Chapter 7 - Electric Potential

Main Points

- An **electric potential field** measures the amount of potential energy (U) per unit charge available at all points in the region of a field-producing charge. It can be associated with any charge configuration, and one exists wherever there is charge/an electric field. They are measures in volts (joules/coulomb).
- Electric potential fields generate a **conservative force** on particles. Conservation of energy principles can be applied to solve electric potential problems.
- An **equipotential line** is a line upon which every point has the same electrical potential. They are always perpendicular to electric field lines.
- It takes no energy to move one point charge around, but as soon as a second point charge is introduced, it takes W = -qV to move the second point charge. Bringing in a third point charge requires work that combats eletric potential fields from the first and second charges.
- Because we can integrate the e-field to find V, we can take the derivative of V to find the e-field. This may require use of the del operator.
- Behavior with conductors
    - free charge on a conductor will distribute itself to create an equipotential surface (same voltage at every point on the surface)
    - the electric field inside a conductor = 0 so the electric potential field is constant
- An **electric dipole** is a system of two equal but opposite charges a fixed distance apart. An electric **dipole moment** p = qd occurs when the distance of the point P from the dipole is greater than the distance between charges in the dipole. d points from the negative charge to the positive charge.

Equations

electric potential field

$$\left[V = \frac{U}{q}\right] \begin{matrix}\text{potential energy} \\ \text{charge}\end{matrix}$$

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{\overbrace{q_1 q_2}^{\text{if this is a point charge, use Q}}}{\underbrace{r}_{\text{radius btwn. } q_1 + q_2 \text{ or } Q + \text{point you're measuring from}}}\right)$$

$$W = -\Delta U$$

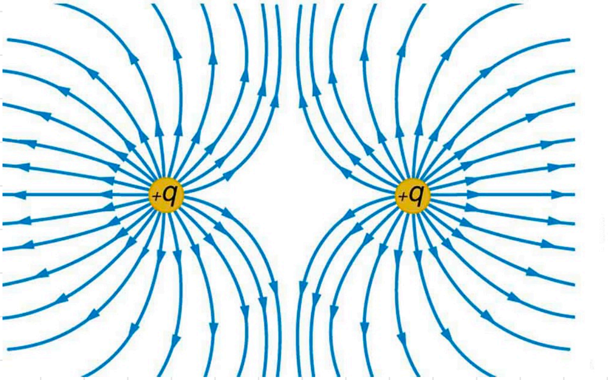
$$-\Delta V = \left[\frac{W}{q}\right] \text{work}$$

$$-\Delta V = \left[\int_0^r \underbrace{E}_{\text{e-field}} \cdot dr\right] \text{distance between two points}$$

or = Ed, when the e-field is constant.

Practice Problems

1. (easy) Draw equipotential lines on the following image of an electric field surrounding two positive point charges.

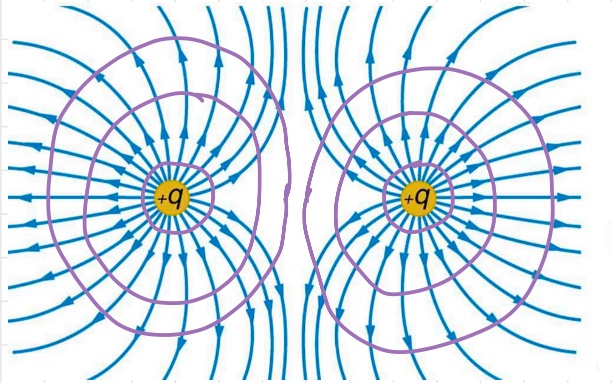


2. (medium) An electric field does 18 J of work on a charged particle, moving it from a potential of 4 V to 6 V. What is the charge of the particle?

3. (hard) An electron is to be accelerated in a uniform electric field having a strength of 2.00 x 10^6 V/m. (a) What energy in keV is given to the electron if it is accelerated through 0.400 m? (b) Over what distance would it have to be accelerated to increase its energy by 50.0 GeV?

Solutions

1.



$$\Delta V = \frac{\Delta U}{q} \text{ so } q = \frac{\Delta U}{\Delta V} = \frac{U_f - U_1}{V_f - V_1} = \frac{-18}{6-4} = -9\,C$$

3. a) $\Delta K = q\Delta V$ and $\Delta V = Ed$ so $\Delta K = qEd$

$$\Delta K = (1)(2.00 * 10^6 \, V/m)(0.4)$$
$$= 800 \text{ keV}$$

b) $50 \text{ GeV} = 5 * 10^{10} \text{ eV} = \Delta K$

$$\Delta K = qEd$$
$$5 * 10^{10} = (1)(2 * 10^6)(d)$$
$$d = 25,000 \text{ m} = 25 \text{ km}$$