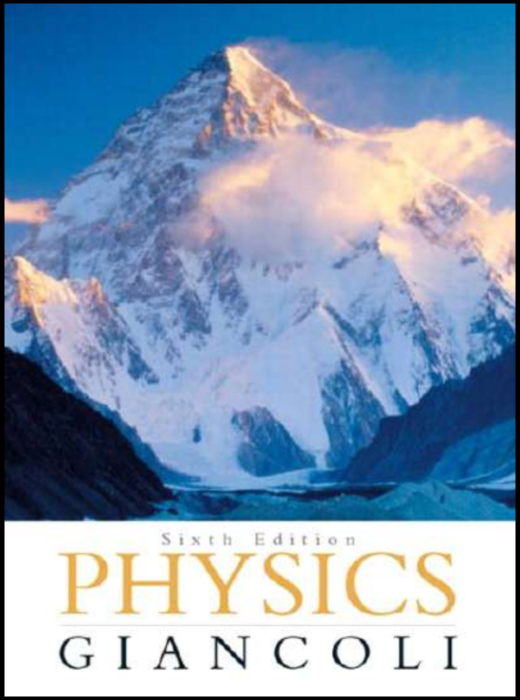


Lecture PowerPoints

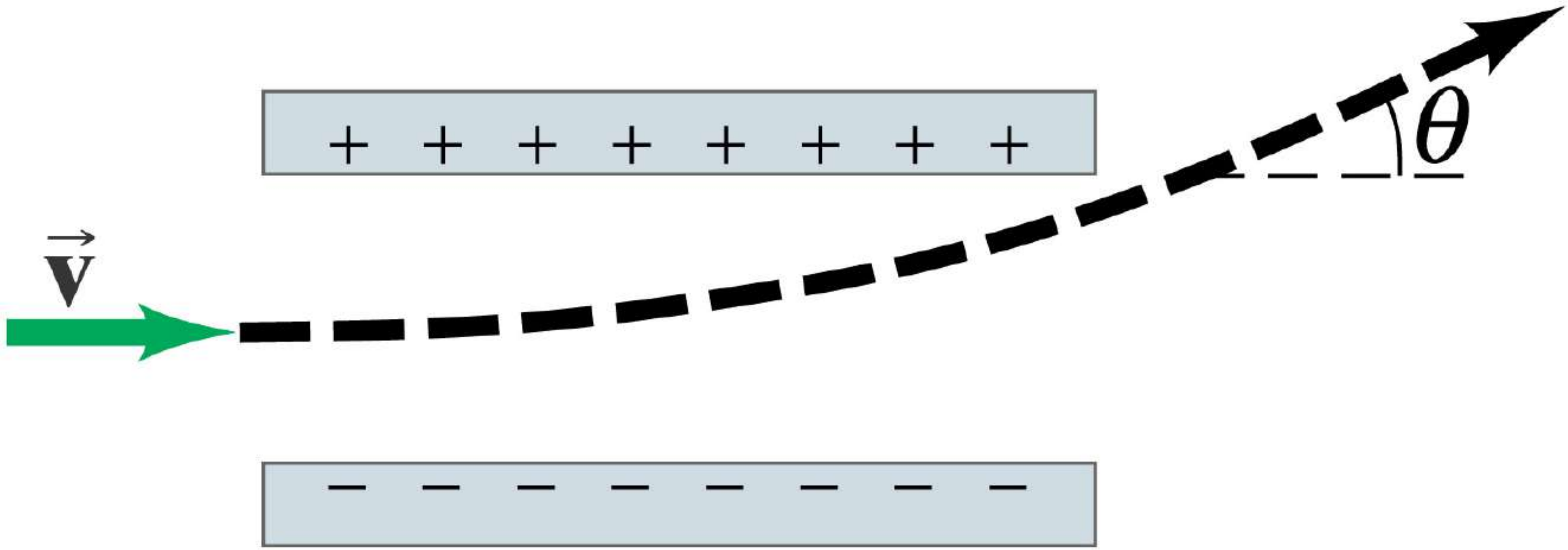
Chapter 17

Physics: Principles with Applications, 6th edition

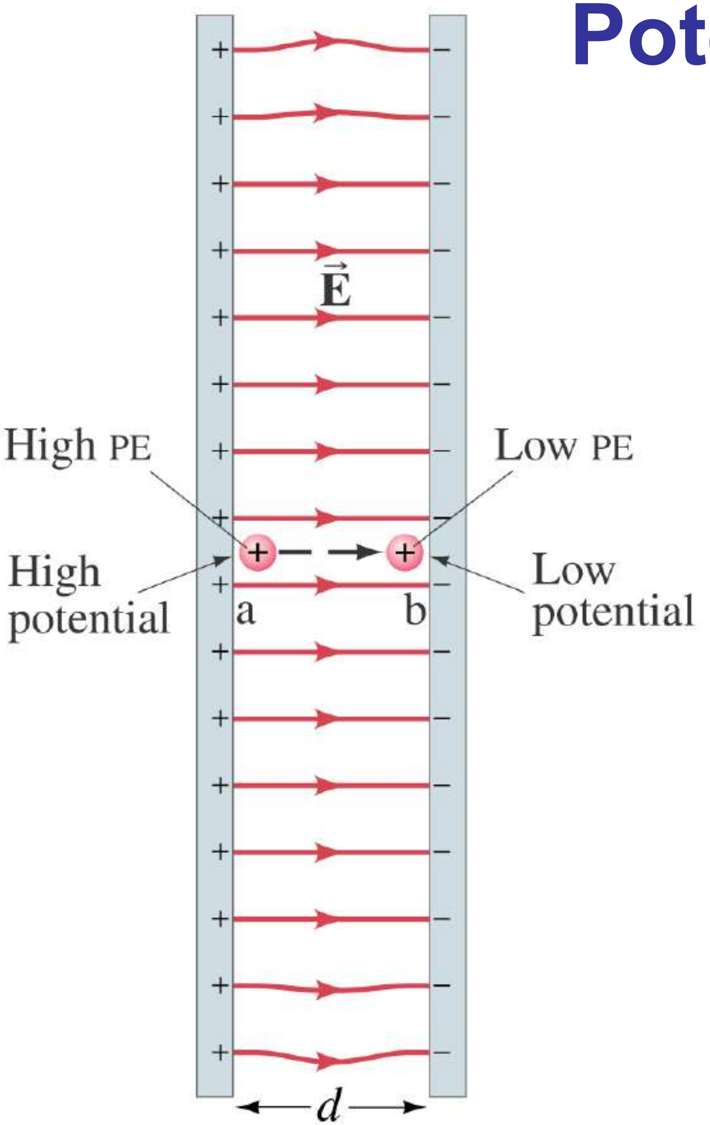
Giancoli

Chapter 17

Electric Potential



17.1 Electrostatic Potential Energy and Potential Difference



Change in electric potential energy is negative of work done by electric force:

$$\mathrm{PE_b} - \mathrm{PE_a} = -qEd \qquad \textbf{(17-1)}$$

(What is qE?)

17.1 Electrostatic Potential Energy and Potential Difference

Electric potential (or Potential Difference) is defined as potential energy per unit charge:

$$V_a = \frac{PE_a}{q}$$

Electric potential is not Potential Energy.

Unit of electric potential: the volt (V).

1 V = 1 J/C.

17.1 Electrostatic Potential Energy and Potential Difference

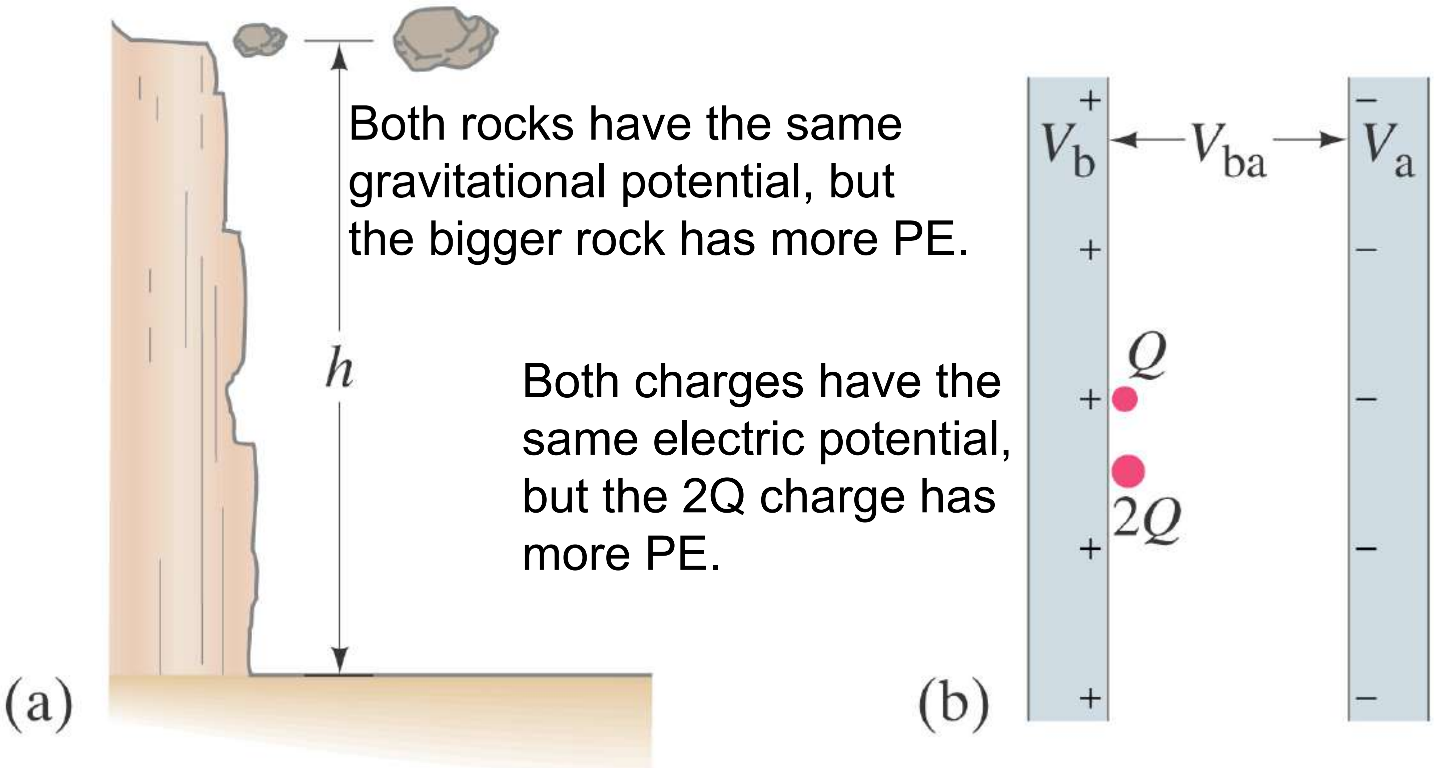
Only changes in potential can be measured, allowing free assignment of V = 0.

$$V_{\mathrm{ba}} = V_{\mathrm{b}} - V_{\mathrm{a}} = \frac{\mathrm{PE_b} - \mathrm{PE_a}}{q} = -\frac{W_{\mathrm{ba}}}{q}$$

ΔPE (or U_E) = qV (on formula sheet)

17.1 Electrostatic Potential Energy and Potential Difference

Analogy between gravitational and electrical potential energy:



Both rocks have the same gravitational potential, but the bigger rock has more PE.

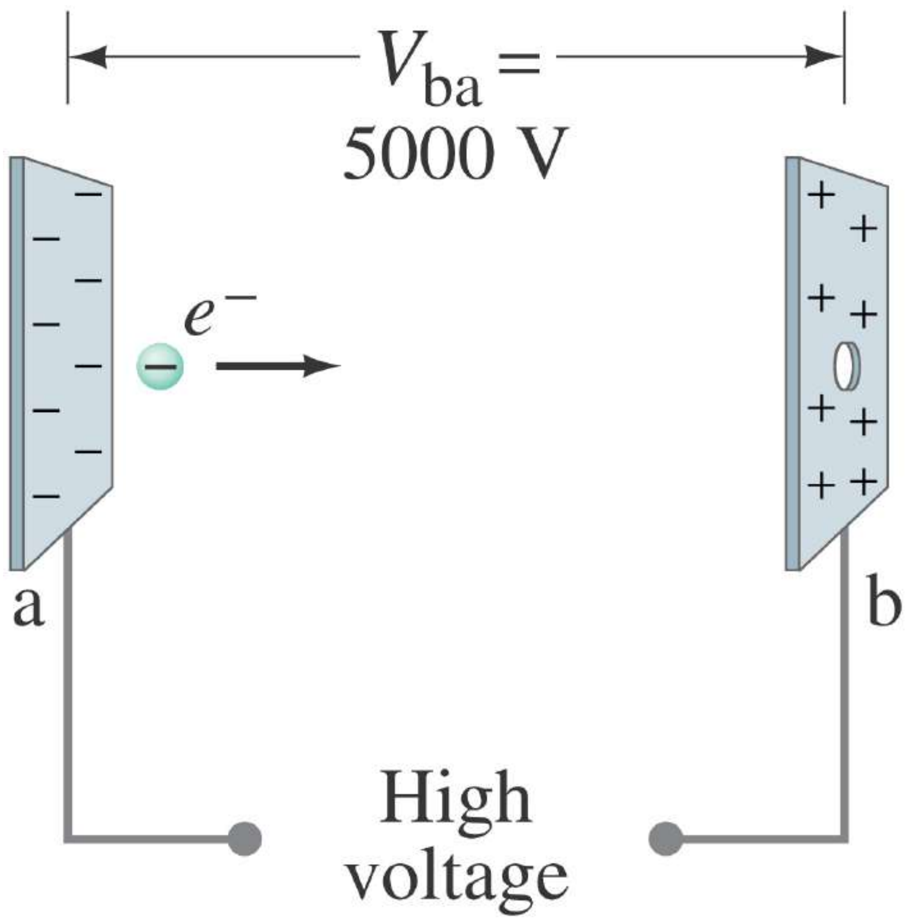
Both charges have the same electric potential, but the 2Q charge has more PE.

Table 17-1
Some Typical Potential Differences (Voltages)

TABLE 17–1 Some Typical Potential Differences (Voltages)

Source	Voltage (approx.)
Thundercloud to ground	10^8 V
High-voltage power line	10^5–10^6 V
Power supply for TV tube	10^4 V
Automobile ignition	10^4 V
Household outlet	10^2 V
Automobile battery	12 V
Flashlight battery	1.5 V
Resting potential across nerve membrane	10^{-1} V
Potential changes on skin (EKG and EEG)	10^{-4} V

Example 17-1



What is the change in potential energy of the electron in going from a to b?

What is the speed of the electron as a result of this acceleration?

Repeat both calculations for a proton.

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17.2 Relation between Electric Potential and Electric Field

Work is charge multiplied by potential:

$$W = -q(V_{\mathrm{b}} - V_{\mathrm{a}}) = -qV_{\mathrm{ba}}$$

Work is also force multiplied by distance:

$$W = Fd = qEd$$

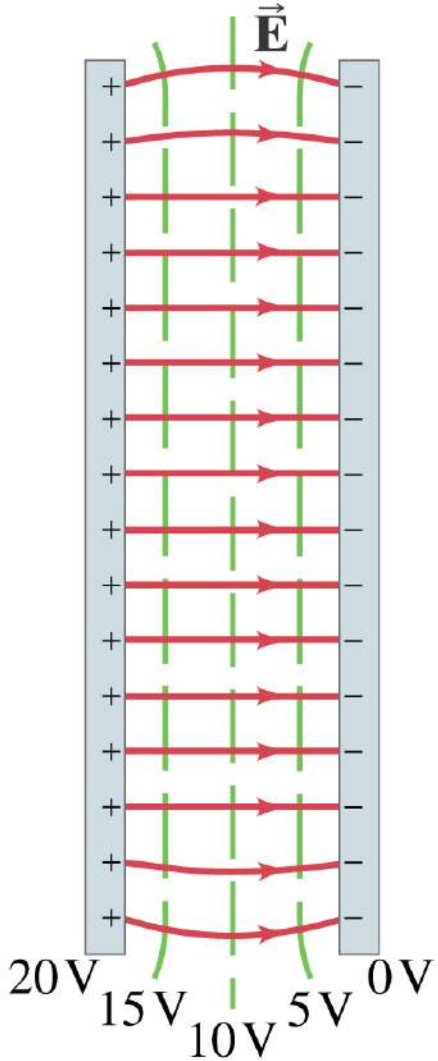
17.2 Relation between Electric Potential and Electric Field

Solving for the field,

$$E = -\frac{V_{\mathrm{ba}}}{d}$$

The minus sign tells us the Electric field direction. It points in the direction of decreasing potential V.

17.3 Equipotential Lines

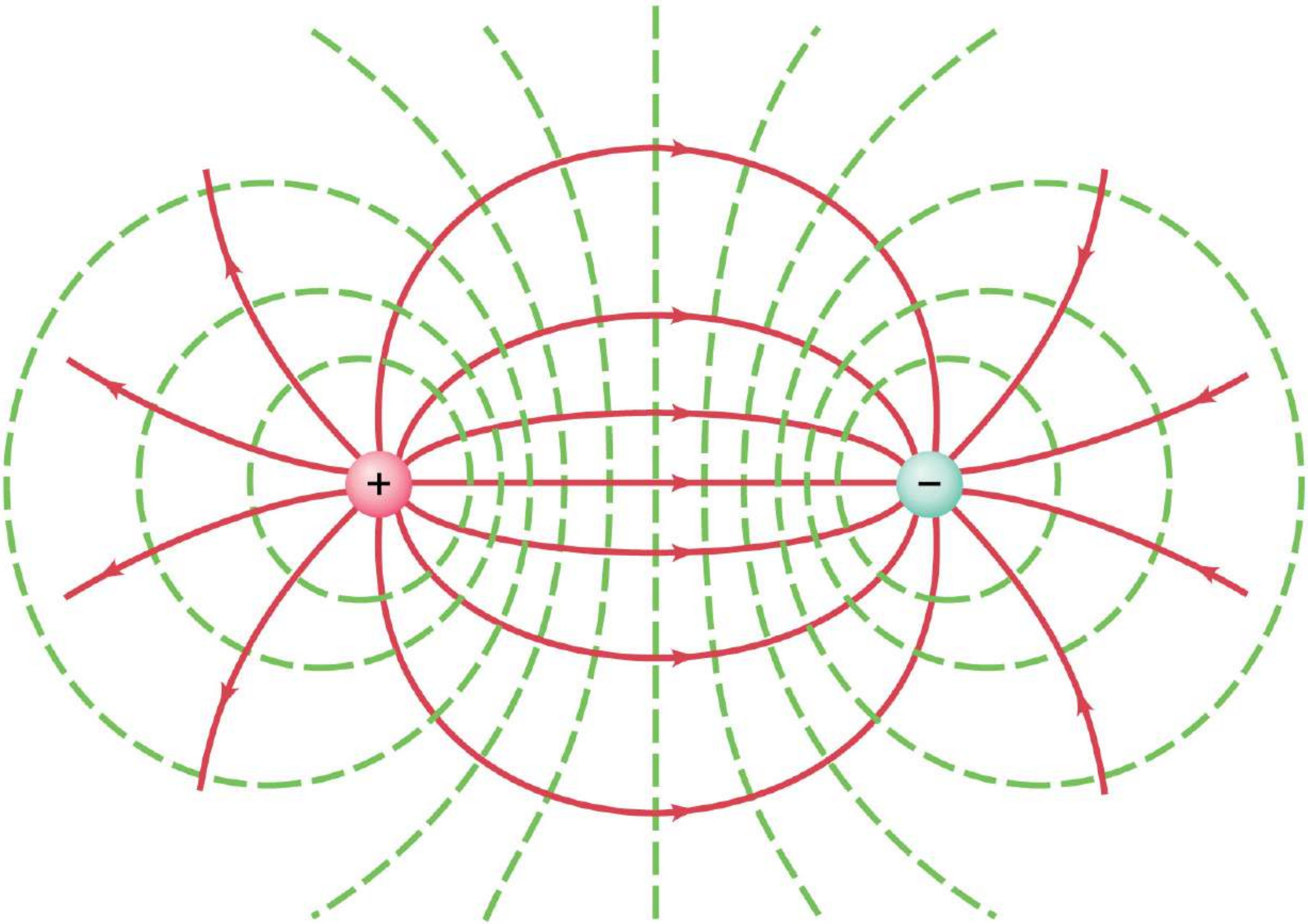


An equipotential (represented by the green dashed lines) is a line or surface over which the potential is constant.

Electric field lines are perpendicular to equipotentials.

The surface of a conductor is an equipotential.

17.3 Equipotential Lines



17.4 The Electron Volt, a Unit of Energy

A Joule is too large when dealing with electrons or atoms, so electron volts are used. One electron volt (eV) is the energy gained by an electron moving through a potential difference of one volt.

$$1\ \text{eV} = 1.6 \times 10^{-19}\ \text{J}$$

17.5 Electric Potential Due to Point Charges

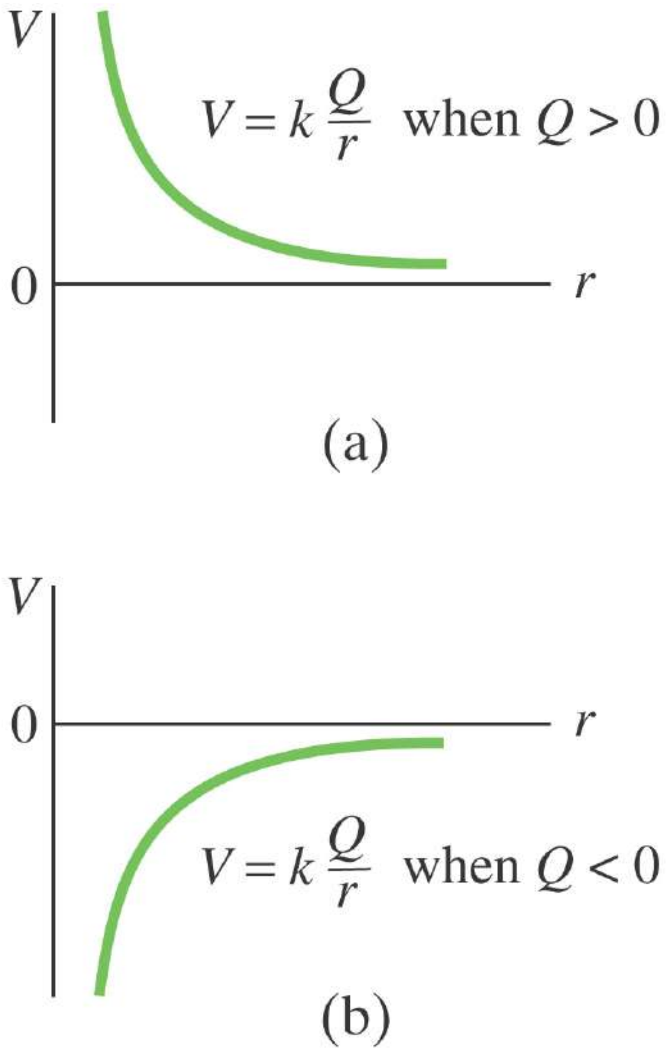
The electric potential due to a point charge can be derived using calculus.

$$V = k\frac{Q}{r}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$$

(on formula sheet)

17.5 Electric Potential Due to Point Charges



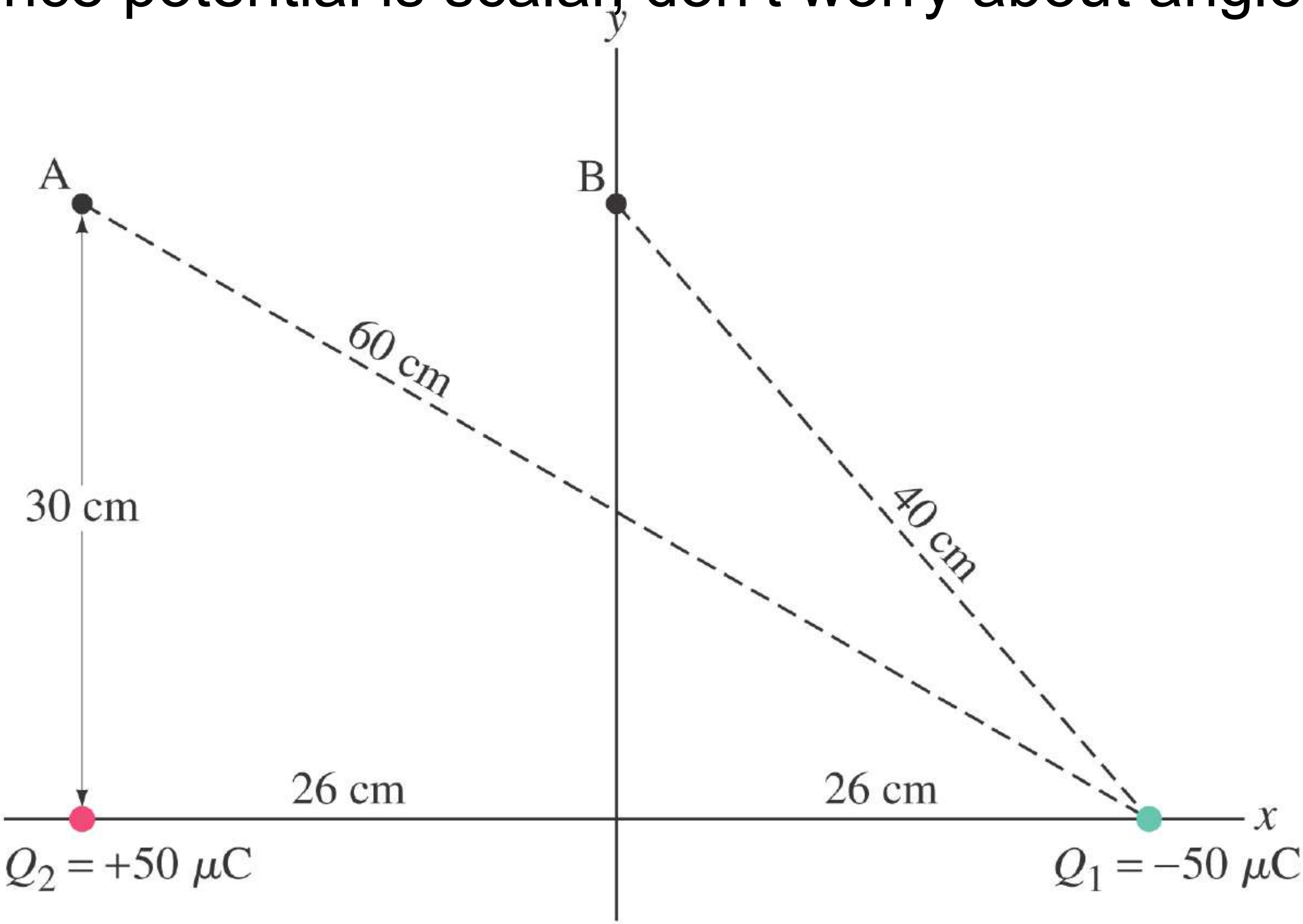
These plots show the potential due to (a) positive and (b) negative charge.

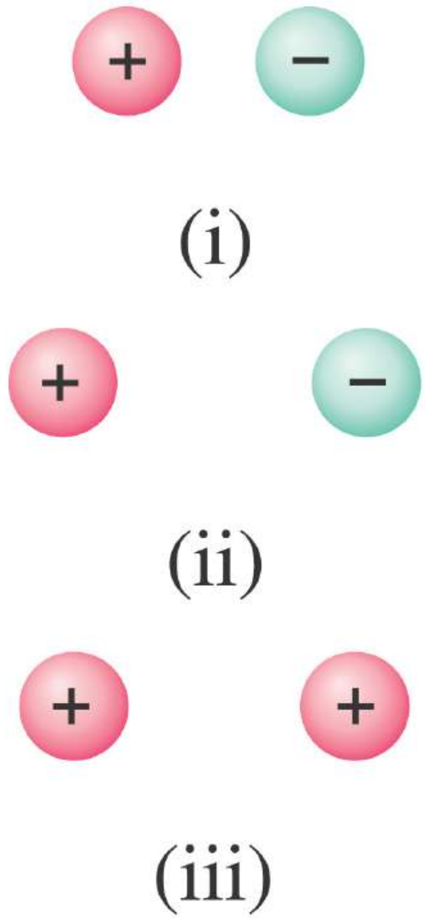
What minimum work is required by an external force to bring a charge q = 3.00 μC from a great distance away (r = infinity) to a point 0.500 m from a charge Q = 20.0 μC ?

17.5 Electric Potential Due to Point Charges

Using potentials instead of fields can make solving problems much easier – potential is a scalar quantity, whereas the field is a vector.

Calculate the electric potential at points A and B. (Since potential is scalar, don't worry about angles)





Which pair of charges has a positive potential energy?

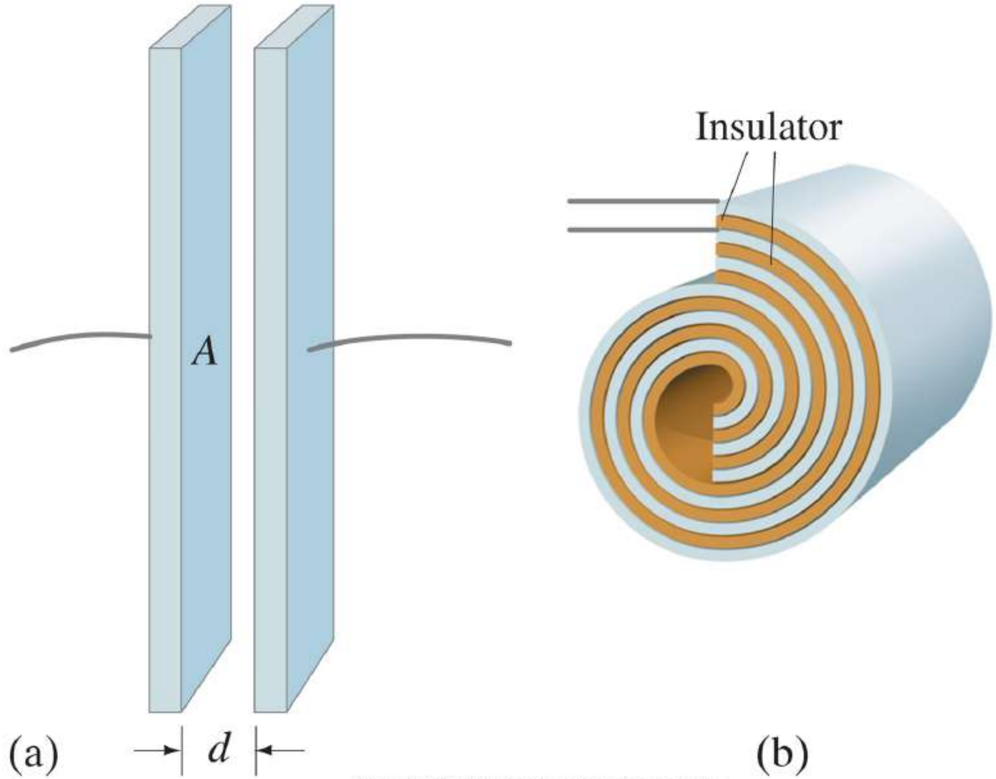
Which pair of charges has the most negative potential energy?

Which pair of charges requires the most work to separate the charges to infinity?

The potential energy equals the work required to bring the two charges near each other, starting at a great distance.

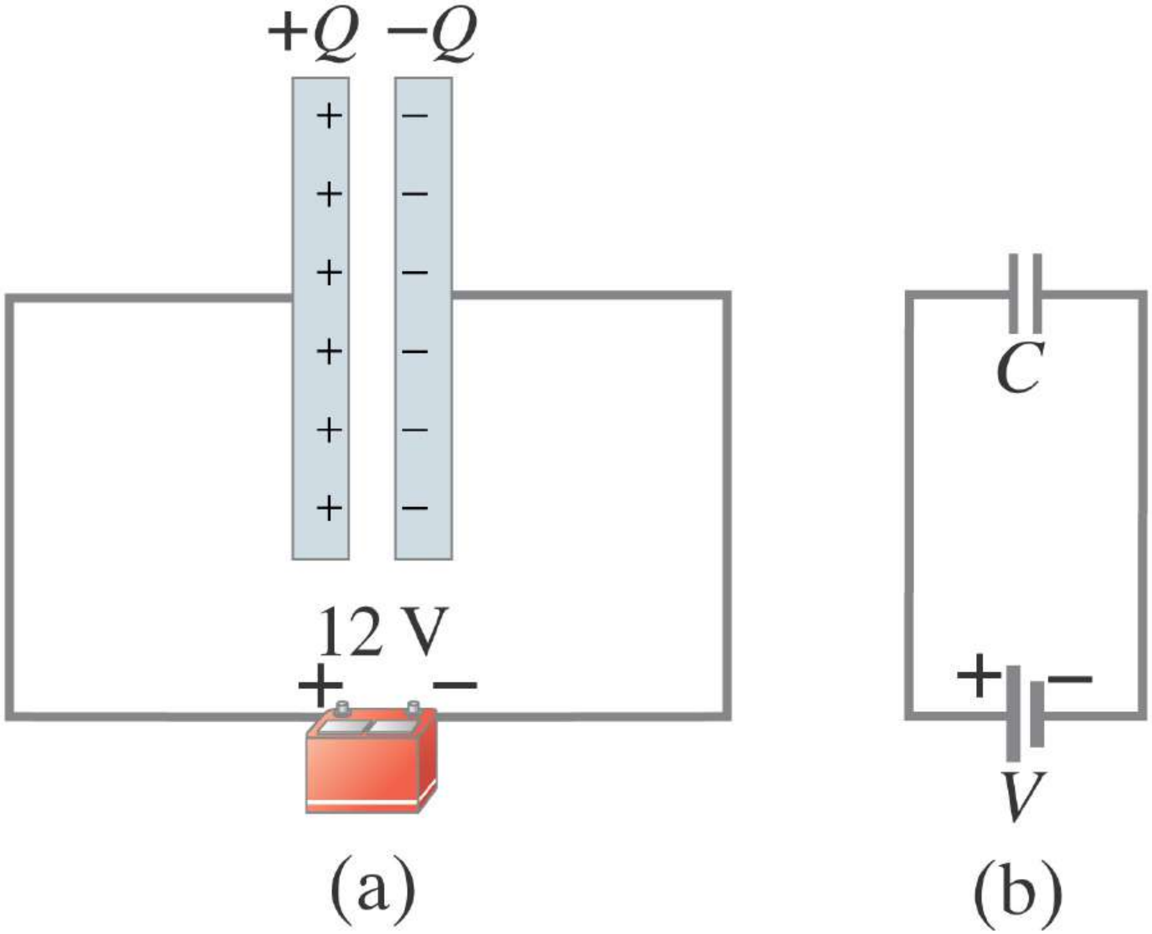
17.7 Capacitance

A capacitor consists of two conductors that are close but not touching. A capacitor has the ability to store electric charge.



17.7 Capacitance

Parallel-plate capacitor connected to battery. (b) is a circuit diagram.



17.7 Capacitance

When a capacitor is connected to a battery, the charge on its plates is proportional to the voltage:

$$Q = CV$$

(on formula sheet)

The quantity C is called the capacitance.

Unit of capacitance: the farad (F)

1 F = 1 C/V

17.7 Capacitance

The capacitance does <u>not</u> depend on the voltage; it is a function of the geometry and materials of the capacitor.

For a parallel-plate capacitor:

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

(on formula sheet)

17.8 Dielectrics

A dielectric is an insulator, and is characterized by a dielectric constant K.

Capacitance of a parallel-plate capacitor filled with dielectric:

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

17.8 Dielectrics

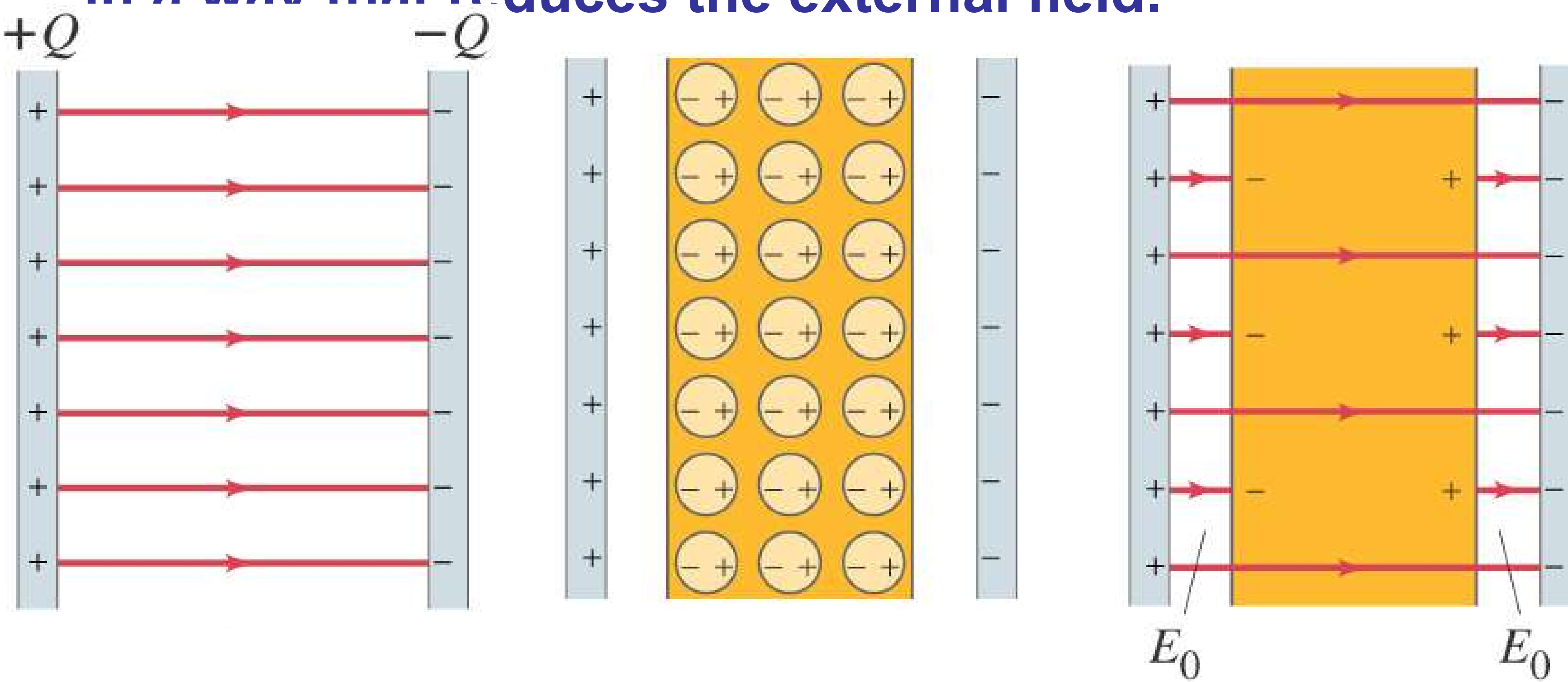
TABLE 17–3 Dielectric constants (at 20°C)

Material	Dielectric constant K	Dielectric strength (V/m)
Vacuum	1.0000	
Air (1 atm)	1.0006	3×10^6
Paraffin	2.2	10×10^6
Polystyrene	2.6	24×10^6
Vinyl (plastic)	2–4	50×10^6
Paper	3.7	15×10^6
Quartz	4.3	8×10^6
Oil	4	12×10^6
Glass, Pyrex	5	14×10^6
Rubber, neoprene	6.7	12×10^6
Porcelain	6–8	5×10^6
Mica	7	150×10^6
Water (liquid)	80	
Strontium titanate	300	8×10^6

Dielectric strength is the maximum field a dielectric can experience without breaking down.

17.8 Dielectrics

The molecules in a dielectric tend to become oriented in a way that reduces the external field.



The dielectric blocks some of the electric field lines, so the voltage decreases. Since Q=CV, if V decreases, C increases. Q must stay constant because the capacitor is not connected to a voltage source.

17.8 Dielectrics

This means that the electric field within the dielectric is less than it would be in air, allowing more charge to be stored for the same potential.

An air filled capacitor consisting of two parallel plates separated by a distance d is connected to a battery of voltage V and acquires a charge Q. While it is still connected to the battery, a slab of dielectric material with K=3 is inserted between the plates of the capacitor. Will Q increase, decrease, or stay the same?

Suppose the air filled capacitor in the previous question is charged and then disconnected from the battery. Next a dielectric is inserted between the plates. Will Q, C, or V change?

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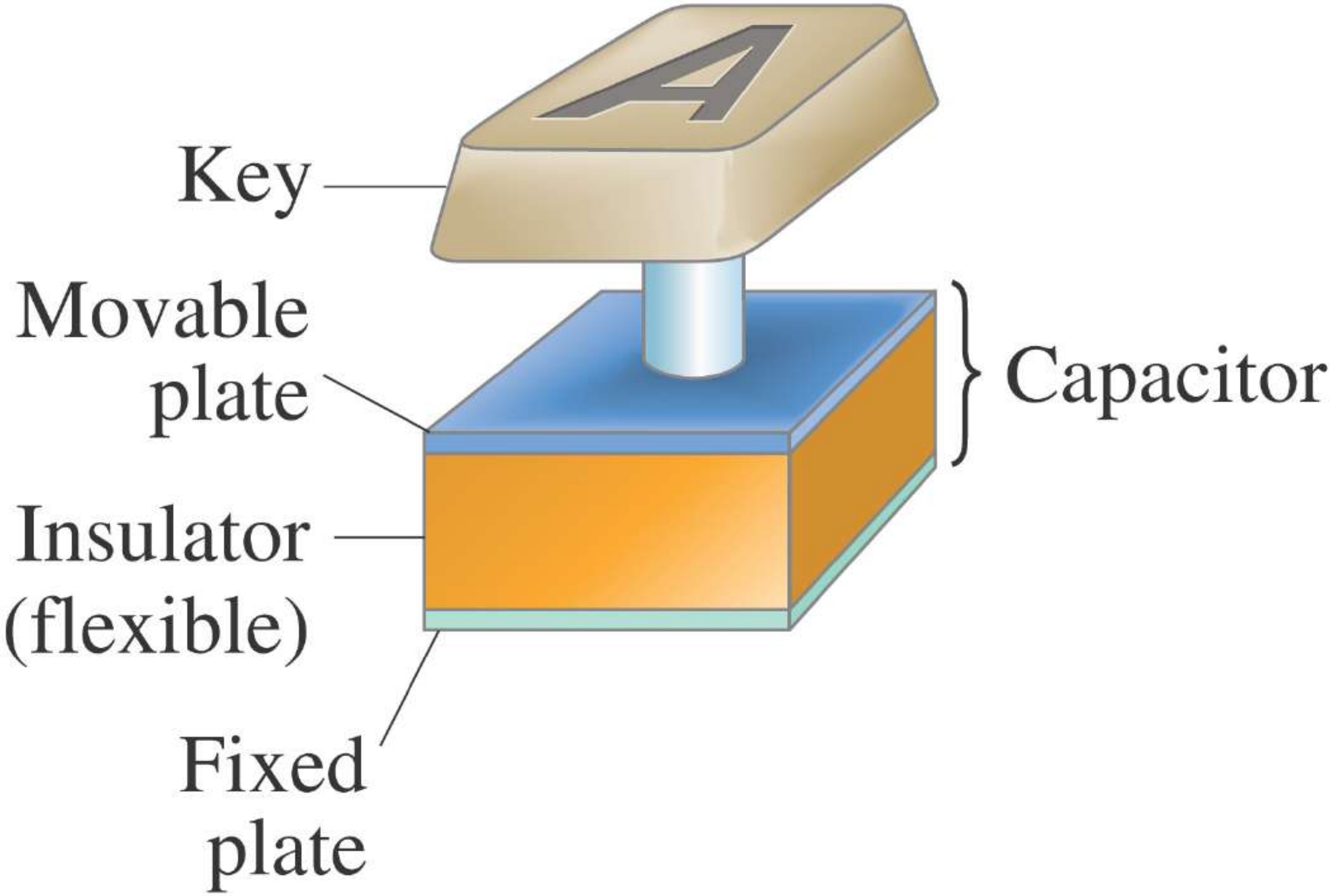
Key of a computer keyboard



17.9 Storage of Electric Energy

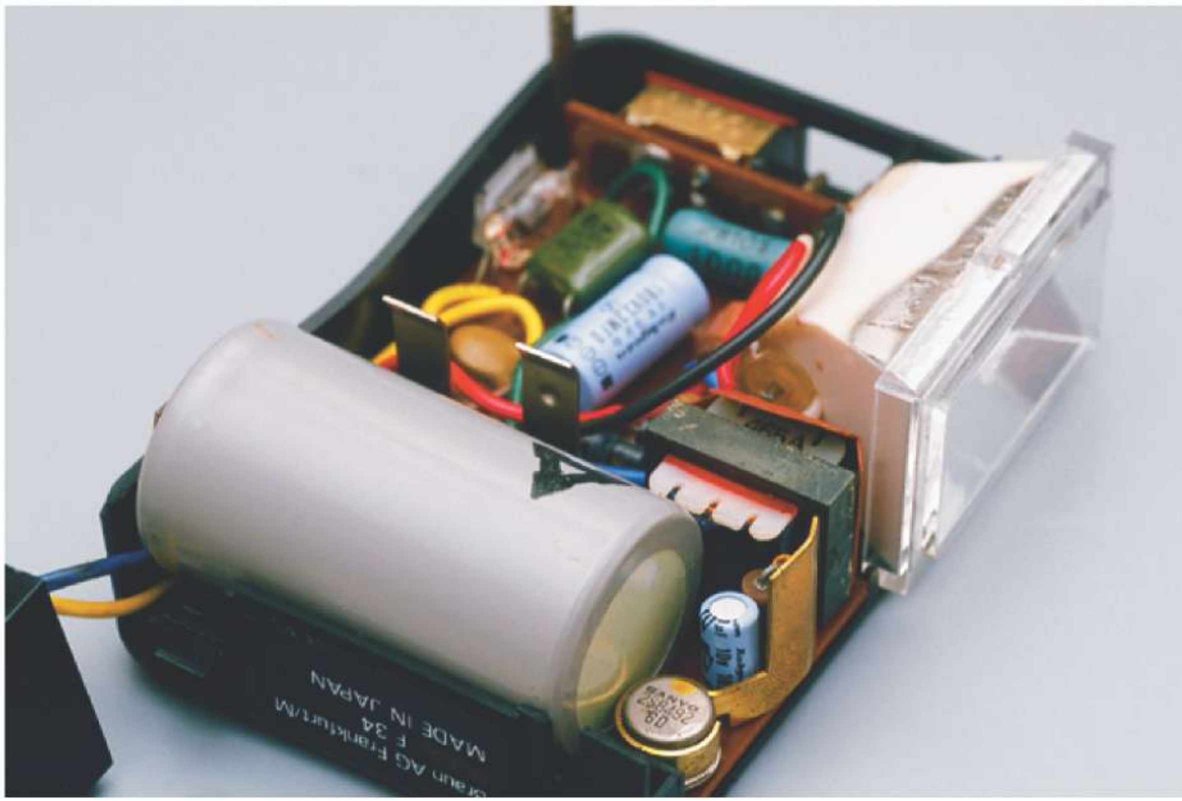
A charged capacitor stores electric energy; the energy stored is equal to the work done to charge the capacitor.

$$\text{PE} = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \tfrac{1}{2}\frac{Q^2}{C}$$

(Using Q = CV and substituting)

(U_c = ½ QV is on formula sheet)

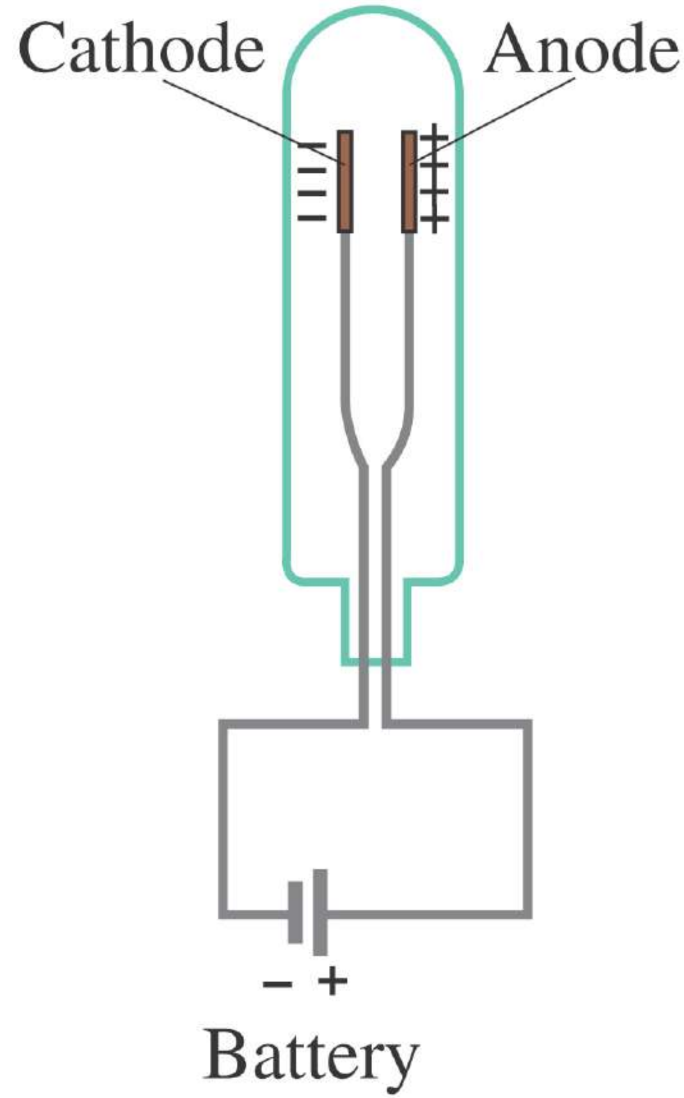
A camera flash unit stores energy in a 150 μF capacitor at 200 V. How much electric energy can be stored?



A parallel plate capacitor carries charge Q and is then disconnected from a battery. The two plates are initially separated by a distance d. Suppose the plates are pulled apart until the separation is 2d. How has the energy stored in this capacitor changed?

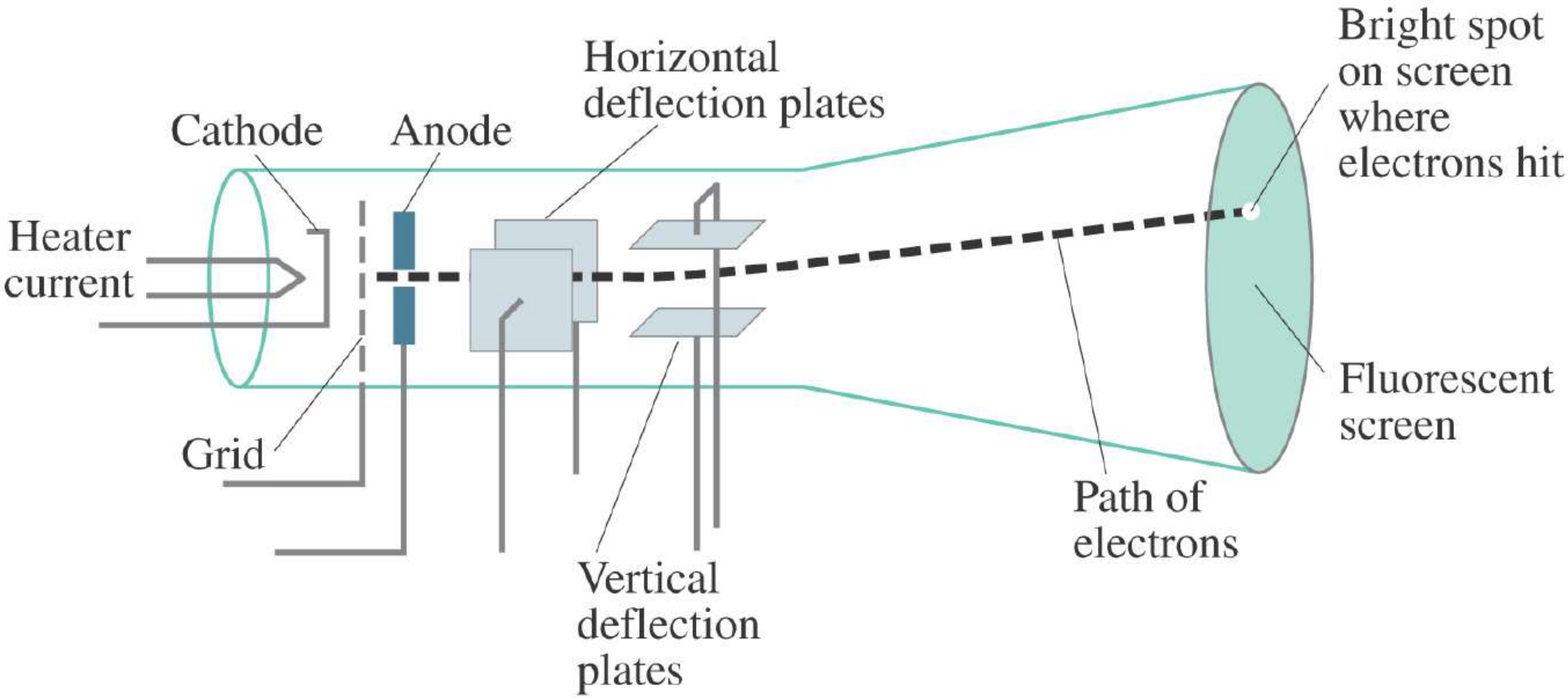
17.10 Cathode Ray Tube: TV and Computer Monitors, Oscilloscope

A cathode ray tube contains a wire cathode that, when heated, emits electrons. A voltage source causes the electrons to travel to the anode.



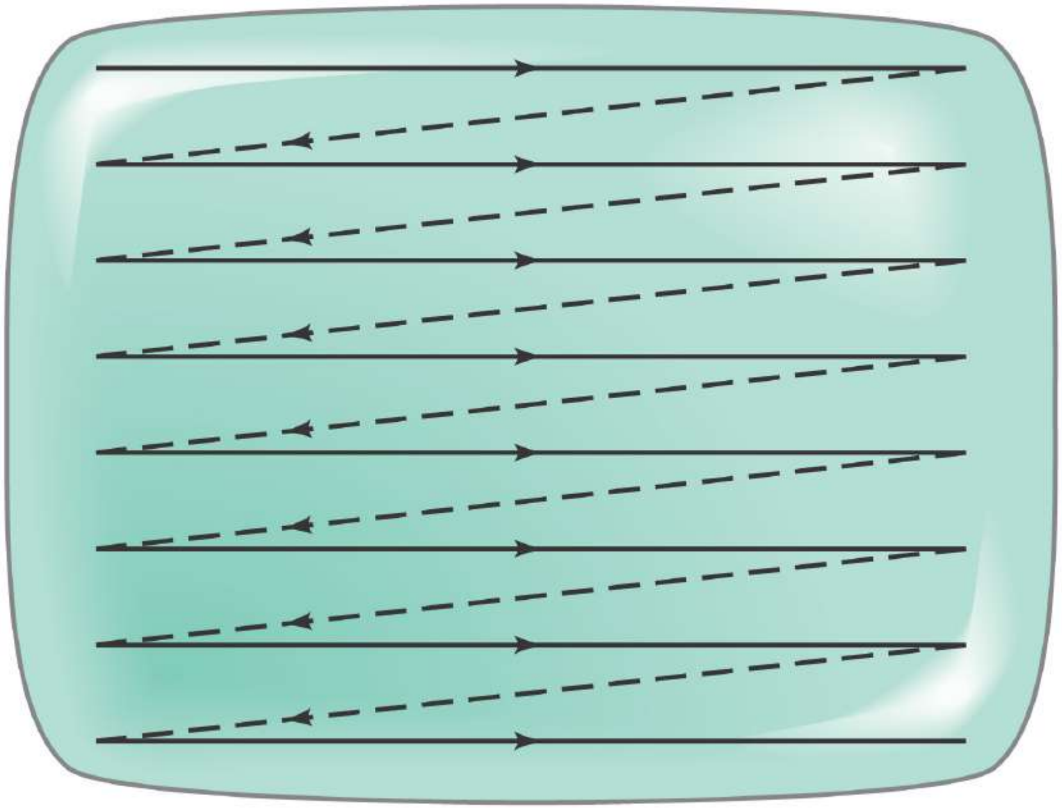
17.10 Cathode Ray Tube: TV and Computer Monitors, Oscilloscope

The electrons can be steered using electric or magnetic fields.



17.10 Cathode Ray Tube: TV and Computer Monitors, Oscilloscope

Televisions and computer monitors (except for LCD and plasma models) have a large cathode ray tube as their display. Variations in the field steer the electrons on their way to the screen. For standard TV, 525 lines are drawn in 1/30 s. High definition is more than double this number.



17.10 Cathode Ray Tube: TV and Computer Monitors, Oscilloscope

An oscilloscope displays en electrical signal on a screen, using it to deflect the beam vertically while it sweeps horizontally.