LESSON 6

BOOK CHAPTERS 24 and 25

ELECTRIC POTENTIAL and CAPACITANCE

Problem 21 (Book Chapter 24)

The ammonia molecule NH_3 has a permanent electric dipole moment equal to 1.47 D, where $1D = 1 debye\ unit = 3.34 \times 10^{-30} C.m$. Calculate the electric potential due to an ammonia molecule at a point 52.0 nm away along the axis of the dipole. (Set $V = 0$ at infinity.)

Answer:

We have

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{p\cos\theta}{r^2}\right)$$

Given

$$p = 1.47\ D = 1.47 \times 3.34 \times 10^{-30}\ C - m$$

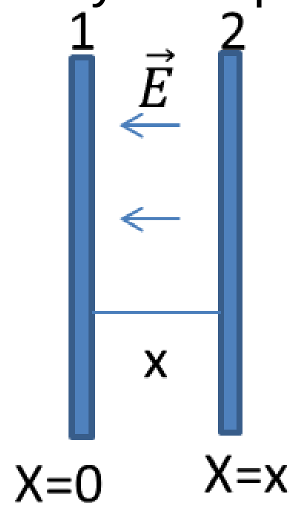
$$r = 52\ nm = 52 \times 10^{-9}\ m$$

$$\theta = 0^0 \ \ and \cos 0^0 = 1 \qquad V = ?$$

$$V = \frac{9\times10^9\times1.47\times3.34\times10^{-30}}{(52\times10^{-9})^2} = 16.34 \times 10^{-6}\ \text{Volt}$$

Problem 36 (Book Chapter 24)

The electric potential *V* in the space between two flat parallel plates 1 and 2 is given (in volts) by $V = 1500x^2$, where *x* (in meters) is the perpendicular distance from plate 1. At $x = 1.3\ cm$, (a) what is the magnitude of the electric field and (b) is the field directed toward or away from plate 1?



Given

$$V = 1500\ x^2$$

At x = 1.3 cm= 0.013 m ,

$$E = ?$$

The direction of electric field,

$$\vec{E} = ?$$

(a) We have

$$E_x = -\frac{\partial V}{\partial x} = -\frac{\partial}{\partial x}(1500x^2) = -3000\ x$$

$$E_x = -3000 \times 0.013 = -39\ \frac{V}{m}$$

$$\vec{E} = E_x\hat{\imath} = 39(-\ \hat{\imath}\ \ )$$

Magnitude of $\vec{E}$ is

$$E = 39\ \frac{V}{m}$$

(b) The direction of electric field is toward plate 1, because $\vec{E} = 39(-\ \hat{\imath})\frac{V}{m}$

Problem 37 (Book Chapter 24)

What is the magnitude of the electric field at the point $(3.00\hat{\imath} - 2.00\hat{\jmath} + 4.00\hat{k})\ m$ if the electric potential in the region is given by $V = 2.00xyz^2$, where *V* is in volts and coordinates *x*, *y*, and *z* are in meters?

Answer:

We know

$$E_x = -\frac{\partial V}{\partial x} = -\frac{\partial}{\partial x}(2xyz^2) = -2yz^2 = -(2)(-2)(4^2) = 64\frac{V}{m}$$

$$E_y = -\frac{\partial V}{\partial y} = -\frac{\partial}{\partial y}(2xyz^2) = -2xz^2 = -(2)(3)(4^2) = -96\frac{V}{m}$$

$$E_z = -\frac{\partial V}{\partial z} = -\frac{\partial}{\partial z}(2xyz^2) = -4xyz = -(4)(3)(-2)(4) = 96\frac{V}{m}$$

$$\vec{E} = E_x\hat{\imath} + E_y\hat{\jmath} + E_z\hat{k} = 64\hat{\imath} - 96\hat{\jmath} + 96\hat{k}$$

Therefore,

$$\left|\vec{E}\right| = \sqrt{(64)^2+(-96)^2+(96)^2} = 150.09\frac{V}{m}$$

Given

$$V = 2xyz^2$$

And

$$(x, y, z) = (3, -2, 4)$$

$$\left|\vec{E}\right| = ?$$

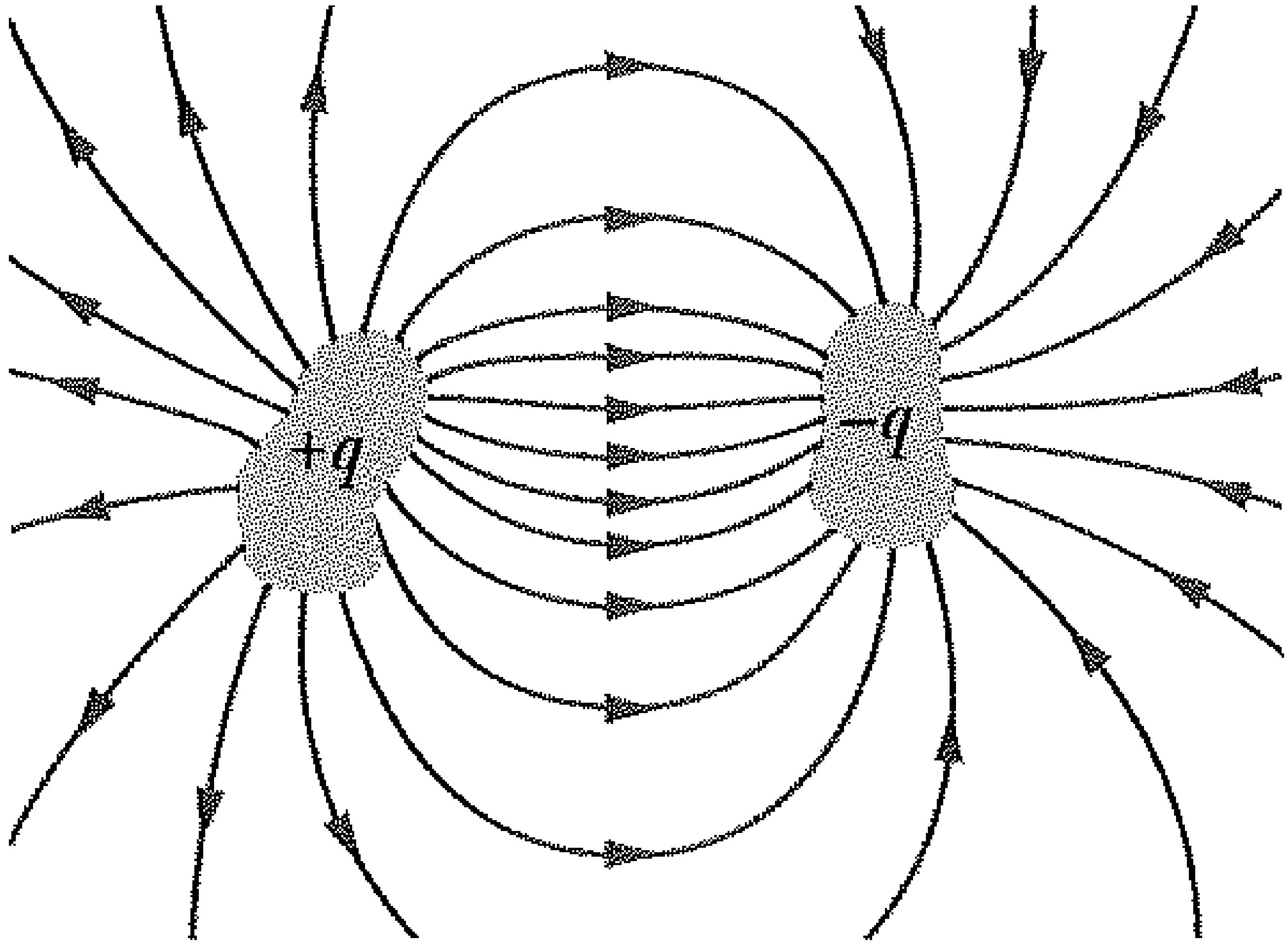
BOOK CHAPTER 25

CAPACITANCE

Paul Silvermann/Fundamental Photographs

An assortment of capacitors.

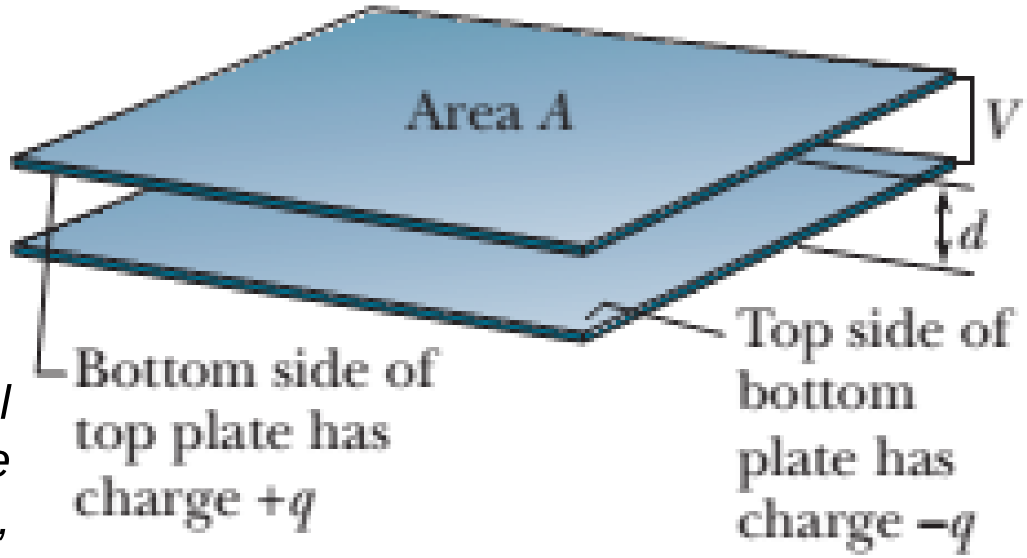
Capacitor:



Two conductors, isolated electrically from each other and from their surroundings, form a *capacitor.* When the capacitor is charged, the charges on the conductors, or *plates* as they are called, have the same magnitude *q* but opposite signs.

Capacitance

A capacitor consists of two isolated conductors (the plates) with charges $+q$ *and* $-q$.



The charge q and the potential difference V for a capacitor are proportional to each other; that is,

$$q \propto V$$

Therefore,

$$q = CV$$

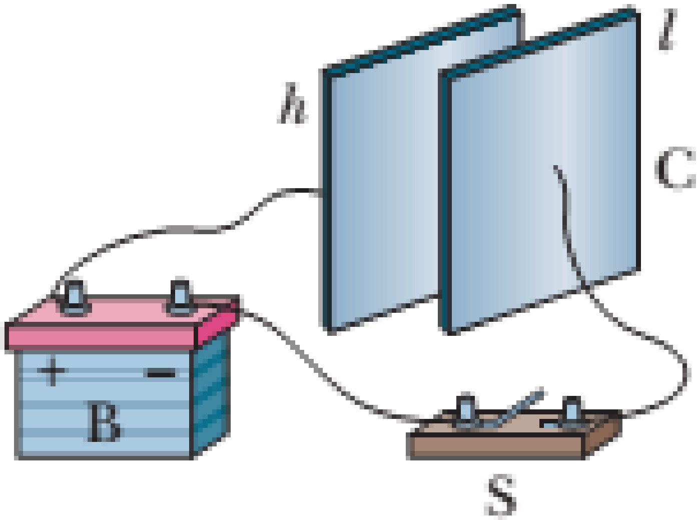
The proportionality constant C is called the capacitance of the capacitor.

The value of C depends only on the geometry of the plates and *not* on their charge or potential difference. The capacitance is a measure of how much charge must be put on the plates to produce a certain potential difference between them: The *greater the capacitance, the more charge is required.*

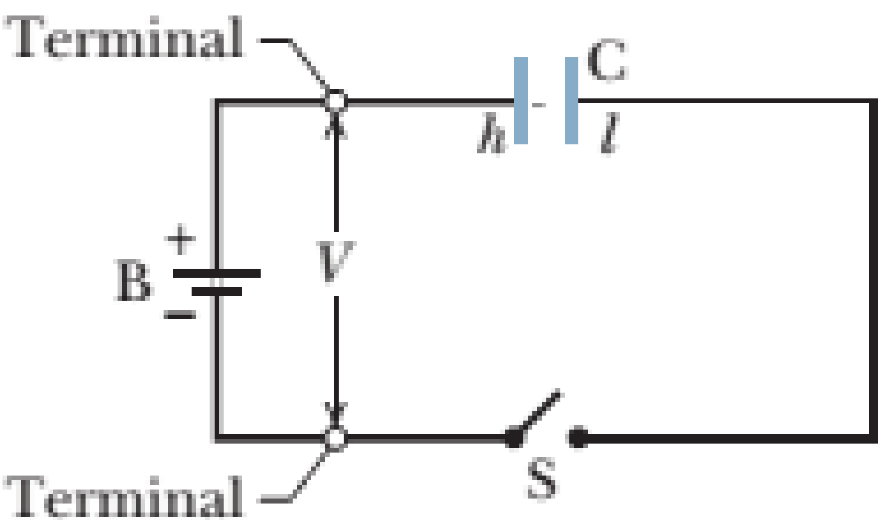
$$C = \frac{q}{V}$$

The SI unit of capacitance is the coulomb per volt. Common name is Farad (F):

Charging a Capacitor:



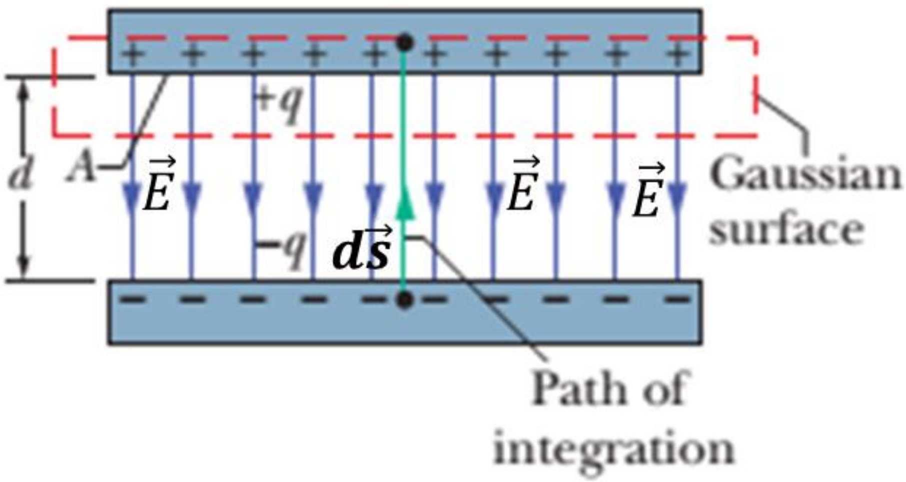
(a)



(b)

(*a*) Battery B, switch S, and plates *h* and *l* of capacitor C, connected in a circuit.
(*b*) A schematic diagram with the *circuit elements* represented by their symbols.

Calculating the Capacitance: A parallel-Plate Capacitor:



Applying Gauss' Law:

$$\varepsilon_0 \oint \vec{E}.d\vec{A} = q$$

Here q is the charge enclosed by a Gaussian surface and $\oint \vec{E}.d\vec{A}$ is the net electric flux through that surface.

$$\varepsilon_0 \oint E(dA)cos0^0 = q$$

Since $\vec{E}$ and $d\vec{A}$ are parallel

Therefore, $\varepsilon_0 EA = q$

A is the area of that part of the Gaussian surface through which there is a flux.

The potential difference between the plates of a capacitor is related to the field $\vec{E}$ by

$$\mathrm{V_f} - \mathrm{V_i} = -\int_i^f \vec{E}.d\vec{s} = -\int_-^+ Ecos180\, ds$$

$$V = \int_-^+ E\, ds$$ Where, $\mathrm{V} = \mathrm{V_f} - \mathrm{V_i}$

$$V = E\int_{s=0}^{s=d} ds = Ed$$

We have $C = \frac{q}{V} = \frac{\varepsilon_0 EA}{Ed} = \frac{\varepsilon_0 A}{d}$

$$\boxed{C = \frac{\varepsilon_0 A}{d}}$$

Thank You