Name ____

UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

PH 106-4 / LeClair Fall 2008

Quiz 2: Gauss

$\vec{\mathbf{E}} = \frac{k_e q}{r^2}\,\hat{\mathbf{r}}$ point charge $\Phi_E = \oint_S \vec{\mathbf{E}} \cdot \hat{\mathbf{n}}\, dA = 4\pi k_e q_{\text{encl}}$ $\oint \vec{\mathbf{E}} \cdot \hat{\mathbf{n}}\, dA = |\vec{\mathbf{E}} \cdot \hat{\mathbf{n}}| A_{\text{surf}}$ (clever surface)

1. If the net flux through a closed surface is *zero*, the following four statements *could be true.* Which of the statements *must be true?*

- □ There are no charges inside the surface
- ■ The net charge inside the surface is zero
- □ The electric field is zero everywhere on the surface
- ■ The number of electric field lines entering the surface equals the number leaving the surface

Only the second and fourth choices *must* be true.

The first statement is not necessarily true because an equal number of positive and negative charges could be present inside the surface. The third is not necessarily true either: consider a point charge located *outside* of a Gaussian surface (say, a point charge located just outside a sphere). A nonzero electric field exists everywhere on the surface, but the charge is not enclosed within the surface, so the net flux is still zero.

2. A point charge q is located at the center of a spherical shell of radius a that has a charge $-q$ uniformly distributed on its surface. Find the electric field for a point a distance $r > a$ from the center of the shell (*i.e.*, outside the sphere).

- □ $E = \frac{k_e q}{r^2}$
- □ $E = \frac{k_e q}{4\pi r^2}$
- ■ $E = 0$
- □ $E = \frac{k_e q^2}{r^2}$

From Gauss' law, we can find the field at a distance r from some point by finding the flux through a sphere of radius r centered on that point. The flux through that sphere must simply be the net charge enclosed within the sphere (divided by ϵ_0).

Outside of the spherical shell, what charge would be enclosed by a sphere of radius r? The *net* charge enclosed would be the point charge plus the spherical shell, $q_{\text{tot}} = q + (-q) = 0$. Since there is no charge enclosed, the flux through our Gaussian sphere is zero, and the electric field is zero.

Remember, the spherical shell looks like a point charge of magnitude $-q$ if we are at a distance $r > a$. This means the whole arrangement of charges looks like two point charges, q and $-q$ at the same position, which just cancel each other out.

3. A spherical surface surrounds a point charge q. Describe what happens to the total flux through the surface if the charge is moved outside the surface

- □ The flux is increased.
- □ The flux is decreased.
- □ The flux remains constant.
- ■ The flux goes to zero.

See the answers to the previous two questions: no enclosed charge means no flux.

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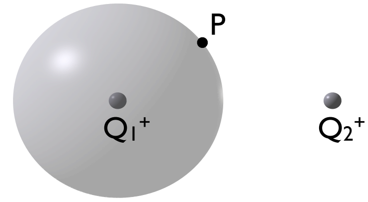
4. A spherical surface surrounds a point charge q. Describe what happens to the total flux through the surface if the volume of the sphere is doubled.



- □ The flux is tripled.
- □ The flux decreases by 1/3.
- ■ The flux remains constant.
- □ The flux goes to zero.

The total flux through *any* closed surface containing a charge q is always q/ϵ_0, irrespective of the size or shape of the surface. Doubling the volume of the sphere makes no difference, since the same charge q is enclosed..

5. In the figure above, a point charge $1Q^+$ is at the center of an imaginary spherical Gaussian surface and another point charge $2Q^+$ is outside of the Gaussian surface. Point P is on the surface of the sphere. Which one of the following statements is true?

- □ Both contribute to the net electric flux through the sphere but only $1Q^+$ contributes to the electric field at point P.
- □ Both charges contribute to the net electric flux through the sphere but only $2Q^+$ contributes to the electric field at point P.
- ■ Only $1Q^+$ contributes to the net electric flux through the sphere but both charges contribute to the electric field at point P.
- □ Only $2Q^+$ contributes to the net electric flux through the sphere but both charges contribute to the electric field at point P.
- □ Only $1Q^+$ contributes to the net electric flux through the sphere and to the electric field at point P on the sphere.
- □ Only $2Q^+$ contributes to the net electric flux through the sphere and to the electric field at point P on the sphere.
- □ I don't know (this answer is worth 1/10 of full credit)

We first note that only Q_1^+ can contribute to the flux through the Gaussian surface, since it is the only charge enclosed by the surface. However, *both* charges contribute to the electric field at the particular point P. Imagine that the spherical surface wasn't there at all - the electric field at P would clearly have a contribution from both charges. The total flux through the *entire* sphere does depend on only Q_1^+, as Gauss' law says it must, but the field at any *particular* point on the sphere does depend on Q_2^+.