# Physics 24 Problem Set 3

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**due Monday, January 30**

Please make your work neat, clear, and easy to follow. It is hard to grade sloppy work accurately. Generally, make a clear diagram, and label quantities. Derive symbolic answers, and then plug in numbers after a symbolic answer is available.

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1. How long does it take light to travel from Isla Vista to:
   (a) Los Angeles (85 miles away)
   (b) San Francisco (277 miles away)
   (c) Mexico City, Mexico (1635 miles away)
   (d) Mumbai, India (8666 miles away)
   (e) Johannesburg, South Africa (10443 miles away).

2. The lifetime of a common elementary particle, the muon ($\mu$), is $2 \times 10^{-6}$ seconds. These particles are frequently produced at the top of our atmosphere by protons that originate from supernovas, and somehow they survive all the way down to sea level. The top of the atmosphere is about 10 kilometers above sea leval.
   (a) Ignore time dilitation, and compute how far a muon could go if it traveled at the speed of light... what is the numerical result?
   (b) Taking time dilitation into account, what is the minimum speed needed for a muon to survive to sea level from the top of the atmosphere? Get a numerical result.

3. Two atomic clocks are carefully synchronized. One remains in Isla Vista, and the other is loaded on a jet from Santa Barbara Airport that travels at an average speed of 400 m/s and then returns to the Airport. When the plane returns, the elapsed time on the Isla Vista clock is exactly four hours. By how much will the reading on the two clocks differ, and which clock will show the shorter elapsed time? Feel free to simplify $\sqrt{1-(u/c)^2}$ with a Taylor expansion.

4. As measured by an observer on Mars, a spacecraft runway on Mars has a length of 4000 meters.
   (a) What is the length of the runway as measured by a pilot of a spacecraft flying past Mars at a speed of $1.5 \times 10^8$ m/s?
   (b) An observer on Mars measures the time interval from when the spacecraft is directly over one end of the runway until it is directly over the other end. What time interval do they measure?
   (c) The pilot of the spacecraft measures the time it takes to travel from one end of the runway to the other end. What value do they get?

5. Imagine two coordinate systems that share a common origin at $t = t' = 0$, so at that time $x = x'$, $y = y'$, $z = z'$. The primed coordinate system moves with velocity $u\hat{\boldsymbol{x}}$ with respect to the unprimed coordinate system. At exactly $t = 0$, a tiny lightbulb flashes at the origin of the coordinate systems, and a spherical light wavefront propagates out from the origin(s) of the systems. The points on the growing sphere of light are characterized in the unprimed system by the equation for a sphere with radius $ct$:

$$x^2 + y^2 + z^2 - c^2t^2 = 0$$

What equation do the points on the wavefront of light as characterized in the primed system satisfy? (Use the Lorentz transformations and plug into the above equation). Physically, can you interpret the result?

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