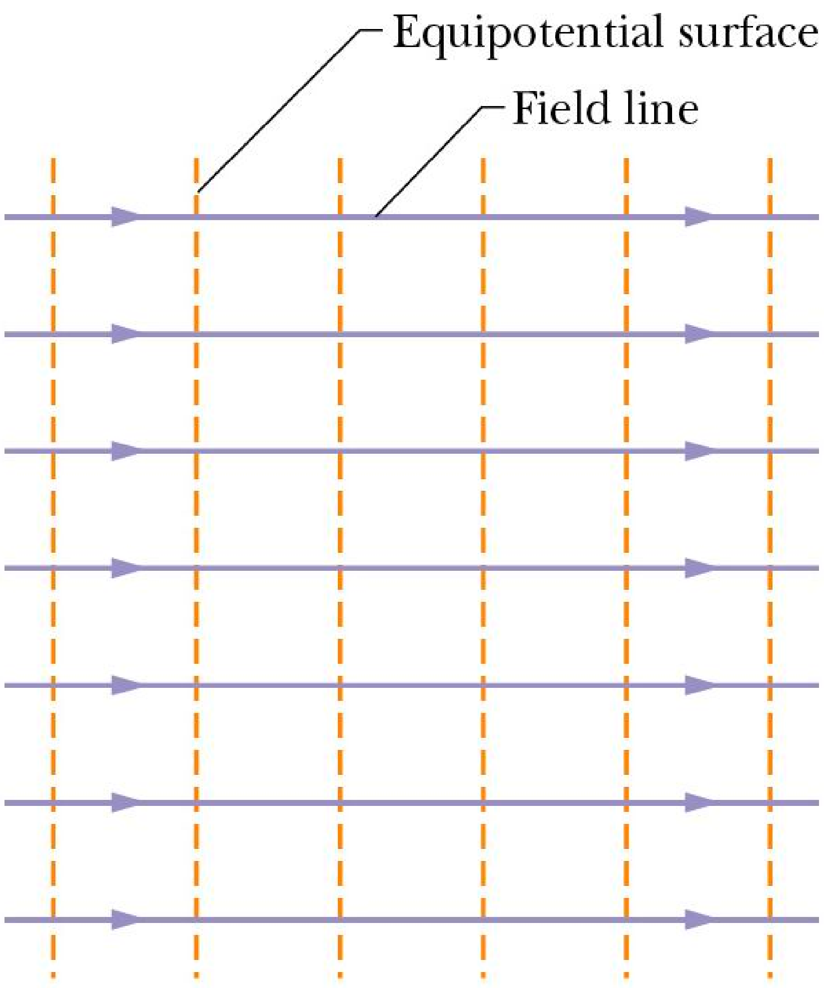
Equipotential Surfaces

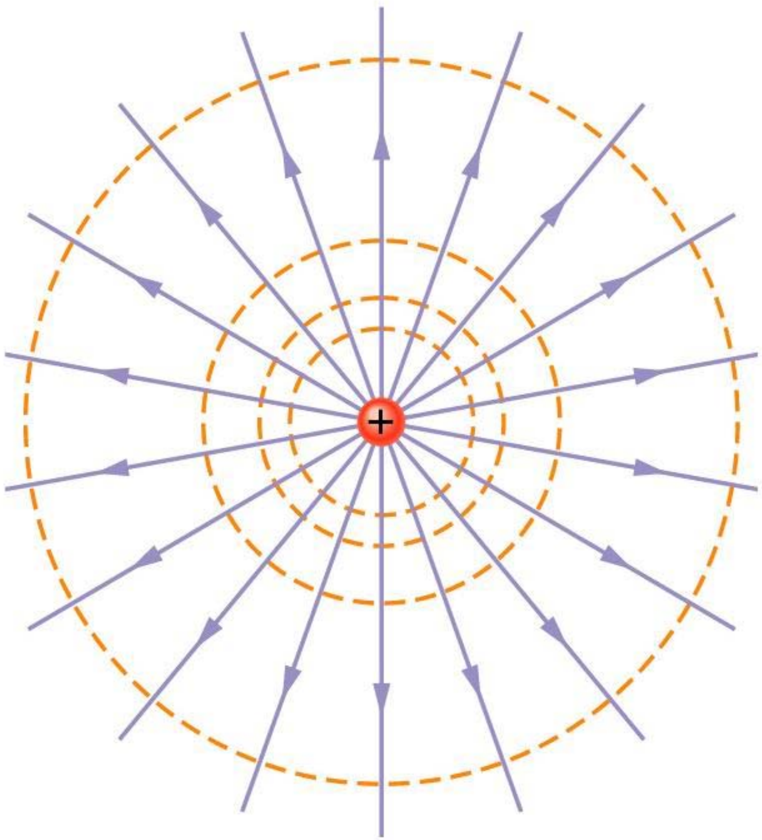
- Draw equipotential surfaces for distributions of charges

- Equipotential surfaces are always ⊥ to electric field lines and to *E*

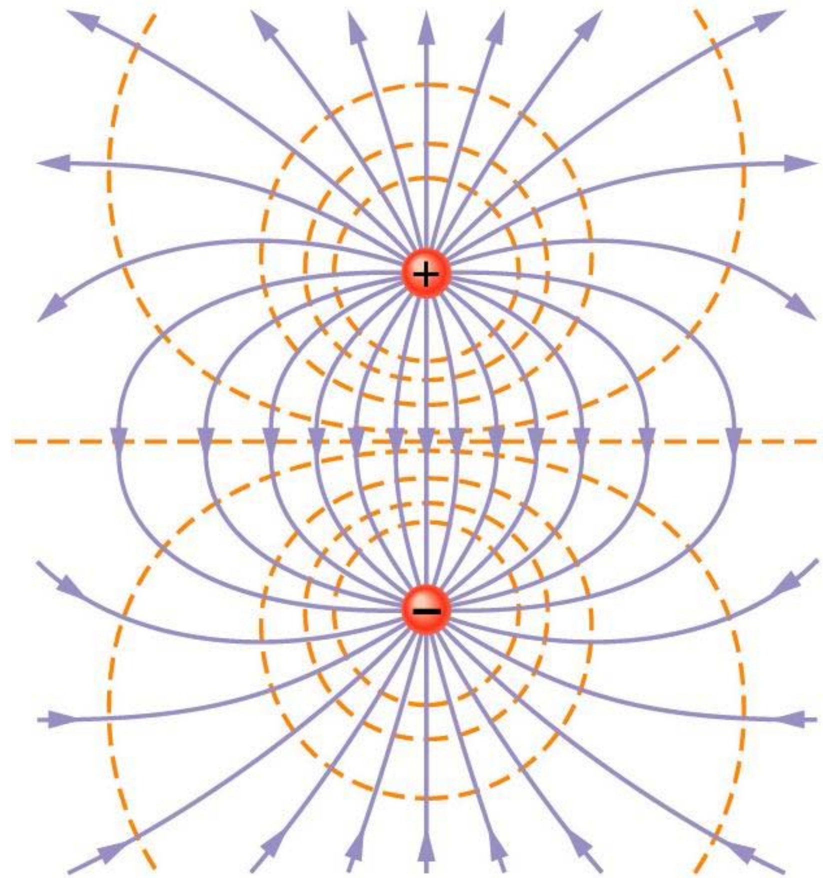


(*a*)

Equipotential Surfaces

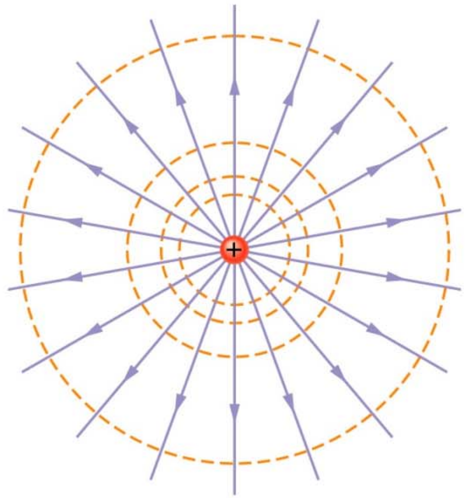


(b)

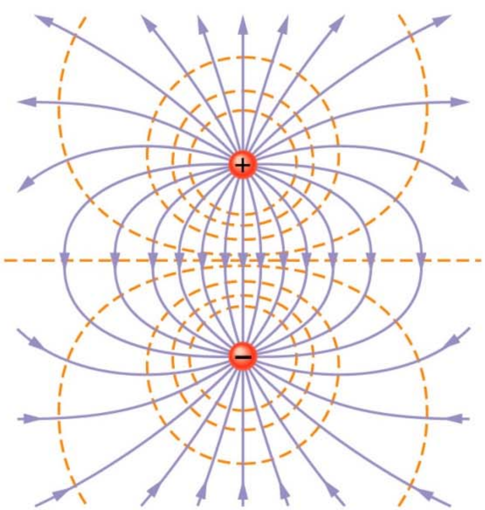


(c)

Equipotential Surfaces



(b)



(c)

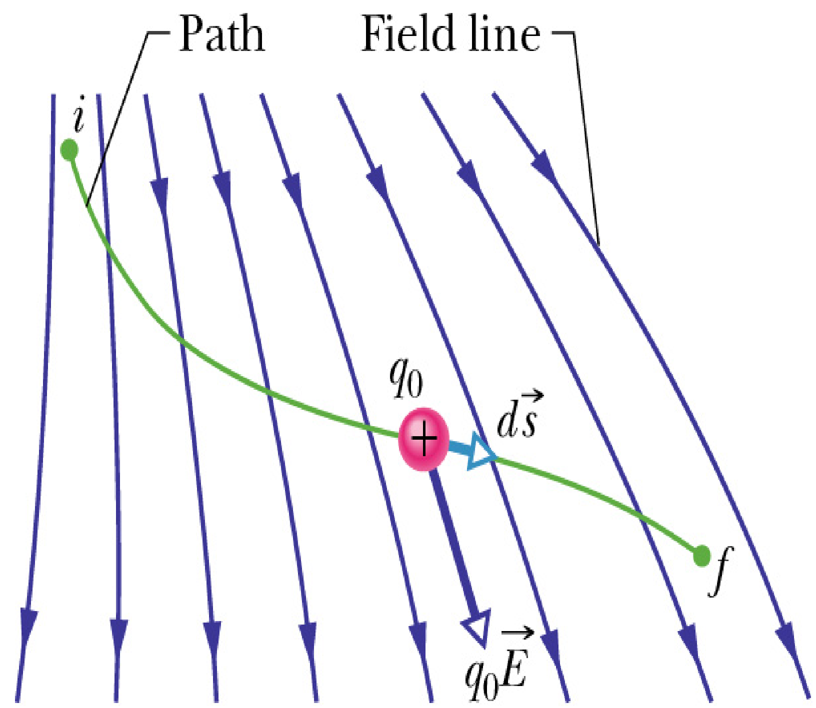
- *E* field lines are $\perp$ to the equipotential surface
- If given equipotential surfaces can draw *E* field lines

Potential Difference

- Calculate ΔV between points *i* and *f* in an electric field *E*

$$\Delta V = V_f - V_i = -\frac{W}{q_0}$$

- Need to find *W* when *E* is not constant.



Potential Difference

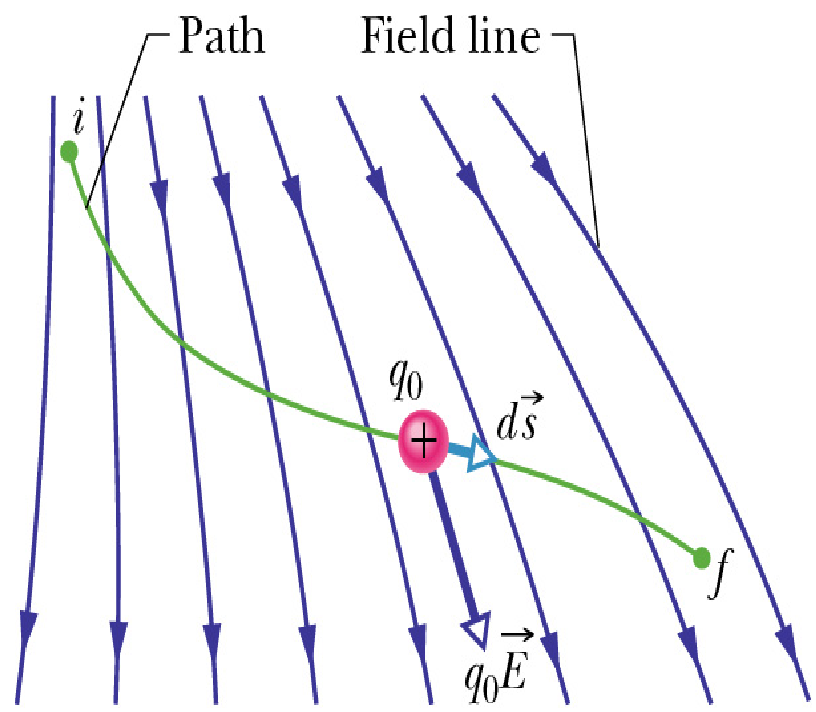
- Calculate differential amount of work

$$dW = \vec{F} \bullet d\vec{s}$$

- Remember

$$\vec{F} = q\vec{E}$$

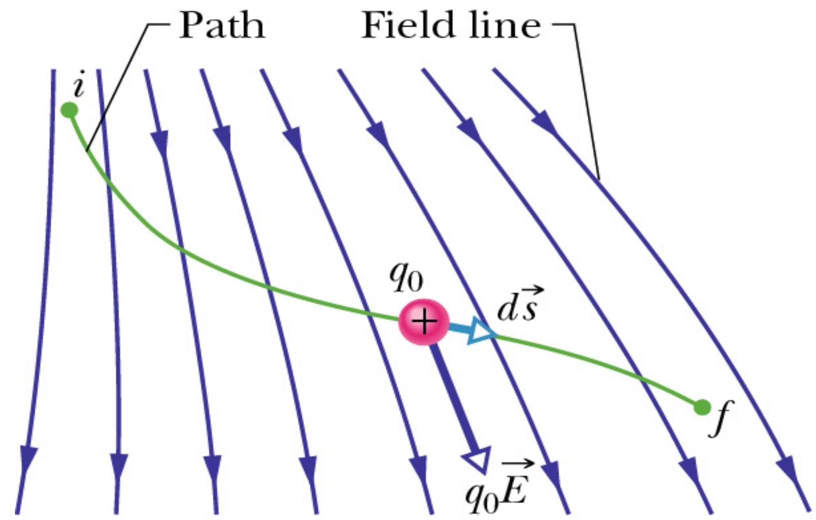
$$dW = q_0\vec{E} \bullet d\vec{s}$$



Potential Difference

- Work is

$$W = q_0 \int_i^f \vec{E} \bullet d\vec{s}$$



- Substitute to find ΔV

$$\Delta V = V_f - V_i = -\frac{W}{q_0} = -\int_i^f \vec{E} \bullet d\vec{s}$$

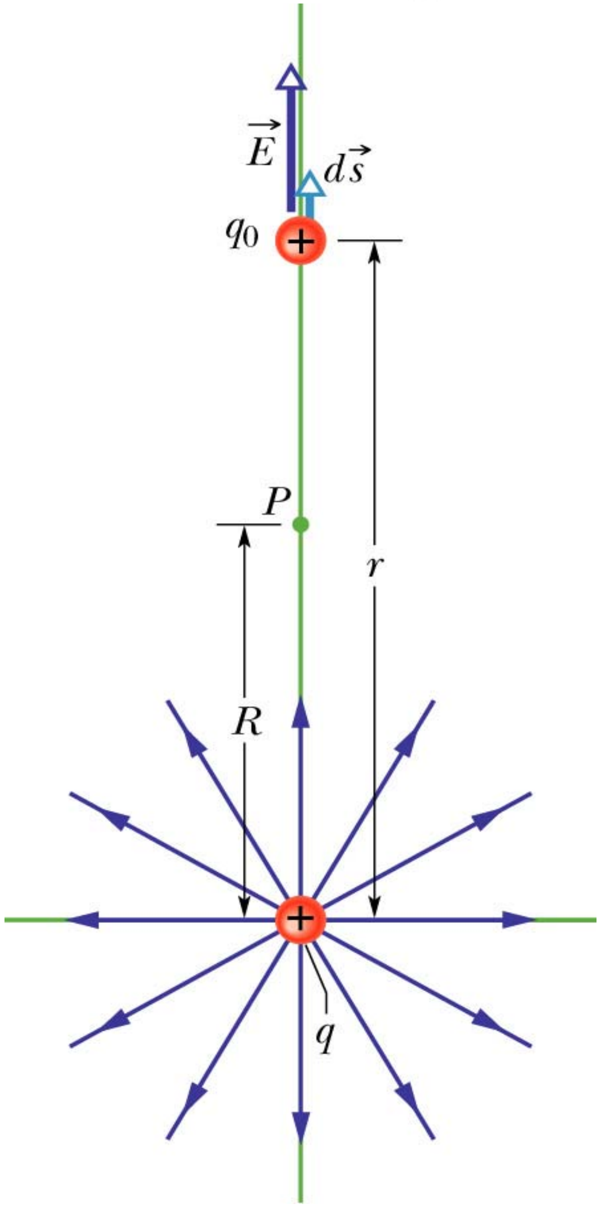
- Potential decreases if path is in the direction of the electric field

Electric Potential of a Point Charge

- Derive potential *V* around a charged particle

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

- Imagine moving a + test charge from *P* to ∞
- Path doesn't matter so choose line radially with *E*

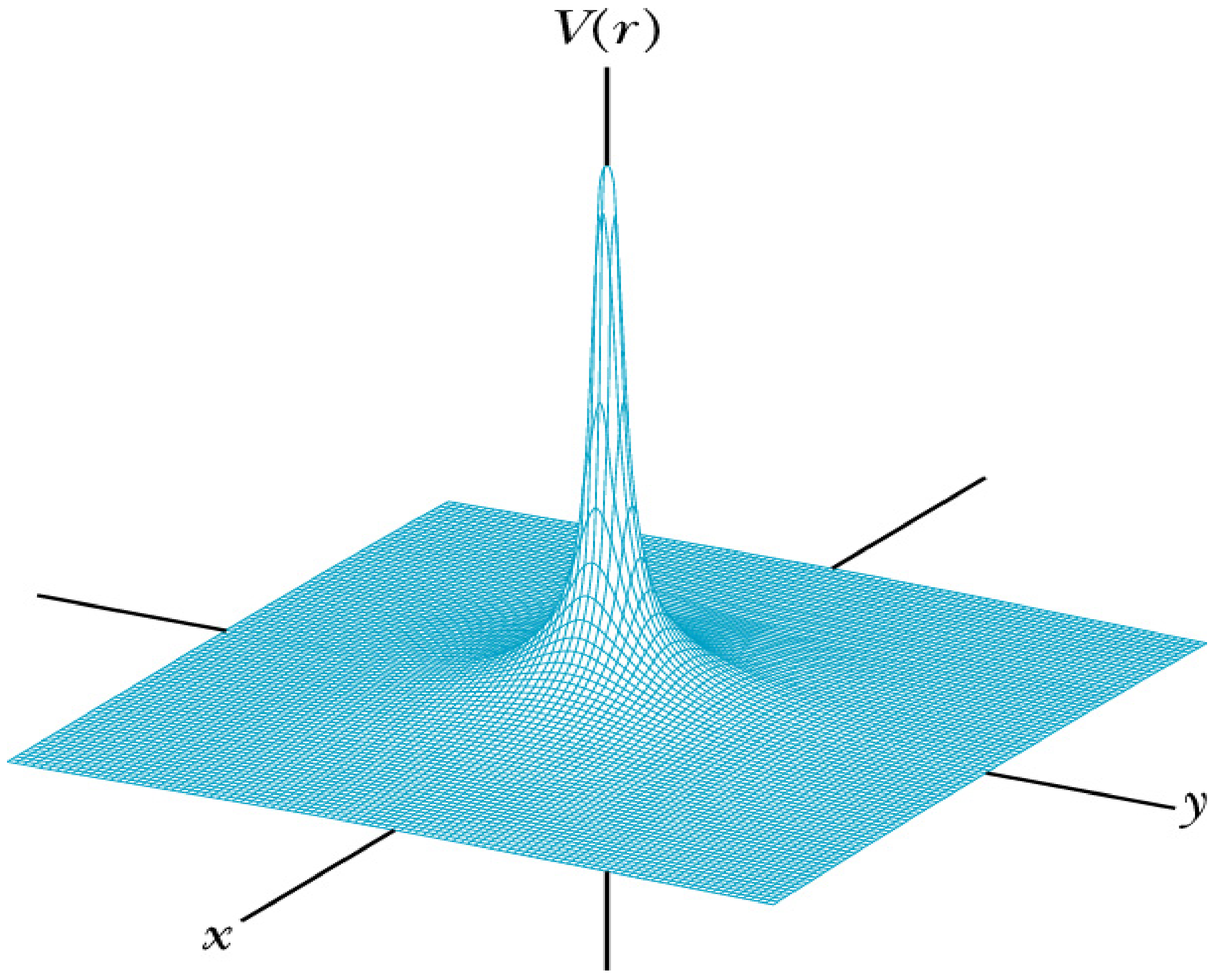


Electric Potential of a Point Charge

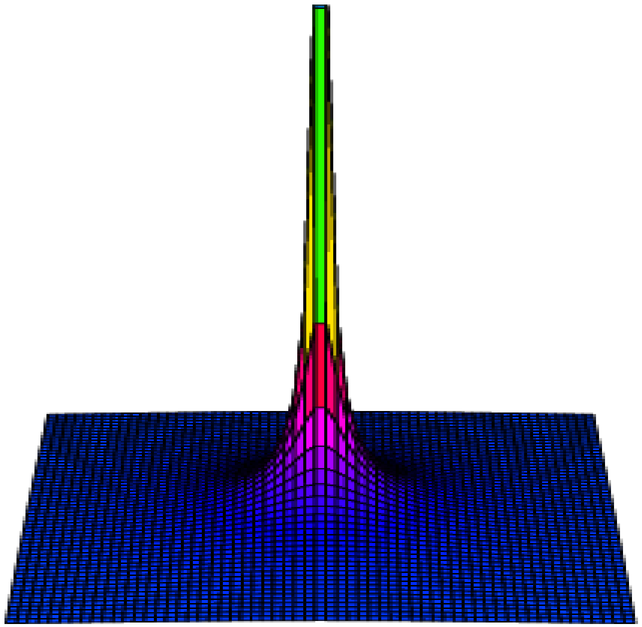
$$V = k\frac{q}{r}$$

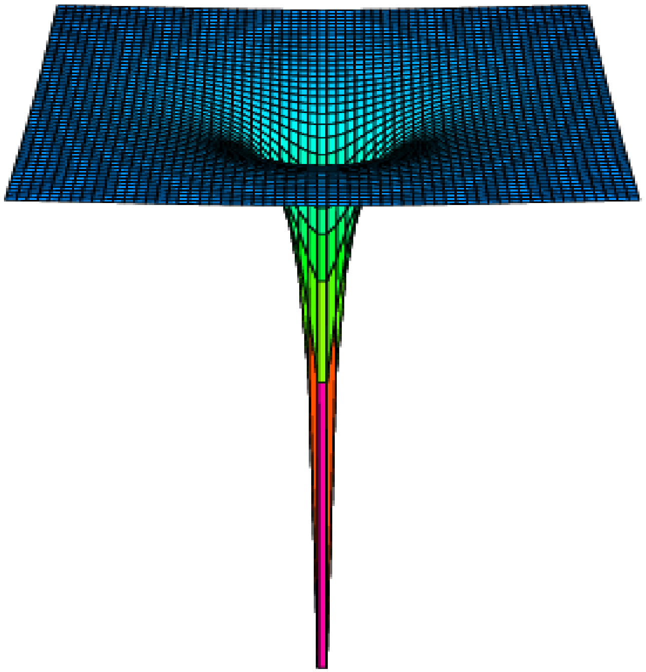
- Sign of V is same sign as q
  - + charge produces $+V$
  - - charge produces $-V$
- $|V|$ gets larger as r gets smaller
  - In fact $V = \infty$ when $r = 0$ (on top of charge)
- Graphical representation of V for charges in the x-y plane – plot value of V on the z-axis as a function of x-y position

Electric Potential of a Point Charge



Electric Potential of a Point Charge





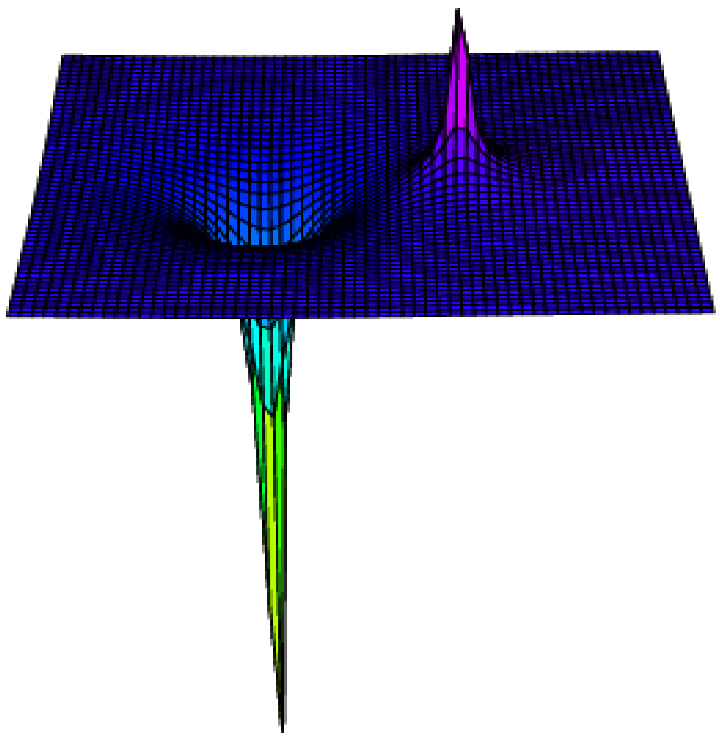
Electric Potential of n Charges

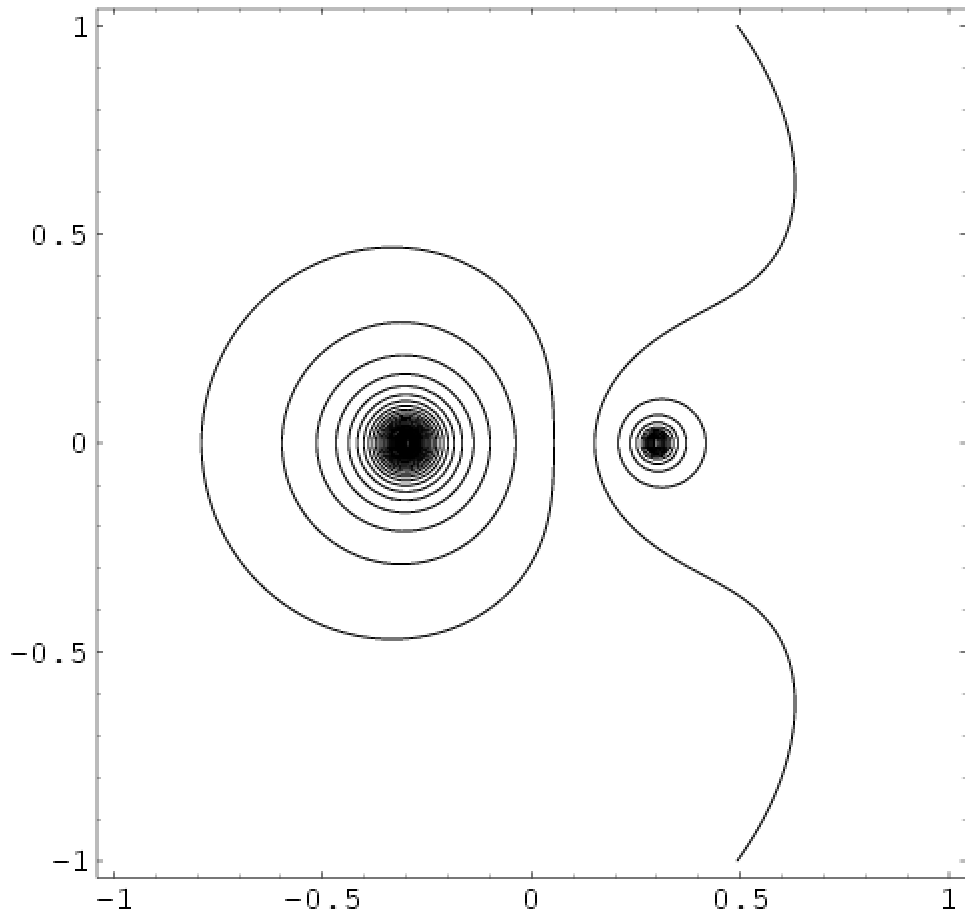
- Use superposition principle to find the potential due to *n* point charges

$$V = \sum_{i=1}^{n} V_i = k \sum_{i=1}^{n} \frac{q_i}{r_i}$$

- This is an algebraic sum, not a vector sum
- Include the sign of the charge

Electric Potential of 2 Unequal Charges





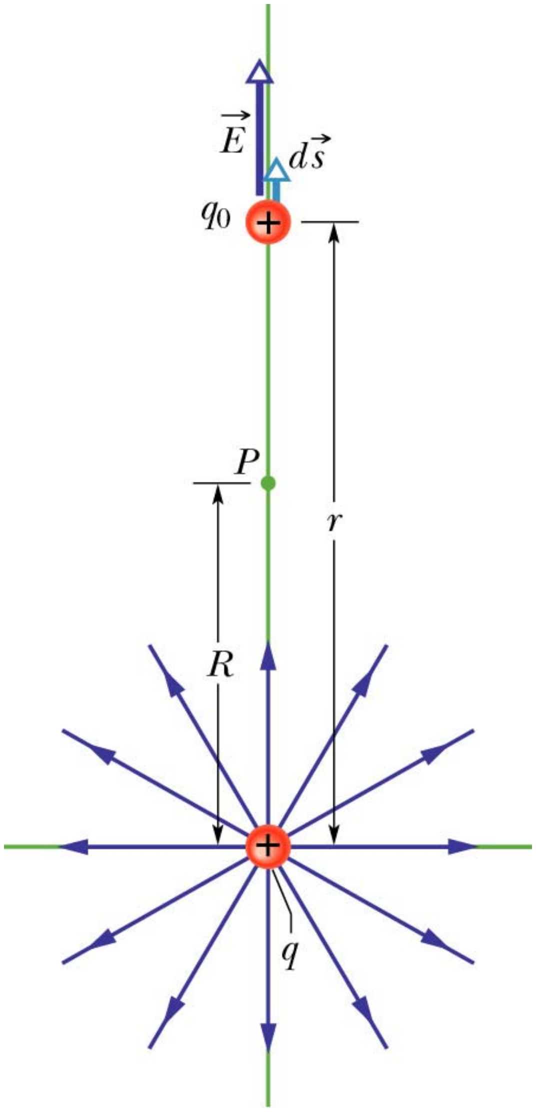
Force, Field & Potential of Point Charge

- What is the force *F*, electric field *E*, and potential *V*, at a point *P* a distance *r* away from a point charge?

$$F = k\frac{|q||q_0|}{r^2}$$

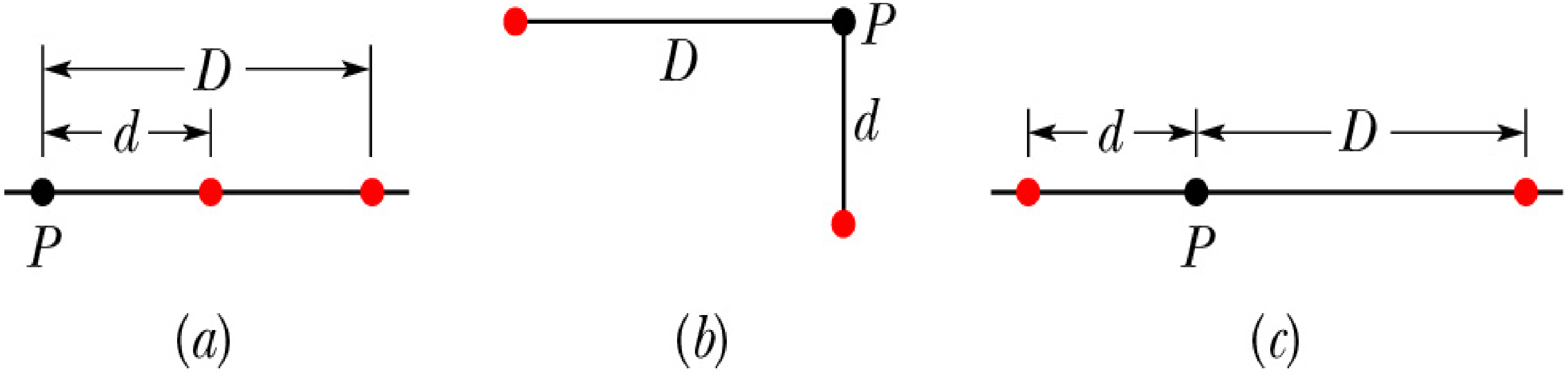
$$E = k\frac{q}{r^2}$$

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



Electric Potential (Exercise)

- Rank a), b) and c) according to net electric potential V produced at point P by two protons. (Greatest first.)

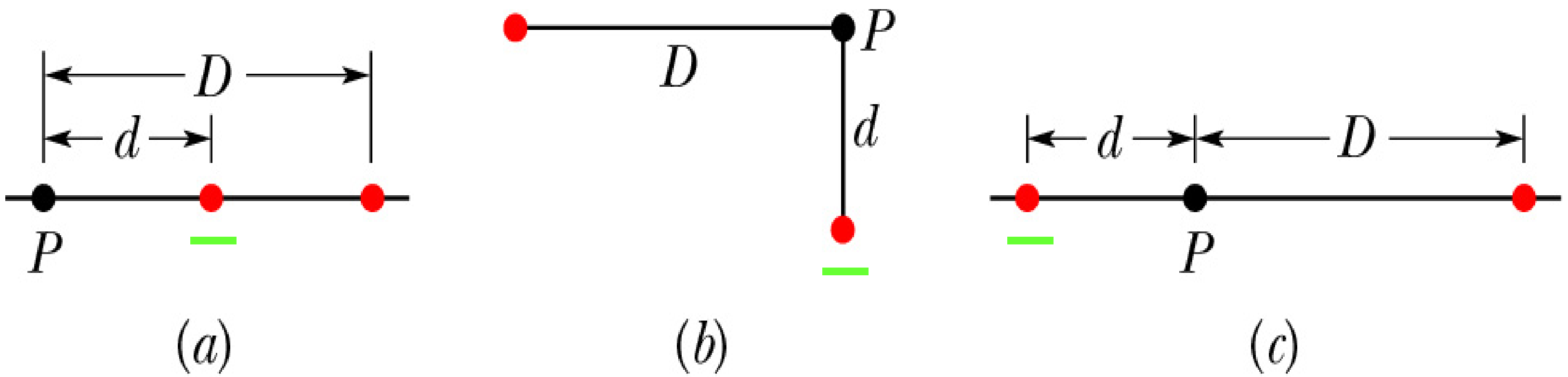


$$V = k\left(\frac{q}{d} + \frac{q}{D}\right)$$

ALL EQUAL

Electric Potential

- Replace one of the protons by an electron. Rank the arrangements now.



$$V = k\left(-\frac{q}{d} + \frac{q}{D}\right)$$

ALL EQUAL

Electric Field

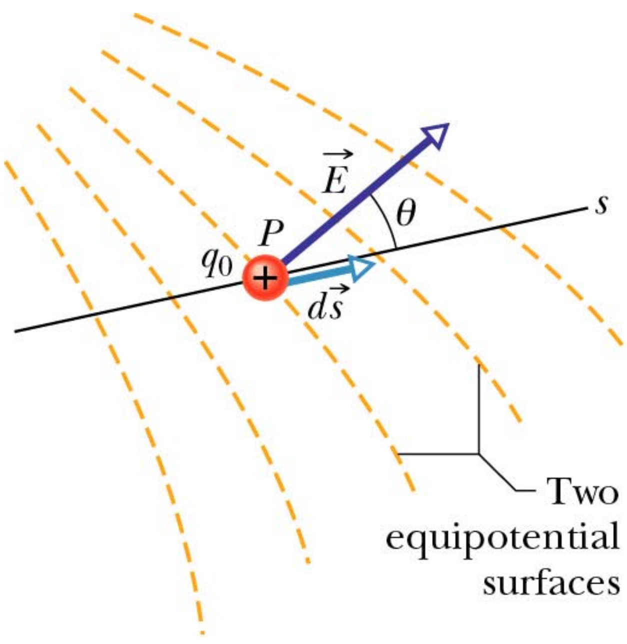
- How do we calculate *E* from *V*?

$$W = -q_0 \Delta V$$

$$W = \vec{F} \bullet \vec{d} = q \vec{E} \bullet \vec{d}$$

$$-q_0 \, dV = q_0 E \cos\theta \, ds$$

$$E \cos\theta = -\frac{dV}{ds}$$



Electric Field

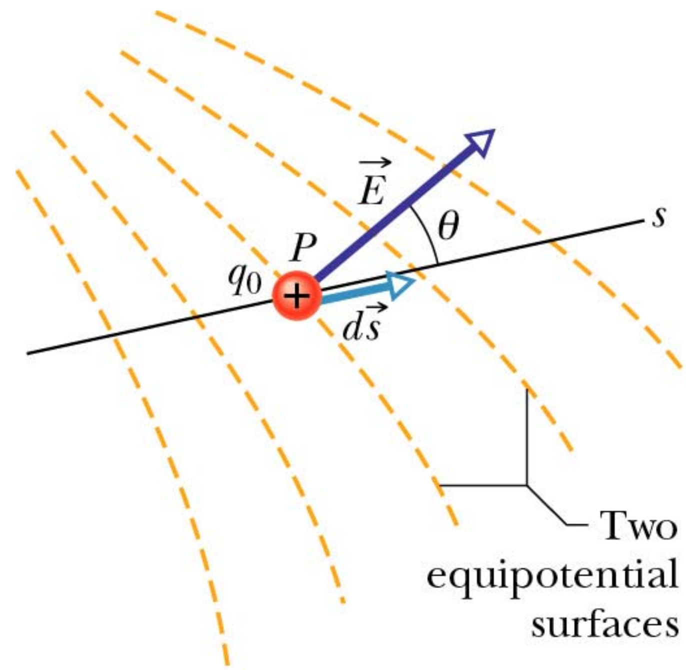
- How do we calculate *E* from *V*?

$$E\cos\theta = -\frac{dV}{ds}$$

- Component of *E* in direction of *ds*

$$E_s = -\frac{\partial V}{\partial s}$$

- Component of *E* in any direction is negative rate of change of *V* with distance in that direction



Electric Field

- Take *s* axis to be *x*, *y*, or *z* axes

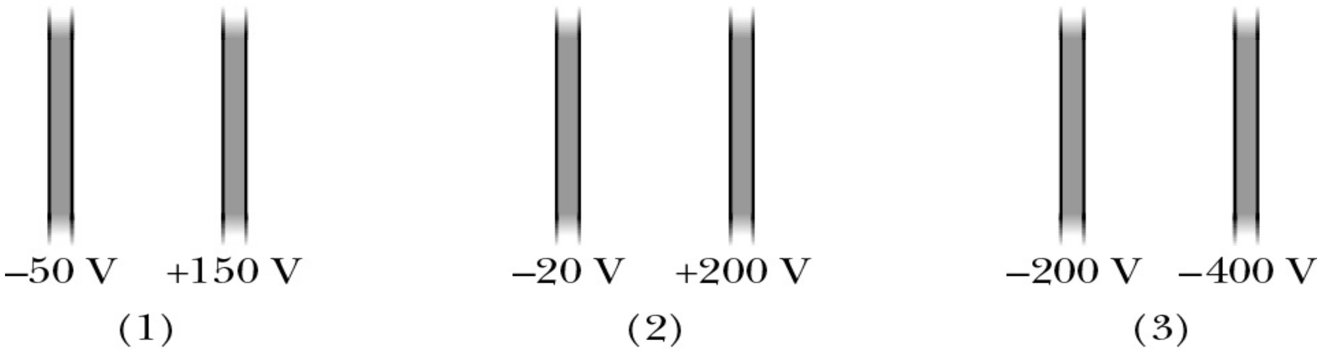
$$E_x = -\frac{\partial V}{\partial x}, \quad E_y = -\frac{\partial V}{\partial y}, \quad E_z = -\frac{\partial V}{\partial z}$$

- If *E* is uniform and *s* is ⊥ to equipotential surface

$$E = -\frac{\Delta V}{\Delta s}$$

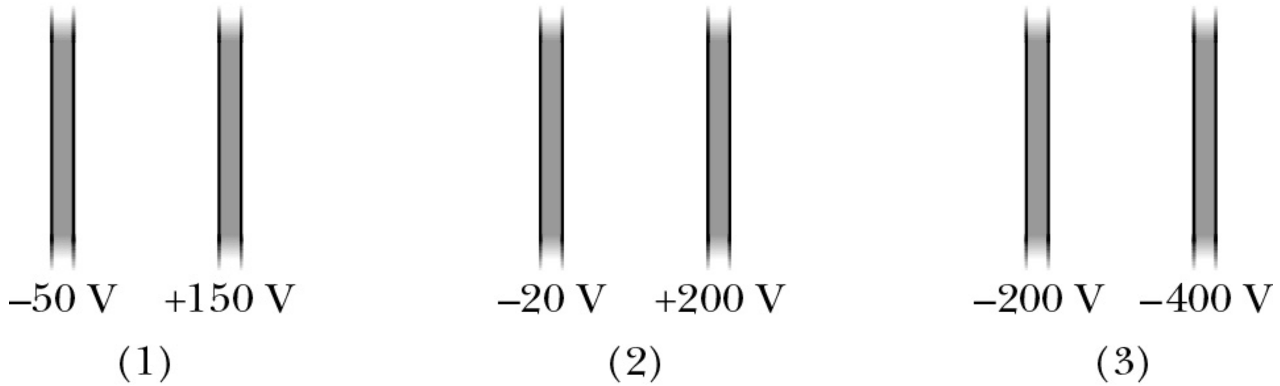
Electric Field (Exercise)

- 3 pairs of parallel plates with same separation and V of each plate. *E* field is uniform between plates and ⊥ to the plates.



- A) Rank (greatest first) magnitude of *E* between the plates

Electric Field (Exercise)



$$E = -\frac{\Delta V}{\Delta s}$$

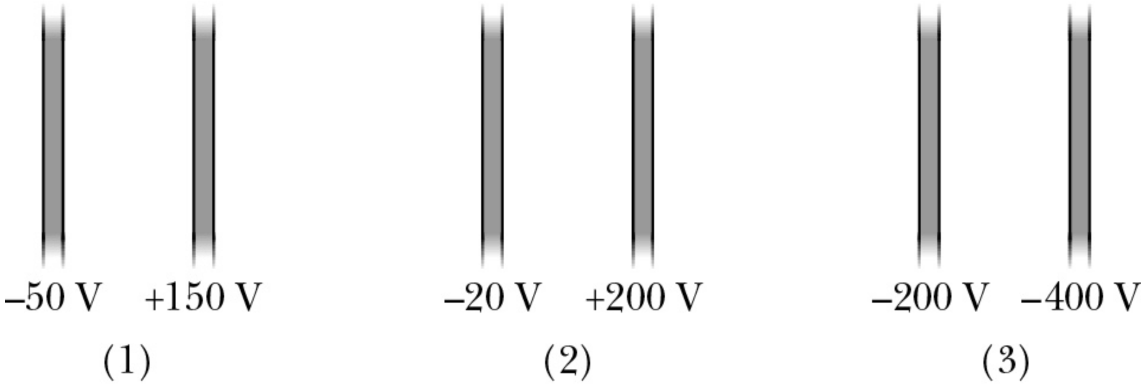
but asked for magnitude of *E*

$$E_1 = \frac{200}{d} \qquad E_2 = \frac{220}{d} \qquad E_3 = \frac{200}{d}$$

2, then 1 & 3

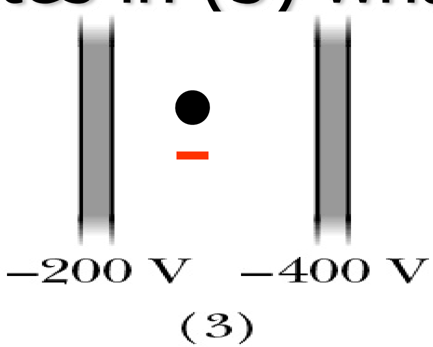
Electric Field (Exercise)

- B) For which pair does E point to the right?



#3

- C) If an electron is released midway between plates in (3) what does it do?



Accelerate to the left