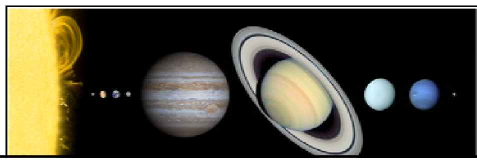
Outline for 05 October (Thursday)

- Questions about scaling
  (20 minutes)
- Comparative Planetology I (Chapter 7 of text)
  (55 minutes)



How does it scale?

- Are the numbers matching?

How does it scale?

- If one thing increases what happens to something else?

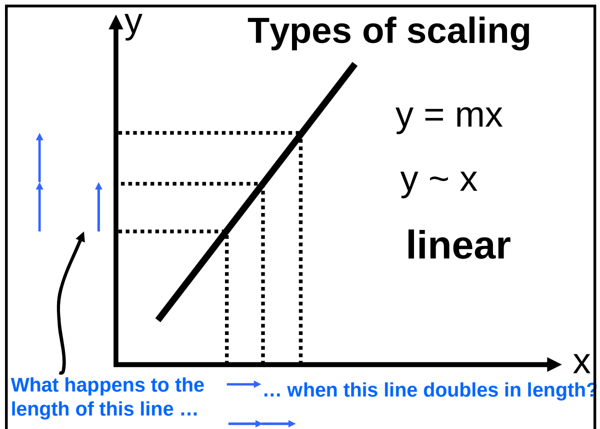
How does it scale?

- In computer science
- In physics and astronomy
- Economics
- Other usage

How does it scale?

- In computer science
  - How does Java 2 Enterprise Edition or Ruby on Rails **scale**?
- In physics and astronomy
  - Mass of a sphere **scales** with the cube of its radius.
  - Energy flux from a blackbody **scales** with the fourth power of its temperature.
- Economics
  - Bang for the buck
  - Economies of scale
- Other usage
  - Level of success **scales** with the amount of quality practice
  - Amount of paint needed to paint a sphere **scales** with the square of the radius. Amount of paint needed to fill a sphere **scales** with the cube of the radius.

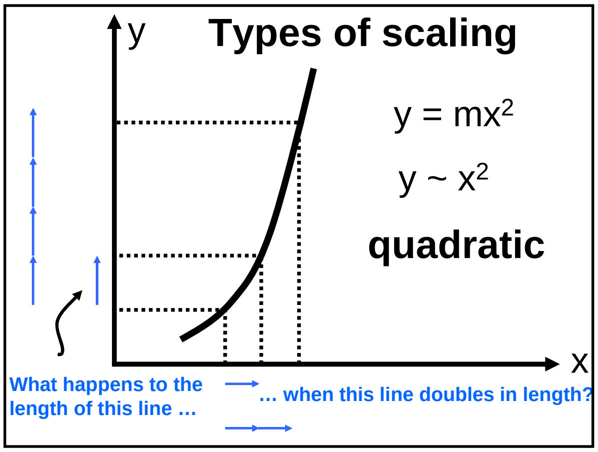
Types of scaling



List of things that scale linearly

- Body weight to the number of years after you turn 25
- The mass of a cylinder to its height $m = \rho h \pi r^2 \sim h$

Types of scaling



$y = mx^2$

$y \sim x^2$

quadratic

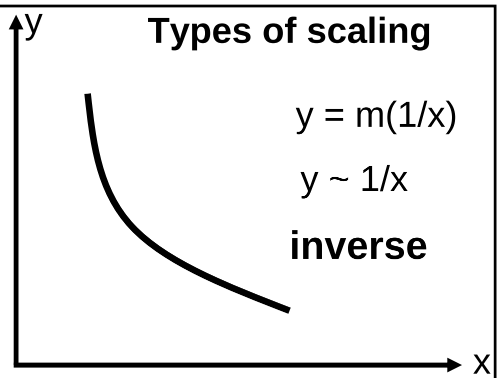
List of things that scale quadraticly

- Gallons of paint needed to paint a disk to the radius of the disk – $A = \pi r^2 \sim r^2$
- The amount of light collected from a lens to its radius - $L = m\pi r^2 \sim r^2$

Discuss

- I real life, the cost of making a lens does not scale quadratically. If the radius doubles, the cost goes up by a factor of 8, not 4. Why?
- Also, the cost of a 15 inch LCD display is about 100 dollars, but the cost of a 30 inch display is 1,000 dollars. What does scaling tell you the cost should be?

Types of scaling



$y = m(1/x)$

$y \sim 1/x$

inverse

List of things that scale inversely

- Frequency of a photon and it wavelength $\lambda \sim 1/\nu$ (because $c = \lambda\nu$)
- Energy of a photon and wavelength $E \sim 1/\lambda$

Question

- How much more energy does a 4 cm radius circular collector absorb than a 1 cm radius collector?
  - Same
  - 2x
  - 4x
  - 16x
  - Need more info

Area of circle is proportional to r^2
A2 is proportional to $(1\ cm)^2 = 1\ cm^2$
A1 is proportional to $(4\ cm)^2 = 16\ cm^2$

Question

- If the temperature of a blackbody increases by a factor of two, what happens to the total energy flux it radiates?
  - Same
  - 2x
  - 4x
  - 16x
  - 32x
  - Need more info

Question

- If the temperature of a blackbody increases by a factor of two, what happens to the total energy flux it radiates?
  - Same
  - 2x
  - 4x
  - 16x
  - 32x
  - Need more info

Total energy flux, F, is proportional to T^4
F1 is proportional to (1) = 1
F2 is proportional to $(2)^4 = 16$

Question

- Wavelength of a electromagnetic wave is about 400 nm. How does its frequency compare to a wave with double this wavelength?
  - Same
  - 2x
  - 4x
  - 16x
  - 32x
  - Need more info

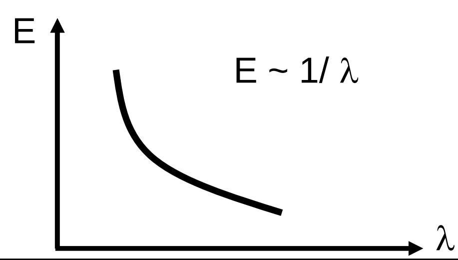
Question

- Wavelength of a electromagnetic wave is about 400 nm. How does its frequency compare to a wave with double this wavelength?
  - Same
  - one half
  - two times
  - quarter
  - four times
  - Need more info

Frequency, ν, is proportional to $1/\lambda$
$\nu 1$ is proportional to 1
$\nu 2$ is proportional to 1/2

Wait!

- If energy is inversely proportional to wavelength, why doesn't a blackbody curve look like this?



- Blackbody curve represents amount of energy at a given wavelength.
- As wavelength gets small, E goes to infinite, but amount of energy emitted at that wavelength goes to zero.

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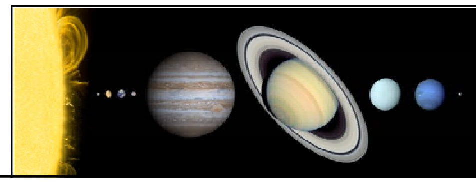
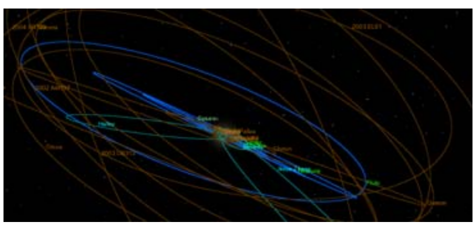
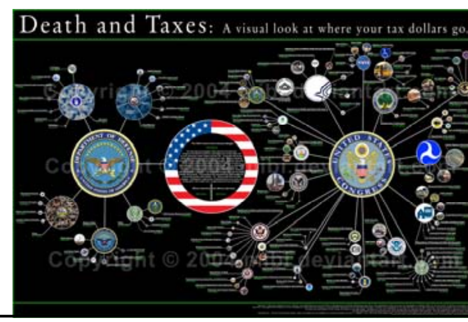


Solar System Exploration with Celestia



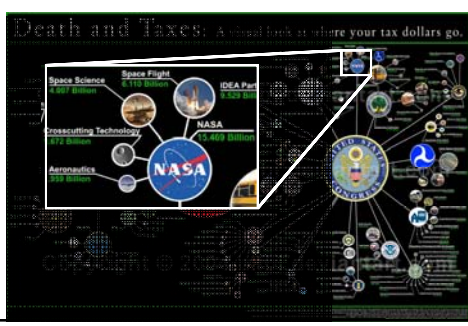
http://www.shatters.net/celestia/

We should/should not send humans to Mars



http://www.deviantart.com/deviation/

We should/should not send humans to Mars



http://www.deviantart.com/deviation/

Key Words

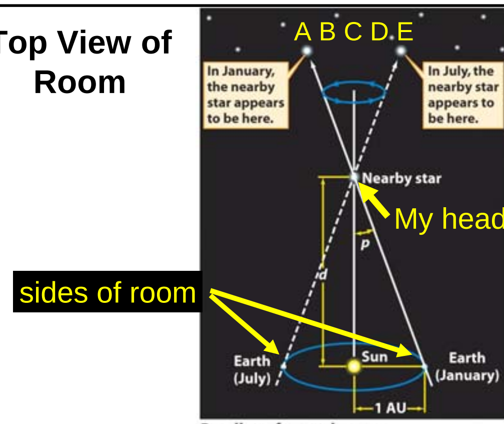
- Scaling
- Parallax
- Escape speed
- Jovian planet
- Comet
- Asteroid
- Meteoroid

Parallax

- What letter does my head block most?

A B C D E

Top View of Room



Parallax of a nearby star

Key Questions

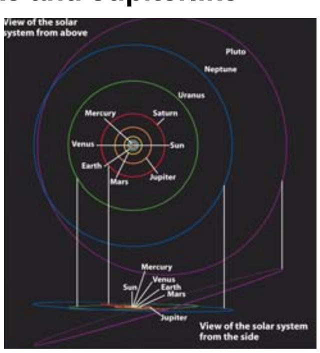
- What is escape speed?
  - The velocity needed for something to escape something else's gravitational pull.
  - To kick a ball so that it never returns, it must leave your foot with a certain escape speed.

Key Questions

- Are all the other planets similar to Earth, or are they very different?
- Do other planets have moons like Earth's Moon?

There are two broad categories of planets: Earthlike and Jupiterlike

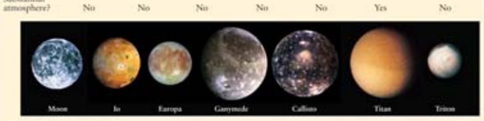
- All of the planets orbit the Sun in the same direction and in almost the same plane
- Most of the planets have nearly circular orbits



Seven large satellites are almost as big as the terrestrial planets

table 7-2 The Seven Giant Satellites

	Moon	Io	Europa	Ganymede	Callisto	Titan	Triton
Parent planet	Earth	Jupiter	Jupiter	Jupiter	Jupiter	Saturn	Neptune
Diameter (km)	3476	3642	3130	5268	4806	5150	2706
Mass (kg)	7.35×10^{22}	8.93×10^{22}	4.80×10^{22}	1.48×10^{23}	1.08×10^{23}	1.34×10^{23}	2.15×10^{22}
Average density (kg/m^3)	3340	3530	2970	1940	1850	1880	2050
Substantial atmosphere?	No	No	No	No	No	Yes	No



(JPL/NASA) R I V U X G

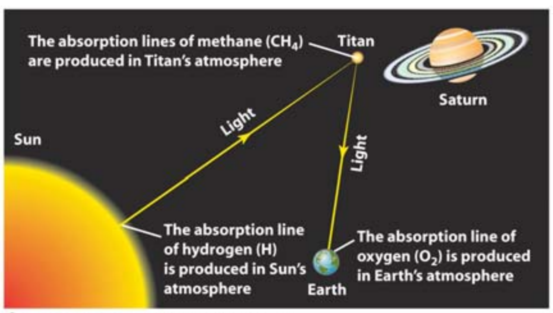
- Comparable in size to the planet Mercury
- The remaining satellites of the solar system are much smaller

Key Questions

- How do astronomers know what the other planets are made of?
- Are all the planets made of basically the same material?

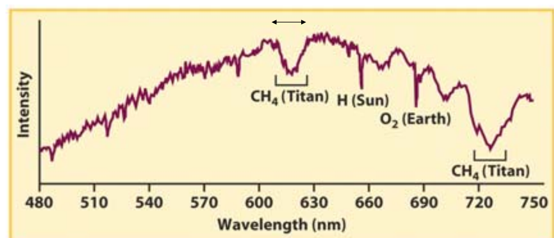
Spectroscopy reveals the chemical composition of the planets

- The spectrum of a planet or satellite with an atmosphere reveals the atmosphere's composition
- If there is no atmosphere, the spectrum indicates the composition of the surface.
- The substances that make up the planets can be classified as gases, ices, or rock, depending on the temperatures at which they solidify
- The terrestrial planets are composed primarily of rocky materials, whereas the Jovian planets are composed largely of gas



(b) Interpreting Titan's spectrum

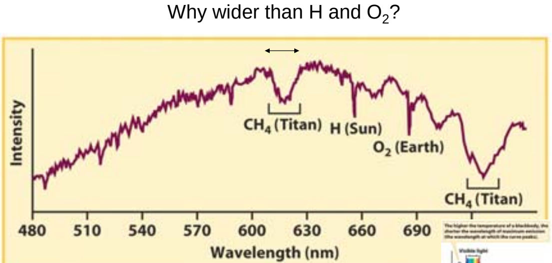
Why wider than H and O_2?



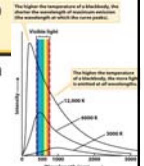
(a) The spectrum of sunlight reflected from Titan

Why is shape so different from blackbody?

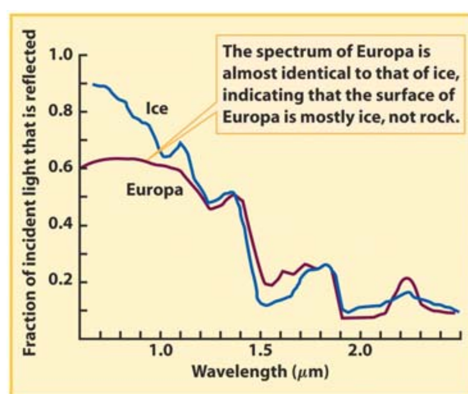
Why wider than H and O_2?



(a) The spectrum of sunlight reflected from Titan



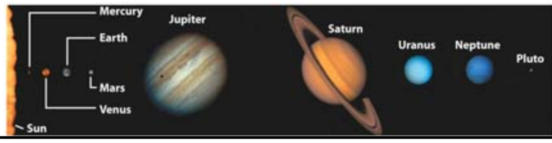
Why is shape so different from blackbody?



Density

$$D = \frac{m}{V}$$

- The average density of any substance depends in part on its composition
- An object sinks in a fluid if its average density is greater than that of the fluid, but rises if its average density is less than that of the fluid
- The terrestrial (inner) planets are made of rocky materials and have dense iron cores, which gives these planets high average densities
- The Jovian (outer) planets are composed primarily of light elements such as hydrogen and helium, which gives these planets low average densities

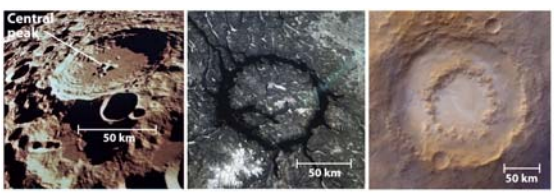


Key Questions

- What is the difference between an asteroid and a comet?
- Why are craters common on the Moon but rare on the Earth?

Cratering on planets and satellites is the result of impacts from interplanetary debris

- When an asteroid, comet, or meteoroid collides with the surface of a terrestrial planet or satellite, the result is an impact crater
- Geologic activity renews the surface and erases craters, so a terrestrial world with extensive cratering has an old surface and little or no geologic activity
- Because geologic activity is powered by internal heat, and smaller worlds lose heat more rapidly, as a general rule smaller terrestrial worlds are more extensively cratered

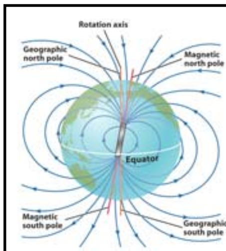


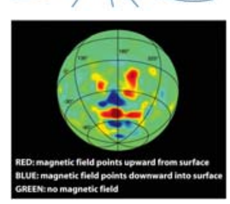
Key Questions

- Why do interplanetary spacecraft carry devices for measuring magnetic fields?
- Do all the planets have a common origin?

A planet with a magnetic field indicates a fluid interior in motion

- Planetary magnetic fields are produced by the motion of electrically conducting liquids inside the planet
- This mechanism is called a dynamo
- If a planet has no magnetic field, that is evidence that there is little such liquid material in the planet's interior or that the liquid is not in a state of motion





- The magnetic fields of terrestrial planets are produced by metals such as iron in the liquid state
- The stronger fields of the Jovian planets are generated by liquid metallic hydrogen or by water with ionized molecules dissolved in it

The diversity of the solar system is a result of its origin and evolution

table 7-3 Comparing Terrestrial and Jovian Planets

	Terrestrial Planets	Jovian Planets
Distance from the Sun	Less than 2 AU	More than 5 AU
Size	Small	Large
Composition	Mostly rocky materials containing iron, oxygen, silicon, magnesium, nickel, and sulfur	Mostly hydrogen and helium
Density	High	Low

- The planets, satellites, comets, asteroids, and the Sun itself formed from the same cloud of interstellar gas and dust
- The composition of this cloud was shaped by cosmic processes, including nuclear reactions that took place within stars that died long before our solar system was formed
- Different planets formed in different environments depending on their distance from the Sun and these environmental variations gave rise to the planets and satellites of our present-day solar system

Independent reading: Read Chapter 7

Review Questions For Topics Covered in Lecture and Reading

1. Do all the planets orbit the Sun in the same direction? Are all of the orbits circular?
2. What are the characteristics of a terrestrial planet?
3. What are the characteristics of a Jovian planet?
4. In what ways does Pluto not fit the usual classification of either terrestrial or Jovian planets?
5. What is meant by the average density of a planet? What does the afveage density of a planet tell us?
6. In what ways are the largest satellites similar to the terrestrial planets? In what ways are they different?
7. The absorption lines in the spectrum of a planet or satellite do not necessarily indicate the composition of the planet or satellite's atmosphere. Why not.
8. Why are hydrogen and helium abundant in the atmospheres of the Jovian planets but present in only small amounts in the Earth's atmosphere?
9. What is an asteroid? What is a comet? In what ways are these minor members of the solar system like or unlike the planets?

Review Questions For Topics Covered in Lecture and Reading

10. What are the asteroid belt and the Kuiper belt? Where are they located? How do the objects found in these two regions compare?
11. What is the one piece of evidence that impact craters are actually caused by impacts?
12. What is the relationship between the extent to which a planet or satellite is cratered and the amount of geologic activity on that planet or satellite?
13. How do we know that the surface of Venus is older than the Earth's surface but younger than the Moon's surface?
14. Why do smaller worlds retain less of their internal heat?
15. How does the size of a terrestrial planet influence the amount of catering on the planets surface?
16. How is the magnetic field of a planet different from that of a bar magnet? Why is a large planet more likely to have a magnetic field than a small planet?