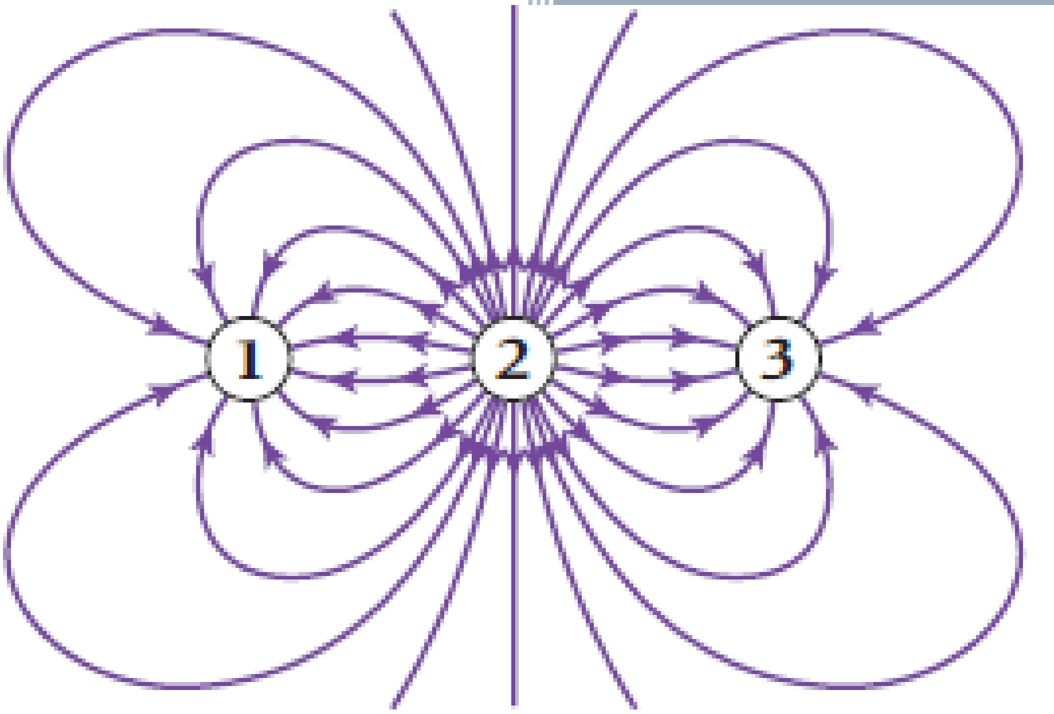
2021 - 2022

Electric Fields and Gausses's Law



Grade: 12 A

2021-2022 Trimester 1

Name: ______________________________

Class: ______________________________

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مدرسة النخبة – قسم الفيزياء

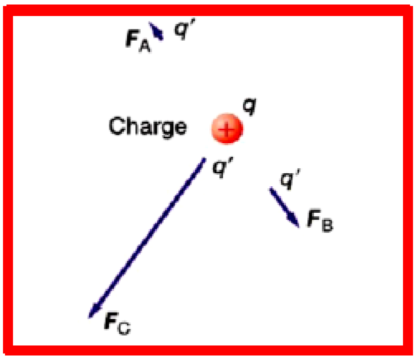
2021 - 2022

2.1 Definition of an Electric Field

A field is defined as a property of space in which a material object experiences a force.

The electric field is the space around an electrical charge.

An electric field: E(r) is defined at any point in space, as the net electric force on a charge, divided by that charge



1. Now, consider point P a distance r from +q/.

2. An electric field E exists at P if a test charge +q/ has a force F at that point.

3. The direction of the E is the same as the direction of a force on + (pos) charge.

4. The magnitude of E is given by the formula (Electric Field Strengh)

$$E = \frac{F_{on\ q/}}{q/}$$

The strength of an electric field is equal to the force on a positive test charge divided by the strength of the test charge

Unit of $E = \frac{N}{C}$

The direction of E at a point is the same as the direction that a positive charge would move IF placed at that point.

Exercises

1. Calculate the electric field strength on a proton (q = 1.6 **x 10** $^{-19}$ C), if you know that the electric force acting on it equal **3.2 x 10** $^{-15}$ **N. Toward the negative x-axis**

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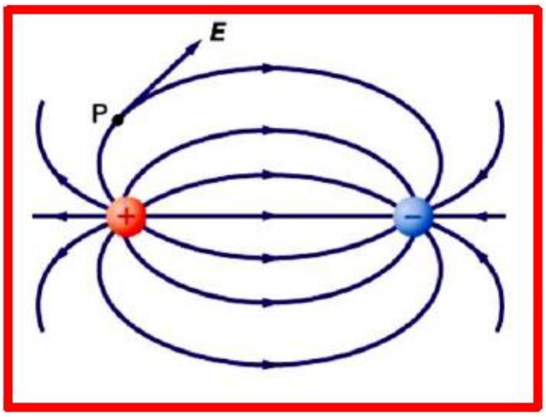
2.2 Field Lines

Electric Field Lines are:

imaginary lines representing the path of a test charge when it placed free in an electric field.

The following rules apply to electric field lines:

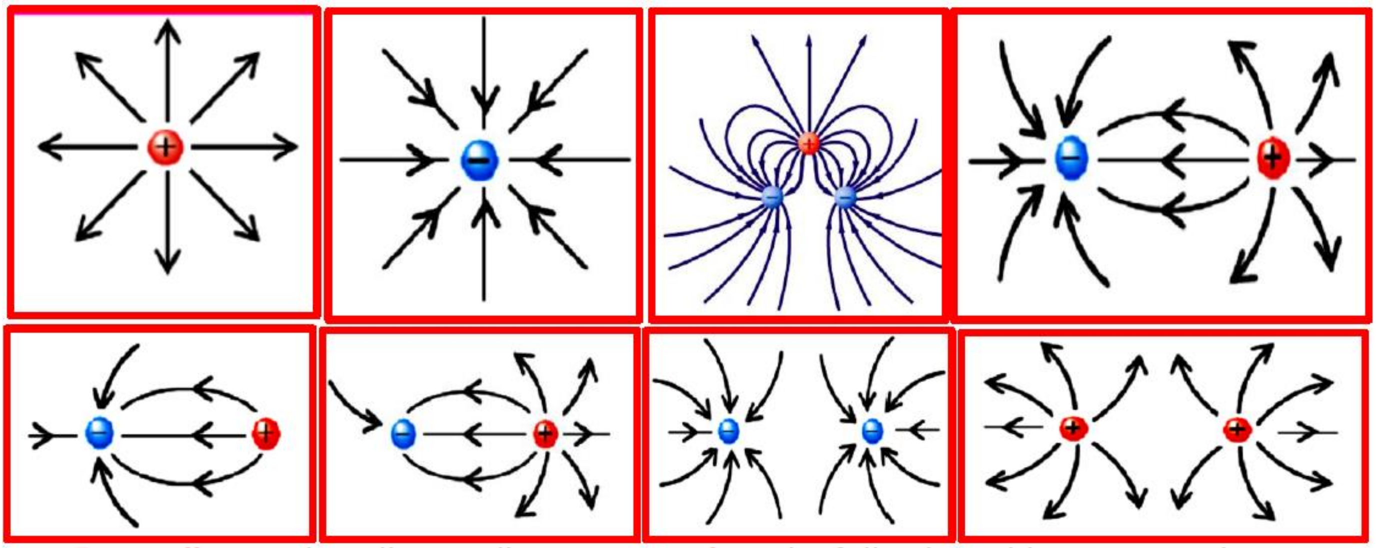
- Lines begin and end only at charges (beginning at + charges, ending at - charges) or at Infinity.(lines go away from positive charges and toward negative charges)
- Lines are closer together where the field is stronger.
- Larger charges have more field lines beginning or ending on them.
- Electric Field lines never cross (Because if the intersection of two lines would have to the field intensity at the intersection point more than the direction this can not)
- At any location, the direction of the electric field is tangent to the electric field line that passes through that location.



(Notice that lines leave + charges and enter - charges. Also, E is strongest where field lines are most dense dense.

Before starting to draw the lines of the electric field, the following ratio should be applied

$$\frac{n_1}{n_2} = \frac{q_1}{q_2}$$



Multiple-Choice Questions

1. Electric Field lines always point from:

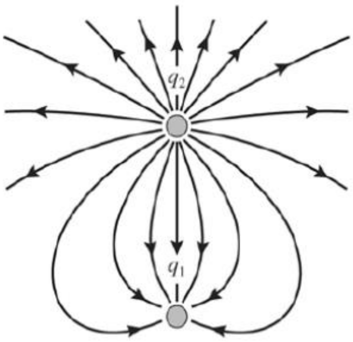
   Positive charges to positive charges

   Negative charges to negative charges

   Positive charges to negative charges

   Negative charges to positive charges

2. What can you deduce from the sketch:



q_1 is negative and q_2 is positive; the magnitudes are equal

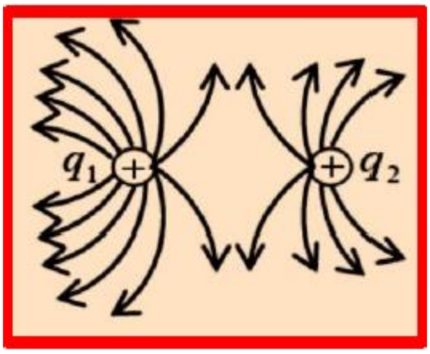
q_1 and q_2 have the same sign; the magnitudes are equal

q_1 is positive and q_2 is negative; the magnitude of q_1 is greater than the magnitude of q_2

q_1 is negative and q_2 is positive; the magnitude of q_1 is less than the magnitude of q_2

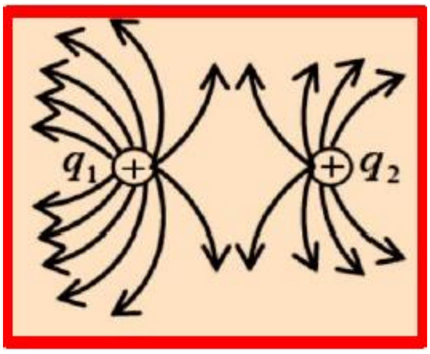
Exercises

1. **Depending** on the adjacent diagram, **complete** the following table as appropriate

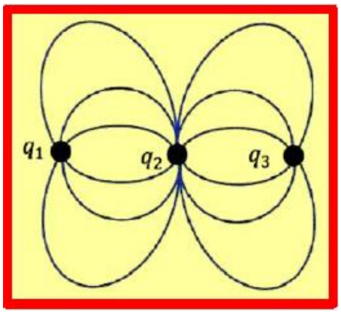


q_2	q_1	
		Type of charge
	$12nC$	Amount of

2. **Depending** on the adjacent shape, **calculate the ratio** between the two charges



3. The diagram shows the electric field lines for three dot matrix charges



- **Calculate the ratio** $\frac{|q_1|}{|q_3|}$

- If q_1 is negative, **what type** of q_2 and q_3

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4. There is an area between the two similar charges where there are no field lines? What does that mean and why?

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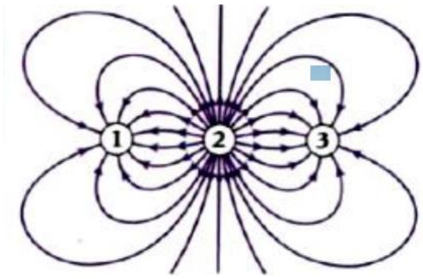
5. Draw the lines of field between two different charges, but they are unequal in the following figure?

7. ❖ Which of the charges shown in the figure is positive?



❖ Calculate the ratio between charge 1 and charge 2?

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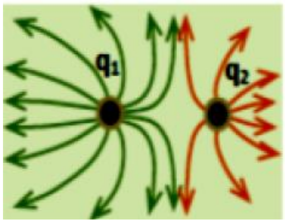
8. The adjacent figure shows the electric field lines of two-point charges ($|q_1|$=3.0 nC, q_2)

❖ determine the type of every charge?

❖ Calculate the amount of charge $q2$



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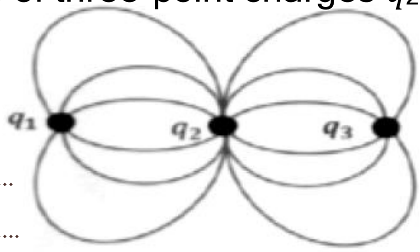
9. The adjacent figure shows the electric field lines of three-point charges q_2, q_3, q_1

➢ determine the type of q_2, q_3 if q_1 is negative?

➢ Calculate the ratio q_2/q_3?



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10. Two adjacent point charges were placed in the air as in the adjacent figure $q_1 = 1.4\ \mu C$, $q_2 = -4.2\ \mu C$

➢ Draw the electric field lines in the same shape.

2.3 Electric Field due to Point Charges

Electric field strength (E): is equal to the force on a positive test charge divided by the strength of the test charge

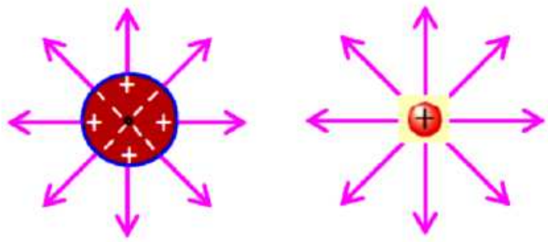
$$F_e = k_c \frac{|q q_0|}{r^2} = \frac{1}{4\pi \in_0} \frac{|q q_0|}{r^2}$$

$$E = \left|\frac{F}{q_0}\right| = \frac{1}{4\pi \in_0} \frac{|q|}{r^2}$$

Electric field strength is vector quantity

The superposition principle for the total electric field, $\vec{E}_t$, at any point in space with , due to n electric field sources can be stated as $\vec{E}_t = \vec{E}_1 + \vec{E}_2 + \cdots + \vec{E}_n$

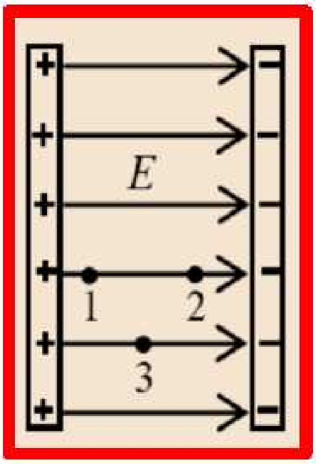
Types of electric field :



1- Irregular field

- ❖ Its intensity changes with the dimension
- ❖ Field lines are not parallel
- ❖ produced in point and spherical charges

2- Regular field



- Fixed at the magnitude and direction at all points in it
- Its field lines are straight and parallel
- How to get it: By two parallel plates charged with two Equal and opposite different charges

Multiple-Choice Questions

1. Two ions are placed on the x-axis. One has a charge of +e and is located at the origin. The other has a charge of -4e and is located at x=+d, where d > 0.

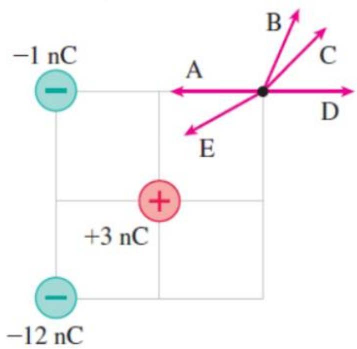
Where on the x-axis is the net electric field equal to zero?

X = -2 d
X = 2 d
X = -d
X = d

2. In the opposite corners of a square there are two identical ions. Each has a charge of -e. The length of one side of the square is L. What is the magnitude of the net electric field caused by the two negative ions at both of the empty corners of the square?

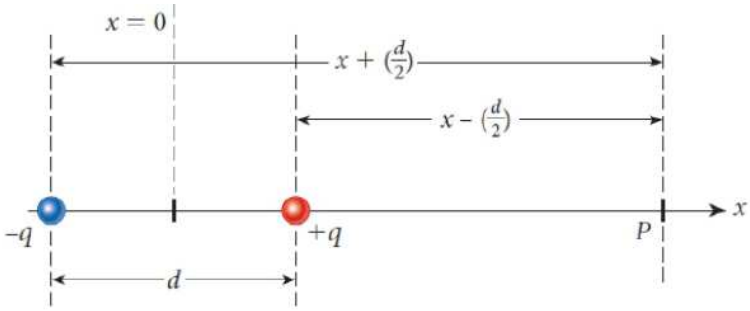
$ke/2L^2$
ke/L^2
$\sqrt{2}\,ke/L^2$
$2ke/L^2$

3. Three-point charges are arranged as shown in the figure which arrow best represents the direction of the electric field vector at the position of the dot?



A
B
C
D
E

4. The electric field at point P is ....



$\frac{qd}{2\pi\varepsilon_0 x^2}$ in + x-direction

$\frac{qd}{4\pi\varepsilon_0 x^2}$ in – x-direction

$\frac{qd}{4\pi\varepsilon_0 x^3}$ in – x-direction

$\frac{qd}{2\pi\varepsilon_0 x^3}$ in + x-direction

5. Two identical point charges Q are placed each diagonally opposite corners of a square (1.0 m on a side). The magnitude of the electric field at either of the two unoccupied corners is 19.1 N/C. The absolute value of the charge Q is...........

1.5 nC

2.4 nC

3.2 nC

4.7 nC

5.9 nC

6. A +5.00 nC point charge is placed on the X axis at x= 1.00 m, and a -6.00 nC point charge is placed on the Y axis at y= -2.00 m. What is the direction of the electric field at the origin?

189°

191°

193°

195°

197°

7. Two tiny particles having charges +20.0 μC and -8.00 μC are separated by 20.0 cm. What are the magnitude and direction of electric field midway between these two charges?

25.2×10^6 N/C directed towards the negative charge

25.2×10^6 N/C directed towards the positive charge

25.2×10^5 N/C directed towards the negative charge

25.2×10^5 N/C directed towards the positive charge

8. Three charges are placed at the corners of an equilateral triangle that is 0.16 m on each side. The first charge is 3.4 μC, the second is 2.2 μC, and the third is 1.6 μC. What is the magnitude of the electric field at the center of the triangle due to the three charges?

2.9×10^5 N/C

5.9×10^4 N/C

2.3×10^5 N/C

1.7×10^6 N/C

9. The electric field is zero at some point on a line that runs between the centers of two charged spheres. What can one say about this situation?

The charges on the two spheres are opposite in sign

The charges on the two spheres have the same sign

The point of interest is equidistant from the two spheres' center

There is no such point on the line

None are correct

Exercises

1. In the adjacent figure, if the electric field strength at point (a) is 72 N / C, answer the following:

❖ Calculate the distance from point (a) to the charge

❖ How much is the intensity of the field at a point in the infinity

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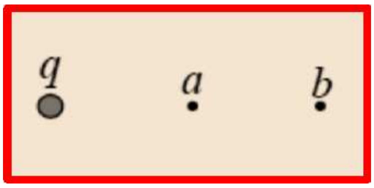
2. in the adjacent figure, if the distance (b) from the charge (q) is twice as much the distance the point (a), find the ratio between the intensity Field at (a) and field strength at point (b)?



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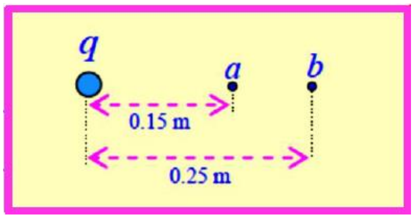
3. Points (a) and (b) are located in In the electric field of the point charge (q) As in the adjacent figure If the electric field strength at point (b) is equal (900 N / C) Calculate the electric field strength at point (a)



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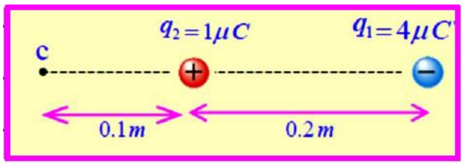
4. Based on the data in the figure Calculate the electric field strength at point (c)



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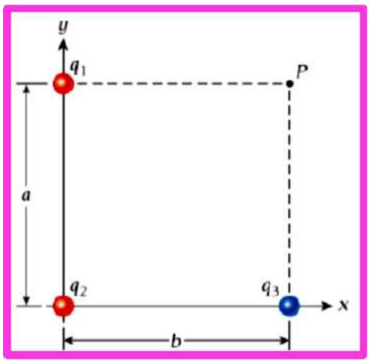
5. Figure shows three fixed point charges: $q_1 = +1.50\ \mu C$, $q_2 = +2.50\ \mu C$, and $q_3 = -3.50\ \mu C$.
Charge q_1 is located at (0, a), q_2 is located at (0, 0), and q_3 is located at (b, 0), where a = 8.00 m and b = 6.00 m.
What electric field (E) do these three charges produce at the point P = (b, a)



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6. Calculate the field strength at a point 3.0 m away from a generated charge equal to 2.0 C.

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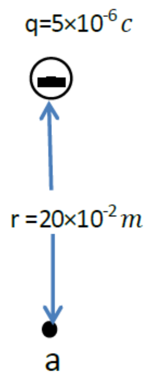
7. Depending on the adjacent figure calculate:
   A) field strength at point (a).
   B) Determine the direction of the field at point (a).



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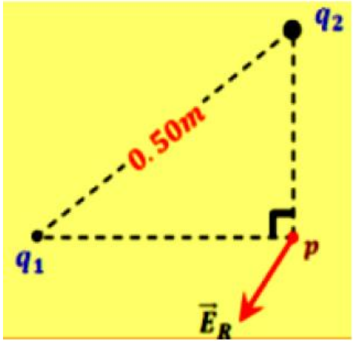
8. The adjacent figure shows the vector of the electric field strength obtained at the point (p) placed in the electric field by two-point charges. If the air surrounds the charges and the point, do the following:
   - ❖ What is the type of both charges?
   - ❖ Calculate the amount of electric field strength affecting on the charge q_2? if $|q_1|=3.0\ nC$



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9. Two identical charges (-8.0 nC), placed at the two positions (0.0 cm, 0.0 cm), (+3.0 cm , +4.0 cm)

- Calculate the net electric field strength at the position (0.0 cm , +3.0 cm)?
- Calculate the net electrostatic force effect on an electron located at the position (0.0 cm , +3.0 cm)?

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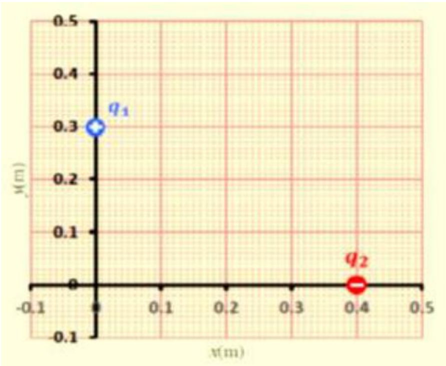
10. The two-point charges were placed in the air on the axes of the coordinates as in the adjacent figure if $q_2 = -32.0\ \mu C$, $q_1 = +16.0\ \mu C$

- What is the electric field strength at the point of origin (0,0)
- If the charge q_2 is removed, will the amount of electric field increase at the point of origin or decreased or not changed? Justify your answer.



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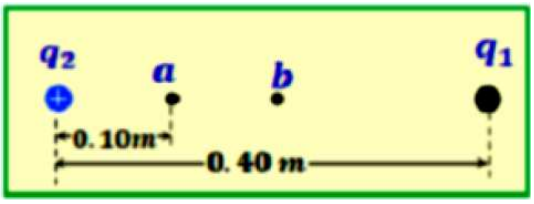
11. If the amount of electric field strength is at point a shown in the adjacent shape is zero and $q_2= -25.0\ nC$

❖ Calculate the amount of charge q_1. and determine its type?



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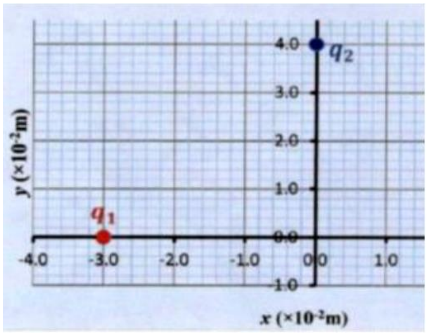
12. The adjacent figure shows two-point charges $q_1= 4.0\ x\ 10^{-12}\ C$, $q_2= 16\ x\ 10^{-12}\ C$ if the air surrounds the two charges.

➢ Find the amount of electric field strength at the point of origin (0,0)

➢ Calculate the wattage affecting the charge q_1.



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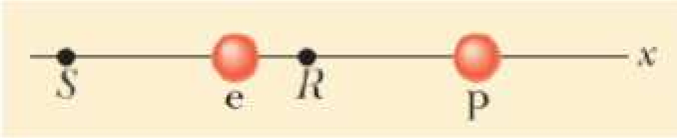
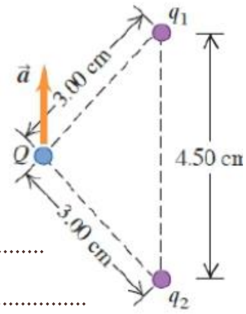
13. The figure here shows a proton p and an electron e on an x axis.

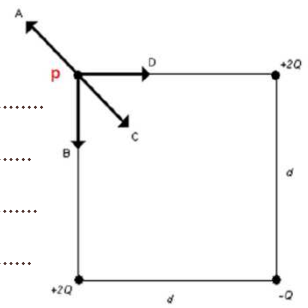
- ❖ What is the direction of the electric field due to the electron at point S and point R?
- ❖ What is the direction of the net electric field at point R and point S?



14. Two point charges q_1 and q_2 are held in place 4.50 cm apart. Another point charge Q= -1.75 mC of mass 5.00 g, is initially located 3.00 cm from both of these charges and released from rest. You observe that the initial acceleration of Q is 324 m/s^2 upward, parallel to the line connecting the two point charges. Find q_1 and q_2.



15. What is the direction of the net electric field at P?



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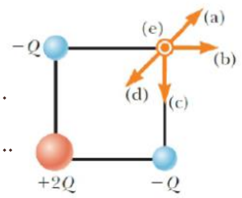
16. What is the direction of the net electric field at the upper right corner which is a point in empty space?



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2.5 General Charge Distributions

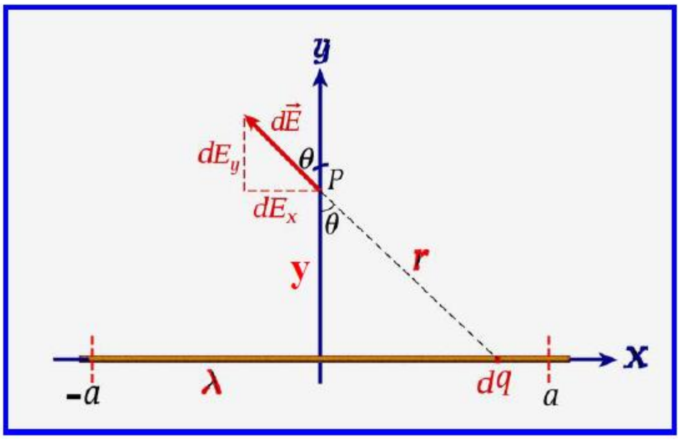
Now let's consider the electric field due to a general charge distribution. To do this, we divide the charge into differential elements of charge, *dq*, and find the electric field

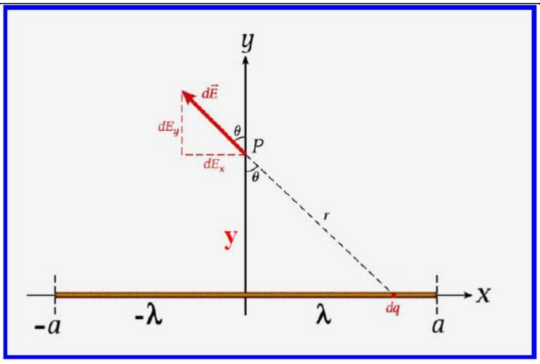
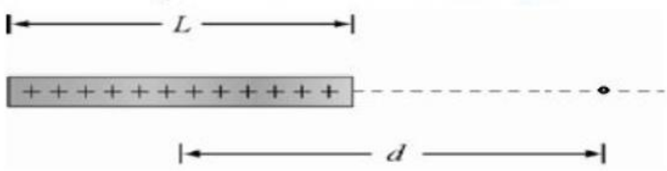
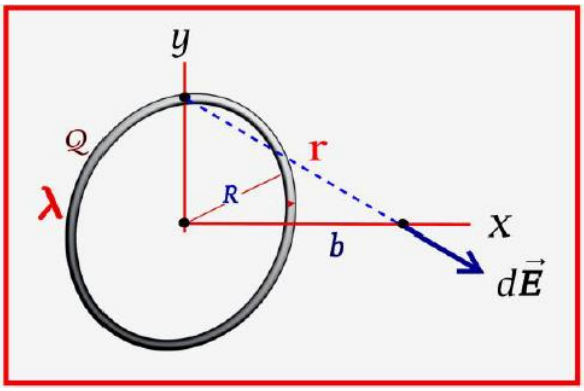
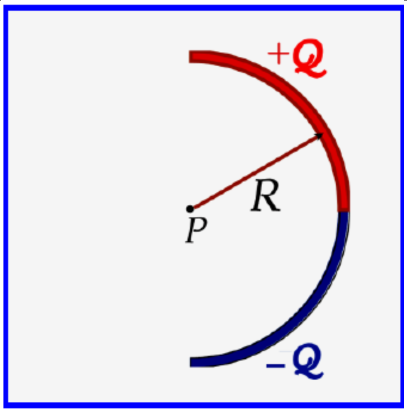
$dq = \lambda dx$	For a charge distribution	along a line;
$dq = \sigma dA$		over a surface;
$dq = \rho dV$		throughout a volume

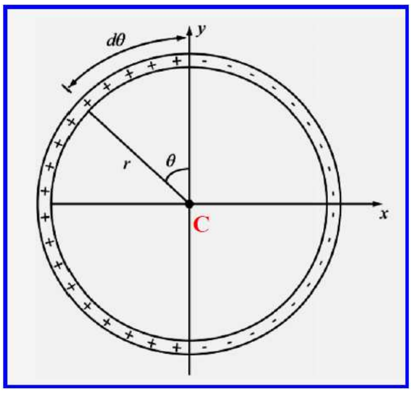
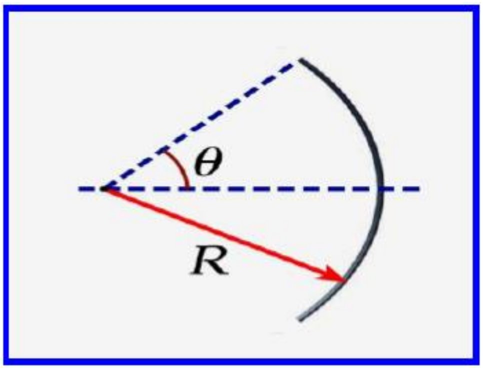
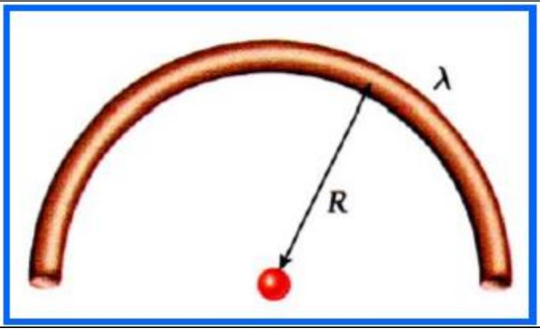
The magnitude of the electric field resulting from the charge distribution is then obtained from the differential charge.

$$dE = k\frac{dq}{r^2}$$

The electric field resulting from the general distributions of charge.

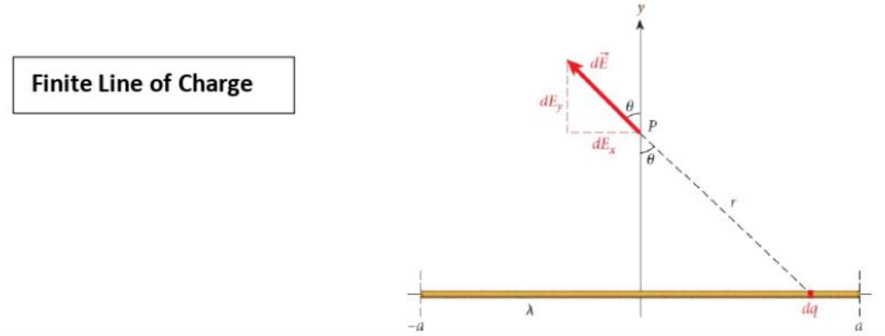
The electric field due to the charge on a straight wire and the uniform distribution of the charge with density (ƛ) The electric field is at a distance (Y) along a line that bisects the wire $E_y = \frac{2k\lambda}{y}\frac{a}{\sqrt{y^2+a^2}}$ The wire is infinite length $E_y = \frac{2k\lambda}{y}$	

The field due to the charge on a straight wire and the uniform distribution of the charge with density (ƛ) over one half of its length and with density (-ƛ) over the other $$E_p = 2K\lambda\left[\frac{1}{\sqrt{y^2+a^2}} - \frac{1}{y}\right]$$	
The field due to the charge on a straight wire and the uniform distribution of the charge with density (ƛ) and the measurement point in the same plane of the wire $$E = \frac{4kQ}{4d^2 - L^2}$$	
The field due to the charge on a circular ring is a uniform distribution of charge with uniform longitudinal density (ƛ) $$E_x = \frac{kQb}{(R^2+b^2)^{3/2}}$$ If R << b $$E = \frac{Kq}{b^2}$$ If b = 0 (in the center of the loop) E=0	
A thin glass stem in the form of a semicircle of radius (R) and the (+q) charge is uniformly distributed on the upper half and the (-q) charge is uniformly distributed on the lower half so that the field is at the center (P) $$E_c = \frac{-4Kq}{\pi R^2}$$	

The field due to the charge on a ring of an insulating material (glass) and a uniform distribution of charge (+λ) on one half of it and density (-λ) on the other half so the field is at the center (C) $$E_c = \frac{4Kq}{\pi R^2}$$	
A thin insulating leg (glass) in the form of an arc of radius (R) on which charge (+q) is uniformly distributed (less than half of a loop) $$E_c = \frac{Kq\sin(\theta)}{\theta_{rad} R^2}$$	
The electric field at the center of a wire of length (L) in the form of a semi-ring of radius (R) $$E = \frac{2\pi K\lambda}{L} = \frac{2K\lambda}{R}$$	

Multiple-Choice Questions

1. The electric field at point P is

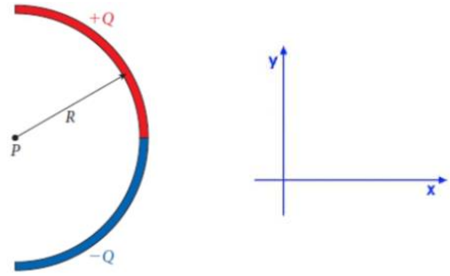


	E_y	E_x
A	$2k\lambda y \int_0^a \frac{dx}{(x^2+y^2)^{3/2}}$	0
B	0	$2k\lambda y \int_0^a \frac{dx}{(x^2+y^2)^{3/2}}$
C	$2k\lambda \int_0^a \frac{dq}{r^2} \sin\theta$	0
D	$2k \int_0^a \frac{dq}{r^2} \cos\theta$	0

A B

C D

2. A thin glass rod is bent into a semi-circle of radius R. A charge +Q is uniformly distributed along the upper half, and a charge -Q is uniformly distributed along the lower half, as shown in the figure.
If Q=10 nC and R= 10 cm find the magnitude and direction of the electric field E (in component form) at point P, the center of the semi-circle.



3.61×10^4 N/C in +Y direction

3.61×10^4 N/C in -Y direction

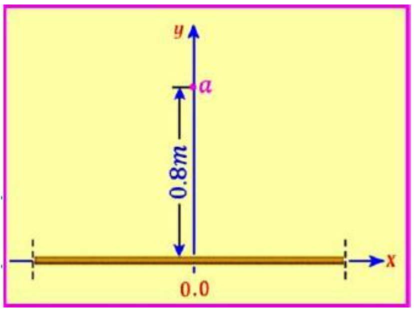
1.15×10^4 N/C in +Y direction

1.15×10^4 N/C in -Y direction

Exercises

1. The adjacent figure shows a straight wire of 1.2 m length and a positive charge with a
longitudinal density of 4.0 μC / m using the base.

$$\int \frac{1}{(a^2+x^2)^{3/2}}dx = \frac{1}{a^2}\frac{x}{\sqrt{a^2+x^2}} + c$$



Answer the following :

1. **Calculate the field** strength of the wire charge at point a
2. Repeat Calculation if the wire is **infinite**

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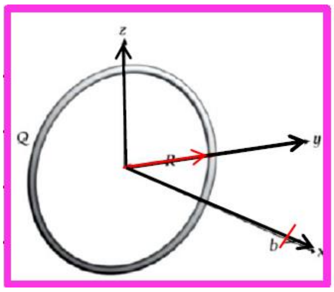
2. Consider a charged ring with radius $R = 0.250$ m (Figure). The ring has uniform linear charge density and the total charge on the ring is $Q = +5.00$ μC. **What is the electric** field at a distance $d = 0.500$ m along the axis of the ring?



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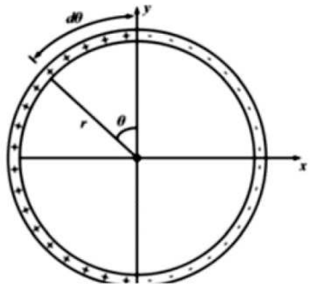
3. 2.34 Two uniformly charged insulating rods are bent in a semicircular shape with radius r = 10.0 cm. If they are positioned so they form a circle but do not touch and have opposite charges of +1.00 μC and -1.00 μC, find the magnitude and direction of the electric field at the center of the composite circular charge configuration.



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4. A long conducting wire with charge distribution λ and radius r produces an electric field of 2.73 N/C just outside the surface of the wire. What is the magnitude of the electric field just outside the surface of another wire with charge distribution 0.81λ and radius 6.5r?

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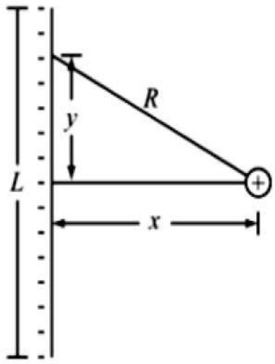
5. A total of $3.05X10^{6}$ electrons are placed on an initially uncharged wire of length 1.33 m.

a) What is the magnitude of the electric field a perpendicular distance of 0.401 m away from the midpoint of the wire?

b) What is the magnitude of the acceleration of a proton placed at that point in space?

c) In which direction does the electric field force point in this case?



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2.6 Force due to an Electric Field

The force **F** exerted by an electric field ***E*** on a point charge **q** is given by

$$F_e = qE$$

Dipole in an electric Field

The force **F** exerted by an electric field *E* Eon a point charge **q** is given by

Where force produces a torque that can be calculated from the equation

$$\tau = Frsin\theta$$

Where r = d

$$\tau = qEdsin\theta$$

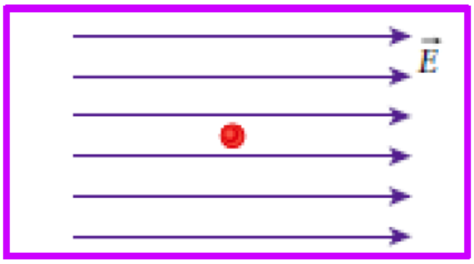
$$\tau = PEsin\theta$$

$$\vec{\tau} = \vec{P}\ x\ \vec{E}$$

As with all vector products, the direction of the torque is given by a right-hand rule. As shown in Figure, the thumb indicates the direction of the first term of the vector product, in this case p, and the index finger indicates the direction of the second term, E. The result of the vector product, τ, is then directed along the middle finger and is perpendicular to each of the two terms

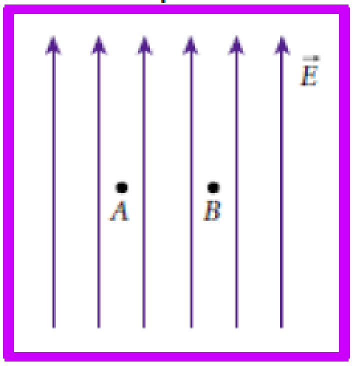
Multiple-Choice Questions

1. A small positively charged object is placed at rest in a uniform electric field as shown in the figure. When the object is released, it will



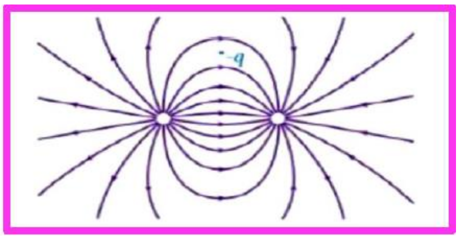
not move
begin to move with a constant speed
begin to move with a constant acceleration
begin to move with an increasing acceleration
move back and forth in simple harmonic motion

2. A small positively charged object could be placed in a uniform electric field at position *A* or position *B* in the figure. How do the electric forces on the object at the two positions compare.



The magnitude of the electric force on the object is greater at position *A*
The magnitude of the electric force on the object is greater at position *B*
There is no electric force on the object at either position *A* or position *B*
The electric force on the object at position *A* has the same magnitude as the force on the object at position *B* but is in the opposite direction
The electric force on the object at position *A* is the same nonzero electric force as that on the object at position *B*

3. A negative charge -q is placed in a nonuniform electric field as shown in the figure. What is the direction of the electric force on this negative charge?



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The force is zero

4. A 22-g metal ball hangs from a string. An electric field of 15000 N/C, pointing to the right, is then turned on. After the electric field is turned on, the ball hangs at a 25 degree angle away from the vertical. What is the charge on the ball?

6.8×10^{-7} C

6.7×10^{-6} C

6.1×10^{-6} C

1.4×10^{-5} C

3.1×10^{-5} C

5. The electrons in a particle beam each have a kinetic energy of 1.6×10^{-16} J. The magnitude of the electric field that would stop the electrons in a distance of 1 m is .....

2000 N/C

1000 N/C

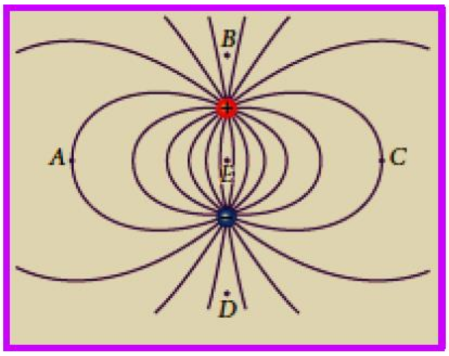
780 N/C

620 N/C

545 N/C

Exercises

The figure shows a two-dimensional view of electric field lines due to two opposite charges. What is the direction of the electric field at the five points *A, B, C, D,* and *E*? At which of the five points is the magnitude of the electric field the largest?



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Indicate whether each of the following statements about electric field lines is true or false.
a) Electric field lines point inward toward negative charges.
b) Electric field lines make circles around positive charges.
c) Electric field lines may cross.
d) Electric field lines point outward from positive charges.
e) A positive point charge released from rest will initially accelerate along the tangent to the electric field line at that point.

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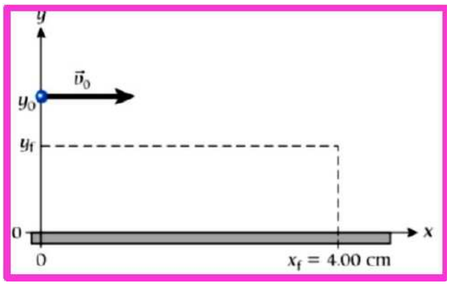
An electron with a kinetic energy of 2000.0 ev (1 ev = 1.602×10^{-19} J) is fired horizontally across a horizontally oriented charged conducting plate with surface charge density $+4.00 \times 10^{-6}$ C/m^2. Taking the positive direction to be upward (away from the plate), what is the vertical deflection of the electron after it has traveled a horizontal distance of 4.00 cm?



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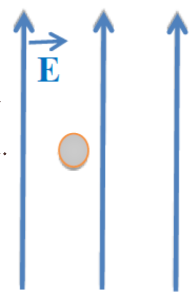
The adjacent figure shows a charged Pilsen marrow ball weighing 1.2 mN placed in a regular vertical electric field with a magnitude of 4.00 kN/C and balanced by the effect of wattage and weight.

- Calculate the amount of electric charge on the ball? And select their type?



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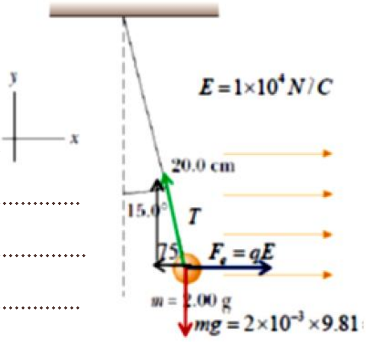
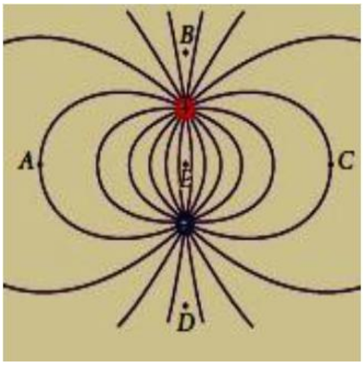
A small 2.0 g plastic ball was suspended inside a regular electric field by a 20 cm rope as shown in the adjacent figure.

- What is the ball charge?
- If the ball is in equilibrium when the thread is tilted at an angle of 15 ° with the vertical. Calculate the amount of charge collected on the ball**?**



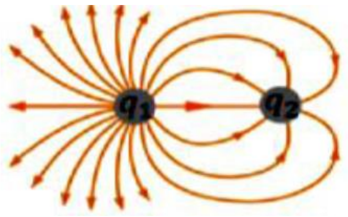
The figure shows a two-dimensional view of electric field lines due to two opposite charges.



- What is the direction of the electric field at the five points *A, B, C, D,* and *E*?

At which of the five points is the magnitude of the electric field the largest?

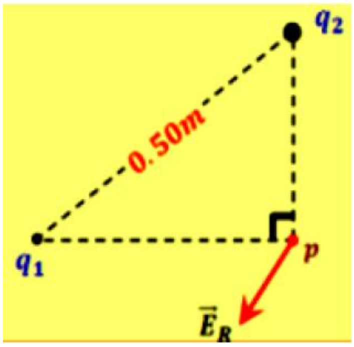
The adjacent figure shows the electric field lines around two adjacent point charges. Depending on the shape



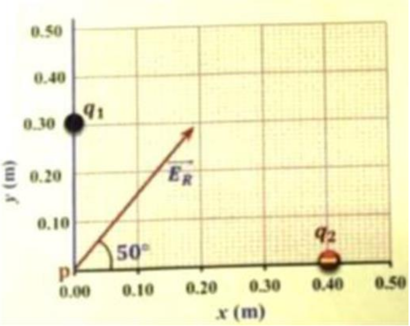
- What the kind of charge q_2
- Which charge is larger?

The adjacent figure shows the vector of the electric field strength obtained at the point (p) placed in the electric field by two-point charges. If the air surrounds the charges and the point, do the following:

- What is the type of both charges?
- Calculate the amount of electric field strength affecting on the charge q_2? if $|q_1|=3.0\ nC$



If we put the two dot charges (q_1, q_2) in the air on Axes coordinates as in the adjacent figure where E_R The sum of the field strength at point P (0,0 ,) If $q_2 = -8.0\ nC$
Calculate the quantity of charge q_1 and determine its type



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An electron is observed traveling at a speed of 27.5×10^6 m/s parallel to an electric field of magnitude 11,400 N/C.
How far will the electron travel before coming to a stop?

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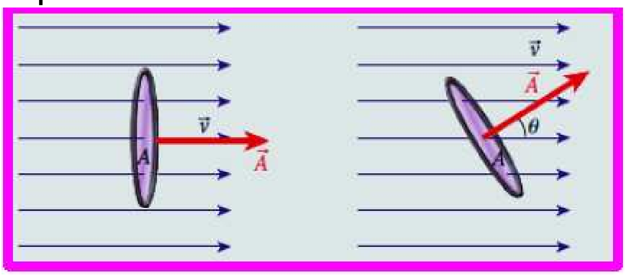
2.7 Electric Flux

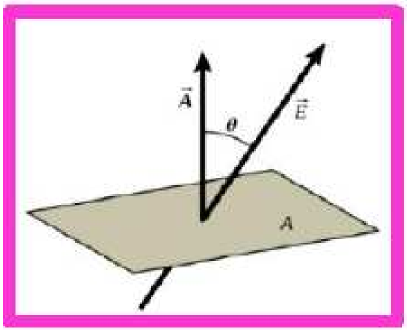
The number of electric field lines that cross a certain surface perpendicular to it **Or** the total number of electric field lines that passing throuh the unit area of this surface perpendicular to it (the electric flux is proportional to the number of electric field lines passing through the area.)

Or is the product of the field vector and the area vector



We can be calculated the Electric Flux by relationship

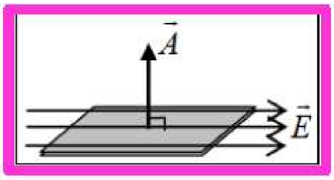
$$\emptyset = E.A = EAcos\theta$$



Electric Flux is scalar quantity

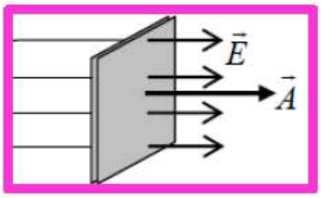
- If the field is parallel to the surface (θ = 90)

$$\emptyset = 0$$



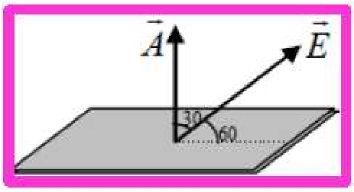
- If the field is perpendicular to the surface (θ = 0)

$$\emptyset = E.A$$



- If the angle between the field the surface for example (θ = 60)

$$\emptyset = E.A = EAcos30$$



Multiple-Choice Questions

1. A 3.5 C point charge sits in the center of a 1 m cube. What is the electric flux through one side of the cube?

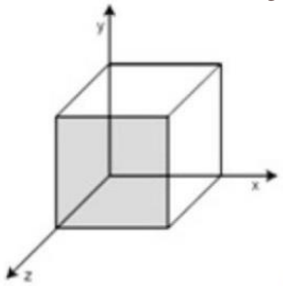
5.0×10^{10} Nm^2/C
3.3×10^{10} Nm^2/C
4.5×10^{10} Nm^2/C
6.6×10^{10} Nm^2/C
7.2×10^{10} Nm^2/C

2. A 3.5 C point charge sits in the center of a cube and the electric flux through one of the cube's sides is 6.6×10^{10} Nm^2/C. What is the length of one of the edges of the cube?

0.50 m
1.0 m
1.5 m
0.67 m
The size of the cube cannot be uniquely determined from the given information

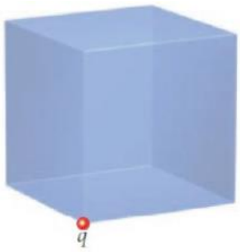
3. A cube with edge length of 50.00 cm is positioned as shown. There is an electric field throughout the region, given (in N/C) by $\mathbf{E} = 1.30\,\hat{x} + 4.70\,\hat{y} + 8.30\,\hat{z}$

But there is no charge within the cube. What is the magnitude of the total flux (in Nm^2/C) through the five nonshaded faces?



1.30
1.52
1.77
2.08

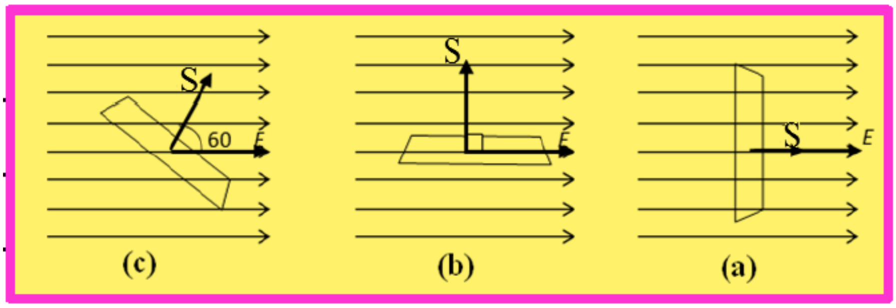
4. A single positive point charge (q) is at one corner of a cube with sides of length L, as shown in the figure. The net electric flux through the three adjacent sides is zero. The net electric flux through each of the other three sides is



$q/3\epsilon_0$
$q/6\epsilon_0$
$q/24\epsilon_0$
$q/8\epsilon_0$

Exercises

1. Electric field E, passing thrugh a flat surface of area S, as in figure, finds the electric field flow from the surface in cases a, b, c



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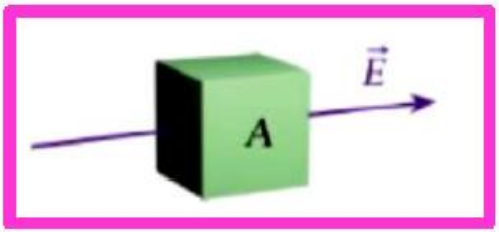
2. Figure shows a cube that has faces with area A in a uniform electric field, E, that is perpendicular to the plane of one face of the cube. What is the net electric flux passing though the cube?



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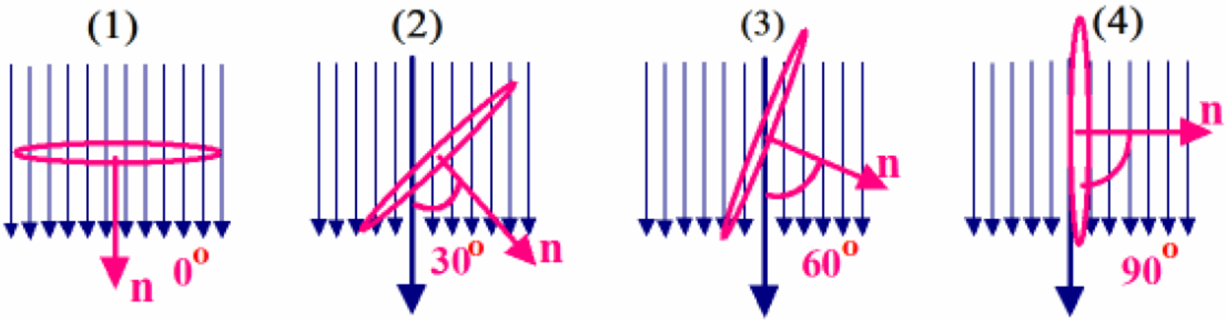
3. Calculate the electrical flux for each of the following forms, noting the electric field strength 60 N/C and the radius of the ring surface 20 cm?



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2.8 Gauss's Law

Calculation the electrical flux in the case of a closed and not open surface

If the surface area is closed, we use the: $\emptyset = \oiint \vec{E} \cdot d\vec{A}$

Unit of flux $\frac{N \cdot m^2}{C}$

❖ When an object with a closed surface (box) does not contain charges, the electrical flow is zero because the resultant field effect. On the test charge placed inside the body is equal zero

❖ When there is a charge inside the box (a closed surface) is called: Surface of Gauss

$$\emptyset = \frac{q}{\epsilon_0}$$

❖ There is another version of Gaussian law:

$$\emptyset = \oiint E.dA = \frac{q}{\epsilon_0}$$

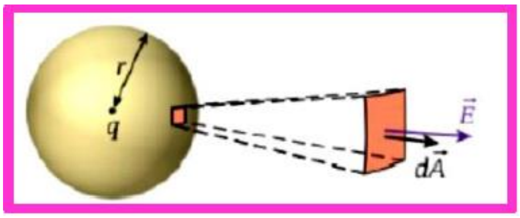
Gauss's Law and Coulomb's Law

Can Coulomb's Law be deduced by Gauss's Law?

Coulomb's law can be deduced by Gaussian law where we assume a point charge q surrounded by a Gaussian radius r.To calculate the electric field strength we use Gaussian law.

$$\phi_E = \oint \vec{E}.d\vec{SA} = \frac{qin}{\epsilon_0}$$

$$\phi_E = \oint EdA\cos\theta = \frac{qin}{\epsilon_0}$$



Since the field is regular, it comes out of integration

$$\phi = E\oint d\vec{A} = \frac{qin}{\epsilon_0}$$

$$\phi = E \times A = \frac{qin}{\epsilon_0}$$

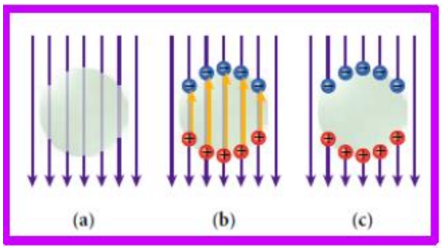
$$\phi = E \times (4\pi r^2) = \frac{qin}{\epsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

$$\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} \times 4\pi r^2 = \frac{qin}{\epsilon_0} = \phi$$

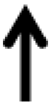
Shielding

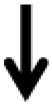
- The electrostatic field inside any isolated conductor is always zero
- Cavitie s inside conductors are shielded from electric fields
- When placing a conductor inside an electric field (Conductors contain free electrons) (a)
- Electrons move with the effect of the electric field, leaving behind positive ions (b)
- The electrons assembled at one end and the positive ions create a field within the conductor that eliminates the outer field (c)



Multiple-Choice Questions

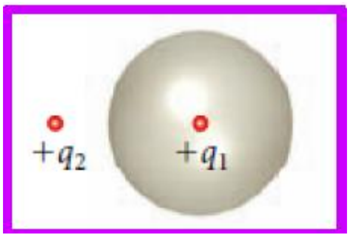
1. A hollow, conducting sphere is initially given an evenly distributed negative charge. A positive charge $+q$ is brought near the sphere and placed at rest as shown in the figure. What is the direction of the electric field inside the hollow sphere?





The force is zero

2. A hollow, conducting sphere is initially uncharged. A positive charge, $+q_1$, is placed inside the sphere, as shown in the figure. Then, a second positive charge, $+q_2$, is placed near the sphere but outside it. Which of the following statements describes the net electric force on each charge?



There is a net electric force on $+q_2$ but not on $+q_1$

There is a net electric force on $+q_1$ but not on $+q_2$

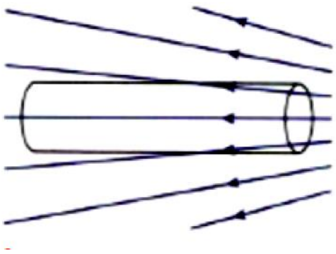
Both charges are acted on by a net electric force with the same magnitude and in the same direction

Both charges are acted on by a net electric force with the same magnitude but in opposite directions

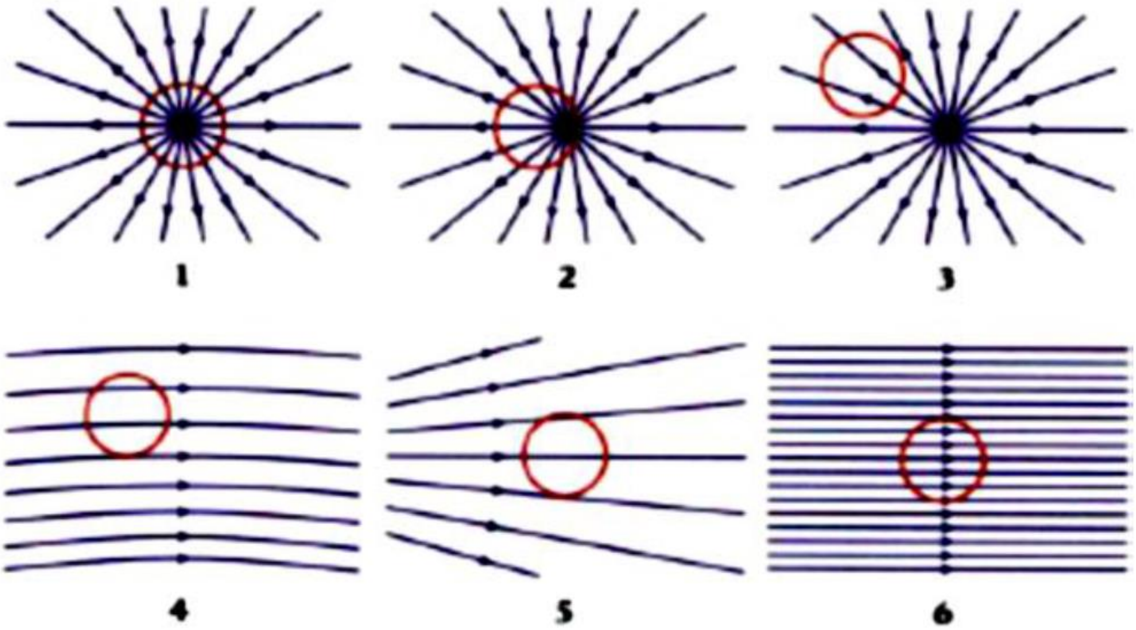
There is no net electric force on either charge

3. Cylinder made of insulating material is placed in electric field as shown in Figure. The result of the electric flux passing through the cylinder surface will be:

positive
negative
zero



4. The lines shown in the figure are the electric field lines and the Gaussian surface circle. What situations it is the total electrical flux is non-zero



1 4

2 5

3 6

5. Under what conditions do Faraday cages work best?

when grounded when made of graphite

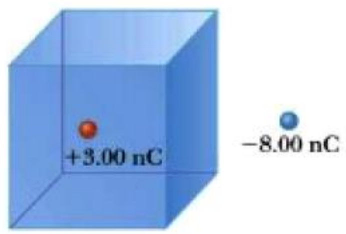
when they have very large holes

6. Which of the following is a good example of the Faraday cage

Closed metal ball A metal ball with large openings

Closed plastic ball Plastic ball with large holes

7. An electric charge $q_1 = 3.00\ nC$ is placed in the center of a metal cube conductor with a length of 1 m. A second electric charge $q_2 = -8.00\ nC$ was placed next to the lateral sur-face of the cube as shown in Figure. After 1 m, the electric power exchanged between the two charges is equal

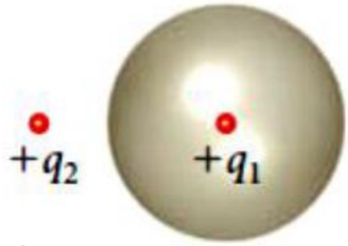


0.096 N - 0.096 N

0.192 N - 0.192 N

zero

8. A hollow, conducting sphere is initially uncharged. A positive charge, $+q_1$, is placed inside the sphere, as shown in the figure. Then, a second positive charge, $+q_2$, is placed near the sphere but outside it. Which of the following statements describes the net electric force on each charge?



There is a net electric force on $+q_2$ but not on $+q_1$.

There is a net electric force on $+q_1$but not on $+q_2$.

Both charges are acted on by a net electric force with the same magnitude and in the same direction.

Both charges are acted on by a net electric force with the same magnitude but in opposite directions.

There is no net electric force on either charge.

9. A point charge +Q is located on the X-axis at X=a, and a second point charge -Q is located on the X-axis at X=-a. A cubic Gaussian surface with sides l=3a is cantered at the origin.
The flux through this Gaussian surface is…….

Zero Greater than zero

Less than zero None are correct

10. Choose the **incorrect** statement:

Gauss' law can be derived from coulomb's law.

Gauss' law states that the net number of lines crossing any closed surface in an outward direction is proportional to the net charge enclosed within the surface.

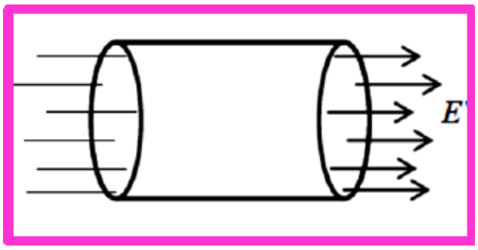
Coulomb's law can be derived from Gauss' law and symmetry.

Gauss' law applies to a closed surface of any shape.

According to Gauss' law, if a closed surface encloses no charge, then the electric field must vanish everywhere on the surface.

Exercises

1. Cylinder with a base radius of (0.1 m) and a height of (0.8m). Its axis is parallel to the positive (x) axis as in the figure affected by a uniform electric field of intensity (400 N / C). **Calculate the electrical flux** through the cylinder



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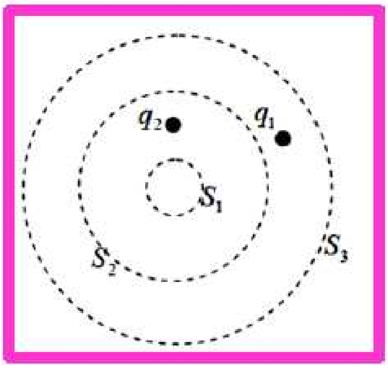
2. The adjacent figure shows two-point charges $q_1 = +4\mu C$ and $q_2 = -6\mu C$ and three closed surfaces S_1, S_2, S_3 **Find the electrical flux that traverses each surface**



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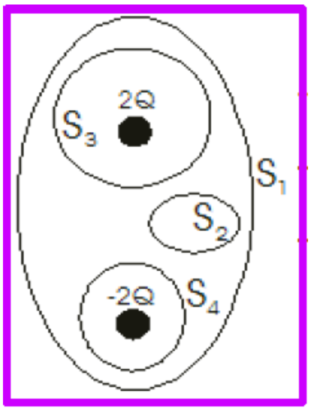
3. In the figure below calculate the total flow (Ø) of surfaces S_1, S_2, S_3, S_4



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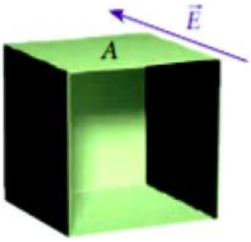
4. The figure shows a cube with faces of area *A* and one face missing. This five-sided cubical object is in a uniform electric field, *E*, perpendicular to one face.
What is the net electric flux passing through the object?



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5. Why is it a bad idea to stand under a tree in a thunderstorm? What should one do in-stead to avoid getting struck by lightning?

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6. Many people had been sitting in a car when it was struck by lightning. Why were they able to survive such an experience?

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7. In the cone the diameter of its base is 0.4 m and its height is 2 m vertically crossed on its base a uniform electric field of 5000 N / C as in the figure

- ❖ what amount The flux that passes only the conical surface?
- ❖ what that flux becomes when it becomes the horizontal field is towards +x?

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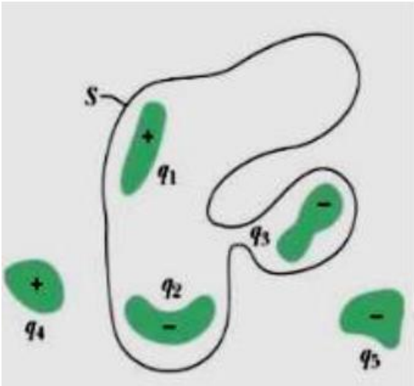
8. From the fig. If $q_1=q_4= 4.0\ \mu C$,$q_2=q_3=q_5= -2.0\ \mu C$

- ❖ what amount The flux that passes only the conical surface ?



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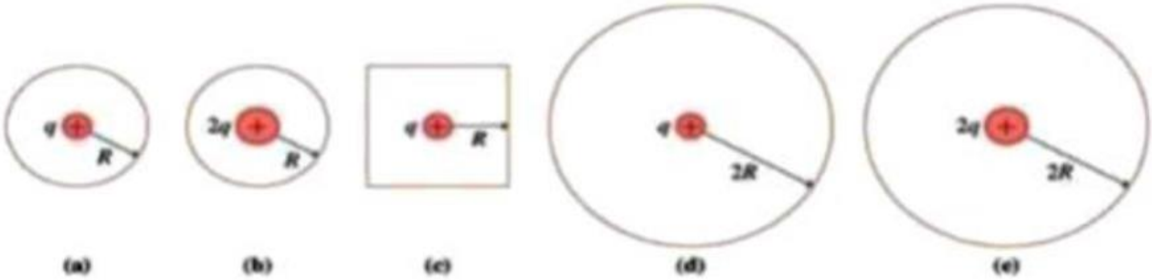
9. A charge Q is placed inside a closed cube along its side a.

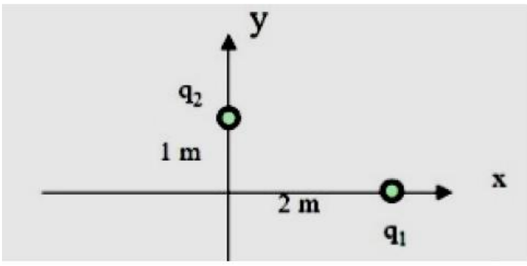
❖ calculated electric flux through one of its faces.



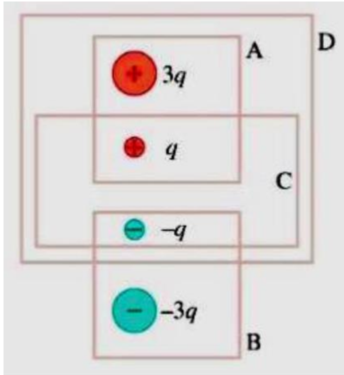
10. In the figure if it is $q_1 = 4.0\ nC$, $q_2 = -6.0\ nC$

❖ Find the flux through a centered cube at the origin and the length of its side takes values 0.75m, 1.5 m, 2.5 m.

❖ Repeat the issue if the shape is a sphere its center at the origin the radius has the same values.



11. Sort the surfaces according to the amount of flux from largest to lowest



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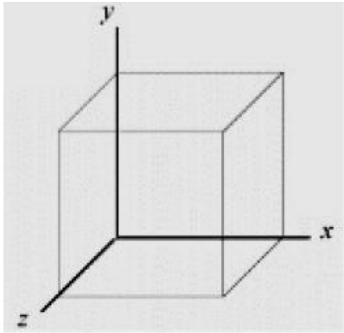
12. In the adjacent figure a cubic length 0.4 m traverses an electric field in the direction of the positive x-axis and its amount changes according to the equation:

❖ Find the electrical flux that passes the cube.



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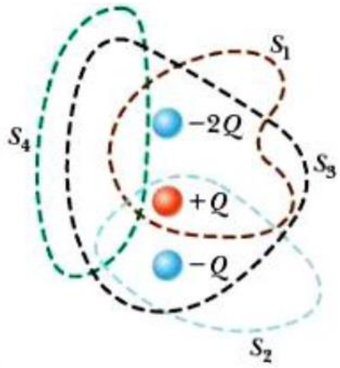
13. In the figure aside represent closed surfaces and electrical charges Calculate the electrical flux across each of the four closed surfaces?



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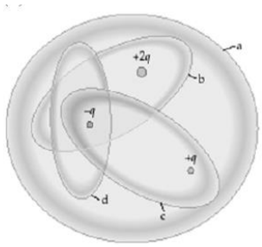
14. The figure shows four Gaussian surfaces surrounding a distribution of charges.

A) Which Gaussian surfaces have an electric flux of $+q/€_0$ through them?

B) Which Gaussian surfaces have no electric flux through them?



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2.9 Special Symmetries

Cylindrical Symmetry

To calculate the amount of electric field produced by a straight, long-term wire with a linear charge density λ $$dq = \lambda dl$$

- We place a Gaussian surface in the form of a cylinder that surrounds the wire of length L and radius r
- The electric field resulting from the wire is perpendicular to the wire
- If the wire rotates around an axis along its length, the shape of the wire remains the same (Circular symmetry)
- If the wire is too long, the shape of the wire remains constant and the electric field remains unchanged (Transitional symmetry)

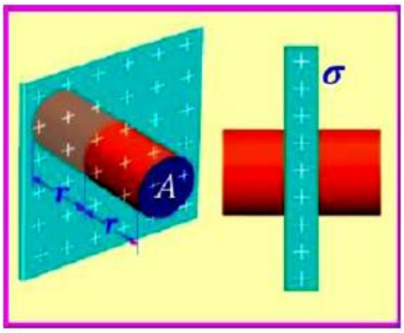
Planar Symmetry

To calculate the amount of electric field produced by a thin, non-conductive flat plate whose
area is infinite and carries a regulated charge Surface charge σ hence $dq = \sigma dA$

- We select a Gaussian surface in the form of a closed cylinder with an area of cross-section A and a length of 2r
- The electric field shall be perpendicular to both ends of the cylinder and parallel to its wall

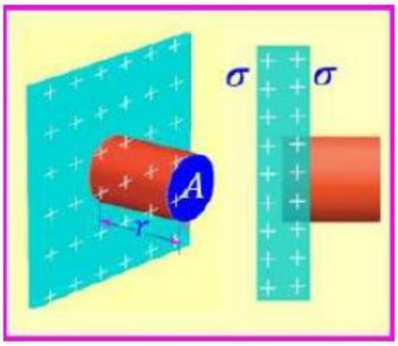
The electric field resulting from a flat, thin, non-conducting board Its area is infinite and carries a positive charge, and its charge per unit area is σ> 0

$$E = \frac{\sigma}{2\,\epsilon_0}$$



For an infinite conducting sheet with charge density $\sigma > 0$ on each surface, we can find the electric field by choosing a Gaussian surface in the form of a right cylinder

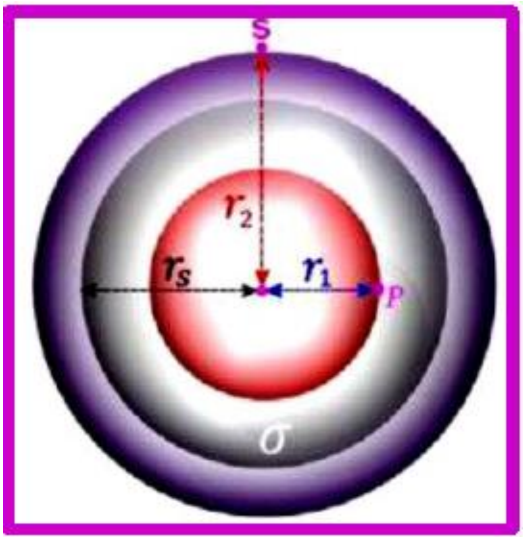
$$E = \frac{\sigma}{\epsilon_0}$$



Spherical Symmetry

The spherical surface is hollow:

To calculate the electric field strength resulting from a symmetrical distribution of charges on the surface of a hollow sphere radius (r_s)



1- Out of the charged body (greater than (r_s))

$$E = K\frac{q}{{r_2}^2}$$

2- Inside the charged body (less than (r_s))

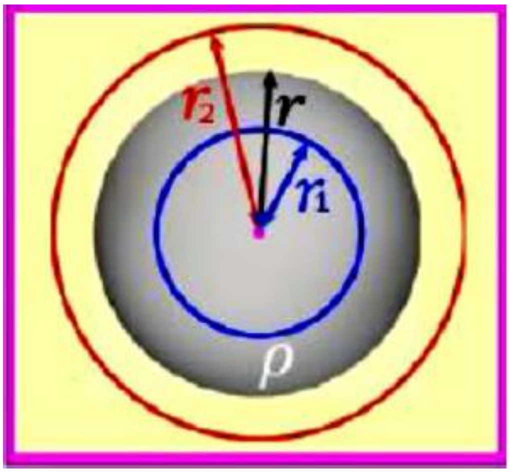
$$E = 0$$

3- On the charged body (r_s)

$$E = K\frac{q}{{r_s}^2}$$

The spherical surface is solid

Calculate the intensity of the electric field resulting from an even uniform distribution over the size of a solid sphere with a radius (r) and a volumetric density (ρ)



1- Out of the charged body (greater than (r))

$$E = K\frac{q}{{r_2}^2}$$

2- Inside the charged body (less than (r))

$$E = K\frac{q\,r_1}{r^3} \quad \text{Or} \quad E = K\frac{\rho\,r_1}{3\epsilon_0}$$

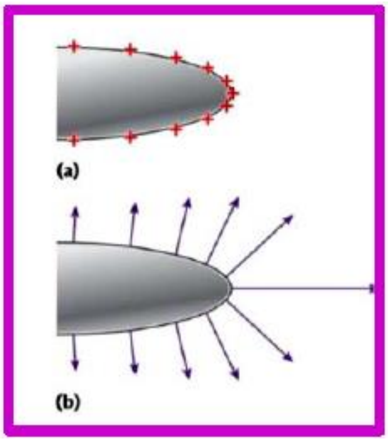
The field resulting from a point charge in the center of a thin sphere (Spherical structure) Made of conductive material:

1- Inside the cavity $(r_2 < r_1)$ $E_s = k\frac{q}{r_2^2}$

2- Inside the spherical structure $E = 0$

3- Outside the spherical structure $E_w = k\frac{q}{r^2}$

Sharp Points and Lightning rods



- ❖ The electric field is always perpendicular to any charged conductive surface (b)
- ❖ There is no component for the electric field parallel to the surface (There is no force or field along the surface of the conductor)
- ❖ Charges are distributed on the outer surface and concentrated at the pointed heads so that the field strength is as large as possible
- ❖ Field lines are convergent to each other at sharp points (b)

Lightning rod

- ❖ Lightning conductors are made of metal materials with sharp ends
- ❖ The sharp-edged lightning rod is heavily charged, creating a severe electric field
- ❖ The electric field ionizes air, allowing lightning to be discharged away from buildings

Multiple-Choice Questions

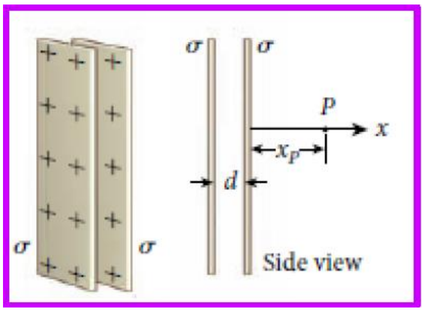
1. A total of 1.45×10^6 excess electrons are on an initially electrically neutral wire of length 1.13 m. What is the magnitude of the electric field at a point at a perpendicular distance of 0.401 m away from the center of wire? (*Hint:* Assume that 1.13 m is close enough to "infinitely long")

9.21×10^{-3} N/C 2.92×10^{-1} N/C

6.77×10^{1} N/C 8.12×10^{2} N/C

3.31×10^{3} N/C

2. Two infinite nonconducting plates are parallel to each other, with a distance $d = 10.0$ cm between them, as shown in the figure. Each plate carries a uniform charge distribution of $\sigma = 4.5\ \mu C/m^2$. What is the electric field, E, at point P (with $x_P = 20.0$ cm)?



- 0 N/C
- $2.54\ \hat{x}$ N/C
- $(-5.08 \times 10^5)\ \hat{x}$ N/C
- $(5.08 \times 10^5)\ \hat{x}$ N/C
- $(-1.02 \times 10^6)\ \hat{x}$ N/C
- $(1.02 \times 10^6)\ \hat{x}$ N/C

3. A solid sphere of diameter 20 cm has a nonuniform charge density $\rho = Ar^2$ where A= 0.600×10^{-14} C/m^5. Determine the total charge, Q, within the volume of the sphere.

- 1.5×10^{-19} C
- 2.4×10^{-19} C
- 3.6×10^{-19} C
- 4.0×10^{-19} C

4. A total charge of 6.3×10^{-8} C is distributed uniformly throughout a 2.7 cm radius sphere. The volume charge density is:

- 3.7×10^{-7} C/m^3
- 6.9×10^{-6} C/m^3
- 2.5×10^{-4} C/m^3
- 7.6×10^{-4} C/m^3

5. A spherical shell has an inner radius of 3.7 cm and an outer radius of 4.5 cm. If charge is distributed uniformly throughout the shell with a volume density of 6.1×10^{-4} C/m^3 the total charge is..........

- 1.0×10^{-7} C
- 1.3×10^{-7} C
- 2.0×10^{-7} C
- 2.3×10^{-7} C
- 4.0×10^{-7} C

6. A cylinder has a radius of 2.1 cm and a length of 8.8 cm. Total charge 6.1×10^{-7} C is distributed uniformly throughout. The volume charge density is.........

- 5.3×10^{-5} C/m^3
- 5.3×10^{-5} C/m^2
- 8.5×10^{-4} C/m^3
- 5.0×10^{-3} C/m^3
- 6.3×10^{-2} C/m^3

7. A point charge of 7.8 µC is located inside a hemisphere, which consists of two surfaces, a flat disk topped by half a sphere. If the electric flux through the half- sphere is 5.3×10^5 Nm^2/C, what is the flux through the flat disk section?

2.3×10^5 Nm^2/C 3.5×10^5 Nm^2/C

5.3×10^5 Nm^2/C 8.83×10^5 Nm^2/C

8. A point charge of -1.4 µC is located at the center of a right cylinder. If the electric flux through one of the circular and caps is -2.4×10^4 Nm^2/C, what is the flux through the cylindrical section between the end caps?

1.1×10^5 Nm^2/C -1.1×10^5 Nm^2/C

1.3×10^5 Nm^2/C -1.3×10^5 Nm^2/C

9. Inside a spherical surface is a 5.3×10^{-6} C a -2.2×10^{-6} C charge. What is the total electric flux through the surface of the sphere in the units of Nm^2/C?

3.4×10^{-16} 2.8×10^4

3.5×10^5 3.1×10^6

10. A point charge q is located at the center of a sphere of radius R. Also concentrically inside the sphere is a uniform ring having linear charge density ƛ and radius a (a<R). The flux through the sphere is

$q/€_0$ $(q + ƛ*2\pi a)/€_0$

0 $(q - ƛ*2\pi a)/€_0$

11. Cosider the earth to have a uniformly charged surface with density σ per unit area. What is the value of σ if objects near the surface carrying charg Q and having mass m, experience no net force?

$+€_0 mg/Q$ $-€_0 mg/Q$

$+2€_0 mg/Q$ $-2€_0 mg/Q$

Either A or B is correct, depending on the sign of Q

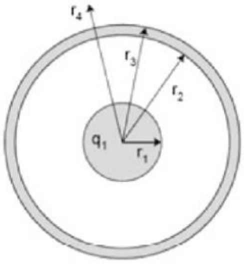
12. Two infinite, uniformly charged, flat surface are mutually perpendicular. One of the sheets has a charge density of +20.0 pc/m^2, and the other carries a charge density of -50.0 pc/m^2. What is the magnitude of the electric field at any point not on either surface?

2.75 N/C 2.82 N/C

3.04 N/C 3.37 N/C

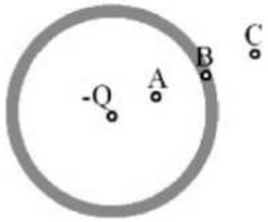
4.45 N/C

13. A conducting sphere of radius r_1= 0.180 m has a charge 9.00 µC on it. This sphere is placed within a conducting spherical shell of inner radius r_2= 0.410 m and outer radius r_3= 0.460 m outside the spherical shell at a distance r_4= 0.700 m the electric field is measured to be 1590 N/C pointing away from the center of the sphere. What is the amount of charge on the spherical shell (in µC)



-6.177
-7.888
-6.980
-8.913

14. A charge -Q is placed at the center of a conducting sphere. Which of the following statements concerning the electric field at A, B, and C is true?



It is outward at A and C and zero at B
It is inward at A and C and zero at B
It is inward at A, B, and C
It is inward at A and outward at B and C

Exercises

1. A 4.5 m-long wire holds charges that are regularly distributed the amount is 8 nC. Find the electric field at a point away vertically about the middle of the wire by 0.2 m (suppose the wire is infinite)

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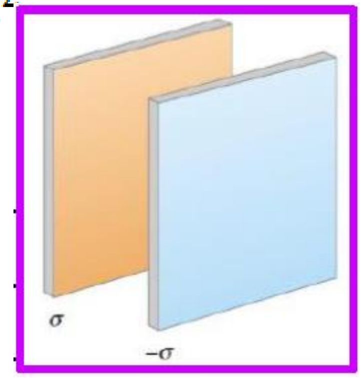
2. Two infinite thin parallel plates' nonconductors are a certain distance apart if the charge density Surface For the first plate is equal $\sigma_1 = 3\mu c/m^2$ and for the second plate is equal $\sigma_2 = -3\mu c/m^2$



Find

- ❖ The intensity of the electric field at the point between the plates
- ❖ The intensity of the electric field is at the point outside the plates and to the right of the negative charge plate

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3. Spherical conductor carrying an electric charge of +6μC and a radius of 20 cm

Find the electric field at:

- ❖ A point located on the Gaussian level, beyond the center of the spherical conductor 15cm
- ❖ A point located on the Gaussian level, away from the center of the spherical conductor 20cm
- ❖ A point located on the Gaussian level, away from the center of the spherical conductor 30cm

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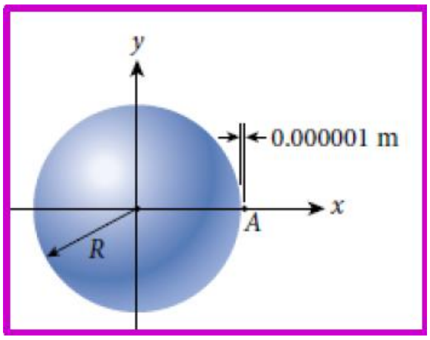
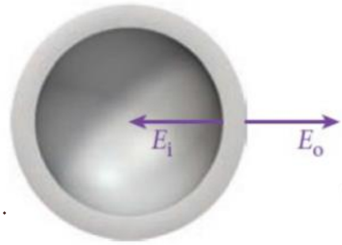
4. A conducting solid sphere ($R = 0.15$ m, $q = 6.1 \times 10^{-6}$ C) is shown in the figure. Using Gauss's Law and two different Gaussian surfaces, **determine the electric field** (magnitude and direction) at point A, which is 0.000001 m outside the conducting sphere. (Hint: One Gaussian surface is a sphere, and the other is a small right cylinder.)



5. A hollow conducting spherical shell has an inner radius of 8.00 cm and an outer radius of 10.0 cm. The electric field at the inner surface of the shell, E_i, has a magnitude of 80.0 N/C and points toward the center of the sphere, and the electric field at the outer surface E_0, has a magnitude of 80.0 N/C and points away from the center of the sphere (see the figure). Determine the magnitude of the charge on the inner surface and on the outer surface of the spherical shell.



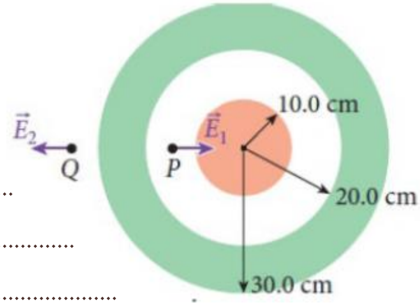
6. A hollow metal sphere has inner and outer radius of 20.0 cm and 30.0 cm, respectively. As shown in the figure, a solid metal sphere of radius 10.0 cm is located at the center oh the hollow sphere. The electric field at a point p, 15.0 cm from the center, is found to be $E_1 = 1.00 \times 10^4$ N/C, directed radially inward. At point Q, 35.0 cm from the center, the electric field is found to be $E_2 = 1.00 \times 10^4$ N/C, directed radially outward.

Determine the total charge on:

A - the surface of the inner sphere.

B - the inner surface of the hollow sphere.

C - the outer surface of the hollow sphere.



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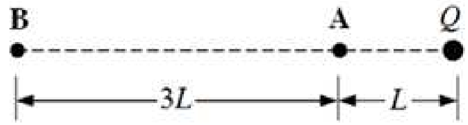
Additional Exercises

Multiple-Choice Questions

1. Which one of the following statements is true concerning the magnitude of the electric field at a point in space?
   - It is a measure of the total charge on the object.
   - It is a measure of the electric force on any charged object.
   - It is a measure of the ratio of the charge on an object to its mass.
   - It is a measure of the electric force per unit mass on a test charge.
   - It is a measure of the electric force per unit charge on a test charge.

2. In the figure, point **A** is a distance *L* away from a point charge *Q*. Point **B** is a distance 4*L* away from *Q*. What is the ratio of the electric field at **B** to that at **A**, E_B/E_A?

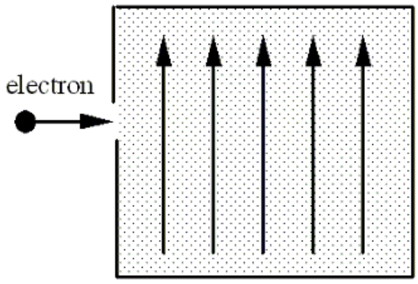


   - 1/16
   - 1/9
   - 1/4
   - 1/3
   - This cannot be determined since neither the value of *Q* nor the length *L* is specified.

3. At which point (or points) is the electric field zero N/C for the two point charges shown on the *x* axis?

   - The electric field is never zero in the vicinity of these charges.
   - The electric field is zero somewhere on the *x* axis to the left of the +4*q* charge.
   - The electric field is zero somewhere on the *x* axis to the right of the −2*q* charge.
   - The electric field is zero somewhere on the *x* axis between the two charges, but this point is nearer to the −2*q* charge.
   - The electric field is zero at two points along the *x* axis; one such point is to the right of the −2*q* charge and the other is to the left of the +4*q* charge.

4. An electron traveling horizontally enters a region where a uniform electric field is directed upward. What is the direction of the force exerted on the electron once it has entered the field?



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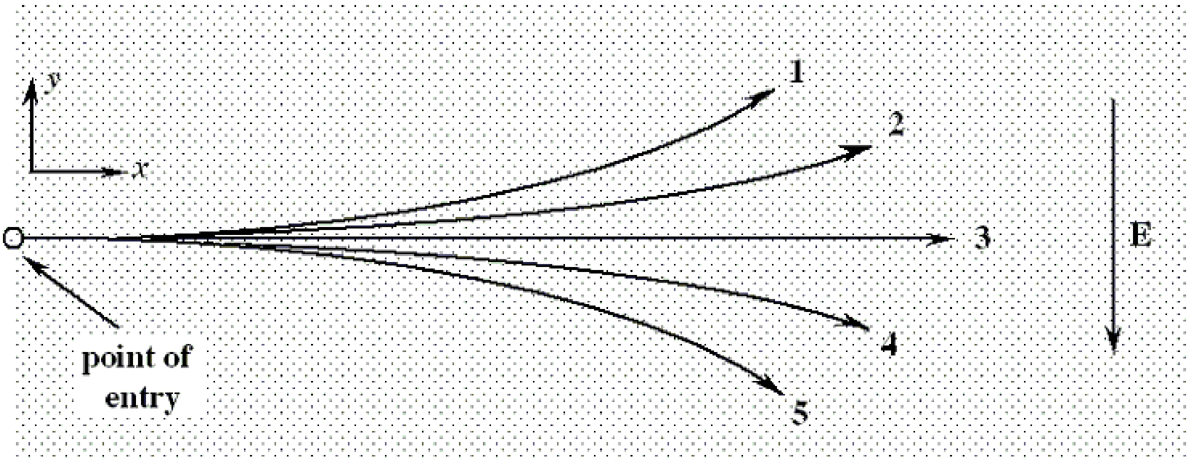
5. Which one of the following statements is true concerning the strength of the electric field between two oppositely charged parallel plates?

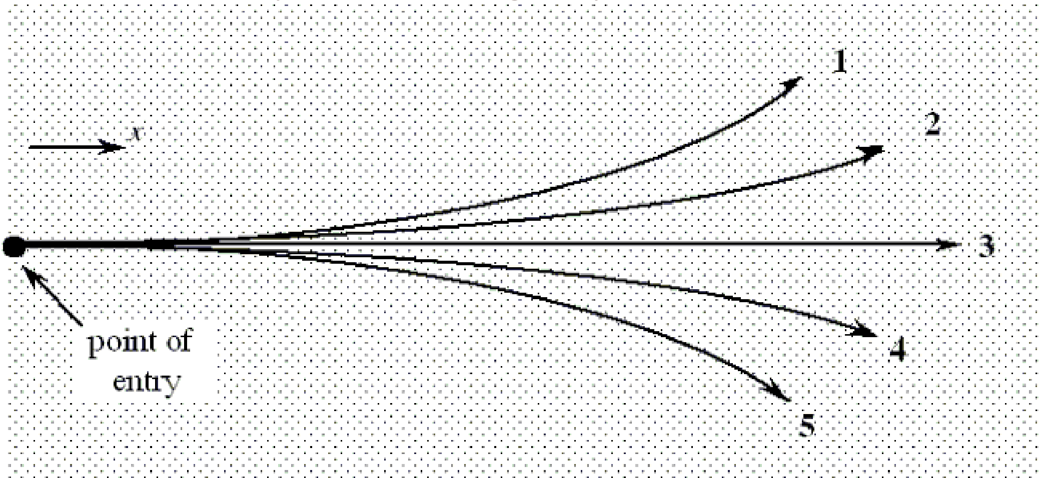
It is zero midway between the plates.
It is a maximum midway between the plates.
It is a maximum near the positively charged plate.
It is a maximum near the negatively charged plate.
It is constant between the plates except near the edges.

6. Two particles of the same mass carry charges +3*Q* and –2*Q*, respectively. They are shot into a region that contains a uniform electric field as shown. The particles have the same initial velocities in the positive *x* direction. The lines, numbered 1 through 5, indicate possible paths for the particles. If the electric field points in the negative *y* direction, what will be the resulting paths for these particles?



path **1** for +3*Q* and path **4** for –2*Q*
path **3** for +3*Q* and path **2** for –2*Q*
path **4** for +3*Q* and path **3** for –2*Q*
path **2** for +3Q and path **5** for –2Q
path **5** for +3Q and path **2** for –2Q

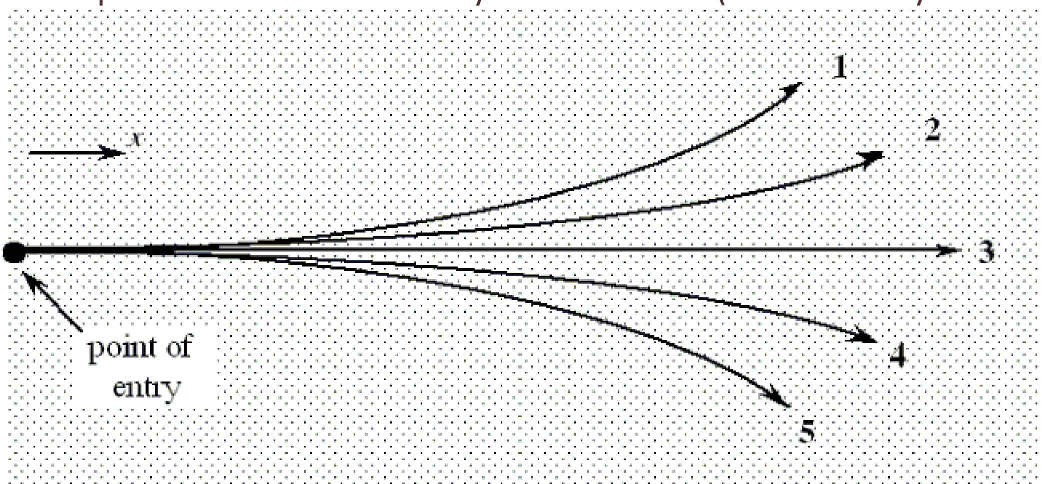
7. Five particles are shot from the left into a region that contains a uniform electric field. The numbered lines show the paths taken by the five particles. A negatively charged particle with a charge –3*Q* follows path **2** while it moves through this field. Do not consider any effects due to gravity.



In which direction does the electric field point?

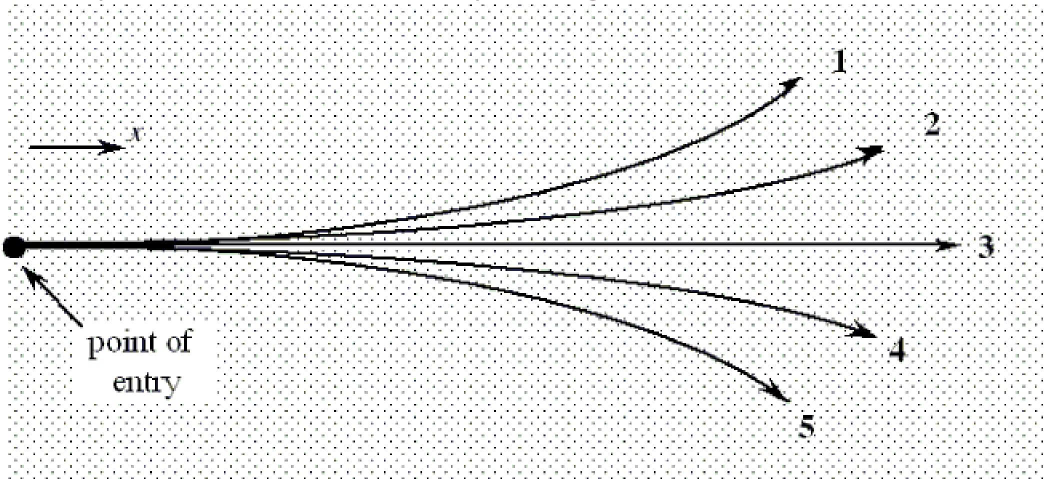
A) toward the top of the page
B) toward the left of the page
C) toward the right of the page
D) toward the bottom of the page
E) out of the page, toward the reader

8. Which path would be followed by a helium atom (an electrically neutral particle)?



path **1**
path **2**
path **3**
path **4**
path **5**

9. Which path would be followed by a charge +6*Q*?

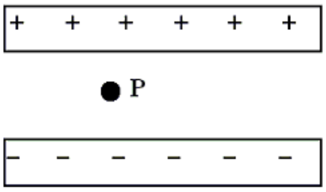


path **1**
path **2**
path **3**
path **4**
path **5**

10. What is the magnitude of the electric field due to a 6.0×10^{-9} C charge at a point located 0.025 m from the charge?

8.6×10^{2} N/C
1.2×10^{4} N/C
1.8×10^{5} N/C
3.6×10^{6} N/C
7.2×10^{7} N/C

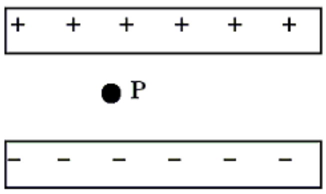
11. The figure shows a parallel plate capacitor. The surface charge density on each plate is 8.8×10^{-8} C/m^2. The point **P** is located 1.0×10^{-5} m away from the positive plate.



Which one of the following statements concerning the direction of the electric field between the plates is true?

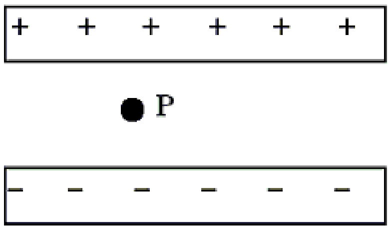
It points to the left.
It points to the right.
It points toward the negative plate.
It points toward the positive plate.
It points up out of the plane of the page.

12. What is the magnitude of the electric field at the point **P**?



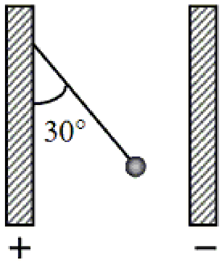
8.8 N/C
88 N/C
1.0×10^{2} N/ C
8.8×10^{2} N/C
9.9×10^{3} N/C

13. If a $+2.0 \times 10^{-5}$ C point charge is placed at **P**, what is the force exerted on it?



0.2 N, toward the negative plate
0.2 N, toward the positive plate
5×10^{4} N, toward the positive plate
5×10^{4} N, toward the negative plate
5×10^{4} N, into the plane of the page

14. A small sphere of mass 2.5×10^{-5} kg carries a total charge of 6.0×10^{-8} C. The sphere hangs from a silk thread between two large parallel conducting plates. The excess charge on each plate is equal in magnitude, but opposite in sign. If the thread makes an angle of 30° with the positive plate as shown, what is the magnitude of the charge density on each plate?

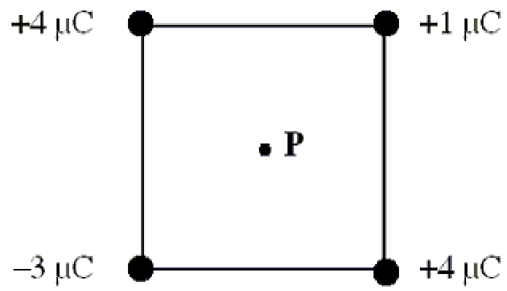


2.5×10^{-9} C/m^2
5.2×10^{-9} C/m^2
1.0×10^{-9} C/m^2
2.1×10^{-8} C/m^2
4.2×10^{-8} C/m^2

15. Complete the following statement: The magnitude of the electric field at a point in space does *not* depend upon

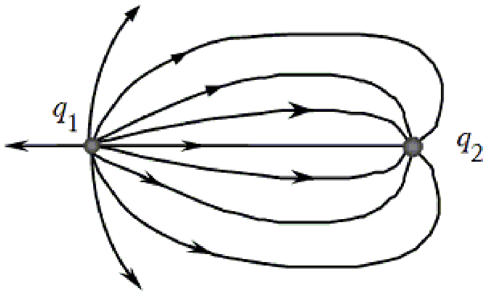
the distance from the charge causing the field.
the sign of the charge causing the field.
the magnitude of the charge causing the field.
the force that a unit positive charge will experience at that point.
the force that a unit negative charge will experience at that point.

16. Four point charges are placed at the corners of a square as shown in the figure. Each side of the square has length 2.0 m. Determine the magnitude of the electric field at the point **P**, the center of the square.



2.0×10^{-6} N/C
3.0×10^{-6} N/C
9.0×10^{3} N/C
1.8×10^{4} N/C
2.7×10^{4} N/C

17. The figure shows the electric field lines in the vicinity of two point charges. Which one of the following statements concerning this situation is true?



q_1 is negative and q_2 is positive.
The magnitude of the ratio (q_2/ q_1) is less than one.
Both $q_1$and q_2 have the same sign of charge.
The magnitude of the electric field is the same everywhere.
The electric field is strongest midway between the charges.

18. Which one of the following statements is true concerning the electrostatic charge on a conductor?

The charge is uniformly distributed throughout the volume.
The charge is confined to the surface and is uniformly distributed.
Most of the charge is on the outer surface, but it is not uniformly distributed.
The charge is entirely on the surface and it is distributed according to the shape of the object.
The charge is dispersed throughout the volume of the object and distributed according to the object's shape.

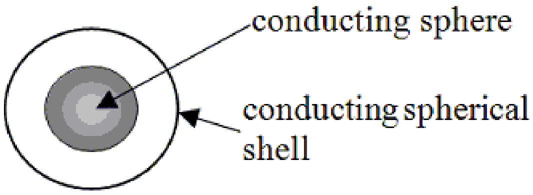
19. The magnitude of the electric field at a distance of two meters from a negative point charge is *E*. What is the magnitude of the electric field at the same location if the magnitude of the charge is doubled?

$E/4$
$E/2$
E
$2E$
$4E$

20. What is the magnitude and direction of the electric force on a –3.0 μC charge at a point where the electric field is 2800 N/C and is directed along the +*y* axis.

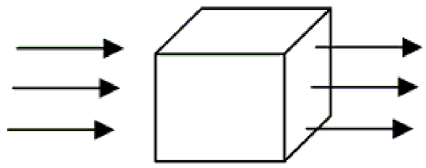
0.018 N, –*y* direction
0.012 N, +*y* direction
0.0084 N, –*y* direction
0.0056 N, +*y* direction
0.022 N, +*x* direction

21. A conducting sphere carries a net charge of +6 μC. The sphere is located at the center of a conducting spherical shell that carries a net charge of –2 μC. Determine the excess charge on the outer surface of the spherical shell.



–4 μC
+4 μC
–8 μC
+8 μC
+6 μC

22. A cubical Gaussian surface is placed in a uniform electric field as shown in the figure. The length of each edge of the cube is 1.0 m. The uniform electric field has a magnitude of 5.0×10^8 N/C and passes through the left and right sides of the cube perpendicular to the surface. What is the total electric flux that passes through the cubical Gaussian surface?



5.0×10^8 N×m²/C
3.0×10^9 N×m²/C
2.5×10^6 N×m²/C
1.5×10^7 N×m²/C
zero N×m²/C

23. What is the electric flux passing through a Gaussian surface that surrounds a +0.075 C point charge?

8.5×10^9 N×m²/C
6.8×10^8 N×m²/C
1.3×10^7 N×m²/C
4.9×10^6 N×m²/C
7.2×10^5 N×m²/C

24. A uniform electric field with a magnitude of 125 000 N/C passes through a rectangle with sides of 2.50 m and 5.00 m. The angle between the electric field vector and the vector normal to the rectangular plane is 65.0°. What is the electric flux through the rectangle?

1.56×10^6 N×m²/C
6.60×10^5 N×m²/C
1.42×10^5 N×m²/C
5.49×10^4 N×m²/C
4.23×10^4 N×m²/C

25. A straight, copper wire has a length of 0.50 m and an excess charge of -1.0×10^{-5} C distributed uniformly along its length. Find the magnitude of the electric field at a point located 7.5×10^{-3} m from the midpoint of the wire.

1.9×10^{10} N/C
1.5×10^{6} N/C
6.1×10^{13} N/C
7.3×10^{8} N/C
4.8×10^{7} N/C

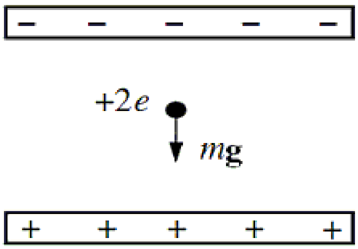
26. A total charge of -6.50 μC is uniformly distributed within a sphere that has a radius of 0.150 m. What is the magnitude and direction of the electric field at 0.300 m from the surface of the sphere?

2.89×10^{5} N/C, radially inward
6.49×10^{5} N/C, radially outward
4.69×10^{5} N/C, radially inward
9.38×10^{5} N/C, radially outward
1.30×10^{6} N/C, radially inward

27. A circular loop of wire with a diameter of 0.626 m is rotated in a uniform electric field to a position where the electric flux through the loop is a maximum. At this position, the electric flux is 7.50×10^{5} N×m^2/C. Determine the magnitude of the electric field.

8.88×10^{5} N/C
1.07×10^{6} N/C
2.44×10^{6} N/C
4.24×10^{6} N/C
6.00×10^{6} N/C

28. A helium nucleus is located between the plates of a parallel-plate capacitor as shown. The nucleus has a charge of +2e and a mass of 6.6×10^{-27} kg. What is the magnitude of the electric field such that the electric force exactly balances the weight of the helium nucleus so that it remains stationary?



4.0×10^{-7} N/C
6.6×10^{-26} N/C
2.0×10^{-7} N/C
5.0×10^{-3} N/C
1.4×10^{-8} N/C

29. Two identical conducting spheres carry charges of +5.0 mC and –1.0 mC, respectively. The centers of the spheres are initially separated by a distance *L*. The two spheres are brought together so that they are in contact. The spheres are then returned to their original separation *L*. What is the ratio of the magnitude of the electric force on either sphere *after* the spheres are touched to that *before* they were touched?

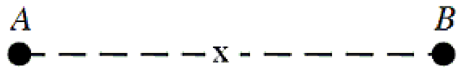
1/1
4/5
9/5
5/1
4/9

30. Two point charges, *A* and *B*, lie along a line separated by a distance *L*. The point **x** is the midpoint of their separation.

Which combination of charges would yield the greatest *repulsive* force between the charges?

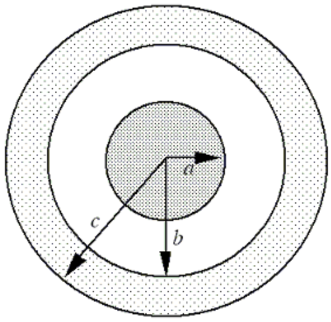
–2q and –4q
+1q and –3q
–1q and –4q
–2q and +4q
+1q and +7q

31. Which combination of charges will yield zero electric field at the point **x**?



+1q and –1q
+2q and –3q
+1q and –4q
–1q and +4q
+4q and +4q

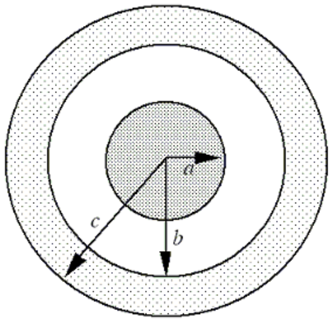
32. A solid, conducting sphere of radius *a* carries an excess charge of +6 μC. This sphere is located at the center of a hollow, conducting sphere with an inner radius of *b* and an outer radius of *c* as shown. The hollow sphere also carries a total excess charge of +6 μC.



Determine the excess charge on the *inner surface* of the outer sphere (a distance *b* from the center of the system).

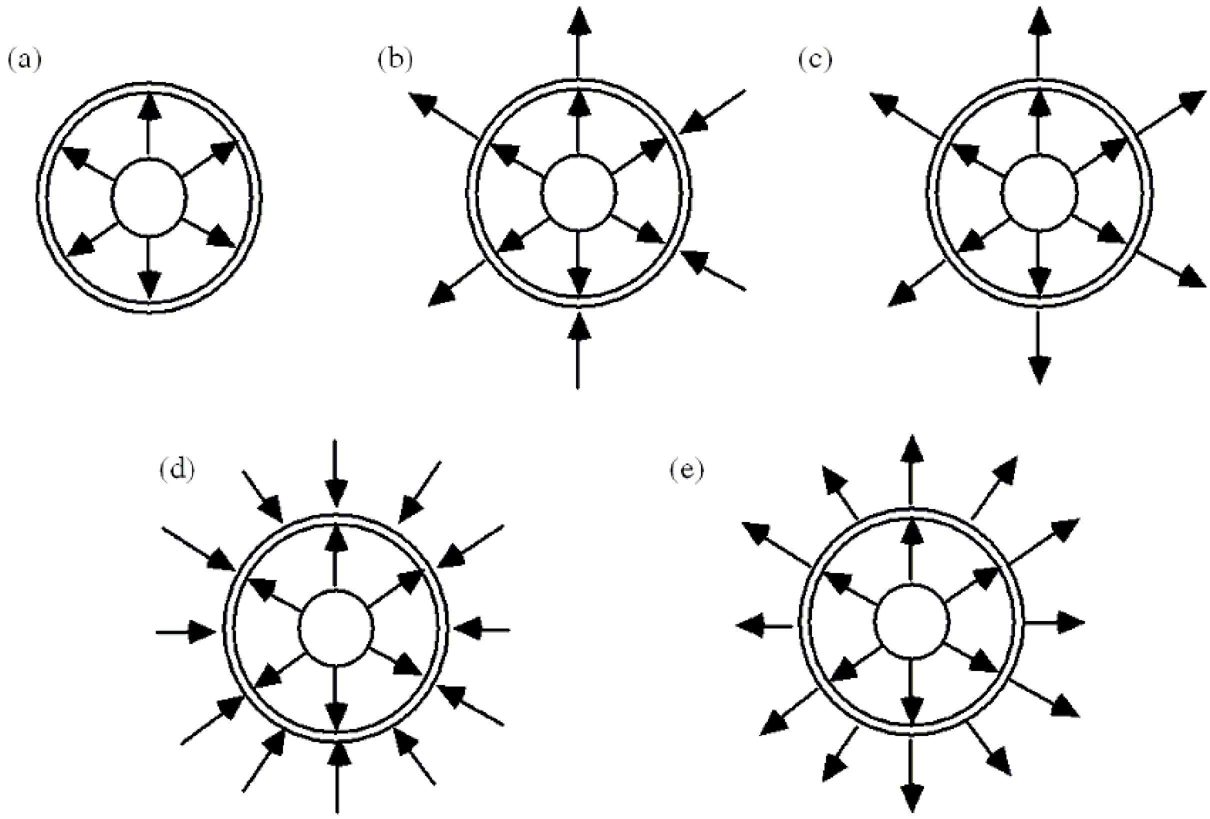
zero coulombs
–6 mC
+6 mC
+12 mC
–12 mC

33. Determine the excess charge on the *outer surface* of the outer sphere (a distance *c* from the center of the system).



zero coulombs
–6 mC
+6 mC
+12 mC
–12 mC

34. Which one of the following figures shows a qualitatively accurate sketch of the electric field lines in and around this system?



a
b
c
d
e

35. Which of the following is not a vector?
electric force
electric field
electric charge
electric line of force

36. At twice the distance from a point charge, the strength of the electric field

is four times its original value.
is twice its original value.
is one-half its original value.
is one-fourth its original value.

37. Is it possible to have a zero electric field value between a negative and positive charge along the line joining the two charges?

Yes, if the two charges are equal in magnitude.
Yes, regardless of the magnitude of the two charges.
No, a zero electric field cannot exist between the two charges.
cannot be determined without knowing the separation between the two charges

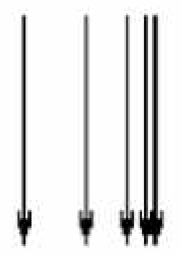
38. Is it possible to have a zero electric field value between two positive charges along the line joining the two charges?

Yes, if the two charges are equal in magnitude.
Yes, regardless of the magnitude of the two charges.
No, a zero electric field cannot exist between the two charges.
cannot be determined without knowing the separation between the two charges

39. Electric field lines near psitive point charges

circle clockwise.
circle counter-clockwise.
radiate inward.
radiate outward.

40. The electric field shown



increases to the right.
increases down.
decreases to the right.
decreases down.
is uniform.

41. Can electric field lines intersect in free space?

Yes, but only at the midpoint between two equal like charges.
Yes, but only at the midpoint between a positive and a negative charge.
Yes, but only at the centroid of an equilateral triangle with like charges at each corner.
No.

42. If a solid metal sphere and a hollow metal sphere of equal diameters are each given the same
charge, the electric field (E) midway between the center and the surface is

greater for the solid sphere than for the hollow sphere.
greater for the hollow sphere than for the solid sphere.
zero for both.
equal in magnitude for both, but one is opposite in direction from the other.

43. A solid block of metal in electrostatic equilibrium is placed in a uniform electric field. Give a statement concerning the electric field in the block's interior.

The interior field points in a direction opposite to the exterior field.
The interior field points in a direction that is at right angles to the exterior field.
The interior points in a direction that is parallel to the exterior field.
There is no electric field in the block's interior.

44. A cubic block of aluminum rests on a wooden table in a region where a uniform electric field is directed straight upward. What can be said concerning the charge on the block's top surface?

The top surface is charged positively
The top surface is charged negatively
The top surface is neutral
The top surface's charge cannot be determined without further information

45. If a conductor is in electrostatic equilibrium near an electric charge

the total charge on the conductor must be zero
the force between the conductor and the charge must be zero
the total electric field of the conductor must be zero
the electric field on the surface of the conductor is perpendicular to the surface

46. A positive point charge is enclosed in a hollow metallic sphere that is grounded. As compared to the case without the hollow sphere, the electric field at a point directly above the hollow sphere has

diminished to zero
diminished somewhat
increased somewhat
not changed

47. An atomic nucleus has a charge of +40e. What is the magnitude of the electric field at a distance of 1.0 m from the nucleus?

5.6×10^{-8} N/C
5.8×10^{-8} N/C
6.0×10^{-8} N/C
6.2×10^{-8} N/C

48. What are the magnitude and direction of the electric field at a distance of 1.50 m from a 50.0-nC charge?

20 N/C away from the charge
20 N/C toward the charge
200 N/C away from the charge
200 N/C toward the charge

49. A 5.0-C charge is 10 m from a small test charge. What is the magnitude of the electric field at the location of the test charge?

4.5×10^6 N/C
4.5×10^7 N/C
4.5×10^8 N/C
4.5×10^9 N/C

50. A 5.0-C charge is 10 m from a small test charge. What is the direction of the electric field?

toward the 5.0 C
away from the 5.0 C
perpendicular to a line joining the charges
none of the given answers

51. Two point charges each have a value of 3.0 C and are separated by a distance of 4.0 m. What is the electric field at a point midway between the two charges?

zero
9.0×10^7 N/C
18×10^7 N/C
4.5×10^7 N/C

52. A 5.0-mC charge is placed at the 0 cm mark of a meter stick and a -4.0 mC charge is placed at the 50 cm mark. What is the electric field at the 30 cm mark?

4.0×10^5 N/C
5.0×10^5 N/C
9.0×10^5 N/C
1.4×10^6 N/C

53. A 5.0-mC charge is placed at the 0 cm mark of a meter stick and a -4.0 mC charge is placed at the 50 cm mark. At what point on a line joining the two charges is the electric field zero?

1.4 m from the 0 cm mark
2.9 m from the 0 cm mark
3.3 m from the 0 cm mark
4.7 m from the 0 cm mark

54. Two point charges of +3.0 mC and -7.0 mC are placed at x = 0 and x = 0.20 m. What is the
magnitude of the electric field at the point midway between them?

1.8 ¸ 10^6 N/C | 3.6 ¸ 10^6 N/C
4.5 ¸ 10^6 N/C | 9.0 ¸ 10^6 N/C

55. Three 3.0 mC charges are at the three corners of an square of side 0.50 m. The last corner is occupied by a -3.0 mC charge. Find the electric field at the center of the square.

2.2 ¸ 10^5 N/C | 4.3 ¸ 10^5 N/C
6.1 ¸ 10^5 N/C | 9.3 ¸ 10^5 N/C

56. Consider a square which is 1.0 m on a side. Charges are placed at the corners of the square as follows: +4.0 mC at (0, 0); +4.0 mC at (1, 1); +3.0 mC at (1, 0); -3.0 mC at (0, 1). What is the magnitude of the electric field at the square's center?

1.1 ¸ 10^5 N/C | 1.3 ¸ 10^5 N/C
1.5 ¸ 10^5 N/C | 1.7 ¸ 10^5 N/C

57. A force of 10 N acts on a charge of 5.0 mC when it is placed in a uniform electric field. What is the magnitude of this electric field?

50 MN/C | 2.0 MN/C
0.50 MN/C | 1000 MN/C

58. A particle with a charge of 4.0 mC has a mass of 5.0 ¸ 10-3 kg. What electric field directed upward will exactly balance the weight of the particle?

4.1 ¸ 10^2 N/C | 8.2 ¸ 10^2 N/C
1.2 ¸ 10^4 N/C | 5.1 ¸ 10^6 N/C

59. A Styrofoam ball of mass 0.120 g is placed in an electric field of 6000 N/C pointing downward.
What charge must be placed on the ball for it to be suspended?

-16.0 nC | -57.2 nC
-125 nC | -196 nC

60. A foam ball of mass 0.150 g carries a charge of -2.00 nC. The ball is placed inside a uniform electric field, and is suspended against the force of gravity. What are the magnitude and direction of the electric field?

573 kN/C down | 573 kN/C up
735 kN/C down | 735 kN/C up

61. A metal sphere of radius 10 cm carries a charge of +2.0 mC. What is the magnitude of the electric field 5.0 cm from the sphere's surface?

4.0×10^5 N/C
8.0×10^5 N/C
4.0×10^7 N/C
8.0×10^7 N/C

62. A metal sphere of radius 2.0 cm carries a charge of 3.0 mC. What is the electric field 6.0 cm from the center of the sphere?

4.2×10^6 N/C
5.7×10^6 N/C
7.5×10^6 N/C
9.3×10^6 N/C

63. An electric field is most directly related to:

the momentum of a test charge
the kinetic energy of a test charge
the potential energy of a test charge
the force acting on a test charge
the charge carried by a test charge

64. As used in the definition of electric field, a "test charge":

has zero charge
has charge of magnitude 1C
has charge of magnitude 1.6×10^{-19} C
must be an electron
none of the above

65. Experimenter A uses a test charge q0 and experimenter B uses a test charge −2q0 to measure an electric field produced by stationary charges. A finds a field that is:

the same in both magnitude and direction as the field found by B
greater in magnitude than the field found by B
less in magnitude than the field found by B
opposite in direction to the field found by B
either greater or less than the field found by B, depending on the accelerations of the test charges

66. The units of the electric field are:

$N \cdot C^2$
C/N
N
N/C
C/m^2

67. The units of the electric field are:

J/(C·m)
J/C
J·C
J/m
none of these

68. Electric field lines:

are trajectories of a test charge
are vectors in the direction of the electric field
form closed loops
cross each other in the region between two-point charges
are none of the above

69. A certain physics textbook shows a region of space in which two electric field lines cross each other. We conclude that:

at least two-point charges are present
an electrical conductor is present
an insulator is present
the field points in two directions at the same place
the author made a mistake

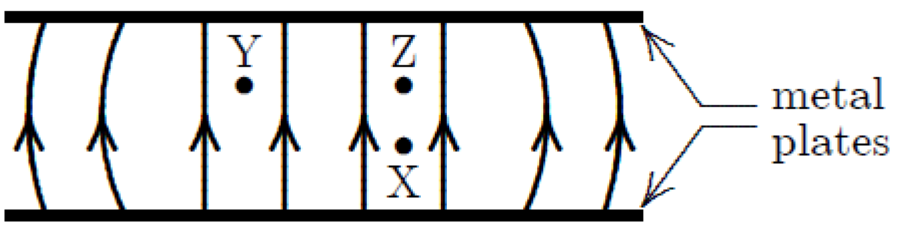
70. Two thin spherical shells, one with radius R and the other with radius 2R, surround an isolated charged point particle. The ratio of the number of field lines through the larger sphere to the number through the smaller is:

1
2
4
1/2
1/4

71. Choose the correct statement concerning electric field lines:

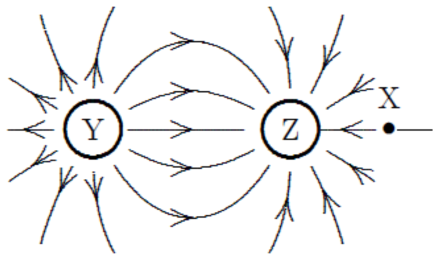
field lines may cross
field lines are close together where the field is large
field lines point away from a negatively charged particle
a charged point particle released from rest moves along a field line
none of these are correct

72. The diagram shows the electric field lines due to two charged parallel metal plates. We conclude that:



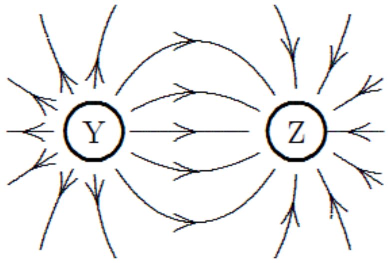
the upper plate is positive, and the lower plate is negative
a proton at X would experience the same force if it were placed at Y
a proton at X experiences a greater force than if it were placed at Z
a proton at X experiences less force than if it were placed at Z
an electron at X could have its weight balanced by the electrical force

73. The diagram shows the electric field lines in a region of space containing two small charged spheres (Y and Z). Then:



Y is negative and Z is positive
the magnitude of the electric field is the same everywhere
the electric field is strongest midway between Y and Z
the electric field is not zero anywhere (except infinitely far from the spheres)
Y and Z must have the same sign

74. The diagram shows the electric field lines in a region of space containing two small charged spheres (Y and Z). Then:



Y is negative and Z is positive
the magnitude of the electric field is the same everywhere
the electric field is strongest midway between Y and Z
Y is positive and Z is negative
Y and Z must have the same sign

75. Let k denote $1/4\pi\epsilon_0$ The magnitude of the electric field at a distance r from an isolated point particle with charge q is:

kq/r
kr/q
kq/r^3
kq/r^2
kq^2/r^2

76. The electric field at 10 cm from an isolated point particle with a charge of 2×10^{-9} C is:

1.8N/C
180N/C
18N/C
1800N/C
none of these

77. An isolated charged point particle produces an electric field with magnitude E at a point 2m away from the charge. A point at which the field magnitude is E/4 is:

1m away from the particle
0.5m away from the particle
2m away from the particle
4m away from the particle
8m away from the particle

78. An isolated charged point particle produces an electric field with magnitude E at a point 2m away. At a point 1m from the particle the magnitude of the field is:

E
2E
4E
E/2
E/4

79. Two-point particles, with a charges of q_1 and q_2, are placed a distance r apart. The electric field is zero at a point P between the particles on the line segment connecting them. We conclude that:

q_1 and q_2 must have the same magnitude and sign
P must be midway between the particles
q_1 and q_2 must have the same sign but may have different magnitudes
q_1 and q_2 must have equal magnitudes and opposite signs
q_1 and q_2 must have opposite signs and may have different magnitudes

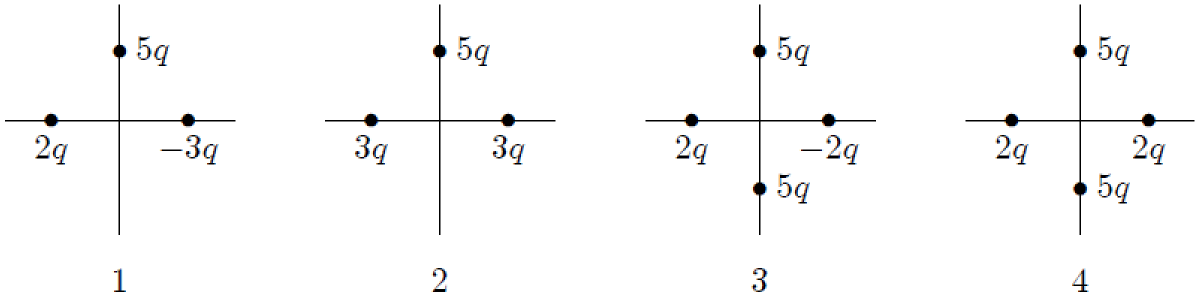
80. Two protons (p_1 and p_2) are on the x axis, as shown below. The directions of the electric field at points 1, 2, and 3, respectively, are:

$\rightarrow, \leftarrow, \rightarrow$
$\leftarrow, \rightarrow, \leftarrow$
$\leftarrow, \rightarrow, \rightarrow$
$\leftarrow, \leftarrow, \leftarrow$
$\leftarrow, \leftarrow, \rightarrow$

81. Two-point particles, one with charge $+8 \times 10^{-9}$ C and the other with charge -2×10^{-9} C, are separated by 4m. The electric field in N/C midway between them is:

9×10^{9}
13, 500
135, 000
36×10^{-9}
22.5

82. The diagrams below depict four different charge distributions. The charge particles are all the same distance from the origin. The electric field at the origin:



is greatest for situation 1
is greatest for situation 3
is zero for situation 4
is downward for situation 1
is downward for situation 3

83. The diagram shows a particle with positive charge Q and a particle with negative charge −Q. The electric field at point P on the perpendicular bisector of the line joining them is:

↑
→
zero
↓
←

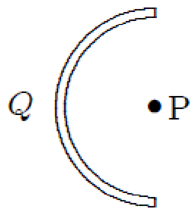
84. The diagram shows two identical particles, each with positive charge Q. The electric field at point P on the perpendicular bisector of the line joining them is:

↑
→
zero
↓
←

85. Two charged point particles are located at two vertices of an equilateral triangle and the electric field is zero at the third vertex. We conclude:

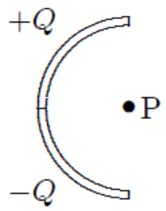
the two particles have charges with opposite signs and the same magnitude
the two particles have charges with opposite signs and different magnitudes
the two particles have identical charges
the two particles have charges with the same sign but different magnitudes
at least one other charged particle is present

86. Positive charge Q is uniformly distributed on a semicircular rod. What is the direction of the electric field at point P, the center of the semicircle?



↑ ↓
← →
non

87. Positive charge +Q is uniformly distributed on the upper half a semicircular rod and negative charge −Q is uniformly distributed on the lower half. What is the direction of the electric field at point P, the center of the semicircle?

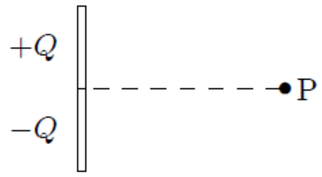


↑ ↓
← →
non

88. Two-point particles, with the same charge, are located at two vertices of an equilateral triangle. A third charged particle is placed so the electric field at the third vertex is zero. The third particle must:

be on the perpendicular bisector of the line joining the first two charges
be on the line joining the first two charges
have the same charge as the first two particles
have charge of the same magnitude as the first two charges but its charge may have a different sign
be at the center of the triangle

89. Positive charge +Q is uniformly distributed on the upper half a rod and negative charge −Q is uniformly distributed on the lower half. What is the direction of the electric field at point P, on the perpendicular bisector of the rod?



↑ ↓
← →
non

90. The electric field due to a uniform distribution of charge on a spherical shell is zero:

everywhere
nowhere
only at the center of the shell
only inside the shell
only outside the shell

91. The magnitude of the force of a 400-N/C electric field on a 0.02-C point charge is:

8.0N
8×10^{-5} N
8×10^{-3} N
0.08N
2×10^{11} N

92. An electron traveling north enters a region where the electric field is uniform and points north. The electron:

speeds up
slows down
veers east
veers west
continues with the same speed in the same direction

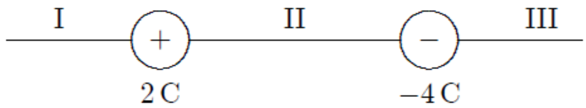
93. An electron traveling north enters a region where the electric field is uniform and points west. The electron:

speeds up
slows down
veers east
veers west
continues with the same speed in the same direction

94. A charged particle is placed in an electric field that varies with location. No force is exerted on this charge:

at locations where the electric field is zero
at locations where the electric field strength is $1/(1.6 \times 10^{-19})$N/C
if the particle is moving along a field line
if the particle is moving perpendicularly to a field line
if the field is caused by an equal amount of positive and negative charge

95. Two charged particles are arranged as shown. In which region could a third particle, with charge +1 C, be placed so that the net electrostatic force on it is zero?



I only
III only
II only
I and II only
I and III only

96. A 200-N/C electric field is in the positive x direction. The force on an electron in this field is:

200N in the positive x direction
200N in the negative x direction
3.2×10^{-17} N in the positive x direction
3.2×10^{-17} N in the negative x direction
0

97. An electric dipole consists of a particle with a charge of $+6\times10^{-6}$ C at the origin and a particle with a charge of -6×10^{-6} C on the x axis at $x = 3\times 10^{-3}$ m. Its dipole moment is:

1.8×10^{-8} C · m, in the positive x direction
1.8×10^{-8} C · m, in the negative x direction
0 because the net charge is 0
1.8×10^{-8} C · m, in the positive y direction
1.8×10^{-8} C · m, in the negative y direction

98. The force exerted by a uniform electric field on a dipole is:

parallel to the dipole moment
perpendicular to the dipole moment
parallel to the electric field
perpendicular to the electric field
none of the above

99. A charged oil drop with a mass of 2×10^{-4} kg is held suspended by a downward electric field of 300N/C. The charge on the drop is:

$+1.5 \times 10^{-6}$ C
$+6.5 \times 10^{-6}$ C
0
-1.5×10^{-6} C
-6.5×10^{-6} C