Mr. Wright's Math Extravaganza

Physical Sciences

(Chemistry, Physics, Physical Science)

Electromagnetism

Units 07 Static Electricity, 08 Circuits, 09 Magnetism

Average Level for All Three Units

Level 2.0: 70% on test, Level 3.0: 80% on test, Level 4.0: level 3.0 and success on electric motor lab

Score	I Can Statements
4.0	**09 Magnetism** ☐ I can build a device that relies on electric currents producing a magnetic field or changes to a magnetic field producing electric currents to function.
3.5	In addition to score 3.0 performance, partial success at score 4.0 content.
3.0	**07 Static Electricity/09 Magnetism** ☐ I can identify similarities and differences between electrical and magnetic fields. **09 Magnetism** ☐ I can draw conclusions about the ability of electric currents to produce magnetic fields. ☐ I can draw conclusions about the ability of magnetic fields to produce electric currents.
2.5	No major errors or omissions regarding score 2.0 content, and partial success at score 3.0 content.
2.0	**07 Static Electricity** ☐ I can diagram electric fields around various charged objects by drawing appropriate field lines. ☐ I can explain how electric monopoles and dipoles create different electrical fields. **08 Circuits/09 Magnetism** ☐ I can explain the effects of creating a series of loops in a wire carrying electric current. **09 Magnetism** ☐ I can diagram magnetic fields around various charged objects by drawing appropriate field lines. ☐ I can explain how the behavior of north and south poles affects the magnetic field they create. ☐ I can explain the effects of wrapping wire carrying electric current around a core. ☐ I can explain how an electromagnet differs from a permanent magnet. ☐ I can diagram a magnetic field produced by an electric current using the right-hand rule. ☐ I can explain how multiple magnetic fields can be added together to amplify the power of a magnetic field. ☐ I can relate the ability of electric currents to create magnetic fields to the ability of changes in magnetic fields to create electric currents. ☐ I can explain the effects of moving a bar magnet through a coil of copper wire. ☐ I can explain that currents produced by changes in magnetic fields represent systems wanting to avoid change. ☐ I can use the right-hand rule to determine the direction of a current. ☐ I can relate the changes in a magnetic field and the size of the magnetic field to the amount of electric current created. ☐ I can use the Faraday-Lenz law to calculate how the change in magnetic flux generates electromotive force.

1.5	Partial success at score 2.0 content, and major errors or omissions regarding score 3.0 content.
1.0	With help, partial success at score 2.0 content and score 3.0 content.
0.5	With help, partial success at score 2.0 content but not at score 3.0 content.
0.0	Even with help, no success.

Physics 09-01 Magnets and B-Fields **Name: ____________________**

Magnets

Magnets have two ____________ called ____________

- ____________ and ____________ poles
- There are no ____________ poles

Like poles ____________, Opposite poles ____________

Electromagnetism

- It was discovered that running ____________ through a ____________ produced a ____________
- The magnetism around ____________ magnets and ____________ are very similar, so both must have common __________.
- ____________ is the cause of all ____________

Ferromagnetism

- Magnetic materials have an ____________ outer ____________.
- ____________ near each other line up so that the unpaired ____________ spin the ____________ direction.
- This ____________ creates ____________

In permanent magnet the current is ____________ in atoms.

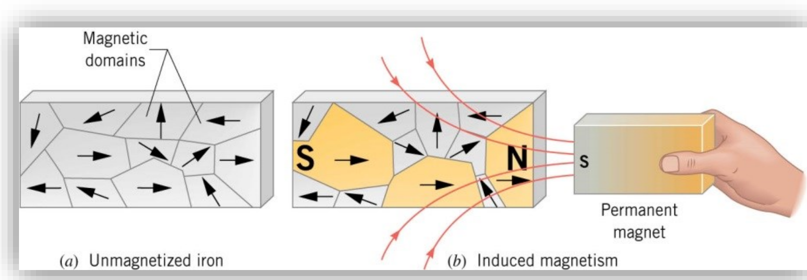
- Move around ____________ and ____________
- Most materials ____________ out except in ___________________ materials

Ferromagnetic materials

- Electron magnetic effects ____________ cancel over large ____________ of atoms.
- This gives ____________ magnetic ____________ size of ____________ to ____________ mm called magnetic ____________.
- In a permanent magnet, these ____________ are aligned.
- Common magnetic materials are ____________, ____________, ____________, and ___________________________.

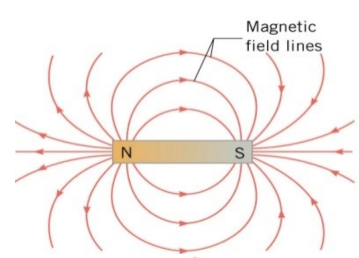
Induced Magnetism

- Usually the magnetic ____________ are ____________ arranged.
- When it is placed in a ____________, the domains that are aligned with the B-field grow ____________ and the orientation of other domains may ____________ until they are aligned.
- This gives the material an ____________ magnetism.



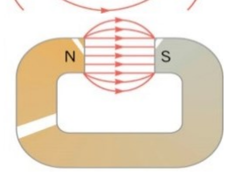
Magnetic Fields

- Around a magnet is a magnetic _______________ (B-field)
- At _______________ point in _______________ there is a magnetic _______________
- Can be seen with a _______________
- Unit is _______________ (T)



Magnetic Field Lines

- Magnetic fields can be _______________ with field _______________.
- Start at _______________ pole and end at _______________ pole
- The more lines in one area means _______________ field



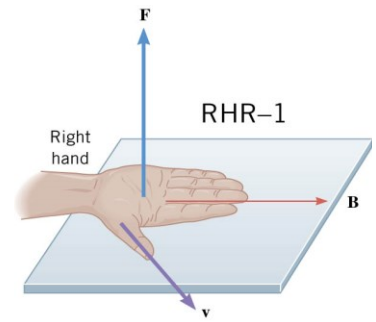
Physics 09-01 Magnets and B-Fields	***Name: ________________________***
Practice Work	

1. Sketch the magnetic field around the earth.
2. Is the Earth's magnetic field parallel to the ground at all locations? If not, where is it parallel to the surface? Is its strength the same at all locations? If not, where is it greatest?
3. (a) Sketch the magnetic field around a bar magnet. (b) Where is the field the strongest? (c) Where is it the weakest?
4. Compare and contrast electric and magnetic field lines.
5. Compare and contrast electromagnets and permanent ferromagnets.
6. What is the cause of all magnetic fields?
7. Explain how inducing a ferromagnet to have a stronger field works.

Force on a Moving Charge

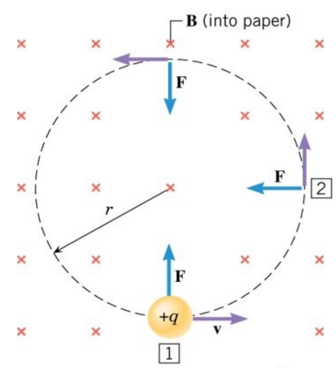
- Since currents (moving charges) make ______________, then other B-fields apply a ______________ to ______________ charges.
- For a moving charge to experience a ______________
  - Charge must be ______________
  - The ______________ vector of the charge must have a ______________ ______________ to the ______________
- $\vec{F} = qvB\sin\theta$
  - Where F = force, q = charge, v = speed of charge, B = magnetic field, θ = angle between v and B

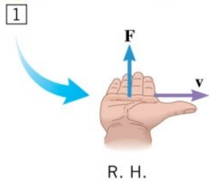
Direction of force on positive moving charge



Right Hand Rule
- Fingers point in direction of ______________
- Thumb in direction of ______________
- Palm faces direction of ______________ on ______________ charge
- Force will be _________ if v and B are parallel, so a moving charge will be unaffected

Motion of moving charged particle in uniform B-field
- ______________
- $r = \frac{mv}{qB}$





A particle with a charge of -1.6×10^{-19} C and mass 9.11×10^{-31} kg moves along the positive x-axis from left to right. It enters a 3 T B-field is in the x-y plane and points at 45° above the positive x-axis.
What is the direction of the force on the particle?

After it has been in the B-field, the particle moves in a circle. If the radius of its path is 2×10^{-10} m, what is the speed of the particle?

What is the magnitude of the force on the particle?

Physics 09-02 Magnetic Force on a Moving Charge *Name:* ______________________

Practice Work

1. If a charged particle moves in a straight line through some region of space, can you say that the magnetic field in that region is necessarily zero?
2. How can the motion of a charged particle be used to distinguish between a magnetic and an electric field?
3. What are the signs of the charges on the particles in Figure 1?
4. Which of the particles in Figure 2 has the greatest velocity, assuming they have identical charges and masses?
5. Which of the particles in Figure 2 has the greatest mass, assuming all have identical charges and velocities?
6. What is the direction of the magnetic force on a positive charge that moves as shown in each of the six cases shown in Figure 3? (OpenStax 22.1) **left, into, up, no, right, down**
7. Repeat Exercise 7 for a negative charge. (OpenStax 22.2) **right, out, down, no, left, up**
8. What is the direction of the velocity of a negative charge that experiences the magnetic force shown in each of the three cases in Figure 4, assuming it moves perpendicular to *B*? (OpenStax 22.3) **right, into, down**
9. Repeat Exercise 9 for a positive charge. (OpenStax 22.4) **left, out, up**
10. What is the direction of the magnetic field that produces the magnetic force on a positive charge as shown in each of the three cases in the Figure 5, assuming *B* is perpendicular to *v*? (OpenStax 22.5) **into, left, out**
11. Repeat Exercise 11 for a negative charge. (OpenStax 22.6) **out, right, into**
12. What is the maximum force on an aluminum rod with a 0.100-μC charge that you pass between the poles of a 1.50-T permanent magnet at a speed of 5.00 m/s? In what direction is the force? (OpenStax 22.7) $\mathbf{7.50 \times 10^{-7}}$**N,** $\perp$
13. (a) Aircraft sometimes acquire small static charges. Suppose a supersonic jet has a 0.500-μC charge and flies due west at a speed of 660 m/s over the Earth's south magnetic pole, where the 8.00×10^{-5}-T magnetic field points straight down. What are the direction and the magnitude of the magnetic force on the plane? (b) Discuss whether the value obtained in part (a) implies this is a significant or negligible effect. (OpenStax 22.8) $\mathbf{2.64 \times 10^{-8}}$ **N, south, negligible**
14. (a) A cosmic ray proton moving toward the Earth at 5.00×10^{7} m/s experiences a magnetic force of 1.70×10^{-16} N. What is the strength of the magnetic field if there is a 45° angle between it and the proton's velocity? (b) Is the value obtained in part (a) consistent with the known strength of the Earth's magnetic field on its surface? Discuss. (OpenStax 22.9) $\mathbf{3.01 \times 10^{-5}}$ **T, yes**
15. A cosmic ray electron moves at 7.50×10^{6} m/s perpendicular to the Earth's magnetic field at an altitude where field strength is 1.00×10^{-5} T. What is the radius of the circular path the electron follows? (OpenStax 22.12) **4.27 m**
16. A proton moves at 7.50×10^{7} m/s perpendicular to a magnetic field. The field causes the proton to travel in a circular path of radius 0.800 m. What is the field strength? (OpenStax 22.13) **0.979 T**
17. (a) Viewers of Star Trek hear of an antimatter drive on the Starship Enterprise. One possibility for such a futuristic energy source is to store antimatter charged particles in a vacuum chamber, circulating in a magnetic field, and then extract them as needed. Antimatter annihilates with normal matter, producing pure energy. What strength magnetic field is needed to hold antiprotons, moving at 5.00×10^{7} m/s in a circular path 2.00 m in radius? Antiprotons have the same mass as protons but the opposite (negative) charge. (b) Is this field strength obtainable with today's technology or is it a futuristic possibility? (OpenStax 22.14) **0.261 T, yes**
18. (a) An oxygen-16 ion with a mass of 2.66×10^{-26} kg travels at 5.00×10^{6} m/s perpendicular to a 1.20-T magnetic field, which makes it move in a circular arc with a 0.231-m radius. What positive charge is on the ion? (b) What is the ratio of this charge to the charge of an electron? (c) Discuss why the ratio found in (b) should be an integer. (OpenStax 22.15) $\mathbf{4.80 \times 10^{-19}}$ **C, 3**

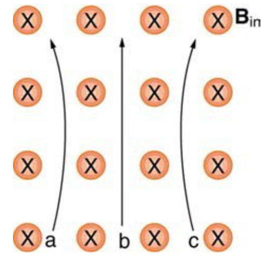


Figure 1

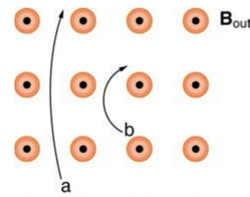


Figure 2

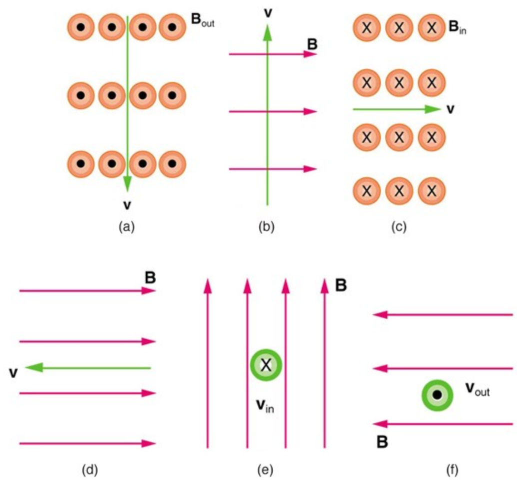


Figure 3

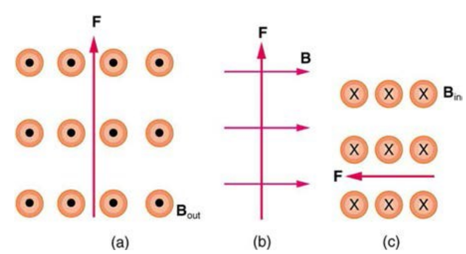


Figure 4

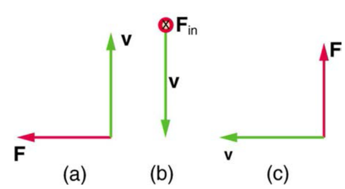
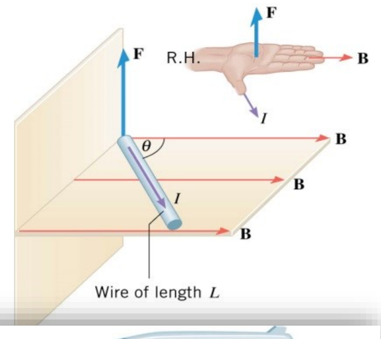


Figure 5

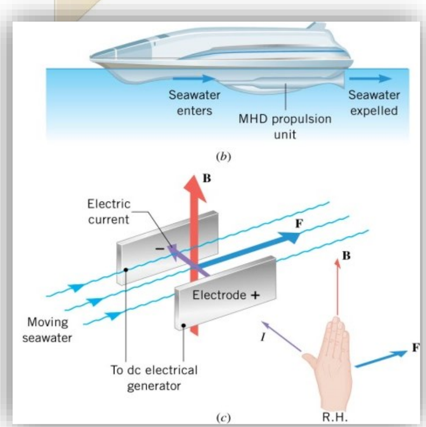
Physics 09-03 Magnetic Force on a Current-Carrying Wire **Name:** ________________________

Force on a Current-Carrying Wire in B-field



- Direction Follows _______________
- $F = ILB\sin\theta$

A 2 m wire is in a 2×10^{-6} T magnetic field pointing into the page. It carries 2 A of current flowing up. What is the force on the wire?



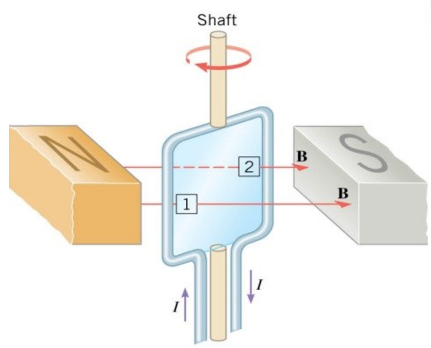
Magnetohydrodynamic Propulsion

- Way to _______________ boats with _______________ moving parts
- _______________ enters tube under ship
- In the tube are electrodes that run _______________ through the water
- Also in the tube is a strong _______________ field created by _______________
- The interaction with the electric _______________ and _______________ push the _______________ out the back of the tube which pushes boat forward
- $F = ILB\ sin\ \theta$

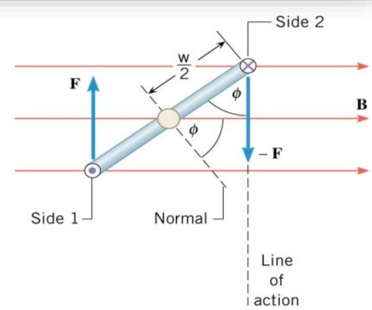
Torque on a Current Loop in B-field

What happens when you put a loop of wire in a magnetic field?

- Side 1 is forced _______________ and side 2 is forced _______________ (RHR)
- This produces a _______________
- The loop turns until its normal is _______________ with the B-field
- Torque on Loop of Wire
  - $\tau = NIAB\sin\phi$
    - Where N = Number of loops, I = Current, A = Area of loop, B = Magnetic Field, ϕ = Angle between normal and B-field
  - NIA = Magnetic _______________
    - Magnetic _______________ ↑, torque ↑



(a)

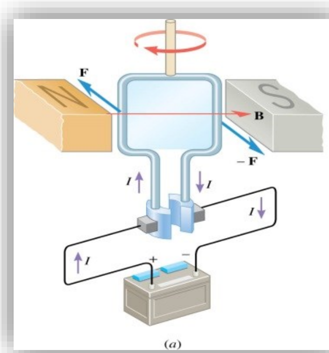


(b)

A simple electric motor needs to supply a maximum torque of 10 Nm. It uses 0.1 A of current. The magnetic field in the motor is 0.02 T. If the coil is a circle with radius of 2 cm, how many turns should be in the coil?

Electric Motor

- Many loops of ____________-carrying wire placed between two ____________ (B-field)
- The loops are attached to _______________
- The ____________ turns the ____________ until the normal is ____________ to B-field
- At that point the half-rings _______________ connect to electric _______________
- _______________ makes the loop turn more
- The half-rings _______________ with the current to _______________ the process



(a)

Physics 09-03 Magnetic Force on a Current-Carrying Wire *Name: ________________________*

Practice Work

1. Why would a magnetohydrodynamic drive work better in ocean water than in fresh water? Also, why would superconducting magnets be desirable?
2. Which is more likely to interfere with compass readings, AC current in your refrigerator or DC current when you start your car? Explain.
3. What is the direction of the magnetic force on the current in each of the six cases in Figure 1? (OpenStax 22.31) **left, into, up, no, right, down**
4. What is the direction of a current that experiences the magnetic force shown in each of the three cases in Figure 2, assuming the current runs perpendicular to B? (OpenStax 22.32) **left, out, up**
5. (a) What is the force per meter on a lightning bolt at the equator that carries 20,000 A perpendicular to the Earth's 3.00×10^{-5}-T field? (b) What is the direction of the force if the current is straight up and the Earth's field direction is due north, parallel to the ground? (OpenStax 22.34) **0.600 N/m, West**

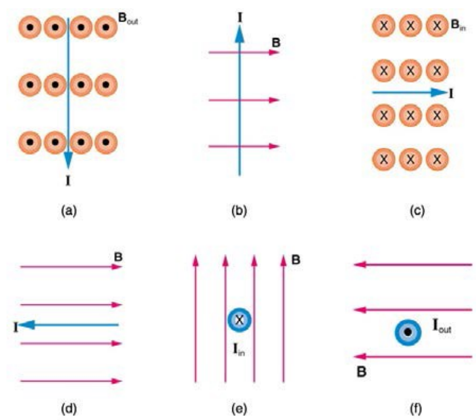


Figure 1

6. (a) A DC power line for a light-rail system carries 1000 A at an angle of 30.0° to the Earth's 5.00×10^{-5}-T field. What is the force on a 100-m section of this line? (b) Discuss practical concerns this presents, if any. (OpenStax 22.35) **2.50 N, must attach them**

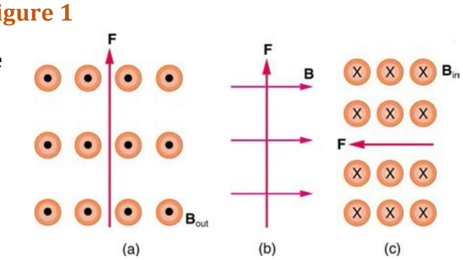
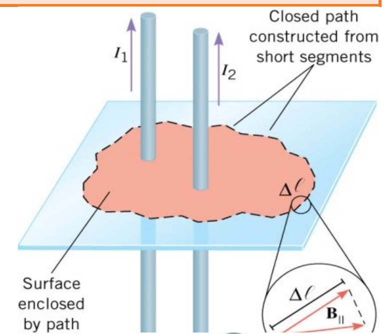


Figure 2

7. What force is exerted on the water in an MHD drive utilizing a 25.0-cm-diameter tube, if 100-A current is passed across the tube that is perpendicular to a 2.00-T magnetic field? (The relatively small size of this force indicates the need for very large currents and magnetic fields to make practical MHD drives.) (OpenStax 22.36) **50.0 N**
8. A wire carrying a 30.0-A current passes between the poles of a strong magnet that is perpendicular to its field and experiences a 2.16-N force on the 4.00 cm of wire in the field. What is the average field strength? (OpenStax 22.37) **1.80 T**
9. (a) What is the maximum torque on a 150-turn square loop of wire 18.0 cm on a side that carries a 50.0-A current in a 1.60-T field? (b) What is the torque when ϕ is 10.9°? (OpenStax 22.42) **389 Nm, 73.5 Nm**
10. Find the current through a loop needed to create a maximum torque of 9.00 N·m. The loop has 50 square turns that are 15.0 cm on a side and is in a uniform 0.800-T magnetic field. (OpenStax 22.43) **10.0 A**
11. Calculate the magnetic field strength needed on a 200-turn square loop 20.0 cm on a side to create a maximum torque of 300 N·m if the loop is carrying 25.0 A. (OpenStax 22.44) **1.50 T**
12. A proton has a magnetic field due to its spin on its axis. The field is similar to that created by a circular current loop 0.650×10^{-15} m in radius with a current of 1.05×10^{4} A (no kidding). Find the maximum torque on a proton in a 2.50-T field. (This is a significant torque on a small particle.) (OpenStax 22.47) $\mathbf{3.48 \times 10^{-26}}$ **Nm**

Physics 09-04 Magnetic Fields Produced by Currents   Name: ____________________

Ampere's Law



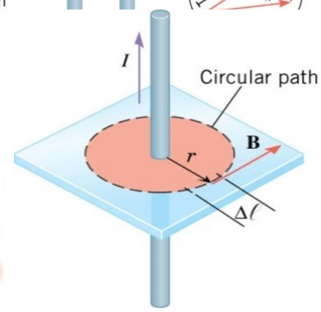
$$\sum \vec{B} \cdot \Delta\vec{\ell} = \mu_0 I$$
$$\sum B_{||} \Delta\ell = \mu_0 I$$

- Where B = the magnetic field ($B_{||}$ is the B-field ______________ to ℓ), $\Delta\ell$ = a portion of the ______________ surround the current, μ_0 = ___________________ of free space = $4\pi \times 10^{-7}$ Tm/A, I = current ______________ by path

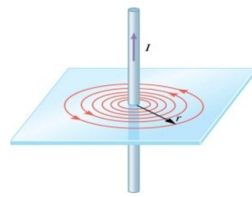
Long Straight Wire

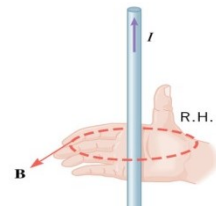
- To make it simpler, let's use a ______________ for our path around ______________ wire.

$$\sum \vec{B} \cdot \Delta\vec{\ell} = \mu_0 I$$
$$B(2\pi r) = \mu_0 I$$
$$B = \frac{\mu_0 I}{2\pi r}$$



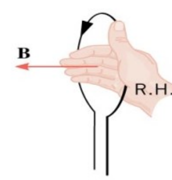
- Right-Hand Rule
  - Grab the wire with ______________ hand
  - Thumb points in direction of ______________
  - Fingers curl in direction of ______________ field

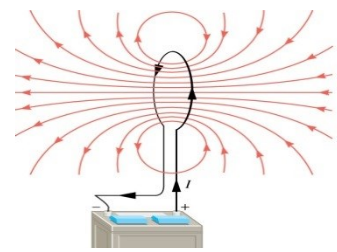




Loop

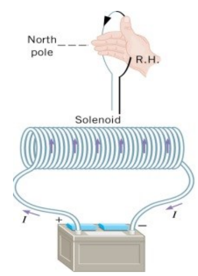
- Right Hand Rule
- At ______________ of loop
- $B = N\frac{\mu_0 I}{2R}$
  - N=number of loops

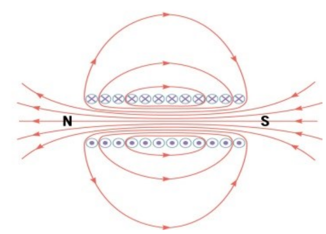




Solenoid

- $B = \mu_0 n I$
  - n=loops/m





A long straight current-carrying wire runs from north to south.
A compass needle is placed above the wire points with its N-pole toward the east. In what direction is the current flowing?

If a compass is put underneath the wire, in which direction will the needle point?

A single straight wire produces a B-field. Another wire is parallel and carries an identical current. If the two currents are in the same direction, how would the magnetic field be affected? What if the currents are in the opposite direction?

Suppose a piece of coaxial cable is made with a solid wire at the center. A metal cylinder has a common center with the wire and its radius is 1 mm. A 2 A current flows up the center wire and a 1.5 A current flows down the cylinder.
Find the B-field at 4 mm from the center.

Find the B-field at 0.5 mm from the center.

What current should be in the cylinder to have no B-field outside of the cylinder?

Two wires are 0.2 m apart and 2 m long and both carry 2 A of current. What is the force on the wires?

- Force of one wire on another _______________ wire
    - $\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}$
    - Attractive if same I's in _______________ direction, repulsive if _______________

Practice Work

1. Suppose two long straight wires run perpendicular to one another without touching. Does one exert a net force on the other? If so, what is its direction? Does one exert a net torque on the other? If so, what is its direction? Justify your responses by using the right-hand rules.
2. Use the right-hand rules to show that the force between the two loops in Figure 1 is attractive if the currents are in the same direction and repulsive if they are in opposite directions. Is this consistent with like poles of the loops repelling and unlike poles of the loops attracting? Draw sketches to justify your answers.

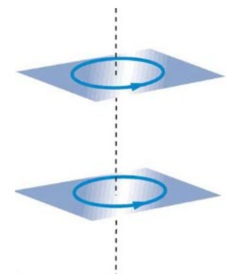


Figure 1

3. (a) The hot and neutral wires supplying DC power to a light-rail commuter train carry 800 A and are separated by 75.0 cm. What is the magnitude and direction of the force between 50.0 m of these wires? (b) Discuss the practical consequences of this force, if any. (OpenStax 22.50) **8.53 N, repulsive**
4. The force per meter between the two wires of a jumper cable being used to start a stalled car is 0.225 N/m. (a) What is the current in the wires, given they are separated by 2.00 cm? (b) Is the force attractive or repulsive? (OpenStax 22.51) **150 A, repulsive**
5. A 2.50-m segment of wire supplying current to the motor of a submerged submarine carries 1000 A and feels a 4.00-N repulsive force from a parallel wire 5.00 cm away. What is the direction and magnitude of the current in the other wire? (OpenStax 22.52) **400 A, opposite**

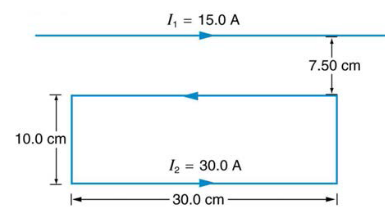


Figure 2

6. The wire carrying 400 A to the motor of a commuter train feels an attractive force of 4.00×10^{-3} N/m due to a parallel wire carrying 5.00 A to a headlight. (a) How far apart are the wires? (b) Are the currents in the same direction? (OpenStax 22.53) **0.100 m, Yes**
7. Figure 2 shows a long straight wire near a rectangular current loop. What is the direction and magnitude of the total force on the loop? (OpenStax 22.55) $\mathbf{2.06 \times 10^{-4}}$ **N, repulsive**

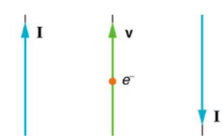


Figure 3

8. Indicate whether the magnetic field created in each of the three situations shown in Figure 3 is into or out of the page on the left and right of the current. (OpenStax 22.58) **out, into; into, out; into, out**
9. What are the directions of the fields in the center of the loop and coils shown in Figure 4? (OpenStax 22.59) **out, right, left**

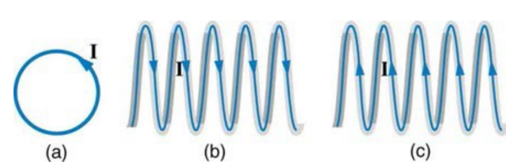


Figure 4

10. What are the directions of the currents in the loop and coils shown in Figure 5? (OpenStax 22.60) **CW, CW as seen from left, CW as seen from right**
11. Inside a motor, 30.0 A passes through a 250-turn circular loop that is 10.0 cm in radius. What is the magnetic field strength created at its center? (OpenStax 22.62) $\mathbf{4.71 \times 10^{-2}}$ **T**
12. How strong is the magnetic field inside a solenoid with 10,000 turns per meter that carries 20.0 A? (OpenStax 22.64) **0.251 T**

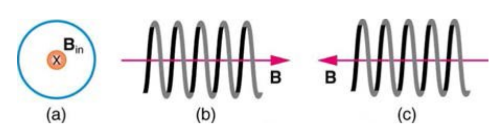
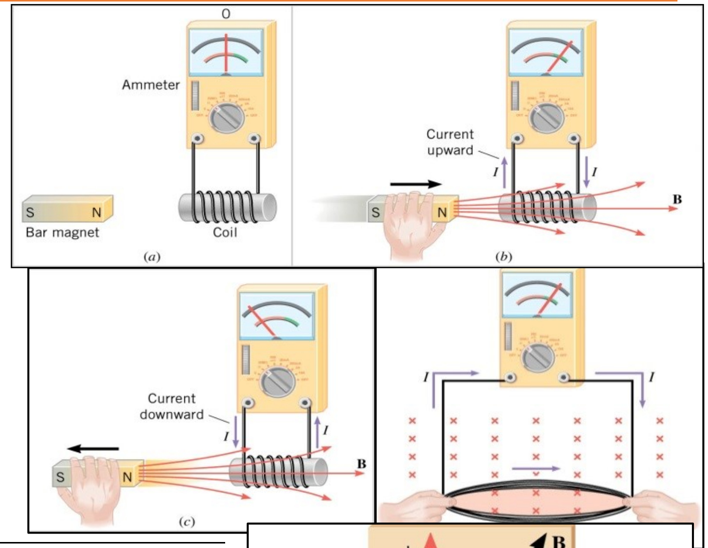


Figure 5

13. How far from the starter cable of a car, carrying 150 A, must you be to experience a field less than the Earth's (5.00×10^{-5} T)? Assume a long straight wire carries the current. (OpenStax 22.66) **0.600 m**
14. Calculate the size of the magnetic field 20 m below a high voltage power line. The line carries 450 MW at a voltage of 300,000 V. (OpenStax 22.72) $\mathbf{1.5 \times 10^{-5}}$ **T**

Physics 09-05 Faraday's Law of Induction and Lenz's Law **Name: ________________________**

Faraday's Law of Induction



Magnetic _____________ can produce _____________.

- The magnetic field must be _____________ to create current.
- The current created is called _____________ current.
- The emf that _________ the current is called __________ emf.
- Another way to induce emf is by changing the _____________ of a _____________ of wire in a magnetic field.

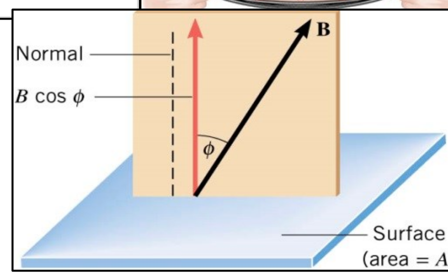
Magnetic Flux through a surface

$$\Phi = \vec{B} \cdot \vec{A}$$

$$\Phi = BA\cos\phi$$

- The angle is between the _____________ and the _____________ to the surface.
- The magnetic flux is proportional to the _____________ of field _____________ that pass through a _____________.
- Any _____________ in magnetic flux causes a _____________ to flow

A rectangular coil of wire has a length of 2 cm and a width of 3 cm. It is in a 0.003 T magnetic field. What is the magnetic flux through the coil if the face of the coil is parallel to the B-field lines? What is the flux if the angle between the face of the coil and the magnetic field is 60°?



- _____________ is produced when there is a _____________ in magnetic _____________ through a _____________ of wire.
- _____________ change in flux; no _____________.
- Experiments (and mathematics) show that $emf = -\frac{\Delta\Phi}{\Delta t}$ for a _____________ of wire
- If there are _____________ than _____________ loop, _____________ by the number of loops.

Faraday's Law of Electromagnetic Induction

$$emf = -N\left(\frac{\Phi - \Phi_0}{t - t_0}\right) = -N\frac{\Delta\Phi}{\Delta t}$$

- where N = number of loops, Φ = magnetic flux, t = time
- Remember $\Phi = BA\cos\phi$
- So changing _____________, _____________, or _____________ will produce a _____________

A coil of wire (N = 40) carries a current of 2 A and has a radius of 6 cm. The current is decreased at 0.1 A/s. Inside this coil is another coil of wire (N = 10 and r = 3 cm) aligned so that the faces are parallel. What is the average emf induced in the smaller coil during 5 s?

Lenz's Law

- The induced emf resulting from a changing magnetic flux has a _____________ that leads to an _____________ current whose direction is such that the induced magnetic _____________ _____________ the original flux _____________.

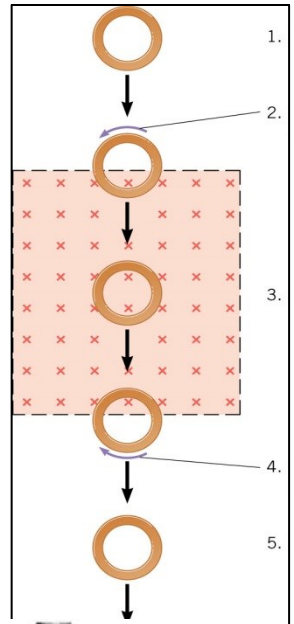
Reasoning Strategy

- Determine whether the magnetic flux is _____________ or _____________.

Physics 09-05 Faraday's Law of Induction and Lenz's Law *Name:* ________________________

- Find what direction the induced magnetic field must be to ____________ the change in flux by ____________ or ____________ from the original field.
- Having found the ____________ of the magnetic field, use the ______________________ to find the direction of the ____________ current.

A copper ring falls through a rectangular region of a magnetic field as illustrated. What is the direction of the induced current at each of the five positions?



Practice Work

1. Explain how magnetic flux can be zero when the magnetic field is not zero.
2. A particle accelerator sends high-velocity charged particles down an evacuated pipe. Explain how a coil of wire wrapped around the pipe could detect the passage of individual particles. Sketch a graph of the voltage output of the coil as a single particle passes through it.
3. What is the value of the magnetic flux at coil 2 in Figure 1(a) due to coil 1? (OpenStax 23.1) **0**
4. What is the value of the magnetic flux through the coil in Figure 1(b) due to the wire? (OpenStax 23.2) **0**
5. Referring to Figure 2(a), what is the direction of the current induced in coil 2: (a) If the current in coil 1 increases? (b) If the current in coil 1 decreases? (c) If the current in coil 1 is constant? (OpenStax 23.3) **CCW, CW, no**
6. Referring to Figure 2(b), what is the direction of the current induced in the coil: (a) If the current in the wire increases? (b) If the current in the wire decreases? (c) If the current in the wire suddenly changes direction? (OpenStax 23.4) **CCW, CW, CW**
7. Referring to Figure 3, what are the directions of the currents in coils 1, 2, and 3 (assume that the coils are lying in the plane of the circuit): (a) When the switch is first closed? (b) When the switch has been closed for a long time? (c) Just after the switch is opened? (OpenStax 23.5) **CCW, CCW, CW; no, no, no; CW, CW, CCW**
8. Repeat the previous problem with the battery reversed. (OpenStax 23.6) **CW, CW, CCW; no, no, no; CCW, CCW, CW**
9. Suppose a 50-turn coil lies in the plane of the page in a uniform magnetic field that is directed into the page. The coil originally has an area of 0.250 m^2. It is stretched to have no area in 0.100 s. What is the direction and magnitude of the induced emf if the uniform magnetic field has a strength of 1.50 T? (OpenStax 23.8) **188 V CW**
10. (a) An MRI technician moves his hand from a region of very low magnetic field strength into an MRI scanner's 2.00 T field with his fingers pointing in the direction of the field. Find the average emf induced in his wedding ring, given its diameter is 2.20 cm and assuming it takes 0.250 s to move it into the field. (b) Discuss whether this current would significantly change the temperature of the ring. (OpenStax 23.9) **3.04 mV, no**
11. Referring to the situation in the previous problem: (a) What current is induced in the ring if its resistance is 0.0100 Ω? (b) What average power is dissipated? (c) What magnetic field is induced at the center of the ring? (d) What is the direction of the induced magnetic field relative to the MRI's field? (OpenStax 23.10) **0.304 A, 0.924 mW, $\mathbf{1.74 \times 10^{-5}}$ T, opposite**
12. A 0.250 m radius, 500-turn coil is rotated one-fourth of a revolution in 4.17 ms, originally having its plane perpendicular to a uniform magnetic field. (This is 60 rev/s.) Find the magnetic field strength needed to induce an average emf of 10,000 V. (OpenStax 23.12) **0.425 T**
13. (a) A lightning bolt produces a rapidly varying magnetic field. If the bolt strikes the earth vertically and acts like a current in a long straight wire, it will induce a voltage in a loop aligned like that in Figure 2(b). What voltage is induced in a 1.00 m diameter loop 50.0 m from a 2.00×10^6 A lightning strike, if the current falls to zero in 25.0 μs? (b) Discuss circumstances under which such a voltage would produce noticeable consequences. (OpenStax 23.14) **251 V**

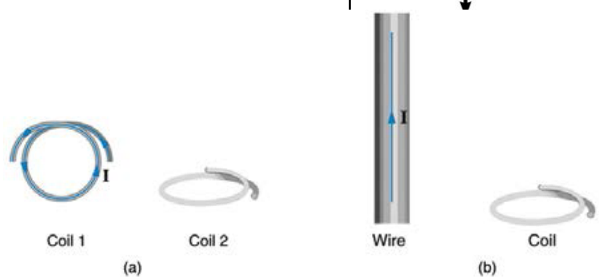


Figure 1

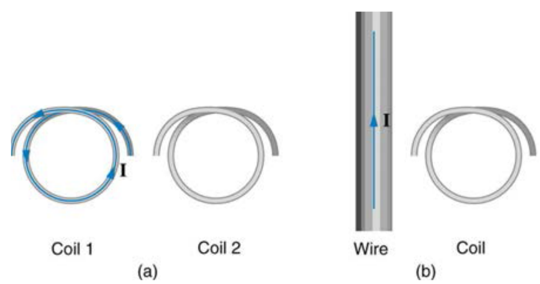


Figure 2

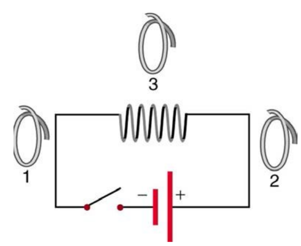


Figure 3

Physics 09-06 Motional emf and Magnetic Damping	*Name: ______________________*

Motional emf

- Another way to produce an induced emf is by moving a conducting ____________ through a constant magnetic ____________.
- Each ____________ in the rod is ____________ through the magnetic field with velocity, *v*.
- So, each charge experiences a magnetic ____________.

$$F = qvB\sin\theta$$

- Since the ____________ can move they are _________ to one end of the rod leaving __________ charges at the other end.
- If there was a ____________ connecting the ____________ of the rod, the electrons would flow through the ____________ to get back to the ____________ charges.
    - This is called ____________ ____________ ($\mathcal{E}$)
- If the rod did ____________ have the wire, the electrons would move until the ____________ electrical force is balanced with the ____________ force.

$$emf = vBL$$

- It takes a ____________ to move the ____________.
- Once the electrons are ____________ in the rod, there is another ____________. The moving electrons in a B-field create a magnetic ____________ on the rod itself.
- According to the RHR, the force is ____________ the motion of the rod. If there were no ____________ pushing the rod, it would ____________.

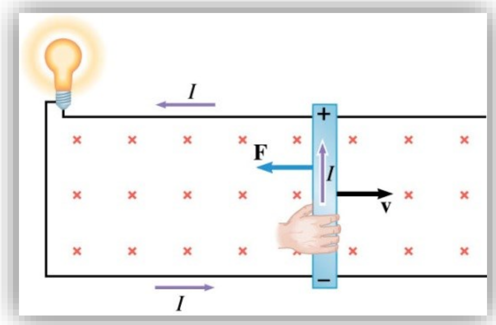


Figure 1

Damping

- When a conductor moves ____________ (or out of) a magnetic field, an ____________ current is created in the conductor
- As the conductor moves into B-field, the ____________ increases
- This produces a current by ____________ Law and is ____________ in way that ____________ change in flux.
- This current's ____________ causes a ____________ on the conductor
- The direction of the force will be ____________ the ____________ of the conductor

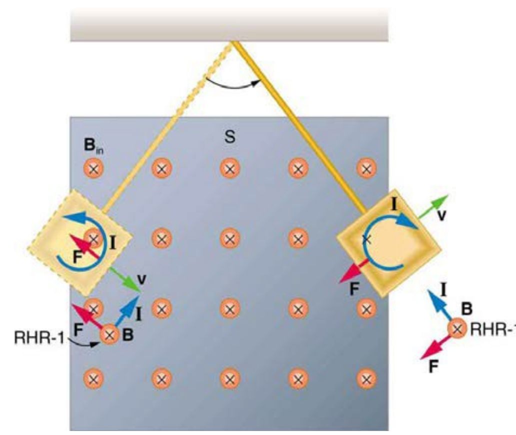


Figure 2

Applications of Magnetic Damping

- Stopping a ____________ from moving
- ____________ on trains/rollercoasters
    - No actual ____________ parts, not effected by rain, smoother
    - Since based on speed, need _________________ brakes to finish
- Sorting ____________
    - Metallic objects move ____________ down ramp with ____________ under it
- ____________ Detectors

Practice Work

1. Why must part of the circuit be moving relative to other parts, to have usable motional emf? Consider, for example, that the rails in Figure 1 above are stationary relative to the magnetic field, while the rod moves.
2. A powerful induction cannon can be made by placing a metal cylinder inside a solenoid coil. The cylinder is forcefully expelled when solenoid current is turned on rapidly. Use Faraday's and Lenz's laws to explain how this works. Why might the cylinder get live/hot when the cannon is fired?

3. An induction stove heats a pot with a coil carrying an alternating current located beneath the pot (and without a hot surface). Can the stove surface be a conductor? Why won't a coil carrying a direct current work?

4. (a) A jet airplane with a 75.0 m wingspan is flying at 280 m/s. What emf is induced between wing tips if the vertical component of the Earth's field is 3.00×10^{-5} T? (b) Is an emf of this magnitude likely to have any consequences? Explain. (OpenStax 23.17) **0.630 V, no**

5. (a) A nonferrous screwdriver is being used in a 2.00 T magnetic field. What maximum emf can be induced along its 12.0 cm length when it moves at 6.00 m/s? (b) Is it likely that this emf will have any consequences or even be noticed? (OpenStax 23.18) **1.44 V, no**

6. At what speed must the sliding rod in Figure 1 move to produce an emf of 1.00 V in a 1.50 T field, given the rod's length is 30.0 cm? (OpenStax 23.19) **2.22 m/s**

7. The 12.0 cm long rod in Figure 1 moves at 4.00 m/s. What is the strength of the magnetic field if a 95.0 V emf is induced? (OpenStax 23.20) **198 T**

8. A coil is moved through a magnetic field as shown in Figure 3. The field is uniform inside the rectangle and zero outside. What is the direction of the induced current and what is the direction of the magnetic force on the coil at each position shown? (OpenStax 23.27) **none; CW I, left F; none; CCW I, left F; none**

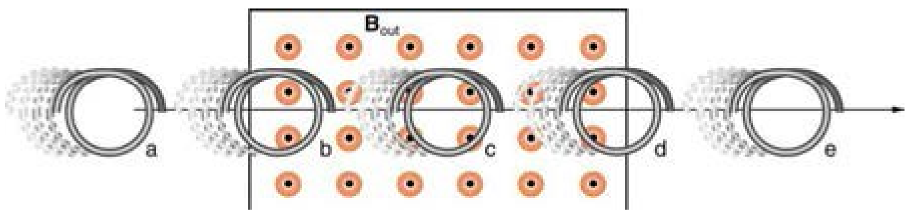
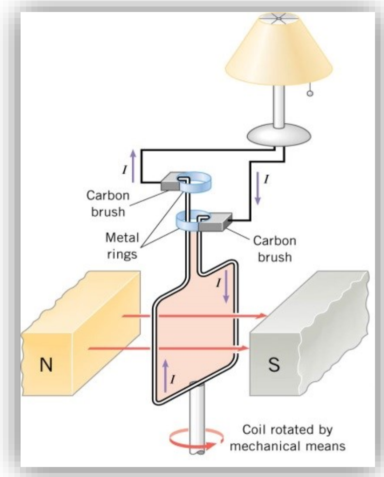


Figure 3

Physics 09-07 Electric Generators and Back emf **Name: ______________________**

Electric Generators



- A ____________ of wire is ____________ in a ____________ field.
- Since the ____________ between the loop and the B-field is ____________, the ____________ is changing.
- Since the magnetic ____________ is changing an *emf* is ____________.
- *emf* produced in ____________ ____________ coil

$$emf = NBA\omega \sin \omega t$$

- Where N = number of loops, B = magnetic field, A = area of each loop, ω = angular velocity = $2\pi f$, t = time in seconds
- According to ____________ Law, the current will flow the one direction when the angle is ____________ and it will flow the ____________ direction when the angle is ____________.
- These generators often called ____________ current ____________.

You have made a simple generator to power a TV. The armature is attached the rear axle of a stationary bike. For every time you peddle, the rear axel turns 10 times. Your TV needs a V_{rms} of 110V to operate. If the B-field is 0.2 T, each loop is a circle with r = 3 cm, and you can comfortably peddle 3 times a second; how many loops must you have in your generator so that you can watch TV while you exercise?

Back emf

- When a coil is ____________ in a B-field an *emf* is ____________
- If an electric motor is ____________, its coil is ____________ in a B-field
- By ____________ Law, this *emf* will ____________ the *emf* used to ____________ the motor (called back *emf*)
- It will ____________ the ____________ across the motor and cause it to draw ____________ current ($V = IR$)
- The back *emf* is ________________ to the ____________, so when motor starts it draws ____________ I, but as it speeds up the I ____________

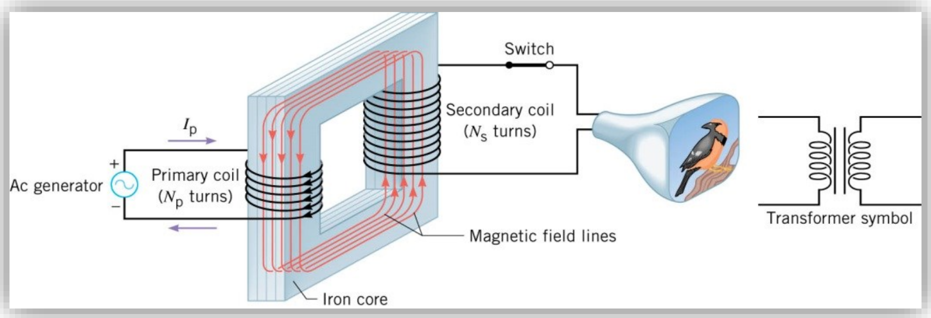
Physics 09-07 Electric Generators and Back emf	***Name: ______________________***
Practice Work	

1. Suppose you find that the belt drive connecting a powerful motor to an air conditioning unit is broken and the motor is running freely. Should you be worried that the motor is consuming a great deal of energy for no useful purpose? Explain why or why not.
2. Calculate the peak voltage of a generator that rotates its 200-turn, 0.100 m diameter coil at 3600 rpm in a 0.800 T field. (OpenStax 23.28) **474 V**
3. At what angular velocity in rpm will the peak voltage of a generator be 480 V, if its 500-turn, 8.00 cm diameter coil rotates in a 0.250 T field? (OpenStax 23.29) $\mathbf{7.30 \times 10^3}$ **rpm**
4. (a) A bicycle generator rotates at 1875 rad/s, producing an 18.0 V peak *emf*. It has a 1.00 by 3.00 cm rectangular coil in a 0.640 T field. How many turns are in the coil? (b) Is this number of turns of wire practical for a 1.00 by 3.00 cm coil? (OpenStax 23.32) **50.0, Yes**
5. This problem refers to the bicycle generator considered in the previous problem. It is driven by a 1.60 cm diameter wheel that rolls on the outside rim of the bicycle tire. (a) What is the velocity of the bicycle if the generator's angular velocity is 1875 rad/s? (b) What is the maximum *emf* of the generator when the bicycle moves at 10.0 m/s, noting that it was 18.0 V under the original conditions? (c) If the sophisticated generator can vary its own magnetic field, what field strength will it need at 5.00 m/s to produce a 9.00 V maximum emf? (OpenStax 23.33) **15m/s, 12.0 V, 0.960 T**
6. (a) A car generator turns at 400 rpm when the engine is idling. Its 300-turn, 5.00 by 8.00 cm rectangular coil rotates in an adjustable magnetic field so that it can produce sufficient voltage even at low rpms. What is the field strength needed to produce a 24.0 V peak *emf*? (b) Discuss how this required field strength compares to those available in permanent and electromagnets. (OpenStax 23.34) **0.477 T, can use normal magnet**
7. Suppose a motor connected to a 120 V source draws 10.0 A when it first starts. (a) What is its resistance? (b) What current does it draw at its normal operating speed when it develops a 100 V back *emf*? (OpenStax 23.39) **12.0 Ω, 1.67 A**
8. A motor operating on 240 V electricity has a 180 V back *emf* at operating speed and draws a 12.0 A current. (a) What is its resistance? (b) What current does it draw when it is first started? (OpenStax 23.40) **5.00 Ω, 48.0 A**
9. What is the back *emf* of a 120 V motor that draws 8.00 A at its normal speed and 20.0 A when first starting? (OpenStax 23.41) **72.0 V**
10. The motor in a toy car operates on 6.00 V, developing a 4.50 V back *emf* at normal speed. If it draws 3.00 A at normal speed, what current does it draw when starting? (OpenStax 23.42) **12.0 A**

Physics 09-08 Transformers and Electrical Safety	Name: ________________________

Transformers

- The _____________ in a wall outlet is approximately _____________.
- Many electrical appliances _____________ handle that many _____________.
  - Computer speakers
    ____
  - Projection TV
    ____



- A ________________ changes the voltage for the _____________.
- The _____________ coil creates a _____________ field in the _____________ core.
- Since the _____________ in the coil is _____________, the *B*-field is always _____________.
- The _____________ makes the *B*-field go through the _____________ coil.
- The _____________ *B*-field means the _____________ in the _____________ coil is also _____________ and thus _____________ a *emf*.

Transformer equation

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

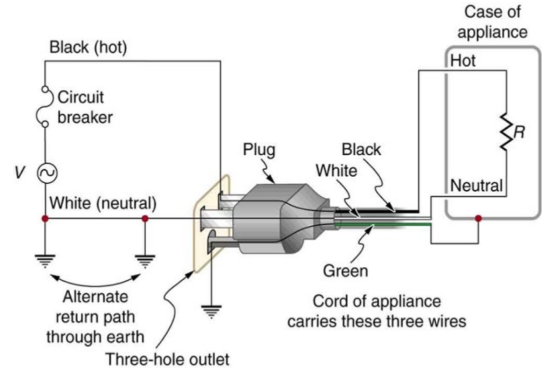
- A transformer that steps _____________ the _____________, steps _____________ the _____________ and vise versa.
- To keep electrical lines from getting _____________, electrical companies use transformers to step _____________ the voltage to up to _____________. The box on electrical pole is a ________________ that steps the voltage down to _______.

A TV requires 15000V and 0.01 A to accelerate the electron beam. The outlet in the house supplies 120V. The primary coil of the transformer in the TV has 100 turns. How many turns should the secondary coil have?

How much current does the TV draw from the outlet?

Safety

- Two _____________
  - _____________ wire
    - _____________ prong
    - _____________ through ground
  - _____________ wire
    - _____________prong
    - Grounds the _____________
- _____________ wire
  - ___________________________
  - Carries the _____________ voltage



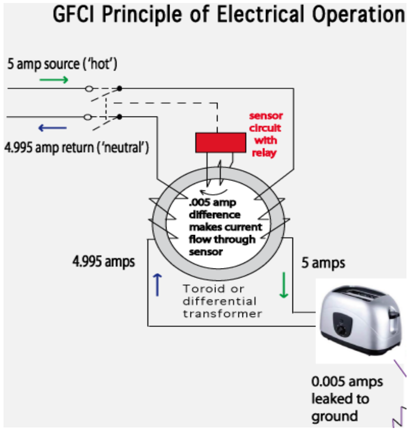
Physics 09-08 Transformers and Electrical Safety   *Name:* ________________________

Circuit Breaker

- If the current load gets too _____________, an _________________ pulls a _____________ to stop the current
- Stops wires from getting _____________ in _____________ circuits

Ground Fault Interrupter

- Both sides (hot and neutral) are wrapped around a metal _____________ like a _________________, but the number of loops are _____________
- Normally the induced current is _______ since the two sides _____________
- If an _____________ occurs (like current going through a person to the ground), an ____________________ pulls a _____________



Practice Work

1. Explain what causes physical vibrations in transformers at twice the frequency of the AC power involved.
2. Does plastic insulation on live/hot wires prevent shock hazards, thermal hazards, or both?
3. Why are ordinary circuit breakers and fuses ineffective in preventing shocks?
4. A plug-in transformer supplies 9.00 V to a video game system. (a) How many turns are in its secondary coil, if its input voltage is 120 V and the primary coil has 400 turns? (b) What is its input current when its output is 1.30 A? (OpenStax 23.44) $\mathbf{30.0, 9.75 \times 10^{-2}\ A}$
5. An American traveler in New Zealand carries a transformer to convert New Zealand's standard 240 V to 120 V so that she can use some small appliances on her trip. (a) What is the ratio of turns in the primary and secondary coils of her transformer? (b) What is the ratio of input to output current? (c) How could a New Zealander traveling in the United States use this same transformer to power her 240 V appliances from 120 V? (OpenStax 23.45) **2.00, 0.500**
6. A cassette recorder uses a plug-in transformer to convert 120 V to 12.0 V, with a maximum current output of 200 mA. (a) What is the current input? (b) What is the power input? (c) Is this amount of power reasonable for a small appliance? (OpenStax 23.46) **20.0 mA, 2.40 W, yes**
7. (a) What is the voltage output of a transformer used for rechargeable flashlight batteries, if its primary has 500 turns, its secondary 4 turns, and the input voltage is 120 V? (b) What input current is required to produce a 4.00 A output? (c) What is the power input? (OpenStax 23.47) **0.96 V, 32.0 mA, 3.84 W**
8. (a) The plug-in transformer for a laptop computer puts out 7.50 V and can supply a maximum current of 2.00 A. What is the maximum input current if the input voltage is 240 V? Assume 100% efficiency. (b) If the actual efficiency is less than 100%, would the input current need to be greater or smaller? Explain. (OpenStax 23.48) **0.063 A, greater**

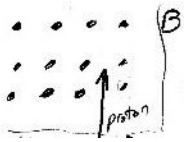
Physics Unit 9: Magnetism Review

1. Know the fundamental properties of permanent magnets.
2. Know how to induce emf.
3. Know the RHR's, and Lenz's Law.
4. A loose proton enters a magnetic field whose direction is coming out of the page. What does its path look like? If the path is bent, what way does it bend?
5. The path of a charged particle is bent clockwise in a magnetic field that is pointed out of the page. What is sign of the charge of the particle?
6. A current goes down and the magnetic field points to the right. What is the direction of the force on the wire carrying the current?
7. A 5 cm section of wire with a 10.0 A current runs perpendicular to a 3.00-T magnetic field. What is the magnitude of the force on the wire?
8. A single circular loop of wire of radius 0.25 m carries a constant current of 10.0 A. The loop may be rotated about an axis that passes through the center and lies in the plane of the loop. When the orientation of the normal to the loop with respect to the direction of the magnetic field is 75°, the torque on the coil is 0.80 N·m. What is the magnitude of the uniform magnetic field exerting this torque on the loop?
9. A solenoid that is 2 m long and has a diameter of 0.5 m has 150 turns. Find the magnitude and direction of the magnetic field at the center of the solenoid if the current is 5 A clockwise.
10. A straight wire carries 5 A of current. If the wire is vertical and the current runs down, find the magnitude and direction of the magnetic field 2 cm from the wire.
11. A 5.00-T magnetic field is directed 15° to the plane of a circular loop of radius 0.75 m. What is the magnitude of the magnetic flux through the loop?
12. Two wires are side by side and very close to each other. One wire carries 2 A and the other 3A in the same direction. What is magnetic field 5 cm from the wires?
13. A circular loop of wire (r = 5 cm) is in a magnetic field (B = 0.5 T) with the normal of the loop parallel to the B-field. The B-field increases from 0.2 T to 0.4 T in 2 s. What is the induced emf in the loop? What direction would a current flow through the loop?
14. What is the emf between the ends of the wings of an airplane if its wings are 50.0 m long and flying at 305 m/s. as it flies perpendicular to the 4.00×10^{-5} -T earth's magnetic field?
15. A circular coil has 500 turns and a radius of 0.10 m. The coil is used as an AC generator by rotating it in a 1.0 T magnetic field, as shown in the figure. At what angular speed should the coil be rotated so that the maximum emf is 140 V?
16. An electric motor runs on 120 V and draws 15 A of current when starting. At normal operation it only draws 2.0 A of current. What is the back emf when the motor is running normally?
17. A transformer's primary coil has 160 turns and 240 V. How many turns are needed in the secondary coil to get 80 V? Is this a step-up or step-down transformer?
18. A power plant produces a voltage of 14 kV and 200 A. The voltage is stepped up to 120 kV by a transformer before it is transmitted to a substation. The resistance of the transmission line between the power plant and the substation is 200Ω. What is the current in the transmission line from the plant to the substation?

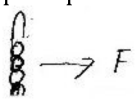
Physics Unit 9: Magnetism Review

Answers

4. Since the proton is charged, the path is bent in a circle.

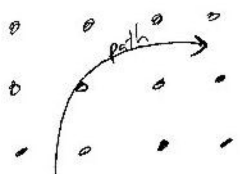


RHR – fingers
- thumb in direction of v
- palm points in direction of F

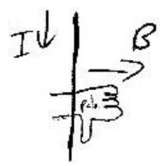


Bends to clockwise (electron would bend counterclockwise)

5. **Positive**



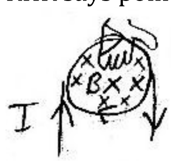
6. RHR – fingers B
thumb I
palm F
F is out of page



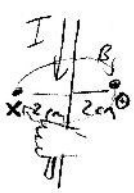
7. $F = ILB \sin\Theta$
$F = (10.0\ A)(0.05\ m)(3.00\ T)\sin 90° = \mathbf{1.5\ N}$

8. $\tau = NIAB \sin\phi$
$0.80\ N \cdot m = (1)(10.0\ A)(\pi(0.25\ m)^2)B \sin 75°$
$B = \mathbf{0.422\ T}$

9. $L = 2\ m, d = 0.5\ m, N = 150, I = 5\ A$
$B = \mu_0 nI;\ n = \frac{N}{L} = \frac{150}{2\ m} = 75\ m^{-1}$
$B = \left(4\pi \times 10^{-7}\frac{Tm}{A}\right)(75\ m^{-1})(5\ A) = \mathbf{4.71 \times 10^{-4}\ T}$
RHR says points **into paper**

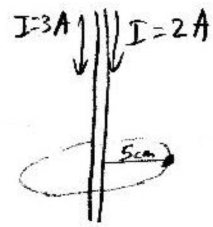


10. $I = 5\ A, r = 0.02\ m$
$B = \frac{\mu_0 I}{2\pi r}$
$B = \frac{\left(4\pi\times10^{-7}\frac{Tm}{A}\right)(5\ A)}{2\pi(0.02\ m)} = \mathbf{5 \times 10^{-5}\ T}$
Goes in on left, out on right



11. The angle should be to the normal to the loop instead of the plane of the loop. $\phi = 90° - 15° = 75°$
$\Phi = BA\cos\phi$
$\Phi = (5.00\ T)(\pi(0.75\ m)^2)\cos 75° = \mathbf{2.29\ Wb}$

12. Ampere's Law



$\Sigma B \cdot \Delta\ell = \mu_0 I$
$B(2\pi r) = \mu_0 I$
$B(2\pi 0.05\ m) = \left(4\pi \times 10^{-7}\frac{Tm}{A}\right)(3\ A + 2\ A)$
$B(0.31416\ m) = 6.2832 \times 10^{-6}\ Tm$
$\mathbf{B = 2 \times 10^{-5}\ T}$

13. $N = 1, r = 0.05\ m, B = 0.5\ T, \frac{\Delta B}{\Delta t} = 0.1\frac{T}{s}$
$emf = -N\frac{\Delta\Phi}{\Delta t}, \Phi = BA\cos\theta$
$emf = -1 \cdot \frac{B_f A\cos 0 - B_0 A\cos 0}{\Delta t}$
$emf = -\left(\frac{(0.4\ T)(\pi(0.05\ m)^2) - (0.2\ T)(\pi(0.05\ m)^2)}{2\ s}\right)$
$emf = -(\pi(0.05\ m)^2)\left(0.1\frac{T}{s}\right) = \mathbf{-7.85 \times 10^{-4}\ V}$
Flux is getting stronger so induced B-field should cancel the original B-field.
RHR – curl your fingers through the loop in the direction of the induced B-field. Your thumb will point the direction of the current.

14. $emf = vBL$
$emf = \left(305\frac{m}{s}\right)(4.00 \times 10^{-5}\ T)(50.0\ m)$
$= \mathbf{0.61\ V}$

15. $emf = NBA\omega \sin\omega t$
Maximum emf occurs when $\sin\omega t = 1$
$140\ V = (500)(1.0\ T)(\pi(0.10\ m)^2)\omega(1)$
$\omega = \mathbf{8.91\frac{rad}{s}}$

16. When starting: $V = IR$
$120\ V = (15\ A)R \to R = 8\ \Omega$
When running: $V = IR$
$120\ V - emf = (2.0\ A)(8\ \Omega)$
$emf = \mathbf{104\ V}$

17. $N_p = 160, V_p = 240\ V, V_s = 80\ V$
$\frac{V_s}{V_p} = \frac{N_s}{N_p} \to \frac{80\ V}{240\ V} = \frac{N_s}{160}$
$N_s = 53.3$
54 turns; Step-down since V decreases.

18. $\frac{V_S}{V_P} = \frac{I_P}{I_S} \to \frac{120\ kV}{14\ kV} = \frac{200\ A}{I_S} \to I_S = \mathbf{23.3\ A}$