1. **Cosmic Rays**. Some of the largest particle accelerators can impart one TeV ($10^{12}eV$) to a proton. This is eclipsed by cosmic accelerators such as supernovae or active galactic nuclei, which accelerate particles to energies of $10^{21}eV$.
(a) If you gave a tennis ball ($\approx 0.05kg$) a kinetic energy of $10^{21}eV$, how fast would it go according to Newtonian mechanics? Does a relativistic description apply?
(b) Do the same for a proton ($10^{-27}kg$) with a kinetic energy of $10^{21}eV$. How long would it take this proton (in its own reference frame) to cross the full length of the Milky Way Galaxy? ($\approx 10^5$ lightyears)

2. **Relativistic Lorentz Force**. The relativistic Lorentz Force Law has the same form as the ordinary Lorentz Force Law

$$\mathbf{F} = q(\mathbf{E} + v \times \mathbf{B}) \tag{1}$$

The left hand side belies internal modifications, however.
(a) Derive the relativistic Newton's Second Law from

$$\mathbf{F} = \frac{\partial \mathbf{p}}{\partial t} \tag{2}$$

where $\mathbf{p}$ is the relativistic momentum.
(b) Now equate your result from part (a) with the Lorentz Force Law and solve for the acceleration on a relativistic charged particle due to an electromagnetic field. [Hint: Take the dot product of both sides with $\mathbf{v}$, and recall that for any vectors $\mathbf{a}$ and $\mathbf{b}$, $\mathbf{a}.(\mathbf{a} \times \mathbf{b}) = 0$]