Quantity	**Symbol**	**Value**
One Astronomical Unit	1 AU	1.50×10^{11} m
Speed of Light	c	3.0×10^{8} m/s
One parsec	1 pc	3.26 Light Years
One year	1 y	$\simeq \pi \times 10^{7}$ s
One Light Year	1 ly	9.5×10^{15} m
Radius of Earth	R_E	6.4×10^{6} m
Radius of Sun	$R_\odot$	6.95×10^{8} m
Gravitational Constant	G	$6.67 \times 10^{-11} \mathrm{m}^3/(\mathrm{kg\,s}^3)$

Part I.

1. Describe qualitatively the funny way that the planets move in the sky relative to the stars. Give a qualitative explanation as to why they move this way.

2. Draw a set of pictures approximately to scale showing the sun, the earth, the moon, α-centauri, and the milky way *and* the spacing between these objects. Give an approximate size for all the objects you draw (for example example next to the moon put $R_{\rm moon} \sim 1700\,\rm km$) *and* the distances between the objects that you draw. Indicate many times is one picture magnified relative to another.

   Important: More important than the size of these objects is the relative distance between these objects. Thus for instance you may wish to show the sun and the earth on the same graph, with the circles for the sun and the earth having the correct ratios relative to to the spacing between the sun and the earth.

3. A common unit of distance in Astronomy is a parsec.

$$1\,\rm pc \simeq 3.1 \times 10^{16} m \simeq 3.3\,ly$$

   (a) Explain how such a curious unit of measure came to be defined. Why is it called parsec?

   (b) What is the distance to the nearest stars and how was this distance measured?

4. Describe qualitatively what is the precession of perihelion.

   (a) What are the dominant cause of this precession?

   (b) What is the approximate magnitude of this precession?

   (c) How long would it take before you could see this precession shift by the naked eye. Explain.

Part II. (Pick one out of two)

1. During the moon's orbit around the sun, in a given time Δt the moon will fall a distance

$$\frac{1}{2} a_m \Delta t^2$$

   towards the center of the earth, where a_m is the acceleration of the moon. a_m is analogous to the free fall acceleration $g = 10\,\rm m/s^2$ on earth. The orbital period of the moon is 27 days and the distance to the moon is $R_{EM} = 384,000\,\rm km$

   (a) What is the speed of the moon?

   (b) What is the ratio between $g = 10\,\rm m/s^2$ and a_m.

   (c) How did Newton use this number to understand the distance dependence of the gravitational force?

2. A clock in a satellite is orbiting 200 km above the earth (in a low earth orbit). The orbital speed of the satellite is approximately 7.7 km/s.

   (a) Determine the orbital period as measured by earth $\Delta t_{\mathrm{earth}}$.

   (b) After orbiting once, the clock in the satellite and on earth read different times. Which clock (the earth or the satellite) shows a longer elapsed time? Explain.

   (c) Determine the time that the satellite reads after one orbit, Δt_{sat}. More specifically, compute the time difference between the earth and the satellite after one orbit

   $$\Delta t_{\mathrm{earth}} - \Delta t_{\mathrm{sat}}$$

   in microseconds. (Hint: the approximate formulas for $\gamma - 1 \simeq \frac{1}{2}(v/c)^2$ and $1 - \frac{1}{\gamma} \simeq \frac{1}{2}(v^2/c^2)$ can be useful here.)