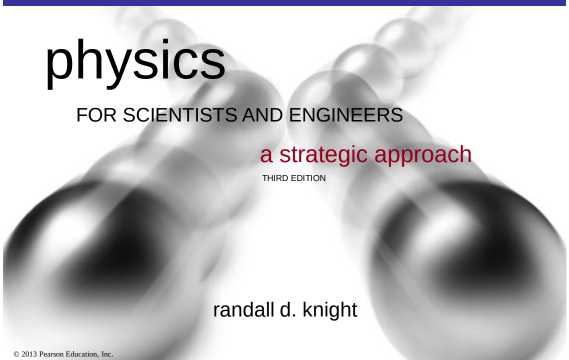
## Class 12, Sections 28.4 – 28.7 Preclass Notes



# physics

FOR SCIENTISTS AND ENGINEERS

a strategic approach

THIRD EDITION

randall d. knight



ALWAYS LEARNING PEARSON

## The Electric Potential

- We define the electric potential $V$ (or, for brevity, just the potential) as

$$V \equiv \frac{U_{q+\text{sources}}}{q}$$

- The unit of electric potential is the joule per coulomb, which is called the volt V:

$$1 \text{ volt} = 1 \text{ V} \equiv 1 \text{ J/C}$$


This battery is a source of *electric potential*. The electric potential difference between the + and – sides is 1.5 V.



## The Electric Potential

- We define the electric potential $V$ (or, for brevity, just the potential) as

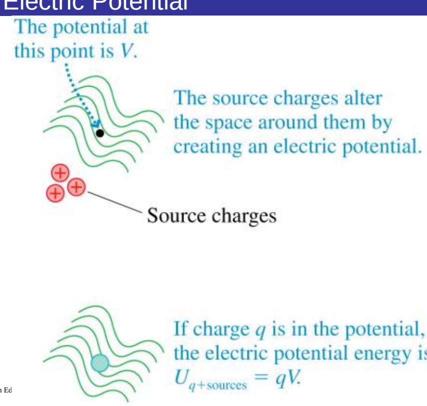
$$V \equiv \frac{U_{q+\text{sources}}}{q}$$

- Another word for "electric potential difference" is **voltage**.

Electrical outlets are also a source of electric potential. The potential difference varies on a cycle of 60 Hertz, but the average electric potential difference between the holes is 120 V.

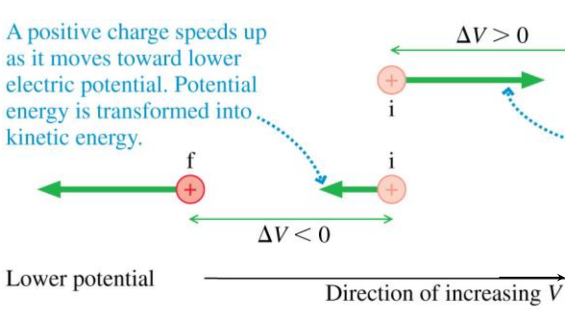


## The Electric Potential






## Using the Electric Potential




$$K_f + qV_f = K_i + qV_i$$



## Using the Electric Potential

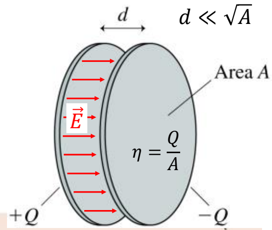
As a charged particle moves through a changing electric potential, energy is conserved:

$$K_f + qV_f = K_i + qV_i$$

| | Electric potential | |
|---|---|---|
| | Increasing ($\Delta V > 0$) | Decreasing ($\Delta V < 0$) |
| + charge | Slows down | Speeds up |
| − charge | Speeds up | Slows down |

## The Electric Field Inside a Parallel-Plate Capacitor

Recall from Chapter 26:




$$\vec{E}_{\text{capacitor}} = \vec{E}_+ + \vec{E}_- = \left(\frac{\eta}{\epsilon_0}, \text{ from positive to negative}\right)$$
$$= \left(\frac{Q}{\epsilon_0 A}, \text{ from positive to negative}\right)$$

## The Electric Potential Inside a Parallel-Plate Capacitor

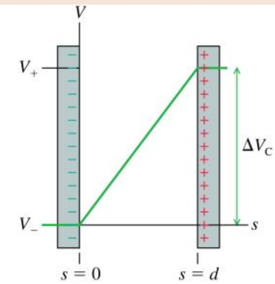
- The electric potential inside a parallel-plate capacitor is

$V = Es$ (electric potential inside a parallel-plate capacitor)

where $s$ **is the distance from the** ***negative*** **electrode.**

- The *potential difference* $\Delta V_C$, or "voltage" between the two capacitor plates is

$$\Delta V_C = V_+ - V_- = Ed$$






## Units of Electric Field

- If we know a capacitor's voltage $\Delta V$ and the distance between the plates $d$, then the electric field strength within the capacitor is:

$$E = \frac{\Delta V_C}{d}$$

- This implies that the units of electric field are volts per meter, or V/m.
- Previously, we have been using electric field units of newtons per coulomb.
- In fact, as you can show that these units are equivalent to each other:

$$1 \text{ N/C} = 1 \text{ V/m}$$



Voltage Units Check.

The definition of Electric Potential, V, comes from the Electric Potential Energy, $U_e$, of a charge, q.

$$U_e = qV$$



$$U_e = qV$$

Units: Joules = Coulombs · Volts

To get Newtons, use

Work = Force × distance

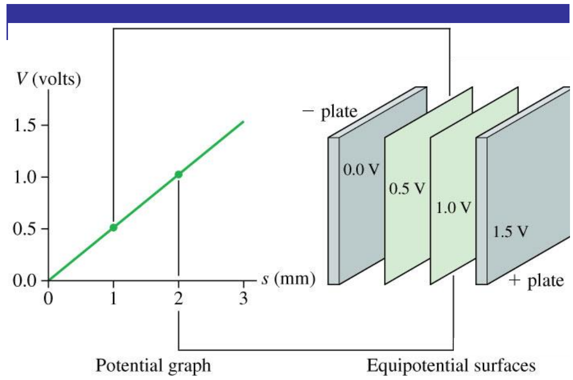
Joules = Newtons × m

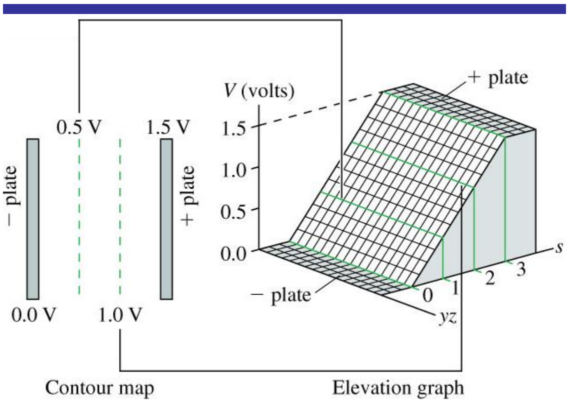
$[N \cdot m] = [C \cdot V]$

$$\frac{N \cdot m}{m \cdot C} = \frac{C \cdot V}{m \cdot C}$$

both units of $\vec{E}$ → $\left[\frac{N}{C}\right] = \left[\frac{V}{m}\right]$

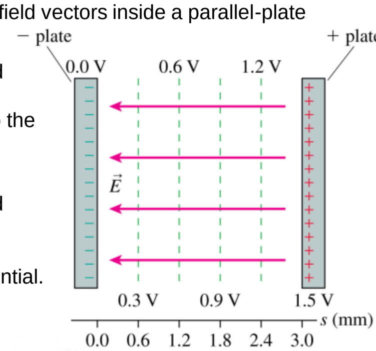







## The Parallel-Plate Capacitor

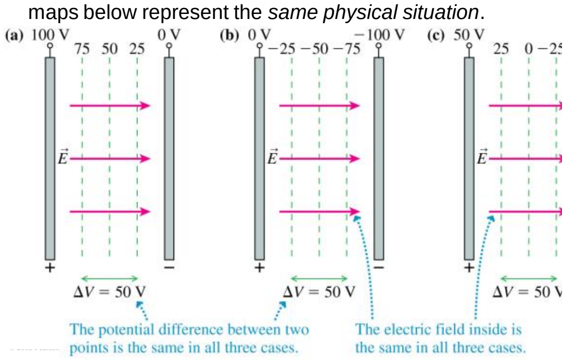
- The figure shows the contour lines of the electric potential and the electric field vectors inside a parallel-plate capacitor.
- The electric field vectors are *perpendicular* to the equipotential surfaces.
- The electric field points in the direction of *decreasing* potential.






## The Zero Point of Electric Potential

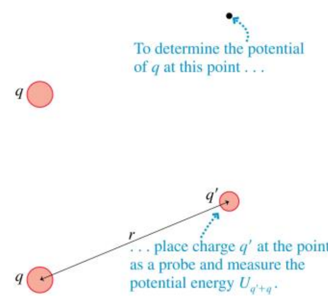
Where you choose $V = 0$ is arbitrary. The three contour maps below represent the *same physical situation*.




## The Electric Potential of a Point Charge

- Let $q$ in the figure be the source charge, and let a second charge $q'$, a distance $r$ away, probe the electric potential of $q$.
- The potential energy of the two point charges is

$$U_{q'+q} = \frac{1}{4\pi\epsilon_0}\frac{qq'}{r}$$






## The Electric Potential of a Point Charge

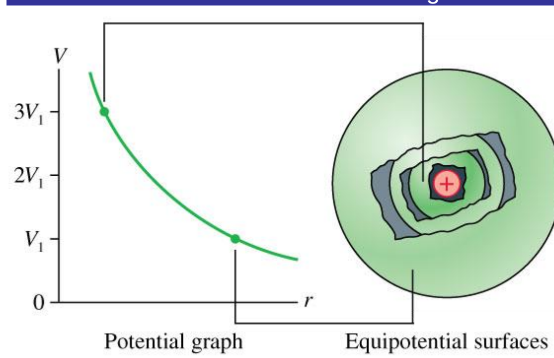
- The electric potential due to a point charge $q$ is

$$V = \frac{U_{q'+q}}{q'} = \frac{1}{4\pi\epsilon_0}\frac{q}{r} \quad \text{(electric potential of a point charge)}$$

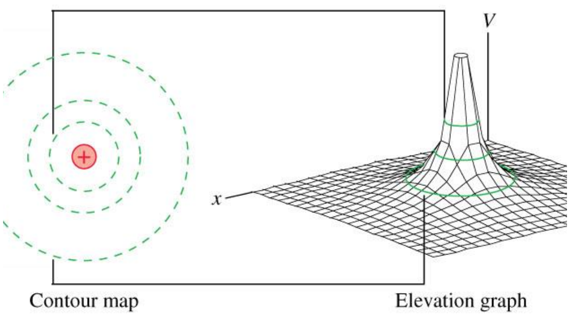
- The potential extends through all of space, showing the influence of charge $q$, but it weakens with distance as $1/r$.
- This expression for $V$ assumes that we have chosen $V = 0$ to be at $r = \infty$.



## The Electric Potential of a Point Charge



## The Electric Potential of a Point Charge






## The Electric Potential of a Charged Sphere

Outside a uniformly charged sphere of radius $R$, the electric potential is identical to that of a point charge $Q$ at the center.

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

where $r > R$.
If the potential at the surface $V_0$ is known, then the potential at $r > R$ is:

$$V = \frac{R}{r}V_0$$

A *plasma ball* consists of a small metal ball charged to a potential of about 2000 V inside a hollow glass sphere filled with low-pressure neon gas. The high voltage of the ball creates "lightning bolts" between the ball and the glass sphere.



## The Electric Potential of Many Charges

- The electric potential $V$ at a point in space is the sum of the potentials due to each charge:

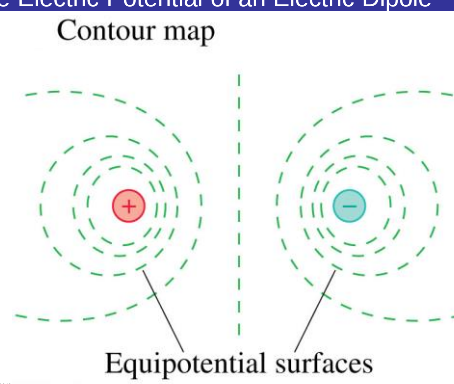
$$V = \sum_i \frac{1}{4\pi\epsilon_0}\frac{q_i}{r_i}$$

where $r_i$ is the distance from charge $q_i$ to the point in space where the potential is being calculated.

- **The electric potential, like the electric field, obeys the principle of superposition.**



## The Electric Potential of an Electric Dipole






## The Electric Potential of a Human Heart

- Electrical activity within the body can be monitored by measuring equipotential lines on the skin.
- The equipotentials near the heart are a slightly distorted but recognizable *electric dipole.*