Astraviator

SPACE WORKBOOK

FOR AGES 9–14

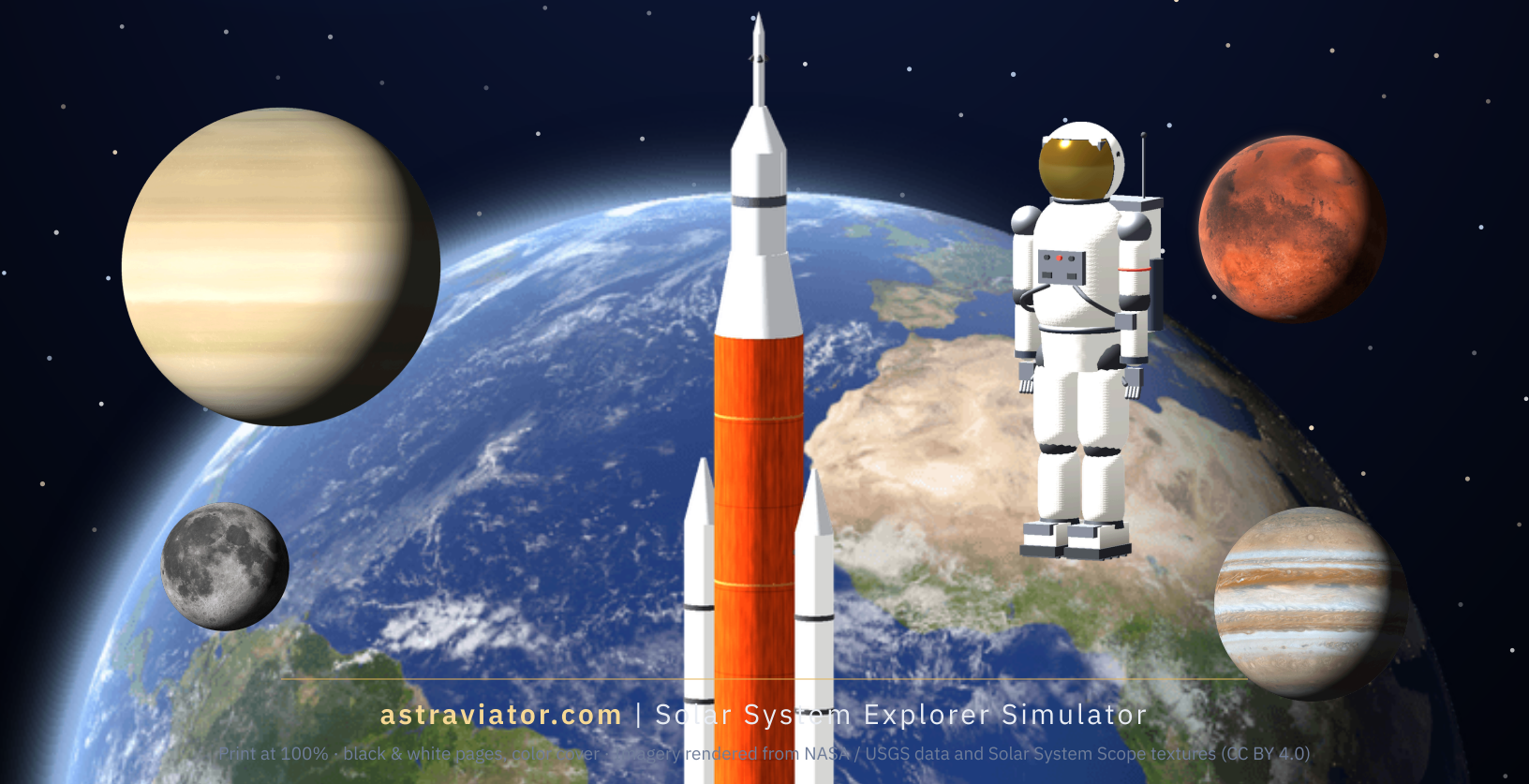
Space Workbook

8 units · 120+ activities · a field guide

Puzzles · Math labs · Cut-out games · Experiments · Coloring

Ages 9–14 · three levels · answer key included

★ Explorer · ★★ Navigator · ★★★ Commander



astraviator.com | Solar System Explorer Simulator

Print at 100% · black & white pages, color cover · Imagery rendered from NASA / USGS data and Solar System Scope textures (CC BY 4.0)

FREE SIMULATOR

Scan to fly to the Moon

SOLAR SYSTEM EXPLORER

astraviator.com/explore

Assemble the rocket, launch, cross to the Moon and explore real space data. Play the free simulator in your browser, on a phone, tablet or computer: no install, no account.

SAFETY FIRST Children should do the experiments with an adult, using ordinary household materials and eye protection when asked. Never look directly at the Sun, never cap a bottle that fizzes, and do not point anything at people or pets. Adults are responsible for supervision and for deciding whether an activity is suitable for the child.

Point your phone’s camera at the code and tap the link.

Welcome, Space Explorer!

This workbook takes you on a tour of the Solar System and beyond. Each unit works on its own, so you can start anywhere. Every unit has a different mix of activities: puzzles, math labs, coloring, mazes, ciphers, cut-out cards and games, and experiments to try at home.

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Three levels

★ EXPLORER ages 9–10 ★★ NAVIGATOR ages 11–12 ★★★ COMMANDER ages 13–14

Tips

- Print at 100% (Letter size, no scaling). Pages are black and white, ready to print.
- Have a pencil, colored pencils, scissors, glue and a calculator handy.
- Cut-out pages are marked with *cut-out*. Keep your cards in an envelope.
- Numbers use US customary units (miles, feet, pounds, °F). Light-years are used for stars.

> Explore the real thing: every destination in this workbook is in the Astraviator Solar System Explorer simulator. Visit astraviator.com.

Astraviator

SPACE WORKBOOK

UNIT 1 OF 8

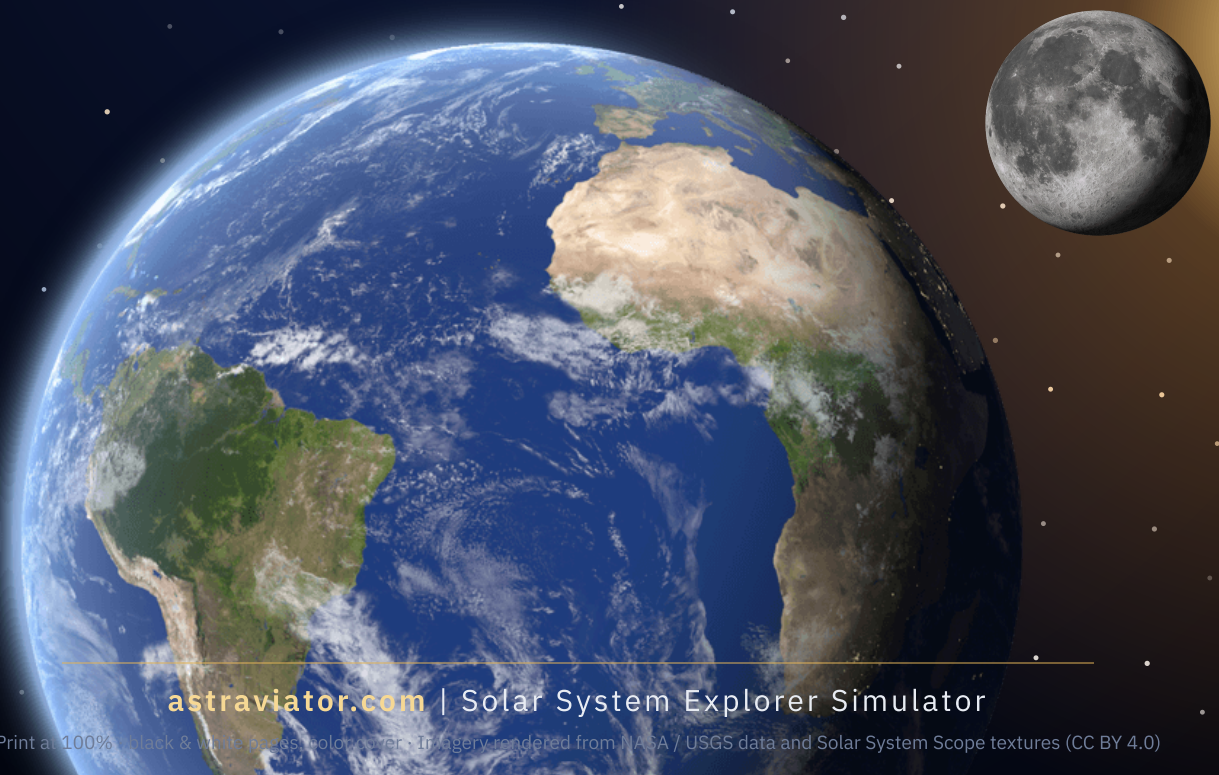
Earth, Moon & Sun

Days · Seasons · Moon phases · Eclipses · Tides

Puzzles · Math labs · Coloring · Experiments · Games

Ages 9–14 · three levels · answer key included

★ Explorer · ★★ Navigator · ★★★ Commander



astraviator.com | Solar System Explorer Simulator

Print at 100% · black & white or color · Imagery rendered from NASA / USGS data and Solar System Scope textures (CC BY 4.0)

Think First & Mission Briefing ★ EXPLORER

Think first! Before you read, fill in the first two columns. Come back to the last one when you finish the unit.

What I KNOW	What I WANT to know	What I LEARNED

Three bodies shape our days and nights: the **Sun**, the **Earth** and the **Moon**.

The **Sun** is a star, a giant ball of hot gas about 109 Earths wide. Its light takes about 8 minutes and 20 seconds to reach us.

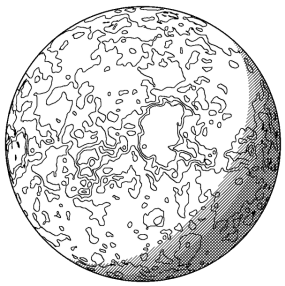
The **Earth rotates** once every 24 hours, giving us day and night, and **revolves** around the Sun once every 365 days. Its axis is tilted about 23.5°, which gives us the **seasons**.

The **Moon** orbits Earth once every 27 days, and its **phases** repeat every 29½ days. It always shows us the same face. Its gravity pulls on the oceans and makes the **tides**.

When the Moon, Earth and Sun line up, we get an **eclipse**.



The Moon

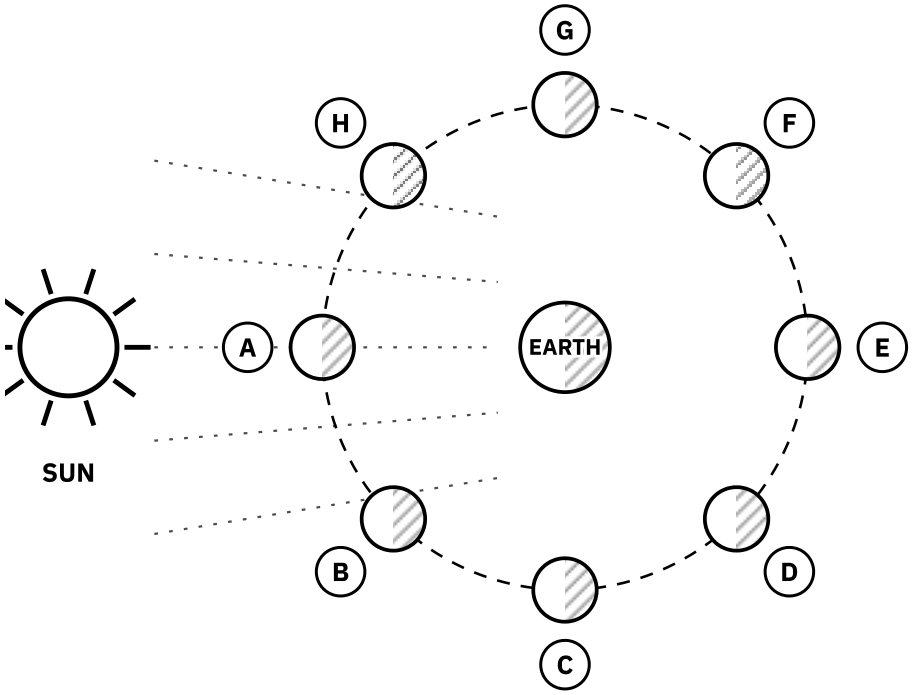


The Sun

	Sun	Earth	Moon
Width	864,000 mi	7,918 mi	2,159 mi
Distance from Earth	93 million mi	–	238,855 mi
Gravity (Earth = 1)	28	1	0.17

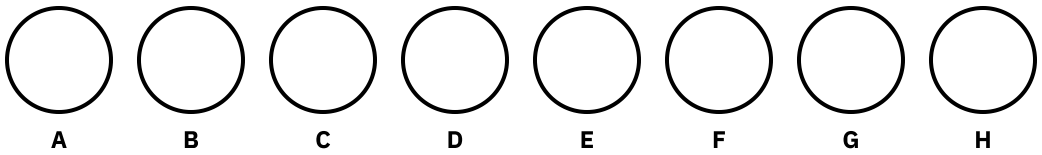
The Moon Goes Around ★★ NAVIGATOR

The Moon orbits Earth. Sunlight always lights up **half** of the Moon, but from Earth we see more or less of that lit half. Look at the diagram (seen from above the North Pole) and name each position.



New Moon · Waxing Crescent · First Quarter · Waxing Gibbous · Full Moon · Waning Gibbous · Last Quarter · Waning Crescent

What would each position look like from Earth? Shade the part of the Moon you could NOT see.



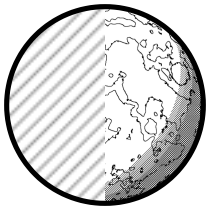
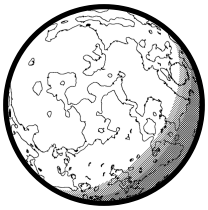
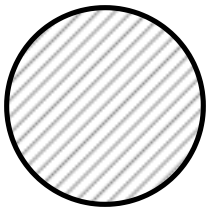
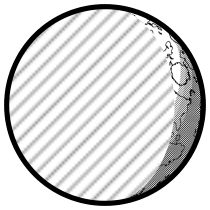
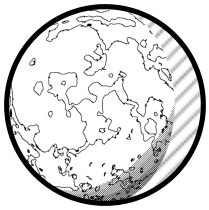
1. Which letter shows the Moon between Earth and the Sun? _____ What phase is it? _____

2. How many days from one New Moon to the next? _____ Hint: 29½ days.

Moon Phase Memory Game

★ EXPLORER cut-out

Cut out the 12 cards and mix them face down. Take turns flipping two cards: match each Moon picture with its name. The player with the most pairs wins.

Waning Gibbous	**Last Quarter**		
		**Waxing Crescent**	**Full Moon**
New Moon			**First Quarter**

Play it again with the whole cycle: put your cards in order from New Moon to Last Quarter.

Math Lab 1 · Day, Night & Time Zones

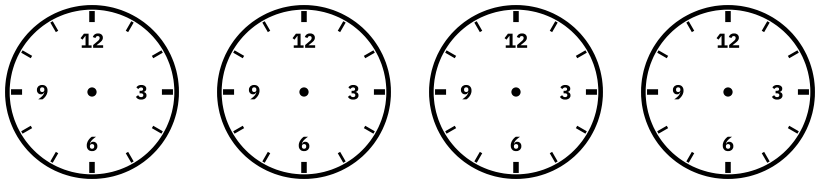
★★ NAVIGATOR ★★★ COMMANDER

Earth turns 360° in 24 hours. Different places face the Sun at different times, so the world is divided into **time zones**, each about 15° wide.

1. How many degrees does Earth turn in **one hour**? (360 ÷ 24) _____ ° In **6 hours**? _____ °

2. **US time zones.** It is **3:00 PM** in New York (Eastern). Each zone to the west is one hour earlier. Fill in the clocks:

New York (Eastern)	Chicago (Central)	Denver (Mountain)	Los Angeles (Pacific)
3:00 PM	_____	_____	_____



New York Chicago Denver Los Angeles

Draw the clock hands for each city.

3. A TV show starts at 8:00 PM Eastern. What time does it start in Los Angeles? _____

4. The continental US spans about 57° of longitude. How many time zones is that? (57 ÷ 15 = _____) → about _____ zones.

★★★ **How fast do you spin?** Earth's circumference at the equator is about 24,901 miles. Speed = distance ÷ time. At the equator you move _____ miles per hour (24,901 ÷ 24).

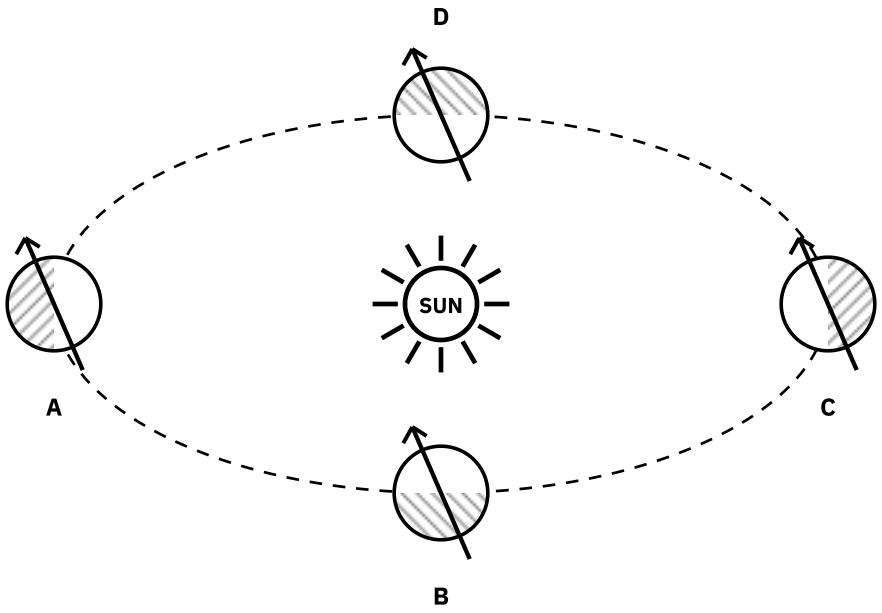
★★★ **How fast does Earth travel around the Sun?** Its orbit is about 584,000,000 miles long and takes 365 days. First change days to hours (365 × 24 = _____). Speed = _____ mph (584,000,000 ÷ hours).

5. **Call planner.** Ana lives in Miami (Eastern) and her friend Ben lives in Seattle (Pacific). Ana's school ends at 3:30 PM. What time is it for Ben? _____ Ben wants to call at 7:00 PM his time. What time is it for Ana? _____

> Why do we not feel this speed? Discuss with a friend: we move along with Earth, the same way you do not feel a smooth car ride.

Why Do We Have Seasons? ★★ NAVIGATOR

Seasons are **not** caused by Earth being closer to or farther from the Sun. They happen because Earth's axis is **tilted 23.5°**. When the Northern Hemisphere leans *toward* the Sun, it gets more direct light and longer days: **summer**.

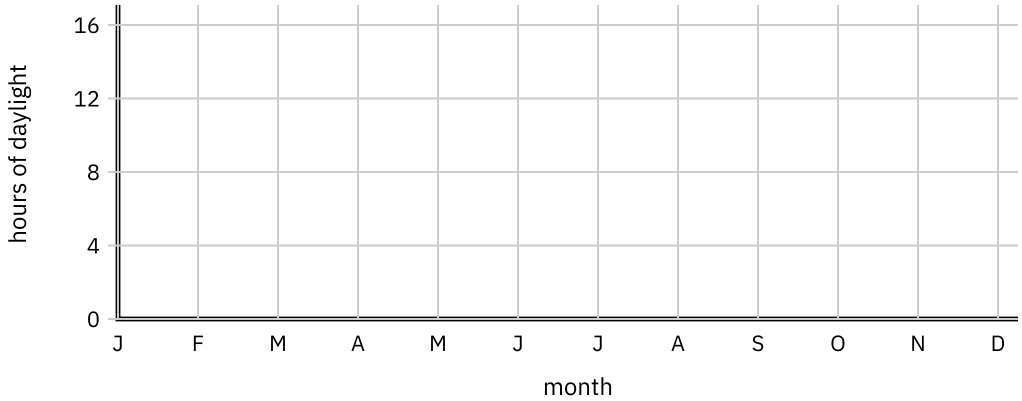


Not to scale. The axis always points the same way in space.

1 In which position is it **summer** in the Northern Hemisphere? _____ **Winter**? _____ **Spring** (Earth moves counterclockwise from winter)? _____ **Fall**? _____

Plot the daylight (about 40° N, like Denver or Philadelphia)

Hours of daylight each month: Jan 9.6 · Feb 10.6 · Mar 11.9 · Apr 13.3 · May 14.5 · Jun 15.0 · Jul 14.6 · Aug 13.5 · Sep 12.2 · Oct 10.8 · Nov 9.8 · Dec 9.3



2 Which month has the most daylight? _____ The least? _____ How many more hours is the longest day than the shortest? _____

3 It is July in Texas (hot summer). What season is it in Argentina? _____ Why? _____

Eclipse Detective ★★ NAVIGATOR

Solar eclipse



The Moon passes between the Sun and Earth. Its shadow falls on Earth.

Lunar eclipse



Earth passes between the Sun and the Moon. Earth's shadow falls on the Moon.

Safety first! Never look at the Sun, even during an eclipse, without special eclipse glasses. A lunar eclipse is safe to watch with your eyes.

1. The dark center of a shadow is the **umbra**; the lighter outer part is the **penumbra**. Label them on one of the diagrams with arrows.

2. Which Moon phase happens during a **solar** eclipse? _____ During a **lunar** eclipse? _____

3. If the Moon passes between the Sun and Earth every month at New Moon, why don't we have a solar eclipse every month? (Hint: the Moon's orbit is tilted about 5° compared with Earth's orbit.)

4. **Try it!** In a dim room, use a flashlight (Sun), a ball (Earth) and a smaller ball (Moon). Make each kind of eclipse and draw what you see. (Draw what you see on the back of this page.)

Sun & Moon Word Search ★ EXPLORER

Find the 14 words. They can go forward, backward, down or diagonally.

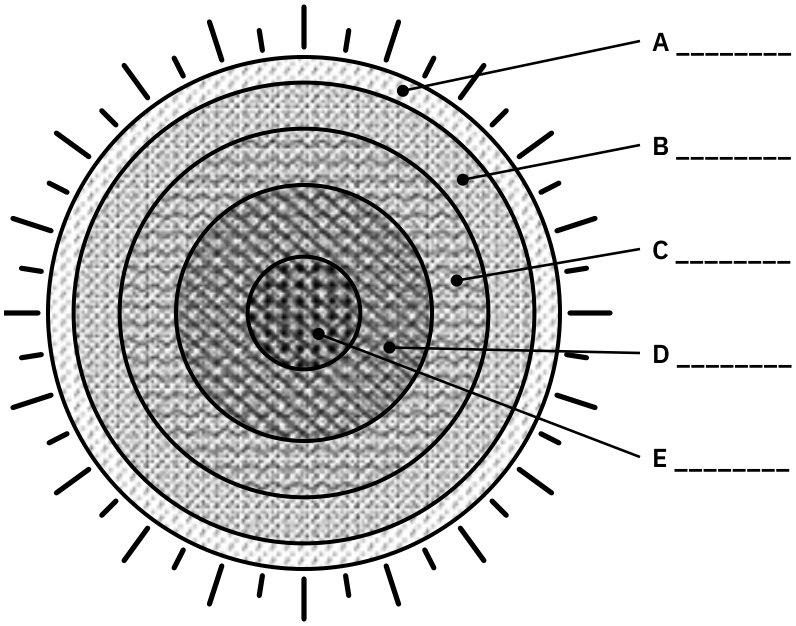
R D U I J R E S P I L C E O Z
C O Y H S Q N I T I B R O J O
R F N O S A E S C B E A T H Q
E S J E D R H U K T I L T E C
S B Z P H A S E C V S I X A H
C H O Q I Q Q F L U J Z S F I
E H P O Z S U O B B I G E U G
N P A R A N U L D B M D X Q N
T G O J E Y X Q A Z O A C G X
O T T F A L J X F Y O Z I W H
Z Z M I R O J D F K N U O L Z
X Q T R T U W B J T Q D Q T E
X F O O H F A D Q X A S J B C
E D I T X P H D H H N U M X T
K J J X M N N C S M O S O D M

- ☐ AXIS
- ☐ CRESCENT
- ☐ EARTH
- ☐ ECLIPSE
- ☐ GIBBOUS
- ☐ LUNAR
- ☐ MOON
- ☐ ORBIT
- ☐ PHASE
- ☐ SEASON
- ☐ SHADOW
- ☐ SUN
- ☐ TIDE
- ☐ TILT

Bonus ★★: Choose three words and write a sentence about the Sun, Earth or Moon with each one.

Inside the Sun

★★ NAVIGATOR ★★★ COMMANDER



The Sun has layers. Label the diagram with the words in the bank and **color** it with warm colors, hottest in the middle.

Corona · Photosphere (surface) · Convection zone · Radiative zone · Core

Not to scale. The core is about 27 million °F; the surface is about 10,000 °F.

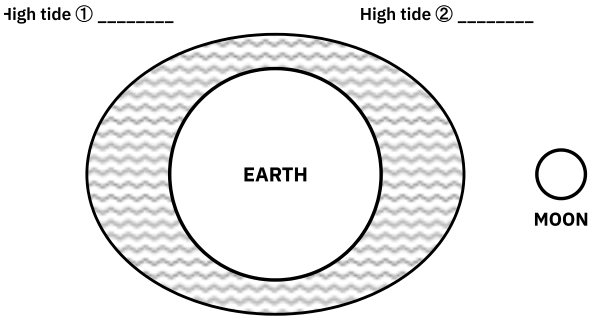
Sun math

1. How many Earths wide is the Sun? (864,000 ÷ 7,918 = _____) About _____ Earths.
2. Sunlight travels at 186,282 miles per second. The Sun is 93,000,000 miles away. How many seconds does its light take to reach us? _____ s ÷ 60 = about _____ minutes.
3. Moonlight really is sunlight bouncing off the Moon (238,855 miles away). How long does the light from the Moon take to reach us? _____ seconds
4. If the Sun disappeared right now, how long would we keep seeing it shine? _____ Explain: _____
5. **Temperature converter.** The Sun's surface is about 5,500 °C. In °F: 5,500 × 9 ÷ 5 + 32 = _____ °F. Its core is about 15,000,000 °C, which is about _____ °F.
6. The Sun has about 333,000 times the mass of Earth. If Earth weighed 1 pound, the Sun would weigh _____ pounds.

Fun fact: the Sun holds 99.8% of all the mass in the solar system.

Tides: Ocean Clock

★★ NAVIGATOR ★★★ COMMANDER



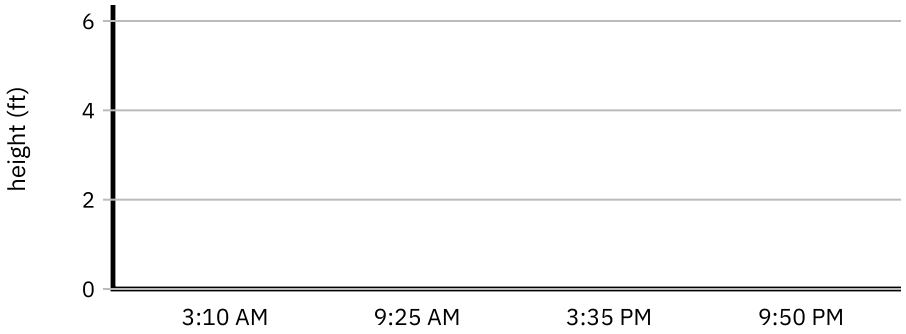
Not to scale. The Moon pulls the ocean toward it, and also a bulge on the far side.

The Moon's gravity pulls on Earth's oceans. Water bulges toward the Moon and on the opposite side, so most beaches have **two high tides** and **two low tides** each day. The Sun adds a smaller pull: when Sun, Earth and Moon line up (New or Full Moon), tides are strongest (**spring tides**); at the quarter moons they are weakest (**neap tides**).

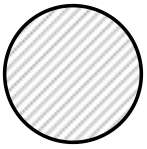
Read the tide table (sample beach)

Time	3:10 AM	9:25 AM	3:35 PM	9:50 PM
Tide	High	Low	High	Low
Height (ft)	5.8	0.6	5.5	0.9

1. How long is it from the first high tide to the second one? _____ (3:10 AM to 3:35 PM)
2. What is the tidal range (highest minus lowest)? _____ ft
3. Tides arrive about 50 minutes later each day. When will the first high tide be tomorrow? _____
4. Draw the four tide heights as bars below.



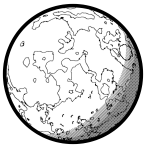
Strong or weak tides?



New Moon
spring / neap: _____



First Quarter
spring / neap: _____



Full Moon
spring / neap: _____



Last Quarter
spring / neap: _____

Shadow Clock Experiment ★★ NAVIGATOR

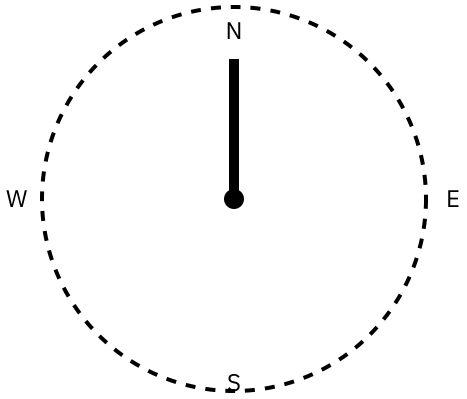
SAFETY Do this with an adult. **Never look directly at the Sun** : look only at the shadow on the ground.

You need

- A sunny day and a flat spot outside
- A straight stick or pencil in a lump of clay
- Chalk or tape
- A ruler and a watch

Do it

1. Stand the stick upright and mark its base.
2. Every hour, mark the tip of its shadow and measure its length.
3. Note the time next to each mark.



Draw each shadow here, with its time.

Time	9:00	10:00	11:00	12:00	1:00	2:00	3:00
Shadow length (in)							
Direction							

1. When was the shadow shortest? _____ The Sun was highest then, around **solar noon**.

2. Which way did the shadow move: from west to east, or east to west? _____ Why?

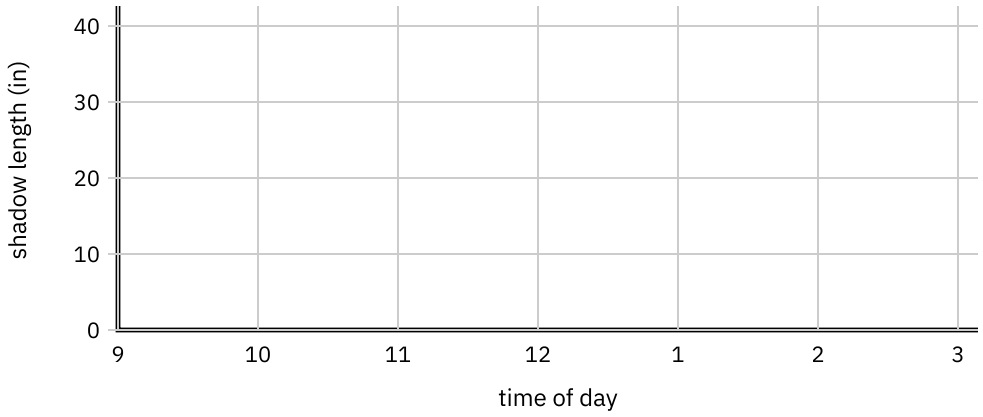
_____

_____

3. Make a graph of shadow length against time on a separate sheet. What shape do you get?

_____

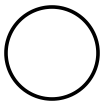
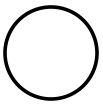
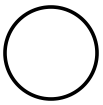
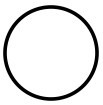
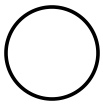
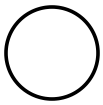
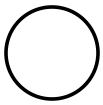
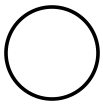
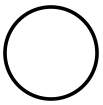
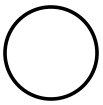
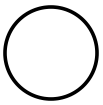
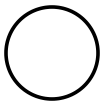
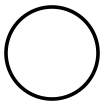
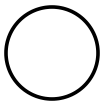
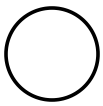
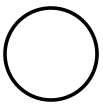
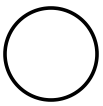
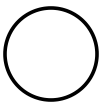
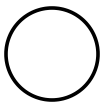
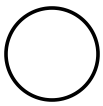
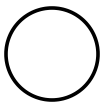
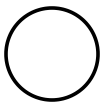
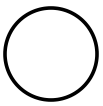
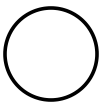
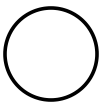
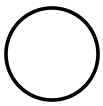
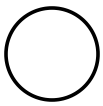
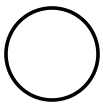
Graph your results



Safety: never look directly at the Sun.

My Moon Journal ★ EXPLORER ★★ NAVIGATOR

For 4 weeks, look at the Moon each evening (when you can see it). Shade the part you **cannot** see and write the date. Cloudy? Write “clouds”.

Day 1  Date: _____	**Day 2**  Date: _____	**Day 3**  Date: _____	**Day 4**  Date: _____	**Day 5**  Date: _____	**Day 6**  Date: _____	**Day 7**  Date: _____
Day 8  Date: _____	**Day 9**  Date: _____	**Day 10**  Date: _____	**Day 11**  Date: _____	**Day 12**  Date: _____	**Day 13**  Date: _____	**Day 14**  Date: _____
Day 15  Date: _____	**Day 16**  Date: _____	**Day 17**  Date: _____	**Day 18**  Date: _____	**Day 19**  Date: _____	**Day 20**  Date: _____	**Day 21**  Date: _____
Day 22  Date: _____	**Day 23**  Date: _____	**Day 24**  Date: _____	**Day 25**  Date: _____	**Day 26**  Date: _____	**Day 27**  Date: _____	**Day 28**  Date: _____

1. What pattern did you notice?

_____

2. Which phase did you see on day 1? _____ On day 15? _____

Logic Lab: Sudoku & the Great Coincidence

★ EXPLORER ★★★ COMMANDER

A · Sky sudoku ★

Each row, column and 2×2 box must have **Su** (Sun), **Mo** (Moon), **Ea** (Earth) and **St** (Star) once.

St	**Mo**		**Ea**
	Ea		
			Su
Ea		**Mo**	

B · The Great Coincidence ★★★

The Sun and the Moon look about the same size in our sky. Why? Let's compare numbers.

	Sun	Moon	Sun ÷ Moon
Width (mi)	864,000	2,159	_____
Distance from Earth (mi)	93,000,000	238,855	_____

1. The Sun is about _____ times wider than the Moon, and also about _____ times farther away.

2. Because the two numbers are almost equal, the Moon can just cover the Sun in a total solar eclipse. Do you think this is luck? Discuss.

_____

_____

C · Odd one out ★★

1. Sun · Moon · Earth · lamp (which one makes its own light?) → _____ because _____

2. spring · summer · tide · winter → _____ because _____

3. umbra · penumbra · phase · shadow → _____ because _____

3. Fun fact: the Moon moves away from Earth about 1.5 inches every year. In a billion years total eclipses will stop. Why? _____

Create · The Moon Legend ★ EXPLORER

Long ago, people made up stories to explain why the Moon changes shape. Write your own legend and illustrate it!

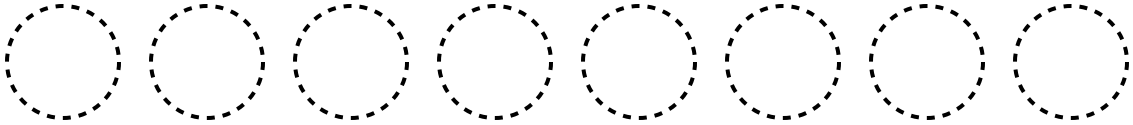
ILLUSTRATION

Title: _____

Write a Moon poem or song

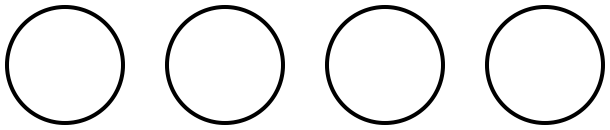
Design a Moon-phase mobile

Draw each phase on a paper circle, cut them out and hang them in order on a string.



Unit Review · Mission Check ★ EXPLORER ★★ NAVIGATOR ★★★ COMMANDER

1 **Draw** how the Moon looks at each phase (shade the dark part):



New First Quarter Full Last Quarter

2 **True or false?** Fix the false ones. a) Seasons happen because Earth is closer to the Sun in summer. T / F _____

b) A lunar eclipse happens at Full Moon. T / F _____

c) We always see the same side of the Moon. T / F _____

3 **Calculate.** It is 10:00 AM in Chicago. What time is it in Los Angeles? _____ How many degrees does Earth rotate in 5 hours? _____ °

4 **Read the table.** High tide at 4:00 AM (6.0 ft) and low tide at 10:15 AM (0.4 ft). The tidal range is _____ ft. About what time will the next high tide be? _____

5 **Explain.** Why is the Sun hot but the Moon only reflects light?

_____

_____

6 **Compare.** Write one way a solar eclipse and a lunar eclipse are the same and one way they are different.

_____

_____

8 **Match** each word to its meaning (write the letter). rotate ____ · revolve ____ · umbra ____ · tide ____

A. travel around another body · B. spin on an axis · C. the dark center of a shadow · D. the rise and fall of the ocean

7 **Predict.** How would seasons change if Earth's axis were not tilted at all?

_____

_____

Mission Log ★ EXPLORER

Check the boxes when you can do each one. Color a star for each section you enjoyed.

☐ I can name the eight Moon phases in order.

☐ I can explain why we have day and night.

☐ I can explain why we have seasons.

☐ I can tell a solar eclipse from a lunar eclipse.

☐ I can explain what causes tides.

☐ I can work out time differences between time zones.

☐ I can measure and graph shadow lengths.

☐ I can compare the Sun, Earth and Moon using numbers.

My favorite activity was

Something new I learned

A question I still have about space

UNIT 1
EARTH, MOON & SUN
★ ★ ★
MISSION COMPLETE

Signed: _____

Date: _____

Astraviator

SPACE WORKBOOK

UNIT 2 OF 8

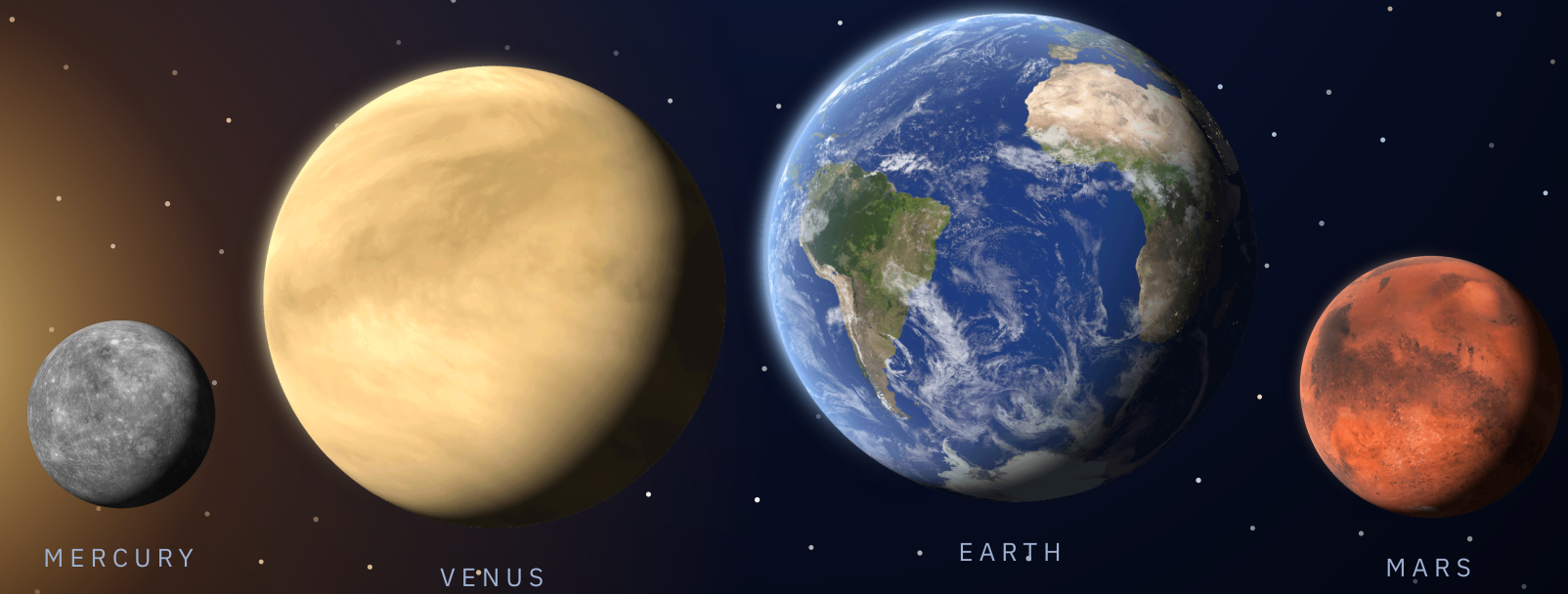
Rocky Planets

Mercury · Venus · Earth · Mars

Puzzles · Math labs · Coloring · Experiments · Games

Ages 9–14 · three levels · answer key included

★ Explorer · ★★ Navigator · ★★★ Commander



astraviator.com | Solar System Explorer Simulator

Print at 100% · black & white pages, color cover · Imagery rendered from NASA / USGS data and Solar System Scope textures (CC BY 4.0)

Mission Briefing ★ EXPLORER

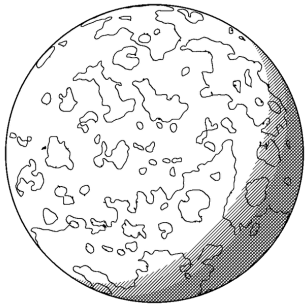
Four worlds, one family. **Mercury, Venus, Earth** and **Mars** are the **rocky planets**: they are made mostly of rock and metal, they have solid surfaces, and they circle closest to the Sun.

Mercury is the smallest planet and the fastest, racing around the Sun in just 88 days. With almost no **atmosphere** to hold in heat, its surface swings from about 800 °F in the day to −290 °F at night.

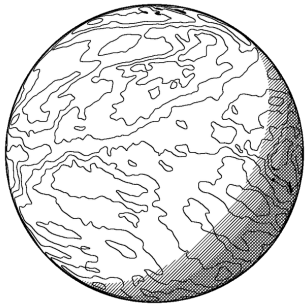
Venus is wrapped in thick clouds and a heavy atmosphere of carbon dioxide. This **greenhouse effect** traps heat and makes Venus the hottest planet, hot enough to melt lead! It also spins backward, so the Sun rises in the west.

Earth is our home: the only planet we know with liquid water on its surface, and with life. Its **magnetic field** and atmosphere protect us.

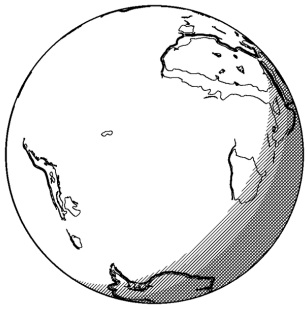
Mars is a cold, dusty desert. Rusty iron dust gives it the nickname *the Red Planet*. It has two tiny moons, polar ice caps, and signs of ancient rivers and lakes. Robot **rovers** explore it today.



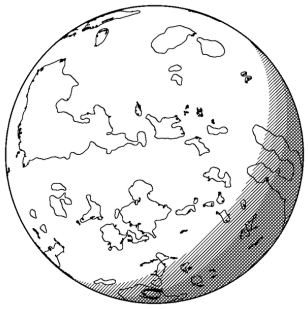
Mercury



Venus



Earth



Mars

Color the planets while you read. Use what the text tells you!

Planet snapshot

	Mercury	Venus	Earth	Mars
Width	3,032 mi 4,879 km	7,521 mi 12,104 km	7,918 mi 12,742 km	4,212 mi 6,779 km
One year (Earth days)	88	225	365	687
Gravity (Earth = 1)	0.38	0.90	1.00	0.38
Moons	0	0	1	2
Temperature	−290 to 800 °F	about 870 °F	about 59 °F (average)	about −81 °F (average)

Vocabulary to spot: rocky planet · atmosphere · greenhouse effect · magnetic field · rover · crater · gravity · orbit · crust · mantle · core

Planet Word Search ★ EXPLORER

Find the 14 hidden words. They run **across, down** and **diagonally** (down-right and up-right).

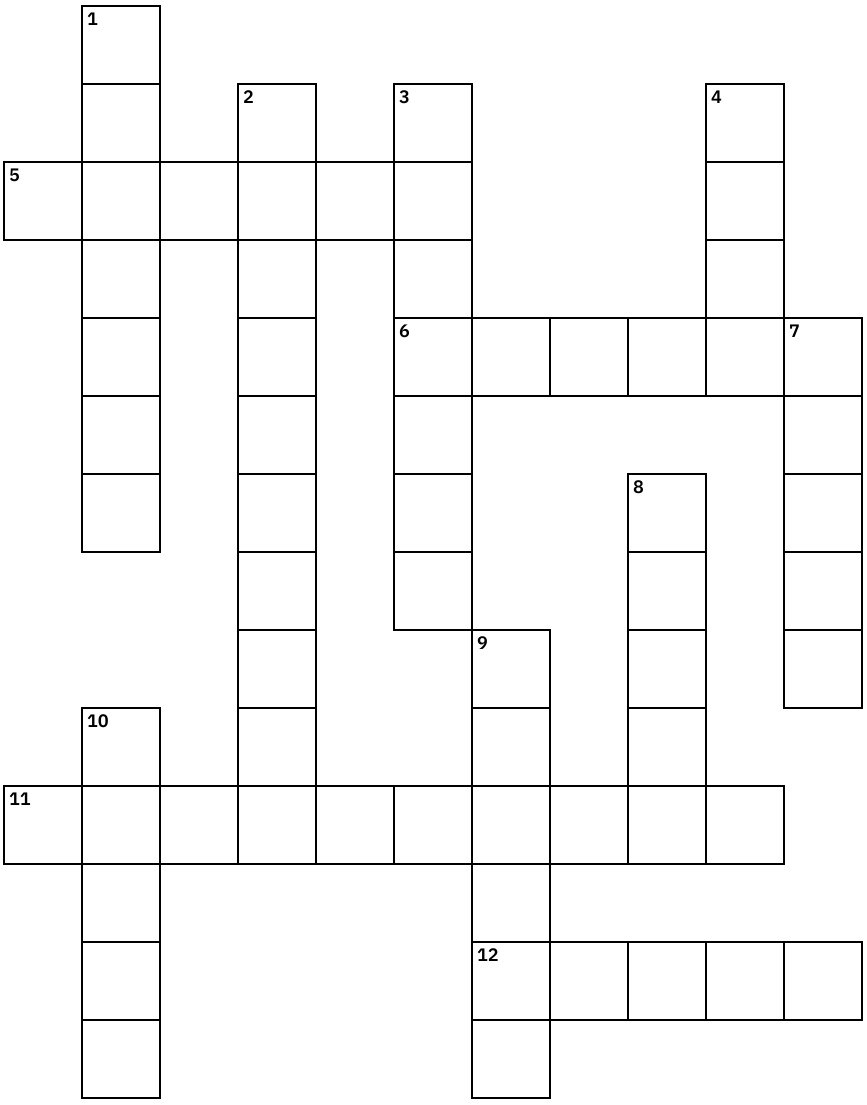
V D V J H D B A R O V E R P
Y L F E G P C O R E P E Y N
O U A T M O S P H E R E Q Y
K P K U D F R F C V E E A G
M A N T L E X O C R E W V W
N W I H M B B M I K A N F T
E Z L O E C A R B C G T U G
A A T I R R H V Q R R Y E S
R O V R C U H O Z L A A M R
T M Q O U S V L Z B V D S C
H M W N R T C C Q N I J K R
C A N X Y W O A X J T H I Q
R R R V J D S N R E Y H K G
U S Z K Y X U O U O R B I T

- ☐ ATMOSPHERE
- ☐ CORE
- ☐ CRATER
- ☐ CRUST
- ☐ EARTH
- ☐ GRAVITY
- ☐ IRON
- ☐ MANTLE
- ☐ MARS
- ☐ MERCURY
- ☐ ORBIT
- ☐ ROVER
- ☐ VENUS
- ☐ VOLCANO

Bonus ★★: Pick any three words from the list and write a sentence for each one.

Rocky Planet Crossword ★★ NAVIGATOR

Use the clues to fill in the grid. Every answer is a word from this unit.



ACROSS →

5. The thick layer of hot rock between the crust and the core

6. A bowl-shaped hole made when something smashes into a planet

11. The ___ effect traps heat in the atmosphere of Venus

12. The curved path a planet follows around the Sun

DOWN ↓

1. The force that pulls objects toward the center of a planet

2. The blanket of gases around a planet

3. The smallest planet, and the closest to the Sun

4. The hot, metal center of a planet

7. A robot vehicle that drives across another world

8. The hottest planet; its day is longer than its year

9. The larger of the two moons of Mars

10. The thin, rocky outer layer of a planet

Scrambled & Missing Words ★ EXPLORER

A · Unscramble the words

1. CRMUYRE	_____	The planet closest to the Sun
2. UVNSE	_____	The hottest planet
3. MRSA	_____	The Red Planet
4. ACERTR	_____	A bowl-shaped hole made by an impact
5. ERRVO	_____	A robot that drives on another world
6. OTBIR	_____	The path of a planet around the Sun
7. NMTELA	_____	The thick layer of rock under the crust
8. IYVAGTR	_____	The force that pulls things down

B · Fill in the blanks

Word bank: **Venus · atmosphere · greenhouse · Red · rover · crater** (use each word once)

The rocky planets are Mercury, _____, Earth and Mars. Venus is the hottest of them because its thick _____ traps heat in a _____ effect. Mars is called the _____ Planet because of the rusty iron dust on its surface. A robot explorer that drives across Mars is called a _____. A bowl-shaped hole made by an impact is a _____.

C · Spot the mistake ★★

Each sentence has ONE wrong fact. Cross it out and write the right one.

1. Mercury is the biggest of the rocky planets.

_____

2. Venus is the coldest planet because it is covered in ice.

_____

3. Mars has no moons at all.

_____

4. A year on Earth lasts 88 days.

_____

D · Which planet am I?

1. I have two tiny moons and a red-orange color. **I am** _____
2. I am the smallest planet. I zip around the Sun in 88 days. **I am** _____
3. I spin backward, and my day is longer than my year. **I am** _____
4. I am the only world known to have life. **I am** _____

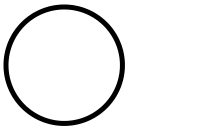
Math Lab 1 · Scale Models ★★ NAVIGATOR

Scientists use **scale models** to compare huge things. In our model, **1 inch = 5,000 miles**. Divide each planet's width by 5,000 to find its model size. Round to one decimal place.

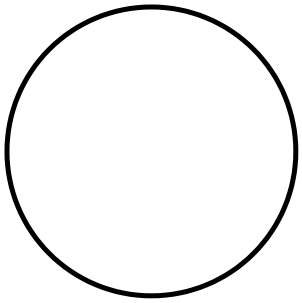
Planet	Real width (mi)	÷ 5,000 = model width (in)
Mercury	3,032	_____
Venus	7,521	_____
Earth	7,918	_____
Mars	4,212	_____

Draw to scale

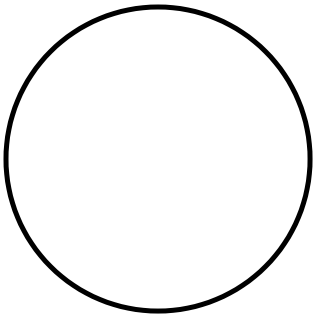
These circles are the planets at true model size (print at 100%). Which is which? Label them, then color.



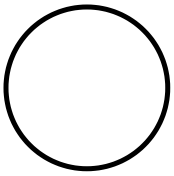
Planet: _____



Planet: _____



Planet: _____



Planet: _____

1. Which planet is the largest? _____ The smallest? _____

2. How much wider is Earth than Mercury? Show your work. _____ _____ miles

3. About how many Mars-widths fit across Earth? _____ (Earth width ÷ Mars width, rounded to the nearest whole number)

★★★ Earth is about 24,901 miles around. If you could drive around it at 60 miles per hour without stopping, how many hours would it take? _____ hours. How many days? _____

Math Lab 2 · Weight & Jump ★★ NAVIGATOR

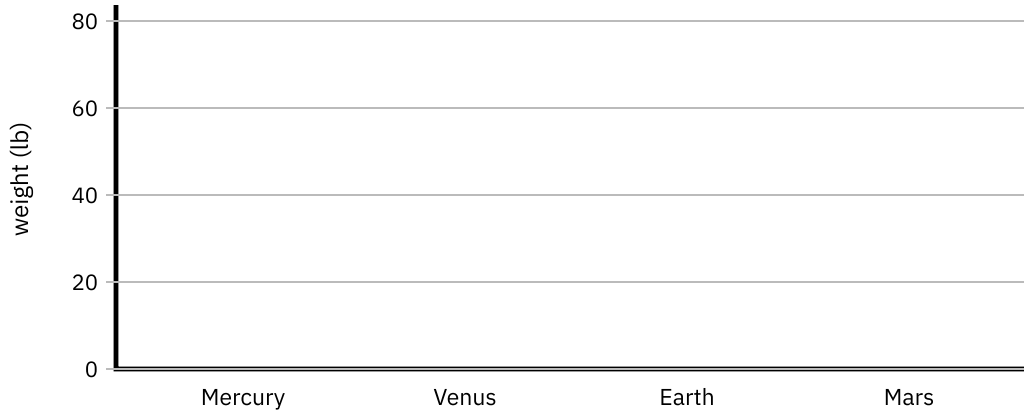
Gravity pulls on you. On a world with weaker gravity you would weigh less and jump higher! To find your weight on another planet: **weight on Earth × gravity**. To find your jump height: **jump on Earth ÷ gravity**.

Our astronaut weighs **80 lb** on Earth and jumps **2 ft** high.

Planet	Gravity (Earth = 1)	Weight (lb)	Jump (ft)
Mercury	0.38	_____	_____
Venus	0.90	_____	_____
Earth	1.00	_____	_____
Mars	0.38	_____	_____

Graph it

Draw a bar for each planet's weight.



1. A rover weighs 2,200 lb on Earth. How much does it weigh on Mars? _____ lb

2. An astronaut in a space suit weighs 300 lb on Earth. On Mercury she would weigh _____ lb.

3. Which two planets give the same weight? _____ and _____

4. ★★★ You can jump 3 ft high on Earth. How high could you jump on Mars? Show your work: _____ ft

5. Write one more question about weight or jumping on another world, then trade with a friend to solve it.

_____

_____

Math Lab 3 · Days, Years & Ages ★★★ COMMANDER

A planet's **year** is the time it takes to go around the Sun once. Mercury is close and fast; Mars is far and slow. Use the year lengths (in Earth days) to solve the puzzles. Round to one decimal.

	Mercury	Venus	Earth	Mars
Year (Earth days)	88	225	365	687

1. How many Mercury years fit in one Earth year? (365 ÷ 88) _____

2. **How old would a 12-year-old be on each planet?** Age on a planet = (12 × 365) ÷ the planet's year.

Mercury	Venus	Earth	Mars
_____	_____	12	_____
Now try your own age: _____ years → Mercury _____ Venus _____ Mars _____			

3. On Venus, one day (243 Earth days) is longer than one year (225 Earth days). How many days longer? _____

4. On Mercury, sunrise to sunrise takes 176 Earth days. Compare that with its 88-day year. A Mercury day is _____ times as long as its year.

5. **Road trip to Mars!** At its closest, Mars is about 33,900,000 miles away. A spacecraft flies in a straight line at 25,000 mph. Travel time in hours = distance ÷ speed. _____ hours = _____ days (divide by 24)

6. One Mars year is 687 Earth days. How many Earth years is that? _____ (687 ÷ 365)

7. Which planet has the **shortest** year? _____ The **longest**? _____ Why do you think the farther planets take longer?

Real spacecraft take about 7 months, because they follow curved paths and Mars is usually much farther than its closest approach.

Hot, Cold & Inside Earth ★★★ COMMANDER

A · Temperature converter

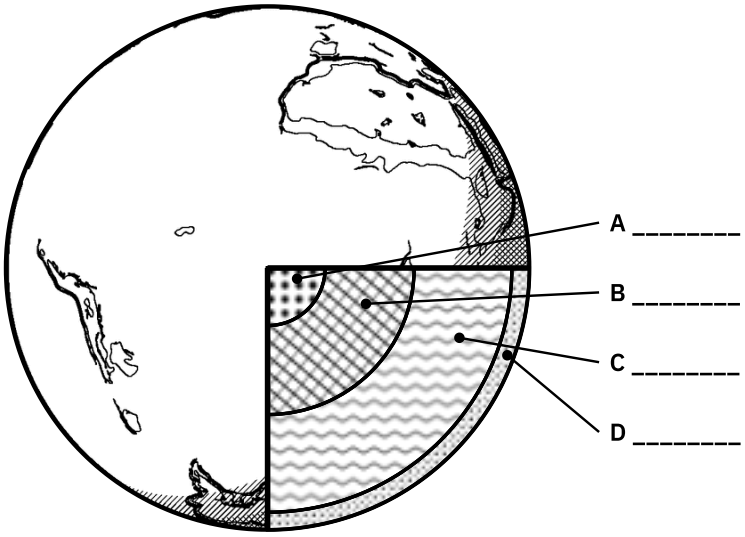
Scientists often use degrees Celsius (°C). Convert to Fahrenheit: **°F = °C × 9 ÷ 5 + 32**.

Place	°C	°F
Mercury, daytime	430	_____
Mercury, nighttime	-180	_____
Venus, surface	465	_____
Earth, average	15	_____
Mars, average	-63	_____

1. How big is Mercury's temperature swing between day and night? _____ °F

2. How much hotter is the surface of Venus than Earth's average? _____ °F

B · Inside a rocky planet



Rocky planets have layers. Label the diagram with the words below and **color** each layer.

Crust · Mantle · Outer core (liquid metal) · Inner core (solid metal)

★★★ Earth's layers are roughly: crust 20 mi + mantle 1,800 mi + outer core 1,400 mi + inner core 760 mi. Add them: _____ mi. Earth's radius is 3,959 mi. How close is your total? _____ mi off.

Color by Number · Mars ★ EXPLORER

Solve each problem. The answer is the number of that color. Then color every square with its number to reveal the picture.

Black (space)
9 − 8 = _____

Light orange (the surface of Mars)
12 ÷ 6 = _____

Brown (dark regions)
5 − 2 = _____

White (the polar ice cap)
2 × 2 = _____

Gray (craters)
20 ÷ 4 = _____

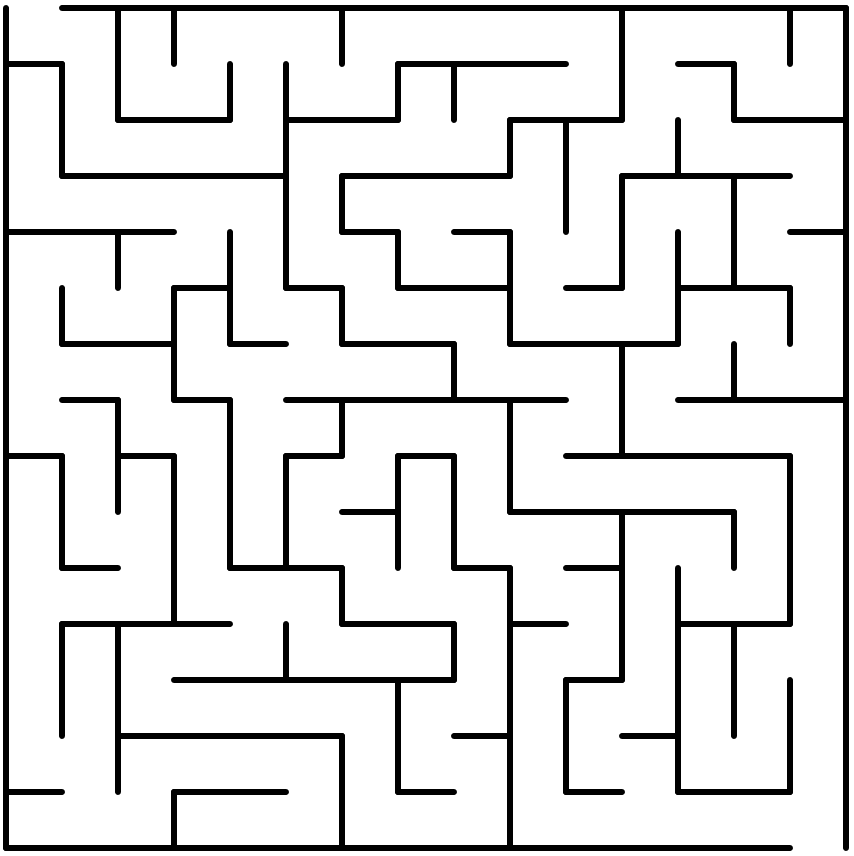
Yellow (stars)
3 + 3 = _____

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	4	4	1	1	1	1	1	1	1	1
1	1	1	1	1	1	4	4	4	4	4	4	4	4	6	1	1	1	1	1
1	1	1	1	4	4	4	4	4	4	4	4	4	4	4	4	1	1	1	1
1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1
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1	1	1	1	1	1	6	1	1	1	1	6	1	1	1	1	1	1	1	1

Rover Maze & Planet Sudoku ★ EXPLORER ★★ NAVIGATOR

A · Guide the rover to the ice

The rover starts at the top-left. Find the path to the ice at the bottom-right.



B · Planet sudoku

Fill the grid so that each row, each column and each 2×2 box has **all four planets once**: **Me** = Mercury, **Ve** = Venus, **Ea** = Earth, **Ma** = Mars.

	Ve	**Ma**	**Ea**
	Ea		**Ve**
	Ma		**Me**
Ve			

Secret Mission Messages ★★ NAVIGATOR ★★★ COMMANDER

A · Decode it ★★

Mission Control sent a coded message! Each letter was moved **5 places forward** in the alphabet (A → F, B → G, …). Use the strips to decode it.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E

top row = real letter · bottom row = coded letter

B F Y J W T S H J K Q T B J I T S R F W X

_____ _____ _____ _____

B · Crack it ★★★

This one has a **secret shift** you must discover. Hint: the most common letter in English is **E**. Which coded letter shows up most often? Try shifts until the words make sense!

A O L Y V C L Y M V B U K Y V J R Z

_____ _____ _____ _____

M Y V T H U H U J P L U A Y P C L Y

_____ _____ _____ _____

The shift was _____ places. (Write the message on the lines below.)

C · Your turn ★★

Write a secret message about space (shift **3**: A → D, B → E…) for a friend to decode.

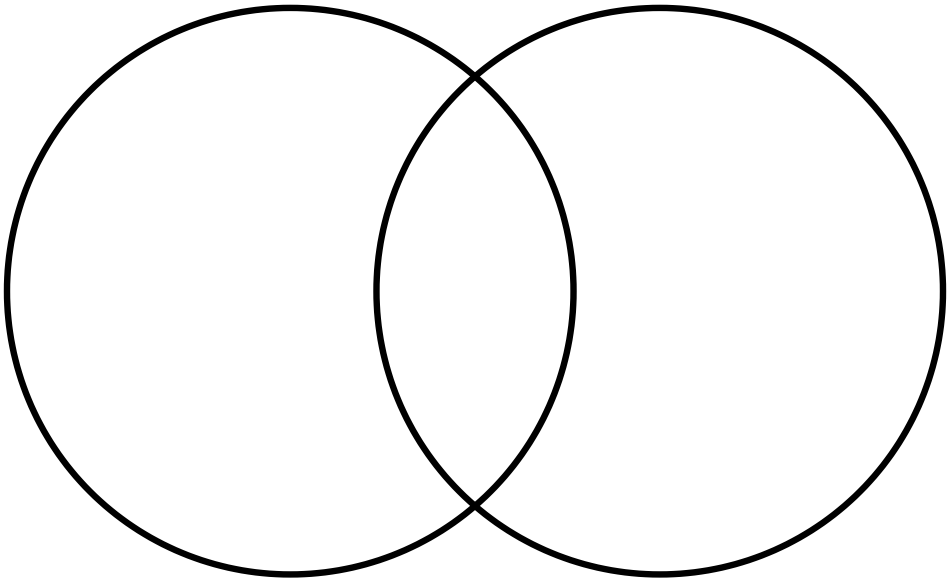
Message: _____

Coded: _____

Compare & Contrast · Earth vs Mars ★★ NAVIGATOR

Cut out the fact strips, or write each letter in the right place. Put a fact in **Earth**, **Mars**, or the overlap (**both**).

EARTH ONLY **BOTH** **MARS ONLY**



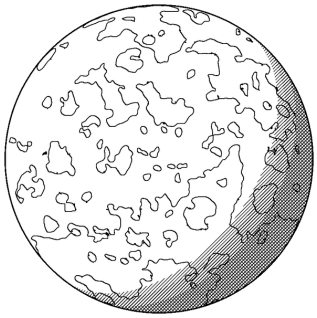
(A) Has polar ice caps	(B) Is a rocky planet	(C) Has seasons
(D) Has volcanoes (active or extinct)	(E) Has liquid water on its surface	(F) Has clouds in its atmosphere
(G) Has one large moon	(H) A day lasts about 24 hours	(I) Average temperature is far below freezing
(J) Only robots have visited so far	(K) Atmosphere is mostly nitrogen and oxygen	(L) Has two tiny moons

Which fact surprised you most? _____

Rocky Planet Trading Cards ★ EXPLORER cut-out & color

Cut along the dashed lines. Color the planets. Play with a friend: pick a number, compare cards, and the higher (or lower!) number wins the round.

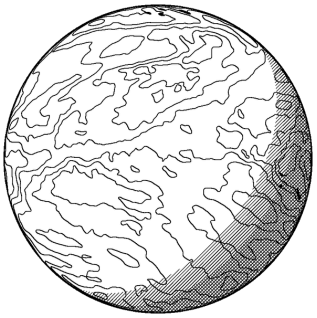
MERCURY



Width	**3,032 mi**
Day	**176 Earth days**
Year	**88 days**
Gravity	**0.38 g**
Moons	**0**
Temp	**−290 to 800 °F**

★ Smallest planet

VENUS



Width	**7,521 mi**
Day	**243 Earth days**
Year	**225 days**
Gravity	**0.90 g**
Moons	**0**
Temp	**about 870 °F**

★ Spins backward

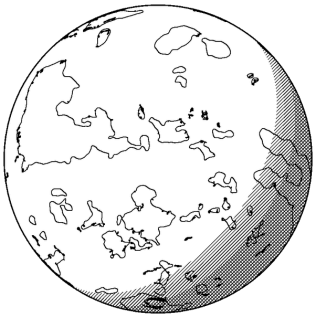
EARTH



Width	**7,918 mi**
Day	**24 hours**
Year	**365 days**
Gravity	**1.00 g**
Moons	**1**
Temp	**about 59 °F**

★ Home of life

MARS



Width	**4,212 mi**
Day	**24 h 37 min**
Year	**687 days**
Gravity	**0.38 g**
Moons	**2**
Temp	**about −81 °F**

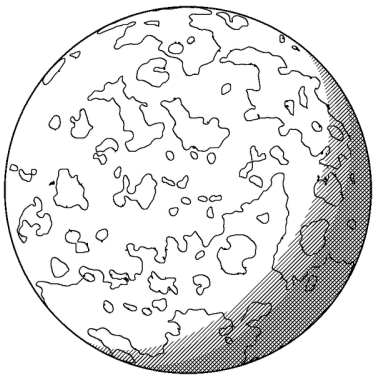
★ The Red Planet

Crater Lab · Hands-On Experiment ★★ NAVIGATOR

SAFETY Do this with an adult. Drop the balls gently, keep your face back from the flour, and pick up any that roll away.

You need

- A shallow baking pan or box lid
- Flour (about 1 inch deep) and cocoa powder to dust on top
- 2 balls of different sizes (marble and golf ball)
- A ruler and newspaper under the pan



Mercury is covered with craters like the ones you will make!

Do it

1. Smooth the flour and sprinkle cocoa on top.
2. Drop the small ball from **1 ft**. Remove it. Measure the crater's **width** across.
3. Repeat from **2 ft** and **3 ft**. Smooth the surface between drops.
4. Repeat with the large ball.

Predict: What will happen to the crater when you drop the ball from higher up?

_____

Ball size	Height	Crater width (in)	Rays / splash? (draw or describe)
small	1 ft	_____	
small	2 ft	_____	
small	3 ft	_____	
large	1 ft	_____	
large	2 ft	_____	
large	3 ft	_____	

1. Did higher drops make bigger craters? _____ Did bigger balls? _____

2. Why do you think the Moon and Mercury have so many craters, while Earth has few? (Hint: wind, water and plants change Earth's surface.)

_____

_____

Safety: do this on a floor you can sweep, and wash hands afterward.

Create · Postcard from Mars ★ EXPLORER

Imagine you are an astronaut who has just landed on Mars. Draw the view on the front. Write your message on the back.

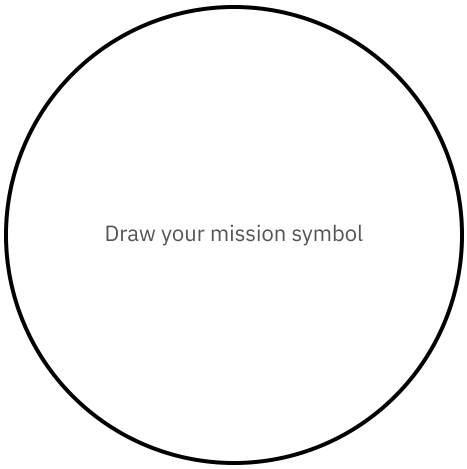
FRONT · draw what you see on Mars

STAMP

Dear _____,

From _____

Design your mission patch



Real crews design a patch for every mission. Include:

- A planet or rocket
- A short mission name
- The names of your crew

Mission name: _____

Unit Review · Mission Check

★ EXPLORER ★★ NAVIGATOR ★★★ COMMANDER

1. **Match** each planet to its clue (write the letter).
   Mercury ____ Venus ____ Earth ____ Mars ____
   A. Has liquid water and life · B. Smallest planet · C. Has two tiny moons · D. Spins backward

2. **Put in order** from **closest to the Sun** to farthest: _____ → _____ → _____ → _____

3. **True or false?** Fix each false statement.
   a. Venus is hotter than Mercury. T / F because _____
   b. Mars has more moons than Earth. T / F because _____
   c. A crater is made by a volcano only. T / F because _____
   d. Gravity on Mars is stronger than on Earth. T / F because _____

4. **Odd one out.** Circle it and explain: Mercury · Venus · Jupiter · Mars. _____

5. **Calculate.** A 100 lb student visits Mars (gravity 0.38). Weight on Mars: _____ lb

6. **Explain.** Venus is farther from the Sun than Mercury, yet it is hotter. Why?

7. **Label.** Name the three main layers of a rocky planet, from the outside in: _____ , _____ , _____

8. **Decide.** You can send one rover to one rocky planet. Which would you choose and why? Use at least two facts.

Mission Log ★ EXPLORER

Check the boxes when you can do each one. Color a star for each section you enjoyed.

☐ I can name the four rocky planets in order from the Sun.

☐ I can explain why Venus is the hottest planet.

☐ I can describe how a crater forms.

☐ I can use gravity to find my weight on another planet.

☐ I can convert °C to °F.

☐ I can name the layers inside a rocky planet.

☐ I can compare Earth and Mars using facts.

☐ I can solve a code using a pattern.

My favorite activity was

Something new I learned

A question I still have about space

UNIT 2
ROCKY PLANETS
★ ★ ★
MISSION COMPLETE

Signed: _____
Date: _____

Astraviator

SPACE WORKBOOK

UNIT 3 OF 8

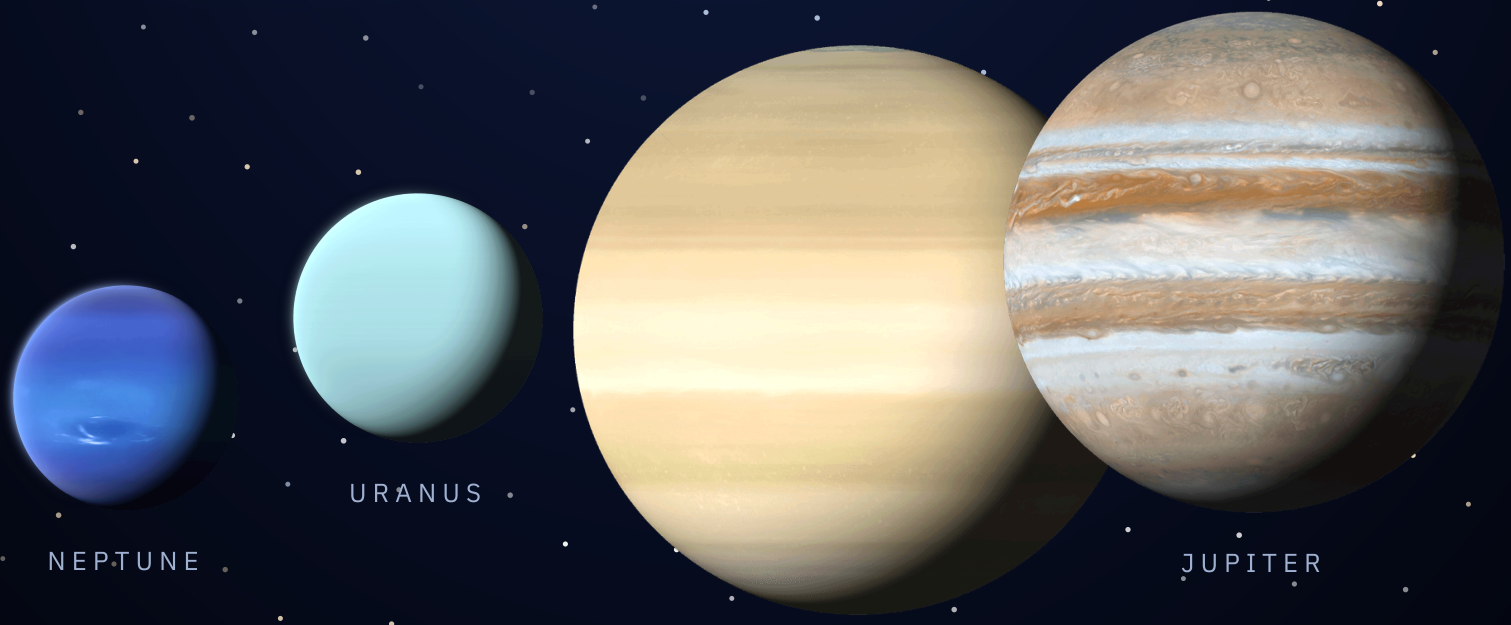
Giant Planets

Jupiter · Saturn · Uranus · Neptune

Puzzles · Math labs · Coloring · Experiments · Games

Ages 9–14 · three levels · answer key included

★ Explorer · ★★ Navigator · ★★★ Commander



astraviator.com | Solar System Explorer Simulator

Print at 100% · black & white pages, color cover · Imagery rendered from NASA / USGS data and Solar System Scope textures (CC BY 4.0)

Mission Briefing: Meet the Giants ★ EXPLORER

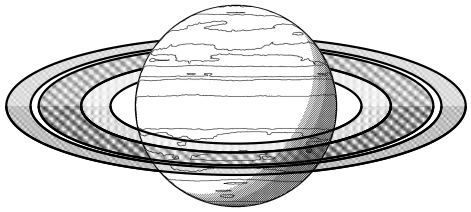
Beyond the asteroid belt live four enormous worlds. **Jupiter** and **Saturn** are **gas giants**, made mostly of hydrogen and helium. **Uranus** and **Neptune** are **ice giants**, with more water, ammonia and methane.

None of them has a solid surface to land on: you would sink through thicker and thicker clouds. All four have **rings** and dozens of moons.

Jupiter is so big that all the other planets would fit inside it. Its **Great Red Spot** is a storm as wide as Earth.

Saturn has the most spectacular rings, made of billions of pieces of ice. It is so light for its size that it would float in a giant bathtub!

Uranus spins on its side. **Neptune**, the farthest planet, has winds of up to 1,200 miles per hour, the fastest in the solar system.



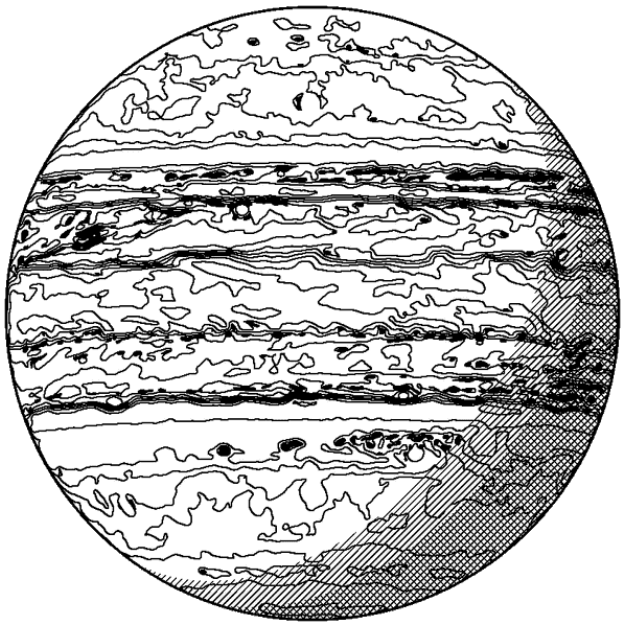
Saturn and its rings

	Jupiter	Saturn	Uranus	Neptune
Width (mi)	86,881	72,367	31,518	30,599
Distance from the Sun	484 million mi	886 million mi	1.78 billion mi	2.79 billion mi
One day	9 h 56 min	10 h 33 min	17 h 14 min	16 h 6 min
One year (Earth years)	12	29	84	165

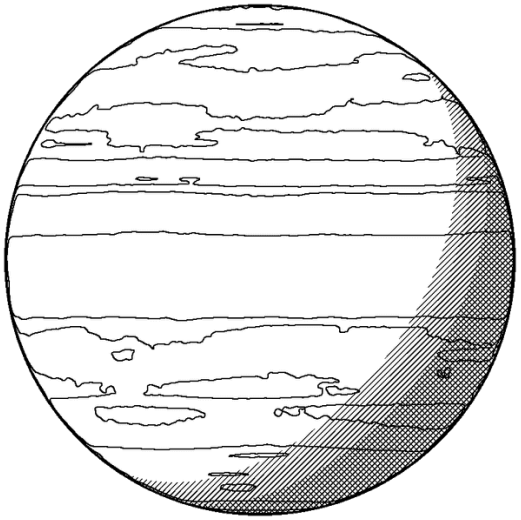
Vocabulary to spot: gas giant · ice giant · atmosphere · ring · storm · hydrogen · helium · methane · moon · probe

Draw the Giants to Scale ★ EXPLORER ★★ NAVIGATOR

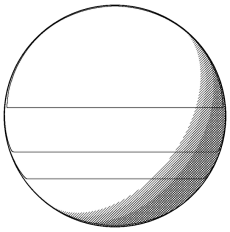
In this model **1 inch = 25,000 miles** (print at 100%). Color each planet and write its name. Earth is the tiny dot!



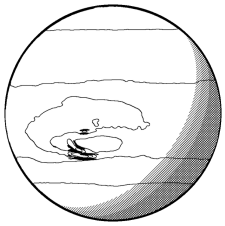
_____



_____



_____



_____



Earth

1. How many inches wide is Jupiter in this model? (86,881 ÷ 25,000 = _____) Saturn? _____

2. Measure with a ruler: how many Earth dots would fit across Jupiter? _____ (Use the table: 86,881 ÷ 7,918.)

3. Which two giants are almost the same size? _____ and _____

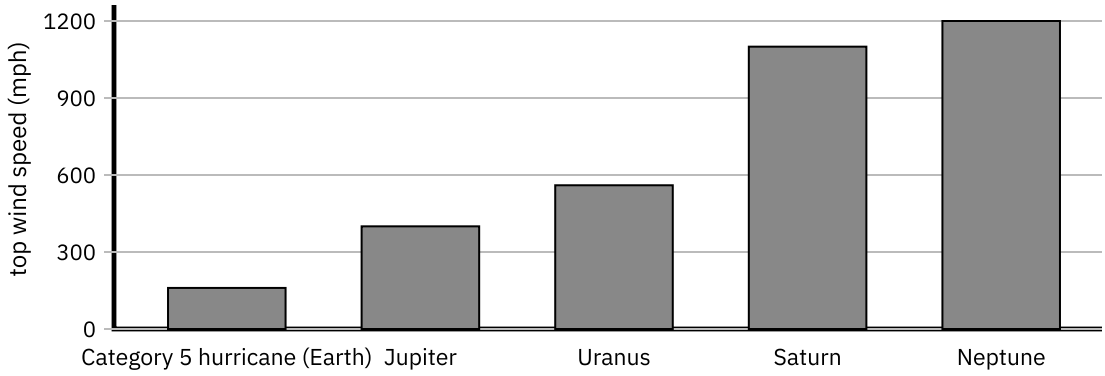
Math Lab 1 · Giant Numbers ★★ NAVIGATOR ★★★ COMMANDER

Use a calculator. Round to one decimal place, or to the nearest minute for times.

Planet	Width (mi)	Earths wide (÷ 7,918)	Distance from Sun (mi)	Sunlight takes… (min) (÷ 186,282 ÷ 60)
Jupiter	86,881	_____	484,000,000	_____
Saturn	72,367	_____	886,000,000	_____
Uranus	31,518	_____	1,784,000,000	_____
Neptune	30,599	_____	2,793,000,000	_____

1 Sunlight reaches Earth in about 8 minutes. How many times longer does it take to reach Neptune? _____ (Neptune's minutes ÷ 8)

Wind speed record



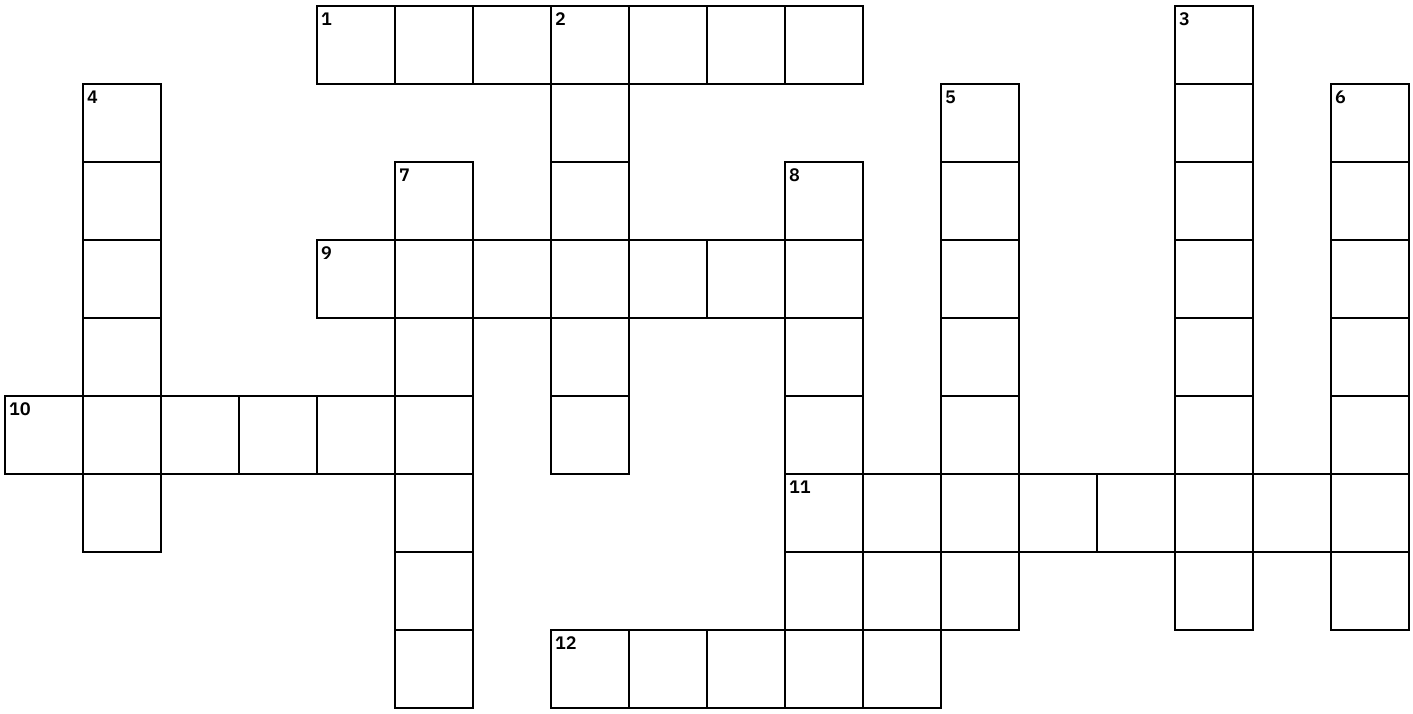
2 Which planet has the fastest wind? _____ How much faster than a Category 5 hurricane? (1,200 ÷ 160 = _____ times)

3 Saturn's wind is 1,100 mph. How many miles does it blow in 3 hours? _____ miles

★★★ Jupiter has about 318 times the mass of Earth. If Earth were a 1-pound ball, Jupiter would weigh _____ pounds. And Saturn (95 Earths) would weigh _____ pounds.

Giant Planets Crossword ★★ NAVIGATOR

Every answer is a word from this unit.



ACROSS →

1. A gas that makes Uranus and Neptune look blue

9. He discovered four moons around Jupiter in 1610

10. The giant planet that rolls around the Sun tilted on its side

11. Jupiter's moon, the largest moon in the solar system

12. The Great Red Spot is a giant _____ on Jupiter

DOWN ↓

2. The second most common gas in Jupiter and Saturn

3. The lightest gas, and the main ingredient of the gas giants

4. The planet famous for its bright rings

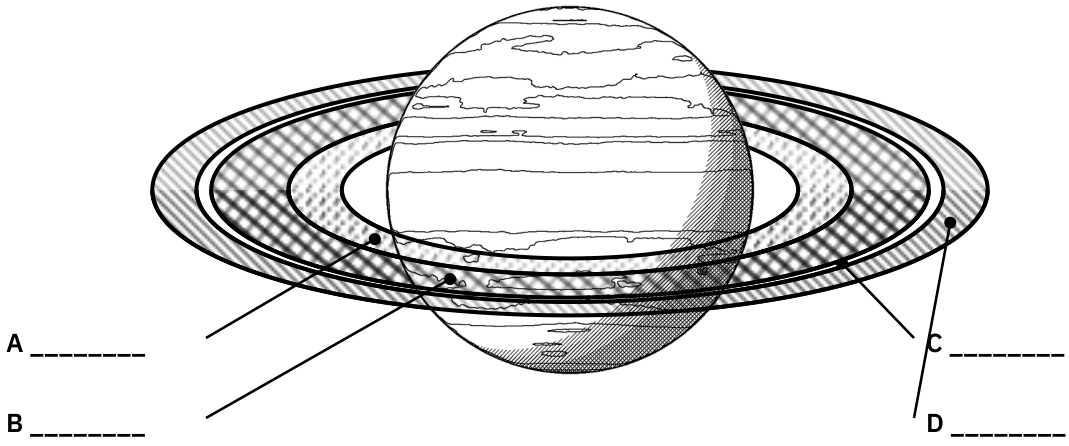
5. The windiest planet, farthest from the Sun

6. The largest planet in the solar system

7. Spacecraft that studied Saturn for 13 years

8. Name of two probes launched in 1977 that toured the giants

Saturn's Rings: Color & Calculate ★ EXPLORER ★★★ COMMANDER



Saturn's main rings are named with letters in the order they were discovered. Label the diagram with the words below, then color the rings. Use different colors for each ring and leave the **Cassini Division** gap white.

C ring · B ring (brightest and widest) · Cassini Division (gap) · A ring

The rings are made of ice, from dust-sized grains to house-sized boulders. They span about **175,000 miles** but are often only about **30 feet** thick.

1 Change 175,000 miles into feet (1 mile = 5,280 feet): _____ feet

★★★ The rings are _____ times wider than they are thick (feet wide ÷ 30). If a sheet of paper is 0.004 inch thick, a paper-thin ring of the same proportion would be about _____ inches wide (answer ÷ 12 = feet).

Logic Grid: Who Studies Which Giant? ★★ NAVIGATOR ★★★ COMMANDER

Four students each study a different giant planet. Use the clues to find out who studies which. Put an **X** for "no" and an **O** for "yes". Each row and column gets exactly one O.

	Jupiter	Saturn	Uranus	Neptune
Ana				
Ben				
Cara				
Dev				

Clues

1. Ana does not study Saturn or Uranus.
2. Ben studies either the planet with the Great Red Spot or the planet with the fastest winds.
3. The planet that is tilted on its side is not studied by Cara.
4. Ben does not study Jupiter.
5. Dev does not study Jupiter either.

Ana: _____ Ben: _____ Cara: _____ Dev: _____

> Facts to use: Jupiter has the Great Red Spot · Saturn is famous for its rings · Uranus is tilted on its side · Neptune has the fastest winds.

Riddles ★

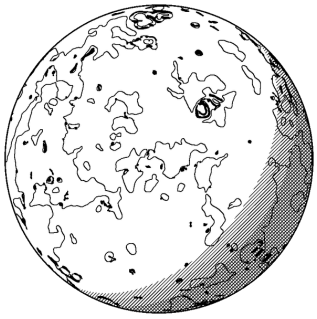
1. I am the biggest planet and I have a red storm. I am _____.
2. My rings are famous and I could float in water. I am _____.
3. I am farthest from the Sun and I have supersonic winds. I am _____.

Moons of Jupiter: Trading Cards

★ EXPLORER cut-out & color

Galileo discovered these four moons in 1610 with his telescope. Cut out the cards and play: pick a number and compare. Bigger wins… except for orbit time, where the smaller number wins!

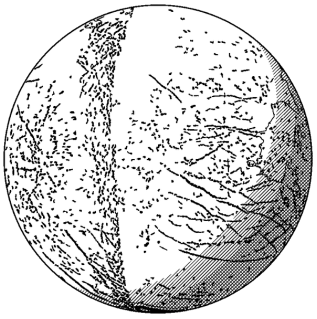
IO



Width	**2,263 mi**
Orbit time	**1.8 days**
Distance from Jupiter	**262,000 mi**

★ Most volcanic world in the solar system

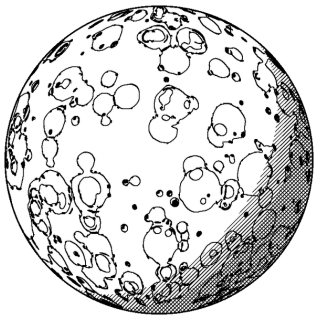
EUROPA



Width	**1,940 mi**
Orbit time	**3.6 days**
Distance from Jupiter	**417,000 mi**

★ A salty ocean hides under its ice

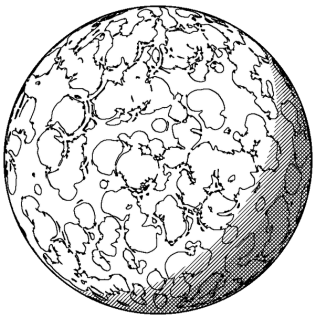
GANYMEDE



Width	**3,273 mi**
Orbit time	**7.2 days**
Distance from Jupiter	**665,000 mi**

★ Largest moon: bigger than Mercury

CALLISTO

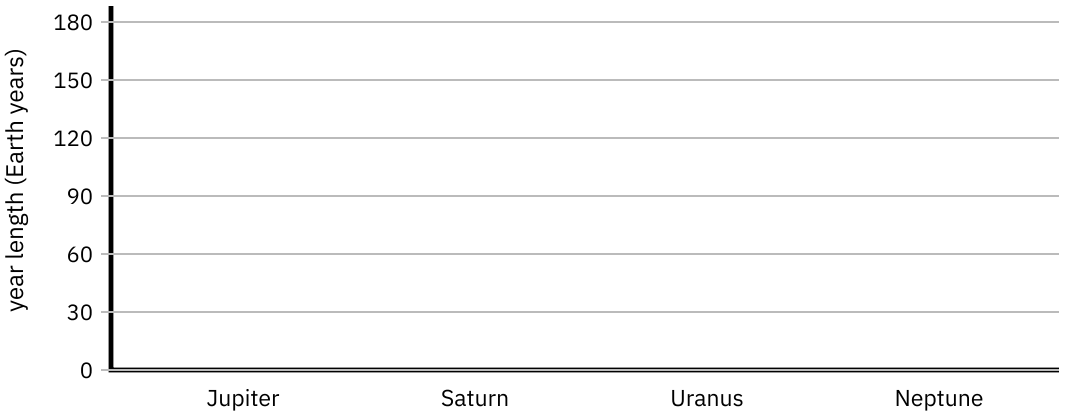


Width	**2,995 mi**
Orbit time	**16.7 days**
Distance from Jupiter	**1,170,000 mi**

★ One of the most cratered surfaces known

Math Lab 2 · Giant Years & Ages ★★ NAVIGATOR

The farther a planet is from the Sun, the longer its year. Draw a bar for each planet's year length (in Earth years).



Year lengths: Jupiter 12 · Saturn 29 · Uranus 84 · Neptune 165 Earth years.

1. How many Earth years does it take Neptune to circle the Sun once? _____ Neptune was discovered in 1846. In what year did it complete its **first full orbit** since being discovered? (1846 + 165 = _____)

2. **Your age on the giants.** Age = your Earth age ÷ the planet's year. For a 12-year-old: Jupiter _____ Saturn _____ Uranus _____ Neptune _____ (round to 2 decimals)

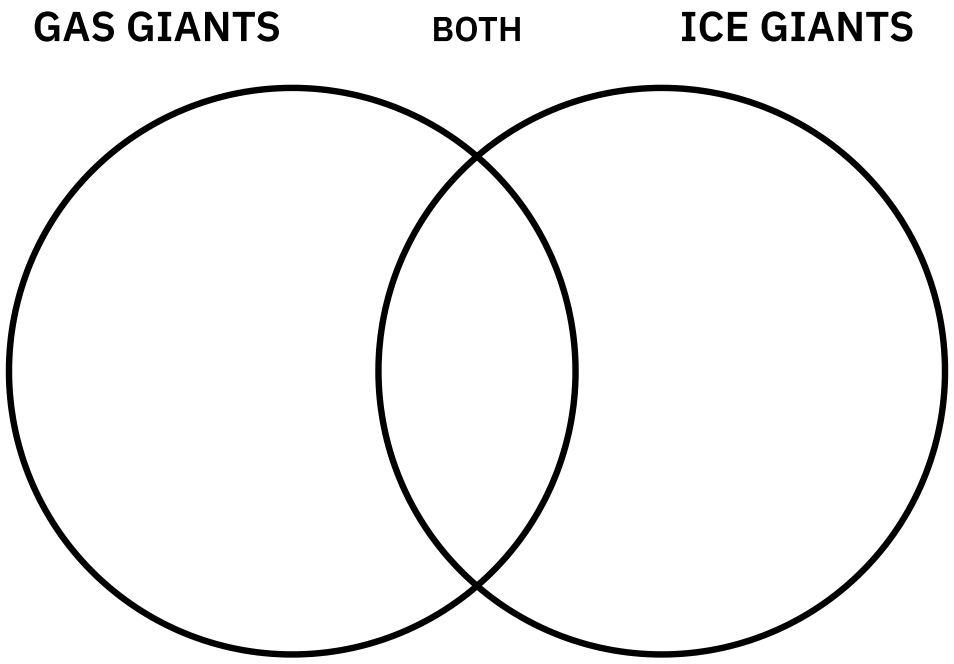
3. A day on Jupiter lasts about 10 hours. How many Jupiter days pass in one Earth day (24 hours)? _____

4. Jupiter spins so fast that it bulges at its equator. Why might fast spinning make a planet flatten? Try the spinning-paper experiment on page 11 to find out.

_____

Gas Giants vs Ice Giants ★★ NAVIGATOR

Sort the fact strips: **gas giants** (Jupiter and Saturn), **ice giants** (Uranus and Neptune) or **both**. Write each letter in the right place, or cut and paste.



(A) Includes the two biggest planets	(B) Much bigger than Earth	(C) Has rings
(D) Has no solid surface	(E) Has many moons	(F) Made mostly of hydrogen and helium
(G) Includes Uranus and Neptune	(H) Methane gives it a blue-green color	(I) Spins in less than 20 hours
(J) Contains lots of water, ammonia and methane		

Why do you think Uranus and Neptune are called “ice” giants even though they are not frozen? (They contain water, ammonia and methane that were ices when the planets formed.)

Giant Planet Labs ★★ NAVIGATOR

SAFETY Do this with an adult. Do not taste or drink any of the liquids, use a plastic or sturdy glass, and wipe up spills right away so nobody slips.

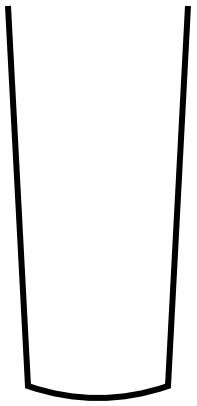
A · Density tower: layers in a giant

Heavier liquids sink, lighter ones float, just like the materials inside a giant planet.

- A tall clear glass
- Corn syrup or honey
- Dish soap
- Water with food coloring
- Vegetable oil

1. Pour a little of each liquid slowly down the side of the glass, in this order: syrup, soap, water, oil.
2. Do not stir. Watch the layers form.

Draw and color your layers



1 Predict the order from bottom to top: _____

2 In a gas giant, heavy materials sink to the center. What do you think is at the center of Jupiter?

_____

B · Spin it flat!

- A strip of paper about 1 × 11 inches
- A pencil and tape

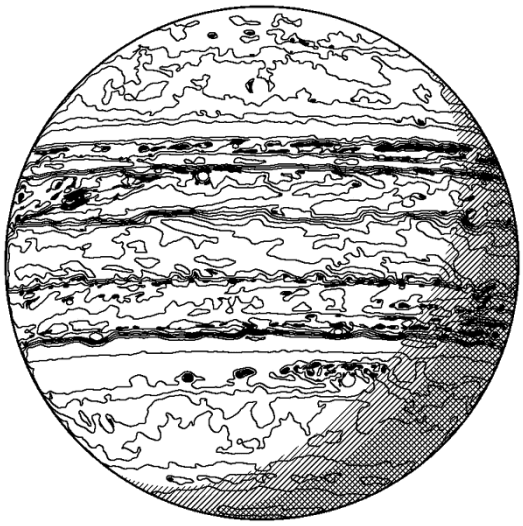
1. Tape the ends of the strip together to make a loose ring.
2. Hold the ring on the pencil with a loop of tape and spin the pencil quickly between your palms.
3. Watch the ring: where does it bulge?

Saturn spins in about 10.5 hours, so it bulges: its width across the equator is about 74,900 miles but only about 67,600 from pole to pole. How much flatter is it? (74,900 − 67,600 = _____ miles)

Jupiter: Read, Color & Decide ★ EXPLORER ★★ NAVIGATOR

The Great Red Spot

The Great Red Spot is a storm on Jupiter that astronomers have watched for well over a century. It is an enormous whirlwind, an **anticyclone**, wide enough to swallow about one Earth, though it has been shrinking. Its winds blow faster than any hurricane on our planet. Jupiter has no ground, so there is nothing to slow a storm down: it can last for hundreds of years.



Color the bands: pale cream **zones**, brown-orange **belts**, and a red-orange spot.

True or false?

1. The Great Red Spot is a storm. T / F _____
2. Jupiter has a solid surface where the storm hits the ground. T / F _____
3. The spot is about as wide as Earth. T / F _____
4. Storms on Jupiter die quickly. T / F _____

1 **Why does the storm last so long?** Use evidence from the text.

_____

_____

2 **Decide.** A probe can visit Jupiter's storm or Saturn's rings, but not both. Which would you choose? Give two reasons.

_____

_____

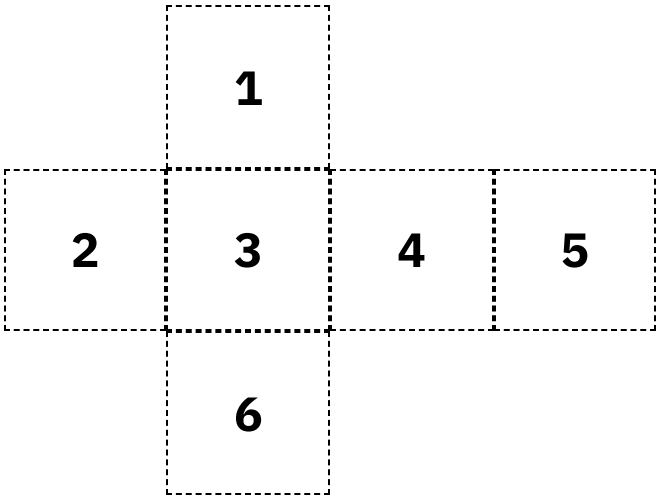
_____

Board Game: Gas Giant Grand Tour

★ EXPLORER cut-out

2–4 players. Use a coin or small paper pieces as tokens. Roll the die (cut and fold the net below) and race from Jupiter to the finish. Follow the instructions in the shaded squares!

START	**2**	**3**	**4** Great Red Spot storm! Go back 2.	**5**	**6**
12	**11**	**10** Jupiter gravity assist (like Voyager)! Move ahead 3.	**9**	**8**	**7** Io volcano show! Move ahead 2.
13 Question: what are the rings of Saturn made of? (Ice) Right = move ahead 2.	**14**	**15**	**16** Saturn is less dense than water: it would float! Slide to 18.	**17**	**18**
24 Voyager 2 flies past Uranus (1986). Move ahead 2.	**23**	**22**	**21** Uranus rolls on its side. Miss a turn.	**20**	**19** Cassini Division gap: slip through to 22.
25	**26** Neptune winds at 1,200 mph push you ahead 3!	**27**	**28** Cold and dark out here: go back 2.	**29**	**FINISH**



Cut and fold the cross along the dashed lines. Fold the edges to make a cube and glue the flaps. Or use any 6-sided die.

Create · Front Page News ★ EXPLORER

You are a reporter on a space probe near Jupiter. Write a front-page story about something you see: the Great Red Spot, the moon Io erupting, or Saturn's rings.

The Giant Planet Gazette

Edition: Outer Solar System · Price: 1 credit Date: _____

_____

Draw the photo

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Unit Review · Mission Check

★ EXPLORER ★★ NAVIGATOR ★★★ COMMANDER

1. **Sort** the planets: Jupiter · Saturn · Uranus · Neptune. Gas giants: _____ Ice giants: _____

2. **Match** each planet to its fact (write the letter): Jupiter ___ Saturn ___ Uranus ___ Neptune ___
   A. fastest winds · B. spins on its side · C. spectacular rings · D. Great Red Spot

3. **Calculate.** Neptune is 2,793,000,000 miles from the Sun. Sunlight travels 186,282 miles per second. How many minutes does it take? _____

4. **Complete.** The four largest moons of Jupiter were discovered by _____ in the year _____.

5. **True or false?** a) Saturn would sink in water. T / F b) Neptune's year is longer than Uranus's. T / F c) Jupiter has a solid surface. T / F

6. **Explain.** Why are Uranus and Neptune blue?

7. **Draw.** Sketch Saturn with its rings in the box and label two parts.

8. **Decide.** Could a spaceship land on Jupiter? Explain.

Mission Log ★ EXPLORER

Check the boxes when you can do each one. Color a star for each section you enjoyed.

☐ I can name the four giant planets and say which are gas and which are ice.

☐ I can explain why the giants have no solid surface.

☐ I can compare sizes of the giants with Earth.

☐ I can work out light travel times with a calculator.

☐ I can describe Saturn's rings and what they are made of.

☐ I can use a density tower to explain layers in a planet.

☐ I can solve a logic grid using clues.

☐ I can name the four Galilean moons.

My favorite activity was

Something new I learned

A question I still have about space

UNIT 3
GIANT PLANETS
★ ★ ★
MISSION COMPLETE

Signed: _____
Date: _____

Astraviator

SPACE WORKBOOK

UNIT 4 OF 8

Moons, Dwarf Planets & Small Bodies

Moons · Dwarf planets · Asteroids · Comets

Puzzles · Math labs · Coloring · Experiments · Games

Ages 9–14 · three levels · answer key included

★ Explorer · ★★ Navigator · ★★★ Commander



astraviator.com | Solar System Explorer Simulator

Print at 100% · black & white pages, color cover · Imagery rendered from NASA / USGS data and Solar System Scope textures (CC BY 4.0)

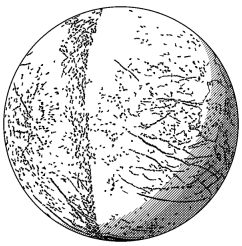
Field Guide: The Small Worlds ★ EXPLORER

Not every world is a planet. Our solar system is full of smaller worlds: **moons** that orbit planets, **dwarf planets**, rocky **asteroids** and icy **comets**.

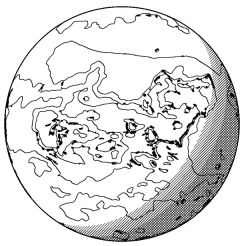
What is a dwarf planet? It orbits the Sun and is round, like a planet, but it has *not cleared its neighborhood* of other objects. Pluto and Ceres are dwarf planets.



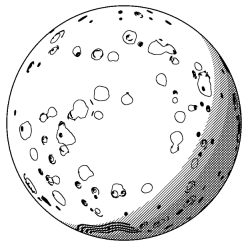
The Moon
Earth's only natural satellite. 2,159 mi wide. Gravity is about 1/6 of Earth's.



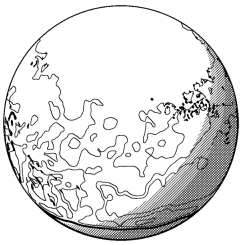
Europa
Moon of Jupiter. An icy crust covers a salty ocean.



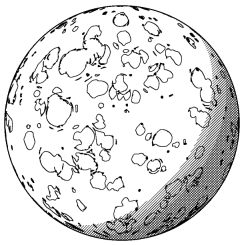
Titan
Moon of Saturn, 3,200 mi wide. Thick orange atmosphere and methane lakes.



Enceladus
Moon of Saturn, only 313 mi wide, with geysers at its south pole.



Pluto
Dwarf planet, 1,477 mi wide. Visited by New Horizons in 2015.



Ceres
Dwarf planet in the asteroid belt, 592 mi wide.

Asteroids are rocky leftovers from the birth of the solar system. Most orbit in the **asteroid belt** between Mars and Jupiter. **Comets** are dirty snowballs: when they get close to the Sun, they grow glowing tails. **Halley's Comet** returns about every 76 years.

Vocabulary to spot: moon · dwarf planet · asteroid · comet · crater · geyser · ocean · orbit

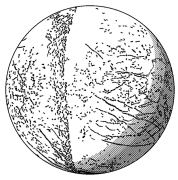
Who Am I? Draw the Lines ★ EXPLORER

Draw a line from each picture to the clue that matches it. Then write the name under the picture.



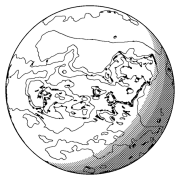
_____

A. I have a thick orange atmosphere and lakes of liquid methane.



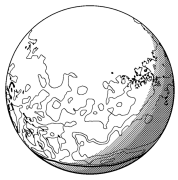
_____

B. I am a dwarf planet with a heart-shaped plain. A spacecraft flew by me in 2015.



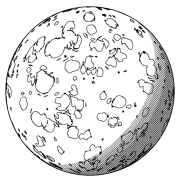
_____

C. Geysers of water ice spray from my south pole.



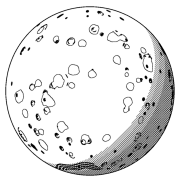
_____

D. Humans have walked on me.



_____

E. I am the biggest object in the asteroid belt, and a dwarf planet.



_____

F. A salty ocean hides under my icy crust.

★ Which clue could describe **two** of these worlds? Explain. _____

Sorting Hat: Planet, Dwarf, Moon, Asteroid or Comet?

★★ NAVIGATOR

cut-out

Cut out the cards at the bottom and paste each one in the right column.

Planet	Dwarf planet	Moon	Asteroid	Comet

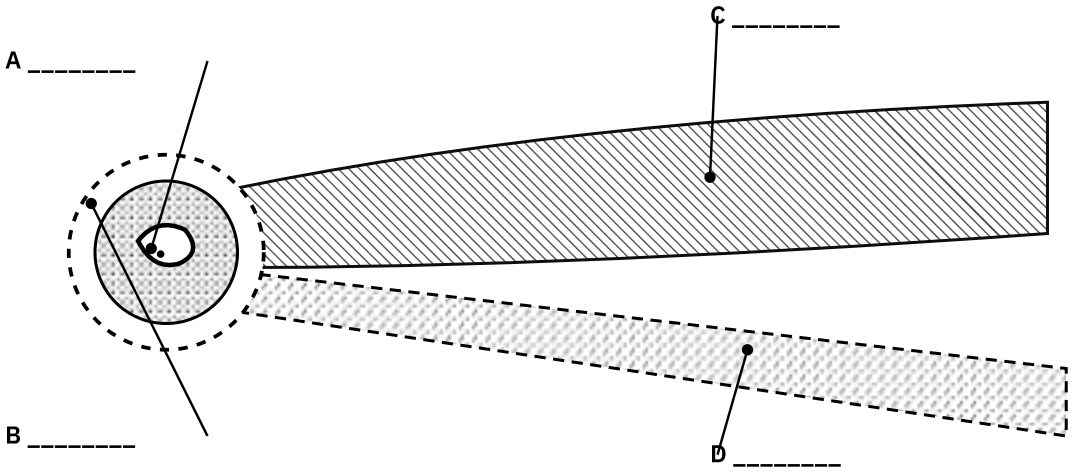
Mars	**Ceres**	**Titan**	**Enceladus**	**The Moon**
Vesta	**Halley's Comet**	**Europa**	**Earth**	**Pluto**

> Remember the dwarf-planet test: orbits the Sun · round · has NOT cleared its orbit. A moon orbits a planet.

★★ Ceres is round and orbits the Sun, but it shares the asteroid belt with millions of other objects. Why is it a dwarf planet and not a planet?

Comet Lab: Anatomy & Orbit ★ EXPLORER ★★ NAVIGATOR

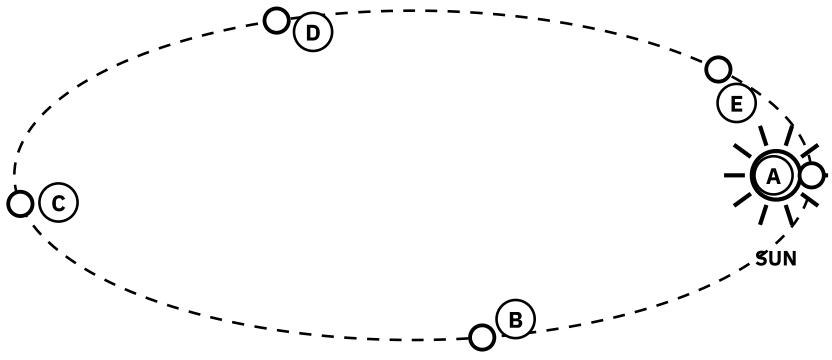
A comet is a ball of ice and dust. Near the Sun it heats up and sheds gas and dust. Label the parts with the word bank.



Nucleus (solid center) · Coma (glowing cloud) · Dust tail (curved) · Gas / ion tail (straight)

Draw the tails

A comet's tail always points **away from the Sun**, pushed by sunlight and the solar wind. Draw the tail at each position (A–E). Make it longest when the comet is closest to the Sun.



Not to scale.

1 Halley's Comet last passed the Sun in 1986 and returns about every 76 years. In which year will it return? 1986 + 75 ≈ _____. How old will you be then? _____

Small Worlds Word Search ★ EXPLORER

Find the 14 words. They can go in any direction, even backward.

O I X J N A T I T H Z J C R S
K J W N Y R Z E J V W M V H G
E A T A O C E R E S J E F N P
K I A E T V G N E V H T L Z J
C T I C U Y W T N E T E Q D F
N S L O L N R T C Q B O A N C
D Z Q E P O M I E H G R P L P
D A C E X O C B L W I S O O O
A S O R G M M R A K N W R F K
I T M C R W X O D L A G U Z D
Q E E S W Q C P U S G O E I M
I R T W V F V W S N Y P X K Z
W O G J J X Q C Y E R N L U Y
U I D T R E S Y E G X X X F M
W D T B C R A T E R B J T K U

- ☐ ASTEROID
- ☐ CERES
- ☐ COMET
- ☐ CRATER
- ☐ ENCELADUS
- ☐ EUROPA
- ☐ GEYSER
- ☐ METEOR
- ☐ MOON
- ☐ OCEAN
- ☐ ORBIT
- ☐ PLUTO
- ☐ TAIL
- ☐ TITAN

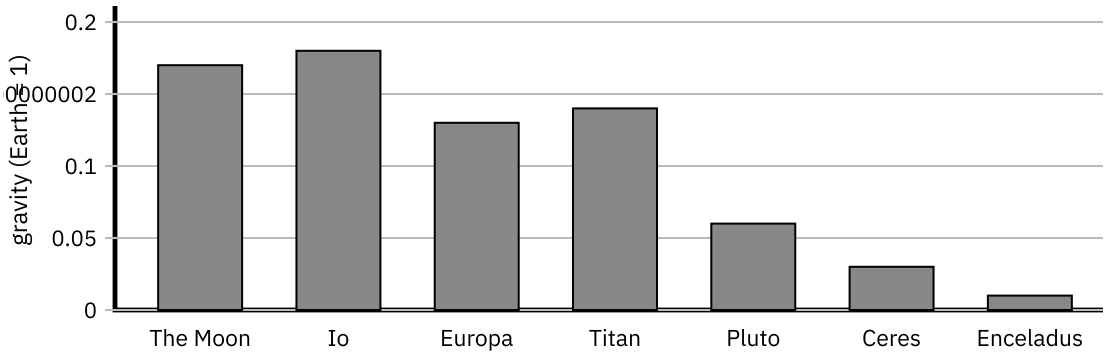
Secret challenge ★★: Write a riddle for one of the words and give it to a friend to solve.

Math Lab 1 · Light Weights, High Jumps ★★ NAVIGATOR

On small worlds gravity is weak. Use **weight on Earth × gravity** and **jump on Earth ÷ gravity**. Our astronaut weighs **90 lb** and jumps **2 ft** on Earth. Round to one decimal.

World	Gravity (Earth = 1)	Weight (lb)	Jump (ft)
The Moon	0.17	_____	_____
Io	0.18	_____	_____
Europa	0.13	_____	_____
Titan	0.14	_____	_____
Pluto	0.06	_____	_____
Ceres	0.03	_____	_____
Enceladus	0.01	_____	_____

Gravity ranking



1. Which world has the weakest gravity? _____ The strongest? _____

2. On Enceladus you could jump _____ feet high! Why would it be risky to jump on such a small world? (Hint: escape velocity is tiny.) _____

3. A 160 lb astronaut with a 140 lb suit visits the Moon (gravity 0.17). Total weight on the Moon: _____ lb

Math Lab 2 · Journey to Pluto ★★★ COMMANDER

The spacecraft **New Horizons** launched in January 2006 and flew past Pluto on July 14, 2015. It traveled about **3,000,000,000 miles** in about **9.5 years**.

1. How many hours is 9.5 years? (9.5 × 365 × 24 = _____ hours)

2. Average speed = distance ÷ time = 3,000,000,000 ÷ _____ ≈ _____ miles per hour

3. A jet airliner flies about 550 mph. How many times faster than a jet is New Horizons? _____

4. At the flyby, Pluto was about 3 billion miles from Earth. A radio signal travels at 186,282 miles per second. How many seconds does a message take? _____ How many hours? _____

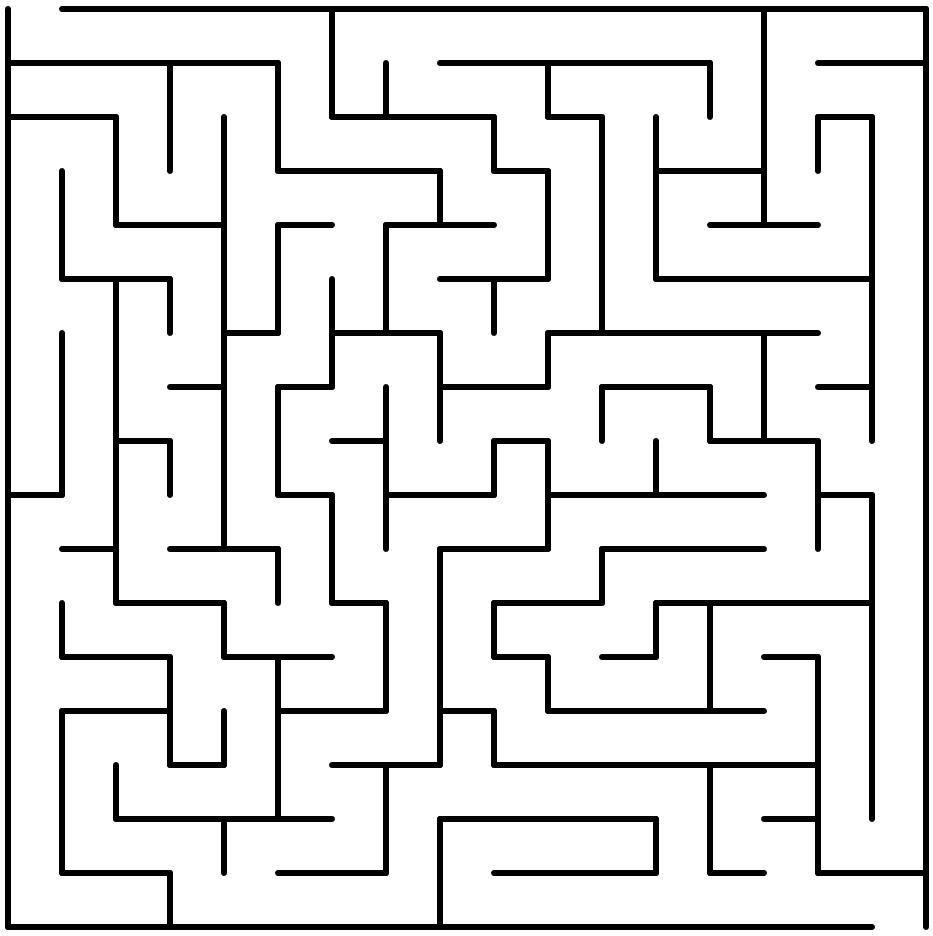
5. **Compare.** Apollo astronauts reached the Moon (238,855 miles) in about 3 days. How many miles per hour is that? (238,855 ÷ 72 = _____) mph

Time capsule question

Pluto takes 248 Earth years to orbit the Sun once. Since its discovery in 1930, has Pluto finished even one orbit? 1930 + 248 = _____ . What does that mean for the year 2026? _____

Asteroid Belt Maze ★★ NAVIGATOR

Your spacecraft starts at the top-left and must reach **Ceres** at the bottom-right. Don't touch the walls (the asteroids)!



Belt facts

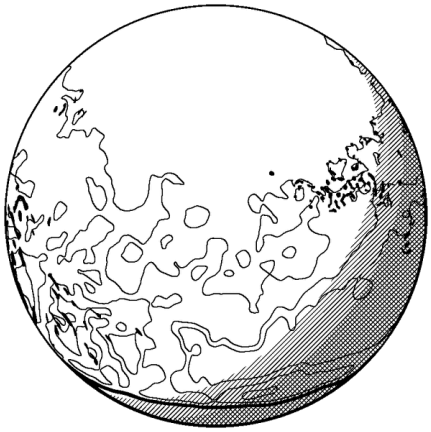
- It lies between Mars and Jupiter.
- Asteroids are usually hundreds of thousands of miles apart, so spacecraft rarely come close to one.
- All its asteroids together weigh less than the Moon.

1. The belt is about 2.2 to 3.2 AU from the Sun. How wide is it in AU? _____ In miles (1 AU = 93,000,000 mi)? _____

Pluto: Planet or Dwarf Planet? ★★ NAVIGATOR

Clyde Tombaugh discovered Pluto in 1930, and for 76 years it was called the ninth planet. In 2006 astronomers agreed on a new definition of **planet**: it must orbit the Sun, be round, and have **cleared its orbit** of other objects. Pluto did not pass the last test, so it became a **dwarf planet**.

In 2015, the New Horizons probe flew past and revealed mountains of water ice, a huge heart-shaped plain of nitrogen ice and a blue haze. Its largest moon, **Charon**, is about half its size.



Pluto, seen by New Horizons (our drawing)

The planet test

	Orbits the Sun?	Is round?	Cleared its orbit?	So it is a…
Earth	_____	_____	_____	_____
Pluto	_____	_____	_____	_____
Ceres	_____	_____	_____	_____

1 Charon is 751 miles wide and Pluto is 1,477 miles wide. What fraction of Pluto's width is Charon? (751 ÷ 1,477 = _____) About _____

Debate: should Pluto be a planet?

2 Choose a side and write your argument with two reasons.

_____

_____

_____

_____

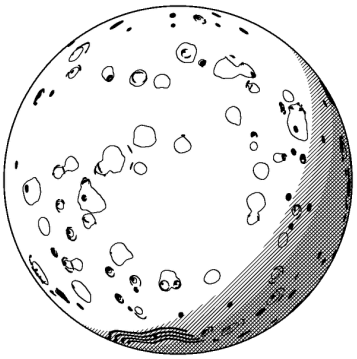
Cryovolcano Experiment: Geysers of Enceladus

★★ NAVIGATOR

SAFETY Do this with an adult, outdoors or over a sink, and wear eye protection. **Never put a cap, cork or lid on the bottle** : the gas needs to escape. Do not taste the mixture.

You need

- A small plastic bottle (or cup)
- Modeling clay or play dough
- Baking soda (2 tablespoons)
- Vinegar (1/4 cup) with blue food coloring
- A drop of dish soap
- A tray to catch the mess



Enceladus: geysers of water ice spray from cracks near its south pole.

Do it

1. Mold clay around the bottle to make an icy moon, leaving the opening free.
2. Put the baking soda and the soap in the bottle.
3. Pour in the blue vinegar and step back!

1 **Observe.** What happened when the vinegar met the baking soda?

2 **Draw** your cryovolcano in action in the box and add arrows showing where the “ice” flies.

3 On Enceladus, geysers shoot salty water, ice grains and simple chemicals into space from an ocean under the ice. Why do scientists find this exciting?

Safety: eye protection for younger students; do it outdoors or on a tray.

Small Worlds Bingo

★ EXPLORER cut-out

One player reads a clue from the list; the others cover the answer on their board with a button or paper piece. First to cover a whole row, column or diagonal wins!

BINGO · 1

Ceres	The Moon	Europa
An asteroid	A geyser	A crater
A comet tail	Pluto	Titan

BINGO · 2

The Moon	Enceladus	An asteroid
Ceres	Pluto	Titan
Halley's Comet	A comet tail	Europa

BINGO · 3

Titan	Europa	A comet tail
Ceres	Halley's Comet	An asteroid
The Moon	Io	Pluto

BINGO · 4

Halley's Comet	A crater	An asteroid
The Moon	A comet tail	Ceres
A geyser	Io	Enceladus

Caller's clues (cut out and shuffle)

I orbit Earth. Astronauts have walked on me.

A salty ocean may hide under my ice.

I have lakes of liquid methane and thick orange haze.

My geysers spray ice from my south pole.

My volcanoes make me the most volcanic world.

I am a dwarf planet with a heart-shaped plain.

I am the largest object in the asteroid belt.

I come back about every 76 years.

I am a rocky leftover from the early solar system.

I always point away from the Sun.

I am a bowl-shaped hole made by an impact.

I shoot water from underground.

Logic Lab: Moon Sudoku ★★★ COMMANDER

Fill the 6×6 grid so that each row, each column and each 2×3 box has all six worlds once: **Mo** = Moon, **Eu** = Europa, **Ti** = Titan, **En** = Enceladus, **Pl** = Pluto, **Ce** = Ceres.

	Ti	**Mo**		**Eu**	
En	**Eu**		**Ti**		**Pl**
Ce		**En**	**Eu**		**Mo**
Ti		**Eu**	**Ce**		**En**
Mo			**Pl**	**En**	
	En	**Pl**			

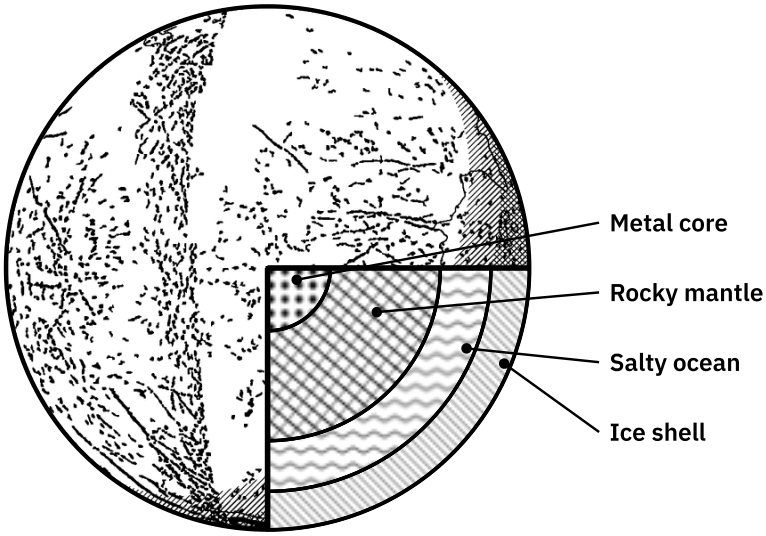
Mystery world ★★

Read the clues and name the world:

1. I orbit Saturn. I am bigger than Mercury. I have thick orange air. I am _____.
2. I am a dwarf planet. I live in the asteroid belt. I am the biggest object there. I am _____.
3. I orbit Jupiter. My ocean is under an icy shell. I am the fourth smallest of the big four moons. I am _____.

Create · A Base on Europa

★ EXPLORER ★★ NAVIGATOR



Scientists think Europa has a deep salty ocean under an ice shell. Imagine you must build a research base here!

Not to scale.

Design your base

DRAW your base here (surface and underwater parts)

1. **What does your crew need?** Tick what your design provides: ☐ air ☐ water ☐ power ☐ warmth ☐ food ☐ radio contact with Earth ☐ protection from radiation

2. Name your base and describe how it works:

Unit Review · Mission Check

★ EXPLORER ★★ NAVIGATOR ★★★ COMMANDER

1. **Define** in your own words: dwarf planet _____ comet _____

2. **Match** (write the letter): Europa ___ Titan ___ Enceladus ___ Pluto ___
   A. geysers · B. heart-shaped plain · C. salty ocean under ice · D. methane lakes

3. **True or false?** a) A comet's tail points toward the Sun. T / F b) Pluto is a planet. T / F c) Gravity on Titan is weaker than on Earth. T / F

4. **Calculate.** A 100 lb student visits Europa (gravity 0.13). Weight: _____ lb

5. **Calculate.** Halley's Comet last appeared in 1986. About what year will it come back? _____

6. **Explain.** Why might scientists want to explore Europa or Enceladus?

7. **Compare.** How are an asteroid and a comet alike? How are they different?

8. **Create.** Draw a comet in the box and label its nucleus and tail.

Mission Log ★ EXPLORER

Check the boxes when you can do each one. Color a star for each section you enjoyed.

☐ I can tell planets, dwarf planets, moons, asteroids and comets apart.

☐ I can name moons with oceans and geysers.

☐ I can explain why Pluto is a dwarf planet.

☐ I can label the parts of a comet and say which way its tail points.

☐ I can calculate weight and jump height on small worlds.

☐ I can work out the speed of a spacecraft.

☐ I can use clues to solve a sudoku and riddles.

☐ I can design a base for a distant moon.

My favorite activity was

Something new I learned

A question I still have about space

UNIT 4
SMALL WORLDS
★ ★ ★
MISSION COMPLETE

Signed: _____
Date: _____

Astraviator

SPACE WORKBOOK

UNIT 5 OF 8

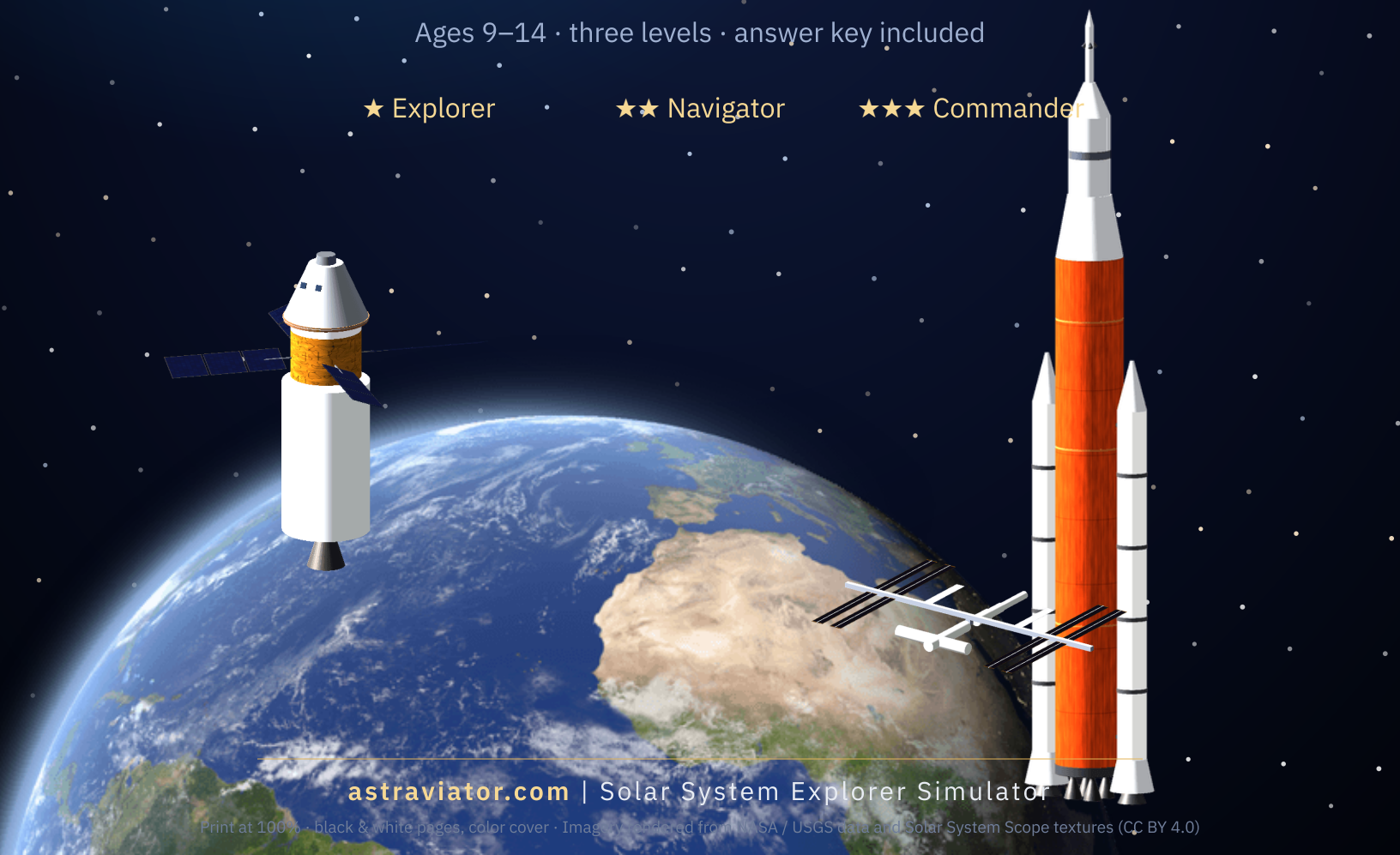
Rockets, Orbits & Missions

Launch · Orbit · Spacecraft · Mission control

Puzzles · Math labs · Coloring · Experiments · Games

Ages 9–14 · three levels · answer key included

★ Explorer · ★★ Navigator · ★★★ Commander



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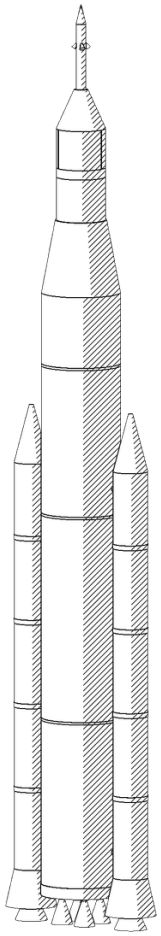
Mission Briefing: How Rockets Work ★ EXPLORER

To reach space, a rocket must beat **gravity**. It burns fuel and pushes hot gas downward; the gas pushes the rocket upward. That push is called **thrust**.

Big rockets are built in **stages**. Each stage drops away when its fuel runs out, so the rocket gets lighter and faster.

Getting into **orbit** is not about going up, but about going *sideways* very fast: about 17,500 miles per hour. Then the spacecraft keeps falling around Earth without hitting it.

The Artemis rocket, the **Space Launch System (SLS)**, is 322 feet tall. It carries the **Orion** capsule with four astronauts toward the Moon.

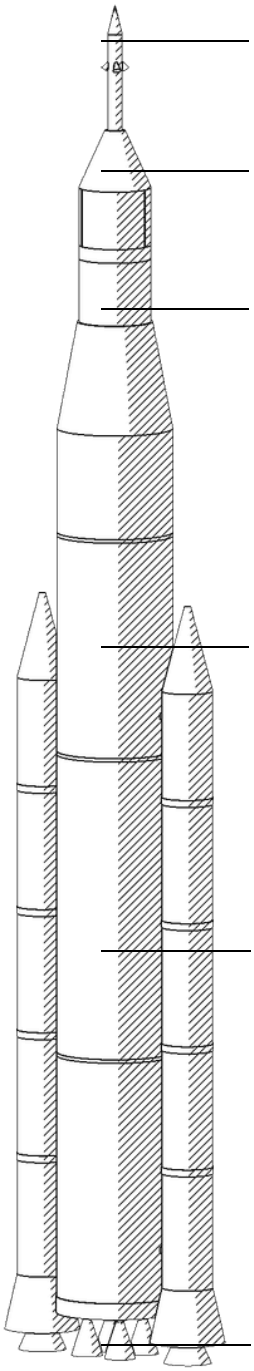


The SLS rocket

	SLS	Space Station (ISS)	Moon
Size	322 ft tall	357 ft long	238,855 mi away
Speed	liftoff to 17,500 mph	17,500 mph	–
Altitude	–	~250 mi	–

Vocabulary to spot: thrust · gravity · stage · capsule · orbit · probe · rover · telescope · mission control

Rocket Anatomy: Label & Stack ★ EXPLORER ★★ NAVIGATOR



Label the six parts of the SLS rocket with the names in the bank.

Launch abort system · Orion capsule + service module · Upper stage and adapter · Core stage (orange) · Solid rocket boosters · RS-25 engines

Stacking order (like in the Vehicle Assembly Building)

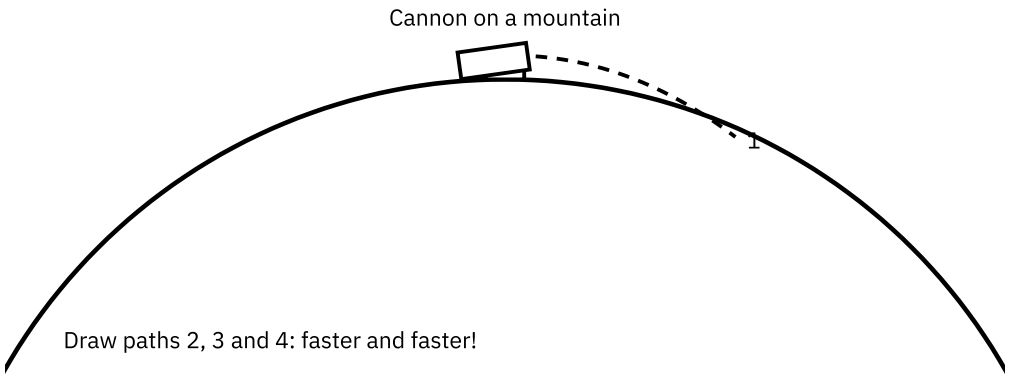
Rockets are built from the bottom up. Number the parts 1 to 8 in the order they are stacked.

_____	European Service Module
_____	Launch vehicle stage adapter
_____	Solid rocket boosters
_____	Orion crew capsule
_____	Upper stage (ICPS)
_____	RS-25 engines
_____	Launch abort system
_____	Core stage

★ Which part saves the crew in an emergency by pulling the capsule away? _____

Newton's Cannon & Orbit Math ★★ NAVIGATOR ★★★ COMMANDER

Isaac Newton imagined a cannon on a very tall mountain. A slow cannonball falls to the ground. A faster one lands farther away. If it is fast enough, the ground curves away as fast as the ball falls, and the ball **orbits**!



1. Which path shows a ball that **orbits**? _____

The Space Station

The ISS flies at 17,500 mph, about 250 miles above Earth. Earth's radius is 3,959 miles.

2. Radius of the orbit = 3,959 + 250 = _____ mi. Circumference = 2 × 3.14 × radius = _____ mi

3. Time for one orbit = distance ÷ speed = _____ ÷ 17,500 = _____ hours = _____ minutes

4. How many orbits does the ISS make in 24 hours? _____ So the crew sees about _____ sunrises every day!

5. How many miles does the ISS travel every second? (17,500 ÷ 3,600 = _____)

Mission Control Morse Code ★★ NAVIGATOR

Before voice radio, messages were sent in **Morse code**, with short signals (dots •) and long signals (dashes –). Use the chart to decode each message. A slash **/** separates words.

A •–	**B** –•••	**C** –•–•	**D** –••	**E** •	**F** ••–•	**G** ––•	**H** ••••	**I** ••	**J** •–––	**K** –•–	**L** •–••	**M** ––
N –•	**O** –––	**P** •––•	**Q** ––•–	**R** •–•	**S** •••	**T** –	**U** ••–	**V** •••–	**W** •––	**X** –••–	**Y** –•––	**Z** ––••

1. • •– •–• – •••• / –•–• •– •–•• •–•• •• –• ––• / –– •– •–• •••

2. •–• ––– •••– • •–• / •–•• •– –• –•• • –•• / ••• •– ••–• • •–•• –•––

3. •–•• •• •••–• – ––– •••–• •••–• / •• –• / – • –• / ••• • –•–• ––– –• –•• •••

4. **Your turn!** Write your first name in Morse code: _____

5. **Send it!** Tap the message on a table (short tap = dot, long tap = dash) for a friend to decode. What was the hardest letter? _____

> Fun fact: the distress signal SOS is • • • – – – • • • in Morse code.

Space Exploration Timeline

★ EXPLORER ★★ NAVIGATOR cut-out

Cut out the event cards, mix them up and put them in order from the oldest to the newest. Then glue them on the timeline.

Artemis I sends Orion around the Moon without a crew

Sputnik 1, the first satellite, orbits Earth

The first crew arrives at the International Space Station

The Hubble Space Telescope is launched

Perseverance lands on Mars; the James Webb telescope is launched

Voyager 1 and 2 are launched

Apollo 11 astronauts land on the Moon

Yuri Gagarin becomes the first human in space

1. How many years passed between Sputnik (1957) and the first human in space (1961)? _____

2. From Apollo 11 (1969) to Artemis I (2022): _____ years. Which came first: Voyager or Hubble? _____

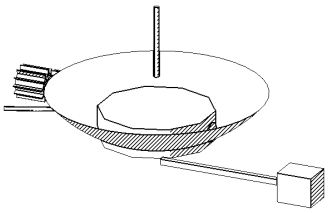
3. The ISS has had astronauts living on board since 2000. If today is 2026, for how many years? _____

Spacecraft Trading Cards (1)

★ EXPLORER cut-out & color

Cut out and color. Play: pick a number (year, weight…) and compare. Bigger wins, except for launch year: the earlier launch wins!

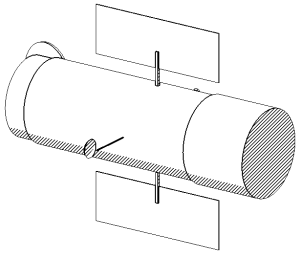
VOYAGER 1



Launched	**1977**
Weight	**1,592 lb**
Job	**Tour the giant planets**
Type	**Probe**

★ **First human-made object in interstellar space**

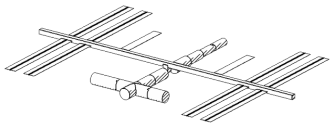
HUBBLE



Launched	**1990**
Length	**43 ft**
Weight	**24,500 lb**
Orbit height	**340 mi**

★ **A telescope that orbits Earth**

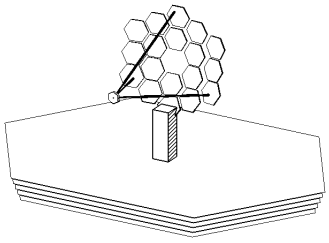
SPACE STATION (ISS)



First crew	**2000**
Length	**357 ft**
Speed	**17,500 mph**
Orbit height	**250 mi**

★ **A laboratory with astronauts on board**

JAMES WEBB



Launched	**2021**
Mirror	**21 ft**
Distance	**~1 million mi**
Looks at	**Infrared light**

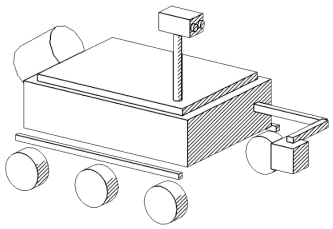
★ **Sees the first galaxies**

Spacecraft Trading Cards (2)

★ EXPLORER cut-out & design

Two more real spacecraft, plus two blank cards: invent your own spacecraft and fill in its card!

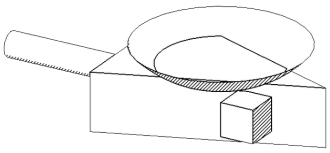
PERSEVERANCE



Landed	**2021 · Mars**
Weight	**2,263 lb**
Wheels	**6**
Place	**Jezero Crater**

★ Searches for signs of ancient life

NEW HORIZONS



Launched	**2006**
Weight	**1,054 lb**
Launch speed	**36,373 mph**
Visited	**Pluto, 2015**

★ Fastest launch of its time

YOUR SPACECRAFT

Draw it here

Name	_____
Launch year	_____
Weight	_____
Mission	_____

YOUR SPACECRAFT

Draw it here

Name	_____
Launch year	_____
Weight	_____
Mission	_____

Math Lab · Rocket Numbers ★★ NAVIGATOR ★★★ COMMANDER

Use a calculator. Round to one decimal.

1. **Thrust-to-weight.** At liftoff the SLS weighs about 5,750,000 pounds and its engines push with 8,800,000 pounds of thrust. Thrust ÷ weight = _____ . A rocket can lift off only if this number is greater than ____ .

2. **Height.** The SLS is 322 feet tall. A 10-story building is about 100 feet. How many 10-story buildings stacked equal the SLS? _____

3. **Timing.** The side boosters separate 132 seconds after liftoff, and the core stage stops at 484 seconds. How many seconds does the core stage work alone? _____ How many minutes is 484 seconds? _____

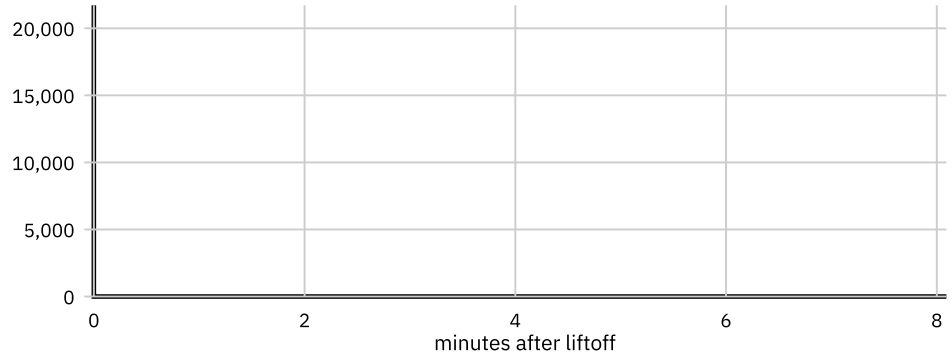
4. **Speed up!** A rocket reaches orbit speed (17,500 mph) in about 8 minutes. How many miles per hour does it gain each minute? (17,500 ÷ 8 = _____) mph

5. **Trip to the Moon.** The Moon is 238,855 miles away. Orion travels about 4 days outbound. Average speed = 238,855 ÷ _____ hours = _____ mph

6. **Escape!** To leave Earth completely, a spacecraft needs about 25,000 mph. How many times faster is that than a jet airliner (550 mph)? _____

Graph: speed of a rocket

Plot these points and join them with a line: 0 min → 0 mph · 2 min → 4,000 mph · 4 min → 8,500 mph · 6 min → 13,000 mph · 8 min → 17,500 mph.



Straw Rocket Lab ★★ NAVIGATOR

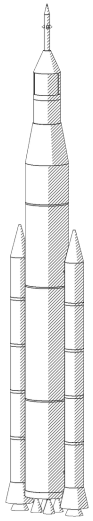
SAFETY Do this with an adult. Never aim the rocket at people, pets or faces, and wear eye protection. An adult handles the scissors.

You need

- A strip of paper (2 × 4 in)
- A straw (drinking straw)
- Tape and scissors
- A tape measure or yardstick

Build & launch

1. Roll the paper around the straw to make a tube and tape it. Pinch and tape one end closed: that is your rocket.
2. Slide the rocket on the straw and blow hard through the straw.
3. Measure how far it flew. Do 3 launches at each angle (30°, 45°, 60°).



Real rockets also need fins and a smooth shape.

Angle	Launch 1 (ft)	Launch 2 (ft)	Launch 3 (ft)	Average (ft)
30°				
45°				
60°				

1. Which angle sent the rocket farthest on average? _____

2. Why did you launch each angle three times?

_____

3. Change one thing (add fins, make it longer, use a heavier paper) and test again. What did you change and what happened?

_____

_____

Mission Control: Go or No-Go? ★★★ COMMANDER

Before a launch, each Mission Control station says **GO** (ready) or **NO-GO** (not ready). Use the clues to find out who says what. Write GO or NO-GO next to each station.

Flight	
Guidance	
Propulsion	
Weather	
Range Safety	
Crew	

Clues

1. Exactly two stations are No-Go.
2. If Weather is Go, then Range Safety is Go.
3. Flight and Crew give the same answer.
4. Either Propulsion or Guidance is No-Go, but not both.
5. Weather is No-Go.
6. Crew is Go.
7. Guidance is Go.

1 Should the launch proceed? _____ Which system needs repair? _____

2 **Your turn.** Write 3 clues for a new Go/No-Go puzzle for a friend.

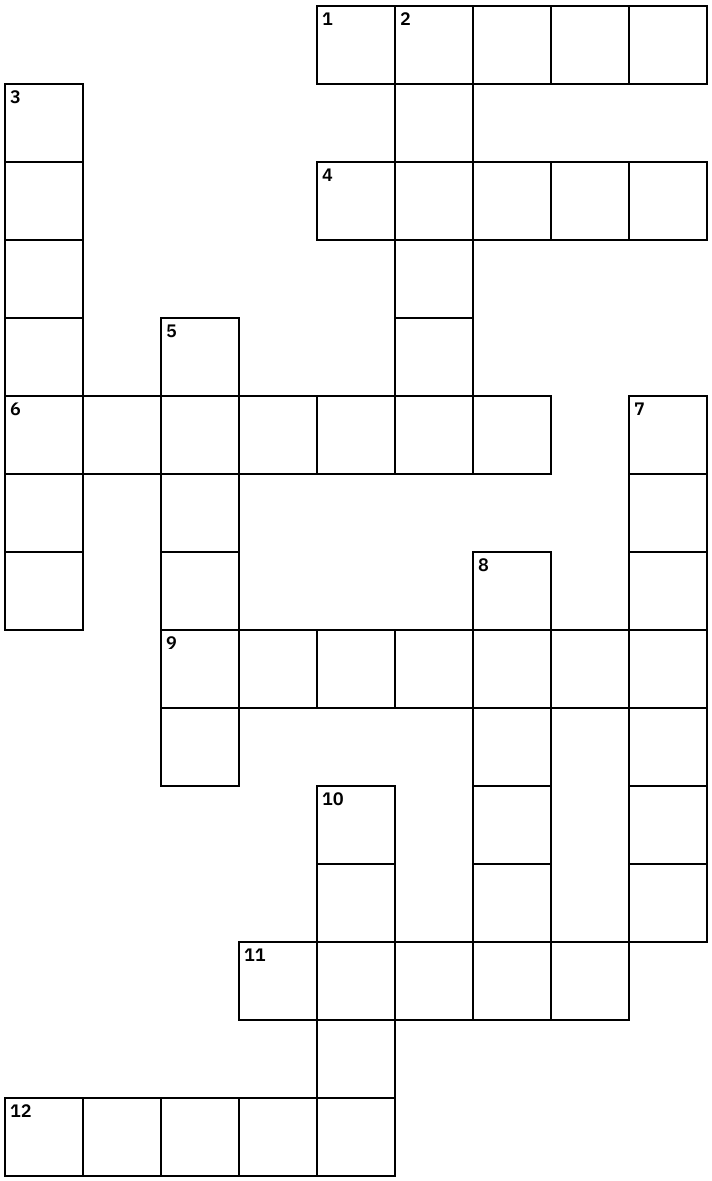
_____

_____

_____

Rocket Crossword ★★ NAVIGATOR

Every answer is a word from this unit.



ACROSS →

1. A rocket section that falls away when its fuel is used up

4. The path of a spacecraft around a planet

6. The force that pulls a rocket back down

9. The part of the rocket where the crew rides

11. A robot that drives on another world

12. Code of dots and dashes

DOWN ↓

2. The push that lifts a rocket

3. Probe now in interstellar space

5. To blast a rocket into the sky

7. NASA program to return people to the Moon

8. Space telescope launched in 1990

10. A robotic spacecraft that explores the solar system

Launch Day Sequence ★ EXPLORER cut-out

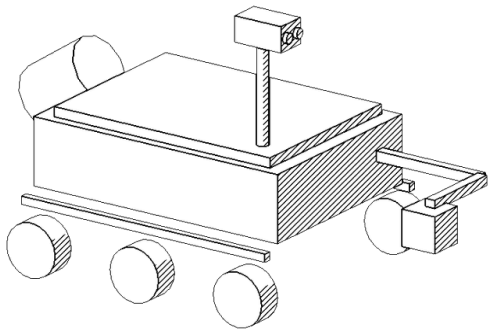
Cut out the cards, shuffle them and put them in the correct order from the morning of the launch until Orion reaches orbit.

- ☐ Boosters ignite: LIFTOFF!
- ☐ Orion reaches orbit around Earth.
- ☐ The crew wakes up and eats breakfast.
- ☐ The crew climbs into the Orion capsule.
- ☐ The crew puts on their orange launch suits.
- ☐ Mission Control polls every station: Go or No-Go.
- ☐ The solid boosters separate (about 2 minutes up).
- ☐ The countdown reaches T–10 seconds.
- ☐ The core stage shuts down (about 8 minutes up).
- ☐ The crew rides to the launch pad.

1 How many seconds are there in the last 10 seconds of the countdown? _____ In 1 minute? _____ In 10 minutes? _____

Create · Design Your Rover

★ EXPLORER ★★ NAVIGATOR



Perseverance: a real rover on Mars

A rover needs wheels to drive, cameras to see, a robot arm to touch rocks, an antenna to talk to Earth, and power. Design your own rover to explore another world.

DRAW your rover here and label at least four parts

1. Name: _____ Destination: _____

2. What question about that world will your rover answer?

_____

_____

Unit Review · Mission Check

★ EXPLORER ★★ NAVIGATOR ★★★ COMMANDER

1. **Match** (write the letter): thrust ___ orbit ___ stage ___ probe ___
   A. a rocket section that drops away · B. the push that lifts a rocket · C. a robotic explorer · D. the path around a planet

2. **Why** does a spacecraft in orbit not fall to the ground?

3. **Calculate.** The ISS orbits in about 90 minutes. How many orbits in one day (1,440 minutes)? _____

4. **Decode** this Morse message: • • • – – – • • • = _____

5. **Order** from oldest to newest: Hubble · Sputnik · Perseverance · Apollo 11:

6. **True or false?** a) Rockets are built in one piece. T / F b) The ISS stays in orbit because it moves sideways very fast. T / F c) Voyager 1 is an orbiter of Mars. T / F

7. **Compare.** How are a rover and a probe alike and different?

8. **Decide.** Which spacecraft would you like to build and why?

Mission Log ★ EXPLORER

Check the boxes when you can do each one. Color a star for each section you enjoyed.

☐ I can name the main parts of a rocket.

☐ I can explain how thrust beats gravity.

☐ I can explain why an orbit is falling around Earth.

☐ I can calculate orbit times and speeds.

☐ I can decode and write Morse code.

☐ I can put space history events in order.

☐ I can compare real spacecraft.

☐ I can design a rover for another world.

My favorite activity was

_____

Something new I learned

_____

_____

A question I still have about space

_____

_____

UNIT 5
ROCKETS & MISSIONS
★ ★ ★
MISSION COMPLETE

Signed: _____
Date: _____

Astraviator

SPACE WORKBOOK

UNIT 6 OF 8

Stars, Constellations & Galaxies

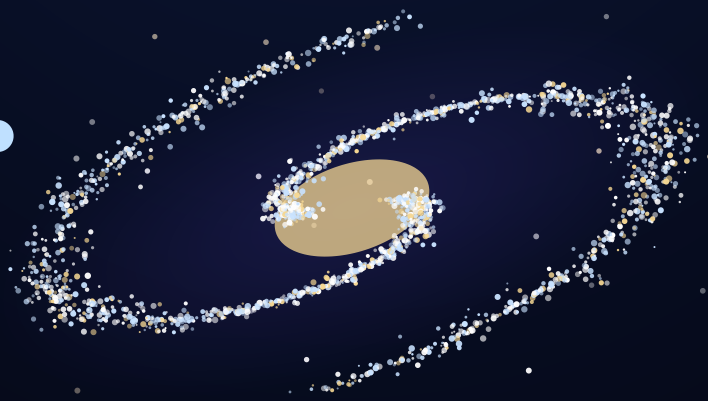
Light-years · Star maps · Galaxies · Black holes

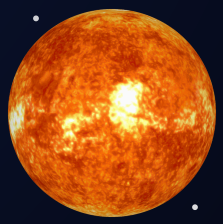
Puzzles · Dot-to-dot · Cut-out cards · Star lab

Ages 9–14 · three levels · answer key included

★ Explorer · ★★ Navigator · ★★★ Commander







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Mission Briefing: Stars All Around ★ EXPLORER

Every star you see at night is a Sun, a giant ball of hot gas that makes its own light. They look tiny only because they are **very** far away.

Light-year

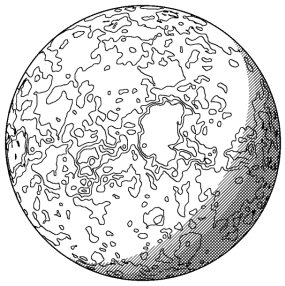
Space is so big that miles are too small. Astronomers use the **light-year**: the distance light travels in one year, about **5.88 trillion miles**. Light moves at 186,282 miles per second!

Constellations

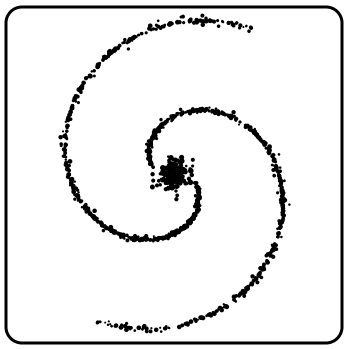
A **constellation** is a pattern of stars that people imagined as a picture: a hunter, a swan, a cross. The stars in a pattern are usually *not* near each other; they only look close from Earth.

Galaxies

A **galaxy** is a huge family of stars, gas and dust held together by gravity. Our Sun lives in the **Milky Way**, which has 100 to 400 billion stars.



Our Sun, the nearest star



A spiral galaxy like the Milky Way

Star	Distance	Light takes
Sun	93 million miles	8.3 minutes
Proxima Centauri	4.24 light-years	4.24 years
Sirius	8.6 light-years	8.6 years
Betelgeuse	~550 light-years	~550 years

Life Story of a Star

★ EXPLORER ★★ NAVIGATOR cut-out

Stars are born, live and die. A small star like the Sun and a massive star have very different endings. Cut out the cards, sort them into two paths, and glue them in order from left to right.

Path 1 · A small star like the Sun

1	2	3	4	5	6

Path 2 · A massive star

1	2	3	4	5	6

1 · A planetary nebula: the outer layers drift away

1 · A white dwarf: a hot, tiny core that slowly cools

1 · A main-sequence star burns hydrogen for billions of years

1 · A cloud of gas and dust (nebula)

1 · A red giant swells up as hydrogen runs out

1 · A protostar: the cloud collapses and heats up

2 · A neutron star or a black hole is left behind

2 · A cloud of gas and dust (nebula)

2 · A massive star shines blue-white and burns fast

2 · A red supergiant swells to hundreds of times the Sun

2 · A supernova: the star explodes!

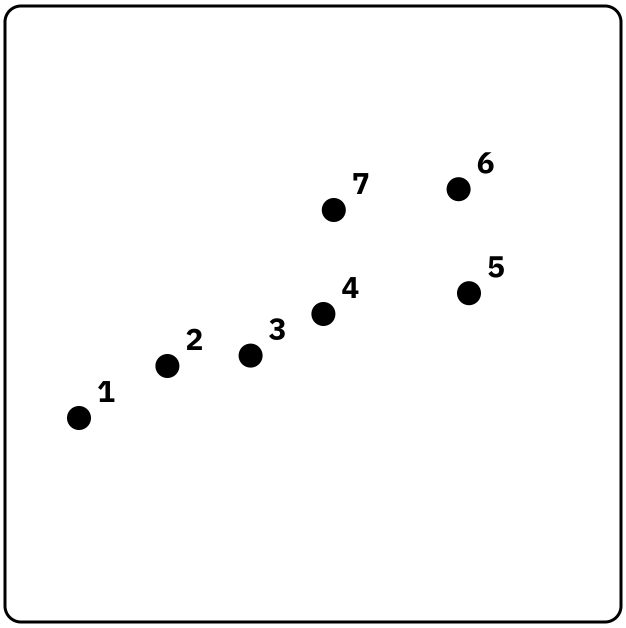
2 · A protostar: the cloud collapses and heats up

1 Which stage do both paths share at the beginning? _____

2 Our Sun is about 4.6 billion years old and will live about 10 billion in total. How many billion years does it have left? _____

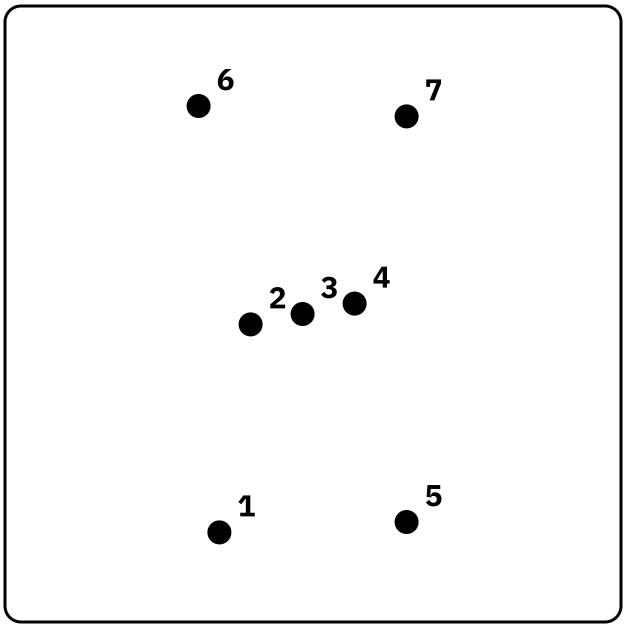
Connect the Dots: Star Patterns ★ EXPLORER

Join the stars to reveal the constellation. Follow the instructions under each picture.



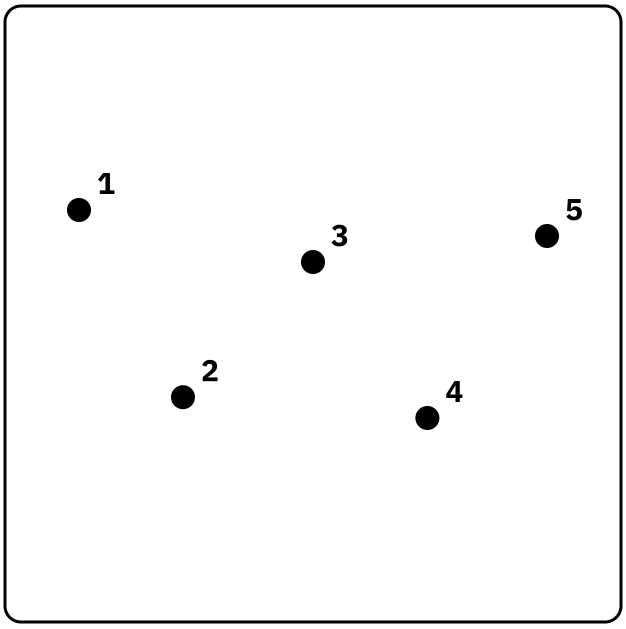
Big Dipper

Join 1→2→3→4→5→6→7, then 7→4.



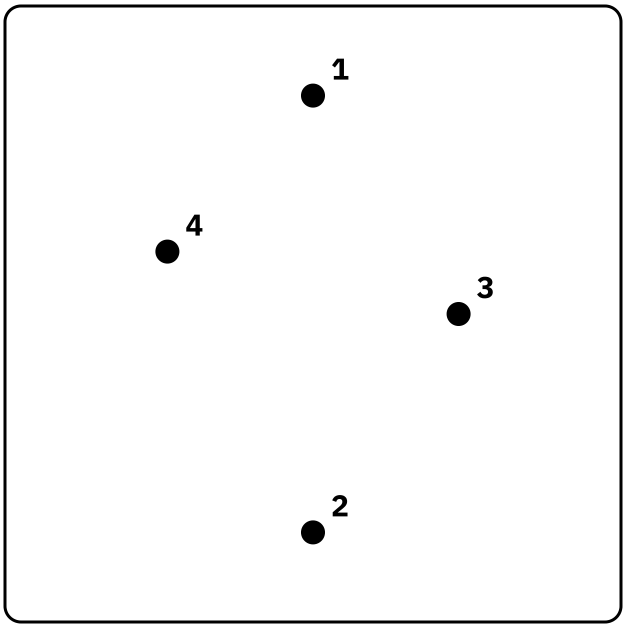
Orion

Join 1→2→3→4→5, then 6→2, 7→4 and 6→7.



Cassiopeia

Join 1→2→3→4→5. It makes a big W!



Southern Cross

Join 1→2 and 3→4. Only visible south of the equator.

Orion has a red star, **Betelgeuse** (6), and a blue star, **Rigel** (5). Color them lightly with a red and a blue pencil. The Southern Cross points to the south, and the Big Dipper points to Polaris, the North Star.

Math Lab · Light and Distance

★★ NAVIGATOR ★★★ COMMANDER

Use a calculator. 1 light-year = 5,878,000,000,000 miles. Light speed = 186,282 miles per second.

1. **Sunlight.** The Sun is 93,000,000 miles away. Time = distance ÷ speed = _____ seconds = _____ minutes.

2. **Moonlight.** The Moon is 238,855 miles away. How many seconds does its light take to reach us? _____

3. **Looking into the past.** Sirius is 8.6 light-years away. You see it as it was _____ years ago. If you are 11 years old, in which year of your life was this light leaving Sirius? Age _____

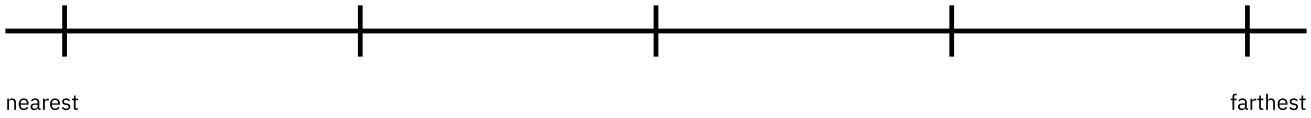
4. **Miles to Proxima.** Proxima Centauri is 4.24 light-years away. 4.24 × 5,878,000,000,000 = _____ miles (about _____ trillion).

5. **The long trip.** The fastest probe, New Horizons, left Earth at 36,373 mph. About how many years would it take to reach Proxima? Hours = _____ ; ÷ 8,766 hours per year = _____ years.

6. **Compare.** About how many human generations (25 years each) is your answer to question 5? _____

Number line · Which light left first?

Place the stars on the line by their distance in light-years: Sun (0.0000158), Proxima (4.24), Sirius (8.6), Vega (25), Betelgeuse (550). The line is not to scale: write each name above its tick and its distance below.



nearest farthest

Star Colors and Temperatures ★★ NAVIGATOR

A star's color tells its surface temperature. Blue stars are the hottest and red stars are the coolest, like a flame: the blue part of a candle flame is hotter than the orange tip. Astronomers sort stars into classes **O, B, A, F, G, K, M** (remember: *"Oh, Be A Fine Girl, Kiss Me!"*).

Class	Color	Surface temperature	Color it
O	Blue	> 53,500 °F	
B	Blue-white	17,500–53,500 °F	
A	White	12,000–17,500 °F	
F	Yellow-white	9,700–12,000 °F	
G	Yellow	8,400–9,700 °F	
K	Orange	6,200–8,400 °F	
M	Red	< 6,200 °F	

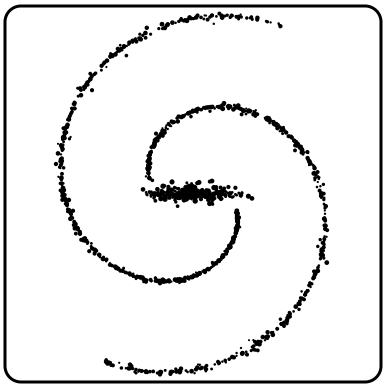
1 **Match each star with its class** using the clues: Sun, Rigel, Betelgeuse, Sirius, Aldebaran, Proxima Centauri, Spica, Procyon.

Star	Clue	Class
Sun	Our star: yellow, about 9,900 °F	_____
Rigel	The blue-white hunter's foot in Orion	_____
Betelgeuse	The red shoulder of Orion	_____
Sirius	The brightest star in the night sky, white	_____
Aldebaran	The orange eye of the Bull	_____
Proxima Centauri	The closest star after the Sun, a small red dwarf	_____
Spica	Blue-white star of Virgo	_____
Procyon	Yellow-white, in the Little Dog	_____

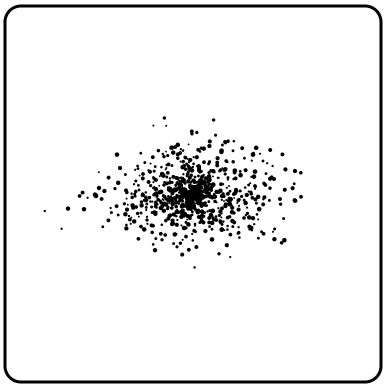
2 Is the Sun's surface hotter or cooler than Rigel's? _____

Galaxy Zoo ★ EXPLORER ★★ NAVIGATOR

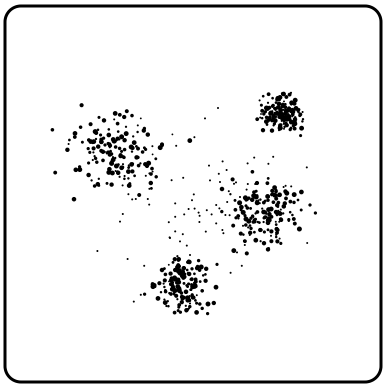
Galaxies come in different shapes. Look at each drawing, read the clues, and write its type.



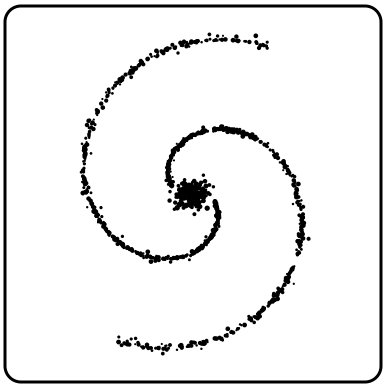
A _____



B _____



C _____



D _____

Spiral · Barred spiral · Elliptical · Irregular

1. Round or oval ball of old, reddish stars with no arms.
2. A flat disk with curved arms of young blue stars. Our Milky Way is one.
3. A spiral whose arms start from a straight bar of stars in the middle.
4. No clear shape: messy clumps, often after a collision.

1 Write the number of the clue that matches each drawing: A ____ B ____ C ____ D ____

2 The Milky Way is about 100,000 light-years wide, and our Sun is about 26,000 light-years from its center. About what fraction of the way from the center to the edge is that? (26,000 ÷ 50,000) _____

3 The Andromeda galaxy is 2.5 million light-years away. Its light left when no humans yet existed on Earth. About how many times farther is it than Betelgeuse (550 ly)? _____

Star Word Search ★ EXPLORER

Find the 14 words. They can go in any direction, even backward.

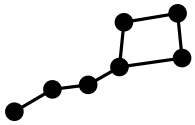
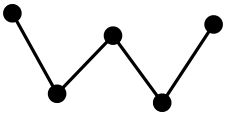
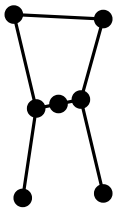
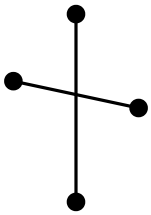
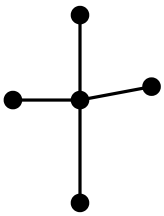
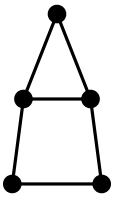
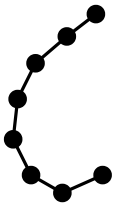
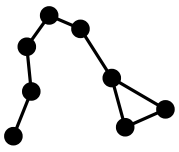
N U P N E I T F R A W D S P B
S V G T R O H T M C B F Y V Z
U X R D J G A L U B E N V E U
I H H B V Z N C Y L A S R U L
R C O N S T E L L A T I O N V
I G D Z J O R Q A C R J E O X
S P O L A R I S Q Z J L L R O
S X P Z X C A N V O L I O I B
A D J D F L X X F Y G G H O B
Y I Z W R R V N P K A H K N L
A V O N R E P U S P L T C K J
A D E M O R D N A O A Y A C G
E S U E G L E T E B X E L N O
R A S L U P G L O M Y A B N V
N P R O X I M A Z S W R Q K S

- ☐ ANDROMEDA
- ☐ BETELGEUSE
- ☐ BLACKHOLE
- ☐ CONSTELLATION
- ☐ DWARF
- ☐ GALAXY
- ☐ LIGHTYEAR
- ☐ NEBULA
- ☐ ORION
- ☐ POLARIS
- ☐ PROXIMA
- ☐ PULSAR
- ☐ SIRIUS
- ☐ SUPERNOVA

Constellation Memory Game

★ EXPLORER cut-out

Cut out the 16 cards, mix them face down, and take turns flipping two. Match each star pattern with its name. The player with the most pairs wins.

	**Big Dipper**		**Cassiopeia**
	**Orion**		**Southern Cross**
	**Cygnus (Swan)**		**Lyra**
	**Scorpius**		**Leo**

Only some constellations can be seen from every place: the Big Dipper and Cassiopeia from the north, the Southern Cross from the south. Orion, Leo and Scorpius are visible from almost everywhere on Earth.

Star Chart: Brightness vs. Color ★★★ COMMANDER

Astronomers plot stars on a chart of **color class** (hot → cool, left to right) and **brightness** (bottom to top). Most stars fall along a band called the **main sequence**. Plot each star as a dot and write its name beside it.

Star	Class	Brightness (1–5)
Sun	G	3
Rigel	B	5
Betelgeuse	M	5
Proxima	M	1
Sirius B	A	1
Aldebaran	K	4
Spica	B	4
Altair	A	3

Brightness	O	B	A	F	G	K	M
Brilliant							
High							
Medium							
Low							
Dim							

1. Draw a line that follows most of the dots from the upper left to the lower right. This is the **main sequence**. Which stars are far from it? _____

2. Betelgeuse is cool but very bright: it must be very _____ (small / huge). Sirius B is hot but dim: it must be very _____ .

Star Code Breakers ★★ NAVIGATOR

A **Caesar cipher** shifts each letter forward in the alphabet. Use the code wheel strip: the top row is the real letter, the bottom row is the secret one. Find the real letters.

Message 1 · shift 3

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C

top row = real letter · bottom row = coded letter

V W D U V D U H V X Q V

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Message 2 · shift 7

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G

top row = real letter · bottom row = coded letter

A O L T P S R F D H F O H Z

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

I P S S P V U Z V M Z A H Y Z

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Message 3 · you decide!

Write a secret message about a star or galaxy, pick a shift, and write the coded version. Swap with a friend.

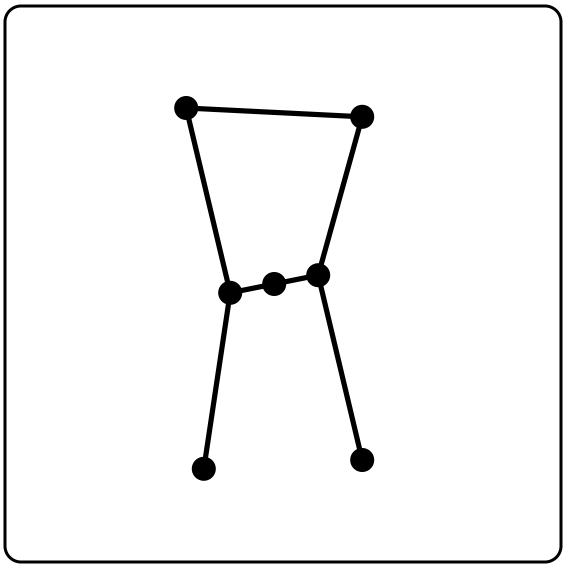
___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Star Lab · Pinhole Planetarium ★ EXPLORER ★★ NAVIGATOR

SAFETY An adult makes the holes with the pin or thumbtack. **Never point the tube at the Sun** or look at it through the tube. Use a flashlight only.

You need

- A cardboard tube or a paper cup
- A pin or thumbtack
- Black paper or foil
- A flashlight
- The Orion pattern below



Orion pattern. Copy it onto black paper.

Steps

1. Cut a circle of black paper to cover one end of the tube.
2. Place the pattern on it and poke a pin through each dot. Make Betelgeuse and Rigel a little bigger.
3. In a dark room, shine the flashlight through the open end and look at the wall.
4. Check your pattern against the real constellation on a clear night.

Hand measuring (outdoors)

Hold your arm straight. Your **fist** covers about 10° of sky, your **hand span** (thumb to pinky) about 20°, and your **pinky** about 1°. Measure these angles:

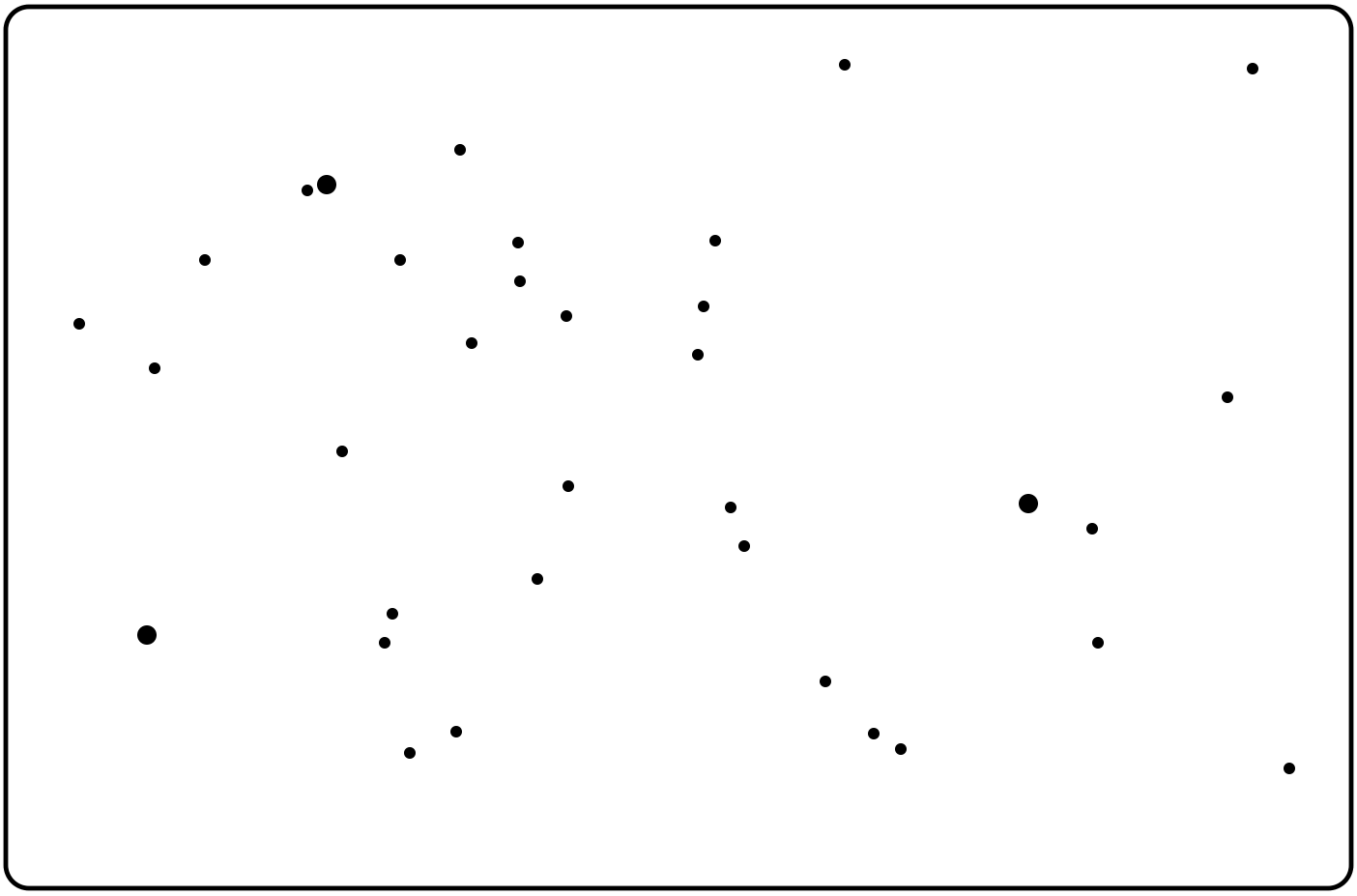
What I measured	Fists / spans	Angle
Orion's belt to Rigel		
Width of the Big Dipper (or Southern Cross)		
Moon to a bright star or planet		

1 Which was farther apart in the sky? _____ Does that mean the stars are really farther apart in space?

_____

Create Your Own Constellation ★ EXPLORER ★★ NAVIGATOR

Here is a patch of night sky. Connect some stars to make a picture: an animal, a hero, a machine, a monster… Draw it, name it, and write its story.



1. Name of my constellation: _____

2. Its story (who is it and why is it in the sky?):

_____

_____

_____

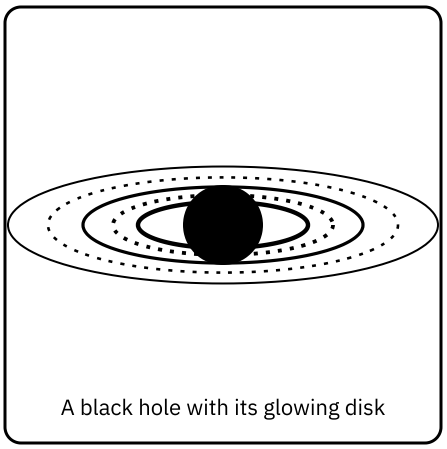
> Many cultures saw different pictures in the same stars. The Big Dipper is a plow, a wagon or a bear in different places!

Reading: Black Holes ★★ NAVIGATOR ★★★ COMMANDER

When a very massive star dies in a supernova, its core can collapse into a **black hole**: a place where gravity is so strong that nothing, not even light, can escape once it gets too close. The boundary is called the **event horizon**.

A black hole is not a hole or a giant vacuum cleaner. If the Sun were replaced by a black hole of the same mass, Earth would keep orbiting just as it does now, only in the dark and the cold.

We cannot see a black hole, but we can see hot gas swirling around it. In 2019 and 2022, the Event Horizon Telescope made the first images: the black holes in the galaxy M87 and at the center of our own Milky Way, called **Sagittarius A***.



A black hole with its glowing disk

1. **True or false?** a) Nothing can escape a black hole's event horizon. T / F b) A black hole would suck in the whole solar system if it replaced the Sun. T / F c) We can see the gas around a black hole. T / F

2. In your own words, why is a black hole called "black"?

3. Name two things you could do to "see" something you cannot see directly.

Unit Review · Mission Check ★ EXPLORER ★★ NAVIGATOR ★★★ COMMANDER

1. **Match**: light-year ___ constellation ___ galaxy ___ supernova ___
   A. an exploding star · B. a pattern of stars that look like a picture · C. the distance light travels in a year · D. a huge family of stars, gas and dust

2. **Order** the star colors from hottest to coolest: red · blue · yellow · orange:
   _____

3. **Calculate.** A star is 20 light-years away. Its light left it _____ years ago.

4. **Decode** (shift 3 back): **VWDU** = _____

5. **Sequence** the life of a Sun-like star: white dwarf · nebula · red giant · main sequence · protostar:
   _____

6. **Which is true?** T / F The stars of a constellation are close together. T / F The Sun is a star. T / F A galaxy is a kind of star.

7. **Compare** a spiral galaxy and an elliptical galaxy.
   _____
   _____

8. **Explain** why Betelgeuse looks red and Rigel looks blue.
   _____
   _____

Mission Log ★ EXPLORER

Check the boxes when you can do each one. Color a star for each section you enjoyed.

☐ I can explain what a light-year is.

☐ I can calculate how long light takes to travel.

☐ I can find and draw constellations.

☐ I can sort stars by color and temperature.

☐ I can tell the life story of a star.

☐ I can name the main types of galaxies.

☐ I can decode a Caesar cipher.

☐ I can explain what a black hole is.

My favorite activity was

Something new I learned

A question I still have about space

UNIT 6
STARS & GALAXIES
★ ★ ★
MISSION COMPLETE

Signed: _____

Date: _____

Astraviator

SPACE WORKBOOK

UNIT 7 OF 8

Life Beyond Earth

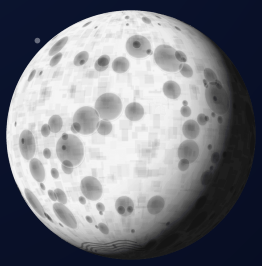
Habitable zones · Extremophiles · Exoplanets · Signals

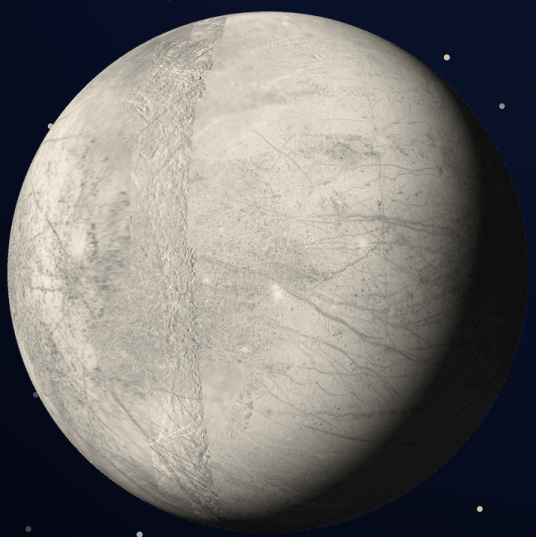
Puzzles · Cut-out cards · Experiments · Alien design

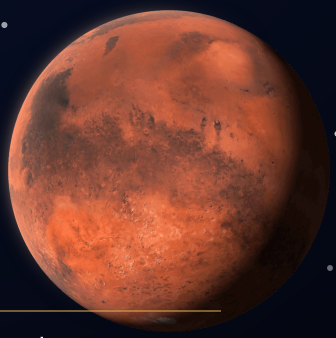
Ages 9–14 · three levels · answer key included

★ Explorer ★★ Navigator ★★★ Commander









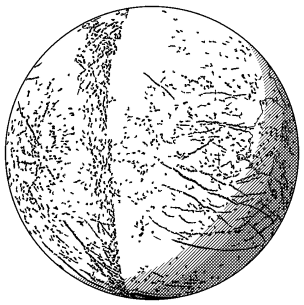
Print at 100% · black & white pages, color cover · Imagery rendered from NASA / USGS data and Solar System Scope textures (CC BY 4.0)

Mission Briefing: Is Anybody Out There? ★ EXPLORER

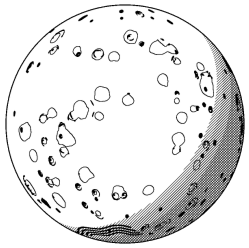
So far, Earth is the only place where we know life exists. But scientists search for it on other worlds. What do they look for?

Ingredients for life

1. **Liquid water**: it lets chemicals mix and move.
2. **Energy**: sunlight, heat from inside a planet, or chemical reactions.
3. **Building blocks**: carbon, nitrogen, hydrogen, oxygen and more.
4. **Time**: life on Earth took hundreds of millions of years to appear.



Europa



Enceladus

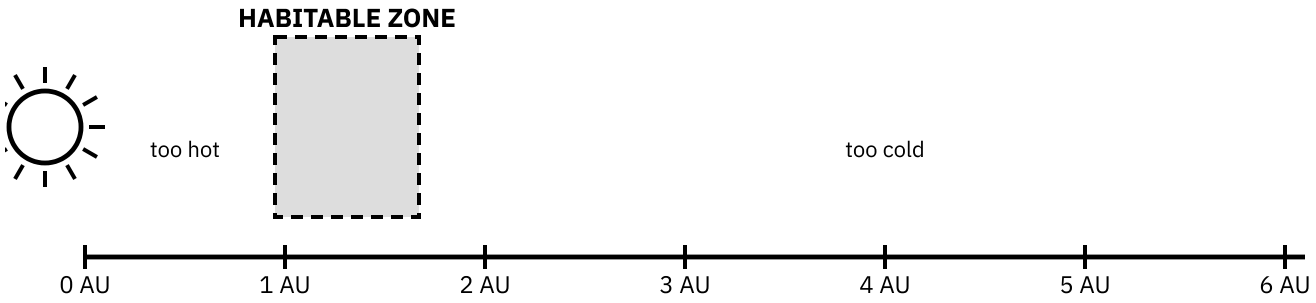
Where do we look?

Mars once had rivers and lakes. **Europa** and **Enceladus** hide salty oceans under their ice. **Titan** has lakes of liquid methane. Beyond our solar system, telescopes have found more than 5,000 **exoplanets**, planets around other stars.

World	Liquid water?	Where
Earth	Yes, surface oceans	–
Mars	Ice and briny water underground; past lakes	Jezero Crater (ancient lake)
Europa	Ocean under an ice shell 10–15 mi thick	Moon of Jupiter
Enceladus	Ocean under ice; geysers	Moon of Saturn

The Goldilocks Zone ★ EXPLORER ★★ NAVIGATOR

A planet that is too close to its star is too hot and its water boils away. Too far, and the water freezes. The area in between, where liquid water can exist on a planet's surface, is called the **habitable zone** (the "Goldilocks zone"). Distances are measured in **AU**: 1 AU = Earth's distance from the Sun = 93 million miles.



1. **Place the planets.** Draw a circle on the line at each distance and write its name above: Venus 0.72 AU · Earth 1 AU · Mars 1.52 AU · Jupiter 5.2 AU.

2. Which planets are inside the habitable zone (0.95 to 1.67 AU)? _____

3. How many miles is Mars from the Sun? 1.52 × 93,000,000 = _____ miles

4. **Red dwarf stars** are small and cool, so their habitable zone is very close in. Proxima Centauri's zone is about 0.05 AU. How many miles is that? _____ Is that closer to its star than Mercury (0.39 AU) is to the Sun? _____

5. Why might Europa and Enceladus have liquid water even though they are far outside the habitable zone?

_____

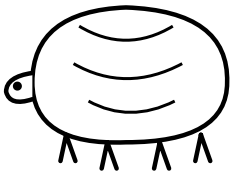
_____

Extremophile Trading Cards

★ EXPLORER cut-out & color

Extremophiles are living things that thrive in extreme places. If life can survive there on Earth, maybe it can survive on other worlds. Cut out, color and play: pick a category and compare with a friend's card. Two blank cards are for your own creature!

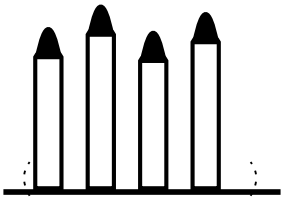
TARDIGRADE



Size	**0.02 in**
Lives	**Moss, water drops**
Survives	**Vacuum, radiation, −458 °F to 300 °F**
Space test	**Flew outside the ISS**

★ **Nicknamed "water bear"**

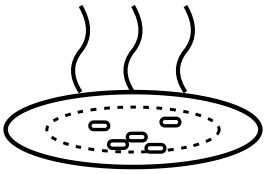
GIANT TUBE WORM



Size	**Up to 8 ft**
Lives	**Deep-sea vents**
Energy	**Chemicals, not sunlight**
Space link	**Hints for Europa's ocean floor**

★ **Lives with no sunlight at all**

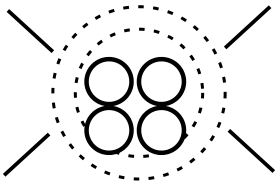
HOT-SPRING MICROBES



Size	**Microscopic**
Lives	**Yellowstone hot springs**
Survives	**Water above 160 °F**
Space link	**Models for hot places on Mars**

★ **Some enzymes made from them are used in labs**

RADIATION-PROOF BACTERIUM



Name	**Deinococcus radiodurans**
Lives	**Soil, dry places**
Survives	**Radiation 1,000× a human's limit**
Space link	**Could survive on Mars' surface?**

★ **Repairs its own DNA**

Extremophile Cards: Create & Compare ★★ NAVIGATOR

YOUR EXTREMOPHILE

Draw it here

Name	_____
Lives in	_____
Survives	_____
Space link	_____

YOUR EXTREMOPHILE

Draw it here

Name	_____
Lives in	_____
Survives	_____
Space link	_____

1 Which extremophile survives the most extreme temperature range? _____

2 The tube worm lives where there is no sunlight. Why does that make scientists more hopeful about life on Europa?

_____

_____

3 Temperature conversion: 160 °F − 32 = _____ ; × 5 ÷ 9 = _____ °C. Water boils at 212 °F. How many degrees below boiling is 160 °F? _____

4 Design a creature that could live on Titan (−290 °F, methane lakes, orange haze). Describe it here:

_____

_____

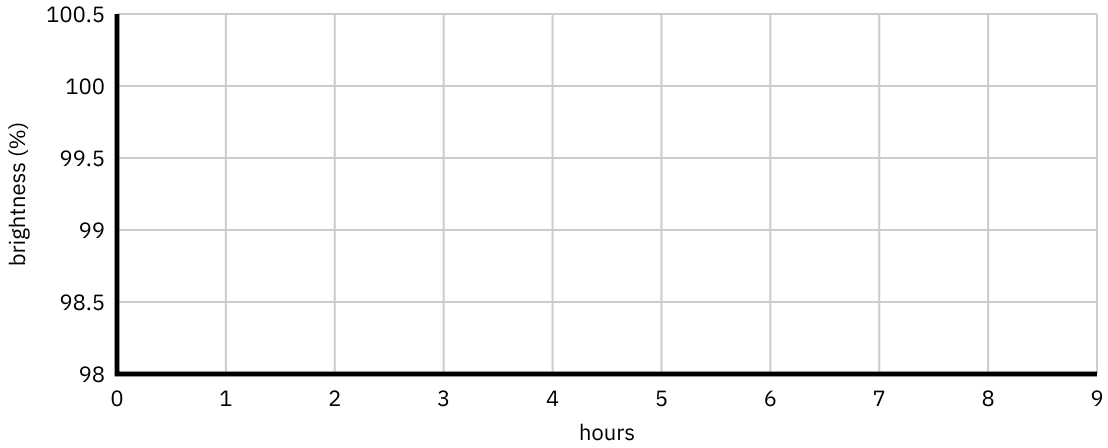
_____

Planet Hunter · The Transit Method ★★★ COMMANDER

How do we find planets around other stars? When a planet passes in front of its star, it blocks a little light, and the star gets slightly **dimmer**. This is a **transit**. Telescopes like **Kepler** and **TESS** look for these tiny dips.

Hour	0	1	2	3	4	5	6	7	8	9
Brightness (%)	100	100	100	99	99	99	99	100	100	100

Plot the table on the graph and join the dots.



1. How many hours did the transit last (from the first dip to the end)? _____

2. By how much did the star dim? _____ % That is 1/100 of its light.

3. **Planet size.** The dip equals (planet radius ÷ star radius)². If the dip is 0.01, then planet radius ÷ star radius = _____. The star is a Sun twin with a radius of 432,000 miles, so the planet's radius is _____ miles.

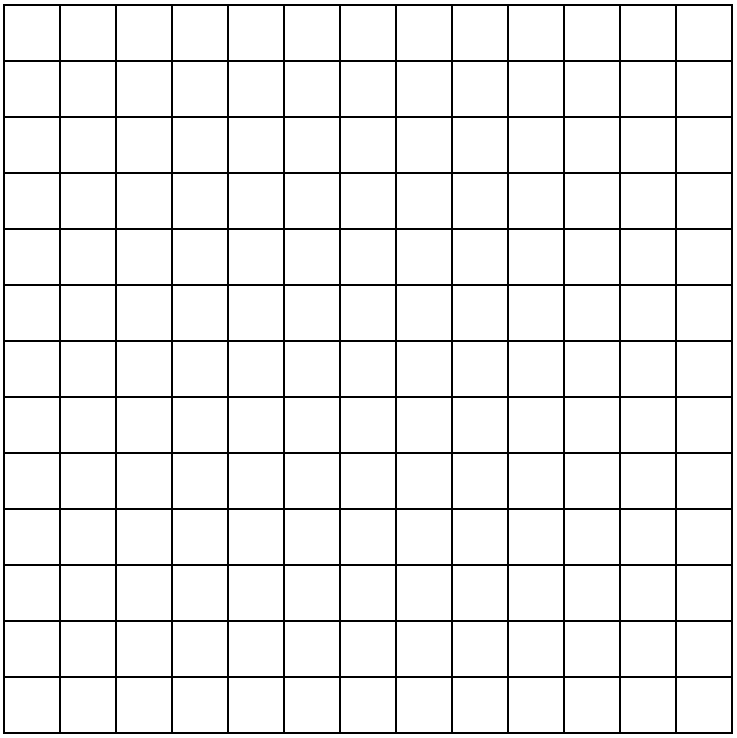
4. Compare it: Jupiter's radius is 43,400 miles and Earth's is 3,959. Is this planet more like _____ (Jupiter / Earth)?

5. This planet transits every 3 days. How many transits would the telescope see in 30 days? _____

Message to the Stars: Color by Code ★ EXPLORER ★★ NAVIGATOR

In 1974, scientists beamed the **Arecibo message** toward a star cluster 25,000 light-years away. It was a string of 1,679 ones and zeros that, arranged in a grid, made a picture. Try it yourself! Each row below is a code: **1 = color the square**, **0 = leave it white**. What picture appears?

1	1000000000001
2	0100000000010
3	0011111111100
4	0111111111110
5	1111111111111
6	1100111110011
7	1100111110011
8	1111111111111
9	0111111111110
10	0011111111100
11	0001110111000
12	0000111110000
13	0000011100000



1. What does the picture show? _____

2. Count the ones in row 5 (**1111111111111**): _____ . How many squares are colored in the whole picture? _____

3. **Your turn.** On the back of this page (or on grid paper), design a 9 × 9 picture and write its code, row by row, for a friend to decode. If a friend 25,000 light-years away received your message, how many years would it take to arrive? _____

Mission Planner Puzzle ★★ NAVIGATOR ★★★ COMMANDER

Four life-hunting probes launch on four different days, one to each world. Use the clues to find which world each day's probe visits. Write the world in the table.

Monday	
Tuesday	
Wednesday	
Thursday	

Mars · Europa · Enceladus · Titan

Clues

1. The Europa probe does not launch on Monday.
2. The Titan probe launches after the Enceladus probe.
3. The Mars probe launches the day right before the Europa probe.
4. The Titan probe launches last.
5. The Enceladus probe does not launch on Monday.

1 Which probe launches on Wednesday? _____

2 **Your turn.** Write three clues for a new puzzle with these worlds on three days.

_____

_____

_____

Alive or Not? Sorting Cards

★ EXPLORER cut-out

Scientists say something is **alive** if it grows, uses energy, reacts to its surroundings, makes copies of itself, and is made of cells. Cut out the cards and sort them into three groups: **ALIVE**, **NOT ALIVE** and **TRICKY** (scientists disagree!). Glue them in the boxes.

ALIVE	NOT ALIVE	TRICKY

Fire	**Oak tree**	**Mars rover**	**Cloud**
Bacteria	**Car**	**Dog**	**Virus**
Robot	**Seed**	**Crystal**	**Mushroom**

1. Fire grows, moves and uses energy. Why is it **not** alive?

2. If a rover found a rock on Mars that “grew” over time, how could you tell whether it was alive?

Lab · Does Salt Stop Ice? ★★ NAVIGATOR

SAFETY Do this with an adult. Do not taste the salty water. Frozen cups can be very cold: let an adult take them out and do not hold the ice against your skin.

On Mars, water can stay liquid at freezing temperatures if it is full of salt (**brine**). Scientists think Europa's ocean is salty too. Test how salt changes freezing!

You need

- 3 small cups
- 1½ cups of water
- Table salt
- A marker and a spoon
- A freezer

Steps

1. Put ½ cup of water in each cup.
2. Cup A: no salt. Cup B: 1 teaspoon of salt. Cup C: 4 teaspoons of salt. Stir until dissolved. Label the cups.
3. Place all cups in the freezer. Check every hour for 4 hours.

My prediction: _____

	Cup A (no salt)	Cup B (1 tsp)	Cup C (4 tsp)
Hour 1			
Hour 2			
Hour 3			
Hour 4			

Write: liquid, slushy or solid.

1 Which cup froze first? _____ Which stayed liquid longest? _____

2 Explain why salty water could stay liquid on cold Mars.

_____

_____

Math Lab · How Many Alien Worlds? ★★ NAVIGATOR ★★★ COMMANDER

Scientist **Frank Drake** proposed a chain of guesses to estimate how many civilizations might exist in the galaxy. Let's try a simple version. Each step uses a fraction of the previous number. These are *guesses*, not facts!

Step	Question	Fraction	Result
1	Stars in the Milky Way	–	100,000,000,000
2	Stars with planets	1/2	_____
3	…with a habitable planet	1/5	_____
4	…where life appears	1/1,000	_____
5	…and becomes intelligent	1/1,000	_____

1. Fill in the Result column. How many planets with simple life are there in the Milky Way (step 4)?
   _____

2. **What if?** Change the step 4 fraction to 1/1,000,000. How many planets with life now?
   _____

3. Would you say life in the universe is common or rare? Explain with your numbers.

   _____

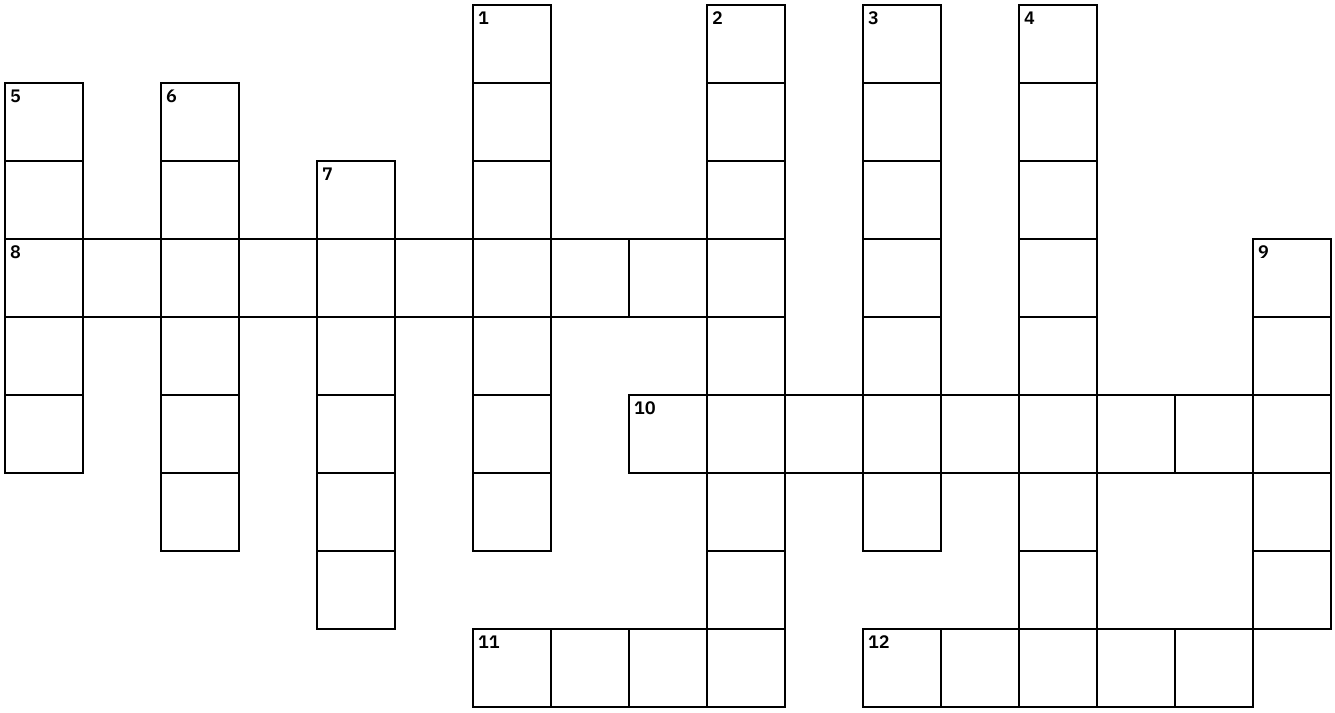
   _____

4. **Radio talk.** A radio signal travels at the speed of light. If a signal takes 4.24 years to reach Proxima Centauri, how long would a conversation take (one question and one reply)? _____ years

5. The first radio signals from Earth began about 100 years ago. Up to how many light-years have they traveled? _____

Astrobiology Crossword ★★ NAVIGATOR

Every answer is a word from this unit.



ACROSS →

8. Tiny “water bear” that survives space

10. A place where life could live

11. The Red Planet, once wetter

12. Moon with methane lakes

DOWN ↓

1. A living thing too small to see

2. Saturn moon with geysers

3. When a planet passes in front of its star

4. A planet around another star

5. The liquid life needs

6. Icy moon of Jupiter

7. A message sent by radio

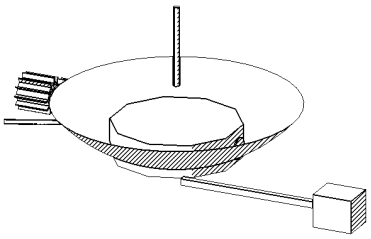
9. Europa and Enceladus hide one under the ice

Create · Your Golden Record

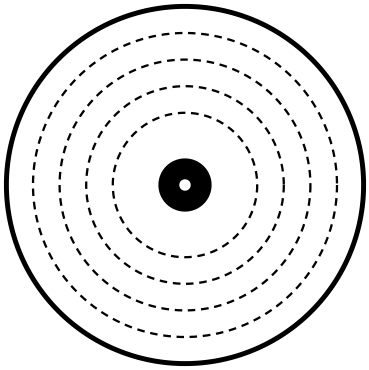
★ EXPLORER ★★ NAVIGATOR

In 1977, the **Voyager** probes each carried a **Golden Record** with sounds and pictures of Earth, in case someone finds it one day. Now you decide what to send. Choose **five** items from this list (or invent your own) and explain why.

- ☐ Sounds of rain and thunder
- ☐ A baby laughing
- ☐ Music by Bach
- ☐ A greeting in 55 languages
- ☐ A photo of a family
- ☐ A map of the solar system
- ☐ A drawing of a human
- ☐ A song of whales
- ☐ A recipe for pizza
- ☐ Photos of Earth's landscapes
- ☐ The sound of a heartbeat
- ☐ A children's song



Voyager carries the record



Decorate your record: draw 3 symbols

1. I choose: _____ because _____
2. I choose: _____ because _____
3. I choose: _____ because _____
4. I choose: _____ because _____
5. I choose: _____ because _____
6. Write a greeting for the aliens in one sentence:

_____

_____

Unit Review · Mission Check ★ EXPLORER ★★ NAVIGATOR ★★★ COMMANDER

1. **Match**: habitable zone ___ extremophile ___ exoplanet ___ transit ___
   A. a planet around another star · B. a living thing in extreme places · C. where liquid water can exist on the surface · D. a planet passing in front of its star

2. **List** three ingredients life needs:

3. **True or false?** a) Scientists have found life on Mars. T / F b) Europa may have an ocean under its ice. T / F c) A planet that is too close to its star is too cold. T / F

4. **Calculate.** A star dims by 4% during a transit. Its brightness drops from 100% to _____ %.

5. **Explain** why tardigrades interest astronomers.

6. **Order** from closest to farthest from the Sun: Europa · Mars · Earth · Enceladus:

7. **Argue.** Should we send a message to aliens? Give one reason for and one against.

8. **Predict.** Where in the solar system would you send the next life-detecting probe and why?

Mission Log ★ EXPLORER

Check the boxes when you can do each one. Color a star for each section you enjoyed.

☐ I can list what life needs to exist.

☐ I can explain the habitable zone.

☐ I can describe extremophiles and why they matter.

☐ I can explain how the transit method finds planets.

☐ I can decode a binary picture.

☐ I can solve a logic puzzle.

☐ I can tell alive from not alive.

☐ I can design a message for aliens.

My favorite activity was

Something new I learned

A question I still have about space

UNIT 7
LIFE BEYOND EARTH
★ ★ ★
MISSION COMPLETE

Signed: _____
Date: _____

Astraviator

SPACE WORKBOOK

UNIT 8 OF 8

Astronaut Life

Training · Spacewalks · Space food · Living in orbit

Puzzles · Experiments · Role cards · Mission patch

Ages 9–14 · three levels · answer key included

★ Explorer ★★ Navigator ★★★ Commander



Print at 100% · black & white pages, color cover · Imagery rendered from NASA / USGS data and Solar System Scope textures (CC BY 4.0)

Mission Briefing: Becoming an Astronaut ★ EXPLORER

Astronauts are scientists, engineers, pilots and doctors. They train for years to live and work where there is no air, no up and no down.

Training

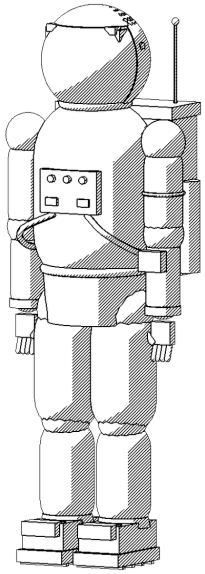
Trainees practice underwater in a giant pool to feel weightless, ride jets that fly in arcs, learn to speak Russian (for the ISS) and rehearse every emergency in simulators.

Living in microgravity

In orbit, astronauts float because they are in **free fall** around Earth. Sleeping bags are fixed to walls, food is eaten from pouches, and water forms floating balls. Without gravity, bones and muscles weaken, so astronauts exercise about 2 hours every day.

Spacewalks

A spacewalk, or **EVA** (extravehicular activity), lasts about 6 or 7 hours. The suit gives air, water, pressure and protection from heat and cold.

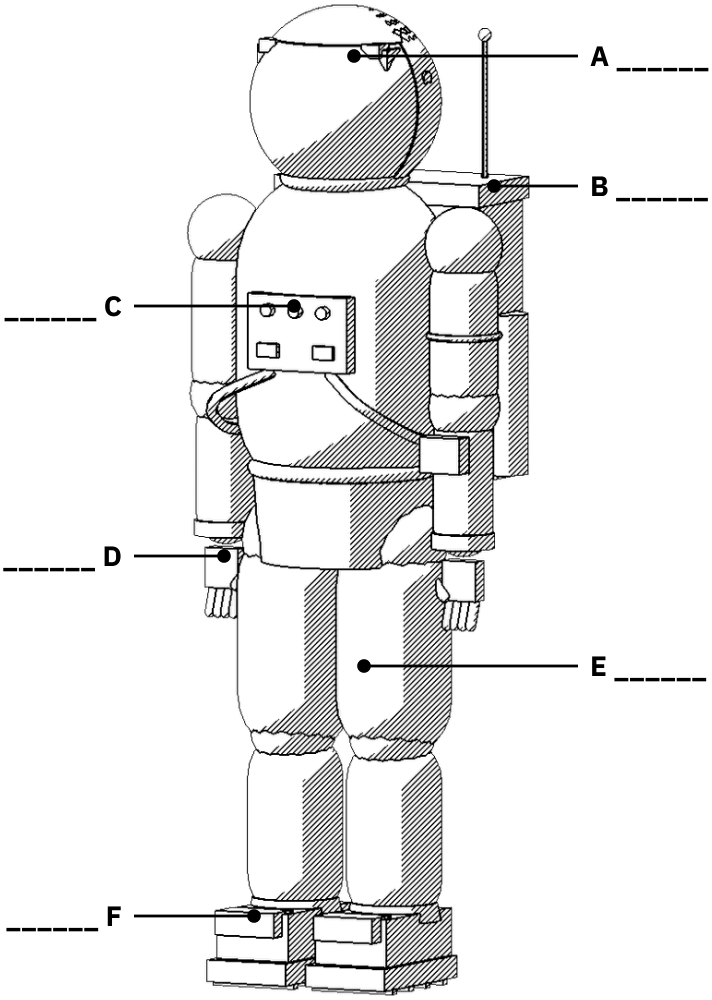


An astronaut in a spacesuit

Fact	Number
Sunrises per day on the ISS	16
Suit weight on Earth	~300 lb
Longest single spaceflight	437 days
Exercise per day	2 hours

Label the Spacesuit

★ EXPLORER ★★ NAVIGATOR



Helmet with a gold sun visor · Life-support backpack · Chest control panel · Gloves with fingertip heaters · Layers · Boots

Jobs

1. Keep fingers warm while gripping tools → _____
2. Protects the head and blocks glare → _____
3. Protect the feet and grip handrails → _____
4. Lets the astronaut control the suit's systems → _____
5. Gives oxygen, water and power for 8 hours → _____
6. Keep the astronaut at a safe pressure and temperature → _____

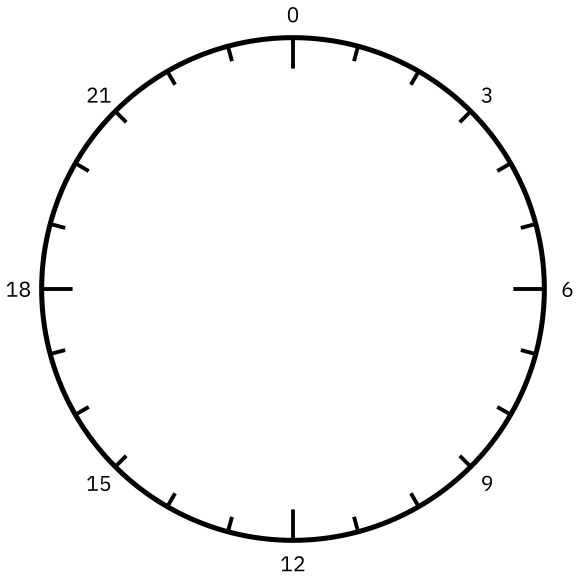
1. Write the name of each part (A–F) on its line, using the bank.
2. Write the letter of the part that does each job. Which part would you want to work best?

_____

A Day on the Space Station ★★ NAVIGATOR

The ISS runs on Greenwich time. Here is a typical day for an astronaut. Use the table to color a wedge for each activity on the 24-hour clock, starting at 0 (top) and going clockwise.

Activity	Hours	°
Sleep	8	_____
Exercise	2	_____
Meals & hygiene	3	_____
Science & work	7	_____
Station repairs	2	_____
Free time	2	_____
Total	_____	



1. Add the hours and write the total in the table. _____ Each hour is 360° ÷ 24 = _____ °. Fill in the degrees column (hours × 15).

2. What percent of the day is spent sleeping? 8 ÷ 24 = _____ %. And working on science? _____ %

3. The ISS circles Earth every 90 minutes. How many sunrises does an astronaut see during the 8 hours of sleep? _____

4. If you could change one activity, which would you change and why?

_____

_____

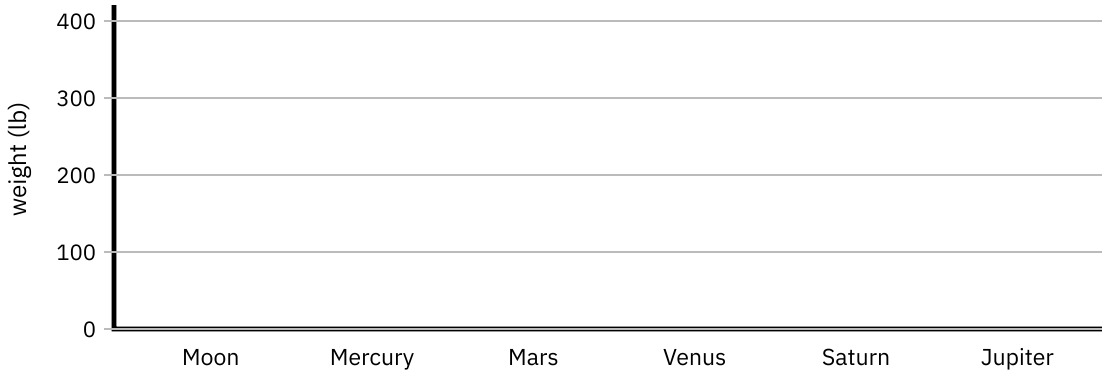
Math Lab · Your Weight on Other Worlds

★★ NAVIGATOR ★★★ COMMANDER

Mass is how much matter you are made of. It never changes. **Weight** is how hard gravity pulls on you, so it changes from world to world. In orbit you feel **weightless**, but you still have the same mass!

An astronaut weighs **160 lb** on Earth. Multiply by each world's gravity (Earth = 1).

World	Gravity	Weight (lb)
Moon	×0.165	_____
Mercury	×0.38	_____
Mars	×0.38	_____
Venus	×0.91	_____
Saturn	×1.07	_____
Jupiter	×2.53	_____
ISS (orbit)	≈ 0 (free fall)	



Draw a bar for each world.

1. On which world would the astronaut weigh the least? _____ The most? _____

2. The suit and backpack weigh 300 lb on Earth. How much do they weigh on the Moon? 300 × 0.165 = _____ lb

3. **Your weight.** Write your own weight: _____ lb. On the Moon you would weigh _____ lb. On Mars _____ lb.

4. Mass stays the same everywhere. Why can an astronaut still not lift a heavy satellite easily in orbit?

_____

_____

Pack the Food Box ★★ NAVIGATOR ★★★ COMMANDER

Every pound that goes to space is very expensive, so astronauts' food must be light and full of energy. You must pack one day of meals for one astronaut: **at most 18 ounces** and **at least 2,000 calories**. Choose from the list. Check the boxes of the items you pack.

	Food	Weight (oz)	Calories
☐	Oatmeal pouch	2.0	280
☐	Scrambled eggs	1.8	190
☐	Tortilla	1.0	90
☐	Peanut butter packet	1.2	200
☐	Trail mix	2.0	310
☐	Dried apricots	1.5	100
☐	Beef jerky	1.0	80
☐	Chicken & rice	4.0	350
☐	Mac & cheese	3.5	380
☐	Chocolate pudding	3.0	250
☐	Granola bar	1.5	190
☐	Drink powder	1.0	60

1. Total weight of your box: _____ oz. Is it at most 18? _____

2. Total calories: _____ . Is it at least 2,000? _____

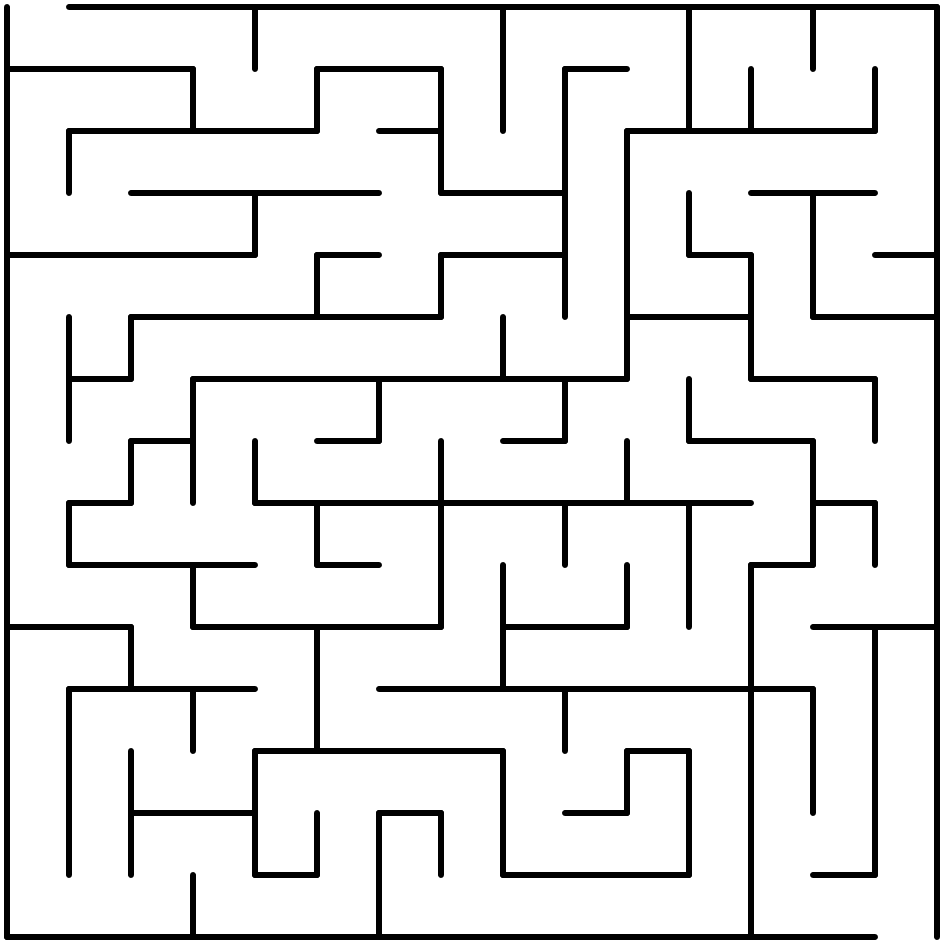
3. **Calories per ounce** shows which foods give the most energy for the least weight. Find the best food: calories ÷ weight = _____ . Which is it? _____

4. Why are most space foods dried, and how are they prepared before eating?

_____

Spacewalk Maze ★ EXPLORER ★★ NAVIGATOR

An astronaut must climb along the handrails from the airlock (top-left) to the broken antenna (bottom-right) without crossing the walls of the station. Draw the safe route!



1 The astronaut moves 1 foot every 2 seconds. If the route has 119 blocks of 4 feet each, how many seconds does the walk take? _____

Word Scramble ★ EXPLORER

The letters of each word are mixed up. Unscramble them with the clues. Then copy the letters from the shaded boxes (the first letter of each answer) to find the hidden word!

1	**OTARASUNT**	A person trained to travel in space	
2	**GVTYAIR**	The force that pulls things down	
3	**TLMHEE**	Protects an astronaut's head	
4	**TTRHEE**	A cord that keeps you from floating away	
5	**CSUEPLA**	Where the crew rides in the rocket	
6	**SHETLSGEWI**	How you feel in orbit	
7	**CRSEEIXE**	Astronauts do it 2 hours a day	
8	**OSTIANT**	The ISS is a space ____	
9	**MSIONSI**	A trip with a goal	
10	**RNNTGIIA**	Years of it come before launch	

1. Hidden word (first letters, in order): _____

2. Use three of the words in a sentence about a space mission:

_____

_____

Logic Lab: Crew Sudoku ★ EXPLORER ★★★ COMMANDER

A · Suit sudoku ★

Each row, column and 2×2 box must have **H** (helmet), **G** (gloves), **B** (boots) and **P** (backpack) once.

	H	B	G
G			
		P	H
			B

B · Crew sudoku ★★★

Fill the 6×6 grid with the six crew roles once per row, column and 2×3 box: **Co** commander, **Pi** pilot, **En** engineer, **Dr** doctor, **Sc** scientist, **Ge** geologist.

		En	Dr		Ge
Ge		Dr	Pi	Sc	
			Ge		
Dr		Co	Sc	En	
En					Dr
Co		Pi	En	Ge	Sc

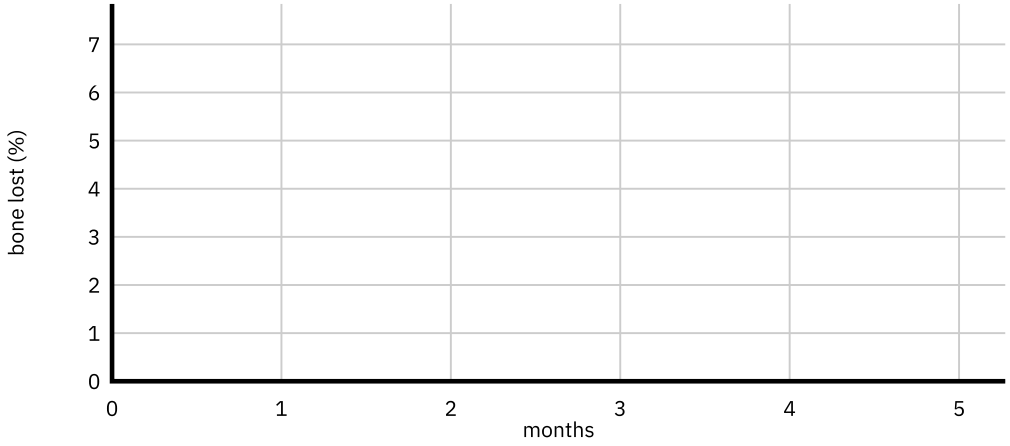
Graph Lab: Bones in Space ★★ NAVIGATOR ★★★ COMMANDER

Without gravity pulling on them, bones lose density. Doctors estimate that astronauts lose about **1 percent** of bone density in the legs and hips each month on long missions (about 1.2% in this model). Exercise helps, but does not stop it completely.

Months in space	0	1	2	3	4	5
Bone lost (%)	0	1.2				

1 Complete the table: each month the loss grows by 1.2%. Fill in months 2 to 5. (Month 2: 1.2 + 1.2 = _____)

2 Make a line graph of the table below. Mark one point per month and join them.



3 A mission to Mars could last about 30 months. How much bone could be lost? 30 × 1.2 = _____ %

4 Name two ways to keep bones and muscles strong in space.

_____

_____

What Would You Do? Scenario Cards

★ EXPLORER cut-out

Cut out the cards. Take turns reading one aloud: the other players choose A, B or C. The answers are in the answer key.

SCENARIO 4

Radio contact with Mission Control is lost.

A. Panic and shout.

B. Follow the checklist and try the backup radio.

C. Turn off the station.

SCENARIO 6

It is bedtime and nothing holds you down.

A. Float in the middle of the module.

B. Zip into a sleeping bag fixed to the wall.

C. Sleep inside the airlock.

SCENARIO 3

You feel dizzy in your first days in orbit.

A. Move slowly, rest and tell the flight doctor.

B. Do flips to get used to it.

C. Stop drinking water.

SCENARIO 7

You skipped exercise for three days.

A. It is fine, space is easy.

B. Bones and muscles weaken: return to your 2 hours a day.

C. Only exercise your arms.

SCENARIO 8

After splashdown, your body feels very heavy.

A. Run around to celebrate.

B. Sit and let the recovery team help you: gravity is back!

C. Jump out of the capsule alone.

SCENARIO 5

A drifting ball of water escapes from your drink pouch.

A. Swat it with your hand.

B. Catch it with a towel or sip it with a straw.

C. Ignore it.

SCENARIO 1

A smoke alarm rings on the station.

A. Ignore it and keep working.

B. Put on masks, tell Mission Control and look for the source.

C. Open a hatch to let the smoke out.

SCENARIO 2

A tool floats away during a spacewalk.

A. Chase it without your tether.

B. Stay tethered and tell your crewmate and Mission Control.

C. Throw another tool after it.

Lab · Falling Water (Microgravity at Home) ★★ NAVIGATOR

SAFETY An adult makes the hole with the thumbtack or nail and handles it carefully. Do this outdoors or over a sink, and do not drop the bottle on anyone's feet.

Astronauts float because they are in **free fall**. You can see how free fall changes things with a bottle of water. Do this experiment over a sink, tub or outdoors!

You need

- A plastic bottle (16 oz) filled with water
- A thumbtack or nail (an adult makes the hole)
- A sink, bathtub or outdoor space
- A friend to watch

Steps

1. An adult pokes one small hole near the bottom of the bottle.
2. Fill it with water and cover the hole with your thumb.
3. Hold the bottle high over the sink. Remove your thumb: water squirts out.
4. Drop the bottle while the water squirts. Watch the stream as it falls!

My prediction:

	Water squirts while held still?	Water squirts while falling?
Trial 1		
Trial 2		
Trial 3		

1. What happened to the stream of water while the bottle was falling?

2. In free fall, both the bottle and the water fall at the same rate, so the water does not push on the hole. How is this like an astronaut in orbit?

3. Draw what the water stream looked like before and during the fall:

Reading: A Spacewalk Day ★★ NAVIGATOR

Maya floats through the hatch of the airlock. For the past two hours she has breathed pure oxygen to get nitrogen out of her blood, and now she is wearing a suit that weighs 300 pounds on Earth but feels like nothing in orbit. Her partner Leo helps her check the seals twice. Then the hatch opens and the Earth appears beneath her boots: a bright blue ball slipping by at 17,500 miles per hour.

Maya clips her tether to a handrail before she moves an inch. “Always one hand on the station,” says Leo. Her job is to replace a broken antenna cable. She works slowly with big gloves, tools tied to her suit so they cannot float away. After six and a half hours, she and Leo return, tired but happy. Tonight she will sleep strapped to the wall and dream of the blue Earth.

1. Why did Maya breathe pure oxygen for two hours before the walk?

2. What is the purpose of the tether?

3. How many minutes did the spacewalk last? (6.5 hours × 60) _____

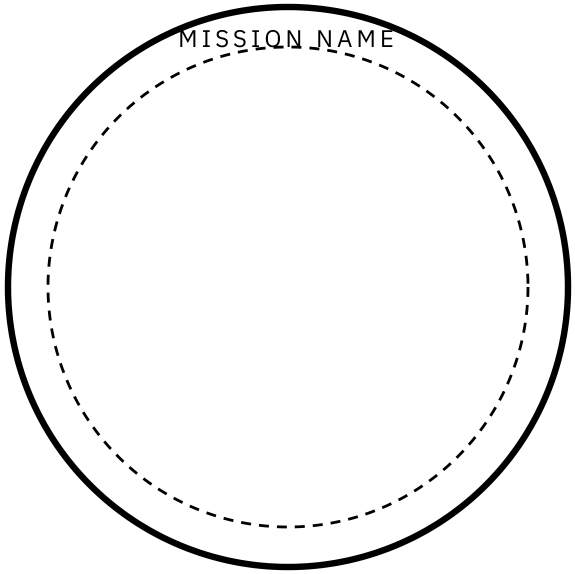
4. How many miles does the station travel during the walk? 17,500 × 6.5 = _____

5. **True or false?** a) Maya’s suit feels heavy in orbit. T / F b) Tools are tied to the suit. T / F c) Maya works alone, with no partner. T / F

6. Write a title for the story and a sentence about how Maya feels.

Create · Mission Patch & Letter Home ★ EXPLORER ★★ NAVIGATOR

Every mission has a **patch**: a badge that shows its goal, its crew and its spirit. Design yours in the circle, then write a letter from space to someone at home.



- Pick a symbol for your goal (planet, rocket, star…)
- Write the crew names around the edge
- Choose a motto in Latin or your language: *Ad astra* = “to the stars”
- Add a year

1 Mission name: _____

2 Destination: _____

Letter from space

Tell what you see out the window, what you eat, how you sleep and what you miss.

Unit Review · Mission Check ★ EXPLORER ★★ NAVIGATOR ★★★ COMMANDER

1. **Match**: EVA ___ microgravity ___ tether ___ airlock ___

   A. a cord that stops you floating away · B. the chamber used to enter and leave the station · C. a spacewalk · D. the feeling of weightlessness in orbit

2. **Why** do astronauts float in the ISS even though gravity there is almost as strong as on Earth?

3. **Calculate.** An astronaut who weighs 120 lb on Earth would weigh _____ lb on Mars (×0.38).

4. **Explain** why astronauts exercise 2 hours every day.

5. **Order** the steps before a spacewalk: open the hatch · check the seals · breathe pure oxygen · put on the suit:

6. **Choose** the best action: a smoke alarm rings. ☐ Ignore it. ☐ Put on masks and tell Mission Control. ☐ Open a hatch.

7. **Compare** eating on Earth and eating in orbit.

8. **Decide.** Which crew role would you like to have, and what would your first task be?

Mission Log ★ EXPLORER

Check the boxes when you can do each one. Color a star for each section you enjoyed.

☐ I can explain why astronauts float.

☐ I can name the parts of a spacesuit.

☐ I can plan a day in orbit.

☐ I can calculate weight on other worlds.

☐ I can pack food for space.

☐ I can read a graph about bones in space.

☐ I can solve a maze and sudoku puzzles.

☐ I can design a mission patch.

My favorite activity was

_____

Something new I learned

_____

_____

A question I still have about space

_____

_____

UNIT 8
ASTRONAUT LIFE
★ ★ ★
MISSION COMPLETE

Signed: _____
Date: _____

Astraviator

SPACE WORKBOOK

APPENDIX

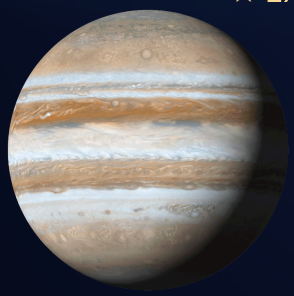
Field Guide

29 destinations of the Solar System Explorer

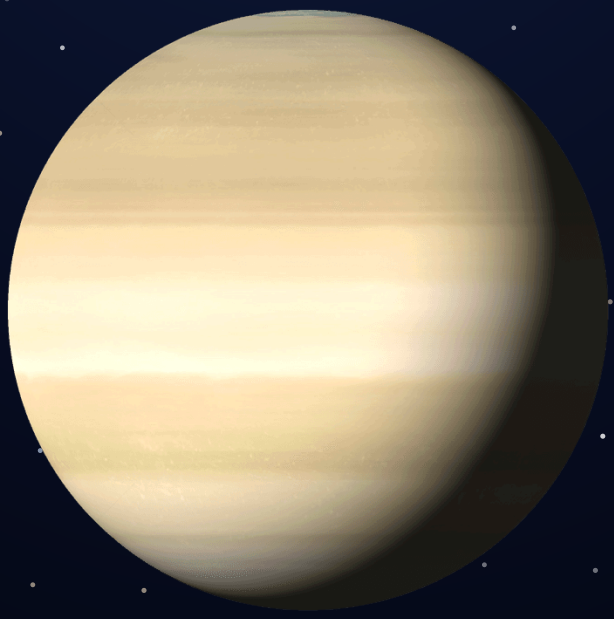
Facts · Records · Spacecraft · Check-list

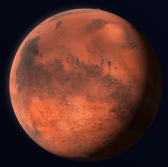
Ages 9–14 · three levels · answer key included

★ Explorer · ★★ Navigator · ★★★ Commander











astraviator.com | Solar System Explorer Simulator

Print at 100% · black & white pages, color cover · Imagery rendered from NASA / USGS data and Solar System Scope textures (CC BY 4.0)

How to Use This Field Guide

This appendix collects the key facts of every destination in the **Astraviator Solar System Explorer** simulator. Use it with any unit, as a quick reference while you solve puzzles, or take it along as you explore the game.

Check-list: destinations visited

Tick the box each time you visit the destination in the simulator and pass its quiz.

PLANETS

- ☐ Mercury
- ☐ Venus
- ☐ Earth
- ☐ Mars
- ☐ Jupiter
- ☐ Saturn
- ☐ Uranus
- ☐ Neptune

MOONS & SMALL WORLDS

- ☐ The Moon
- ☐ Pluto
- ☐ Ceres
- ☐ Europa
- ☐ Io
- ☐ Titan
- ☐ Enceladus
- ☐ Halley's Comet
- ☐ Asteroid belt

SPACECRAFT

- ☐ International Space Station
- ☐ Hubble Space Telescope
- ☐ James Webb Space Telescope
- ☐ Voyager 1
- ☐ New Horizons
- ☐ Perseverance rover

STARS

- ☐ The Sun
- ☐ Proxima Centauri
- ☐ Sirius
- ☐ Betelgeuse

DEEP SKY

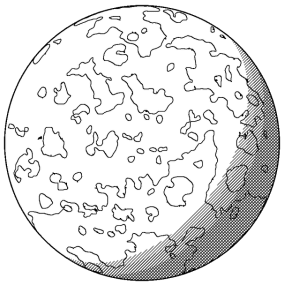
- ☐ Orion and its nebula
- ☐ Andromeda Galaxy

> Numbers are rounded and shown in US customary units (miles, feet, pounds, °F). Distances to stars are in light-years: 1 light-year ≈ 5.88 trillion miles.

Field Guide · 01–03

Mercury

Rocky planet · PLANETS



☐ Visited in the simulator

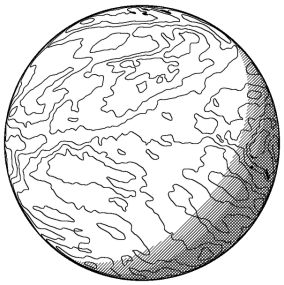
Diameter	**3,032 mi**
Mass	**0.055 Earths**
Gravity	**12 ft/s² (0.38 g)**
Solar day	**176 Earth days**
Year	**88 days**
Temperature	**−292 °F to +806 °F**
Atmosphere	**Exosphere of sodium and potassium**
Moons	**0**
Missions	**Mariner 10, MESSENGER, BepiColombo**

★ **Wow:** A solar day on Mercury (sunrise to sunrise) lasts 176 Earth days: twice as long as its year.

◆ **Real mission:** MESSENGER took 6.6 years with six gravity assists. BepiColombo, launched in 2018, reaches its orbit in late 2026.

Venus

Rocky planet · PLANETS



☐ Visited in the simulator

Diameter	**7,521.1 mi**
Mass	**0.815 Earths**
Gravity	**29.1 ft/s² (0.9 g)**
Rotation	**243 days, retrograde**
Year	**225 days**
Mean temperature	**867 °F**
Pressure	**92 times Earth's**
Atmosphere	**96.5% CO_2, sulfuric acid clouds**
Missions	**Venera, Magellan, Venus Express, Akatsuki**

★ **Wow:** Venus spins backwards compared with almost all planets: the Sun rises in the west there.

◆ **Real mission:** Probes take 4 to 5 months. Venus Express needed 153 days.

Earth

Our planet · PLANETS



☐ Visited in the simulator

Diameter	**7,917.5 mi**
Mass	**5.97 × 10^{24} kg**
Gravity	**32.2 ft/s²**
Day	**23 h 56 min (sidereal)**
Year	**365.25 days**
Mean temperature	**59 °F**
Atmosphere	**78% N_2, 21% O_2**
Water	**Covers 71% of the surface**
Moons	**1**

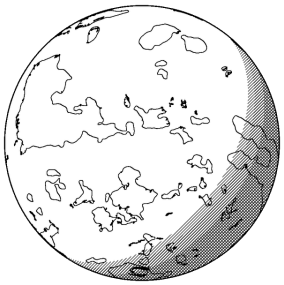
★ **Wow:** It is the only place in the universe where we know life exists. Its magnetic field protects us from the solar wind.

◆ **Real mission:** From the Moon, Apollo 11 returned in about 2.5 days. Artemis's Orion enters the atmosphere at about 24,900 mph.

Field Guide · 04–06

Mars

Rocky planet · PLANETS



☐ Visited in the simulator

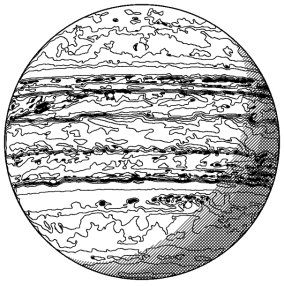
Diameter	**4,212 mi**
Mass	**0.107 Earths**
Gravity	**12.2 ft/s² (0.38 g)**
Day (sol)	**24 h 37 min**
Year	**687 days**
Temperature	**−220 °F to +68 °F**
Atmosphere	**95% CO_2, pressure 0.6% of Earth's**
Moons	**Phobos and Deimos**
Missions	**Viking, Curiosity, Perseverance, Tianwen-1**

★ **Wow:** Olympus Mons is almost 14 mi high, two and a half times Everest, and its base is about 373 mi wide, more than the distance between Madrid and Barcelona.

◆ **Real mission:** Perseverance took 203 days (2020–2021). Launch windows open every 26 months.

Jupiter

Gas giant · PLANETS



☐ Visited in the simulator

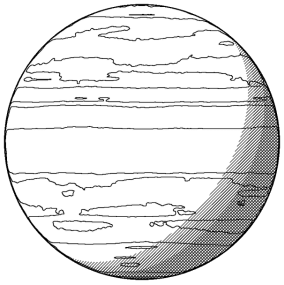
Diameter	**86,880 mi (11 Earths)**
Mass	**318 Earths**
Gravity	**81.4 ft/s² (2.5 g)**
Day	**9 h 56 min**
Year	**11.9 years**
Temperature (clouds)	**−166 °F**
Atmosphere	**90% hydrogen, 10% helium**
Moons	**More than 90 known**
Missions	**Pioneer, Voyager, Galileo, Juno, JUICE, Europa Clipper**

★ **Wow:** Its mass is 2.5 times that of all the other planets combined. Its magnetosphere is the largest structure in the solar system after the heliosphere.

◆ **Real mission:** Juno took almost 5 years (2011–2016). JUICE (ESA) will arrive in 2031.

Saturn

Gas giant · PLANETS



☐ Visited in the simulator

Diameter	**72,365 mi**
Mass	**95 Earths**
Density	**0.69 g/cm³ (less than water)**
Gravity	**34.1 ft/s²**
Day	**10 h 33 min**
Year	**29.4 years**
Temperature	**−220 °F**
Moons	**274 confirmed**
Missions	**Pioneer 11, Voyager 1 and 2, Cassini-Huygens**

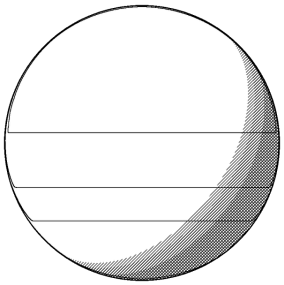
★ **Wow:** Its rings are about 174,000 mi across, but their typical thickness is only about 33 feet.

◆ **Real mission:** Cassini took 6 years and 9 months (1997–2004), with gravity assists from Venus, Earth and Jupiter.

Field Guide · 07–09

Uranus

Ice giant · PLANETS



☐ Visited in the simulator

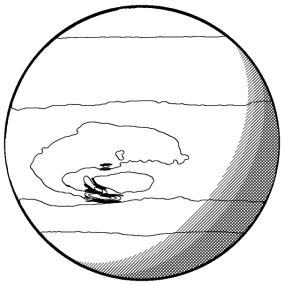
Diameter	**31,518 mi**
Mass	**14.5 Earths**
Gravity	**28.5 ft/s²**
Day	**17 h 14 min (retrograde)**
Year	**84 years**
Axial tilt	**97.8°**
Minimum temperature	**−371 °F**
Atmosphere	**H_2, He and methane (blue-green color)**
Moons and rings	**29 moons, 13 rings**

★ **Wow:** It rotates lying on its side: each pole gets 42 years of continuous daylight followed by 42 years of night.

◆ **Real mission:** Only Voyager 2 has visited it, in 1986, after 8.5 years of travel.

Neptune

Ice giant · PLANETS



☐ Visited in the simulator

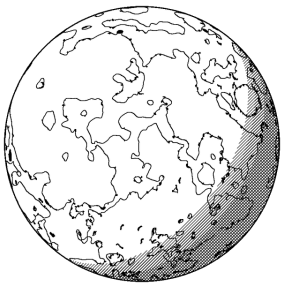
Diameter	**30,599 mi**
Mass	**17.1 Earths**
Gravity	**36.58 ft/s²**
Day	**16 h 6 min**
Year	**164.8 years**
Winds	**Up to 1,300 mph**
Temperature	**−353 °F**
Moons	**16**
Missions	**Voyager 2 (1989)**

★ **Wow:** It was discovered with pencil and paper. Le Verrier calculated where it should be from Uranus's perturbations, and Galle found it in 1846 less than 1° from the prediction.

◆ **Real mission:** Voyager 2 took 12 years (1977–1989).

The Moon

Natural satellite of the Earth · MOONS & SMALL WORLDS



☐ Visited in the simulator

Diameter	**2,159 mi**
Mass	**7.35×10^{22} kg (1.2% of Earth)**
Gravity	**5.31 ft/s² (0.17 g)**
Day	**29.5 Earth days**
Temperature	**−279 °F to +261 °F**
Atmosphere	**Almost empty exosphere**
Mean distance	**238,900 mi**
People who have walked on it	**12 (1969–1972)**
Key missions	**Apollo, Luna, Chang'e, Chandrayaan-3, Artemis**

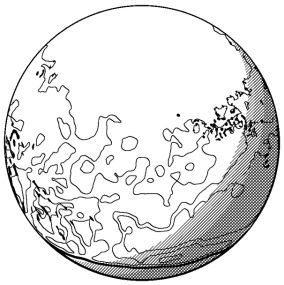
★ **Wow:** It drifts away from the Earth 1.5 in every year. We know this thanks to the laser retroreflectors the Apollo astronauts left behind.

◆ **Real mission:** Apollo 11 took 3 days and 3 hours to get there (1969). Artemis II needed about 4 days.

Field Guide · 10–12

Pluto

Dwarf planet · MOONS & SMALL WORLDS



☐ Visited in the simulator

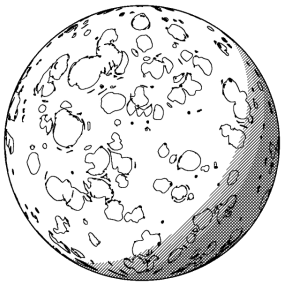
Diameter	**1,477 mi**
Mass	**0.0022 Earths**
Gravity	**2 ft/s²**
Day	**6.4 days**
Year	**248 years**
Temperature	**−382 °F**
Atmosphere	**Thin, nitrogen-based, with blue hazes**
Moons	**5 (Charon is the largest)**
Mission	**New Horizons (14 July 2015)**

★ **Wow:** Its “heart” is a 621 mi nitrogen glacier that renews itself by convection: the surface is less than 10 million years old.

◆ **Real mission:** New Horizons took 9.5 years (2006–2015), with a gravity assist from Jupiter.

Ceres

Dwarf planet in the belt · MOONS & SMALL WORLDS



☐ Visited in the simulator

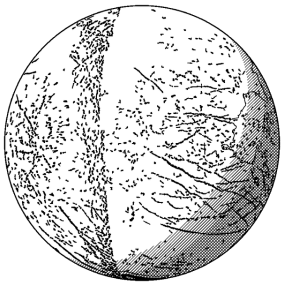
Diameter	**584 mi**
Mass	**About a third of the belt**
Gravity	**0.92 ft/s²**
Day	**9 h 4 min**
Year	**4.6 years**
Temperature	**−157 °F on average**
Discovery	**Giuseppe Piazzi, 1 January 1801**
Mission	**Dawn (2015–2018)**

★ **Wow:** The bright spots in Occator Crater are sodium carbonate salts left behind when underground brine evaporated.

◆ **Real mission:** Dawn arrived in 2015 after 7.5 years of travel and a stop at Vesta.

Europa

Moon of Jupiter · MOONS & SMALL WORLDS



☐ Visited in the simulator

Diameter	**1,940 mi**
Gravity	**4.30 ft/s²**
Orbit	**3.55 days around Jupiter**
Temperature	**−256 °F (equator)**
Crust	**9.3 to 16 mi of ice**
Ocean	**About 62 mi deep**
Missions	**Galileo, Juno, Europa Clipper (2030)**

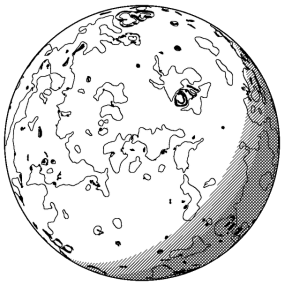
★ **Wow:** Beneath its ice lies a salty ocean holding more than twice as much water as all of Earth’s oceans.

◆ **Real mission:** Europa Clipper: launched in October 2024, it will arrive in April 2030.

Field Guide · 13–15

Io

Moon of Jupiter · MOONS & SMALL WORLDS



Diameter	**2,264 mi**
Gravity	**5.9 ft/s²**
Orbit	**1.77 days**
Active volcanoes	**More than 400**
Temperature	**–202 °F (lava at 2,912 °F)**
Plumes	**Up to 311 mi high**
Missions	**Voyager, Galileo, Juno**

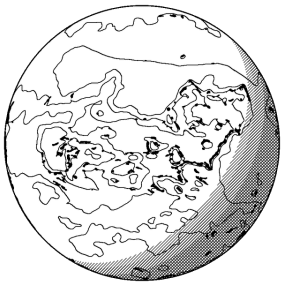
☐ Visited in the simulator

★ **Wow:** It is the most volcanically active body known. Its surface renews itself so fast that it has not a single impact crater.

◆ **Real mission:** Galileo took 6 years (1989–1995) to reach the Jupiter system.

Titan

Moon of Saturn · MOONS & SMALL WORLDS



Diameter	**3,200 mi (larger than Mercury)**
Gravity	**4.43 ft/s²**
Orbit	**15.9 days**
Atmosphere	**95% N_2, methane; 1.5 times Earth's pressure**
Temperature	**–290 °F**
Lakes	**Liquid methane and ethane**
Missions	**Cassini-Huygens, Dragonfly (2034)**

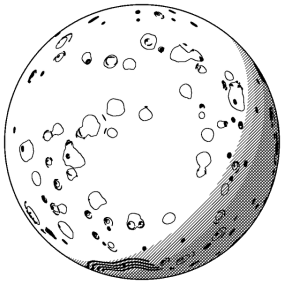
☐ Visited in the simulator

★ **Wow:** It is the only place, apart from Earth, with lakes and rivers on its surface. It rains methane.

◆ **Real mission:** Huygens landed in 2005, 7 years after launch. Dragonfly will launch in 2028 and arrive in 2034.

Enceladus

Moon of Saturn · MOONS & SMALL WORLDS



Diameter	**313 mi**
Gravity	**0.36 ft/s²**
Orbit	**1.37 days**
Temperature	**–324 °F**
Reflectivity	**The highest in the solar system**
Ocean	**Global, salty, beneath the ice**
Mission	**Cassini (23 flybys)**

☐ Visited in the simulator

★ **Wow:** Its geysers shoot water from an underground ocean into space. That water forms Saturn's E ring.

◆ **Real mission:** Cassini reached Saturn in 2004 and flew through Enceladus's plumes just 30 mi above the ground.

Field Guide · 16–18

Halley's Comet

Periodic comet · MOONS & SMALL WORLDS

Sketch it here

Nucleus	**9.3 × 5 mi**
Period	**75–76 years**
Last perihelion	**9 February 1986**
Next perihelion	**July 2061**
Aphelion	**≈ 35 AU (beyond Neptune)**
Albedo	**0.04: darker than coal**
Missions	**Giotto, Vega 1 and 2, Suisei, Sakigake**

☐ Visited in the simulator

★ **Wow:** Every October the Earth crosses its dust trail. These are the Orionids, a meteor shower made of little pieces of Halley.

◆ **Real mission:** The European Giotto probe reached it in 8 months in 1986 and passed 370 mi from the nucleus.

Asteroid belt

Region between Mars and Jupiter · MOONS & SMALL WORLDS

Sketch it here

Location	**Between 2.2 and 3.2 AU from the Sun**
Total mass	**About 3% of the Moon**
Cataloged objects	**More than 1.3 million**
The largest	**Ceres, Vesta, Pallas, Hygiea**
Mean spacing	**Nearly 620,000 mi**
Missions	**Dawn, Lucy, Psyche (2029)**

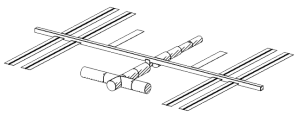
☐ Visited in the simulator

★ **Wow:** If we gathered all its asteroids together, they would form a body smaller than the Moon.

◆ **Real mission:** Probes cross it in a few months. None has ever hit an asteroid by accident: it is almost empty.

International Space Station

Orbital laboratory · 261 mi · SPACECRAFT



☐ Visited in the simulator

Altitude	**≈ 261 mi**
Speed	**17,100 mph (4.76 mi/s)**
Orbit	**92 minutes**
Mass	**≈ 463 tons**
Length	**358 ft (a football field)**
Inhabited since	**2 November 2000**
Partners	**NASA, Roscosmos, ESA, JAXA, CSA**
Planned retirement	**2030**

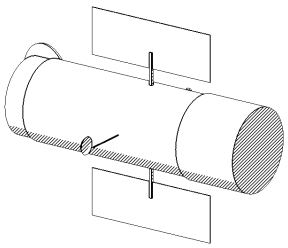
★ **Wow:** It has been continuously inhabited for more than 25 years. It is the most expensive object humanity has ever built.

◆ **Real mission:** A Crew Dragon takes 5 to 30 hours to dock. A Soyuz or a Progress has done it in about 3 hours.

Field Guide · 19–21

Hubble Space Telescope

Orbital observatory · 320 mi · SPACECRAFT



☐ Visited in the simulator

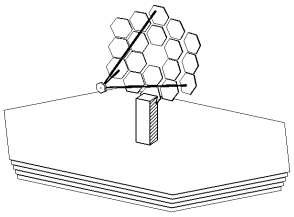
Launch	**24 April 1990 (Discovery)**
Mirror	**7.9 ft**
Altitude	**≈ 320 mi**
Speed	**17,000 mph**
Size	**43.3 ft, like a bus**
Mass	**12 tons**
Servicing missions	**5 (1993–2009)**
Observations	**More than 1.6 million**

★ **Wow:** Its mirror came out with an error of 2.2 microns, 50 times smaller than the thickness of a hair. It was enough to blur the images until astronauts fitted it with “glasses” in 1993.

◆ **Real mission:** The Space Shuttle Discovery released it into orbit on 25 April 1990, the day after launch.

James Webb Space Telescope

Infrared observatory · L2 · SPACECRAFT



☐ Visited in the simulator

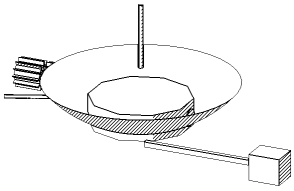
Launch	**25 December 2021 (Ariane 5, Kourou)**
Location	**L2 point, 930,000 mi away**
Mirror	**21 ft, 18 gold-plated beryllium segments**
Sunshield	**5 layers, like a tennis court**
Temperature	**≈ –387 °F; MIRI at –447 °F**
Light	**Infrared**
Agencies	**NASA, ESA, CSA**

★ **Wow:** The gold on its mirror is a layer about 100 billionths of a yards thick: in total, about 48 grams, like a golf ball.

◆ **Real mission:** It took 30 days to reach L2 and 6 months to deploy, cool down and calibrate.

Voyager 1

Interstellar probe · SPACECRAFT



☐ Visited in the simulator

Launch	**5 September 1977**
Speed	**≈ 37,900 mph (11 mi/s)**
Interstellar space	**Since 25 August 2012**
Power	**Radioisotope generators (plutonium)**
On board	**The Golden Record**

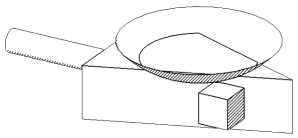
★ **Wow:** In November 2026 it will be one light-day from Earth: its signal will take 24 hours to arrive.

◆ **Real mission:** Voyager 1 has been traveling for 49 years. It passed Jupiter in 1979 and Saturn in 1980.

Field Guide · 22–24

New Horizons

Kuiper Belt probe · SPACECRAFT



Launch	**19 January 2006 (Atlas V)**
Departure speed	**36,373 mph, a record**
Pluto	**14 July 2015, at 7,770 mi**
Arrokoth	**1 January 2019**
Mass	**1,050 lb, like a grand piano**
Curiosity	**Carries some of Clyde Tombaugh's ashes**

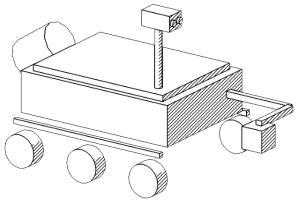
☐ Visited in the simulator

★ **Wow:** It is the fastest spacecraft ever launched from Earth: it crossed the Moon's orbit in under 9 hours. Its speed is the one used in this game.

◆ **Real mission:** It reached Pluto in 9.5 years. It keeps moving away at about 31,100 mph.

Perseverance rover

Explorer on Mars · Jezero Crater · SPACECRAFT



☐ Visited in the simulator

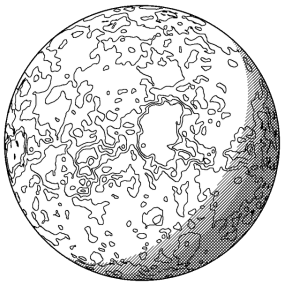
Landing	**18 February 2021**
Site	**Jezero Crater (ancient lake)**
Mass	**2,260 lb**
Size	**Like a car (9.8 ft)**
Power	**Plutonium generator (MMRTG)**
Top speed	**0.093 mph**
Companion	**Ingenuity helicopter (72 flights)**

★ **Wow:** Ingenuity made the first powered flight on another planet on 19 April 2021. It was planned to fly 5 times and flew 72.

◆ **Real mission:** Perseverance took 203 days to go from Earth to Mars and landed with the "7 minutes of terror".

The Sun

G2V yellow dwarf star · STARS



☐ Visited in the simulator

Diameter	**864,000 mi (109 Earths)**
Mass	**99.86% of the solar system**
Gravity	**899 ft/s² (28 g)**
Surface	**9,932 °F**
Nucleus	**27 million °F**
Corona	**2–5 million °F**
Age	**4,600 million years**
Light to Earth	**8 min 20 s**

★ **Wow:** Every second it converts about 4.4 million tons of matter into energy.

◆ **Real mission:** Parker Solar Probe, launched in 2018, passed 3.8 million mi from the surface in December 2024, at 430,000 mph.

Field Guide · 25–27

Proxima Centauri

Red dwarf · nearest star · STARS

Sketch it here

☐ Visited in the simulator

Distance	**4.25 light-years**
Type	**M5.5 red dwarf**
Size	**0.15 times the Sun**
Mass	**0.12 times the Sun**
Temperature	**≈ 5,072 °F**
Brightness	**0.17% of the Sun's luminosity**
Planets	**Proxima b (habitable zone) and Proxima d**
System	**Triple, with Alpha Centauri A and B**

★ **Wow:** It will live about 4 trillion years, hundreds of times longer than the Sun, burning its hydrogen very slowly.

◆ **Real mission:** At Voyager 1's speed it would take about 75,000 years. The Breakthrough Starshot project proposes laser sails at 20% of the speed of light: about 20 years.

Sirius

Double star · the brightest · STARS

Sketch it here

☐ Visited in the simulator

Distance	**8.6 light-years**
Apparent brightness	**−1.46: the brightest star of the night**
Sirius A	**2 solar masses, 25 times more luminous**
Temperature	**9,940 K**
Sirius B	**Earth-sized white dwarf**
Orbital period	**50.1 years**
Constellation	**Canis Major**

★ **Wow:** Sirius B has almost the mass of the Sun squeezed into the size of the Earth: a teaspoon of its matter would weigh about 11 tons.

◆ **Real mission:** No spacecraft is heading for Sirius. At Voyager 1's speed, about 150,000 years.

Betelgeuse

Red supergiant · STARS

Sketch it here

☐ Visited in the simulator

Distance	**≈ 550 light-years**
Size	**≈ 760 times the Sun**
Mass	**15–20 Suns**
Luminosity	**≈ 100,000 Suns**
Temperature	**≈ 3,600 K**
Age	**8–10 million years**
Fate	**Supernova within the next ~100,000 years**

★ **Wow:** If it took the Sun's place, its surface would reach past the asteroid belt.

◆ **Real mission:** At Voyager 1's speed it would take almost 10 million years.

Field Guide · 28–29

Orion and its nebula

Constellation · M42 at 1,344 light-years · DEEP SKY

Sketch it here

Type	**Constellation and emission nebula**
Nebula M42	**At 1,344 light-years, 24 light-years wide**
Main stars	**Betelgeuse, Rigel, Bellatrix, Saiph**
Belt	**Alnitak, Alnilam and Mintaka (the Three Marys)**
Distances	**From 250 to 2,000 light-years**
Visible	**In winter (northern hemisphere)**

☐ Visited in the simulator

★ **Wow:** Orion's stars are not close together: they only appear so from Earth. If we move, the hunter's figure falls apart.

◆ **Real mission:** At Voyager 1's speed, reaching the nebula would take about 24 million years.

Andromeda Galaxy

Spiral galaxy M31 · DEEP SKY

Sketch it here

Distance	**2.5 million light-years**
Diameter	**≈ 220,000 light-years**
Stars	**≈ 1 trillion**
Central black hole	**≈ 100 million Suns**
Speed	**Approaching at about 68 mi/s**
Satellites	**M32, M110 and dozens more**
Visible	**Naked eye, in autumn**

☐ Visited in the simulator

★ **Wow:** The light we see today left Andromeda when modern humans did not yet exist on Earth.

◆ **Real mission:** Even at the speed of light it would take us 2.5 million years. At our speed, more than 46,000 million: 3 times the age of the universe.

My Field Notes

Use these lines for your discoveries, new questions and sketches.

Sketch