Quiz 5 solutions

June 19, 2012

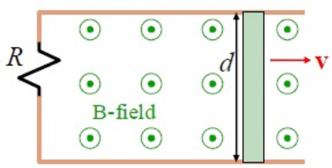

Figure 1

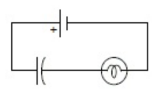

Figure 2

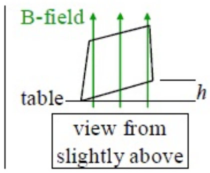

Figure 3

1. An electron starts from rest in an electric field of 0.025 N/C. After 0.0030 s, how far has it moved, in m?
2.0e4
Distance $s = v_0 t + \frac{1}{2}at^2$. Here initial velocity $v_0 = 0$, acceleration

$$a = \frac{F}{m_e} = \frac{eE}{m} = \frac{1.6 \times 10^{-19}C \times 0.025N/C}{9.1 \times 10^{-31}kg} = 4.4 \times 10^9 m/s^2,$$

so the distance is:

$$s = \frac{1}{2} \times 4.4 \times 10^9 m/s^2 \times (0.003s)^2 = 2 \times 10^4 m.$$

2.How many electrons are in -0.15 C of charge?
9.4e17

$$\frac{-0.15C}{-1.6 \times 10^{-19}C} = 9.4 \times 10^{17}$$

3.How much work is required to bring a proton from far away to within 1.5 mm of another proton, in J?
1.5e-25

According to the energy conservation, the work you do to push them together transforms into electric potential energy: $U_i + W = U_f$. The initial electric potential energy U_i is 0. The final electric potential energy is:

$$U_f = k_e \frac{1.6 \times 10^{-19} C \times 1.6 \times 10^{-19} C}{1.5 \times 10^{-3} m} = 1.5 \times 10^{-25} J.$$

So we need to do work $W = 1.5 \times 10^{-25} J$.

4. A 2.0 m wire has 0.010 volts across it, and carries a current of 0.50 amps. It perpendicular to a B-field of 0.20 T. What is the magnetic force on the wire, in N?
0.20

$$F_m = |I\vec{l} \times \vec{B}| = IlB = 0.5A \times 2m \times 0.2T = 0.2N$$

5. A platinum wire is 0.50 mm in radius and carries a current. What fraction of the B-field at its surface exists at a radius of 0.25 mm from the center of the wire?
1/2
Using the Ampere's law, we can get the magnitude of the magnetic field as a distance r from a long, straight wire carrying current I:

$$B = \frac{\mu_0 I}{2\pi r}.$$

For this problem, we know that $I = I_{total} \frac{\pi r^2}{\pi R^2}$, where I_{total} is the total current carried by the wire, and $R = 0.5mm$ is the radius of the wire. So we get:

$$B(r) = \frac{\mu_0 I_{total} r}{2\pi R^2} \propto r,$$

which gives $B(\frac{1}{2}R) = \frac{1}{2}B(R)$.

6.The current in a 27 ohm resistor increases linearly in time from 0 to 3.0 A in 5.0 s. How much charge passes through the resistor in that time, in C?
7.5

First we can get the expression of current I as a function of time t:

$$I(t) = 0.6t,$$

where t is in s and I is in A. Then we can get the total charge:

$$Q = \int_0^5 I(t)dt = \int_0^5 0.6tdt = 0.6 \times 25/2 = 7.5(C).$$

7.A capacitor with a dielectric is charged, and remains connected to the battery. It stores energy. I then remove the dielectric between the plates. What happens to the stored energy?
it decreases
Because $C = \kappa C_0$ and $\kappa > 1$. This dielectric increases the capacitance of the capacitor. According to electric potential energy $U = \frac{C(\Delta V)^2}{2}$, C decreases while ΔV is the same(because the capacitor is connected to the battery), so U drops.

8. A sphere of radius 2.0 mm has a charge of +0.10 C. A second sphere of radius 1.5 mm has a charge of -0.20 C. Their centers are spaced 0.30 m apart. The force between them, in N, is ...
2e9 attractive
Their charges are of opposite signs, so they are attractive to each other. The magnitude of the force is:

$$F = k_e \frac{0.10C \times 0.20C}{(0.3m)^2} = 2 \times 10^9 N.$$

9.A cylinder of resistive material makes a resistor. If I double the radius, keeping the length the same, the resistance ...
is cut to 1/4
We need to use the equation of resistance: $R = \rho \frac{l}{S}$, where ρ is the resistivity of the material, l is the length, and S is the cross-section area of it. If we double the radius, the cross-section area quadruples, and the length is the same, so the resistance drops to 1/4 of the initial value.

10.A small test charge is immersed in an external electric field. If the test charge is doubled, the electric field ...
stays the same
A small test charge would not affect the external electric field.

11. A coil of wire floats in space directly above a second coil of wire. When viewed from above, currents in both coils are counter-clockwise. Gravity pulls downward, as usual. The force between the coils is ...
attractive
Because the currents in these two wires are of the same direction, so their magnetic fields point south to north, which attracts.

12.A 27 ohm resistor carries 0.50 amperes. How much power does it dissipate, in W?
6.8

$$P = I^2 R = (0.5A)^2 \times 27\Omega = 6.75W$$

13. See figure 3. A square loop of wire is 2.0 m on a side. The left edge lies on a table, while the opposite edge is raised h = 1.2 m above the table. A magnetic field of 0.0030 T is perpendicular to the table. What is the magnitude of the flux through the loop, in $T-m^2$?
9.6e-3

Because the magnetic field is uniform and the loop is lying in a plane, the magnetic flux is:

$$\Phi_B = \int \vec{B} \cdot d\vec{A} = \int BdAcos\theta = BAcos\theta,$$

where $B = 0.003T$, $A = (2m)^2 = 4m^2$. The direction of $\vec{A}$ is perpendicular with the plane of the loop, so the angle between $\vec{A}$ and $\vec{B}$ is $\theta = arcsin(1.2m/2m) = arcsin(0.6)$, so $cos\theta = \sqrt{1 - sin^2\theta} = \sqrt{1 - 0.6^2} = 0.8$. So we have:

$$\Phi_B = BAcos\theta = 0.003T \times 4m^2 \times 0.8 = 9.6 \times 10^{-3}Tm^2.$$

14.A capacitor has square plates 0.050 m on a side, spaced by 1.0 mm. It stores a voltage of 5.0 V. What is the electric field between the plates, in N/C?
5.0e3

$$E = \frac{\Delta V}{d} = \frac{5V}{10^{-3}m} = 5 \times 10^3 N/C$$

15. An electromagnet comprises a vertical bar with a coil around it, as in the class demonstration. It carries a steady current. An aluminum ring is gently held around the bar above the coil. The current is rapidly decreased to zero. During the decrease, the net force on the ring is ...
down
According to Lenz's law, the magnetic field of the induced current would oppose this change. So the induced magnetic field would have the same direction with the original one. So their magnetic fields point south to north, which attracts.

16.See figure 1. R is 56 ohms. The induced voltage is 3.0 V. How much power is needed to pull the bar, in W?
0.16

$$P = Fv = |I\vec{l} \times \vec{B}|v = IdBv = \frac{Bdv}{R}dBv = \frac{(Bdv)^2}{R} = \frac{\mathcal{E}^2}{R} = \frac{(3V)^2}{56\Omega} = 0.16W$$

17.A B-field is directed into the page. An electron travels on the page to the right. The force on the electron is ...
down the page
$\vec{F_e} = q\vec{v} \times \vec{B}$. Because the charge carried by electron is negative, so $q\vec{v}$ points to the left.

Then you can judge the direction of $\vec{F}_e$ using your right hand.

18.If I double the voltage on a capacitor, its stored energy ...
quadruples
The electric potential energy stored in a capacitor is $U = \frac{1}{2}C(\Delta V)^2$. Here ΔV doubles while C is the same, so U quadruples.

19.A 27 ohm resistor is in parallel with a 56 ohm resistor. What is the effective resistance of the pair, in ohms?
18
$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2}$, so $R_{total} = \frac{R_1 R_2}{R_1+R_2} = \frac{27\Omega\times 56\Omega}{27\Omega+56\Omega} = 18\Omega$.

20.See figure 2. The battery by itself is enough to fully light the bulb. After the system reaches steady state, the bulb is ...
dark
After the system reaches steady state, the capacitor is fully charged, so there is no current, so the bulb is dark.

21. A loop of wire has 5.0 turns, and is made of wire with radius 0.50 mm. The flux through it is 0.010 Tm^2. The flux drops uniformly to zero in 2.0 s. What is the induced EMF during that time, in V?
0.025

$$|\mathcal{E}| = N\frac{d\Phi_B}{dt} = 5 \times \frac{0.01Tm^2}{2s} = 0.025V.$$

22.Two charges exert a force on each other. How does that force change if both charges are doubled?
increase by factor of 4
Assuming $F = k_e\frac{q_1 q_2}{r^2}$, then $F' = k_e\frac{2q_1 2q_2}{r^2} = 4F$.

23.A circular loop of wire has radius 0.20 m. A constant B-field of 0.25 T penetrates the loop. What is the voltage induced in the loop, in V?
0.0
Because the B-field is constant, so the magnetic flux doesn't change. According to Faraday's Law, there is no induced voltage.

24.A conducting sphere has a radius of 0.10 m and carries a charge of -15 micro C. What is the electric potential 0.20 m from the surface of the sphere, in V?
-450,000
Note that the point that is 0.2m from the surface of the sphere is $0.2m + 0.1m = 0.3m$ from

the center of the sphere.

$$k_e \frac{-15 \times 10^{-6} C}{0.3m} = -4.5 \times 10^5 V$$

25. An electric motor has a rotor coil with 50 turns of wire, which carries 2.0 A. The coil is a square 0.10 m on a side, and is immersed in a magnetic field of 1.0e-4 T. What is the maximum torque (= force x distance) of the motor, in N-m?

1.0e-4

The maximum torque appears when the plane of the wire is parallel with B-field if the rotating axes of the wire is perpendicular with B-field. Then the force on each side that is parallel with the rotating axes is $F_m = N|I\vec{l} \times \vec{B}| = NIlB$, so the maximum torque is $\frac{l}{2} \times F_m \times 2 = NIl^2B = 50 \times 2A \times (0.1m)^2 \times 10^{-4}T = 10^{-4}Nm$, where $\frac{l}{2}$ is the distance from the rotating axes to each side that is parallel with it, and the factor 2 is the sum of the two sides that is parallel with the rotating axes.