The formula for relativistic momentum is: 
\[ p = \frac{m_0 u}{\sqrt{1 - \frac{u^2}{c^2}}} \]

\[ \Rightarrow \quad p = \frac{(1.67 \times 10^{-27} \text{ kg}) \times (0.01c)}{\sqrt{1 - (0.01c)^2}} = 5.01 \times 10^{-21} \text{ kg m/s} \]

b) Do the same with \( u = 0.5c \).
\[ p = 2.89 \times 10^{-20} \text{ kg m/s} \]

c) For \( u = 0.9c \), we have
\[ p = 1.03 \times 10^{-20} \text{ kg m/s} \]

d) Since an electron volt (eV) is equal to \( 1.602 \times 10^{-19} \text{ J} \), then \( 1 \text{ MeV/c} = 10^6 \text{ eV/c} = 5.34 \times 10^{-22} \text{ kg m/s} \).

So, for (a), we have \( p = \frac{5.01 \times 10^{-21} \text{ kg m/s}}{5.34 \times 10^{-22} \text{ kg m/s}} (1 \text{ MeV/c}) = 9.38 \text{ MeV/c} \)

And for (b) we have \( \frac{(0.01c)}{(1 - (0.01c)^2)} \text{ MeV/c} \) and \( \frac{(0.9c)}{(1 - (0.9c)^2)} = 1.79 \text{ MeV/c} \), respectively.

Note: the mass of a proton is expressed as 938 MeV/c², so you can just substitute that in for \( m_p \) in the equations and get the same results.

2-5 First, let's start with \( \mathbf{F} \) in relativistic form:
\[ \mathbf{F} = q \mathbf{v} \times \mathbf{B} = \frac{d\mathbf{p}}{dt} = \mathbf{F}(\frac{m \mathbf{v}}{\sqrt{1 - (\mathbf{v}/c)^2}}) \]

where \( \mathbf{v} \) is the velocity of the charge, and \( \mathbf{B} \) is the applied magnetic field (note: \( \mathbf{v} \) and \( \mathbf{B} \) are constant).

Assuming the magnetic field is perpendicular to the circular orbit on the charge (and thus perpendicular to \( \mathbf{v} \)), we have \( q \mathbf{v} \times \mathbf{B} = q \mathbf{v} \mathbf{B} \)

Thus:
\[ q \mathbf{v} \mathbf{B} = \frac{d}{dt} \frac{m \mathbf{v}}{\sqrt{1 - (\mathbf{v}/c)^2}} = \frac{m}{\sqrt{1 - (\mathbf{v}/c)^2}} \frac{d\mathbf{v}}{dt}. \]

Note that \( \mathbf{v} \), the magnitude of \( \mathbf{v} \), is constant, but since \( \mathbf{v} \) changes direction continuously (uniform circular motion), \( \frac{d\mathbf{v}}{dt} \) is known as centripetal acceleration and is defined by:
\[ a_c = \frac{\mathbf{v}^2}{r} \quad \text{The direction points inward, along the radial direction.} \]

Substituting for \( \frac{d\mathbf{v}}{dt} \), we have:
\[ q \mathbf{v} \mathbf{B} = \frac{m \mathbf{v}}{\sqrt{1 - (\mathbf{v}/c)^2}} \frac{d\mathbf{v}}{dt} = \frac{m \mathbf{v}}{\sqrt{1 - (\mathbf{v}/c)^2}} \mathbf{a}_c \]

\[ v = \frac{q \mathbf{B}}{m \sqrt{1 - (\mathbf{v}/c)^2}} \]
Finally, the period \( T \) is the time it takes to complete one orbit:
\[
T = \frac{2\pi r}{v} = \frac{\sqrt{1 - v^2/c^2}}{v} \Rightarrow T = \frac{2\pi m}{\gamma B \sqrt{1 - v^2/c^2}}
\]

Thus the frequency of the orbital motion is:
\[
f = \frac{1}{T} = \frac{\gamma B}{2\pi m \sqrt{1 - v^2/c^2}}
\]

2.6 Notice from the previous problem we get this expression for \( v \):
\[
v = \frac{\gamma B r}{m} \sqrt{1 - \frac{v^2}{c^2}} \Rightarrow \frac{\gamma B r}{v} = \sqrt{1 - \frac{v^2}{c^2}} = \gamma
\]

As you can see, we just needed to do a little rearranging to get \( \gamma \)!

So, \( \gamma = \frac{\gamma B r}{v} = (1.60 \times 10^{-19} \text{ T} \cdot \text{m}) \frac{1.7 \times 10^{-8} \text{ m/s}}{5.84 \times 10^{-32} \text{ kg/m/s}} \) where we assume normal SI units for \( B \) and \( r \) (Tesla and meter, respectively).

Using our conversion from Problem 2-1: \( 1 \text{ MeV} = 1.8 \times 10^{-32} \text{ kg/m/s} \) and we see that \( \gamma = 3.8 \times 10^3 \text{ MeV/c} \).

2.8 a) The rest mass is just \( E_r = mc^2 = (1.67 \times 10^{-27} \text{ kg}) (3 \times 10^8 \text{ m/s})^2 = 1.50 \times 10^{-8} \text{ J} \)
\( \text{or} \quad 18.9 \text{ MeV} \)

b) Total energy: \( E = \sqrt{mc^2} = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} = 4.81 \times 10^{-10} \text{ J} \) or \( 5.01 \times 10^3 \text{ MeV} \)

c) Kinetic energy: \( K = E - mc^2 = \sqrt{E^2 - mc^2} = 3.31 \times 10^{-10} \text{ J} \) or \( 2.07 \times 10^3 \text{ MeV} \)

2.9 Use: \( K = (\gamma - 1) mc^2 = (\gamma - 1) E_r \) Since we know \( K = 5E_r = 5mc^2 \), then \( \gamma = 6 \) and:

a) \( E = \gamma mc^2 = 6 (1.51 \text{ MeV}) = 30.7 \text{ MeV} \)
\( \text{used mass of electron from book: } 5.11 \text{ MeV/c}^2 \)

b) Use the fact that \( \sqrt{1 - \frac{v^2}{c^2}} = 0.936 \) and you'll get a speed of
\[ v = 0.936c \]
2-12 a) \( K_\nu = \nu p \Rightarrow mc^2 (\gamma - 1) = \nu p c^2 (\gamma - 1) \). Solving for \( \gamma \) yields:

\[
\gamma = 1 + \frac{mc^2 (\gamma - 1)}{\nu p c^2}
\]

Now, let's use \( m_e = 0.511 \text{ MeV}/c^2 \) and \( \nu p = 938 \text{ MeV}/c^2 \), as well as:

\[
\gamma = \left(1 - (0.75)^2\right)^{-\frac{1}{2}} = 1.5719
\]

Substituting everything in, we have: \( \gamma p = 1.000249 \), which gives us \( \gamma = \frac{1.000249}{0.0036} \approx 0.023 e_c \).

b) \( \nu e = \nu p \Rightarrow \gamma p \nu e = \gamma e \nu e \Rightarrow \nu p = \frac{\gamma e \nu e}{\gamma p} \)

Substituting in all these constants gives us \( \gamma p = 6.17 \times 10^{-4} \).

We should expect these lower speeds since \( \nu p \approx 2000 \text{ meV} \).

2-13 a) \( E = \gamma mc^2 = 4900 \text{ meV}^2 \). Thus, \( \gamma = 4900 \) and use \( \gamma = \left(1 - 0.999 \nu c^2\right)^{-\frac{1}{2}} \) and you will get \( \nu = 0.9999999 \) (Damn!)

b) \( K = (\gamma - 1) mc^2 = 4900 \text{ meV}^2 \times 4.9999999 \text{ MeV} = 399 (938 \text{ MeV}/c^2) = 3.74 \times 10^{-4} \text{ MeV} \)

2-14 a) \( E = mc^2 \) to get the mass radiated per second:

\[
\frac{m c^2}{\gamma} = \frac{4.0 \times 10^{-6}}{(3 \times 10^8 \text{ m/s})^2} = 4.0 \times 10^{-9} \text{ kg/s}
\]

b) The sun can survive for \( t = \frac{2.0 \times 10^{24} \nu p^2}{4.0 \times 10^{13} \text{ kg/s}} = 4.5 \times 10^5 \text{ or } 1.5 \times 10^3 \text{ yr} \). Considering the sun is only 4.5 billion years old, I think we're safe here!

2-15 The mass difference is \( \Delta m = (226.0254 + 222.0175 - 4.0026) \text{ u} = 0.0053 \text{ u} \)

(Note: \( 1 \text{ u} = 931.5 \text{ MeV}/c^2 \))

Then the energy released is:

\[
E = \Delta mc^2 = (0.0053 \text{ u}) (931 \text{ MeV/c}^2) c^2 = 4.9 \text{ MeV}
\]
2-19 The mass difference between the carbon atom and its constituents is:
\[ \Delta m = 6m_p + 6m_e - M_c = [6(1.007276\ u) + 6(1.001815) - 12] \]
\[ = 0.095646\ u \]

So, use \( E = mc^2 \) to find the binding energy:
\[ BE = \Delta m c^2 = (0.095646\ u) (938.49\ MeV/u) = 89.09\ MeV \]

So, the binding energy per nucleon (\( p^+ \) and \( n \)) is:
\[ \frac{89.09\ MeV}{2\ \text{nucleons}} = 44.54\ MeV \]

2-20 Again, find the mass difference between the neutron and its decay products:
\[ \Delta m = m_n - m_p - m_e = 8.404 \times 10^{-4}\ u \]

Thus, the energy expelled is:
\[ E = mc^2 = (8.404 \times 10^{-4}\ u) (938.49\ MeV/u) = 0.783\ MeV \]

This falls in the error bounds of the problem: 0.781 MeV ± 0.005 MeV.

2-22 a) Note, from Problem 6, that we have: \( p \) (in MeV/c) = 300 B/2 where \( B \) is in teslas and \( R \) is in meters.

So, \[ p = \frac{300}{2} (2\ T)(2.34\ m) = 206\ \text{MeV/c} \]

Since the \( K^0 \) was at rest before decay, conservation of momentum forces the momenta of the two pions to be equal in magnitude and in opposite directions.

There are many ways to find the speed \( v \), but here's a slick one. Notice:
\[ \frac{E_p}{m_p c} = \frac{E_n}{m_n c} = \frac{v}{c} = \frac{E_p}{E_n} \]

Using \( E^2 = (pc)^2 + (mc^2)^2 \), we have:
\[ \frac{v}{c} = \frac{pc}{\sqrt{(pc)^2 + (mc^2)^2}} = \frac{206\ \text{MeV}}{\sqrt{(206\text{MeV})^2 + (104.6\text{MeV})^2}} = 0.827 \]
b) Conservation of energy dictates that the rest energy of the \( V^0 \) must be equal to the total energy of the pions. Thus:
\[
E_{\text{rest}} = 2E_\gamma = 2\sqrt{(p_\gamma c)^2 + (m_\gamma c^2)^2} = 2\sqrt{(206 \text{ MeV})^2 + (140 \text{ MeV})^2} = 492 \text{ MeV}
\]
or \( m_{V^0} = 498 \text{ MeV/c}^2 \)

\[
2-23
\begin{array}{c}
0 \\
\rightarrow
\end{array}
\begin{array}{c}
m_1 \\
\cdot \uparrow \gamma \\
\rightarrow
\end{array}
\begin{array}{c}
m_2 \\
\downarrow \gamma \\
\rightarrow
\end{array}
\]

Known:
\[
\begin{align*}
M &= 3.34 \times 10^{-24} \text{ kg} \\
v &= 0.38 \text{c} \\
v_2 &= -0.868 \text{c}
\end{align*}
\]

Since the unstable particle of mass \( M \) is at rest before it decays, the momenta of both particles 1 and 2 must be the same:
\[
|p_1| = |p_2| \Rightarrow \frac{m_1 |v_1|}{\sqrt{1-v_1^2c^2}} = \frac{m_2 |v_2|}{\sqrt{1-v_2^2c^2}}
\]

If you plug in all the numerical values, you get:
\[
m_1 = 0.284 \text{ kg}
\]

Conservation of energy also dictates that:
\[
E_M = E_1 + E_2 \Rightarrow M^2 = \frac{m_1 c^2}{\sqrt{1-v_1^2c^2}} + \frac{m_2 c^2}{\sqrt{1-v_2^2c^2}}
\]

After plugging in numerical values, you get:
\[
3.34 \times 10^{-24} \text{ kg} = 6.22 m_1 + 2.01 m_2
\]

Substitute the first equation involving \( m_1 \) and \( m_2 \) into this equation:
\[
3.34 \times 10^{-24} \text{ kg} \approx (6.22)(0.284)m_2 + 2.01 m_2
\]
\[
\Rightarrow \boxed{m_2 = 8.84 \times 10^{-24} \text{ kg}} \]

Thus,
\[
\boxed{m_1 = 0.284 m_2 = 2.51 \times 10^{-24} \text{ kg}}
\]