46. The q in the denominator is to be interpreted as $|q|$ (so that the orbital radius r is a positive number). We interpret the given 10.0 MeV to be the kinetic energy of the electron. In order to make use of the mc^2 value for the electron given in Table 38-3 (511 keV = 0.511 MeV) we write the classical kinetic energy formula as

$$K_{\text{classical}} = \frac{1}{2}mv^2 = \frac{1}{2}\left(mc^2\right)\left(\frac{v^2}{c^2}\right) = \frac{1}{2}\left(mc^2\right)\beta^2 .$$

(a) If $K_{\text{classical}} = 10.0\,\text{MeV}$, then

$$\beta = \sqrt{\frac{2K_{\text{classical}}}{mc^2}} = \sqrt{\frac{2(10.0\,\text{MeV})}{0.511\,\text{MeV}}} = 6.256 ,$$

which, of course, is impossible (see the Ultimate Speed subsection of §38-2). If we use this value anyway, then the classical orbital radius formula yields

$$\begin{aligned} r &= \frac{mv}{|q|B} = \frac{m\beta c}{eB} \\ &= \frac{\left(9.11\times10^{-31}\,\text{kg}\right)(6.256)\left(2.998\times10^{8}\,\text{m/s}\right)}{\left(1.6\times10^{-19}\,\text{C}\right)(2.20\,\text{T})} \\ &= 4.85\times10^{-3}\ \text{m} . \end{aligned}$$

If, however, we use the correct value for β (calculated in the next part) then the classical radius formula would give about 0.77 mm.

(b) Before using the relativistically correct orbital radius formula, we must compute β in a relativistically correct way:

$$K = mc^2(\gamma-1) \implies \gamma = \frac{10.0\,\text{MeV}}{0.511\,\text{MeV}} + 1 = 20.57$$

which implies (from Eq. 38-8)

$$\beta = \sqrt{1 - \frac{1}{\gamma^2}} = 0.99882 .$$

Therefore,

$$\begin{aligned} r &= \frac{\gamma mv}{|q|B} = \frac{\gamma m\beta c}{eB} \\ &= \frac{(20.57)\left(9.11\times10^{-31}\,\text{kg}\right)(0.99882)\left(2.998\times10^{8}\,\text{m/s}\right)}{\left(1.6\times10^{-19}\,\text{C}\right)(2.20\,\text{T})} \\ &= 1.59\times10^{-2}\ \text{m} . \end{aligned}$$

(c) The period is

$$T = \frac{2\pi r}{\beta c} = \frac{2\pi(0.0159\,\text{m})}{(0.99882)\left(2.998\times10^{8}\,\text{m/s}\right)} = 3.34\times10^{-10}\ \text{s} .$$

Whereas the purely classical result gives a period which is independent of speed, this is no longer true in the relativistic case (due to the γ factor in the equation).