Electric Potential (II)

Text sections 25.3, 25.5

- Potential of a point charge
- Potential of several point charges
- Potential energy of a collection of charges

Practice: Chapter 25,
Objective Questions 5, 7, 9, 10
Problems 18, 21, 27, 35

Review: Electric Potential

$$V \equiv \frac{\text{potential energy}}{\text{charge}}$$

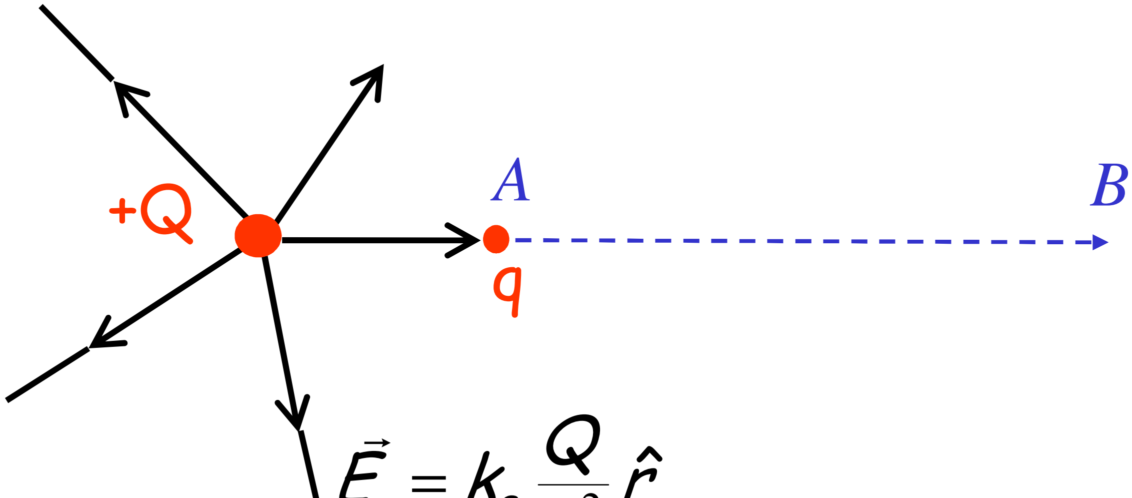
So,

$$dW = -q\,dV = q\,\mathbf{E} \bullet \mathbf{ds}$$

$$-\,dV = \mathbf{E} \bullet \mathbf{ds}$$

$$E_x = -\frac{dV}{dx}$$

What is the electric potential near a point charge Q?



$$\vec{E} = k_e \frac{Q}{r^2}\hat{r}$$

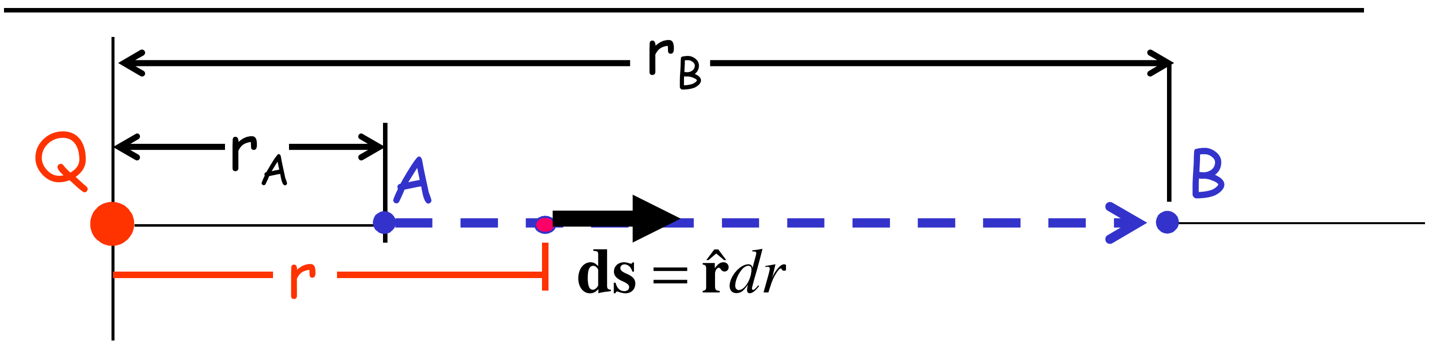
Move *another* charge q in the field:
its **potential energy** changes as the field does work.

$$q(V_B - V_A) = -(\text{work}) \;= -\int_{r_A}^{r_B} (q\mathbf{E}) \bullet \mathbf{ds}$$

... then cancel q on each side.

Details: Move from A to B along a radial line,

$$-dV = \mathbf{E} \bullet \mathbf{ds} = E dr = k_e \frac{Q}{r^2} dr$$



$$\int_A^B dV = -\int_{r_A}^{r_B} \frac{k_e Q}{r^2} dr$$

$$\Rightarrow \quad V_B - V_A = +k_e Q \left[\frac{1}{r_B} - \frac{1}{r_A} \right]$$

Set V=0 as $r \rightarrow \infty$

Then…

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

(potential around a single point charge Q)

What shape are the equipotential sufaces near a single point charge?

What is the potential 10 cm *from a (point) charge of* 100 nC *?*

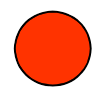
How will the result change for a spherical charge (which is not a "point charge")?

QUIZ

What shape are the equipotential sufaces near a single positive point charge?

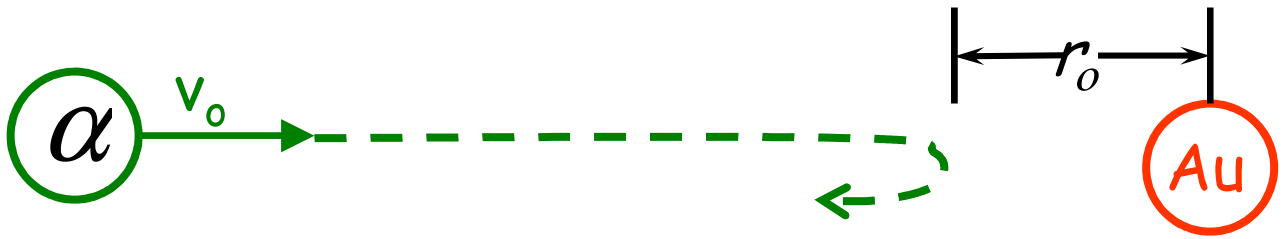
A) radial lines outwards
B) radial lines inwards
C) concentric spheres
D) vertical planes
E) horizontal planes

Equipotentials



Example: Rutherford Experiment

How close can a fast charged particle get to a gold nucleus?



Alpha particle:

$m_\alpha = 6.67 x 10^{-27} kg$

$q = +2e$

$v_o = 1.0 x 10^7 m/s$

Gold nucleus:

Q = +79e

(stationary)

Find: a) Initial K.E. of α in electron-volts. *(answer: 2.08 MeV)*

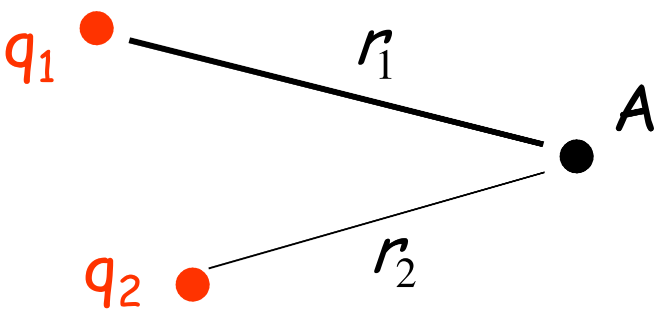
b) P.E. of α at $r = r_o$

c) V at $r = r_o$

d) r_o *(answer: 1.13×10^{-13} m)*

Potential of Several Point Charges

- Potentials add (as *scalars!*)



At A: $$V = k\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

<u>In General:</u>

$$V = \sum_i k_e \frac{q_i}{r_i}$$

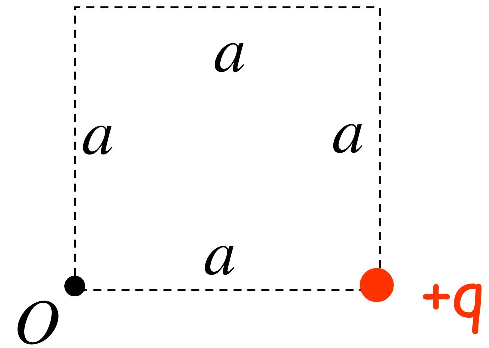
Or…

$$V = \int k_e \frac{dq}{r}$$

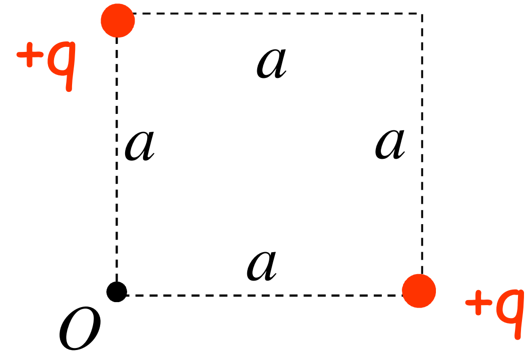
← (continuous charge distribution)

Quiz:

A single charge q produces a potential V_0 = 1000 V at point O.



What is the potential at point O due to the two identical charges?

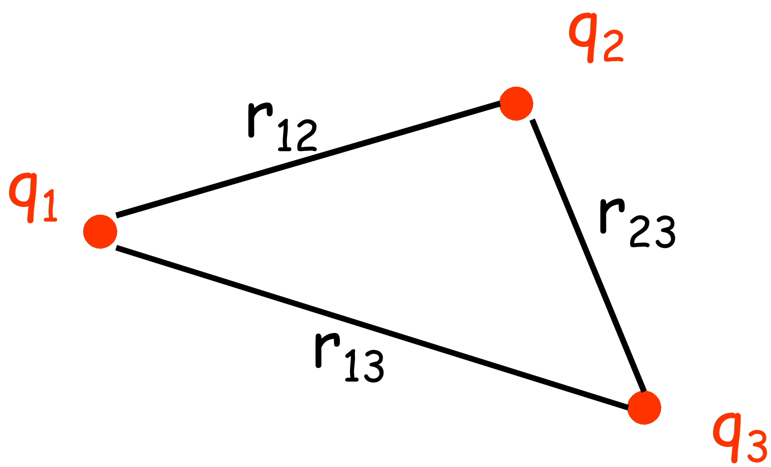


A) 1000 V
B) 1414 V
C) 2000 V
D) 2828 V

Electrostatic Potential Energy

What is the total potential energy of 3 (or more) point charges?

(Fine Print: assume U = 0 when all point charges are at infinity)



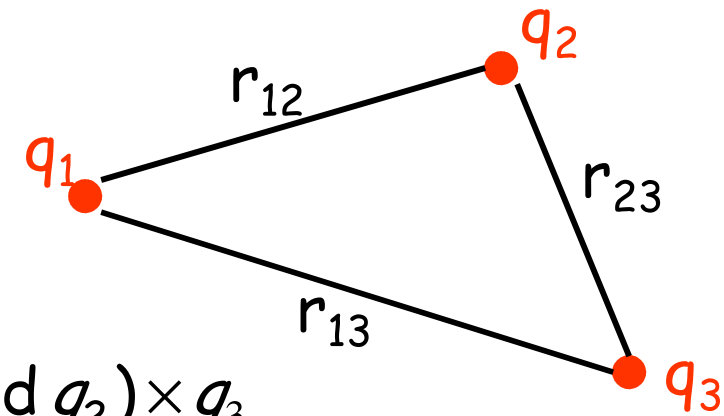
$$U = \sum_{pairs\ ij} k \frac{q_i q_j}{r_{ij}}$$

Derivation: Bring 3 charges in from infinity…

First Charge: no work needed (q_1)

Second Charge: $U_{12} = (V \text{ of } q_1) \times q_2$

$$= k\frac{q_1 q_2}{r_{12}}$$



Third Charge: Work needed

$$= (\text{potential of } q_1 \text{ and } q_2) \times q_3$$

$$= k\left(\frac{q_1}{r_{13}} + \frac{q_2}{r_{23}}\right)q_3$$

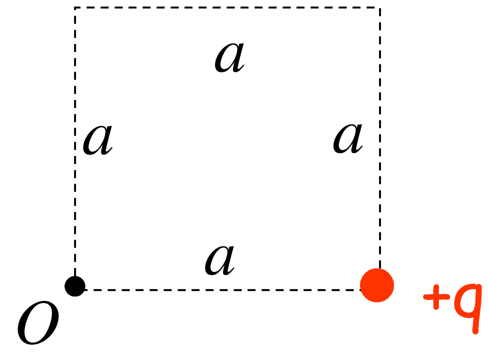
Total =

$$U_{total} = k\left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right)$$

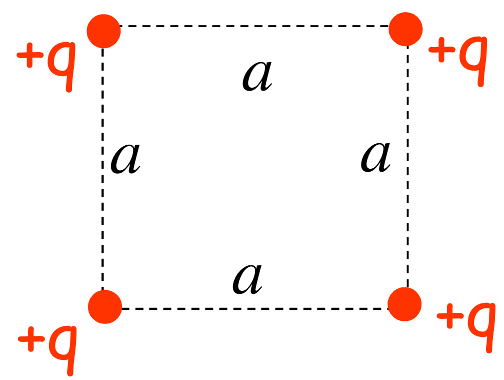
$$U = \sum_{pairs\ ij} k\frac{q_i q_j}{r_{ij}}$$

Quiz:

A single charge q=1.0μC produces a potential V_0 = 1000 V at point O.



What is the total potential energy of the four identical charges?



A) 4.0 mJ
B) 3.0 mJ
C) 6.0 mJ
D) none of the above