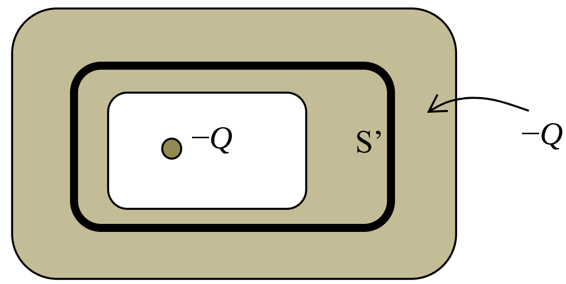
Name: ____ Section: ____

Tuesday, September 22

Quiz 4A

Consider a block made of a conducting material that has a cavity inside of it. A charge $-Q$ is inside the cavity, and the block (shaded area) has a net charge of $-Q$.



a. What is the total charge on the outer surface of the block? Justify your answer.

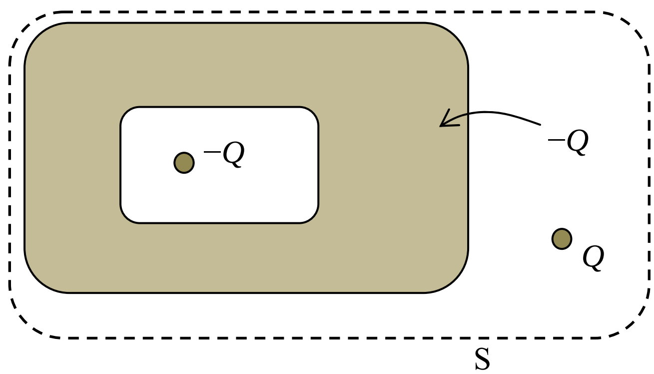
E = 0 inside the block. Thus, the flux through S' is zero. But this means that the charge inclosed by S' is zero:

$$-Q + Q_{inner} = 0 \quad \Rightarrow \quad Q_{inner} = Q.$$

But since the total charge in the block is −Q

$$Q_{outer} + Q_{inner} = -Q \quad \Rightarrow \quad Q_{outer} = -Q - Q_{inner} = -2Q$$

b. Now, another charge Q is brought near the block from outside far away. What is the total charge on the outer surface of the block? Justify your answer.



It's still −2Q, because nothing changes in the reasoning above. The only thing that will change is the distribution of the charge throughout the surface.

c. Find the total electric flux through the closed surface S (which encloses the block and the point charge Q).

Using Gauss's law,

$$\Phi = \frac{q_{\text{enclosed by S}}}{\varepsilon_0} = \frac{-Q - Q + Q}{\varepsilon_0} = -\frac{Q}{\varepsilon_0}$$

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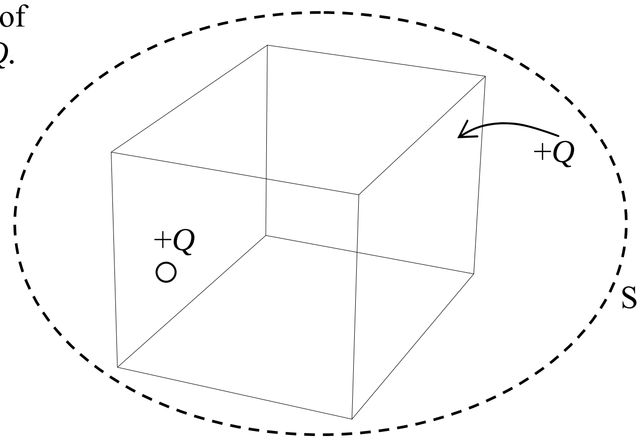
Quiz 4B

A positive charge +*Q* is inside a cubic box made of conducting material. The box has a net charge +*Q*.



a. What is the total charge on the outer surface of the conducting cube?

E = 0 inside the walls of the cube. Thus, the flux through a Gaussian surface that is inside these walls is zero. But this means that the charge inclosed by it is zero:

$$Q + Q_{inner} = 0 \quad \Rightarrow \quad Q_{inner} = -Q.$$

But since the total charge in the block is +Q

$$Q_{outer} + Q_{inner} = Q \quad \Rightarrow \quad Q_{outer} = Q - Q_{inner} = 2Q$$

b. What is the total electric flux through a closed surface S enclosing the cube?

Using Gauss's law,

$$\Phi = \frac{q_{\text{enclosed by S}}}{\varepsilon_0} = \frac{+Q+Q}{\varepsilon_0} = \frac{2Q}{\varepsilon_0}$$

c. Now the cube is grounded. What is the total charge on the outer surface of the conducting cube?

If the cube is grounded, all the charge on the outer surface flows to the ground, so $Q_{outer} = 0$.

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Quiz 4C

Consider a very large non-conducting sheet with uniform surface charge density σ. There is a cube to the right of the sheet with two opposing surfaces parallel to the charged sheet as shown in figure 1. The edge length of the cube is a.

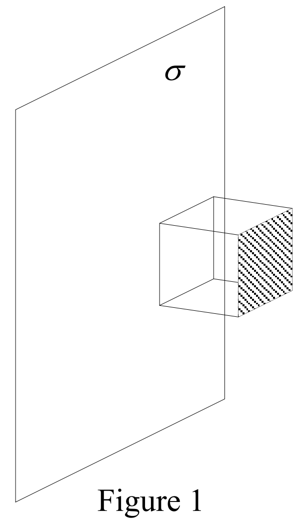

Figure 1

a. Find the flux through the shaded surface (side parallel to the sheet and far from the sheet).

The electric field produced by a large uniformly charged sheet is $E = \dfrac{\sigma}{2\varepsilon_0}$ *directed perpendicularly to the sheet.*

Thus, the flux is $\Phi = Ea^2 = \dfrac{\sigma}{2\varepsilon_0}a^2$

b. Now, another uniformly charged non-conducting sheet with surface charge density 2σ is placed to the right of the cube, parallel to the first sheet (figure 2). What is now the flux through the shaded surface?

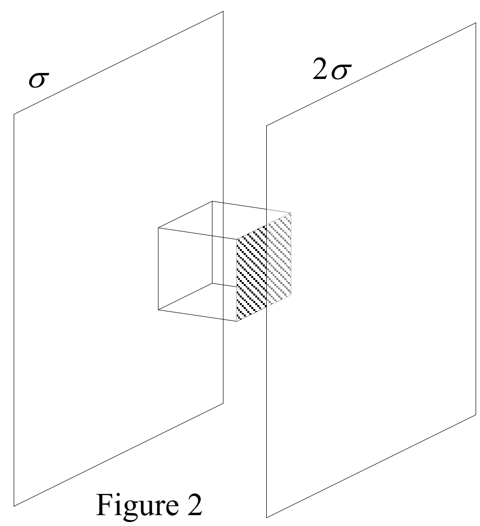

Figure 2

The net electric field is the superposition of the electric fields produced by both sheets, so

$$E = \frac{\sigma}{2\varepsilon_0} - \frac{2\sigma}{2\varepsilon_0} = -\frac{\sigma}{2\varepsilon_0}$$

The minus sign indicated that the electric field points toward the first sheet. Because this a closed surface, we should take the area vector pointing outward, which in this case means opposite to the electric field. Thus, the flux is $\Phi = Ea^2 = -\dfrac{\sigma}{2\varepsilon_0}a^2$

c. With the situation described in part b, what is the total flux through the whole cube that is between these two charged sheets?

There is no charge enclosed by the cube, so the net flux must be zero.

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Quiz 4D

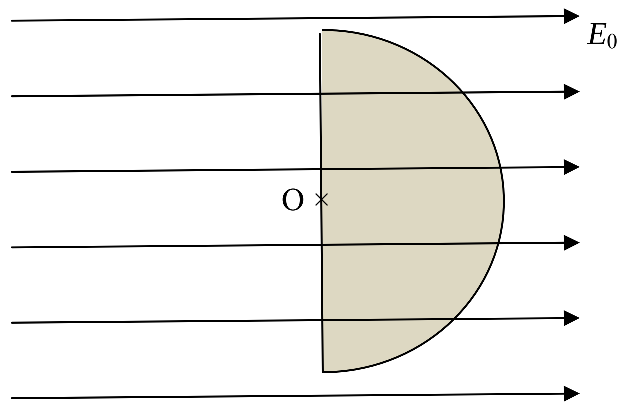
There is a uniform electric field of magnitude E_0 in the positive x direction.

a. What is the electric flux through a circular surface of radius R whose normal direction is parallel to the electric field?

Since the electric field and the area vector are parallel, the flux is simply

$$\Phi = E_0 A = E_0 \pi R^2$$

b. Now consider a spherical shell of radius R whose center is at the origin. The shell is then cut in two by a blade that runs along the yz plane. The left hemisphere is removed. What is the net electric flux through the right hemisphere? (see figure)



The effective area (projection of this area into the direction perpendicular to the electric field) is πR^2, so $\Phi = E_0 A = E_0 \pi R^2$ again.
You can also think in terms of number of lines: every electric field line that goes through the hemispherical surface also goes through the "base" circle.

c. A charge $+Q$ is placed at the origin. What is the net electric flux through the hemisphere described in part b?

Now we have the electric flux due to the the uniform electric field from part b plus the electric flux produced by the new charge. If we had a whole sphere, the flux through it would be $\Phi = \frac{Q}{\varepsilon_0}$ because of Gauss's law. When we remove half of the sphere, the flux is also half. Thus, the total flux is $\Phi = E_0 \pi R^2 + \frac{Q}{2\varepsilon_0}$.