PHYS 2025  
Test #2  
Fall 2009 (Buckley)

Short Answer (2 points each). Answer each of the following questions. If in the multiple choice format, circle the letter corresponding to the best answer.

1. An ohmic resistor is classified as one that
   a. generates heat when carrying a current through it
   b. shows a linear dependence between voltage applied and current through the resistor
   c. shows an exponential dependence between the voltage applied and current through the resistor
   d. shows a potential drop in the direction of the current through the resistor
   e. shows a potential gain in the direction of the current through the resistor

2. 27-gauge wire has a diameter that is one-half that of 21-gauge wire. How would the resistance of the same length of 27-gauge wire compare to that of 21-gauge wire assuming both wires are made of the same material?
   a. the resistance of the 27-gauge wire would be $\frac{1}{2}$ that of the 21-gauge wire
   b. the resistance of the 27-gauge wire would be twice that of the 21-gauge wire
   c. the resistance of the 27-gauge wire would be $\frac{1}{4}$ that of the 21-gauge wire
   d. the resistance of the 27-gauge would be four times that of the 21-gauge wire
   e. the answer cannot be determined without knowing the type of material and the length of wire

3. The electric company bills its users by the kilowatt-hour. What quantity does the kilowatt-hour represent?
   a. the energy delivered
   b. the total charge delivered
   c. the power delivered
   d. the current delivered
   e. the voltage delivered

4. A hairdryer is rated at 1200 W and runs from a 120 Volt outlet. The current drawn by the hairdryer is
   a. 0.1 A  
   b. 1320 W  
   c. 10 A  
   d. 1080 A  
   e. 144000 A
You are given three resistors: 10 Ω, 20 Ω, and 40 Ω. Use these resistors to answer questions 5-7.

5. The largest equivalent resistance attainable with these three resistors is
   a. 40 Ω   b. 70 Ω   c. 5.7 Ω   d. 0.014 Ω   e. 240 Ω

6. What is the smallest equivalent resistance one can obtain from the three resistors?
   a. 40 Ω   b. 70 Ω   c. 5.7 Ω   d. 0.014 Ω   e. 240 Ω

7. What is the equivalent resistance of the three resistors if the 10 Ω and 20 Ω are connected in parallel and this combination is then connected in series to the 40 Ω?
   a. 46.7 Ω   b. 17.1 Ω   c. 5.7 Ω   d. 70 Ω   e. 25.0 Ω

8. An RC circuit is set up and connected via a switch to a battery. The time constant, RC, represents what?
   a. the length of time it takes the voltage across the capacitor to reach the \( \frac{1}{e} \) of the battery when the switch is closed
   b. the length of time it takes the voltage across the capacitor to reach zero when the switch is closed
   c. the length of time it takes the \( \frac{1}{e} \) of the battery to drop to zero once the switch is closed
   d. the length of time it takes the \( \frac{1}{e} \) of the battery to drop to one-half of its initial value once the switch is closed
   e. the length of time it takes the voltage of the capacitor to reach 63% of \( \frac{1}{e} \) once the switch is closed

9. Wire 1 carries a current of \( I \) upwards and generates a magnetic field of \( B \) at a distance of \( r \) meters from the wire. If the current is changed to \( 5I \), what will the magnetic field strength be at a distance of \( 4r \) meters from the wire?
   a. 5B   b. \( \frac{5B}{r} \)   c. \( \frac{4B}{5} \)   d. \( \frac{5B}{4} \)   e. 20B

\[ B = \frac{\mu_0I}{2\pi r} \]

10. Consider Figure 1. The current is coming out of the page. When looking at the diagram from the front of the page, will the magnetic field generated be:
    a. counterclockwise (or anticlockwise)
    b. clockwise
    c. zero

   \[ \oint \vec{B}_{\text{New}} = \oint \vec{B} \]

Figure 1
11. Still consider Figure 1. If a small (working) compass is placed at point A when the current is flowing, in which direction will the compass needle point?
   a. east   b. west   c. north   d. south   e. not affected by current

12. A current flows from the north to the south in a horizontal wire. The wire passes through the poles of a magnet oriented so the magnetic field lines are parallel to the current and in the same direction as the current. In which direction will the force experienced by the wire point?
   \[ \theta = 90^\circ, \quad \int B \cdot dl = 0 \]
   a. east   b. west   c. north   d. south   e. up   f. down   g. no force

13. A current flows from the north to the south in a horizontal wire. The wire passes through the poles of a magnet oriented so the magnetic field lines are also horizontal but 90° to the current-carrying wire. If the wire experiences a force in the downward direction due to the magnetic field, in which direction do the magnetic field lines point?
   a. east   b. west   c. north   d. south   e. up   f. down

14. Three particles, a, b, and c, enter a magnetic field as shown in Figure 2. What can you say about the charge on each particle?
   a. a is neutral, b is negative, c is positive
   b. a is positive, b is neutral, c is positive
   c. a is positive, b is positive, c is negative
   d. a is negative, b is neutral, c is positive
   e. a is positive, b is neutral, c is negative
   \[ \text{Particles: a, b, c} \]
   \[ \text{Magnetic field vectors:} \]
   \[ \text{Particle a:} \]
   \[ \text{Particle b:} \]
   \[ \text{Particle c:} \]
Problems and short answer. Show your work on numerical problems to receive credit. Point totals are indicated in parentheses to the right of each problem number.

15. (10 points) Consider the circuit shown in the figure.

a. Determine the equivalent resistance of the circuit.

For I: \( R_{eq} = \frac{1}{\frac{1}{8} + \frac{1}{4}} \Rightarrow R_{eq} = 2.7 \Omega \)

For II: \( R_{eq} = 6.0 + 2.7 = 8.7 \Omega \)

For III: \( R_{eq} = \frac{1}{10} + 1.7 \Rightarrow R_{eq} = 4.7 \Omega \)

Total: \( R_{eq} = 2.7 \Omega + 8.7 \Omega + 4.7 \Omega = 10.2 \Omega \)

b. What is the current running through the circuit at point a?

\[ V = IR \quad I = \frac{V}{R} = \frac{9.0V}{10.2\Omega} = 0.88A \]

\[ \boxed{0.88A} \]

c. What is the current running through the 10.0 \( \Omega \) resistor at the top of the circuit?

Potential drop across III:

\( R_{eq} = 4.7 \Omega \) \( \Rightarrow I = 0.88 A \)

\[ V = IR = 6.88A(4.7\Omega) = 4.1V \]

So, for 10.0 \( \Omega \):

\[ I = \frac{V}{R} = \frac{4.1V}{10\Omega} = 0.41A \]

\[ \boxed{0.41 A} \]

d. How much power is dissipated in the 10.0 \( \Omega \) resistor at the top of the circuit?

\[ P = VI = 4.1V(0.41A) = 1.7 W \]

\[ \boxed{1.7 W} \]
16. (10 points) Consider the following circuit diagram.

![Circuit Diagram]

a. Draw the necessary number of current vectors labeled $I_1$, $I_2$, ... showing clearly the direction you are assuming each current will flow.

b. Write the junction equation for the top junction using your indicated currents from Part a.

$$I_2 = I_1 + I_3$$

c. Write the loop equations for each loop in the diagram – there are three of them.

**Left Loop:** Starting at point A and going counterclockwise

$$6.0 - 12I_1 - 8I_1 + 6I_3 = 0$$

**Right Loop:** Starting at point A and going counterclockwise

$$-6I_3 - 10I_2 + 3 - 2I_2 = 0$$

**Back Loop:** Starting at A and going counterclockwise

$$+6.0 - 12I_1 - 8I_1 - 10I_2 + 3.0 - 2I_2 = 0$$
17. (5 points) Alpha particles with a charge of \( q = +2e \) and mass \( m = 6.6 \times 10^{-27} \) kg are emitted from a radioactive source at a speed of \( 1.6 \times 10^7 \) m/s.

a. What magnetic field strength would be required to bend them into a circular path of radius = 0.25 m?

\[
B = \frac{mv}{qr} = \frac{(6.6 \times 10^{-27} \text{kg})(1.6 \times 10^7 \text{m/s})}{(2 \times 1.6 \times 10^{-19} \text{C})(0.25 \text{m})} = 1.32 \text{T}
\]

b. If the particles were traveling horizontally northward, in what direction would the magnetic field have to point to confine the alpha particles to traveling in a horizontal circle in a clockwise direction?

\[\text{Vertically Upward}\]
18. (10 points) The Figure is a cross-section of a solenoid with the indicated current directions.

We will attempt here to arrive at the equation for the magnetic field inside a solenoid using Ampere's Law ($\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{enc}$). The loop to be considered is the rectangle abcd.

If one considers the loop to be comprised of the four sides of the rectangle, the integral on the left in Ampere's Law is simply the sum of the integral for each of the four sides.

a. For which, if any of the segments ab, bc, cd, and da would the term $B \cdot dl$ be zero? Explain your reasoning for each one that is zero.

b. Evaluate the integral for any remaining integrals after removing all of those for which the value is zero.

\[
\oint \mathbf{B} \cdot d\mathbf{l} = B \int_{c}^{d} dl = B \ell
\]

c. How much current is enclosed by the rectangle abcd? Assume the current is given by $I$ and there are $N$ loops of wire enclosed within the rectangle.

\[I_{enc} = NI\]

d. Use Ampere's law and the results of parts b and c to write out the equation for the magnetic field within the solenoid.

\[B = \frac{\mu_0 NI}{\ell}\]
Potentially Helpful Mathematical Relationships and Constants

Remember you don’t have to use any or all of these. Don’t force any of them just because you think you need to use them all.

\[ V = IR \]
\[ R = \frac{\rho L}{A} \]
\[ P = IV \]
\[ P = I^2 R = \frac{V^2}{R} \]
\[ \tau = RC \]
\[ V_C = \xi(1 - e^{-tRC}) \]
\[ Q = Q_o(1 - e^{-tRC}) \]
\[ V_C = V_o e^{-tRC} \]
\[ Q = Q_o e^{-tRC} \]
\[ F = 1 \ell B \sin \theta \]
\[ F = qvB \sin \theta \]
\[ B = \frac{\mu_o I}{2\pi r} \]
\[ B = \mu_o NI / \ell \]
\[ \tau = NIAB \sin \theta \]
\[ r = \frac{mv}{qB} \]
\[ \mu_o = 4\pi \times 10^{-7} T \cdot m / A \]
\[ e = 1.6 \times 10^{-19} C \]