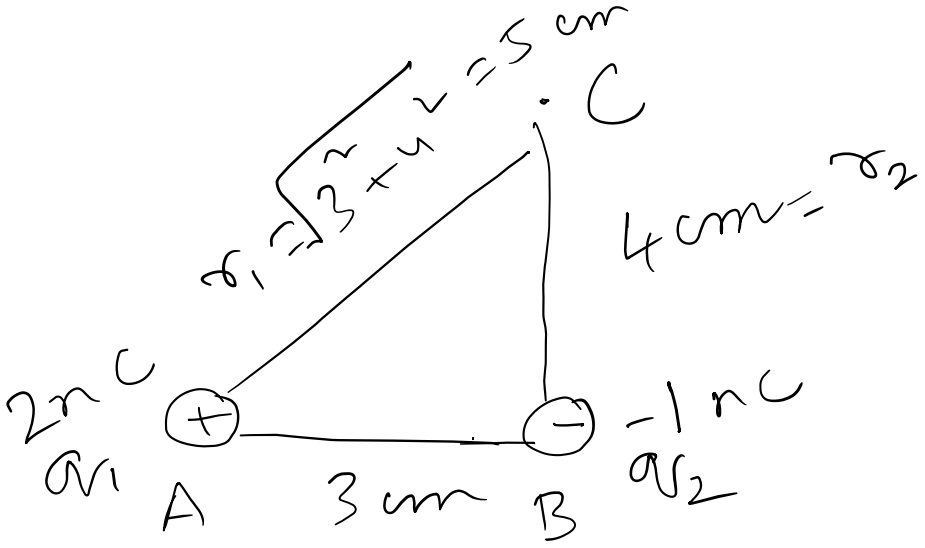
Welcome to the Physics class

Principles of Physics II

Lecture 11

Problem 1: **What is the potential at point C**



$$V = K\sum_i \frac{q_i}{r_i}$$

$$V = K\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

$$= 9\times10^{9} \times \left(\frac{2\times10^{-9}}{0.05} + \frac{-1\times10^{-9}}{.04}\right)$$

$$V = 135\ V$$

Problem 2: **what is the electric potential 1 cm from a + 1nC charge? What is the potential difference between a point 1 cm and a second point 3 cm away?**

The potential V_1 at $r = 1\ cm = 0.01\ m$

$$V_1 = \frac{1}{4\pi\epsilon_0}\frac{q}{r} = \frac{9\times10^{9}\times1\times10^{-9}}{0.01\ m} = 900\ V$$

at 3 cm
$r = 0.03\ m$

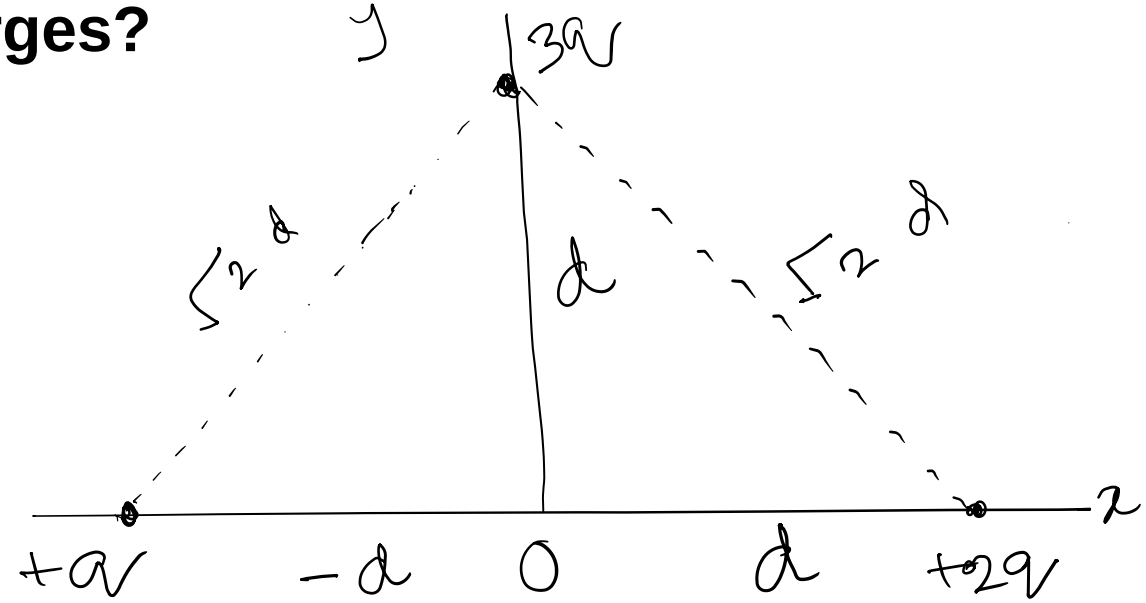
$$V_3 = \frac{9\times10^{9}\times1\times10^{9}}{0.03} = 300\ V$$

$$\Delta V = V_1 - V_3 = 900 - 300 = 600\ V$$

Problem 3: Two charges +q and +2q are held in place on the x-axis at the location x = - d and x = + d respectively. A third charge, + 3q is released from rest on the y axis at y = d. Find,
a) Electric potential due to first two charges at the initial location of the third charge. b) Find the initial potential energy of the third charge. c) What is the K.E. of the third charge when it moves to infinity far away from the other two charges?

(a) $$V = \frac{1}{4\pi\epsilon_0}\left(\frac{q}{\sqrt{2}d} + \frac{2q}{\sqrt{2}d}\right)$$

$$= \frac{3kq}{\sqrt{2}d}$$



(b) $U_i = Vq = \frac{3kq}{\sqrt{2}d} 3q = \frac{9kq^2}{\sqrt{2}d}$

(c) Total Energy at initial position = Total Energy at infinity.

$$U_i + K_i = U_f + K_f$$

$K_i = 0$ since $3q$ is initially at rest.

At infinity $r = \infty$ $U_f = 0$ since $U = \frac{kqq_1}{r} = \frac{kqq}{\infty} = 0$

$\therefore U_i = K_f$

$\therefore K_f = U_i = \frac{9kq^2}{\sqrt{2}d}$

Problem 4. **What is the magnitude of the electric field at the point ($3.0\hat{i} - 2.0\hat{j} + 4.0\hat{k}$) 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?**

Given $V = 2xyz^2$ $\qquad \vec{E} = -\vec{\nabla} V$

$\vec{\nabla}$ is a gradient operator (a vector operator)

$$\vec{\nabla} = \hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$$

$$\therefore \quad \vec{E} = -\left(\hat{i}\frac{\partial V}{\partial x} + \hat{j}\frac{\partial V}{\partial y} + \hat{k}\frac{\partial V}{\partial z}\right)$$

put the value of V

$$\vec{E}_x = -\hat{i}\frac{\partial(2xyz^2)}{\partial x} = -2yz^2\hat{i}$$

$$\vec{E}_y = -\hat{j}\,\frac{\partial(2xyz^2)}{\partial y} = -2xz^2\,\hat{j}$$

$$\vec{E}_z = -\hat{k}\,\frac{\partial(2xyz^2)}{\partial z} = -4xyz\,\hat{k}$$

Now the electric field at the point $(3\hat{i} - 2\hat{j} + 4\hat{k})$ ie $E = E(3, -2, 4)$

$$\therefore \quad \vec{E}_x = -2yz^2\hat{i} = -2(-2).4^2\hat{i} = 64\hat{i} \ \text{V/m}$$

$$\vec{E}_y = -2xz^2\hat{j} = -2.3.4^2\hat{j} = -96\hat{j} \ \text{V/m}$$

$$\vec{E}_z = -4xyz\,\hat{k} = -4.3.(-2).4\,\hat{k} = 96\,\hat{k} \ \text{V/m}$$

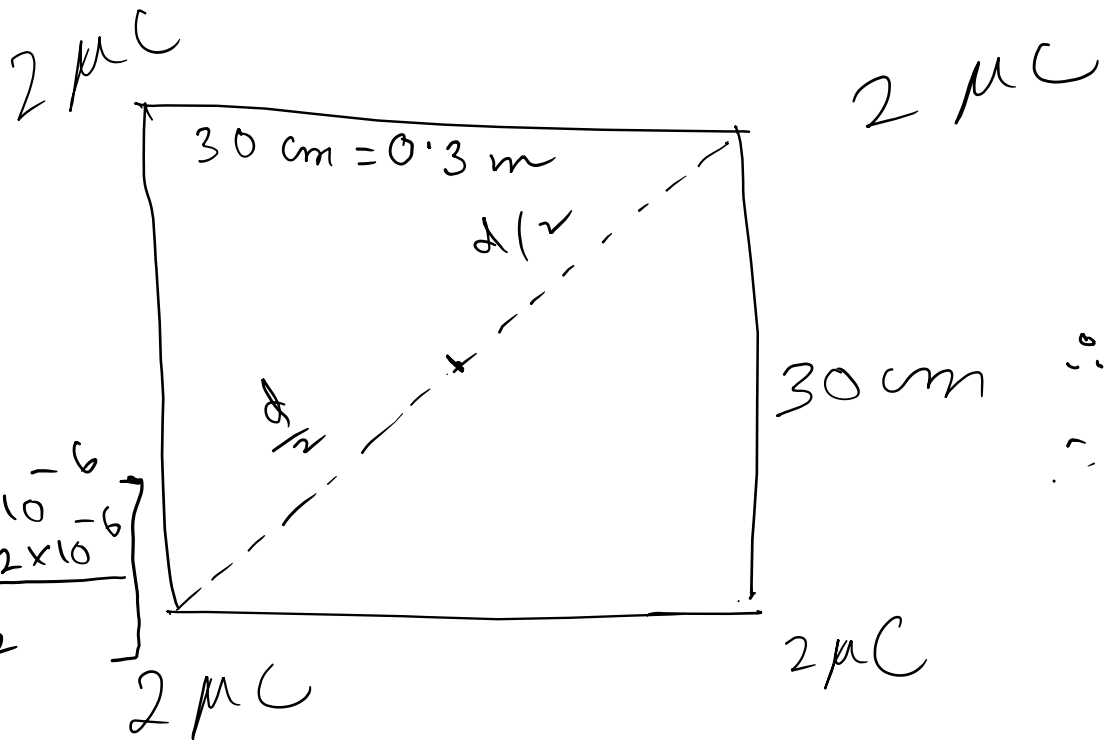
$$|\vec{E}| = \left(E_x^2 + E_y^2 + E_z^2\right)^{1/2} = \sqrt{64^2 + (-96)^2 + 96^2} = 150\,\frac{V}{m} = 150\,\frac{N}{C}$$

Problem 5: **Four point charges are placed at four corners of a square that is 30 cm on each side. Find the potential at the center of the square if (a) the four charges are each + 2uC and (b) two of the four charges are + 2uC and two are – 2uC.**

(a) $V_a = K \sum_{i=1} \frac{q_i}{r_i}$

$= 9 \times 10^9 \frac{2 \times 10^{-6} \times 4}{.3 \times \frac{\sqrt{2}}{2}}$

$= 3.4 \times 10^5 \, V.$



$d^2 = .3^2 + .3^2$

$\therefore d = \sqrt{2} \times .3$

$\therefore \frac{d}{2} = \frac{\sqrt{2}}{2} \times 0.3 \, m$

(b) $V_b = 9 \times 10^9 \left[\frac{-2\times10^{-6} + 2\times10^{-6} - 2\times10^{-6} - 2\times10^{-6}}{0.3 \times \sqrt{2}/2} \right]$

$= 0$

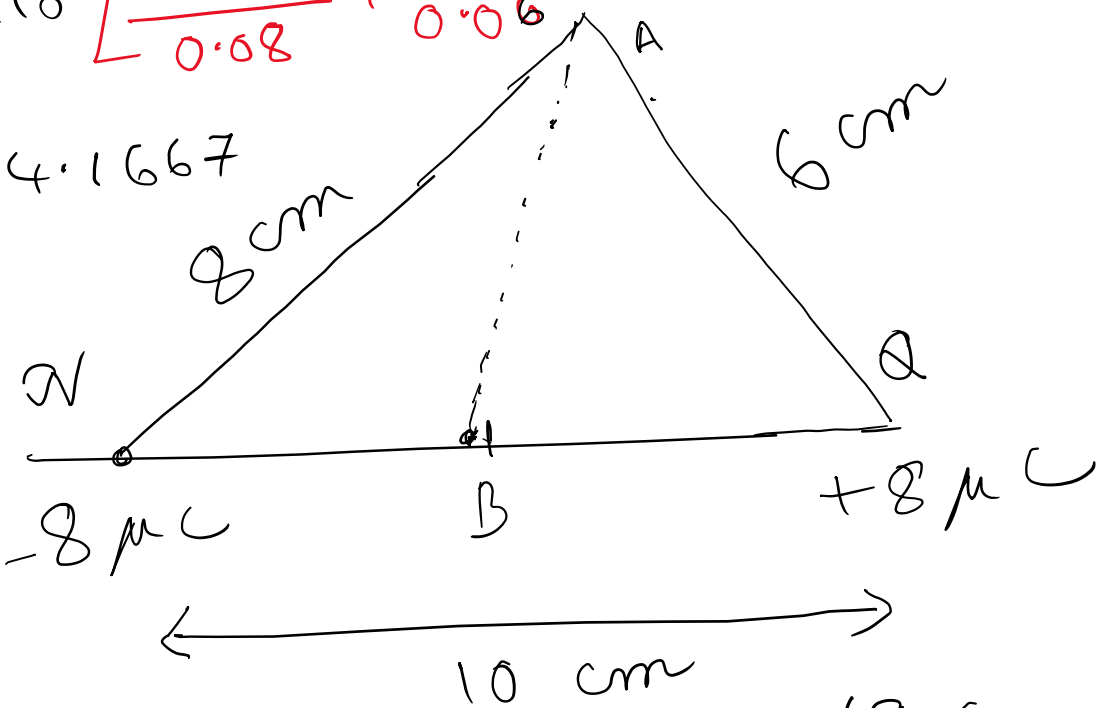
$\therefore V_b = 0$

Problem 6: Two charges q=-8μC and Q = +8 μC are at a distance 10 cm apart as shown in figure. a) Find the electric potential at points A and B . Point B is the mid point between the charges. b) How much work will be done to move proton from point A to point B.

(a) $V_A = k \sum \frac{q_i}{r_i} = 9\times10^9 \left[\frac{-8\times10^{-6}}{0.08} + \frac{8\times10^{-6}}{0.06}\right] = 9\times10^{-6} \times 8\times10^{-6}\left[\frac{1}{.06} - \frac{1}{.08}\right]$

$= 9\times10^9 \times 8\times10^{-6} \times 4.1667$

$V_A = 3\times10^5\ V$



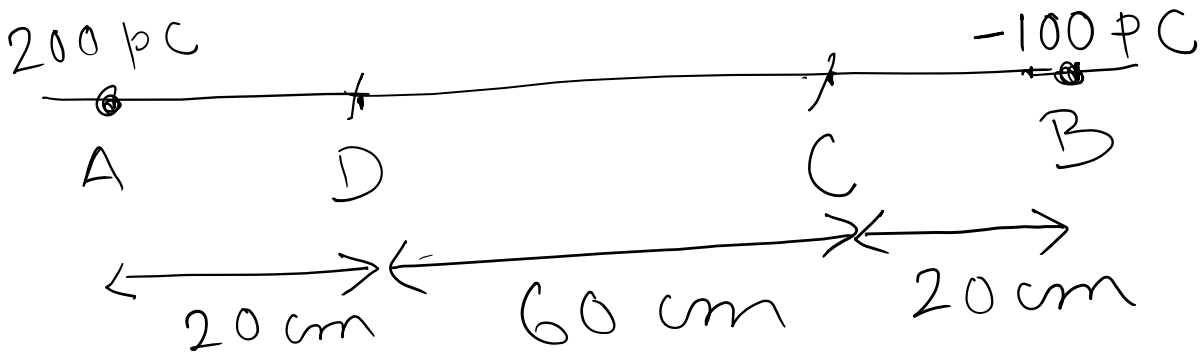
$V_B = k \sum \frac{q_i}{r_i} = 9\times10^9 \left[\frac{-8\times10^{-6}}{0.05} + \frac{8\times10^{-6}}{.05}\right]$

$= 0$

(b) $W_a = q\Delta V = \Delta U = q(V_B - V_A) = 1.6\times10^{-19}(0 - 3\times10^5)$

$= -4.8\times10^{-14}\ J$ (work by the external agent)

Problem 7: **a) Find V at points C and D. b) How much work must be done to transfer a charge of 500 μC from point C to point D?**



$$V_C = K\sum_{i=1}^{2}\frac{q_i}{r_i} = 9\times10^{9}\left(\frac{2\times10^{-10}}{0.80} + \frac{-1\times10^{-10}}{0.2}\right) = -2.25\,V$$

$$V_D = K\sum_{i=1}^{2}\frac{q_i}{r_i} = 9\times10^{9}\left(\frac{2\times10^{-10}}{0.20} + \frac{-1\times10^{-10}}{0.8}\right)$$

$$V_D = 7.88\ V$$

(b) We know work done (here by an external agent)

$$W = \Delta V q$$

$$\Delta V = V_D - V_C = 7.88 - (-2.25)$$

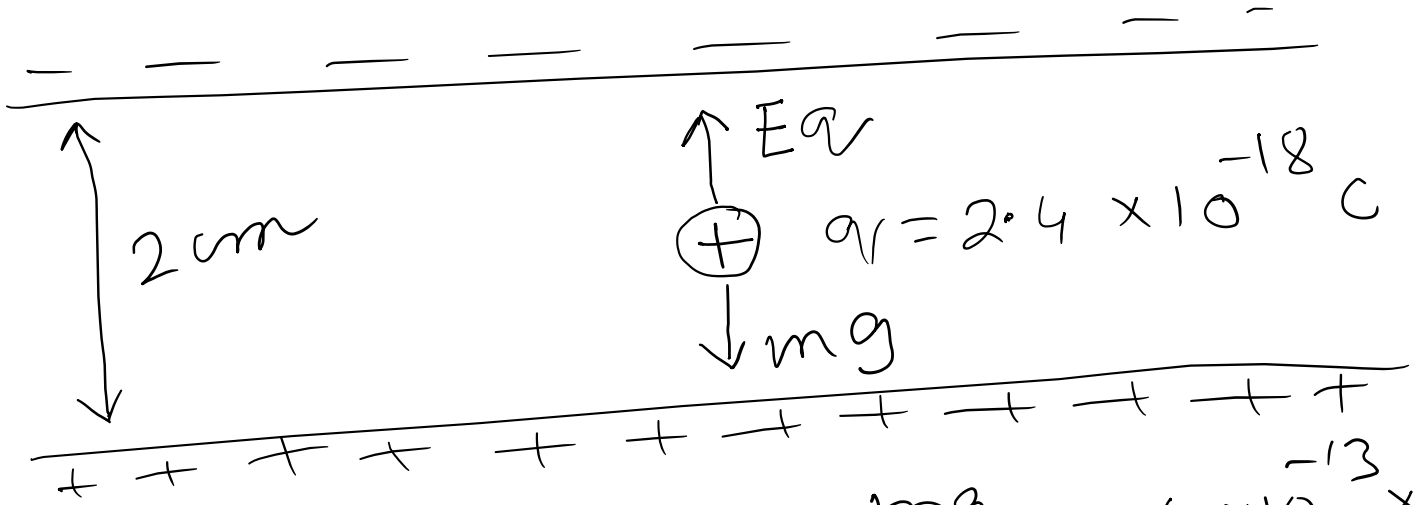
$$= 10.13 \text{ J/C}$$

$$\Delta U = \Delta V q$$

$$\therefore \quad W = 10.13 \times 500 \times 10^{-6} \text{ C}$$

$$= 5.1 \text{ mJ.}$$

Problem 8 : **A charged particle remain stationary between two horizontal charged plates. The plates separation is 2 cm and mass m= 4x10(-13) Kg and charge q = 2.4x 10 (-18) C for the particle. Find the potential difference between the plates.**



$F_g = F_e$

$$mg = qE \quad \therefore \quad E = \frac{mg}{q} = \frac{4 \times 10^{-13} \times 9.8}{2.4 \times 10^{-18}}$$

$$= 1.63 \times 10^{6} \ V/m$$

$$E = \frac{V}{d}$$

$$V = Ed = 1.63 \times 10^{6} \times 2 \times 10^{-2} \ m$$

$$= 33 \ KV.$$

CHAPTER 25

Capacitance

CHAPTER 25

Capacitance

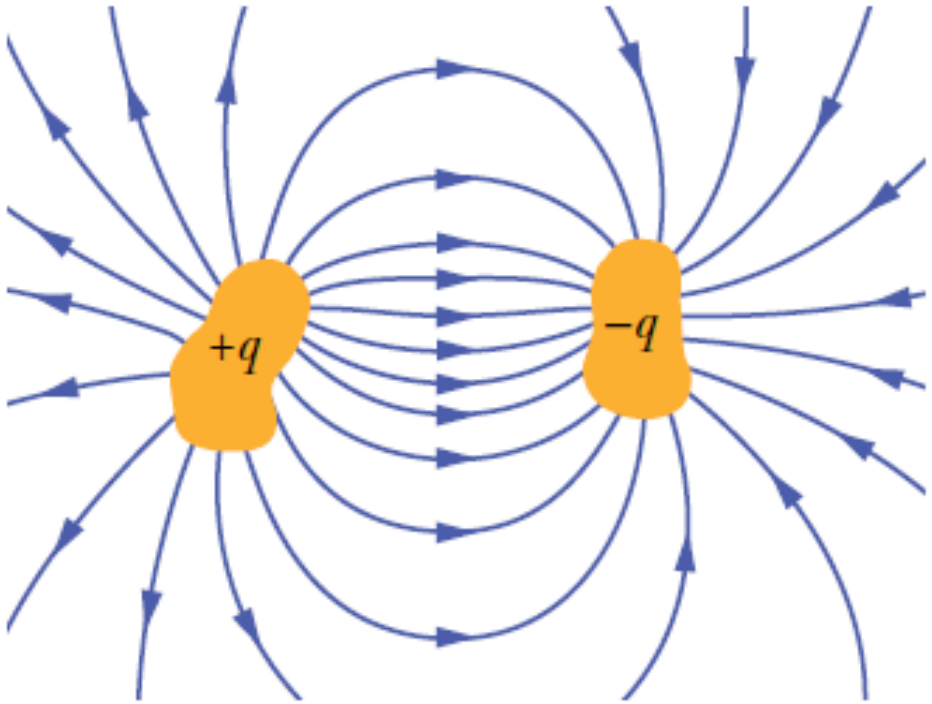


Fig. 25-2 Two conductors, isolated electrically from each other and from their surroundings, form a *capacitor*. When the capacitor is charged, the charges on the conductors, or *plates* as they are called, have the same magnitude q but opposite signs.

Fig. 25-1 An assortment of capacitors.

1. Parallel plate capacitors
2. Spherical capacitors
3. Cylindrical capacitors

} depending on the structure of the conductors.

a. Electrolytic capacitor
b. Ceramic capacitor
c. Variable air capacitor

} depending on the type of the dielectric used.

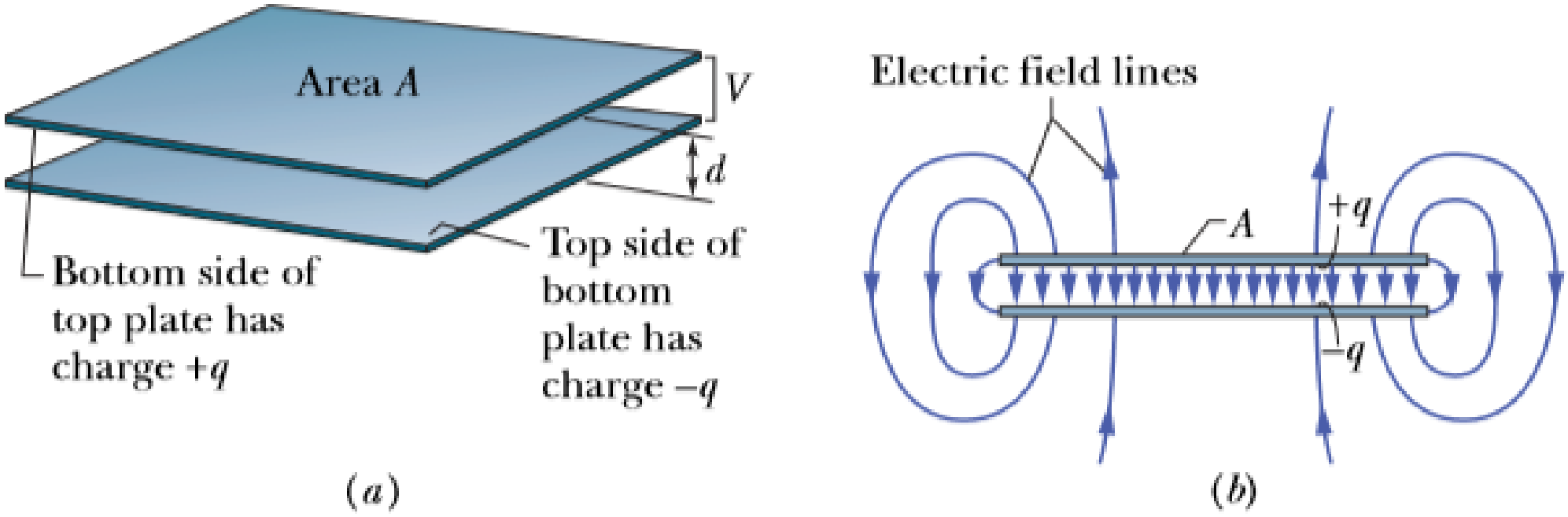


Fig. 25-3 (*a*) A parallel-plate capacitor, made up of two plates of area A separated by a distance d. The charges on the facing plate surfaces have the same magnitude q but opposite signs. (*b*) As the field lines show, the electric field due to the charged plates is uniform in the central region between the plates. The field is not uniform at the edges of the plates, as indicated by the "fringing" of the field lines there.

—||— Symbol of a capacitor —|— symbol of a cell.

When a capacitor is charged equal and opposite types of charges are accumulated on the (+) and (−)ve plates. That introduces a potential difference V betn its plates and $q \propto V$ $\quad q = CV$ or $C = \frac{q}{V}$

The proportionality constant C is called the capacitance. Its unit is Farad. $1 \text{ Farad} = \frac{1\,C}{1\,V}$.

μF
nF etc
pF

$C = \frac{q}{V}$ is the defining equation of any capacitor.

The expression for capacitors in terms of the geometrical parameters will be different for different geometrical shaped capacitor.

Defining equation of capacitance: **C = Q/ V**

Q in Coulomb, V in Volts and C is in Farad (F)

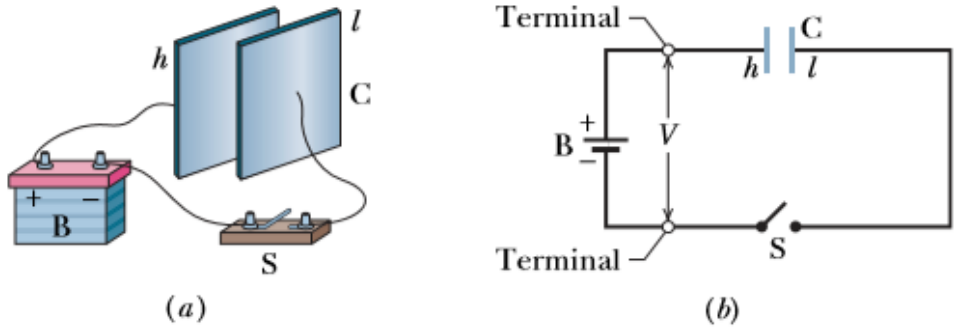
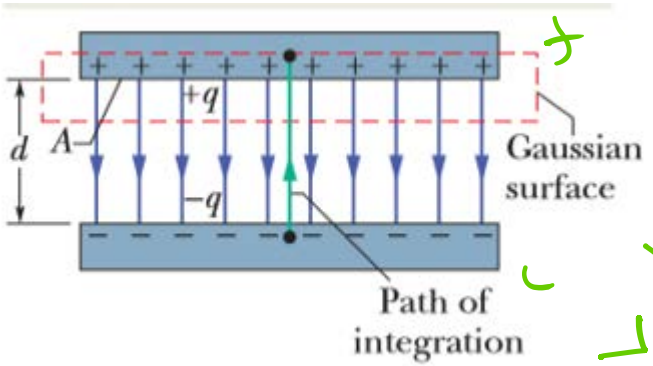


Fig. 25-4 (*a*) Battery B, switch S, and plates *h* and *l* of capacitor C, connected in a circuit. (*b*) A schematic diagram with the *circuit elements* represented by their symbols.

In terms of the geometry of the capacitor, e.g.,

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



$V_f = V$

$V_i = 0$

Gauss' law $\epsilon_0 \oint \vec{E} \cdot d\vec{A} = q$

$\therefore \; q = \epsilon_0 E A$

<u>PD</u> Dif

$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s}$

$V - 0 = \int_-^+ E\,ds$ dir. of $\vec{E}$ and $d\vec{s}$ are opposite.

$\therefore \; V = \int_-^+ E\,ds$