LISTRIK

Muatan listrik memiliki sifat-sifat berikut :

1. Muatan yang berlawanan tanda akan saling tarik-menarik, dan muatan yang sama akan saling tolak-menolak.
2. Jumlah muatan total dalam sistem terisolasi tetap.
3. Muatan listrik dapat dikuantifikasi.

Konduktor : bahan yang mampu menghantarkan elektron dengan bebas.

Insulator : bahan yang tidak mampu menghantarkan elektron dengan bebas.

Semikonduktor : bahan yang memiliki sifat kelistrikan di antara konduktor dan isolator

Coulomb dan Ampere

Satuan muatan listik adalah **coulomb** (C).

Bila dinyatakan dalam satuan arus listrik disebut dengan **ampere** (A),

Bila muatan melewati suatu titik dalam waktu 1 detik, dimana terdapat arus listrik sebesar 1 ampere pada titik tersebut maka dinyatakan sebagai :

$$1\,\mathrm{C} = (1\,\mathrm{A})(1\,\mathrm{s}).$$

Arus listrik

Hubungan antara arus listrik dengan kecepatan muatan melewati suatu titik dinyatakan dengan :

$$i = \frac{dq}{dt} \qquad \text{(electric current).}$$

Hukum Coulomb

Gaya listrik yang diberikan oleh suatu muatan q1 pada muatan q2 dinyatakan sebagai :

$$\mathbf{F}_{12} = k_e \frac{q_1 q_2}{r^2} \hat{\mathbf{r}}$$

dengan r : jarak antar 2 muatan

r^ : vektor satuan yang mengarah dari q1 ke q2

ke : konstanta Coulomb = 8.99 X 10^9 Nm^2/C^2.

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \mathrm{N \cdot m^2/C^2}.$$

where the constant ϵ_0 (lowercase Greek epsilon) is known as the *permittivity of free space* and has the value $8.854\,2 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$.

Satuan muatan bebas yang terkecil yang ada di alam, e, adalah muatan elektron (- *e*) atau proton (+*e*), dengan *e* = 1.602 X 10^{-19} C.

Charge and Mass of the Electron, Proton, and Neutron		
Particle	**Charge (C)**	**Mass (kg)**
Electron (e)	$-1.6021917 \times 10^{-19}$	9.1095×10^{-31}
Proton (p)	$+1.6021917 \times 10^{-19}$	1.67261×10^{-27}
Neutron (n)	0	1.67492×10^{-27}

Medan listrik (*Electric Field*)

Medan listrik : tegangan listrik F*e* yang bekerja pada suatu muatan yang menempati titik tertentu, dibagi dengan besarnya muatan *q*0

$$\mathbf{E} \equiv \frac{\mathbf{F}_e}{q_0}$$

Sehingga, gaya listrik F*e* pada suatu muatan *q* yang menempati medan listrik E dinyatakan sebagai :

$$\mathbf{F}_e = q\mathbf{E}$$

Pada jarak *r* dari muatan *q*, medan listrik yang ditimbulkan muatan tersebut memenuhi persamaan :

$$\mathbf{E} = k_e \frac{q}{r^2}\,\hat{\mathbf{r}}$$

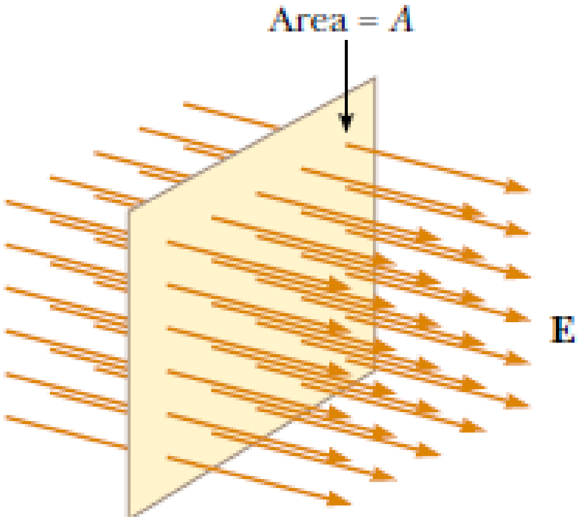
where r̂ is a unit vector directed from the charge toward the point in question. The electric field is directed radially outward from a positive charge and radially inward toward a negative charge.

Fluks listrik (*Electric Flux*)

Merupakan sejumlah garis-garis medan listrik yang menembus suatu permukaan :

$$\Phi_E = EA$$

ϕE [=] Nm^2/C



Potensial listrik (*Electric Potential*)

Bila muatan positif *q*0 bergerak antara titik A dan B dalam suatu medan listrik E, perubahan energi potensial pada sistem muatan-medan adalah :

$$\Delta U = -q_0 \int_A^B \mathbf{E} \cdot d\mathbf{s}$$

Potensial listrik *V* = *U*/*q*0 adalah besaran skalar dan memiliki satuan J/C, dengan 1 J/C = 1 V.

Arus listrik (*Electric Current*)

Adalah kecepatan muatan listrik mengalir melalui suatu permukaan.

Satuan internasional (SI) adalah ampere (A):

$$I = \frac{dQ}{dt}$$

$$1\ \mathrm{A} = \frac{1\ \mathrm{C}}{1\ \mathrm{s}}$$

Tahanan *(Resistance)*

Satuan internasional (SI) untuk tahanan R [=] ohm (Ω) yang didefinisikan sebagai volt/Ampere

$$R = \frac{\Delta V}{I}$$

$$1\ \Omega = \frac{1\ \text{V}}{1\ \text{A}}$$

Resistor

Rangkaian listrik menggunakan resistor untuk mengendalikan tingkat aliran listrik pada berbagai bagian dalam rangkaian.

The inverse of conductivity is **resistivity**[3] ρ:

$$\rho = \frac{1}{\sigma} \tag{27.10}$$

where ρ has the units ohm-meters ($\Omega \cdot \text{m}$). Because $R = \ell / \sigma A$, we can express the resistance of a uniform block of material along the length ℓ as

$$R = \rho \frac{\ell}{A} \tag{27.11}$$

Resistivities and Temperature Coefficients of Resistivity for Various Materials

Material	Resistivity[a] ($\Omega \cdot m$)	Temperature Coefficient[b] $\alpha[(°C)^{-1}]$
Silver	1.59×10^{-8}	3.8×10^{-3}
Copper	1.7×10^{-8}	3.9×10^{-3}
Gold	2.44×10^{-8}	3.4×10^{-3}
Aluminum	2.82×10^{-8}	3.9×10^{-3}
Tungsten	5.6×10^{-8}	4.5×10^{-3}
Iron	10×10^{-8}	5.0×10^{-3}
Platinum	11×10^{-8}	3.92×10^{-3}
Lead	22×10^{-8}	3.9×10^{-3}
Nichrome[c]	1.50×10^{-6}	0.4×10^{-3}
Carbon	3.5×10^{-5}	-0.5×10^{-3}
Germanium	0.46	-48×10^{-3}
Silicon	640	-75×10^{-3}
Glass	10^{10} to 10^{14}	
Hard rubber	$\sim 10^{13}$	
Sulfur	10^{15}	
Quartz (fused)	75×10^{16}	

Daya listrik (*Electrical Power*)

$$\mathcal{P} = I\,\Delta V$$

$$\mathcal{P} = I^2 R = \frac{(\Delta V)^2}{R}$$

Capacitance

(KAPASITANSI)

Kapasitansi (*C*) dari suatu kapasitor :

rasio besarnya muatan dari tiap konduktor terhadap besarnya beda potensial antar konduktor :

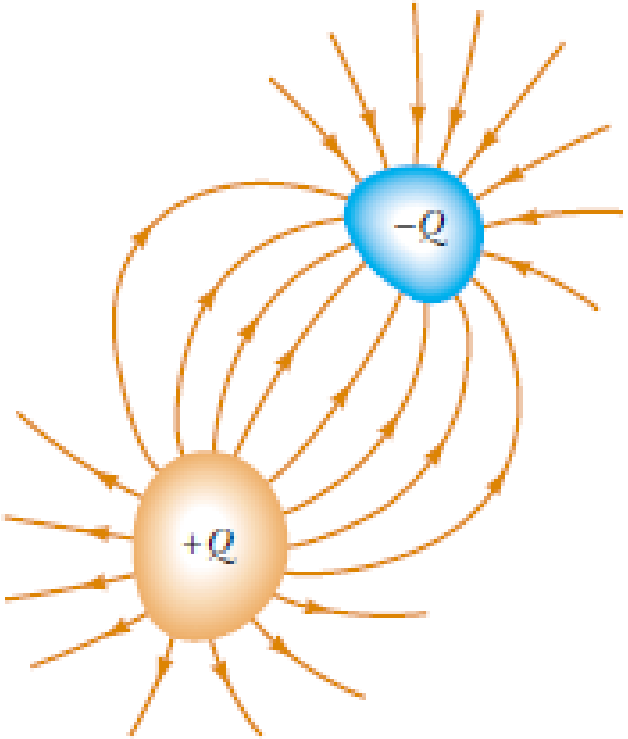


Figure 26.1 A capacitor consists of two conductors. When the capacitor is charged, the conductors carry charges of equal magnitude and opposite sign.

$$C = \frac{Q}{\Delta V}$$

capacitance is always a positive quantity

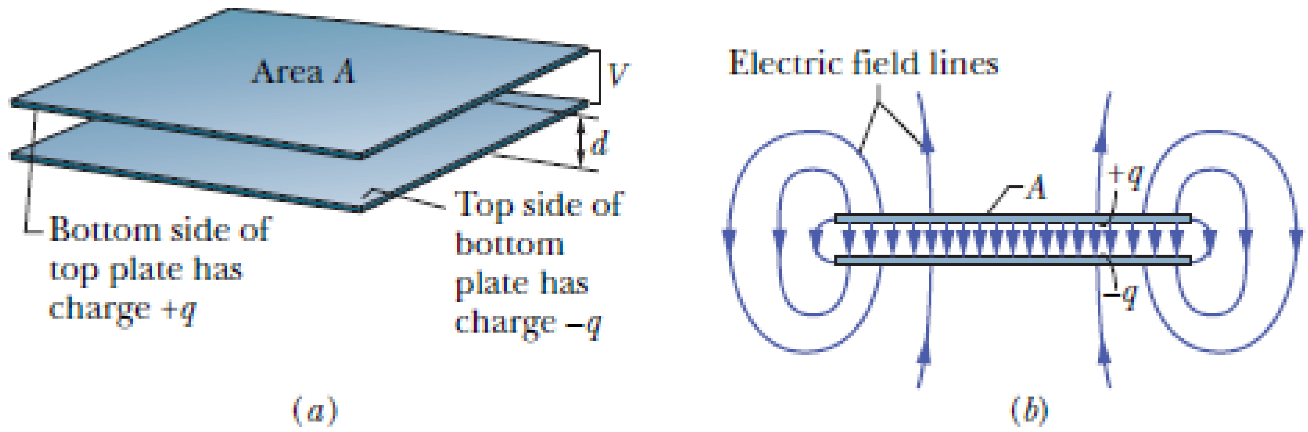
Satuan SI dari kapasitansi adalah Farad (F), sebagai penghargaan terhadap Michael Faraday

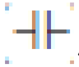
$$1\ F = 1\ C/V$$

Farad merupakan satuan yang sangat besar dari kapasitansi.

Pada prakteknya, alat-alat memiliki kapasitansi antara microfarads (10^{-6} F) sampai picofarads (10^{-12} F).

a *parallel-plate capacitor*



a *parallel-plate capacitor,* consisting of two parallel conducting plates of area *A* separated by a distance *d*. The symbol we use to represent a capacitor () is based on the structure of a parallel-plate capacitor but is used for capacitors of all geometries.

$$\sigma = Q/A$$

$$\Delta V = Ed = \frac{Qd}{\epsilon_0 A}$$

$\epsilon_0 = 1/(4\pi k_e)$ is the permittivity of free space.

- σ : surface charge density
- Q : muatan
- A : luas permukaan
- d : jarak antar permukaan
- E : medan listrik
- ΔV : beda potensial

$$E = \frac{\sigma}{\epsilon_0} = \frac{Q}{\epsilon_0 A}$$

$$C = \frac{Q}{\Delta V} = \frac{Q}{Qd/\epsilon_0 A}$$

$$C = \frac{\varepsilon_0 A}{d} \qquad \text{(parallel-plate capacitor).}$$

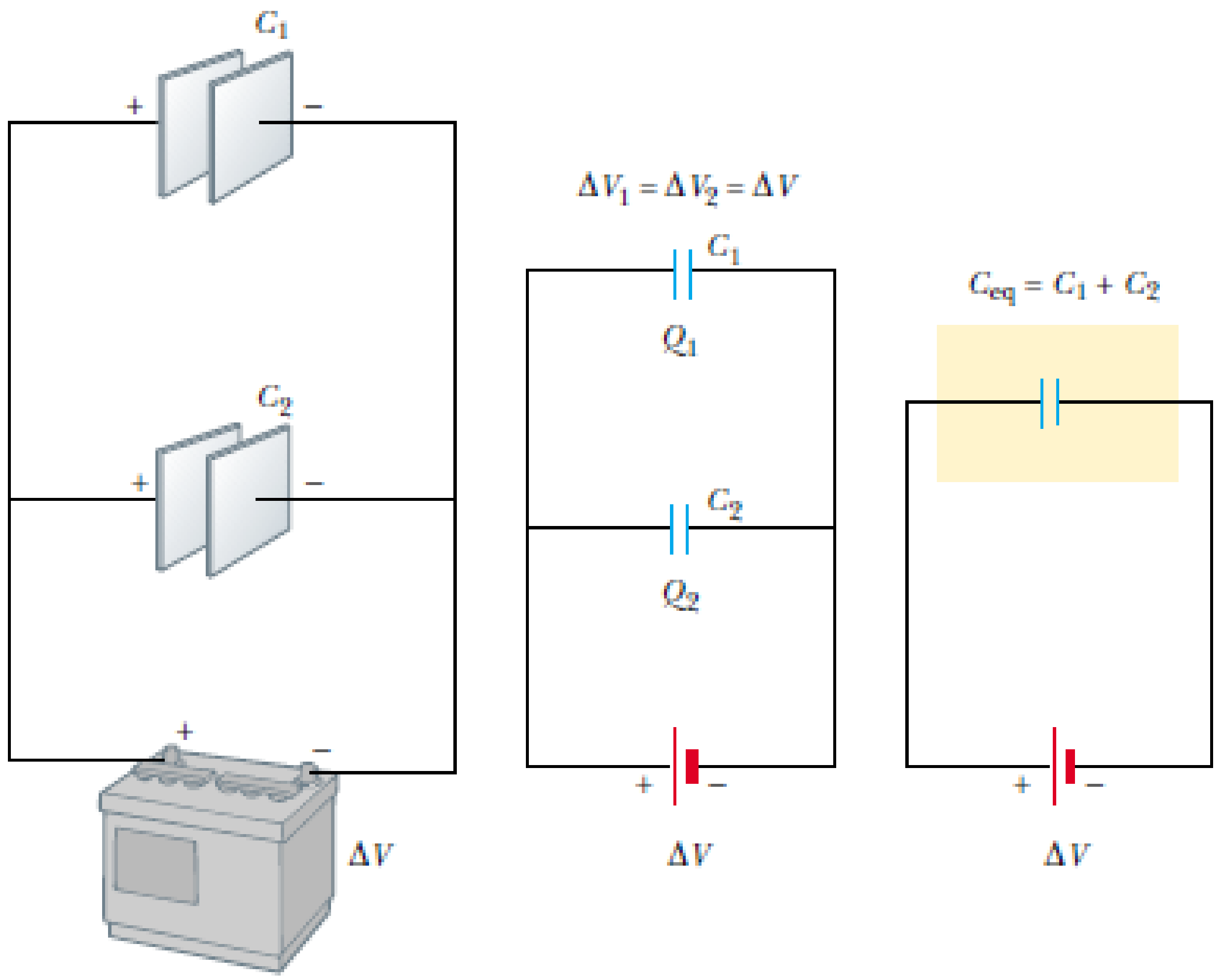
Kombinasi kapasitor

Dua atau lebih kapasitor seringkali dikombinasikan dalam suatu rangkaian listrik.

Kapasitansi ekivalen (yang setara) dari suatu susunan dapat dihitung dengan metode tertentu.

Pada kondisi tersebut, kapasitor yang akan digabungkan diasumsikan mula-mula tidak bermuatan.

Parallel Combination



the individual potential differences across capacitors connected in parallel are the same and are equal to the potential difference applied across the combination.

$$Q = Q_1 + Q_2$$

$$C_{eq} = C_1 + C_2 + C_3 + \cdots \qquad \text{(parallel combination)}$$

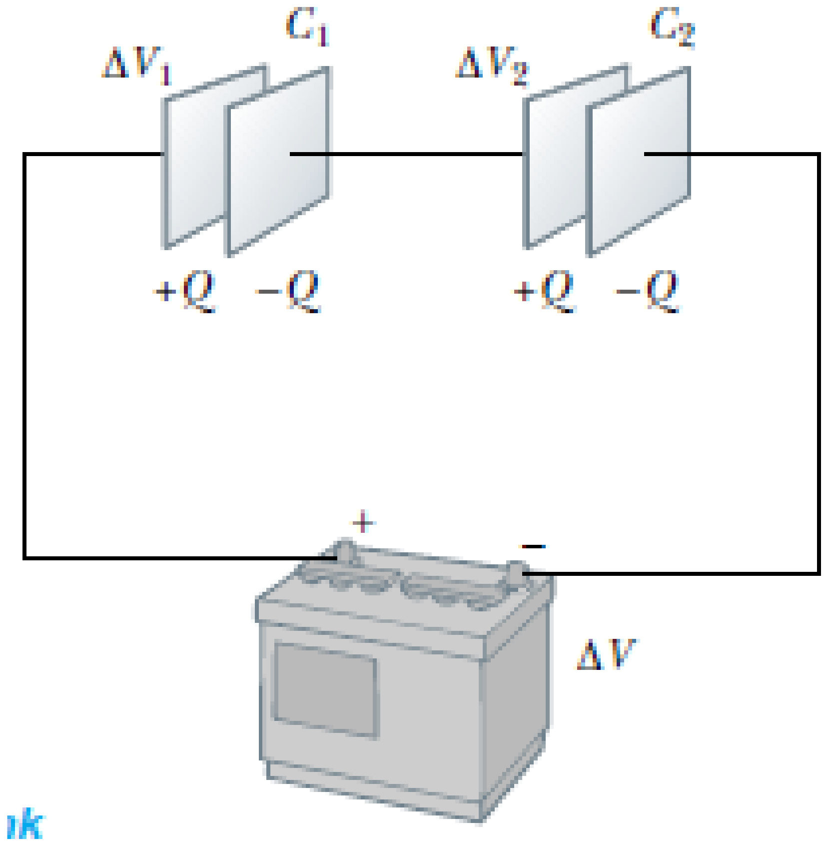
$$Q = C_{eq}\,\Delta V$$

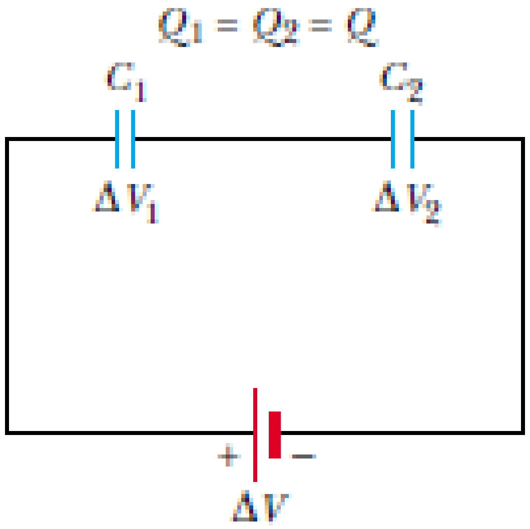
$$Q_1 = C_1\,\Delta V \qquad Q_2 = C_2\,\Delta V$$

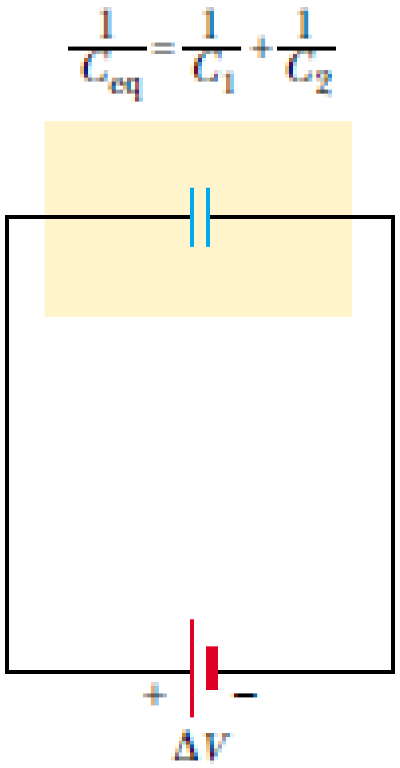
$$C_{eq}\,\Delta V = C_1\,\Delta V + C_2\,\Delta V$$

$$C_{eq} = C_1 + C_2 \qquad \text{(parallel combination)}$$

Series Combination







$$\Delta V = \Delta V_1 + \Delta V_2$$

$$\Delta V = \frac{Q}{C_{eq}}$$

$$\Delta V_1 = \frac{Q}{C_1} \qquad \Delta V_2 = \frac{Q}{C_2}$$

$$\frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \quad \text{(series combination)}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots \quad \text{(series combination)}$$

Example 1

The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately 5.3 x 10^{-11} m. Find the magnitudes of the electric force and the gravitational force between the two particles.

$$F_e = k_e \frac{|e||-e|}{r^2} = (8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}) \frac{(1.60 \times 10^{-19}\ \mathrm{C})^2}{(5.3 \times 10^{-11}\ \mathrm{m})^2}$$

$$= \boxed{8.2 \times 10^{-8}\ \mathrm{N}}$$

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}.$$

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$$F_g = G\frac{m_e m_p}{r^2}$$

$$= (6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2) \times \frac{(9.11 \times 10^{-31}\ \text{kg})(1.67 \times 10^{-27}\ \text{kg})}{(5.3 \times 10^{-11}\ \text{m})^2}$$

$$= 3.6 \times 10^{-47}\ \text{N}$$

The ratio $F_e/F_g \approx 2 \times 10^{39}$. Thus, the gravitational force between charged atomic particles is negligible when compared with the electric force. Note the similarity of form of Newton's law of universal gravitation and Coulomb's law of electric forces.

Example 2

The nucleus in an iron atom has a radius of about 4.0×10^{-15} m and contains 26 protons.

(a) What is the magnitude of the repulsive electrostatic force between two of the protons that are separated by 4.0×10^{-15} m?

(b) What is the magnitude of the gravitational force between those same two protons?

$$F = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$= \frac{(8.99 \times 10^{9}\ \mathrm{N \cdot m^2/C^2})(1.602 \times 10^{-19}\ \mathrm{C})^2}{(4.0 \times 10^{-15}\ \mathrm{m})^2}$$

$$= 14\ \mathrm{N}. \qquad \text{(Answer)}$$

$$F = G\frac{m_p^2}{r^2}$$

$$= \frac{(6.67 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2})(1.67 \times 10^{-27}\ \mathrm{kg})^2}{(4.0 \times 10^{-15}\ \mathrm{m})^2}$$

$$= 1.2 \times 10^{-35}\ \mathrm{N}. \qquad \text{(Answer)}$$

Example 3

What is the electric flux through a sphere that has a radius of 1.00 m and carries a charge of +1.00 μC at its center?

$$E = k_e \frac{q}{r^2} = (8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2) \frac{1.00 \times 10^{-6}\text{ C}}{(1.00\text{ m})^2}$$

$$= 8.99 \times 10^3 \text{ N/C}$$

The field points radially outward and is therefore everywhere perpendicular to the surface of the sphere. The flux through the sphere (whose surface area $A = 4\pi r^2 = 12.6 \text{ m}^2$) is thus

$$\Phi_E = EA = (8.99 \times 10^3 \text{ N/C})(12.6 \text{ m}^2)$$

$$= 1.13 \times 10^5 \text{ N}\cdot\text{m}^2/\text{C}$$

Example 4. Parallel-Plate Capacitor

A parallel-plate capacitor with air between the plates has an area A = 2.00×10^{-4} m^2 and a plate separation d = 1.00 mm. Find its capacitance.

$$C = \frac{\epsilon_0 A}{d} = \frac{(8.85 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2})(2.00 \times 10^{-4}\ \mathrm{m^2})}{1.00 \times 10^{-3}\ \mathrm{m}}$$

$$= 1.77 \times 10^{-12}\ \mathrm{F} = \boxed{1.77\ \mathrm{pF}}$$

- If a charge Q is uniformly distributed throughout a volume V, the **volume charge density** ρ is defined by

$$\rho \equiv \frac{Q}{V} \quad (\mathrm{C/m^3}).$$

If a charge Q is uniformly distributed on a surface of area A, the **surface charge density** σ (lowercase Greek sigma) is defined by

$$\sigma \equiv \frac{Q}{A} \quad (\mathrm{C/m^2}).$$

If a charge Q is uniformly distributed along a line of length ℓ, the **linear charge density** λ is defined by

$$\lambda \equiv \frac{Q}{\ell}$$