Homework #7

Due at 5pm on Monday, October 30

You may submit Parts 1, 3 and 4 either (a) electronically via Moodle or (b) on paper to my mailbox outside Merrill 213. Do NOT leave under my door or in the boxes outside my office.

Part 1 – Questions

1. Complete the midterm course survey at https://goo.gl/forms/1qP7P4TQNBVpJyS33. Enter your name at the end to receive credit. These will be removed from the data before I consider the results and nothing you say will be held against you. Your honest feedback is welcome.

2. The Earth gains about 10^8 kg from meteorite impacts every year. How much is this as a <u>percentage</u> of the mass of the Earth, which is 6×10^{24}kg?

3. The Earth loses ~1×10^{-7} "Earth masses" per year due to the solar wind's interaction with the upper atmosphere. How much is this as a <u>percentage</u> of the mass of the Earth, which is 6×10^{24}kg?

4. Using your answers to questions 2 and 3, explain whether the Earth is gaining or losing mass with time

5. Using the table below, answer parts a-d

Planet	**Mass (in kg)**	**Radius (km)**
Earth	6×10^{24}	6,400
Venus	5×10^{24}	6,000
Mars	6×10^{23}	3,400
Jupiter	2×10^{27}	70,000
Moon	7×10^{22}	1,700
Pluto	1×10^{22}	1,180
Planet X	3×10^{24}	12,500
Planet Y	2×10^{25}	4,800

   a. Convert the columns to Earth radii and Earth masses and provide a new table. Show at least one worked example of how you've done the unit conversions. Round your answers to 1-2 non-zero digits.

b. Explain why the conversion to Earth radii and Earth masses is useful in building intuition about your weight on each planet rather than using the original numbers in kg and km.
c. Answer the following questions using the numbers in your table from (a). Show your work in each case.
    i. On which planet would you weight the most? How many times more would you weigh there than on Earth?
    ii. On which planet would you weigh the least? How many times less would you weigh there than on Earth?
    iii. How many times more would you weigh on Jupiter than on Earth?
    iv. How many times less would you weigh on Mars than on Earth?
d. Explain in words which quantities you were able to ignore in Newton's Law of Universal Gravitation when answering (c) and why you were able to ignore them.

Part 2 – Mastering Astronomy

Please complete this part through the course Moodle page. It's due at the same time as the rest of the assignment.

Part 3 – Checking in

Answer this portion on the same sheet of paper as Part 1.

a) What was the most interesting concept that you learned in class last week?
b) What was the most difficult concept that you learned in class last week? What is still confusing about it?

Part 4 – Observing

This week's observations require a set of simulations designed to help you understand some of the basics of gravitational escape from a planet and gas dynamics, both of which will be relevant as we discuss planet atmospheres in the coming weeks. The simulators can all be found at the webpage: http://astro.unl.edu/naap/atmosphere/atmosphere.html. Use the background information and simulators that you find there to answer the following questions.

Background Information

Read/Work through the background sections on Escape Velocity, Projectile Simulation, and Speed Distribution **on the website**. Then complete the following questions related to the background information.

Question 1: Imagine that asteroid A that has an escape velocity of 50 m/s. If asteroid B has twice the mass and twice the radius, it would have an escape velocity _______________ the escape velocity of asteroid A.

a) 4 times b) Twice c) the same as d) half e) one-fourth

Describe your reasoning/show work below.

Question 2: **Fill in the third column in the** table below by using the Projectile Simulator to determine the escape velocities for the objects **listed**. Since the masses and radii are given in terms of the Earth's, you can easily check your values by using the mathematical formula for escape velocity **outlined in the escape velocity background section**. **Do this in column 4.**

Object	**Mass (Mearth)**	**Radius (Rearth)**	**v_{esc} (km/s)**	**v_{esc} (km/s) calculation**
Mercury	0.055	0.38		$\sqrt{\frac{(0.055)}{(0.38)}}\left(11.2\frac{km}{s}\right) = 4.3\frac{km}{s}$
Uranus	15	4.0		
Io	0.015	0.30		
Vesta	0.00005	0.083		
Krypton	100	10		

Question 3: Experiment with the Maxwell Distribution Simulator **(under the "Speed Distribution" review section)**. Then a) draw a sketch of a typical gas curve below, b) label both the x-axis and y-axis appropriately, c) draw in the estimated locations of the most probable velocity v_{mp} and average velocity v_{avg}, and d) shade in the region corresponding to the fastest moving 3% of the gas particles.

Maxwell Speed Distribution

Gas Retention Simulator

Open the **gas retention simulator**. Begin by familiarizing yourself with the capabilities of the gas retention simulator through experimentation.

- The **gas retention simulator** provides you with a **chamber** in which you can place various gases and control the temperature. The dots moving inside this chamber should be thought of as tracers where each represents a large number of gas particles. The walls of the chamber can be configured to be a) impermeable so that they always rebound the gas particles, and b) sufficiently penetrable so that particles that hit the wall with velocity over some threshold can escape. You can also view the distributions of speeds for each gas in relation to the escape velocity in the **Distribution Plot** panel.
- The lower right panel entitled **gases** allows you to add and remove gases in the experimental chamber. The lower left panel is entitled **chamber properties**. In its default mode it has **allow escape from chamber** unchecked and has a **temperature** of 300 K. Click **start simulation** to set the particles in motion in the chamber panel. Note that **stop simulation** must be clicked to change the temperature or the gases in the simulation.
- The upper right panel entitled distribution plot allows one to view the Maxwell distribution of the gas as was possible in the background pages. Usage of the show draggable cursor is straightforward and allows one to conveniently read off distribution values such as the most probable velocity. The show distribution info for selected gases requires that a gas be selected in the gas panel. This functionality anticipates a time when more than one gas will be added to the chamber.

Exercises

- Use the pull-down menu to add hydrogen to the chamber.

Question 4: Complete the table using the draggable cursor to measure the most probable velocity for hydrogen at each of the given temperatures. Write a short description of the relationship between T and v_{mp}.

T (K)	v_{mp} (m/s)
300	
200	
100	

Question 5: If the simulator allowed the temperature to be reduced to 0 K, what would you guess would be the most probable velocity at this temperature? Why?

- Return the temperature to 300 K. Use the gas panel to add Ammonia and Carbon Dioxide to the chamber.

Question 6: Complete the table using the draggable cursor to measure the most probable velocity at a temperature of 300 K and recording the atomic mass for each gas. Write a short description of the relationship between mass and vmp and the width of the Maxwell distribution.

Gas	Mass (u)	v_{mp} (m/s)
H2		
NH3		
CO2		

Question 7: Check the box entitled allow **escape from chamber** in the chamber properties panel. You should still have an evenly balanced mixture of hydrogen, ammonia, and carbon dioxide. Run each of the simulations specified in the table below for the mixture. Click **reset proportions** to restore the original gas levels. Write a description of the results similar to the example completed for you.

Run	T (K)	v_{esc} (m/s)	Description of Simulation
1	500	1500	H_2 is very quickly lost since it only has a mass of 2u and its most probable velocity is greater than the escape velocity, NH_3 is slowly lost since it is a medium mass gas (18u) and a significant fraction of its velocity distribution is greater than 1500 m/s, CO_2 is unaffected since its most probable velocity is far less than the escape velocity.
2	500	1000	
3	500	500	
4	100	1500	
5	100	1000	
6	100	500	

Question 8: Write a summary of the results contained in the table above. Under what circumstances was a gas likely to be retained? Under what circumstances is a gas likely to escape the chamber?