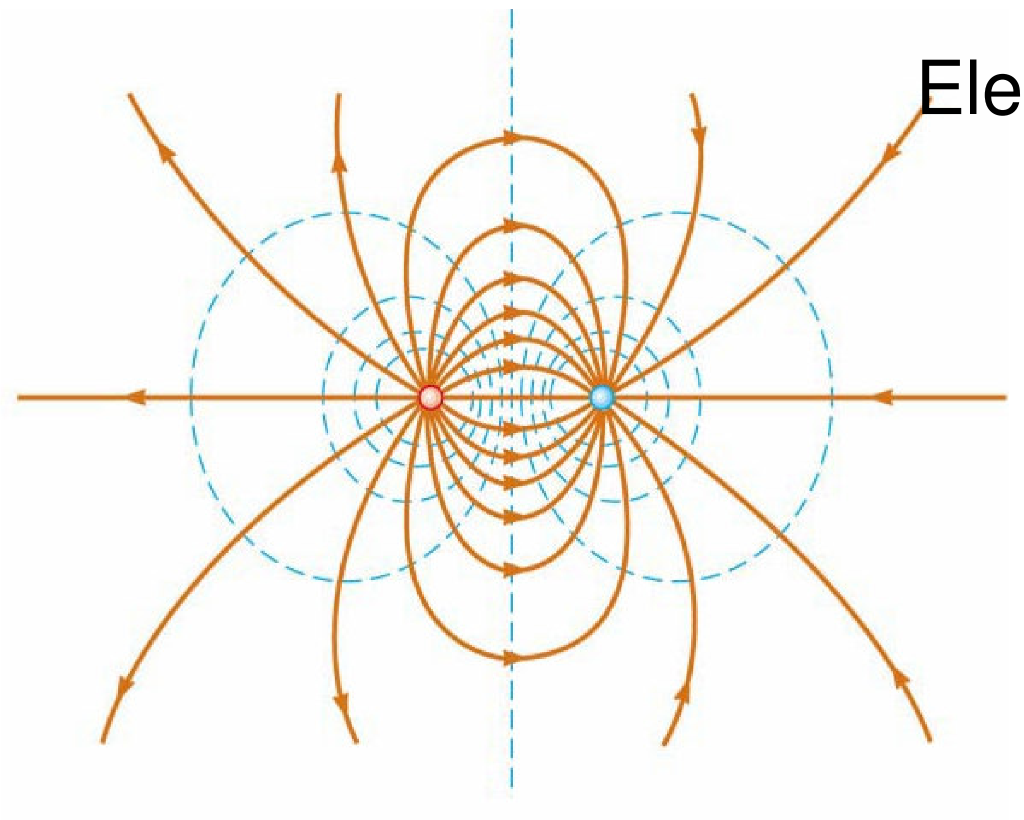
Chapter 23



Electric Potential

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Goals for Chapter 23

- To study and calculate electrical potential energy
- To define and study examples of electric potential
- To trace regions of equal potential as equipotential surfaces
- To find the electric field from electrical potential

Electrical Potential Energy

$$F_G = G\frac{m_1 m_2}{r^2}$$ Gravitational force

$$F_e = k\frac{q_1 q_2}{r^2}$$ Coulomb force

- similar to gravitational, electrostatic force is a conservative force

$$W_{net} = \oint \vec{F} \cdot d\vec{\ell} = 0$$

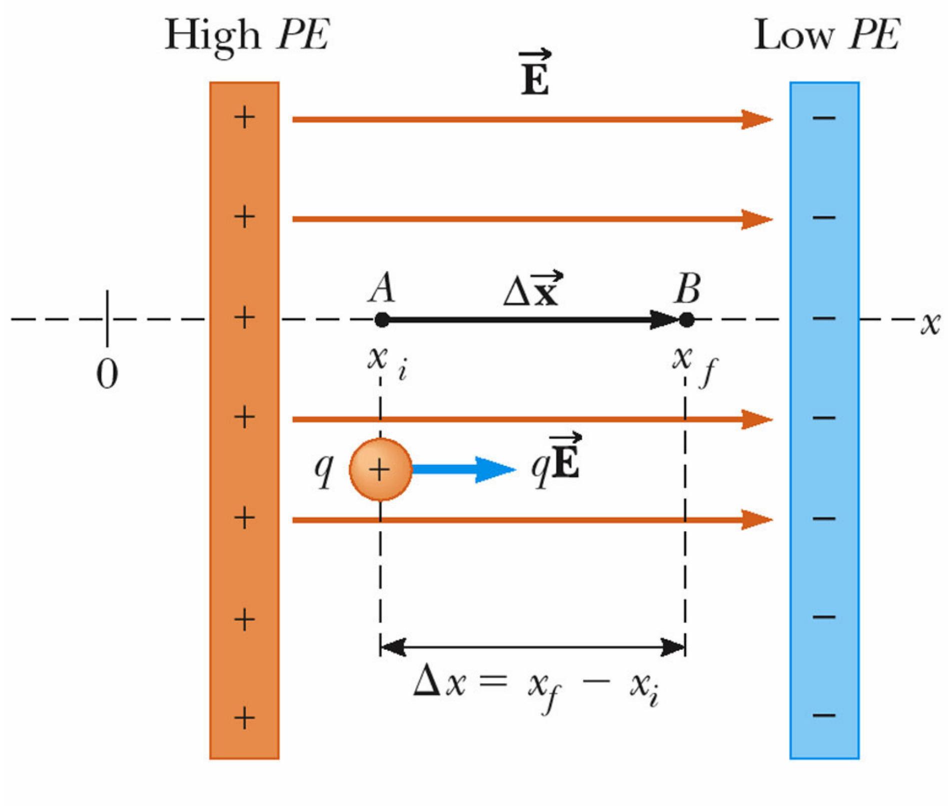
- which means there is a potential energy associated with this force such that

$$F = -\frac{dU}{dx}$$ or gradient in 3D

Work and Potential Energy

- There is a uniform field between the two plates
- As the charge moves from A to B, work is done on it
- $W = Fd = q\,E_x\,(x_f - x_i)$
- $\Delta PE = -W$

  $= -q\,E_x\,\Delta x$
  - Only for a uniform field

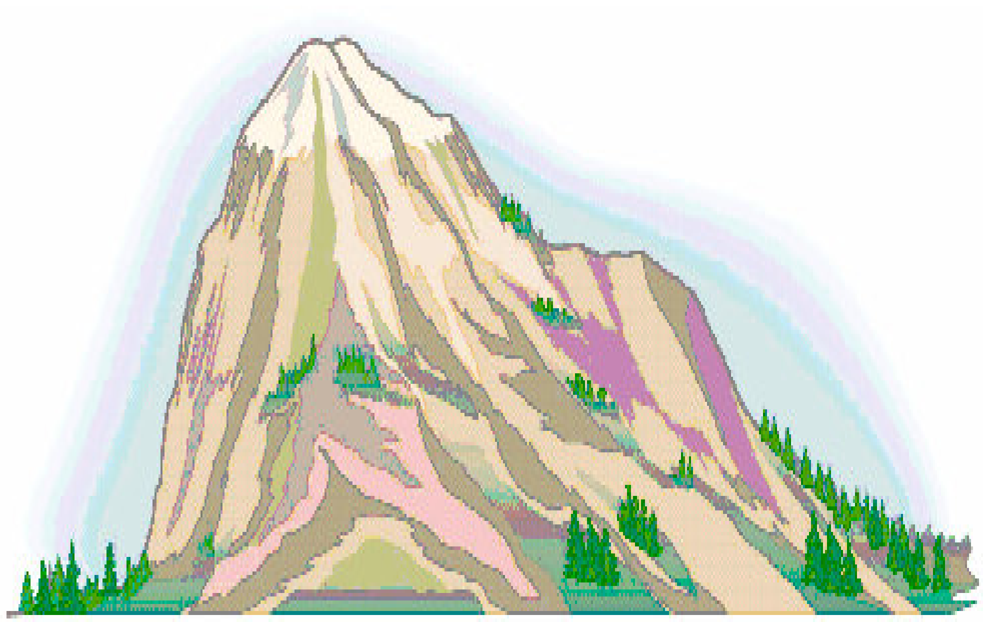


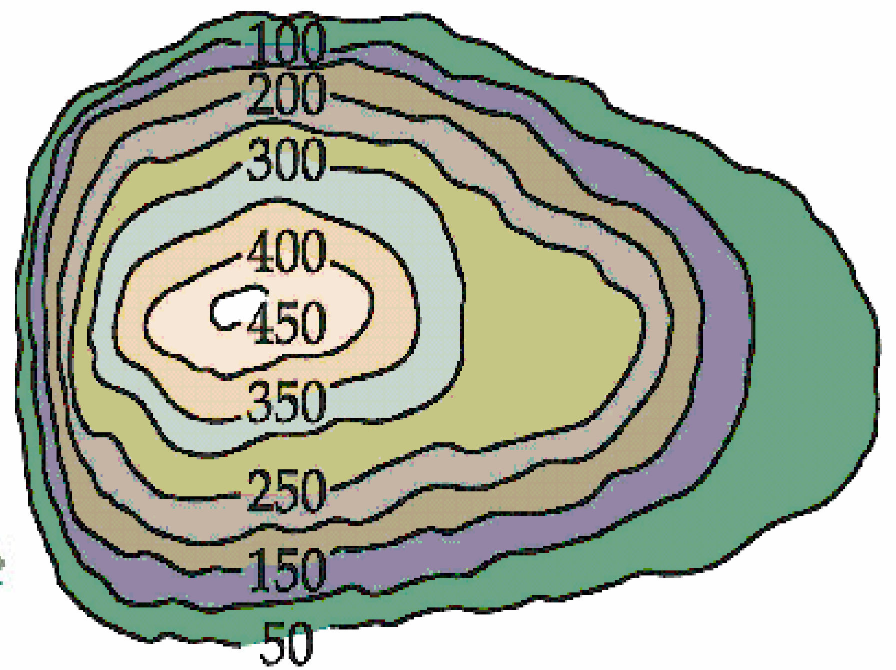
Potential Difference (voltage)

- Potential difference is *not* the same as potential energy
- The potential energy and the potential difference are related by : $\Delta PE = q\,\Delta V$
- Both electric potential energy and potential difference are *scalar* quantities
- Units of potential difference
  - $V = J/C$
- A special case occurs when there is a *uniform electric field*
  - $\Delta V = V_B - V_A = -E_x\,\Delta x$
    - Gives more information about units: $N/C = V/m$

Equipotential Contour (2D)

On a contour map, the curves mark constant elevation; the steepest slope is perpendicular to the curves. The closer together the curves, the steeper the slope.



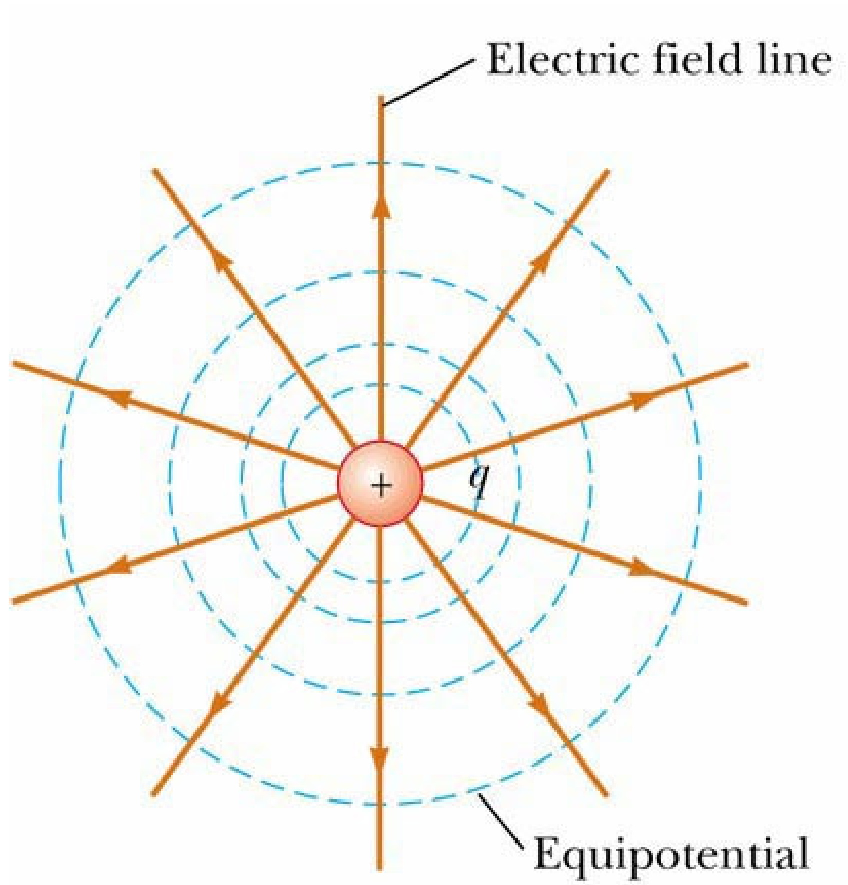


Equipotential Surfaces (3D)

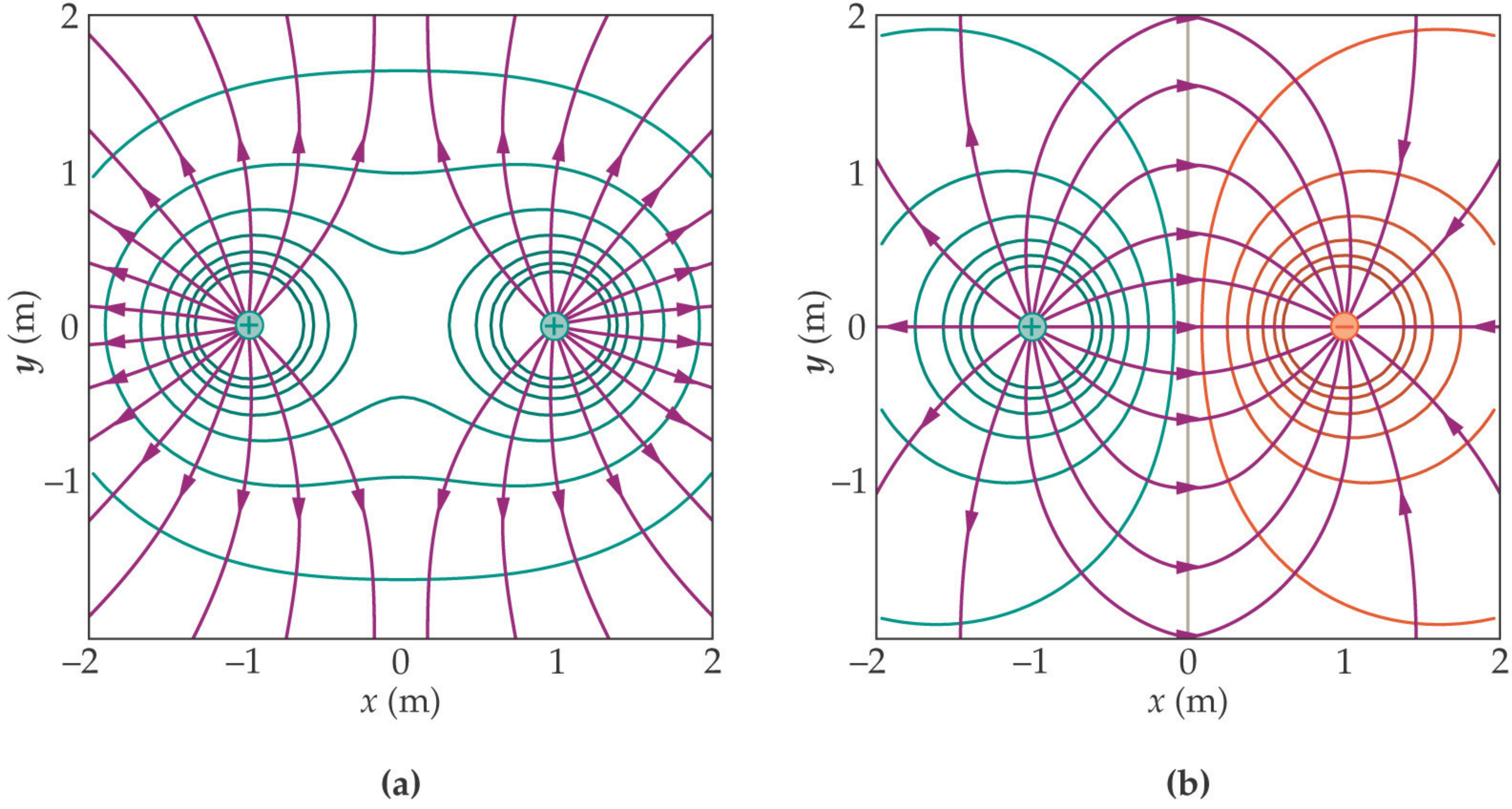
- An *equipotential surface* is a surface on which all points are at the same potential
  - No work is required to move a charge at a constant speed on an equipotential surface
  - The electric field at every point on an equipotential surface is perpendicular to the surface

Equipotentials and Electric Fields Lines – Positive Charge

- The equipotentials for a point charge are a family of spheres centered on the point charge
- The field lines are perpendicular to the electric potential at all points

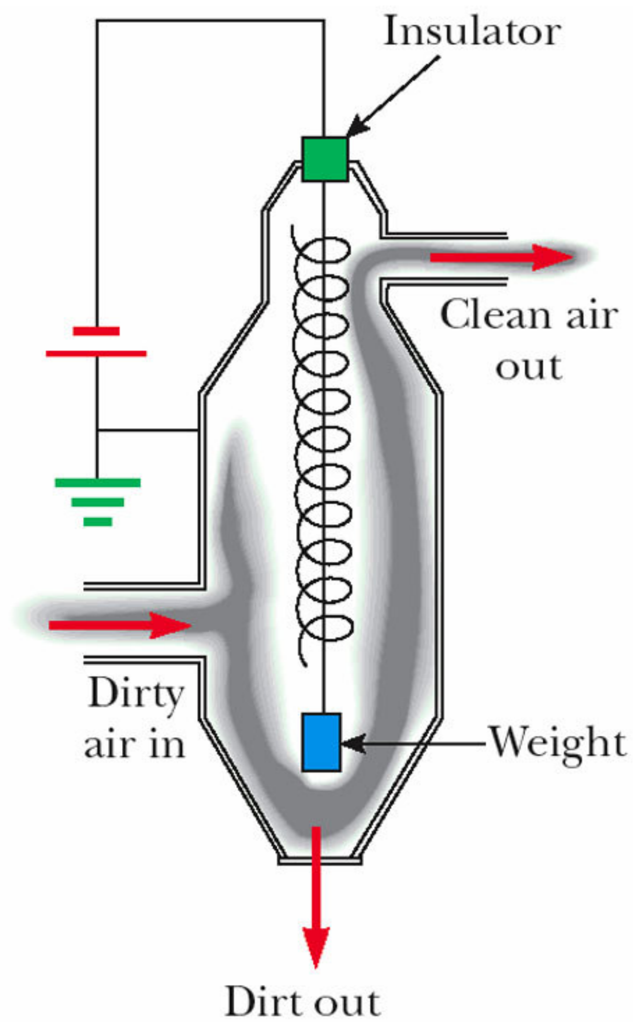


For two point charges



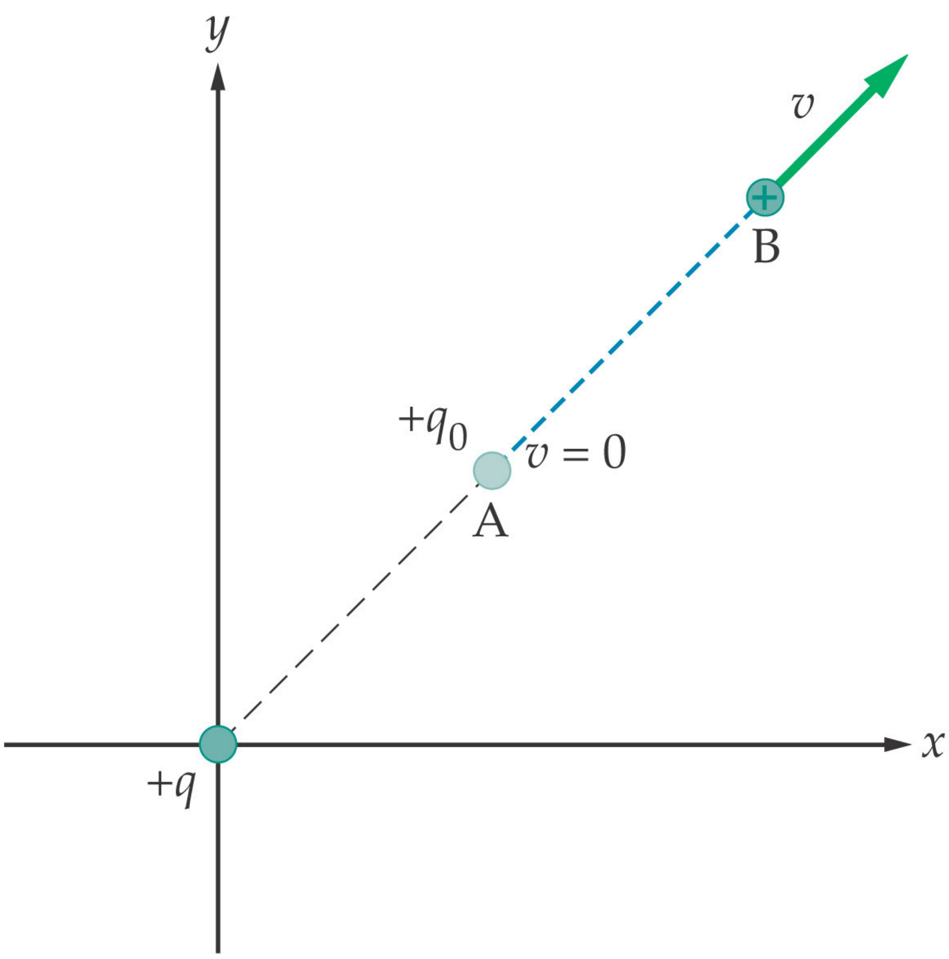
Application – Electrostatic Precipitator

- It is used to remove particulate matter from combustion gases
- Reduces air pollution
- Can eliminate approximately 90% by mass of the ash and dust from smoke
- Recovers metal oxides from the stack



Electric Potential of Point Charges

The difference in potential energy between points A and B is



$$W = \int \vec{F} \cdot d\vec{r} = \int_A^B k \frac{q_o q}{r^2} dr$$

$$-\Delta U = -k \frac{q_o q}{r_B} + k \frac{q_o q}{r_A}$$

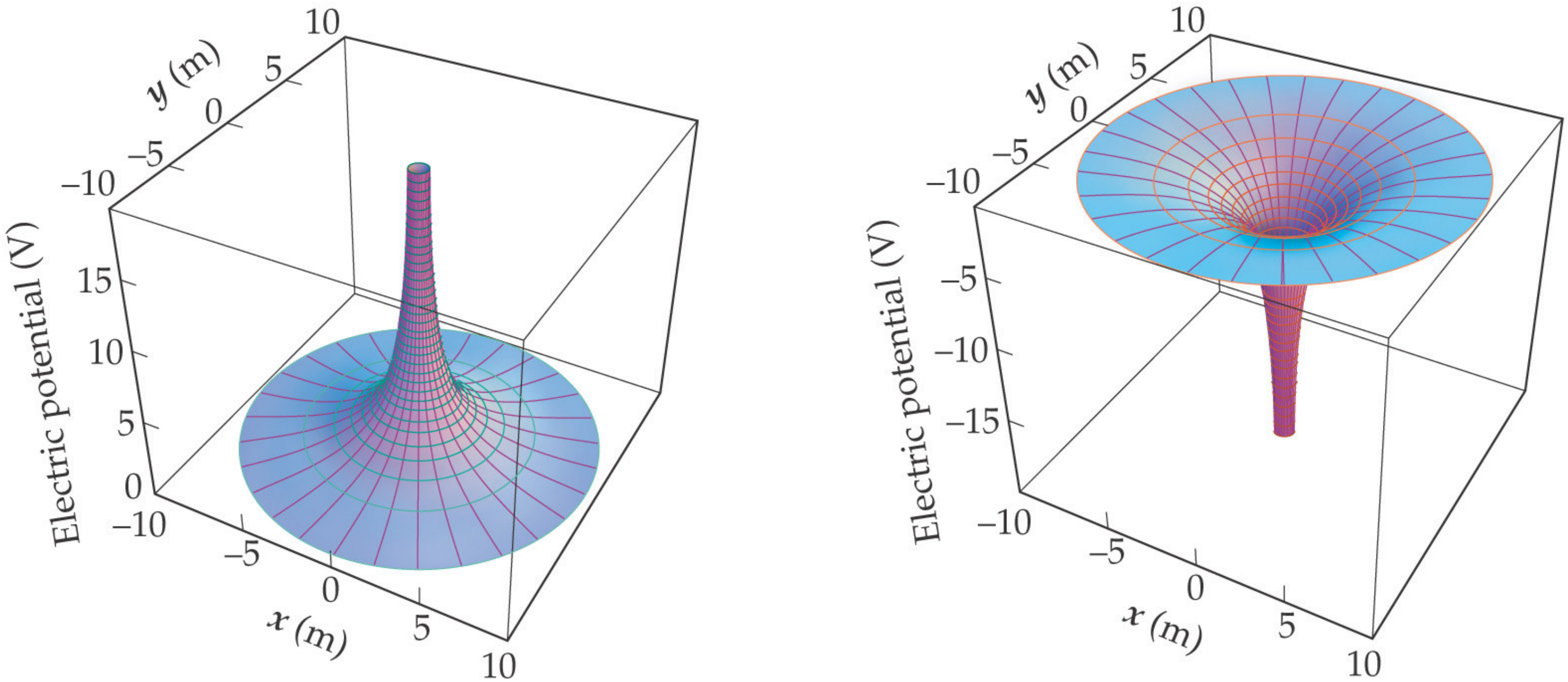
$$-(U_B - U_A) = -k \frac{q_o q}{r_B} + k \frac{q_o q}{r_A}$$

$$U_A - U_B = k \frac{q_o q}{r_A} - k \frac{q_o q}{r_B}$$

The Electric Potential of a Point Charge

PE between 2 pt charges: $$U = k\frac{q_1 q_2}{r}$$

Electric potential from 1 pt charge: $$V = k\frac{q}{r}$$



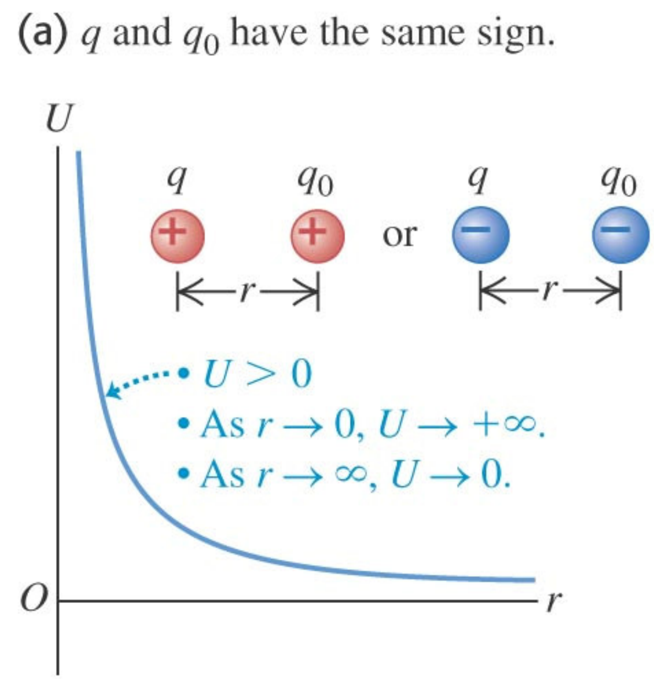
shown here is V for a positive and negative charge.

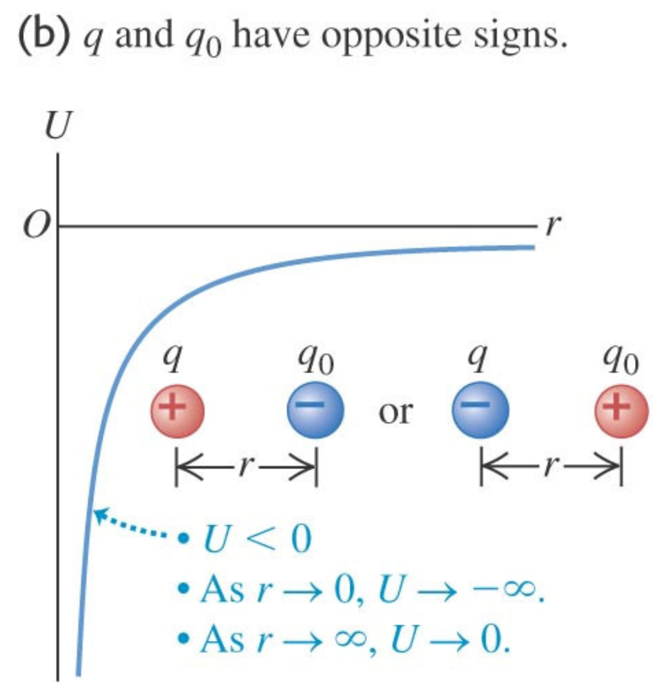
Potential energy curves —PE versus r

$$U = k\frac{q_1 q_2}{r}$$

U > 0 for like charges.
U < 0 for opposite charges.

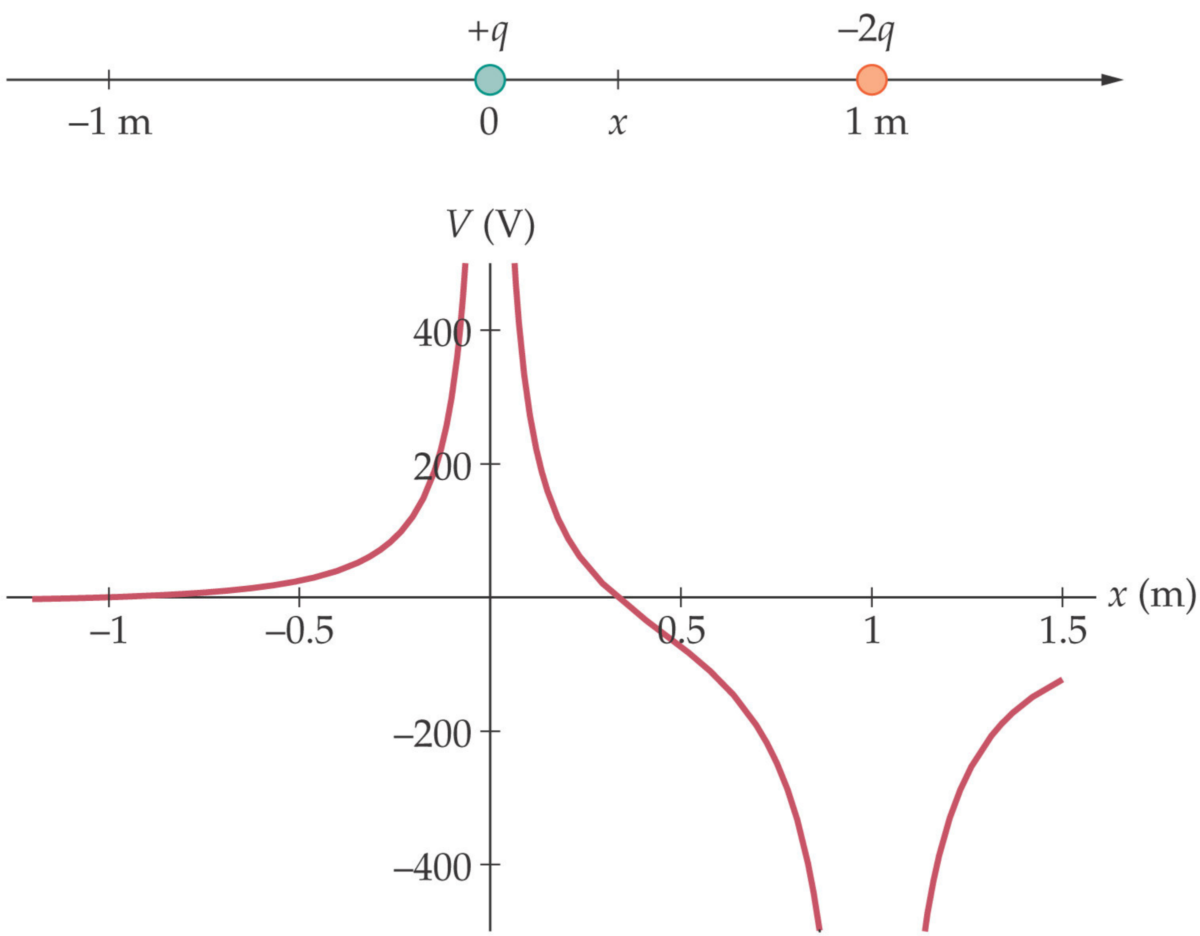
F = - dU/dr





The Electric Potential of Point Charges

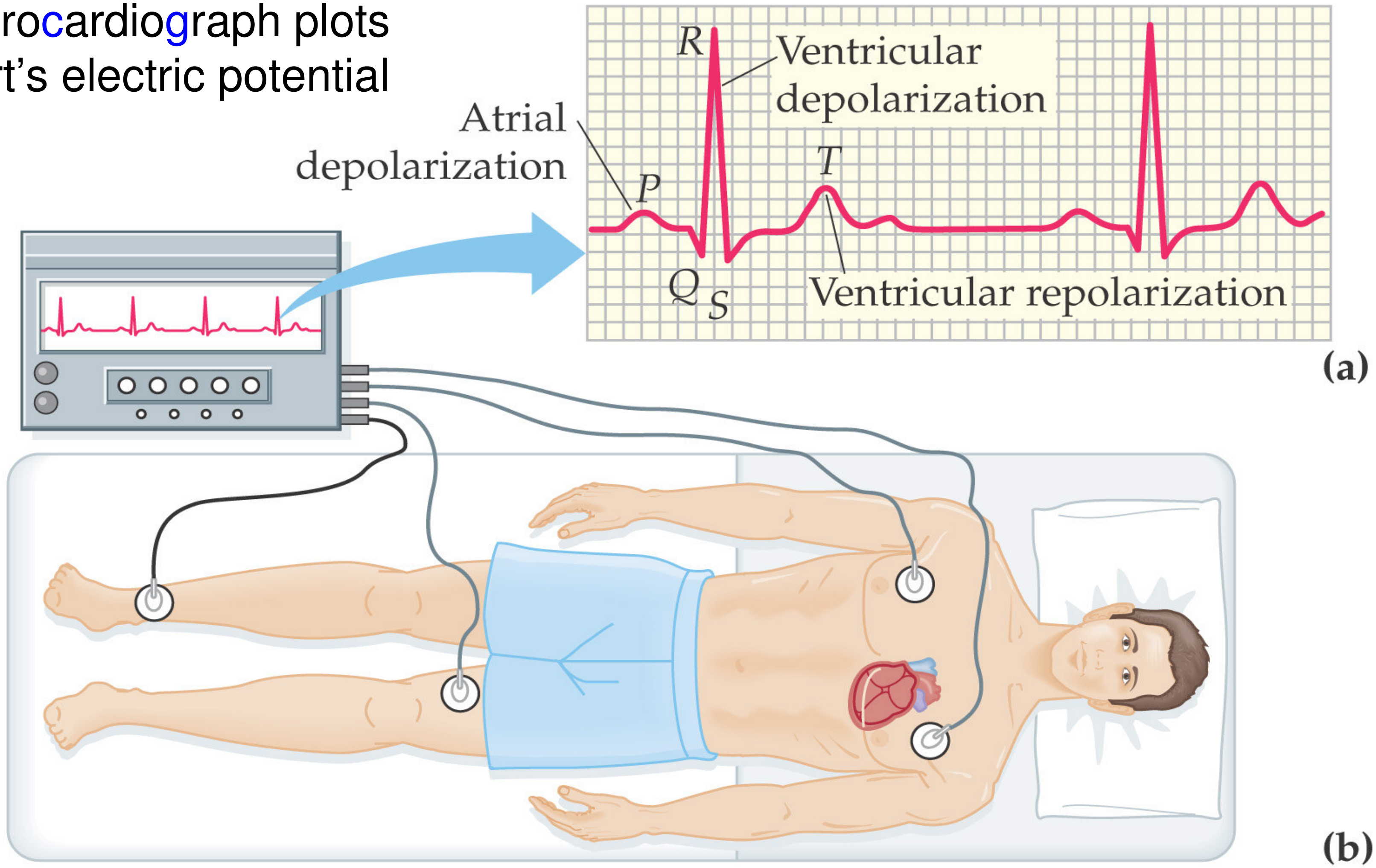
The electric potential of a group of point charges is the algebraic sum of the potentials of each charge.



Human – a complex circuit?

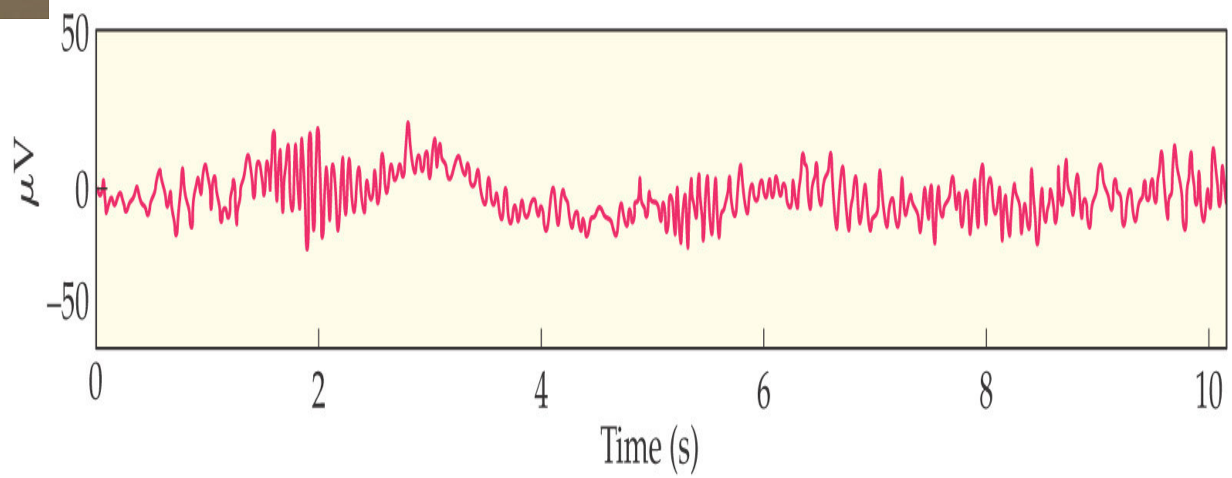
An electrocardiograph plots the heart's electric potential

ECG



EEG

An electroencephalograph measures the electrical activity of the brain.



The Electron Volt

- The electron volt (eV) is defined as the energy that an electron gains when accelerated through a potential difference of 1 V
  - Electrons in normal atoms have energies of 10's of eV
  - Excited electrons have energies of 1000's of eV
  - High energy gamma rays have energies of millions of eV
- 1 eV = 1.6×10^{-19} J

Example