Mercury

Similarities to the Moon

- The Moon and Mercury have several similarities:
  - Both have heavily
  - Both are virtually
  - Both have extreme
  - Neither one has a permanent atmosphere

Orbital Properties

- Mercury is the planet to the Sun
- The Sun viewed from Mercury looks almost as large as it does from Earth
- Mercury is difficult to observe from Earth because
- Mercury has a very (eccentricity-the amount by which an orbit deviates from a perfect circle)
  - Mercury is km from the Sun at its closest point in orbit
  - Mercury is as far away as km from the Sun

Rotation and Revolution Rates

- Until 1965, scientists thought that the same side of Mercury always faced the Sun
- Astronomers discovered that Mercury rotates
- Mercury takes days to orbit the Sun
- Mercury takes days to rotate
- Mercury's day is longer than it's year
  - Mercury has a solar day (time from noon to noon) of
- Mercury's speed is nearly 50 km/sec faster than any other planet

Rotation and Revolution Rates

- Imagine that at the beginning of a rotation, a feature is pointing directly to the Sun (this position is the equivalent of noon—position 1 in the diagram). When Mercury

has completed one revolution around the Sun, this feature will end up pointing directly away from the Sun, or at midnight (position 4). It will take another full revolution before the feature points directly to the Sun again, ending up at noon. Therefore, the solar day in Mercury (noon to noon) is exactly twice its orbital period. If you lived on Mercury, you would be two years older every solar day!

The Name

- The planet Mercury is named after Mercury, the Roman god of
  - This Roman god was based on the Greek god
  - Hermes was the for the other Greek gods
  - The planet Mercury changes position in the sky from night to night more quickly than the other planets, which is probably why it was named after this speedy Roman god

Atmosphere

- Mercury is too small for its gravity to retain any significant atmosphere over long periods of time
- Mercury has a very thin atmosphere consisting of atoms blasted off its surface by the
- Because Mercury is so hot, the atoms quickly escape into space
- The atoms are continuously lost and
- Contains
- There is no atmosphere to protect the surface
  - Meteorites do not burn up due to

Surface

- Mercury's surface is heavily cratered
- Shortly following its formation, Mercury was heavily bombarded by
- The planet was once
- There are also smooth plains and rugged highlands

Mariner 10

- For a long time, astronomers could only speculate about the markings on Mercury because even the largest ground-based telescopes can resolve surface features on Mercury about as well as we can perceive features on the Moon with our unaided eyes
- The Mariner 10 probe is the only probe that has visited Mercury
-
- The spacecraft used the gravity of to adjust its orbital velocity so that it could approach Mercury
- Mariner 10 provided the first close-up images of Mercury's surface, which immediately showed its heavily cratered nature, and also revealed many other types of geological features

Caloris Basin

-
- Impact crater about 1300 km (810 miles) in diameter
- Surrounded by mountains up to 2 km high
- Caused by an asteroid impact on the planet's surface early in the solar system's history
- The probable cause of the strange surfaces on the of the planet

Temperature

- The average surface temperature of Mercury is
- The temperature ranges from
  - Largest surface temperature variation in the solar system
  - The temperature range is so high due to the absence of an atmosphere and the incredibly long days and nights
- The sunlight on Mercury's surface is as intense as it is on Earth

Structure

- One of the four terrestrial planets
- Second smallest planet (including Pluto)
- Earth is about bigger than Mercury
- Has the in the solar system
- The density is 5.43 g/cm^3, which is slightly less than Earth's
- Mercury's core occupies 42% of its volume and 70% of its mass
  - Earth's core only occupies 17%
- The core is made of
- Surrounding the core is a 600 km
- Mercury's is 100-200 km thick

Magnetic Field

- Mariner 10 discovered a
- Mercury's magnetic field is about 1/100 that of Earth
- Scientists have no clear understanding of the origin of Mercury's magnetic field

1991

- Astronomers used radar observations that showed:
  - Mercury may have
  - Ice exists inside deep craters
  - Floors of the craters remain in perpetual shadow so the Sun cannot melt ice

MESSENGER

- NASA has plans for a new mission to Mercury
- MErcury Surface, Space ENvironment, GEochemistry, and Ranging
- Launched on August 3, 2004
- Will have three Mercury flybys in 2008

- During the flybys, MESSENGER will map nearly the entire planet in and measure the of the surface, , and

- The MESSENGER mission, spacecraft, and science instruments are focused on answering six questions:
  - Why is Mercury so dense?
  - What is the geologic history of Mercury?
  - What is the structure of Mercury's core?
  - What is the nature of Mercury's magnetic field?
  - What are the unusual materials at Mercury's poles?
  - What volatiles are important on mercury?

Bepi-Columbo

- Mission by the
- Composed of three parts
  - A spacecraft in low orbit to make
  - Another craft in eccentric orbit to study the
  - Surface lander
- Planned to launch in 2013

Fast Facts

Namesake	
Mean distance from the Sun	
Orbital period	
Rotational period	

Diameter	4,879 km
Mass	0.06 of Earth's
Gravity	0.38 of Earth's
Atmosphere (primary contents)	
Temperature range	-298oF to 800oF
Number of Moons	
Number of rings	

Significant Dates

1610	Galileo observed Mercury with a telescope
1631	Pierre Gassendi observed the transit of Mercury across the face of the Sun with a telescope
1639	Giovani Zupus discovered that Mercury has phases, which was evidence that the planet circled the Sun
1641	Johann Franz Encke made the first mass determination using the gravity effect on the comet Encke
1889	Giovanni Schiaparelli produced the first map of Mercury's surface features
1965	Gordon Pettengill and Rolf Dyce measured Mercury's rotation period to be about 59 days
1968	Surveyor 7 took first spacecraft pictures of Mercury from the lunar surface
1974	Mariner 10 made first flyby within 705 km of Mercury
1975	Mariner 10 made third and final flyby of Mercury at 327 km

Venus

Earth's Sister Planet

Venus vs. Earth

- Venus and Earth are similar in:
  -
  -
  -
  -
  -
- At formation, they must have been almost indistinguishable from one another
- They are now about as different as two terrestrial planets can be
- However, Earth is teeming with life while Venus is an uninhabitable inferno
- Somewhere along their respective evolutionary paths, Venus and Earth diverged

Orbital Properties

- planet from the Sun
- Always fairly close to the
- brightest object in the sky
- You can see Venus in the daytime if you know where to look

Brightness

- Venus is highly
- Nearly 70% of the sunlight reaching Venus is reflected back into
- Only 10% of light is reflected off of the
- Most of the sunlight is reflected off of the clouds high in the atmosphere
- Venus appears full when it is at its
- When Venus is closest to Earth, we cannot see the sunlit side of the planet at all

Radius, Mass, and Density

- Radius-3761 miles or of Earth's radius
- Mass-4.9×10^{24} kg or of Earth's mass
- Density- of Earth's density

Rotation Rate

- The clouds of Venus made it impossible for us to discern any on the planet
- Astronomers didn't know the rotation period of Venus until radars were used in the 1960's
- It takes Venus
- The spin of Venus is also -opposite of Earth and the orbit of Venus
- Venus takes to orbit

Why is Venus rotating backwards and slowly?

- At present, the best explanation planetary scientists can offer is that early in Venus's evolution, the planet was struck by a large body, much like the one that may have hit Earth and formed the Moon, and that impact was sufficient to reduce the planet's spin almost to zero

Observing Venus

- Venus has a dense that are opaque to visible radiation, making its surface completely invisible from the outside at optical wavelengths
- Atmospheric patterns are more evident when looking at
- This is an ultraviolet image taken in 1979 by the U.S. *Pioneer Venus* spacecraft at a distance of 200,000 km from the planet

Surface

- Detailed radar observations have been made both from Earth and from the *Venera, Pioneer Venus,* and *Magellan* spacecraft
- This image of the surface of Venus was made by a radar transmitter and receiver on board the *Pioneer* spacecraft, which is still in orbit about the planet but now inoperative
- The two continent-sized landmasses are named Ishtar Terra (upper left) and Aphrodite (lower right)
- Colors represent altitude: blue is lowest, red highest

Topography

- The surface of Venus appears to be relatively , resembling rolling plains with modest
- Mountains comparable in height to those on Earth
- The elevated "continents" occupy only of Venus's total surface area
- The remainder of Venus's surface is classified as lowlands (27 percent) or rolling plains (65 percent)
-

Lakshmi Planum

-
- across at its widest point
- Ringed by mountain ranges
- Including the Maxwell Montes range, which rises almost 9 miles

Ovda Regio

- A portion of
- These cracks in the surface were detected by
- The crust appears buckled and fractured, with ridges running in two distinct directions across the image, suggesting that large compressive forces are distorting the crust
- There seem to have been repeated periods when extensive lava flows occurred
- The dark regions are probably solidified lava flows

Volcanism and Cratering

- Many areas of Venus have extensive volcanic features
- probably formed when lava oozed out of the surface, formed the dome, and then withdrew, leaving the crust to crack and subside
- Most volcanoes on the planet are shield volcanoes
  - They form when lava wells up through a " " in the crust, and are built up over long periods of time by successive eruptions and lava flows

- *A* , or crater, forms at the summit when the underlying lava and the surface collapses
- The distribution of volcanoes over the surface of Venus appears

➢ The largest volcanic structures on Venus are huge, roughly circular regions known as
- Roughly circular regions thought to have been caused by upwelling mantle material causing the planet's crust to bulge outward
- They generally have volcanoes both in and around them

Current Volcanic Activity?

➢ There is overwhelming evidence for past surface activity on Venus
➢ Two pieces of indirect evidence suggest that volcanism continues today
- The level of above Venus's clouds shows large and fairly frequent
  - It is quite possible that these variations result from
  - If so, volcanism may be the primary cause of
- Both the *Pioneer Venus* and the *Venera* orbiters observed bursts of from Aphrodite and other regions of the planet's surface
  - These bursts are similar to those produced by lightning discharges that often occur in the plumes of erupting volcanoes on Earth, again suggesting ongoing activity

Atmosphere

➢ The atmosphere of Venus is about 90 times than Earth's, and it extends to a much greater height above the surface
➢ The surface temperature and pressure of Venus's atmosphere are much greater than Earth's
- However, the temperature drops , and the upper atmosphere of Venus is actually colder than our own

➢ Carbon dioxide-96.5%
➢ Nitrogen-3.5%
➢ Water vapor, carbon monoxide, sulfur dioxide, argon-
➢ The clouds are composed of

Greenhouse Effect

➢ The average surface temperature is around
➢ Venus is very hot because of the
➢ The thick blanket absorbs nearly of all the infrared radiation released from the surface of Venus, and it is the immediate cause of the planet's sweltering surface temperature
➢ Because Venus's atmosphere is much thicker and denser than Earth's, a much smaller fraction of the infrared radiation leaving the planet's surface actually escapes into space
➢ The result is a much stronger greenhouse effect than on Earth and a correspondingly hotter planet

Magnetic Field

➢ In 1962, flew by Venus, carrying magnetometers to measure the strength of the planet's magnetic field

- , and subsequent Soviet and U.S. missions, carrying more sensitive detectors, have confirmed this finding
- The lack of any detectable magnetic field on Venus is almost surely the result of the planet's

Exploration

- In all, some 20 spacecraft have visited Venus since the 1970s, far more than have spied on any other planet in the solar system
- The American *Mariner 2* and *Mariner 5* missions passed within 35,000 km of the planet in 1962 and 1967, and *Mariner 10* grazed Venus at a distance of 6000 km en route to its rendevous with Mercury
- The Soviet *Venera* (derived from the Russian word for Venus) program got under way, and the Soviet *Venera 4* through *Venera 12* probes parachuted into the planet's atmosphere between 1967 and 1978

Venera

- The early *Venera* probes were destroyed by enormous before reaching the surface
- in 1970, *Venera 7* became the first spacecraft to soft-land on the planet
  - During the 23 minutes it survived on the surface, it radioed back information on atmospheric
- A number of *Venera* landers have transmitted photographs of the surface back to Earth and have analyzed the
  - None of them survived for more than an in the planet's hot, dense atmosphere
  - The data they sent back make up the entirety of our direct knowledge of Venus's surface

Pioneer Venus

- The U.S. *Pioneer Venus* mission in 1978 placed an orbiter at an altitude of some 150 km above Venus's surface and dispatched a " " consisting of five separate into the planet's atmosphere
- During its hour-long descent to the surface, the probe returned information on the variation of with altitude in the atmosphere
- The orbiter's radar produced images of most of the planet's surface

Magellan

- Entered orbit around Venus in August 1990
- Between 1991 and 1994 the probe mapped of the surface of Venus with unprecedented clarity and made detailed measurements of the planet's
- The mission ended in October 1994 with a (planned) plunge into the planet's dense atmosphere, sending back one final stream of high-quality data

Venus Express

- It took less than three years from the approval to the launch of the mission
- Launched by the European Space Agency in 2005
- Arrived at Venus in April of 2006

Planet-C

- Also known as the Venus Climate Orbiter
- A (JAXA) mission to study the dynamics of the atmosphere of Venus from orbit
- It will also measure atmospheric temperatures and look for evidence of volcanic
- Planned to be launched in 2010

Mars

Orbital Properties

- planet from the Sun
- Outermost of the terrestrial planets
- Noticeably
- The planets are in conjunction when the planets are on opposite sides of the Sun
- The intensity of sunlight on the Martian surface is almost greater when the planet is at **perihelion** than when it is at **aphelion**
- Mars is at its largest and brightest in the night sky when it is at —that is, when Earth lies between Mars and the Sun

Brightness

- Mars is quite bright and easily seen at opposition, the planet is still considerably fainter than Venus
- Mars is more than as far from the Sun as is Venus
- The surface area of Mars is only about that of Venus
- Mars is much than Venus-about 15 percent of the sunlight striking the planet is reflected back into space

Physical Properties

- Mars has a radius of 0.53 Earth radii
- Two small moons
  -
  -
  - Large rocks trapped by the planet's gravity
- Slightly more dense than the moon
- Core of
- Rotates once every
- The equator is inclined to the orbit plane at an angle of 24.0°
- Mars has daily and seasonal cycles

Polar Ice Caps

- Viewed from Earth, the most obvious Martian surface features are the
- Mostly frozen
- Do contain water, but it remains permanently frozen
- Each cap consists of two distinct parts
  - -grows and shrinks each year
  - -remains permanently frozen

Surface

- Mars has huge volcanoes, deep canyons, vast dune fields, and many other geological wonders
- Some 5000 km across, the region bulges out from the planet's equatorial zone, rising to a height of about 10 km
  - The large volcanoes on the left mark the approximate peak of the bulge

Topography

- Northern hemisphere
  - Made up largely of rolling
    - Formed by eruptions involving enormous volumes of lava
  - Much less cratered than the
    - This smoother surface suggests that the northern surface is
- Southern hemisphere
  - Consists of heavily cratered highlands lying some 5 kilometers above the level of the lowland north
  - Most scientists assume that the southern terrain is the of the planet

Volcanism

- Mars contains the known volcanoes in the solar system
-
  - Largest volcano
  - Only slightly smaller than
  - Nearly 3 times taller than
  - Seems currently inactive
- These volcanoes are not associated with
- The great height of Martian volcanoes is a direct consequence of the planet's
  - The lower the gravity, the less the weight and the higher the mountain
- Scientists have found no direct evidence for recent or ongoing eruptions
  - Were active as recently as 100 million years ago

Impact Cratering

- The surfaces of Mars and its two moons are pitted with impact craters formed by falling in from space
- The Martian atmosphere is an efficient , transporting dust from place to place and erasing surface features
- The ejecta blanket on Mars gives the distinct impression of a liquid that has splashed or flowed out of the crater
  - Geologists believe that this fluidized ejecta crater indicates that a layer of lies just under the surface
  - The explosive impact heated and liquefied the ice, resulting in the fluid appearance of the ejecta

Running Water?

- Surveyor mission scientists reported the discovery of numerous small-scale in Martian cliffs and crater walls that apparently were carved by running water in the relatively recent past
- Liquid water could exist in some regions of Mars at depths of less than
- Runoff channels
  - Found in the
  - Bear a strong resemblance to on Earth
  - It is believed by geologists that they are dried-up beds of long-gone rivers that once carried rainfall on Mars from the mountains down into the valleys
- Outflow channels
  - Probably relics of catastrophic flooding on Mars long ago

- They are probably the paths taken by huge volumes of water draining from the southern highlands into the northern plains
- Judging from the width and depth of the channels, the flow rates must have been truly enormous—perhaps as much as a than the 105 tons per second carried by the Amazon river, the largest river system on Earth

Valles Marinares

- Planetary astronomers believe that it was formed by
- Runs for almost 4000 km along the Martian equator, about of the way around the planet

Atmosphere

- Quite thin, the atmospheric pressure is only about 1/150 the pressure of Earth's
- components
  - 95.3%
  - 2.7%
  - 1.6% argon
  - 0.13%
  - 0.07% carbon monoxide
  - 0.03% water vapor

Weather

- The average temperature is
- The temperature can range from
- The low early-morning temperatures often produce water-ice "fog" in the Martian canyons
- Only in the southern summer does the daily routine change
- Strong surface winds sweep up the dry dust, carry it high into the stratosphere, and eventually deposit it elsewhere on the planet
- The dust can remain airborne for months at a time

Evolution

- Around 4 billion years ago Mars may have had a fairly dense atmosphere, complete with
- Sometime during the next billion years, most of the Martian atmosphere disappeared
- Possibly some of it was lost because of
- More likely, the Martian atmosphere became , in a kind of reverse runaway greenhouse effect
  - As the level of carbon dioxide declined and the greenhouse-heating effect diminished, the planet cooled
  - The water froze out of the atmosphere, lowering still further the level of atmospheric greenhouse gases, and accelerating the cooling