PHYS 1444 – Section 003
Lecture #19, Review Part 1

Tues.-Thurs. November 6,8 2012

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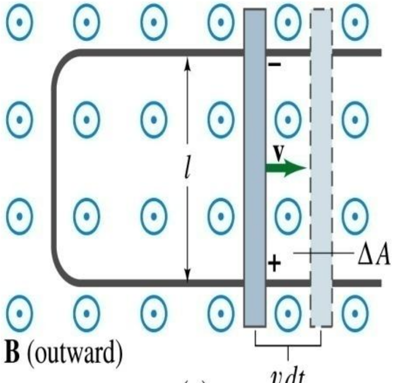
Chapter 29

- Motional emf
- Domains

REVIEW Part 1 (some of part 2 also included in slides)

EMF Induced on a Moving Conductor



- Another way of inducing emf is using a U shaped conductor with a movable rod resting on it.
- As the rod moves at a speed v, it travels $v$dt in time dt, changing the area of the loop by dA=lvdt.
- Using Faraday's law, the induced emf for this loop is

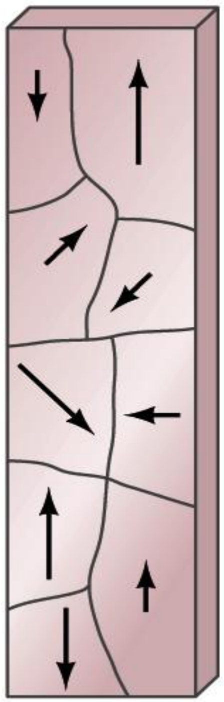
$$|\varepsilon| = \frac{d\Phi_B}{dt} = \frac{BdA}{dt} = \frac{Blvdt}{dt} = Blv$$

  – This equation is valid as long as B, l and v are perpendicular to each other.

•An emf induced on a conductor moving in a magnetic field is called a **motional emf**

Magnetic Materials - Ferromagnetism

- Iron is a material that can turn into a strong magnet
  - This kind of material is called **ferromagnetic**
- In the microscopic sense, ferromagnetic materials consists of many tiny regions called **domains**
  - Domains are like little magnets usually smaller than 1mm in length or width
- What do you think the alignment of domains are like when they are not magnetized?
  - Randomly arranged
- What if they are magnetized?
  - The number of domains aligned with the external magnetic field direction grows
  - This gives magnetization to the material
- How do we demagnetize a bar magnet?
  - Hit the magnet hard or heat it over the Curie temperature



B in Magnetic Materials

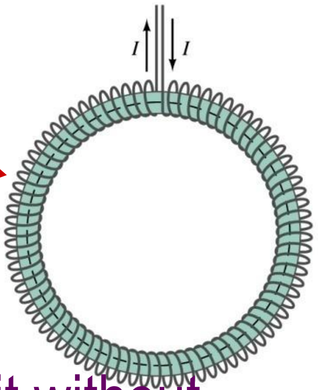
- What is the magnetic field inside a solenoid?
- $B_0 = \mu_0 n I$
  - Magnetic field in a long solenoid is directly proportional to the current.
  - This is valid only if air is inside the coil
- What do you think will happen to B if we have something other than the air inside the solenoid?
  - It could be increased dramatically: if a ferromagnetic material such as iron is put inside, the field could increase by several orders of magnitude
- Why?
  - Since the domains in the iron are aligned by the external field.
  - The resulting magnetic field is the sum of that due to the current in the solenoid and due to the iron

B in Magnetic Materials

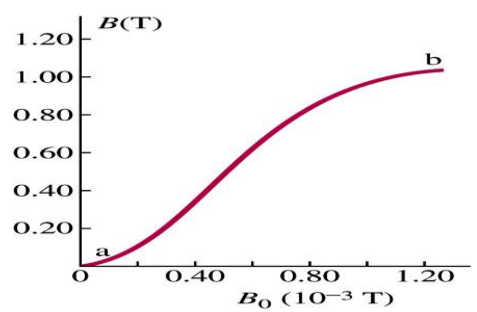
- It is sometimes convenient to write the total field as the sum of two terms
- $\vec{B} = \vec{B}_0 + \vec{B}_M$
  - **B_0** is the field due only to the current in the wire, namely the external field
    - The field that would be present without a ferromagnetic material
  - **B_M** is the additional field due to the ferromagnetic material itself; often **B_M>>B_0**
- The total field in this case can be written by replacing μ_0 with another proportionality constant μ, the magnetic permeability of the material $B = \mu n I$
  - μ is a property of a magnetic material
  - μ is not a constant but varies with the external field

Hysteresis

Iron Core Toroid

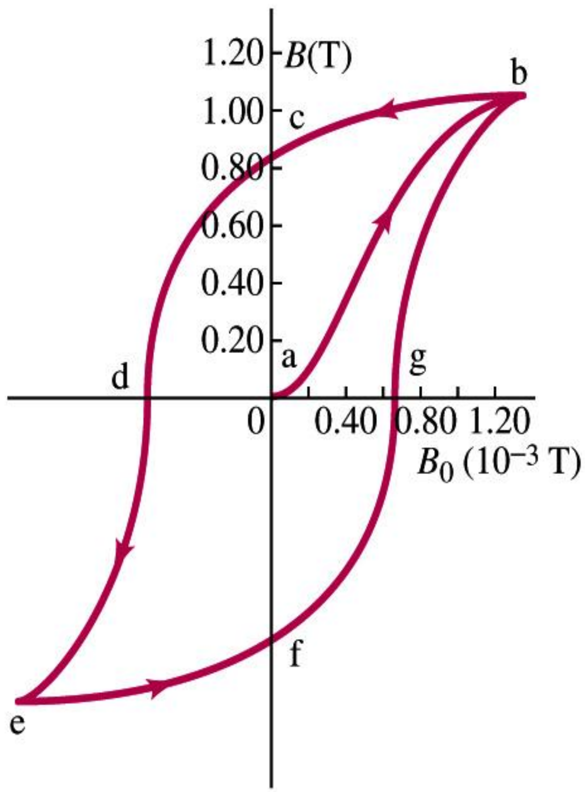


- What is a toroid?
  - A solenoid bent into a circle
- Toroids can be used for magnetic field measurement
  - A toroid fully contains all the magnetic field created within it without leakage
- Consider an un-magnetized iron core toroid, without any current flowing in the wire
  - What do you think will happen if the current slowly increases?
  - B_0 increases linearly with the current.
  - And B increases also but follows the curved line shown in the graph
  - As B_0 increases, the domains become more aligned until nearly all are aligned (point b on the graph)
    - The iron is said to be approaching saturation
    - Point b is typically at 70% of the max



Hysteresis

- What do you think will happen to B if the external field B_0 is reduced to 0 by decreasing the current in the coil?
  - ~~Of course it goes to 0!!~~
  - Wrong! Wrong! Wrong! They do not go to 0. Why not?
  - The domains do not completely return to random alignment state
- Now if the current direction is reversed, the external magnetic field direction is reversed, causing the total field B to pass 0, and the direction reverses to the opposite side
  - If the current is reversed again, the total field B will increase but never goes through the origin
- This kind of curve whose path does not retrace themselves and does not go through the origin is called **Hysteresis**.



Example 29 – 9: Power Transmission

Transmission lines. An average of 120kW of electric power is sent to a small town from a power plant 10km away. The transmission lines have a total resistance of 0.4Ω. Calculate the power loss if the power is transmitted at (a) 240V and (b) 24,000V.

We cannot use $P=V^2/R$ since we do not know the voltage along the transmission line. We, however, can use $P=I^2R$.

(a) If 120kW is sent at 240V, the total current is $I=\frac{P}{V}=\frac{120\times10^3}{240}=500A.$

Thus the power loss due to the transmission line is

$$P=I^2R=\left(500A\right)^2\cdot\left(0.4\Omega\right)=100kW$$

(b) If 120kW is sent at 24,000V, the total current is $I=\frac{P}{V}=\frac{120\times10^3}{24\times10^3}=5.0A.$

Thus the power loss due to transmission line is

$$P=I^2R=\left(5A\right)^2\cdot\left(0.4\Omega\right)=10W$$

The higher the transmission voltage, the smaller the current, causing less loss of energy. This is why power is transmitted w/ HV, as high as 170kV.

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

transformer

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

$$B = \mu_0 n I$$

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

Review Chapter 26

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

Terminal voltage

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

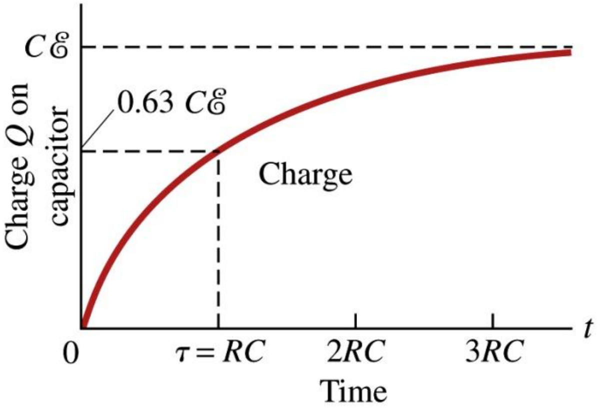
Resistors in series

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

Resistors in parallel

Kirchoff's rules (example)

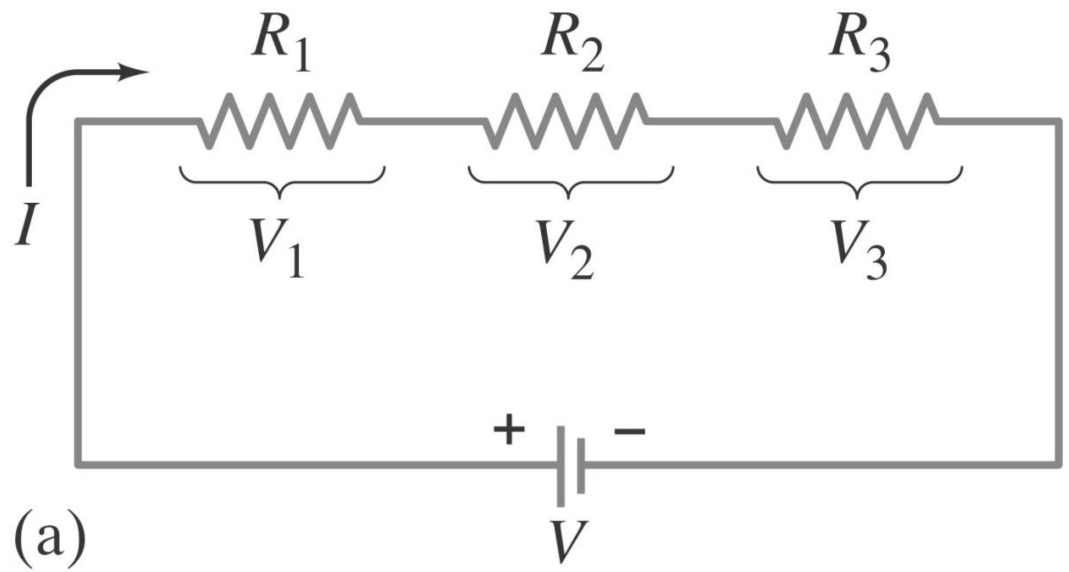
RC circuits



26-2 Resistors in Series and in Parallel

A series connection has a single path from the battery, through each circuit element in turn, then back to the battery.

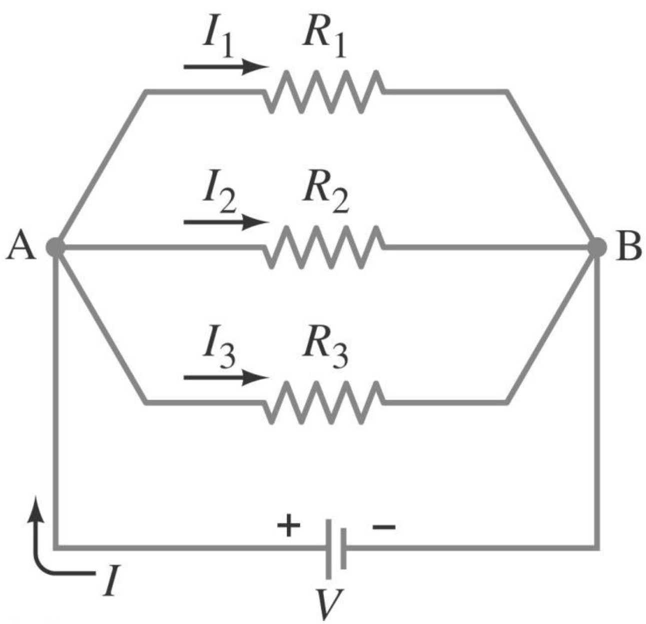
The current through each resistor is the same; the voltage drop depends on the resistance. The sum of the voltage drops across the resistors equals the battery voltage:

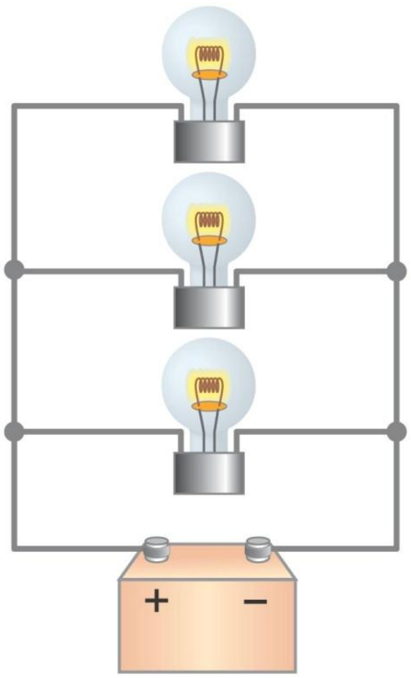


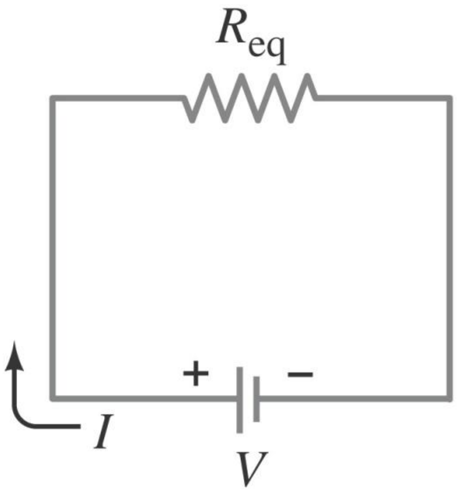
$$V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3. \qquad \text{[series]}$$

26-2 Resistors in Series and in Parallel

A parallel connection splits the current; the voltage across each resistor is the same:



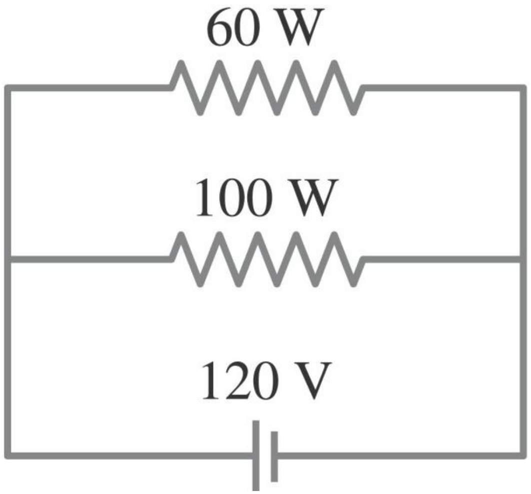


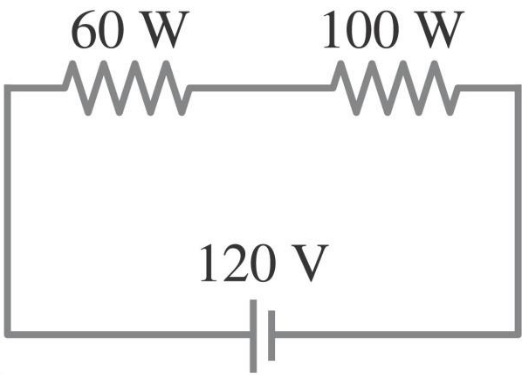


26-2 Resistors in Series and in Parallel

Conceptual Example 26-3: An illuminating surprise.

A 100-W, 120-V lightbulb and a 60-W, 120-V lightbulb are connected in two different ways as shown. In each case, which bulb glows more brightly? Ignore change of filament resistance with current (and temperature).

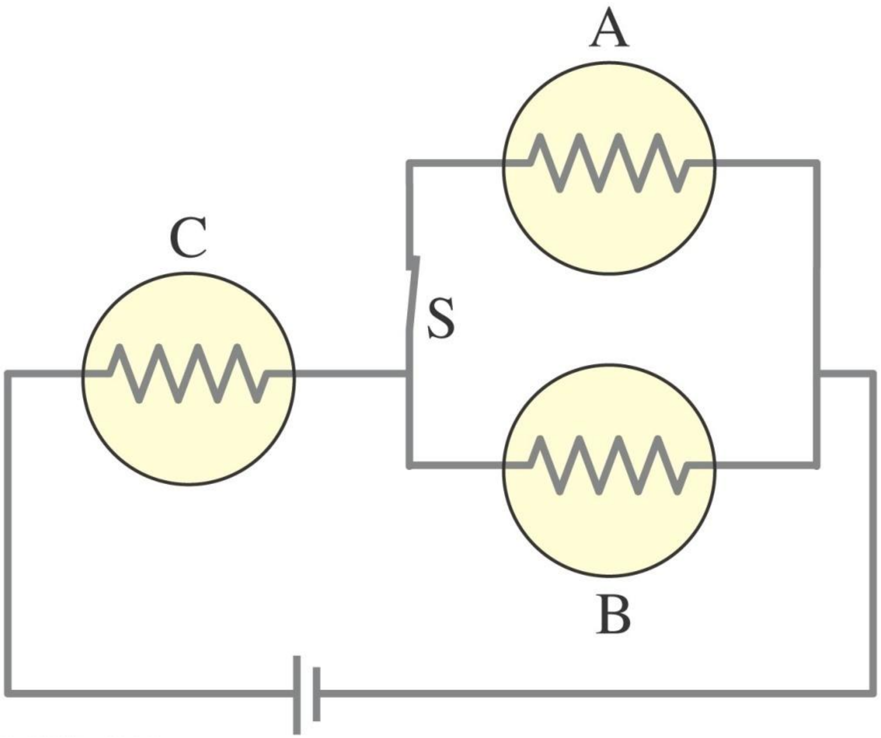




Solution: a.) Each bulb sees the full 120V drop, as they are designed to do, so the 100-W bulb is brighter. b.) $P = V^2/R$, so at constant voltage the bulb dissipating more power will have lower resistance. In series, then, the 60-W bulb – whose resistance is higher – will be brighter. (More of the voltage will drop across it than across the 100-W bulb).

26-2 Resistors in Series and in Parallel

Conceptual Example 26-6: Bulb brightness in a circuit. The circuit shown has three identical light bulbs, each of resistance *R*.
(a) When switch S is closed, how will the brightness of bulbs A and B compare with that of bulb C? (b) What happens when switch S is opened? Use a minimum of mathematics in your answers.

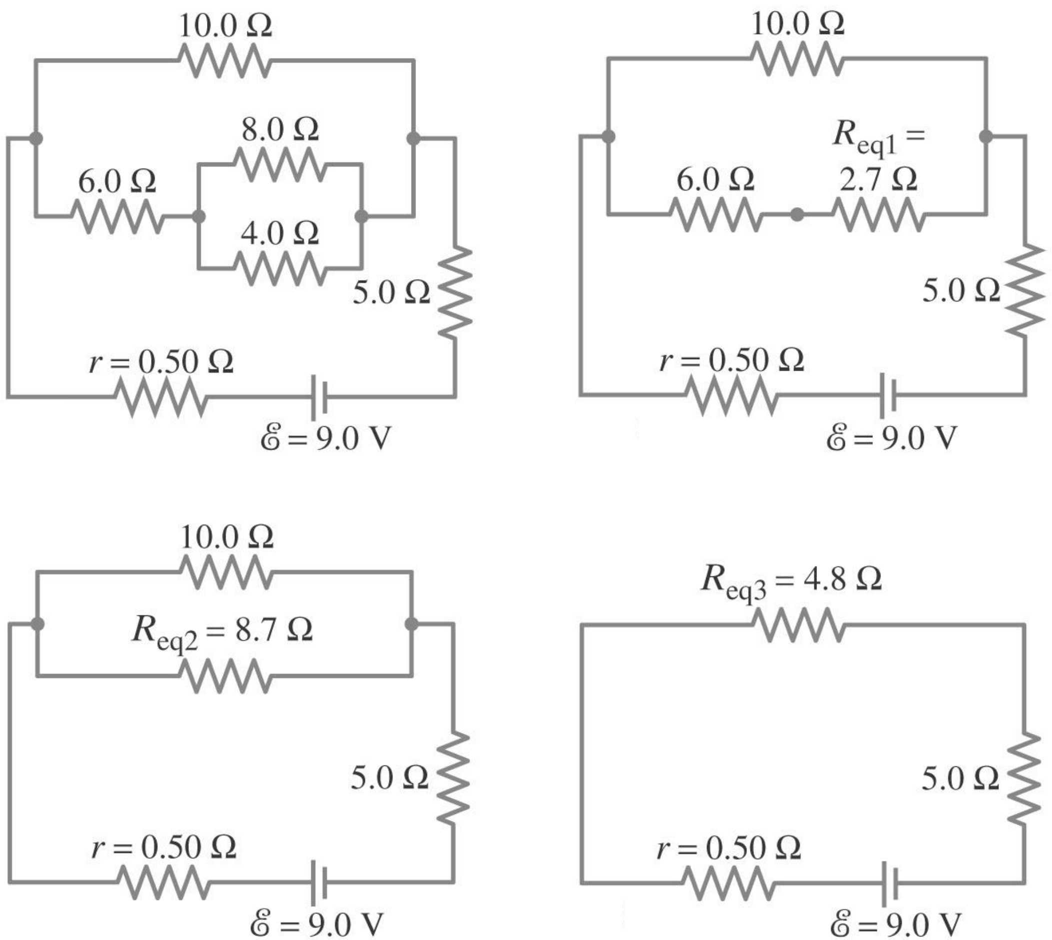


Solution: a. When S is closed, the bulbs in parallel have half the resistance of the series bulb. Therefore, the voltage drop across them is smaller. Bulbs A and B will be equally bright, but much dimmer than C.
b. With switch S open, no current flows through A, so it is dark. B and C are now equally bright, and each has half the voltage across it, so C is somewhat dimmer than it was with the switch closed, and B is brighter.

26-2 Resistors in Series and in Parallel

Example 26-8: Analyzing a circuit.(a) How much current is drawn from the battery? (b) what is the current in the 10 Ω resistor

a.) Overall resistance is 10.3 Ω. The current is 9.0 V/10.3 Ω = 0.87 A b.) The voltage across the 4.8 Ω is 0.87*4.8=4.2V, so the current in the 10 Ω is I=V/R=4.2/10=0.42A



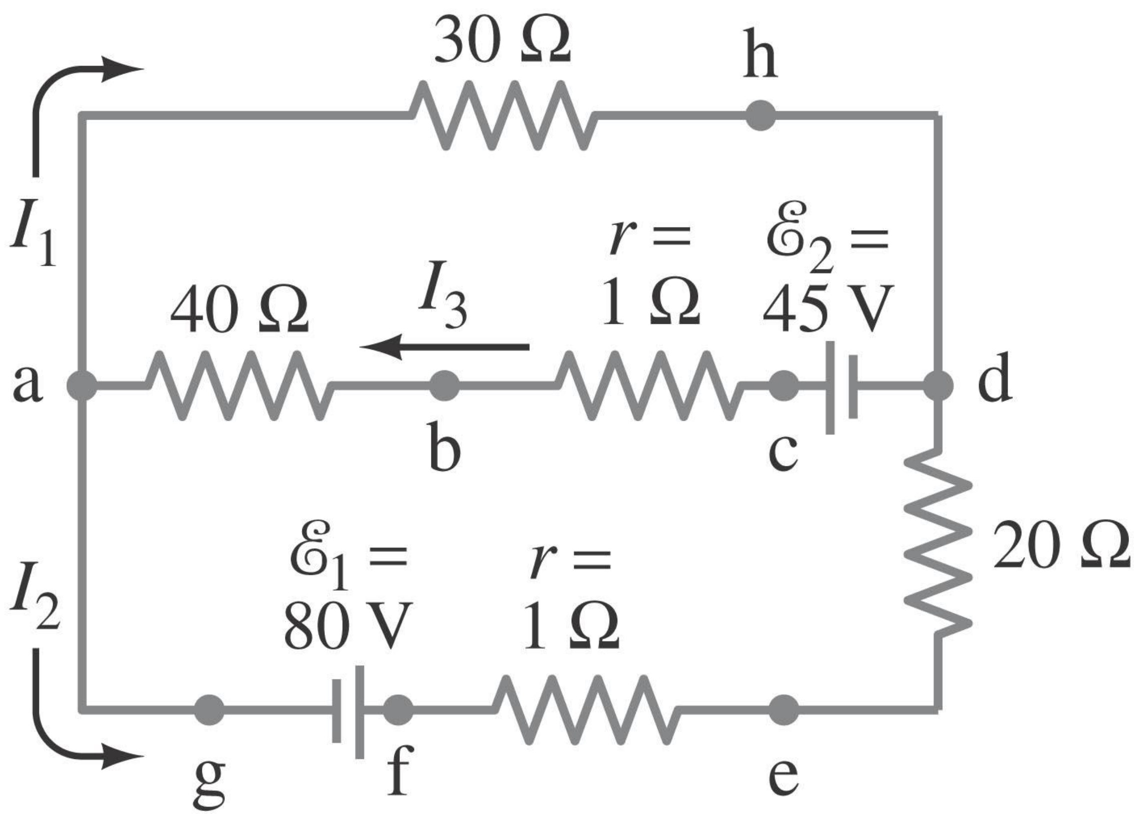
Using Kirchhoff's Rules

1. Determine the flow of currents at the junctions.
2. Write down the current equation based on Kirchhoff's 1st rule (conservtion of charge) at various junctions.
3. Choose closed loops in the circuit
4. Write down the potential in each interval of the junctions, keeping the sign properly.
5. Write down the potential equations for each loop (conservation of energy).
6. Solve the equations for unknowns.

26-3 Kirchhoff's Rules

Example 26-9: Using Kirchhoff's rules.

Calculate the currents I_1, I_2, and I_3 in the three branches of the circuit in the figure.



Solution: You will have two loop rules and one junction rule (there are two junctions but they both give the same rule, and only 2 of the 3 possible loop equations are independent). Algebraic manipulation will giveS I_1 = -0.87 A, I_2 = 2.6 A, and I_3 = 1.7 A.

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

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

Hall effect

Example 27 – 4

Electron's path in a uniform magnetic field. An electron travels at a speed of 2.0x10^{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 $r = \frac{mv}{eB} = \frac{(9.1\times10^{-31}kg)\cdot(2.0\times10^{7}\ m/s)}{(1.6\times10^{-19}C)\cdot(0.010T)} = 1.1\times10^{-2}m$

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.

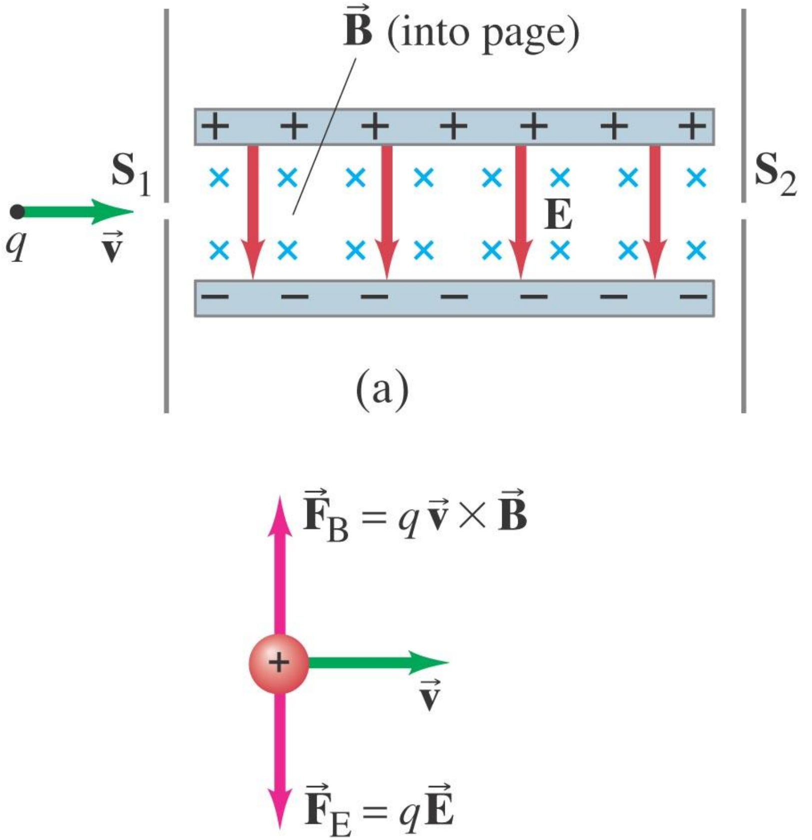
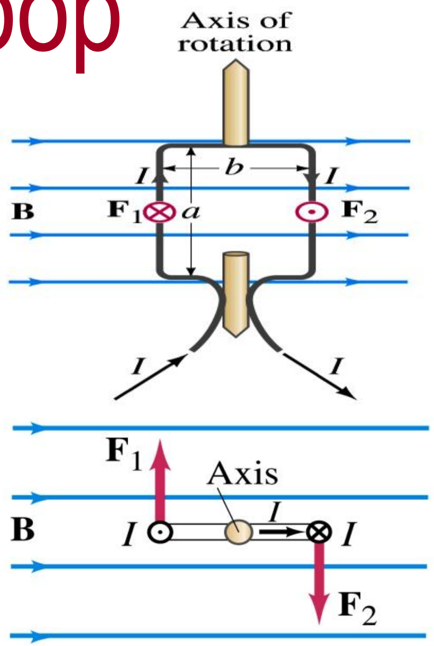


Figure 27-21: A velocity selector: if v = E/B, the particles passing through S_1 make it through S_2. Solution: Only the particles whose velocities are such that the magnetic and electric forces exactly cancel will pass through both slits. We want qE = qvB, so v = E/B.

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 $\tau = NIAB\sin\theta$

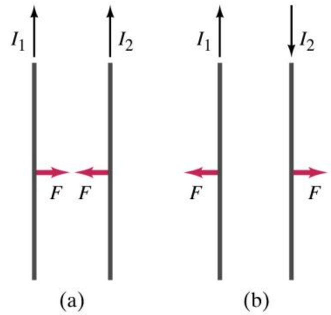
Review Chapter 28

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

Magnetic field from long straight wire

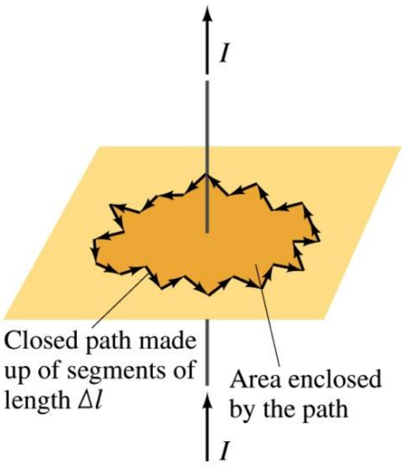
$$\frac{F}{l} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d}$$

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

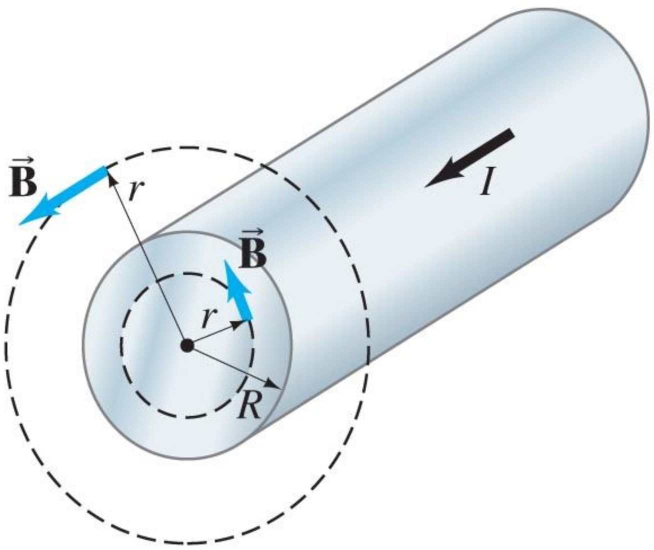
$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l} \times \hat{r}}{r^2}$$

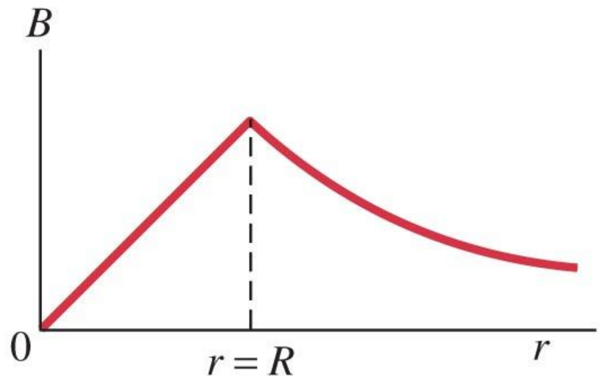
Biot-Savart Law

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?



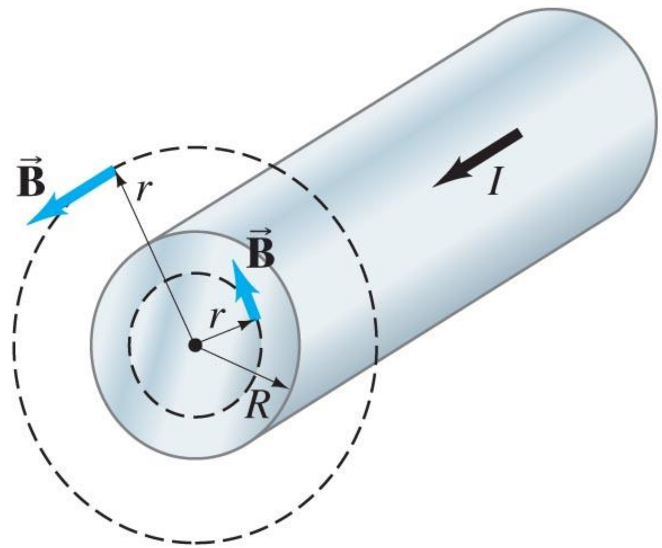


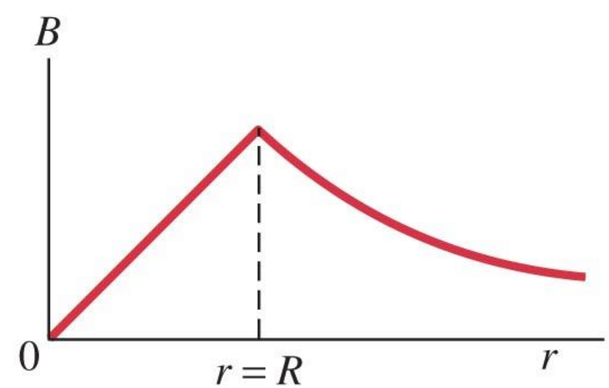
Solution: We choose a circular path around the wire; if the wire is very long the field will be tangent to the path.

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 $B = \mu_0 Ir/2\pi R^2$.

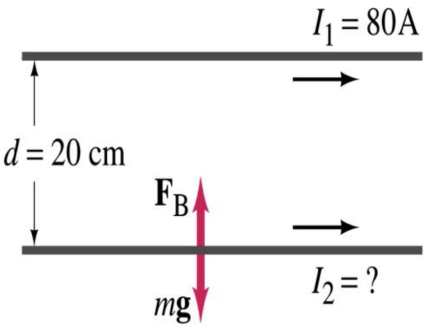
c. 1 mm is inside the wire and 3 mm is outside; 2 mm is at the surface (so the two results should be the same). Substitution gives $B = 3.0 \times 10^{-3}$ T at 1.0 mm, 6.0×10^{-3} T at 2.0 mm, and 4.0×10^{-3} T at 3.0 mm.





Example 28 – 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.

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

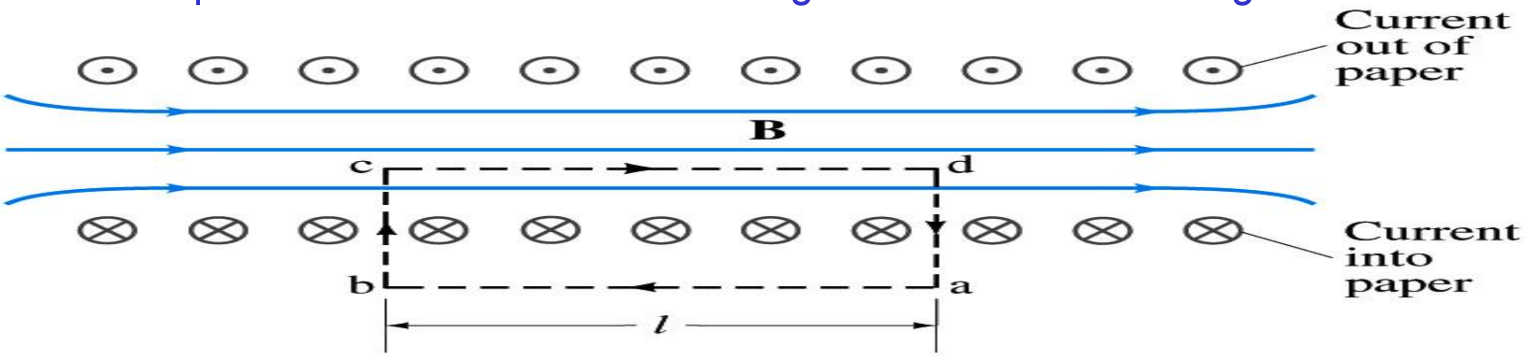
Solving for I_2

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

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

Solenoid Magnetic Field

- Use Ampere's law to determine the magnetic field inside a long solenoid



- Let's choose the path *abcd*, far away from the ends

$$\oint \vec{B}\cdot d\vec{l} = \int_a^b \vec{B}\cdot d\vec{l} + \int_b^c \vec{B}\cdot d\vec{l} + \int_c^d \vec{B}\cdot d\vec{l} \quad \int_d^a \vec{B}\cdot d\vec{l}$$

– The field outside the solenoid is negligible, and the internal field is perpendicular to the end paths, so these integrals also are 0

- So the sum becomes: $\oint \vec{B}\cdot d\vec{l} = \int_c^d \vec{B}\cdot d\vec{l} = Bl$
- Thus Ampere's law gives us $Bl = \mu_0 NI$

$$B = \mu_0 nI$$