Lecture 9: Planetary Motion: Kepler’s Laws

Schedules:
- **Sep 20, Wed: (Today)**
  - Homework #7 due (see solutions below).
- **Sep 25, Mon:**
  - Quiz #2 on homeworks 5, 6, 7, 8 (Chapter 3 & 4, Lunar & Planetary Motion, covering up through Kepler, Galileo, but possibly not Newton’s Laws, pending how far we get in lecture)
  - Homework #8 due (see assignment below)
- **Sep 27, Wed:**
  - Homework #9 due

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HOMEWORK #8 due next time at beginning of class.

18. **Venus Cycles**
The planet Venus last reached inferior conjunction January 1, 2006, and will soon become a morning star for most of the year. Generally, Babylonian records show that Venus is invisible for 66 ± 5 days at superior conjunctions, and 9 ± 8 days at inferior conjunction (i.e. invisibility can be anywhere from 1 to 18 days). The total synodic period is 583 ± 7 days, hence the planet is generally visible as a morning or evening star for 254 days or 8 months and 10 days each time.

(a) As a priest of the Chaldeans, what date would you suggest your acolyte to start looking for Venus to first appear as a morning star (after the inferior conjunction)?

(b) On what date would you predict the next superior conjunction to happen?

(c) The last GEE of Venus of that year was 2005 Nov 2. What date would you predict for the next GEW (after the inferior conjunction)?

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19. **Planetary Configuration**: Make a drawing of the following

(a) Put sun in center. Make 6 circles around it for the orbits of Mercury, Venus, Earth, Mars Jupiter and Saturn. Draw in the position of the earth (anywhere you want!)

(b) Draw Mercury at GEW

(c) Draw Venus at superior conjunction

(d) Draw Mars at conjunction

(e) Draw Jupiter at opposition

(f) Draw Saturn at Eastern Quadrature (90 degrees elongation).

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20. **Elliptical Orbits** (reference text page 71 in Freedman) [Kepler’s first law]
Use the method of a string and two pins to draw an ellipse which will fit comfortably on a single page of paper. I would suggest having the two "pin-holes" (the two foci) 5 cm (centimeters, or about 2 inches) apart and choose the length of the string about 25 cm (OR sometimes it is easier to use a loop of string, make it 30 cm tied into a loop).

(a) Draw your ellipse. What is the total length of string you used?
(b) **Draw the major axis.** What is the length of the semimajor axis "a" in cm? [it should be between 10 and 13 cm]

(c) **What are the closest (perihelion) and furthest points (aphelion) from the "sun" in cm?**

(d) **Estimate the eccentricity of your ellipse.** [HINT: note that the aphelion = a(1+e), and perihelion = a(1-e), where a = semimajor axis measured in part (b). Solving we get e = r/a -1, where r = aphelion distance, measured in part (c).]

Solutions to HOMEWORK #7 due today at beginning of class.

15. **Lunar Synodic Motion** Below are 1997 phases of the moon for Jan thru Mar

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date*</th>
<th>Time*</th>
<th>Date</th>
<th>Time*</th>
<th>Difference or</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>Jan 09</td>
<td>04:26</td>
<td>Feb 07</td>
<td>15:06</td>
<td>29d10h40m</td>
</tr>
<tr>
<td>First</td>
<td>Jan 15</td>
<td>20:02</td>
<td>Feb 14</td>
<td>08:57</td>
<td>29d12h55m</td>
</tr>
<tr>
<td>Full</td>
<td>Jan 23</td>
<td>15:11</td>
<td>Feb 22</td>
<td>10:27</td>
<td>29d19h16m</td>
</tr>
<tr>
<td>Last</td>
<td>Jan 31</td>
<td>19:40</td>
<td>Mar 02</td>
<td>09:37</td>
<td>29d13h57m</td>
</tr>
</tbody>
</table>

*GMT

(a) See the "difference" column in the above table. Clearly they are NOT the same, but vary by as much as 9 hours (more than a third of a day).

(b) The average is about 29.59 days, abit above the expected average of 29.53 days.

(c) Starting with the Jan 9 New moon, the quarters are:

- New to First: \(6d15h36m\)  FAST! (Perigee was Jan 10)
- First to Full: \(7d19h09m\)
- Full to Last: \(8d04h29m\)  SLOW! (Apogee was Jan 25 !)
- Last to New: \(6d19h26m\)

16. **Eclipses and Metonic Cycle:** Consult the "Pattern of Eclipses" handout

(a) New Moons: The years which had 13 were: 1978, 81, 84, 86, 89, 92, 95, 97, 2000

(b) Calendar: The "Metonic" cycle would begin with year 1=1978 and 1997

(c) On average, the eclipses take place an average of 10-11 days earlier each year (down one row, over to the right slightly).

(d) The year 1982 (18 years earlier) looks very similar to 2000 (but note the eclipses are about 10 to 12 days earlier).

(e) We would then predict that the eclipses of 2001 should resemble 1983, but 10 to 11 days later.

<table>
<thead>
<tr>
<th>Type</th>
<th>Known</th>
<th>Predict 2001</th>
<th>True 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunar</td>
<td>1982 Dec 30</td>
<td>Jan 9-10, total</td>
<td>Jan 9 (total?)</td>
</tr>
<tr>
<td>Lunar</td>
<td>1983 Jun 25</td>
<td>Jul 5-6, partial</td>
<td>Jul 5 (partial?)</td>
</tr>
<tr>
<td>Solar</td>
<td>1983 Jun 11</td>
<td>Jun 21-22, total</td>
<td>Jun 21 (total)</td>
</tr>
<tr>
<td>Solar</td>
<td>1983 Dec 4</td>
<td>Dec 14-15, annular</td>
<td>Dec 14 (annular)</td>
</tr>
</tbody>
</table>
X17. Fifteenth Proposition of Aristarchus (xtra credit)

(a) The moon is about 5.3 cm from the shadow’s edge.
(b) The center of the earth is about 7.3 cm from the shadow’s edge.
(c) The earth is about 6 mm
(d) Hence Aristarchus would think the earth is 3 times the moon (actually he got 2.85x) and then the sun about 6 times bigger than the earth.

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More SAMPLE QUIZ QUESTIONS on planetary motions [for quiz 2]

11. Planets are generally found
   a. on the equator   b. near the equator   c. on the ecliptic   d. near the ecliptic   e. none of these
12. Retrograde motion means a planet is
   a. revolving opposite the rotation of the sun    e. none of these
   b. revolving opposite the direction that the rest of the planet(s) orbit the sun
   c. rotating opposite the rotation of the sun
   d. has apparent westward motion against the background stars as viewed from the earth
14. Which planet is between Jupiter and the Earth? ___________
15. On a star map, draw the position of the sun for November 21, and the position of “Mars” if it were in OPPOSITION. LABEL the ASCENDING LUNAR node.
11. Make a diagram with planets labeled in correct order in the solar system, with Jupiter at opposition, Venus at greatest eastern elongation, Mars at quadrature and Mercury at inferior conjunction.
23. Can a superior planet ever be a morning star?
24. Name the planets IN ORDER from the sun outward.
25. Which planets are the inferior ones?