Problem 1: Tipler 1-56

1-56. (a) \( t_1' = \gamma(t_2 - \nu x_2/c^2) \) and \( t_1' = \gamma(t_1 - \nu x_1/c^2) \)

\[
t_2' - t_1' = \gamma(t_2 - t_1 - \nu(x_2 - x_1)/c^2) = \gamma(T - vD/c^2)\]

(b) For simultaneity in \( S' \), \( t_2' = t_1' \), or \( T - vD/c^2 \to \nu/c = cT/D \). Because \( \nu/c < 1 \), \( cT/D \)

is also \(<1 \) or \( D > cT \).

(c) If \( D < cT \), then \( (T - vD/c^2) > (T - \nu cT/c^2) = T(1 - \nu/c) \). For \( T > 0 \) this is always positive

because \( \nu/c < 1 \). Thus, \( t_2' - t_1' = \gamma(T - vD/c^2) \) is always positive.

(d) Assume \( T = D/c' \) with \( c' > c \). Then \( T - vD/c^2 = (D/c') - (vD/c^2) = (D/c)

\[
\left(\frac{c}{c'} - \frac{\nu}{c}\right)
\]

This changes sign at \( \nu/c = c/c' \) which is still smaller than 1. For any larger \( \nu \) (still smaller

than \( c \)) \( t_2' - t_1' = \gamma(T - vD/c^2) < 0 \) or \( t_1' > t_2' \)

In (b) something is missing; it should say \( T - vD/c^2 = 0 \Rightarrow \nu/c = cT/D \). In (c) the

first step follows because subtracting something larger (\( cT \) instead of \( D \)), we get a smaller result.

Problem 2: Tipler 1-62

The angle of \( u' \) with the \( x' \) axis is:

\[
\tan \theta' = \frac{u'_y}{u'_x} = \frac{u_y}{\gamma \left(1 - \nu u_x/c^2\right)} \frac{1 - \nu u_x/c^2}{u_x - \nu}
\]

\[
\tan \theta' = \frac{u_y}{\gamma(u'_x - \nu)} = \frac{u \sin \theta}{\gamma(u \cos \theta - \nu)} = \frac{\sin \theta}{\gamma(\cos \theta - \nu/u)}
\]

(Why is this a Level III problem?)
**Problem 3: Tipler 2-3**

The rest mass energy of an electron (measured in electron-volts, defined on p. 82) is $mc^2 = 0.511$ MeV. Its speed in the lab frame is $u = 0.6\, c$.

$$\sqrt{1-\left(\frac{u}{c}\right)^2} = \sqrt{1-(0.6)^2} = \sqrt{1-0.36} = \sqrt{0.64} = 0.8;$$

a) $$\gamma = \frac{1}{\sqrt{1-\left(\frac{u}{c}\right)^2}} = \frac{1}{0.8} = 1.25$$

b) $$p = \gamma mu = \gamma(mc^2)\left(\frac{u}{c}\right) = (1.25)(0.511\, \text{MeV})(0.6)\frac{1}{c} = 3.8325 \times 10^{-1} \frac{\text{MeV}}{c}$$

c) $$E = \gamma mc^2 = (1.25)(0.511\, \text{MeV}) = 0.639\, \text{Mev} = 1.25 mc^2$$

d) $$E_k = E - mc^2 = 0.25mc^2 = 0.128\, \text{MeV}$$

**Problem 4: Tipler 2-7**

a) $$u = \frac{3.80 \times 10^8\, \text{m}}{1.50\, \text{s}} = 2.53 \times 10^8\, \frac{\text{m}}{\text{s}}; \quad \beta = \frac{u}{c} = \frac{2.53 \times 10^8}{3.00 \times 10^8} = 0.844$$

Also, $$\gamma = \frac{1}{\sqrt{1-\beta^2}} = 1.87.$$ 

b) The rest mass energy of a proton is (inside back cover of book) $m_p c^2 = 938.3\, \text{MeV}$. The kinetic energy is

$$E_k = mc^2 \left(\gamma - 1\right) = (938.3\, \text{MeV})(0.87) = 816\, \text{MeV}.$$ 

c) Earth observer would measure $\gamma m$ for the mass. $\gamma m = (1.87)(938.3\, \text{MeV}/c^2) = 1754\, \text{MeV}/c^2$.

d) The non-relativistic kinetic energy is $\frac{1}{2} mu^2 = \frac{1}{2} mc^2(u/c)^2 = \frac{1}{2} (938.3\, \text{MeV})(0.844) = 334\, \text{MeV}$. So the percent error is $100(816 - 334)/816 = 59\%$ error.