

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) A bar magnet whose moment of inertia is 7.6 kg m^2 and whose magnetic dipole moment is $.90 \text{ A m}^2$ is suspended horizontally by a vertical silk thread. The bar magnet is in a uniform magnetic field of $17 \text{ } \mu\text{T}$ 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.

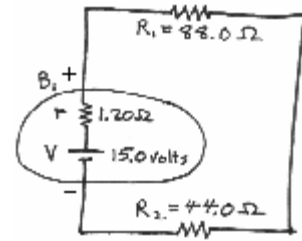
1) A two-conductor capacitor has a capacitance of 268 pF and carries a charge of 3.22 nC. Find the potential difference between the two conductors.

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.

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



3) A point charge of $-6.25 \times 10^{-7} \text{ C}$ is at the common center of a spherical shell of radius 1.50 m and another spherical shell of radius 4.00 m. $+1.00 \times 10^{-6} \text{ C}$ of charge is uniformly distributed on the smaller shell and $+2.00 \times 10^{-6} \text{ C}$ 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.

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 $x > 0$.

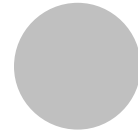
- 1) Positions in a region of space are specified by Cartesian coordinates. In that region of space there is a uniform 8500 N/C electric field in the $+x$ direction. Then, a particle having a charge of $0.460 \mu\text{C}$ is placed, and fixed in position, at the origin.
- a. Find the electric field at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

1) A 6.05 volt battery, a 157,000 ohm 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) 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) How thick must the $n_1 = 1.21$ antireflective coating on an $n_2 = 1.46$ glass lens be in order to minimize the reflection of normally incident light of wavelength 550 nm?

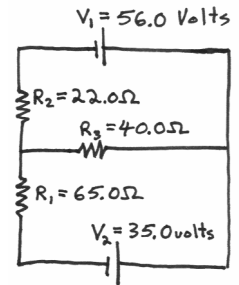
2. Depicted at right is the circular cross section of a long (treat it as infinitely long) straight wire of diameter d . The wire is carrying current I directly toward you. The current density (the current per area of the cross section) is uniform over the entire cross section.



- 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.

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

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.



1) The area of a horizontal wire loop depends on time t as: $A = 0.850\text{m}^2 e^{-125\text{s}^{-1}t}$ (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 T magnetic field. Find the EMF in the loop at $t = .100$ s.

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?

1) (Formerly SAC16e) 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. Find the electric field valid for positions to the right of A on the x axis.

2) (Formerly SAC16b) 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.

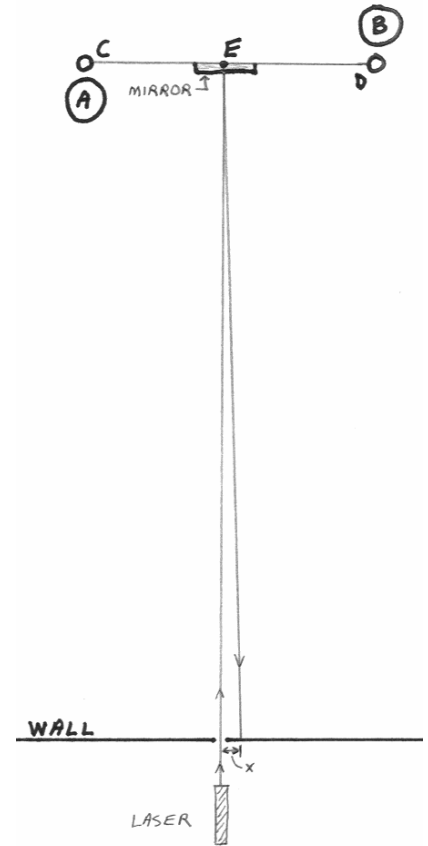
1. The electric potential due to a specific charge distribution is determined to be

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

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{i} , \hat{j} , \hat{k} notation.

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 m, that is centered on the origin and oriented so that every edge is parallel to a coordinate axis?

3) 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 particle having a mass of $5.01 \mu\text{g}$ 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 $-6.45 \mu\text{C}$. Find the speed of the positively charged particle when it is 1.00 cm from the negatively charged particle.

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.

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

- a) Find the electric field vector, expressed in unit vector notation, at the point whose position vector is $2.0 \text{ cm } \hat{i} + 3.0 \text{ cm } \hat{j}$.
- 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 $+0.055 \text{ nC}$.

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) (You need a metric ruler for this one.) Construct a ray-tracing diagram for the case of a 4.0 cm tall object that is 4.5 cm from a thin converging lens whose focal points are each 10 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) 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. 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.

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

+ 2.0×10^{-7} C at (0,0)

- 4.0×10^{-7} C at (3.0 cm, 0)

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

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

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 $\lambda = c x$ where c is a constant having units of C/m^2 .

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.

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.

9) For the circuit at right:

a) Label the two terminals of each seat of EMF “+” or “-“ as appropriate.

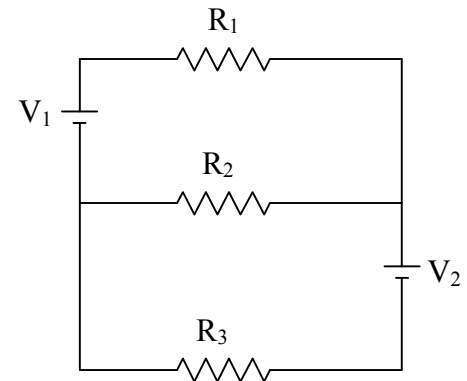
b) Draw arrows representing the currents in the various legs of the circuit. Label the arrows with symbols such as I_2 chosen to represent the currents.

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.

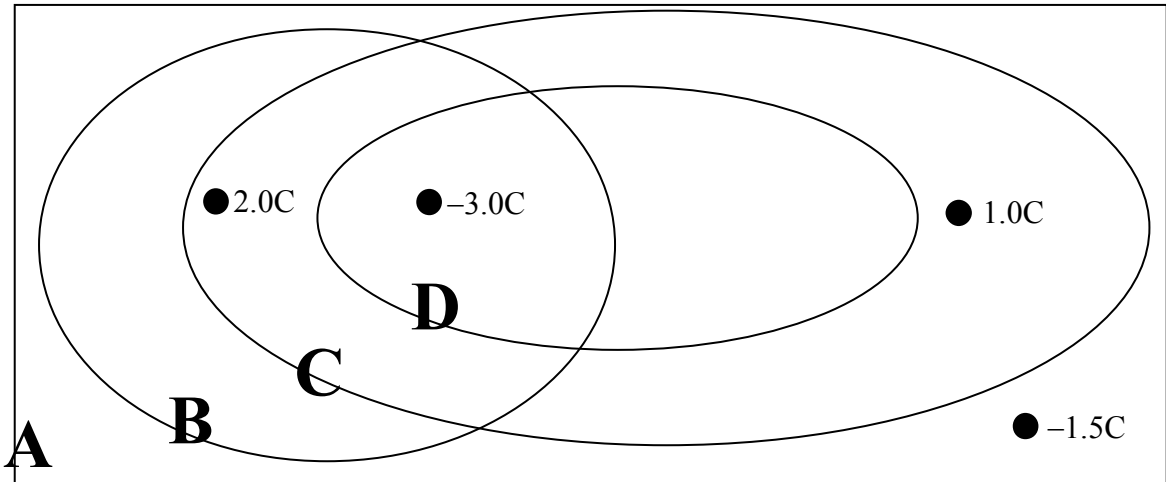
e) Clearly indicate one junction at which one can apply Kirchoff’s Junction Rule (a.k.a. Kirchoff’s Current Law) and write the equation for that junction.

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.)

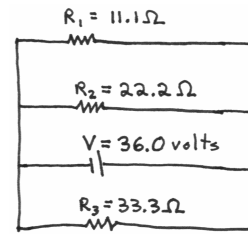


3) An upward-directed electric field passes through a horizontal circle of radius 6.00 cm. Inside the imaginary vertical cylinder whose surface contains the circle, the electric field is uniform. Outside that cylinder, there is no electric field. Where it exists, the electric field is increasing at the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

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.



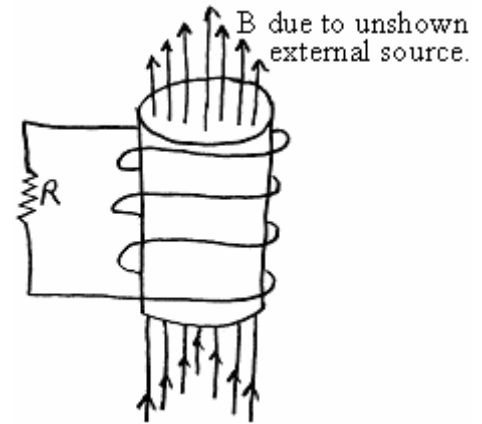
2) For the circuit at right, find the current through the battery.



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.

3) An electron has an initial velocity of $125,000 \text{ m/s}$ 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) 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.

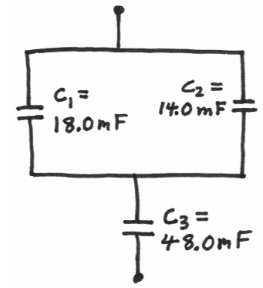


1) (You need a metric ruler for this one.) Construct a ray-tracing diagram for the case of a 7.0 cm tall object that is 12.0 cm from a thin diverging lens whose focal points are each 9.0 cm from the lens. Use the ray-tracing diagram (not calculations) to determine:

- 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.

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



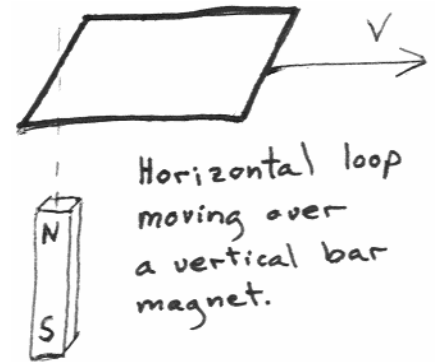
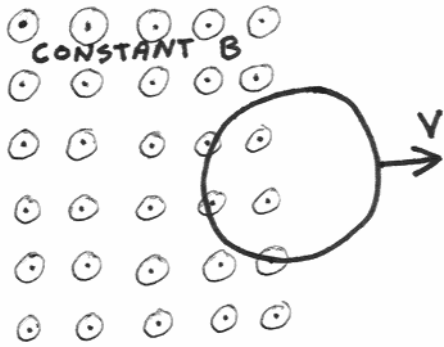
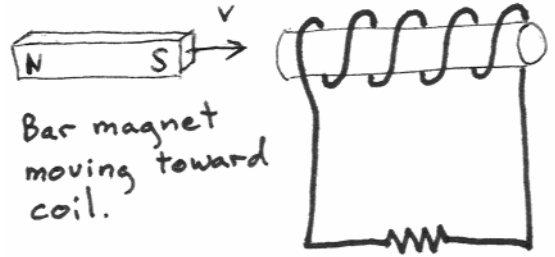
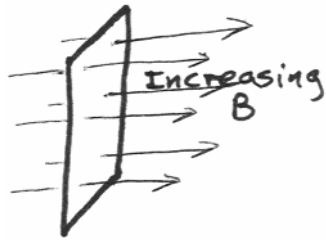
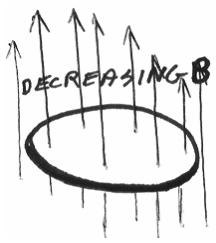
3) Find the power of a lens whose focal length is 0.750 m.
Hint: Write the power in units of diopters.

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 magnitude of the electric field E at that point.

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 $1.30 \text{ cm } \hat{i} + 1.95 \text{ cm } \hat{j} - 1.00 \text{ cm } \hat{k}$. The position vector of a second particle, this one of charge $0.450 \mu\text{C}$, is $1.88 \text{ cm } \hat{i} - 1.05 \text{ cm } \hat{j} + 1.40 \text{ cm } \hat{k}$. Find the force exerted on the second particle by the first.

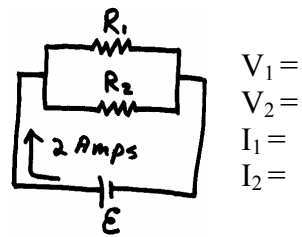
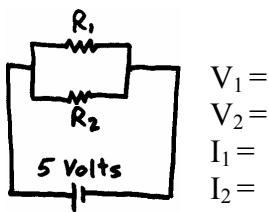
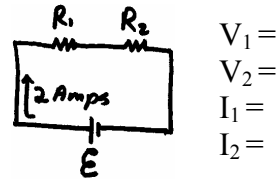
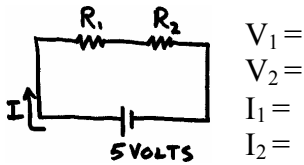
Hint: Force is a vector. Because vectors given in the problem are specified in unit vector notation, the answer should be specified in unit vector notation.

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.)



- 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 any and all of the indicated quantities whose value can be determined by inspection (no calculation). Write nothing for quantities whose values 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.



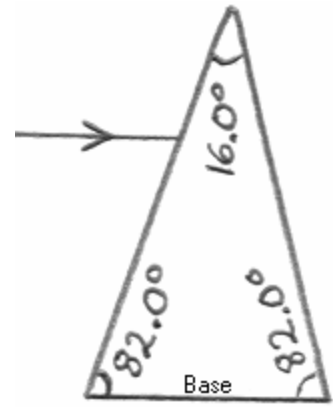
2) A proton that is 5.00 cm from particle A, a particle which has a charge of 6.42 pC, has a velocity of 9225 m/s straight at particle A. Particle A is fixed in space. How close does the proton get to particle A?

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.

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.

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.

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.



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.

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

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.