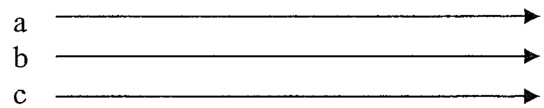
Force between parallel currents

1.



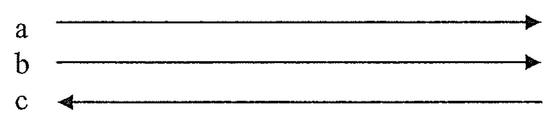
Wires a, b, and c are 20.0 m long and carry equal currents of 100 A. What is the net force on each of the wires (Give **magnitude** and **direction**)?

$F_a =$

$F_b =$

$F_c =$

2.



The current in wire c is reversed. What is the net force on each of the wires now (Give **magnitude** and **direction**)?

$F_a =$

$F_b =$

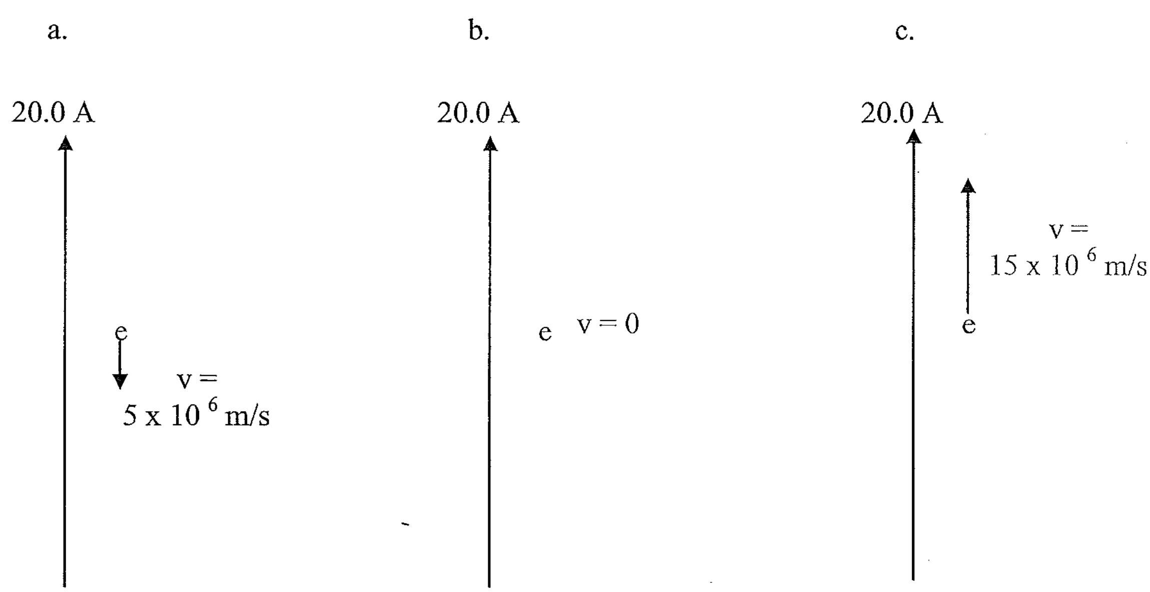
$F_c =$

Force between lightning bolts

1. Two lightning bolts traveling in the same direction are separated by 0.4 m. One lightning bolt carries a current of 1.5×10^{4} A. The other lightning bolt carries a current of 6.0×10^{4} A.

a. What is the force **and direction** between a 10-meter length of the two lightning bolts?

2. A vertical wire carries an upward current of 20.0 A. An electron is located 1.0 cm to the right of the wire, and is moving vertically. The charge on an electron is 1.6×10^{-19} C. For each of the three velocities given what is the force on the electron (Give **magnitude** and **direction**)?



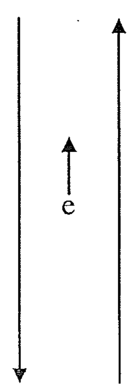
Force between wire and charge

3. In each case of the charge and wire above, what would be the effect on the force
a. if the charge were moving twice as fast?

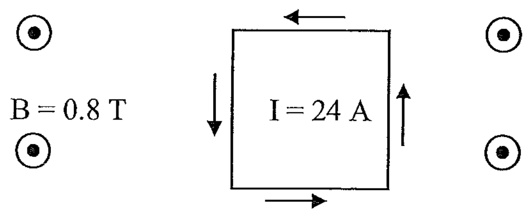
b. if the charge were twice as far from the wire?

c. if the current in the wire were twice as large?

4. Two wires carry 40 A currents in opposite directions. The wires are 1.0 cm apart. What will be the effect on an electron moving at a speed of 3×10^5 m/s, if it is moving parallel to the wires, but half way in between the two? Show the path of the electron and calculate its acceleration. ($q_e = 1.6 \times 10^{-19}$ C, and $m_e = 9.11 \times 10^{-31}$ kg).



Net force on a current loop



1. A square loop is 0.2 m on a side and carries a current I = 24 A in a counterclockwise direction. The coil is immersed in a uniform field of 0.8 T, directed out of the page.

a. What is the value and direction of the force on each side of the coil?

top

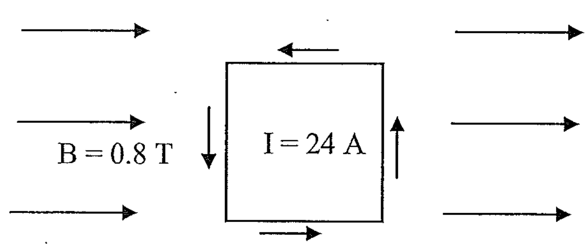
bottom

right

left

b. What is the net force on the loop?

2. Now the same loop is immersed in a **horizontal** uniform field of 0.8 T.



a. What is the value and direction of the force on each side of the loop?

top

bottom

right

left

b. What is the net force on the coil?

MiniLab Magnetic force on Charged Isotopes

Aktivphysics simulation of a mass spectrometer. Instructor will tell you the URL which contains the simulation.

In a mass spectrometer, a beam of charged particles of unknown mass are injected into a region of space where a magnetic field is directed perpendicular to the particles' velocity. In this simulation, the beam is comprised of a pair of singly ionized isotopes of the same element. The two beams can be separated by the spectrometer.

1. What will happen to the radius of curvature of the trajectory if the magnitude of the magnetic field is doubled?

2. What will happen to the radius of curvature of the trajectory if the magnitude of the velocity is doubled?

3. Using your knowledge of the magnetic force and the mechanics of a particle exhibiting circular motion, derive a relationship between the radius of the particle's trajectory, the particle's velocity, and the magnetic field.

4. Calculate the radius of curvature for both of the isotopes of carbon, ^{12}C and ^{14}C. Assume isotopes are singly ionized and that one atomic mass unit is 1.66×10^{-27} kg.

5. Is uranium harder or easier to separate into its constituent isotopes than carbon? **Explain why.**

6. Inject the unknown element into the mass spectrometer. Determine the masses of the two isotopes of the unknown element. From your knowledge of the Periodic Table, determine the identity of the unknown element.

Ion in Magnetic Field – Circular Orbit

Question: A $^{40}Ca^{++}$ ion has a mass of $40 \times 1.67 \times 10^{-27}$ kg. It is moving at a speed of 1×10^{5} m/s. The charge on it is $2 \times 1.6 \times 10^{-19}$ C.

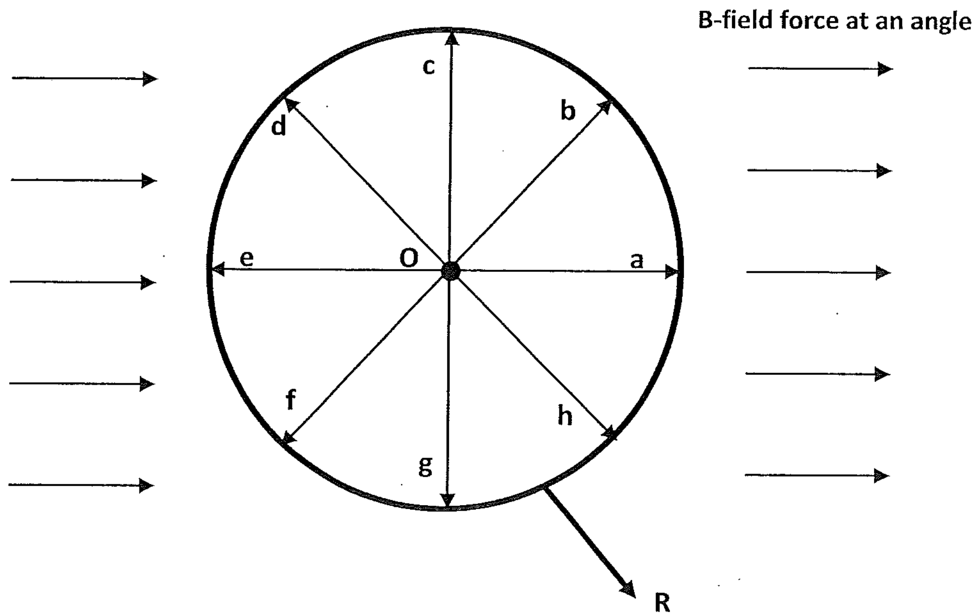
a) What is the radius of its orbit in a magnetic field of 0.1 T?

b) What is orbit size for a heavier isotope $^{42}Ca^{++}$?

Question: A $^{4}He^{+}$ ion has a mass of $4 \times 1.67 \times 10^{-27}$ kg. It is moving at a speed of 1×10^{5} m/s. The charge on it is $1 \times 1.6 \times 10^{-19}$ C.

a) What is the radius of its orbit in a magnetic field of 0.1 T?

b) What is orbit size for a doubly ionized $^{4}He^{++}$?



1. A current of 80 A enters a wheel at the hub, O, divides into the spokes a-h as shown, rejoins on the rim and leaves the rim through the connection at R. The radius of the wheel is 25 cm. The spokes are separated by 45° angles. A magnetic field having magnitude 0.14 T is pointed to the right, and is in the plane of the wheel. Find the force on each spoke

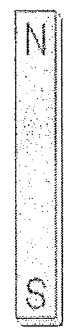
	|F|	**direction**
a)		
b)		
c)		
d)		
e)		
f)		
g)		
h)		

b. What is the net force (**magnitude** and **direction**) on all the spokes taken together?

Magnetic field shape

Question: Draw the magnetic field lines, showing relative strength in terms of line density, and including arrows for direction, for

a. bar magnet

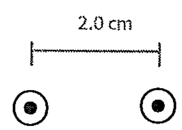


b. the earth

c. current loop

Magnetic field shape - Wires

1. Two wires are 2.0 cm apart and both carry parallel currents of 50 A out of the page.



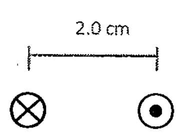
a. What is the magnetic field exactly half way in between the two wires?

b. What is the magnetic field 5 cm to the left of the lefthand wire?

c. What is the magnetic field 5 cm to the right of the righthand wire

d. Draw arrows at the points defined by a), b) and c) above to show the direction and relative magnitude of the fields you have calculated.

2. Now reverse the current in the lefthand wire.



a. What is the magnetic field exactly half way in between the two wires?

b. What is the magnetic field 5 cm to the left of the lefthand wire?

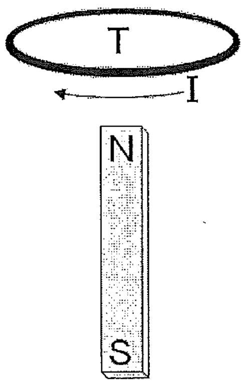
c. What is the magnetic field 5 cm to the right of the righthand wire?

d. Draw arrows at the points defined by a), b) and c) above to show the direction and relative magnitude of the fields you have calculated.

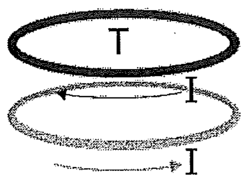
Forces on Current Loops and their Motion

In each of the following figures, a-e, what will be the motion of Current Loop **T**? Assume any magnets or loops other than **T** are held fixed in position.

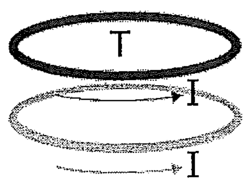
a)



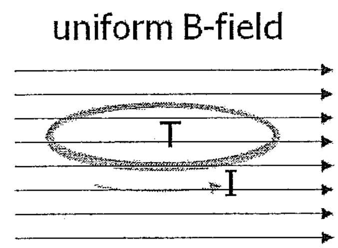
b)

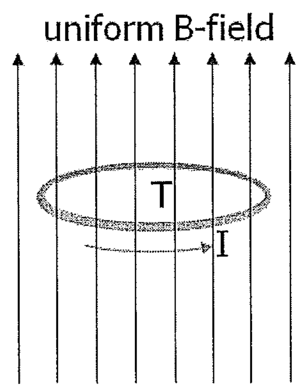


c)



d)



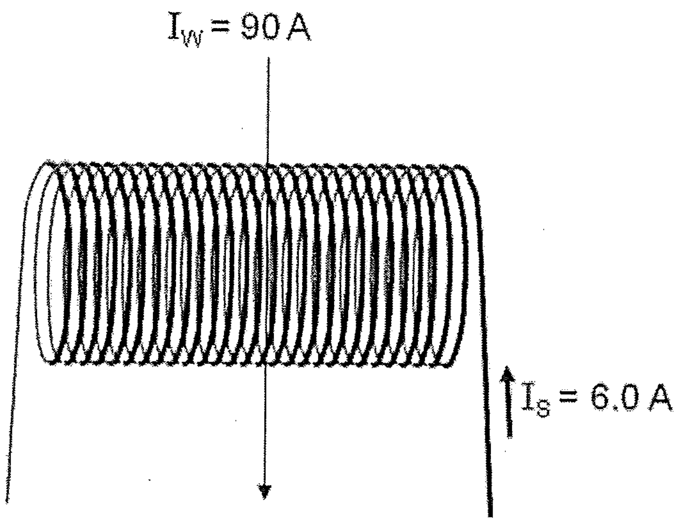


e)

Wire through Solenoid

A 'long' solenoid has 10,000 turns. It is 0.12 m in diameter, and 0.40 meter long. The current in the solenoid is 6.0A.
A wire carrying 90A passes through the center of the solenoid and at right angles to its long axis, as shown.

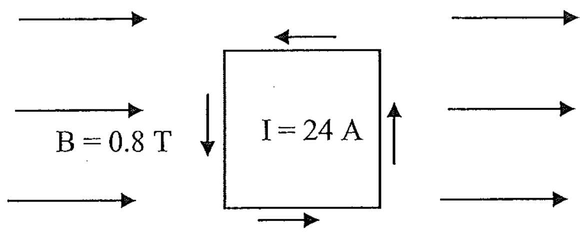
Question:
a) What is the force on the wire and what is its direction?



Hint: First find the field in the solenoid and then work out the force on the 90A current.

Torque on a current loop

1. A square loop is 0.2 m on a side and carries a current I = 24 A in a counterclockwise direction. It is immersed in a **horizontal** uniform field of 0.8 T.



a. What is the value and direction of the force on each side of the loop?

top

bottom

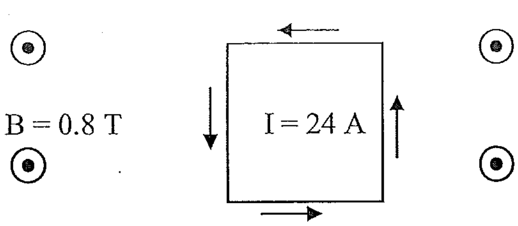
right

left

b. Use (a) to find the net torque on the loop?

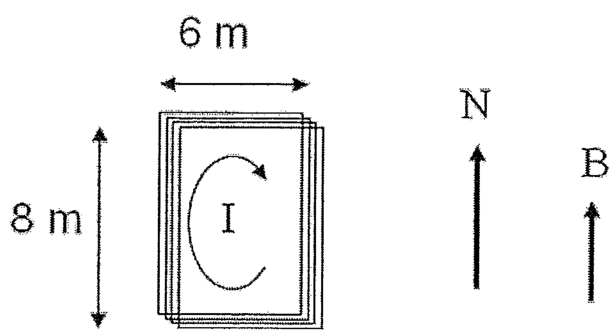
c. Use the formula, $\tau = NIAB \cos\theta$ to find the net torque on the loop:

d.



What is the torque on the loop now (same dimensions as (a) above)?

Torque on a rectangle

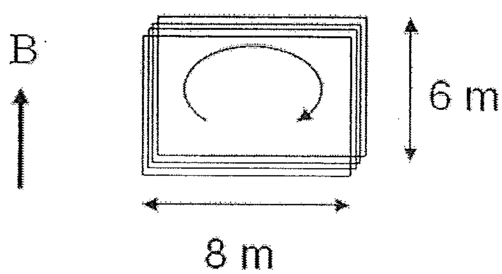


1. The Earth's magnetic field is 5.5×10^{-5} T. Assume we are at the equator and there is zero dip angle. A square wire coil that is 8 m long and 6 m wide is lying flat on the ground. The coil has 25 turns and is energized with a current of 10 A in the wire.

a) What is the torque on the coil due to the Earth's field? (Hint: find the force on each of the sides of the rectangle; pick an axis of rotation, and add up the torque due to each force)

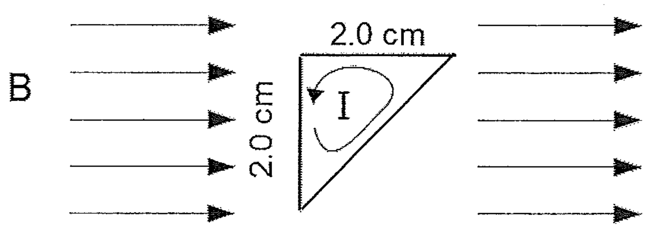
b) What is the net force on the coil?

2. Turn the coil 90° and repeat a) and b) above.



Torque on a triangle

A uniform magnetic field B = 0.78 T pointing from left to right is illustrated below. A loop shaped as a right-triangle is completely immersed in the B-field, and has dimensions shown.



A current I = 25 A flows as shown by the arrow. Give the forces on each of the left, diagonal and top sides of the loop.

left side F = direction =

diagonal side F = direction =

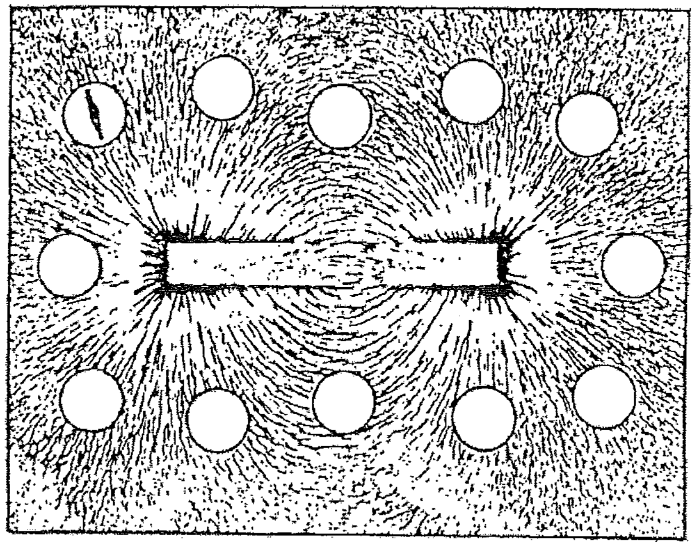
top side F = direction =

b. What is the net force on the coil?

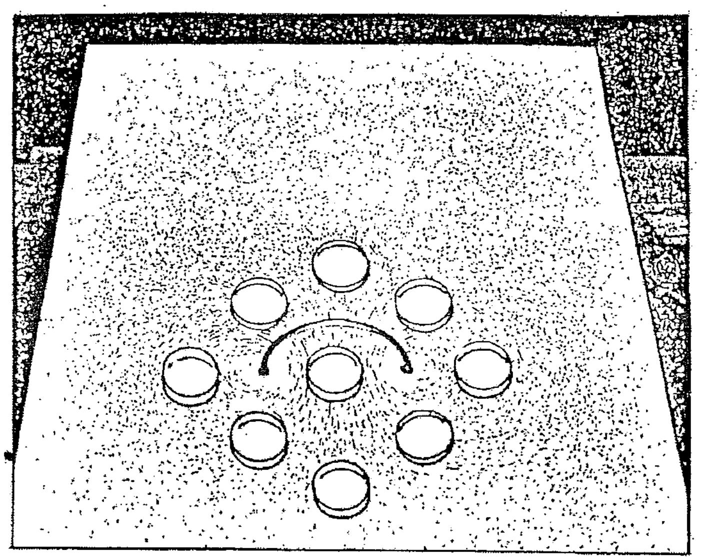
c. What is the direction of the axis around which the coil will rotate?

d. What is the torque on the loop?

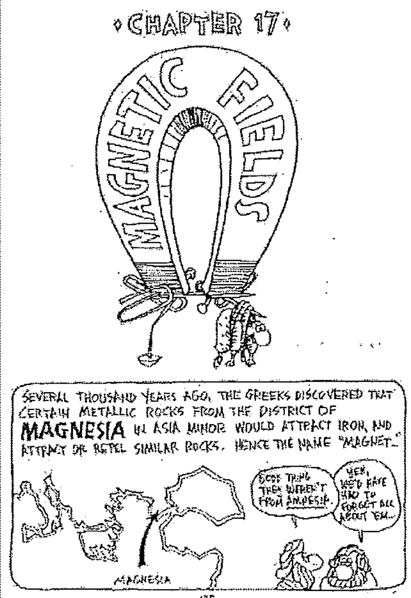
11. The illlustration below is similar to Figure 24.2 in your textbook. Iron filings trace out patterns of magnetic field lines about a bar magnet. In the field are some magnetic compasses. The compass needle in only one compass is shown. Draw in the needles with proper orientation in the other compasses.

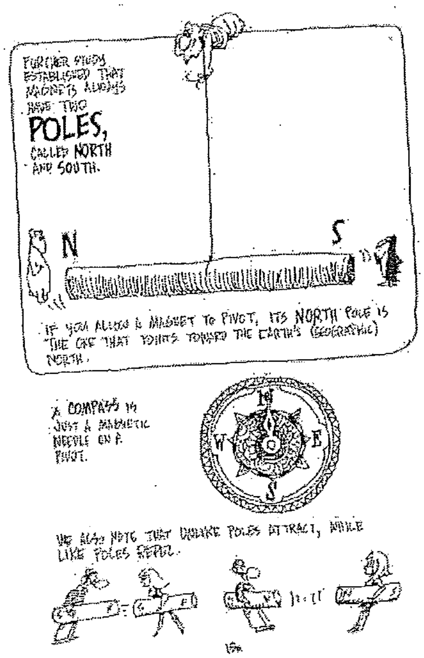


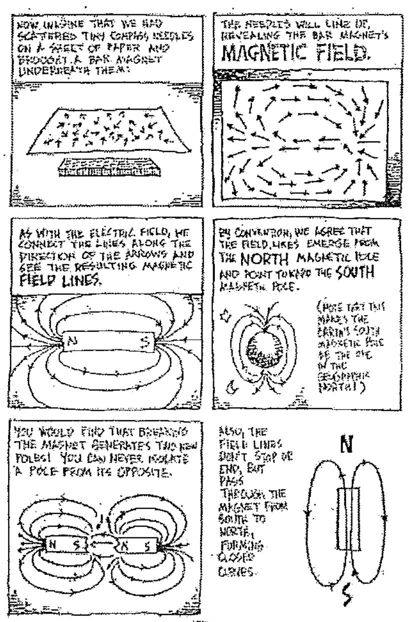
12. The illustration below is similar to Figure 24.10 (center) in your textbook. Iron filings trace out the magnetic field pattern about the loop of current-carrying wire. Draw in the compass needle orientations for all the compasses.

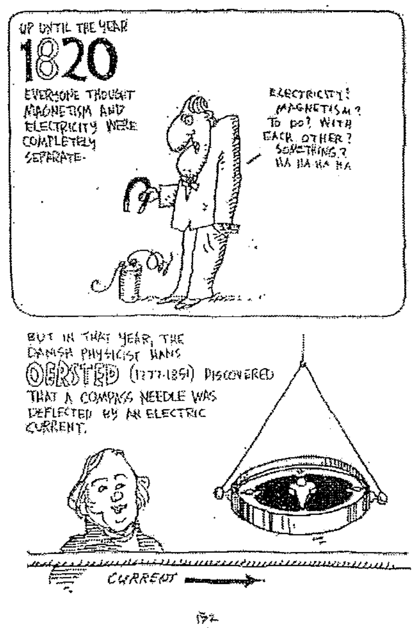


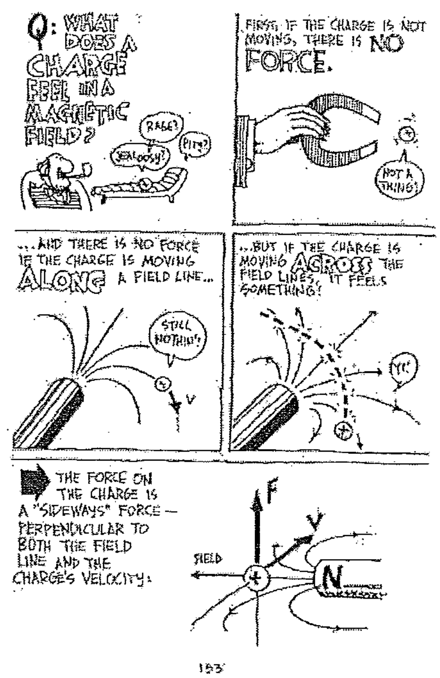
Ferromagnetism Cartoons

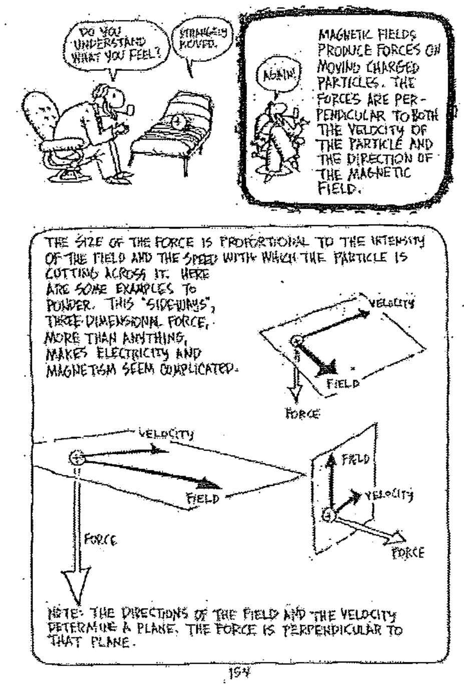


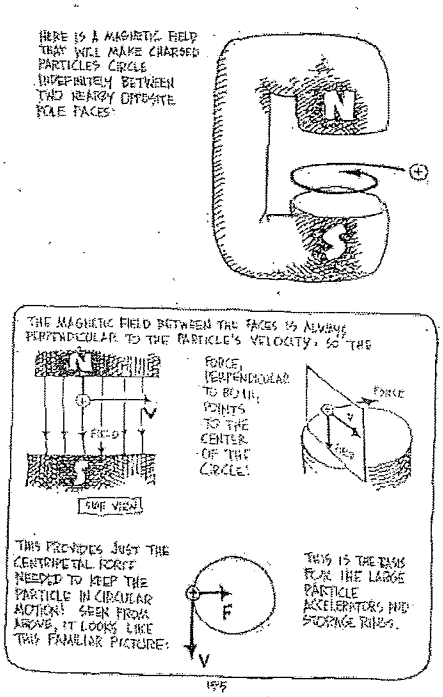


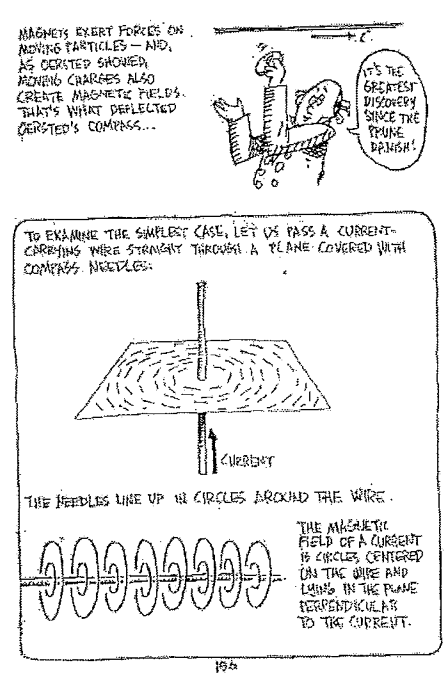


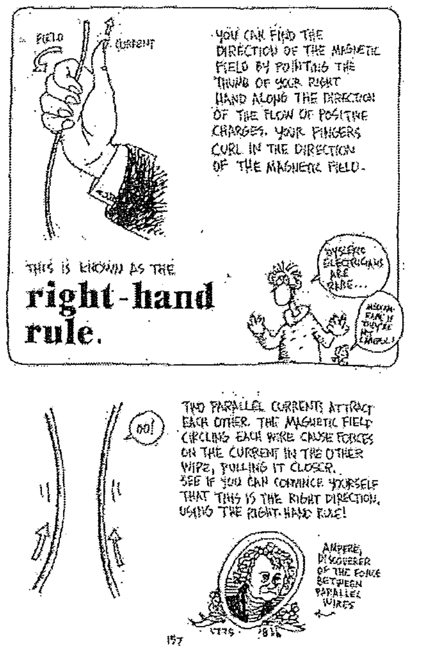


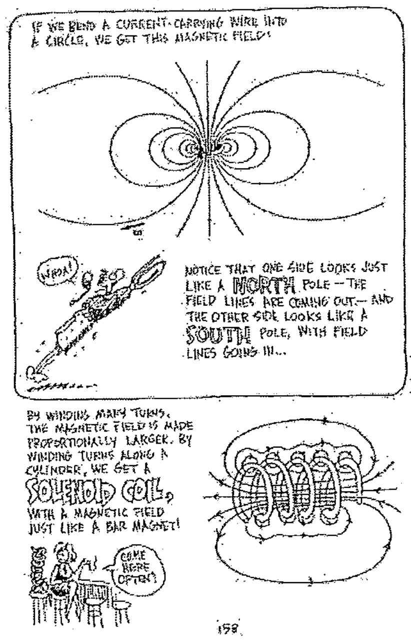

Q: WHAT DOES A CHARGE FEEL IN A MAGNETIC FIELD?
RAGE?
JEALOUSY?
PITY?
FIRST, IF THE CHARGE IS NOT MOVING, THERE IS NO FORCE.
NOT A THING!
...AND THERE IS NO FORCE IF THE CHARGE IS MOVING ALONG A FIELD LINE...
STILL NOTHIN'!
V
...BUT IF THE CHARGE IS MOVING ACROSS THE FIELD LINES, IT FEELS SOMETHING!
YI!
THE FORCE ON THE CHARGE IS A "SIDEWAYS" FORCE— PERPENDICULAR TO BOTH THE FIELD LINE AND THE CHARGE'S VELOCITY:
F
V
FIELD
N
153

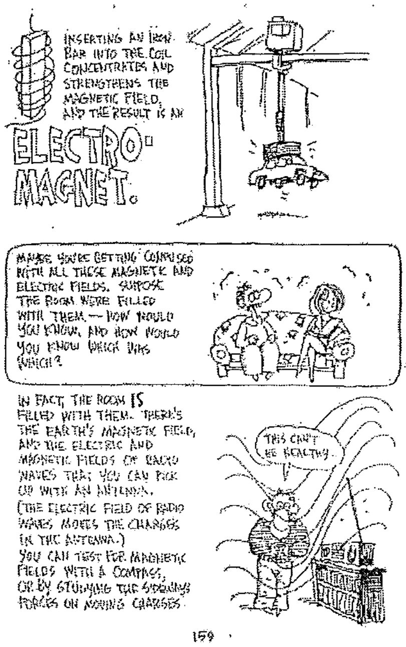

DO YOU UNDERSTAND WHAT YOU FEEL?
STRANGELY MOVED.
AGAIN!
MAGNETIC FIELDS PRODUCE FORCES ON MOVING CHARGED PARTICLES. THE FORCES ARE PERPENDICULAR TO BOTH THE VELOCITY OF THE PARTICLE AND THE DIRECTION OF THE MAGNETIC FIELD.
THE SIZE OF THE FORCE IS PROPORTIONAL TO THE INTENSITY OF THE FIELD AND THE SPEED WITH WHICH THE PARTICLE IS CUTTING ACROSS IT. HERE ARE SOME EXAMPLES TO PONDER. THIS "SIDEWAYS", THREE-DIMENSIONAL FORCE, MORE THAN ANYTHING, MAKES ELECTRICITY AND MAGNETISM SEEM COMPLICATED.
VELOCITY
FIELD
FORCE
VELOCITY
FIELD
FORCE
FIELD
VELOCITY
FORCE
NOTE: THE DIRECTIONS OF THE FIELD AND THE VELOCITY DETERMINE A PLANE. THE FORCE IS PERPENDICULAR TO THAT PLANE.
154

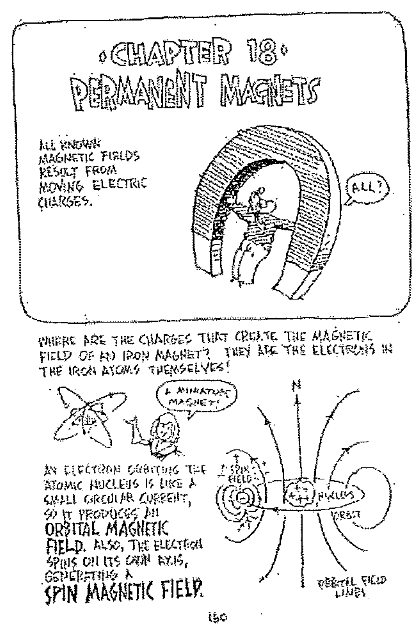

HERE IS A MAGNETIC FIELD THAT WILL MAKE CHARGED PARTICLES CIRCLE INDEFINITELY BETWEEN TWO NEARBY OPPOSITE POLE FACES:
N
S
THE MAGNETIC FIELD BETWEEN THE FACES IS ALWAYS PERPENDICULAR TO THE PARTICLE'S VELOCITY, SO THE
N
V
FIELD
S
SIDE VIEW
FORCE, PERPENDICULAR TO BOTH, POINTS TO THE CENTER OF THE CIRCLE!
FORCE
THIS PROVIDES JUST THE CENTRIPETAL FORCE NEEDED TO KEEP THE PARTICLE IN CIRCULAR MOTION! SEEN FROM ABOVE, IT LOOKS LIKE THIS FAMILIAR PICTURE:
F
V
THIS IS THE BASIS FOR THE LARGE PARTICLE ACCELERATORS AND STORAGE RINGS.
155

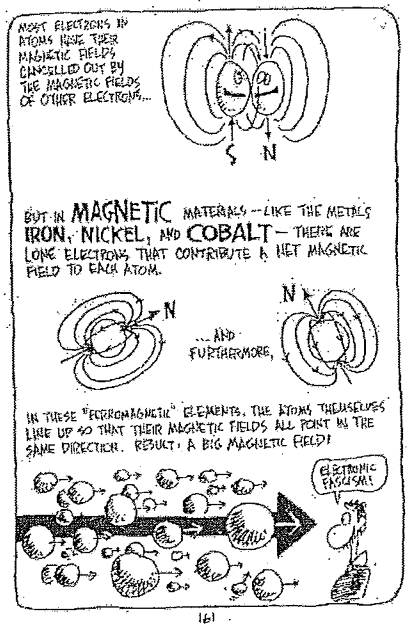

MAGNETS EXERT FORCES ON MOVING PARTICLES — AND, AS OERSTED SHOWED, MOVING CHARGES ALSO CREATE MAGNETIC FIELDS. THAT'S WHAT DEFLECTED OERSTED'S COMPASS...
IT'S THE GREATEST DISCOVERY SINCE THE PRUNE DANISH!
TO EXAMINE THE SIMPLEST CASE, LET US PASS A CURRENT-CARRYING WIRE STRAIGHT THROUGH A PLANE COVERED WITH COMPASS NEEDLES:
CURRENT
THE NEEDLES LINE UP IN CIRCLES AROUND THE WIRE.
THE MAGNETIC FIELD OF A CURRENT IS CIRCLES CENTERED ON THE WIRE AND LYING IN THE PLANE PERPENDICULAR TO THE CURRENT.
156

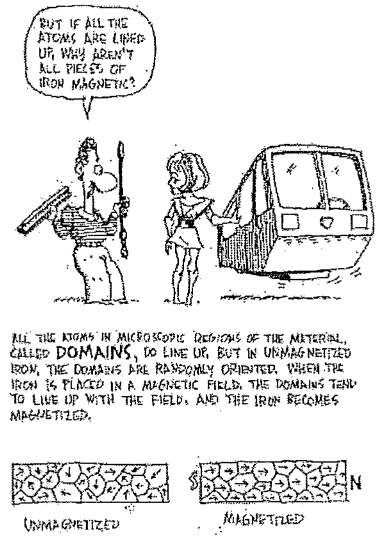

FIELD
CURRENT
YOU CAN FIND THE DIRECTION OF THE MAGNETIC FIELD BY POINTING THE THUMB OF YOUR RIGHT HAND ALONG THE DIRECTION OF THE FLOW OF POSITIVE CHARGES. YOUR FINGERS CURL IN THE DIRECTION OF THE MAGNETIC FIELD.
THIS IS KNOWN AS THE
right-hand rule.
DYSLEXIC ELECTRICIANS ARE RARE...
NO!
TWO PARALLEL CURRENTS ATTRACT EACH OTHER. THE MAGNETIC FIELD CIRCLING EACH WIRE CAUSE FORCES ON THE CURRENT IN THE OTHER WIRE, PULLING IT CLOSER.
SEE IF YOU CAN CONVINCE YOURSELF THAT THIS IS THE RIGHT DIRECTION, USING THE RIGHT-HAND RULE!
AMPERE, DISCOVERER OF THE FORCE BETWEEN PARALLEL WIRES
157


IF WE BEND A CURRENT-CARRYING WIRE INTO A CIRCLE, WE GET THIS MAGNETIC FIELD:
WHOA!
NOTICE THAT ONE SIDE LOOKS JUST LIKE A NORTH POLE — THE FIELD LINES ARE COMING OUT — AND THE OTHER SIDE LOOKS LIKE A SOUTH POLE, WITH FIELD LINES GOING IN...
BY WINDING MANY TURNS, THE MAGNETIC FIELD IS MADE PROPORTIONALLY LARGER. BY WINDING TURNS ALONG A CYLINDER, WE GET A
SOLENOID COIL,
WITH A MAGNETIC FIELD JUST LIKE A BAR MAGNET!
COME HERE OFTEN?
158


INSERTING AN IRON BAR INTO THE COIL CONCENTRATES AND STRENGTHENS THE MAGNETIC FIELD, AND THE RESULT IS AN
ELECTRO-MAGNET.
MAYBE YOU'RE GETTING CONFUSED WITH ALL THESE MAGNETIC AND ELECTRIC FIELDS. SUPPOSE THE ROOM WERE FILLED WITH THEM. — HOW WOULD YOU KNOW, AND HOW WOULD YOU KNOW WHICH WAS WHICH?
IN FACT, THE ROOM IS FILLED WITH THEM. THERE'S THE EARTH'S MAGNETIC FIELD, AND THE ELECTRIC AND MAGNETIC FIELDS OF RADIO WAVES THAT YOU CAN PICK UP WITH AN ANTENNA.
(THE ELECTRIC FIELD OF RADIO WAVES MOVES THE CHARGES IN THE ANTENNA.)
YOU CAN TEST FOR MAGNETIC FIELDS WITH A COMPASS, OR BY STUDYING THE SIDEWAYS FORCES ON MOVING CHARGES.
THIS CAN'T BE HEALTHY.
159


CHAPTER 18
PERMANENT MAGNETS
ALL KNOWN MAGNETIC FIELDS RESULT FROM MOVING ELECTRIC CHARGES.
ALL?
WHERE ARE THE CHARGES THAT CREATE THE MAGNETIC FIELD OF AN IRON MAGNET? THEY ARE THE ELECTRONS IN THE IRON ATOMS THEMSELVES!
A MINIATURE MAGNET!
N
AN ELECTRON ORBITING THE ATOMIC NUCLEUS IS LIKE A SMALL CIRCULAR CURRENT, SO IT PRODUCES AN ORBITAL MAGNETIC FIELD. ALSO, THE ELECTRON SPINS ON ITS OWN AXIS, GENERATING A SPIN MAGNETIC FIELD.
SPIN FIELD
NUCLEUS
ORBIT
ORBITAL FIELD LINES
160


MOST ELECTRONS IN ATOMS HAVE THEIR MAGNETIC FIELDS CANCELLED OUT BY THE MAGNETIC FIELDS OF OTHER ELECTRONS...
S
N
BUT IN MAGNETIC MATERIALS -- LIKE THE METALS IRON, NICKEL, AND COBALT -- THERE ARE LONE ELECTRONS THAT CONTRIBUTE A NET MAGNETIC FIELD TO EACH ATOM.
N
...AND FURTHERMORE,
N
IN THESE "FERROMAGNETIC" ELEMENTS, THE ATOMS THEMSELVES LINE UP SO THAT THEIR MAGNETIC FIELDS ALL POINT IN THE SAME DIRECTION. RESULT: A BIG MAGNETIC FIELD!
ELECTRONIC FASCISM!


BUT IF ALL THE ATOMS ARE LINED UP, WHY AREN'T ALL PIECES OF IRON MAGNETIC?
ALL THE ATOMS IN MICROSCOPIC REGIONS OF THE MATERIAL, CALLED DOMAINS, DO LINE UP, BUT IN UNMAGNETIZED IRON, THE DOMAINS ARE RANDOMLY ORIENTED. WHEN THE IRON IS PLACED IN A MAGNETIC FIELD, THE DOMAINS TEND TO LINE UP WITH THE FIELD, AND THE IRON BECOMES MAGNETIZED.
S
N
UNMAGNETIZED
MAGNETIZED


SOME METAL ALLOYS ARE MAGNETICALLY "HARD." IT TAKES A STRONG EXTERNAL MAGNETIC FIELD TO ORIENT THEIR DOMAINS-- BUT ONCE ORIENTED, THE DOMAINS TEND TO STAY LINED UP.
ALNICO V,
AN ALLOY OF ALUMINUM, NICKEL, COBALT, IRON, AND COPPER, IS VERY MAGNETICALLY HARD. PURE IRON, ON THE OTHER HAND IS MAGNETICALLY "SOFT": EASILY MAGNETIZED, BUT EASILY DEMAGNETIZED BY REMOVING THE EXTERNAL FIELD.
BOING
CAN'T SHAKE IT!
THE FERROMAGNETIC EFFECT OPERATES ONLY BELOW A CRITICAL TEMPERATURE, 770°C FOR IRON. HEATING DISRUPTS MAGNETISM.
PSST! WANNA BUY A "HOT" MAGNET?
CERTAINLY NOT
PRESUMABLY, THE EARTH'S MAGNETISM IS CAUSED BY CIRCULATING ELECTRIC FIELDS IN THE EARTH'S CORE. THE EXACT MECHANISM REMAINS A MYSTERY. DO YOU FIND IT RATHER AMUSING THAT THE FIRST MAGNETIC EFFECTS EVER DISCOVERED ARE STILL NOT SATISFACTORILY EXPLAINED?
HA
HA
HA
HA
HA
HA

Loudspeaker Mini Lab

You can make a loudspeaker from a magnet, a coil of wire, and a piece of paper.

1. Take 3 ft of fine wire and scrape the two ends of the wire to expose copper.

2. Coil up the wire around a 'C' cell, or other form, leaving 6" inches free at each end.

3. Glue the coiled part of the wire down to a piece of paper, or to a fancier cone you tape together.
4. Attach the stripped ends of the wire to a radio or signal generator.

5. Bring the magnet into proximity with the coil, and listen to the music!

Questions:

1. What is the position of the magnet, relative to the speaker coil, which gives the loudest and best sound?

2. Draw the above configuration of the coil and magnet, showing the magnetic field lines and magnet poles. What is the reason for the force between the magnet and the coil?

3. Why can you feel the vibrations of the music in your hand holding the magnet? Is it the sound hitting your fingers?

4. With the audio signal connected to the wires, move the magnet over to the fine wire. What effect do you see on the wire?

WB-22

transformers and generators

1. Transformer Problem – Peak Voltage

A telephone pole transformer takes 75000 VAC from the power company and converts it to 120 VAC.

If there are 160 turns on the secondary, how many turns in the primary coil?

If the neighborhood served has the capacity to use 5000 Amps, what is the current carried by the wire from the power company?

What is the peak voltage that the power company must design the insulation for the 75000 V line to withstand?

What is the instantaneous peak power the neighborhood can draw?

What is the 'resistance' of the neighborhood when it is taking the full 5000 Amps?

2. Motor Generators

20 V is applied to a rail gun electric motor. Assume there is no resistance in the circuit.

Assume there is no mechanical load, the motor achieves free-running speed. What is the current in the motor at this speed?

Next the rail experiences a force load which reduces the speed of the rail in half. What is the back emf of the motor now?

When the rail experiences a force which cuts the speed of the rail in half as described above, the power going to the mechanical load is 50 W. What is the current in the rail motor at this point?

Transformer Problems

1. You have a computer that requires 15 VAC to charge the battery. You use a transformer to step the voltage down from house current. The transformer has 700 turns in the primary.

a. How many turns must there be in the secondary of the transformer?

b. If the battery charger requires AC input current of 0.5 A rms, what will be the current draw from the house current outlet? (Assume the transformer is 100% efficient).

c. How much average power will be used by your transformer power supply?

2. A bank of theater lights uses a variable transformer to dim the lights. When the lights are dimmed to ½ power, the voltage required at the output of the transformer will be 84 VAC. If the input to the transformer primary is 120 VAC, what is the turns ratio of the stepdown transformer (primary:secondary ratio)?

3. A camera flash unit requires an output of 250 VAC to be produced from a 2.5 VAC source at the input of the transformer.

a. What is the turns ratio the transformer should have (primary:secondary) to accomplish this?

b. If the primary current is 1.2 A rms, what is the secondary current?

Motors / Generators

I. Motors: Describe the following essential components of a motor – how they are realized and how they are used:

A. Magnetic field

B. Coil of wire

C. Electric current

D. Mechanical System

II. Generators: Describe the following essential components of a generator – how they are realized and how they are used:

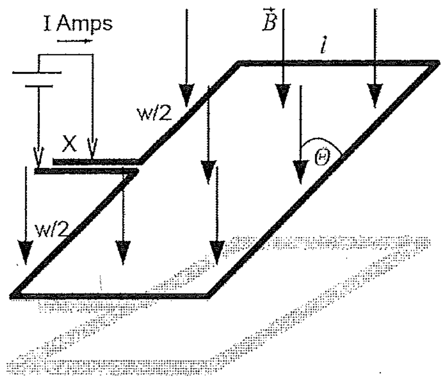
A. Magnetic field

B. Coil of wire

C. Electric current

D. Mechanical System

Dependence of torque on coil angle



Suppose the above coil has 150 turns, area A = .1 m^2, and B = 1.1 T. The current I is 40 A. The drawing shows angle Θ = 60°. Find the torque at each of the following angles Θ:

Θ = 30° τ =

Θ = 60° τ =

Θ = 90° τ =

Θ = 120° τ =

Θ = 150° τ =

Θ = 180° τ =

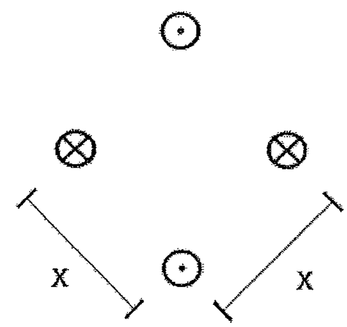
Θ = 210° τ =

Question: What really happens to the current in between Θ = 60° and Θ = 240°, due to the two switches?

Power Line – Force within square Array

Exercise in magnetic force and magnetic field

A power line consists of 4 wires arranged in a square array as shown. Assume the same current in each of the wires as in the previous problem: 126 A.



1. In the arrangement of lines shown, x = 0.30 m. What is B at the center of the arrangement of cables?

B =

2. Find the net force on a 1.0 m length of the wires in this arrangement. (One way is to find the x-component of force on the righthand wire. The other wires have the same magnitude of force, different direction).

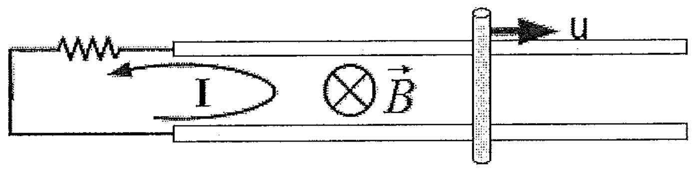
F =

3. What is the magnetic field B due to one of the wires, at a distance x from that wire?

B =

4. Think about this: Far from the foursome of wires, does the net magnetic field of the 4 wires together vary as 1/R, and why?

Faraday Rail Problem



Problem. Two rails are immersed in a magnetic field B = 0.32 T. The rails are 4.0 m apart. A conducting bar is moving along the rail at speed u = 12.0 m/s.

a. What is the rate at which B*Area is increasing due to the motion of the rail?

b. According to Faraday's Law, how much voltage is generated by the motion of the rail?

c. If the resistor in the circuit is R = 1.0 ohm, how much current I is flowing in the circuit?

d. Based on the amount of current and the magnetic field, what is the force on the conducting bar (magnitude and direction)?

Questions on Ferromagnetism

1. In what ways does ferromagnetism differ from ordinary magnetism?

2. What is a magnetic domain?

3. What metals are common for ferromagnetism?

4. What materials are used in the most powerful magnets?

5. What are the most powerful magnets used for in current technology?

6. What is the difference between permanent and non-permanent magnets?

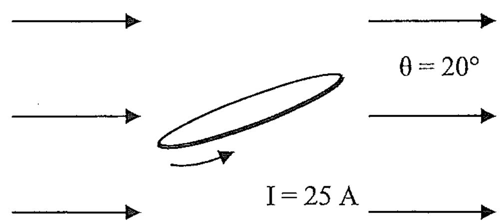
7. What is the role of atoms involved in ferromagnetism?

8. In a ferromagnetic material, what is the smallest entity that is magnetic aligned?

9. What is the difference between domains in iron that is not magnetized versus iron that is magnetized?

10. What is the difference between atoms in iron that is not magnetized versus atoms in iron that is magnetized?

Torque on round coil



Question 1. A round coil of wire having area 5.0 m^2 is immersed in a **uniform** magnetic field of 0.10 T, at an angle, as shown in the drawing. The loop has 450 turns. The wire in the loop is carrying 25 A.

a. What is the torque on the coil?

b. In what direction(s) will the coil tend to move and/or rotate?

c. The torque will be a maximum when the angle θ is 0° 45° 90° (circle one)

Electric Car Homework

Useful info:

- R = V/I the resistance given by the voltage V and current I
- P = V*I the power given by the voltage V and the current I
- I = Q/t the current is an amount of charge Q flowing in time t
- 1 hp = 755 Watts

Joe's Electric Car Information:

• 150 V	total voltage from battery
• 80	number of cells in battery
• 180 Ampere-hours	total charge in fully-charged battery
• 100 Amps	operating current at cruise
• 400 Amps	protective fuse blowout value
• 100 miles	range
• 85%	DC motor efficiency
• 95%	battery efficiency
• 100 hp	maximum horsepower
• 800 lbs	weight of the battery pack

Numerical questions:

1. 80 cells make up Joe's car battery. Are they connected in series or parallel? If the voltage output of the battery is 150 V, what is the voltage of each individual battery?

2. The battery charge capacity is 180 Ampere-hours. An Amp-hour is the amount of charge when one ampere flows for one hour. What is the charge of the battery in Coulombs?

3. Given the amount of stored charge you found in question 2), how much energy in Joules is stored in the car battery pack? Express this amount of energy in kWh (kilowatt hours).

4. Suppose Joe charges the vehicle every night. Although the battery itself is very efficient -- assume 100% efficient, his battery charger is only about 75% efficient. In order to charge the battery up to the energy level found in 3), how much money does Joe spend on electricity for the car every month? (Assume a typical cost of electricity for kWh – you may check your bill or use a value similar to what we discussed in class).

5. The electric car cruises while drawing a current of about 100 Amps. What is the power based on the voltage and this current? How many horsepower is this?

6. At cruising at 100 Amps, what is the effective electrical resistance of the motor?

7. Maximum power is 100 hp. Convert this into Watts of power. Given the voltage of 150 V, what is the current? What is the effective resistance of the motor at this voltage and current?

8. You make a trip in your electric car from Flagstaff (altitude 2100 m) to Prescott (altitude 1500 m), a distance of 92 miles. The car weighs 1200 kg. The range of your car is exactly 92 miles on level ground, but your car has a motor which is able to act as a generator and recover and store all the energy due to the height change (gravitational PE). What type of motor is this (AC or DC)? What is the amount of energy you recover on this trip?

General Questions:

1. Why does an electric motor run easily at 7000 rpm, whereas an ordinary gasoline engine struggles above 3-4000 rpm?

2. Why are the wires that feed your house with electricity just about the same thickness as the wires in Joe's car?

3. If nuclear power plants produce wasted energy during the off-peak hours late at night, why couldn't that energy be stored in everyone's electric car battery, and then used during the day?

4. Are the electrical safety problems in electric cars primarily a) dangerous voltage levels or b) dangerous current levels?

5. In your opinion (based on some facts), what are the main obstacles to greater usage of electric vehicles?

6. What are the major challenges of Li batteries for automobiles?

MiniLab: Vowels and Multiple modes

The human vocal cords produce a fundamental frequency and multiple harmonics, not just the fundamental. The harmonics which escape your throat are 'filtered' by the position of the lips and tongue.

In this experiment you will observe the harmonic freqencies of your voice using the Labpro in a special analyzer mode. The relative proportions of the different frequency components will depend upon what vowel you are pronouncing.

Procedure

Hook up the Labpro with a microphone. Open up the folder called PhysicsWithComputers, and select #22 Tones Vowels Telephone.xmbl. Click 'Collect' and sing a steady note into the microphone, as directed below. The upper graph will trace out the pressure variations over a brief time period.

You can't see how your vocal chords are vibrating, but the lower trace analyzes the specific frequencies that make up the tone. This is similar to shaking the slinky and getting a mixture of different modes with different numbers of nodes – each having a different frequency. The lower trace shows the several equally spaced frequencies and the relative proportion of each frequency.

1. Sing a very low pitch tone into the microphone. You would expect the fundamental frequency to be the strongest component of a low pitch. Is this the case?

Explain:

2. Sing a tone at medium pitch. How do expect the lowest pitch to move from 1) above?

Write down the first 5 harmonic frequencies:

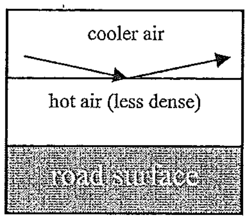
Write a formula for the first 5 pitches that depends on n (=1, 2, 3, ...):

3. Sing each of the different vowel sounds, Ay, Eee, Eye, Ooh , Yoou, and observe the pattern of harmonics. Which vowel has the strongest low frequency components? Which vowel sound has the stongest high frequency components?

Explain in terms of the relative opening of the mouth:

Total Internal Reflection

1. The refractive index of air is not exactly 1, it's really 1.000292 at room temperature. However, at the surface of a hot road, the air is less dense and the the refractive index is 1.000245. Consider the air



above the road as a sandwich of hot and cool air. If a light ray approaches the boundary between the two layers at a large angle of incidence, what is the critical angle at which there will be total internal reflection?

What is your experience with this type of reflection?

2. Find the critical angle for total internal reflection in diamond (n = 2.419).

What is the liklihood that a light ray inside diamond will escape without being reflected back inside?

3. Find the critical angle for total internal reflection in water (n = 1.33).

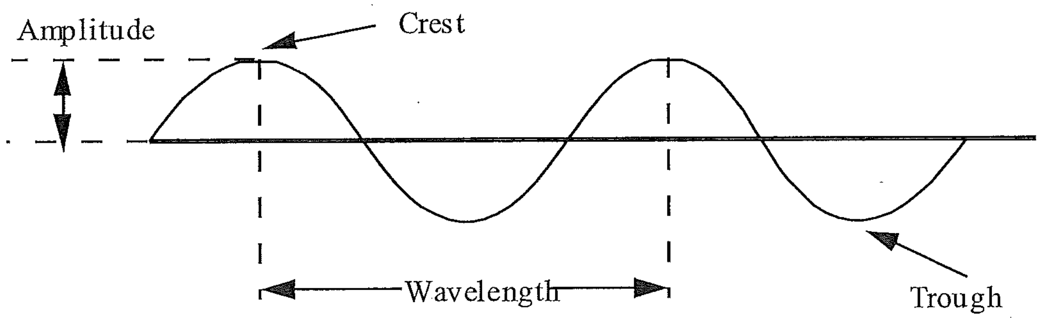
What would you see if you looked up at the sky from under the surface of a large body of still water?

4. How do light pipes use total internal reflection?

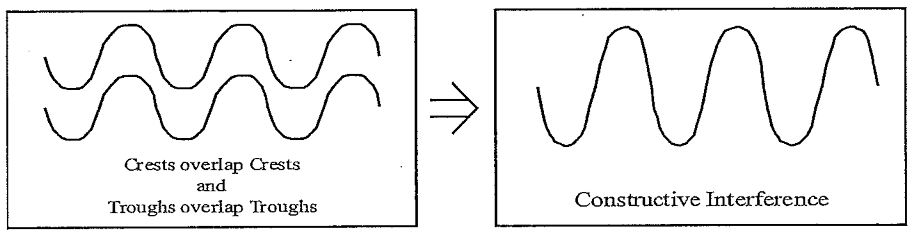
Interference

Investigation #1: Introduction

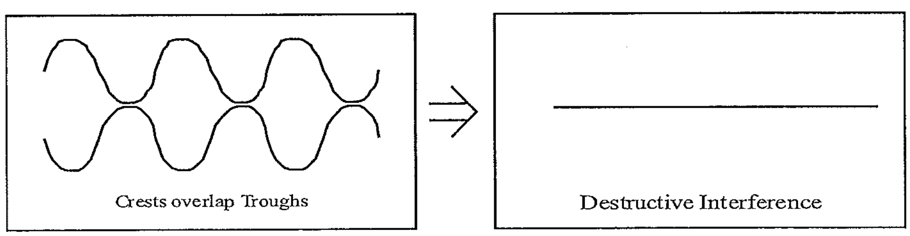
Introduction The diagram below shows a transverse wave traveling along a string. The terms 'crest', 'trough', 'amplitude', and 'wavelength' are labeled on the wave.

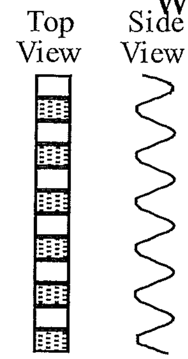


Interference occurs when two waves travel along the same string. Constructive interference occurs when the crest of one wave lines up with the crest of the other. Constructive interference also occurs when the troughs of the two waves overlap.

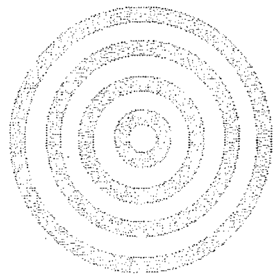


Destructive interference occurs when the crest of one wave lines up with the trough of the other.

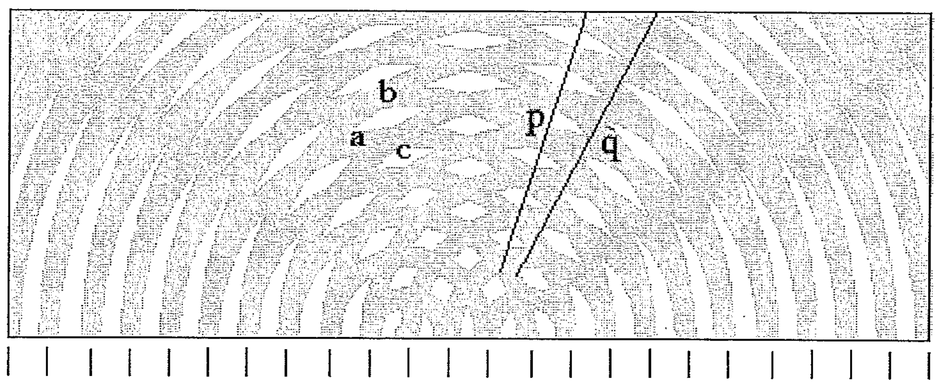




In many examples it is helpful to visualize these waves from a *top view*, a view where one is looking directly down onto the wave. The pattern may look something similar to the diagram at right. In this diagram the dark bands represent the troughs of a wave and the light bands represent the crests.



In the top view, it is easy to represent two-dimensional waves. For example, the pattern at left is a top view of the ripples that are created when a small stone is dropped into a pool of water. The experiment that follows focuses on what happens when two such waves interfere with each other.



Question

The grid lines along the edge of the above pattern are spaced 0.5cm apart. What is the distance between the two sources in the diagram above? (Q2)

What is the distance between the two sources in terms of (as a multiple of) the wavelength of the two waves? (Q3)

Is point 'a' in the diagram above a region of constructive or destructive interference? Explain your reasoning. (Q4)

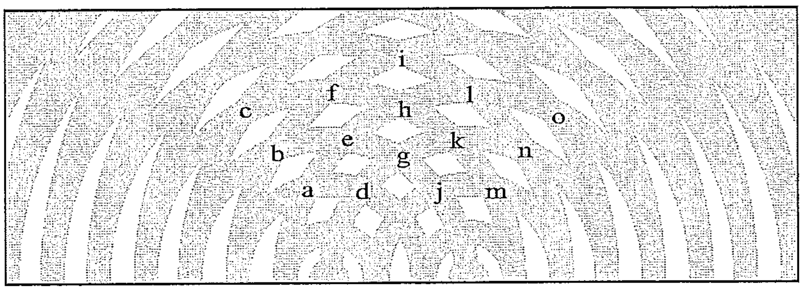
Is point 'b' in the diagram above a region of constructive or destructive interference? Explain your reasoning. (Q5)

Is point 'c' in the diagram above a region of constructive or destructive

interference? Explain your reasoning. (Q6)

Is constructive interference, destructive interference or a combination of the two occurring at each of the points along line 'p' in the diagram? (Q7)

Is constructive interference, destructive interference or a combination of the two occurring at each of the points along line 'q' in the diagram? (Q8)



Questions

Suppose you place the two patterns so that they overlap as shown above. The letters 'a' thru 'o' on this pattern identify several locations. Are the locations that have been labeled regions of constructive interference, destructive interference, both, or neither? (Q9)

Complete the table below by determining the distance (measured in wavelengths) that each labeled point is from the two wave sources. (Q10)

Point	Distance from Left Source	Distance from Right Source
a		
b		
c		
d		
e		
f		
g		
h		

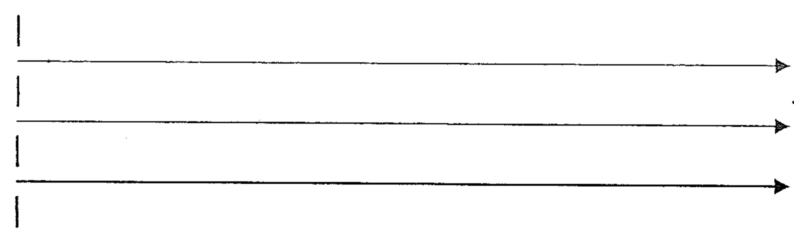
Point	Distance from Left Source	Distance from Right Source
i		
j		
k		
l		
m		
n		
o		

Questions

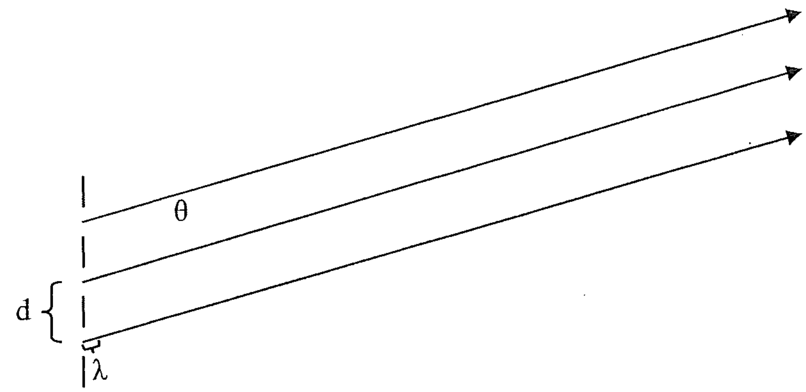
Suppose a line is drawn thru points a, b, and c. This line is often labeled n=2. A line drawn thru points d, e, and f is often labeled n=1. Examine the numbers you wrote in the table in the previous question and explain why this convention is used. (Q11)

Suppose now that waves come from a large number of equally-spaced sources – say, light coming from slits. Imagine that they are being viewed on a screen at a very large distance. The slits are separated an amount d meters.

In the forward direction (along $\theta = 0$, called 'n = 0', or 'principle maximum') the paths are all the same length, and the interference is constructive.

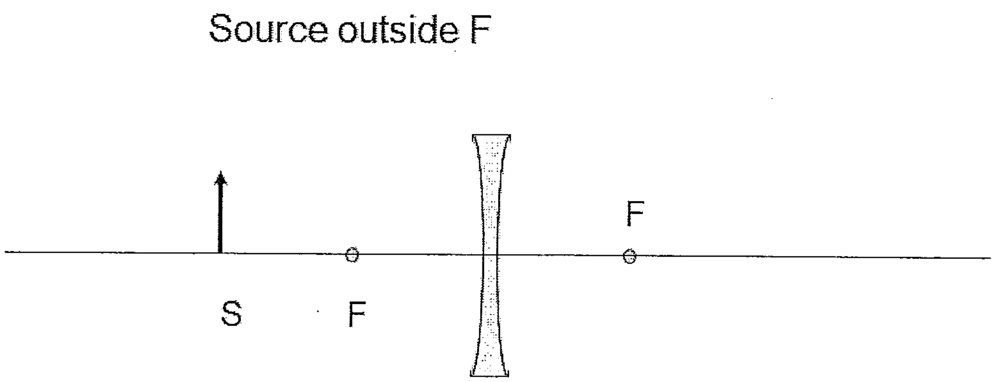


At an angle along θ such that the wavelength, $\lambda = d^*\sin\theta$, the interference is also constructive, because each path is one wavelength longer than the next. This is called the 'n = 1' fringe. There may be additional fringes for n = -1, n = ± 2, n = ± 3, etc.



Diverging Lens Imaging

1. Source outside F



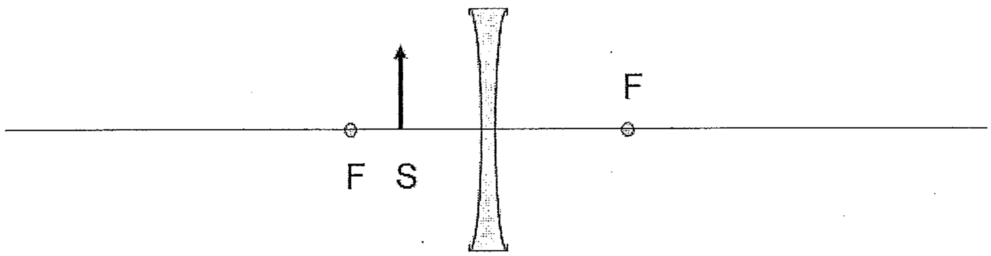
The object at location S is 24 cm from a **di**verging lens with a focal length of f = -12 cm.

a. Construct a ray trace to find the approximate location and size of the image.

b. Calculate the distance of the image from the lens in cm.

c. Find the magnification of the image.

2. Source inside F



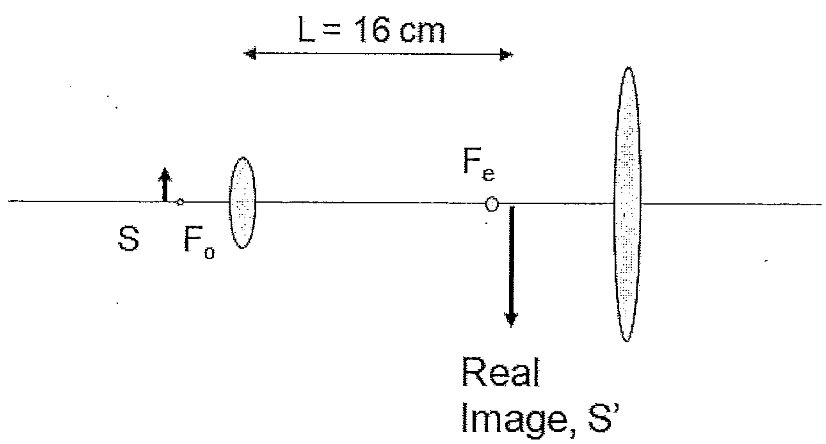
The object at location S is 8 cm from a **di**verging lens with a focal length of f = -12 cm.

a. Construct a ray trace to find the approximate location and size of the image.

b. Calculate the distance of the image from the lens in cm.

c. Find the magnification of the image.

PHY112 **Microscope**



a. Basic configuration: The object is placed near enough to Fo that a real image is formed at the top of the microscope whose length L = 16 cm. This real image is adjusted to be just inside the eyepiece focus Fe. The overall magnification will be the product of the first lens and second lens magnifications.

b. The objective lens has a focal length of 0.16 cm. What is its magnification, assuming the source distance $S \approx F_o$?

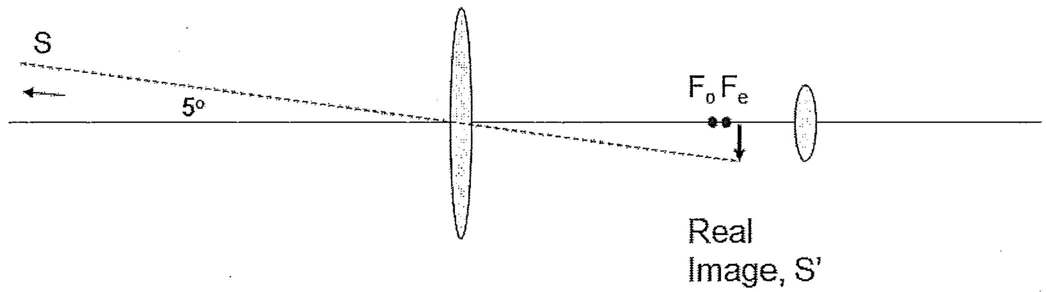
c. The eyepiece has a focal length of 2.5 cm. What is it's magnification assuming the Real Image $S \approx F_e$ and the image distance is –25 cm?

d. What is the overall magnification?

e. Draw the final virtual image at the correct location.

Telescope

(Magnifies angles, not objects)



a. Basic configuration: The object is very far away and produces a real image at or near Fo. This real image is adjusted to be just inside the eyepiece focus Fe.
The size of the image is smaller than the size of the object (of course) but *angles are magnified.*
b. The objective lens has a focal length of 50 cm. Assume the incoming angle is 5°. How far is the image arrow tip from the optical axis?

c. The eyepiece has a focal length of 2.5 cm. Assuming the image arrow S' is ≈ at Fe, what is the angle of the real image arrow tip as viewed from the eyepiece?

d. What is the angular magnification?

e. Draw the final virtual image at the correct location.

Cellphone Camera

Question 1. A cellphone camera is capturing the image of a dog. The dog is 0.65 m tall. The dog is 2.1 m away from the camera lens. The focal length of the lens is 0.50 cm.

a. What is the distance between the lens and the sensor, if the image is in focus on the camera sensor?

b. How large is the image of the dog on the camera sensor?

c. The width of a pixel in the camera is 2.0×10^{-6} m. What is the width of a spot on the dog if its image is exactly one pixel in width?

Question 2. For most people, a comfortable reading distance is 25 cm. A magnifying lens has a focal length = 5.0 cm.

a. How far should you place it from some very fine print in order that the image of the print is 25 cm from the lens?

b. What will be the image size, if the typeface is 5-point (5/72 inches) high?

Lens Power in Diopters

A diopter (D) is a unit of measurement of the optical power of a lens or curved mirror, which is equal to the reciprocal of the focal length measured in meters (that is, 1/metres). It is thus a unit of reciprocal length. For example, a 3-diopter lens brings parallel rays of light to focus at 1⁄3 meter. If the lens is concave, the focus is regarded as negative. The term was proposed by French ophthalmologist Felix Monoyer in 1872.

One benefit of quantifying a lens in terms of its optical power rather than its focal length is that when relatively thin lenses are placed close together their powers approximately add. Thus a thin 2-diopter lens placed close to a thin 0.5-diopter lens yields almost the same focal length as a 2.5-diopter lens would have.

Question 1. My contact lens prescription is – 2.50 D. With these contacts I can just barely adjust my eye muscles to focus images of very distant objects. Assume the muscles remain in that position throughout this problem.

a. If the focal length of my eye's lens with contacts is 1.82 cm, what is the combined power (in D) of the my eye's lens + contacts?

b. What is the power of my eye's lens alone with contacts removed?

c. I remove my contacts. What is the maximum distance I can see clearly without contacts?

d. Am I near-sighted or far-sighted?

Question 2. Repeat a-c assuming the contact lens prescription is – 3.50 D.

WB-48

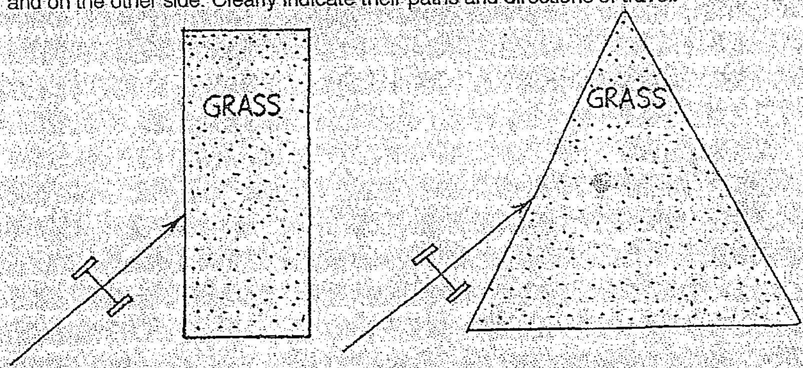
Name ______________________________ Date ____________

CONCEPTUAL *Physics* PRACTICE PAGE

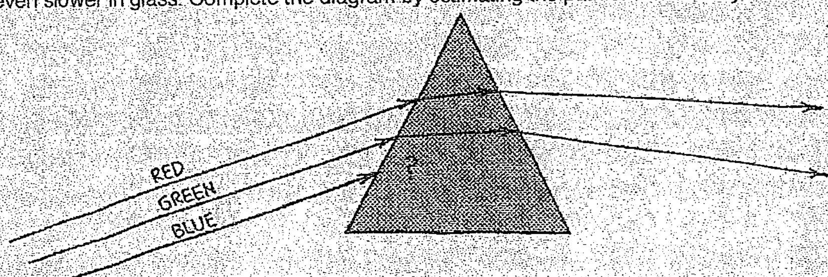
Chapter 28 Reflection and Refraction

Refraction

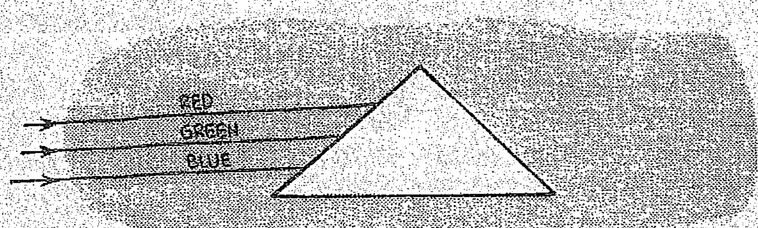
1. A pair of toy cart wheels are rolled obliquely from a smooth surface onto two plots of grass—a rectangular plot on the left, and a triangular plot on the right. The ground is on a slight incline so that after slowing down in the grass, the wheels speed up again when emerging on the smooth surface. Finish each sketch and show some positions of the wheels inside the plots and on the other side. Clearly indicate their paths and directions of travel.



2. Red, green, and blue rays of light are incident upon a glass prism as shown below. The average speed of red light in the glass is less than in air, so the red ray is refracted. When it emerges into the air it regains its original speed and travels in the direction shown. Green light takes longer to get through the glass. Because of its slower speed it is refracted as shown. Blue light travels even slower in glass. Complete the diagram by estimating the path of the blue ray.



3. Below we consider a prism-shaped hole in a piece of glass—that is, an "air prism." Complete the diagram, showing likely paths of the beams of red, green, and blue light as they pass through this "prism" and then into glass.



Hewitt Drew it!

Name ______________________ Date __________

CONCEPTUAL Physics PRACTICE PAGE

Chapter 28 Reflection and Refraction

More Refraction

1. The sketch to the right shows a light ray moving from air into water, at 45° to the normal. Which of the three rays indicated with capital letters is most likely the light ray that continues inside the water?

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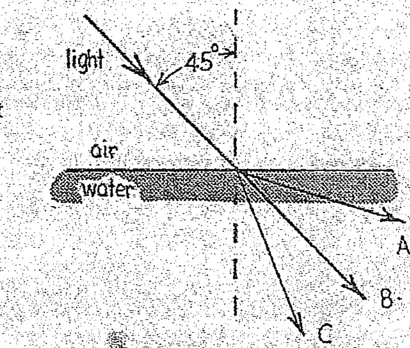
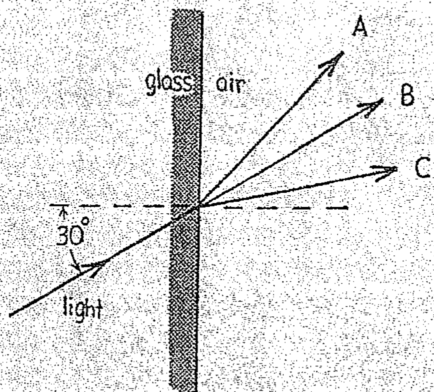
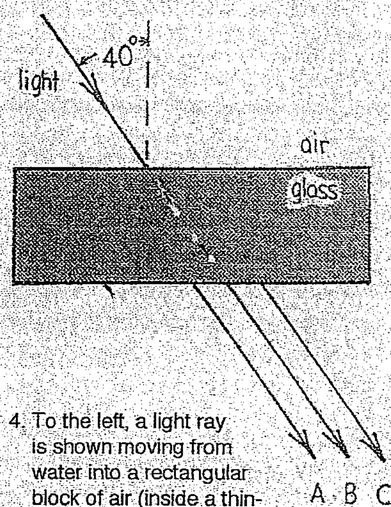




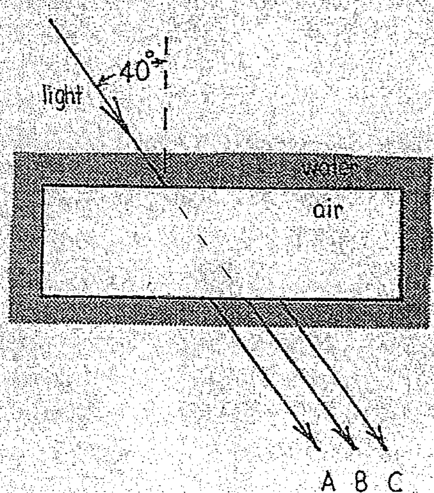
2. The sketch on the left shows a light ray moving from glass into air, at 30° to the normal. Which of the three is most likely the light ray that continues in the air?

____



3. To the right, a light ray is shown moving from air into a glass block, at 40° to the normal. Which of the three rays is most likely the light ray that travels in the air after emerging from the opposite side of the block? (Sketch the path the light would take inside the glass.)

____



4. To the left, a light ray is shown moving from water into a rectangular block of air (inside a thin-walled plastic box), at 40° to the normal. Which of the rays is most likely the light ray that continues into the water on the opposite side of the block?

____

Sketch the path the light would take inside the air.

thanx to Clarence Bakken

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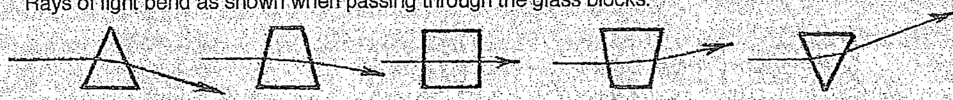
Name ______________________ Date __________

CONCEPTUAL **Physics** PRACTICE PAGE

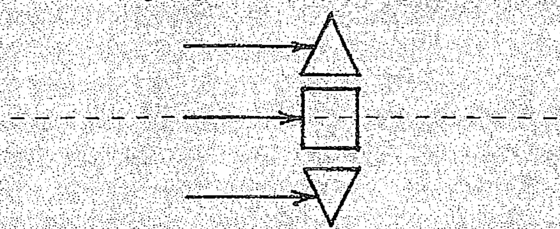
Chapter 28 Reflection and Refraction

Lenses

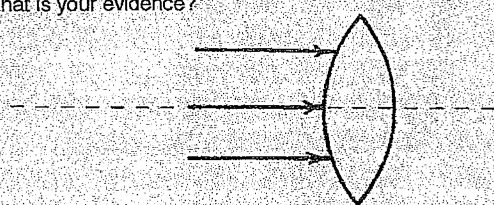
Rays of light bend as shown when passing through the glass blocks.



1. Show how light rays bend when they pass through the arrangement of glass blocks below.



2. Show how light rays bend when they pass through the lens below. Is the lens a converging or a diverging lens? What is your evidence?



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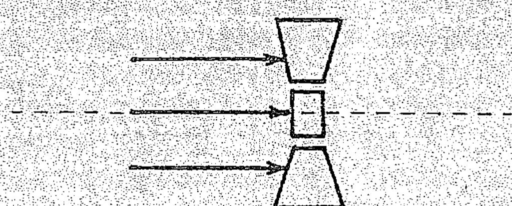
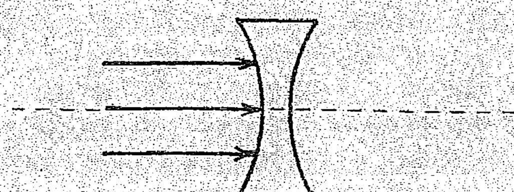
3. Show how light rays bend when they pass through the arrangement of glass blocks below.



4. Show how light rays bend when they pass through the lens shown below. Is the lens a converging or diverging lens? What is your evidence?



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Hewitt Drew it!

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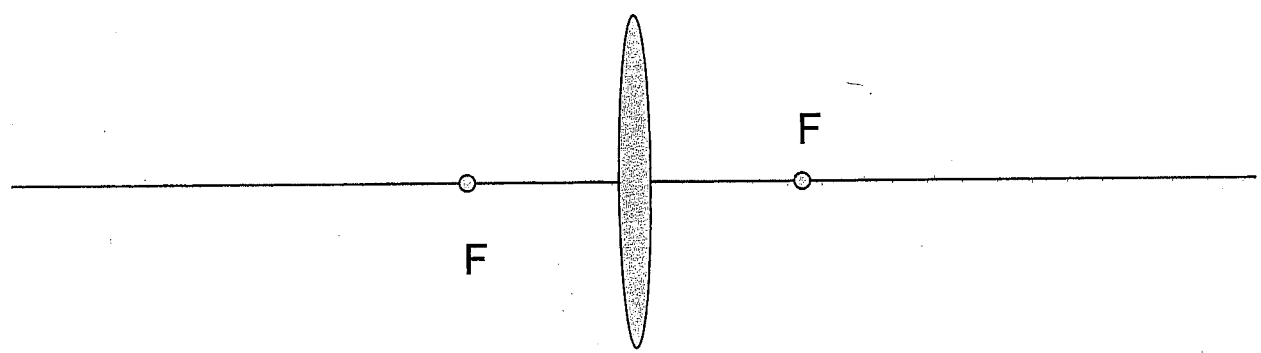
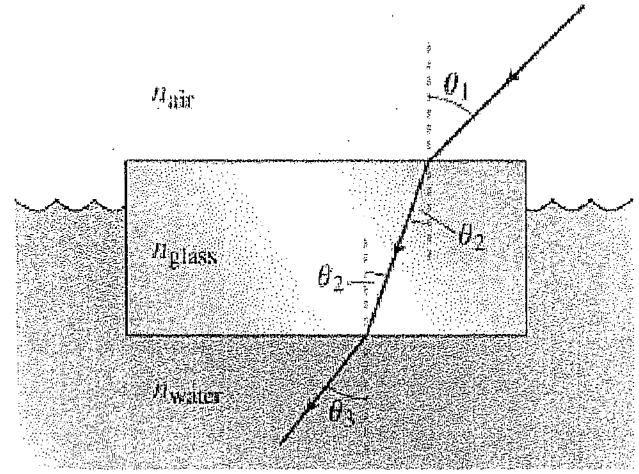
Convex Lens Imaging



WB-50



A plate of glass with parallel faces having a refractive index of 1.57 is resting on the surface of water in a tank. A ray of light coming from above in air makes an angle of incidence 37.0 with the normal to the top surface of the glass. (Figure 1)

Part A

What angle does the ray refracted into the water make with the normal to the surface? Use 1.33 for the index of refraction of water.