THE EGYPTIAN E-LEARNING UNIVERSITY

Physics (2)

Section (4)

Electric Flux

$$\Phi_E = EA_\perp = EA\cos\theta$$

$$\Phi_{E,i} = E_i\,\Delta A_i\,\cos\theta_i = \vec{\mathbf{E}}_i \cdot \Delta\vec{\mathbf{A}}_i$$

$$\Phi_E \approx \sum \vec{\mathbf{E}}_i \cdot \Delta\vec{\mathbf{A}}_i$$

$$\Phi_E \equiv \int_{\text{surface}} \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}}$$

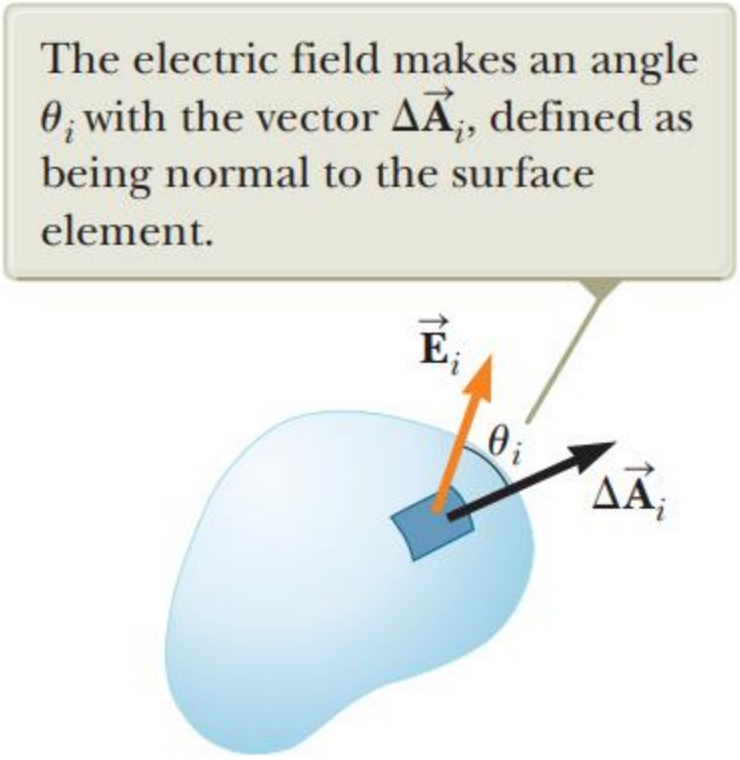


Figure 24.3 A small element of surface area ΔA_i in an electric field.

Electric Flux

MCQ:

1- A 40.0-cm-diameter circular loop is rotated in a uniform electric field until the position of maximum electric flux is found. The flux in this position is measured to be $5.20 \times 10^5\ \mathrm{N \cdot m^2/C}$. What is the magnitude of the electric field?

a) $4.14 \times 10^6\ \mathrm{N/C}$
b) $4.14 \times 10^3\ \mathrm{N/C}$
c) $9.45 \times 10^9\ \mathrm{N/C}$
d) $0\ \mathrm{N/C}$

Answer: a

Gauss's Law

In this section, we describe a general relationship between the net electric flux through a closed surface (often called a *gaussian surface*) and the charge enclosed by the surface. This relationship, known as *Gauss's law*, is of fundamental importance in the study of electric fields.

the net flux through *any* closed surface surrounding a point charge q is given by q/ϵ_0 and is independent of the shape of that surface.

$$\Phi_E = \oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{q_{\text{in}}}{\epsilon_0} \qquad \textbf{(24.6)}$$

Gauss's Law

Exercise 2:

Find the net electric flux through the spherical closed surface shown in Figure P24.8. The two charges on the right are inside the spherical surface.

Solution:

The gaussian surface encloses the +1.00-nC and –3.00-nC charges, but not the +2.00-nC charge. The electric flux is therefore

$$\Phi_E = \frac{q_{\text{in}}}{\epsilon_0} = \frac{\left(1.00\times 10^{-9}\ \text{C} - 3.00\times 10^{-9}\ \text{C}\right)}{8.85\times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2} = \boxed{-226\ \text{N}\cdot\text{m}^2/\text{C}}$$

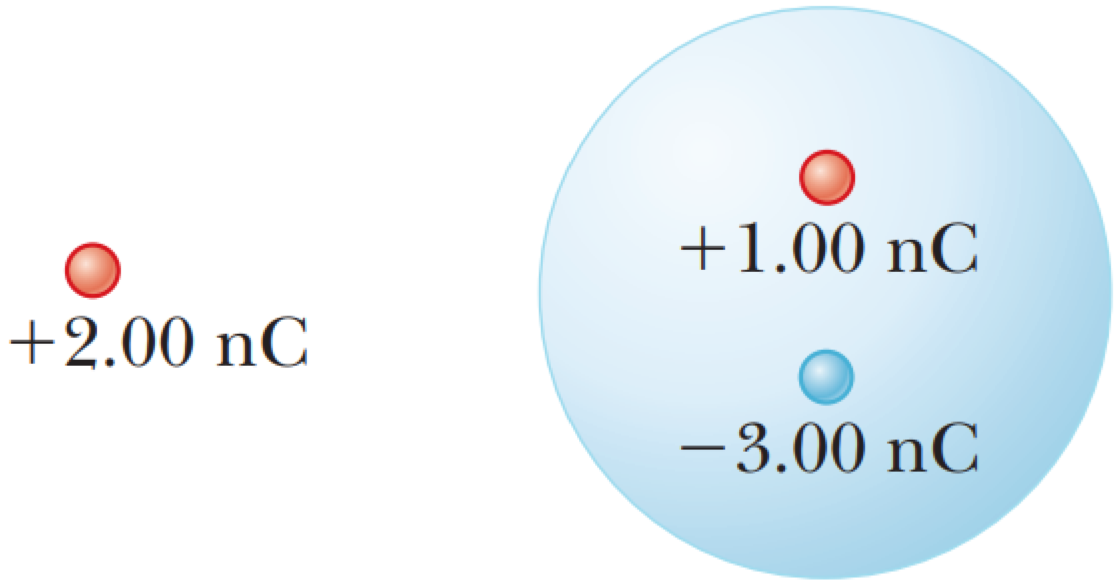


Figure P24.8

Gauss's Law

MCQ:

2- The following charges are located inside a submarine: 5.00 μC, -9.00 μC, 27.0 μC, and -84.0 μC.

Calculate the net electric flux through the hull of the submarine.

a) $-6.89 \times 10^6\ \mathrm{N \cdot m^2/C}$
b) $6.89 \times 10^6\ \mathrm{N \cdot m^2/C}$
c) $-6.89 \times 10^3\ \mathrm{N \cdot m^2/C}$
d) $6.89 \times 10^3\ \mathrm{N \cdot m^2/C}$

Answer: a

Gauss's Law

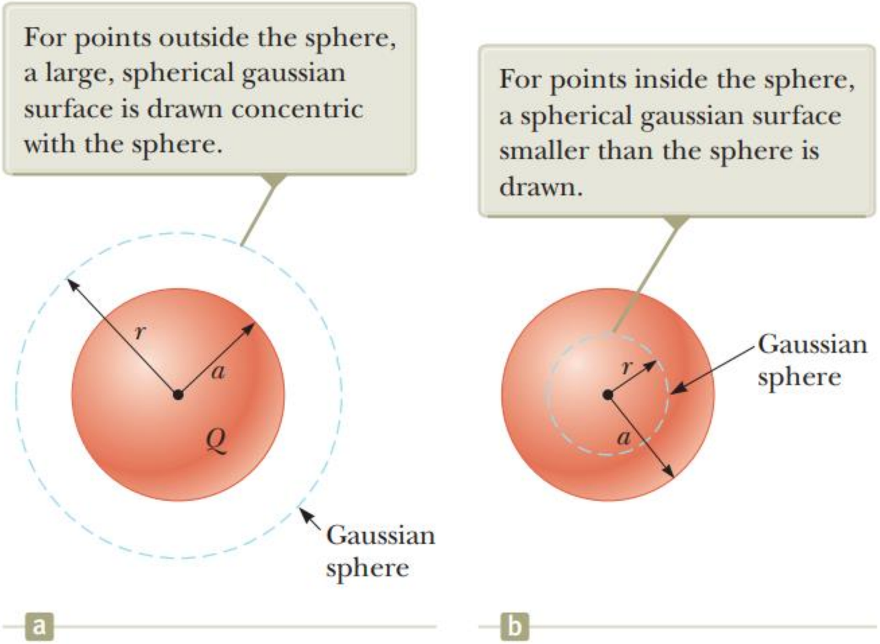
Exercise 2:

An insulating solid sphere of radius 0.5 m has a uniform volume charge density and carries a total positive charge of 5 nC.

a) Calculate the magnitude of the electric field at a point 0.8 m from the centre of the sphere.

b) Calculate the magnitude of the electric field at a point 0.3 m from the centre of the sphere.

c) Calculate the magnitude of the electric field at a point on the surface of the sphere.



Gauss's Law

a) Calculate the magnitude of the electric field at a point 0.8 m from the centre of the sphere.

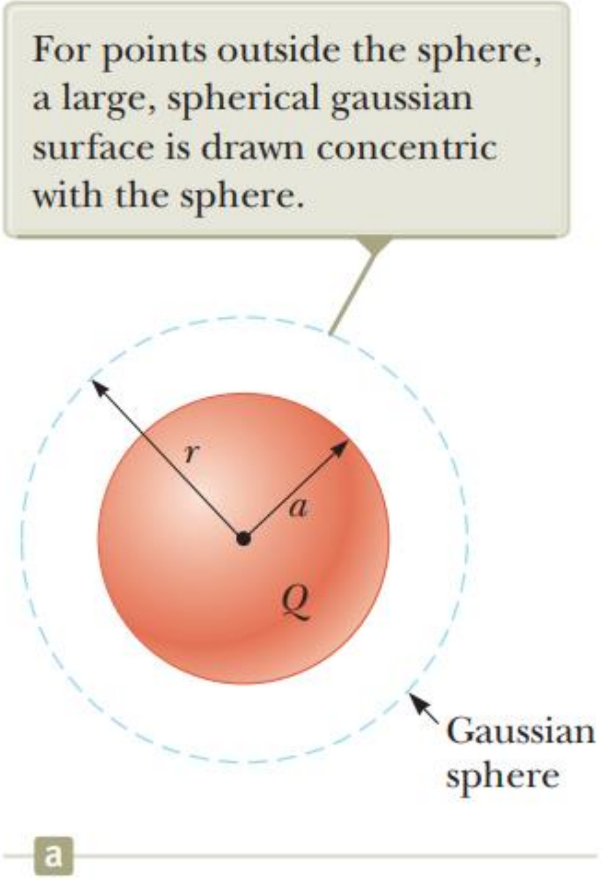
Solution:

We use the formula for calculating the electric field for a point outside the sphere.

$$(1) \quad E = \frac{Q}{4\pi\epsilon_0 r^2} = \boxed{k_e \frac{Q}{r^2} \quad (\text{for } r > a)}$$

For $Q = 5 \text{ nC} = 5 \times 10^{-9} \text{ C}$, and $r = 0.8 \text{ m}$ we get:

$$\text{E} = 8.99 \times 10^9 \times \frac{5 \times 10^{-9}}{0.8^2} = 70.23 \text{ N/C}$$



Gauss's Law

b) Calculate the magnitude of the electric field at a point 0.3 m from the centre of the sphere.

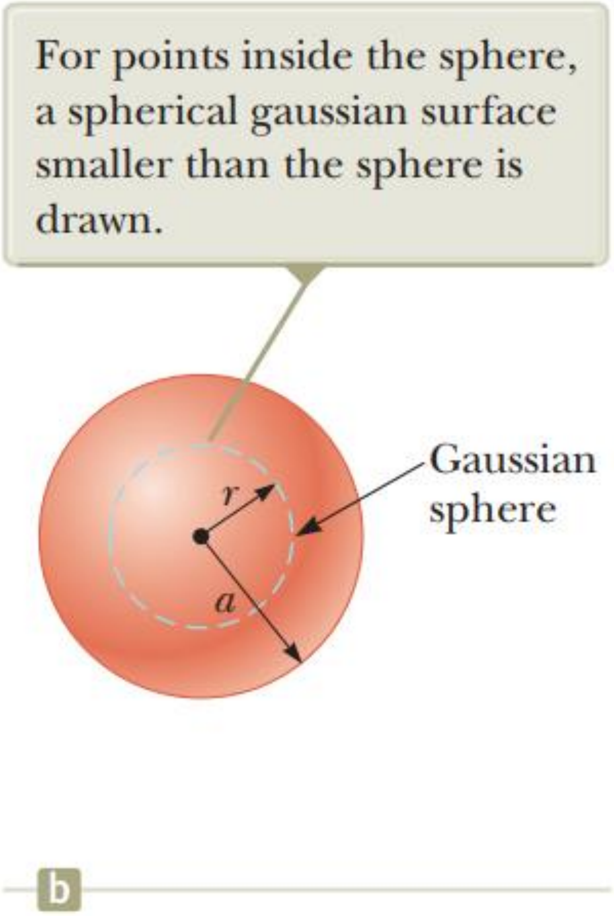
Solution:

We use the formula for calculating the electric field for a point inside the sphere.

$$(2) \quad E = \frac{Q/\frac{4}{3}\pi a^3}{3(1/4\pi k_e)} r = \boxed{k_e \frac{Q}{a^3} r \quad (\text{for } r < a)}$$

For $Q = 5\ \mathrm{nC} = 5 \times 10^{-9}\ \mathrm{C}$, $r = 0.3\ \mathrm{m}$, and $a = 0.5\ \mathrm{m}$ we get:

$$\mathrm{E} = 8.99 \times 10^9 \times \frac{5 \times 10^{-9}}{0.5^3} \times 0.3 = 107.88\ \mathrm{N/C}$$



Gauss's Law

c) Calculate the magnitude of the electric field at a point on the surface of the sphere.

Solution:

Equation (1) shows that the electric field approaches a value from the outside given by

$$E = \lim_{r \to a} \left(k_e \frac{Q}{r^2} \right) = k_e \frac{Q}{a^2}$$

From the inside, Equation (2) gives

$$E = \lim_{r \to a} \left(k_e \frac{Q}{a^3} r \right) = k_e \frac{Q}{a^3} a = k_e \frac{Q}{a^2}$$

Using either formula and substituting for $Q = 5 \text{ nC} = 5 \times 10^{-9}$ C, and $a = 0.5$ m we get:

$$\mathrm{E} = 8.99 \times 10^9 \times \frac{5 \times 10^{-9}}{0.5^2} = 179.8 \text{ N/C}$$

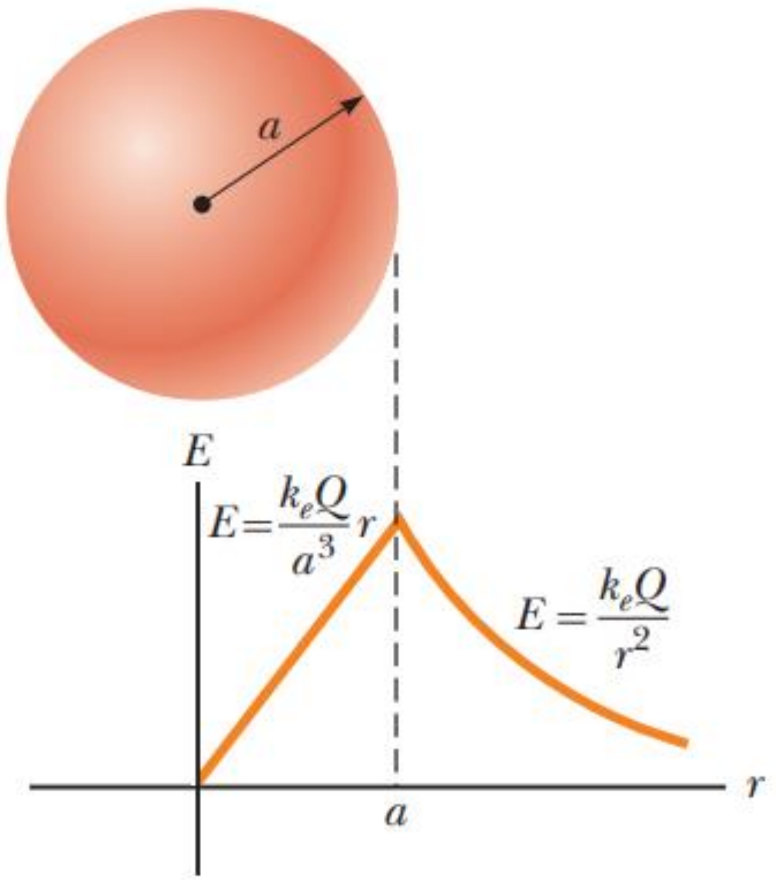


Figure 24.11

Gauss's Law

MCQ:

3- An insulating solid sphere of radius 0.7 m has a uniform volume charge density and carries a total positive charge of 9 μC.

(a) Calculate the magnitude of the electric field at a point 1.2 m from the centre of the sphere.

a) 51.88×10^9 N/C
b) 56.19×10^3 N/C
c) 12.74×10^2 N/C
d) 97.17×10^6 N/C
Answer: b

(b) Calculate the magnitude of the electric field at a point 0.4 m from the centre of the sphere.

a) 91.61×10^6 N/C
b) 54.79×10^9 N/C
c) 94.36×10^3 N/C
d) 92.86×10^2 N/C
Answer: c