

Background:

The electric field around a point charge is found by: $E = kq/r^2$

If there are multiple charges, the net field at any point is the vector sum of the fields. For a large number of point charges distributed uniformly on the surface or throughout an object, Gauss's law is a convenient way of simplifying this calculation.

Gauss's Law says that the electric flux, which is the dot product of the electric field and the surface area of the Gaussian surface that encloses the charge, is equal to the amount of charge enclosed divided by the permittivity of free space:

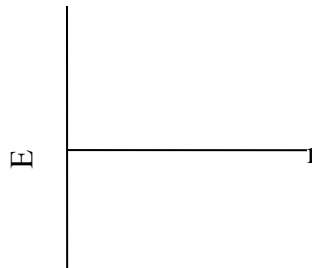
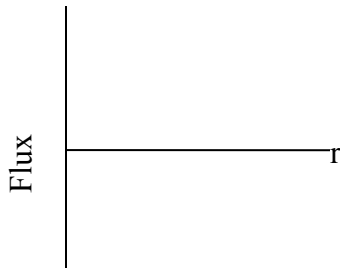
$$\mathbf{E} \cdot \mathbf{A} = q_{\text{enc}}/\epsilon_0$$

The area vector is perpendicular to the surface area, so a Gaussian surface is chosen so that the electric field passes through either perpendicular or parallel to the surface. If the field is parallel to the surface, the flux is equal to zero and if the field is perpendicular to the surface, the dot product becomes simple multiplication: $E \times A$. Common Gaussian surfaces are spheres, and cylinders, though other shapes can be used.

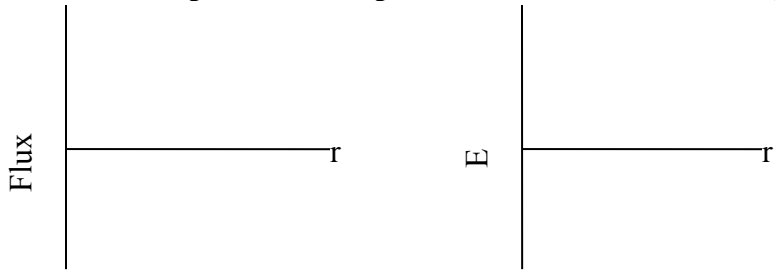
Simulation 1: Point Charge

Before you start, answer the following questions:

1. What shape would you choose for your Gaussian surface?
2. On the graphs below, predict what you think the graphs of flux v. radius and electric field v. radius will look like:



Now open the simulation for the point charge. Press “Play” and the Gaussian surface will expand with respect to the radius. Draw the graphs you observe below.



1. Why do you think the Flux graph looks the way it does?
2. What would you have to do to change the Flux?
3. How would you describe the Electric Field graph? Is it consistent with what you know about point charges?

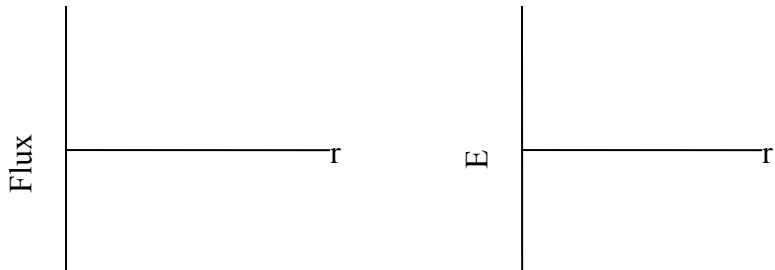
Increase the amount of charge and drag the radius back to 0.1m.

4. Describe any similarities and differences you see in the two graphs.
5. What happens if you make the charge negative?

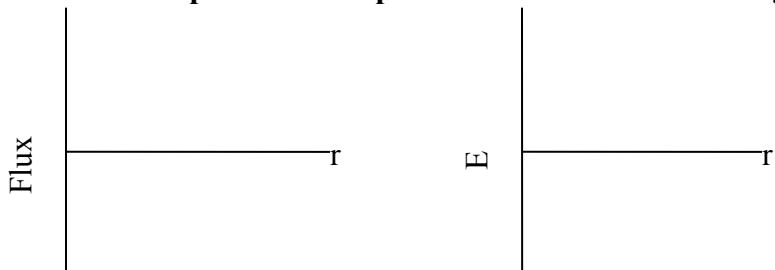
Simulation 2: Spherical Conductor

Before you start, answer the following questions:

1. What shape would you choose for your Gaussian surface?
2. On the graphs below, predict what you think the graphs of flux v. radius and electric field v. radius will look like:



Now open the simulation for the point charge. Press “Play” and the Gaussian surface will expand with respect to the radius. Draw the graphs you observe below.



3. Why do you think the Flux graph looks the way it does?
4. How would you describe the Electric Field graph? Use Gauss’s Law to explain why the field is zero inside the conductor. Compare the field outside the conductor to the graph seen with the point charge.

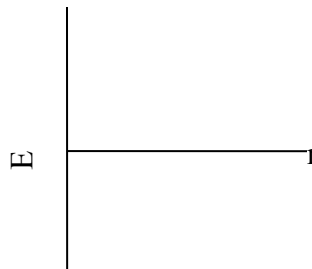
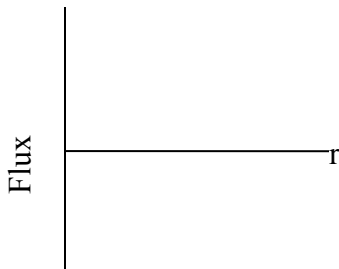
Increase the amount of charge and drag the radius back to 0 m.

- Describe any similarities and differences you see in the two graphs.
- What happens if you make the charge negative?
- The graph experiences a transition at one particular radius. What is special about this radius?

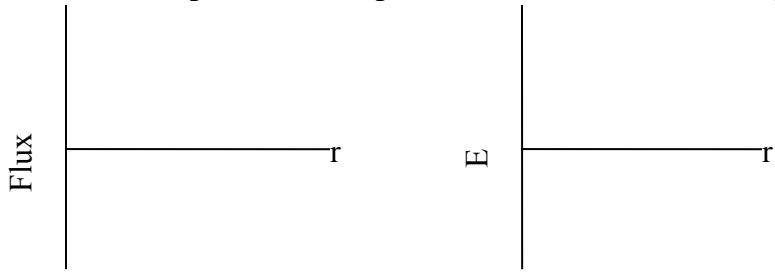
Simulation 3: Sphere with a Uniform Charge Distribution

Before you start, answer the following questions:

- What shape would you choose for your Gaussian surface?
- On the graphs below, predict what you think the graphs of flux v. radius and electric field v. radius will look like:



Now open the simulation for the point charge. Press “Play” and the Gaussian surface will expand with respect to the radius. Draw the graphs you observe below.



3. Why do you think the Flux graph looks the way it does?
4. Why does the first portion of this graph look so different from what we have seen in the previous two examples?
5. How would you describe the Electric Field graph? Why does the field increase at first? Outside the sphere, how does the electric field compare to the previous simulations? Use Gauss's Law to justify your answers.

Increase the charge density and drag the radius back to 0 m.

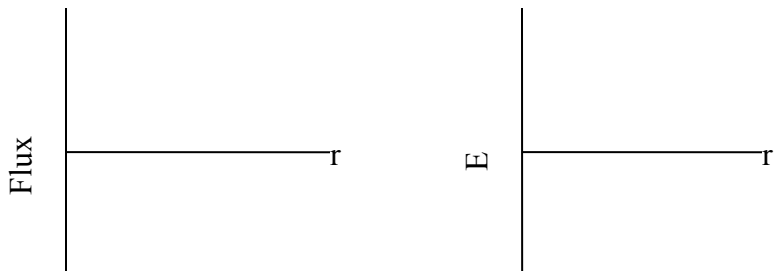
6. Describe any similarities and differences you see in the two graphs.

7. What happens if you make the charge negative?

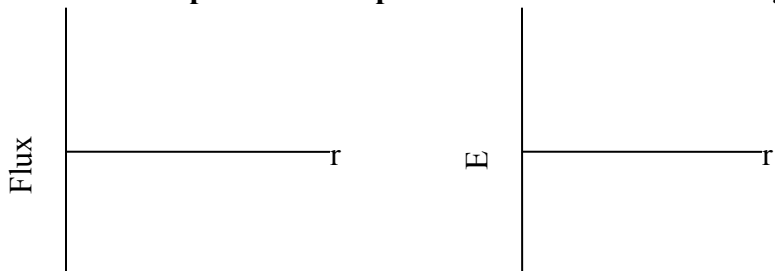
Simulation 4: Line of Charge

Before you start, answer the following questions:

1. What shape would you choose for your Gaussian surface?
2. On the graphs below, predict what you think the graphs of flux v. radius and electric field v. radius will look like:



Now open the simulation for the point charge. Press “Play” and the Gaussian surface will expand with respect to the radius. Draw the graphs you observe below.



3. Why do you think the Flux graph looks the way it does? How could the amount of flux be changed?
4. Is there any portion of the cylinder that experiences a flux of zero? Why/Why not?

5. How would you describe the Electric Field graph? Is it consistent with what you know about point charges?

Increase the linear charge density and drag the radius back to 0.1m.

6. Describe any similarities and differences you see in the two graphs.

7. What happens if you make the charge negative?