PHYS 1444 – Section 003
Lecture #19, Review Part 2

Tues. November 13 2012

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HW28 solution posted

HW29 (50 points) due tonight at 11pm

Test 11/15

REVIEW Part 2

Inductance

1444 Test 2 Eq. Sheet

$$V_{ab} = \varepsilon - Ir$$

Terminal voltage

$$B = \frac{\mu_0 I}{2\pi r}$$

Magnetic field from long straight wire

$$R_{eq} = \sum_i R_i$$

Resistors in series

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{encl}$$

Ampére's Law

$$\frac{1}{R_{eq}} = \sum_i \frac{1}{R_i}$$

Resistors in parallel

$$V_{rms} = I_{rms} X_L$$

$$M_{21} = N_2 \Phi_{21} / I_1$$

Mutual (M) and self (L) Inductance

$$\varepsilon_2 = -M_{21} \frac{dI_1}{dt}$$

$$\vec{F} = I\vec{l} \times \vec{B}$$

$$\vec{F} = q\vec{v} \times \vec{B}$$

$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{l} \times \hat{r}}{r^2}$$

Biot-Savart Law

$$\varepsilon = -N \frac{d\Phi_B}{dt}$$

Faraday's Law

$$L = \frac{N\Phi_B}{I}$$

$$\tau = NIAB \sin\theta$$

Flux

$$\Phi_B = BA\cos\theta = \vec{B} \cdot \vec{A}$$

$$\vec{\mu} = NI\vec{A}$$

Magnetic dipole

Solenoid

$$B = \mu_0 n I$$

transformer

$$\frac{I_S}{I_P} = \frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$U = -\mu B \cos\theta = -\vec{\mu} \cdot \vec{B}$$

Review Chapter 27

Magnets, magnetic fields

$\vec{F} = I\vec{l} \times \vec{B}$ Force on current carrying wire due to external field

$\vec{F} = q\vec{v} \times \vec{B}$ Force on moving charge due to external field

$\tau = NIAB\sin\theta$ Torque on a current loop

$\vec{\mu} = NI\vec{A}$ Magnetic dipole moment and energy of dipole

$$U = -\mu B\cos\theta = -\vec{\mu}\cdot\vec{B}$$

Skip Hall effect

Example 27 – 4

Electron's path in a uniform magnetic field. An electron travels at a speed of 2.0×10^{7}m/s in a plane perpendicular to a 0.010-T magnetic field. Describe its path.

What is the formula for the centripetal force? $F = ma = m\frac{v^2}{r}$

Since the magnetic field is perpendicular to the motion of the electron, the magnitude of the magnetic force is

$$F = evB$$

Since the magnetic force provides the centripetal force, we can establish an equation with the two forces

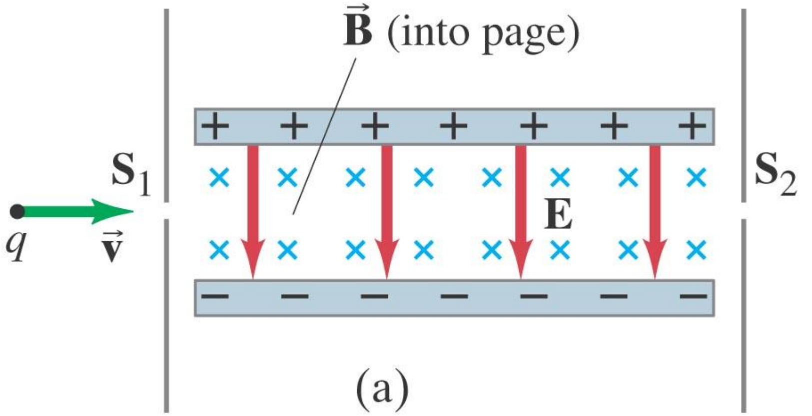
$$F = evB = m\frac{v^2}{r}$$

Solving for r

$$r = \frac{mv}{eB} = \frac{\left(9.1\times10^{-31}kg\right)\cdot\left(2.0\times10^{7}\ m/s\right)}{\left(1.6\times10^{-19}C\right)\cdot\left(0.010T\right)} = 1.1\times10^{-2}m$$

Conceptual Example 27-10: Velocity selector

Some electronic devices and experiments need a beam of charged particles all moving at nearly the same velocity. This can be achieved using both a uniform electric field and a uniform magnetic field, arranged so they are at right angles to each other. Particles of charge *q* pass through slit S_1 If the particles enter with different velocities, show how this device "selects" a particular velocity, and determine what this velocity is.



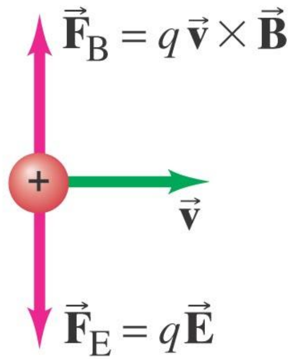
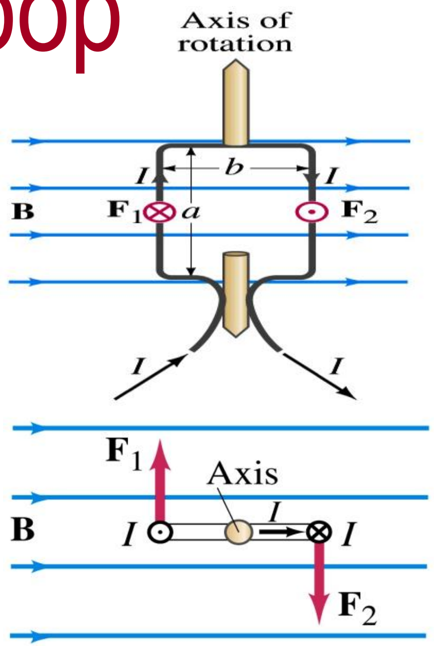


Figure 27-21: A velocity selector: if v = E/B, the particles passing through S_1 make it through S_2. Solution: Only the particles whose velocities are such that the magnetic and electric forces exactly cancel will pass through both slits. We want qE = qvB, so v = E/B.

COULD I ADD GRAVITY TO THIS PROBLEM?

Torque on a Current Loop



- So what would be the magnitude of this torque?
  - What is the magnitude of the force on the section of the wire with length a?
    - $F_a = IaB$
    - The moment arm of the coil is $b/2$
  - So the total torque is the sum of the torques by each of the forces

$$\tau = IaB\frac{b}{2} + IaB\frac{b}{2} = IabB = IAB$$

    - Where $A=ab$ is the area of the coil
  - What is the total net torque if the coil consists of N loops of wire?

$$\tau = NIAB$$

  - If the coil makes an angle θ w/ the field $\tau = NIAB\sin\theta$

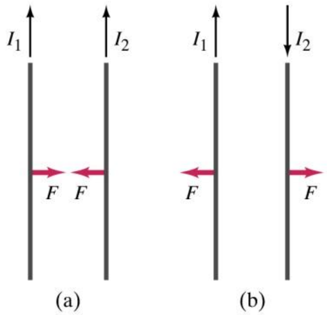
Review Chapter 28

$$B = \frac{\mu_0 I}{2\pi r}$$

Magnetic field from long straight wire

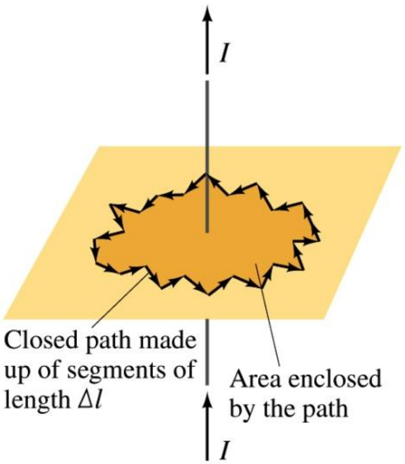
$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d}$$

Magnetic force for two parallel wires



$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{encl}$$

Ampére's Law



Ex. 28-4

$$B = \mu_0 n I$$

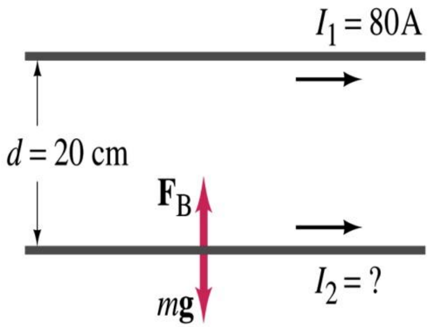
solenoid

$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l} \times \hat{r}}{r^2}$$

Skip Biot-Savart Law

Example 28 – 2

Suspending a wire with current. A horizontal wire carries a current I_1=80A DC. A second parallel wire 20cm below it must carry how much current I_2 so that it doesn't fall due to the gravity? The lower has a mass of 0.12g per meter of length.



Which direction is the gravitational force? Downward

This force must be balanced by the magnetic force exerted on the wire by the first wire.

$$\frac{F_g}{l} = \frac{mg}{l} = \frac{F_M}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d}$$

Solving for I_2

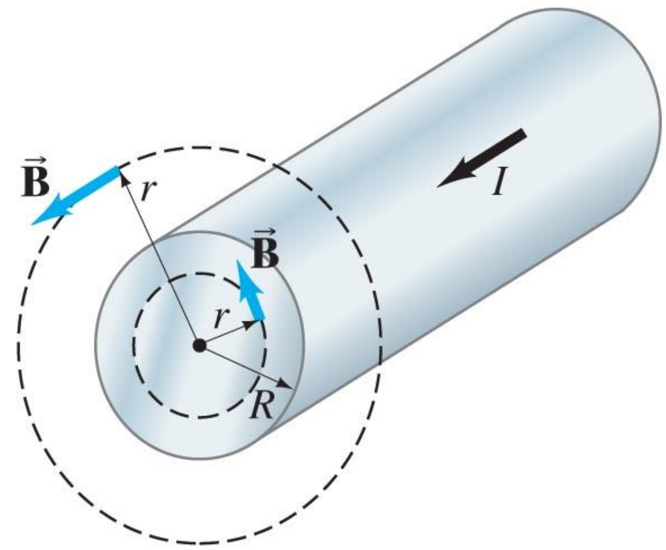
$$I_2 = \frac{mg\ 2\pi d}{\mu_0 I_1} =$$

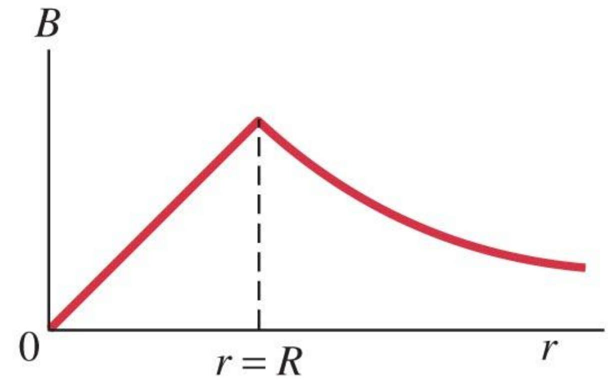
$$\frac{2\pi\left(9.8\, m/s^2\right)\cdot\left(0.12\times10^{-3}\, kg\right)\cdot\left(0.20m\right)}{\left(4\pi\times10^{-7}\ T\cdot m/A\right)\cdot\left(80A\right)} = 15A$$

28-4 Ampère's Law

Example 28-6: Field inside and outside a wire.

A long straight cylindrical wire conductor of radius R carries a current I of uniform current density in the conductor. Determine the magnetic field due to this current at (a) points outside the conductor ($r > R$) and (b) points inside the conductor ($r < R$). Assume that r, the radial distance from the axis, is much less than the length of the wire. (c) If R = 2.0 mm and I = 60 A, what is B at r = 1.0 mm, r = 2.0 mm, and r = 3.0 mm?



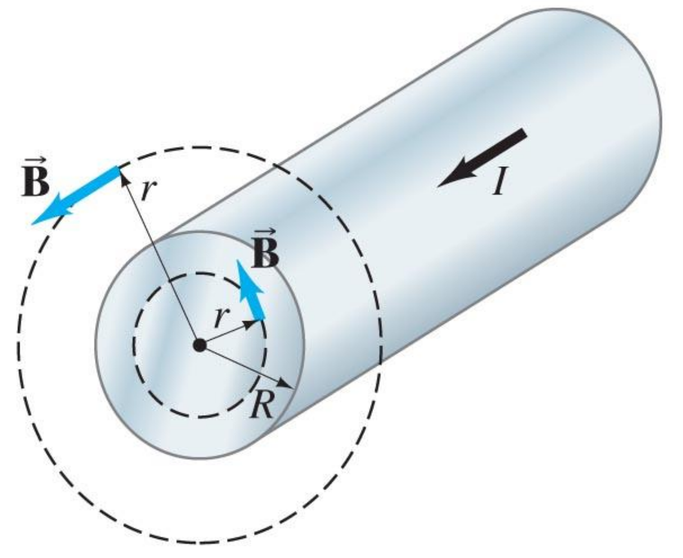


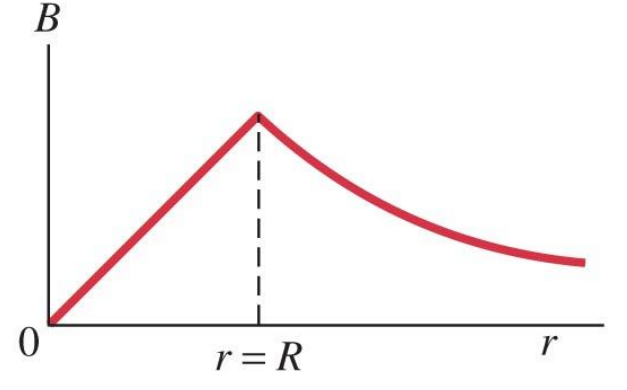
Solution: We choose a circular path around the wire; if the wire is very long the field will be tangent to the path.

a. The enclosed current is the total current; this is the same as a thin wire. $B = \mu_0 I/2\pi r$.

b. Now only a fraction of the current is enclosed within the path; if the current density is uniform the fraction of the current enclosed is the fraction of area enclosed: $I_{encl} = Ir^2/R^2$. Substituting and integrating gives $B = \mu_0 Ir/2\pi R^2$.

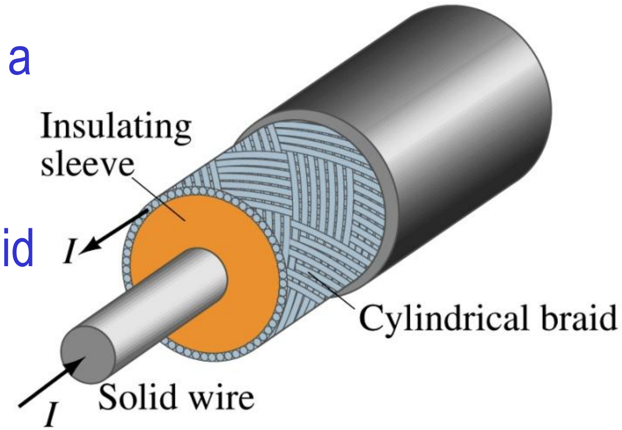
c. 1 mm is inside the wire and 3 mm is outside; 2 mm is at the surface. Substitution gives $B = 3.0 \times 10^{-3}$ T at 1.0 mm, 6.0×10^{-3} T at 2.0 mm, and 4.0×10^{-3} T at 3.0 mm.





Example 28 – 5

Coaxial cable. A coaxial cable is a single wire surrounded by a cylindrical metallic braid, as shown in the figure. The two conductors are separated by an insulator. The central wire carries current to the other end of the cable, and the outer braid carries the return current and is usually considered ground. Describe the magnetic field (a) in the space between the conductors and (b) outside the cable.



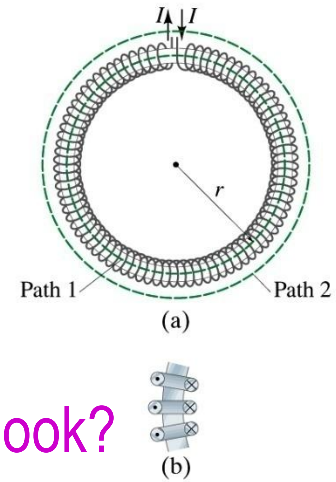
(a) The magnetic field between the conductors is the same as the long, straight wire case since the current in the outer conductor does not impact the enclosed current.

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

(b) Outside the cable, we can draw a similar circular path, since we expect the field to have a circular symmetry. What is the sum of the total current inside the closed path? $I_{encl} = I - I = 0.$

So there is no magnetic field outside a coaxial cable. In other words, the coaxial cable is self-shielding. The outer conductor also shields against external electric fields, which could cause noise.

Example 28 – 8



Toroid. Use Ampere's law to determine the magnetic field (a) inside and (b) outside a toroid, (which is like a solenoid bent into the shape of a circle).

(a) How do you think the magnetic field lines inside the toroid look?

Since it is a bent solenoid, it should be a circle concentric with the toroid.

If we choose path of integration one of these field lines of radius r inside the toroid, path 1, to use the symmetry of the situation, making B the same at all points on the path, we obtain from Ampere's law

$$\oint \vec{B} \cdot d\vec{l} = B(2\pi r) = \mu_0 I_{encl} = \mu_0 NI$$

Solving for B

$$B = \frac{\mu_0 NI}{2\pi r}$$

So the magnetic field inside a toroid is not uniform. It is larger on the inner edge. However, the field will be uniform if the radius is large and the toroid is thin ($B = \mu_0 n I$).

(b) Outside the solenoid, the field is 0 since the net enclosed current is 0.

Faraday's Law of Induction

- In terms of magnetic flux

$$\Phi_B = B_\perp A = BA\cos\theta = \vec{B}\cdot\vec{A}$$

  - The emf induced in a circuit is equal to the rate of change of magnetic flux through the circuit

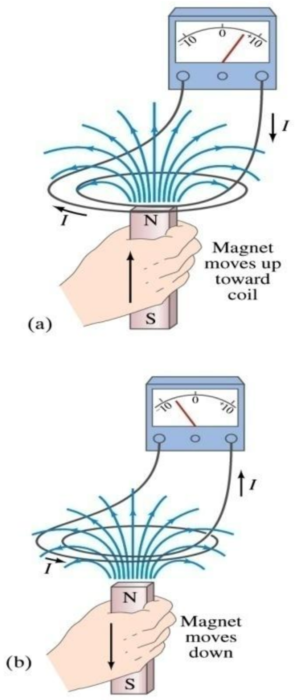
Faraday's Law of Induction

$$\varepsilon = -N\frac{d\Phi_B}{dt}$$

- For a single loop of wire N=1, for closely wrapped loops, N is the number of loops
- The negative sign has to do with the direction of the induced emf (Lenz's Law)

Lenz's Law

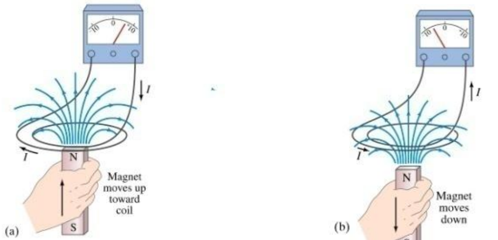
- It is experimentally found that
  - An induced emf gives rise to a current whose magnetic field opposes the original change in flux → This is known as **Lenz's Law**
  - We can use Lenz's law to explain the following cases :



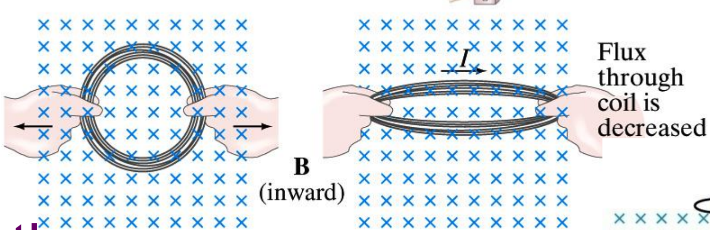
- When the magnet is moving into the coil
  - Since the external flux increases, the field inside the coil takes the opposite direction to minimize the change and causes the current to flow clockwise
- When the magnet is moving out
  - Since the external flux decreases, the field inside the coil takes the opposite direction to compensate the loss, causing the current to flow counter-clockwise

Induction of EMF

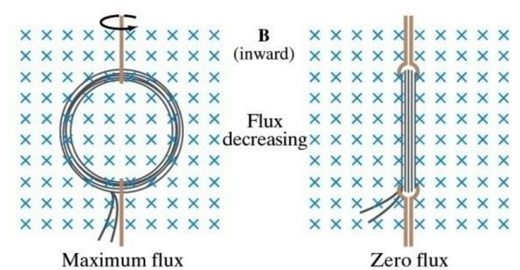
- How can we induce an emf?
- Let's look at the formula for magnetic flux
- $$\Phi_B = \int \vec{B} \cdot d\vec{A} = \int B \cos\theta \, dA$$
- What are the things that can change with time to result in change of magnetic flux?
  - Magnetic field



  - The area of the loop



  - The angle θ between the field and the area vector



How does a transformer work?

- When an AC voltage is applied to the primary, the changing B it produces will induce voltage of the same frequency in the secondary wire
- So how would we make the voltage different?
  - By varying the number of loops in each coil
  - From Faraday's law, the induced emf in the secondary is
  - $V_S = N_S \frac{d\Phi_B}{dt}$
  - The input primary voltage is
  - $V_P = N_P \frac{d\Phi_B}{dt}$
  - Since $d\Phi_B/dt$ is the same, we obtain
  - $\frac{V_S}{V_P} = \frac{N_S}{N_P}$

Transformer Equation