Physics 222, August 31

Key Concepts:

- The electric force
- The electric field
- Gauss' law
- Polarization

Please find a seat.

Keep all walkways free for safety reasons and to comply with the fire code.

Electronic Devices

Please separate your professional from your social life.

Do not use social media during class.

Electric charge

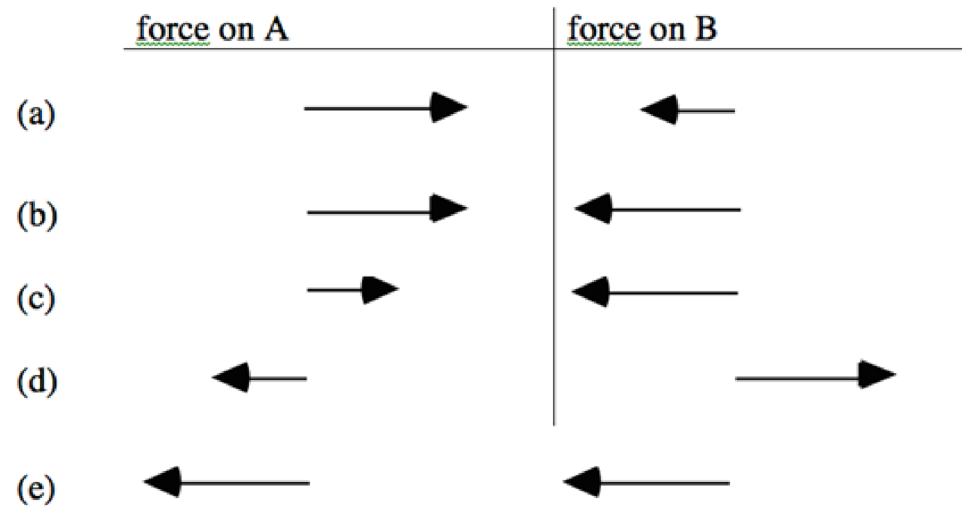
- Electric charge can be either positive or negative, but comes in individual units, or quanta, in multiples of the charge on the electron or proton, with magnitude $q_e = 1.6 * 10^{-19}$ C.
- In an isolated system, the total electric charge is conserved and remains constant in time.
- The fundamental force law between two point electric charges, q_1 and q_2, separated by a distance r is given by Coulomb's law.

$$\mathbf{F}_{12} = k_e \frac{q_1 q_2}{r_{12}^2} \hat{\mathbf{r}}_{12}$$

$\mathbf{F}_{12}$ is the force object 1 exerts on object 2.
Forces are interactions. $\mathbf{F}_{12} = -\mathbf{F}_{21}$ (Newton's third law)
$1/(4\pi\varepsilon_0) = k_e = 9*10^9 \text{ Nm}^2/\text{C}^2$ SI unit of charge: Coulomb (C)

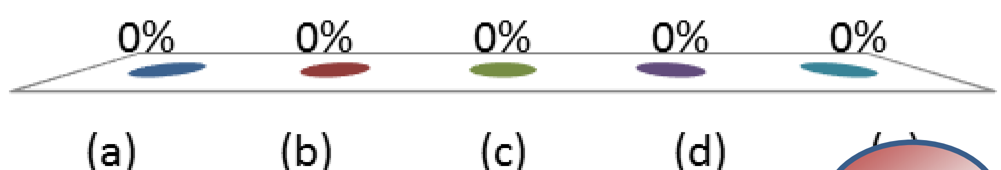
- Principle of superposition: $\mathbf{F}_1 = \mathbf{F}_{21} + \mathbf{F}_{31} + \mathbf{F}_{41} + \ldots$

A and B represent objects with -2 and +1 unit of charge respectively. Choose the pair of force vectors that correctly compare the electric force on A (caused by B) with the electric force on B (caused by A).



Hint: Newton’s 3rd law

A. (a)
B. (b)
C. (c)
D. (d)
E. (e)



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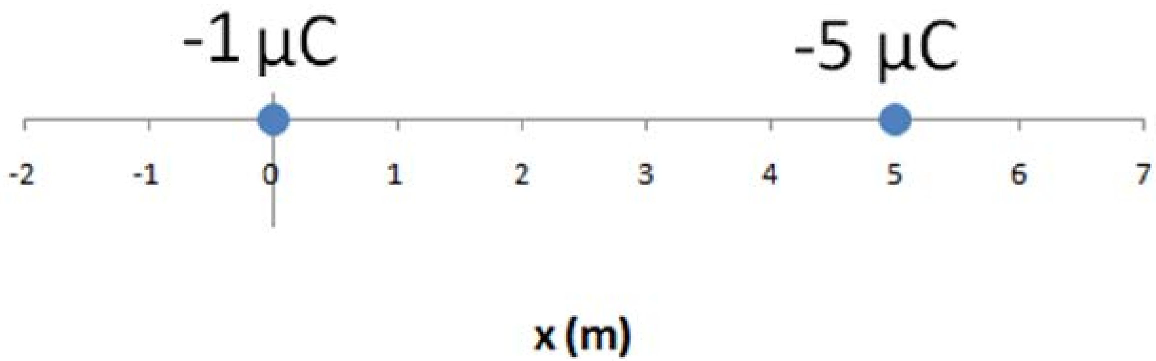
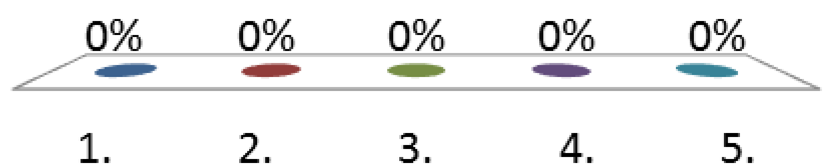
What is the force (magnitude and direction) on a -1 μC charge located at the origin from a -5 μC charge at x = 5 m?



1. 0.009 N into positive x-direction
2. 0.0018 N into negative x-direction
3. 0.018 N into negative x-direction
4. 1800 N into negative x-direction
5. 0.0018 N into positive x-direction



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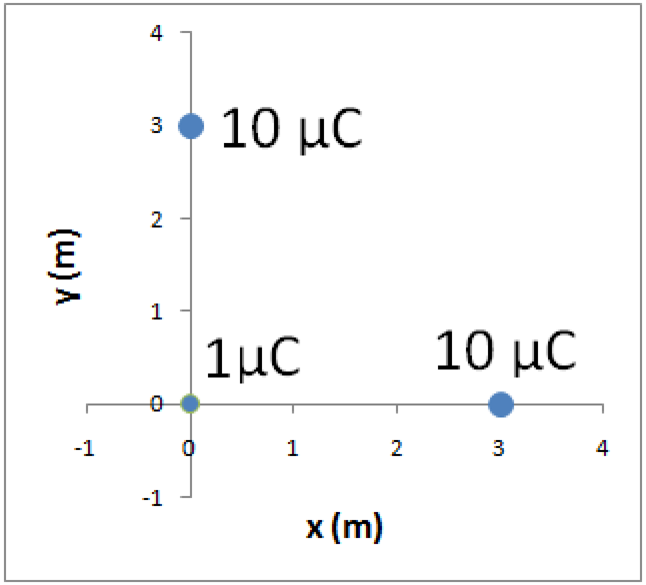
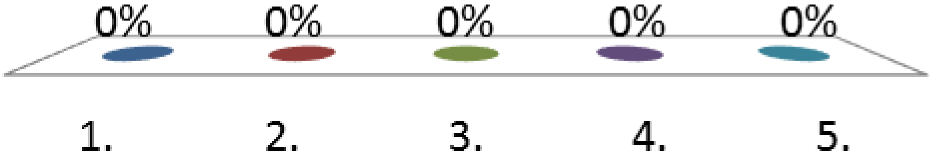
Two 10 μC charges are located at (x, y) = (0, 3m) and (3 m, 0), respectively. What is the magnitude of the force on the 1 μC charge at the origin?



1. $1*10^{-2}$ N
2. $2*10^{-2}$ N
3. $1.41*10^{-2}$ N
4. $2.82*10^{-2}$ N
5. $4*10^{-2}$ N



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Electric Field

- The electric field **E**(**r**) at a position **r** is defined as the force **F**(**r**) on a positive test charge q' at position **r** divided by q'.

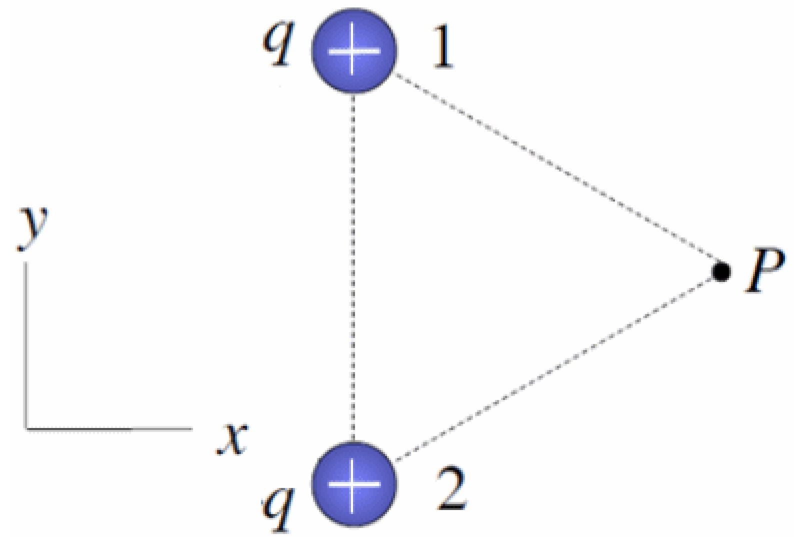
  E = **F**/q'

- A point charge q at the origin produces an electric field at position **r** a distance r from the origin given by

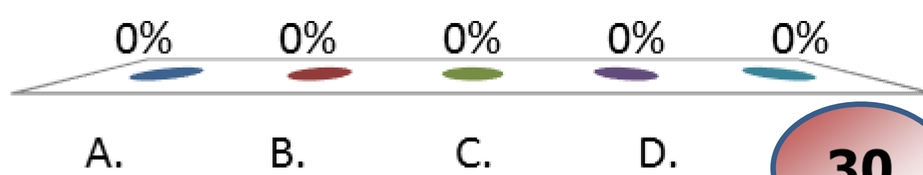
$$\vec{E} = \frac{q}{4\pi\varepsilon_0 r^2}\hat{r}.$$

- Principle of superposition: $\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2 + \mathbf{E}_3 + \ldots$

Two point charges with charge q and a point P are located as shown, at the vertices of an equilateral triangle. What is the direction of the electric field due to the two point charges at point P?



A. The +x direction
B. The +y direction
C. The –x direction
D. The –y direction
E. None of the above



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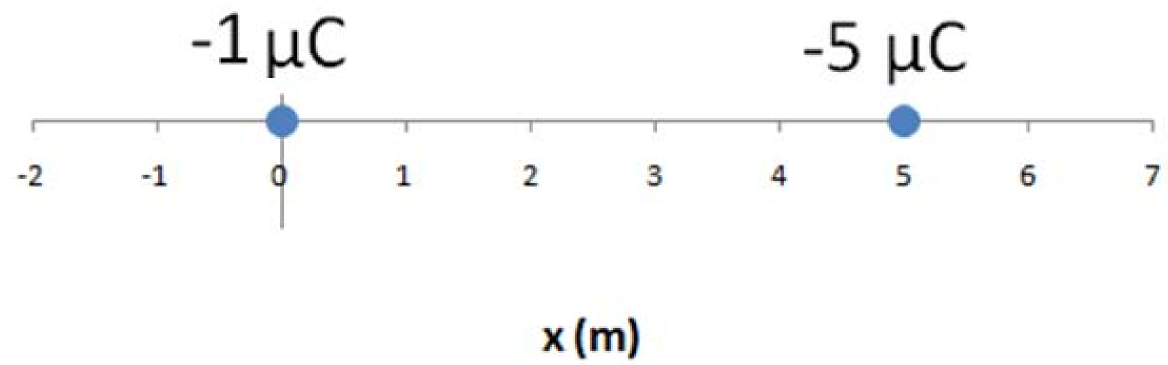
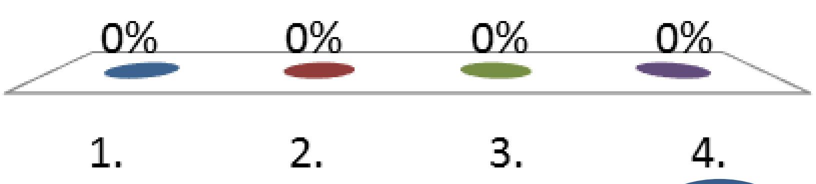
What is the direction of the electric field produced by the -5 μC charge located at x = 5 m at the position of the -1 μC charge at the origin?



1. to the left
2. to the right
3. perpendicular to the x-axis
4. E = 0, since both charges are negative.



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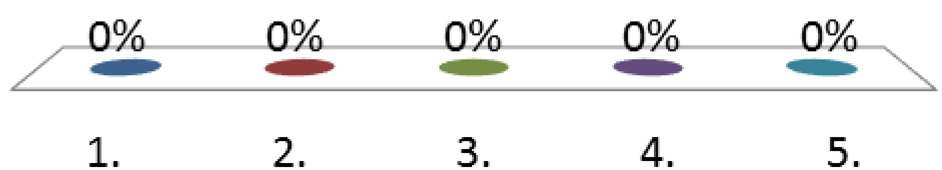
When a positive charge is released from rest in a uniform electric field, it will

1. remain at rest.
2. move with constant acceleration.
3. move with constant velocity.
4. move with linearly increasing acceleration.
5. You cannot tell from the information given.



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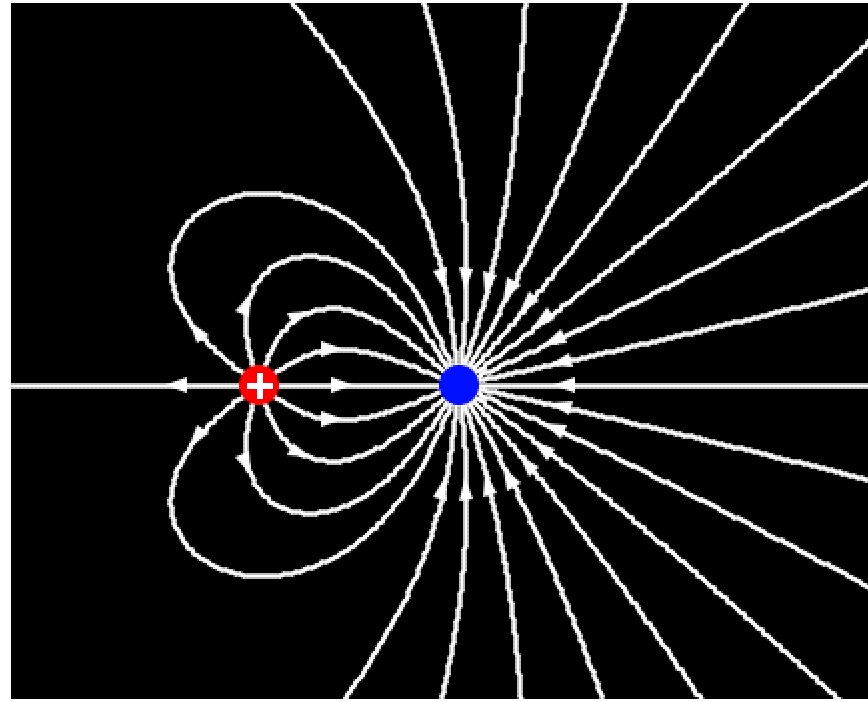
Field lines

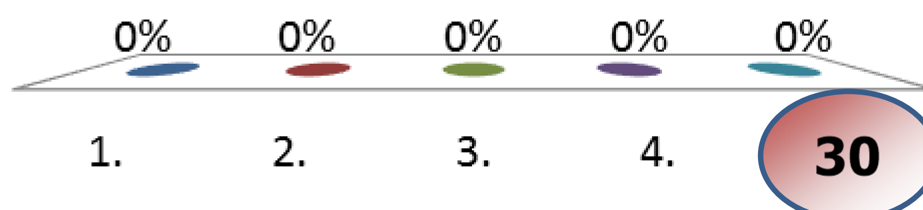
Rules for drawing field lines:

- Electric field lines begin on positive charges and end on negative charges, or at infinity.
- Lines are drawn symmetrically leaving or entering a charge.
- The number of lines entering or leaving a charge is proportional to the magnitude of the charge.
- The density of lines at any point (the number of lines per unit length perpendicular to the lines themselves) is proportional to the field magnitude at that point.
- At large distances from a system of charges, the field lines are equally spaced and radial as if they came from a single point charge equal in magnitude to the net charge on the system (presuming there is a net charge).
- No two field lines can cross since the field magnitude and direction must be unique.

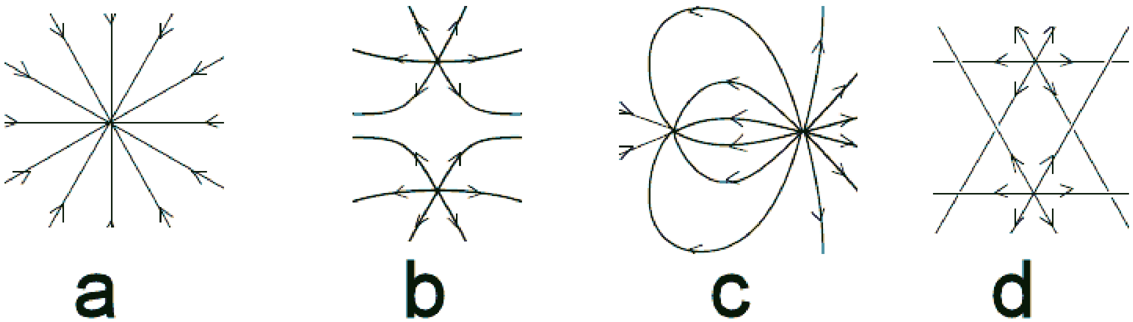
The red charge on the left is a positive 1 microCoulomb charge.
What is the magnitude and sign of the blue charge on the right?



1. +1 microCoulomb
2. +2.2 microCoulomb
3. -2.6 microCoulomb
4. +3.6 microCoulomb
5. -3.6 microCoulomb



Are all the diagrams below valid field line diagrams?



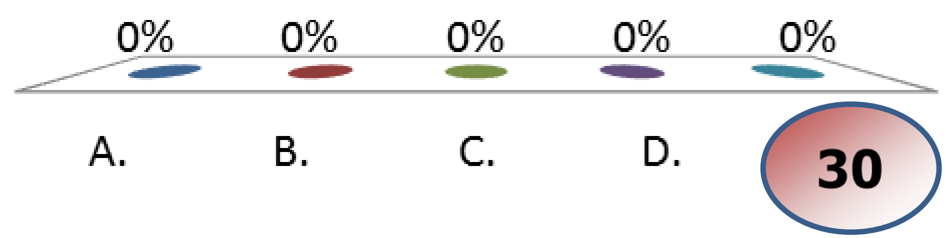
A. Yes.

B. No, diagrams
b and d are not valid.

C. Only diagram b is not valid.

D. Only diagram d is not valid.

E. Diagram c is not valid.



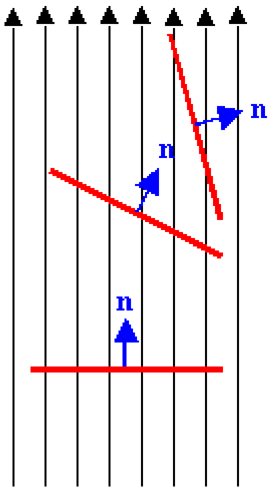
Flux

The flux of a vector field through a surface area is the amount of whatever the field represents passing through the area.

Flux is the total amount of something crossing the surface, it is not something per unit area.

Field lines help us to visualize a vector field.

The density of the field lines is proportional to the strength of the field.



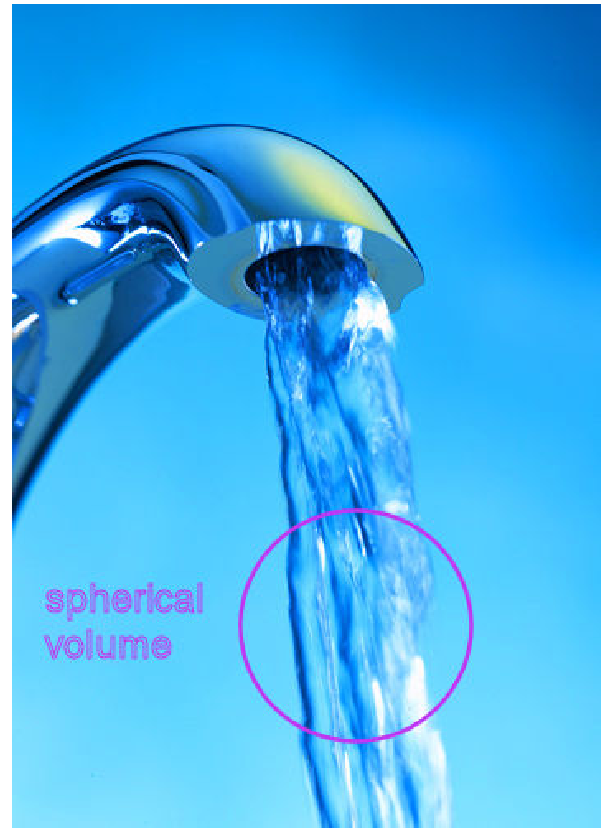
The number of field lines passing through an area A is proportional to the flux through that area.

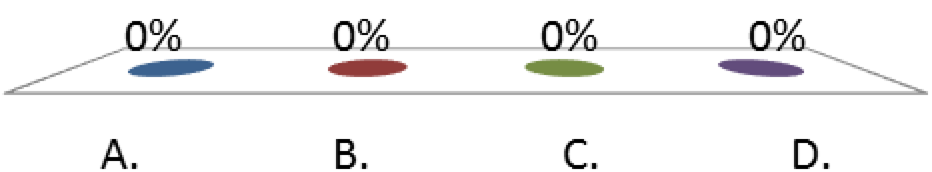
The net flux through a surface enclosing a volume can be positive or negative. It is proportional to the number of field lines leaving a volume minus the number of field entering the volume.

If there is no source or sink of field lines inside the volume, the net flux is zero.

The flux of water through this spherical volume is

A. Positive,
B. Negative,
C. Zero,
D. Undefined.





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Gauss' law

Gauss's law relates the electric flux over a closed surface to the enclosed charge,

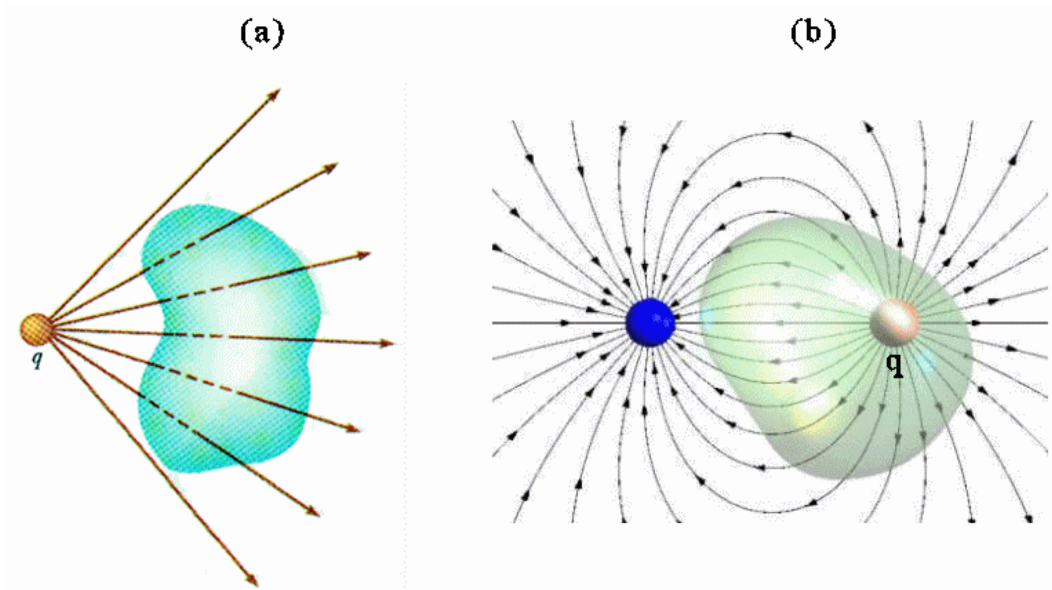
$$\Phi_e = Q_{enclosed}/\varepsilon_0$$

where the flux is defined as $\Phi_e = \sum \Delta\phi_e$, with

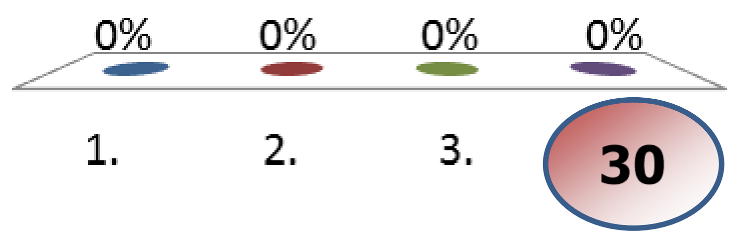
$$\Delta\Phi_e = \mathbf{E}\cdot\Delta\mathbf{A} = E_{perpendicular}*\Delta A = E\ \Delta A\cos\theta.$$

If a charge distribution has a high degree of symmetry, then Gauss' law alone can be used to determine the magnitude of the electric field. The direction must be deduced from the symmetry of the situation.

Compare the electric flux through surfaces (a) and (b). All charges have magnitude q.

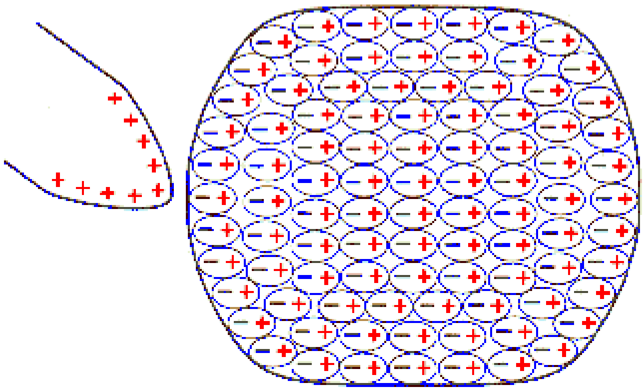


1. The flux through both surfaces is q/ε_0.
2. The flux through both surfaces is 0.
3. The flux through the right surface surfaces is $2q/\varepsilon_0$ while the flux through the left surface is q/ε_0 .
4. None of the above.

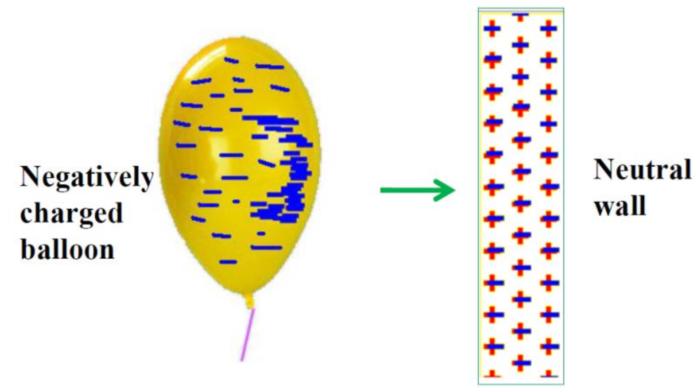


Polarization

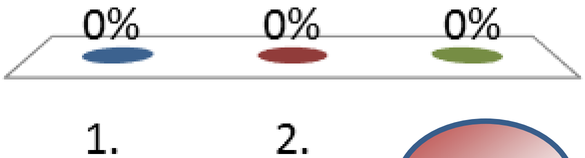
When a charged object is brought near a neutral object it can polarize the neutral object. If electrons are repelled by the charged object, nuclei are attracted, or vice versa. Even in insulators the average position of the electrons can shift by a small amount with respect to the position of the nuclei, resulting in an effective surface charge density.



What do you think will happen when a negatively charged balloon is moved towards the neutral wall?



1. The balloon will be attracted to the wall.
2. The balloon will be repelled by the wall.
3. The balloon will feel no force since the wall is neutral.



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