Student's Name ______________________________ Date __________ Class ________

Student Sheet PA: Investigation Results (page 1 of 6)

Investigation PA.1: Phases of the Moon

1. How often does a full moon appear? ______________________________

2. How often does a new moon appear? ______________________________

3. What other patterns, if any, can you see in the month of pictures? ______________________________

____

4. Why is a portion of the Moon lit and the other portion of the Moon dark in some of the images?

____

____

5. Where is the Moon located with respect to Earth and the Sun during the new moon? __________

____

____

6. Where is the Moon located with respect to Earth and the Sun during the full moon? __________

____

____

Investigation PA.2: Gravity

1. What factors did you consider in deciding which bodies would be the Sun, planets, and moons?

____

____

2. What factors did you consider when deciding how far apart the bodies in your solar system should be? ______________________________

____

3. Think about the factors you considered as you constructed your model. Describe how you think gravity holds the solar system together. ______________________________

____

4. What do you know about patterns in solar systems that may have influenced your model?

____

Student's Name ______________________________ Date ____________ Class __________

Student Sheet PA: Investigation Results (page 2 of 6)

Investigation PA.3: Scale Properties

1. Which moon do you think is larger, A or B? Explain. ______________________________

2. Which crater do you think is larger, A or B? Explain. ______________________________

3. What is the diameter (in kilometers) of crater B? Show your work.

4. What is the distance of Europa's orbit around Jupiter? Show your work.

5. What is the radius of Europa's orbit around Jupiter? Show your work.

Student's Name ____ Date _____________ Class __________

Student Sheet PA: Investigation Results (page 3 of 6)

Investigation PA.4: Scientific Explanation

Directions: For each question, construct your explanation using a claim, evidence, and reasoning.

1. Does a planet's surface gravity depend on its mass?

a. Make a claim. (State whether or not you think a planet's surface gravity depends on its mass.)

____

____

b. State your evidence. (Select data from the table that supports your claim.) ____________________

____

____

____

c. State your reasoning. (Explain how your evidence supports your claim.) ______________________

____

____

____

2. Does a planet's orbital period relate to its distance from the Sun?

a. Make a claim. (State whether or not you think a planet's orbital period relates to its distance from the Sun.) ____

____

b. State your evidence. (Select data from the table that supports your claim.) ____________________

____

____

c. State your reasoning. (Explain how your evidence supports your claim.) ______________________

____

____

____

Student's Name ______________________________ Date ____________ Class __________

Student Sheet PA: Investigation Results (page 4 of 6)

Investigation PA.5: Camera Container Design Criteria

1. Specify the design for your container in Table A. Use the information in your Student Guide on overall requirements. Use appropriate units and sufficient precision to ensure a successful solution. Explain how you decided on your design, including any calculations you made, in the space provided.

Table A. Satellite Container Design Criteria

Criterion	Criterion Specification	Design Explanation
Maximum dimensions (cm)		
Maximum weight (kg)		
Power range (mW)		
Power mode		
Power schedule		

Student's Name ____ Date _____________ Class ___________

Student Sheet PA: Investigation Results (page 5 of 6)

Investigation PA.6: Camera Design Evaluation

1. For each criterion, list any cameras that do not meet the specification and explain why.

a. Resolution: ____

b. Focal length: ____

c. Field of view: ____

d. Depth of field: ____

e. Hyperfocal distance: ____

f. Exposure time: ____

g. Compression rate: ____

h. Frame transfer rate: ____

2. For each camera, summarize how well it meets the overall design specifications.

a. Blue: ____

____

b. Yellow: ____

____

c. Red: ____

____

d. Orange: ____

____

e. Green: ____

____

Student's Name ____ Date _____________ Class ___________

Student Sheet PA: Investigation Results (page 6 of 6)

Investigation PA.7: Testing Solar Panel Performance

1. Describe your plan for generating data to determine the best combination of design options.

2. What would you do if your test results showed that two different combinations of layers had different benefits? Describe your thinking and any steps you would take.

Student's Name ____ Date _____________ Class ___________

Student Sheet 1.1a: The Sun-Earth-Moon System

Directions: Fill in Table A by completing #1–4.

Table A. Measurements for the Sun-Earth-Moon System				
Body Name	**Diameter (km)**	**Number of Earths Across**	**Distance from Earth (km)**	**Number of Earths Away**
Earth		1.00		
Sun				
Moon				

1. Refer to the reading selection "The Sun-Earth-Moon System" and fill in the diameter of each body in Table A.

2. Scale the Sun and Moon in terms of how many Earths across they are. You need to find the ratio between the diameters of the Earth and Moon. A ratio is a comparison of two quantities. It is found by dividing one quantity by the other. For example, if the Moon were 50 km across and Earth were 150 km across, you would set up the equation as follows:

   $x = D_M/D_E$ where D_M is the diameter of the Moon, and D_E is the diameter of Earth.

   For this example, $x = \frac{50}{150} = 0.33$. The Moon's diameter would be 0.33 the diameter of Earth, or 0.33 Earths, across. Follow this example to determine the number of Earths across the Moon and Sun really are. Show your work in the space below. Then record your findings in Table A.

3. Refer to "The Sun-Earth-Moon System" and fill in the distance between each body and Earth in Table A.

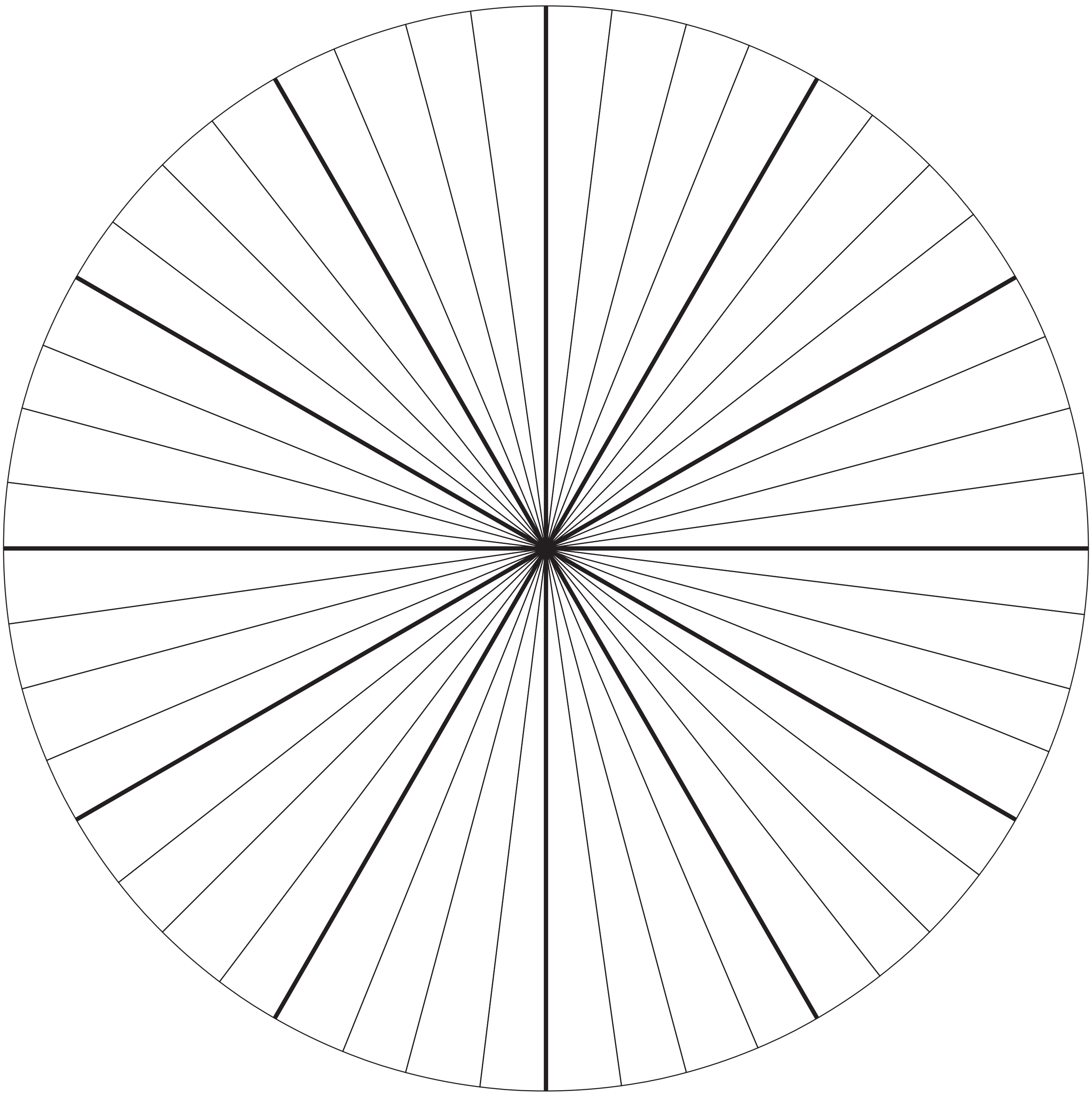
4. Scale the distance to the Sun and Moon in terms of how many Earths away they are. To do this, you must divide the distance to each body by the diameter of Earth. Show your work here. Then record your findings in Table A.

Student's Name ____ Date ____________ Class __________

Student Sheet 1.1b: Earth Orbit Compass Rose

Darker lines represent monthly interval.

Lighter lines represent approximate weekly interval.



Student's Name ____________________ Date __________ Class __________

Student Sheet 2: Modeling Lunar Phases (page 1 of 2)

Directions: Use this sheet to record your ideas as you plan, construct, and use your model of the Sun-Earth-Moon system. Discuss each question with your group.

1. Do Earth and the Moon revolve on the same plane? ____________________

2. Will the Moon usually be higher or lower than Earth, or level with it, as Earth orbits the Sun?

3. In which direction do Earth and the Moon rotate around their axes, clockwise or counterclockwise?

4. What do you think the rods on your Sun-Earth-Moon Board™ represent? ____________________

5. Why are the rods different heights? ____________________

6. Why does the rod go through the globe at an angle? ____________________

7. Is the tilt of the Moon's orbital plane exaggerated in the model? ____________________

Student's Name ______________________________ Date __________ Class __________

Student Sheet 2: Modeling Lunar Phases (page 2 of 2)

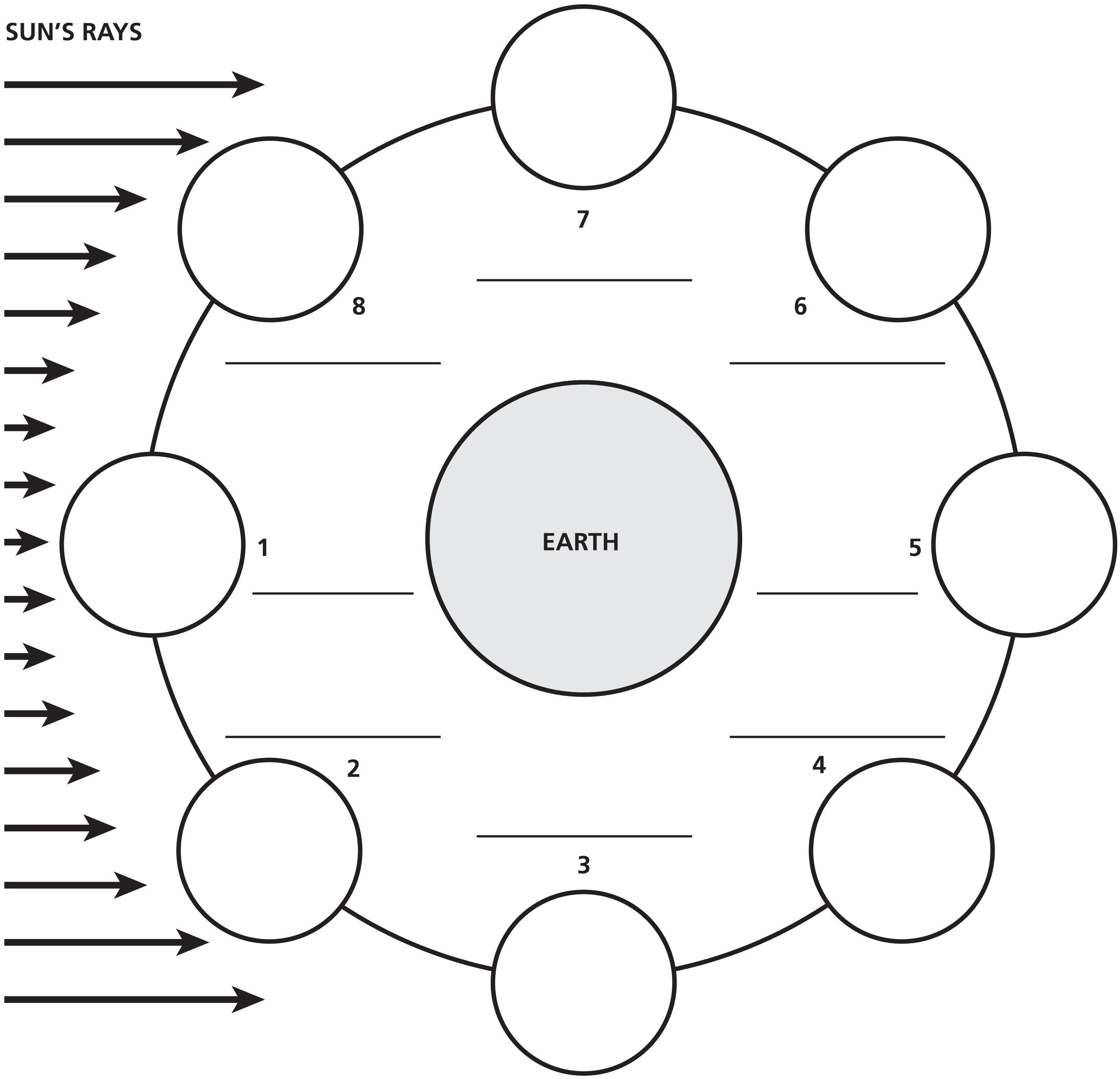


Figure A
How the Moon is illuminated by the Sun over a lunar cycle

Student's Name ______________________________ Date __________ Class __________

Student Sheet 3.1a: Analyzing Tidal Data (page 1 of 6)

Directions: Use this sheet to analyze the tidal data from Virginia Beach, Virginia. Carefully record all of your work for each of the investigation questions.

Table A. Predicted Tides and Lunar Cycles for Virginia Beach, Virginia, April 2014 (Tidal Datum = MLLW)

Day	Time	Tide	Height (ft)	Height (cm)	Moonrise Time	Moonset Time	Percentage of Moon Visible	Lunar Phase
1 Tu	3:37 a.m.	Low	−0.6	−18	7:55 a.m.		4	
	9:35 a.m.	High	3.8	116				
	3:40 p.m.	Low	−0.5	−15		9:43 p.m.		
	9:55 p.m.	High	4.4	134				
2 W	4:24 a.m.	Low	−0.4	−12	8:36 a.m.		10	
	10:19 a.m.	High	3.6	110				
	4:24 p.m.	Low	−0.3	−9				
	10:39 p.m.	High	4.2	128		10:44 p.m.		
3 Th	5:10 a.m.	Low	−0.2	−6	9:20 a.m.		17	
	11:03 a.m.	High	3.4	104				
	5:07 p.m.	Low	0.0	0				
	11:23 p.m.	High	3.9	119		11:41 p.m.		
4 F	5:56 a.m.	Low	0.1	3	10:07 a.m.		25	
	11:49 a.m.	High	3.2	98				
	5:52 p.m.	Low	0.2	6				
5 Sa	12:09 a.m.	High	3.7	113		12:33 a.m.	34	
	6:45 a.m.	Low	0.4	12	10:56 a.m.			
	12:37 p.m.	High	3.0	91				
	6:41 p.m.	Low	0.5	15				
6 Su	12:59 a.m.	High	3.4	104		1:21 a.m.	43	
	7:37 a.m.	Low	0.6	18	11:47 a.m.			
	1:31 p.m.	High	2.8	85				
	7:36 p.m.	Low	0.7	21				

Student's Name ____ Date ______________ Class ___________

Student Sheet 3.1a: Analyzing Tidal Data (page 2 of 6)

Table A. Predicted Tides and Lunar Cycles for Virginia Beach, Virginia, April 2014 (continued) **(Tidal Datum = MLLW)**

Day	Time	Tide	Height (ft)	Height (cm)	Moonrise Time	Moonset Time	Percentage of Moon Visible	Lunar Phase
7 M	1:55 a.m.	High	3.2	98		2:04 a.m.	50	
	8:35 a.m.	Low	0.7	21	12:39 p.m.			
	2:32 p.m.	High	2.8	85				
	8:37 p.m.	Low	0.7	24				
8 Tu	2:55 a.m.	High	3.1	94		2:43 a.m.	62	
	9:34 a.m.	Low	0.7	21	1:33 p.m.			
	3:35 p.m.	High	2.8	85				
	9:42 p.m.	Low	0.8	24				
9 W	3:57 a.m.	High	3	91		3:19 a.m.	71	
	10:28 a.m.	Low	0.7	21	2:27 p.m.			
	4:34 p.m.	High	3.0	91				
	10:43 p.m.	Low	0.7	21				
10 Th	4:53 a.m.	High	3.1	94		5:53 a.m.	79	
	11:15 a.m.	Low	0.5	15	3:23 p.m.			
	5:25 p.m.	High	3.2	98				
	11:35 p.m.	Low	0.5	15				
11 F	5:42 a.m.	High	3.2	98		4:25 a.m.	87	
	11:56 a.m.	Low	0.4	12	4:19 p.m.			
	6:09 p.m.	High	3.4	104				
12 Sa	12:21 a.m.	Low	0.3	9		4:56 a.m.	93	
	6:25 a.m.	High	3.3	101				
	12:34 p.m.	Low	0.2	6	5:16 p.m.			
	6:49 p.m.	High	3.7	113				

Student's Name ______________________________ Date __________ Class __________

Student Sheet 3.1a: Analyzing Tidal Data (page 3 of 6)

Table A. Predicted Tides and Lunar Cycles for Virginia Beach, Virginia, April 2014 (continued) **(Tidal Datum = MLLW)**

Day	Time	Tide	Height (ft)	Height (cm)	Moonrise Time	Moonset Time	Percentage of Moon Visible	Lunar Phase
13 Su	1:03 a.m.	Low	0.1	3		5:28 a.m.	97	
	7:05 a.m.	High	3.4	104				
	1:12 p.m.	Low	0.1	3	6:14 p.m.			
	7:27 p.m.	High	3.9	119				
14 M	1:44 a.m.	Low	−0.1	−3		6:02 a.m.	100	
	7:45 a.m.	High	3.5	107				
	1:49 p.m.	Low	−0.1	−3	7:14 p.m.			
	8:06 p.m.	High	4.1	125				
15 Tu	2:25 a.m.	Low	−0.2	−6		6:37 a.m.	100	
	8:24 a.m.	High	3.5	107				
	2:28 p.m.	Low	−0.2	−6	8:16 p.m.			
	8:45 p.m.	High	4.2	128				
16 W	3:06 a.m.	Low	−0.3	−9		7:17 a.m.	98	
	9:05 a.m.	High	3.6	110				
	3:09 p.m.	Low	−0.2	−6	9:19 p.m.			
	9:26 p.m.	High	4.3	131				
17 Th	3:50 a.m.	Low	−0.3	−9		8:01 a.m.	94	
	9:47 a.m.	High	3.5	107				
	3:51 p.m.	Low	−0.2	−6				
	10:09 p.m.	High	4.3	131	10:21 p.m.			
18 F	4:35 a.m.	Low	−0.3	−9		8:50 a.m.	87	
	10:32 a.m.	High	3.5	107				
	4:37 p.m.	Low	−0.1	−3				
	10:56 p.m.	High	4.3	131	11:21 p.m.			

Student's Name ____ Date ______________ Class ___________

Student Sheet 3.1a: Analyzing Tidal Data (page 4 of 6)

Table A. Predicted Tides and Lunar Cycles for Virginia Beach, Virginia, April 2014 (continued) **(Tidal Datum = MLLW)**

Day	Time	Tide	Height (ft)	Height (cm)	Moonrise Time	Moonset Time	Percentage of Moon Visible	Lunar Phase
19 Sa	5:24 a.m.	Low	−0.2	−6		9:45 a.m.	79	
	11:20 a.m.	High	3.4	104				
	5:28 p.m.	Low	−0.1	−3				
	11:46 p.m.	High	4.2	128				
20 Su	6:16 a.m.	Low	−0.1	−3	12:18 a.m.	10:45 a.m.	69	
	12:14 p.m.	High	3.3	101				
	6:24 p.m.	Low	0.1	3				
21 M	12:42 a.m.	High	4.0	122	1:11 a.m.		58	
	7:13 a.m.	Low	0.0	0		11:48 a.m.		
	1:14 p.m.	High	3.3	101				
	7:27 p.m.	Low	0.2	6				
22 Tu	1:43 a.m.	High	3.8	116	1:58 a.m.		50	
	8:14 a.m.	Low	0.0	0		12:54 p.m.		
	2:19 p.m.	High	3.4	104				
	8:36 p.m.	Low	0.2	6				
23 W	2:49 a.m.	High	3.7	113	2:41 a.m.		35	
	9:18 a.m.	Low	0.0	0		2:01 p.m.		
	3:28 p.m.	High	3.5	107				
	9:49 p.m.	Low	0.1	3				
24 Th	3:57 a.m.	High	3.7	113	3:21 a.m.		24	
	10:20 a.m.	Low	−0.1	−3		3:07 p.m.		
	4:35 p.m.	High	3.7	113				
	10:58 p.m.	Low	0.0	0				

Student's Name ____ Date ______________ Class ___________

Student Sheet 3.1a: Analyzing Tidal Data (page 5 of 6)

Table A. Predicted Tides and Lunar Cycles for Virginia Beach, Virginia, April 2014 (continued)
(Tidal Datum = MLLW)

Day	Time	Tide	Height (ft)	Height (cm)	Moonrise Time	Moonset Time	Percentage of Moon Visible	Lunar Phase
25 F	5:02 a.m.	High	3.7	113	5:58 a.m.		15	
	11:17 a.m.	Low	−0.2	−6		4:13 p.m.		
	5:35 p.m.	High	4.0	122				
26 Sa	12:01 a.m.	Low	−0.2	−6	4:35 a.m.		8	
	6:01 a.m.	High	3.7	113				
	12:10 p.m.	Low	−0.3	−9		5:19 p.m.		
	6:29 p.m.	High	4.2	128				
27 Su	12:57 a.m.	Low	−0.3	−9	5:11 a.m.		3	
	6:54 a.m.	High	3.7	113				
	1:00 p.m.	Low	−0.4	−12		6:23 p.m.		
	7:18 p.m.	High	4.4	134				
28 M	1:48 a.m.	Low	−0.4	−12	5:49 a.m.		0	
	7:44 a.m.	High	4.4	134				
	1:46 p.m.	Low	−0.4	−12		7:27 p.m.		
	8:04 p.m.	High	4.5	137				
29 Tu	2:36 a.m.	Low	−0.4	−12	6:29 a.m.		0	
	8:29 a.m.	High	3.6	110				
	2:30 p.m.	Low	−0.3	−9		8:29 p.m.		
	8:48 p.m.	High	4.4	134				
30 W	3:21 a.m.	Low	−0.4	−12	7:12 a.m.		2	
	9:13 a.m.	High	3.5	107				
	3:13 p.m.	Low	−0.2	−6		9:28 p.m.		
	9:30 p.m.	High	4.3	131				

Source: NOAA (http://tidesandcurrents.noaa.gov/noaatidepredictions/NOAATidesFacade.jsp?Stationid=8639168) and UNSO (http://aa.usno.navy.mil/data/docs/RS_OneDay.php)

Student's Name ____________________ Date __________ Class __________

Student Sheet 3.1a: Analyzing Tidal Data (page 6 of 6)

1. A high tide occurs when the tide reaches its maximum height on each rise. How many high tides normally occur along Virginia Beach in 24 hours? ____________________

2. A low tide occurs when the tide reaches its minimum height on each fall. How many low tides normally occur along Virginia Beach in 24 hours? ____________________

3. Why do you think this pattern in high and low tides exists? ____________________

4. Examine the height of the high tides from April 5th through April 7th. How does the height of the high tide change from tide to tide? ____________________

5. Compare the times that high and low tides occur each day over a 2-week period. What do you observe? Explain why you think this happens. ____________________

6. Examine the data showing moonrise and moonset times. Compare these times to the timing of high tide and low tide. What patterns do you observe? What explanation can you give for these patterns?

7. Examine the data showing how much of the Moon is visible. Add the names of the lunar phases in the right-hand column. Compare the phases of the Moon to the heights of the high and low tides. During which phases do the lowest high tides occur? During which phases do the highest high tides occur? What explanation can you give for these patterns? ____________________

Student's Name ______________________________ Date ____________ Class __________

Student Sheet 3.1b: Graphing Tidal Data

Student's Name ____ Date _____________ Class ___________

Student Sheet 3.1c: Suggestions for Making a Graph of Tidal Data

1. Give each graph a title that describes the displayed data.

2. Cover as much space on the graph as possible with plotted data. Leave enough space along the axes for labels, even scale divisions, and units of measure.

3. Label horizontal and vertical axes with a description of the plotted data and the units of measure.

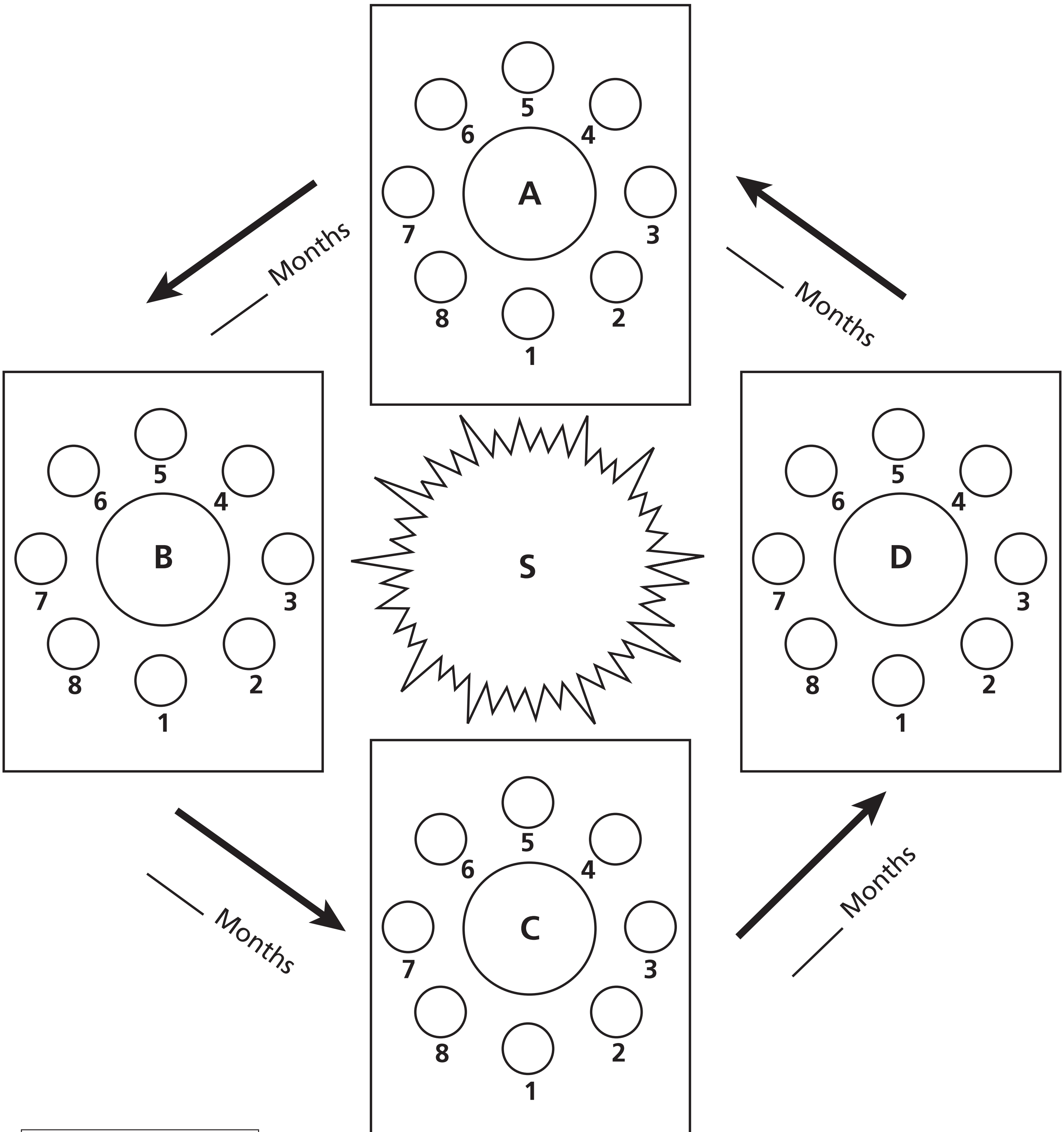
4. Plot the independent variable (in this case time in days or hours) on the horizontal, or x axis. Plot the dependent variable (for example, tide height in cm) on the vertical, or y axis.

5. Set the scale for each axis with even divisions, letting the highest measured value in the data fit on the axis. Label each axis, including the units shown.

Student's Name ______________________________ Date __________ Class _________

Student Sheet 4.2: Analyzing the Geometry of Eclipses (page 1 of 2)

Directions: Use this sheet to record and analyze your observations from using the Sun-Earth-Moon Board.



KEY: N = New moon
F = Full moon

Student's Name ______________________________ Date __________ Class _________

Student Sheet 4.2: Analyzing the Geometry of Eclipses (page 2 of 2)

1. Does the new moon cast a shadow on Earth? ______________________________

____

2. Does Earth cast a shadow on the full moon? ______________________________

____

3. How many months later does dot B represent? ______________________________

____

4. Can you create a solar eclipse (cast a shadow on Earth) with your new moon? __________

____

5. Can you create a lunar eclipse (cast a shadow on your full moon)? ______________

____

6. How many months later does dot C represent? ______________________________

____

7. Can you create a solar eclipse (cast a shadow on Earth) with your new moon? __________

____

8. Can you create a lunar eclipse (cast a shadow on your full moon)? ______________

____

9. How many months later does dot D represent? ______________________________

____

10. Can you create a solar eclipse (cast a shadow on Earth) with your new moon? __________

____

11. Can you create a lunar eclipse (cast a shadow on your full moon)? ______________

____

Student's Name ________________________________ Date ____________ Class __________

Student Sheet 5.1: Planning Sheet

Natural phenomenon I am trying to understand: How does ________________________ affect ______________________________?
What I think will happen:

Materials I will use:	Procedures I will follow:
What I will change:	
What I will keep the same:	

What I will look for:
What I will measure:

Student's Name ____ Date ______________ Class ___________

Student Sheet 6.1: Scaling the Solar System (page 1 of 6)

Directions: Table A lists information for each of the eight planets in our solar system. Review the table and read the Table Notes. Then complete the student sheet.

Table A. Planetary Data

	Planet	Distance from the Sun at the Perihelion (10^6 km)	Distance from the Sun at the Aphelion (10^6 km)	Length of Semi-minor Axis (10^6 km)	Planet Diameter (km)	Axial Tilt (degrees)	Orbital Inclination (degrees)
Inner planets	Mercury	46.0	69.8	56.7	4,879	0.01	7.0
	Venus	107.5	108.9	108.2	12,104	177.4	3.4
	Earth	147.1	152.1	149.6	12,756	23.4	0.0
	Mars	206.6	249.2	226.9	6,792	25.2	1.9
Outer planets	Jupiter	740.5	816.6	778.6	142,984	3.1	1.3
	Saturn	1,352.6	1,514.5	1,433.6	120,536	26.7	2.5
	Uranus	2,741.3	3,003.6	2,872.5	51,118	97.8	0.8
	Neptune	4,444.5	4,545.7	4,495.1	49,528	28.3	1.8

Source: NASA Planetary Fact Sheet – Metric (nssdc.gsfc.nasa.gov/planetary/factsheet/)

Table Notes

1. Distances from the Sun are given in 10^6 km. Here, 10^6 simply means that the value shown is multiplied by 10 six times (or by 1 million). Therefore, the distances shown are in millions of kilometers. For example, Mercury's distance from the Sun at the perihelion is 46.0×10^6 km, or 46 million km.

2. It is also important to note that the distances are rounded to the nearest 100,000 km. Mercury's actual distance from the Sun at the perihelion is 46,001,009 km.

3. You have learned that Earth's axis is not perpendicular to its orbital plane. It is tilted. This is also true for all of the other planets. In Table A, the axial tilt of each planet is relative to a line perpendicular to that planet's orbital plane.

4. The orbital inclination of each planet is the angle between that planet's orbital plane and Earth's orbital plane. That is why Earth's orbital inclination is 0.0. It is the reference plane from which all other planes are measured.

Student's Name ____ Date _____________ Class ___________

Student Sheet 6.1: Scaling the Solar System (page 2 of 6)

Choosing a Scale Factor

1. Look at the distances from the Sun for the different planets. Can you see why the first four are called the inner planets and the last four are called the outer planets? Explain your ideas.

____

____

____

2. Your scale model will consist of two scaled drawings on graph paper: one plan view and one side view. You will need to calculate a scale factor for distance that will let you show the complete orbit of the outermost planet—Neptune. Look at Neptune's distance from the Sun at the aphelion and perihelion (Table A). Add these two distances together in the space provided below. You will want your model of the solar system to cover at least this distance (round up).

3. Take your piece of graph paper and hold it lengthwise (in landscape view). Count how many squares it is across. Leave a little space on each end for a border. Now figure out how many millions of kilometers each square can represent. To do this, take your answer from #2 and divide by the number of squares you count. You will also need to measure the size of one square in millimeters and record it. Show your work here:

Student Sheet 6.1: Scaling the Solar System (page 3 of 6)

4. Using your answers from #2 and #3, calculate the scale factor you will use for Neptune. To do this, you need to convert the number of kilometers per square to millimeters and show your work. (**Hint:** 1 million mm = 1 km.)

5. Many models include different scales to show different parts. This works as long as the scale for each part is clearly stated. Using more than one scale in a model is particularly common in maps and in mechanical drawings. These models often show an inset map or drawing at a different scale to show more or less detail than the primary drawing.

Look at Table A and compare the planet diameters with their distances from the Sun. Do not forget that the distances are shown in millions of kilometers, while the planet diameters are shown in kilometers. Explain why more than one scale is necessary for some planets in this model. Based on your scale for Neptune, which you can use for the planets that have very large values, come up with reasonable scales for the inner planets and Jupiter. (**Hint:** The inner planets can have the same scale.)

Student Sheet 6.1: Scaling the Solar System (page 4 of 6)

Calculating Scaled Values

6. Now that you have decided on your scale factors, you must convert the perihelion distances, aphelion distances, and semi-minor axes in Table A to scaled values. Show your work and record your scaled values in Table B.

Table B. Scaled Value of Planetary Data

	Original Value (10^6 km)	Scale Factor (10^{12} mm)	Calculations	Scaled Value (mm)
Mercury				
Perihelion distance				
Aphelion distance				
Semi-minor axis				
Venus				
Perihelion distance				
Aphelion distance				
Semi-minor axis				
Earth				
Perihelion distance				
Aphelion distance				
Semi-minor axis				
Mars				
Perihelion distance				
Aphelion distance				
Semi-minor axis				

Student's Name ______________________________ Date ____________ Class __________

Student Sheet 6.1: Scaling the Solar System (page 5 of 6)

Table B. Scaled Value of Planetary Data (continued)

	Original Value (10^6 km)	Scale Factor (10^{12} mm)	Calculations	Scaled Value (mm)
Jupiter				
Perihelion distance				
Aphelion distance				
Semi-minor axis				
Saturn				
Perihelion distance				
Aphelion distance				
Semi-minor axis				
Uranus				
Perihelion distance				
Aphelion distance				
Semi-minor axis				
Neptune				
Perihelion distance				
Aphelion distance				
Semi-minor axis				

Student's Name ____ Date _____________ Class ___________

Student Sheet 6.1: Scaling the Solar System (page 6 of 6)

7. Convert the planet diameters from Table A to scaled values. Show your work and record your values in Table C.

Table C. Scaled Diameter

Planet	Original Value (km)	Scale Factor	Calculations	Scaled Value (mm)

Student's Name ______________________________ Date ____________ Class __________

Student Sheet 6.2: Graph Paper

Student's Name ______________________________ Date ______________ Class ___________

Student Sheet EA.1: Graph Paper

Student's Name ____________________ Date __________ Class __________

Student Sheet 7.1a: Weight in Space (page 1 of 4)

Many people think that there is no difference between the terms "weight" and "mass." But there is! Mass is related to the amount of matter (or "stuff") in an object, regardless of how much space the object takes up. As long as you do not add or take away any matter from an object, its mass stays the same, even at different locations.

If you take an object to the Moon or Mars, it will have the same mass that it had on Earth. But it will not have the same weight. That is because the weight of an object is a measure of the force of gravity on it, and the force of gravity is different on each planet.

To make things simpler, scientists use a surface gravity factor to compare the force of gravity on other planets with the force of gravity on Earth. (**Note:** There is no actual surface to stand on in the case of the four outer planets.) They assign Earth a surface gravity factor of 1.0. Any planet (or moon) with less gravity than Earth will have a surface gravity factor less than 1.0. Any planet with more gravity than Earth will have a surface gravity factor greater than 1.0. To find the weight of an object on a specific planet, just multiply its mass by the surface gravity factor of that planet.

Table A. Mass, Radius, and Surface Gravity of Each Planet

Planet	Surface Gravity Factor	Mass (10^{22} kg)	Radius (km)
Mercury	0.38	33	2,440
Venus	0.91	487	6,052
Earth	1.0	597	6,371
Mars	0.38	64	3,390
Jupiter	2.36	189,813	69,911
Saturn	0.92	56,832	58,232
Uranus	0.89	8,681	25,362
Neptune	1.12	10,241	24,622

Source: solarsystem.nasa.gov

Part 1.

Look at the surface gravity factors listed in Table A, and answer the following questions:

1. Would you weigh more, less, or the same on Jupiter than you do on Earth? ____________________
2. Would you weigh more, less, or the same on Mercury as you would on Mars? ____________________
3. On which planet would your weight be most similar to what it is on Earth? ____________________

Note that all gravity factors are positive. This is because the force of gravity, even if small, is always attractive.

Student's Name ____ Date ______________ Class ___________

Student Sheet 7.1a: Weight in Space (page 2 of 4)

Look at the surface gravity and mass columns in Table A together.

4. Which planet has the greatest mass?____

5. Which planet has the highest surface gravity factor? ____

Part 2.

Let's explore this relationship more closely. Use Student Sheet 7.1b: "Graph Paper" to create a graph of planet mass versus surface gravity factor. To do this, you need a pencil, an eraser, and a ruler. Do not use a pen!

Follow these steps:

1. Put Planet Mass along the x axis. Make the scale from 0 to $200{,}000 \times 10^{22}$ kg.

2. Put Surface Gravity Factor along the y axis. Make the scale from 0 to 3.

3. Use a ruler to draw a horizontal line across the graph at the level of each surface gravity factor value. Label which planet each line is for, as you draw them, on the far-right side of the graph.

4. Use a ruler to draw a vertical line at the approximate mass values for each planet. Draw the line up until you reach the surface gravity line for that planet and make a dot at the intersection.

5. Erase the lines and leave the dots. Make sure each dot is labeled with the planet name.

The graph shows the relationship between planet mass and surface gravity. Look it over carefully. Then create a simple scientific explanation using the options below.

6. Select one claim from the following possibilities: (Circle one.)

   A. Planet mass and surface gravity are not related.

   B. Planet mass alone determines a planet's surface gravity.

   C. Planets with greater mass tend to have higher surface gravity.

   D. Planets with greater mass tend to have lower surface gravity.

7. Select your evidence from the following choices: (Circle one.)

   A. The points on the graph are randomly distributed.

   B. The points on the graph are in a perfectly straight line.

   C. The points on the graph show a general positive trend.

   D. The points on the graph show a general negative trend.

Student Sheet 7.1a: Weight in Space (page 3 of 4)

8. It is always important to use reasoning to explain why your evidence supports your claim. Select reasoning from the following choices: (Circle one.)

   A. Randomly distributed points on a graph indicate that there is no correlation between the two variables plotted. This suggests that objects of different mass do not have different and predictable effects on other objects in the space-time continuum. Other factors are responsible for differences in the planets' surface gravities.

   B. Points on a graph arranged in a straight line indicate a strong correlation between the two variables plotted. This suggests that a planet's surface gravity can be directly predicted from its mass alone and no other factors are involved.

   C. Points on a graph are not perfectly aligned but their arrangement suggests a positive correlation. Therefore, as one variable increases, the other generally also increases. Planets with greater mass exert a stronger gravitational force on other bodies in the space-time continuum, but other factors are also involved.

   D. Points on a graph are not perfectly aligned but their arrangement suggests a negative correlation. Therefore, planets with greater mass exert a weaker gravitational force on other bodies in the space-time continuum, and it is likely that other factors are involved.

Part 3.

Now we will look at planet radius. This is the distance from a planet's center to its surface.

1. Compare Uranus and Neptune. They have a similar radius, but Neptune has greater mass and higher surface gravity.

2. Compare Mercury and Mars. They have the same surface gravity, even though Mars has almost twice as much mass as Mercury. But Mars is also a larger planet. Note that its radius is much greater than Mercury's.

3. Create another graph on a new copy of Student Sheet 7.1b to further explore the relationship between planet radius and surface gravity. This time, put Surface Gravity Factor on the y axis as you did before, but put Planet Radius on the x axis. Make the x axis scale from 0 to 80,000 km. Label each point with the corresponding planet's name.

4. Draw an approximate line of best fit to help you visualize the relationship between radius and surface gravity. Describe the relationship you see between planet radius (or size) and surface gravity.

   ____

   ____

5. Create another graph on a new copy of Student Sheet 7.1b to explore the relationship between planet mass and planet radius. Put Planet Mass on the x axis and Planet Radius on the y axis. Label each point with the planet name.

Student's Name ________________________________ Date ____________ Class __________

Student Sheet 7.1a: Weight in Space (page 4 of 4)

6. Describe the relationship you see between planet mass and planet radius. ____________________

7. Now use all three graphs to revise your explanation. First, make a claim about the relationship between planet mass, planet radius, and surface gravity. ____________________

8. Next, provide at least four pieces of evidence from your graphs to support your claim.

9. Now explain your reasoning in the space below.

Student's Name ______________________________ Date __________ Class ________

Student Sheet 7.1b: Graph Paper

Student's Name ____________________ Date __________ Class __________

Student Sheet 8.1: Orbiting Bodies (page 1 of 2)

Directions: Use this sheet to record your data from Investigation 8.1.

Table A. Investigation 8.1 Results		
Trial	**Time for 10 Revolutions (secs)**	**Orbital Period (secs)**
0 washers		
5 washers		
25 washers		

1. How does the mass of the cylinder affect how fast or slow the sphere orbits your hand?

____

____

____

Table B. Planet and Moon Data					
Solar System Body	**Mass (10^{22} kg)**	**Diameter (km)**	**Distance from Planet (km)**	**Orbital Speed (km/sec)**	**Orbital Period (days)**
Jupiter	189,813	139,822			
Earth	597	12,742			
Io	9	3,643	421,800	17	2
Moon	7	3,475	384,400	1	27

Source: solarsystem.nasa.gov

2. Compare the mass of Jupiter with the mass of Earth. Which planet has more mass?

____

Student Sheet 8.1: Orbiting Bodies (page 2 of 2)

3. How are Earth's Moon and Jupiter's moon, Io, alike? How are they different? ____________

4. Which planetary satellite (Io or the Moon) travels faster (has a greater orbital speed)? Given your results from the investigation, why do you think this is? ____________

5. Which planetary satellite has a shorter orbital period? What is the relationship between orbital speed and orbital period? ____________

6. Can you think of a way that scientists could determine the mass of a newly discovered planet? Explain. ____________

Student's Name ______________________________ Date __________ Class ________

Student Sheet 8.2a: Distance and Speed of an Orbiting Body

Directions: Use this sheet to record your data from Investigation 8.2.

Table A. Investigation 8.2 Results		
Trial Length of Line (cm)	**Time for 10 Revolutions (secs)**	**Orbital Period (secs)**

1. How does the orbital period change as the sphere's distance from the handle decreases?

____

____

____

Table B. Data for Jupiter's Moons		
Name	**Distance from Jupiter (km)**	**Orbital Period (days)**
Io	421,800	2
Europa	671,100	4
Ganymede	1,070,400	7
Calisto	1,882,700	17

Source: solarsystem.nasa.gov

2. Describe the relationship between distance from the planet and orbital period of moons orbiting the same body. ____

____

____

Student's Name ______________________________ Date ______________ Class ___________

Student Sheet 8.2b: Graph Paper

Student's Name ______________________________ Date __________ Class ________

Student Sheet 9.1: Martian Geology (page 1 of 2)

Directions: Use this sheet to record your data from your investigations.

Valles Marineris: A Martian Canyon

1. Image height (mm): ____________

2. Image scale (km/mm): ____________

3. **a.** Describe the Valles Marineris Canyon:

____

____

b. Width of canyon in three locations (mm): ____________

c. Average width of canyon in photograph (mm): ____________

4. Actual average width of canyon (km): ____________

Channels in the Apsus Vallis region

5. Calculate the image scale (km/mm): ____________

6. Average channel width (km): ____________

7. Scale of the Mississippi River Delta image (km/mm): ____________

8. Average widths of the Mississippi River Delta channels:

a. Main channel (km): ____________

b. Side channels (km): ____________

Student's Name ______________________________ Date __________ Class ________

Student Sheet 9.1: Martian Geology (page 2 of 2)

Sediment Fans in Melas Chasma

9. Calculate the image scale (km/mm): ______________

10. Length of the blue fan (km): ______________

11. Width of the blue fan (km): ______________

12. Length and width of Mississippi River Delta first (upper) fan to the right of the main channel (km):

____

Gullies on Mars

13. Calculate the scale of the Mars image (m/mm): ______________

14. Mars gully dimensions:
    - **a.** Length of the left-hand alcove (m): ______________
    - **b.** Length of the left-hand channel (m): ______________
    - **c.** Width of the left-hand apron (m): ______________

15. Scale of the Mount St. Helens inset (cm/mm): ______________

16. Length of Mount St. Helens gully alcove (m): ______________

Student's Name ______________________________ Date __________ Class ________

Student Sheet 10.GS: Mars and Earth

1. How is the Martian atmosphere similar to and/or different from Earth's? ________________

2. What temperatures will explorers encounter on Mars? ________________

3. How are the seasons and day length on Earth and Mars different? How are they similar?

4. Would you weigh more or less on Mars? Explain why. ________________

5. Which locations on Mars might have more comfortable temperatures for human habitation and why?

6. How could people meet the need for water in a habitation on Mars? ________________

Student's Name ______________________________ Date ____________ Class __________

Student Sheet 10.2: Design Planning Sheet

1. Use information from the readings to identify criteria, constraints, and design solution ideas for a human habitation on Mars.

Table A. Criteria, Constraints, and Design Solution Ideas for a Human Habitation on Mars		
Criterion	**Constraints**	**Design Solution Ideas**

Student's Name ____ Date _____________ Class __________

Student Sheet 10.3: Design Feedback Form

Project/Group Members:

1. Describe how the design meets the following habitability conditions:

Keeping temperatures in a livable range

____

____

____

Keeping oxygen levels sufficient for human needs

____

____

____

Providing food and water

____

____

____

Providing protection

____

____

____

2. What do you think are the greatest strengths of the overall design?

____

____

____

3. Describe suggestions for improvement.

____

____

____

Student's Name ______________________________ Date __________ Class ________

Student Sheet A.1: Modeling the Uranus-Moons System (page 1 of 5)

Table A. The Five Largest Moons of Uranus

Moon Name	Diameter (km)	Mass (10^{18} kg)	Orbital Radius (km)	Orbital Period (days)	Orbital Inclination (degrees)
Miranda	472	66	129,390	1.41	4.23°
Ariel	1,158	1,353	191,020	2.52	0.31°
Umbriel	1,169	1,172	266,300	4.14	0.36°
Titania	1,577	3,527	435,910	8.71	0.34°
Oberon	1,522	3,014	583,520	13.46	0.10°

Source: http://en.wikipedia.org/wiki/Moons_of_Uranus

Other Important Facts

1. The diameter of Uranus is 51,118 km.
2. The surface gravity factor of Uranus is 0.89.
3. Each of Uranus' five largest moons has an almost circular orbit.
4. Earth's Moon has a radius of 1,737 km, a mass of 73,420 × 10^{18} kg, and an orbital period of 27.3 days.

Student's Name ______________________________ Date __________ Class _________

Student Sheet A.1: Modeling the Uranus-Moons System (page 2 of 5)

Table B. Scale Factor Calculations

Moon	Orbital Radius (km)	Scale Factor	Calculations	Scaled Value (mm)
Miranda	129,390			
Ariel	191,020			
Umbriel	266,300			
Titania	435,910			
Oberon	583,520			

Student's Name ______________________________ Date __________ Class ________

Student Sheet A.1: Modeling the Uranus-Moons System (page 3 of 5)

Moon	Diameter (km)	Scale Factor	Calculations	Scaled Value (mm)
Miranda	472			
Ariel	1,158			
Umbriel	1,169			
Titania	1,577			
Oberon	1,522			

Student's Name ______________________________ Date __________ Class ________

Student Sheet A.1: Modeling the Uranus-Moons System (page 4 of 5)

Making the Model

1. Write one or two sentences about how well your model can help you understand each of the following aspects of the Uranus-moons system.

   a. Relative size of Uranus and its moons: ______________________________

   b. Relative distances between Uranus and its moons: ______________________________

   c. Axial tilt of Uranus and its moons: ______________________________

   d. Orbital paths of the moons: ______________________________

   e. Orbital inclinations of the moons: ______________________________

   f. Orbital periods of the moons: ______________________________

   g. Phases of the moons: ______________________________

   h. Seasons experienced on the moon: ______________________________

2. Describe how you could improve your model. ______________________________

Student's Name ____ Date _____________ Class ___________

Student Sheet A.1: Modeling the Uranus-Moons System (page 5 of 5)

Using the Model

Use your model to make a prediction to answer each question below. Record your prediction in the first column. Then, in the second column, provide evidence from your model that supports your predictions.

Table C. Predictions and Evidence	
Question	**Prediction and Evidence**
1. Which moon has the most gravity?	
2. Which moon travels fastest?	
3. Which moon is eclipsed least?	
4. Which moon is eclipsed most?	
5. Which moon eclipses the Sun most often?	

Student's Name ____________________ Date __________ Class __________

Student Sheet A.2: Written Assessment (page 1 of 6)

Part 1: Multiple Choice

Think about the Sun-Earth-Moon Board model you worked with in this unit.

Select one claim for each question. Then describe the evidence from the models you used in this unit to support the claim.

1. What causes a crescent moon?

A. Earth's shadow covers part of the Moon, making it dark.

B. The Moon changes shape as it goes from one phase to another.

C. The Moon is aligned with Earth and the Sun.

D. We can only see a small portion of the lit side of the Moon.

Evidence that supports the claim: ____________________

____

2. Why are total solar eclipses rare events?

A. The Moon is too close to block the Sun.

B. Earth's shadow rarely falls on the Sun.

C. The Moon's orbit is inclined with respect to Earth's orbit.

D. Most eclipses cannot be seen from Earth.

Evidence that supports the claim: ____________________

____

3. What is the primary cause of Earth's seasons?

A. Earth's axial tilt

B. Earth's elliptical orbit

C. Changes in solar energy

D. Earth's rotation

Evidence that supports the claim: ____________________

____

Student's Name ________________________________ Date __________ Class ________

Student Sheet A.2: Written Assessment (page 2 of 6)

Part 2: True/False

Think about the model you made of the solar system.

Circle True or False for each statement.

4. The Sun, planets, and moons in our solar system all have surface gravity. True False

5. The amount of surface gravity a planet has depends mostly on the planet's distance from the Sun. True False

6. Provide evidence to support your answer to #4. ______________________________

____

____

____

7. Provide evidence to support your answer to #5. ______________________________

____

____

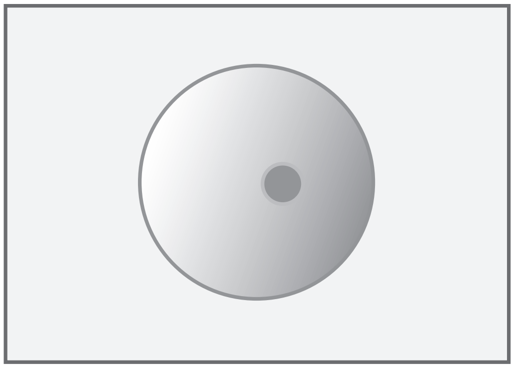
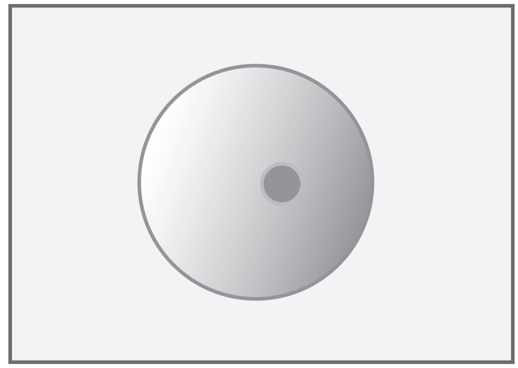
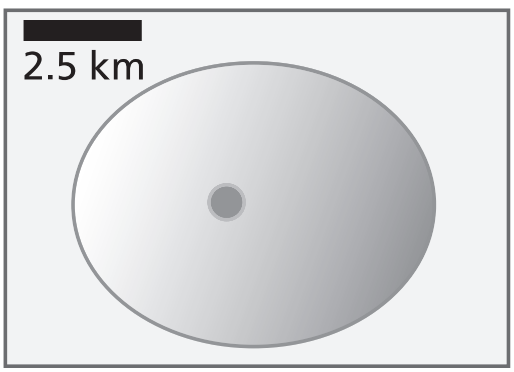
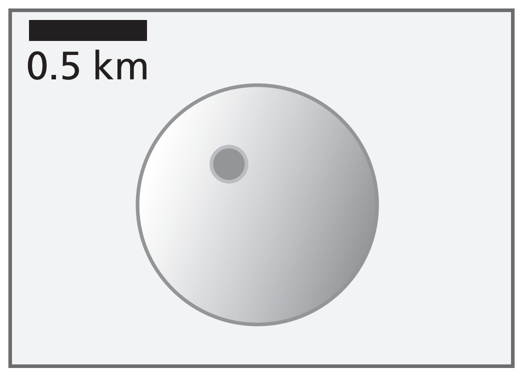
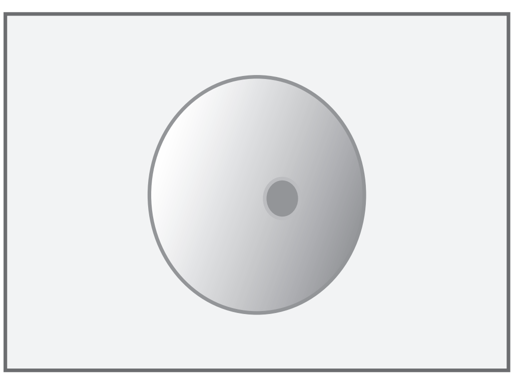
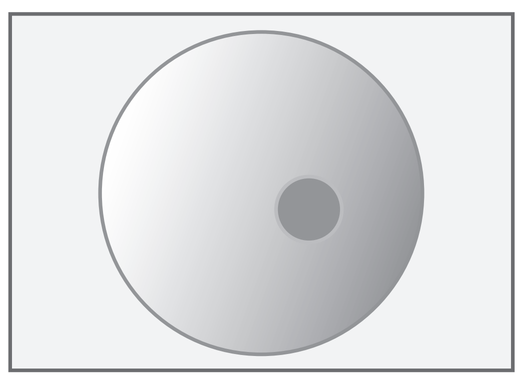
____

Student's Name ____ Date ______________ Class ___________

Student Sheet A.2: Written Assessment (page 3 of 6)

Part 3: Circle One

Think about the images from Mars that you analyzed in Lesson 9. Then look at the paired diagrams of volcanoes discovered on the imaginary planets Zolo and Arturus. For each pair, circle the name of the volcano that is larger.

	Zolo	**Arturus**
8. Comparison 1	 Volcano "Zolo 1" Image covers 4 km across.	 Volcano "Arturus 1" Image covers 7 km across.
9. Comparison 2	 Volcano "Zolo 2"	 Volcano "Arturus 1"
10. Comparison 3	 Volcano "Zolo 3." Scale is 48 m/mm.	 Volcano "Arturus 3." Scale is 8 m/mm.

Student's Name ____ Date _____________ Class ___________

Student Sheet A.2: Written Assessment (page 4 of 6)

Part 4: Short Answer

Study the table below showing Tomas's weight on different planets and other planet characteristics.

Table A. Weight on Different Planets and Planet Data

Planet	Tomas's Weight (lbs)	Planet Mass (10^{22} kg)	Planet Radius (km)	Planet Distance from Sun (10^{6} km)
Earth	100	597	6,371	150
Mercury	38	33	2,440	58
Venus	90	487	6,052	108
Mars	38	64	3,390	228
Jupiter	253	189,813	69,911	778
Saturn	106	56,832	58,232	1,400
Uranus	90	8681	25,362	2,900
Neptune	114	10,241	24,622	4,500

Source: solarsystem.nasa.gov

11. Which factor is most important in determining a planet's surface gravity? Construct a scientific explanation to answer this question that includes all three parts (claim, evidence, and reasoning):

Explanation

Make a *claim* to answer the question:

____

State your *evidence* for your answer:

____

____

____

Provide *reasoning* to support your claim:

____

____

____

Student's Name ______________________________ Date __________ Class ________

Student Sheet A.2: Written Assessment (page 5 of 6)

12. You are part of an engineering design team developing a new spacesuit. Astronauts will use the spacesuits during spacewalks to repair the spacecraft. Spacewalks can last up to 10 hours. Repairs are usually made with hand tools. Astronauts must follow instructions and report information to space command while they are making the repairs.

The team has suggested eight components that should be considered when designing the spacesuit. These include:

- Two-way radio
- Drinking water dispenser
- Articulated gloves
- White fabric
- Lightweight fabric
- Oxygen pack
- Insulated boots
- Helmet lamp

In the table below, choose four components you think are important and record what specifics you need to know to better define the criteria for each.

Table B. Spacesuit Components and Criteria	
Component	**Specific Information Needed to Define Component Criteria**

Student's Name ______________________________ Date __________ Class __________

Student Sheet A.2: Written Assessment (page 6 of 6)

13. Spacesuit fabric is made up of many layers of material. Each layer has a distinct purpose. Three samples of fabric have been tested for performance in meeting six criteria. The results are shown in the table below.

Table C. Performance Ratings of Sample Fabrics for Six Criteria			
Criterion*	**Silver Fabric**	**Puffy Fabric**	**Neon Green Fabric**
Puncture resistance	Excellent	Good	Good
Insulating ability	Poor	Good	Fair
Fire resistance	Good	Excellent	Fair
Tear resistance	Good	Fair	Excellent
Flexibility	Good	Fair	Excellent
Waterproofing	Excellent	Good	Fair

*Note: *Criterion* is the singular of *criteria*. For example, one criterion, many criteria.

Which fabric is the best overall design solution achieved so far? Provide evidence from the test data to support your claim. ______________________________

____

____

14. How should the fabric you selected be improved? Provide evidence from the test data to support your claim. ______________________________

____

____

____

15. How would you test the improvements? List the steps in your testing process. ______________

____

____

____