Part I. Questions 1-10. 8 points each. Multiple choice: For full credit, circle only the correct answer. For half credit, circle the correct answer and one incorrect answer. For ¼ credit, circle the correct answer and two incorrect answers.

1. The curve that best illustrates the relation between the current in a metallic conductor and the potential difference between its terminals is
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

2. Two pieces of copper wire have the same length, but wire A has a square cross section of width $s$ whereas wire B has a circular cross section of diameter $s$. Which of the following statements is true?
   a. The resistance of both wires is the same.
   b. The resistivity of both wires is the same.
   c. Both the resistance and the resistivity of A and B are the same.
   d. The resistance of A is greater than that of B.
   e. The resistivity of A is greater than that of B.

3. In a parallel circuit, the
   a. current is the same in every branch.
   b. potential drop is the sum of those in all branches.
   c. potential drop is the same for each element of the parallel circuit.
   d. heat generated is the same in all the branches.
   e. overall resistance is the sum of the individual resistances of the branches.

4. You want to use three resistors in a circuit. If each of them has a resistance of 2 $\Omega$, the configuration that will give you an equivalent resistance of 3 $\Omega$ is
   a. 1
   b. 2
   c. 3
   d. 4
   e. None of these is correct.
5. A charged particle is fired towards the center of a cubical region of space where there is a uniform magnetic field oriented perpendicular to the initial velocity of the particle. Outside this region, there is no magnetic field.

a. The particle will pass straight through, undeflected.
b. The particle's motion will be deflected. In fact, the particle will remain trapped inside the cubical region.
c. The particle's motion will be deflected. However, the particle will not remain trapped inside the cubical region.
d. I would have answered b or c, but I need to know the strength of the field.
e. I would have answered b or c, but I need to know the strength of the field and whether the charge is positive or negative.

6. A uniform magnetic field is parallel to and in the direction of the positive \( z \) axis. For an electron to enter this field and not be deflected by the field, the electron must be traveling in which direction?

a. any direction as long as it is in the \( xy \) plane
b. any direction as long as it is in the \( xz \) plane
c. along the positive \( x \) axis
d. along the positive \( y \) axis
e. along the positive \( z \) axis

7. The sketch shows a circular coil in the \( xz \) plane carrying a current \( I \). The direction of the magnetic field at the origin \( O \) is

a. +x
b. -x
c. +y
d. -y
e. +z
f. -z
8. A metallic weight is suspended from a metal spring. If now a current is passed through the spring,
a. the spring will contract, raising the weight.
b. the spring will elongate, lowering the weight.
c. the weight will not move.
d. whether or not the weight moves up or down depends on what the weight is made of (i.e. whether or not it is magnetizable).
e. None of these is correct.

9. A wire loop moves through a uniform magnetic field with acceleration \( \mathbf{a} \). If the magnetic field points into the page, and the velocity and acceleration of the loop is to the right, in which direction is a current induced in the loop?
a. clockwise
b. counterclockwise
c. it would be an AC current; the current oscillates back and forth between being clockwise and counterclockwise
d. there is no induced current
e. not enough information is given

10. A loop rests in the xy plane. The z axis is normal to the plane and positive upward. The direction of the changing flux is indicated by the arrow on the z axis. The diagram that correctly shows the direction of the resultant induced current in the loop is
a. 1
b. 2
c. 3
d. 4
e. 5
Part II. Short answer/sketch. Answer questions 11-13 as completely as possible. **Show your work to earn partial credit!**

11. (25 points)
Consider an electrically-conducting elastic wire loop that lies in the xy plane, initially stretched to a radius $R_0$ at $t=0$. It is immersed in a uniform magnetic field $B$ that makes an angle $\theta$ with the $z$ axis. **EVALUATE ALL DERIVATIVES AND INTEGRALS.**

a) What is the magnetic flux through the elastic loop at $t=0$?
   You may express your answer using some or all of the following: $R_0$, $B$, $\theta$.

b) When the elastic loop is released, it remains oriented in the xy plane but its radius shrinks at a constant rate $r'$ (ie $r'$ has units of m/s). What is the expression for the radius as a function time, $r(t)$?
   You may express your answer using some or all of the following: $r'$, $R_0$, $t$, $B$, $\theta$.

c) What is the magnetic flux at time $t>0$?
   You may express your answer using some or all of the following: $r(t)$, $r'$, $t$, $R_0$, $B$, $\theta$.

d) What is the magnitude of (absolute value of) the induced electromotive force $\varepsilon$ ('emf') in the elastic loop at time $t>0$?
   You may express your answer using some or all of the following: $r(t)$, $r'$, $t$, $R_0$, $B$, $\theta$.

e) If the resistance of the elastic loop band is $R_\Omega$, what is the current $I$?

f) When viewed from above (looking down the $z$ axis), in which direction does the induced current flow?

g) According to Lenz's Law, would the effects of magnetic induction work to speed up or slow down the shrinking of the elastic loop?
12. (25 points)
A circuit is comprised of a battery, an (initially uncharged) capacitor, and two identical resistors. The switch is closed at t=0.

a) The two resistors are in parallel. True or False?

b) What is the equivalent resistance of the circuit for t>0?

c) Immediately after the switch is closed, what is the voltage across the capacitor?

d) Immediately after the switch is closed, what is the voltage across the top resistor?

e) Immediately after the switch is closed, what is the current through the top resistor?

f) Immediately after the switch is closed, how large is the current through the battery compared to the current through the top resistor?

g) After a very long time, what is the voltage across the capacitor?

h) if ε=10 V, R=5 Ω, and C=10 mF, how long does it take for the capacitor to charge to 85% of its final charge?
13. (25 points)
A magnetic balance is used to weigh objects. The mass $m$ to be measured is hung from the center of the bar of length $L$ suspended in a uniform magnetic field $B$ directed into the page. The battery voltage $\epsilon$ can be adjusted to vary the current in the circuit. The horizontal bar is made of extremely lightweight conducting material, and is connected to the battery by thin elastic conducting wire.

a) To measure the mass, an upward force must balance the downward force due to gravity. What is this upward force? You can either use words or an equation for your answer.

b) Which point, $a$ or $b$, should be the positive terminal of the battery?

c) If the maximum terminal voltage of the battery is $\epsilon_{\text{max}}$, what is the greatest mass $m_{\text{max}}$ that this instrument can measure?

d) Now suppose a long wire with current $I_2$ is placed at a fixed distance $h$ directly below the magnetic balance. How does this additional current affect the net magnetic field at the location of the bar? (ie stronger, weaker, same, same but different direction, ...)

e) Derive an expression for the new maximum mass that can be measured in this situation.