer question 1.

1. Explain in a few sentences the purpose of the Kepler project. Specifically, explain what is it designed to observe, exactly, and how that leads to the discovery of planets.

2. Read under the “Transits” tab to answer questions 2-5. Do all exoplanets create dips in their parent star’s light curve? Explain why or why not.

3. What does the light curve look like for a transiting planet?

4. How do light curves compare for larger and smaller transiting planets?

5. Explain how dips in the light curve due to star spots will differ from dips caused by transiting planets.

6. Read under the "Simulations" tab, and explain why the project includes simulated transits in the data sets instead of only real transits.

Part 2

Now at the top of the page, go to the Tutorial tab, and select "Classify." Work through the tutorial shown and answer the following questions.

7. How many transits are in the tutorial data? __________

8. What is the period of the transiting planet, rounded to the nearest day? __________ days

Next, in the tutorial menu, select “Blog,” and find the post entitled “Tabby’s Star,” then watch the 14-minute TED talk about this star (or google “Youtube Tabby’s Star TED talk”), answering questions 9-12 below.

9. What were the two unusual features about the May 2009 transit detected in the light curve of the star KIC 8462852?

10. What was different and unusual about the March 2011 transit compared to other normal planetary transits?

11. One early hypothesis about the strange light curve is that the dips were caused by some huge cloud of dust, perhaps the result of a collision between planets. What evidence contradicted this hypothesis?

12. Describe the “Alien Megastructures” hypothesis and how it would possibly explain the light curve we see.

Part 3

Now that you know how the website works, your group needs to analyze the data for at least 36 stars. Split up the work so that each person in your group is in charge of classifying an equal number of stars.

For each star you analyze, it really helps to use the zoom feature to look closely for transits. Ask your TA to observe your group as you analyze a star to make sure you are doing everything properly.

Once your group has analyzed 36 stars, you can look under the menu that has your account name as the title and select “My Stars” to see your totals. You can then go back and see what you did for each star. Show this to your TA so that he or she can verify in the space below that you completed this part with a signature, and your group is done!

____

Lab #7

Citizen Science: Planet Four

Introduction

In today's lab, we are continuing our semester-long theme with another Citizen Science project, this time dealing with the planet Mars. Before we visit the Planet Four website, it would be helpful to review some of the important scientific work that has already been done by the Mars Global Surveyor and (the mission we will be working with on our project) the Mars Reconnaissance Orbiter (MRO).

To do this, you will read a recent (May 2013) Scientific American article about recent discoveries on Mars by the two orbiting spacecraft. This article is in the form of a pdf file at http://personal.tcu.edu/dingram/mars.pdf. Load this article and read through it, answering the following questions (that are arranged in the same order that the topics are covered in the article).

Part 1

1) Describe the evidence observed by the Mars Global Surveyor in 2000 and 2006 that led scientists to believe running water may exist on Mars currently.

2) Explain two related pieces of evidence collected by the HiRISE camera that indicates the gullies first seen by the Mars Global Surveyor are more likely related to Carbon Dioxide than liquid water flow.

3) According to the diagram on page 63 of the article (page 6 of the pdf), why does the Southern hemisphere of Mars experience warmer summers compared to the Northern hemisphere?

4) Explain two pieces of evidence that led the author to believe the dark lines seen by the HiRISE camera, the Recurring Slope Lineae (RSL), were caused by intermittently flowing liquid water.

5) Name and briefly explain the two things limit the ability of the Mars Reconnaissance Orbiter (MRO) to directly identify actual flowing water on the surface?

Part 2

Now load http://planetfour.org and log in. You may wish to use the same username and password you have used for previous Zooniverse labs. First, visit the "About" page and read the description of the project, then answer the questions below.

1) Describe the cause of fans and what we can learn about Martian weather from mapping their size and orientations.

2) What is L_s?

3) When $L_s = 0$, it is the beginning of what season in the Southern hemisphere of Mars?

4) At what value of L_s does sunlight begin to penetrate the ground, resulting in vent and fan formation?

5) What are araneiform terrains, or spiders, and what causes them?

6) Check the FAQ in the sidebar on the “About” page and answer: Why are there bright spots at the origin of many fans? Explain what is going on with this phenomenon.

Part 3

Ok, enough with all of the background information, let’s start getting some work done! Click on “Classify” in the sidebar, then click on the “Show Tutorial” button to complete a brief walkthrough of how the classification process works. I also recommend you look at the “Show Examples” button to see what kinds of things you will be looking for.

Once you start classifying, as usual, just do your best job. It doesn’t have to be perfect since this is crowdsourced data. The scientists simply want everyone to do their best job classifying, and then they will use the consensus result. You may also discover something interesting in the images that the scientists will follow up with further images and more detail in the future You never know what discoveries lay waiting in the millions of close-up images of the Martian surface.

If you see a feature you want to classify, but you can only see part of it, then go ahead and mark what you can see. If you aren’t sure about a feature because it seems to be mostly off the screen, then don’t bother marking it. You may see the same image twice but with different features because the photos were taken at different times. That’s okay! The scientists are looking at how the features change over time so that they can get a measurement of global wind and weather patterns over time, just like how water flow in the RSL features was discovered.

Once you and/or your group has classified 36 images (make sure each member of your group gets an equal chance to control things), this part is complete. To learn how many classifications you have completed, look to the top right of the page and click on the little circle to the right of your username. This will take you to the Zooniverse home page for your account. There you will see how many classifications you have done for each project, including Planet Four.

Once you have completed 36 Planet Four classifications, show the screen to your TA who will initial below to indicate that you have completed the last portion of your lab.

____

Lab #8

The Moons of the Outer Planets

Introduction

In this lab, we will explore the outer planets and their fascinating moons using the latest information on the Web. There are several processes at work in these systems that are also seen in the solar system as a whole. For example, the same type of tidal force that affects the Earth and the Moon is also present between Jupiter and its moons. Jupiter’s gravitational pull, however, is much stronger on its moons than the Earth’s, so the effects of tides are much more pronounced on Jupiter’s moons.

One effect of tidal forces is that they tend to squeeze a planet out of its natural spherical shape into an oblong shape a little like a football. The effect is small enough that it is difficult to detect with the naked eye, but the squeezing is real, and it serves to provide a tremendous amount of heat energy to the moons the closer they are to Jupiter.

On Jupiter’s moons, we also see evidence of geological forces such as volcanism and surface flows just like we see on the Earth. And we can also see the scars of impact craters. On Earth’s moon, we can use the relative density of craters to guess that the smoother maria are geologically younger than the densely cratered highlands, since the maria have obviously been exposed to bombardment from incoming material for a shorter time. Similarly on Jupiter’s moons, we can say a lot about their histories by simply looking at the craters on their surfaces. We’ll also find that Saturn’s moons are somewhat icier than Jupiter’s moons, and one of Saturn’s moons even has a thick atmosphere of its own.

Tonight's Sky

First, fire up your favorite browser, and search for "Sky at a Glance". This will take you to the very useful web page from the amateur Astronomy magazine Sky and Telescope. The page summarizes what's worth looking out for in the sky each week, and it is updated weekly. Scroll down on this page to find out what is going on right now with Jupiter and Saturn, and answer the associated questions below:

What constellation is Jupiter located in today?

____

What constellation is Saturn located in today?

____

If Jupiter is visible tonight, state what time and what direction on the sky it can be found. Otherwise, write "not visible".

If Saturn is visible tonight, state what time and what direction on the sky it can be found. Otherwise, write "not visible".

Jupiter's Moons

Most of the information we will gather to answer the remaining questions in this lab can be found at the website http://nineplanets.org. Please navigate to that website to answer questions about Jupiter and its major moons.

What is the rotation period of Jupiter, in hours?

____

What is the length of Jupiter's year (in Earth years)?

____

List the four major satellites of Jupiter (with radii larger than 1500 km), in order according to their distance from Jupiter:

1)

2)

3)

4)

Which of these four moons appears to have the most active geology, as evidenced by the molten surface and active volcanism?

____

Explain why this moon is thought to have more geological activitity than the other three moons.

Why does Io have so little water compared to the other three major satellites?

Europa is thought to have a thin Oxygen atmosphere, but it is not of biological origin like Earth’s Oxygen. Explain where Europa’s Oxygen atmosphere originates.

On Callisto, the feature named “Gipul Catena” is a series of impact craters in a straight line across the face of Callisto. What is the explanation for this phenonmenon?

Saturn's moons

Saturn has recently been explored by the Cassini mission, and we have many updated pictures and discoveries about its moons as a result. Visit the Saturn page and its associated moons pages on the Nine Planets website to answer the questions on your worksheet about Saturn and its moons. I will ask other questions about Saturn's moons in the essay portion of the lab.

Which of Saturn's satellites has an enormous crater that makes the moon look like the Death Star from "Star Wars"? And what is the name of the crater?

Moon: ___________________ Crater name: ___________________

What is the name of Saturn's largest moon? __________________

What are the three main components of the atmosphere of Saturn's largest moon?

____________________, ____________________, ____________________

Uranus and Neptune

Read the Nine Planets website to discover information about the moons of these two outermost giant planets, and answer the associated questions on your worksheet.

Which of the five most massive moons of Uranus has a surface that appears to be mixed up terrain?

____

What is the name of Neptune's most massive moon?

____

What is unusual about Triton's orbit?

Essay

For your essay, you'll need to summarize some information about two NASA spacecraft that have taught us more about the two largest planets in our solar system, Jupiter and Saturn (and their moons). Two recent NASA missions that have successfully concluded are Juno (which explored Jupiter) and Cassini (which explored Saturn). The associated web sites for each are http://www.nasa.gov/juno and http://www.nasa.gov/cassini .

For the first part of your essay (the Juno mission), click "Overview" on the menu bar of the Juno mission home page, below the image of the spacecraft. This is a brief overview of the mission. Read through this and then for your essay, describe three things Juno is scheduled to observe and briefly what we hope to learn from each observation.

Next, go to the Cassini website and look on for the search box on the upper right. Enter "Enceladus powerhouse" in that box, and click on the first article to appear in the results. View the related images and read the story. In your essay, describe what Cassini discovered on Enceladus.

Next, return to the Cassini mission homepage and search for "Titan mixture", then read the news release from 2010 about Titan and summarize what the Cassini mission learned about Titan's interior and <u>how</u> it is different from Jupiter's largest moon Ganymede (and <u>why</u> it is different).

Lab #9

Citizen Science: Comet Hunters

Introduction

In today's lab, we are working on another Citizen Science project, this time hunting for comets in the asteroid belt.

Part 1 (Science)

First, visit http://comethunters.org and sign in. This URL will redirect you to the Comet Hunters project, a part of the Zooniverse family of Citizen Science projects. Click on the "About" tab on the top of the page, and read through the introduction, then answer the following questions:

1) Describe where these comets we hope to discover are found in the solar system, and explain how we will identify them.

2) Explain why comets have tails.

3) Explain why the project designers feel humans are necessary in order to properly classify these previously undiscovered comets (why can’t computers find them easily?).

4) Briefly describe three things astronomers hope to learn by studying MBC’s (main-belt comets)

5) Explain what are disrupted asteroids and why they mimic MBC’s.

6) Explain why the designers of this project will periodically insert images of actual comets that have already been discovered and classified into the data stream.

Part 2 (Finding Comets)

Now on the top menubar, click on “Classify”, then click through the short tutorial to learn how to classify the images. After you are done, it would be a good idea to also click on the “Need some help with this task?” button for further background information.

The little “play” arrow on the lower left of the images will invert colors back and forth, making it easier to spot faint features. This is a useful thing to do for most of the data.

Classify at least 100 examples (spend at least 15 seconds per sample), and have your TA initial your lab assignment here when you are finished (take turns controlling the mouse and keyboard within your group). You can check the total number of data sets you have studied by clicking on the circular icon in the upper right corner of the page to the right of your username. This takes you to the home screen for Zooniverse projects you have completed, with an indication of how many samples you have studied for each project, including “Comet Hunters.”

____

Lab #10

Citizen Science: Radio Meteor Zoo

Introduction

In today's lab, we are working on another Citizen Science project, this time hunting for data about meteors in the Earth's atmosphere.

Part 1 (Science)

Visit http://radiometeorzoo.org and click on the "About" tab. Read through the description of the project and answer the associated questions below.

1) Describe two reasons why radio observations of meteors have an advantage over optical observations.

2) Define "meteoroid", "meteor" and "meteorite".

3) Explain what causes a meteor shower, and explain what the radiant of a meteor shower is.

4) Briefly explain how radio transmitters and receivers can be used to detect meteors.

5) Briefly describe three different kinds of signals that appear in the data that are not meteors.

6) Explain why the project needs the help of human observers to find signals from meteors instead of just relying on a computer algorithm.

Part 2 (Finding Meteors)
Now on the top menubar, click on “Classify”, then work through the short tutorial to see how to mark meteors for the project. After you have looked at a few screens, you may wish to return to the “About” page and click on the “FAQ” link to see a description of the variety of different kind of signals you may see and what causes them.

Classify at least 36 examples (spend at least 60 seconds per data set), and have your TA initial your lab assignment here when you are finished (take turns controlling the mouse and keyboard within your group). You can check the total number of data sets you have studied by clicking on the circular icon in the upper right corner of the page to the right of your username. This takes you to the home screen for Zooniverse projects you have completed, with an indication of how many samples you have studied for each project, including “Radio Meteor Zoo.”

____

Lab #11

Impact Craters

Introduction

It is clear from the surface features of geologically old planets (the Moon, Mercury) and some of the unusual phenomena in the solar system (Earth's large moon, the rotation of Venus) that planetary impacts have played an important role in the history and evolution of the solar system. Despite this, impact craters on Earth were not well-understood until this century. In today's lab, we will study how the characteristics of a crater (particularly its size) can lead a careful observer to many conclusions about the properites of the impactor that made the crater.

When a small object collides with the Earth, it has a certain amount of kinetic energy. This energy depends on the object's mass and its velocity. After the object impacts the Earth, its kinetic energy drops to zero...the object stops moving, but this energy doesn't vanish completely. Instead, the kinetic energy translates into other forms, such as explosive energy, heat and light. This explosive energy will dig out a bowl of material called a crater (the original impactor itself will often remain buried deep underground after the crater is formed).

Often by experimenting on small scales like this, scientists can successfully extrapolate to much larger scale situations, such as impacts of objects with diameters of several miles across. It is this sort of logic that first led scientists to theorize that a large asteroid impact may have resulted in the extinction of the dinosaurs about 65 million years ago. One can calculate the expected kinetic energy of an incoming 10-km diameter asteroid using the same principles as in today's lab. If only a small fraction of that energy is deposited into the Earth's crust and atmosphere and energy, it is easy to imagine a significant portion of life on Earth being destroyed.

Step 1

Our first step is to prepare our “surface” for impacts. Each group of 2-3 students should have a plastic bowl full of fine sand and two small ball bearings made of iron. Your TA will tell you what the mass of each ball bearing is.

Before you start dropping ball bearings into the sand, you’ll need to level the surface (by gently shaking the bowl back and forth). This will make it much easier to measure the diameter of the craters you create.

Once you’ve done this, start filling in the table on your worksheet using the following steps:

- Use your meter-stick to estimate the height of the sand surface above the table top to the nearest centimeter.

- Drop the smaller mass from a height of 20 centimeters above the sand surface.

- Measure the diameter of the crater (to the nearest 0.1 cm).

- ***Repeat this three times*** and average your three results.

  Write your average value in column 4 of the appropriate table with a precision of 0.1 cm.

- Repeat for the larger mass from a height of 20 centimeters above the sand surface. Again, record in your table the average value of three measurements.

- Do similar measurements for masses dropped from each height listed on table. Try to get as many craters as possible measured without having to “reset” the entire surface.

- When the surface is too dense with craters, gently shake the bowl again until the surface is flat and smooth and sprinkle another fine layer of flour on top.

After you've recorded your data in column 4 in each table of the worksheet, fill in columns 5 and 6 as follows:

- Calculate the Kinetic Energy of the impactor using the formula $^1/_2mv^2$.
- Calculate the crater diameter to the third power with your calculator.

Step 2

The volume excavated by the impactor is a half-sphere, so the amount of sand displaced in an impact depends on the diameter of the crater cubed. This volume should be directly proportional to the kinetic energy ($^1/_2mv^2$) of the impactor. Thus, we expect to find a linear relationship between the cube of the crater diameter and the kinetic energy of the impactor. Let's test that by drawing a simple graph using the data from the table we generated in step 1.

- For each of the four rows in each data table, plot a data point on the graph on your worksheet (the y-axis is crater diameter cubed, the x-axis is kinetic energy).
- Draw your best-fit line as close as possible to the eight data points using a straight-edge.
- Calculate the slope of this line using slope = $^{Dy}/_{Dx}$. Write this answer on your worksheet with two significant figures.

Essay

In your first paragraph, discuss the uncertainties in this lab. In particular, provide at least two ways this lab could be done differently that would significantly reduce the amount of error a typical student is likely to achieve. One idea: If you used even more ball bearings with different masses, dropped from different heights, would they still show the same trend as your graph in step 2? Did your plotted points for the two different masses show different slopes or roughly the same slope? Explain.

We can use information like that found in step 2 to estimate the properties of impactors that cause large craters on Earth (where the diameters are measured in kilometers instead of centimeters...the Physics is still the same!). From this kind of analysis, scientists have concluded that an ancient 100-km diameter crater found on the Yucatan peninsula in Mexico was caused by a massive meteorite (more than 1 km in diameter and weighing as much as some of the biggest mountains on Earth) that slammed into the Earth about 65 million years ago. It turns out that such impacts (the type of which can dramatically alter Earth’s climate and wipe out a large fraction of life) are thought to occur on the Earth about once every 100 million years.

Given that it would cost our government about $10 million per year to adequately monitor the sky for such impacts (given enough warning, we do have the technology to prevent such impacts), do you think this would be a worthwhile investment? Or would you rather use the money to provide, say, small tax cuts for everyone or build more roads? Explain.

Lab #11 Worksheet

Name:
Home TA:

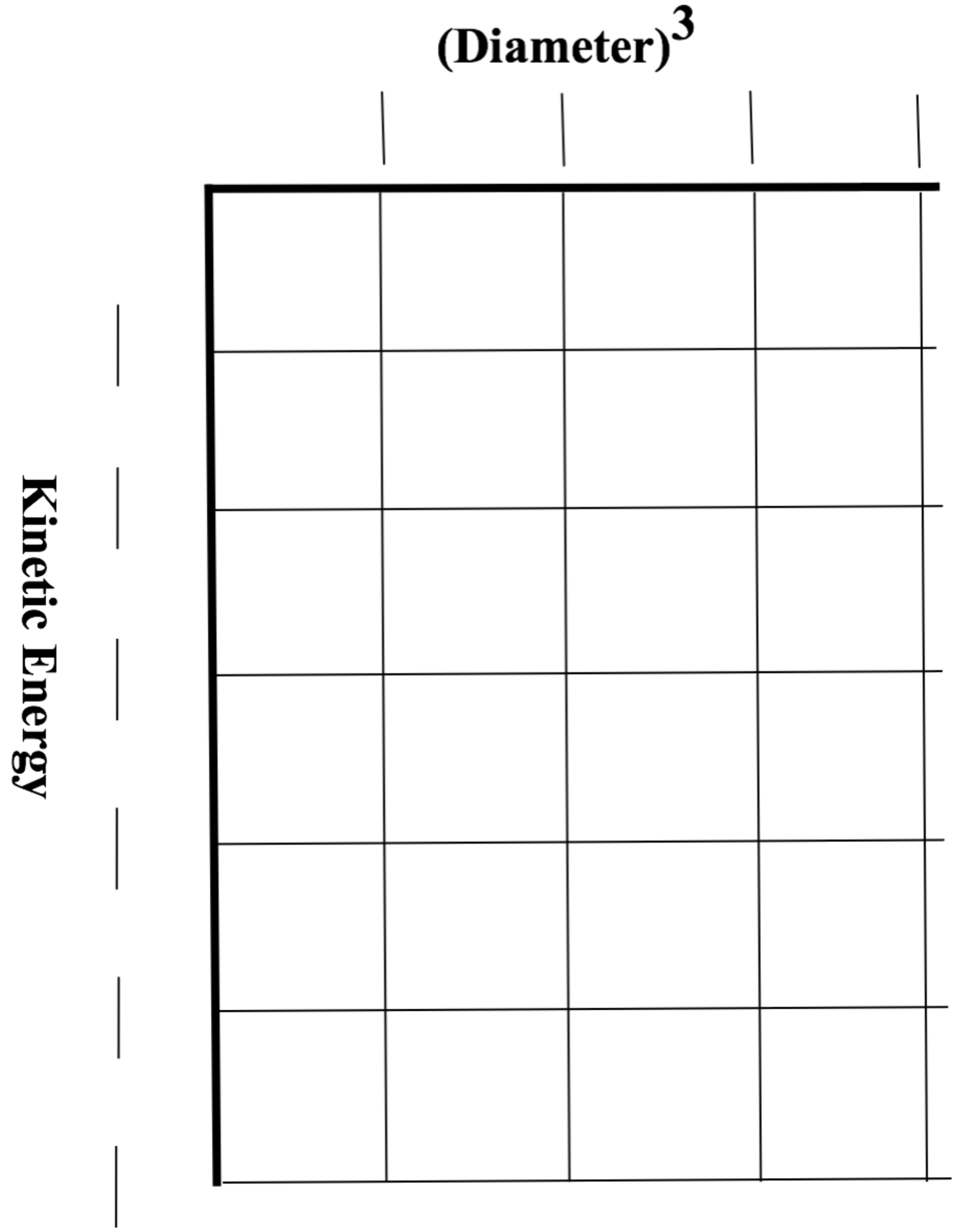
Smaller mass

Mass (grams)	Height (cm)	Velocity (cm/sec)	Average Diameter (cm)	Energy (ergs)	Diameter^3 (cm^3)
	20.	19			
	40.	28			
	60.	34			
	80.	39			

Larger mass

Mass (grams)	Height (cm)	Velocity (cm/sec)	Average Diameter (cm)	Energy (ergs)	Diameter^3 (cm^3)
	20.	19			
	40.	28			
	60.	34			
	80.	39			

Graph of Volume Displaced vs Kinetic Energy of Impactor



Slope of smaller ball = __________ Larger ball = ______________