University of Alabama
Department of Physics and Astronomy

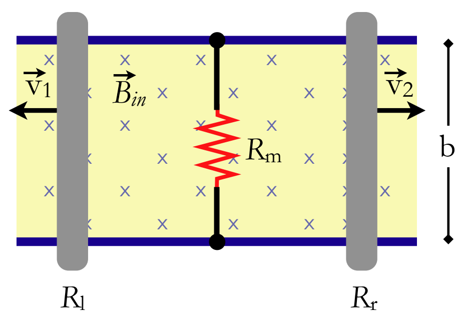
PH 102 Spring 2015

Exam 3

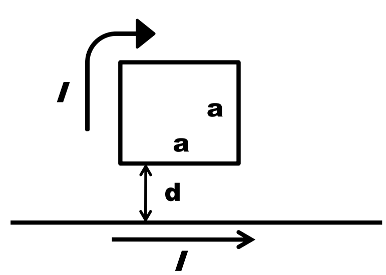
Instructions

1. Solve **three** of the five problems below.
2. All problems have equal weight. Do your work on separate sheets.
3. You are allowed 1 sheet of standard 8.5×11 in paper and a calculator.

□ **1.** Two parallel rails with negligible resistance are a distance d apart and connected by a resistor R_m. The circuit also contains two metal rods, of resistance R_l and R_r, begin pulled away from the resistor at speeds of v_1 and v_2, respectively. A uniform magnetic field B is applied into the plane of the figure. Determine the current in the central resistor R_m.

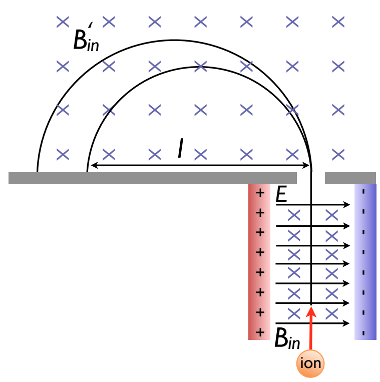


□ **2.** Find the force on a square loop (side a) placed as shown below, near an infinite straight wire. Both loop and wire carry a steady current I.



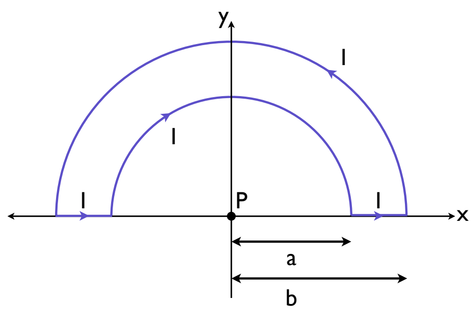
□ **3.** In a mass spectrometer, a beam of ions is first made to pass through a *velocity selector* with perpendicular $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ fields. Here, the electric field $\vec{\mathbf{E}}$ is to the right, between parallel charged plates, and the magnetic field $\vec{\mathbf{B}}$ in the same region is into the page. The selected ions are then made to enter a region of different magnetic field $\vec{\mathbf{B}}'$, where they move in arcs of circles. The radii of these circles depend on the masses of the ions. Assume that each ion has a single charge e. Show that in terms of the given field values and the impact distance l the mass of the ion is

$$m = \frac{eBB'l}{2E}$$



□ **4.** A technician wearing a brass bracelet enclosing an area $0.00500\,\mathrm{m}^2$ places her hand in a solenoid whose magnetic field is $5.00\,\mathrm{T}$ directed perpendicular to the plane of the bracelet. The electrical resistance around the circumference of the bracelet is $0.0200\,\Omega$. A power failure causes the field to drop to $1.50\,\mathrm{T}$ in a time of $20.0\,\mathrm{ms}$. Find **(a)** the current in the bracelet, and **(b)** the power delivered to the bracelet. *Hint:* don't wear metal jewelry when working with strong magnetic fields.

□ **5.** Find the magnetic field at point P due to the current distribution shown below. *Hint: Break the loop into segments, and use superposition.*



Constants:

$$
\begin{aligned}
g &\approx 9.81\,\mathrm{m/s}\\
N_A &= 6.022\times10^{23}\ \text{things/mol}\\
k_e &= \frac{1}{4\pi\epsilon_o} = 8.98755\times10^{9}\ \mathrm{N\cdot m^2\cdot C^{-2}}\\
\mu_o &\equiv 4\pi\times10^{-7}\ \mathrm{T\cdot m/A}\\
\epsilon_o &= \frac{1}{4\pi k_e} = 8.85\times10^{-12}\ \mathrm{C^2/N\cdot m^2}\\
e &= 1.60218\times10^{-19}\ \mathrm{C}\\
c &= \frac{1}{\sqrt{\mu_0\epsilon_0}} = 2.99792\times10^{8}\ \mathrm{m/s}\\
m_{e^-} &= 9.10938\times10^{-31}\ \mathrm{kg}\\
m_{p^+} &= 1.67262\times10^{-27}\ \mathrm{kg}\\
hc &= 1239.84\,\mathrm{eV\cdot nm}
\end{aligned}
$$

Unit	Symbol	equivalent to
newton	N	$\mathrm{kg\cdot m/s^2}$
joule	J	$\mathrm{kg\cdot m^2/s^2} = \mathrm{N\cdot m}$
watt	W	$\mathrm{J/s = m^2\cdot kg/s^3}$
coulomb	C	$\mathrm{A\cdot s}$
amp	A	C/s
volt	V	$\mathrm{W/A = m^2\cdot kg/\cdot s^3\cdot A}$
farad	F	$\mathrm{C/V = A^2\cdot s^4/m^2\cdot kg}$
ohm	Ω	$\mathrm{V/A = m^2\cdot kg/s^3\cdot A^2}$
tesla	T	$\mathrm{Wb/m^2 = kg/s^2\cdot A}$
electron volt	eV	1.6×10^{-19} J
-	$1\,\mathrm{T\cdot m/A}$	$1\,\mathrm{N/A^2}$
-	$1\,\mathrm{T\cdot m^2}$	$1\,\mathrm{V\cdot s}$
-	1 N/C	1 V/m

Basic Equations:

$$\vec{\mathbf{F}}_{\text{net}} = \frac{\Delta\vec{\mathbf{p}}}{\Delta t} = m\vec{\mathbf{a}} \qquad \text{Newton's Second Law}$$

$$\vec{\mathbf{F}}_{\text{centr}} = -\frac{mv^2}{r}\hat{\mathbf{r}} \qquad \text{Centripetal}$$

$$|\vec{\mathbf{F}}| = \sqrt{F_x^2+F_y^2} \quad \text{mag} \qquad \theta = \tan^{-1}\left[\frac{F_y}{F_x}\right] \quad \text{dir}$$

$$0 = ax^2+bx^2+c \Longrightarrow x = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

Magnetism

$$
\begin{aligned}
|\vec{\mathbf{F}}_B| &= q|\vec{\mathbf{v}}||\vec{\mathbf{B}}|\sin\theta_{vB}\\
|\vec{\mathbf{F}}_B| &= BIl\sin\theta \ \ \text{wire}\\
|\vec{\mathbf{B}}| &= \frac{\mu_0 I}{2\pi r} \ \ \text{wire}\\
|\vec{\mathbf{B}}| &= \frac{\mu_0 I}{2r} \ \ \text{loop}\\
|\vec{\mathbf{B}}| &= \mu_0\frac{N}{L}I \ \equiv \mu_0 nI\,\hat{\mathbf{z}} \ \ \text{solenoid}\\
\frac{|\vec{\mathbf{F}}_{12}|}{l} &= \frac{\mu_0 I_1 I_2}{2\pi d} \ \ \text{2 wires, force per length}
\end{aligned}
$$

Current/resistors/circuits:

$$
\begin{aligned}
\Delta V &= \frac{\varrho l}{A}I = RI\\
R &= \frac{\Delta V}{I} = \frac{\varrho l}{A}\\
\mathscr{P} &= E\cdot\Delta t = I\Delta V = I^2R = \frac{[\Delta V]^2}{R} \ \ \text{power}\\
R_{\text{eq, series}} &= R_1+R_2\\
\frac{1}{R_{\text{eq, par}}} &= \frac{1}{R_1}+\frac{1}{R_2}
\end{aligned}
$$

Induction:

$$
\begin{aligned}
\Phi_B &= B_\perp A = BA\cos\theta_{BA}\\
\Delta V &= -N\frac{\Delta\Phi_B}{\Delta t} \qquad N = \text{number of turns}\\
\Delta V &= -L\frac{\Delta I}{\Delta t}\\
\Delta V &= |\vec{\mathbf{v}}||\vec{\mathbf{B}}|l = |\vec{\mathbf{E}}|l \ \ \text{motional voltage}
\end{aligned}
$$