Electricity and Magnetism
Capacitance

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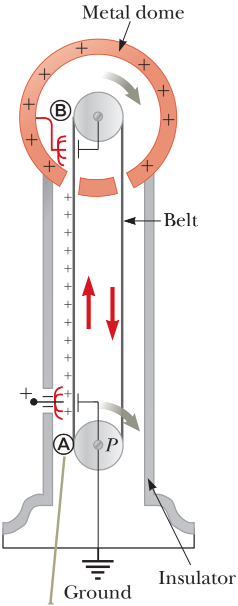
Last time

- Potential of charged conductor
- dipole in a magnetic field
- Millikan's experiment - skipping for now

Overview

- Van de Graaf generator
- Capacitors
- Potential difference and charged plates
- Capacitance
- Capacitance of a parallel plate capacitor
- Capacitance of a spherical and cylindrical capacitors

Van de Graaf generator



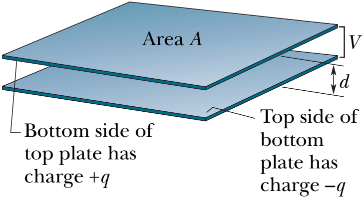
Can (in principle) build up to 3 million Volts when used in air.

Capacitance

capacitor

Any two isolated conductors separated by some distance that can store different charges.

(When the capacitor is discharged this stored charge is 0.)



The **capacitance** of a capacitor relates the potential difference across the capacitor to its stored charge.

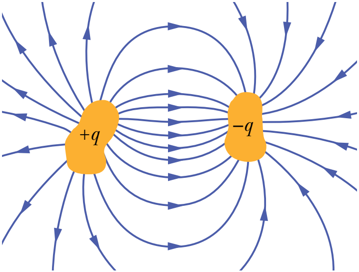
Capacitors

Capacitors can be thought of as devices that store charge at some particular potential difference.

They can also be thought of as storing energy in an electric field.

Capacitors

Usually capacitors are diagrammed and thought of as parallel sheets of equal area, but paired, isolated conductors of any shape can act as capacitors.



In fact, even isolated conductors on their own (not part of a pair) can also be said to have a capacitance.

Capacitors

Capacitors for use in circuits can have a number of different appearances, but often they have a cylindrical shape.

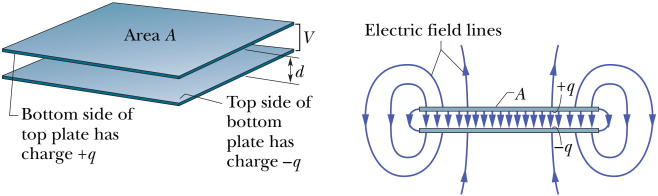
(This does not mean they are cylindrical capacitors! This usually means they are rolled parallel plate capacitors.)

Capacitors

When a capacitor is **charged** is has a net charge $+Q$ on one plate and a net charge $-Q$ on the other plate.

An electric field exists between the plates.

For the case of parallel sheet plates, the field is uniform, except at the edges of the plates.



Charge of a Capacitor

The net charge on a capacitor is zero: $(+Q) + (-Q) = 0$.

However, when we speak of the **charge of a capacitor**, Q, we mean that the absolute value of the charge on either plate is Q.

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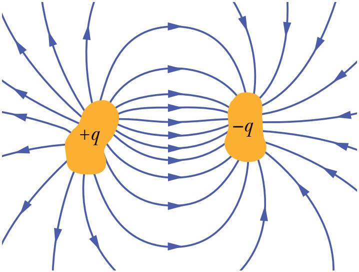
The charge on this capacitor is q:



Potential Difference

The **potential difference** between two points *a* and *b* is the difference between the electric potential at *a* and the potential at *b*.

$$\Delta V = V_b - V_a$$

This can be positive or negative, but very, very often, people also just are interested in the magnitude of it, so quote it as:

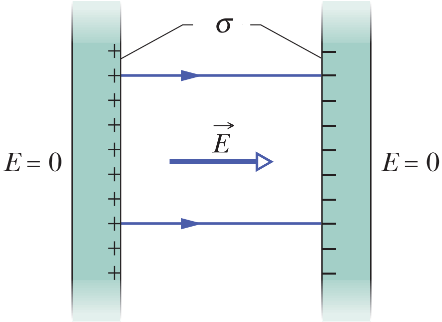
$$|\Delta V| = |V_b - V_a|$$

Warning: In some books, V is also used to denote potential difference, as well as electric potential.

Potential Difference across a pair of charged plates

If we have a pair of charged plates at a separation, d, there is a uniform E-field between them: $E = \frac{\sigma}{\epsilon_0}$.

$$\Delta V = -\int_0^d \mathbf{E} \cdot d\mathbf{s} = -E\,d$$

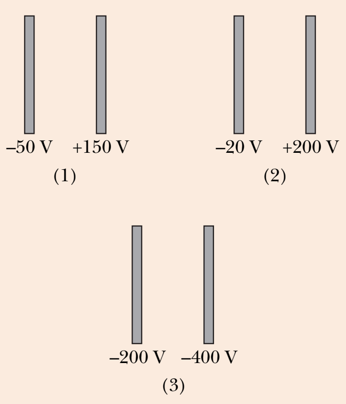


The potential difference between the two plates, separation, d:

$$|\Delta V| = E\,d$$

Question

Consider three pairs of parallel plates with the **same separation**. The electric field between the plates is uniform and perpendicular to the plates.
(a) Rank the pairs according to the magnitude of the electric field between the plates, greatest first.



(A) 1, 2, 3
(B) (1 and 3), 2
(C) 2, (1 and 3)
(D) 3, 2, 1

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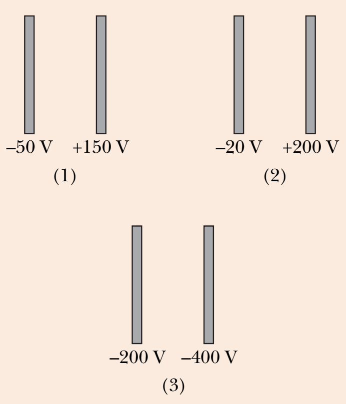

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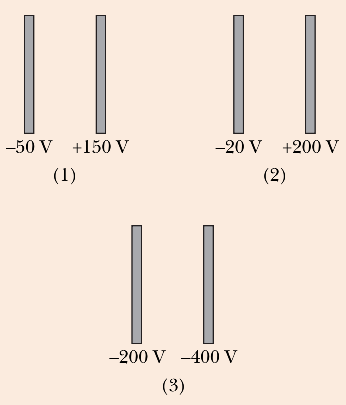
(b) For which pair is the electric field pointing rightward?



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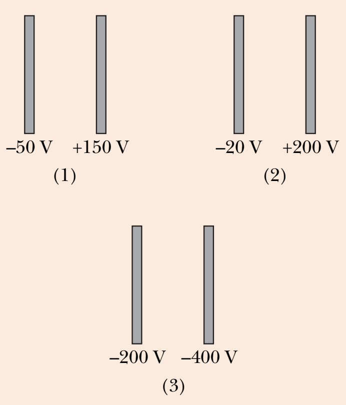

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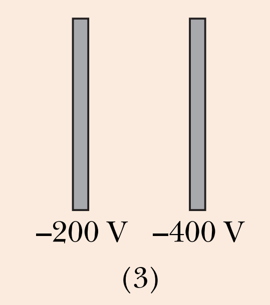
Question

Consider three pairs of parallel plates with the **same separation**. The electric field between the plates is uniform and perpendicular to the plates.
(c) If an **electron** is released midway between the third pair of plates, does it



(A) remain there
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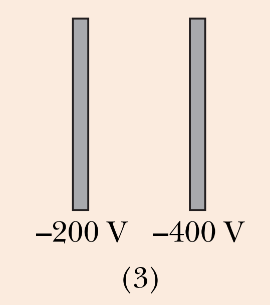

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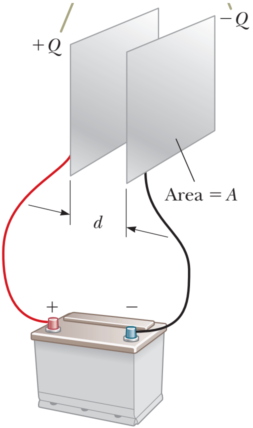
Capacitance

When a battery is connected to a pair of plates so that one plate is connected to the positive terminal of the battery and the other is connected to the negative terminal, the plates become charged.



[1]Diagram from Serway & Jewett, 9th ed, page 778.

Capacitance

capacitance, C

The constant of proportionality relating the charge on the capacitor to the potential difference across it:

$$Q = C\,|\Delta V|\,; \quad C = \frac{Q}{|\Delta V|}$$

Capacitance is always positive by convention.

ΔV is the potential difference between one plate of the capacitor and the other (chosen positive).

Capacitance is measured in Farads. $1\ \mathrm{F} = 1\ \mathrm{C/V}$.

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Capacitance

$$Q = C\,(\Delta V) \quad \Rightarrow \quad C = \frac{Q}{\Delta V}$$

C is a property of the geometry of the capacitor.

A particular capacitor will have a particular fixed value of C, just like a given resistor will have a constant value of resistance R.

For a parallel plate capacitor:

$$C = \frac{\epsilon_0 A}{d}$$

where d is the separation distance of the plates and A is the area of each plate

Capacitance Questions

Imagine a parallel plate capacitor.

Does the capacitance

(A) increase

(B) decrease

(C) remain the same

when the separation of the plates d is doubled?

[1] Halliday, Resnick, Walker, page 661.

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If the potential difference is fixed, *eg.* the capacitor plate are charged by a constant 9 V battery, does the charge on the capacitor

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Capacitance

Capacitors with different construction will have different values of C.

For example,
for a **cylinderical** capacitor of length L, inner radius a and outer radius b:

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for an **isolated charged sphere** of radius R:

$$C = 4\pi\epsilon_0 R$$

Summary

- capacitance
- parallel plate capacitors
- cylindrical and spherical capacitors

Homework

Serway & Jewett:

- Ch 26, onward from page 799. Problems: 1, 5, 7, 11, 50, 51