Quiz 8  
PHYS 2020, spring 2016, Michelle Arnold

Name: _______________________________

Instructions: Answer all questions.
Multiple choice: There is only one correct answer to each multiple choice question. Circle the letter of
the answer you choose, and make sure if you change your mind it is clear which of the two answers you
want as your actual answer.
Problems: Show all of your work.

Some Useful, or Not-so-Useful, Equations and Constants:

\[ k = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \]
\[ e = 1.602 \times 10^{-19} \text{ C} \]
\[ G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \]
\[ g = 9.81 \text{ m/s}^2 \]
\[ \varepsilon_0 = 8.85 \times 10^{-12} \text{ F/m} \]
\[ 1\text{eV} = 1.602 \times 10^{-19} \text{ J} \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m/A} \]
\[ c = 3 \times 10^8 \text{ m/s} = 1 \text{ ly/yr} \]
\[ 1 \text{ lightyear} = 9.5 \times 10^{15} \text{ m} \]

mass of a neutron = 1.675 \times 10^{-27} \text{ kg}
mass of a proton = 1.673 \times 10^{-27} \text{ kg}
mass of an electron = 9.109 \times 10^{-31} \text{ kg}

\[ \Delta t = \gamma \Delta t \]
\[ L = \ell \]
\[ E_{\text{total}} = E_0 + K \]
\[ E_{\text{total}} = \gamma mc^2 \]
\[ E_0 = mc^2 \]
\[ K = (\gamma - 1)mc^2 \]

\[ \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \]
\[ u = \frac{u' + v}{\gamma} \]
\[ u' = \frac{u - v}{1 - \frac{v^2}{c^2}} \]
\[ p = \gamma mu \]

1. [3 points] After completing introductory physics you conclude that you must change your career
plans and become a particle physicists! As a graduate student you are conducting an experiment
with extremely fast moving particles. You measure that one of these particles travels an 8 km
beam line (tube) in 33 \mu s. How long does the journey take according to the particle?

\[ \text{Solution:} \]
\[ v = \frac{\Delta x}{\Delta t} = \frac{8000 \text{ m}}{33 \times 10^{-6} \text{ s}} = 2.42 \times 10^8 \text{ m/s} \]
\[ \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - (2.42 \times 10^8)^2}} = \frac{1}{\sqrt{1 - 0.81^2}} \]
\[ \gamma = 1.71 \]

\[ \Delta t = \gamma \Delta t \]
\[ \Delta t = \frac{33 \mu s}{1.71} = 19.3 \mu s \]
2. [2.5 points] As you sit out in your backyard looking up at the stars you see two alien spaceships flying through the sky. The first ship (ship A) is travelling at 40% the speed of light as measured by you. The second ship (ship B) is behind the first ship, chasing it at 75% the speed of light, once again measured by you. What would be the speed of ship B as measured by the pilot of ship A?

\[ u = 0.4c \text{ (speed of moving } \hat{x} \text{ rel, to ground) } \]

Measures \( u' = ? \) for ship B

\[ u' = u - \frac{uv}{c^2} \]

measures \( u = 0.75c \) for ship B

\[
\begin{align*}
\text{So, if } & u = 0.75c, \\
\text{then } & u' = u - \frac{uv}{c^2} = 0.75c - \frac{0.4c \cdot 0.75c}{c^2} = \frac{0.35c}{1 - 0.75(0.4)} = 0.35c = 0.5c \\
\end{align*}
\]

3. [2.5 points] How fast is a particle travelling if its total energy is six times its rest energy?

\[ E_{\text{total}} = 6E_0 \]

\[ \gamma mc^2 = 6mc^2 \]

\[ \gamma = 6 \]

\[ \gamma = \frac{1}{\sqrt{1 - \beta^2}} \]

\[ \frac{1}{\sqrt{1 - \beta^2}} = 6 \]

\[ 1 - \beta^2 = \frac{1}{6} \]

\[ 1 - \frac{1}{6} = \beta^2 \]

\[ \beta = \sqrt{1 - \frac{1}{6}} \]

\[ \beta = 0.986 \]

\[ \frac{v}{c} = 0.986 \]

\[ v = 0.986c \]

98.6% of c