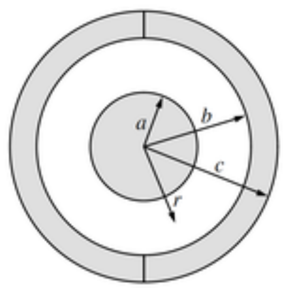
Practice FRQ

Name

1.

An isolated conducting sphere of radius *a* = 0.20 m is at a potential of –2,000 V.

(a) Determine the charge $\square_0$ on the sphere.



The charged sphere is then concentrically surrounded by two uncharged conducting hemispheres of inner radius *b* = 0.40 m and outer radius *c* = 0.50 m, which are joined together as shown above, forming a spherical capacitor. A wire is connected from the outer sphere to ground, and then removed.

(b) Determine the magnitude of the electric field in the following regions as a function of the distance r from the center of the inner sphere.

i. r

ii. a

iii. b

iv. r

(c) Determine the magnitude of the potential difference between the sphere and the conducting

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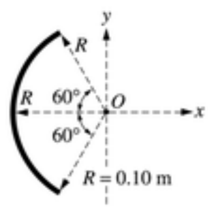
shell.

(d) Determine the capacitance of the spherical capacitor.

Please respond on separate paper, following directions from your teacher.

2.



A rod of uniform linear charge density ☐ = +1.5 × 10^{-5} C/m is bent into an arc of radius R = 0.10 m. The arc is placed with its center at the origin of the axes shown above.

a. Determine the total charge on the rod.

b. Determine the magnitude and direction of the electric field at the center O of the arc.

c. Determine the electric potential at point O.

A proton is now placed at point O and held in place. Ignore the effects of gravity in the rest of this problem.

d. Determine the magnitude and direction of the force that must be applied in order to keep the proton at rest.

e. The proton is now released. Describe in words its motion for a long time after its release.

Please respond on separate paper, following directions from your teacher.

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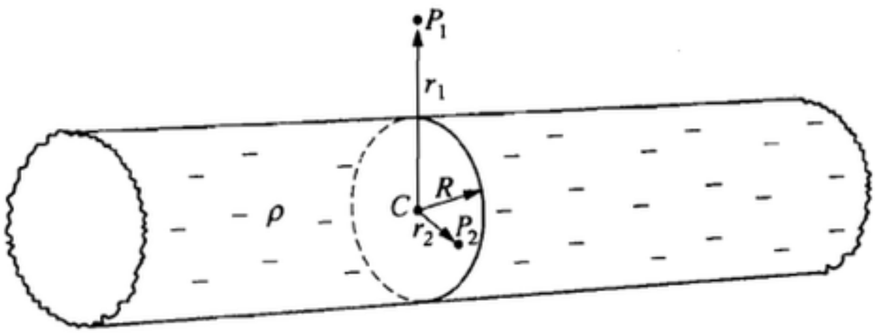
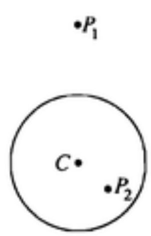
3.



The solid nonconducting cylinder of radius R shown above is very long. It contains a negative charge evenly distributed throughout the cylinder, with volume charge density ☐ . Point P_1 is outside the cylinder at a distance r_1 from its center C and point P_2 is inside the cylinder at a distance r_2 from its center C. Both points are in the same plane, which is perpendicular to the axis of the cylinder.

a. On the following cross-sectional diagram, draw vectors to indicate the directions of the electric field at points P_1 and P_2 .



a. Using Gauss's law, derive expressions for the magnitude of the electric field E in terms of r, R, ☐ , and fundamental constants for the following two cases

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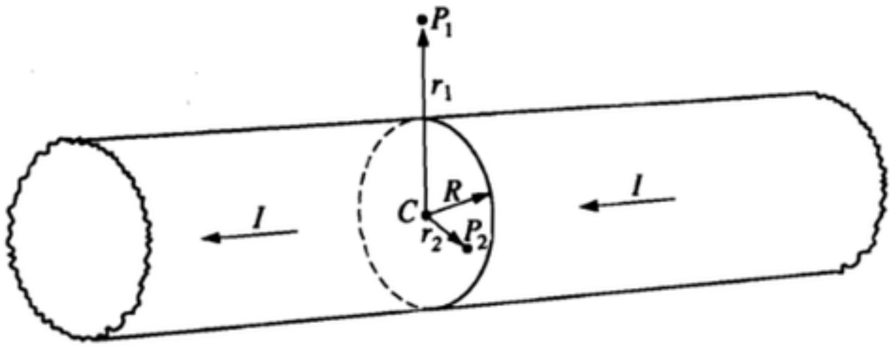
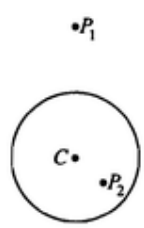


Another cylinder of the same dimensions, but made of conducting material, carries a total current *I* parallel to the length of the cylinder, as shown in the diagram above. The current density is uniform throughout the cross-sectional area of the cylinder. Points P_1 and P_2 are in the same positions with respect to the cylinder as they were for the nonconducting cylinder.

i. $r > R$ (outside the cylinder)

ii. *r (inside the cylinder)*

b. On the following cross-sectional diagram in which the current is out of the plane of the page (toward the reader), draw vectors to indicate the directions of the magnetic field at points P_1 and P_2 .



c. Use Ampère's law to derive an expression for the magnetic field *B* inside the cylinder in terms of *r, R, I*, and fundamental constants.

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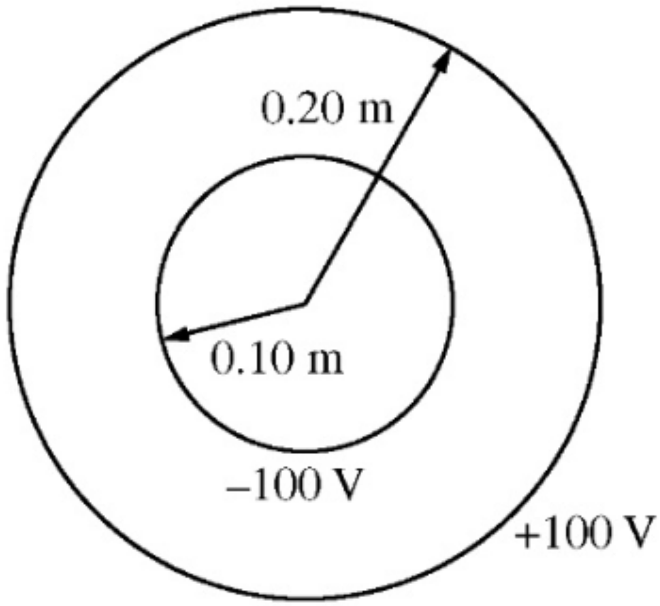
4.



Two thin, concentric, conducting spherical shells, insulated from each other, have radii of 0.10 m and 0.20 m, as shown above. The inner shell is set at an electric potential of -100 V , and the outer shell is set at an electric potential of +100 V, with each potential defined relative to the conventional reference point. Let Q_i and Q_0 represent the net charge on the inner and outer shells, respectively, and let r be the radial distance from the center of the shells. Express all algebraic answers in terms of Q_i , Q_o , r, and fundamental constants, as appropriate.

a. Using Gauss's Law, derive an algebraic expression for the electric field *E(r)* for 0.10 m

b. Determine an algebraic expression for the electric field *E(r)* for $r > 0.20$ m .

c. Determine an algebraic expression for the electric potential *V(r)* for $r > 0.20$ m .

d. Using the numerical information given, calculate the value of the total charge Q_T on the two spherical shells ($Q_T = Q_i + Q_0$) .

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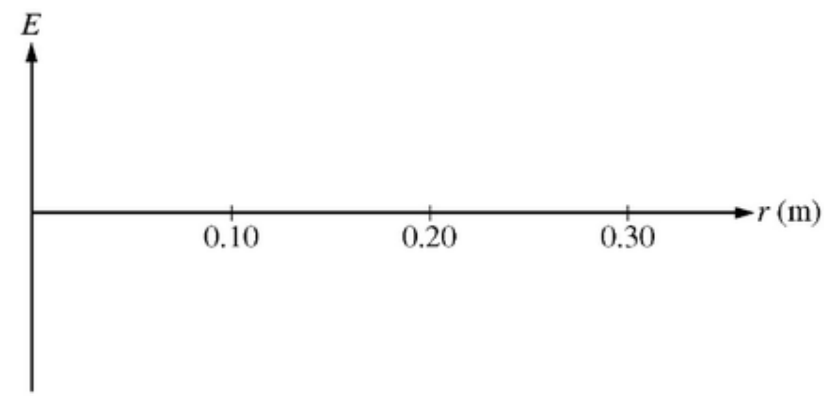
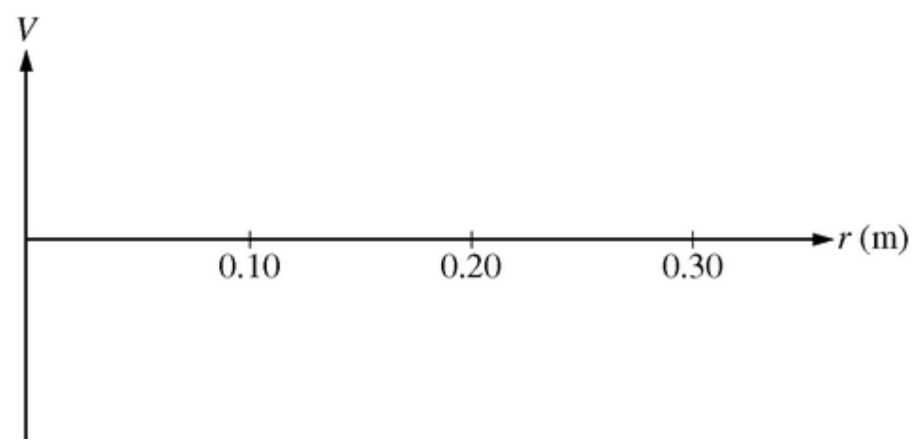
e. On the axes below, sketch the electric field E as a function of r. Let the positive direction be radially outward.



f. On the axes below, sketch the electric potential V as a function of r .



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5.

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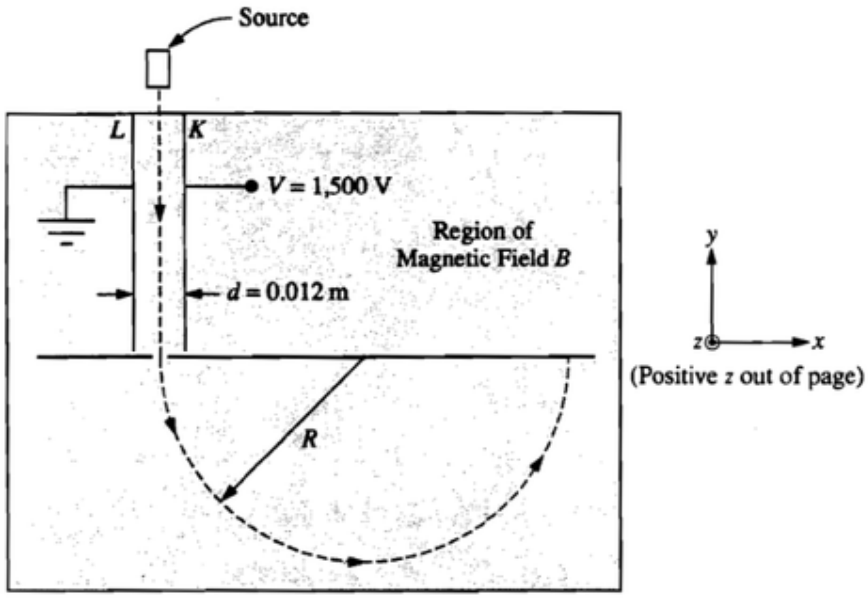

A mass spectrometer, constructed as shown in the diagram above, is to be used for determining the mass of singly ionized positively charged ions. There is a uniform magnetic field B = 0.20 tesla perpendicular to the page in the shaded region of the diagram. A potential difference V = 1,500 volts is applied across the parallel plates L and K, which are separated by a distance d = 0.012 meter and which act as a velocity selector.

a. In which direction, relative to the coordinate system shown above on the right, should the magnetic field point in order for positive ions to move along the path shown by the dashed line in the diagram above?

b. Should plate K have a positive or negative voltage polarity with respect to plate L ?

c. Calculate the magnitude of the electric field between the plates.

d. Calculate the speed of a particle that can pass between the parallel plates without being deflected.

e. Calculate the mass of a hypothetical singly charged ion that travels in a semicircle of radius R = 0.50 meter.

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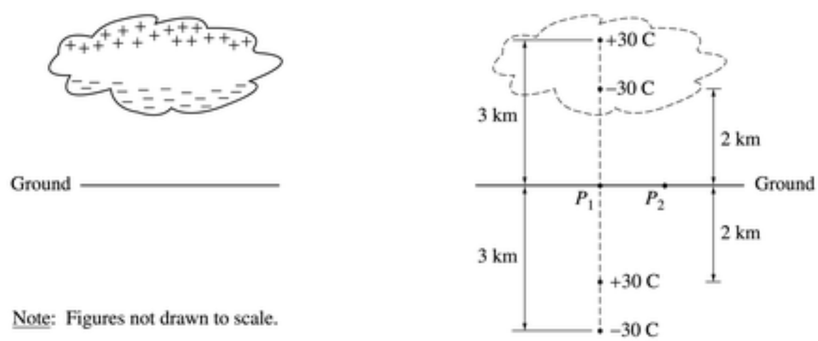
f. A doubly ionized positive ion of the same mass and velocity as the singly charged ion enters the mass spectrometer. What is the radius of its path?

Please respond on separate paper, following directions from your teacher.

6.



A thundercloud has the charge distribution illustrated above left. Treat this distribution as two point charges, a negative charge of –30 C at a height of 2 km above ground and a positive charge of +30 C at a height of 3 km. The presence of these charges induces charges on the ground. Assuming the ground is a conductor, it can be shown that the induced charges can be treated as a charge of +30 C at a depth of 2 km below ground and a charge of –30 C at a depth of 3 km, as shown above right. Consider point P_1, which is just above the ground directly below the thundercloud, and point P_2, which is 1 km horizontally away from P_1.

(a) Determine the direction and magnitude of the electric field at point P_1.

(b)

i. On the diagram above, clearly indicate the direction of the electric field at point P_2.

ii. How does the magnitude of the field at this point compare with the magnitude at point P_1?

_____Greater _____Equal _____Less

Justify your answer.

(c) Letting the zero of potential be at infinity, determine the potential at these points.

i. Point P_1

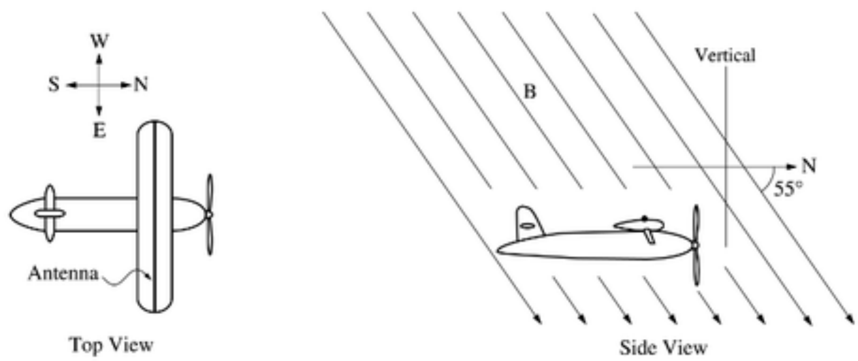
ii. Point P_2

(d) Determine the electric potential at an altitude of 1 km directly above point P_1.

(e) Determine the total electric potential energy of this arrangement of charges.

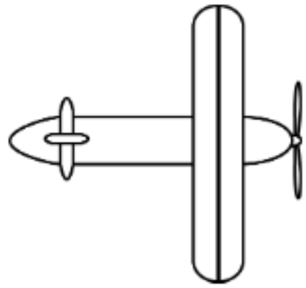
Please respond on separate paper, following directions from your teacher.

7.



An airplane has an aluminum antenna attached to its wing that extends 15 m from wingtip to wingtip. The plane is traveling north at 75 m/s in a region where Earth's magnetic field has both a vertical component and a northward component, as shown above. The net magnetic field is at an angle of 55 degrees from horizontal and has a magnitude of 6.0×10^{-5} T.

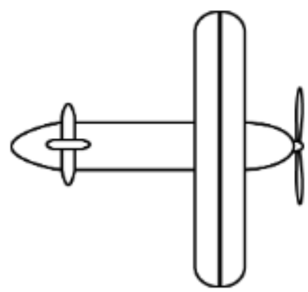
a. On the figure below, indicate the direction of the magnetic force on electrons in the antenna. Justify your answer.



b. Determine the magnitude of the electric field generated in the antenna.

c. Determine the potential difference between the ends of the antenna.

d. On the figure below, indicate which end of the antenna is at higher potential.



e. The ends of the antenna are now connected by a conducting wire so that a closed circuit is formed.

  i. Describe the condition(s) that would be necessary for a current to be induced in the circuit. Give a specific example of how the condition(s) could be created.

  ii. For the example you gave in i. above, indicate the direction of the current in the antenna on the figure below.

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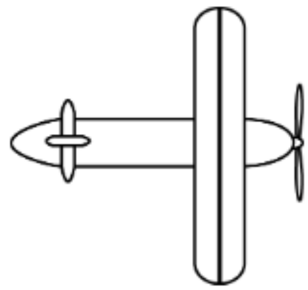
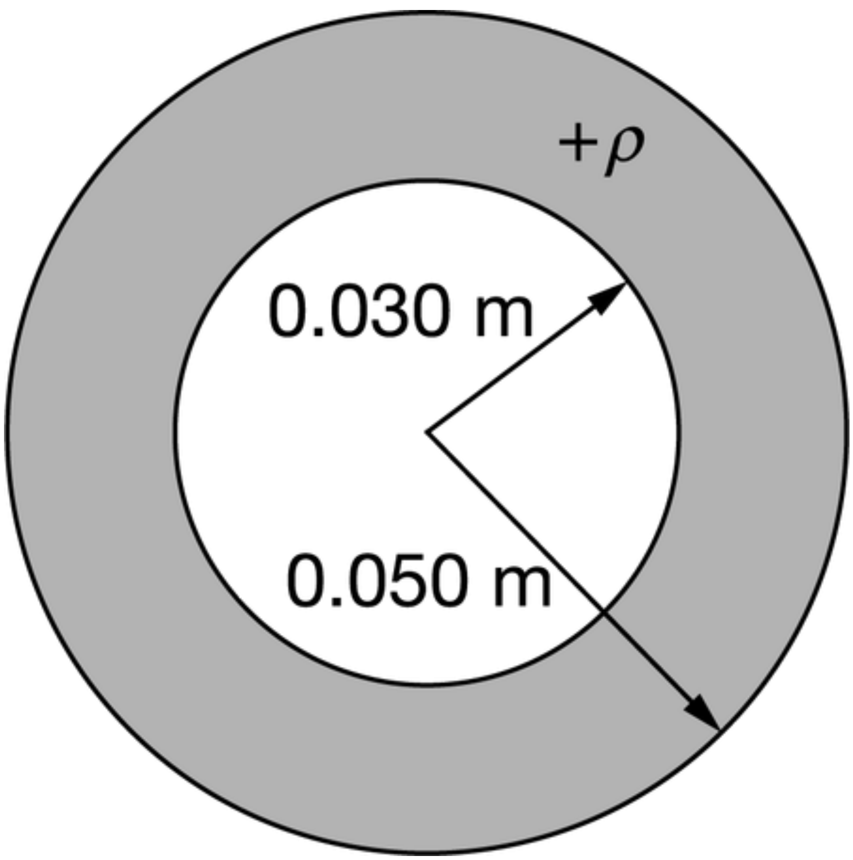


Please respond on separate paper, following directions from your teacher.

8. Read each question carefully. Show all your work for each part of the question. The parts within the question may not have equal weight.



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A nonconducting hollow sphere of inner radius $0.030\ \mathrm{m}$ and outer radius $0.050\ \mathrm{m}$ carries a positive volume charge density ρ, as shown in the figure above. The charge density ρ of the sphere is given as a function of the distance r from the center of the sphere, in meters, by the following.

$r < 0.030\ \mathrm{m}:\ \ \rho = 0$

$0.030\ \mathrm{m} < r < 0.050\ \mathrm{m}:\ \ \rho = b/r$, where $b = 1.6 \times 10^{-6}\ \mathrm{C/m^2}$

$r > 0.050\ \mathrm{m}:\ \ \rho = 0$

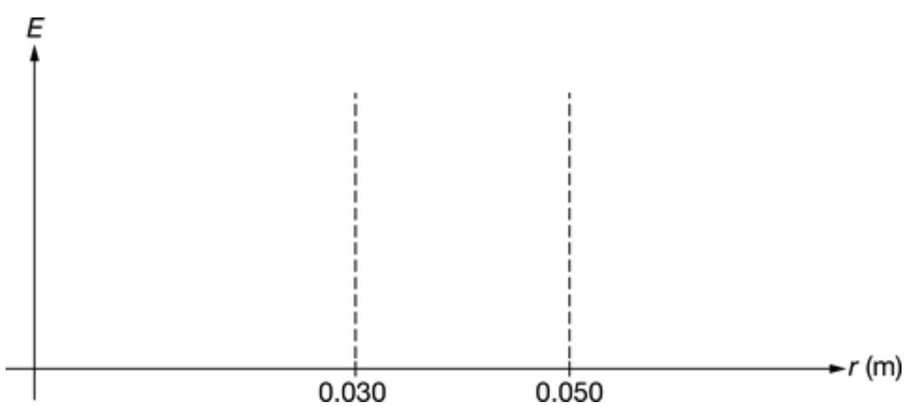
(a) Calculate the total charge of the sphere.

Please respond on separate paper, following directions from your teacher.

(b) Using Gauss's law, calculate the magnitude of the electric field E at the outer surface of the sphere.

Please respond on separate paper, following directions from your teacher.

(c) On the axes below, sketch the magnitude of the electric field E as a function of distance r from the center of the sphere.



Please respond on separate paper, following directions from your teacher.

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(d) Calculate the electric potential V at the outer surface of the sphere. Assume the electric potential to be zero at infinity.

Please respond on separate paper, following directions from your teacher.

(e) A proton is released from rest at the outer surface of the sphere at time $t = 0$ s.

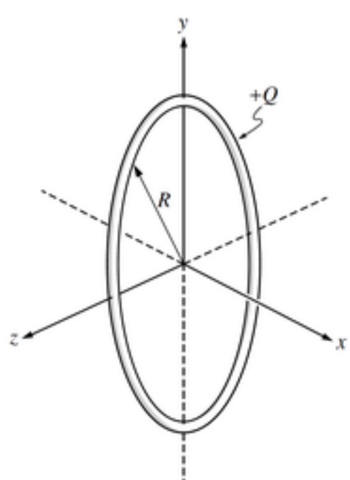
i. Calculate the magnitude of the initial acceleration of the proton.

Please respond on separate paper, following directions from your teacher.

ii. Calculate the speed of the proton after a long time.

Please respond on separate paper, following directions from your teacher.

9.



The nonconducting ring of radius *R* shown above lies in the *yz*-plane and carries a uniformly distributed positive charge ☐ .

a. Determine the electric potential at points along the x-axis as a function of x.

i. Show that the x-component of the electric field along the x-axis is given by $E_x = \frac{Qx}{4\pi\varepsilon_0 \left(R^2+x^2\right)^{\frac{3}{2}}}$

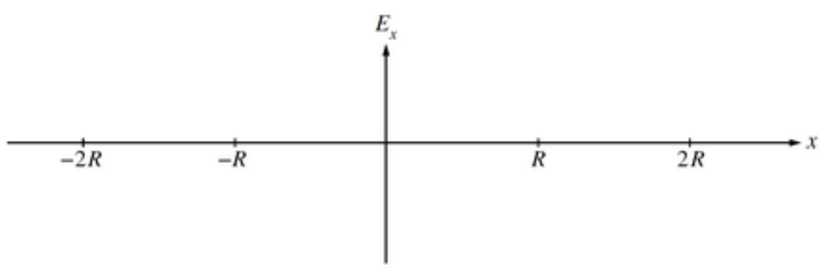
ii. What are the y- and z- components of the electric field along the x-axis?

c. Determine the following.

i. The value of x for which E_x is a maximum

ii. The maximum electric field $E_{x\ \max}$

d. On the axes below, sketch E_x *versus* x for points on the x-axis from x = –2R to x = +2R.



e. An electron is placed at $x = R/2$ and released from rest. Qualitatively describe its subsequent motion.

Please respond on separate paper, following directions from your teacher.

10.

Three particles, A, B, and C, have equal positive charges ☐ and are held in place at the vertices of an equilateral triangle with sides of length ℓ , as shown in the figures below. The

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dotted lines represent the bisectors for each side. The base of the triangle lies on the *x*-axis, and the altitude of the triangle lies on the *y*-axis.

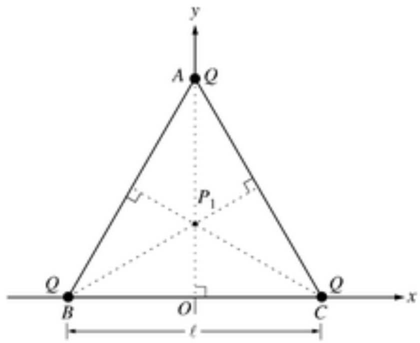

Figure 1

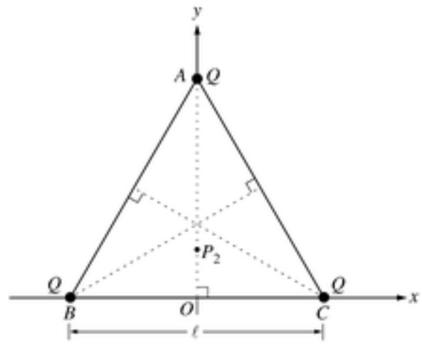

Figure 2

(a)

i. Point P_1, the intersection of the three bisectors, locates the geometric center of the triangle and is one point where the electric field is zero. On Figure 1 above, draw the electric field vectors $\mathbf{E}_A$, $\mathbf{E}_B$, and $\mathbf{E}_C$ at P_1 due to each of the three charges. Be sure your arrows are drawn to reflect the relative magnitude of the fields.

ii. Another point where the electric field is zero is point P_2 at $(0, y_2)$. On Figure 2 above, draw electric field vectors $\mathbf{E}_A$, $\mathbf{E}_B$, and $\mathbf{E}_C$ at P_2 due to each of the three point charges Indicate below whether the magnitude of each of these vectors is greater than, less than, or the same as for point P_1.

	Greater than at P_1	Less than at P_1	The same as at P_1
E_A			
E_B			
E_C			

(b) Explain why the *x*-component of the total electric field is zero at any point on the *y*-axis.

(c) Write a general expression for the electric potential *V* at any point on the *y*-axis inside the

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triangle in terms of ☐, *ℓ*, and *y*.

(d) Describe how the answer to part (c) could be used to determine the *y*-coordinates of points P_1 and P_2 at which the electric field is zero. (You do not need to actually determine these coordinates.)

Please respond on separate paper, following directions from your teacher.