Electricity and Magnetism Problems

Concepts and principles from electricity and magnetism can solve the problems in this section. The problems are divided into five groups according to the major principles required for solution: (1) electric force and field; (2) electric potential energy; (3) electric power; (4) circuits; and (5) magnetic force and field. The specific principles required are indicated in Italics at the beginning of each problem.

Electric Force and Field

1. *Electric Force:* You and a friend are doing the laundry when you unload the dryer and the discussion comes around to static electricity. Your friend wants to get some idea of the amount of charge that causes static cling. You immediately take two empty soda cans, which each have a mass of 120 grams, from the recycling bin. You tie the cans to the two ends of a string (one to each end) and hang the center of the string over a nail sticking out of the wall. Each can now hangs straight down 30 cm from the nail. You take your flannel shirt from the dryer and touch it to the cans, which are touching each other. The cans move apart until they hang stationary at an angle of 10° from the vertical. Assuming that there are equal amounts of charge on each can, you now calculate the amount of charge transferred from your shirt.

2. *Electric Force:* You are part of a design team assigned the task of making an electronic oscillator that will be the timing mechanism of a micro-machine. You start by trying to understand a simple model which is an electron moving along an axis through the center and perpendicular to the plane of a thin positively charged ring. You need to determine how the oscillation frequency of the electron depends on the size and charge of the ring for displacements of the electron from the center of the ring which are small compared to the size of the ring. A team member suggests that you first determine the acceleration of the electron along the axis as a function of the size and charge of the ring and then use that expression to determine the oscillation frequency of the electron for small oscillations.

3. *Electric Force:* You are spending the summer working for a chemical company. Your boss has asked you to determine where a chlorine ion of effective charge -e would situate itself near a carbon dioxide ion. The carbon dioxide ion is composed of 2 oxygen ions each with an effective charge -2e and a carbon ion with an effective charge +3e. These ions are arranged in a line with the carbon ion sandwiched midway between the two oxygen ions. The distance between each oxygen ion and the carbon ion is 3.0×10^{-11} m. Assuming that the chlorine ion is on a line that is perpendicular to the axis of the carbon dioxide ion and that the line goes through the carbon ion, what is the equilibrium distance for the chlorine ion relative to the carbon ion on this line? For simplicity, you assume that the carbon dioxide ion does not deform in the presence of the chlorine ion. Looking in your trusty physics textbook, you find the charge of the electron is 1.60×10^{-19} C.

4. *Electric Force:* You have been asked to review a new apparatus, which is proposed for use at a new semiconductor ion implantation facility. One part of the apparatus is used to slow down He ions which are positive and have a charge twice that of an electron (He^{++}). This part consists of a circular wire that is charged negatively so that it becomes a circle of charge. The ion has a velocity

of 200 m/s when it passes through the center of the circle of charge on a trajectory perpendicular to the plane of the circle. The circle has a charge of 8.0 μC and radius of 3.0 cm. The sample with which the ion is to collide will be placed 2.5 mm from the charged circle. To check if this device will work, you decide to calculate the distance from the circle that the ion goes before it stops. To do this calculation, you assume that the circle is very much larger than the distance the ion goes and that the sample is not in place. Will the ion reach the sample? You look up the charge of an electron and mass of the helium in your trusty Physics text to be 1.6×10^{-19} C and 6.7×10^{-27} Kg.

5. *Electric Force:* You've been hired to design the hardware for an ink jet printer. You know that these printers use a deflecting electrode to cause charged ink drops to form letters on a page. The basic mechanism is that uniform ink drops of about 30 microns radius are charged to varying amounts after being sprayed out towards the page at a speed of about 20 m/s. Along the way to the page, they pass into a region between two deflecting plates that are 1.6 cm long. The deflecting plates are 1.0 mm apart and charged to 1500 volts. You measure the distance from the edge of the plates to the paper and find that it is one-half inch. Assuming an uncharged droplet forms the bottom of the letter, how much charge is needed on the droplet to form the top of a letter 3 mm high (11 pt. type)?

6. *Electric Force:* While working in a University research laboratory your group is given the job of testing an electrostatic scale, which is used to precisely measure the weight of small objects. The device consists of two very light but strong strings attached to a support so that they hang straight down. An object is attached to the other end of each string. One of the objects has a very accurately known weight while the other object is the unknown. A power supply is slowly turned on to give each object an electric charge. This causes the objects to slowly move away from each other. When the power supply is kept at its operating value, the objects come to rest at the same horizontal level. At that time, each of the strings supporting them makes a different angle with the vertical and that angle is measured. To test your understanding of the device, you first calculate the weight of an unknown sphere from the measured angles and the weight of a known sphere. Your known is a standard sphere with a weight of 2.000 N supported by a string that makes an angle of 10.00° with the vertical. The unknown sphere's string makes an angle of 20.00° with the vertical. As a second step in your process of understanding this device, estimate the net charge on a sphere necessary for the observed deflection if a string were 10 cm long. Make sure to give the assumptions you used for this estimate.

7. *Electric Force:* You and a friend have been given the task of designing a display for the Physics building that will demonstrate the strength of the electric force. Your friend comes up with an idea that sounds neat theoretically, but you're not sure it is practical. She suggests you use an electric force to hold a marble in place on a sloped plywood ramp. She would get the electric force by attaching a uniformly charged semicircular wire near the bottom of the ramp, laying the wire flat on the ramp with each of its ends pointing straight up the ramp. She claims that if the charges on the marble and ring and the slope of the ramp are chosen properly, the marble would be balanced midway between the ends of the wire.

To test this idea, you decide to calculate the necessary amount of charge on the marble for a reasonable ramp angle of 15 degrees and a semicircle of radius 10 cm with a charge of 800 micro-coulombs. The marble would roll in a slot cut lengthwise into the center of the ramp. The mass of the lightest marble you can find is 25 grams.

8. *Electric Force, Gauss's Law:* You have a great summer job in a research laboratory with a group investigating the possibility of producing power from fusion. The device being designed confines a hot gas of positively charged ions, called plasma, in a very long cylinder with a radius of 2.0 cm. The charge density of the plasma in the cylinder is 6.0×10^{-5} C/m^3. Positively charged Tritium ions are to be injected into the plasma perpendicular to the axis of the cylinder in a direction toward the center of the cylinder. Your job is to determine the speed that a Tritium ion should have when it enters the plasma cylinder so that its velocity is zero when it reaches the axis of the cylinder. Tritium is an isotope of Hydrogen with one proton and two neutrons. You look up the charge of a proton and mass of the tritium in your trusty Physics text to be 1.6×10^{-19} C and 5.0×10^{-27} Kg.

Electric and Gravitational Force: You and a friend are reading a newspaper article about nuclear fusion energy generation in stars. The article describes the helium nucleus, made up of two protons and two neutrons, as very stable so it doesn't decay. You immediately realize that you don't understand why the helium nucleus is stable. You know that the proton has the same charge as the electron except that the proton charge is positive. Neutrons you know are neutral. Why, you ask your friend, don't the protons simply repel each other causing the helium nucleus to fly apart? Your friend says she knows why the helium nucleus does not just fly apart. The gravitational force keeps it together, she says. Her model is that the two neutrons sit in the center of the nucleus and gravitationally attract the two protons. Since the protons have the same charge, they are always as far apart as possible on opposite sides of the neutrons. What mass would the neutron have if this model of the helium nucleus works? Is that a reasonable mass? Looking in your physics book, you find that the mass of a neutron is about the same as the mass of a proton and that the diameter of a helium nucleus is 3.0×10^{-13} cm.

10. *Electric Field:* You are helping to design a new electron microscope to investigate the structure of the HIV virus. A new device to position the electron beam consists of a charged circle of conductor. This circle is divided into two half circles separated by a thin insulator so that half of the circle can be charged positively and half can be charged negatively. The electron beam will go through the center of the circle. To complete the design your job is to calculate the electric field in the center of the circle as a function of the amount of positive charge on the half circle, the amount of negative charge on the half circle, and the radius of the circle.

11. *Electric Field:* You have a summer job with the telephone company working in a group investigating the vulnerability of underground telephone lines to natural disasters. Your task is to write a computer program which will be used determine the possible harm to a telephone wire from the high electric fields caused by lightning. The underground telephone wire is supported in the center of a long, straight steel pipe that protects it. When lightening hits the ground it charges the steel pipe. You are concerned that the resulting electric field might harm the telephone wire. Since

you know that the largest field on the wire will be where it leaves the end of the pipe, you calculate the electric field at that point as a function of the length of the pipe, the radius of the pipe, and the charge on the pipe.

Electric Potential Energy

12. *Electric Potential Energy:* While sitting in a restaurant with some friends, you notice that some "neon" signs are different in color than others. You know that these signs are essentially just gas sealed in a glass tube. The gas, when heated electrically, gives off light. One of your friends, who is an art major, and makes such signs as sculpture, tells you that the color of the light depends on which gas is in the tube. All "neon" signs are not made using neon gas. You know that the color of light tells you its energy. Red light is a lower energy than blue light. Since the light is given off by the atoms, which make up the gas, the different colors must depend on the structure of the different atoms of different gases. Suppose that atomic structure is as given by the Bohr theory which states that electrons are in uniform circular motion around a heavy, motionless nucleus in the center of the atom. This theory also states that the electrons are only allowed to have certain orbits. When an atom changes from one allowed orbit to another allowed orbit, it radiates light as required by the conservation of energy. Since only certain orbits are allowed, so the theory goes, only light of certain energies (colors) can be emitted. This seems to agree with the observations of your artist friend. You decide to test the theory by calculating the energy of light emitted by a simple atom when an electron makes a transition from one allowed orbit to another. You decide to consider hydrogen since you know it is the simplest atom with one electron and a nucleus consisting of one proton. You remember that the proton has a mass 2000 times that of an electron. When you get home you look in your textbook and find the electron mass is 9×10^{-31} kg and its charge is 1.6×10^{-19} C. The radius of the smallest allowed electron orbit for hydrogen is 0.5×10^{-10} meters, which determines the normal size of the atom. The next allowed orbit has a radius 4 times as large as the smallest orbit.

13. *Electric Potential Energy:* You have a great summer job working in a cancer research laboratory. Your team is trying to construct a gas laser that will give off light of an energy that will pass through the skin but be absorbed by cancer tissue. You know that an atom emits a photon (light) when an electron goes from a higher energy orbit to a lower energy orbit. Only certain orbits are allowed in a particular atom. To begin the process, you calculate the energy of photons emitted by a Helium ion in which the electron changes from an orbit with a radius of 0.30 nanometers to another orbit with a radius of 0.20 nanometers. A nanometer is 10^{-9} m. The helium nucleus consists of two protons and two neutrons.

14. *Electric Potential Energy:* Your job is to evaluate an electron gun designed to initiate an electron beam. The electrons have a 20 cm path from the heating element, which emits them to the end of the gun. This path is through a very good vacuum. For most applications, the electrons must reach the end of the gun with a speed of at least 10^7 m/s. After leaving the heating element, the electrons pass through a 5.0 mm diameter hole in the center of a 3.0 cm diameter charged circular disk. The

disk's charge density is kept at 3.0 $\mu C/m^2$. The heating element is a spherical electrode 0.10 mm in diameter that is kept at a very high charge of -0.10C. There is 1.0 cm between the heating element and the hole in the disk. Your first step is to determine if the electrons are going fast enough. Your boss has pointed that the hole in the disk is too large to ignore in your calculations. Using your physics text you find that the mass of the electron is 9.11 x 10^{-31} kg.

15. *Electric Potential Energy - Gauss's Law:* You have landed a summer job working with an Astrophysics group investigating the origin of high-energy particles in the galaxy. The group you are joining has just discovered a large spherical nebula with a radius 1.2 million km. The nebula consists of about 5 x 10^{10} hydrogen nuclei (protons) which appear to be uniformly distributed in the shape of a sphere. At the center of this sphere of positive charge is a very small neutron star. Your group had detected electrons emerging from the nebula. A friend of yours has a theory that the electrons are coming from the neutron star. To test that theory, she asks you to calculate the minimum speed that an electron would need to start from the neutron star and just make it to outside the nebula. From the inside cover of your trusty physics text you find that the charge of a proton (and an electron) is 1.6 x 10^{-19} C, the mass of the proton is 1.7 x 10^{-27} kg, and the mass of the electron is 9.1 x 10^{-31} kg.

16. *Electric Potential Energy, Gauss's Law:* You are working in cooperation with the Public Health department to design an electrostatic trap for particles from auto emissions. The average particle enters the device and is exposed to ultraviolet radiation that knocks off electrons so that it has a charge of +3.0 x 10^{-8} C. This average particle is then moving at a speed of 900 m/s and is 15 cm from a very long negatively charged wire with a linear charge density of -8.0 x 10^{-6} C/m. The detector for the particle is located 7.0 cm from the wire. In order to design the proper kind of detector, your colleagues need to know the speed that an average emission particle will have if it hits the detector. They tell you that an average emission particle has a mass of 6.0 x 10^{-9} kg.

17.. *Electric Potential Energy, Heat Energy (Heat Capacity, Latent Heat):* You are reading a newspaper report of a lightning strike in Jackson, Wyoming. Two men were sitting at a table outside a small cafe on a beautiful 30 ^oC day when a thunderstorm approached. Suddenly, a bolt of lightning struck a large aspen tree near their table. Needless to say, the men were very startled. One of the men remarked, "It just about scared the espresso out of me." They reported that when the bolt hit the tree and there was a loud hiss and a release of much steam from the tree. The lightning had boiled away some of the tree's sap. You are curious, and wonder how much water could be evaporated in this manner. So you study your physics book and make a few estimates and assumptions. You estimate that the electric potential difference between the tree and the thunderhead cloud was about 10^8 volts, and the amount of charge released by the bolt was about 50 Coulombs. You also assume that about 1% of the electrical energy was actually transferred into the sap, which is essentially water. The specific heat capacity of water is 4200 J/(kg ^oC) and its heat of vaporization is 2.3 x 10^6 J/kg.

18. *Electric Potential Energy, Gravitational Force:* NASA has asked your team of rocket scientists about the feasibility of a new satellite launcher that will save rocket fuel. NASA's idea is

basically an electric slingshot that consists of 4 electrodes arranged in a horizontal square with sides of length d at a height h above the ground. The satellite is then placed on the ground aligned with the center of the square. A power supply will provide each of the four electrodes with a charge of +Q/4 and the satellite with a charge -Q. When the satellite is released from rest, it moves up and passes through the center of the square. At the instant it reaches the square's center, the power supply is turned off and the electrodes are grounded, giving them a zero electric charge. To test this idea, you decide to use energy considerations to calculate how big Q will have to be to get a 100 kg satellite to a sufficient orbit height. Assume that the satellite starts from 15 meters below the square of electrodes and that the sides of the square are each 5 meters. In your physics text you find the mass of the Earth to be 6.0 x 10^{24} kg.

19.. *Electric Potential Energy, Mechanical Energy:* You have been able to get a part-time job in a University laboratory. The group is planning a set of experiments to study the forces between nuclei in order to understand the energy output of the Sun. To do this experiment, you shoot alpha particles from a Van de Graaf accelerator at a sheet of lead. The alpha particle is the nucleus of a helium atom and is made of 2 protons and 2 neutrons. The lead nucleus is made of 82 protons and 125 neutrons. The mass of the neutron is almost the same as the mass of a proton. To assure that you are actually studying the effects of the nuclear force, an alpha particle should come into contact with a lead nucleus. Assume that both the alpha particle and the lead nucleus have the shape of a sphere. The alpha particle has a radius of 1.0 x 10^{-13} cm and the lead nucleus has a radius 4 times larger. Your boss wants you to make two calculations:
(a) What is the minimum speed of such an alpha particle if the lead nucleus is fixed at rest?
(b) What is the potential difference between the two ends of the Van de Graaf accelerator if the alpha particle starts from rest at one end (from a bottle of helium gas)?

Electric Power

20. It's a cool day, about 10 ^{o}C, so you plan to make about 5.0 kg of clear soup using your slow cooking crockpot. To decide whether the soup will be ready for dinner, you estimate how long it will take before the soup gets to its boiling point. Before adding the ingredients, you turn the crockpot over and read that it is a 200-ohm device that operates at 120 volts. Since your soup is mostly water, you assume it has the same thermal properties as water, so its specific heat capacity is 4200 J/(kg ^{o}C) and its heat of vaporization is 2.3 x 10^{6} J/kg.

21. You are working with a company that has the contract to design a new, 700-foot high, 50-story office building in Minneapolis. Your boss suddenly bursts into your office. She has been talking with an engineer who told her that when the elevator is operating at maximum speed, it would take the 6500-lb loaded elevator one minute to rise 20 stories. She thinks this is too long a time for these busy executives to spend in an elevator after returning from lunch at the Minneapolis Athletic Club. She wants you to buy a bigger power supply for the elevator. You look up the specifications for the new supply and find that it is the same as the old one except that it operates at

twice the voltage. Your boss's assistant argues that the operating expenses of the new power supply will be much more than the old one. Your boss wants you to determine if this is correct. You estimate that while the elevator runs at maximum speed, the whole system, including the power supply, is 60% efficient. The cost of electricity is $0.06 per kilowatt-hour (commercial rate).

22. You have finally graduated from college and found a job with the Washington State Agricultural Concerns Group. Farmers and fishermen are concerned that the rate that water flows in the Columbia river, which is controlled by dams, will not be adequate for both irrigation needs and salmon spawning. The dams control the river's flow rate to produce most of the electrical power for cities along the West Coast. Your group leader assigns you the task of calculating the volume of water per second (flow rate) which normally would flow through the Grand Coulee Dam, the largest on the Columbia River. She tells you that this dam typically generates 2000 megawatts (MW) of power and is 50% efficient in converting the water's energy to electrical energy. The dam is 170 meters high ,and the water is kept in a lake 10 meters below the top of the dam. The Columbia River is 170 meters wide at the dam. The density of water is 1.00 g/cm^3.

Circuits

23. *Ohm's Law:* Because of your physics background, you landed a summer job as an assistant technician for a telephone company in California. During a recent earthquake, a 1.0-mile long underground telephone line is crushed at some point. This telephone line is made up of two parallel copper wires of the same diameter and same length, which are normally not connected. At the place where the line is crushed, the two wires make contact. Your boss wants you to find this place so that the wire can be dug up and fixed. You disconnect the line from the telephone system by disconnecting both wires of the line at both ends. You then go to one end of the line and connect one terminal of a 6.0-V battery to one wire, and the other terminal of the battery to one terminal of an ammeter (which has essentially zero resistance). When the other terminal of the ammeter is connected to the other wire, the ammeter shows that the current through the wire is 1 A. You then disconnect everything and travel to the other end of the telephone line, where you repeat the process and find a current of 1/3 A.

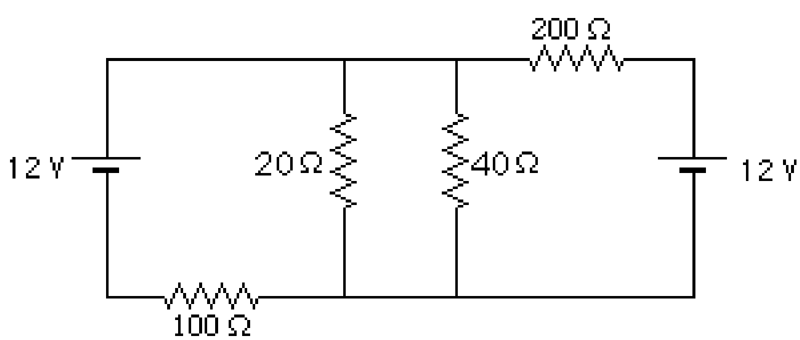
24. *Ohm's Law:* You have a summer job in the University ecology lab. Your supervisor asks you to duplicate an electromagnet that she has borrowed. She tells you that this electromagnet is made by wrapping a wire many times around a piece of iron and provides you with all the parts, the same type of wire of the same diameter and an identical iron core. What you need to know is how much wire to wrap around the iron. Unfortunately, you cannot simply unwrap the wire from the borrowed magnet because that will destroy it. On the side of the electromagnet, it tells you that when a potential difference of 12 V is put across the ends of its wire, there is a current of 0.06 A through the wire. With a brilliant flash of insight, you realize that the cross-sectional area and the conductivity is the same for both the magnet's wire and the wire you have, so you can find the length with a simple experiment. You cut off a 100-foot piece of identical wire from your supply,

attach it to a 1.5-V flashlight battery and measure a current of 0.10 A through that wire. Eureka! you can now find the length of the magnet's wire.

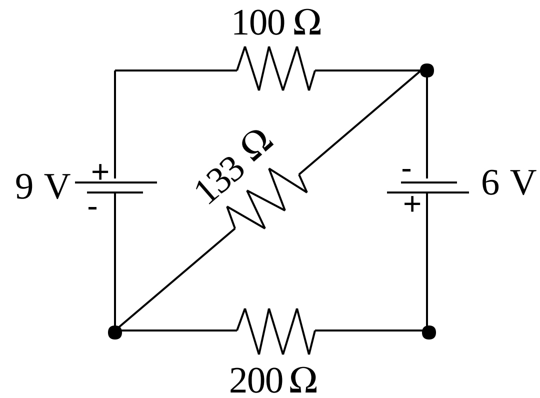
25 *Electric Power:* You and a friend are studying for an exam and the session goes until the early morning. At about 4 am you decide to cook some breakfast. Despite being sleepy you've got the coffee perking. Now you want to make some waffles but you realize there might be a problem. The 1000-watt waffle iron and the 600-watt coffee maker are plugged into the 110 V kitchen electrical outlets. If you plug in your 700-watt blender, will you overload the 20 A circuit breaker? The circuit breaker protects those kitchen circuit wires that have the most current from carrying too much current. You are trying to figure out how the electrical outlets are connected together in a circuit when your friend reminds you that when you disconnect the coffeepot, the waffle iron stays on. Now everything is clear.

26. *Electric Power:* You and a friend are studying for a final and the session goes until the early morning. About 4 AM you decide to cook some breakfast. Despite being sleepy, things are going well. The waffles are cooking and the coffee is perking. Should you make some toast now? The 1000-watt waffle iron and the 600-watt coffee maker are plugged into kitchen wall electrical outlets. You will also use a kitchen wall outlet for the toaster. The kitchen wall outlets are all part of the same 110-V circuit which has a 20-A circuit breaker (with negligible resistance) to protect the wire carrying the largest current from getting too hot. (Some homes have fuses to do the same job). You know that if you plug in too many appliances you will overload the circuit breaker. The toaster label says that its power output is 700 watts.

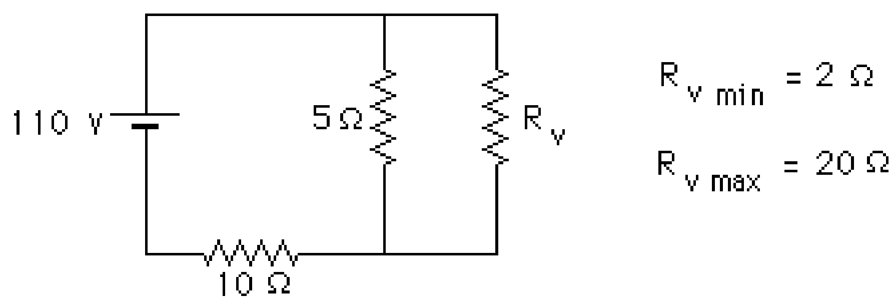
27. *Electric Power:* As a member of the safety group for the space shuttle scientific program, you have been asked to evaluate an electronics design change. In order to improve the reliability of a circuit to be used in the next shuttle flight, the experimental design team has suggested adding a second 12 V battery to the circuit. The equivalent resistances of the proposed design are shown below. You are worried about the heat generated by the device with the 20 ohm resistance since it will be located next to a sensitive low temperature experiment so you do the appropriate calculation.



28. *Electric Power:* As part of your summer job as a design engineer at an electronics company, you have been asked to inspect the circuit shown below. The resistors are rated at 0.5 Watts, which means they burn-up if more than 0.5 Watts of power passes through them. Will the 100Ω resistor in the circuit burn-up?



29. *Electric Power:* While trying to find the power ratings of your appliances you find their circuit diagrams. Looking them over, your friend believes there must be a typo in the circuit diagram of your toaster. The heating element that toasts the bread is listed as having a resistance of 5 ohms. A variable resistor, which is changed by a knob on front of the toaster, has a range of from 2 to 20 ohms. Your friend feels that an element with this resistance will not toast bread properly. Based on the circuit diagram, given below, you decide to calculate the maximum power output by the heating element.



Magnetic Force and Field

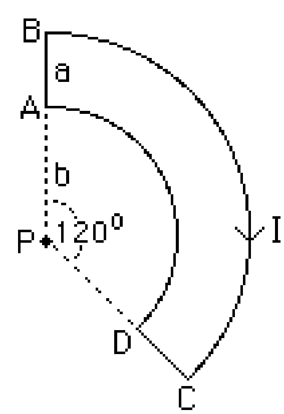
30. *Magnetic Force:* You are working on a project to make a more efficient engine. Your team is investigating the possibility of making electrically controlled valves that open and close the input and exhaust openings for an internal combustion engine. Your assignment is to determine the stability of the valve by calculating the force on each of its sides and the net force on the valve. The valve is made of a thin but strong rectangular piece of non-magnetic material that has a loop of current carrying wire along its edges. The rectangle is 0.35 cm x 1.83 cm. The valve is placed in a uniform magnetic field of 0.15 T such that the field lies in the plane of the valve and is parallel to the short sides of the rectangle. The region with the magnetic field is slightly larger than the valve. When a switch is closed, a 1.7 A current enters the short side of the rectangle on one side of the valve and leaves on the opposite side. To give different currents through the wires along the long

sides of the valve, a resistor is inserted into the wire on each of these sides. The value of the resistor on one side is twice that on the other side.

31. *Magnetic Force:* You have landed a great summer job in the medical school assisting in a research group investigating short lived radioactive isotopes which might be useful in fighting cancer. Your group is working on a way of transporting alpha particles (Helium nuclei) from where they are made to another room where they will collide with other material to form the isotopes. Since the radioactive isotopes are not expected to live very long, it is important to know precisely how much time it will take to transport the alpha particles. Your job is to design that part of the transport system which will deflect the beam of alpha particles ($m = 6.64 \times 10^{-27}$ kg, $q = 3.2 \times 10^{-19}$ C) through an angle of 90^o by using a magnetic field. The beam will be traveling horizontally in an evacuated tube. At the place the tube is to make a 90^o turn you decide to put a dipole magnet which provides a uniform vertical magnetic field of 0.030 T. Your design has a tube of the appropriate shape between the poles of the magnet. Before you submit your design for consideration, you must determine how long the alpha particles will spend in the uniform magnetic field in order to make the 90^o-turn.

32. *Magnetic Force:* You've just learned about the earth's magnetic field and how a compass works and you are relaxing in front of the TV. Tired of your show, you think about how the picture tube works in relation to what you have learned. In a typical color picture tube for a TV, the electrons are boiled off of a cathode at the back of the tube and are accelerated through about 20,000 volts towards the picture tube screen. On the screen is a grid of ``color dots'' about 1/100 inch apart. When the electrons hit them, the dots scintillate their appropriate colors producing the color picture. Without taking apart the set, you determine whether the manufacturer needed to shield the color picture tube from the earth's magnetic field?

33. *Magnetic Field (Biot-Savart Law):* You are continually having troubles with the CRT screen of your computer and wonder if it is due to magnetic fields from the power lines running in your building. A blueprint of the building shows that the nearest power line is as shown below. Your CRT screen is located at point P. Calculate the magnetic field at P as a function of the current I and the distances a and b. Segments BC and AD are arcs of concentric circles. Segments AB and DC are straight-line segments.



34. *Magnetic Field - Ampere's Law:* While studying intensely for your physics final you decide to take a break and listen to your stereo. As you unwind, your thoughts drift to newspaper stories about the dangers of household magnetic fields on the body. You examine your stereo wires and find that most of them are coaxial cable, a thin conducting wire at the center surrounded by an insulator, which is in turn surrounded by a conducting shell. The inner wire and the conducting shell

are both part of the circuit with the same current (I) passing through both, but in opposite directions. As a way to practice for your physics final you decide to calculate the magnetic field in the insulator, and outside the coaxial cable as a function of the current and the distance from the center of the cable. As an additional challenge to yourself, you calculate what the magnetic field would be (as a function of the current and the distance from the center of the cable) inside the outer conducting shell of the coaxial cable. For this you assume that the inner radius of the conducting shell is R_1 and the outer radius is R_2.

35. *Magnetic Force - Faraday's Law:* You have a summer job working at a company developing systems to safely lower large loads down ramps. Your team is investigating a magnetic system by modeling it in the laboratory. The safety system is a conducting bar that slides on two parallel conducting rails that run down the ramp. The bar is perpendicular to the rails and is in contact with them. At the bottom of the ramp, the two rails are connected together. The bar slides down the rails through a vertical uniform magnetic field. The magnetic field is supposed to cause the bar to slide down the ramp at a constant velocity even when friction between the bar and the rails is negligible. Before setting up the laboratory model, your task is to calculate the constant velocity of the bar sliding down the ramp on rails in a vertical magnetic field as a function of the mass of the bar, the strength of the magnetic field, the angle of the ramp from the horizontal, the length of the bar which is the same as the distance between the tracks, and the resistance of the bar. Assume that all of the other conductors in the system have a much smaller resistance than the bar.