About Quiz 2

The average was 60%, up from 52%. Distribution

Makeup for extra credit, up to 2 points

For up to 4 of the questions you missed:

• Look up or figure out the correct answer
• Write a sentence or two explaining what you did wrong or why the right answer is correct. Just giving the answer will not earn credit!
• Turn it in at the beginning of class Monday, Feb. 22
About the extra credit quiz corrections

For those responding on paper: please do not write on your test paper. Turn in the corrections on a separate sheet.

For those responding by email

• Be sure to indicate which version of the quiz you had.
• Please do not send followup emails until I announce the grading is done.
• If possible, please do not use attachments. Just type or paste your corrections into your message.
More announcements

Great turnout for Monday’s optional tour of Ritter Observatory!

A second tour will be offered after class in case of clear weather, announced that day on the web if possible.

Mon. - Thurs., Feb. 22 - 26: next Brooks Observatory telescope session, see the web page for weather updates.

Assignment 3 from Mastering Astronomy is now on line.

• It will be due Friday, February 19 at 5:30 PM.

• After the due date, you can still work on it, but you won’t get credit for it.
Advance notice of Quiz 3

Telescopes (chapter 5, last Monday)

Solar system overview (chapter 6, today)

Solar system formation or origin (chapter 6, Wednesday)
Components of the solar system

The Sun

- Ultimate source of virtually all light in the solar system
- Contains more than 99.9% of the mass in the solar system
- Gravitation holds planets in orbit around it
The planets and their satellites; the most massive planet is Jupiter with 1/1000 the Sun’s mass

Small objects: comets (icy) and asteroids (rocky)

- Asteroids located mainly in *main asteroid belt* between orbits of Mars & Jupiter

- Comets located in two outer regions; we see only occasional visitors to inner solar system
  - *Kuiper belt* beginning near Pluto’s orbit and extending unknown distance outward
  - Huge, spherical *Oort cloud* 50,000 AU in radius surrounding solar system
Scale of Oort Cloud, 50,000 AU from the Sun

• Recall nearest neighbor star is 4 light years away from the Sun, or 270,000 AU.

• 50,000 AU equals about 10 light months.

• Solar system viewed from a distance of 50 AU . . . 200 AU . . . 50,000 AU (shrinks to a point)
Dwarf planets, a newly defined group

- Orbit the Sun, large enough for gravity to pull them into a spherical shape, but are in a belt with other small bodies
- Pluto, in the Kuiper Belt
- Eris, also in the Kuiper Belt, discovered in 2005, a bit farther away than Pluto and larger than Pluto
- Ceres, the largest asteroid (in the main asteroid belt)

Sedna, another interesting object in the outer solar system
Bulk properties of planets

Atmosphere; if any, how much; composition

Surface temperature

- Determine from measurements of \textit{thermal radiation} in the infrared

- Influenced by
  - Distance from Sun
  - Presence of atmosphere. Atmosphere traps heat, warms surface

- Affects whether planet’s constituents are solids, liquids, or gases
Size, determine from angular diameter & distance at time of observation (known from planet’s orbit)

Mass, determine from satellite orbits

Density = mass ÷ volume

Lead brick
(high density)

Styrofoam block
(low density)
<table>
<thead>
<tr>
<th>Planets</th>
<th>Density*</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury, Venus, Earth</td>
<td>5</td>
<td>Terrestrial</td>
</tr>
<tr>
<td>(Moon)</td>
<td>3.3</td>
<td>&quot;</td>
</tr>
<tr>
<td>Mars</td>
<td>4</td>
<td>&quot;</td>
</tr>
<tr>
<td>...asteroid belt...</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Jupiter, Saturn, Uranus</td>
<td>1</td>
<td>Jovian</td>
</tr>
<tr>
<td>Neptune</td>
<td>2</td>
<td>&quot;</td>
</tr>
<tr>
<td>Pluto</td>
<td>2</td>
<td>Dwarf</td>
</tr>
</tbody>
</table>

*Grams per cubic centimeter (c. c.)
## Classification as terrestrial vs. jovian

<table>
<thead>
<tr>
<th></th>
<th>Terrestrial (inner)</th>
<th>Jovian (giant, outer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (Earth = 1)</td>
<td>0.4–1</td>
<td>4–11</td>
</tr>
<tr>
<td>Surface</td>
<td>Solid</td>
<td>None*</td>
</tr>
<tr>
<td>Density (grams per c.c.)</td>
<td>3 – 5</td>
<td>1–2</td>
</tr>
<tr>
<td>Location / asteroid belt</td>
<td>Interior</td>
<td>Exterior</td>
</tr>
</tbody>
</table>

*Thick massive, atmosphere; small, solid core
Using a planet’s bulk density as a clue to its composition: start with objects whose composition and density we know

- Earth
  - Density of crustal rock: 2 to 3 grams per cubic centimeter
  - Most abundant elements in crustal rock (combine to form minerals)
    * oxygen
    * silicon
    * aluminum
    * iron

Same combination applies to Earth as a whole
### Some density values for common planetary materials

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density (grams per cubic centimeter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.0</td>
</tr>
<tr>
<td>Terrestrial crustal rock</td>
<td>2.4</td>
</tr>
<tr>
<td>Terrestrial mantle rock</td>
<td>3.3</td>
</tr>
<tr>
<td>Earth, average</td>
<td>5.5</td>
</tr>
<tr>
<td>Iron</td>
<td>8</td>
</tr>
</tbody>
</table>
Likely significance of the bulk density of a planet for its composition

- Density near 1 gram per c. c. suggests light elements (hydrogen, helium, carbon, nitrogen, oxygen) abundant
- Density near 3 grams per c. c. suggests rocky composition, medium mass elements
- Density near 5 grams per c. c. suggests mixture of rock and iron (iron is the most abundant heavy element)
What about small, solid *planetary bodies* with densities between 2 and 3? (too low for a purely rocky composition)

- Probably include solidified compounds of hydrogen, carbon, nitrogen, oxygen

- These elements are the most abundant ones (except for helium, which will not condense into a solid or form any compounds)

- Examples of compounds: water, carbon dioxide, methane, ammonia

- Such compounds are called *ices* when solid
More about motion: angular momentum

The angular momentum of a rotating object is determined by its rotation rate, its total mass, and how its mass is distributed.

More spread out $\implies$ more angular momentum (all else equal)

If an object is isolated from its surroundings, its angular momentum always remains constant (physical law).

So if the object expands/contracts, its spin rate decreases/increases to compensate.

This is how figure skaters, for example, slow down and speed up their spins.
Clues to origin

Features of the solar system that can’t be explained by present-day conditions or physical laws

1. Orderly motions suggest that the solar system formed out of a *single, large, rotating object*, whose *angular momentum* is preserved.
   - All the planets and the Kuiper Belt objects orbit the Sun in the same plane, traveling in the same direction.
   - The Sun and most of the planets rotate on their axes in this same direction.
2. There are two basic types of planets: terrestrial and jovian
   - The inner (terrestrial) planets are smaller and denser than the outer (jovian) planets.
   - Moreover, among the terrestrial planets, the densities are greater, the closer the planet is to the Sun.
   - Exception: the Earth and the Moon are at essentially the same distance from the Sun, but have quite different densities (5.5 vs. 3.3)
3. The solar system includes many thousands of small bodies.
   - Asteroids: rocky composition
   - Comets: icy composition

These clues suggest a theory for the origin of the solar system.

A successful theory must explain them and also explain exceptions.
   - The large size of the Moon in relation to Earth
   - Uranus’s rotation axis is tipped “on its side”
   - Venus’s rotation is retrograde, opposite to the general direction in the solar system
Distribution of Quiz 2 Scores

Median = 12 out of 20 or 60%, high score = 19