Potential Energy

- Total electric potential energy, *U*, of a system of charges is obtained from the work done by an external *F*, (*W**) to assemble the system, bringing each charge in from ∞. In terms of work done by the field, $W^* = -W$.

- Bring q_1 from ∞, $W^* = 0$ since no electric *F* yet

Potential Energy

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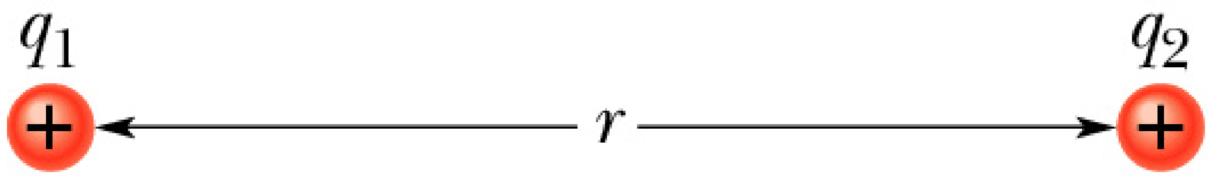
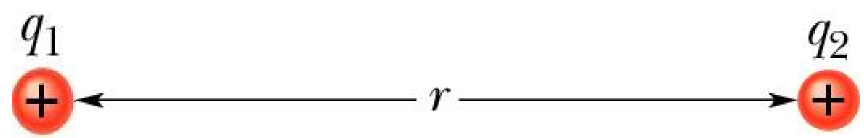


- Bring q_1 from ∞, *W** = 0 since no electric *F* yet

Potential Energy

- Potential due to q_1 is

$$V = k\frac{q_1}{r}$$



- Bring q_2 in from infinity. From definition of potential energy

$$U = -W = W^* = q_2 V = k\frac{q_1 q_2}{r}$$

or

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

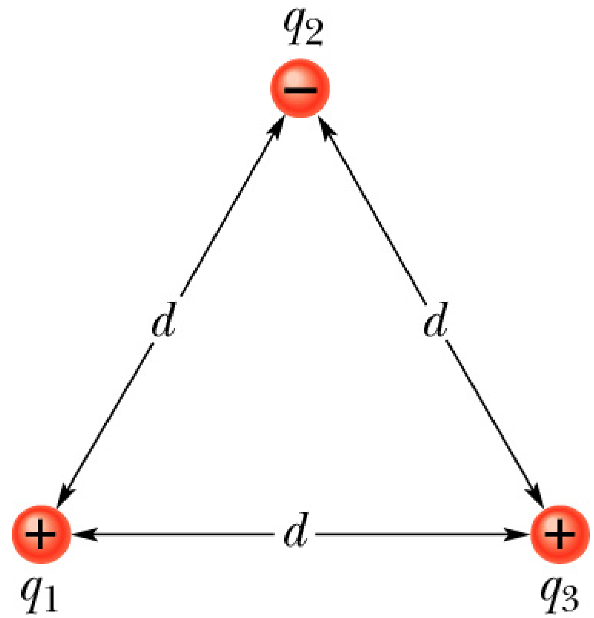
- Charges of like sign, W^* and U are +
- Charges of opposite sign, W^* and U are -

Potential Energy

- What is the potential energy when add an additional charge to system?

- Move q_1 from ∞, $W^* = U = 0$
- Move q_2 from ∞

$$W^*_{12} = U_{12} = k\frac{q_1 q_2}{d}$$



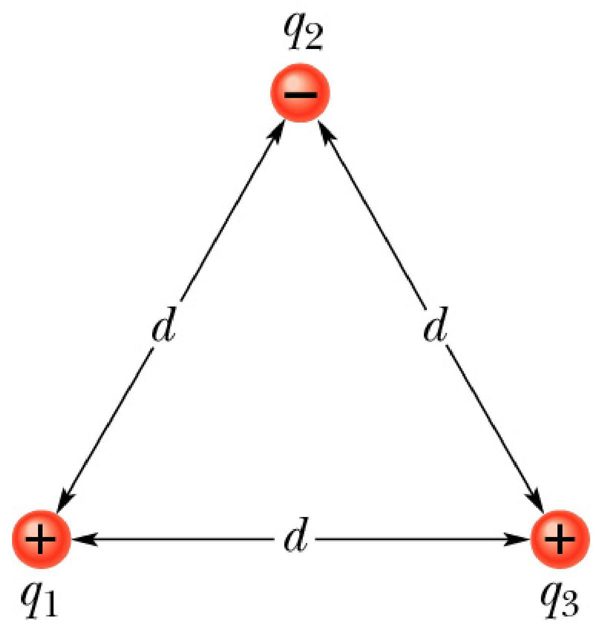
Potential Energy

- Now bring in q_3

$$W^*_{13} = U_{13} = k\frac{q_1 q_3}{d}$$

- Must also remember q_2

$$W^*_{23} = U_{23} = k\frac{q_2 q_3}{d}$$

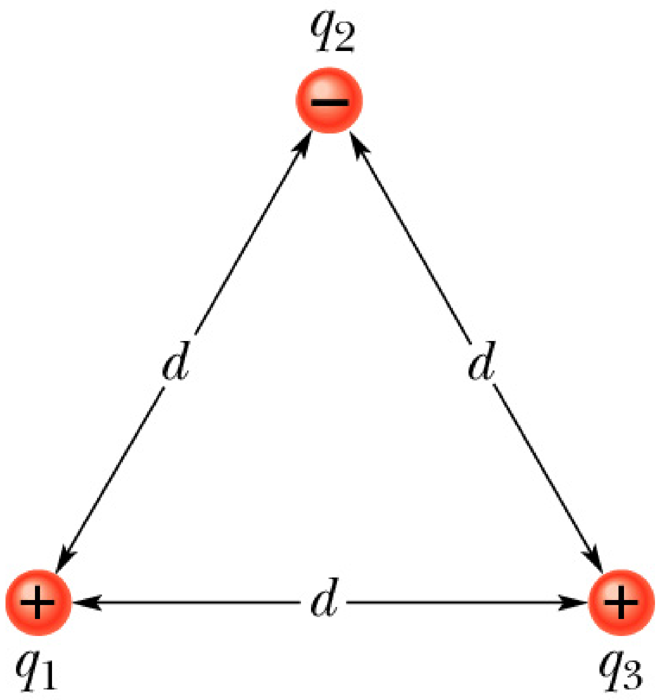


Potential Energy

- Total potential energy is the scalar sum

$$U = U_{12} + U_{13} + U_{23}$$

$$q_1 = +q, \quad q_2 = -4q, \quad q_3 = +2q$$

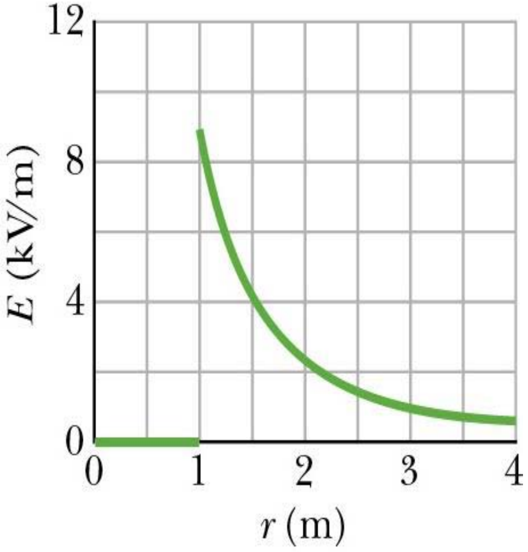


$$U = k\left(\frac{(+q)(-4q)}{d} + \frac{(+q)(+2q)}{d} + \frac{(-4q)(+2q)}{d}\right) = -k\frac{10q^2}{d}$$

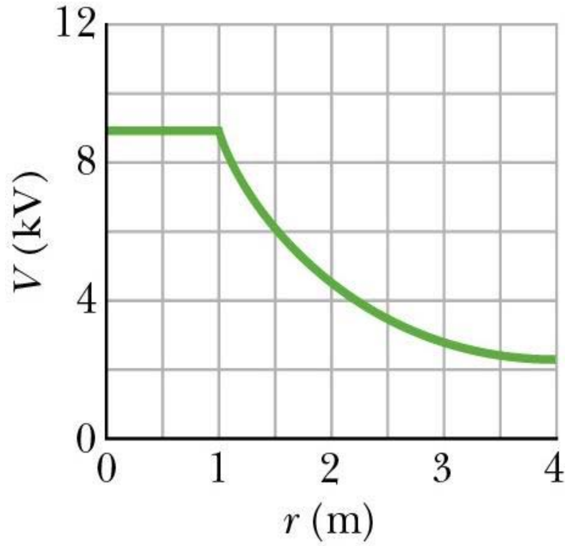
Electric Potential for Conductors

- Using what we know about conductors
  - $E = 0$ inside
  - All excess charge is on surface
- All points of a conductor – whether inside or on the surface – are at the same potential
  - A conductor is an equipotential

Electric Potential for Conductors



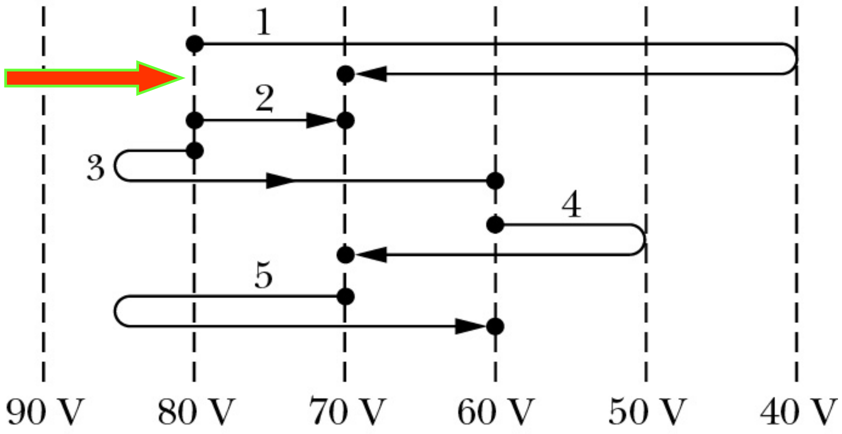
(b)



(a)

Electric Potential (Exercise)

- An electron moves along 5 different paths between parallel equipotential surfaces
- a) What is the direction of the *E* associated with the surfaces?



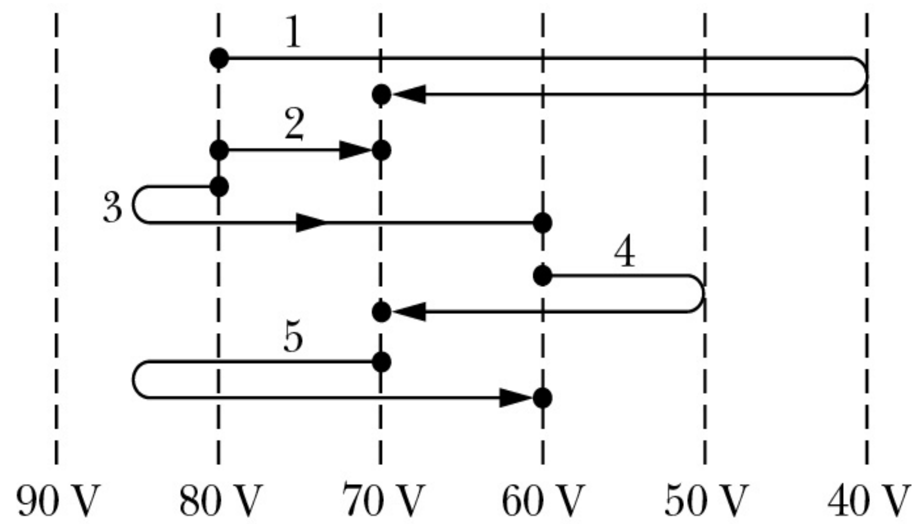
- Positive potentials which decrease going to the right.

Electric Potential (Exercise)

- b) Rank the paths by amount of work we do (greatest first).

$$W^* = -W = q\Delta V$$

$$W^* = q\left(V_f - V_i\right)$$



- Electron gives $W^*_{Path-1} = -q\left(70-80\right) = +10q$

3, then 1 & 2 & 5, last 4

Uniformly Charged Sphere

- Electric field outside R

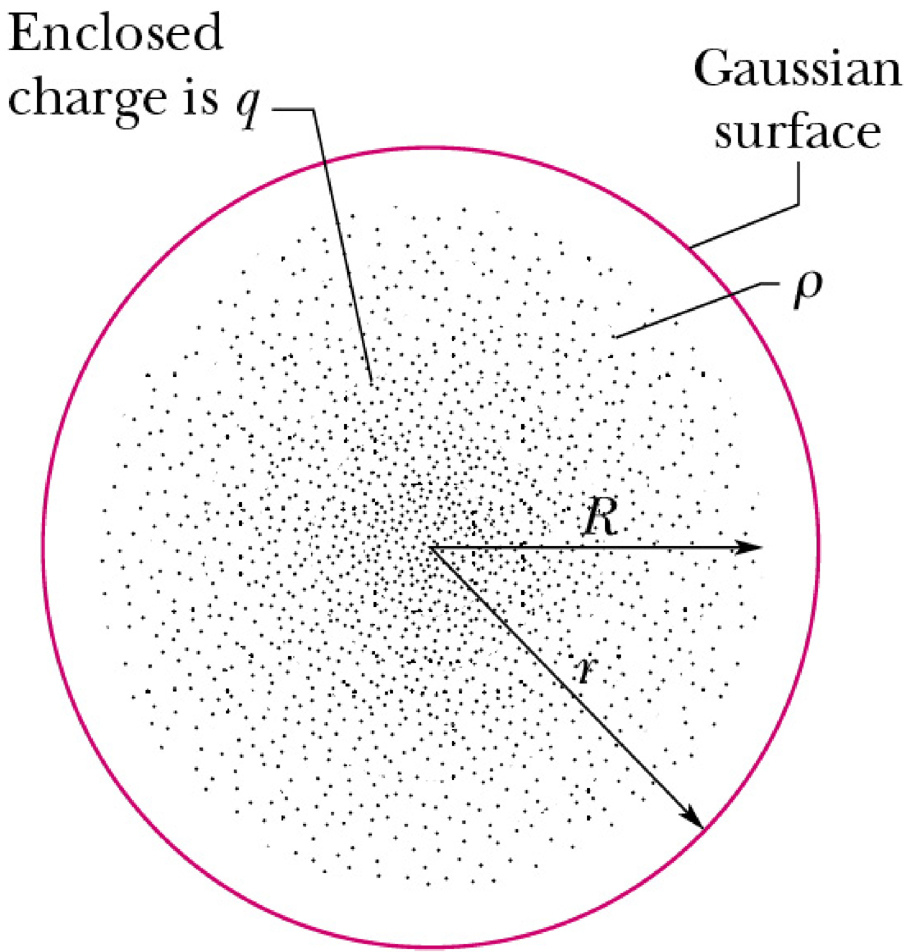
$$E = k\frac{Q}{r^2}$$

- Integrate from to r'=r to r'=∞

$$V_\infty - V_r = -\int_r^\infty E_{r'} dr'$$

$$= -kQ\left[\frac{1}{r} - \frac{1}{\infty}\right]$$

$$V_r = \frac{kQ}{r}, \quad for \;\; r > R$$



(a)

Uniformly Charged Sphere

- *E* field inside sphere

$$E = \frac{kQr}{R^3}, r \le R$$

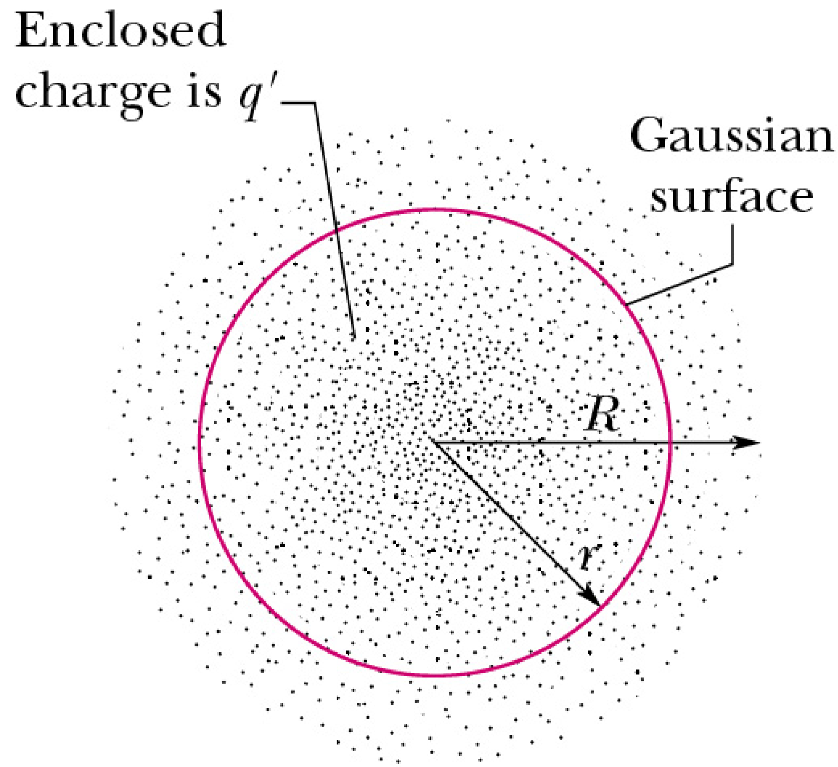
- Integrate from r'=r to r=R

$$V_r - V_R = -\int_r^R E_{r'} dr'$$

$$= -\frac{kQ}{R^3}\int_r^R r'\,dr' = \frac{kQ}{2R^3}\left[r^2 - R^2\right]$$

$$V_R = \frac{3kQ}{2R}, \quad \Rightarrow$$

$$V_r = \frac{kQ}{2R}\left[3 - \frac{r^2}{R^2}\right] \quad for \quad r < R$$



(b)

Read also book examples 25.5, 25.6 and 25.7