CHAPTER 22
GAUSS'S LAW

Discussion Questions

Q22.1 The total flux through the balloon is q/ϵ_0, regardless of the size of the balloon.

Q22.2 The flux through each surface is equal to $\dfrac{Q_{\text{encl}}}{\varepsilon_0}$, where Q_{encl} is the net charge enclosed by the surface. Surface *A*: $Q_{\text{encl}} = +q$ and $\Phi_{EA} = +q/\varepsilon_0$. Surface *B*: $Q_{\text{encl}} = +q$ and $\Phi_{EB} = +q/\varepsilon_0$. Surface *C*: $Q_{\text{encl}} = +2q$ and $\Phi_{EC} = +2q/\varepsilon_0$. Surface *D*: $Q_{\text{encl}} = 0$ and $\Phi_{ED} = 0$.

Q22.3 The electric flux through a surface depends only on the charge within the surface. The net flux through the surface due to charges outside the surface is zero. The total flux through each of these surfaces would remain the same.

Q22.4 The electric field doesn't need to be zero on the surface, only the total electric flux through the surface needs to be zero. The electric field would be zero everywhere on the surface, for example, if the surface was totally in the material of a conductor.

Q22.5 The electric field is inversely proportional to the square of the distance from the point charge, so the field at each point on the surface changes. Gauss's law says that the total flux through a closed surface depends only on the net charge enclosed by the surface and that hasn't changed, so the total flux doesn't change. All the field lines from the point charge still pass outward through the surface.

Q22.6 Measure the electric field flux through a Gaussian surface that encloses the box. The total flux through the surface is nonzero if and only if there is no net charge in the box.

Q22.7 The electric field inside the conductor is still zero. The point charge polarizes the charge on the surface of the sphere such that the electric field of the surface charge exactly cancels the electric field of the point charge at all points within the sphere. The net charge on the sphere is still on its surface. But this charge is not distributed uniformly over the surface of the sphere. There is more positive charge in the area near the negative point charge, because the negative point charge pushes away electrons on the sphere.

Q22.8 Gauss's law would not be valid. For a Gaussian sphere of radius r with a point charge at the center, the electric field at the surface would be proportional to $1/r^3$. The area of the sphere is proportional to r^2, so the total flux through the sphere will be proportional to $1/r$ and will depend on the radius of the sphere.

Q22.9 No. These free electrons aren't excess charges; their negative charge is exactly balanced by the positive charge of the ions in the material.

Q22.10 Negative charge on the sphere is pulled toward the van de Graff generator and this leaves positive charge on the side of the sphere that is farthest from the generator. The sphere has zero net charge. For a Gaussian surface that lies just outside the surface of the sphere the enclosed charge is $Q_{\text{encl}} = 0$. Therefore, Gauss's law says the net flux through the sphere is zero. Any Gaussian surface that is entirely inside the sphere encloses zero charge and the electric field inside the sphere is zero.

Q22.11 Lightning is a flow of electrons. The lightning current runs through the copper cables since copper is a good conductor of electricity whereas the house material is not. The rods are pointed because the electric field is strong there when the rod gains some charge. The strong electric field ionizes the air near the sharp point and provides a conducting path.

Q22.12 A point charge affects the electric field outside the conductor. The point charge induces a charge of equal magnitude and opposite sign on the inner surface of the conductor. The conductor is overall neutral so there is a charge equal to the point charge spread over the exterior surface of the conductor. This exterior charge produces an electric field outside the conductor. Charge outside the conductor doesn't produce any electric field inside the cavity. The electric field of the external charge is shielded by the conductor.

Q22.13 A component of field parallel to the surface would exert a force on the free electrons in the conductor and cause them to move. In an insulator there are no charges free to move and there is no reason why the electric field at the surface of an insulator can't have a component parallel to the surface.

Q22.14 (a) Consider a small Gaussian surface somewhere in the region. Since the electric field is uniform the flux through the surface must be zero. Therefore, the enclosed charge $Q_{\text{encl}} = \int \rho \, dV$ must be zero. But since this must be true for any volume in the region, $\rho = 0$ everywhere in the region. (b) No. For example, consider the region near a point charge. There is no charge there but the electric field, which is due to the nearby point charge, is not uniform.

Q22.15 (a) If $\rho > 0$ and uniform, then the charge inside any closed surface is greater than zero. Therefore, $\Phi_E > 0$ for any Gaussian surface. But if the field is uniform then $\Phi_E = 0$ for any Gaussian surface, so the field can't be uniform. (b) Yes. The flux through the surface of the bubble must be zero but that is true for a uniform field within the bubble, so that kind of field is allowed. (See Problem 22.57.)

Q22.16 Apply Gauss's law to a Gaussian surface that lies entirely within the metal. $E = 0$ at all points within the meal conductor so the flux through this surface is zero. By Gauss's law the Gaussian surface must enclose zero net charge. This means that there is net charge $+Q$ on the inner surface of the metal. Since the solid is grounded there is no excess charge on the outer surface of the metal. Any excess charge there would be neutralized by charge from the earth. A gaussian surface entirely outside the piece of metal would enclose zero net charge ($-Q$ from the charge in the cavity plus $+Q$ on the inner surface of the metal). The flux through the surface, for any shape, would be zero so the electric field at all points outside the piece of metal is zero. It is reasonable to say the grounded conductor has shielded the region outside the conductor from the effects of the charge $-Q$. There is nothing like positive and negative mass (the gravity force is always attractive), so this cannot be done for gravity.