Midterm 2 for Algebra-Based Physics: Electricity and Magnetism

Dr. Jordan Hanson - Whittier College Dept. of Physics and Astronomy

April 17, 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: $V(t) = \epsilon\left(1 - \exp\left(-t/\tau\right)\right)$, where ϵ is the battery voltage and the time constant is $\tau = RC$.
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 **long straight 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: $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}
13. The Hall Effect: $V_H = Blv$.
14. Charge of an electron/proton: $q_e = 1.6 \times 10^{-19}$ C.
15. Mass of proton: 1.67×10^{-27} kg.

2 Exercises

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

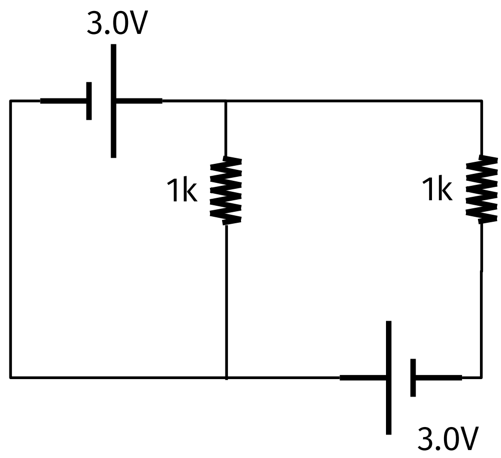

Figure 1: A circuit with three resistors powered by two voltages.

(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 22: Magnetic fields**

(a) What Hall voltage is produced by a 0.1 T field applied across a 5 mm diamter blood vessel when blood velocity is 90.0 cm/s?

(b) (a) An iron ion with a mass of 9.28×10^{-26} kg travels at 2.00×10^6 m/s perpendicular to a 1.0 T magnetic field, which makes it move in a circular path. If it is singly-ionized, it has the charge of $q_e = 1.6 \times 10^{-19}$ C. (a) What is the radius of the circular path it traverses? (b) What would happen to the radius of the path if the B-field value was slowly increased?

(c) Determine the direction of the Lorentz force in each of the following cases:

  i. B-field is to the right, velocity of positively charged particle is up:
  ii. B-field is out of the page, velocity of positively charged particle to the left:
  iii. B-field is to the right, velocity of negatively charged particle is down:

(d) Determine the direction of the velocity of the charge in each of the following cases:

  i. B-field is to the right, force of positively charged particle is up:
  ii. B-field is out of the page, force of positively charged particle to the right:
  iii. B-field is down, force of negatively charged particle is out of page:

(e) What is the (a) maximum torque on a 200-turn circular loop of wire with radius 4.0 cm that carries a 10.0-A current in a 0.5 T B-field? (b) What is the magnetic moment of this object?

(f) Model an arch of electricity from a faulty transformer to the wooden pole holding it as a **long straight wire**. A typical current is 30.0 A. (a) Estimate the magnetic field 1 m from the arch of electricity. (b) How does the result compare to the magnetic field of the Earth at the ground (≈ 0.5 Gauss)?

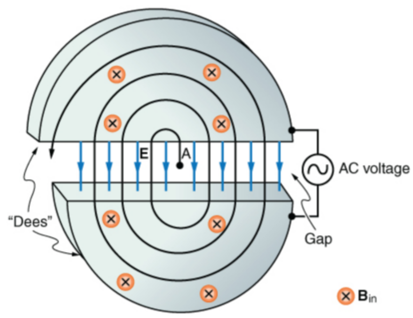

Figure 2: Each diagram depicts the force on a negatively-charged particle in a B-field.

(g) 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 $T = 2\pi m/(qB)$. (a) What is the frequency $f = T^{-1}$ at which protons circulate as shown in Fig. 2? Assume the B-field is 2.0 T and the charge and mass of protons are given in the equations list. (b) What is the frequency for alpha particles? (The mass of an alpha is 4 times the mass of a proton, and the charge is twice that of a proton - think of this as a scaling problem).