

Modern Physics

Problem Set 2

For all problems where values of the numbers given is less than 100, take all digits given as significant. For example, 60 would have 2 significant digits.

JC-5) Kelly's Spaceship

(10 points) Kelly passes you at a speed of $0.50c$ in her new spaceship. Though the spaceship window, you observe Kelly doing a physics calculation. By your watch, the calculation takes her 1.0 minutes. According to Kelly, how much time did the calculation take?

JC-6) Pole in Barn Paradox

A pole-vaulter holds a 16 ft pole. A barn has doors at both ends, 10.0 ft apart. The pole-vaulter on the outside of the barn begins running toward one of the open barn doors, holding the pole level in the direction he is running. When passing through the barn, the pole fits (barely) entirely within the barn all at once.

- (10 points) How fast is the pole-vaulter running?
- (10 points) According to whom -- the pole vaulter or an observer stationary in the barn -- does the pole fit in all at once? Explain your answer.
- (10 points) According to the pole vaulter, which occurs first, the front end of the pole leaving the barn or the back end of the pole entering the barn? Justify your answer by calculating the time interval between the two events.

JC-7) Pions at Fermilab

A burst of π^+ mesons (pions) travels down an evacuated beam tube at Fermilab moving at $0.92c$ with respect to the laboratory.

- (10 points) Compute γ for this group of pions.
- (10 points) The proper mean lifetime of pions is 2.6×10^{-8} s. What mean lifetime is measured in the lab?
- (10 points) If the burst contained 50,000 pions, how many remain after the group has traveled 50 m down the beam tube?
- (10 points) What would the answer to (c) be if we ignored time dilation?

Hint: Pions decay according to the statistical law of radioactivity where $\tau = t_0$.

$$N(t) = N_0 e^{-(t/\tau)}$$

JC-8) Einstein's Puzzle

(10 points) Einstein reported that as a boy he wondered about the following puzzle. If you hold a mirror at arm's length and look at your reflection, what will happen as you begin to run? In particular, suppose you run with speed $v = 0.99c$. Will you still be able to see yourself? If so, what would your image look like, and why?

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JC-9) Agreement Between Observers

(10 points) What two speed measurements will two observers in relative motion always agree upon?

JC-10) H_α Spectral Line

(10 points) Stars typically emit the red light of atomic hydrogen with wavelength 656.3 nm (called the H_α spectral line). Compute the wavelength of that light observed at Earth from stars receding directly from us with relative speed $v = 10^{-3}c$, $v = 10^{-2}c$ and $v = 10^{-1}c$. Assume the relative speed is exact to four significant figures.

JC-11) Speed of Quasars

(10 points) Quasars are among the most distant objects in the universe. As discussed in class, they are moving away from us at very high speeds that can be described by the redshift parameter z . Find the speed of two quasars having z values of 1.9 and 4.9.