Part A

8. d (The magnetic force depends on the velocity of the charge; if the velocity is zero, the magnetic force is likewise zero)

9. a (The magnetic field due to a straight wire is directed *around* the wire; using the right-hand-rule # 2, one can show that the field must be into the paper on the right side and out of the paper on the left side)

10. a (This has to do with Ampere's Law; the strength of the magnetic field that circulates around the edge of a path is written as $B_{\|}\ell$ which, according to Ampere's Law, is proportional to the current flowing through the "surface enclosed" by that path; in this case, the path is the hoop and there is no wires present that would provide a current through the ground on which it rests)

11. e (From the right-hand-rule # 2, the left wire's magnetic field circulates around it clockwise; that field is parallel to the left and right parts of the hoop and perpendicular to the upper and lower parts of the hoop; consequently, a magnetic force is exerted upon only the upper and lower parts; however, those forces must be opposite, since the currents are opposite in those two parts; alternatively, there is a torque present that aligns the loop up/down but there is no net force)

12. e (The magnetic flux is zero both before and after the change because the field is perpendicular to the solenoid axis; with no change in magnetic flux, no current is induced)

13. a (the induced voltage (emf) tries to maintain the current that was flowing initially; decreasing the clockwise current induces a clockwise voltage (emf) that "attempts" to maintain the current flowing as it was before the change)

14. d (the induced voltage (emf) tries to maintain the current that was flowing initially; since the current was initially zero, the voltage (emf) counters the increase in current; it must be less than the applied voltage (emf) – if it were the same, no current would flow at all)

Part C

1. (a) Since the velocity and magnetic field are perpendicular, the magnetic force is

$$\begin{aligned} F &= qvB \\ &= (1.6 \times 10^{-19}\ \mathrm{C})(10,000\ \mathrm{m/s})(0.025\ \mathrm{T}) \\ &= 4 \times 10^{-17}\ \mathrm{N}. \end{aligned}$$

(b) To get the direction, we need to recognize that the magnetic force, being perpendicular to both the velocity (north) and magnetic field (east), must be directed either up or down. The right-hand rule (# 3) shows that the magnetic force is directed downward. Since this is an electron (with negative charge), the force is upward (opposite that given by the right-hand rule.

(c) The electric force is given by $F = qE$, so the electric field must be

$$\begin{aligned} E &= F/q \\ &= (4 \times 10^{-17}\ \mathrm{N})/(1.6 \times 10^{-19}\ \mathrm{C}) \\ &= 250\ \mathrm{N/C}. \end{aligned}$$

Since the magnetic force is directed downward, the electric force must be up. Since the charge on the electron is negative, that means that the electric field must be down.

Note that it would've been easier to combine the steps in (a) and (c) algebraically first:

$$\begin{aligned} E &= F/q \\ &= (qvB)/q \\ &= vB \\ &= (10,000\ \mathrm{m/s})(0.025\ \mathrm{T}) \\ &= 250\ \mathrm{N/C}. \end{aligned}$$

2. (a) Initially, the area of the loop that is in the magnetic field is 1.0 m^2 (multiply length by width of the portion of the loop that experiences the magnetic field). The magnetic flux is defined as $\Phi = BA$ (I don't include the dependence on θ since the field is parallel to the loop axis). Multiply the magnetic field (0.5 T) by the area to get an initial magnetic flux of 0.5 $\mathrm{T{\cdot}m^2}$ (or 0.5 Wb).

During the first 0.1 seconds, the loop has been pulled 0.2 m (multiply the velocity by the time) and so the area in the magnetic field has decreased to 0.8 m^2 (because one side has decreased to 0.8 m). The magnetic flux is then decreased to 0.4 Wb.

Consequently, the magnetic flux has decreased by 0.1 Wb.

(b) The voltage induced in the loop is related to how quickly the magnetic flux changes:

$$V_{\text{induced}} = \frac{\Delta\Phi}{\Delta t}$$

Plug in 0.1 Wb for $\Delta\Phi$ and 0.1 s for Δt. This gives a voltage of 1.0 V.

(c) No, there is no difference if we used 0.2 s. The change in flux would be twice that in (a) (since the loop moves twice as far) but we'd be dividing by 0.2 s instead of 0.1 s in (b). In other words, the rate at which the magnetic flux changes is constant because the velocity of the loop is constant.

(d) Yes. After 0.5 seconds, the loop is no longer in the magnetic field and so the magnetic flux is no longer changing. Consequently, the induced voltage will be zero (and the average induced voltage will go down as Δt increases and $\Delta\Phi$ remains the same).

(e) To determine the current produced by this voltage (emf), we use

$$V = IR$$

where R is given as 0.25 Ω. Solve for I to get (1 V)/(0.25 Ω) = 4 A.

(f) Before determining the force, first consider why there would be a force at all. The answer is that, once current is set up on the loop, there will be a force on it since it is experiencing an external magnetic field.

To determine the force, examine each part of the loop separately. The part outside the field experiences no force since it is not experiencing an external magnetic field. The force on the top part is opposite that on the bottom part. Consequently, those two forces cancel.

This means we only need to concern ourselves with the force on the left part of the loop. The force is given as

$$F = I\ell B$$

$$= (4 \text{ A})(1.0 \text{ m})(0.5 \text{ T})$$
$$= 2 \text{ N}.$$

I left out the $\sin\theta$ since the current direction is perpendicular to the magnetic field direction.

Note: By the right-hand-rule, one can show that the current in the loop is flowing clockwise. Consequently, the force on the current is directed to the left, i.e., the force is opposite the motion. That is why one would need to apply a force to move the loop out of the field.