

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: $V(t) = \epsilon(1 - \exp(-t/\tau))$, 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.
12. Magnetic permeability: $\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$

2 Exercises

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

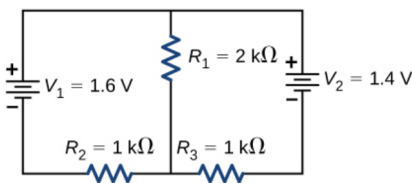


Figure 1: A circuit with three resistors powered by two voltages.

- (a) What are the currents flowing through each resistor in Fig. 1? What is the total power consumption?

- (b) An automobiles intermittent wiper system is based on an RC circuit and uses a $0.5\text{-}\mu\text{F}$ capacitor and a variable resistor. Over what range must R be made to vary to achieve time constants from 2.0 to 15.0 seconds?
- (c) Determine how much time is required to charge an initially uncharged 100-pF capacitor through a $75.0\text{-M}\Omega$ 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. What is the B-field 10 m from a wire carrying 10.0 A of current?

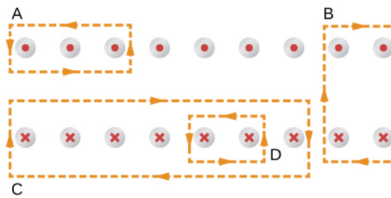


Figure 2: Several paths above correspond to line-integrals around a solenoid.

- (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 $\oint \vec{B} \cdot d\vec{\ell}$ for the paths indicated.