PASSPORT TO THE SOLAR SYSTEM TEACHER RESOURCE

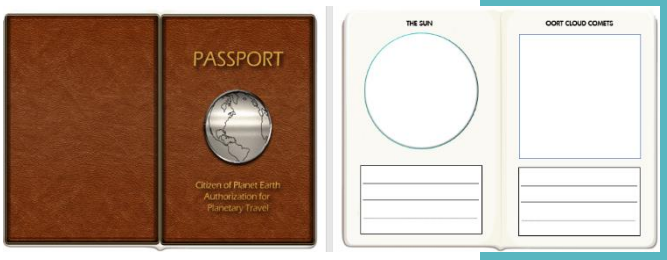
This guide is a companion to the Solar System astronomy program. It includes:

- Stopping points and time codes where the discussion questions appear in the show.

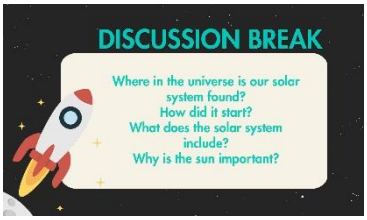
- A student questionnaire with an answer key organized by section.
- A copy of the student supplemental hands-on activities. Student versions are in separate files for easier distribution by grade level.

The student activities include:

K-3 Planetary Passport
K-3 Model the Sun (Simplified)
K-5 Solar System Bracelet



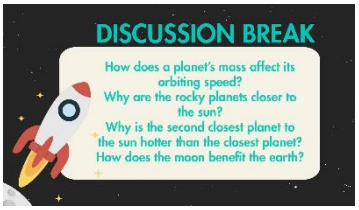
4-8 Model the Sun
4-8 Student Questionnaire
4-8 Solar System Walk
6-8 Calculate the travel time to other planets



DISCUSSION BREAK 1 – Introduction to the Solar System and the Sun **(Time 7:07)**

1. Where in the universe is our solar system? The Orion arm of the milky Way Galaxy.
2. How did the solar system start? The solar system began with the birth of the sun out of interstellar clouds and dust like those typically found in a nebula. A pre star called a protostar collapsed into a spinning disk. The core will eventually become at star. Once hydrogen begins to produce helium, a process called nuclear fusion, a star is born. The leftover heavier elements became the rocky planets whereas the colder elements or those elements that require colder temperatures became the gas and ice planets and the comets.
3. What does the solar system include: The sun, (a solar system must have a star), 8 planets, moons, asteroids, comets, dwarf planets, and humanmade satellites. Explain the formation of the sun.
4. What does our solar system include? 1 star, 8 planets, several moons, dwarf planets, the asteroid belt, Kuiper belt, Oort cloud, comets, and satellites.

DISCUSSION BREAK 2 – THE ROCKY PLANETS (Time 27:22)



1. How does a planet's mass affect its orbiting speed? Heavier objects rotate faster due to gravity.
2. Why are the rocky planets closer to the sun? Gravity.
3. Why is the second closest planet to the sun hotter than the closest planet? Venus has runaway greenhouse gases in the atmosphere due to high levels of volcanic activity.
4. How does the moon benefit the earth? Corrects the earth's wobble. Assists in tides. The moon provides night light which some animals use for migration and reproduction.

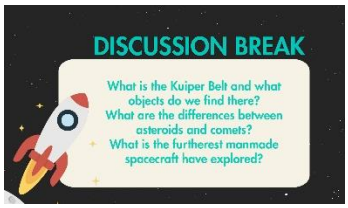
DISCUSSION BREAK 3 – THE GAS GIANTS

(Time 40:20)

1. Where do planet rings come from and what are they made of? The are often the result of cosmic collisions due to gravity and proximity.
2. How are the storms on Jupiter different than those on Earth? Some of the storms lie the one of the great red spot have raging for 300 years and up to 400 MPH, nearly double the top hurricane speed on the earth..
3. Of all the moons of Jupiter and Saturn which one would you like to explore and why? (open ended)

DISCUSSION BREAK 4 (6-8) – ON THE EDGE

(Not included)



1. What is the Kuiper Belt and what objects do we find there? The Kuiper belt is similar to the asteroid belt but it's 20 times larger. It contains some of the leftovers from the formation of the solar system. This is where the dwarf planets are found. Examples include Eris, Haumea, Makemake, and Pluto.
2. What are the differences between asteroids and comets? Both are space rocks that orbit the suns. Asteroids typically contain rock and metal and originate in the asteroid belt between mars and Jupiter. Comets contain frozen gases, water, and carbon dioxide. They typically originate in the Oort cloud. As comets move closer to the sun the frozen gases warm up and create the famous comet tails.
3. What is the furthermost manmade spacecraft have explored?

SAMPLE PASSPORT

GET TO KNOW THE PLANET DISTANCES (6-8)

Here are two ways to get familiar with the distances between the planets. You can walk the steps which is a healthy and fun way to enjoy the outdoors while thinking about space. Next you can calculate your travel time to the planets by foot, bike, car, rocket, or light speed with this NASA activity.

OBJECT	DIAMETER	STEPS
SUN	1,392,000	0
MERCURY	4,980	12
VENUS	12,360	22
EARTH	12,742	30
MARS	6,760	46
JUPITER	142,600	156
SATURN	120,600	286
URANUS	47,000	574
NEPTUNE	44,600	898

The solar system is huge! Using current technology, it takes a long time to get from Earth to another planet. Do the math and figure out just how long! Then, figure out how long it would take if we could travel at the speed of light (~1,079,000,000 km/hr).

First, figure out how far you would have to travel, on average, if you could travel in a straight line to your destination. Write an equation for determining the distance Mercury is from Earth:

Mercury distance from Earth = Earth distance from the Sun - Mercury dist. from the Sun

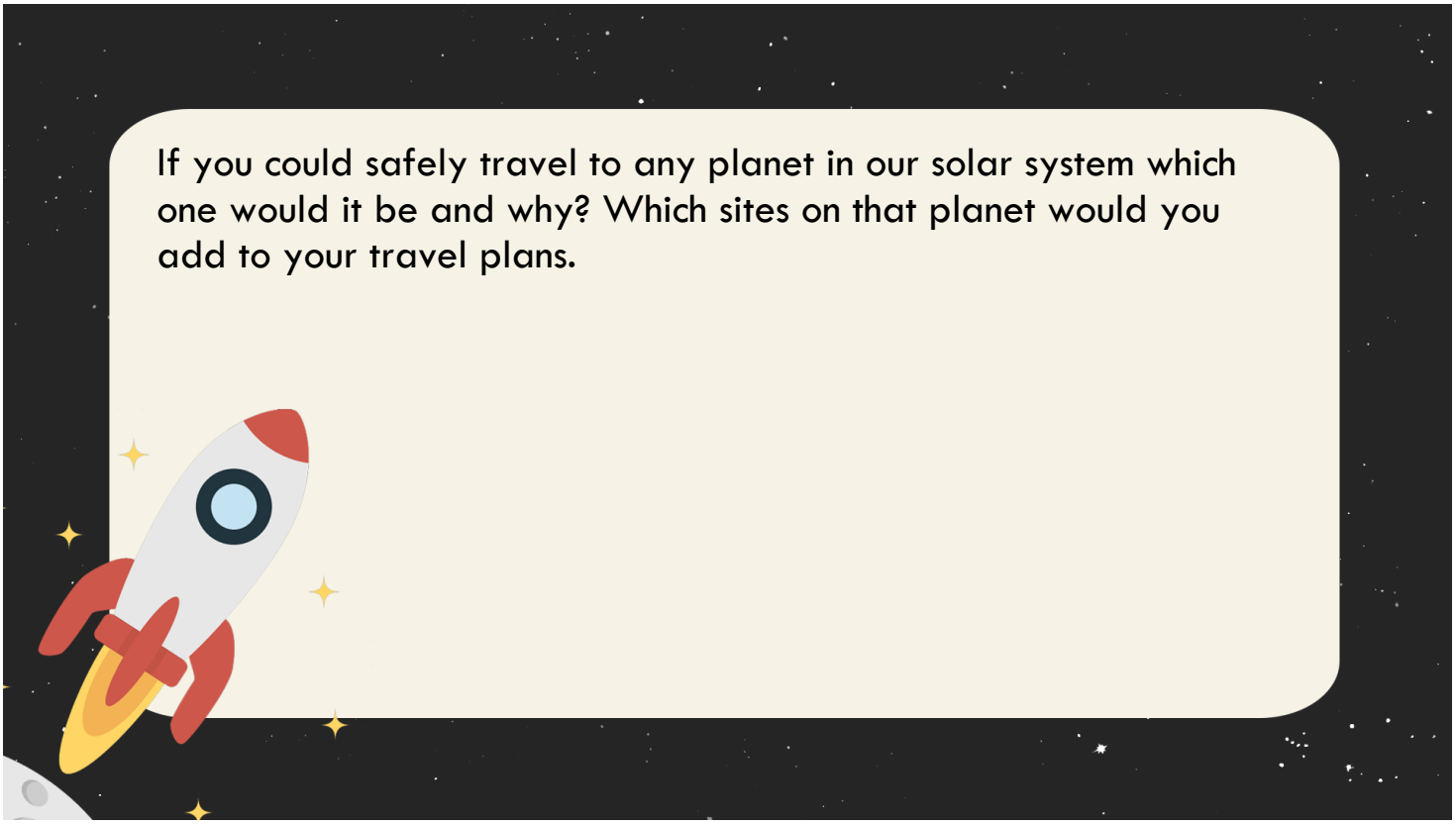
Write an equation for determining the distance Jupiter is from Earth:

Planet/Dwarf Planet	Distance from the Sun (km)	Distance from Earth (km)
Mercury	57,900,000	**91,700,000**
Venus	108,200,000	**41,400,000**
Earth	149,600,000	**0**
Mars	227,900,000	**78,300,000**
Jupiter	778,600,000	**629,000,000**
Saturn	1,433,500,000	**1,283,900,000**
Uranus	2,872,500,000	**2,722,900,000**
Neptune	4,495,100,000	**4,345,500,000**
Pluto	5,906,400,000	**5,756,800,000**

Planet / Dwarf Planet	Walking (5 km/hr)	Riding Bike (20 km/hr)	Driving Car (120 km/hr)	Riding Rocket (365,000 km/hr)	Traveling at the speed of light
Mercury	18,340,000	4,585,000	764,167	251.23	0.08
Venus	8,280,000	2,070,000	345,000	113.42	0.04
Earth	0	0	0	0	0
Mars	15,660,000	3,915,000	652,500	214.52	0.07
Jupiter	125,800,000	31,450,000	5,241,667	1,723.29	0.58
Saturn	256,780,000	64,195,000	10,699,167	3,517.53	1.19
Uranus	544,580,000	136,145,000	22,690,833	7,460.00	2.52
Neptune	869,100,000	217,275,000	36,212,500	11,905.48	4.03

Next, compute the length of time (in hours) it would take you if you were walking, riding a bike, driving a car, riding on a rocket, or traveling at the speed of light.

Write an equation for determining travel time, t: **t = distance ÷ rate of travel**



STUDENT QUESTIONNAIRE KEY

1. Name 1 layer of the sun (Corona, Chromosphere, Photosphere, Convection Zone, Radiative Zone, Core)
2. Where in the universe is our solar system? The Orion Spur of the Milky Way Galaxy
3. Name one of the most abundant gases in the universe Hydrogen, Helium
4. How does the moon benefit the earth? Stabilizes the Earth's orbit and prevents it from wobbling
5. Which planet has the largest volcano of the solar system? Mars
6. Which planet has the largest canyon of the solar system? Mars
7. What is the giant red spot on Jupiter? A Giant Storm
8. Name the terrestrial planets The rocky planets: Mercury, Venus, Earth and Mars.
9. Name the Jovian planets Jupiter Saturn Uranus and Neptune
10. Which is the hottest planet? Venus
11. Which is the coldest planet? Uranus
12. Which planet experiences double sun rises and sunsets? Mercury
13. Name a planet that rotates in retrograde Venus, Uranus
14. Which planet has the shortest year? Mercury
15. Name a planet that has storms Venus, Earth, Jupiter,
16. Which planet has the most volcanoes in the solar system Venus
17. Which planet has the highest wind speeds Neptune, up to 1,200 mph
18. Which of the following planets do not have moons? Mercury, Venus
19. Which planets have volcanoes? Venus, Earth, Mars
20. Which planet is the closest in size and distance to the earth? Venus (Mars is 2nd)
21. Which planet is the most like the earth? Mars
22. What is the name of the biggest asteroid? Ceres
23. Which planet has the biggest impact crater in the solar system. Mars
24. Name two planets with rings. Jupiter, Saturn, Uranus, and Neptune
25. What is the most volcanic object in our solar system? Jupiter's moon Io
26. Which planet is nicknamed the cosmic vacuum cleaner? Jupiter
27. What protects the earth from frequent meteor impacts like those on the moon? The Atmosphere
28. Which planet experiences atmospheric lightning storms and sulfuric acid clouds. Venus
29. Which moon of Saturn blasts freezing geysers at up to 1,400 mph? Enceladus
30. Name of the planets and 1 distinguishing fact about each of them.

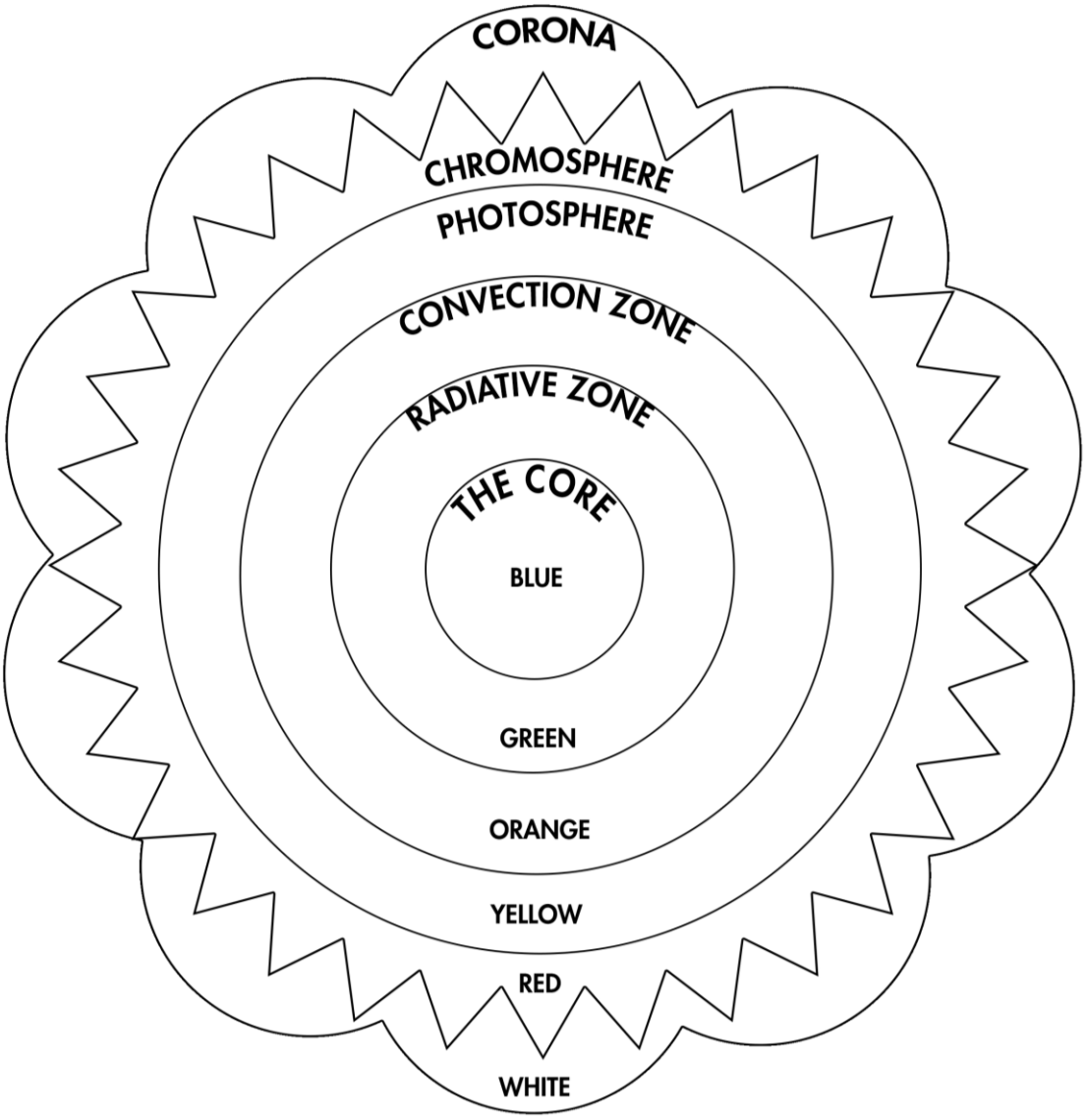
MODEL THE LAYERS OF THE SUN

DID YOU KNOW THAT THE SUN HAS LAYERS LIKE AN ONION?

In this activity you can build a Sunion, a model that will help you remember the layers of the sun.

DIRECTIONS:

1. Color in the shapes with the color listed on pages one and two.
2. Cut out the Photosphere on page two. Bend it on the dashed line.
3. Glue or staple the top of the photosphere to the photosphere on page one creating a cover that opens and closes.
4. Cut along the edges of the corona.

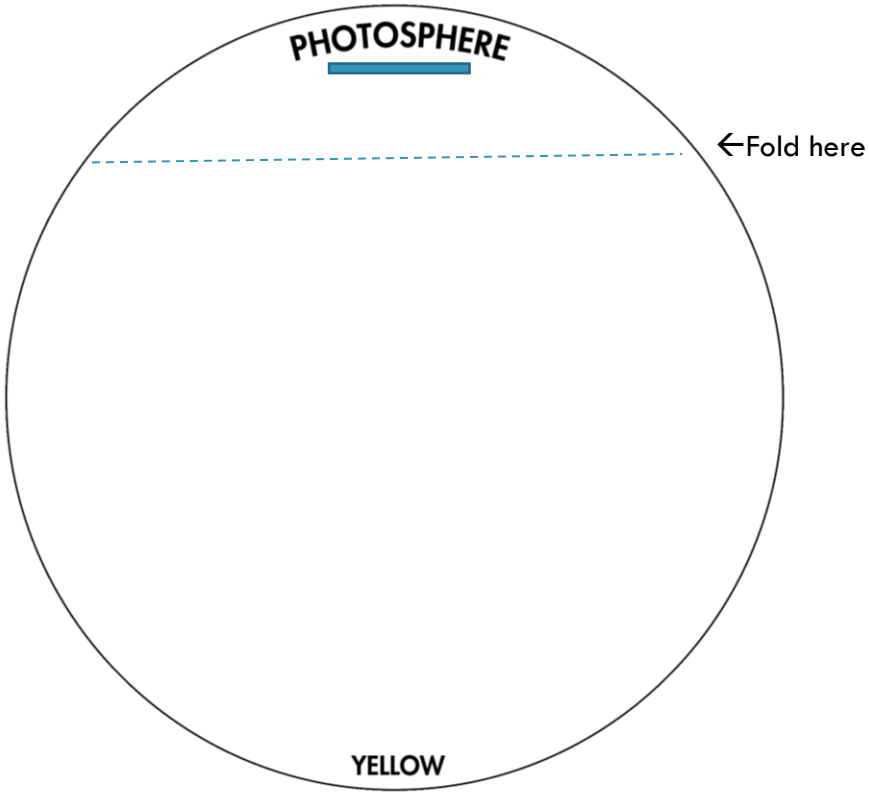


RECORD SUNSPOTS ON THE PHOSPHERE (4-8)

K-3 groups can simply cut color and add the photosphere to the model from the easy version of the activity. Older groups can optionally look up and incorporate sunspots.

DIRECTIONS:

1. Color the Photoshere yellow below.
2. Look up the Sun's photosphere as it looks today from https://umbra.nascom.nasa.gov/images/latest_mdi_igram.gif. Use this picture to draw today's sunspots (cooler spots) onto the photosphere part of your Sunion below. Make sure to write down today's date. **Never look directly at the sun.**
3. Cut out and attach the photoshere below to the top of the model on page one.



KEY CONCEPTS

1. The sun is the only star in our solar system and it has multiple layers that are different tempertures.
2. The sun is made of mostly hydrgen and helium gas and has no solid surface.
3. The surface of the sun, the photosphere, is the only layer we can observe from earth. The exception is during an eclipse when we can view the corona.
4. The sun is so large that all of the planets and moons in our system could fit inside of it. Over a million earths could fit inside the sun.

The sun and our solar system live in on the Orion arm of the Milky Way galaxy.

THESE LAYERS ARE INSIDE THE SUN

THE CORE (COLOR BLUE): The Sun's Core is 15 million degrees! A handful of the hydrogen and helium gas in the Core would weigh more than 5 pounds! In the Core the Sun smashes hydrogen, which becomes helium and releases the great amount of energy that powers the Sun.

THE RADIATIVE ZONE (COLOR GREEN): In the Radiative Zone, energy from the Core shines outward as light. Even though this energy is moving at the speed of light, it bounces back and forth in every direction, and may take hundreds of thousands of years to travel through the Radiative Zone.

THE CONVECTION ZONE (COLOR ORANGE): In the Convection Zone, energy has a difficult time moving outward around as light. Instead, the energy ix carried outward by gas. Like warm and cool air on Earth, the Convection Zone's hotter gases rise upward (like a hot air balloon), cool by releasing their heat, and then sink again. The released energy shines into space from the Photosphere as visible light.

THESE LAYERS ARE OUTSIDE THE SUN

THE PHOTOSPHERE (COLOR YELLOW) "Sphere of Light" It's 6000 degrees (ouch!). It has "cooler" (only 4000 degrees!) spots we call sunspots, which we can think of as magnetic "storms" on the Sun's surface. It is also speckled all over by "convection cells," which are where hot gases rising from inside the Sun dump their heat into space. The photosphere shines in mostly visible light.

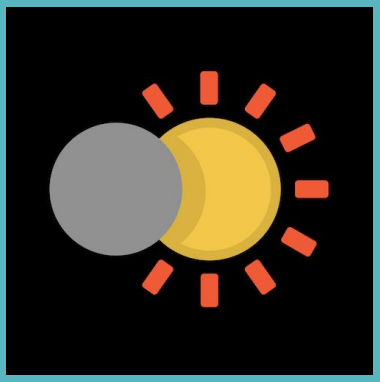
THE CHROMOSPHERE (COLOR RED) "Sphere of Color" It's above the photosphere, it's 50,000 degrees (double ouch!), and has arcs and plumes of gases called prominences. Because it's hotter, it shines with a lot of energetic ultraviolet light—though there is a lot of red light from hydrogen as well.

THE CORONA (KEEP WHITE) "THE CROWN" It's the hottest of all the Sun's atmosphere: a million degrees! It's the Sun's "crown" of very hot, thin gas—gas that forms looping and arcing shapes because of the Sun's powerful magnetic fields. Powerful explosions happen here. The corona is so hot that it shines a lot of very energetic X-rays, the kind that dentists and doctors use to see inside you!

Annular Solar Eclipse

October 14, 2023

The Moon will slide within the disk of the Sun revealing the normally invisible corona.

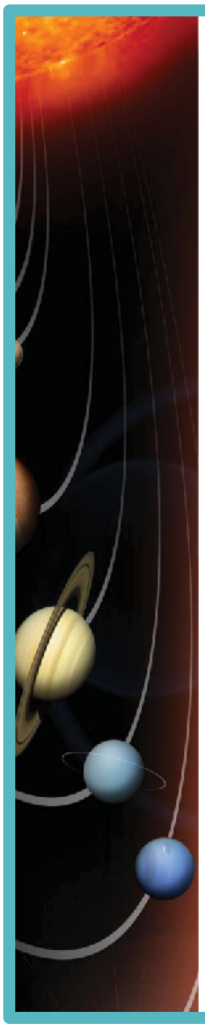


MAKE A WEARABLE SOLAR SYSTEM

MATERIALS:

- 1 pipe cleaner
- *Pony beads: silver, green, blue, red, brown, orange, black, gold, purple, white, pink, yellow, glow, and ultra-violet.

*You can change the bead colors and types on the version on the next page.



DISTANCE FROM THE SUN	
	SUN
58 Million km 35 million miles	MERCURY
108 million km 65 million miles	VENUS
150 million km 93 million miles	EARTH
228 million km 137 million miles	MARS
314 million km 195 million miles	ASTEROID BELT & CERES Ceres is a Dwarf Planet
778 million km 467 million miles	JUPITER
Place Holder 383 million miles	OUTER SPACE (1 Bead)
1.4 billion km 850 million miles	SATURN
Place Holder 850 Million Miles	OUTER SPACE (2 Beads)
2.9 billion km 1.7 billion miles	URANUS
Place Holder 1 billion miles	OUTER SPACE (3 Beads)
4.5 billion km 2.7 billion miles	NEPTUNE
Place Holder 800 million miles	KUIPER BELT
2.7-7.4 billion km 2.7-4.6 billion miles	OTHER KUIPER BELT OBJECTS
Place Holder 2.7 billion miles	OUTER SPACE Includes dwarf planets: Haumea, Sedna, and
5.5-14.5 billion km 3.4-9 billion miles	ERIS
Approximately 50,000 light years A light year = 10 trillion kilometres or 6 trillion miles	OUTER SPACE
	OORT CLOUD A spherical cloud of of comets

GLOSSARY

Asteroid	Any of the small rocky celestial bodies found especially between the orbits of Mars and Jupiter
Comet	A celestial body that appears as a fuzzy head usually surrounding a bright nucleus, that has a usually highly eccentric orbit, that consists primarily of ice and dust, and that often develops one or more long tails when near the sun
Galaxy	Any of the very large groups of stars and associated matter that are found throughout the universe
Greenhouse effect	Warming of the surface and atmosphere of a planet (such as Earth or Venus) that is caused by an accumulation of heat trapping gases like carbon dioxide resulting shifts in increasingly hotter global temperatures.
Interstellar	Among or in the stars
Jovian	Another term for the giant gas/ice planets
Kuiper Belt	A band of small celestial bodies beyond the orbit of Neptune that includes the dwarf planets and some near comets
Nebula	Any of numerous clouds of gas or dust in space
Oort Cloud	A sphere of icy rocky bodies at the furthest region of our solar system which contains long term comets
Orbit	The path of an object around it's gravitationally governing body.
Prograde	Being a direction of rotation or revolution that is counterclockwise as viewed from the north pole of the sky or a planet
Protostar	A cloud of gas and dust in space believed to develop into a star (baby star)
Retrograde	Having or being a direction of rotation or revolution that is clockwise as viewed from the north pole of the sky or a planet or backwards
Rotation	The time it takes a celestial object like a planet or moon to complete a full turn on its axis.
Star	Super-hot burning ball of gas held together by nuclear fusion.
Solar System	To have a solar system you must have 1 star with at least 1 orbiting planet.
Terrestrial	Another term for earthlike solid planets with rocky cores.

STANDARDS, SKILLS, AND CONCEPTS (NGSS)

KEY CONCEPTS:

1. The solar system contains 1 star, 8 planets, several moons, asteroids, comets, dwarf planets, spacecraft and many volatile hazards.
2. The sun is the only star in our solar system. It's responsible for the processes that generate light, heat and energy. It's an average star in size and temperature.
3. Objects that are closer to a star orbit faster than those at greater distances due to gravity. Distances in the solar system are measured in astronomical units, the mean distance between the earth and the sun. and light years approximately 6 trillion miles.
4. The planets were formed from the leftover dust and gas from the formation of the sun. The heavier elements like metal and rock remained closer to the sun due to gravity. Conversely the lighter gassier elements like hydrogen that require colder temperatures to function escaped to greater distances.

NEXT GENERATION SCIENCE STANDARDS

Completing these activities and experiments will satisfy the following NGSS standards:

- **5-ESS1** Earth's Place in the Universe
  - **ESS1.A:** The sun is a star that appears larger and brighter than other stars because it is closer.
  - **ESS1.B:** Earth and the Solar System.
- **4-PS3** Energy – Conservation of energy and energy transfer.
- **MS-P22** Motion and Stability- Forces and Interactions
- **MS-ESS2** Earth's Systems

PRACTICES FOR K-12 CLASSROOMS

Throughout these activities, learners of all ages will practice skills such as:

- **Developing and Using Models**
- **Carrying out Investigations**
- **Analyzing and Interpreting Data**
- **Using Mathematics and Computational Thinking**