This test consists of three parts. Please note that in parts II and III, you can skip one question of those offered.

**Possibly useful formulas:**

<table>
<thead>
<tr>
<th>Constants</th>
<th>Cyclotron Motion</th>
<th>RC Circuits</th>
<th>Biot-Savart</th>
<th>Force Between Wires</th>
<th>Hall Effect</th>
<th>Ampere’s Law</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e = 1.602 \times 10^{-19}$ C</td>
<td>$mv = qRB$</td>
<td>$Q = Q_0 e^{-i\tau}$</td>
<td>$B = \mu_0 I/(2\pi a)$</td>
<td>$F = \mu_0 I_1 I_2/L$</td>
<td>$\Delta V_H = IBq$</td>
<td>$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I$</td>
</tr>
<tr>
<td>$\mu_0 = 4\pi \times 10^{-7}$ T ⋅ m/A</td>
<td>$\omega = qB/m$</td>
<td>$Q = CE(1 - e^{-i\tau})$</td>
<td>$\mathbf{B} = \frac{\mu_0 I}{2\pi a}$</td>
<td>$B = \frac{\mu_0 I}{4\pi a}$</td>
<td>$\mathbf{B} = \mu_0 I / (2\pi R)$</td>
<td></td>
</tr>
</tbody>
</table>

**Part I: Multiple Choice [20 points]**

For each question, choose the best answer (2 points each)

1. What is the current $I$ in the diagram at right?
   A) 10 A  B) 6 A  C) 4 A  D) 2 A  E) 0 A

2. In general, magnetic field lines will point which way near a wire?
   A) They make loops which curl around the wire
   B) They point parallel to the wire in the direction the current is flowing
   C) They point parallel to the wire opposite the direction the current is flowing
   D) They point towards the wire
   E) They point away from the wire

3. If you want to get 5 A through a resistor with resistance 10 $\Omega$, what voltage do you need?
   A) 0.0200 V  B) 0.500 V  C) 2.00 V  D) 25.0 V  E) 50.0 V

4. If the voltage across a resistor is increased by a factor of four, the power consumed will increase by a factor of
   A) Two  B) Four  C) Eight  D) Sixteen  E) None of these
5. What determines the total amount of magnetic flux coming from an enclosed region?
   A) The total electric charge in the region
   B) The total magnetic charge in the region
   C) The total amount of current entering or exiting the region
   D) The total amount of current flowing within the region
   E) Nothing – the total net flux is always zero

6. Assume in the figure at right, the number of charges drawn represents the relevant charge density of the two types of charge carriers, whose charges are equal and opposite, and the arrows represent the drift velocities. What direction is the current density?
   A) Right
   B) Left
   C) There is no current density
   D) It is impossible to tell without knowing the drift velocity of each charge carrier
   E) It is impossible to tell, even if you know the drift velocity of each charge carrier

7. How is the formula \( B = \mu_0 NI / L \) to be used for calculating the magnetic field inside and outside an infinitely long solenoid?
   A) The formula is to be applied equally both inside and outside the solenoid
   B) The formula applies inside but has the opposite sign outside
   C) The formula applies inside, but the magnetic field vanishes outside
   D) The formula applies outside, but the magnetic field vanishes inside
   E) The formula applies only to finite length solenoids, not infinite ones.

8. If two wires are parallel to each other, will they be attracted to each other or repel each other?
   A) Attract
   B) Repel
   C) Attract if the current is going opposite direction; repel if it is going the same direction
   D) Attract if the current is going the same direction; repel if it is going opposite direction
   E) None of the above

9. If you have a capacitor of capacitance \( C \) discharging through a resistor of resistance \( R \), which of the following would make the time it takes to discharge as long as possible?
   A) Increase \( R \) and \( C \)
   B) Increase \( R \) and decrease \( C \)
   C) Increase \( C \) and decrease \( R \)
   D) Decrease both \( R \) and \( C \)
   E) Insufficient information

10. The three currents sketched at right are pointed directly into or out of the plane of the page. What is the integral of the magnetic field around the dashed line, \( \oint B \cdot ds \)?
    A) \( \mu_0 (-1A) \)
    B) \( \mu_0 (1A) \)
    C) \( \mu_0 (5A) \)
    D) \( \mu_0 (-5A) \)
    E) None of these
Part II: Short answer [20 points]

Choose two of the following questions and give a short answer (1-3 sentences) or brief sketch (10 points each).

11. Explain qualitatively why a voltage develops across a conductor when there is an electrical current moving through it in the presence of a magnetic field (the Hall effect).

12. What sort of forces, if any, are experienced on a loop carrying current in the presence of a constant magnetic field?

13. What sort of path does a charged particle with a general initial velocity undergo in the presence of a constant magnetic field?
Part III: Calculation: [60 points]

Choose three of the following four questions and perform the indicated calculations (20 points each)

14. A circuit consists of a 20.0 V battery, two 10.0 kΩ resistors, two 40.0 kΩ resistors, and a switch.
   (a) What is the equivalent resistance of the four resistors between the points \( x \) and \( y \) if the switch is open?

(b) What is the equivalent resistance of the four resistors between the points \( x \) and \( y \) if the switch is closed?

(c) What is the total current passing through the resistors in each case listed above?
15. A capacitor is initially uncharged, but at $t = 0$ the two-way switch is pushed to the left, connecting it to the battery through the resistor.

(a) What is the charge on the capacitor two seconds later, at $t = 2.00$ s?

(b) At $t = 2.00$ s, the switch is suddenly pushed to the other position, to the right, allowing the capacitor to discharge through the other resistor. What is the charge on the capacitor two seconds later, at $t = 4.00$ s?
16. A nichrome wire with resistivity 
\[ \rho = 1.10 \times 10^{-6} \, \Omega \cdot m \] at 20°C and temperature

coefficient of resistivity \( \alpha = 4.0 \times 10^{-4} / ^\circ C \) has a square cross section of unknown side \( s \) and length \( L = 0.90 \, m \).

(a) If the wire is supposed to have a resistance of 4.00 \( \Omega \) at 20°C, what is the size \( s \) of the wire?

(b) Once a current is flowing through the wire, the resistance has been found to rise to 4.10 \( \Omega \). What is the temperature of the wire at this point?
17. A wire is in the shape of a square of side \( s = 4.00 \) cm, and has \( N = 100 \) loops carrying a current \( I = 3.00 \) A in a clockwise direction.

(a) What is the magnetic field (direction and magnitude) at the center of the loop?

(b) A proton of charge \( e \) and mass \( m = 1.673 \times 10^{-27} \) kg is at the center of the loop moving to the right at \( v = 2.47 \times 10^4 \) m/s. What is the magnitude and direction in which the proton accelerates?