Part I

1. A long straight vertical wire carries a steady current in the upward direction. At a point due north of the wire, what is the direction of the magnetic field that the wire produces?
   (a) North.
   (b) South.
   (c) East.
   (d) West.
   Answer (d).

2. A rectangular loop is placed in a uniform magnetic field with the plane of the loop perpendicular to the direction of the field. When a current flows through the loop it feels
   (a) a net force but no net torque.
   (b) a net torque but no net force.
   (c) a net force and a net torque.
   (d) neither a net force nor a net torque.
   Answer (d).

3. The force per unit length on two long parallel wires is measured to be $6.0 \times 10^{-5}$ N/m when they are separated by 2.0 cm. When the two wires are moved to a distance of 1.0 cm and the current in each of the wires is doubled the new force is
   (a) $4.8 \times 10^{-4}$ N/m
   (b) $3.2 \times 10^{-4}$ N/m
   (c) $1.2 \times 10^{-4}$ N/m
   (d) $0.6 \times 10^{-4}$ N/m
   Answer (a). The force is 8 times as great because each current is doubled and the distance is halved.

4. The diagram on the right shows two current carrying wires which cross but do not touch. At which of the following points is the magnetic field zero.
   (a) At P
   (b) At Q
   (c) At both P and Q
   (d) At neither P nor Q
   Answer (b).
Part II

1. (a) It is desired to produce a magnetic field strength of $2.0 \times 10^{-3}$ T along the axis of a long solenoid. If the solenoid is 0.15 m long and has 200 turns per centimetre, what current in the solenoid will produce this field?

$B = \mu_0 n I$, where $n = (200 \ \text{turns/cm})(100 \ \text{cm/m}) = 2 \times 10^4 \ \text{turns/m}$.

So $I = \frac{B}{\mu_0 n} = \frac{2.0 \times 10^{-3}}{(4\pi \times 10^{-7})(2 \times 10^4)} = 0.080 \ \text{Amps}$.

(b) Suppose the solenoid is uncoiled into a long straight wire and carries the same current. At what distance from the wire will the magnetic field strength be the same as it was inside the solenoid in part (a).

For a long straight wire the field is $B = \frac{\mu_0 I}{2\pi r}$.

So $r = \frac{\mu_0 I}{2\pi B} = \frac{2 \times 10^{-7}(0.08)}{2.0 \times 10^{-3}} = 8 \times 10^{-6} \ \text{cm}$. This is an absurdly small distance from the center of the wire. In fact it is likely to be inside the wire, and here the field would be less than predicted.

2. The following diagram shows a cross sectional view of two wires, each carrying a current of 2.0 amps. The current in wire 1 flows our of the page and current of wire 2 flows into the page.

(a) What is the strength of the force between the two wires? Is it attractive or repulsive?

$F = \frac{\mu_0 I_1 I_2}{2\pi r} \frac{(2^{-7})(2^2)}{\sqrt{0.04^2 + 0.04^2}} = 1.4 \times 10^{-5} \ \text{N}$

Since the currents are opposite they feel a repulsive force.

(b) At the point marked P indicate the direction of the field due to wire A and wire B and the direction of the total field.

(c) A wire, c, is place at point P, parallel to the other two wires and with a current flowing out of the page. Draw an arrow indicating the direction of the force on wire C.
31. A positive ion is shot between the plates of a parallel-plate capacitor.
   a. In what direction is the electric force on the ion?
   Down.
   b. Could a magnetic field exert a magnetic force on the ion that is opposite in direction to the electric force? If so, show the magnetic field on the figure.
   Yes.

32. In a high-energy physics experiment, a neutral particle enters a bubble chamber in which a magnetic field points into the page. The neutral particle undergoes a collision inside the bubble chamber, creating two charged particles. The subsequent trajectories of the charged particles are shown.
   a. What is the sign (+ or −) of particle 1? +
   What is the sign (+ or −) of particle 2? −
   b. Which charged particle leaves the collision with a larger momentum? Explain. (Assume that |q| = e for both particles.)
   Particle 2.
   \[ r = \frac{mv}{qB} \]
   \[ mv = qA \]
   The larger radius particle had the greater momentum.

33. A solenoid is wound as shown and attached to a battery. Two electrons are fired into the solenoid, one from the end and one through a very small hole in the side.
   a. In what direction does the magnetic field inside the solenoid point? Show it on the figure.
   b. Is electron 1 deflected as it moves through the solenoid? If so, in which direction? If not, why not?
   No. \( F = q \vec{v} \times \vec{B} \) There is no force on a charge moving antiparallel to a field because \( \vec{v} \times \vec{B} = 0 \).
   c. Is electron 2 deflected as it moves through the solenoid? If so, in which direction? If not, why not?
   Yes. Out of the page.

34. Two protons are traveling in the directions shown.
   a. Draw and label the electric force on each proton due to the other proton.
   b. Draw and label the magnetic force on each proton due to the other proton. Explain how you determined the directions.
   The moving charge on the left creates a magnetic field in the region between the charges that is into the page. This field exerts a magnetic force on the charge on the right that is to the right.
33.8 Magnetic Forces on Current-Carrying Wires

33.9 Forces and Torques on Current Loops

35. Three current-carrying wires are perpendicular to the page. Construct a force vector diagram on the figure to find the net force on the upper wire due to the two lower wires.

36. Three current-carrying wires are perpendicular to the page.
   a. Construct a force vector diagram on each wire to determine the direction of the net force on each wire.
   b. Can three charges be placed in a triangular pattern so that their force diagram looks like this? If so, draw it below. If not, why not?

   No. Charges must be unlike to exert attractive forces on each other. There are not 3 different unlike charges to be able to achieve this.

37. A current-carrying wire passes in front of a solenoid that is wound as shown. The wire experiences an upward force. Use arrows to show the direction in which the current enters and leaves the solenoid. Explain your choice.

   To experience an upward force, the wire must be in a field that points to the left.

38. A current loop is placed between two bar magnets. Does the loop move to the right, move to the left, rotate clockwise, rotate counterclockwise, some combination of these, or none of these? Explain.

   It rotates counterclockwise. The magnetic field created by the magnets points to the left. Forces on the loop, as shown, tend to rotate the loop ccw.