***Homework Set* 1**

Remember to *present* your solutions to the problem in words. Another student should be able to look at your homework page and be able to figure out what the question was asking without looking at this sheet. please show your work and explain your reasoning. I will grade for clarity of explanation as much as I do for mere “correctness of final answer”!

1) A person in an elevator drops a ball of mass m from rest from a height h above an elevator floor. The elevator is moving at a constant speed v downward with respect to its enclosing building.

Don’t forget the general principles of problem-solving, for this and all problems. Setup the problem, define variables, include a drawing if helpful (it usually is). Solve all equations in variable form before substituting in numbers (but for this problem, there are no numbers). When you do use numbers, be sure to include units and appropriate significant figures.

(a) How far will the ball fall in the building frame before it hits the floor? (*Hint*: $> h$!)

(b) What is the balls’ initial vertical velocity in the building frame? (*Hint*: not zero!)

(c) Use the law of conservation of energy in the building frame to compute the ball’s final speed (as measured in that frame) just before it hits the elevator floor.

(d) Use the Galilean velocity transformation and the result of part **(c)** to find the ball’s final speed in the elevator frame. Hint: You’ll also need to use the fact that the ball is accelerating in the building frame at a rate a_{ff} (free fall acceleration), which will help you relate its initial and final velocities in the building frame.

(e) Use the result of part **(d)** to show that the law of conservation of energy apparently holds in the elevator frame (assuming that it holds in the building frame).

2) A pulse of protons arrives at detector D, where you are standing. Prior to this, the pulse passed through detector C, which lies 60 meters upstream. Detector C sent a light flash in your direction at the same instant that the pulse passed through it. At detector D you receive the light flash and the proton pulse separated by a time of 2.0 nanoseconds ($2.0 \times 10^{-9}\,\text{s}$). What is the speed of the proton pulse?

3) A spaceship leaves earth (event A), travels to Alpha Centauri (which is 4.3 ly of distance away), and then returns (event B) exactly 9.0 years later. If the spaceship’s acceleration time is very short, so that it spends virtually all its time traveling at a constant speed, estimate the time measured between events A and B by the ship’s clock.

4) A jogger runs exactly 22 times around a 0.5-km track in 48 min, as measured by a friend sitting at rest on the side. If the jogger and friend synchronize watches before the run, how much are they out of synchronization afterward? Is this the reason that many people expect joggers to live longer than people who don’t jog? Explain.

Hint: recall the binomial approximation. If you haven’t seen it before in calculus or Math Methods, it’s on page 1168 of Knight Chapter 37; you can skip ahead to this portion even if we haven’t covered Section 37.8 yet.

5) A group of π mesons (pions) are observed to be traveling at $u' = 0.8c$ in a physics laboratory. The mean lifetime (let's call it λ) for unstable particles undergoing exponential decay is the average time for a group of particles to be reduced to 1/*e* of their original number. We can express this mathematically as: $N_t = N_0 e^{(-\Delta t/\lambda)}$. We see then that for $\Delta t = \lambda$, $N_t = N_0 e^{(-1)} = (1/e)\cdot N_0$

(a) What is the γ –factor for the pions?

(b) If the pions' proper mean lifetime is $\lambda = 2.6\times10^{-8}\,\text{s}$, what is the lifetime ($\lambda'$) as observed in the laboratory frame?

(c) If there were initially 32,000 pions, how many will be left after they have traveled down an evacuated pipe of 36 meters, from the source to a detector (as measured in the laboratory frame)?

(d) Show that this number is the same, as calculated in the rest frame of the pions.

(e) What would the answer to **(c)** be if there were no time dilation (*i.e.*, $\Delta\tau = \Delta t'$)?

(f) How long does the distance of 36 meters in the laboratory frame appear to the pions in their rest frame?

(g) Use the result from **(f)** and the proper time elapsed (as calculated in the rest frame of the pions) to find the velocity of the laboratory frame, as calculated in the rest frame of the pions.

6) Your roommate is an intelligent person (but unfortunately, not a physics major) who carefully reads articles about science in the public press. They have the objections to relativity listed below. Respond to each of their objections clearly, decisively, and politely – without criticizing!

(a) "Observer A says that Observer B's clock runs slow, while B says that A's clock runs slow. This is a logical contradiction. Therefore relativity should be abandoned."

(b) "Anybody with common sense knows that travel at high speed in the direction of a receding light pulse decreases the speed with which the pulse recedes. Hence a flash of light cannot have the same speed for observers in relative motion. With this disproof of the Principle of Relativity, all of relativity collapses."

7) An astronaut traveling in an unpowered spaceship celebrates his 18^{th}, 19^{th}, 20^{th}, and 21^{st} birthdays. Five Earth-years elapse between the 18^{th} and 21^{st} birthday parties.

(a) Find the spatial separation between the 18^{th} and 21^{st} birthday parties in the Earth frame. *Hint*: Use the spacetime interval *s*, Equation 37.19 in Knight. What is Δx of the astronaut in his spaceship's frame? Feel free to express your answer in a convenient unit, such as a "lightyear".

(b) Find the speed of his spaceship with respect to Earth.