**Problem 1.** Force on a current in a Magnetic Field: Section 27-3 and Example 27-1. Also see Quiz 10.

The force on a current-carrying wire is

\[ \vec{F} = I\vec{\ell} \times \vec{B} . \]

So, the force on the vertical segment of length \( a \) points in the \( x \) (horizontal) direction and has magnitude \( F_x = IaB \). Similarly, the force on the horizontal segment is in the vertical direction and has magnitude \( F_y = IbB \).

The current has magnitude \( I = V/R = 50 \text{ A} \) so the components are \( F_x = 50 \times 0.03 \times 2 = 3 \text{ N} \) and \( F_y = 4 \text{ N} \). Thus, the magnitude of the net force is

\[ F = \sqrt{F_x^2 + F_y^2} = \sqrt{3^2 + 4^2} = 5 \text{ N} . \]

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**Problem 2a.** Field from a long straight wire was covered from the beginning of Chapter 28. Changing the coordinate system to the center is similar to what you did in homework problem 28-56.

Using the right-hand rule, we see that both wires create magnetic fields that are pointing out of the page. So we just add the fields produced by the two wires. For a single wire,

\[ B = \frac{\mu_0 I}{2\pi r} , \]

so we just have to relate the distance \( r \) from each wire to the distance \( x \) from the center. From the left: \( r = a + x \) and from the right: \( r = a - x \). So

\[
B = \frac{\mu_0 I}{2\pi(a + x)} + \frac{\mu_0 I}{2\pi(a - x)} = \frac{\mu_0 I}{2\pi} \left( \frac{a - x + a + x}{a^2 - x^2} \right) = \frac{\mu_0 I}{2\pi} \frac{2a}{a^2 - x^2} .
\]

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**Problem 2b.** This is like Problem 29-21. That wasn’t an assigned problem, but I worked it in class.

\[ \Phi_B = \int_{\text{area}} \vec{B} \cdot d\vec{A} \]

We take \( d\vec{A} \) to be a vertical strip of width \( dx \) and height \( a \). Then, \( \vec{B} \cdot d\vec{A} = Bdx = B \text{ad}x \).

Using \( B(x) \) from part (a) we have

\[
\Phi_B = \int_{-a/2}^{a/2} B(x) dx = \int_{-a/2}^{a/2} \frac{\mu_0 I}{2\pi} \frac{2a}{a^2 - x^2} adx = \frac{\mu_0 I}{2\pi} \frac{2a2\ln(a + x)}{2a} \bigg|_{-a/2}^{a/2} = \frac{\mu_0 Ia}{2\pi} \left( \ln \left( \frac{3a/2}{a/2} \right) - \ln \left( \frac{a/2}{3a/2} \right) \right) = \frac{\mu_0 Ia}{2\pi} \ln 3 = \frac{\mu_0 Ia}{\pi} \ln 3 = \mu_0 Ia \ln \frac{3}{\pi}.
\]
Problem 3. First look at Example 28-9 and then look at homework Problem 28-37.

There is no simple symmetry that can allow us to use Ampere’s law, so we use the Biot-Savart law:

\[ dB = \frac{\mu_0 I \, \vec{d}\ell \times \hat{r}}{4\pi \, r^2} \]

We choose \( \vec{d}\ell \) to point in the +y-direction, so \( \vec{d}\ell \times \hat{r} = dy \sin\theta \) where \( \sin\theta = a/r \). We integrate \( dy \) from \(-a\) to \(a\):

\[
B = \int_{-a}^{a} \frac{\mu_0 I}{4\pi} \frac{dy}{r^2} = \frac{\mu_0 I a}{4\pi} \int_{-a}^{a} \frac{dy}{r^3} = \frac{\mu_0 I}{2\sqrt{2}\pi a} 
\]

Problem 4. This was based on example 29-1. We went over this in class a lot, remember. All are counter-clockwise.

Problem 5. See section 30-4.

(a) Energizing an LR circuit. The voltage \( V \) is connected across the top \( L \) and \( R \), as well as the middle \( R \), so we can just ignore the middle resistor. As far as energizing the LR, all the middle resistor does is draw more current from the battery. So, the current in the inductor is:

\[ I = \frac{V}{R} \left( 1 - e^{-t/\tau} \right) \]

where \( \tau = L/R \). Note that \( t \to \infty \) gives \( I = V/R \). Substituting the values, \( V/R = 1 \) and \( t/\tau = 1 \) so

\[ I = 1 - e^{-1} \]

(b) De-energizing an LR circuit: \( I = I_0 e^{-t/\tau} \). The infinite time limit above gives us the initial current here, so \( I_0 = V/R \).

Now the inductor de-energizes through the top and middle resistor, so \( \tau = L/(2R) \). Thus

\[ I = e^{-2} \]

Problem 6. See Section 32-1.

Maxwell corrected Ampere’s law to include a changing electric flux:

\[
\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I + \epsilon_0 \mu_0 \frac{d}{dt} \Phi_E
\]