Announcements

Sep 29: Homework #4 is due

Oct 10: Review for Test #2, 3:30pm

Oct 11: Test #2

Oct 13: Fall break, no class





Mass = $3.3 \times 10^{26} \text{ g}$ = $0.055 \text{ M}_{\text{Earth}}$

Radius = 2439 km = $0.38 R_{Earth}$

Density = 5.4 g/cm^3

Semimajor axis = 0.39 AU





<u>Venus</u>

 $Mass = 0.82 M_{Earth}$

Radius = $0.95 R_{Earth}$

Density = 5.2 g/cm^3

Average distance from Sun = 0.72 AU

Orbital period = 225 days

Rotation period = 243 days (longer than orbital period, and retrograde!)

<u>Earth</u>

Mass: $M_{Earth} = 6 \times 10^{27} \text{ g}$ Radius: $R_{Earth} = 6378$ km Density: $\rho = 5.5 \text{ g/cm}^3$ Age: 4.6 billion years Orbital period = 365 days Rotation period = 1 day







 $Mass = 0.11 M_{Earth}$

Radius = $0.53 R_{Earth}$

Density = 3.9 g/cm^3

Average distance from Sun = 1.52 AU

eccentricity = 0.093

Range in distance from Sun = 1.38 - 1.66 AU

Rotation Period = 24.6 hours

Orbital Period = 687 days

Terrestrial Planets' Spin, Habitability



On what sort of planet or moon will we find life?

- A: Eyeball planet tidally locked around an M-dwarf star.
- B: Earth-like planet around a G-type star.
- C: Under the surface of Europa in our solar system.
- D: Moon of a hot Jupiter around an M-dwarf star.

Large scale motions of the crust (plate tectonics) are seen on which planets:

- A: Mercury and Venus
- B: Earth, Venus and Mars
- C: Only the Earth
- D: Mars and Venus
- E: All terrestrial planets Mercury, Venus, Earth and Mars.

It takes 8 minutes for light to travel 1 AU, how long does it take for a radar signal to travel from Earth to Mercury and back at its closest point to Earth in its orbit?

- A: 0.6 minutes
- B: 10 minutes
- C: 2 hours
- D: 2 days
- E: 1 year

Interior of Mars



The Martian Atmosphere

- 95% CO₂

- Surface Pressure 0.006 that of Earth's atmosphere (thin air!)
- Surface Temperature 250 K.
- Dust storms sometimes envelop most of Mars, can last months.

A "Reverse Runaway Greenhouse Effect" may have happened: during volcanic phase (first two billion years), thicker atmosphere, warmer surface, possibly oceans. But gradually most CO_2 dissolved into surface water and combined with rocks, then atmospheric and surface water froze (creating ice caps and possible permafrost layer).

Or: most atmosphere lost due to low gravity and no magnetic field.

Demo - *The Atmosphere of Mars* or *Fun with Carbon Dioxide*

The Martian Surface

+8

0

-4

Olympus Mons

Tharsis Bulge

Valles Marineris Hellas Basin



(Mars Global Surveyor radar data)



Southern Hemisphere ~5 km higher elevation than Northern, and more heavily cratered. South is like lunar highlands, surface ~4 billion years old, North like maria, ~ 3 billion years old.

Valles Marineris - 4000 km long, up to 7 km deep. Ancient crack in crust. Reasons not clear.

Tharsis Bulge - highest (10 km) and youngest (2-3 billion years) region.

Olympus Mons - shield volcano, highest in Solar System, 3x Everest in height. 100 km across.

Hellas Basin - large impact crater, ~4 billion years old.

The View From the Surface

Dry, desert-like. Red => high iron content. Mars didn't differentiate as completely as Earth. Sky has butterscotch hue due to dust.



Viking 1 site (1976)



Sojourner robot from Pathfinder (1997)



"Endurance" crater from Opportunity rover (2004)

Pathfinder (1997) site was an outflow channel



Red arrows: rounded boulders indicating water erosion? White arrows: "conglomerate" rock, like in Earth's riverbeds? Blue arrows: sharp-edged boulders, volcanic rock?

Opportunity's (2004) first pictures from Victoria Crater



Deepest crater explored by far (230 feet, 10 times deeper than Endurance Crater) => more layers of geologic history.

Mars Reconnaissance Orbiter (2006) view of Victoria Crater



Evidence for Past Surface Water



"runoff channels" or dry rivers

"outflow channels"









teardrop "islands" in outflow channels

Evidence for Water on Mars Now



Phoenix Lander (2008) Deployable arm

Did Mars once have a huge ocean?





Long stretches along border are very even in elevation, like a coastline

Ocean fed by outflow channels from higher elevation southern hemisphere?

From Mars, Deimos has an angular diameter of 140 arcseconds. Would colonists on Mars ever see Deimos produce a total solar eclipse?

- A: Yes, every day on Mars
- B: Yes, every new moon
- C: Yes, but rarely
- D: Never

The largest mountain in our solar system is:

- A: Caloris Basin range on Mercury
- B: Gula Mons on Venus
- C: Mt. Everest on Earth
- D: Olympus Mons on Mars

Where is the water that once flowed on the surface of Mars?

- A: In the atmosphere
- B: In the polar caps only

C: In a layer of permafrost below the surface and in the polar caps

D: It was diverted to Los Angeles

Evidence for "Permafrost" layer beneath surface



"Splosh" craters suggesting liquefied ejecta.

Valles Marinaris flyover movie

Mars' History

Smaller than Earth, Mars cooled faster.

Most volcanic activity ended two billion years ago.

Differentiation less complete than on Earth.

No evidence for plate tectonics.

Atmosphere mostly froze out into subsurface ice, polar ice caps and surface rocks.

Mars' Moons Phobos and Deimos



Phobos: $28 \times 20 \text{ km}$ Mass = $1.08 \times 10^{16} \text{ g}$ Discovered in 1877 by Asaph Hall



Deimos: $16 \times 10 \text{ km}$ Mass = 1.48 x 10^{15} g

Properties similar to asteroids. They are probably asteroids captured into orbit by Mars' gravity.

<u>The Face on Mars</u> Viking orbiter photos showed this:



Newer, high resolution photo – Mars Global Surveyor 1998



Isn't this more disturbing???



Martian 'Snick' meteorite ALH84001 shows odd shaped features that are reminiscent of bacteria. General consensus is no life.



Spirit and Opportunity Rovers (Opportunity still going after 12 years!)



Curiosity (landed on Mars in 2012)



- Twice as big, four times as heavy as Spirit
- 6-wheel drive and Nuclear power
- Chemcam and on-board lab



Gale CraterDeep basinAlluvial fan

Mount Sharp next

Methanogens Living on Mars?



MARS SCIENCE LABORATORY "CURIOSITY"

- CRUISE STAGE
- ENTRY, DESCENT, LANDING
- SURFACE OPERATIONS



Curiosity Landing On Mars