Phys 4
Midterm Exam Solutions
S11

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From the bulb ratings we can find their respective resistances:

\[ R_A = \frac{P}{I^2} = \frac{85\text{W}}{(5.0\text{A})^2} = 3.4\Omega \]

\[ R_B = \frac{V^2}{P} = \frac{(2.0\text{V})^2}{205\text{W}} = 51\Omega \]

\[ R_C = \frac{V}{I} = \frac{120\text{V}}{0.6\text{A}} = 200\Omega \]

Now, since the bulbs are essentially resistors, apply the rules for resistors in series and parallel to find the equivalent resistance:

\[
\frac{1}{R_{eq}} = \frac{1}{R_B} + \frac{1}{R_A} \\
R_{eq} = R_B + R_A \\
R_{eq} = \frac{R_B R_C}{R_B + R_C} \\
R_{eq} = \frac{R_A + R_B R_C}{R_B + R_C}
\]

Plugging in the numbers, we find

\[ R_{eq} = 3.4\Omega + \frac{(31\Omega)(200\Omega)}{31\Omega + 200\Omega} \]

\[ R_{eq} = 30 \Omega \]
In Ch. 27 see the section on electrical measuring instruments. Applying a "shunt resistor" in parallel with the internal resistance of the galvanometer. Adjusting Rs allows us to set the full scale current measurement on the galvanometer. The correct diagram for this is the following:

\[ \text{Diagram} \]

First, let's break the circuit down and find an equivalent resistance:

\[ \text{Diagram 1} \rightarrow \text{Diagram 2} \rightarrow \text{Diagram 3} \rightarrow \text{Diagram 4} \]

Thus we can determine the current of this reduced circuit as

\[ I = \frac{V}{R} = \frac{12V}{6\Omega} = 2A \]

With this current, the voltage drop over the 4Ω resistor will be

\[ V = IR = (2A)(4\Omega) = 8V \]

and 12V - 8V = 4V will be distributed to the parallel resistors each. The current through the lower parallel resistors is then \( \frac{4V}{6\Omega} = 0.67A \), which leaves 2A - 0.67A = 1.33 A to pass through the upper parallel resistors. The power dissipated by the 2Ω resistor is thus

\[ P = I^2R = (1.33A)^2(2\Omega) = 3.54W \]
For charging a capacitor, we will use the following

$$I = I_0 e^{-t/RC}$$

The time constant is $RC = (10^5 \text{ohm})(8 \times 10^{-5} \text{F}) = 8$. The initial current is $I_0 = \frac{V}{R} = \frac{40}{10^5} = 0.0004 \text{ A} = 0.4 \text{ mA}$. Thus the current after 20s will be:

$$I = (0.4 \text{ mA}) e^{-20/8}$$

$$I = 5.2 \times 10^{-5} \text{ A} = 0.032 \mu\text{A}$$

The potential difference across the resistor then becomes

$$U = IR = (3.2 \times 10^{-5} \text{ A})(10^5 \text{ohm})$$

$$V = 3.2 \text{ V}$$

The force on the particle is found by

$$F = qvB = m \frac{v^2}{R}$$

and the velocity can be expressed in terms of the period

$$v = \frac{2\pi R}{T}$$

Thus

$$qB = \frac{2\pi R m}{RT}$$

$$T = \frac{2\pi m}{qB}$$

Plugging in the known values, we find $T = 1.3 \times 10^{-6} = 1.3 \mu\text{s}$
6. The electric potential is found by
\[ \frac{1}{2}mu^2 = qV \]
\[ V = \frac{3}{2} \frac{mu^2}{q} \]

Plugging in the numbers we find
\[ V \approx 7 \text{ kV} \]

The sign is negative on account of the direction of the magnetic field.

7. The torque exerted on the loop can be found by
\[ \tau = IBA \sin \psi \]

Since \( \mu = I \Lambda \) and \( \psi = \frac{\pi}{2} \), we have:
\[ \tau = \mu B \sin \frac{\pi}{2} \]
\[ = (0.75 \text{ A} \mu^2)(0.2 \text{ T}) \]
\[ \tau = 0.15 \text{ N} \cdot \text{m} \]

8. \( V = 330 \text{ m/s} \), \( B = -20 \text{ kT} \).
\[ \tau = -20 \times 10^{-6} \text{ T}. \]
\[ B = \frac{\mu_0 I}{2 \pi d} \]
\[ I = \frac{(2\pi d)B}{\mu_0} \]
\[ = \frac{2\pi(0.08 \text{ m})(-20 \times 10^{-6} \text{ T})}{4\pi \times 10^{-7}} \]
\[ I = -0.08 \text{ A} = 80 \text{ mA}, \text{ negative} \]
9. Gauss's law tells us that the magnetic field at point P will not change if the loop is merely distorted.

10. A solenoid with length ℓ and N windings will have a magnetic current given by

\[ B_0 = \mu_0 N I \]

\[ I = \frac{B_0}{\mu_0 N} \]

Plug in the numbers and find that

\[ I \approx 2.8 A \]