1. [10 pts] To initiate a nuclear reaction, an experimental nuclear physicist wants to shoot a proton into a $^{12}$C nucleus. The proton must impact the nucleus with a kinetic energy of 3.00 MeV. The nuclear radius is 3.00 fm. You can assume the nucleus remains at rest and the proton’s velocity is non-relativistic. [Note: 1 eV = $1.6 \times 10^{-19}$ J]

a. [5 pts] With what speed must the proton be fired toward the target?

$$\text{Energy in } \text{II} = \text{Energy in } \text{I}$$

$$\frac{1}{2} m_p v_0^2 = 3.00 \text{ MeV} + \frac{6e^+e^-}{4\pi\varepsilon_0 (2\text{ fm})}$$

The 2nd one being electrostatic potential energy.

$$v_0 \approx \frac{3.35 \times 10^7 \text{ m/s}}{c} \approx 11c$$

b. [5 pts] Through what potential difference must the proton be accelerated from rest to acquire this speed?

Again Energy in $\text{III} = \text{energy in } \text{I}$

$$e^+\Delta V = 9.4 \times 10^{-13} J \approx 5.88 \text{ MeV}$$

$$\Delta V \approx 5.88 \text{ MeV}$$

Rest mass energy of proton: $m_p c^2 = 1.67 \times 10^{-27} \text{ kg} \times \left(3 \times 10^8 \text{ m/s}\right)^2 \approx 1.50 \times 10^{-10} J \leq 1.50 \times 10^{-10} J \times 19/16 \text{ eV/}J \approx 9.39 \text{ MeV}$

which is much larger than 3.00 MeV x $4.6 \times 10^{-13}$ J. Hence cannot use non-relativistic formula.