Midterm 2 for Calculus-Based Physics: Electricity and Magnetism

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1 Equations and constants

1. Kirchhoff's Rules: 1) $I_{in} + I_{out} = 0$ (Junction Rule) 2) $\sum_{loop} V_i = 0$ (Loop Rule)
2. Ohm's Law: $V = IR$
3. Power from current: $P = IV$
4. Voltage in an RC across the capacitor: $V(t) = \epsilon\left(1 - \exp\left(-t/\tau\right)\right)$, where ϵ is the battery voltage and $\tau = RC$.
5. Lorentz Force: $\vec{F} = q\vec{v} \times \vec{B} = I\vec{L} \times \vec{B}$.
6. Centripetal force: $F_C = mv^2/r$.
7. Magnetic torque: $\vec{\tau}_B = \vec{\mu} \times \vec{B}$
8. Magnitude of torque: $|\vec{\tau}_B| = \mu B \sin\theta$
9. Magnetic dipole moment: $\vec{\mu} = I\vec{A}$ (the current times the area vector)
10. Magnetic field at the center of a current-carrying loop: $\vec{B} = (\mu_0 I)/(2R)\hat{z}$, if the current is in the x-y plane.
11. Ampere's Law: $\int \vec{B} \cdot d\vec{s} = \mu_0 I_{enc}$ which is $BS = \mu_0 I_{enc}$ for simple cases where B is constant around the path, and parallel to $d\vec{s}$.
12. Magnetic permeability: $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}.
13. Mass of electron: $m_e = 9.1 \times 10^{-31}$ kg.

2 Exercises

1. **Chapter 10: DC Circuits and Kirchhoff's Rules**

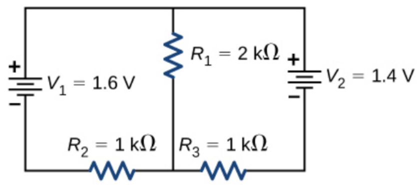

Figure 1: A circuit with three resistors powered by two voltages.

(a) What are the currents flowing through each resistor in Fig. 1?

(b) An automobiles intermittent wiper system is based on an RC circuit and uses a 0.5-μF capacitor and a variable resistor. What resistance R is required to achieve a time constant of 2.0 seconds?

(c) Determine how much time is required to charge an initially uncharged 100-pF capacitor through a 75.0-MΩ resistor to 90.0% of its final voltage.

2. **Chapter 11: Magnetic forces and fields**

(a) A cosmic-ray electron moves at 8×10^6 m/s at a 45 degree angle to the Earths magnetic field at an altitude where the field strength is 5.0×10^{-5} T. What is the radius of the circular path the electron follows?

(b) Calculate the magnetic field strength needed on a 200-turn square loop 20.0 cm on a side to create a maximum torque of 300 N m if the loop is carrying 25.0 A.

3. **Chapter 12: Sources of Magnetic Fields**

(a) How many turns must be wound on a flat, circular coil of radius 20 cm in order to produce a magnetic field of magnitude 8.0×10^{-5} T at the center of the coil when the current through it is 0.5 A?

(b) Using Ampère's Law, re-derive the equation for a magnetic field due to a long staight wire.

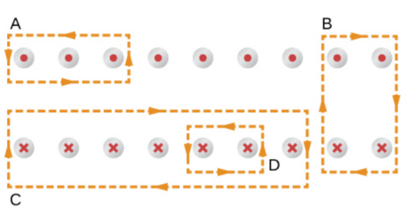

Figure 2: Several paths above correspond to line-integrals around a solenoid.

(c) The coil whose lengthwise cross section is shown in Fig. 2 carries a current I and has N evenly spaced turns distributed along the length L. Evaluate $\oint \vec{B} \cdot d\vec{l}$ for the paths indicated.