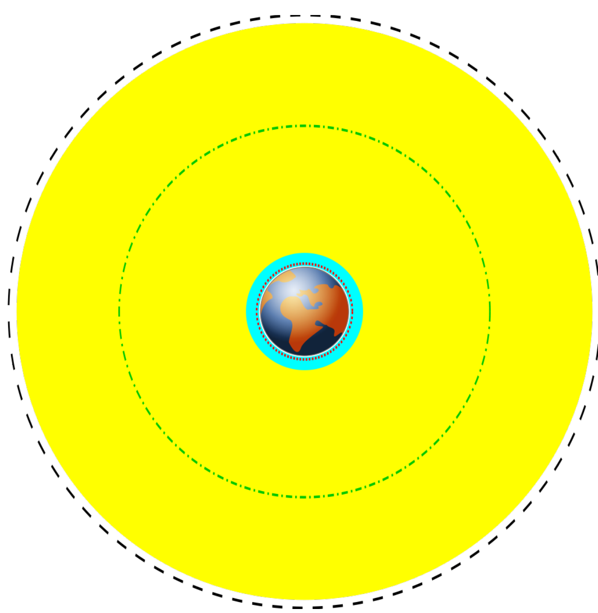
Homework

Choose three problems from Group I. Do the must do problem. Choose two problem from Group II.

- **Group I. Choose three.**
  1. When mercury goes around the sun it moves with a speed of 47 km/s, as you worked out in homework. Estimate the percent correction due to relativity on the motion of Mercury. Use this estimate to get a rough order of magnitude estimate for the precession of the perihelion of mercury. Give your answer in degrees/year.
  2. Why are things weightless in space?
  3. Describe briefly the experiments that confirmed Einsteins formula for the deflection of light.
  4. Describe what is Gravitational lensing and how it is observed.
  5. What is the Schwarzchild radius of a point like massive object, and why is it important. If all the mass of the sun where located at a point, it would have a Schwarzchild radius. What would this Schwarzchild radius be?
  6. At the middle of our Galaxy is a supermassive black hole. Describe how its mass was determined, and how big is this mass in units of the solar mass.

- (**The must do problem**) A clock in a satellite is orbiting 200 km above the earth (in a low earth orbit). The region of low earth orbit is shown below (to scale) as the cyan (or blue) region. (Neglect the differences in gravity between the earth observer and the low earth orbit.)[1]



[1] Select answers: (1) 1.4 h (2) 7.7 km/s. The speed of Mercury is 47 km/s. (5) 3.3×10^{-10} (5) 28 microseconds.

1. Determine the orbital period (in hours) according to the earth observer using Kepler's Law.
2. Determine its speed using Keplers Law. How does this compare to the velocity of mercury? Also give your answer in km/h.
3. 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?
4. Below you will need to compute γ to many digits (14) in order to get a non-zero answer. Go to www.wolframalpha.com. Using the calculator on the wolfram site show that the following approximations are very good (for $v \ll c$).

$$\gamma - 1 \simeq \frac{1}{2}\frac{v^2}{c^2} \qquad \text{and} \qquad 1 - \frac{1}{\gamma} \simeq \frac{1}{2}\frac{v^2}{c^2} \tag{1}$$

5. Use this numerical approximation to compute

$$\frac{\Delta t_{\rm earth} - \Delta t_{\rm sat}}{\Delta t_{\rm earth}} = 1 - \frac{\Delta t_{\rm earth}}{\Delta t_{\rm sat}}$$

6. In a time period of one day, how much do the clocks differ? Express your answer in microseconds. You should find a time of order microseconds as in the GPS system discussed in class.

- **Group II** . Choose two.

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

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

Explain how such a curious unit of measure came to be defined. Why is it called parsec? What is the distance to the nearest stars ?

2. How was the distance to Mars determined?
3. How was the speed of light originally determined?
4. Explain what is meant by the following statement – the forces in Electricity and Magnetism depend on the absolute speed of the observer.
5. Explain in your own words what we mean when we say that the speed of light is constant for all moving observers.
6. Qualitatively explain how the Michelson Morley Experiment showed that the speed of light is not different in different frames?