Problem 1 [2 pts]
The lifetime of the particle called the pi meson (or pion), is $\tau_\pi = 2.5 \times 10^{-8}$ s when the pion is at rest relative to the observer measuring its decay time. What is the lifetime measured by an observer at rest for pions travelling with a speed of $v = 0.999c$?

Problem 2 [3 pts]
Consider a certain small region of the upper atmosphere where muons ($\mu$) are produced from cosmic ray collisions with the upper atmosphere at a rate of 100 per minute and with speeds of 0.995$c$. At what rate will these muons be detected at the Earth’s surface (assuming we can detect all those that make it)?
(Assume the muon lifetime is $\tau_\mu = 2.20 \times 10^{-6}$ s at rest, and the upper atmosphere is at a distance of 100 km above the Earth’s surface (roughly correct).)

Problem 3 [3 pts]
Text problem 1.4

Problem 4 [3 pts]
Text problem 1.6

Problem 5 [3 pts]
(a) Write down the Lorentz transformations relating observations in a reference frame ($t', x', y', z'$) that is moving with constant speed $v$ relative to another reference frame ($t, x, y, z$).
State clearly the assumptions you are making for the form in which you write these.
(b) Show by explicit computation that the proper time interval, $d\tau$, where:

$$c^2 d\tau^2 = c^2 dt^2 - (dx^2 + dy^2 + dz^2)$$

is invariant under Lorentz transformations. That is, $d\tau^2 = (d\tau')^2$.

Problem 6 [3 pts]
In class we derived the relativistic form of the kinetic energy to be:

$$K = m_0c^2(\gamma - 1)$$

Show that this reduces to the familiar $K = \frac{1}{2}m_0v^2$ for $v \ll c$ (the Newtonian limit).
(Hint: using a Taylor expansion will be useful.)
Problem 7 [3 pts]
Show that the total relativistic energy of a particle travelling with speed $v$, $E = \gamma m_0 c^2$, can also be expressed as $E^2 = p^2 c^2 + m_0^2 c^4$, where $m_0$ is the particle’s rest mass, and $p$ is the relativistic momentum, $p = \gamma m_0 v$.

Problem 8 [3 pts]
Text problem 1.9

Problem 9 [5 pts]
Text problem 1.10

Problem 10 [2 pts]
If you are speeding directly towards a red traffic light, at what speed would you need to be travelling for it to appear to you as green? Give you answer both as a fraction of $c$ and in $mph$.
(Although this might appear as a clever way to get out of a traffic violation for running a red light, the fine for speeding will be far worse!!)