Midterm 2 for Algebra-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**

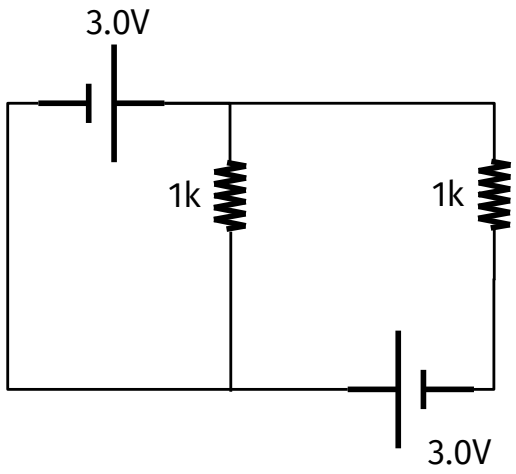

Figure 1: A circuit with three resistors powered by two voltages.

(a) What are the currents flowing through each resistor in Fig. 1? *Hint: first define the current in each segment of the circuit. Then apply the junction rule once and the loop rule twice.*

(b) An RC circuit has a time constant $\tau = 1$ ms. If the resistance is $R = 1$ kΩ, what is the value of the capacitor?

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

(a) A cosmic-ray electron moves at 2×10^7 m/s at a 90 degree angle to the Earths magnetic field at an altitude where the field strength is 2.0×10^{-4} T. How long does it take to go in a circle?

(b) Calculate the maximum torque that can be achieved with a 200-turn square loop 20.0 cm on a side carrying a 30.0 A current, in a magnetic field of 1.0 T.

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

(a) What is the magnetic field produced at the center of a coil of wire with radius 5 cm, that has 100 turns, carrying a current of 0.5 A?

(b) What is the total magnetic dipole moment of a coil of wire that has 100 turns, carries 0.1 A of current, and has a radius of 1.0 cm?

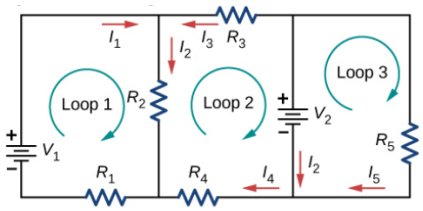

Figure 2: Several paths above correspond to line-integrals around a solenoid.

(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.