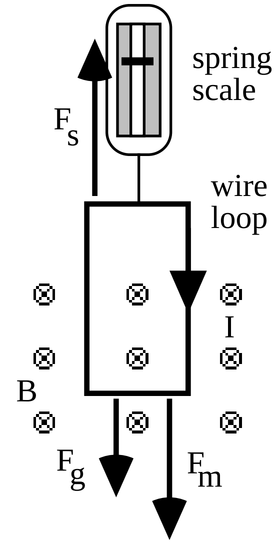
Name:____

Solve the following problems in the space provided. Use the back of the page if needed. Each problem is worth 20 points. You must show your work in a logical fashion starting with the correctly applied physical principles which are on the last page. Your score will be maximized if your work is easy to follow because partial credit will be awarded.

1. A device for measuring magnetic fields is shown. It consists of a spring scale attached to a 25.0g loop of wire carrying a current of 10.0A in the direction shown. The loop is 20.0cm tall and 5.00cm wide. The bottom half of the loop is placed in the field that is perpendicular to the plane of the loop. Find the magnitude and direction of the field when the scale reads 10.0g. Note that the field may or may not be in the direction indicated in the drawing.



There are three forces on the loop; the weight, the magnetic force on the horizontal part of the current, and the force from the scale.
The magnetic force on the wire is given by the definition of magnetic field,
$\vec{F} \equiv I\vec{\ell} \times \vec{B}$ $\quad F_m = IwB$.
The weight is $F_g = mg$ where m is the mass of the loop.
The force from the scale is $F_s = m'g$ where m' is the scale reading.
Applying Newton's Second Law,
$\Sigma F = ma \quad F_s - F_g - F_m = 0$

2. A long straight wire with a 2.00mm radius carries a uniformly distributed current of 5.00mA. Find the magnetic field (a)1.00mm from its center and

Substituting for the forces and solving for the field,

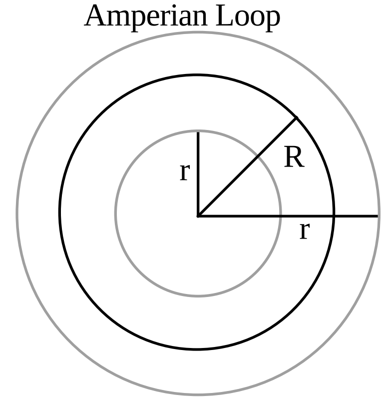
$$m'g - mg - IwB = 0 \qquad B = \frac{(m' - m)g}{Iw}.$$

Putting in the numbers,

$$B = \frac{(0.010 - 0.025)(9.8)}{(10.0)(0.050)} = \underline{\underline{-0.294T}}.$$

The minus sign means that the field is opposite to the way it is shown. The field is out of the page.

(b)3.00mm from its center.



(a)Apply Ampere's Law to the amperian loop of radius r = 1.00mm.

$$\oint \vec{B} \cdot d\vec{s} = \mu_o i_{enclosed}.$$

Symmetry requires that the field be constant and parallel with the circular path of the amperian loop, $B2\pi r = \mu_o i_{enclosed}$.
The current enclosed is found from the ratio of cross sectional areas,

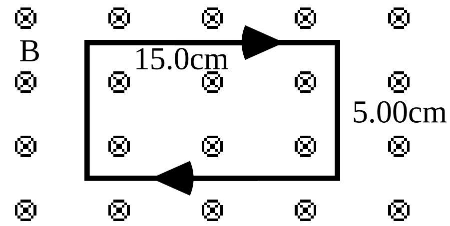
$$\frac{i_{enclosed}}{I} = \frac{\pi r^2}{\pi R^2} \qquad i_{enclosed} = I\frac{r^2}{R^2}.$$

Finally, $B2\pi r = \mu_o I\frac{r^2}{R^2} \qquad B = \frac{\mu_o I r}{2\pi R^2}$.

Putting in the numbers, $B = (2x10^{-7})\frac{(5.00)(1.00)}{(2.00)^2} = \underline{\underline{2.50x10^{-7}T}}$.

(b)Outside the wire the equation for the field of a long straight wire will work.

$$B = \frac{\mu_o I}{2\pi r} = (2x10^{-7})\frac{5.00}{3.00} = \underline{\underline{3.33x10^{-7}T}}$$



3. A plane rectangular loop of wire has 12 turns. It is 15.0cm wide and 5.00cm tall. It has a total resistance of 2.00Ω. A magnetic field of 2.50T is directed perpendicular to the plane of the loop as shown. This field is reduced to 1.00T at a uniform rate in 3.00ms. Find the current induced in the loop and indicate its direction in the sketch.

Apply Faraday's Law $\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$ $\quad V = N\frac{\Delta\Phi_B}{\Delta t}$.

Using the definition of flux and the fact that the field is constant and perpendicular to the plane of the loop,

$\Phi_B \equiv \int \vec{B} \cdot d\vec{A} = Bwh \qquad \Delta\Phi_B = \Phi_f - \Phi_i = B_f wh - B_f wh = wh\Delta B$

The voltage is now, $V = Nwh\frac{\Delta B}{\Delta t}$.

Using Ohm's Rule, $IR = Nwh\frac{\Delta B}{\Delta t} \qquad I = \frac{Nwh\Delta B}{R\Delta t}$.

Putting in the numbers, $I = \frac{Nwh\Delta B}{R\Delta t} = \frac{(12)(0.15)(0.050)(2.50-1.00)}{(2.00)(0.003)} = \underline{\underline{22.5A}}$

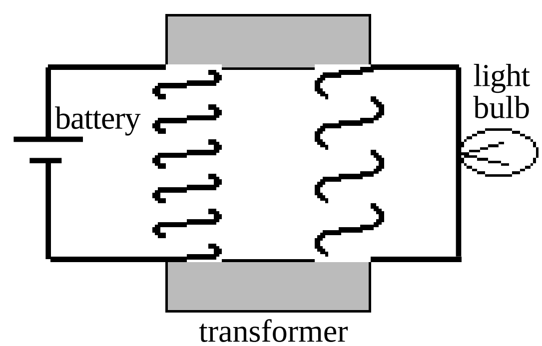
Since the field into the page is decreasing, the field caused by the induced current will try to make up for the loss and point into the page as well. Therefor, the current will be clockwise. This is Lenz's Rule.

4. A 1.00μH inductor is used in a radio tuner with a variable capacitor. Find the capacitance required to have the tuner circuit oscillate at the same frequency as the radio station 93.9MHz.

An LC circuit will oscillate at an angular frequency given by $\omega = \frac{1}{\sqrt{LC}} \qquad f = \frac{1}{2\pi\sqrt{LC}}$.

Solving for the capacitance $C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4\pi^2(93.9x10^6)^2(1.00x10^{-6})} = \underline{\underline{2.87pF}}$

5. In the lab you studied a transformer with the primary coils connected to a battery and the secondary coils connected to a small light bulb as shown at the right. Explain how you got the light bulb to light and what fundamental physical laws are illustrated by the systems behavior.



The bulb lights only while the battery is being connected or disconnected. The bulb does not light while the battery remains connected. This is explained by Faraday's Law. When the current in the primary side with the battery changes, the magnetic field it creates in the iron changes. This changing magnetic field goes through the secondary coil with the light bulb. According to Faraday's Law the changing field induces a voltage that lights the bulb.