2^{nd} Semester SAC Physics Problems

SAC201

1) Particle #2, of charge $1.5\times10^{-7}\,\text{C}$ is $0.56\,\text{m}$ away from particle #1, of charge $-1.2\times10^{-7}\,\text{C}$. Find the force exerted on particle #2 by particle #1.

Hint: Force has both magnitude and direction. The magnitude of your answer should be written as a positive number and the direction should be stated explicitly as part of your answer. In this case, neither a compass direction (no compass directions are identified in the statement of the problem) nor a mathematical convention direction (there is no mention of, or allusion to, a Cartesian coordinate system) is called for, so, the best you can do is to specify the direction of the force in relative terms such as "directly away from particle 1", or, "directly toward particle 2".

2) Two free particles are at one and the same elevation near the surface of the earth. Particle #1 has a mass of 1.10 grams and a charge of $-8.50\times10^{-7}\,\text{C}$. Particle #2 has a mass of 1.20 grams and a charge of $+2.00\times10^{-6}\,\text{C}$. Particle #2 is $4.62\,\text{cm}$ due west of particle #1. Find the horizontal component of the acceleration of each of the particles.
Hints:

- *The earth's gravitational force on each of the particles is downward, in the vertical direction. The question is about the horizontal component of the acceleration, so, the earth's gravitational force plays no role in the problem. Because of the small masses involved, the gravitational force exerted on either particle by the other is negligible.*
- *Acceleration has both magnitude and direction. A direction was given in the problem as a compass direction, hence, a compass direction must be specified explicitly as part of your answer. Examples of compass directions are: West, Northeast, at 129°, 39° S of E, and 51° east of south. Note that the last three examples are all one and the same direction.*

3) The Cartesian coordinates of three charged particles are given as follows:

Particle #1 of charge $0.85\,\mu\text{C}$ is at $(-4.50\,\text{cm}, 0)$.
Particle #2 of charge $2.05\,\mu\text{C}$ is at $(0, -10.60\,\text{cm})$.
Particle #3 of charge $1.40\,\mu\text{C}$ is at $(6.80\,\text{cm}, 0)$.

Find the net force exerted on particle #3.
Hint: Force has both magnitude and direction. The direction must be explicitly stated as part of your answer. Because the particle positions are given in terms of Cartesian coordinates, the direction must be specified in the mathematical convention (angle measured counter-clockwise with respect to the positive x-direction)

SAC202

1) A particle of charge 6.2×10^{-8} C finds itself at a point in space where the electric field is 15 000 N/C upward. Find the force exerted on the particle by the electric field.

2) A proton has a velocity of 1250 m/s directed straight upward. At the instant in question, the proton is at a point in space where the electric field is 2200 N/C eastward. Find the acceleration of the proton.

Hints:

- *The gravitational force exerted on the proton by the earth is negligible in comparison to the force exerted on the proton by the electric field.*
- *You are given more information than you need.*

3) An electron has an initial velocity of 125 000 m/s northward. It is in a southward-directed 1525 N/C uniform electric field. Ignore the gravitational force exerted on the electron by the earth, it is negligible. Relative to its initial position, where is the electron 3.33 ns later?

4) A proton is moving in a uniform 2220 N/C eastward-directed electric field. Initially, it has a velocity of 125 000 m/s directed straight upward. How far east of its initial position is the proton when it has achieved an elevation that is 1.50 m greater than its initial elevation? Ignore the gravitational force exerted on the proton by the earth. It is negligible compared to the electric force.

SAC203

1) Find the electric field due to a particle of charge $1.75 \times 10^{-7}\,\text{C}$ at a location $0.250\,\text{m}$ directly below the particle.
Hint: The electric field has magnitude and direction. In a case such as this one, it is not okay to specify the direction as toward or away from the particle causing the electric field.

2) A uniform electric field exists in a region of space in which positions are specified as Cartesian coordinates. The electric field is 25.0×10^{6} N/C in the +x direction. Then, a particle of charge $2.40\,\mu\text{C}$ is placed at the origin. Find the total electric field at ($1.0\,\text{cm}$, $4.00\,\text{cm}$).

3) A particle of charge $85.4 \times 10^{-9}\,\text{C}$ is at the origin of a Cartesian coordinate system. A second particle, this one of charge $-32.8 \times 10^{-9}\,\text{C}$, is on the x axis at $x = 14.0\,\text{cm}$. Find the point, or points, on the x axis, at which the electric field is zero.

4) A particle of charge $11.2 \times 10^{-8}\,\text{C}$ is at the origin of a Cartesian coordinate system. A second particle, this one also having a positive charge, is on the y axis at $y = -8.20\,\text{cm}$. What must the charge on the second particle be in order for the total electric field at ($6.0\,\text{cm}$, 0) to have a magnitude that is twice that of the magnitude of the electric field due to the first particle alone.
Hint: A vector has both magnitude (how big) and direction (which way). When you see the word "magnitude" in the statement of a problem you should think "easier". You don't have to worry about direction.

5) A particle with charge $1.50\,\mu\text{C}$ is at ($-2.00\,\text{cm}$, $+4.00\,\text{cm}$) on a Cartesian coordinate system. Depict the configuration in a sketch. Characterize the electric field at the point (0, $1.00\,\text{cm}$) by means of a single arrow. Label the arrow E. Calculate the electric field magnitude E at that point.

6) A particle with charge $1.50\,\mu\text{C}$ is at ($-2.00\,\text{cm}$, 0) on a Cartesian coordinate system. A second particle with charge $-2.20\,\mu\text{C}$ is at ($3.30\,\text{cm}$, 0). Find the electric field at the origin. (Recall that the electric field has both magnitude and direction.)

7) A particle with charge $5.25\,\mu\text{C}$ is at ($-2.50\,\text{cm}$, 0) on a Cartesian coordinate system. A second particle with charge $3.00\,\mu\text{C}$ is at ($-2.50\,\text{cm}$, $-4.00\,\text{cm}$). Find the electric field at the origin. (Recall that the electric field has both magnitude and direction.)

8) (Use a computer to solve this one.) 100 particles, each having charge 1.21 nC, are positioned along the x axis at 1.00 centimeter intervals from $x = -100.00$ cm to $x = -1.00$ cm.

a) Find the electric field at (0, 5.00 cm).
b) Find the force that would be experienced by a particle having charge 2.46 pC if it were positioned at the empty point in space having coordinates (0, 5.00 cm).

(*Show all work. Include a printout of the first page of the spreadsheet.*)

SAC204

1) Positions in a region of space are specified by Cartesian coordinates. In that region of space there is a uniform 8500 N/C electric field in the +x direction. Then, a particle having a charge of $0.460\,\mu\text{C}$ is placed, and fixed in position, at the origin.
   a) Find the electric field at point A, (36.5 cm, 0).
   b) Next, a proton finds itself at point A. Use your result from part a to determine the acceleration experienced by the proton.

2) The electric field due to an unspecified but fixed charge distribution, for points on the x axis of a Cartesian coordinate, depends on x as follows: $\vec{\mathbf{E}} = 52\,400\dfrac{\text{N}}{\text{C}\cdot\text{m}}x$ in the +x direction. Without disturbing the original charge distribution, a particle having charge $4.50\times10^{-7}\,\text{C}$ is placed at the position ($0.500\,\text{m}$, $-0.250\,\text{m}$) and held there by means not specified. Next, a particle of mass $1.42\times10^{-4}\,\text{kg}$ and charge $1.40\times10^{-7}\,\text{C}$ is placed at ($0.500\,\text{m}$, 0) and released from rest. Ignore any gravitational force that might be acting on the particle. Find the acceleration of the latter particle at the instant it is released.

3) Four free electrons are, at a given instant in time, at the corners of a square of side length 1.00 cm. Find the acceleration of any one of the electrons by first finding the electric field due to the other electrons, at the position of the electron whose acceleration you have chosen to investigate, and then using that electric field to determine the acceleration.

Hint: While it is expected that you will define a coordinate system in solving the problem, it is not okay to specify the direction part of the answer in terms of that coordinate system (because no coordinate system was given in the problem). Instead, you have to specify the direction in a relative fashion, by saying something such as "directly away from the center of the square," or, "directly toward the center of the square."

SAC205

1) A particle having charge 485 nC moves 1.20 m northward in a uniform, southward-directed, 44 400 N/C electric field. Find the work done on the charged particle by the electric field.

2) A particle having charge 485 nC and mass 50.1 μg has an initial velocity of 1240 m/s northward. The particle is in a uniform, southward-directed, 44 400 N/C electric field. Use the work-energy theorem to determine the velocity of the particle after it has traveled 1.20 m northward.

3) A particle having charge –296 nC moves 0.654 m eastward in an eastward-directed, 25 400 N/C electric field. Find the change in the electric potential energy of the particle.

4) A particle having charge $4.95 \times 10^{-8}\,\text{C}$ finds itself at a location in space where the electric potential is 475 volts. Find the electric potential energy of the particle.

5) A particle having charge 65.4 nC is released from rest at a point in space where the electric potential is 842 volts. The particle has no force on it other than that exerted on it by the electric field characterized by the electric potential in question. Find the kinetic energy of the particle when it arrives at a point in space where the electric potential is 135 volts.

SAC206

1) Find the electric potential at a point in space that is 15.0 cm from a particle having charge 0.154 C.

2) A particle of charge –1.65 μC is at (–22.0 cm, 0). A second particle, this one having charge +4.21 μC, is at (0, –18.0 cm). Find the electric potential at (12.0 cm, 0).

3) A particle having charge 0.465 μC is at the origin of a Cartesian coordinate system. A second particle, this one having a charge of –0.198 μC, is at (13.5 cm, 0.0). Find every position on the x axis at which the electric potential is zero.

4) Given two point charges on an x-y coordinate system:

$+2.0\times10^{-7}\,\text{C at }(0, 0)$

$-4.0\times10^{-7}\,\text{C at }(3.0\,\text{cm}, 0)$

Find the electric potential at (3.0 cm, 4.0 cm).

5) Particle B is 1.00 m to the right of particle A. Each particle has a charge of 1.00 C. Point P is directly above particle B at a distance of 1.00 m from particle B.

a) Find $\vec{\mathbf{E}}$ (direction and magnitude) at point P.
b) Find the electric potential φ at point P.
c) Suppose a particle with charge 0.500 C is placed at point P. What is the force on that particle?
d) What is the potential energy of the particle in part c?

6) (Use a computer to solve this one.) 100 particles, each having charge 1.21 nC, are positioned along the x axis at 1.00 centimeter intervals from x = –100.00 cm to x = –1.00 cm.

a) Find the electric potential at (0, 5.00 cm).
b) Find the electric potential energy that a particle having charge 2.46 pC would have if it were positioned at the empty point in space having coordinates (0, 5.00 cm).

(*Show all work. Include a printout of the first page of the spreadsheet with graphs.*)

SAC207

1) Near the back of a television picture tube, a piece of metal, called a cathode, is heated to the extent that electrons have so much thermal kinetic energy that they escape the metal. A power supply is used to maintain a phosphorescent coating on the front of the picture tube at a potential that is 4250 volts higher than that of the cathode. Consider an electron that leaves the cathode with a velocity of 41.0 m/s toward the phosphorescent coating. With what speed does it hit the phosphorescent coating on the inside of the television screen?

2) A proton that is 5.00 cm from particle A, a particle which has a charge of 6.42 pC, has a velocity of 9225 m/s straight at particle A. Particle A is fixed in space. How close does the proton get to particle A?

3) A particle having a mass of 5.01 μg and charge 85.2 nC is released from rest at a position in space that is 0.750 m from a particle which is fixed in its position and has a charge of –6.45 μC. Find the speed of the positively charged particle when it is 1.00 cm from the negatively charged particle.

4) A proton (charge e) is released from rest, in vacuum, from the positive plate of a capacitor consisting of a pair of parallel plane conducting sheets separated by a distance d and having a potential difference of 50100 volts between them. Find the kinetic energy of the proton the instant before it strikes the negative plate.

5) A proton is released from rest at a distance 0.050 m from a particle which is fixed in space and has a charge of 430 nC. Find the kinetic energy of the proton when it is 0.50 m from the charged particle.

SAC208

1) A two-conductor capacitor has a capacitance of 268 pF and carries a charge of 3.22 nC. Find the potential difference between the two conductors.

2) The potential difference between the plates of a parallel-plate capacitor whose plates are separated by mica is 115 volts. The mica used has a dielectric constant of 7.00 (with no units). The plates are isolated from the surroundings. Without anything touching either plate (except the mica), the mica is slipped out from between the plates and removed from the vicinity of the capacitor. The mica is neutral before, during, and after the process. Find the new (if it is new) value-with-units of the potential difference between the plates of the capacitor.

3) A parallel plate capacitor consists of two metal disks, each having a diameter of 21.0 cm, separated by vacuum. The distance between the plates is 0.500 mm. 14.0 nC of charge is moved from one plate to the other. How much energy is stored in the capacitor?

SAC209

1) A seat of EMF is used to maintain the potential difference between the terminals of a resistor at 6.30 volts. The resistance of the resistor is 222 ohms. At what rate does charge flow through the resistor?

2) A flashlight bulb is a resistor. The pair of batteries in a typical flashlight is a seat of EMF. Consider a flashlight in which the batteries maintain a potential difference of 3.02 volts between the terminals of the bulb and the charge flow rate is 0.414 A.

a) How much charge flows through the bulb in an hour?
b) How much charge flows through the batteries in an hour?
c) What is the resistance of the bulb?

3) What voltage must a seat of EMF maintain between the terminals of a 1400 ohm resistor in order to cause charge to flow through the resistor at the rate of 12 mA?

SAC210

1) Find the resistance of a mile-long piece of copper wire having a diameter of 3.5 mm.

2) A potential difference of 12.3 volts is maintained across a 482 ohm resistor. Find the rate at which energy is dissipated by the resistor.

3) A 1.20 meter length of 1.80 mm diameter Nichrome wire is wrapped around a small ceramic rod to form an immersion heater. An electrically insulating coating is applied to the coil thus formed. In use, the coil is submerged in water and a seat of EMF is used to maintain a potential difference of 28.0 volts between the ends of the wire. Find the rate at which energy is delivered to the water.

4) The terminals of a 25 ohm resistor are held at a potential difference of 95 volts for 45 seconds.

a) What is the value of the current through the resistor (while so connected)?

b) What is the power being delivered to the resistor (while so connected)?

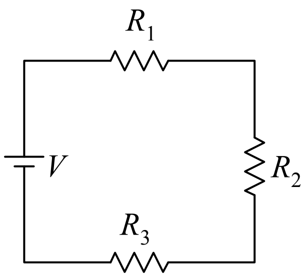
c) How much energy is delivered to the resistor during the entire 45 seconds?

5) Charge flows through a resistor at the rate of 0.522 A when the terminals of the resistor are maintained at a potential difference of 115 volts. Under these circumstances, how long does it take for the resistor to dissipate 10.0 kJ of energy?

6) (Use a computer to solve this one.) At time zero, the voltage across a 49.6 ohm resistor is 236 volts. With each passing 0.860 second time interval, the voltage remains constant at the value it has at the start of the time interval and then, at the end of the 0.860 second time interval, instantaneously drops to one half that value. In other words, starting at time zero, the voltage across the resistor remains at 236 volts until time $t = 0.860$ seconds at which instant the voltage drops to 118 volts. The voltage remains at 118 volts from time $t = 0.860$ seconds until time $t = 1.720$ seconds. At $t = 1.720$ seconds the voltage suddenly drops to 59.0 volts. It remains at 59.0 volts for 0.860 seconds and then suddenly drops to 29.5 volts, etc. How much energy is converted to thermal energy in the resistor during the first 8.60 seconds of its operation? (*Show all work. Include a printout of the first page of the spreadsheet.*)

SAC211

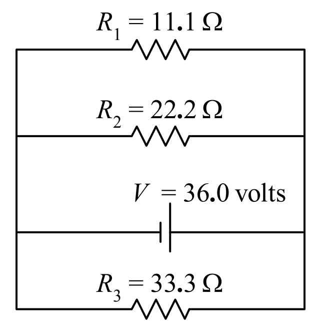
1) For the circuit at right, find the voltage across, and the current through, each of the resistors.



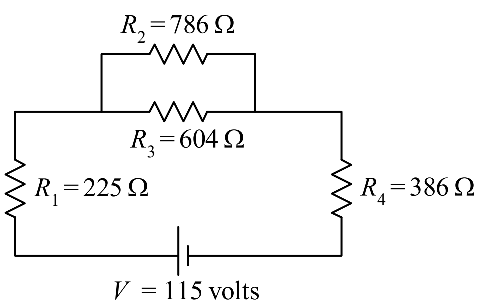
Hints:

- *In applying the method of combining resistors to form effective resistance (also known as the method of ever-simpler circuits), diagrams are a required part of the solution.*
- *In cases where values are not given, symbols provided in the given circuit diagram are to be considered as "givens" unless otherwise stated. In the final answers, each sought quantity is to be expressed in terms of "givens" (not in terms of quantities defined by and/or solved for by the problem solver).*

2) For the circuit at right, find the current through the seat of EMF.



3) For the circuit at right, find the current through R_2.

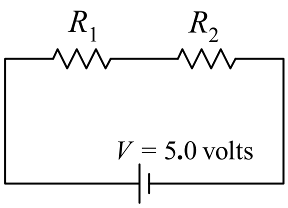


4) Two resistors have one and the same resistance R. If connected in series with each other they form a "single effective resistor" of resistance R_S. If connected in parallel with each other they form a "single effective resistor" of resistance R_P. Indicate all of the following that are true.

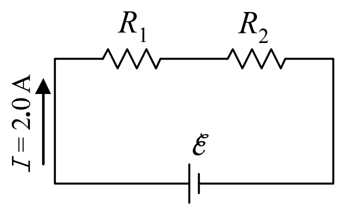
a) $R < R_P$
b) $R_P < R_S$
c) $R < R_S$
d) $R_P < R$
e) $R_S < R$
f) $R_S < R_P$
g) $R_P > R_S$
h) $R_S > R$

5) V_1 is the voltage across R_1
V_2 is the voltage across R_2
I_1 is the current through R_1
I_2 is the current through R_2

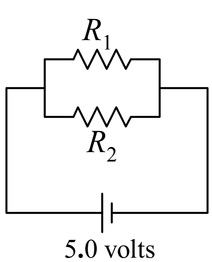
a) Beside each of the circuit diagrams that follow, write the value of each of the indicated quantities whose value can be determined by inspection (no calculation). Write nothing for any quantities whose value cannot be determined by inspection. Do not assume that there is at least one quantity whose value can be determined by inspection for each circuit. Mark each quantity determined by inspection with an asterisk.
b) Assuming $R_1 = 10.\ \Omega$ and $R_2 = 40.\ \Omega$ calculate those values which cannot be determined by inspection.



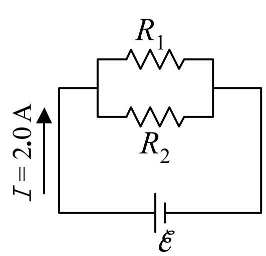
$V_1 =$
$V_2 =$
$I_1 =$
$I_2 =$



$V_1 =$
$V_2 =$
$I_1 =$
$I_2 =$



$V_1 =$
$V_2 =$
$I_1 =$
$I_2 =$

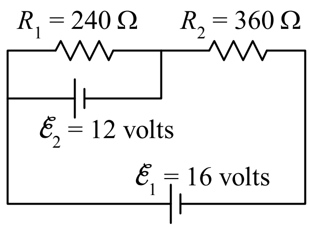


$V_1 =$
$V_2 =$
$I_1 =$
$I_2 =$

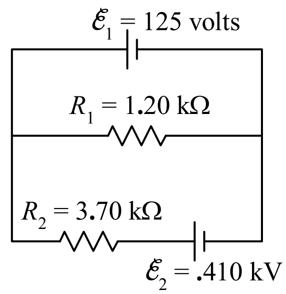
SAC212

1-3) For each circuit, find the voltage across, and the current through, each resistor.

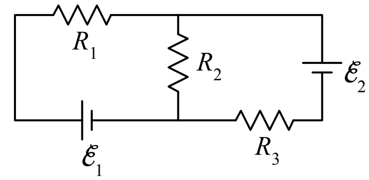
(1)



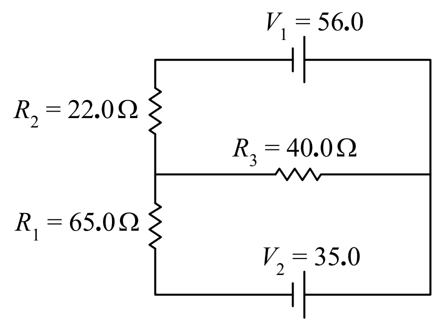
(2)



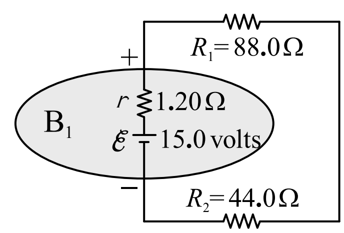
(3)



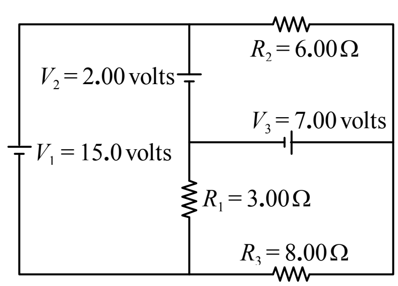
4) Find the current through, and the voltage across, each of the resistors in the circuit at right.



5) Find the terminal voltage for the battery B_1 in the circuit at right.



6) Find the current through, and the voltage across, each of the resistors in the circuit at right.



SAC212 (Continued)

7) A real battery can be modeled by an ideal seat of EMF in series with a resistor known as the internal resistance of the battery. Both the seat of EMF and the internal resistance are inside the battery, in between the terminals. Suppose the ideal seat of EMF value is 9.00 volts and the internal resistance is 1.20 ohms.

a) What is the terminal voltage of the battery when it is not connected to anything?

b) What is the terminal voltage of the battery when it is connected across a 52.0 ohm resistor?

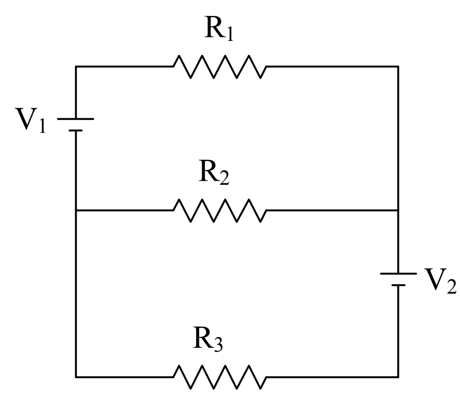
8) You are provided with a voltmeter, a battery, and a 222 ohm resistor. You measure the voltage across the battery when it is not connected to the resistor and find that voltage to be 6.20 volts. Then you measure the voltage across the battery while the battery is connected across the 222 ohm resistor and this time you find the voltage to be 5.80 volts.

a) Find the internal resistance of the battery.

b) Find the power dissipated by the internal resistor when the battery is connected across the 222 ohm resistor.

c) Find the value of a resistor which, when connected by itself across the battery, would cause the battery voltage to be 6.00 volts.

9) For the circuit at right:



a) Label the two terminals of each seat of EMF "+" or "–" as appropriate.

b) Draw arrows representing the currents in the various legs of the circuit. Label the arrows with symbols such as I_2 chosen to represent the currents.

c) Label the two terminals of each resistor "+" or "–" as appropriate.

d) Clearly indicate two loops in the circuit on which one can apply Kirchoff's Loop Rule (a.k.a. Kirchoff's Voltage Law) and write the equation for each loop.

e) Clearly indicate one junction at which one can apply Kirchoff's Junction Rule (a.k.a. Kirchoff's Current Law) and write the equation for that junction.

f) Solve for the voltage across, and the current through, each of the resistors. (Consider V_1, V_2, R_1, R_2, and R_3 to be known.)

SAC213

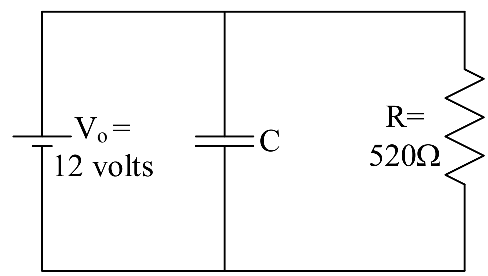
1) A 6.05 volt battery, a 157 kΩ resistor, and an initially-uncharged 472 μF capacitor are connected in series, with the final connection being made at time zero. How long does it take for the charge on the capacitor to reach 2.36 mC?

2) A 52.0 mF capacitor is connected across a 12.0 volt battery and left there until it stops charging. It is then disconnected from the battery and connected across a 37.0 ohm resistor with the final connection being made at time zero.

a) Find the initial current, the current when that final connection has just been made.
b) Find the current at time 3.00 seconds.

3) A capacitor is connected across a 15.0 volt battery and left there until it stops charging. Then the capacitor is disconnected from the battery and connected across a 32.0 MΩ resistor. It is observed that it takes 8.50 minutes for the voltage across the capacitor to drop down to 5.0 volts. Find the capacitance of the capacitor.

4) The resistor in the circuit at right represents a computer. The seat of EMF is a power supply for the computer. The capacitor, always fully charged when the power supply is working, serves as a temporary source of power in the event of a power failure. The computer normally operates at 12.0 volts, but it will continue to operate as long as the voltage is above 9.0 volts. What must the capacitance of the capacitor be if, the user of the computer is to have 4 minutes to save her work and properly shut down the computer in the event of a power failure. Note that, upon power failure, the seat of EMF is to be considered disconnected from the circuit.



5) An initially uncharged 4.70 mF capacitor is connected in series with a 12.0 volt battery and a 222 kΩ resistor. How long does it take for the voltage across the capacitor to become 11.0 volts?

6) A 12 V battery, a 15 MΩ resistor, and a 5.6 nF capacitor are connected in series at time zero.

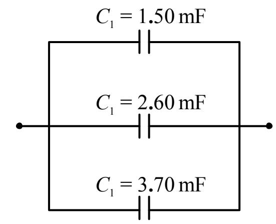
a) Find the initial current.	d) Find the time when the current is one-half its initial value.
b) Find the current at time 0.10 s.	e) Find the maximum voltage across the capacitor.
c) Find the voltage across the capacitor at time 0.10 s.	f) When does this apply?
d) Find the charge on the capacitor at time 0.10 s.	g) Find the maximum charge on the capacitor.

7) A 12 V battery, a 15 MΩ resistor, and a 5.6 nF capacitor are connected in series. After the capacitor is charged to the highest charge possible, the capacitor is removed from the circuit, and, at a new time zero, is connected across a second resistor. After 0.12 s, the voltage across the capacitor is observed to be 6.0 volts.

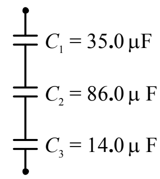
a) Find the resistance of the second resistor .
b) Find the current at t = 0.12 s.
c) At what time will the voltage be 3.0 volts?

SAC214

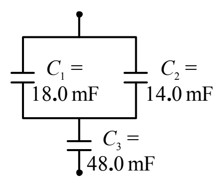
1) Find the effective capacitance of the combination of capacitors depicted at right.



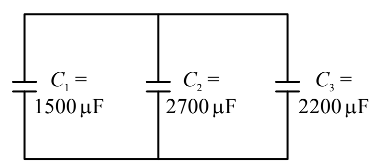
2) Find the effective capacitance of the combination of capacitors depicted at right.



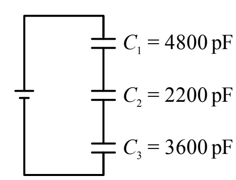
3) Find the effective capacitance of the combination of capacitors depicted at right.



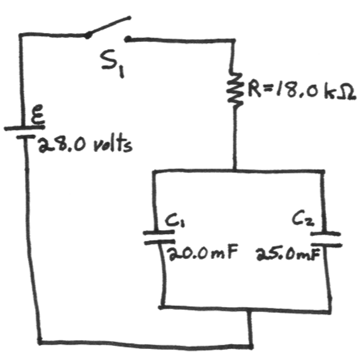
4) Given that the voltage across C_1 is 17.5 volts, find the voltage across, and the charge on, capacitors C_2 and C_3. Consider the given values of capacitance to be good to three significant figures.



5) Given that the voltage across C_1 is 5.00 volts, find the charge on, and the voltage across, C_2 and C_3. Consider the given values of capacitance to be good to three significant figures.



6) Assuming both capacitors in the circuit at right to be initially uncharged, find the current through the resistor 78.0 s after switch S_1 is closed.



SAC215

1) At the instant in question, a proton has a velocity of 14 800 m/s northward and is at a point in space where there is a downward-directed 0.140 tesla magnetic field. Find the force exerted on the proton by the magnetic field.
Hint: Force has both magnitude and direction. There is no page in the problem so it is not okay to specify the direction of the force relative to a page.

2) At the instant in question, a particle having charge 2.25 μC has a velocity of 335 m/s northward and is at a point in space where the magnetic field has a magnitude of 0.0144 T, is horizontal, and is in the compass direction 78.0°. Find the force exerted on the particle by the magnetic field.
Hint: Compass directions given in degrees only are always measured clockwise from northward, as viewed from above, so, a compass direction of 78.0° is the same direction as 78.0° E of N or 12.0° N of E.

3) A proton is moving in a horizontal circle of radius 0.380 m under the influence of a uniform magnetic field. The proton is moving counterclockwise, as viewed from above, at a constant speed of 442 m/s. Find the magnitude and direction of the magnetic field.

4) An electron (charge 1.6×10^{-19}, mass 9.11×10^{-31} kg) has a velocity of 1.50×10^{4} m/s straight downward. It is in a 1.80-mT southward magnetic field. Find the acceleration of the electron assuming that the magnetic force is the only force exerted on the electron.

5) A particle with a charge of +14 μC has a northward velocity of 870 m/s. The particle is in a magnetic field which is exerting an eastward 0.16 mN force on the particle. The northward direction is one of the directions of the velocity which results in the largest possible force being exerted on the particle by the magnetic field that the particle is in. Find the magnitude and direction of the magnetic field.

6) A straight horizontal wire carries 4.0 A due eastward in a uniform downward 0.44 tesla magnetic field. Find the force exerted by the magnetic field on a 25 cm segment of the wire.

7) A straight horizontal wire carries a current of 4.78 A in the compass direction 128°. The wire passes through a region of space where there exists a uniform downward-directed 0.620 tesla magnetic field. Find the force exerted on a 1.20 m long segment of the wire by the magnetic field.

SAC216

1) Find the torque and the force that a magnetic field given by $\vec{\mathbf{B}} = x\frac{\text{T}}{\text{m}}\hat{\mathbf{i}} - y\frac{\text{T}}{\text{m}}\hat{\mathbf{j}}$ (in which the T and m are units and the x and y are variables) exerts on a compass needle that has a magnetic dipole moment of magnitude $25.6\frac{\text{N}\cdot\text{m}}{\text{T}}$ when the compass needle is at x = 5.00 cm on the x axis of a Cartesian coordinate system and is pointing in a direction of 51.6° measured in the x-y plane, counterclockwise (as viewed from a position on the +z axis) from the +x direction.

2) A compass needle having a magnetic dipole moment of $78.6\frac{\text{N}\cdot\text{m}}{\text{T}}$ is pointing in a compass direction of 18.5°. The compass is horizontal. The horizontal component of the earth's magnetic field at the location of the compass needle is 7.80×10^{-7} T. Find the torque exerted on the compass needle by the horizontal component of the earth's magnetic field.

3) A bar magnet whose moment of inertia is $7.6\,\text{kg m}^2$ and whose magnetic dipole moment is $0.90\ \text{A m}^2$ is suspended horizontally by a vertical silk thread. The bar magnet is in a uniform magnetic field of 17 µT northward. The thread exerts no torque on the bar magnet. The bar magnet is pointing in a direction 18 degrees east of due north. Find the angular acceleration of the bar magnet. Give the direction as either clockwise or counterclockwise as viewed from above.

4) A bar magnet whose magnetic dipole moment is $0.65\,\text{A}\cdot\text{m}^2$ is in a uniform 25 µT northeastward (exactly northeastward, not just northeasterly) magnetic field.

   a) For what orientation is the torque, exerted on the bar magnet by the magnetic field, both clockwise as viewed from above and at its maximum value.

   b) With the bar magnet in the orientation determined in part a, what is the magnitude of the torque exerted on the bar magnet by the magnetic field?

5) A horizontal bar magnet makes an angle of 28 degrees with the geographic north direction. The north pole of the bar magnet is geographically farther north than the south pole of the bar magnet is. The magnetic dipole moment of the bar magnet is $14\,\text{A}\,\text{m}^2$. The magnet is in a uniform eastward 0.10 tesla magnetic field. Find the torque (direction and magnitude) exerted on the bar magnet by the magnetic field.

6) Find the torque and the force that a magnetic field given by $\vec{\mathbf{B}} = x\frac{\text{T}}{\text{m}}\hat{\mathbf{i}} - y\frac{\text{T}}{\text{m}}\hat{\mathbf{j}}$ (in which the T and m are units and the x and y are variables) exerts on a bar magnet that has a magnetic dipole moment of $155\frac{\text{N}\cdot\text{m}}{\text{T}}\hat{\mathbf{i}}$ when the bar magnet is at (.0300m, .0500m, 0).

SAC217

1) Find the magnetic field due to a long straight vertical wire carrying a current of 19.8 A straight downward, at a point that is 2.00 cm due east of the wire.
Hint: Don't forget to include the direction in your answer.

2) A long straight horizontal wire carries a 12.0 A current due eastward. An electron, at the same elevation as the wire and at a position 1.50 cm south of the wire, has a northward velocity of 105 m/s directed straight at the wire. Find the acceleration of the electron. Assume the force exerted on the electron by the magnetic field produced by the current in the wire is the only force acting on the electron.

3) A long straight horizontal wire carries a 16.5 A current due northward. Directly below, parallel to, and at a distance of 8.00 mm from the long wire is a 0.460 m long straight wire segment carrying a 4.00 A current due northward. Find the force exerted on the wire segment by the magnetic field of the long wire.

4) (Use a computer to solve this one.) A long straight wire extends such a great distance along the x axis of an x-y coordinate system that we can consider it to extend from –infinity to +infinity. There is a current of 12.0 amperes in the –x direction in the wire. At the start of observations, a particle having charge 3.05 mC, mass $8.93\times10^{-10}\,\text{kg}$, and velocity 12.0 m/s **↑**, is at (0, 1.00 cm). Assuming that no force other than that of the magnetic field acts on the particle, plot the trajectory of the particle up until it exits the square region that has sides parallel to the x and y axes, is centered on the origin, and measures 20.0 cm along a side.
(*Show all work. Include a printout of the first page of the spreadsheet with the graph.*)

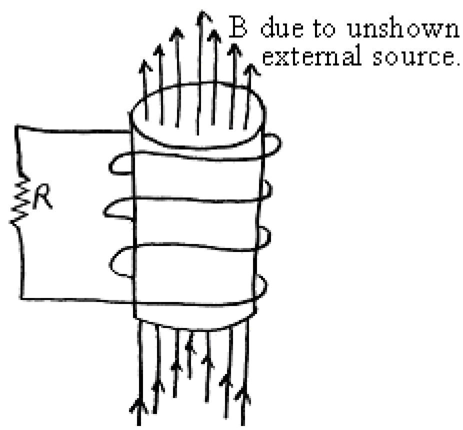
SAC218

1) A horizontal ring of radius 0.280 cm is in a uniform downward-directed 3.68 mT magnetic field. Find the magnetic flux through the ring.

2) A horizontal triangle whose sides are of length 40.0 cm, 30.0 cm, and 20.0 cm respectively, is in a uniform upward-directed 0.500 T magnetic field. Find the magnetic flux through the triangle.

3) A horizontal square of side length 0.200 m is in an upward-directed magnetic field which is increasing at the rate of 5.00 mT/s. Find the rate of change of the magnetic flux through the loop.

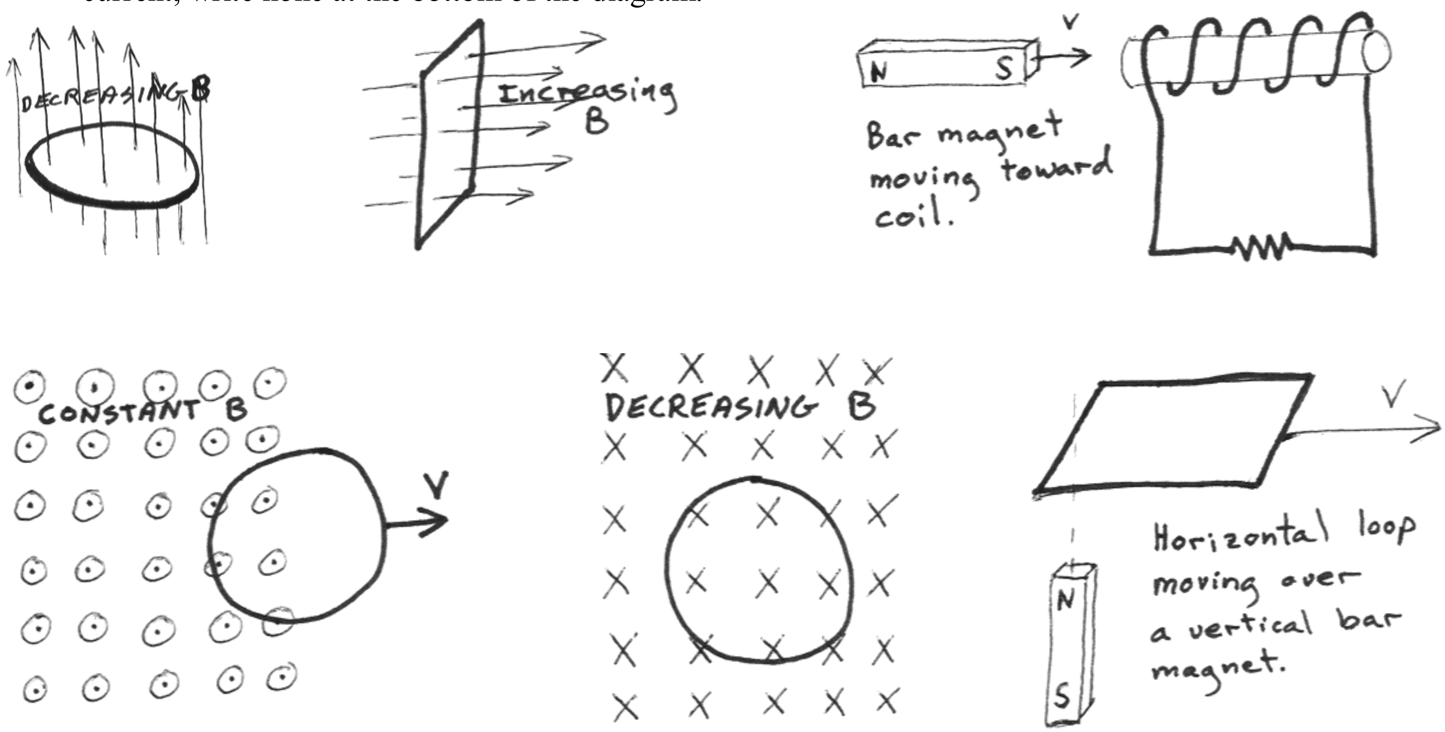
4) At right is depicted a coil of wire through which upward-directed magnetic field lines due to an unspecified source, extend. Because of actions of an external agent (not specified) the magnetic field is decreasing. Which way (upward or downward) does the resulting current flow through the resistor. Explain thoroughly in a step-by-step fashion. Refer to each applicable law by name in your explanation.



SAC219

1) A horizontal loop of radius 0.180 m is in a region of space where there is an upward directed magnetic field that is increasing in strength at the rate of 0.100 T per second. The length of wire making up the loop has a resistance of 0.860 mΩ. Find the current induced in the loop. State the direction of the current as well as the value with units.

2) In each diagram below, indicate, by means of an arrow (a curved arrow if appropriate) the direction of the current induced to flow in the loop or coil depicted. (If there is no induced current, write none at the bottom of the diagram.



3) A wire loop forms the perimeter of a flat circular area of .36 m^2. The resistance of the wire is 1.5 ohms. The loop lies in a horizontal plane in a region of space where there is a downward-directed magnetic field B = .015 tesla. The wire is pulled to one side so that it is completely out of the field after 0.20 s. For the 0.20 s period during which the loop is being pulled out of the magnetic field:

a) Find the average EMF in the loop.
b) Find the average current in the loop.
c) Find the total charge passing any point in the loop.
d) Find the average power dissipated in the loop.
e) Find the total energy dissipated in the loop.
f) Find the direction of the current in the loop.

4) The potential difference between the two terminals of an ordinary electrical receptacle in your home varies sinusoidally with a frequency of 60.0 Hz. The rms value of the oscillating voltage is between 115 volts and 120 volts. For a case in which the rms value is 117 volts, what is the amplitude of the oscillations of the voltage?

SAC220

1) A uniform $0.250\,\mathrm{N/C}$ downward-directed electric field extends through a horizontal circle of radius $13.6\,\mathrm{cm}$. Find the electric flux through the circle.

2) A uniform upward directed electric field is increasing at the rate of $1.20\,\mathrm{kN/C}$ per second. The electric field passes through a horizontal circle of diameter $30.0\,\mathrm{cm}$. Find the rate of change of the electric flux through the circle.

3) An upward-directed electric field passes through a horizontal circle of radius $6.00\,\mathrm{cm}$. Inside the imaginary vertical cylinder whose surface contains the circle, the electric field is uniform. Outside that cylinder, there is no electric field. Where it exists, the electric field is increasing at the rate of $2.10\,\dfrac{\mathrm{kN}}{\mathrm{C}\cdot\mathrm{s}}$. Find the magnetic field on the circle. Give both magnitude and direction.

4) An upward-directed *magnetic* field passes through a horizontal circle of radius $4.00\,\mathrm{cm}$. Inside the imaginary vertical cylinder whose surface contains the circle, the magnetic field is uniform. Outside that cylinder, there is no magnetic field. Where it exists, the magnetic field is increasing at the rate of $0.0370\,\dfrac{\mathrm{T}}{\mathrm{s}}$. Find the electric field on the circle. Give both magnitude and direction.

SAC220a

1) You are facing a tiny bar magnet having a magnetic dipole moment of .110 Am^2. The bar magnet is aligned with the vertical, north end up. Relative to you, the magnet is moving rightward at a speed of 45.0 m/s. Find the electric field, in your reference frame, due to the moving magnetic field of the bar magnet, at a point in space which, at the instant in question is 1.0 cm above position of the bar magnet. (The electric field is a vector, so, you have to find both a magnitude and a direction. In your final answer, write the magnitude as a value with units, and specify the direction in words.)

2) A very long straight horizontal neutral copper wire carries a steady current of 15.0 A due north. Also, relative to you, the wire itself is moving due northward at a speed of 28.0 m/s. Find the electric field, in your reference frame, due to the moving magnetic field of the wire, at a point in space that is .0254 m eastward of the wire (at the same elevation as the wire).

3) Relative to you, a particle have a charge of 1.20 microcoulombs is moving straight downward with a speed of 105 m/s. Find the magnetic field, in your reference frame, due to the moving electric field of the particle, at a point in space which, at the instant in question, is 1.90 cm south of the particle (due south and at the same elevation as the particle).

4) A tiny lead pellet having a charge of 8.88×10^{-8} C is dropped from rest from a point that is 19.5 m above the elevation of point P, an empty point in space that is itself about a meter above the ground. At time *t*, the instant when the lead pellet is at the same elevation as point P (and still falling), the pellet is 1.00 m due south of point P. At time *t*, what is the magnetic field at point P, due to the falling pellet, in the reference frame of a person who is standing at rest on the ground? Neglect air resistance.

SAC221

1) The light-year is a non-SI unit of distance that astronomers find convenient for characterizing how far away stars are. Because the expression "light-year" includes the word year, people often mistake the light-year for a unit of time. But it is not a unit of time, the light-year is a unit of distance. It is the distance that light travels (through vacuum) in a year. Determine the distance, in meters, that a light year is. The speed of light is $c = 3.00 \times 10^8 \frac{\text{m}}{\text{s}}$. There are 365.25 days in a year, 24 hours in a day, 60 minutes in an hour, and 60 seconds in a minute. Make sure that your answer has units of distance, not velocity.

2) Light having a wavelength of 654 nm is visible. It appears red. Find the frequency of such light.

3) The frequency of light does not change when the light passes from one transparent medium to another, but, the wavelength does. Light of wavelength 465 nm in vacuum enters glass whose index of refraction is 1.50 (with no units). Find the frequency of the light and use that value to determine the wavelength of the light in the glass.

4) In a demonstration, a physics professor puts some charge on a Ping Pong ball fastened to the end of a 79 cm long quartz rod. The other end of the rod is fixed to the wall so that the rod protrudes from the wall at right angles to the wall. Then the professor "plucks" the rod near the end where the Ping Pong ball is attached. The Ping Pong ball oscillates up and down on the end of the rod. A radio receiver with a signal analyzer receives the electromagnetic radiation given off by the Ping Pong ball and indicates that the wavelength is 966 km. Find the frequency of oscillations of the Ping Pong ball.

SAC222

1) A diffraction grating is characterized as having "600.0 lines per cm". Assuming uniform spacing between adjacent slits, find the center-to-center distance between adjacent slits. Note: The expression *"center-to-center"* is not really necessary here. The distance between slits in the case of a double slit as well as in the case of a diffraction grating is understood to be the center-to-center distance.

2) Light of wavelength 552 nm is normally incident on a double slit. The distance between the slits is 12.4 µm. After passing through the double slit, the light illuminates a screen 2.60 m away from the double slit. Find the separation of the two first-order maxima.

3) Light of wavelength 619 nm is normally incident on a 65-lines-per-cm diffraction grating. With respect to the straight-ahead direction, at what angle, if any, does the third order interference maximum occur?

4) A person shines a beam of light of wavelength (622.20 ± 0.10) nm horizontally toward a flat vertical mask with two closely-spaced vertical slits in it. The light is normally incident on the mask. The light that passes through the slits hits a screen that is parallel to the mask and is (4.200 ± 0.010) m away from the mask. The brightest part of the first interference maximum to the left of the central maximum is measured to be (0.7200 ± 0.0030) m from the brightest part of the first interference maximum to the right of the central maximum. Find the center-to-center separation of the slits and the uncertainty in that value.

SAC223

1) Light of wavelength 652 nm shines through a single slit and illuminates a screen 4.60 m away from the slit. A diffraction pattern appears on the screen. The first minimum is observed to be 22.0 cm away from the central maximum. Find the width of the slit.

2) Find the angular separation of the two first-order minima (this angular separation is also known as the angular width of the central maximum) for the case of a single slit of width 8.12 μm in a flat mask upon which light of wavelength 555 nm is normally incident.

3) A beam of horizontally-traveling light of wavelength 495 nm is normally incident on the center of a rectangular screen of width 27.94 cm and height 21.59 cm. A person puts a flat mask between the screen and the light source at a distance of 5.19 m from the screen. The mask is oriented so that the light is normally incident on the mask. There is a vertical slit of width 0.0854 mm in the mask. The beam of light is centered on the slit. The diameter of the beam of light, where it hits the mask, is 2.00 mm. How many diffraction minima appear on the screen?

4) Monochromatic light is normally incident on a slit of width 0.100 mm. The first interference minimum occurs at a distance of 2.00 m from the straight ahead position on a screen that is 5.00 m behind the slit. What is the wavelength of the light? Is the light visible light?

SAC223a

Thin Film Interference Problems

1) White light is normally incident on a thin film of soapy water. The thin film is surrounded by air. The index of refraction of the soapy water is 1.40 . The reflected light appears purple. The intensity of the reflected light peaks at a wavelength (of the light in air) of 415 nm. Find the minimum thickness of the film.

2) Two pieces of 5 mm thick plate glass are stacked one on top of the other. At various locations in the glass, a thin film of air is trapped between the two layers of glass. Light from a sodium vapor lamp (wavelength 589 nm) is normally incident on the glass at a location where the thickness of the air layer is known to be greater than 250 nm. Looking at the glass from essentially the same position as the source, the spot on the glass where the light is normally incident on the glass appears dark. **What is the minimum thickness of the layer of air at that location in the glass?** [Include a diagram. At each surface indicate whether the light, upon reflection, experiences phase reversal (P.R.) or no phase reversal (N.P.R.)].

3) A thin coating of material having index of refraction 1.30 is to be placed on some glass having an index of refraction of 1.50 in order to minimize the reflection of normally-incident visible light. (Use 550 nm as the wavelength of visible light in air because that wavelength falls near the middle of the visible light spectrum). Find the minimum coating thickness that one should use.

4) How thick must the $n_1 = 1.21$ antireflective coating on an $n_1 = 1.46$ glass lens be in order to minimize the reflection of normally incident light of wavelength 550 nm?

SAC224

1) Completely unpolarized light of intensity 4.80 W/m^2 is normally incident on a polarizer. What is the intensity of the light that gets through?

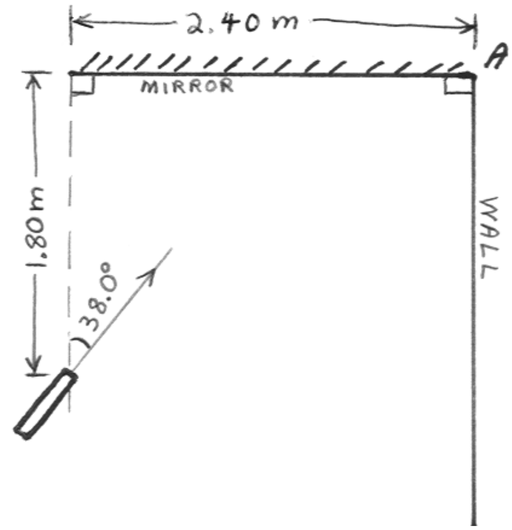
2) Completely unpolarized light of intensity 16.0 W/m^2 has two polarizers, one behind the other, in its path. Each is aligned so that its surface is perpendicular to the path of the light. The polarization direction of the first polarizer is vertical. The polarization direction of the second one is horizontal. Find the intensity of the light that makes it through both polarizers.

3) Completely unpolarized light of intensity 16.0 W/m^2 has two polarizers, one behind the other, in its path. Each is aligned so that its surface is perpendicular to the path of the light. The polarization direction of the first polarizer is vertical. The polarization direction of the second one is horizontal. A third polarizer is inserted in between the original two polarizers. The polarization direction of the third polarizer makes a 38.0° angle with the vertical. Find the intensity of the light that makes it through all three polarizers.

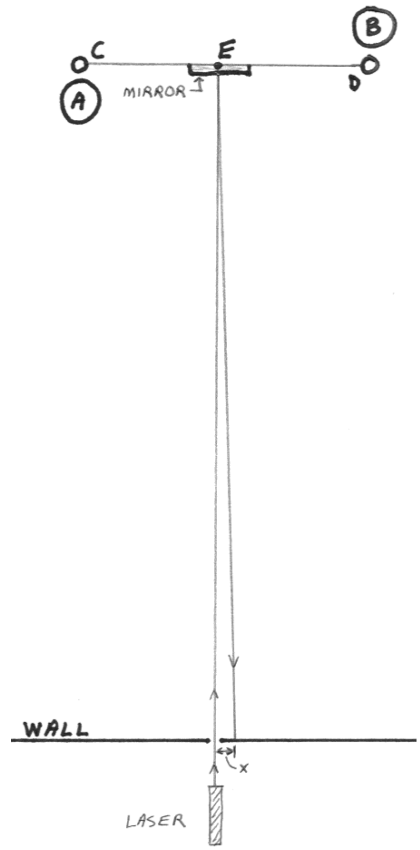
4) Light of intensity 11.7 W/m^2 is traveling straight downward toward a horizontal piece of polarizing material. The incoming light is already polarized in the compass direction 75.0°. The intensity of the light that makes it through the polarizer is 3.87 W/m^2. What are the possible polarization directions of the polarizer (assumed to be an ideal polarizer)?

SAC225

1) A laser shines a horizontal beam of light into a mirror as depicted at right. Where on the wall does the beam hit the wall. Specify your answer as a horizontal distance measured from corner A.



2) A Cavendish balance is used to determine the gravitational force exerted on one lead ball by another as depicted at right. The reader is looking down on the apparatus from above. The rod with the mirror and two small lead balls (C & D) is suspended by a thin gold ribbon at point E. Prior to the lead balls A & B being moved into the positions shown, the mirror was parallel to the wall opposite (that wall being 15.0 m from the mirror) and the incoming laser beam is perpendicular to both the wall and the mirror so that the laser beam reflects straight back on itself. Once lead balls A and B are moved into the positions shown, however, the rod with the mirror on it rotates through a tiny angle causing the beam to hit the wall a distance x = 3.20 mm from the point where the line along which the incoming beam travels, intersects the wall. Find the angle through which the rod rotates.

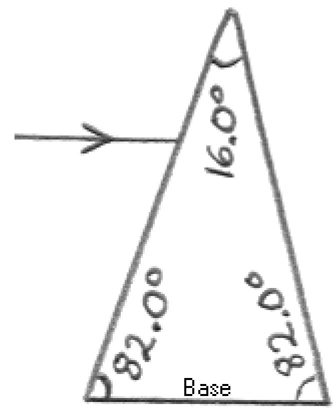


3) A ray of light is incident on a plane mirror at an angle of incidence of 15 degrees. What angle does the reflected ray make with the plane of the mirror? (Note that the angle of incidence is not measured with respect to the plane of the mirror.)

SAC226

1) A ray of light traveling in air (index of refraction 1.00) toward a plane interface between the air and some glass whose index of refraction is 1.50 makes an angle of 49.0° with the surface of the glass. Find the angle of refraction.

2) A ray of light traveling in air, parallel to the base of a quartz (index of refraction 1.46) prism passes through the prism and comes out the other side. Find the angle that the exit ray makes with the base of the prism.



3) Starting with Snell's Law, find the critical angle for light traveling in water and encountering a water-to-air interface.

SAC227

1) (You need a metric ruler for this one.) Construct a life-size (scale 1:1) ray-tracing diagram for the case of an 8.00 cm tall object that is 12.00 cm from a thin converging lens whose focal points are each 4.00 cm from the lens. Use the ray-tracing diagram (not calculations) to determine:

a) the position of the image,

b) the absolute value of the height of the image,

c) whether the image is erect or inverted, and,

d) whether the image is real or virtual.

Hint: In stating the position of the image, use the convention that the real physical object is in front of the lens and anything on the other side of the lens is behind the lens. Use a value-with-units and words to clearly state where the image is.

2) (You need a metric ruler for this one.) Construct a life-size (scale 1:1) ray-tracing diagram for the case of a 4.00 cm tall object that is 4.50 cm from a thin converging lens whose focal points are each 10.0 cm from the lens. Use the ray-tracing diagram (not calculations) to determine:

a) the position of the image,

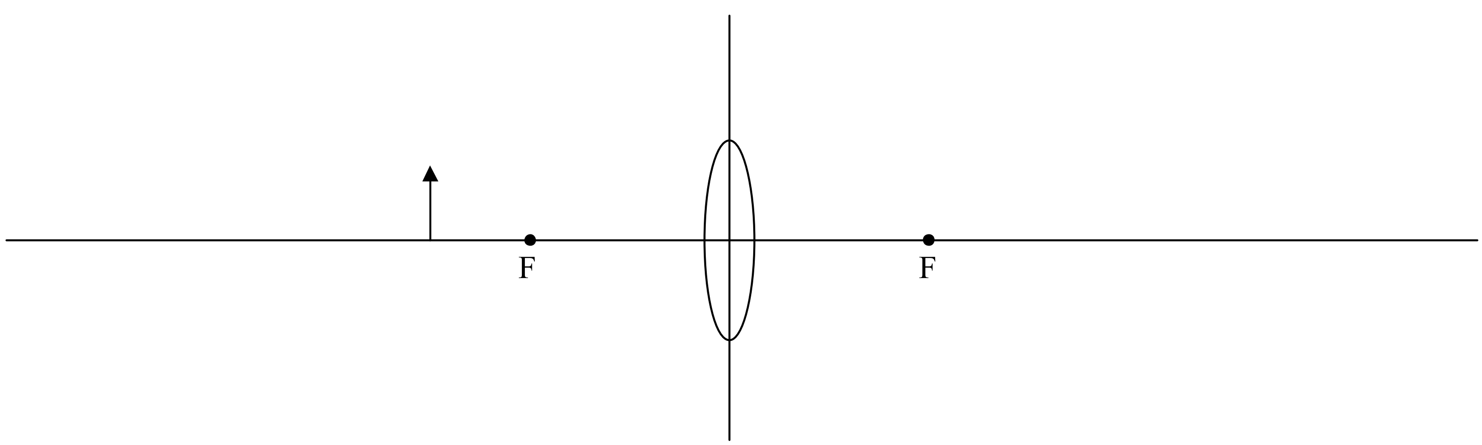
b) the absolute value of the height of the image,

c) whether the image is erect or inverted, and,

d) whether the image is real or virtual.

Hint: In stating the position of the image, use the convention that the real physical object is in front of the lens and anything on the other side of the lens is behind the lens. Use a value-with-units and words to clearly state where the image is.

3) Use a ray diagram to locate the image of the arrow in the life-size (scale 1:1) diagram below. Show all three principle rays. Make measurements with a ruler to answer the questions.



a) At what distance "o" is the object from the lens? (The arrow appearing in the original diagram is the object. All distances "from a lens" are measured from the plane of the lens.)

b) What is the height of the object?

c) What is the image distance i?

d) What is the image height h'

e) What is the magnification?

f) Is the image real, or is it virtual?

g) Is the image erect, or is it inverted?

SAC228

1) (You need a metric ruler for this one.) Construct a life-size (scale 1:1) ray-tracing diagram for the case of a 7.0 cm tall object that is 12.0 cm from a thin diverging lens whose focal points are each 9.0 cm from the lens. Use the ray-tracing diagram (not calculations) to determine:

a) the position of the image,
b) the absolute value of the height of the image,
c) whether the image is erect or inverted, and,
d) whether the image is real or virtual.

Hint: In stating the position of the image, use the convention that the real physical object is in front of the lens and anything on the other side of the lens is behind the lens. Use a value-with-units and words to clearly state where the image is.

2) (You need a metric ruler for this one.) Construct a life-size (scale 1:1) ray-tracing diagram for the case of a 7.0 cm tall object that is 6.0 cm from a thin diverging lens whose focal points are each 11.0 cm from the lens. Use the ray-tracing diagram (not calculations) to determine:

a) the position of the image,
b) the absolute value of the height of the image,
c) whether the image is erect or inverted, and,
d) whether the image is real or virtual.

Hint: In stating the position of the image, use the convention that the real physical object is in front of the lens and anything on the other side of the lens is behind the lens. Use a value-with-units and words to clearly state where the image is.

SAC229

1) For the case of a 15.0 cm tall object that is 27.0 cm from a converging lens whose focal points are each 25.0 cm from the lens, determine algebraically:

a) the position of the image,
b) the absolute value of the height of the image,
c) whether the image is erect or inverted,
d) whether the image is real or virtual, and,
e) the absolute value of the magnification of the lens.

Hint: In stating the position of the image, use the convention that the real physical object is in front of the lens and anything on the other side of the lens is behind the lens. Use a value-with-units and words to clearly state where the image is.

2) For the case of a diverging lens whose focal points are 25.0 cm from each other, find, using algebraic means, for an object of height 4.00 cm that is 7.00 cm closer to the lens than the focal point on the object's side of the lens is:

a) the position of the image,
b) the absolute value of the height of the image,
c) whether the image is erect or inverted,
d) whether the image is real or virtual, and,
e) the absolute value of the magnification of the lens.

Hint: In stating the position of the image, use the convention that the real physical object is in front of the lens and anything on the other side of the lens is behind the lens. Use a value-with-units and words to clearly state where the image is.

3) Find the power of a lens whose focal length is 0.750 m.
Hint: Write the power in units of diopters.

4) Consider an object of height 6.20 cm which is 26.0 cm to the left of lens #1 which is itself 42.0 cm to the left of lens #2. Lens #1 is a converging lens whose focal points are 10.0 cm from the lens itself. Lens #2 is a diverging lens whose focal points are 16.0 cm from the lens itself. Find, using algebraic means, the position, relative to lens #2, of the image formed by the pair of lenses.

Hints:

- Because the object and the lenses are described as being lined up from left to right, you should state that the image is such and such a distance to the right of, or to the left of, as applicable, lens #2.
- You should include a sketch as part of the solution of any problem (which you are supposed to solve algebraically) involving lenses. But it is even more important to do so in cases involving multiple lenses.

SAC401

1) The position vector, with respect to the origin of a Cartesian coordinate system, of a particle with charge $0.640\,\mu\text{C}$ is $1.30\text{ cm}\,\hat{\imath} + 1.95\text{ cm}\,\hat{\jmath} - 1.00\text{ cm}\,\hat{k}$. The position vector of a second particle, this one of charge $0.450\,\mu\text{C}$, is $1.88\text{ cm}\,\hat{\imath} - 1.05\text{ cm}\,\hat{\jmath} + 1.40\text{ cm}\,\hat{k}$. Find the force exerted on the second particle by the first.
Hint: Force is a vector. Because vectors given in the problem are specified in unit vector notation, the answer should be specified in unit vector notation.

SAC403

1) Two particles are at fixed positions in space. Their positions are specified in terms of a Cartesian coordinate system as follows:

One particle, of charge $0.045\,\mu\text{C}$ (recall μC is to be read "micro-Coulombs" and means $\times 10^{-6}\,\text{C}$), is at the origin. The other particle has charge $-0.068\,\mu\text{C}$ and its position vector is $5.0\,\text{cm}\,\mathbf{j}$.

a) Find the electric field vector, expressed in unit vector notation, at the point whose position vector is $3.0\,\text{cm}\,\mathbf{i} + 5.0\text{cm}\,\mathbf{j}$.

b) Find the force that would act on each of the following particles if it were placed at the position at which you found the electric field in part a:
1) an electron,
2) a doubly ionized Helium Ion He^{++} (charge = +2e),
3) a particle whose charge is $+0.055\,\mu\text{C}$.

2) Find the electric field at an empty point in space whose position vector is $-2.40\,\text{cm}\,\hat{\imath} + 1.25\,\text{cm}\,\hat{\jmath} - 3.00\,\text{cm}\,\hat{k}$ due to a particle of charge $0.650\,\mu\text{C}$ whose position vector is $1.30\,\text{cm}\,\hat{\imath} + 1.95\,\text{cm}\,\hat{\jmath}$.

SAC404

1) Two particles are at fixed positions in space. Their positions are specified in terms of a Cartesian coordinate system as follows:

One particle, of charge $-84\,\text{nC}$ (recall nC is to be read "nanocoulombs" and means $\times 10^{-9}\,\text{C}$), is at the origin. The other particle has charge +45 nC and its position vector is $4.0\,\text{cm}\,\hat{\mathbf{i}} + 5.0\,\text{cm}\,\hat{\mathbf{k}}$.

a) Find the electric field vector, expressed in unit vector notation, at the point whose position vector is $2.0\,\text{cm}\,\hat{\mathbf{i}} + 3.0\,\text{cm}\,\hat{\mathbf{j}}$.

b) Find the force that would act on each of the following particles if it were placed at the position at which you found the electric field in part a:

i) an electron,

ii) a doubly ionized Helium Ion He^{++} (charge = +2e),

iii) a particle whose charge is $+.055\,\text{nC}$.

SAC418

1) A copper coil consisting of 475 turns, each of radius $1.17\,\text{cm}$, has a magnetic field, due to an unspecified external source, passing through the coil, parallel to the axis about which the wire is wound. The magnetic field is, at any instant in time, uniform throughout the interior of the coil. The magnetic field depends on time as: $B = 0.0155\,\text{T}\,\sin\left(377\frac{\text{rad}}{\text{s}}t\right)$. Note that the symbols T, rad, and s represent tesla, radians, and seconds respectively, whereas the symbol t is the time variable. Find the EMF induced in the coil. Express your answer as a function of time.

SAC419

1) The area of a horizontal wire loop depends on time t as: $A = 0.850\text{m}^2 e^{-125 s^{-1} t}$ (where m and s are the units meters and seconds respectively). The loop is, at all times, in a horizontal plane in a region of space where there exists a constant uniform upward-directed $0.505\,\text{T}$ magnetic field. Find the EMF in the loop at $t = .100\,\text{s}$.

SAC427

1) For the case of a 15.0 cm tall object that is 27.0 cm from a converging lens whose focal points are each 25.0 cm from the lens, determine algebraically:

a) the position of the image,
b) the absolute value of the height of the image,
c) whether the image is erect or inverted,
d) whether the image is real or virtual, and,
e) the absolute value of the magnification of the lens.

Hint: In stating the position of the image, use the convention that the real physical object is in front of the lens and anything on the other side of the lens is behind the lens. Use a value-with-units and words to clearly state where the image is.

2) For the case of a diverging lens whose focal points are 25.0 cm from each other, find, using algebraic means, for an object of height 4.00 cm that is 7.00 cm closer to the lens than the focal point on the object's side of the lens is:

a) the position of the image,
b) the absolute value of the height of the image,
c) whether the image is erect or inverted,
d) whether the image is real or virtual, and,
e) the absolute value of the magnification of the lens.

Hint: In stating the position of the image, use the convention that the real physical object is in front of the lens and anything on the other side of the lens is behind the lens. Use a value-with-units and words to clearly state where the image is.

3) Find the power of a lens whose focal length is 0.750 m.
Hint: Write the power in units of diopters.

4) Consider an object of height 6.20 cm which is 26.0 cm to the left of lens #1 which is itself 42.0 cm to the left of lens #2. Lens #1 is a converging lens whose focal points are 10.0 cm from the lens itself. Lens #2 is a diverging lens whose focal points are 16.0 cm from the lens itself. Find, using algebraic means, the position, relative to lens #2, of the image formed by the pair of lenses.

Hints:

- Because the object and the lenses are described as being lined up from left to right, you should state that the image is such and such a distance to the right of, or to the left of, as applicable, lens #2.
- You should include a sketch as part of the solution of any problem (which you are supposed to solve algebraically) involving lenses. But it is even more important to do so in cases involving multiple lenses.

SAC428

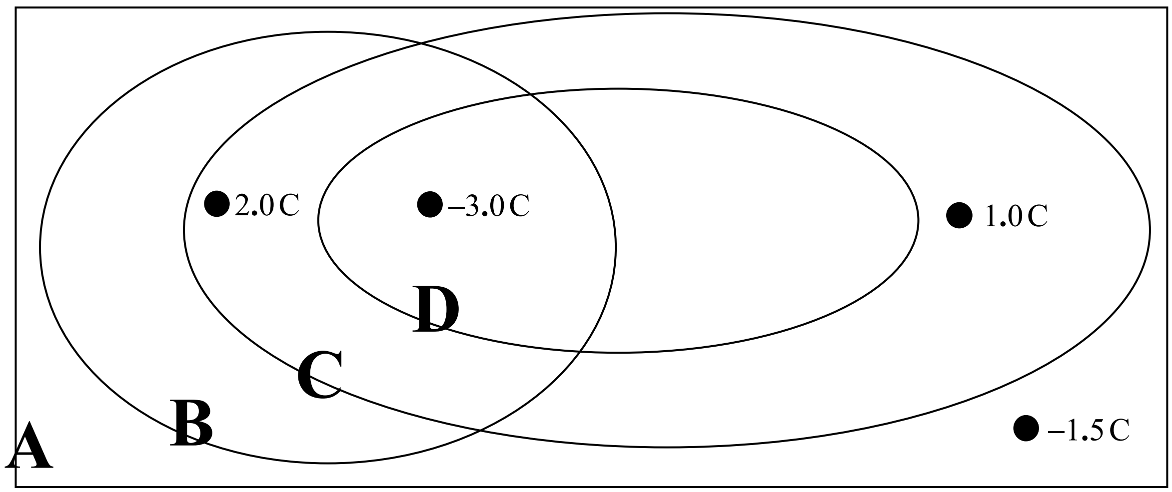
1) A linear charge distribution extends along the x axis from $x = 0$ to $x = A$ (where $A > 0$). In that region, the charge density λ is given by $\lambda = cx$ where c is a constant. Find the electric field valid for positions to the right of $x = A$ on the x axis.

2) An amount of charge $+Q$ is distributed uniformly along a line segment of length L that lies on the y-axis of an x-y coordinate system. The bottom of the line segment is a distance a above the origin. Determine an expression for the x-component (not the y-component) of the electric field on the x-axis. (In other words, find E_x at point P where P is on the x-axis at a distance x to the right of the origin.) Your answer should be a definite integral over a single variable. No variables that depend on the variable of integration should appear in your integrand. Use a diagram to help communicate your solution. As always, show all work.

3) a) A total charge of $5.60 \times 10^{-7}\,\text{C}$ is distributed uniformly along the x-axis in the form of a line segment that extends from $x = -2.00\,\text{cm}$ to $x = +2.00\,\text{cm}$. Find the electric field due to this line segment of charge at $y = 5.00\,\text{cm}$ on the y axis.
b) How does the magnitude of the electric field due to the line segment of charge at $y = 5.00\,\text{cm}$ on the y axis compare to the magnitude of the electric field due to a point charge of $5.60 \times 10^{-7}\,\text{C}$ at a distance of $5.00\,\text{cm}$ from the point charge?

SAC429

1) In the diagram below, each closed loop or rectangle (A, B, C, D) represents the intersection of an imaginary closed surface with the plane of the page. The black dots represent charged particles whose charges are indicated. (You have to use your imagination here. Consider the charged particles to lie in the plane of the page. The rectangle represents the intersection of an imaginary box with the plane of the page. Each oval represents the intersection of an imaginary spheroid with the plane of the page.) Find the electric flux through each of the closed surfaces.



2) Consider a rectangle whose corners are at: (−2.00 cm, 0, −4.10 cm), (0, +3.60 cm, −4.10 cm), (0, +3.60 cm, +4.10 cm), (−2.00 cm, 0, +4.10 cm). The rectangle is to be considered one side of a box which encloses the origin. Find the electric flux outward through the rectangle for the case of a uniform 1460 N/C electric field that is:

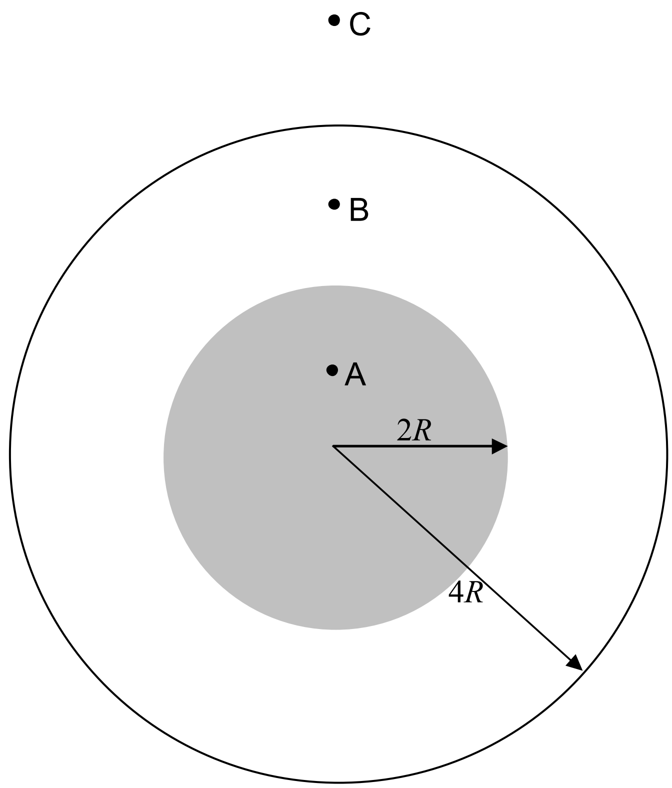
a) in the +x direction.
b) in the +y direction.
c) in the +z direction.

3) Consider a flat circular sheet of radius 3.60 cm whose center is at (4.00 cm, 6.00 cm, 5.00 cm) which is facing away from the origin (the outward direction is away from the origin) in the same direction as the position vector of its center. Find the electric flux outward through the flat circular sheet for the case of a uniform 2250 N/C electric field that is:

a) in the +x direction.
b) in the +y direction.
c) in the +z direction.

SAC430

1) Charge Q is distributed uniformly throughout the volume of the inner sphere of radius $2R$ at right. Charge $-Q/2$ is distributed uniformly on the spherical shell of radius $4R$ at right. The two spheres are centered on one and the same point. Use Gauss's Law to find the electric field at points A, B, and C, at distances R, $3R$, and $5R$ respectively from the center of the charge distribution.



2) You are asked to cover a smooth sphere of radius 3.00 m with contact paper. There is to be no overlap. You are provided with a stack of sheets of contact paper each in the shape of a square, 1.00 meters on a side. You are free to cut the contact paper any way you please. How many sheets of contact paper will you need. Give your answer to the nearest 1/100 of a sheet.

3) A point charge of $-6.25\times10^{-7}\,\text{C}$ is at the common center of a spherical shell of radius 1.50 m and another spherical shell of radius 4.00 m. $+1.00\times10^{-6}\,\text{C}$ of charge is uniformly distributed on the smaller shell and $+2.00\times10^{-6}\,\text{C}$ of charge is uniformly distributed on the larger shell. Find the electric field at a point 3.00 m away from the point charge. Include an appropriate sketch as part of your answer.

SAC431

1) A very thin vertical stick of length $L = 0.250$ meters has an amount of charge $Q = 4.20\,\mu\text{C}$ distributed uniformly over its entire length. Find the electric potential for a point that is 0.250 meters from the upper endpoint of the stick, and, which is in the horizontal plane containing the upper endpoint of the stick.

2) Charge Q is distributed uniformly on a horizontal ring of radius R. Find the electric potential valid for points above the ring that are on the ring's axis of symmetry.

3) Find the electric potential on the positive y axis due to a continuous but non-uniform distribution of charge lying on the x-axis from $x = -L$ to $x = L$ where the charge density in that region is given by $\lambda = cx$ where c is a constant having units of C/m^2.

4) Charge Q is uniformly distributed on a line on the x-axis that extends from $x = -L/2$ to $x = L/2$.

a) Find the electric potential valid for any point in the first quadrant of the x-y plane not on the line of charge. (You are not required to evaluate the resulting integral.)

b) Use your result from a to find the value of the electric potential (in volts) at $(0, L)$ for the case where $Q = 0.85\,\mu\text{C}$ and $L = 15\,\text{cm}$.

SAC432

1) The electric potential due to a specific charge distribution is determined to be

$$V(x) = 15\frac{\text{volts}}{\text{meter}}(x - 5.0\,\text{meters})$$

Find the electric field. Recall that the electric field is a vector, thus, one must either specify magnitude and direction or give the answer using $\hat{\imath}$, $\hat{\jmath}$, $\hat{k}$ notation.

2) The electric potential due to an unspecified charge distribution is given as:

$$V(x) = kq\frac{d}{x^2 - \frac{d^2}{4}}$$

Find the electric field. Recall that the electric field is a vector, thus, one must either specify magnitude and direction or give the answer using $\hat{\imath}$, $\hat{\jmath}$, $\hat{k}$ notation. Note that k, q, and d are constants—k is the Coulomb constant, q is an amount of charge, and d is a distance.

3) The electric potential due to an unspecified charge distribution is given as:

$$V(x, y, z) = \frac{kq}{\sqrt{x^2 + y^2 + z^2}}$$

Find the electric field. Recall that the electric field is a vector, thus, one must either specify magnitude and direction or give the answer using $\hat{\imath}$, $\hat{\jmath}$, $\hat{k}$ notation.

SAC433

Calculating the Electric Field from the Electric Potential

1) Charge Q is uniformly distributed along the x axis from 0 to A (where $A > 0$).
   a) Find the electric potential valid for positions to the right of A on the x axis.
   b) Use the electric potential (and your conceptual understanding of the nature of the electric field that would be produced by such a charge distribution) to determine the electric field valid for positions to the right of A on the x axis.

2) A linear charge distribution extends along the x axis from 0 to A (where $A > 0$). In that region, the charge density λ is given by $\lambda = cx$ where c is a constant.
   a) Find the electric potential valid for positions to the right of A on the x axis.
   b) Use the electric potential (and your conceptual understanding of the nature of the electric field that would be produced by such a charge distribution) to determine the electric field valid for positions to the right of A on the x axis.

3) Given the following arrangement of point charges on an x-y coordinate system:

$+1.5\times10^{-7}\,\text{C}$ at (0.45 meters, 0 meters), and

$-4.6\times10^{-7}\,\text{C}$ at the origin;

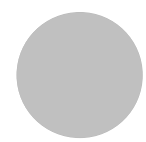
Find the electric potential (everywhere in the x-y plane), and, using it, find the electric field at (0.45 m, 0.50 m).

SAC434

Ampere's Law

1) Depicted at right is a cross section of a long (treat it as infinitely long) straight wire of diameter d. The wire is carrying current I directly away from you. Use Ampere's law to determine the magnitude of the magnetic field outside the wire. Sketch the magnetic field of the current-carrying wire. (The cross section referred to as simply the "cross section" in the case of a long straight object is the transverse cross section, either of the two new faces that would be formed if you made a clean cut of the long object, perpendicular to the direction in which the object extends.)

2) Depicted at right is a cross section of a long (treat it as infinitely long) straight wire of diameter d. The wire is carrying current I directly toward you. The current density (the current per area of the cross section) is uniform over the entire cross section.



a) Sketch the magnetic field of the current-carrying wire.

b) Find the magnetic field, as a function of the distance r from the center of the wire, of the current-carrying wire, valid for points inside the wire.

c) Find the magnetic field, as a function of the distance r from the center of the wire, of the current-carrying wire, valid for points outside the wire.

d) Do not use these values for parts a, b, and c, but now, assume the current I to be 4.0 amperes and the diameter d to be 8.0 cm. For values of r from 0 to 19 cm, make a graph of the magnitude of the magnetic field as a function of the distance r from the center of the wire.

SAC434a

Gauss's Law for the Magnetic Field

1) Consider a bar magnet having a magnetic dipole moment μ and length L. What is the net outward magnetic flux through the surface of an imaginary sphere which is centered on the center of the north end of the bar magnet and has a radius that is half the length of the bar magnet?

2) Charge flows with a current of 5.20 amperes along the x axis from $-\infty$ to ∞. What is the net outward magnetic flux through the surface of an imaginary cube, having edge length $0.850\,\text{m}$, that is centered on the origin and oriented so that every edge is parallel to a coordinate axis?

3) What is the net outward magnetic flux through the earth's surface? (The earth's magnetic field is approximately that of a magnetic dipole having a magnetic dipole moment of $8\times10^{22}\,\dfrac{\text{Nm}}{\text{T}}$ and the shape of the earth is approximately that of a sphere of radius $6.4\times10^{6}\,\text{m}$.)

4) A person has found the net outward magnetic flux through one end cap and the sidewall of an imaginary shell in the shape of a tin can of length $22.0\,\text{cm}$ and diameter $14.0\,\text{cm}$ to be a total of -153 webers. What is the net outward magnetic flux through the other end cap?

SAC435

Biot Savart

1) A wire segment carries a current I along the y axis from $y = L$ to the origin. Find the magnetic field, due to this current-carrying wire segment, at (L, L).

2) A wire segment carries a current I along the x axis from the origin to infinity. Find an expression for the magnetic field, due to the current-carrying wire, on the y axis valid for points at which $y > 0$.

SAC436

Biot Savart

1) Consider a Cartesian coordinate system. A wire is arranged so that a current I flows along the x-axis from a large negative value of x (treat it as $-\infty$) to the origin where the current makes an abrupt right turn and flows along the y axis from the origin to a large negative value of y (treat it as $-\infty$). Find an expression for the magnetic field, due to the current I, valid for points in the first quadrant of the x-y plane. Recall that the magnetic field is a vector.

2) A current I flows along a line (parallel to the x-axis) from $(-\infty, -L/2, 0)$ to $(0, -L/2, 0)$. From there it flows along the y axis from $(0, -L/2, 0)$ to $(0, L/2, 0)$. And finally, from there it flows along another line parallel to the x-axis to $(-\infty, -L/2, 0)$. Use the Biot Savart law to find an expression for the magnetic field valid for points on the x axis for which $x > 0$.

SAC437

Hall Effect Problems

1) Determine the free-electron density, n, the number-of-free-electrons-per-unit-volume, for copper, as follows:

a) Look up the atomic mass of copper.
b) Calculate n_{mass} , the number-of-copper-atoms-per-unit-mass, for copper.
c) Look up the density of copper.
d) Calculate n_{vol} , the number-of-copper-atoms-per-unit-volume, for copper.
e) Assuming that there is 1 free electron for each copper atom; and that, at any given instant, every copper nucleus has exactly one free electron that is closer to it (the copper nucleus) than it (the free electron) is to any other copper nucleus: write down the value of n.

2) A segment of copper wire that has been flattened into the form of a strip with a rectangular cross section that is 1 mm tall and 8 mm wide carries a 10 A current due northward through a region in which there is a downward-directed 0.5 tesla magnetic field. Find the potential difference between the edges of the copper strip. Make it clear which edge is at the higher potential, the east edge, or, the west edge, of the strip. (Assume that there is one free electron per atom of copper. Use the result from problem 1 for the free electron density for copper.)

3) A copper wire having a circular cross section of diameter 3 mm carries a current of 10 A. Find the drift velocity for the copper. (Assume that there is one free electron per atom of copper. Use the result from problem 1 for the free electron density for copper.)

4) A horizontal flat strip of metal having a width of 2.0 cm carries a current eastward through a region of space in which there is a uniform upward-directed 0.50 T magnetic field. The potential difference between the edges of the strip is 125 nV.

a) Which edge of the strip is at the higher potential?
b) Find the drift velocity of the electrons in the metal strip.

5) A flat copper strip that is 0.8 mm thick and 5.00 mm wide carries a 5 A current due south through a region of space in which there is a horizontally-directed magnetic field which is perpendicular to the larger surfaces of the strip. A potential difference of 45 nV develops between the edges of the strip, with the top edge of the strip being at the higher potential. Find the magnitude and direction of the magnetic field. (Assume that there is one free electron per copper atom. Use the result from problem 1 for the free electron density for copper.)

6) Find the electric potential difference that develops between the edges of a horizontal ribbon of copper which is 8 cm wide and only 0.5 mm thick (how long it is doesn't matter, but, to help you picture it, consider it to be about 30 cm long) when it is aligned horizontally to carry a current of 4.5 A eastward in a region of space where the horizontal component of the earth's magnetic field is due northward, where the angle of dip is 70° (meaning that the earth's magnetic field is at an angle of 70° below the horizontal) and where the magnitude of the earth's magnetic field is $6\times10^{-5}\,\text{T}$. Make it clear which edge is at the higher potential, the eastern edge, or, the western edge, of the ribbon. (Assume that there is one free electron per copper atom. Use the result from problem 1 for the free electron density for copper.)