Homework No. 08 (Fall 2024)

PHYS 205B: UNIVERSITY PHYSICS

School of Physics and Applied Physics, Southern Illinois University–Carbondale

Due date: Tuesday, 2024 Oct 29, 9:30 AM, on D2L

Instructions

- You are encouraged to use any of the resources to complete this homework. However, the extent to which you depend on resources while doing homework is usually a measure of how much extra work you need to put in to master the associated concepts. Solutions should be the last resource.
- Describe your thought process in detail and organize it clearly. Make sure your answer has units and the right number of significant digits.
- Additional problems, with hyperlinks to exams, are available in Lecture Notes.
- After completion, scan the pages as a single PDF file, and submit the file on D2L (under Assessments → Assignments).

Problems

1. (**10 points.**) The magnetic field at a distance R from a wire of infinite extent carrying a steady current I is given by

$$\mathbf{B} = \frac{\mu_0}{4\pi}\frac{2I}{R}\hat{\boldsymbol{\phi}}, \tag{1}$$

where the direction of $\hat{\boldsymbol{\phi}}$ is given by the right-hand rule. Find the magnetic field at point o in Fig. 1 in terms of distances a and b and current I. That is, express R in terms of a and b.

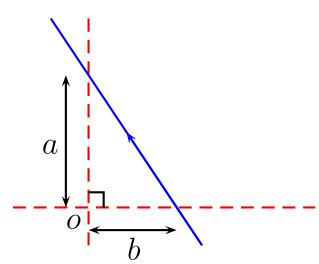

Figure 1: Problem 1

Solution

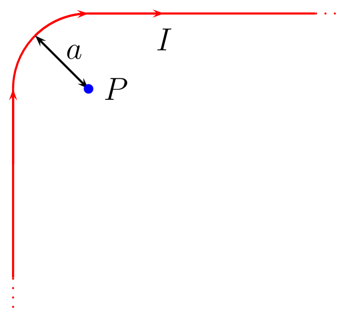

Figure 2: Problem 2

2. (**10 points.**) A steady current I flows through a wire shown in Fig. 2. Determine the magnitude and direction of magnetic field at point P in terms of I and a.

   (a) Determine the magnitude and direction of the magnetic field for $I = 1.0\,\mathrm{A}$ and $a = 10.0\,\mathrm{cm}$.

   (b) Determine the magnitude and direction of the magnetic force on a proton moving with velocity $v = 2.0 \times 10^6\,\mathrm{m/s}$, to the right, while it is passing the point P.

   Solution

3. (**10 points.**) A steady current I flows through a wire in the shape of a square of side L, shown in Fig. 3. Determine the magnitude and direction of the magnetic field at the center of the square, P.

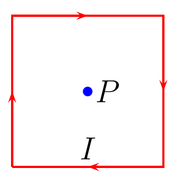

Figure 3: Problem 3

   Solution

4. (**10 points.**) Figure 4 shows two current carrying wires, separated by a distance D. The directions of currents, either going into the page or coming out of the page, are shown in the figure. Determine the point $\times$ where the magnetic field is exactly zero.

   Solution

5. (**10 points.**) Figure 5 shows two current carrying wires, in a plane. The directions of currents, either going into the page or coming out of the page, are shown in the figure. Determine the magnitude and direction of the magnetic field at the point $\times$, the origin. Let $I_1 = 1.0\,\mathrm{A}$, $I_2 = 2.0\,\mathrm{A}$, $x = 12\,\mathrm{cm}$, and $y = 8.0\,\mathrm{cm}$.

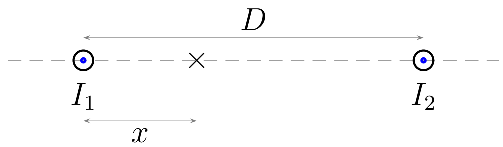

Figure 4: Problem 4

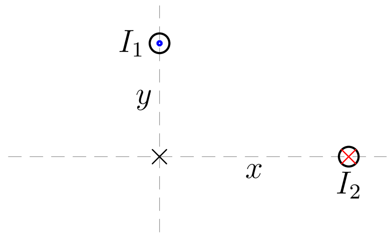

Figure 5: Problem 5

Solution

6. (**10 points.**) A rectangular loop of wire carrying current $I_2 = 2.0\,\mathrm{A}$ is placed near an infinitely long wire carrying current $I_1 = 1.0\,\mathrm{A}$, such that two of the sides of the rectangle are parallel to the current I_1. Let the distances be $a = 5.0\,\mathrm{cm}$, $b = 4.0\,\mathrm{cm}$, and $l = 10.0\,\mathrm{cm}$.

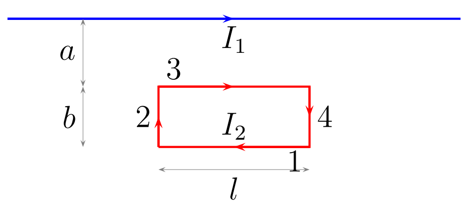

Figure 6: Problem 6

(a) Determine the force on side '1' of the loop.

(b) Determine the force on side '3' of the loop.

(c) Show that the combined force on side '2' and '4' is zero.

(d) Determine the magnitude and direction of the total force on the loop.

[**Solution**]

7. (**10 points.**) Using Ampère's law show that the magnetic field due to a solenoid carrying

a current I is given by,

$$\vec{\mathbf{B}} = \begin{cases} \hat{\mathbf{z}}\,\mu_0 I n, & \text{inside the solenoid,} \\ 0, & \text{outside the solenoid,} \end{cases} \tag{2}$$

where n is the number of turns per unit length.

[**Solution**]

8. (**5 points.**) A resistance R is connected to a battery V. Imagine an abstract Ampèrian loop c encircling the wires as described in Figure 7. Using Ampère's law evaluate

$$\oint_c \mathbf{B} \cdot d\mathbf{l} \tag{3}$$

along the closed curve c.

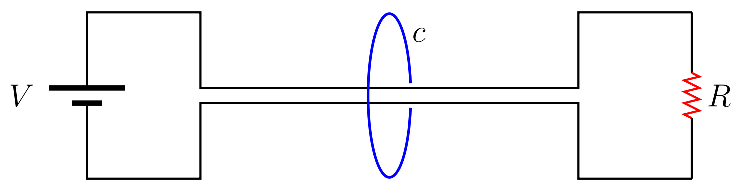

Figure 7: Problem 8

[**Solution**]