Answer to Essential Question 19.8: This situation involves much of what we learned in this chapter. First, what is the connection between all this information? We can connect everything via the magnetic field. With the information about the electron, we can use equation 19.4 to solve for the magnetic field. Equation 19.4 gives the relation between the period of the circular orbit as: $T = 2\pi m/(qB)$. Solving for the magnetic field gives:

$$B = \frac{2\pi m}{qT} = \frac{2\pi\ (9.11\times10^{-31}\ \text{kg})}{(1.60\times10^{-19}\ \text{C})\,(75\times10^{-9}\ \text{s})} = 4.77\times10^{-4}\ \text{T}\ .$$

We can then use equation 19.12, $B = \mu_0 nI$, to solve for the current in the solenoid. This gives: $I = B/(\mu_0 n) = (4.77\times10^{-4}\ \text{T})/(4\pi\times10^{-7}\ \text{T m/A}\times800\ \text{m}^{-1})/ = 0.47\ \text{A}$.

Chapter Summary

Essential Idea: Magnetism and Magnetic Fields.
Magnetism and magnetic fields have many applications, ranging from the Earth's magnetic field, which we use for navigation and which protects us from harmful radiation, to the powerful magnetic field in an MRI machine, which helps doctors diagnose medical problems, to the basic magnets that hold pictures on a refrigerator.

Magnetic Field
- Magnetic fields are associated with two magnetic poles, north and south. Magnetic fields are produced by moving charges.
- Like magnetic poles repel, while unlike poles attract.
- The magnetic field points in the direction of the force experienced by a north pole.
- North and south poles always come in pairs.
- Magnetic field lines are continuous loops. Outside a magnet, the magnetic field is directed from the north pole to the south pole. Inside a magnet, the magnetic field runs from south to north.

The Magnetic Force on a Charged Particle Moving in a Magnetic Field
A charged particle moving through a magnetic field experiences a magnetic force that is perpendicular to both the magnetic field and the velocity of the particle:

$F_M = qvB\ \sin\theta$,　　　(Eq. 19.2: **The magnitude of the magnetic force on a charge q**)

where θ is the angle between the velocity, $\vec{v}$, and the magnetic field, $\vec{B}$. The direction of the force is perpendicular to the plane defined by $\vec{v}$ and $\vec{B}$, and given by the right-hand rule. The steps in the right-hand rule are:

- Point the fingers on your right hand in the direction of the charge's velocity.
- While keeping your fingers aligned with the velocity, rotate your hand so that, when you curl your fingers, you can curl them into the direction of the magnetic field.
- Hold out your thumb so it is perpendicular to your fingers. Your thumb points in the direction of the force experienced by a positively charged particle.
- If the particle has a negative charge, your right hand lies to you. Just reverse the direction of the force. The magnetic force on a negatively charged particle is opposite in direction to that of a positively charged particle if the particles are traveling in the same direction.

The path followed by a moving charge in a magnetic field

A charged particle moving parallel to a magnetic field experiences no force, and moves in a straight line. A charged particle moving perpendicular to a magnetic field experiences a force that makes it travel in a circle, with a radius and period of:

$$r = \frac{mv}{qB},$$
(Equation 19.3: **Radius of the path, when $\vec{v}$ and $\vec{B}$ are perpendicular**)

$$T = \frac{2\pi m}{qB}.$$
(Equation 19.4: **The period of the circular orbit**)

If the velocity of the particle is neither parallel to, not perpendicular to, the magnetic field, the particle follows a spiral path, spiraling around the magnetic field.

Forces and torques on current-carrying wires and loops

The magnitude of the magnetic force exerted on a wire of length L, carrying a current I, by a magnetic field of magnitude B is:

$$F_M = ILB\sin\theta,$$
(Equation 19.7: **The magnetic force on a current-carrying wire**)

where θ is the angle between the current direction and the magnetic field.

The direction of the force is given by a right-hand rule that follows the rule for charges. Point the fingers on your right hand in the direction of the current. Align your hand so that when you curl your fingers, they point in the direction of the magnetic field. Stick out your thumb, and it points in the direction of the magnetic force.

A loop of current in a uniform magnetic field experiences no net magnetic force. The magnitude of the magnetic torque on a coil consisting of N loops carrying a current I is:

$$\tau = NIAB\sin\theta,$$
(Equation 19.8: **Torque on a current-carrying coil in a magnetic field**)

where θ is the angle between the area vector $\vec{A}$ of the loop, which is perpendicular to the plane of the loop, and the magnetic field $\vec{B}$.

Currents produce magnetic fields

Even in permanent magnets, the magnetic field comes from currents, being associated with the angular momentum of electrons in atoms, and the alignment of these angular momenta.

The magnetic field a distance r from a long straight wire carrying a current I is:

$$B = \frac{\mu_0 I}{2\pi r}.$$
(Eq. 19.9: **The magnetic field from a long-straight wire**)

The **permeability of free space** has a value of $\mu_0 = 4\pi \times 10^{-7}$ T m / A .

$$B = \frac{\mu_0 I}{2R}.$$
(Eq. 19.11: **The magnetic field at the center of a current loop of radius R**)

$$B = \frac{\mu_0 NI}{L} = \mu_0 nI,$$
(Equation 19.12: **The magnetic field for an ideal solenoid**)

where N is the number of turns, L is the length of the solenoid, and $n = N / L$ is the number of turns per unit length.