1. You just bought a battery in a store; it is labeled 9 V. You have two light bulbs, connecting wires and a voltmeter. You connect the bulbs to the battery and they both light up. You connect the voltmeter across the battery (while bulbs are glowing) and it reads 8.3 V. You repeat the experiment connecting the bulbs in a different way; they still both light up in a new circuit. This time the voltmeter connected across the battery shows 6.75 V. The explanation for the difference in voltmeter readings is:

   a) The reading of the voltmeter is changing because the light bulbs have a very large internal resistance.
   b) You connected the bulbs in parallel the first time and in series the second time.
   c) You connected bulbs in series the first time and in parallel the second time.
   d) The reading of the voltmeter is changing because the voltmeters internal resistance is not sufficiently large.
   e) None of the other answer

The voltmeter readings are different because the light bulbs are connected in different ways for each case. The series circuit has higher equivalent resistance, hence larger voltage.

2. Which of the following statements is FALSE? To run a current, we need:

   a) Mobile charge carriers
   b) A non-zero electric field inside a conductor
   c) A non-zero net charge density inside a conductor
   d) Non-equipotential conductors
   e) None of the other answers

A non-zero charge density does not necessarily result in current unless it is varying in time.
3. A light bulb is rated at 30 W when operated at 120 V DC. How much charge enters (and leaves) the light bulb in 1.0 min?

\[ P = \frac{V^2}{R} \Rightarrow R = \frac{120^2}{30} = 480 \Omega \]
\[ P = I^2R \Rightarrow I = \sqrt{\frac{30}{480}} = \frac{1}{4} A \]
\[ Q = It = \frac{1}{4} \times 60s = 15 C \]

- a) 17 C
- b) 15 C
- c) 14 C
- d) 13 C
- e) 0 C

4. Light bulb A is rated at 60 W and light bulb B is rated at 100 W. Both are designed to operate at 110 V. Which statement is correct?

- a) The 60 W bulb has a greater resistance and greater current than the 100 W bulb.
- b) The 60 W bulb has a greater resistance and smaller current than the 100 W bulb.
- c) The 60 W bulb has a smaller resistance and smaller current than the 100 W bulb.
- d) The 60 W bulb has a smaller resistance and greater current than the 100 W bulb.
- e) We need to know the resistivities of the filaments to answer this question.

\[ P = \frac{V^2}{R} \Rightarrow \text{For the same voltage, the bulb with smaller power has greater resistance. Greater resistance also implies a lower current (provided } V \text{ is same).} \]

5. A 2.0-m wire carries a current of 15 A directed along the positive x axis in a region where the magnetic field is uniform and given by \( B = 30i - 40j \text{ mT} \). What is the resulting magnetic force on the wire?

\[ \vec{F} = I\vec{L} \times \vec{B} \]
\[ \vec{F} = 15(3\hat{i}) \times (30\hat{i} - 40\hat{j}) \text{ mT} \]
\[ = -1.2 \hat{k} \text{ N} \]

- a) +1.2 \& N
- b) -1.2 \& N
- c) -1.5 \& N
- d) +0.6 \& N
- e) -0.60 \& N
6. The figure shows the orientation of a rectangular loop consisting of 80 closely wrapped turns each carrying a current I. The magnetic field in the region is +1 T. The loop can turn about the y axis. If $\theta = 60^\circ$, $a = 0.40 \text{ m}$, $b = 0.50 \text{ m}$, and $I = 8.0 \text{ A}$, what is the magnitude of the torque exerted on the loop?

\[
\vec{\tau} = \vec{\mu} \times \vec{B} = NI(\vec{A} \times \vec{B})
\]
\[
\tau = (80)(8)(0.2)\sin 30 = 64 \text{ N} \cdot \text{m}
\]

a) 25 N·m
b) 110 N·m
c) 32 N·m
d) 27 N·m
e) 64 N·m

7. The boundary shown is that of a uniform magnetic field directed in the positive z direction. An electron enters the magnetic field with a velocity pointing along the x axis as shown and exits $t$ seconds later at point A. What is the magnitude of the magnetic field?

The electron moves in a circular path of radius $r = \frac{mv}{eB}$ which for this problem is 2m. The distance 'd' covered in time $t$ is one quarter of the circumference of the circle which is $\frac{\pi r}{2} = \pi$. The velocity $v = \frac{d}{t} = \frac{\pi}{t}$. The magnetic field can be calculated from the expression for r, which gives us $B = \frac{mev}{er} = \frac{me\pi}{2et}$

\[
\begin{align*}
a) & \quad \frac{2me\pi R}{e} \\
b) & \quad \frac{2me}{R} \\
c) & \quad \frac{me\pi}{2e t} \\
d) & \quad \frac{me\pi}{e t} \\
e) & \quad \text{It cannot be determined with the given data.}
\end{align*}
\]
8. The point $P$ lies along the perpendicular bisector of the line connecting two long straight wires $S$ and $T$ that are perpendicular to the page. A set of directions $A$ through $H$ is shown next to the diagram. When the two equal currents in the wires are directed up out of the page, the direction of the magnetic field at $P$ is closest to the direction of

- a) $E$
- b) $F$
- c) $G$
- d) $H$
- e) $A$

The magnetic field at $P$ due to wire $T$ is in direction of $H$ and due to wire $S$ is in direction of $B$. From superposition net field comes out to be in direction $A$.

9. The segment of wire (total length including portions of incoming and outgoing wire = $6R$) is formed into the shape shown and carries a current $I$. What is the magnitude of the resulting magnetic field at the point $P$?

- a) $\frac{3\mu I}{8R}$
- b) $\frac{3\mu I}{2R}$
- c) $\frac{3\mu I}{4R}$
- d) $\frac{3\mu I}{6R}$
- e) $\frac{\mu I}{\pi R^2}$
The incoming and outgoing portions do not contribute to the magnetic field at P because the \((l \parallel r \Rightarrow \vec{l} \times \vec{r} = 0)\). For the circular portion, the length is \(3/4\)th the total circumference, which is \(l = \frac{3}{4} \times 2\pi r = \frac{3\pi r}{2}\).

Using the Biot Savart law,

\[
B = \int_0^{3\pi r/2} \frac{\mu_0 l dl \sin \theta}{4\pi R^2} = \frac{\mu_0 l}{4\pi R^2} \int_0^{3\pi r/2} dl = \frac{3\mu l}{8R}
\]

(sin\(\theta\) is 1, here since \(l\) and \(r\) are perpendicular)

10. Which diagram correctly shows the magnetic field lines created by a circular current loop in which current flows in the direction shown?

a) i.  

b) ii.  

c) iii.  

d) iv.  

e) v.

Use Right hand Rule

11. A solenoid consists of 100 circular turns of copper wire. Parts of three turns, A, B and C, are shown in the figure. When a current flows through the coil,

a) both A and C are repelled by B.  

b) A is attracted to B; C is repelled by B.  

(c) neither A nor C is attracted to or repelled by B.  

d) A is repelled by B; C is attracted to B.  

e) both A and C are attracted to B.

The force on wires A and C from wire B acts towards wire B (use right hand rule to get the direction of force from \(\vec{F} = I\vec{L} \times \vec{B}\)
12. Three coplanar parallel straight wires carry equal currents I to the right as shown. Each pair of wires is a distance “d” apart. The direction of the magnetic force on the middle wire
   a) is up out of the plane of the wires.
   b) is down into the plane of the wires.
   c) is in the plane of the wires, directed upwards.
   d) is in the plane of the wires, directed downwards
   e) cannot be defined, because there is no magnetic force on the middle wire.

Using the right hand rule, the force on the middle wire because of the upper wire is in the upward direction and in the downward direction because of the lower wire. The net force is 0 since the magnitudes are the same.

13. What is the equivalent resistance between points A and B?

   a) 6.0 Ω
   b) 10 Ω
   c) 4.0 Ω
   d) 12 Ω
   e) 8.0 Ω

Elements in 1 are in series. 1||2. The resultant is shown in 3. Elements in 3 are in series. 3||4. The resultant is shown in 5. Elements of 5 are in series.
14. Which of the following equations represents a Kirchhoff’s voltage rule for the circuit shown?

\[
- (8\Omega) i_2 + 4V + 6V + (12\Omega) i_1 = 0V \\
+4V - (8\Omega) i_1 - (12\Omega) i_2 = 0V \\
+6V - (12\Omega) i_1 + (8\Omega) i_2 + 4V = 0V \\
-6V + 2V - (6\Omega) = 0V \\
+6V - (12\Omega) i_1 + (6\Omega) i_3 - 2V = 0V
\]

15. A circular loop of wire is placed next to a long straight wire. The current \( I \) in the long straight wire is **increasing** with time. What current does this induce in the circular loop?

a) A clockwise current  
b) A counter-clockwise current  
c) No current is induced  
d) Because the current in the straight wire changes over time so does the direction of the induced current

The magnetic field due to the wire on the loop is ‘out of the page’ and increasing. From Faraday’s law, the increasing flux should imply an induced current that tries to oppose it (i.e. decrease the flux). An opposing effect occurs when the induced current produces a magnetic field that goes ‘into the page’. An induced magnetic field that is into the page \( \Rightarrow \) a clockwise current.
e) More information is needed to decide