National Aeronautics and Space Administration

Exploring Planetary Moons

Exploring Planetary Moons

Working with fractions and proportions is an important skill in mathematics because so many problems that we encounter in life require a working knowledge of proportional relationships. For example, if a Cook wants to enlarge a recipe to feed 25 people rather than 12, the original ingredients need to be 'scaled up' using proportional techniques.

Many textbooks provided 'real world' examples for students using familiar examples drawn from every-day situations, such as the Cook's Dilemma we just mentioned, but there are many other areas where proportional relationships aid in understanding our physical world.

This collection of activities is intended for students looking for additional challenges in the math and physical science curriculum in grades 3 through 6, but where the topics are drawn from astronomy and space science. This book 'Exploring Planetary Moons' introduces students to some of the most unusual places in our solar system that are not planets. Using simple proportional relationships and working with fractions, they will study the relative sizes of the larger moons in our solar system, and explore how temperatures change from place to place using the Celsius and Kelvin scales.

For more weekly classroom activities about astronomy and space visit the NASA website,

http://spacemath.gsfc.nasa.gov

Add your email address to our mailing list by contacting Dr. Sten Odenwald
Sten.F.Odenwald@nasa.gov

Front and back cover credits: Front) Top row: Io, Moon, Europa, Triton, Pluto, Titania Center: Mimas; Bottom Row: Ganymede, Titan, Mercury, Callisto; Back) Two images of Saturn's moon Titan (Cassini), an image of Titan's surface (Huygens), and an image of Titan, Saturn and Saturn's ring shadows (Cassini).

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Table of Contents

AAAS: Project:2061 Benchmarks

(3-5) - Quantities and shapes can be used to describe objects and events in the world around us. 2C/E1 --- Mathematics is the study of quantity and shape and is useful for describing events and solving practical problems. 2A/E1 **(6-8)** Mathematicians often represent things with abstract ideas, such as numbers or perfectly straight lines, and then work with those ideas alone. The "things" from which they abstract can be ideas themselves; for example, a proposition about "all equal-sided triangles" or "all odd numbers". 2C/M1

NCTM: Principles and Standards for School Mathematics

Grades 3-5 :

- Develop understanding of fractions as parts of unit wholes, as parts of a collection, as locations on number lines, and as divisions of whole numbers
- Use models, benchmarks, and equivalent forms to judge the size of fractions

Grade 6-8 :

- Understand and use ratios and proportions to represent quantitative relationships
- Work flexibly with fractions, decimals, and percents to solve problems

Common Core Standards

Develop an understanding of fractions as numbers
3.NF.1. Understand a fraction 1/b as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction a/b as the quantity formed by a parts of size 1/b.

Extend understanding of fraction equivalence and ordering
4.NF.1. Explain why a fraction a/b is equivalent to a fraction (n × a)/(n × b) by using visual fraction models, with attention to how the number and size of the parts differ even though the two fractions themselves are the same size. Use this principle to recognize and generate equivalent fractions

Build fractions from unit fractions by applying and extending previous understandings of operations on whole numbers.
4.NF.4. Apply and extend previous understandings of multiplication to multiply a fraction by a whole number.

Apply and extend previous understandings of multiplication and division to multiply and divide fractions.
5.NF.6. Solve real world problems involving multiplication of fractions and mixed numbers, e.g., by using visual fraction models or equations to represent the problem.

Understand ratio concepts and use ratio reasoning to solve problems
6.RP.1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities
6.RP.2. Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship

NASA Resources

NASA Our World has created many dramatic video programs describing the moon and lunar exploration. Here are a few examples.

Visit **http://tinyurl.com/4xm5sm** and find over 80 other videos for grade K-5 students.

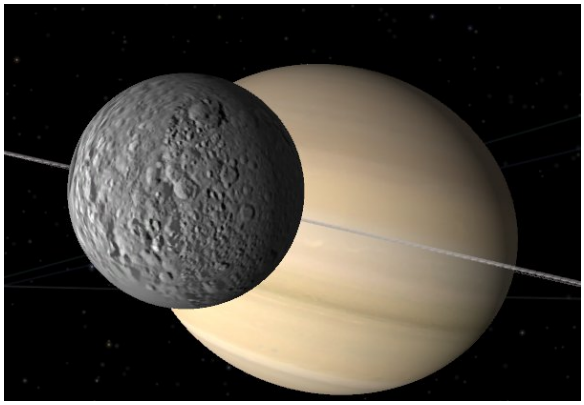
Our World: Moons in our Solar System -

Did you know astronomers have identified more than 168 moons in our solar system? How big is Ganymede? How small is Deimos? Which moons might have what it takes to support life? Follow the NASA missions to learn about these unique bodies in space.

Our World: What is a Solar System?

Find out why one amateur astronomer created an amazing graphic of the 88 largest objects in our solar system. Learn just what makes up a solar system and find out how we classify the thousands of objects in our own solar system.

Eyes on the Solar System is an online, interactive 3-dimensional model of the major bodies in our solar system, suitable for engaging students in open-ended, real-world research. **http://eyes.nasa.gov/index.html**



Introduction to Planetary Moons

Moons -- also called satellites -- come in many shapes, sizes and types. They are solid bodies, and few have atmospheres. Most of the planetary moons probably formed from the gas and dust circulating around the planets when the planets were forming, billions of years ago.

As of 2012, astronomers have found at least 168 moons orbiting the planets in our solar system. This number does not include the six moons of the dwarf planets, nor does it include the tiny satellites that orbit some asteroids. Another 23 moons have been discovered but have not been confirmed yet.

Usually the term *moon* brings to mind a perfectly round object, like Earth's Moon. The two moons of Mars, Phobos and Deimos, are different. Both are lumpy-looking, and are too small in mass to allow all their gravity to pull them into round shapes.

Jupiter has 63 known moons including the largest moon in the solar system: Ganymede. Many of Jupiter's outer moons have highly elliptical orbits and orbit backwards (opposite to the spin of the planet). Saturn, Uranus and Neptune also have some irregular moons, which orbit far from their respective planets. Astronomers think these are captured asteroids from the distant Kuiper Belt Region beyond the orbit of Pluto.

Most moons in our solar system are named after mythological characters from a wide variety of cultures. Uranus is the exception. The moons of this planet are named for characters in William Shakespeare's plays and from Alexander Pope's poems. Moons are given temporary names like 'S/2009 S1', which means the first satellite discovered at Saturn in 2009. The International Astronomical Union approves an official name for a newly-discovered moon, once other astronomers can confirm that it really exists.

Name: Moon (Luna)
Planet: Earth
Diameter: 3,476 kilometers
Composition: Rock

The Moon formed about 4.4 billion years ago when a body the size of Mars collided with Earth.

What percentage of the Moon 's composition is rock?

The Solar System's Many Moons !

Planet	Number of Moons
Mercury	0
Venus	0
Earth	1
Mars	2
Jupiter	63
Saturn	62
Uranus	27
Neptune	13

Astronomers have discovered that most of the planets in our solar system have moons orbiting them!

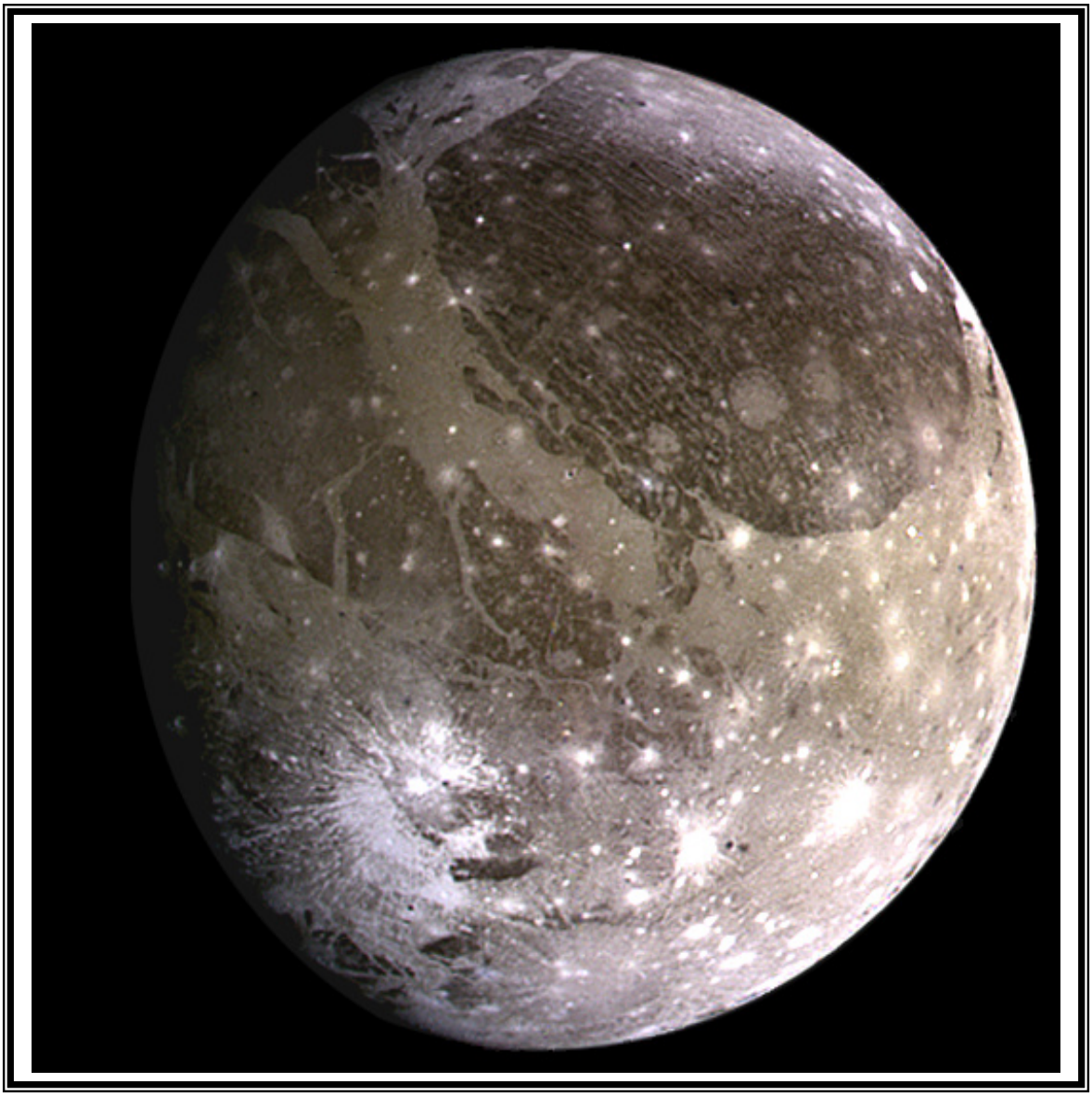
The table above is a tally of the number of moons that orbit each planet as of the year 2012. Can you answer the following questions?

Problem 1 – Which planet has the most moons?

Problem 2 - What is the total number of known moons in our solar system? What fraction of all the moons orbit the planet Saturn?

Problem 3 – The first four planets are the Terrestrial planets. The next four planets are the Gas Giants. Which group has more moons- the Terrestrial planets or Gas Giants?

Problem 4 - What fraction of the moons are found outside the orbit of Jupiter?



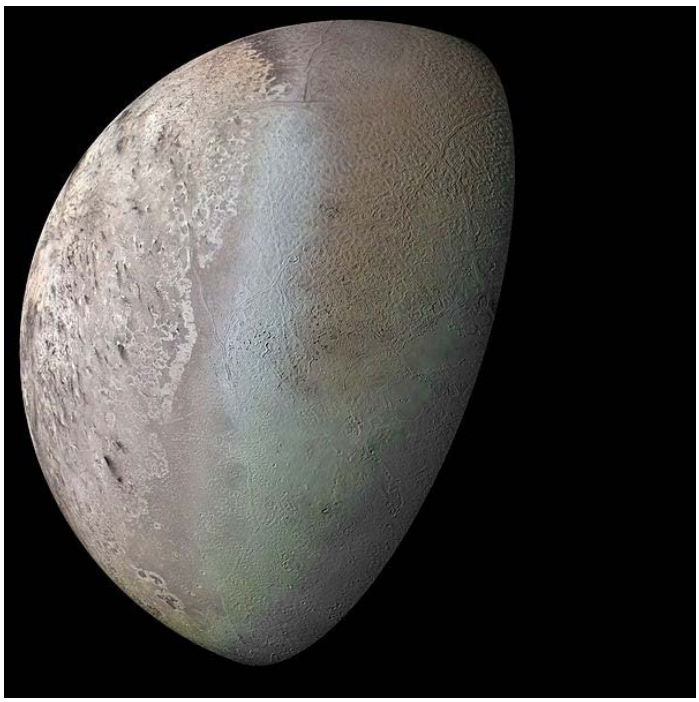
Name: Ganymede
Planet: Jupiter
Diameter: 5,268 kilometers
Composition: 50% rock and 50% ice

The only moon in the solar system that has its own magnetic field, created by liquid salt water under its surface crust.

What is the radius of Ganymede?

The Moons of Neptune!

Moon Name	Diameter (kilometer)
Naiad	66
Thalassa	82
Despina	150
Galatea	176
Larissa	194
Proteus	420
Triton	2720
Nereid	340
Halimede	62
Sao	44
Laomedeia	42
Psamathe	40
Neso	60



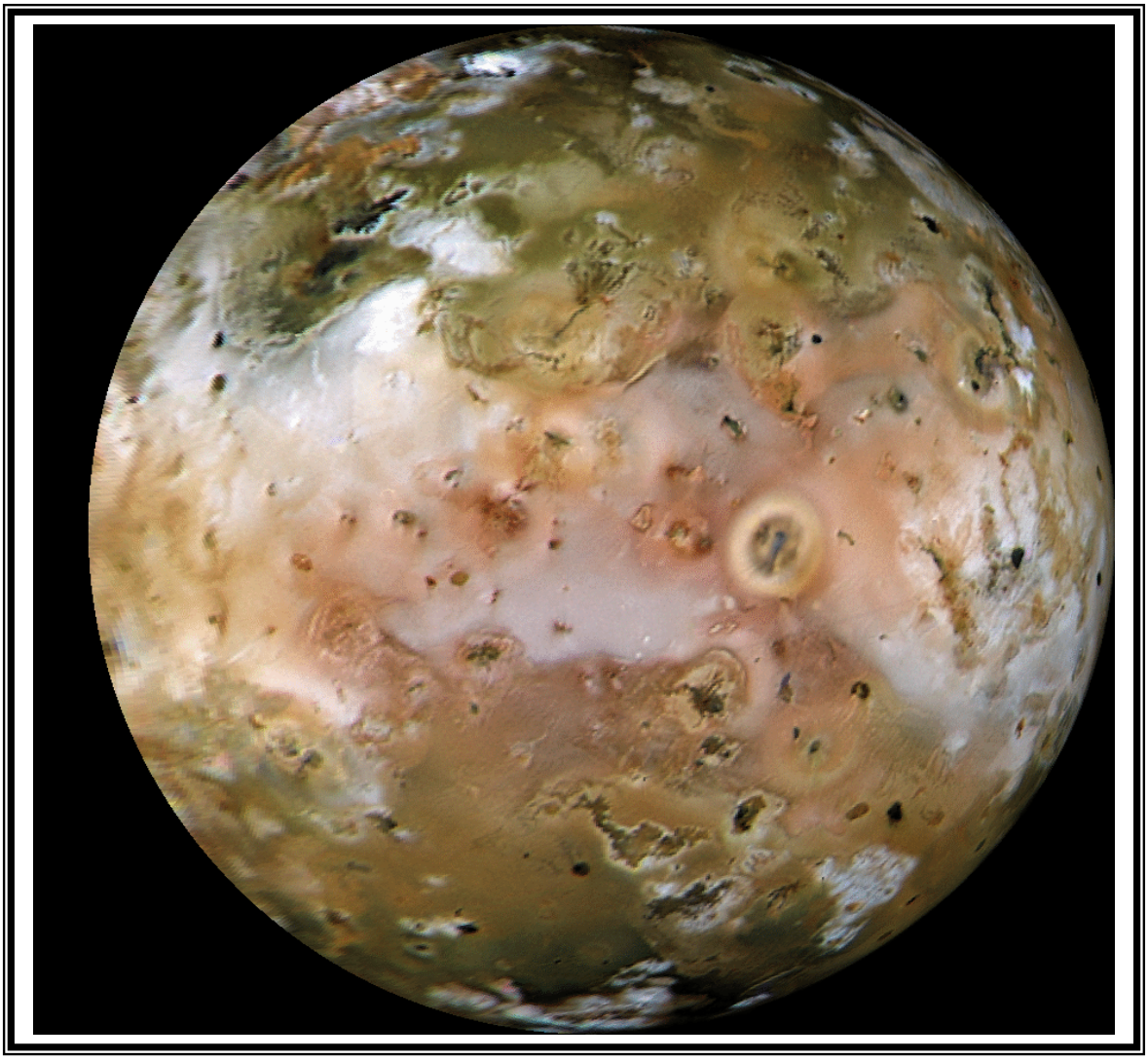
Neptune is located almost 3 billion miles from the sun. Only the most powerful telescopes, or NASA's spacecraft like Voyager 2, can see its moons clearly. The table above gives the diameters of the moons in order of increasing distance from Neptune.

Problem 1 – How many of Neptune's moons have a diameter less than 100 kilometers?

Problem 2 – What moon has the largest diameter? the smallest diameter? What simple fraction expresses how big Nereid is compared to Triton?

Problem 3 – Which moon is larger - Proteus or Neso?

Problem 4- How many times bigger is Proteus than Neso?



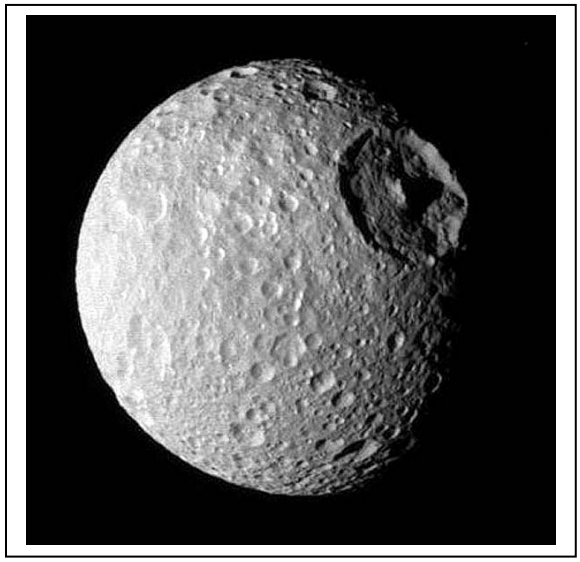
Name: Io
Planet: Jupiter
Diameter: 3,636 kilometers
Composition: 80% rock 20% iron

The most geologically active object in the solar system. Io has over 400 active volcanoes that produce plumes of sulfur dioxide gas and lava!

What is the radius of Io?

Comparing our Moon with Mimas!

3



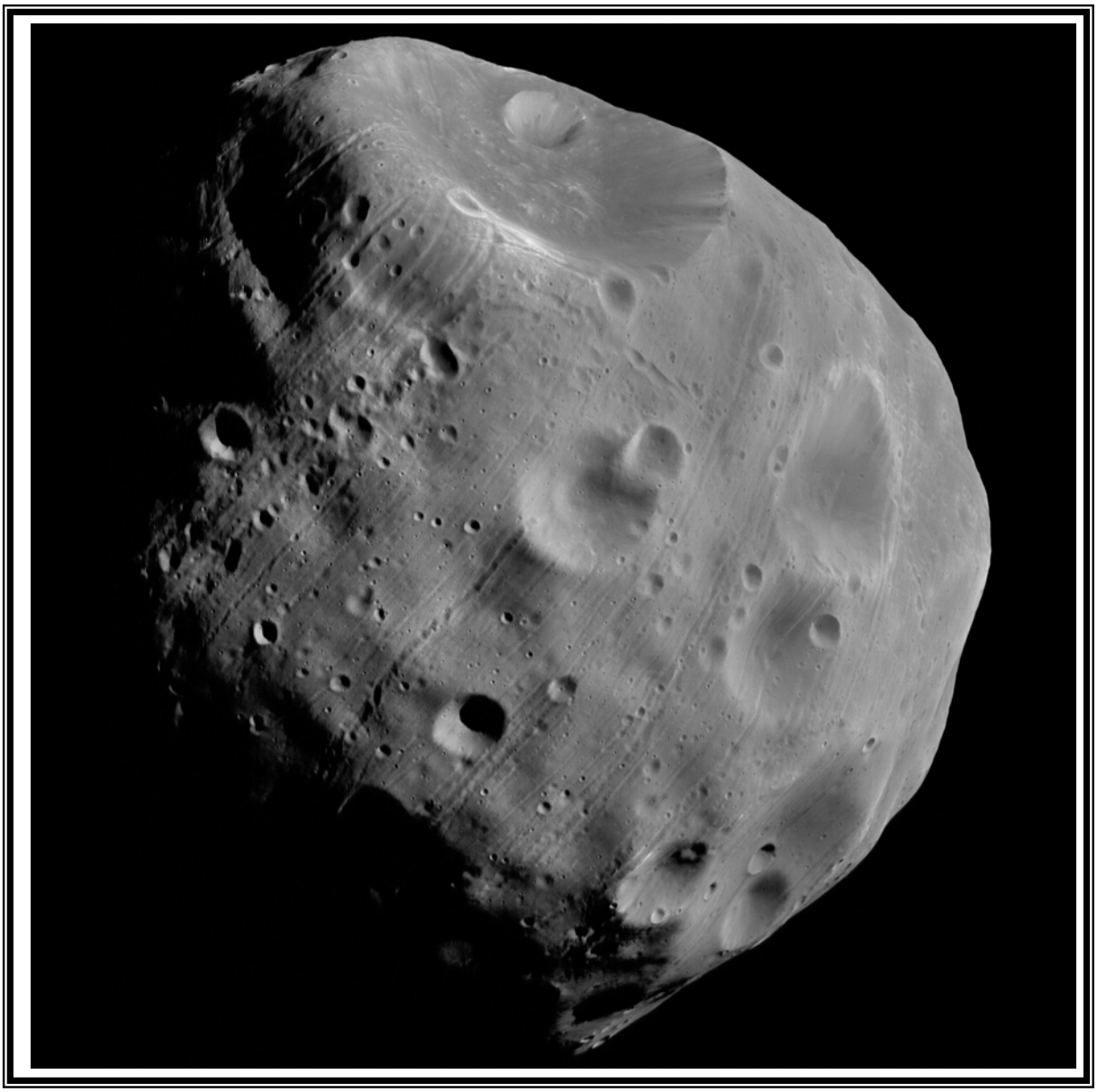
Our own Moon can be seen almost every night. Twelve Apollo astronauts actually walked on the moon between 1969-1972! Our Moon is a rocky moon covered with craters and volcanic lava 'seas' that have long ago turned to solid rock. It has a diameter of 3500 kilometers. It orbits Earth once every 27 days. Mimas is a moon of Saturn. It has a diameter of 400 kilometers. It orbits Saturn once every 22 hours. Mimas is covered with craters. Instead of solid rock, it is almost completely made from solid ice!

Problem 1 – Which planet's moon has the smallest diameter?

Problem 2 – What simple fraction gives the approximate diameter of Mimas compared to our Moon?

Problem 3 – In the photo of Mimas, about what fraction of the diameter of Mimas is the diameter of its largest crater?

Problem 4 -What is the diameter of the crater on Mimas in kilometers?



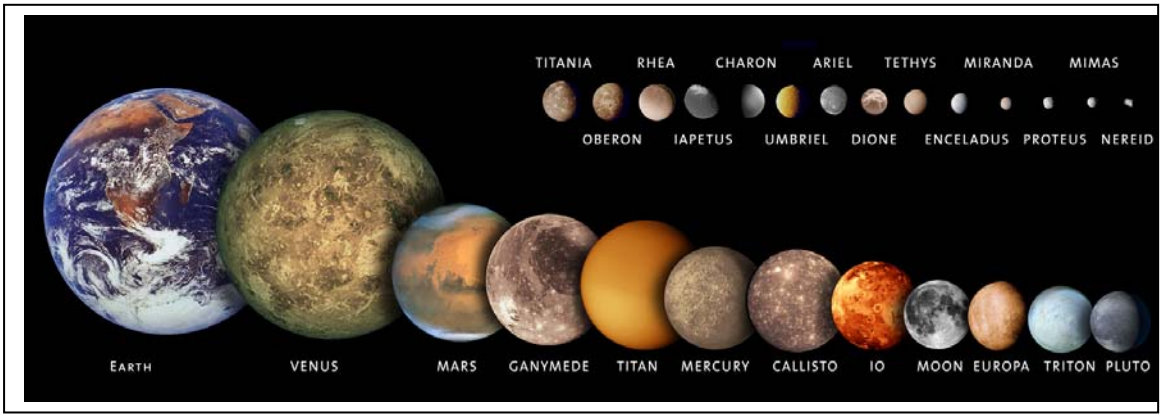
Name: Phobos
Planet: Mars
Diameter: 22 kilometers
Composition: Rock

Phobos orbits so close to Mars that it will crash into Mars in about 10 million years!

What is the radius of Phobos?

Big Moons and Small Planets!

4



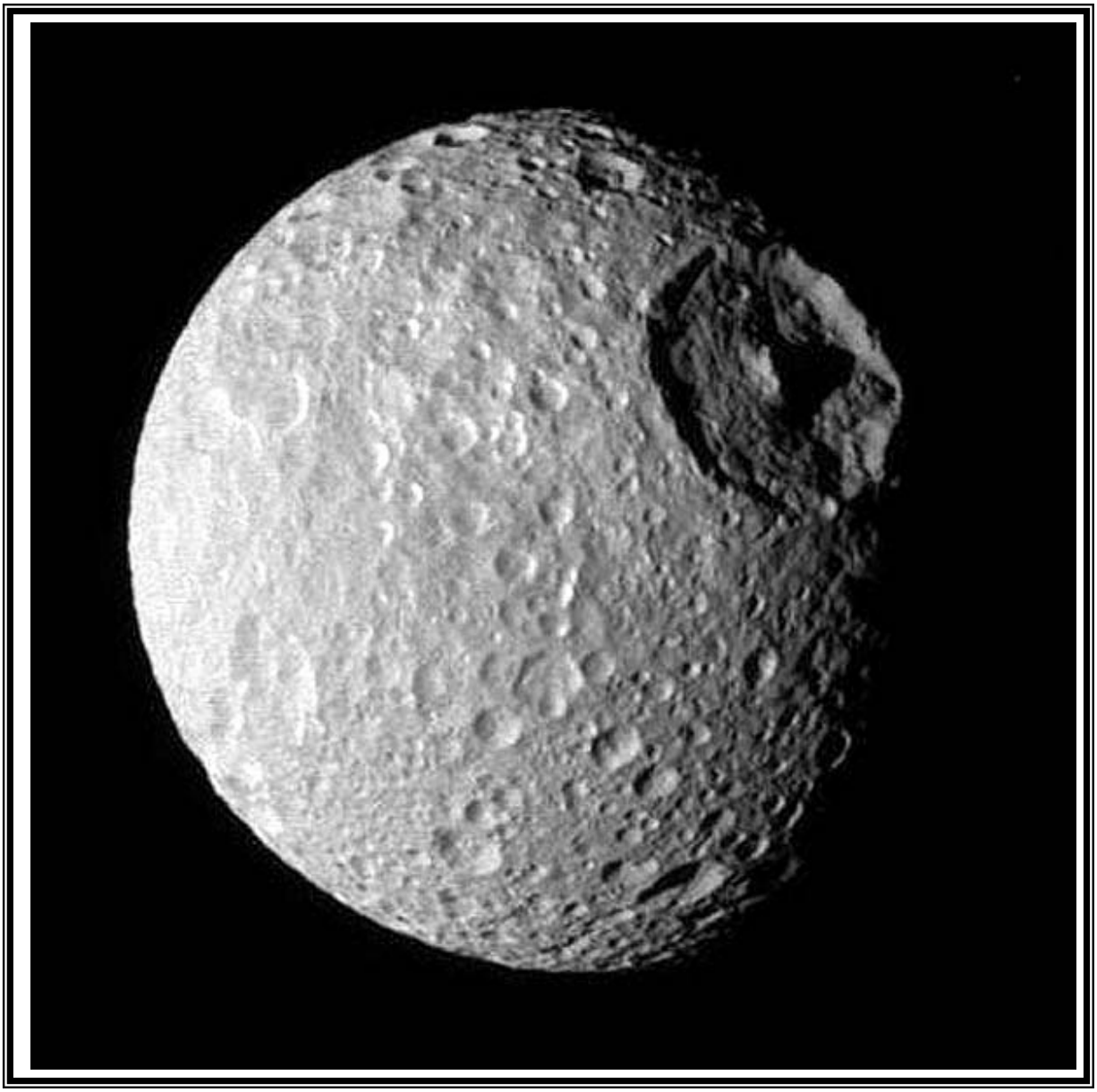
This picture shows the 21 largest moons compared to other small bodies in our solar system. All are drawn to the same scale.

Problem 1 – How many objects are smaller than Earth's Moon?

Problem 2 – How many objects are larger than Earth's Moon?

Problem 3 – What fraction of the objects are larger than our Moon but are not planets?

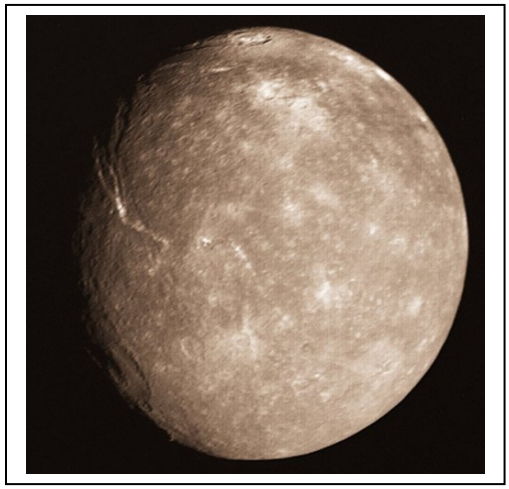
Problem 4– What fraction of the objects are moons?



Name: Mimas
Planet: Saturn
Diameter: 396 kilometers
Composition: 90% ice 10% rock

The gravity from this moon causes the gap in Saturn's rings. This is called the Cassini Division.

Comparing the Sizes of the Solar System Moons



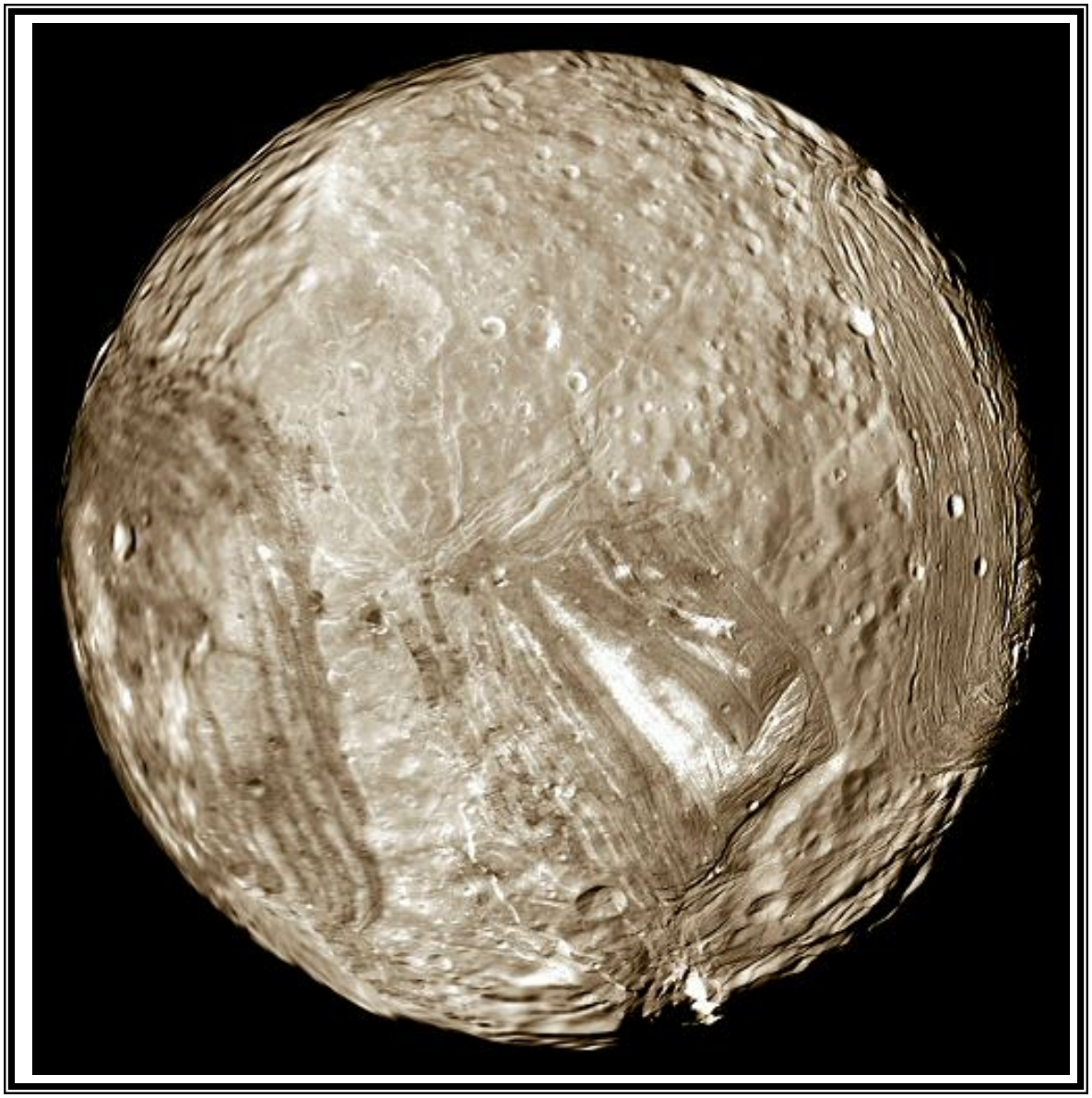
Top left- Dione
Bottom left- Oberon
Top right- Titania.

Problem 1 – Uranus' moon, Oberon, has a diameter of one thousand five hundred and sixteen kilometers. Write this numerically.

Problem 2 – Saturn's moon, Titan, is 2/5 the diameter of Earth. Saturn's moon, Dione, is 1/5 the diameter of Titan. Which one of Saturn's moon is larger?

Problem 3 – Uranus' moon Oberon is 1/8 the diameter of Earth. Io is 3/10 the diameter of Earth. Which moon Oberon or Io is larger?

Problem 4: Saturn's moon Dione has a diameter of 1122 km. Earth's diameter is 12756 km. How many times greater is Earth compared to Dione?



Name: Miranda
Planet: Uranus
Diameter: 472 kilometers
Composition: 50% rock and 50% ice

Miranda's surface is one of the most complex in the solar system.

What is the radius of Miranda?

More Moon Madness!

The moons in our solar system come in a variety of sizes.

Graphic artists and educators often like to show all of the moons on the same picture. Each is drawn to the correct relative size.

Problem 1 – Umbriel and Miranda are moons of Uranus. Umbriel has a diameter of one thousand one hundred seventy kilometers (km.) Write out this number.

Problem 2 – Which of the moons is largest: Charon or Rhea?

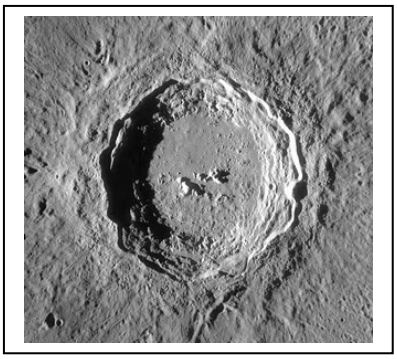
Problem 3 – If Europa has a diameter of 3000 km, to the nearest kilometer, what are the diameters of Charon and Rhea?

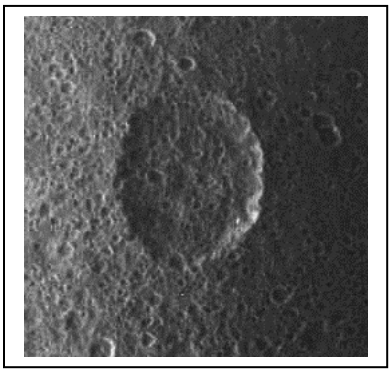
Name: Callisto
Planet: Jupiter
Diameter: 2,410 kilometers
Composition: 50% rock and 50% ice

Callisto has one of the most heavily cratered surfaces in the solar system.

What is the radius of Callisto?

Comparing Crater Sizes





When the planets were forming they were heavily bombarded by large objects. These objects left many craters.

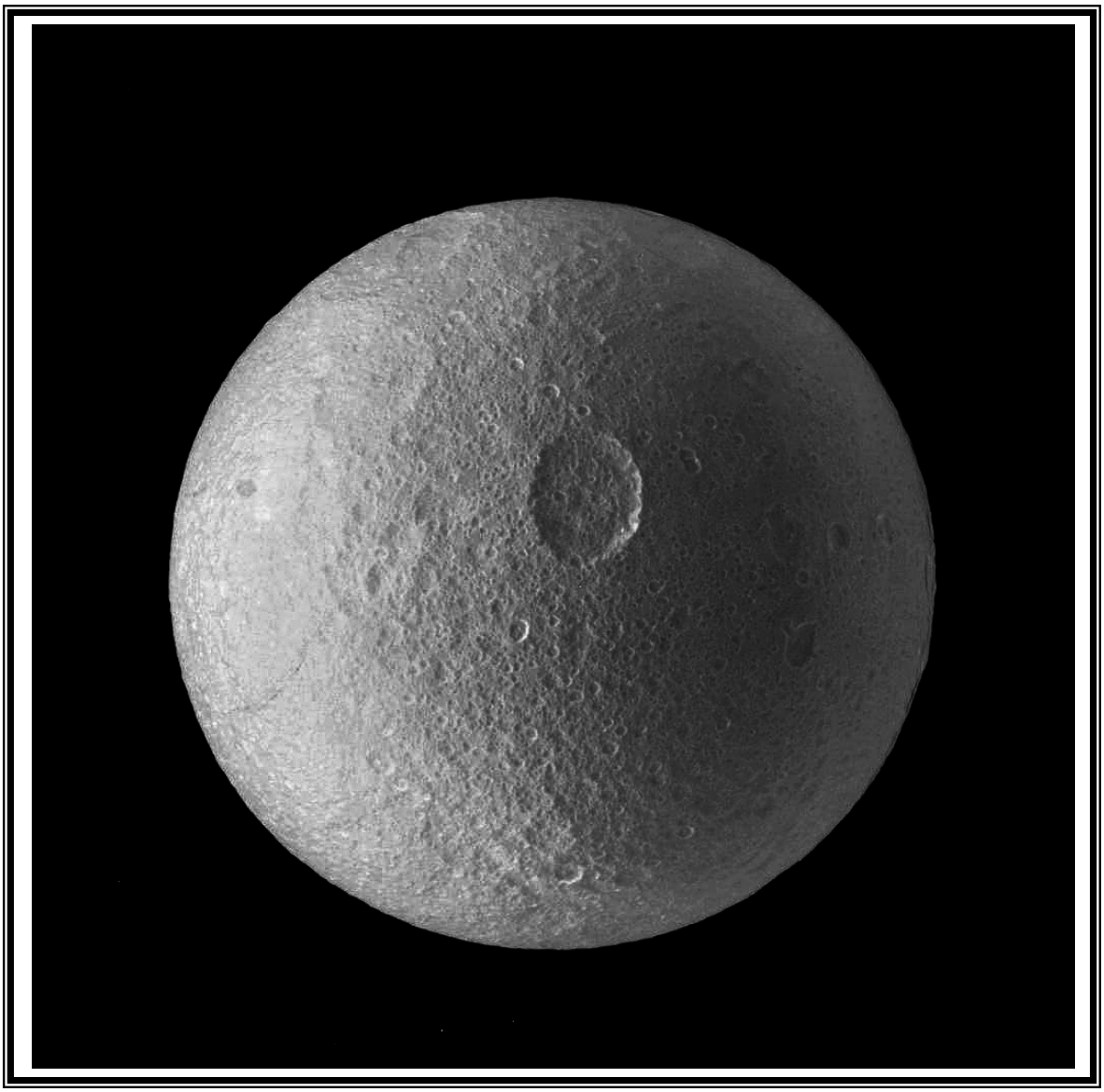
These three images show the largest craters that have been found on our Moon, Tethys and Mimas

Problem 1 – Our moon has a diameter of three thousand five hundred kilometers. Write the diameter of our moon numerically.

Problem 2 – Our Moon's crater Copernicus has a diameter 1/37 that of our Moon. What is Copernicus' diameter?

Problem 3 – The Herschel crater on Mimas is 1/3 the diameter of Mimas. Mimas is 400 km in diameter. What is the diameter of the Herschel crater?

Problem 4 – Saturn's moon Tethys is 3/10 the diameter of our moon. Its crater called Odysseus is 2/5 the diameter of Tethys. What is Odysseus' diameter?



Name: Tethys
Planet: Saturn
Diameter: 1,060 kilometers
Composition: 94% ice 6% rock

The surface is constantly bombarded by ice particles from the outer ring of Saturn.
Is Tethys composed of more ice or rock?

Temperature Extremes across the Solar System

Location	Minimum (Celsius)	Maximum (Celsius)
Mercury	-184	+465
Venus	+462	+480
Earth	-89	+70
Mars	-140	+20
Jupiter	-145	-120
Saturn	-191	-130
Uranus	-224	-187
Neptune	-218	-200
Pluto	-238	-228

The table shows the large objects in our solar system in increasing distance from the sun. The temperatures on the surface of the objects cover a large range. Mercury with no atmosphere is closest to the sun. Venus has a thick atmosphere and nearly constant temperature.

Problem 1 – What location has the coldest temperature? What location has the warmest temperature?

Problem 2 – What is the temperature range on Venus? What is the temperature range on Neptune?

Problem 3 – What location has the greatest temperature range?

Problem 4 - Put in order the objects in terms of their decreasing coldest minimum temperatures.

Name:	Iapetus
Planet:	Saturn
Diameter:	1,492 kilometers
Composition:	80% ice and 20% rock

Some places on Iapetus are as dark as asphalt and others as bright as fresh snow!

What is the radius of Iapetus?

Overlapping Temperature Ranges

Location	Minimum (^{o}Celsius)	Maximum (^{o}Celsius)
Mercury	-184	+465
Venus	+462	+480
Earth	-89	+70
Mars	-140	+20
Jupiter	-145	-120
Saturn	-191	-130
Uranus	-224	-187
Neptune	-218	-200
Pluto	-238	-228
Kuiper Belt	-250	-220

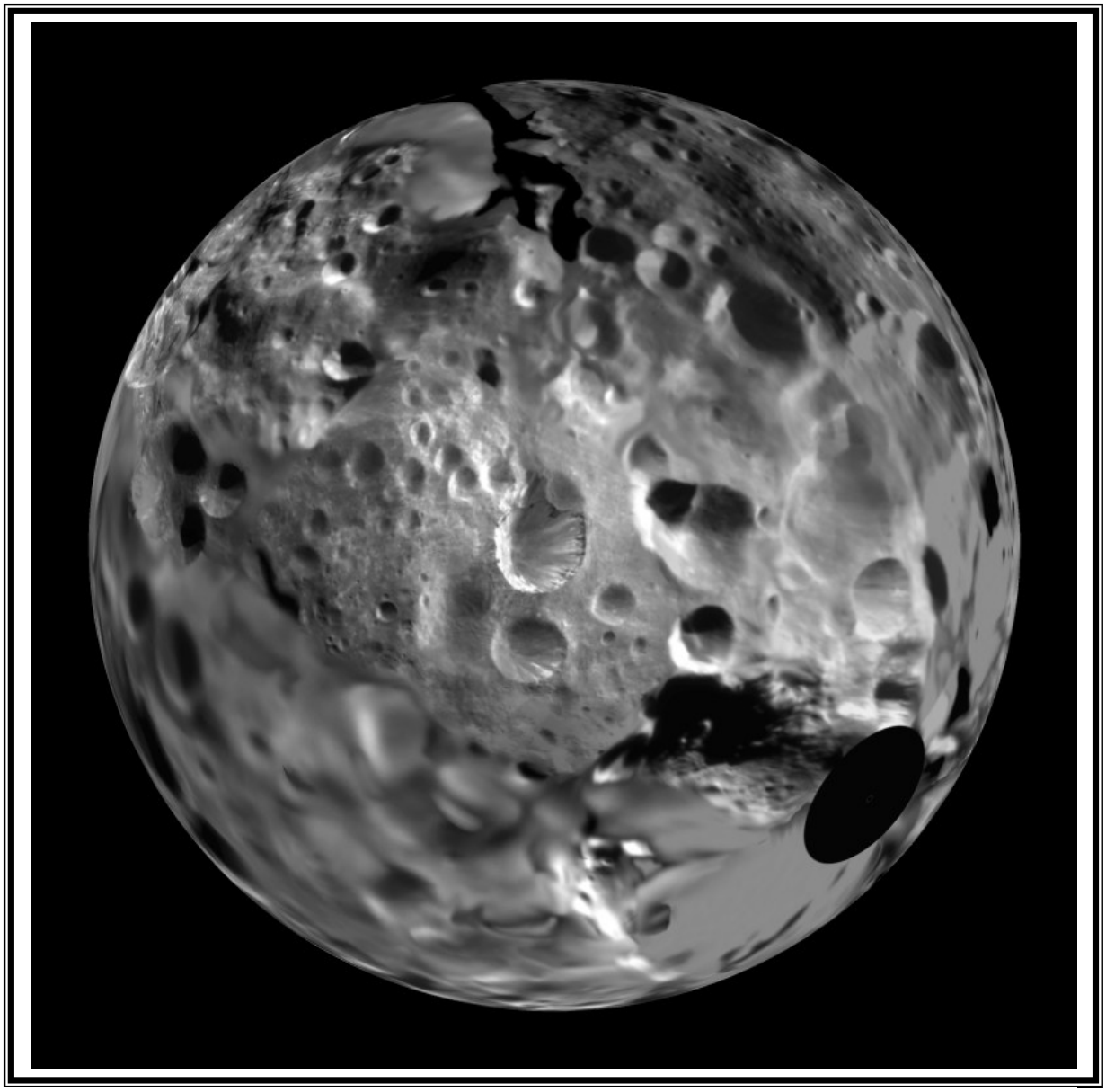
The planets and moons in our solar system are spread out over vast distances from our sun. This means that the temperatures cover many different ranges across the solar system.

Problem 1 – What temperature range is common to Earth and Mars?

Problem 2 – What temperature range is common to Mercury and Saturn?

Problem 3 – Which pair of planets have the smallest range of common temperatures?

Problem 4 – The gas oxygen freezes to a solid at a temperature of -218^{o} Celsius. In which locations could this gas freeze?



Name: Phoebe

Planet: Saturn

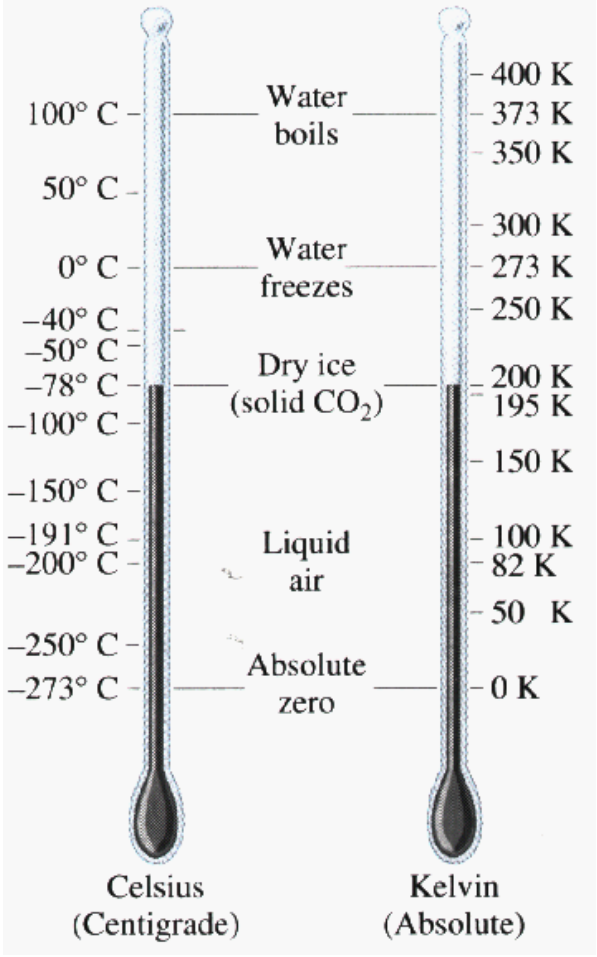
Diameter: 218 kilometers

Composition: 80% ice and 20% rock

Phoebe has created a vast dust ring around Saturn whose particles rain down on the surface of Iapetus to help form the dark areas.

Return to page 17. Which moon is larger Iapetus or Phoebe?

The Kelvin Temperature Scale



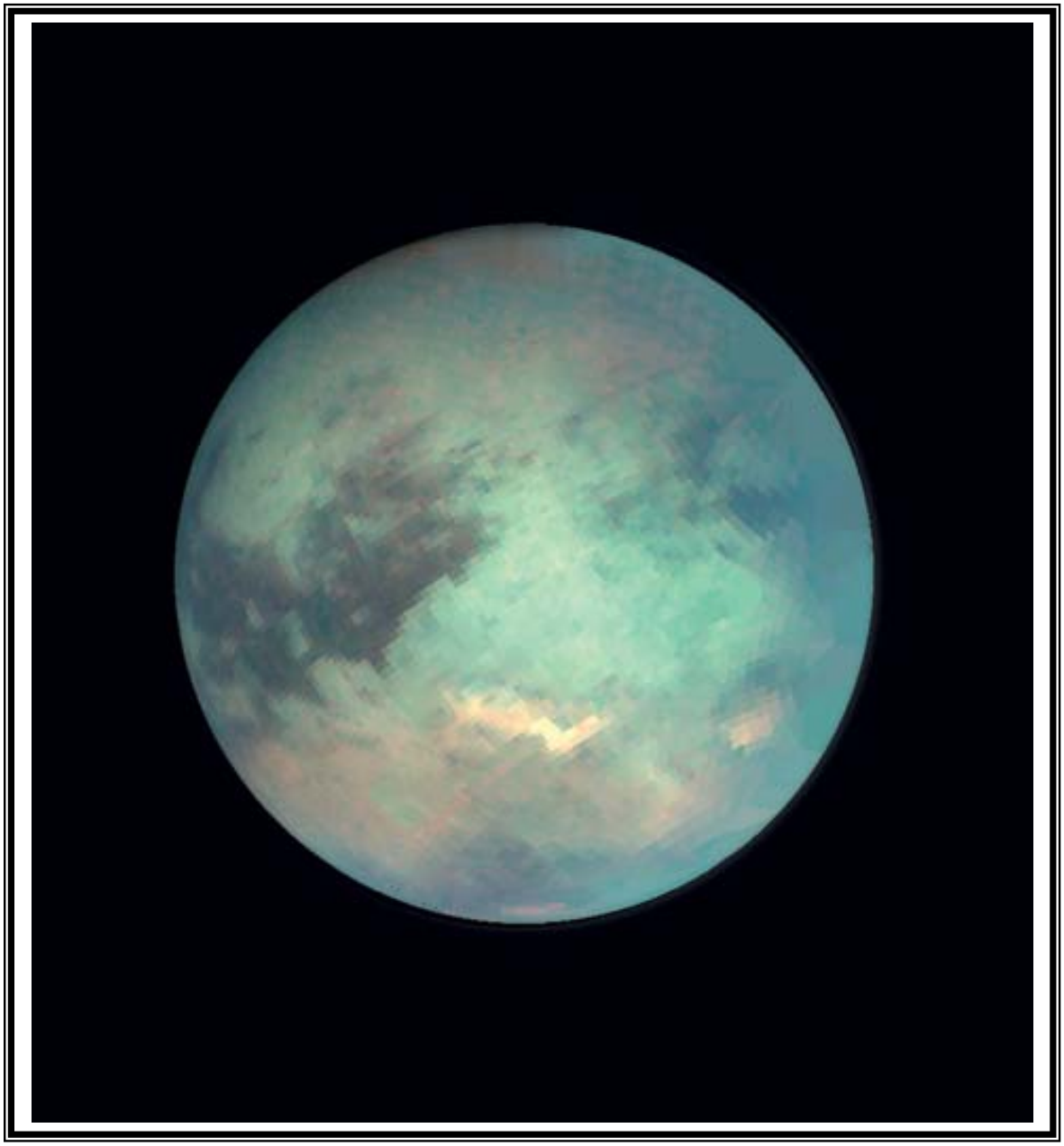
The Celsius temperature scale is based upon the freezing point and boiling point of water. 100 'degrees' separate these two extremes in temperature. But for very cold objects, we can extend this scale to -10° C, -30° C and even -200° C.

Scientists prefer to use the Kelvin scale. It has its Absolute Zero (0 K) at a point where absolutely no heat is produced. This means that all motion of atoms in the object being measured come to a complete stop.

Problem 1 – Water boils at +100° C; on the Kelvin scale its boils at 373 K. What is the difference in these two numbers? If you are converting from Celsius to Kelvin add this number to the Celsius number

Problem 2 - The surface temperature of Earth varies from -89° C to +70° C. What is this range on the Kelvin scale?

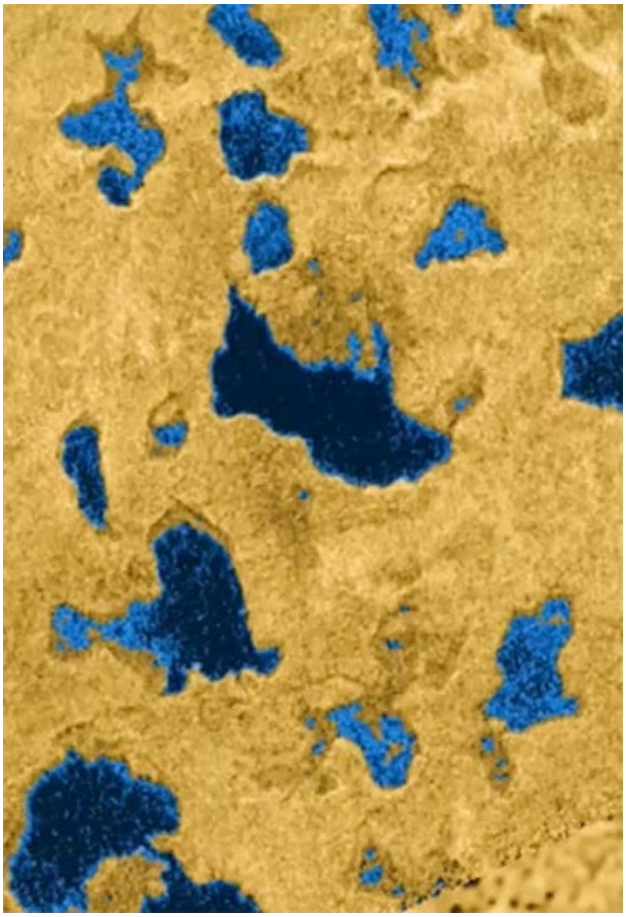
Problem 3 – The surface temperature of Pluto is -228° C. If oxygen freezes at 55 Kelvin, will oxygen freeze out of Pluto's atmosphere and form a frost layer on its surface?



Name: Titan
Planet: Saturn
Diameter: 5,150 kilometers
Composition: 50% rock 50% ice

Titan is the only moon in the Solar System with a dense atmosphere.
Is Titan composed of more rock or ice?

The Gasoline Lakes of Titan!



Titan is the only other object in the solar system besides Earth where we can find a compound in a liquid form on its surface. On Earth, that compound is water.

On Titan, it is so cold that *gases* like methane become a *liquid*. Titan's lakes not only contain liquid methane, but a compound called ethane.

This picture shows the lakes colored blue to make them more easily visible.

Problem 1 – Three oceans have also been discovered on Titan called Kraken Mare, Ligela Mare and Punga Mare. Kraken Mare is the largest, and is one thousand one hundred and seventy kilometers across. Write this number.

Problem 2 – The largest lake on Titan is called Ontario Lacus. It is 234 kilometers across. The smallest lake is called Albano Lacus. It is 6 kilometers across. What is the smallest lake on Titan?

Image Credits

Front Cover: - Mimas (NASA/JPL Cassini)
Back Cover: Titan images(NASA/JPL Cassini); Titan surface(NASA/ESA Huygens); Saturn and moon (NASA/JPL Cassini)
Interior:
I – Planetary Moons to scale – NASA/Solar System Exploration
V – Saturn and Moon – NASA/ESA Cassini
3 – Ganymede – NASA/JPL Galileo
4 – Triton (Voyager 2 NASA/JPL)
5 – Io - NASA/JPL Galileo
6 - Mimas (NASA/JPL Cassini)
7 – Phobos – ESA/Mars Express
9 – Mimas (NASA/JPL Cassini)
10 - Dione, Oberon, Titania
11 – Miranda – NASA/JPL Voyager
12 – Moons graphic - NASA/Solar System Exploration
13 – Callisto - NASA/JPL Galileo
14 - Moon crater Copernicus - NASA/GSFC/Arizona State University-LROC
Tethys crater Odysseus – NASA/JPL Cassini
Mimas crater Herschel - NASA/Cassini; and
Iapetus crater Engelier – NASA/JPL Cassini
15 – Tethys - NASA/JPL Cassini
17 – Iapetus - NASA/JPL Cassini
19 – Phoebe – NASA Cassini-Huygens
21 – Titan – NASA/ESA Cassini - Huygens
22 – Titan Lakes – NASA/ESA Cassini - Huygens

For more images of planetary moons, visit:

http://solarsystem.nasa.gov/planets/profile.cfm?Object=SolarSys

Glossary

Asteroid – A small rocky body typically a few meters to hundreds of kilometers across. Typical orbits are between Mars and Jupiter, but many asteroids orbits exist inside the orbit of Mars including those of the hazardous 'Near Earth Asteroids'.

Comet – Mainly icy bodies a few kilometers to tens of kilometers in size. Some have orbits inside the planet Neptune, but most are found beyond the orbit of Pluto.

Dwarf Planet – A small body that can be hundreds or thousands of kilometers across but has not been able to clear out all the rocky or icy bodies along its orbit. Our solar system has three of these objects: Pluto, Ceres and Vesta which were formerly called a planet and large asteroids.

Kuiper Belt Object – A large number of rocky or icy objects orbiting beyond the planet Neptune of which over 200 are known. Pluto is considered one of the largest of these KBOs.

Moon – A captured satellite of an astronomical object. Small asteroids can have moons (Ida and Dactyl) and of course planets can have moons spanning many different sizes.

Planet – A large body in a solar system which has managed to sweep out the majority of the asteroids and other material along its orbit and is the largest object in its immediate neighborhood.

Additional Resources

Planetary Moons Table (2008) – Windows to the Universe:
http://www.windows2universe.org/our_solar_system/moons_table.html

Our Solar System – Moons
http://solarsystem.nasa.gov/planets/profile.cfm?Display=Moons

Major Moons – The Planetary Society
http://www.planetary.org/explore/space-topics/major-moons/

Habitable Moons around other Planets –
http://www.space.com/14141-alien-planets-moons-life-computer-simulations.html

WikiPedia – Current List of Moons in the Solar System
http://en.wikipedia.org/wiki/List_of_natural_satellites

Answer Key

Lesson 1 –
Moon = 100% rock.
1 – Jupiter
2- 167 ; 61/167
3- Gas Giants
4- 101/167

Lesson 2 -
Radius = 5268/2 = 2634 km
1 – 7/13
2 – Triton ; Psamathe ; 340/2720 = 1/ 8
3 - Neso
4 - 420/60 = 7 times

Lesson 3 –
Radius = 3636/2 = 1810 km
1 – Saturn
2 – 400/3500 = 1/9
3 – about 1 / 4
4 – 100 km

Lesson 4
Radius = 22/2 = 11 km
1 – 17 are smaller
2 – 8 are larger
3 – 4/8 = 1/2
4 – 21/26

Lesson 5 –
1 – 1,516 km
2 – Dione = 1/5 x 2/5 = 2/25 Earth. So Titan is bigger than Dione
3 – Oberon = 1/8 Earth; Io is 3/10 Earth. 3/10 > 1/8 so Io is bigger.
4 – 12756/1122 = 11.4 times bigger.

Lesson 6 –
Radius = 472/2 = 236 km
1 – 1,177 km.
2 – Charon is larger.
4 – Charon = 1244 km. Rhea = 1200 km.

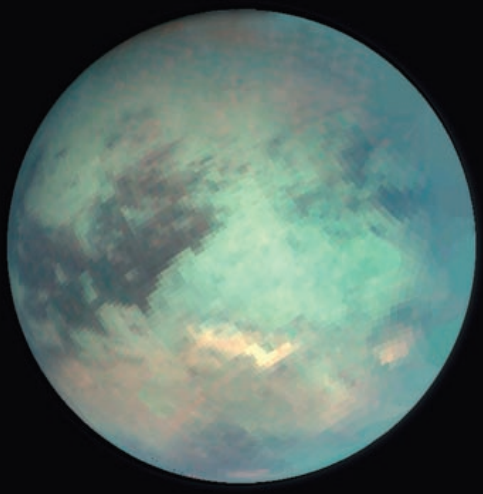
Lesson 7 –
Radius = 2410/2 = 1205 km
1 – 3,500 km
2 – Copernicus: 1/37x3500 = 95 km
3 – Herschel: 400 x 1/3 = 133 km
4 – Odysseus: 3500 x 3/10 x 2/5 = 420 km

Lesson 8 –
94% is larger than 6% so Tethys is mostly ice.
1 - Coldest=Pluto Warmest= Venus
2 – Venus: +462 C to +480 C; Neptune: -218 C to – 200 C
3 - Mercury difference = +465 – (-184) = 649 Celsius.
4 – Venus, Earth, Mars, Jupiter, Mercury, Saturn, Neptune, Uranus, Pluto

Lesson 9 –
Radius = 1492/2 = 746 km
1 - Earth (-89 to +70) Mars (-140 to +20) Common = (-89 to +20)
2 - Mercury (-184 to +465) Saturn (-191 to -130) common = (-191 to -184)
3 - Mercury and Venus: (+462 to +465)
4 – Neptune and Pluto

Lesson 10 –
Iapetus is larger (1492 km vs 218 km)
1 – On the Kelvin scale, 0 C is +273 Kelvins, so to convert from C to Kelvin just add 273 to the Celsius value so K = C + 273.
2 - For Earth -89 C to + 70 C so adding 273 to each we get 184 K to 343 K.
3 – (– 228) + 273 = 45 Kelvin. Since 45 Kelvin is less than 55 Kelvin, oxygen will freeze out

Lesson 11-
It is composed of the same amount of rock and ice
1 – 1,170 km. 2 – Albano Lacus since 6km < 234 km.



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