Center for Academic Resources in Engineering (CARE)
Peer Exam Review Session

PHYS 212 – University Physics: Electricity and Magnetism

Mid-semester Review Worksheet Solutions

The problems in this review are designed to help prepare you for your upcoming exam. Questions pertain to material covered in the course and are intended to reflect the topics likely to appear in the exam. Keep in mind that this worksheet was created by CARE tutors, and while it is thorough, it is not comprehensive. In addition to exam review sessions, CARE also hosts regularly scheduled tutoring hours.

Tutors are available to answer questions, review problems, and help you feel prepared for your exam during these times:

Session 1:

Can't make it to a session? Here's our schedule by course:

`https://care.grainger.illinois.edu/tutoring/schedule-by-subject`

Solutions will be available on our website after the last review session that we host.

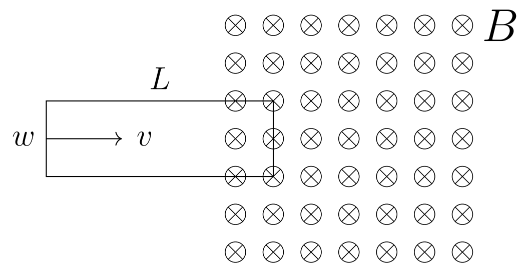
Step-by-step login for exam review session:

1. Log into Queue @ Illinois: https://queue.illinois.edu/q/queue/848
2. Click "New Question"
3. Add your NetID and Name
4. Press "Add to Queue"

Please be sure to follow the above steps to add yourself to the Queue.

Good luck with your exam!

1. A loop of wire with resistance R = 3 Ω enters an infinite uniform magnetic field, B = 3 T. It has a length L = 2 m and width W = 1 m. It enters the field with velocity v = 2 m/s. When the loop is entering the field, what is the force on the rightmost wire?



To determine the force on the wire, we have to use $\vec{F} = I\vec{L} \times \vec{B}$. However, we do not have I. So we have to first determine the EMF ε generated in the loop to find I. We know that the EMF generated by a straight wire moving in the magnetic field is

$$\varepsilon = vBw = 2 \times 3 \times 1 = 6\ V$$

Using Ohm's law, we can calculate the current I on the loop and obtain the force on the rightmost wire.

$$I = \frac{\varepsilon}{R} = \frac{6V}{3\Omega} = 2A$$

The direction of the current is the same as the direction of the EMF. A simple way to determine the direction of EMF in a moving straight wire is to use $q\vec{v} \times \vec{B}$. In this case, we are able to get that the current is going counter-clockwise since the EMF points up on the right wire.

$$\vec{F} = I\vec{l} \times \vec{B} = 2 \times 1 \times 3 = 6N$$

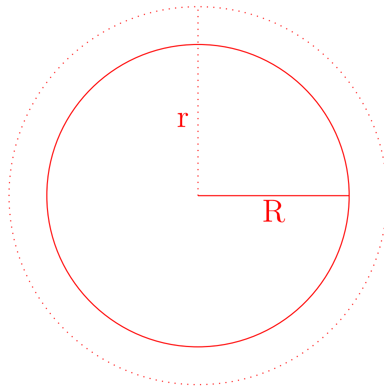
Using the right-hand rule, we can determine that the force points to the left with a magnitude of 6 N.

2. There is an infinite wire with a radius R carrying a current I. Use Ampere's law to find the magnetic field on the inside and outside of the wire for any distance r from the center of the wire.

To determine the magnetic field for an infinite wire, we need to use Ampere's Law which states

$$\int \vec{B} \cdot d\vec{l} = \mu_0 I_{enclosed}$$

First, we consider the case that $r > R$. In this case, the $I_{enclosed}$ would simply be current in the wire. Then, we construct a path around the wire to compute $\int \vec{B} \cdot d\vec{l}$, which is shown as the dotted line:



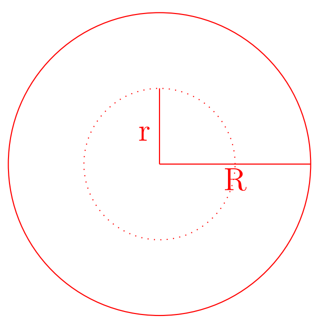
For this outer path, Ampere's Law tells us:

$$\int \vec{B} \cdot d\vec{l} = B_{outer} \times 2\pi r = \mu_0 I_{enclosed} = \mu_0 I$$

$$\boxed{B_{outer} = \frac{\mu_0 I}{2\pi r}}$$

Inside the wire, we can still use the same method to construct a path for integration. However, the difference is that we are now in the wire and the $I_{enclosed}$ would not be the same as I. In fact, $I_{enclosed}$ is proportional to the area bounded by our path:

$$I_{enclosed} = I \times \frac{A_{enclosed}}{A_{wire}}$$



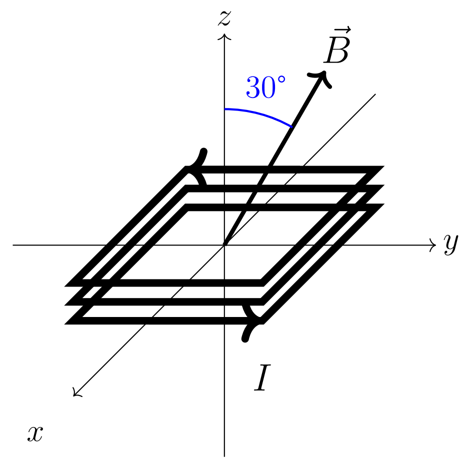
Now that we have the path and the $I_{enclosed}$, we can compute the magnetic field using Ampere's Law:

$$\mu_0 I_{enclosed} = \mu_0 I \times \frac{A_{enclosed}}{A_{wire}} = \mu_0 I \times \frac{\pi r^2}{\pi R^2} = \frac{\mu_0 I r^2}{R^2}$$

$$\int \vec{B} \cdot d\vec{l} = B_{inner} \times 2\pi r = \frac{\mu_0 I r^2}{R^2}$$

$$\boxed{B_{inner} = \frac{\mu_0 I r}{2\pi R^2}}$$

3. A square coil of 5 loops is carrying a current of $I = 2\ A$. The loops all have a width of 1 m. The coil is in a magnetic field of 4 T, and the normal vector to the plane of the coil is at an angle of 30 degrees to the magnetic field.



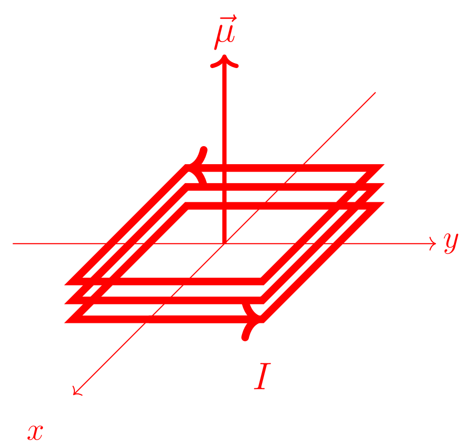
(i) What is the magnitude and direction of torque on the coil?

(ii) What is the potential energy of the coil?

(i) In order to determine the direction of the torque and the potential energy, we first have to determine the magnitude and the direction of the magnetic dipole of the coil. The strength of the magnetic dipole is:

$$\mu = NIA = 5 \times 2A \times 1m^2 = 10\ Am^2$$

To determine the direction of the dipole, we have to use the right-hand rule and curl our fingers in the direction of the current. In this case, the right-hand rule gives us the direction of the dipole to be in the positive z direction.



With the direction and the strength of the magnet dipole, we can calculate the torque on the coil to be:

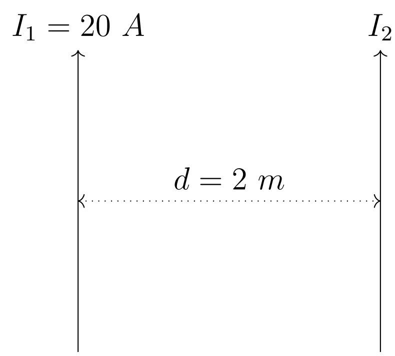
$$|\vec{\tau}| = |\vec{\mu} \times \vec{B}| = \mu B sin(30) = \boxed{20\ Nm}$$

As for the direction of the torque, $\vec{\mu} \times \vec{B}$ gives us a direction in the -x direction. This is the direction of the torque.

(ii) The potential energy of the coil can be computed as:

$$U = -\vec{\mu} \cdot \vec{B} = \mu B \cos(30) = \boxed{-34.64\ J}$$

4. There are two current carrying wires, 2 meters apart. The left wire carries a current $I_1 = 20\ A$. The right wire experience an attractive force of $4 \times 10^{-5}\ N/m$ due to the left wire. What is the direction and magnitude of the second current I_2?



Since the force is attractive, the wires have to carry current in the same direction (up).

To calculate the magnitude of I_2, we have to know the magnetic field at the right wire so we can use $F = ILB$. In this case, the magnetic field is purely from the left wire. So the magnetic field I_2 experiences is:

$$B = \frac{\mu_0 I_1}{2\pi d} = 2 \times 10^{-6}\ T$$

Now that we have the magnetic field at the right wire, we can use $F = ILB$ to determine I_2:

$$I_2 = \frac{F}{L}\frac{1}{B} = 4 \times 10^{-5} \times \frac{1}{2 \times 10^{-6}} = \boxed{20\ A}$$