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# Topics for this week

Area and volume

- Finding extrasolar planets
  - Imaging
  - Astrometric technique
  - Doppler technique
  - Transit technique
- What is found
  - Masses
  - Orbits
  - **Densities and compositions**
- Formation of extrasolar planets

Reading for next week: ch. 14.2 & 15

AST 301 Test #2 Friday Oct. 15

Name:

The Sun has a surface temperature of about 6000 K. Betelgeuse (a star in the constellation Orion) has a surface temperature of about 3000 K. The Sun is brightest at a wavelength of about 500 nm. (1 nm = 10<sup>-9</sup> m)
At about what wavelength is Betelgeuse brightest?
1000 nm. (cut the temperature in half; double the wavelength)

b) How does the energy of a typical photon from Betelgeuse (a photon with the wavelength you gave in part a) compare to the energy of a typical photon from the Sun (at a wavelength of 500 nm)? (Which is larger, and how many times larger?) A Betelgeuse photon has half the energy. Energy/photon α temperature.

c) Which of these objects (the Sun or Betelgeuse) emits more 1000 nm wavelength photons from each square meter of its surface? <u>The Sun</u>. Hotter objects emit more light at all wavelengths.

d) Betelgeuse's diameter is about 100 times the diameter of the Sun. How does its surface area compare to that of the Sun? (Which is larger, and how many times larger?) It is 100<sup>2</sup> = 10,000 times larger. 2. a) Make a sketch of a hydrogen atom, labeling the particles in it.



- b) Give two ways other atoms differ from hydrogen atoms.
- 1. They have more protons in their nuclei.
- 2. They have more electrons.
- 3. They have neutrons in their nuclei (heavy hydrogen does too).

c) Describe a change that might occur to your hydrogen atom if it absorbed a photon. The electron could jump to a bigger orbit. Or it could jump out of the atom entirely. 3. I have a device that beeps (puts out sound waves) with a sound wave frequency of 1 kHz (1000 waves/sec). It is on the end of a string, and I am swinging it around my head in a circle. It is moving at a speed of 30 meters/sec (that's about 70 mph, which is about 1/10 the speed of sound). The path of the beeper, my head, and your head are sketched below.



a) Mark the place on the beeper's path where it is when you hear the highest pitch (or sound frequency).

It's where it's moving toward you (not where it is closest to you).

b) What is the frequency you hear when the beeper is there?

1.1 kHz (if it moves at 1/10 the speed of sound, the frequency changes by 1/10 of the emitted frequency)

c) What frequency do I hear then?1 kHz (it isn't moving toward or away from me)

 Give one fact about the solar system that a theory of its origin should explain, and say how the nebular theory of the origin of the solar system explains that fact. (there are many correct answers)

The planets all orbit in nearly the same plane and in the same direction. The planets formed out of a disk of gas and dust that settled around the young Sun. Since they formed out of a disk, they orbit like the gas and dust in the disk orbited.

The inner planets are made of rocks and metals. The outer planets also have ices and gasses.

Only rocks and metals were solids near the Sun, so the planetesimals were made of rocks and metals. Out farther, ices could freeze onto the dust grains, so they got included in the planetesimals. In addition, the more massive planetary cores made of rocks, metals, and ices could pull gasses in. This made them even more massive.

There are many asteroids, mostly outside of Mars' orbit, and comet nuclei, mostly outside of Neptune's orbit.

These are the leftover or broken up planetesimals that formed in these regions of the solar system.

5. a) Why are asteroids which orbit near the Sun hotter than asteroids which orbit farther away from the Sun?

Close to the Sun, the flux of sunlight was greater because the sunlight spreads out as it goes away from the Sun. The heating of an asteroid, which is due to absorption of sunlight, is proportional to the flux of sunlight.

b) Some asteroids have lighter colors (or aren't as black) as other asteroids. How does the color of an asteroid affect its temperature, and why?

The color of an asteroid tells us what sunlight it reflects (they aren't hot enough to glow visibly). Black asteroids absorb all of the sunlight that hits them, so they are heated more than asteroids that reflect some of the sunlight.

6. Why should increasing the amount of CO<sub>2</sub> and other greenhouse gasses cause the temperature of the surface of the Earth to increase?

Greenhouse gasses absorb the infrared light that is emitted by the Earth and return some of it to the Earth, helping to keep the Earth warm. (They don't block or trap visible sunlight. To make the greenhouse effect work, they need to be transparent to visible light so the sunlight can get in.) More greenhouse effect will result in higher temperatures.

### What sorts of planets have we found?



#### What are their orbits like?



**a** This diagram shows all the orbits superimposed on each other, as if all the planets orbited a single star. Dots are located at the aphelion (farthest) point for each orbit, and their sizes indicate minimum masses of the planets.

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**b** The data from (a) are shown here as a graph. Dots closer to the left represent planets that orbit closer to their stars, and dots lower down represent smaller orbital eccentricities. Green dots are planets of our own solar system.

## What are their masses?



# How about lower masses?



# Any planets like the Earth? $(0.003 M_J)$



# Differences from our planetary system

- 1. (Almost) no terrestrial mass planets
- 2. Many planets more massive than Jupiter
- 3. Jovian mass planets in small orbits
- 4. Eccentric (non-circular) orbits are common
- 5. At least one star has planets in orbits tipped relative to each other

Can we explain these planets with our theory of the formation of the solar system?

## **Selection effects**

Some of these results are due to biases in our observations.

Massive planets have more effect on their stars. It is almost impossible for us to detect the motion of a star due to the pull of a terrestrial planet.

Planets close to their stars cause their stars to move faster, causing bigger Doppler shifts.

(But since their periods are short, the distance the stars move is smaller than for planets in big orbits, so motions in the sky should be harder to observe.)

## We still need to explain

How gas giant planets can be in orbits close to their stars

Why eccentric orbits are common elsewhere, but not in the solar system

Maybe how planets more massive than Jupiter can form

'Hot Jupiters' – Gas giants close to stars

- Maybe they formed there, but not by starting with an icy core.
- Stars gather most of their masses by gravitational collapse: gravity pulled the gas cloud they formed from together.Maybe some massive planets formed in a similar way.
- Or maybe they formed starting with an icy core farther from their star, and then migrated inward.
- A massive planet can pull on the gas in the disk around it, giving some of its orbital energy to the gas. This could cause the planet to spiral inward, like a reentering satellite.
- But then why wouldn't it spiral the whole way in to its star?