Physics 221 – Test 2 – Fall 2010

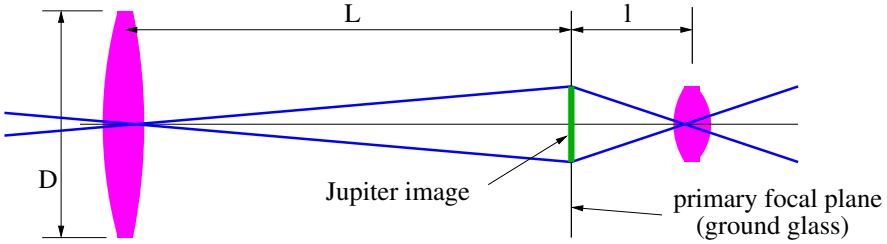
One-page reminder sheet allowed. *Show all work – no credit given if work not shown!*

1. The great refractor telescope of Yerkes Observatory in Wisconson has primary lens $D = 1.02$ m in diameter with a focal length of $L = 19.4$ m. Use the small angle approximation in all calculations.

   (a) Jupiter has a diameter of 1.5×10^5 km and an average distance from the earth of 8×10^8 km. How big is the image of Jupiter (in cm) at the focal plane of the primary lens?

   (b) Given perfect atmospheric "seeing" conditions, how far apart must two features be on Jupiter (in km) for the Yerkes telescope to be able to resolve them?

   (c) What should the focal length l of the secondary lens or eyepiece be for Jupiter to subtend the same angle as the moon subtends to the naked eye? The moon's diameter is 3.5×10^3 km and its distance from the earth is 3.8×10^5 km. Hint: Imagine that a translucent sheet of ground glass is placed at the focal plane so that the image is seen projected on this ground glass, which scatters light over a broad range of angles. The eyepiece can then be thought of as a magnifying glass with which you can examine the image on the ground glass. Using this artiface, you need consider only light rays that pass through the center of each lens.



2. An interstellar spaceship pilot going from Earth to Sirius (8 ly distant) ages by 2 y during this trip.

   (a) Draw a spacetime diagram illustrating her journey. Include and label the world line and a line of simultaneity of the moving spaceship.

   (b) How much does her Earth-bound brother age during this journey? (Calculate in the reference frame of the Earth.)

   (c) How fast (as a fraction of the speed of light) is the spaceship traveling during the trip?

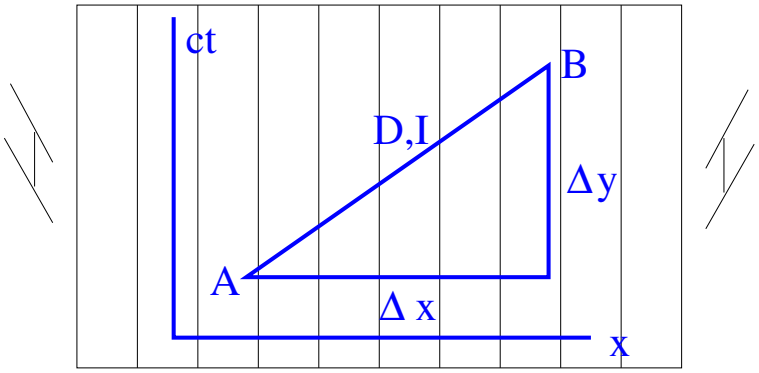
   (d) In the reference frame of the moving spaceship, what is the separation of Earth and Sirius?

3. Imagine a life-sized spacetime diagram drawn on the Rose Bowl football field (a Cal Tech student prank!). The points A and B on the field are separated in the along field direction by Δx and in the cross field direction by Δy. (Continued on opposite side!)

(a) If the referees measure the distance D between A and B with a tape measure, what will D be in terms of Δx and Δy?

(b) Interpreted as events in the spacetime diagram, Δx is the space component of the separation between A and B and Δy is c times the time separation between A and B. What is the invariant interval between A and B?

(c) Determine the factor $F(S) = I/D$ relating the two measures of distance, D and I, as a function of the slope of the hypotenuse $S = \Delta y/\Delta x$.



4. Tachyons: Suppose we consider a relativistic particle with dispersion relation $\omega^2 = k^2c^2 + \mu^2$, but with the constant $\mu^2 = -\kappa^2c^2$ where κ is real. The quantity c is the speed of light and ω and k are the angular frequency and wavenumber.

   (a) Given this dispersion relation, compute the phase speed of the resulting waves. Is this greater or less than the speed of light?

   (b) Compute the group velocity. Is this greater or less than the speed of light?

5. Consider the Doppler shift of *sound* with a source moving to the left at speed v emitting two sound pulses to the right. These are intercepted by a stationary observer at the origin under zero wind conditions.

   (a) Identify the time interval in the spacetime diagram below which is the time T_S between the emission of the two pulses by the source, and the time interval T_O between the observation of the pulses by the observer.

   (b) Derive a relationship between T_O and T_S in terms of the speed of sound c and the speed of the source v.