

# Study Guide for Midterm 2 for Algebra-Based Physics: Electricity and Magnetism

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April 16, 2019

## 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  $\epsilon$  is the battery voltage and  $\tau = RC$ .
5. Centripetal force:  $F_C = mv^2/r$ .
6. Magnetic torque:  $\vec{\tau}_B = \vec{\mu} \times \vec{B}$
7. Magnitude of torque:  $|\vec{\tau}_B| = \mu B \sin \theta$
8. Magnetic dipole moment:  $\vec{\mu} = I\vec{A}$  (the current times the area vector)
9. 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.
10. Magnetic field due to a current-carrying wire at a distance R:  $B = (\mu_0 I)/(2\pi R)$ , right-hand rule gives direction.
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:  $\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$
13. The Hall Effect:  $V_H = Blv$ .

## 2 Exercises

### 1. Chapter 21: DC Circuits and Kirchhoff's Rules

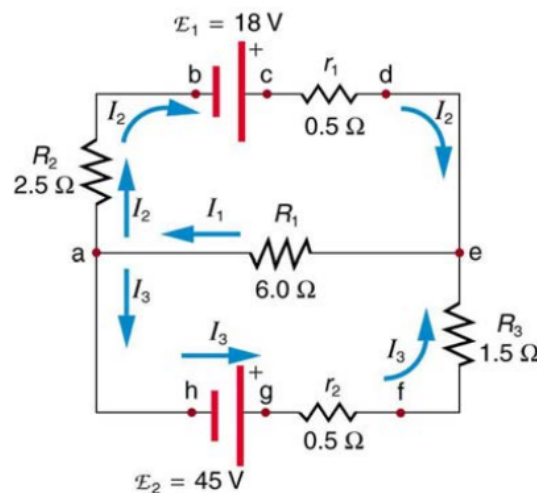


Figure 1: A circuit with five resistors (two are internal to the two batteries).

- (a) Solve for the currents  $I_1$ - $I_3$  in Fig. 1.  
 $I_3 = 8.25 \text{ A}$ ,  $I_2 = -2.83 \text{ A}$ , and  $I_1 = 5.42 \text{ A}$ .

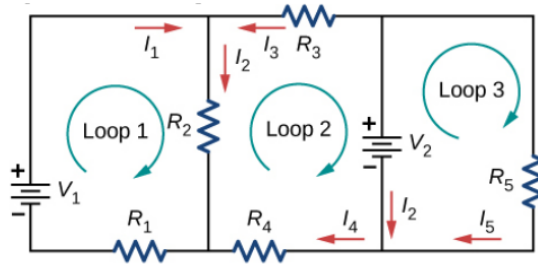


Figure 2: A circuit consisting of two batteries and five resistors.

(b) Solve algebraically for the five currents in Fig. 2. Remember to use the *junction rule* and the *loop rule*.

(c) A person with body resistance between his hands of  $10.0 \text{ k}\Omega$  accidentally grasps the terminals of a  $20.0 \text{ kV}$  power supply. (Do NOT do this!) (a) Draw a circuit diagram to represent the situation. (b) If the internal resistance of the power supply is  $2000 \Omega$ , what is the current through his body? (c) What is the power dissipated in his body? (d) If the power supply is to be made safe by increasing its internal resistance, what should the internal resistance be for the maximum current in this situation to be  $1.00 \text{ mA}$  or less?

## 2. Chapter 22: Magnetic fields

(a) What Hall voltage is produced by a  $0.200\text{-T}$  field applied across a  $2.60\text{-cm}$ -diameter aorta when blood velocity is  $60.0 \text{ cm/s}$ ?

(b) Calculate the Hall voltage induced on a patient's heart while being scanned by an MRI unit. Approximate the conducting path on the heart wall by a wire  $7.50 \text{ cm}$  long that moves at  $10.0 \text{ cm/s}$  perpendicular to a  $1.50\text{-T}$  magnetic field.

(c) (a) An oxygen-16 ion with a mass of  $2.66 \times 10^{-26} \text{ kg}$  travels at  $5.00 \times 10^6 \text{ m/s}$  perpendicular to a  $1.20\text{-T}$  magnetic field, which makes it move in a circular arc with a  $0.231\text{-m}$  radius. What positive charge is on the ion? (b) What is the ratio of this charge to the charge of an electron? (c) Discuss why the ratio found in (b) should be an integer.

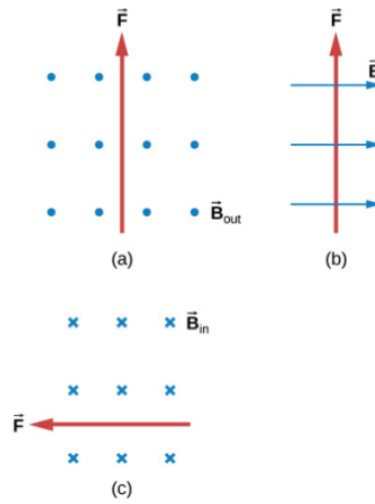


Figure 3: Each diagram depicts the force on a negatively-charged particle in a B-field.

- (d) Determine the velocity of a negatively-charged particle in Fig. 3 (a)-(c).
- (e) A cosmic-ray electron moves at  $6 \times 10^6$  m/s perpendicular to Earth's magnetic field at an altitude where the field strength is  $1.0 \times 10^{-5}$  T. What is the radius of the circular path the electron follows? Show that the *angular velocity*  $\omega$  of the electron around the magnetic field lines is related to the  $q/m$  ratio by  $\omega/B = q/m$ .
- (f) What is the (a) maximum torque on a 150-turn circular loop of wire with radius 8.0 cm that carries a 50.0-A current in a 1.60 T B-field? (b) What is the magnetic moment of this object?
- (g) Using one of the results of Ampère's Law, what is the magnetic field created by the loops in the previous problem, at the center of the loops?
- (h) Model a lightning bolt as a long straight wire. A typical current in a lightning bolt is  $10^4$  A. Estimate the magnetic field 1 m from the bolt, using one of the results of Ampère's Law.
- (i) (a) Show that the period  $T$  of the circular orbit of a charged particle with mass  $m$  and charge  $q$  moving perpendicularly to a uniform magnetic field is  $T = 2\pi m/(qB)$ . (b) What is the frequency  $f$ ? (c) What is the angular velocity  $\omega$ ? (c) A cyclotron accelerates charged particles as shown in Fig. 4. Calculate the frequency of the accelerating voltage needed for a proton in a 0.9 T B-field.

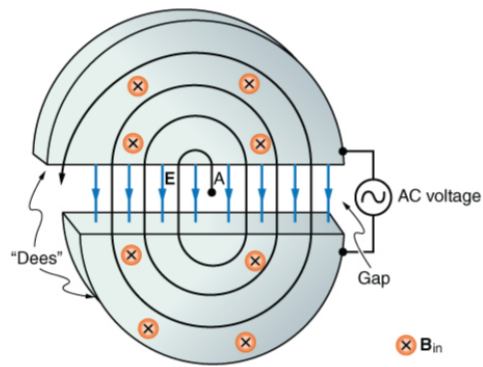


Figure 4: Each diagram depicts the force on a negatively-charged particle in a B-field.