Extra Practice 2

Due: 7:00am on Wednesday, June 8, 2016

To understand how points are awarded, read the Grading Policy for this assignment.

A Test Charge Determines Charge on Insulating and Conducting Balls

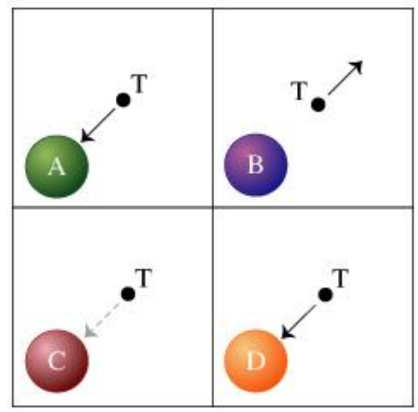
Learning Goal:

To understand the electric force between charged and uncharged conductors and insulators.

When a test charge is brought near a charged object, we know from Coulomb's law that it will experience a net force (either attractive or repulsive, depending on the nature of the object's charge). A test charge may also experience an electric force when brought near a *neutral* object. Any attraction of a neutral insulator or neutral conductor to a test charge must occur through induced polarization. In an insulator, the electrons are bound to their molecules. Though they cannot move freely throughout the insulator, they can shift slightly, creating a rather weak net attraction to a test charge that is brought close to the insulator's surface. In a conductor, free electrons will accumulate on the surface of the conductor nearest the positive test charge. This will create a strong attractive force if the test charge is placed very close to the conductor's surface.

Consider three plastic balls (A, B, and C), each carrying a uniformly distributed charge equal to either $+Q$, $-Q$ or zero, and an uncharged copper ball (D). A positive test charge (T) experiences the forces shown in the figure when brought very near to the individual balls. The test charge T is strongly attracted to A, strongly repelled from B, *weakly* attracted to C, and strongly attracted to D.

Assume throughout this problem that the balls are brought very close together.



Part A

What is the nature of the force between balls A and B?

You did not open hints for this part.

ANSWER:

- strongly attractive
- strongly repulsive
- weakly attractive
- neither attractive nor repulsive

Part B

This question will be shown after you complete previous question(s).

Part C

This question will be shown after you complete previous question(s).

Part D

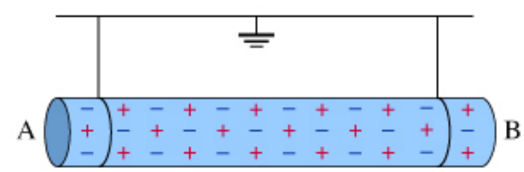
This question will be shown after you complete previous question(s).

Charging a Grounded Conducting Rod

Learning Goal:

To understand interactions between a grounded conductor and a charged ball that is repeatedly brought into contact with it.

This problem explores the behavior of charge on grounded conductors. We take as an example a long conducting rod suspended by conducting wires that are connected to ground. Assume that the rod is initially electrically neutral. For convenience, we will refer to the left end of the rod as end A, and the right end of the rod as end B . In the answer options for this problem, "strongly attracted/repelled" means "attracted/repelled with a force of magnitude similar to that which would exist between two charged balls."



Part A

A small metal ball is given a negative charge, then brought near (i.e., within about 1/10 the length of the rod) to end A of the rod. What happens to end A of the rod when the ball approaches it closely this first time?

Select the expected behavior.

You did not open hints for this part.

ANSWER:

- strongly repelled
- strongly attracted
- weakly attracted
- weakly repelled
- neither attracted nor repelled

Now consider what happens when the small metal ball is repeatedly given a negative charge and then brought *into contact* with end A of the rod.

Part B

After a great many contacts with the charged ball, how is any charge on the rod arranged (when the charged ball is far away)?

Select the best description.

You did not open hints for this part.

ANSWER:

- positive charge on end B and negative charge on end A
- negative charge spread evenly on both
- negative charge on end A with end B remaining neutral
- both ends neutral
- positive charge spread evenly on both

Part C

How does end A of the rod react when the (re)charged ball approaches it after a great many previous contacts with end A?

Select the expected behavior.

You did not open hints for this part.

ANSWER:

- strongly repelled
- strongly attracted
- weakly attracted
- weakly repelled
- neither attracted nor repelled

Part D

How does end B of the rod react when the charged ball approaches it after a great many previous contacts with end A?

Select the expected behavior.

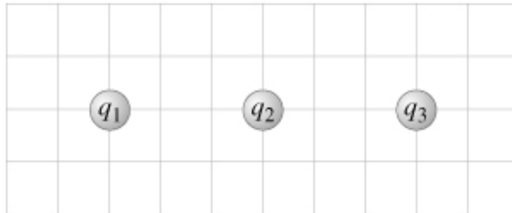
You did not open hints for this part.

ANSWER:

- strongly repelled
- strongly attracted
- weakly attracted
- weakly repelled
- neither attracted nor repelled

Electric Force of Three Collinear Points Ranking Task

In the diagram below, there are three collinear point charges: q_1, q_2, and q_3. The distance between q_1 and q_2 is the same as that between q_2 and q_3. You will be asked to rank the Coulomb force on q_1 due to q_2 and q_3.



Part A

Rank the six combinations of electric charges on the basis of the electric force acting on q_1 . Define forces pointing to the right as positive and forces pointing to the left as negative. Rank positive forces as larger than negative forces.

Rank from largest to smallest, placing the largest on the left and the smallest on the right. To rank items as equivalent, overlap them.

You did not open hints for this part.

ANSWER:

Exercise 21.13

Three point charges are arranged on a line. Charge q_3 = +5.00nC and is at the origin. Charge q_2 = -4.00 nC and is at x = 3.50 cm . Charge q_1 is at x = 2.50 cm .

Part A

What is q_1 (magnitude and sign) if the net force on q_3 is zero?

ANSWER:

q_1 = nC

Exercise 21.15

Three point charges are located on the positive x-axis of a coordinate system. Charge q_1 = 1.5 nC is 2.0 cm from the origin, charge q_2 = -3.5 nC is 4.0 cm from the origin and charge q_3 = 4.0 nC located at the origin. What is the net force ((a)magnitude and (b) direction) on charge q_1 = 1.5 nC exerted by the other two charges?

Part A

Express your answer using two significant figures.

ANSWER:

$\left|\vec{F}\right|$ = N

Part B

ANSWER:

θ = $^\circ$ counterclockwise from the $+x$ direction

Exercise 21.17

Three point charges are arranged along the *x*-axis. Charge q_1 = +3.00 $\mu\mathrm{C}$is at the origin, and charge q_2 = -5.00 $\mu\mathrm{C}$ is at x = 0.200 m. Charge q_3 = -8.00 $\mu\mathrm{C}$.

Part A

Where is q_3 located if the net force on q_1 is 7.00 N in the $-x$ direction?

ANSWER:

x_3 = m

Exercise 21.19

Two point charges are located on the *y*-axis as follows: one charge q_1 = -1.90 nC located at $y =$ -0.610 m , and a second charge q_2 = 3.80 nC at the origin $(y = 0)$.

Part A

What is the magnitude of the total force exerted by these two charges on a third charge q_3 = 5.00 nC located at y_3 = -0.440 m ?

ANSWER:

F = [ ] N

Part B

What is the direction of the total force.

ANSWER:

- in the +y direction
- in the -y direction
- perpendicular to the y-axis
- force is zero

Forces in a Three-Charge System

Coulomb's law for the magnitude of the force F between two particles with charges Q and Q' separated by a distance d is

$$|F| = K\frac{|QQ'|}{d^2},$$

where $K = \frac{1}{4\pi\epsilon_0}$, and $\epsilon_0 = 8.854 \times 10^{-12}\ \mathrm{C}^2/(\mathrm{N}\cdot\mathrm{m}^2)$ is the permittivity of free space.

Consider two point charges located on the *x* axis: one charge, q_1 = -18.5 nC , is located at x_1 = -1.660 m ; the second charge, q_2 = 38.0 nC , is at the origin $(x = 0.0000)$.

Part A

What is the net force exerted by these two charges on a third charge q_3 = 53.0 nC placed between q_1 and q_2 at x_3 = -1.100 m ?

Your answer may be positive or negative, depending on the direction of the force.

Express your answer numerically in newtons to three significant figures.

You did not open hints for this part.

ANSWER:

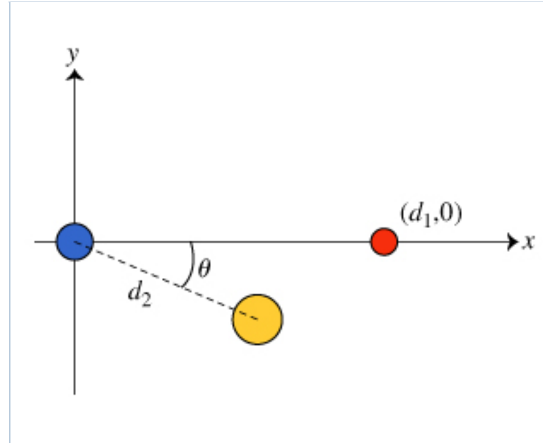
Force on q_3 = [ ] N

Mystery Charge

Consider the following configuration of fixed, uniformly charged spheres in :

- a blue sphere fixed at the origin with positive charge q,
- a red sphere fixed at the point $(d_1, 0)$ with unknown charge q_{red}, and
- a yellow sphere fixed at the point $(d_2\cos(\theta), -d_2\sin(\theta))$ with unknown charge q_{yellow}.

The net electric force on the blue sphere has a magnitude F and is directed in the $-$ *y* direction.



Part A

What is the sign of the charge on the yellow sphere?

ANSWER:

- positive
- negative

Part B

What is the sign of the charge on the red sphere?

ANSWER:

- positive
- negative

Part C

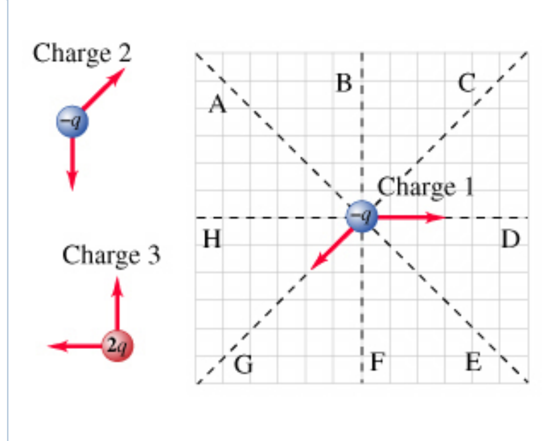
This question will be shown after you complete previous question(s).

Placing Charges Conceptual Question

Below are free-body diagrams for three electric charges that lie in the same plane. Their relative positions are unknown. There are two forces shown on each charge. These two forces represent the force exerted on the charge by each of the other two charges.

Part A

Along which of the lines (A to H) in should charge 2 be placed so that the free-body diagrams of charge 1 and charge 2 are consistent? Note that only one of the forces on each charge will be consistent. The other force on each charge will be addressed in Part B with the introduction of charge 3.



You did not open hints for this part.

ANSWER:

Part B

This question will be shown after you complete previous question(s).

Part C

This question will be shown after you complete previous question(s).

Part D

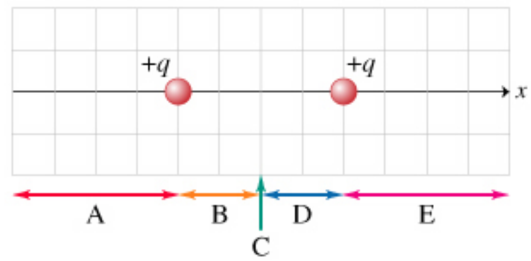
This question will be shown after you complete previous question(s).

Electric Field Conceptual Question

Part A

For the charge distribution provided, indicate the region (A to E) along the horizontal axis where a point exists at which the net electric field is zero.

If no such region exists on the horizontal axis choose the last option (nowhere).



You did not open hints for this part.

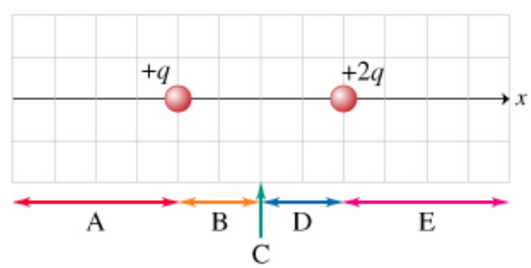
ANSWER:

- A
- B
- C
- D
- E
- nowhere

Part B

For the charge distribution provided, indicate the region (A to E) along the horizontal axis where a point exists at which the net electric field is zero.

If no such region exists on the horizontal axis choose the last option (nowhere).



You did not open hints for this part.

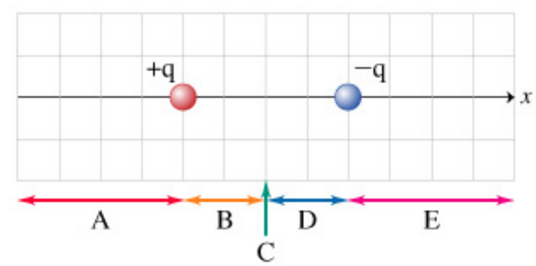
ANSWER:

- A
- B
- C
- D
- E
- nowhere

Part C

For the charge distribution provided, indicate the region (A to E) along the horizontal axis where a point exists at which the net electric field is zero.

If no such region exists on the horizontal axis choose the last option (nowhere).



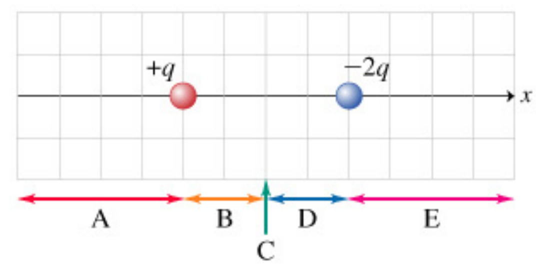
You did not open hints for this part.

ANSWER:

- A
- B
- C
- D
- E
- nowhere

Part D

For the charge distribution provided, indicate the region (A to E) along the horizontal axis where a point exists at which the net electric field is zero.



You did not open hints for this part.

ANSWER:

- A
- B
- C
- D
- E
- Nowhere along the finite *x* axis

Electric Field Vector Drawing

Each of the four parts of this problem depicts a motion diagram showing the position and velocity of a charged particle at equal time intervals as it moves through a region of uniform electric field. For each part, draw a vector representing the direction of the electric field.

Part A

Draw a vector representing the direction of the electric field. The orientation of the vector will be graded. The location and length of the vector will not be graded.

You did not open hints for this part.

ANSWER:

Part B

Draw a vector representing the direction of the electric field. The orientation of the vector will be graded. The location and length of the vector will not be graded.

You did not open hints for this part.

ANSWER:

Part C

Draw a vector representing the direction of the electric field. The orientation of the vector will be graded. The location and length of the vector will not be graded.

You did not open hints for this part.

ANSWER:

Part D

Draw a vector representing the direction of the electric field. The orientation of the vector will be graded. The location and length of the vector will not be graded.

You did not open hints for this part.

ANSWER:

Electric Fields and Forces

Learning Goal:

To understand Coulomb's law, electric fields, and the connection between the electric field and the electric force.

Coulomb's law gives the electrostatic force $\vec{F}$ acting between two charges. The magnitude F of the force between two charges q_1 and q_2 depends on the product of the charges and the square of the distance r between the charges:

$$F = k\,\frac{|q_1\,q_2|}{r^2}\,,$$

where $k = 1/(4\pi\epsilon_0) = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$. The direction of the force is along the line connecting the two charges. If the charges have the same sign, the force will be repulsive. If the charges have opposite signs, the force will be attractive. In other words, opposite charges attract and like charges repel.

Because the charges are not in contact with each other, there must be an intermediate mechanism to cause the force. This mechanism is the electric field. The electric field at any location is equal to the force per unit charge experienced by a charge placed at that location. In other words, if a charge q experiences a force $\vec{F}$, the electric field $\vec{E}$ at that point is

$$\vec{E} = \frac{\vec{F}}{q}.$$

The electric field vector has the same direction as the force vector on a positive charge and the opposite direction to that of the force vector on a negative charge.

An electric field can be created by a single charge or a distribution of charges. The electric field a distance r from a point charge q' has magnitude

$$E = k\,\frac{|q'|}{r^2}.$$

The electric field points away from positive charges and toward negative charges. A distribution of charges creates an electric field that can be found by taking the vector sum of the fields created by individual point charges. Note that if a charge q is placed in an electric field created by q', q will not significantly affect the electric field if it is small compared to q'.

Imagine an isolated positive point charge with a charge Q (many times larger than the charge on a single electron).

Part A

There is a single electron at a distance from the point charge. On which of the following quantities does the force on the electron depend?

Check all that apply.

ANSWER:

- ☐ the distance between the positive charge and the electron
- ☐ the charge on the electron
- ☐ the mass of the electron
- ☐ the charge of the positive charge
- ☐ the mass of the positive charge
- ☐ the radius of the positive charge
- ☐ the radius of the electron

Part B

For the same situation as in Part A, on which of the following quantities does the electric field at the electron's position depend?

Check all that apply.

ANSWER:

- ☐ the distance between the positive charge and the electron
- ☐ the charge on the electron
- ☐ the mass of the electron
- ☐ the charge of the positive charge
- ☐ the mass of the positive charge
- ☐ the radius of the positive charge
- ☐ the radius of the electron

Part C

This question will be shown after you complete previous question(s).

Part D

This question will be shown after you complete previous question(s).

Part E

This question will be shown after you complete previous question(s).

Part F

This question will be shown after you complete previous question(s).

Exercise 21.27

Part A

What must the charge (sign and magnitude) of a 1.45-g particle be for it to remain stationary when placed in a downward-directed electric field of magnitude 600 $\mathrm{N/C}$?

ANSWER:

Q = ____ C

Part B

What is the magnitude of an electric field in which the electric force on a proton is equal in magnitude to its weight?

ANSWER:

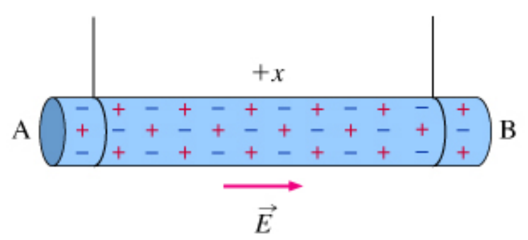
E = ____ $\mathrm{N/C}$

The Electric Field inside a Conductor

Learning Goal:

To understand how the charges within a conductor respond to an externally applied electric field.

To illustrate the behavior of charge inside conductors, consider a long conducting rod that is suspended by insulating strings (see the figure). Assume that the rod is initially electrically neutral, and that it remains so for this discussion. The rod is positioned along the *x* axis, and an external electric field that points in the positive *x* direction (to the right) can be applied to the rod and the surrounding region. The atoms in the rod are composed of positive nuclei (indicated by plus signs) and negative electrons (indicated by minus signs). Before application of the electric field, these atoms were distributed evenly throughout the rod.



Part A

What is the force felt by the electrons and the nuclei in the rod when the external field described in the problem introduction is applied? (Ignore internal fields in the rod for the moment.)

You did not open hints for this part.

ANSWER:

- Both electrons and nuclei experience a force to the right.
- The nuclei experience a force to the right and the electrons experience a force to the left.
- The electrons experience a force to the left but the nuclei experience no force.
- The electrons experience no force but the nuclei experience a force to the right.

Part B

What is the motion of the negative electrons and positive atomic nuclei caused by the external field?

You did not open hints for this part.

ANSWER:

- Both electrons and nuclei move to the right.
- The nuclei move to the right and the electrons move to the left through equal distances.
- The electrons move to the left and the nuclei are almost stationary.
- The electrons are almost stationary and the nuclei move to the right.

Part C

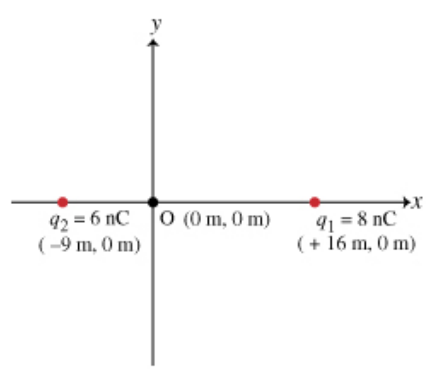
This question will be shown after you complete previous question(s).

Part D

This question will be shown after you complete previous question(s).

Electric Field due to Two Point Charges

Two point charges are placed on the *x* axis.The first charge, q_1 = 8.00 nC , is placed a distance 16.0 m from the origin along the positive *x* axis; the second charge, q_2 = 6.00 nC , is placed a distance 9.00 m from the origin along the negative *x* axis.



Part A

Find the electric field at the origin, point O.

Give the *x* and *y* components of the electric field as an ordered pair. Express your answer in newtons per coulomb to three significant figures. Keep in mind that an *x* component that points to the right is *positive* and a *y* component that points upward is *positive*.

You did not open hints for this part.

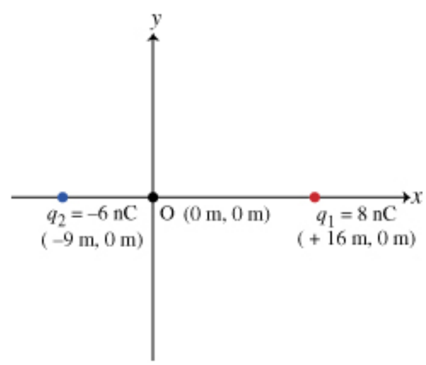
ANSWER:

E_{Ox}, E_{Oy} = $\mathrm{N/C}$

Part B

Now, assume that charge q_2 is negative; $q_2 = -6\ \mathrm{nC}$. What is the net electric field at the origin, point O?

Give the *x* and *y* components of the electric field as an ordered pair. Express your answer in newtons per coulomb to three significant figures. Keep in mind that an *x* component that points to the right is *positive* and a *y* component that points upward is *positive*.



You did not open hints for this part.

ANSWER:

E_{Ox}, E_{Oy} = $\mathrm{N/C}$

Exercise 21.37

Two positive point charges q are placed on the x-axis, one at $x = a$ and one at $x = -a$.

Part A

Find the electric field at $x = 0$.

ANSWER:

E =

Part B

Derive an expression for the electric field at points on the *x*-axis, where $-a < x < a$.

Express your answer in terms of the variables q, x, a and appropriate constants.

ANSWER:

E_x =

Part C

Derive an expression for the electric field at points on the *x*-axis, where $x > a$.

Express your answer in terms of the variables q, x, a and appropriate constants.

ANSWER:

E_x =

Part D

Derive an expression for the electric field at points on the *x*-axis, where $x < -a$.

Express your answer in terms of the variables q, x, a and appropriate constants.

ANSWER:

E_x =

Exercise 21.39

A +2.00nC point charge is at the origin, and a second -5.00nC point charge is on the x-axis at x = 0.800m.

Part A

Find the magnitude of the electric field at x = 0.200m on the x-axis.

ANSWER:

$\left|\vec{E}\right|$ = $\mathrm{N/C}$

Part B

Find the direction of the electric field at x = 0.200m on the x-axis.

ANSWER:

θ = $^\circ$ counterclockwise from the $+x$-direction

Part C

This question will be shown after you complete previous question(s).

Part D

This question will be shown after you complete previous question(s).

Part E

This question will be shown after you complete previous question(s).

Part F

This question will be shown after you complete previous question(s).

Part G

This question will be shown after you complete previous question(s).

Part H

This question will be shown after you complete previous question(s).

Part I

This question will be shown after you complete previous question(s).

Part J

This question will be shown after you complete previous question(s).

Part K

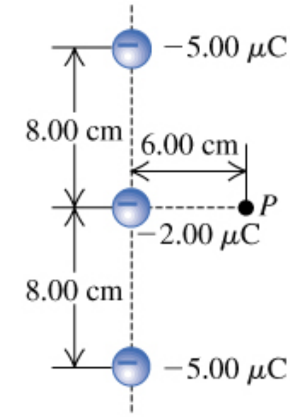
This question will be shown after you complete previous question(s).

Part L

This question will be shown after you complete previous question(s).

Exercise 21.41

Three negative point charges lie along a line as shown in the figure .



Part A

Find the magnitude of the electric field this combination of charges produces at point P, which lies $6.00\ \mathrm{cm}$ from the $-2.00\ \mu\mathrm{C}$ charge measured perpendicular to the line connecting the three charges.

ANSWER:

E = ______ $\mathrm{N/C}$

Part B

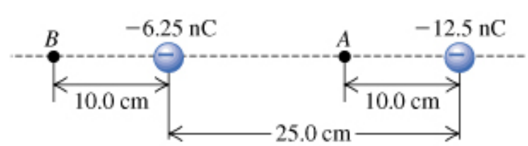
Find the direction of the electric field this combination of charges produces at point P, which lies $6.00\ \mathrm{cm}$ from the $-2.00\ \mu\mathrm{C}$ charge measured perpendicular to the line connecting the three charges.

ANSWER:

- outward $-2.00\ \mu\mathrm{C}$
- toward $-2.00\ \mu\mathrm{C}$

Exercise 21.43

Two point charges are separated by $25.0\ \mathrm{cm}$ (see the figure).



Part A

Find the magnitude of the net electric field these charges produce at point *A*.

ANSWER:

E = ______ $\mathrm{N/C}$

Part B

Find the direction of the net electric field these charges produce at point *A*.

ANSWER:

- The field is directed to the right.
- The field is directed to the left.

Part C

Find the magnitude of the net electric field these charges produce at point *B*.

ANSWER:

E = ______ $\mathrm{N/C}$

Part D

Find the direction of the net electric field these charges produce at point *B*.

ANSWER:

- The field is directed to the right.
- The field is directed to the left.

Part E

What would be the magnitude of the electric force this combination of charges would produce on a proton at *A*?

ANSWER:

F = ______ N

Part F

What would be the direction of the electric force this combination of charges would produce on a proton at *A*?

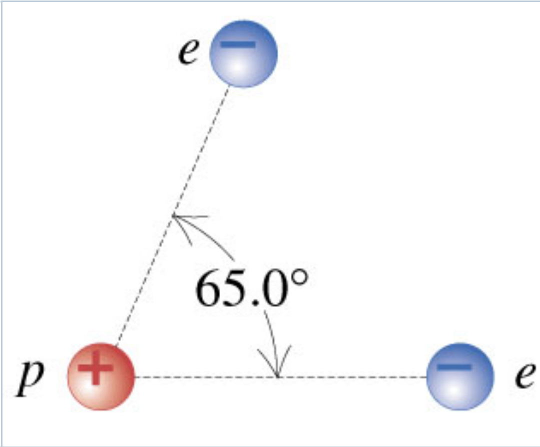
ANSWER:

- The force would be directed to the right.
- The force would be directed to the left.

Exercise 21.45

Part A

If two electrons are each 1.90×10^{-10} m from a proton, as shown in the figure, find the magnitude and of the net electrical force they will exert on the proton.



ANSWER:

F_{net} = N

Part B

Find the direction of the net electrical force electrons will exert on the proton.

Enter your answer as an angle measured relative to the line connecting the proton and the right electron with counterclockwise being positive.

ANSWER:

θ = °

Finding the Zero-Field Point

Two particles with positive charges q_1 and q_2 are separated by a distance s.

Part A

Along the line connecting the two charges, at what distance from the charge q_1 is the total electric field from the two charges zero?

Express your answer in terms of some or all of the variables s, q_1, q_2 and $k = \frac{1}{4\pi\epsilon_0}$. If your answer is difficult to enter, consider simplifying it, as it can be made relatively simple with some work.

You did not open hints for this part.

ANSWER:

Magnitude and Direction of Electric Fields

A small object A, electrically charged, creates an electric field. At a point P located 0.250 m directly north of A, the field has a value of 40.0 $\mathrm{N/C}$ directed to the south.

Part A

What is the charge of object A?

You did not open hints for this part.

ANSWER:

- $1.11\times10^{-9}\ \mathrm{C}$
- $-1.11\times10^{-9}\ \mathrm{C}$
- $2.78\times10^{-10}\ \mathrm{C}$
- $-2.78\times10^{-10}\ \mathrm{C}$
- $5.75\times10^{12}\ \mathrm{C}$
- $-5.75\times10^{12}\ \mathrm{C}$

Part B

This question will be shown after you complete previous question(s).

The Electric Field at a Point Due to Two Point Charges

A point charge $q_1 = -4.00\ \mathrm{nC}$ is at the point $x = 0.600$ meters, $y = 0.800$ meters, and a second point charge $q_2 = +6.00\ \mathrm{nC}$ is at the point $x = 0.600$ meters, $y = 0$.

Part A

Calculate the magnitude E of the net electric field at the origin due to these two point charges.

Express your answer in newtons per coulomb to three significant figures.

You did not open hints for this part.

ANSWER:

E = ______ $\mathrm{N/C}$

Part B

What is the direction, relative to the negative *x* axis, of the net electric field at the origin due to these two point charges.

Express your answer in degrees to three significant figures.

You did not open hints for this part.

ANSWER:

θ = ______ ° up from the negative x axis

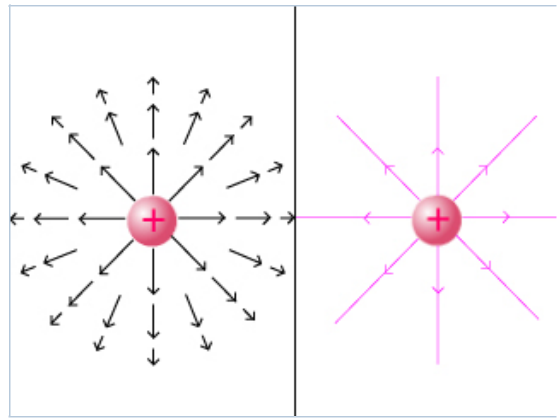
Visualizing Electric Fields

Learning Goal:

To understand the nature of electric fields and how to draw field lines.

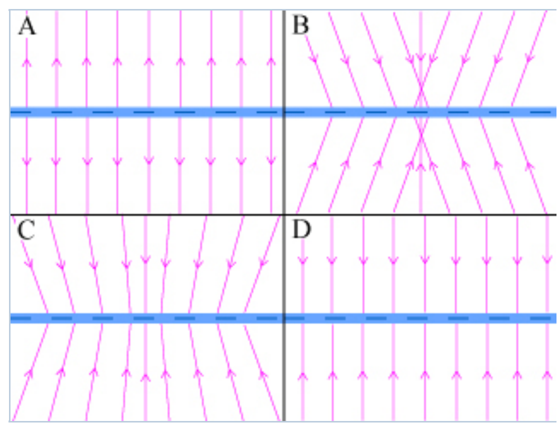
Electric field lines are a tool used to visualize electric fields. A field line is drawn beginning at a positive charge and ending at a negative charge. Field lines may also appear from the edge of a picture or disappear at the edge of the picture. Such lines are said to begin or end *at infinity*. The field lines are directed so that the electric field at any point is tangent to the field line at that point.

shows two different ways to visualize an electric field. On the left, vectors are drawn at various points to show the direction and magnitude of the electric field. On the right, electric field lines depict the same situation. Notice that, as stated above, the electric field lines are drawn such that their tangents point in the same direction as the electric field vectors on the left. Because of the nature of electric fields, field lines never cross. Also, the vectors shrink as you move away from the charge, and the electric field lines spread out as you move away from the charge. The spacing between electric field lines indicates the strength of the electric field, just as the length of vectors indicates the strength of the electric field. The greater the spacing between field lines, the weaker the electric field. Although the advantage of field lines over field vectors may not be apparent in the case of a single charge, electric field lines present a much less cluttered and more intuitive picture of more complicated charge arrangements.



Part A

Which of the following panels (labelled A, B, C, and D) in correctly depicts the field lines from an infinite uniformly negatively charged sheet? Note that the sheet is being viewed edge-on in all pictures.



You did not open hints for this part.

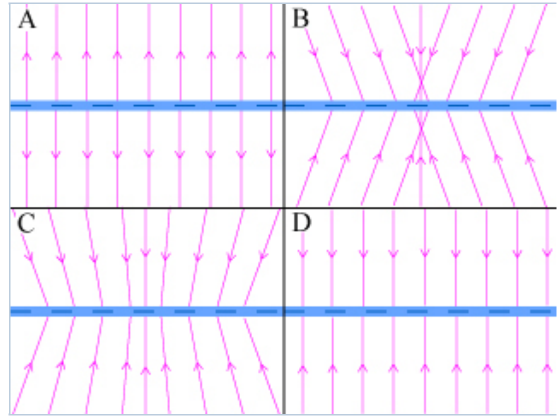
ANSWER:

- A
- B
- C
- D

Part B

In , what is wrong with panel B? (Pick only those statements that apply to panel B.)

Check all that apply.

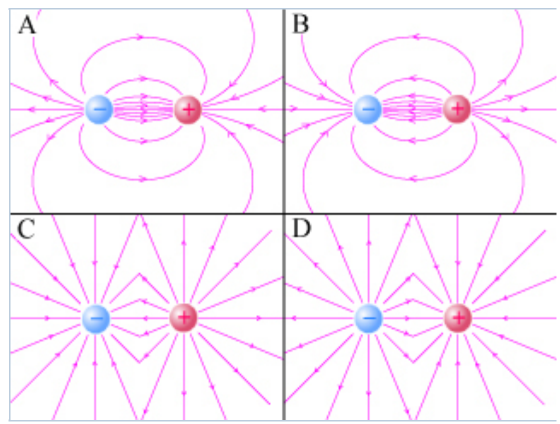


ANSWER:

- Field lines cannot cross each other.
- The field lines should be parallel because of the sheet's symmetry.
- The field lines should spread apart as they leave the sheet to indicate the weakening of the field with distance.
- The field lines should always end on negative charges or at infinity.

Part C

Which of the following panels (labelled A, B, C, and D) in shows the correct electric field lines for an electric dipole?



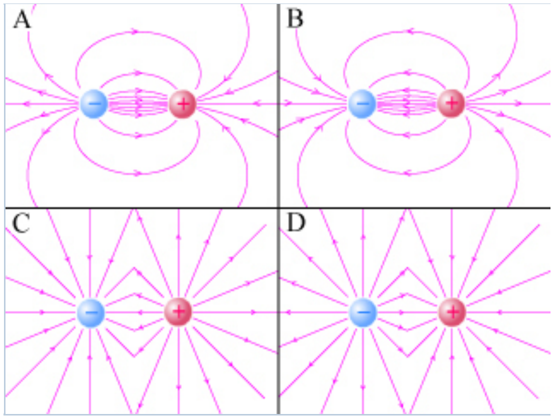
ANSWER:

- A
- B
- C
- D

Part D

In , what is wrong with panel D? (Pick only those statements that apply to panel D.)

Check all that apply.



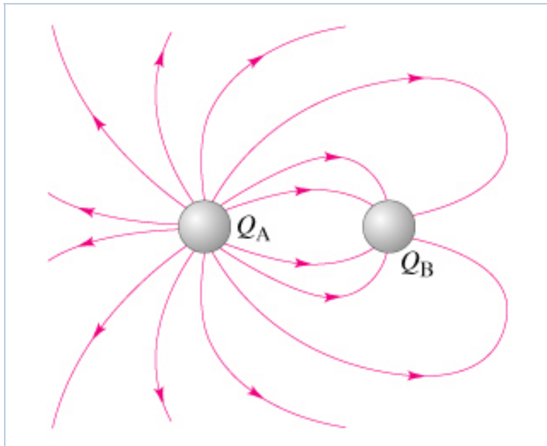
ANSWER:

- Field lines cannot cross each other.
- The field lines should turn sharply as you move from one charge to the other.
- The field lines should be smooth curves.
- The field lines should always end on negative charges or at infinity.

Part E

In , the electric field lines are shown for a system of two point charges, $Q_{\rm A}$ and $Q_{\rm B}$. Which of the following could represent the magnitudes and signs of $Q_{\rm A}$ and $Q_{\rm B}$?

In the following, take q to be a positive quantity.



ANSWER:

- $Q_{\rm A} = +q$, $Q_{\rm B} = -q$
- $Q_{\rm A} = +7q$, $Q_{\rm B} = -3q$
- $Q_{\rm A} = +3q$, $Q_{\rm B} = -7q$
- $Q_{\rm A} = -3q$, $Q_{\rm B} = +7q$
- $Q_{\rm A} = -7q$, $Q_{\rm B} = +3q$

Problem 21.59

Four identical charges Q are placed at the corners of a square of side L.

Part A

Find the magnitude total force exerted on one charge by the other three charges.

Express your answer in terms of the variables Q, L and appropriate constants.

ANSWER:

$\left|\vec{F}\right|$ =

Problem 21.61

A charge 5.00 nC is placed at the origin of an *xy*-coordinate system, and a charge -1.95 nC is placed on the positive *x*-axis at x = 3.98 cm . A third particle, of charge 6.01 nC is now placed at the point x = 3.98 cm , y = 2.96 cm .

Part A

Find the *x*-component of the total force exerted on the third charge by the other two.

ANSWER:

F_x = N

Part B

Find the *y*-component of the total force exerted on the third charge by the other two.

ANSWER:

F_y = N

Part C

Find the magnitude of the total force acting on the third charge.

ANSWER:

F = N

Part D

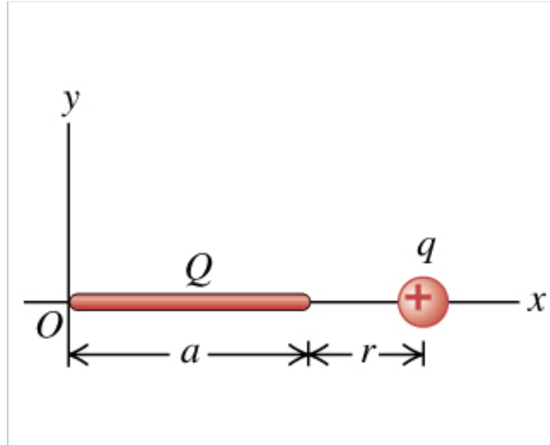
Find the direction of the total force acting on the third charge.

ANSWER:

ϕ = $radians$ between $\vec{F}$ and +*x*-axis

Problem 21.79

Positive charge Q is distributed uniformly along the *x*-axis from $x = 0$ to $x = a$. A positive point charge q is located on the positive *x*-axis at $x = a + r$, a distance r to the right of the end of Q.



Part A

Calculate the *x*-component of the electric field produced by the charge distribution Q at points on the positive *x*-axis where $x > a$.

Express your answer in terms of the variables Q, a, r, and and appropriate constants.

ANSWER:

E_x =

Part B

Calculate the *y*-component of the electric field produced by the charge distribution Q at points on the positive *x*-axis where $x > a$.

Express your answer in terms of the variables Q, a, x, and appropriate constants.

ANSWER:

E_y =

Part C

Calculate the magnitude of the force that the charge distribution Q exerts on q.

Express your answer in terms of the variables Q, q, a, r, and appropriate constants.

ANSWER:

F =

Part D

Calculate the direction of the force that the charge distribution Q exerts on q.

ANSWER:

- to the left
- to the right

Part E

This question will be shown after you complete previous question(s).

Problem 21.81

A negative point charge $q_1 = -4.00\ \mathrm{nC}$ is on the *x*-axis at $x = 0.60m$. A second point charge q_2 is on the *x*-axis at $x = -1.20m$.

Part A

What must the sign and magnitude of q_2 be for the net electric field at the origin to be $50.0\ N/C$ in the +*x*-direction?

ANSWER:

q_2 = ______ C

Part B

What must the sign and magnitude of q_2 be for the net electric field at the origin to be $50.0\ N/C$ in the -*x*-direction?

ANSWER:

q_2 = ______ C

Problem 21.85

Negative charge $-Q$ is distributed uniformly around a quarter-circle of radius a that lies in the first quadrant, with the center of curvature at the origin.

Part A

Find the *x*-component of the net electric field at the origin.

Express your answer in terms of the variables Q, a and appropriate constants.

ANSWER:

E_{x} = ______

Part B

Find the *y*-component of the net electric field at the origin.

Express your answer in terms of the variables Q, a and appropriate constants.

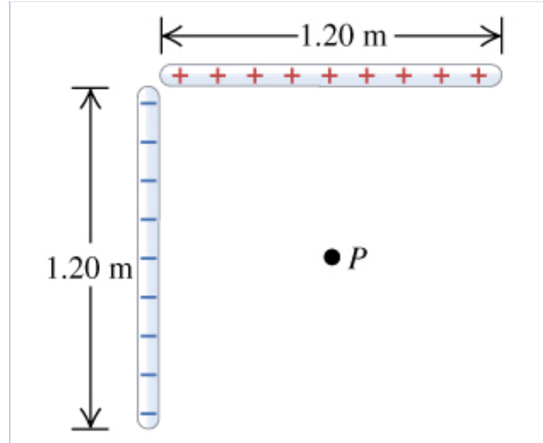
ANSWER:

E_{y} = ______

Problem 21.87

Two 1.20m nonconducting wires meet at a right angle. One segment carries 3.50 $\mu\mathrm{C}$ of charge distributed uniformly along its length, and the other carries

$-$ 3.50 $\mu\mathrm{C}$ distributed uniformly along it, as shown in the figure .



Part A

Find the magnitude of the electric field these wires produce at point P, which is 60.0 cm from each wire.

ANSWER:

$\left|\vec{E}\right|$ = ______ $\mathrm{N/C}$

Part B

Find the direction of the electric field these wires produce at point P, which is 60.0 cm from each wire.(Suppose that the y-axis directed vertically.)

ANSWER:

θ = ______ $^\circ$ countercockwise from the $+y$-axis

Part C

If an electron is released at P, what is the magnitude of the net force that these wires exert on it?

ANSWER:

$\left|\vec{F}_{\mathrm{net}}\right|$ = ______ N

Part D

If an electron is released at P, what is the direction of the net force that these wires exert on it?(Suppose that the y-axis directed vertically.)

ANSWER:

θ = ______ $^\circ$ countercockwise from the $+y$-axis

Exercise 22.1

A flat sheet of paper of area 0.370 m^2 is oriented so that the normal to the sheet is at an angle of 64 $^\circ$ to a uniform electric field of magnitude 18 $\mathrm{N/C}$.

Part A

Find the magnitude of the electric flux through the sheet.

Express your answer using two significant figures.

ANSWER:

Φ = $\mathrm{N \cdot m^2/C}$

Part B

Does the answer to part A depend on the shape of the sheet?

ANSWER:

- yes
- no

Part C

For what angle ϕ between the normal to the sheet and the electric field is the magnitude of the flux through the sheet largest?

Express your answer using two significant figures.

ANSWER:

ϕ = $^\circ$

Part D

For what angle ϕ between the normal to the sheet and the electric field is the magnitude of the flux through the sheet smallest?

Express your answer using two significant figures.

ANSWER:

ϕ = $^\circ$

Part E

Explain your answers in parts C and D.

ANSWER:

Essay answers are limited to about 500 words (3800 characters maximum, including spaces).

3785 Character(s) remaining

(none provided)

Exercise 22.3

You measure an electric field of $1.39 \times 10^6\ \mathrm{N/C}$ at a distance of 0.156 m from a point charge. There is no other source of electric field in the region other than this point charge.

Part A

What is the electric flux through the surface of a sphere that has this charge at its center and that has radius 0.156 m ?

ANSWER:

Φ = ______ $\mathrm{N \cdot m^2/C}$

Part B

What is the magnitude of the charge?

ANSWER:

q = ______ C

Exercise 22.5

A hemispherical surface with radius r in a region of uniform electric field $\vec{E}$ has its axis aligned parallel to the direction of the field.

Part A

Calculate the flux through the surface.

Express your answer in terms of the given quantities and appropriate constants.

ANSWER:

$|\Phi|$ = ______

Exercise 22.9

A charged paint is spread in a very thin uniform layer over the surface of a plastic sphere of diameter 15.0 cm , giving it a charge of -59.0 $\mu\mathrm{C}$.

Part A

Find the electric field just inside the paint layer.

Express your answer with the appropriate units. Enter positive value if the field is directed radially inward and negative value if the field is directed radially outward.

ANSWER:

E = ______

Part B

Find the electric field just outside the paint layer.

Express your answer with the appropriate units. Enter positive value if the field is directed radially inward and negative value if the field is directed radially outward.

ANSWER:

E =

Part C

Find the electric field 8.00 cm outside the surface of the paint layer.

Express your answer with the appropriate units. Enter positive value if the field is directed radially inward and negative value if the field is directed radially outward.

ANSWER:

E =

Exercise 22.11

A 7.25 $\mu\mathrm{C}$ point charge is at the center of a cube with sides of length 0.595 m .

Part A

What is the electric flux through one of the six faces of the cube?

ANSWER:

Φ = $\mathrm{N \cdot m^2/C}$

Part B

How would your answer to part A change if the sides were of length 0.135 m ?

ANSWER:

Φ = $\mathrm{N \cdot m^2/C}$

Part C

Explain.

ANSWER:

Essay answers are limited to about 500 words (3800 characters maximum, including spaces).

3785 Character(s) remaining

(none provided)

Exercise 22.19

A hollow, conducting sphere with an outer radius of 0.260 m and an inner radius of 0.200 m has a uniform surface charge density of +6.57 $\times$ 10^{-6} $\mathrm{C/m^2}$. A charge of -0.500 $\mu\mathrm{C}$ is now introduced into the cavity inside the sphere.

Part A

What is the new charge density on the outside of the sphere?

Express your answer with the appropriate units.

ANSWER:

σ =

Part B

Calculate the strength of the electric field just outside the sphere.

Express your answer with the appropriate units.

ANSWER:

E =

Part C

What is the electric flux through a spherical surface just inside the inner surface of the sphere?

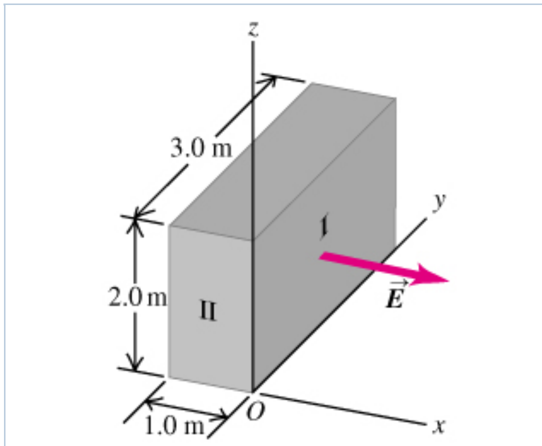
Express your answer with the appropriate units.

ANSWER:

Φ =

Problem 22.35

The electric field $\vec{E}$ in the figure is everywhere parallel to the *x*-axis, so the components E_y and E_z are zero. The *x*-component of the field E_x depends on x but not on y and z. At points in the *yz*-plane (where $x = 0$), $E_x = 125 \text{ N/C}$.



Part A

What is the electric flux through surface I in the figure?

ANSWER:

Φ_I = $\text{N} \cdot \text{m}^2/\text{C}$

Part B

What is the electric flux through surface II?

ANSWER:

Φ_{II} = [ ] $\mathrm{N \cdot m^2/C}$

Part C

The volume shown in the figure is a small section of a very large insulating slab $1.0\ \mathrm{m}$ thick. If there is a total charge $-24.0\ \mathrm{nC}$ within the volume shown, what is the magnitude of $\vec{E}$ at the face opposite surface I?

ANSWER:

E = [ ] $\mathrm{N/C}$

Part D

If there is a total charge $-24.0\ \mathrm{nC}$ within the volume shown, what is the direction of $\vec{E}$ at the face opposite surface I?

ANSWER:

- +*x*-axis
- -*x*-axis

Part E

Is the electric field produced only by charges within the slab, or is the field also due to charges outside the slab? How can you tell?

ANSWER:

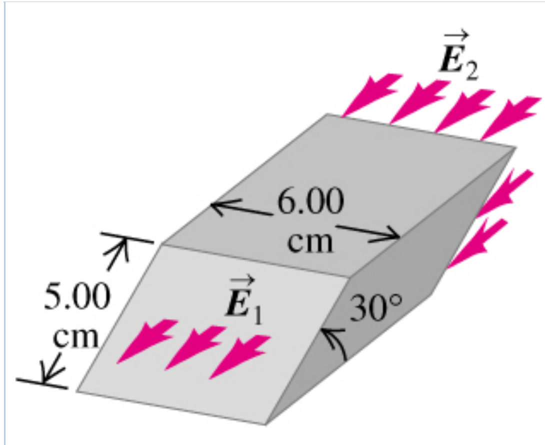
Essay answers are limited to about 500 words (3800 characters maximum, including spaces).

3785 Character(s) remaining

(none provided)

Problem 22.37

The electric field $\vec{E}_1$ at one face of a parallelepiped is uniform over the entire face and is directed out of the face. At the opposite face, the electric field $\vec{E}_2$ is also uniform over the entire face and is directed into that face (the figure). The two faces in question are inclined at 30.0 $^\circ$ from the horizontal, while $\vec{E}_1$ and $\vec{E}_2$ are both horizontal; $\vec{E}_1$ has a magnitude of 2.20×10^4 $\mathrm{N/C}$, and $\vec{E}_2$ has a magnitude of 7.70×10^4 $\mathrm{N/C}$.



Part A

Assuming that no other electric field lines cross the surfaces of the parallelepiped, determine the net charge contained within.

ANSWER:

q = C

Part B

Is the electric field produced only by the charges within the parallelepiped, or is the field also due to charges outside the parallelepiped? How can you tell?

ANSWER:

Essay answers are limited to about 500 words (3800 characters maximum, including spaces).

3785 Character(s) remaining

(none provided)

Problem 22.43

A solid conducting sphere with radius R that carries positive charge Q is concentric with a very thin insulating shell of radius $2R$ that also carries charge Q. The charge Q is distributed uniformly over the insulating shell.

Part A

Find the magnitude of the electric field in the region $0 < r < R$.

Express your answer in terms of the variables R, r, Q, and constants π and ϵ_0.

ANSWER:

E =

Part B

This question will be shown after you complete previous question(s).

Part C

Find the magnitude of the electric field in the region $R < r < 2R$.

Express your answer in terms of the variables R, r, Q, and constants π and ϵ_0.

ANSWER:

E =

Part D

This question will be shown after you complete previous question(s).

Part E

Find the magnitude of the electric field in the region $r > 2R$.

Express your answer in terms of the variables R, r, Q, and constants π and ϵ_0.

ANSWER:

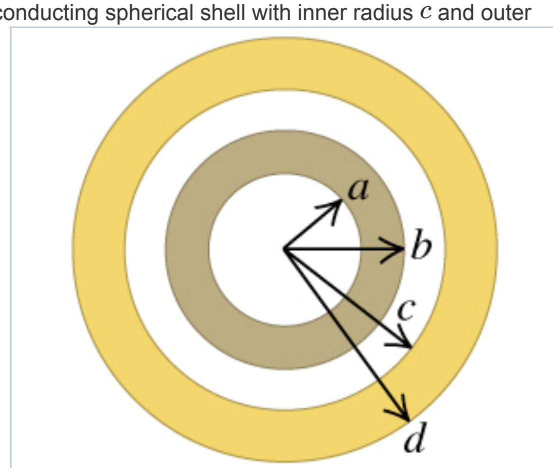
E =

Part F

This question will be shown after you complete previous question(s).

Problem 22.45

A small conducting spherical shell with inner radius a and outer radius b is concentric with a larger conducting spherical shell with inner radius c and outer radius d (see the Figure). The inner shell has total charge $+2q$, and the outer shell has charge $+4q$.



Part A

Calculate the magnitude of the electric field in terms of q and the distance r from the common center of the two shells for $r < a$.

Express your answer in terms of the variables q, r, a, b, c, d, and constants π and ϵ_0.

ANSWER:

E =

Part B

This question will be shown after you complete previous question(s).

Part C

Calculate the magnitude of the electric field in terms of q and the distance r from the common center of the two shells for $a < r < b$.

Express your answer in terms of the variables q, r, a, b, c, d, and constants π and ϵ_0.

ANSWER:

E =

Part D

This question will be shown after you complete previous question(s).

Part E

Calculate the magnitude of the electric field in terms of q and the distance r from the common center of the two shells for $b < r < c$.

Express your answer in terms of the variables q, r, a, b, c, d, and constants π and ϵ_0.

ANSWER:

E =

Part F

This question will be shown after you complete previous question(s).

Part G

Calculate the magnitude of the electric field in terms of q and the distance r from the common center of the two shells for $c < r < d$.

Express your answer in terms of the variables q, r, a, b, c, d, and constants π and ϵ_0.

ANSWER:

E =

Part H

This question will be shown after you complete previous question(s).

Part I

Calculate the magnitude of the electric field in terms of q and the distance r from the common center of the two shells for $r > d$.

Express your answer in terms of the variables q, r, a, b, c, d, and constants π and ϵ_0 .

ANSWER:

Part J

This question will be shown after you complete previous question(s).

Part K

This question will be shown after you complete previous question(s).

Part L

This question will be shown after you complete previous question(s).

Part M

This question will be shown after you complete previous question(s).

Part N

This question will be shown after you complete previous question(s).

Problem 22.47

Negative charge $-Q$ is distributed uniformly over the surface of a thin spherical insulating shell with radius R.

Part A

Calculate the magnitude of the force that the shell exerts on a positive point charge q located a distance $r > R$ from the center of the shell (outside the shell).

Express your answer in terms of the variables q, Q, r, R, and constants π and ϵ_0.

ANSWER:

F =

Part B

This question will be shown after you complete previous question(s).

Part C

Calculate the magnitude of the force that the shell exerts on a positive point charge q located a distance $r < R$ from the center of the shell (inside the shell).

Express your answer in terms of the variables q, Q, r, R, and constants π and ϵ_0.

ANSWER:

F =

Part D

This question will be shown after you complete previous question(s).

Problem 22.49

An insulating hollow sphere has inner radius a and outer radius b. Within the insulating material the volume charge density is given by $\rho\left(r\right) = \frac{\alpha}{r}$,where α is a positive constant.

Part A

What is the magnitude of the electric field at a distance r from the center of the shell, where $a < r < b$?

Express your answer in terms of the variables α, a, r, and electric constant ϵ_0.

ANSWER:

E =

Part B

A point charge q is placed at the center of the hollow space, at $r = 0$. What value must q have (sign and magnitude) in order for the electric field to be constant in the region $a < r < b$?

Express your answer in terms of the variables α, a, and appropriate constants.

ANSWER:

q =

Part C

What then is the value of the constant field in this region?

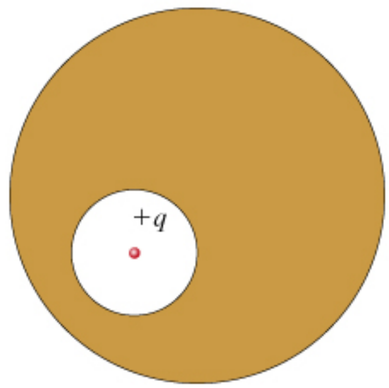
Express your answer in terms of the variable α and electric constant ϵ_0.

ANSWER:

E =

The Charge Inside a Conductor

A spherical cavity is hollowed out of the interior of a neutral conducting sphere. At the center of the cavity is a point charge, of positive charge q.



Part A

What is the total surface charge $q_{\rm int}$ on the interior surface of the conductor (i.e., on the wall of the cavity)?

You did not open hints for this part.

ANSWER:

$q_{\rm int}$ =

Part B

This question will be shown after you complete previous question(s).

Part C

What is the magnitude $E_{\rm int}$ of the electric field inside the cavity as a function of the distance r from the point charge? Let k, as usual, denote $\frac{1}{4\pi\epsilon_0}$.

You did not open hints for this part.

ANSWER:

- 0
- kq/r^2
- $2kq/r^2$

Part D

What is the electric field E_{ext} outside the conductor?

You did not open hints for this part.

ANSWER:

- zero
- the same as the field produced by a point charge q located at the center of the sphere
- the same as the field produced by a point charge located at the position of the charge in the cavity

Now a second charge, q_2, is brought near the outside of the conductor. Which of the following quantities would change?

Part E

The total surface charge on the wall of the cavity, q_{int}:

You did not open hints for this part.

ANSWER:

- would change
- would not change

Part F

The total surface charge on the exterior of the conductor, q_{ext}:

You did not open hints for this part.

ANSWER:

- would change
- would not change

Part G

The electric field within the cavity, E_{cav}:

ANSWER:

- would change
- would not change

Part H

The electric field outside the conductor, E_{ext}:

ANSWER:

- would change
- would not change

The Electric Field and Surface Charge at a Conductor

Learning Goal:

To understand the behavior of the electric field at the surface of a conductor, and its relationship to surface charge on the conductor.

A conductor is placed in an external electrostatic field. The external field is uniform before the conductor is placed within it. The conductor is completely isolated from any source of current or charge.

Part A

Which of the following describes the electric field inside this conductor?

ANSWER:

- It is in the same direction as the original external field.
- It is in the opposite direction from that of the original external field.
- It has a direction determined entirely by the charge on its surface.
- It is always zero.

Part B

The charge density *inside* the conductor is:

ANSWER:

- 0
- non-zero; but uniform
- non-zero; non-uniform
- infinite

Part C

Assume that at some point just outside the surface of the conductor, the electric field has magnitude E and is directed *toward* the surface of the conductor. What is the charge density η on the surface of the conductor at that point?

Express your answer in terms of E and ϵ_0.

You did not open hints for this part.

ANSWER:

η =

The Electric Field of a Ball of Uniform Charge Density

A solid ball of radius r_b has a uniform charge density ρ.

Part A

What is the magnitude of the electric field $E(r)$ at a distance $r > r_b$ from the center of the ball?

Express your answer in terms of ρ, r_b, r, and ϵ_0.

You did not open hints for this part.

ANSWER:

$E(r)$ =

Part B

What is the magnitude of the electric field $E(r)$ at a distance $r < r_b$ from the center of the ball?

Express your answer in terms of ρ, r, r_b, and ϵ_0.

You did not open hints for this part.

ANSWER:

$E(r)$ =

Part C

Let $E(r)$ represent the electric field due to the charged ball throughout all of space. Which of the following statements about the electric field are true?

Check all that apply.

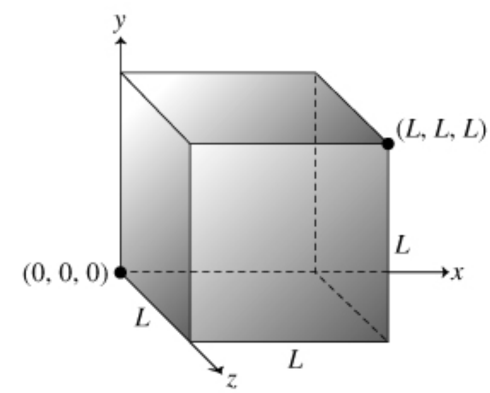
You did not open hints for this part.

ANSWER:

- $E(0) = 0$.
- $E(r_b) = 0$.
- $\lim_{r\to\infty} E(r) = 0$.
- The maximum electric field occurs when $r = 0$.
- The maximum electric field occurs when $r = r_b$.
- The maximum electric field occurs as $r \to \infty$.

Flux through a Cube

A cube has one corner at the origin and the opposite corner at the point (L, L, L). The sides of the cube are parallel to the coordinate planes. The electric field in and around the cube is given by $\vec{E} = (a + bx)\hat{i} + c\hat{j}$.



Part A

Find the total electric flux Φ_E through the surface of the cube.

Express your answer in terms of a, b, c, and L.

You did not open hints for this part.

ANSWER:

Φ_E =

Part B

This question will be shown after you complete previous question(s).

Part C

What is the net charge q inside the cube?

Express your answer in terms of a, b, c, L, and ϵ_0.

You did not open hints for this part.

ANSWER:

q =

Flux out of a Cube

A point charge of magnitude q is at the center of a cube with sides of length L.

Part A

What is the electric flux Φ through each of the six faces of the cube?

Use ϵ_0 for the permittivity of free space.

You did not open hints for this part.

ANSWER:

Φ = $\mathrm{N \cdot m^2/C}$

Part B

What would be the flux Φ_1 through a face of the cube if its sides were of length L_1?

Use ϵ_0 for the permittivity of free space.

You did not open hints for this part.

ANSWER:

Φ_1 = $\mathrm{N \cdot m^2/C}$

Gauss's Law in 3, 2, and 1 Dimension

Gauss's law relates the electric flux Φ_E through a closed surface to the total charge q_{encl} enclosed by the surface:

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\mathrm{encl}}}{\epsilon_0}.$$

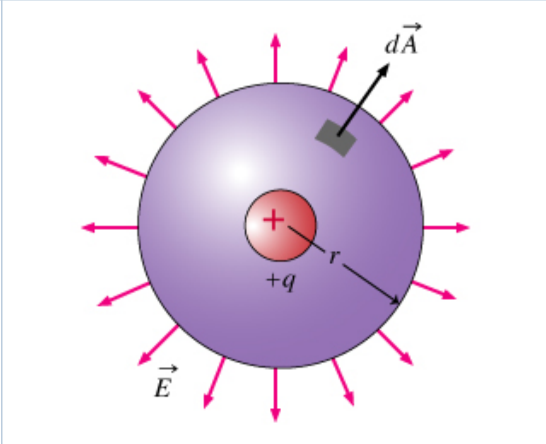
You can use Gauss's law to determine the charge enclosed inside a closed surface on which the electric field is known. However, Gauss's law is most frequently used to determine the electric field from a symmetric charge distribution.

The simplest case in which Gauss's law can be used to determine the electric field is that in which the charge is localized at a point, a line, or a plane. When the charge is localized at a point, so that the electric field radiates in three-dimensional space, the Gaussian surface is a sphere, and computations can be done in spherical coordinates. Now consider extending all elements of the problem (charge, Gaussian surface, boundary conditions) infinitely along some direction, say along the *z* axis. In this case, the point has been extended to a line, namely, the *z* axis, and the resulting electric field has cylindrical symmetry. Consequently, the problem reduces to two dimensions, since the field varies only with *x* and *y*, or with r and θ in cylindrical coordinates. A one-dimensional problem may be achieved by extending the problem uniformly in two directions. In this case, the point is extended to a plane, and consequently, it has planar symmetry.

Three dimensions

Consider a point charge q in three-dimensional space. Symmetry requires the electric field to point directly away from the charge in all directions. To find $E(r)$, the magnitude of the field at distance r from the charge, the logical Gaussian surface is a sphere centered at the charge. The electric field is normal to this surface, so the dot product of the electric field and an infinitesimal surface element involves $\cos(0) = 1$. The flux integral is therefore reduced to

$\int E(r)\,dA = E(r)A(r)$, where $E(r)$ is the magnitude of the electric field on the Gaussian surface, and $A(r)$ is the area of the surface.



Part A

Determine the magnitude $E(r)$ by applying Gauss's law.

Express $E(r)$ in terms of some or all of the variables/constants q, r, and ϵ_0.

You did not open hints for this part.

ANSWER:

$E(r)$ =

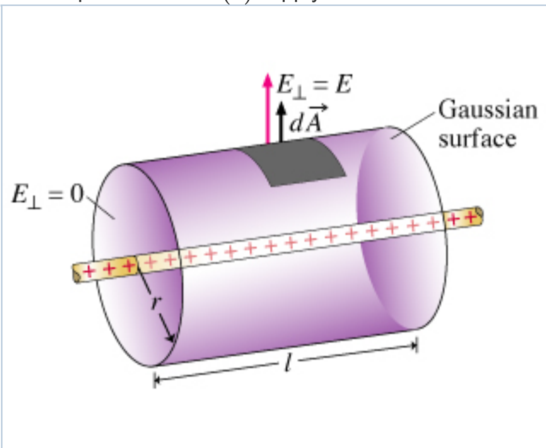
Two dimensions

Now consider the case that the charge has been extended along the *z* axis. This is generally called a line charge. The usual variable for a line charge density (charge per unit length) is λ, and it has units (in the SI system) of coulombs per meter.

Part B

By symmetry, the electric field must point radially outward from the wire at each point; that is, the field lines lie in planes perpendicular to the wire. In solving for the magnitude of the radial electric field $E(r)$ produced by a line charge with charge density λ, one should use a cylindrical Gaussian surface whose axis is the line charge. The length of the cylindrical surface L should cancel out of the expression for $E(r)$. Apply Gauss's law to this situation to find an expression for $E(r)$.

Express $E(r)$ in terms of some or all of the variables λ, r, and any needed constants.



You did not open hints for this part.

ANSWER:

$E(r)$ =

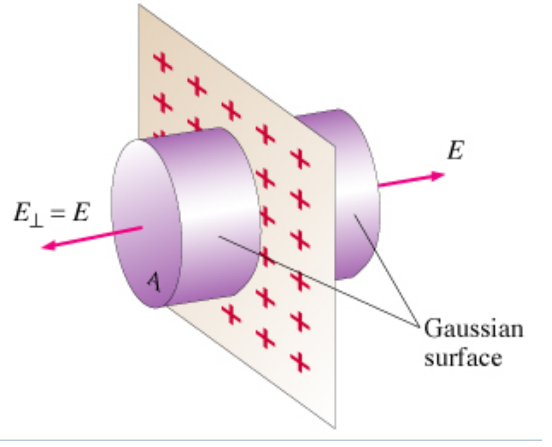
One dimension

Now consider the case with one effective direction. In order to make a problem effectively one-dimensional, it is necessary to extend a charge to infinity along two orthogonal axes, conventionally taken to be *x* and *y*. When the charge is extended to infinity in the *xy* plane (so that by symmetry, the electric field will be directed in the *z* direction and depend only on *z*), the charge distribution is sometimes called a sheet charge. The symbol usually used for two-dimensional charge density is either σ, or η. In this problem we will use σ. σ has units of coulombs per meter squared.

Part C

In solving for the magnitude of the electric field $\vec{E}(z)$ produced by a sheet charge with charge density σ, use the *planar* symmetry since the charge distribution doesn't change if you slide it in any direction of *xy* plane parallel to the sheet. Therefore at each point, the electric field is perpendicular to the sheet and must have the same magnitude at any given distance on either side of the sheet. To take advantage of these symmetry properties, use a Gaussian surface in the shape of a cylinder with its axis perpendicular to the sheet of charge, with ends of area A which will cancel out of the expression for $E(z)$ in the end. The result of applying Gauss's law to this situation then gives an expression for $E(z)$ for both $z > 0$ and $z < 0$.

Express $E(z)$ for $z > 0$ in terms of some or all of the variables/constants σ, z, and ϵ_0.



You did not open hints for this part.

ANSWER:

$E(z)$ =

Gauss's Law

Learning Goal:

To understand the meaning of the variables in Gauss's law, and the conditions under which the law is applicable.

Gauss's law is usually written

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{encl}}}{\epsilon_0},$$

where $\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2/(N \cdot m^2)}$ is the permittivity of vacuum.

Part A

How should the integral in Gauss's law be evaluated?

ANSWER:

- around the perimeter of a closed loop
- over the surface bounded by a closed loop
- over a closed surface

Part B

This question will be shown after you complete previous question(s).

Score Summary:

Your score on this assignment is 0.0%.
You received 0 out of a possible total of 250 points.