

Practice Questions: Topic 2– Electric Fields and Gauss's law

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$$E = \frac{F}{q}$$
 in $E = \frac{F}{q}$ $\rightarrow$ test
 & in $E = \frac{k|Q|}{r^2}$ $\rightarrow$ source

1. Which is a possible unit for electric field?

- A. Volt-meter
- B. Joule-coulomb
- C. Joule per coulomb
- D. Newton per coulomb

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

$$\frac{N}{C}$$
 test charge

2. Electric field lines always point from ____.

- A. positive charges to positive charges
- B. negative charges to negative charges
- C. positive charges to negative charges
- D. negative charges to positive charges

3. A positive charge of $3.0 \times 10^{-7} \text{ C}$ is located in an electric field of magnitude 27 N/C directed towards the south. What is the force acting on the charge?

- A. $3.0 \times 10^{-7} \text{ N}$
- B. $8.1 \times 10^{-6} \text{ N}$
- C. $1.2 \times 10^6 \text{ N}$
- D. $9.0 \times 10^7 \text{ N}$

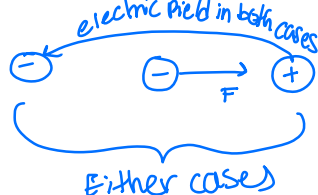
$q = 3 \times 10^{-7} \text{ C}$
 $E = 27 \text{ N/C}$
 $E = \frac{F}{q}$
 $F = E \cdot q$
 $= (27)(3 \times 10^{-7})$
 $= 8.1 \times 10^{-6} \text{ N}$

4. A negative charge of $1.5 \times 10^{-7} \text{ C}$ experiences a force of 0.030 N to the right in an electric field. What is the magnitude and direction of the field?

- A. $4.5 \times 10^{-7} \text{ N/C}$ to the right
- B. $2.0 \times 10^6 \text{ N/C}$ to the right
- C. $4.5 \times 10^{-7} \text{ N/C}$ to the left
- D. $2.0 \times 10^6 \text{ N/C}$ to the left

$q = 1.5 \times 10^{-7} \text{ C}$
 $F = 0.03 \text{ N}$
 $E = ?$
 $E = \frac{F}{q}$
 $= \frac{0.03}{1.5 \times 10^{-7}}$
 $= 200,000$
 $= 2 \times 10^5 \text{ N/C}$

electric field has same direction as force



5. The direction of the electric field is the direction of the ____.

- A. work done moving the test charge
- B. potential difference
- C. force on the positive test charge
- D. force on the negative test charge

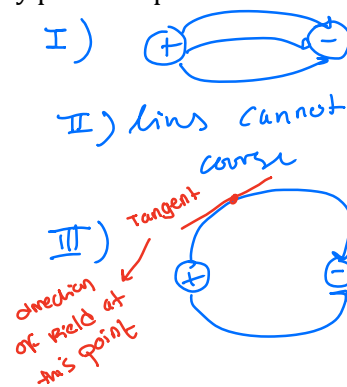
6. Why is an electric field measured only by a small test charge?

- A. so the charge doesn't disturb the field
- B. because small charges have small momentum
- C. so its size doesn't nudge the charge to be measured aside
- D. because an electron always is used as the test charge and electrons are small

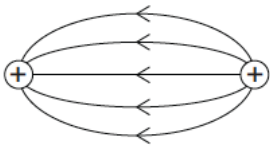
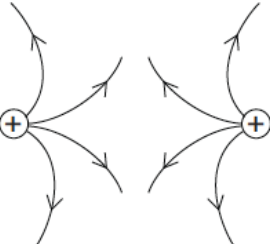
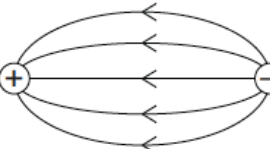
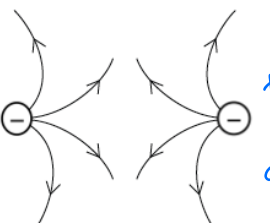
7. Which of the following statements is/are true regarding the electric field lines?

- I. They originate on positive charges and terminate on negative charges *true*
- II. Field lines never cross each other *true*
- III. The direction of electric field is tangent to the field line at any point in space

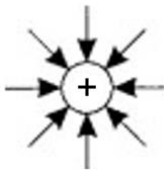
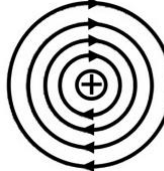
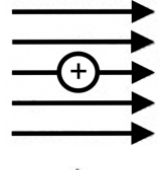
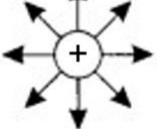
- A. I only
- B. II only
- C. III only
- D. I, II and III



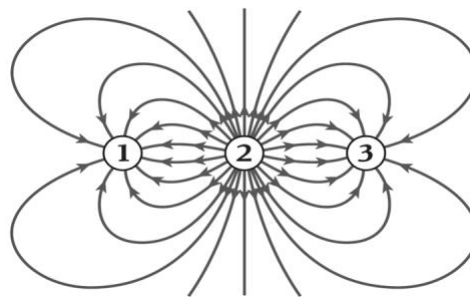
8. Which diagram represents the electric field lines between two small electrically charged spheres?

- A.  *They would repel*
- B. 
- C.  *It must go away from the positive charge*
- D.  *For negative charges, the arrows go in.*

9. Which of the following represents the electric field lines for a single positive charge?

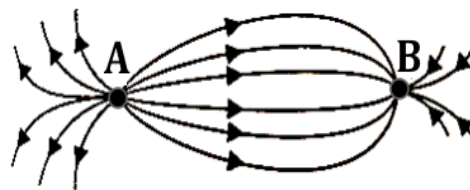
- A. 
- B. 
- C. 
- D. 

10. Which of the charges in the figure is/are positive?



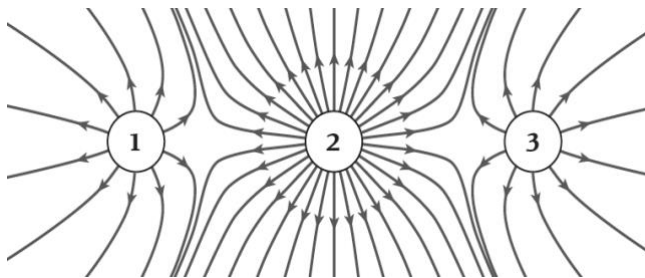
- A. 1
- B. 2
- C. 3
- D. 1 and 3

11. The spatial distribution of the electric field due to charges (A, B) is shown in the figure below. Which of the parameters regarding the charges are correct?



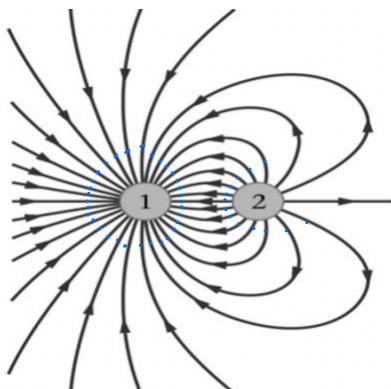
- | | Charge on A | Charge on B | Magnitude of charges |
|----|-------------|-------------|----------------------|
| A. | + | - | $A < B$ |
| B. | + | - | $A > B$ |
| C. | + | + | $A = B$ |
| D. | - | - | $A > B$ |

12. What are the signs of the charges in the configuration shown in the figure?



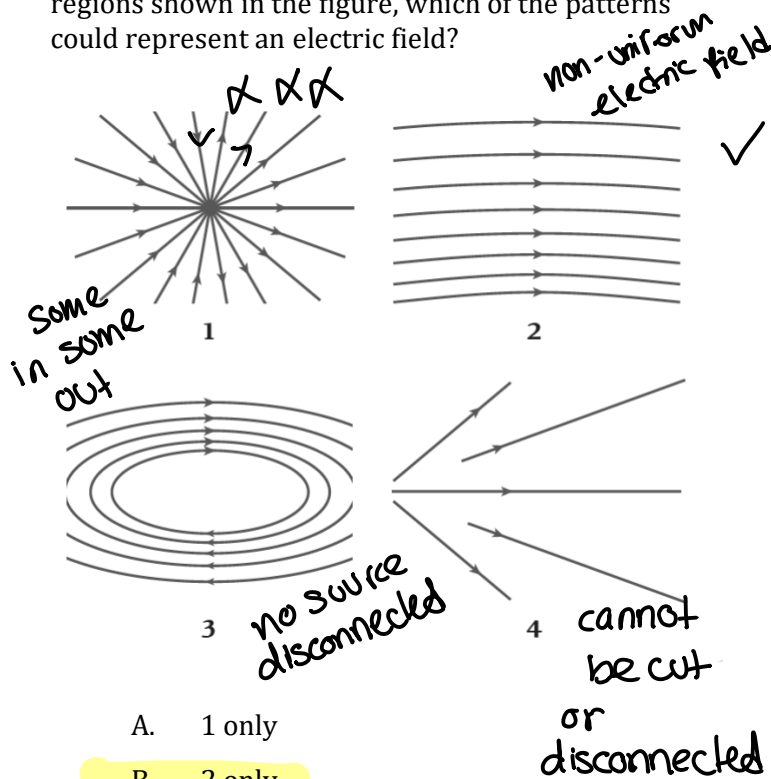
- A. Charges 1, 2, and 3 are negative
- B. Charges 1, 2, and 3 are positive
- C. Charges 1 and 3 are positive, and 2 is negative
- D. Charges 1 and 3 are negative, and 2 is positive

13. The electric field lines for a system of two charges is shown below. Which of the following could be the correct charges 1 and 2?



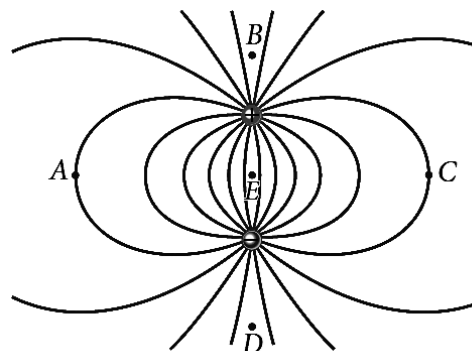
- A. $q_1 = +32 \mu C, q_2 = -16 \mu C$
- B. $q_1 = -32 \mu C, q_2 = +16 \mu C$
- C. $q_1 = -16 \mu C, q_2 = +32 \mu C$
- D. $q_1 = -16 \mu C, q_2 = -32 \mu C$

14. Assuming that there are no charges in the four regions shown in the figure, which of the patterns could represent an electric field?



- A. 1 only
- B. 2 only
- C. 2 and 3
- D. 1 and 4

15. The figure shows a two-dimensional view of electric field lines due to two opposite charges. At which of the five points is the magnitude of the electric field the largest?

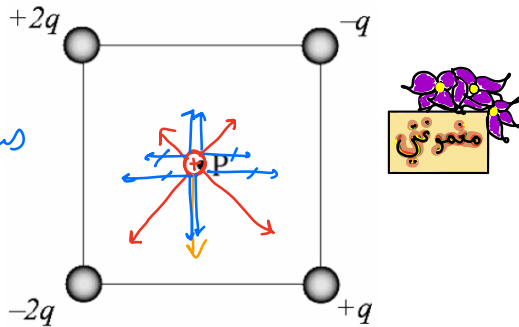


- A. A
- B. B
- C. C
- D. D
- E. E

lines are most dense with the greatest number of lines

16. Four charges are located on the corners of a square as shown in the drawing. What is the direction of the net electric field at the point labeled P?

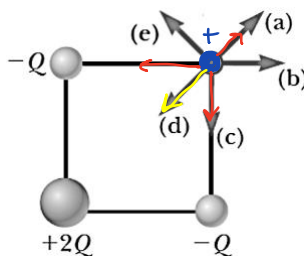
The electric field is directly proportional to the source charges
 $E = \frac{k|Q|}{r^2}$



- A. Toward the upper left corner of the square
- B. Toward the middle of the right side of the square
- C. Toward the middle of the bottom side of the square
- D. Toward the lower right corner of the square

17. Three charged particles are arranged on corners of a square as shown in the figure below. What is the direction of the electric field at the upper right corner, which is a point in empty space?

- A. a
- B. b
- C. c
- D. d
- E. e



18. At a distance d from a charge, the magnitude of the electric field is E . What would be the magnitude of the electric field a distance $d/2$ from the same charge?

- A. $E/4$
- B. $E/2$
- C. $2E$
- D. $4E$

@ distance = d , electric field = E

$$E \propto \frac{1}{r^2}$$

$$E = \frac{1}{(\frac{d}{2})^2}$$

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

$$E = \frac{4}{r^2} = 4\left(\frac{1}{r^2}\right)$$

19. A point charge $q = 4.00 \times 10^{-9} \text{ C}$ is placed on the x-axis at the origin. What is the electric field produce at $x = 40.0 \text{ cm}$?

- A. 108 N/C
- B. 157 N/C
- C. 201 N/C
- D. 225 N/C

$Q = 4 \times 10^{-9} \text{ C}$ at $x = 0$
 $E @ x = 0.4 \text{ m} ?$

$$E = \frac{kQ}{r^2} = 225 \text{ N/C}$$

20. A point charge is placed on the x-axis at the origin. The electric field produce at $x = 40.0 \text{ cm}$ is 157 N/C . What is the point charge?

- A. $1.20 \times 10^{-9} \text{ C}$
- B. $2.80 \times 10^{-9} \text{ C}$
- C. $3.40 \times 10^{-9} \text{ C}$
- D. $4.00 \times 10^{-9} \text{ C}$

$Q = ?$

$r = 0.4 \text{ m}$

$E = 157 \text{ N/C}$

$$E = \frac{kQ}{r^2} \rightarrow Q = \frac{Er^2}{k} = 2.8 \times 10^{-9}$$

21. A $4.00 \times 10^{-9} \text{ C}$ point charge is placed at the origin. Where on the x-axis is the electric field produced by the point charge 157 N/C ?

- A. 22 cm
- B. 28 cm
- C. 40 cm
- D. 48 cm

$Q = 4 \times 10^{-9} \text{ C}$

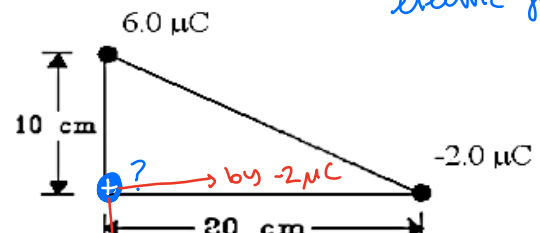
$E = 157 \text{ N/C}$

$r = ?$

$$E = \frac{kQ}{r^2} \rightarrow r = \sqrt{\frac{kQ}{E}} \approx 0.48 \text{ m}$$

22. Two point charges are placed on two of the corners of a triangle as shown. Find the magnitude of the electric field at the third corner of the triangle.

superposition of electric fields



- A. $3.9 \times 10^6 \text{ N/C}$
- B. $4.5 \times 10^6 \text{ N/C}$
- C. $5.4 \times 10^6 \text{ N/C}$
- D. $6.7 \times 10^6 \text{ N/C}$

$$\textcircled{1} E = \frac{kQ}{r^2} = \frac{(8.99 \times 10^9)(6 \times 10^{-6})}{0.1^2} \approx 5.4 \times 10^6 \text{ N/C down}$$

$$\textcircled{2} E = \frac{kQ}{r^2} = \frac{(8.99 \times 10^9)(2 \times 10^{-6})}{0.2^2} \approx 4.5 \times 10^5 \text{ N/C right}$$

$$\textcircled{3} E = \sqrt{E_x^2 + E_y^2} = \sqrt{(5.4 \times 10^6)^2 + (4.5 \times 10^5)^2} \approx 5.4 \times 10^6 \text{ N/C}$$

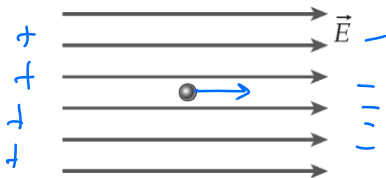
uniform electric field $\rightarrow$ parallel lines equally spaced

field uniform $\rightarrow$ force uniform $\rightarrow$ acceleration uniform/constant

23. A $+5.0\text{ C}$ charge is located at the origin. A -13.0 C charge is placed at $x = 1.0\text{ m}$. At what finite location(s) on the x axis will the electric field be equal to zero?

- A. in between the particles, closer to the positive particle
- B. in between the particles, closer to the negative particle
- C. not in between, but closer to the positive particle
- D. not in between, but closer to the negative particle

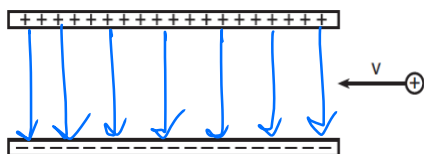
24. A small positively charged object is placed at rest in a uniform electric field as shown in the figure. When the object is released, it will ____.



- A. Not move
- B. Begin to move with a constant speed
- C. Begin to move with constant acceleration
- D. Begin to move with an increasing acceleration

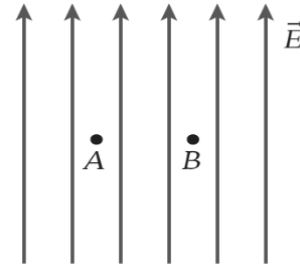
uniform field
= uniform force
= uniform acceleration

25. The diagram below represents a positively charged particle about to enter the electric field between two oppositely charged parallel plates. The electric field will deflect the particle ____



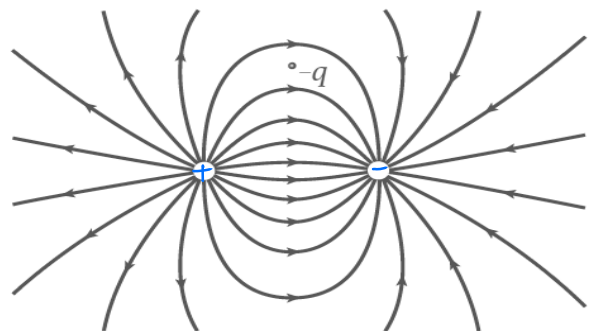
- A. into the page
- B. out of the page
- C. toward the top of the page
- D. toward the bottom of the page

26. 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?



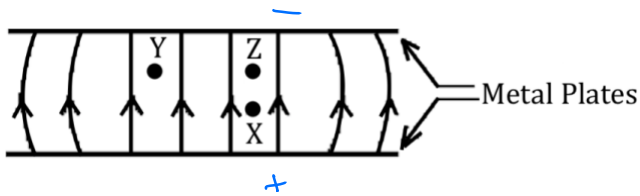
- A. The magnitude of the electric force on the object is greater at position A
- B. The magnitude of the electric force on the object is greater at position B
- C. There is no electric force on the object at either position A or position B
- D. The electric force on the object at position A is the same nonzero electric force as that on the object at position B

27. 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?



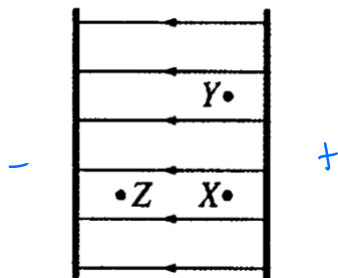
- A. $\rightarrow$
- B. $\uparrow$
- C. $\leftarrow$
- D. $\downarrow$

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



- A. the upper plate is positive and the lower plate is negative
- B. a proton at X would experience the same force if it were placed at Y
- C. a proton at X experiences a greater force than if it were placed at Z
- D. a proton at X experiences less force than if it were placed at Z

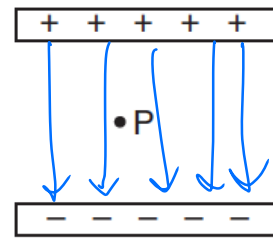
29. The diagram below shows the electric field lines due to two charged metal plates. X, Y and Z are locations where charges may be placed. Which of the following is true?



- A. The left plate is positive and the right plate is negative
- B. A negative charge at X experiences a greater force than if it were placed at Y
- C. A positive charge at X experiences less force than if it were placed at Y
- D. A positive charge at X would experience the same force if it were placed at Z

for electrons, force is opposite to $\vec{v} \times \vec{B}$.

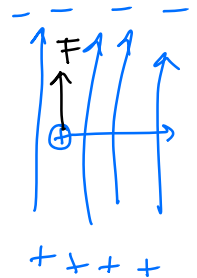
30. In the diagram below, point P is located in the electric field between two oppositely charged parallel plates.



Compared to the magnitude and direction of the electrostatic force on an electron placed at point P , the electrostatic force on a proton placed at point P has ____.

- A. the same magnitude and the same direction
- B. the same magnitude, but the opposite direction
- C. a greater magnitude, but the same direction
- D. a greater magnitude and the opposite direction

31. A proton moving along the positive x-axis enters an electric field that is directed along the positive y-axis. What is the direction of the electric force acting on the proton after it enters the electric field?



- A. Along the negative z-axis
- B. Along the positive z-axis
- C. Along the negative y-axis
- D. Along the positive y-axis

32. A charge is placed at the center of a cube. What is the flux of the electric field through one face of the cube?

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

$$\phi = \frac{9}{2.6}$$

- B. $q/6\epsilon_0$

cube
has 87x
faces

Total flux on enclosed shape = 0
when no. of lines entering = no. of lines exiting.

Questions 33 and 34

A flat surface of area 3.20 m^2 is rotated in a uniform electric field of magnitude $E = 6.20 \times 10^2 \text{ N/C}$.

electric flux
for a flat surface

33. Determine the electric flux through this area when the electric field is perpendicular to the surface.

$$\Phi = EA \cdot \cos \theta$$

A. $0 \text{ Nm}^2/\text{C}$

B. $6.19 \times 10^5 \text{ Nm}^2/\text{C}$

C. $1.40 \times 10^6 \text{ Nm}^2/\text{C}$

D. $1.98 \times 10^6 \text{ Nm}^2/\text{C}$

$$= 620 \times 3.2 \times \cos(0)$$

$$= 1984 \text{ Nm}^2/\text{C}$$

$$1.984 \times 10^3$$

34. Determine the electric flux through this area when the electric field is parallel to the surface.

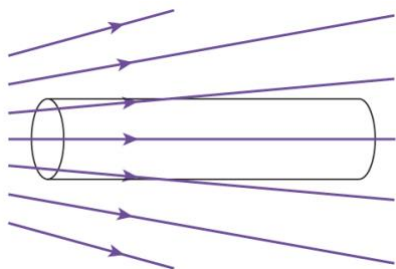
A. $0 \text{ Nm}^2/\text{C}$

B. $6.19 \times 10^5 \text{ Nm}^2/\text{C}$

C. $1.40 \times 10^6 \text{ Nm}^2/\text{C}$

D. $1.98 \times 10^6 \text{ Nm}^2/\text{C}$

35. A cylinder made of an insulating material is placed in an electric field as shown in the figure. The net electric flux passing through the surface of the cylinder is ____.



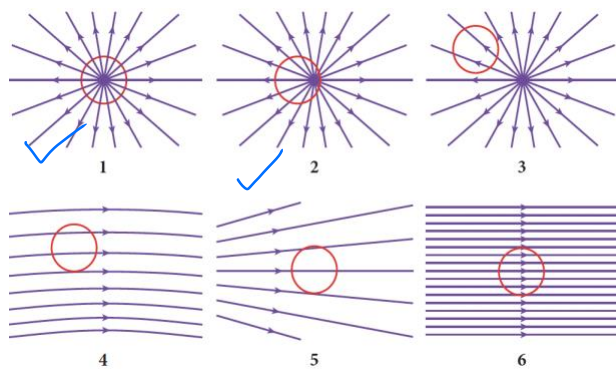
A. Positive

B. Negative

C. zero

lines entering: negative flux
lines exiting: flux positive.

36. The lines in the figure are electric field lines, and the circle is a Gaussian surface.



For which case(s) is (are) the total electric flux nonzero?

A. 1 only

B. 1 and 2

C. 2 and 3

D. 4, 5 and 6

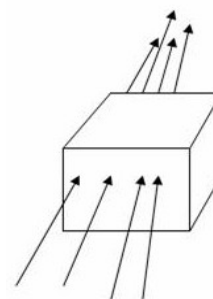
37. A cubical closed surface has N inward electric flux lines passing through one face and N outward electric flux lines passing through the opposite face as shown in the figure below. The flux lines exhibit convergence and there are no flux lines passing through any other face. If the magnitude of the electric field at the center of the cube is E , the total charge inside the cube is ____.

A. zero

B. $\epsilon_0 N$

C. $-\epsilon_0 N$

D. $2\epsilon_0 N$



38. A charge Q is enclosed by a Gaussian spherical surface of radius R . If the radius is doubled, the outward electric flux will ____.

A. reduce to half

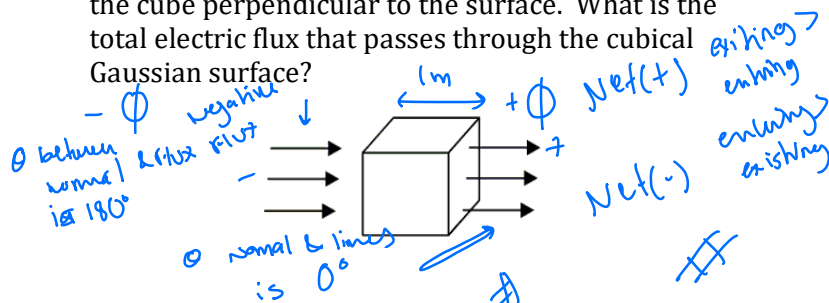
B. be doubled

C. increase four times

D. remain the same

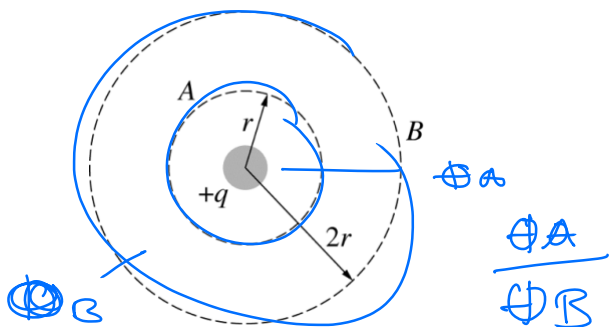
charge: Q
Radius: R
size doesn't change
flux
 $\Phi = \frac{q_{in}}{\epsilon_0}$

39. 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?



- A. $3.0 \times 10^9 \text{ Nm}^2/\text{C}$
- B. $2.5 \times 10^6 \text{ Nm}^2/\text{C}$
- C. $1.5 \times 10^7 \text{ Nm}^2/\text{C}$
- D. zero

40. A small sphere has a charge $+q$. Spherical Gaussian Surfaces A and B are concentric with the sphere, as shown in the figure below. The radii of surfaces A and B are r and $2r$, respectively.



The magnitude of the electric flux through A is ϕ_A . The magnitude of the electric flux through surface B is ϕ_B . The ratio ϕ_A/ϕ_B is ____.

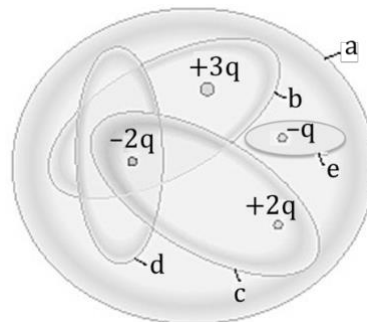
- A. 4/1
- B. 2/1
- C. 1/1
- D. 1/2

41. In order to use Gauss's Law to calculate the electric field created by a known distribution of charge, which of the following must be true?

- A. The charge distribution must be in a nonconducting medium
- B. The charge distribution must be in a conducting medium
- C. The charge distribution must be uniform
- D. The charge distribution must have a high degree of symmetry that allows assumptions about the symmetry of its electric field to be made

Questions 42 and 43

The figure below shows five Gaussian surfaces (a to e) surrounding a distribution of charges.



42. Which of the Gaussian surfaces have an electric flux of $+q/\epsilon_0$ through them?

- A. a
- B. b
- C. c
- D. d
- E. e

43. Which Gaussian surface has no electric flux through it?

- A. a
- B. b
- C. c
- D. d
- E. e

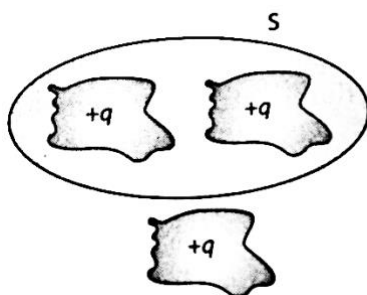
44. The figure below shows a distribution of charges. The flux of the electric field due to these charges through the surface S is ____.

A. zero

B. $\frac{q}{\epsilon_0}$

C. $\frac{2q}{\epsilon_0}$

D. $\frac{3q}{\epsilon_0}$



electric flux

45. Four charges are placed in three-dimensional space. The charges have magnitudes $+3q$, $-q$, $+2q$, and $-7q$. If a Gaussian surface encloses all the charges, what will be the electric flux through that surface?

A. $-13q/\epsilon_0$

B. $-3q/\epsilon_0$

C. $3q/\epsilon_0$

D. $13q/\epsilon_0$

enclosed 3D shape

46. The electric flux through a spherical Gaussian surface of radius R centered about an amount of charge Q is $1200 \text{ N m}^2/\text{C}$. What is the electric flux through a cubic Gaussian surface of side R centered about the same charge Q ? $\Phi = 1200 \text{ N m}^2/\text{C}$

A. Less than $1200 \text{ N m}^2/\text{C}$

B. More than $1200 \text{ N m}^2/\text{C}$

C. Equal to $1200 \text{ N m}^2/\text{C}$

D. It cannot be determined with the given parameters

shape + size don't affect electric flux

47. 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?

A. $5.0 \times 10^{10} \text{ N m}^2/\text{C}$

B. $3.3 \times 10^{10} \text{ N m}^2/\text{C}$

C. $4.5 \times 10^{10} \text{ N m}^2/\text{C}$

D. $6.6 \times 10^{10} \text{ N m}^2/\text{C}$

$$\Phi = \frac{q_n}{\epsilon_0} = \frac{1}{6} \left(\frac{3.5}{8.85 \times 10^{-12}} \right) \approx 6.6 \times 10^{10} \text{ N m}^2/\text{C}$$

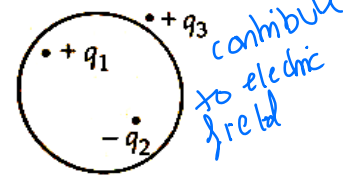
48. The diagram below shows three charges q_1 , q_2 and q_3 , all lying in the plane of the page. The diagram also shows the circle that represents the cross-section of a spherical Gaussian surface. Which of the charges contributes to the electric field at a point on the Gaussian surface?

A. $+q_1$ and $+q_3$

B. $+q_1$ and $-q_2$

C. $-q_2$ and $+q_3$

D. $+q_1$, $-q_2$ and $+q_3$



49. Inside a spherical surface is a $5.3 \times 10^{-6} \text{ C}$ and a $-2.2 \times 10^{-6} \text{ C}$ charge. What is the total electric flux through the surface of the sphere in units of $\text{N m}^2/\text{C}$?

A. 3.4×10^{-16}

B. 2.8×10^4

C. 3.5×10^5

D. 3.1×10^6

$$\Phi = \frac{q_{\text{enc}}}{\epsilon_0} = \frac{(5.3 \times 10^{-6}) + (-2.2 \times 10^{-6})}{8.85 \times 10^{-12}} = \frac{3.1 \times 10^{-6}}{8.85 \times 10^{-12}} = 350282.4859 \approx 3.5 \times 10^5$$

50. Which of the following could be true for a Gaussian surface through which the net flux is zero?

I. There are no charges inside the surface.

II. The net charge enclosed by the surface is zero.

III. The electric field is zero everywhere on the surface.

A. I only

B. II only

C. III only

D. I, II and III

net is zero but not everywhere

51. A point charge sits in the center of a 1 m cube. The electric flux through one side of the cube is $7.2 \times 10^{10} \text{ N m}^2/\text{C}$. What is the charge at the center of the cube?

A. 3.8 C

B. 4.6 C

C. 6.0 C

D. 8.9 C

$$\Phi = \frac{q_n}{\epsilon_0} \Rightarrow 7.2 \times 10^{10} = \frac{1}{6} \times \frac{q_n}{8.85 \times 10^{-12}} \Rightarrow q_n \approx 3.8$$

52. A conducting spherical shell S has a charge Q distributed over its surface. The total electric flux through any imaginary concentric spherical shell of radius r that encloses S is ____.

- A. inversely proportional to r^2
- B. directly proportional to r
- C. directly proportional to r^2
- D. Independent of r



$\Phi_{\text{total}} = \frac{\sum q_{\text{in}}}{\epsilon_0}$
Asking for Flux!

flat surface depends on area & therefore on r

56. 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?

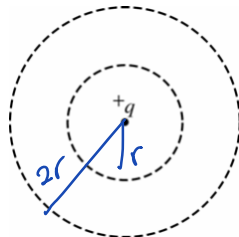


- A. $\rightarrow$
- B. $\uparrow$
- C. $\leftarrow$
- D. The field is zero

shell

53. Two concentric spherical surfaces are drawn around an isolated positive charge +q located at their center, as shown below. The inner surface has a radius that is 1/2 that of the outer surface. If the total electric flux passing through the inner surface is ϕ , what is the total electric flux passing through the outer surface?

- A. $\phi/4$
- B. $\phi/2$
- C. ϕ
- D. 2ϕ



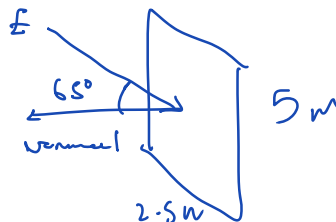
flux independent of r only charged enclosed

54. 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?

- A. $1.56 \times 10^6 \text{ Nm}^2/\text{C}$
- B. $6.60 \times 10^5 \text{ Nm}^2/\text{C}$
- C. $1.42 \times 10^5 \text{ Nm}^2/\text{C}$
- D. $5.49 \times 10^4 \text{ Nm}^2/\text{C}$

$E = 125,000 \text{ N/C}$

$A = 2.5 \times 5$

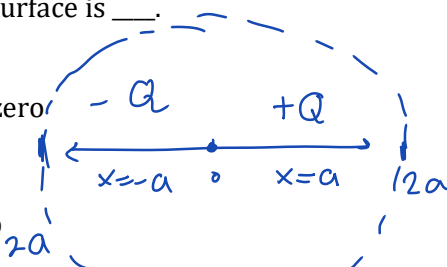


$\Phi = EA \cos \theta$
 $= (5 \times 2.5)(125,000)(\cos 65)$

flat surface that isn't infinite

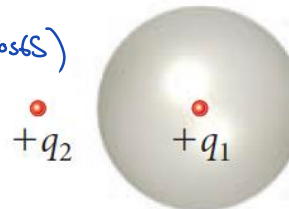
55. A point charge, +Q, is located on the x-axis at $x = a$, and a second point charge, -Q, is located on the x-axis at $x = -a$. A Gaussian surface with radius $r = 2a$ is centered at the origin. The flux through this Gaussian surface is ____.

- A. zero
- B. greater than zero
- C. less than zero
- D. Exactly $2Q/\epsilon_0$



$\Phi_{\text{total}} = \frac{\sum Q}{\epsilon_0} = \frac{-Q + Q}{\epsilon_0} = 0$

57. A hollow, conducting sphere is initially uncharged. A positive charge, +q₁, is placed inside the sphere, as shown in the figure. Then, a second positive charge, +q₂, is placed near the sphere but outside it. Which of the following statements describes the net electric force on each charge?



- A. There is a net electric force on +q₂ but not on +q₁
- B. There is a net electric force on +q₁ but not on +q₂
- C. Both charges are acted on by a net electric force with the same magnitude and in the same direction
- D. Both charges are acted on by a net electric force with the same magnitude but in opposite directions

58. A charge of $+2q$ is placed at the center of an uncharged conducting shell. What will be the charges on the inner and outer surfaces of the shell, respectively?

	Inner surface	Outer surface
A.	$-2q$	$+2q$
B.	$-2q$	$+4q$
C.	$-2q$	$-2q$
D.	$-q$	$+q$



59. Which of the equations below represents the total charge distributed over a surface?

- A. $Q_t = \int q(r) dr$
 B. $Q_t = \int \lambda(r) dl$
 C. $Q_t = \int \sigma(r) dA$
 D. $Q_t = \int \rho(r) dV$

$\sigma = \frac{Q}{A}$
 sigma
 charge distributed over area

60. In order to use Gauss's Law to calculate the electric field created by a known distribution of charge, which of the following must be true?

- A. The charge distribution must be in a nonconducting medium
 B. The charge distribution must be in a conducting medium
 C. The charge distribution must be uniform

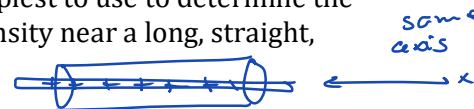
- D. The charge distribution must have a high degree of symmetry that allows assumptions about the symmetry of its electric field to be made

Gaussian surface must have symmetry

61. The electric field for a long wire with charge per unit length λ surrounded by a Gaussian surface in the form of a cylinder with radius r and length L is ____.

- A. $2k\lambda/r$
 B. $2k\lambda/L$
 C. $2k\lambda r$
 D. $2k\lambda L$

62. Which of the following Gaussian surfaces would be the simplest to use to determine the electric field intensity near a long, straight, charged wire?



- A. A cylinder whose axis coincides with the wire
 B. A cylinder whose axis is perpendicular to the wire and passes through the wire
 C. A sphere with the wire through its center
 D. A cube with the wire passing through the centers of opposite faces

63. An insulating solid sphere of radius a has a uniform volume charge density ρ and total positive charge q . The strength of the electric field inside the sphere at a distance r from the center ($r < a$) is proportional to ____.

- A. r
 B. $1/r^2$
 C. $1/r^3$
 D. $1/a^2$

Insulating solid sphere
 $E = \frac{kQr}{R^3}$
 constant radius of sphere that doesn't change

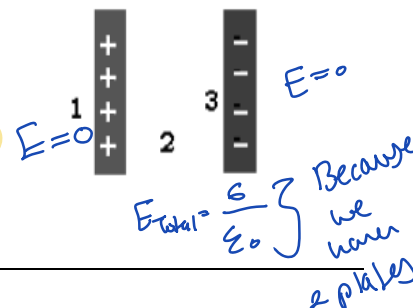
64. The electric field at a distance r from an infinite, flat non-conducting sheet with a charge density σ is ____.

- A. $\sigma/2r\epsilon_0$
 B. $\sigma/r\epsilon_0$
 C. $\sigma/2\epsilon_0$
 D. σ/ϵ_0

sigma

65. The diagram below shows two charged plates placed close to each other. Rank the points 1, 2 and 3 from greatest to the least electric field.

- A. $1 > 2 > 3$
 B. $3 > 1 > 2$
 C. $3 = 2 > 1$
 D. $1 = 2 = 3$



66. Two infinite sheets of uniform charge density $+\sigma$ and $-\sigma$ are parallel to each other as shown in the figure. The electric field at the ____.

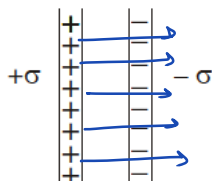
- I. midpoint between the sheets is zero
- II. points to the left or to the right of the sheets is zero
- III. midpoint of the sheets is σ/ϵ_0 and is directed towards right
- IV. midpoint of the sheet is $2\sigma/\epsilon_0$ and is directed towards right

A. I only

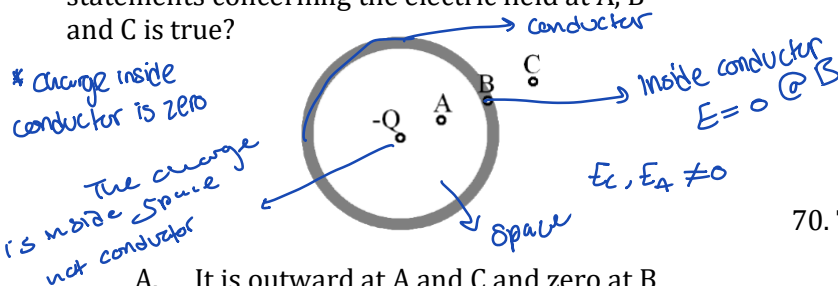
B. II only

C. III only

D. II and III only



67. 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?



A. It is outward at A and C and zero at B

B. It is inward at A and C and zero at B

C. It is inward at A, B, and C

D. It is zero at B and C and inward at A

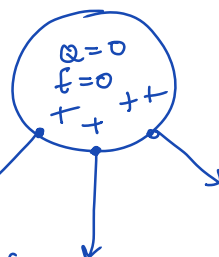
68. Which of the following statements is false regarding a conducting sphere?

A. Inside the charged or neutral conducting sphere, the electric field is zero *True*

B. There is no net charge at any point inside the conducting sphere *True*

C. The potential is constant throughout the volume of the conducting sphere

D. The electric field at the surface of the charged conductor must be tangential to the surface at any point



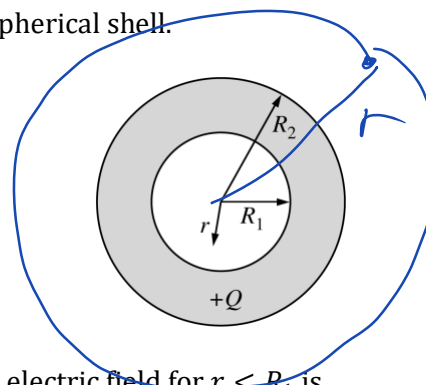
Electric field is perpendicular to surface NOT TANGENTIAL

The line cannot be tangent to the surface, must be perpendicular

* Always perpendicular

Questions 69 and 70.

A charge $+Q$ is uniformly distributed throughout a nonconducting spherical shell of inner radius R_1 and outer radius R_2 as shown below. The electric field is determined at a distance r from the center of the spherical shell.



69. The electric field for $r < R_1$ is ____.

A. zero

B. $\frac{1}{4\pi\epsilon_0} \frac{Q}{R_1^2}$

C. $\frac{1}{4\pi\epsilon_0} \frac{Q}{R_2^2}$

D. $\frac{1}{4\pi\epsilon_0} \frac{Q}{(R_2 - R_1)^2}$

70. The electric field for $r > R_2$ is ____.

A. $\frac{1}{4\pi\epsilon_0} \frac{Q}{R_1^2}$

B. $\frac{1}{4\pi\epsilon_0} \frac{Q}{R_2^2}$

C. $\frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$

D. $\frac{1}{4\pi\epsilon_0} \frac{Q}{r^2 - R_2^2}$

$$E = \frac{Q}{4\pi r^2 \epsilon_0}$$

Free Response:

1. Which of the following statements is/are true?

- a. Electric field lines may cross.
- b. Electric field lines point outward from positive charges.
- c. Positive point charge released from rest will initially accelerate along a tangent to the electric field line at that point.
- d. The closer together the electric field lines are, the weaker the electric field. *Stronger*
- e. The direction of an electric field is the direction of the force on a positive charge placed in the field.
- f. If the number of field lines entering are equal to those leaving the area, the net electric flux is zero.
- g. The electric flux has a minimum value through a surface when the area vector is perpendicular to the electric field.
- h. The electric flux through a closed surface with a given enclosed charge is independent of the size or shape of the surface.
- i. The electric field is zero everywhere inside the conductor, whether the conductor is solid or hollow.
- j. If the conductor is isolated and carries a charge, the charge resides on its surface. *Should be Greatest!*
- k. On an irregularly shaped conductor, the surface charge density is least at locations where the radius of curvature of the surface is smallest. *Charge density is inversely proportional to radius of curvature.*
- l. Any cavity inside a conductor is totally shielded from any external electric field.
- m. On an irregularly shaped conductor, the surface charge density is least at locations where the radius of curvature of the surface is smallest. *must be greatest (same question as above)*
- n. The electric field just outside of a conductor must be completely perpendicular to the surface and have no components tangential to the surface.
- o. A state of electrostatic equilibrium on the conductor is created by mutual attraction of all charges on the surface of the conductor

2. Complete table below on electric fields.

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

Test charge

Test Charge(C)	Force on Test Charge (N)	Electric Field Intensity (N/C)
1.0×10^{-6}	0.30	3×10^5
2.0×10^{-6}	0.66	3.3×10^5
3×10^{-6}	0.45	1.5×10^5

3. The electric field in the atmosphere is about 150 N/C downward.

a. What is the direction of the force on a negatively charged particle?

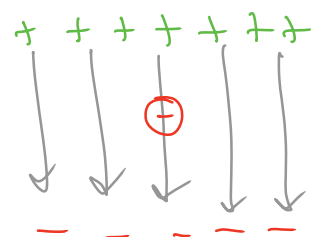
for a negatively charged particle it's upwards

b. Find the electric force on an electron with charge $1.6 \times 10^{-19} \text{ C}$.

$$E = \frac{F}{q} \Rightarrow F = Eq = 150(1.6 \times 10^{-19}) = 2.4 \times 10^{-17} \text{ N/C}$$

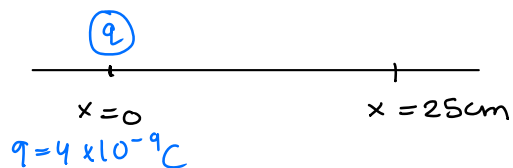
upward

*for electrons the direction of force is opposite to that of the electric field.



$$E = 150 \text{ N/C}$$

4. A point charge, $q = 4.00 \times 10^{-9} \text{ C}$, is placed on the x-axis at the origin. What is the electric field produced at $x = 25.0 \text{ cm}$?



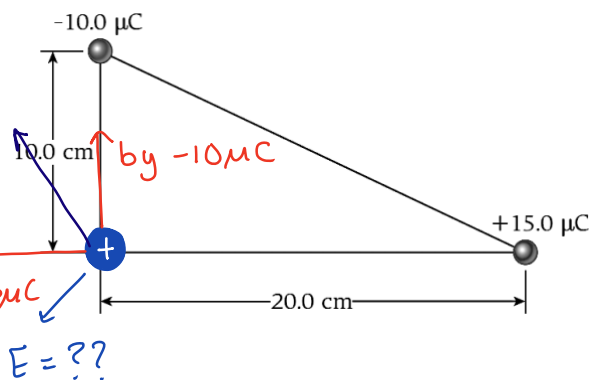
$$E = \frac{kq}{r^2} = \frac{(8.99 \times 10^9)(4 \times 10^{-9})}{0.25^2} = 575.36 \text{ N/C}$$

5. What is the electric field strength 20.0 cm from a point charge of $8.0 \times 10^{-7} \text{ C}$?

$$E = \frac{kq}{r^2} = \frac{(8.99 \times 10^9)(8 \times 10^{-7})}{0.2^2} = 179800 \text{ N/C}$$

6. Two point charges are placed at two of the corners of a triangle as shown in the figure. Find the magnitude and the direction of the electric field at the third corner of the triangle.

$$\begin{aligned} \textcircled{1} E_y &= \frac{kq}{r^2} = \frac{(8.99 \times 10^9)(10 \times 10^{-6})}{0.1^2} = 899 \times 10^4 \text{ N/C up} \\ \textcircled{2} E_x &= \frac{kq}{r^2} = \frac{(8.99 \times 10^9)(15 \times 10^{-6})}{0.2^2} = 3371250 \text{ N/C left} \end{aligned}$$



$$\textcircled{3} E_{\text{total}} = \sqrt{E_y^2 + E_x^2}$$

$$= \sqrt{(899 \times 10^4)^2 + (3371250)^2}$$

$$= 9601324.209 \text{ N/C}$$

$$\textcircled{4} \text{Direction: } \tan^{-1}\left(\frac{y}{x}\right)$$

$$\theta = \tan^{-1}\left(\frac{899 \times 10^4}{-3371250}\right)$$

$$\theta = -69.4^\circ$$

7. A $+1.60\text{-nC}$ point charge is placed at one corner of a square (1.00 m on a side), and a -2.40-nC charge is placed on the corner diagonally opposite. What is the magnitude of the electric field at either of the other two corners?

we'll consider for upper left

$$\textcircled{1} E_x = \frac{kq}{r^2}$$

$$\textcircled{2} E_y = \frac{kq}{r^2}$$

$$= \frac{(8.99 \times 10^9)(2.4 \times 10^{-9})}{1^2}$$

$$= \frac{(8.99 \times 10^9)(1.6 \times 10^{-9})}{1^2}$$

$$= 21.576 \text{ N/C}$$

right

$$= 14.384 \text{ N/C}$$

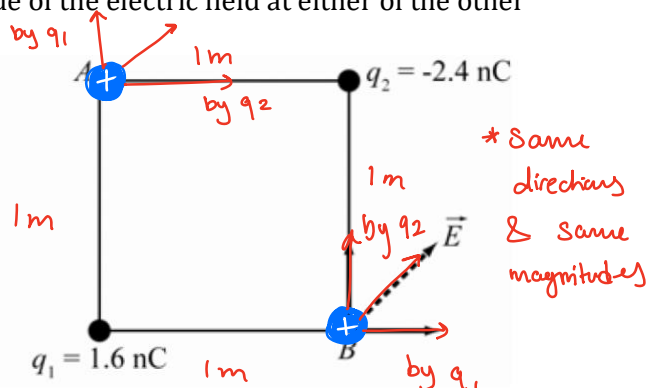
up

$$\textcircled{3} E_{\text{total}} = \sqrt{E_x^2 + E_y^2}$$

$$= \sqrt{(21.576)^2 + (14.384)^2} \approx 25.9 \text{ N/C}$$

$$\textcircled{4} \text{ Direction: } \theta = \tan^{-1}\left(\frac{y}{x}\right)$$

$$\theta = \tan^{-1}\left(\frac{14.384}{21.576}\right) \approx 33.69^\circ \text{ above positive } x\text{-axis.}$$



* Same directions & same magnitudes

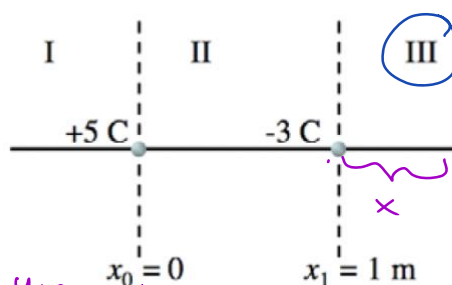
8. A $+5.00\text{ C}$ charge is located at the origin. A -3.00 C charge is placed at $x = 1.00\text{ m}$. At what finite distance(s) along the x -axis will the electric field be equal to zero?

finding point of equilibrium (assumption)

① Since charges have opposite signs it must be @ either side

② It also must be near the smaller charge

Therefore, we assume it's @ III after $x = 1\text{ m}$.



$$\frac{kQ_1}{r^2} = \frac{kQ_2}{r^2}$$

$$\sqrt{\frac{5}{(x+1)^2}} = \sqrt{\frac{3}{x^2}}$$

$$\frac{\sqrt{5}}{x+1} = \frac{\sqrt{3}}{x}$$

$$\sqrt{5}x = \sqrt{3}(x+1)$$

$$\sqrt{5}x = \sqrt{3}x + \sqrt{3}$$

$$(\sqrt{5} - \sqrt{3})x = \sqrt{3}$$

$$x = 3.4\text{ m}$$

(we must add 1 to get distance from origin)

$$x = 4.4\text{ m}$$

Satisfies our assumption!

9. Electric fields of varying magnitudes are directed either inward or outward at right angles on the faces of a cube, as shown in the figure. What is the strength and direction of the field on the face F?

$$\sum \vec{E} \cdot \vec{A} = \frac{q_{\text{in}}}{\epsilon_0} = \frac{0}{\epsilon_0} = 0 \quad \leftarrow \text{since we have no charge inside}$$

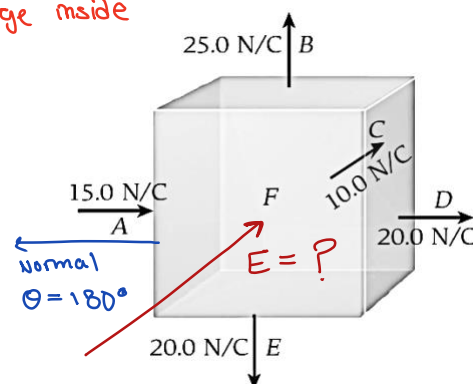
$$\sum E \cdot A = 0$$

$$15A \cos 180^\circ + 25A \cos 0^\circ + 10A \cos 0^\circ + 20A \cos 0^\circ + 20A \cos 0^\circ + E_F A \cos 0^\circ = 0$$

$$A(-15 + 25 + 10 + 20 + 20 + E_F) = 0$$

$$60 + E_F = 0$$

$$E_F = -60 \text{ N/C, \& the direction is going into the surface.}$$



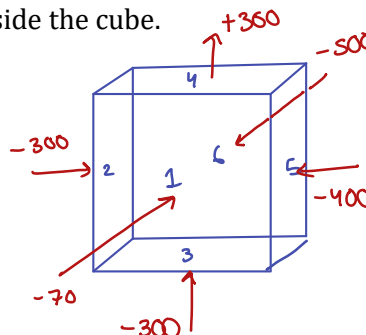
10. The six faces of a cubical box each measure 20.0 cm by 20.0 cm, and the faces are numbered such that faces 1 and 6 are opposite to each other, as are faces 2 and 5, and faces 3 and 4. The flux through each face is given in the table. Find the net charge inside the cube.

$$\sum E \cdot A = \frac{\sum q_{in}}{\epsilon_0}$$

$$\sum q_{in} = \sum E \cdot A \times \epsilon_0$$

$$\sum q_{in} = (8.85 \times 10^{-12}) \times (-300 - 400 + 300 - 300 - 70 - 500)$$

$$\sum q_{in} = -1.12 \times 10^{-8} \text{ C}$$



Face	Flux (N m ² /C)
1	-70.0
2	-300.0
3	-300.0
4	+300.0
5	-400.0
6	-500.0

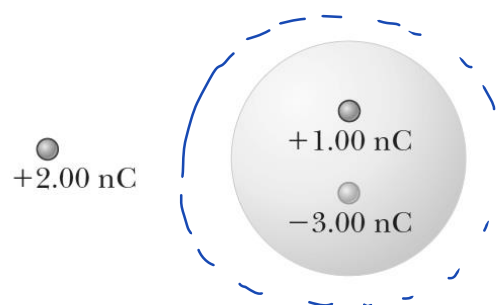
$$\Phi = E \cdot A$$

11. Find the net electric flux through the spherical closed surface shown below. The two charges on the right are inside the spherical surface.

$$\Phi_{Total} = \frac{\sum q_{in}}{\epsilon_0}$$

$$\frac{(1 \times 10^{-9}) + (-3 \times 10^{-9})}{8.85 \times 10^{-12}}$$

$$\approx -225.98 \text{ N m}^2/\text{C}$$



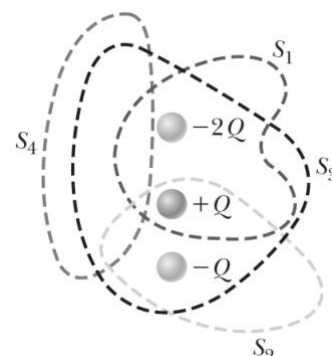
12. Four closed surfaces, S_1 through S_4 , together with the charges $-2Q$, Q , and $-Q$ are sketched in the figure below. (The colored lines are the intersections of the surfaces with the page.) Find the electric flux through each surface.

$$\Phi_1 = \frac{\sum q_{in}}{\epsilon_0} = \frac{-2Q + Q}{\epsilon_0} = -\frac{Q}{\epsilon_0} \text{ N m}^2/\text{C}$$

$$\Phi_2 = \frac{\sum q_{in}}{\epsilon_0} = \frac{+Q - Q}{\epsilon_0} = \frac{0}{\epsilon_0} = 0 \text{ N m}^2/\text{C}$$

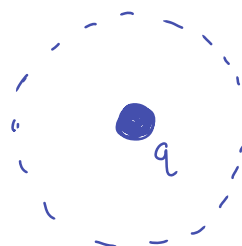
$$\Phi_3 = \frac{\sum q_{in}}{\epsilon_0} = \frac{-2Q + Q - Q}{\epsilon_0} = \frac{-2Q}{\epsilon_0} \text{ N m}^2/\text{C}$$

$$\Phi_4 = \frac{\sum q_{in}}{\epsilon_0} = \frac{0}{\epsilon_0} = 0 \text{ N m}^2/\text{C}$$



13. A spherical gaussian surface surrounds a point charge q . Describe what happens to the **total flux** through the surface if:

$$\text{Total Flux} = \frac{\Sigma q_{in}}{\epsilon_0}$$



- a. the charge is tripled.

Tripled, since they're directly proportional.

- b. the radius of the sphere is doubled.

Same, since they're independent.

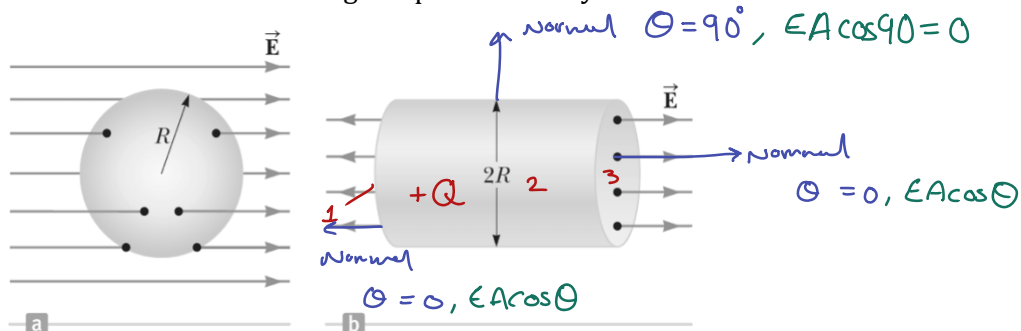
- c. the surface is changed to a cube.

Same, since they're independent.

- d. the charge is moved to another location inside the surface.

Same, since they're independent.

14. The figures below show the electric field lines through a sphere and a cylinder.



- a. Find the net electric flux through the closed spherical surface in a uniform electric field shown in figure a.

Number of lines in = Number of lines out

$\Phi = 0$, no charge in

- b. Find the net electric flux through the closed cylindrical surface shown in figure b.

$$\Phi = \frac{\Sigma q_{in}}{\epsilon_0} = \Sigma EA \cos \theta = EA \cos 0 + EA \cos 0 = 2EA = 2 \times E \times (\pi r^2) = 2E\pi r^2$$

Area of circle

- c. What can you conclude about the charges, if any, inside the cylindrical surface?

The net charge inside the cylindrical surface is positive since the electric field lines are going out.

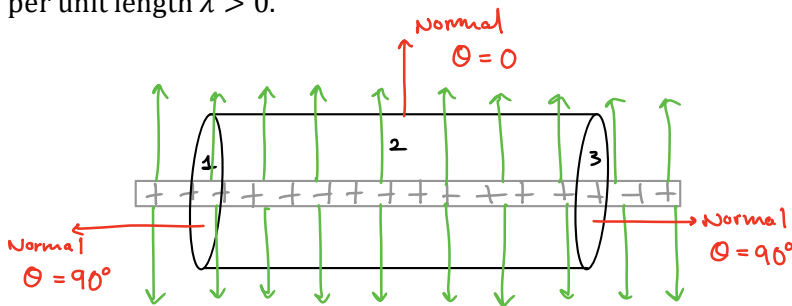
15. A uniform electric field exists in a region of space containing no charges. What can you conclude about the net electric flux through a gaussian surface placed in this region of space?

$$\Phi = \frac{\sum q_{in}}{\epsilon_0} \leftarrow \text{If there are no charges, then the formula will reduce to 0 \& therefore } \Phi_{net} = 0.$$

16. Explain why Gauss's law cannot be used to calculate the electric field near an electric dipole, a charged disk, or a triangle with a point charge at each corner.

Because the cases listed do not have symmetrical charge distribution.

17. Find the electric field a distance r from a line of positive charge of infinite length and constant charge per unit length $\lambda > 0$.



keep in mind

$$\lambda = \frac{Q}{l}$$

λ ← linear density
 Q ← charge
 l ← unit length

$$\Phi_{total} = \int_1 E \cdot dA + \int_2 E \cdot dA + \int_3 E \cdot dA = \frac{q_{in}}{\epsilon_0}$$

$$= \cancel{EA \cos 90^\circ} + EA \cos 0 + \cancel{EA \cos 90^\circ} = \frac{q_{in}}{\epsilon_0}$$

$$EA = \frac{q_{in}}{\epsilon_0}$$

$$E = \frac{q_{in}}{A \epsilon_0} = \frac{q_{in}}{2\pi r l \epsilon_0}$$

$$E = \frac{Q}{2\pi r l \epsilon_0}$$

$$E = \frac{\lambda}{2\pi r \epsilon_0}$$

$$E = \frac{2k\lambda}{r}$$

Remember

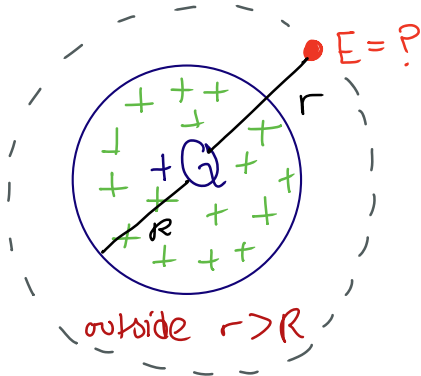
$$2 \times k = \frac{1}{4\pi \epsilon_0} \times 2$$

$$2k = \frac{1}{2\pi \epsilon_0}$$

18. An insulating solid sphere of radius a has a uniform volume charge density ρ and carries a total positive charge Q .

$$\rho = \frac{Q}{V} \rightarrow Q = \rho V$$

a. Calculate the magnitude of the electric field at a point outside the sphere.



$$\int E \cdot dA = \frac{q_{in}}{\epsilon_0}$$

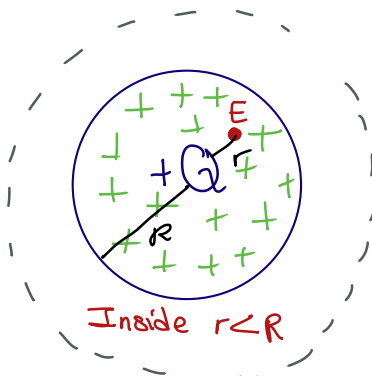
$$EA = \frac{q_{in}}{\epsilon_0}$$

$$E = \frac{Q}{A\epsilon_0}$$

$$E = \frac{\rho V}{4\pi r^2 \epsilon_0}$$

$$E = \frac{k\rho V}{r^2} \quad \text{or} \quad \frac{kQ}{r^2}$$

b. Find the magnitude of the electric field at a point inside the sphere.



$$\frac{Q}{V_{\text{sphere}}} = \frac{q_{in}}{V_{\text{Gaussian}}}$$

$$\frac{Q}{\frac{4}{3}\pi R^3} = \frac{q_{in}}{\frac{4}{3}\pi r^3}$$

$$q_{in} = \frac{Q r^3}{R^3}$$

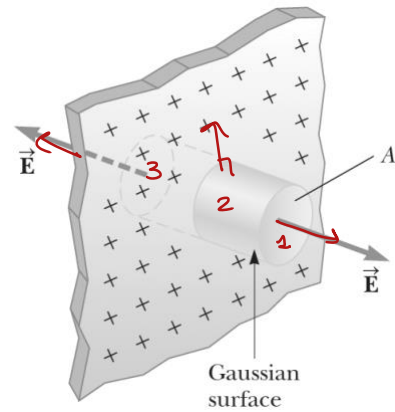
$$E = \frac{q_{in}}{\epsilon_0 A} = \frac{Q r^3}{R^3 \epsilon_0 4\pi r^2} = \frac{Q r}{R^3 \epsilon_0 4\pi} = \frac{kQr}{R^3}$$

$$Q = \frac{\sigma}{A} \rightarrow \sigma = QA$$

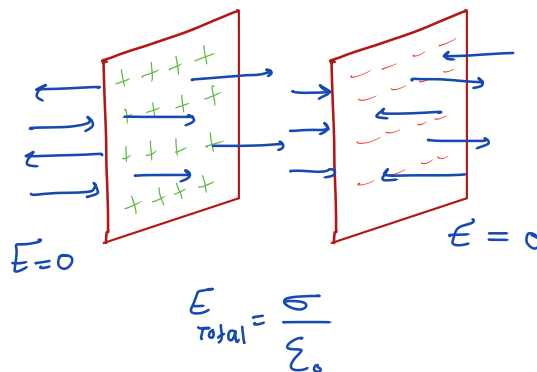
19. An infinite plane of positive charge has a uniform surface charge density σ .

a. Find the electric field due to the infinite plane.

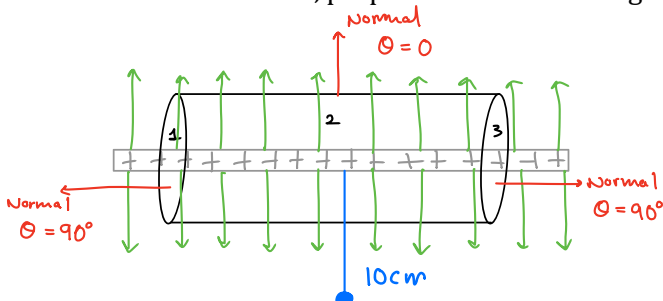
$$\begin{aligned}\Phi &= \int_1 \vec{E} \cdot d\vec{A} + \int_2 \vec{E} \cdot d\vec{A} + \int_3 \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0} \\ &= EA \cos 0 + \cancel{EA \cos 90^\circ} + EA \cos 0 = \frac{q_{in}}{\epsilon_0} \\ EA + EA &= \frac{q_{in}}{\epsilon_0} \rightarrow 2EA = \frac{q_{in}}{\epsilon_0} \\ E &= \frac{Q}{2A\epsilon_0} \rightarrow E = \frac{\sigma A}{2A\epsilon_0} = \frac{\sigma}{2\epsilon_0} \\ E &= \frac{\sigma}{2\epsilon_0}\end{aligned}$$



b. Suppose two infinite planes of charge are parallel to each other, one positively charged and the other negatively charged. The surface charge densities of both planes are of the same magnitude. What does the electric field look like in this situation?



20. The charge per unit length on a long, straight filament is $-90.0 \mu\text{C}/\text{m}$. Find the electric field 10.0 cm from the filament, perpendicular to the length of the filament.



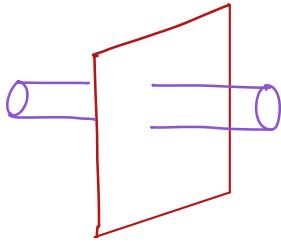
$$\lambda = \frac{Q}{l} = -90 \times 10^{-6} \text{ C/m}$$

$$E = \frac{2k\lambda}{r}$$

$$\begin{aligned} &= \frac{2(8.99 \times 10^9)(90 \times 10^{-6})}{0.1} \\ &= 1.6 \times 10^7 \text{ N/C} \end{aligned}$$

$$\sigma = \frac{Q}{A}$$

21. A large, flat, horizontal sheet of charge has a charge per unit area of $9.00 \mu\text{C}/\text{m}^2$. Find the electric field just above the middle of the sheet.



$$\sigma = 9 \mu\text{C}/\text{m}^2$$

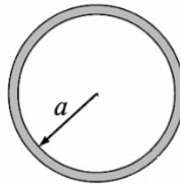
$$\begin{aligned}\Phi &= \int_1 \mathbf{E} \cdot d\mathbf{A} + \int_2 \mathbf{E} \cdot d\mathbf{A} + \int_3 \mathbf{E} \cdot d\mathbf{A} = \frac{q_{\text{in}}}{\epsilon_0} \\ &= EA \cos 0 + EA \cos 0 + EA \cos 0 = \frac{q_{\text{in}}}{\epsilon_0} \\ EA + EA + EA &= \frac{q_{\text{in}}}{\epsilon_0} \rightarrow 2EA = \frac{q_{\text{in}}}{\epsilon_0}\end{aligned}$$

$$E = \frac{Q}{2A\epsilon_0} \rightarrow E = \frac{\sigma A}{2A\epsilon_0} = \frac{\sigma}{2\epsilon_0}$$

$$E = \frac{\sigma}{2\epsilon_0} = \frac{9 \times 10^{-6}}{2(8.85 \times 10^{-12})} = 508,474.5763 \text{ N/C}$$

22. A thin metallic spherical shell of radius a has a charge $+Q$ evenly distributed over its surface.

conducting shell



$+Q$ distributed over surface

a. Determine the electric field at each of the following regions:

i. Inside the shell ($r < a$).

Since there's no charge inside & it's electrically isolated the electric field is ZERO.

ii. Outside the shell ($r > a$).

$$E = \frac{kQ}{a^2}$$

In depth explanation for those who want it =

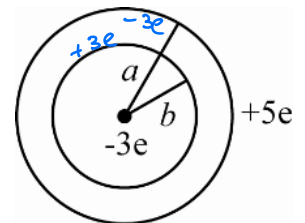
$$E = \frac{\Sigma q_{\text{in}}}{A\epsilon_0} = \frac{Q}{4\pi a^2\epsilon_0} = \frac{kQ}{a^2}$$

23. Consider a hollow spherical conductor with total charge $+5e$. The outer and inner radii are a and b , respectively.

a. Calculate the charge on the sphere's inner and outer surfaces if a charge of $-3e$ is placed at the center of the sphere.

$$\text{Inner} = +3e$$

$$\text{Outer} = -3e + 5e = 2e$$



b. What is the total net charge of the sphere?

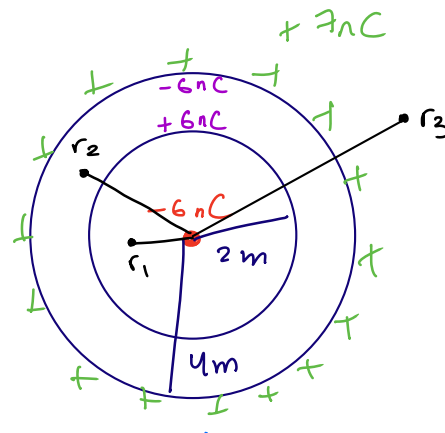
$$+5e + 3e - 3e = 5e$$

Same charge

24. A -6.00 nC point charge is located at the center of a **conducting** spherical shell. The shell has an inner radius of 2.00 m , an outer radius of 4.00 m , and a charge of $+7.00 \text{ nC}$.

- a. What is the electric field at $r_1 = 1.00 \text{ m}$?

$$E = \frac{kq}{r^2} = \frac{(8.99 \times 10^9)(-6 \times 10^{-9})}{1^2} = -53.94 \text{ N/C}$$



- b. What is the electric field at $r_2 = 3.00 \text{ m}$?

The electric field is zero as the electric field within a conductor is zero.

- c. What is the electric field at $r_3 = 5.00 \text{ m}$?

$$E = \frac{k(q+Q)}{r^2} = \frac{(8.99 \times 10^9) \times ((7 \times 10^{-9}) + (-6 \times 10^{-9}))}{5^2} \approx 0.36 \text{ N/C}$$

- d. What is the surface charge distribution, σ , on the outside surface of the shell?

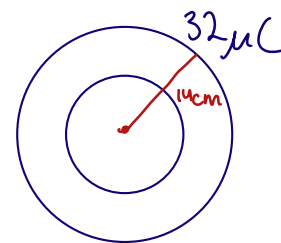
$$\sigma = \frac{(q+Q)}{\text{Area}} = \frac{((7 \times 10^{-9}) + (-6 \times 10^{-9}))}{4\pi r^2} = \frac{1 \times 10^{-9}}{4\pi (4)^2} = 4.97 \times 10^{-12} \text{ C/m}^2$$

25. Consider a thin, spherical shell of radius 14.0 cm with a total charge of $32.0 \text{ } \mu\text{C}$ distributed uniformly on its surface.

- a. Find the electric field 10.0 cm from the ~~center of the charge distribution~~ ^{outer surface}.

this means we are 24 cm away so outside the shell

$$E = \frac{kQ}{r^2}$$



- b. Find the electric field 10.0 cm from the center of the charge distribution.

Since we're inside the shell the electric field is zero.