OBJECTIVE: To see planetary orbits simulated on a computer and to see how this sun-centered model explains retrograde motion.

Initial Procedure:
1. If you don’t have your own device, go to one of the computers in the lab and wake it up by moving the mouse or pressing the Enter key. Double click on the Orbits icon.

2. If you do have your own device, download the Windows version from here: http://facstaff.cbu.edu/~jholmes/N111/Labs/ORBITS.EXE, or download the DOS version for use with the Mac using the DOSBOX program from here: http://facstaff.cbu.edu/~jholmes/N111/Labs/ORBITSd.EXE.

Part 1: Sidereal and Synodic Periods

PROCEDURE:
For the first part of the lab, we will investigate sidereal and synodic periods, so type the letter P from the P/R/I/O/E choices. Read the introduction, and then enter in the planet # of the planet or planets you wish to see. Please look first at the planet Mercury and include the Earth as well. (To un-select a planet, simply type that planet's number again.)

When you have your planets selected, type the letter P to begin the plot. The computer will then allow you to adjust the speed of the motions. Initially just type 1 and Enter. Later you can speed up the plots or slow them down by entering a different factor. The computer will then show each planet orbiting the sun indicating each planet by its first letter. It starts each planet to the right of the sun (what we call angle 0°). It will beep twice and then pause each time one of the planets has made its first circle around the sun. The time for this circle is the period for the planet's orbit. This is called the SIDEREAL PERIOD for that planet.

When the planet has again caught up with the Earth, i.e. 'lapped' the Earth in the case of an INFERIOR planet, or when the Earth has again caught up with the planet, i.e. 'lapped' that planet in the case of a SUPERIOR planet, the computer will beep once and again pause. This time is called the SYNODIC PERIOD for that planet.

To continue the motion past the pause, type the letter C (as indicated on the screen). To quit the plot, type the letter Q - this will return you to the Orbits main menu from which you can choose to run this program again with other planets to watch, run the other two programs, or end the program.

Please check the sidereal and synodic periods for Mercury, Venus, Mars, and at least one of the outer planets. Note which planets have large sidereal periods and which have small sidereal periods. Also note which planets have large synodic periods and which have small synodic periods. Try to see the pattern and the reason for the above.

Compare your values to the accepted values on the last page (or look up more current values on the web).
REPORT:
1. Give your values and compare to the accepted values for the sidereal period for Mercury and for the synodic period for Mercury.

2. Give your values and compare to the accepted values for the sidereal period for Venus and for the synodic period for Venus.

3. Give your values and compare to the accepted values for the sidereal period for the superior planet you chose and for the synodic period for your planet.

4. Report which planet has the biggest sidereal period and which has the biggest synodic period. Explain why each of these planets has the biggest sidereal or synodic period.

Part 2: Retrograde Motion

PROCEDURE:
This time from the program’s main menu (P/R/I/O/E choices), choose R for retrograde motion. Then choose any of the planets listed by typing in the appropriate number. To un-select a planet, simply select a different planet by typing the new planet's number. This will both select the new planet and un-select the old planet. As in the Periods program, there will be a chance to speed up or slow down the plots by entering a speed factor.

The computer will plot the positions of both the earth and the planet you chose, and then draw a line along the line of sight from the earth to that planet. If you follow that line of sight it will point to one of the constellations of the zodiac - which are not shown on the screen, but which you should think of as at the twelve hour positions like on a clock. Note the counter-clockwise progression of the lines - except for an occasional and brief reversal: the retrograde motion. This counter-clockwise rotation through the constellations of the zodiac goes in the regular order of the constellations (e.g., from Aquarius to Pisces to Aries, etc.) which means the planets usually go from West to East through the constellations – but they do go from East to West across the sky during the day (and night) – just a little slower than the constellations.

In watching the planets move, see how many times during one synodic period the motion goes retrograde and how long in time this retrograde motion lasts.

Choose a different planet and see if the same thing happens.

Choose a third planet (make sure at least one is an inferior and one a superior planet) and again see if the same thing happens.

REPORT:
1. Record how often during one synodic period retrograde motion occurs for each of your three choices of planets.

2. Record for how long (in time) the retrograde motion lasted, and what the synodic period was. Then calculate the percentage of time that the motion was retrograde. Do this for each of your three choices of planets.
Part 3: Circular and Elliptical Orbits

PROCEDURE:
This time from the program’s main menu (P/R/I/O/E choices), choose I for the introduction to orbital motions. Read this introduction and be sure to notice the third page which talks about aspect ratio. The computers in the lab should be okay with the default value of 1 for the aspect ratio, but your computer may need to have this value adjusted.

Now choose O from the main menu. This will then provide you with a list of parameters that you have at your disposal. The initial parameter values will show the Earth as it is: going around the Sun with a period of 365 days at a distance of 1 AU (= 93 million miles = 150 million kilometers, or 1.5 E 11 meters). Now enter P for any of the parameters and press Enter, and watch the earth go around the sun in an approximately circular orbit of period 365 days.

After one period, choose Q to quit, and the computer will return you to the program’s main P/R/I/O/E menu. Keep choosing O as long as you wish to play. If the orbit is displayed too quickly, decrease the dt parameters; if the orbit takes too long to display, increase the dt value.

For your second run after getting an acceptable circular orbit for the earth, change the scale factor down to 0.5; then press the Enter key to keep the parameters the same until you come to the initial circular speed (29822 m/s). Slow this speed down by typing in a circular speed about 30% less than the 29822 and press Enter. You may want to decrease the dt value also. Then type P and Enter to start plotting this situation and see what happens. What kind of orbit do you get? How long is the period for this orbit? Does the orbit repeat on itself or not? After you have determined the answers to these questions, type Q to quit or A to abort. Then choose O from the main menu to play again.

For your third run, change the scale factor up to 3; then press the Enter key to keep the parameters the same until you again come to the initial circular speed. Speed this up so that it is about 20% greater than the original circular speed of 29822 m/s. You may want to increase the dt value also. Finally press the P and Enter to start plotting and answer the same questions as in the previous plot.

Keep playing as long as you like, at least until you have investigated the situations asked for in the report section below.

REPORT:
1. Describe the type of orbit that the earth is going in.
2. Describe what happens when you slowed down the earth by about 30%.
3. Describe what happens when you speeded up the earth by about 20%.
4. Predict what would happen if you slowed the earth down to zero.
5. Predict what would happen if you speeded the earth up a lot.
6. What kind of orbits do comets have? Explain the reasons for your answer.
### Appendix – planetary data

<table>
<thead>
<tr>
<th>Planet</th>
<th>radius of orbit in 10^6 miles / A.U</th>
<th>period in days</th>
<th>diameter to earth</th>
<th>rotation period</th>
<th>length of “day”</th>
<th>tilt of axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>36</td>
<td>.387</td>
<td>88 d</td>
<td>58.8 d</td>
<td>176 d</td>
<td>0.3°</td>
</tr>
<tr>
<td>Venus</td>
<td>67</td>
<td>.723</td>
<td>225 d</td>
<td>-244 d</td>
<td>117 d</td>
<td>177.3°</td>
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<tr>
<td>Earth</td>
<td>93</td>
<td>1.00</td>
<td>1 y</td>
<td>24 h</td>
<td></td>
<td>23.5°</td>
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<tr>
<td>Mars</td>
<td>142</td>
<td>1.52</td>
<td>1.88 y</td>
<td>24 h+39m</td>
<td></td>
<td>25.2°</td>
</tr>
<tr>
<td>Jupiter</td>
<td>484</td>
<td>5.20</td>
<td>11.9 y</td>
<td>9 h+58m</td>
<td></td>
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<tr>
<td>Saturn</td>
<td>888</td>
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<td>29.4 y</td>
<td>10 h+41m</td>
<td></td>
<td>26.7°</td>
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<tr>
<td>Uranus</td>
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<td>19.20</td>
<td>83.7 y</td>
<td>-17 h+16m</td>
<td></td>
<td>97.8°</td>
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<tr>
<td>Neptune</td>
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<td>163.7 y</td>
<td>16 h+9m</td>
<td></td>
<td>28.3°</td>
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<tr>
<td>*Pluto</td>
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<td>247.9 y</td>
<td>0.18</td>
<td>6.41 d</td>
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<td>*Eris</td>
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