PHY-112
Principles of Physics-II
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Spring-24 | Class-10

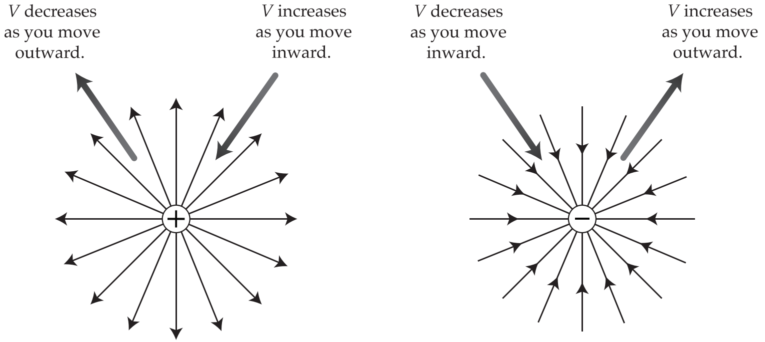
Potential difference experienced by moving a charge from **start**ing location to the **end**ing location.

$$\Delta V = V_{\text{final}} - V_{\text{start}} = \frac{\Delta U}{q_0} = -\int_{\text{start}}^{\text{final}} \vec{E} \cdot d\vec{r}.$$

Physically, Electric Potential is the work done per unit charge (+1 C) to bring a charge from infinity (where the electric field is considered to be zero) **to a particular location r in an electric field**.

$$V_\infty = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

How does Potential Change?



These are mathematical surfaces, not physical surfaces, with the same value of V at every point.

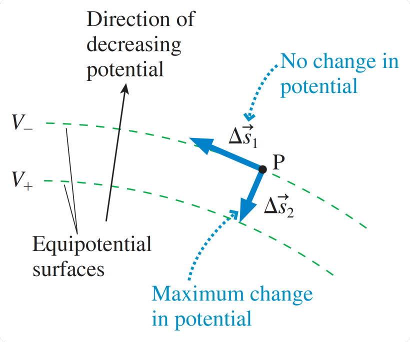
$$\Delta V = 0 = -\oint \vec{E} \cdot d\vec{r}, \qquad V \equiv \text{constant}.$$

Properties of Equipotential Surfaces

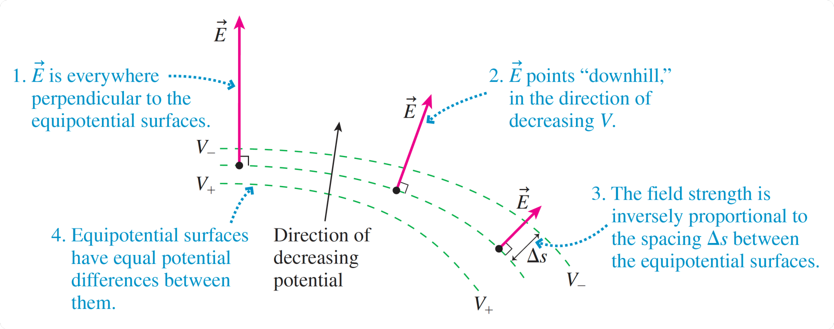
- **Perpendicular to Electric Field Lines**
- **Uniform Potential**. All points have the same electric Potential.
- **No Potential Difference**. No work is required to move a charge along the surface.
- **Closer Spacing Indicates Stronger Field**.
- **Gaussian surfaces** are equipotential surfaces.

$\vec{E}$-field changes between two equipotential surfaces.

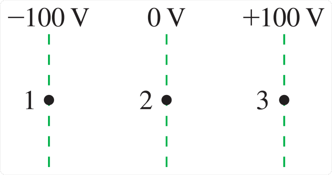
$$\vec{E}_r = -\frac{dV(r)}{dr} = -\left(\frac{dV_x}{dx}\hat{i} + \frac{dV_y}{dy}\hat{j} + \frac{dV_z}{dz}\hat{k}\right)$$



$\vec{E}$-field changes (perpendicular) between two equipotential surfaces toward decreasing potential.

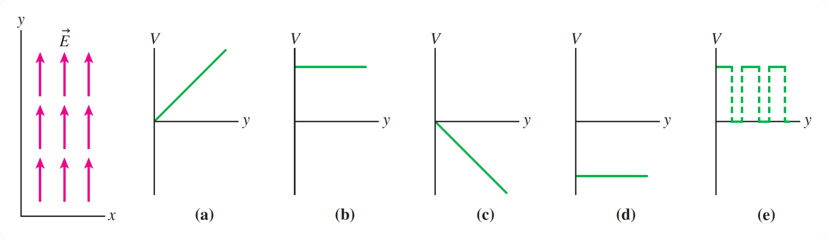


Q: A proton is released from rest at point 2, where the Potential is $0\,\mathrm{V}$. Afterward, the proton.

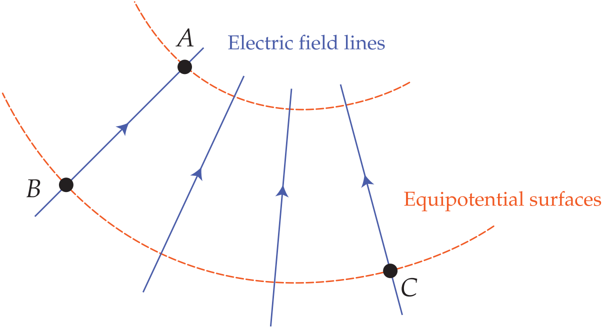


1. Remains at rest at point 2
2. Moves toward point 1 with a steady speed
3. Moves toward point 1 with an increasing speed
4. Moves toward point 3 with a steady speed
5. Moves toward point 3 with an increasing speed

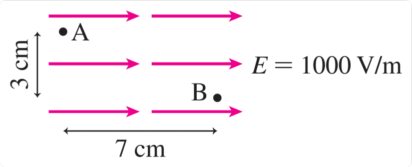
Q: Which potential graph describes the electric field at the left?



Q: When a proton moves from A to B along an electric field line, the electric field does 7.91×10^{-28} GJ (Giga joule) of work on it. Calculate (i) $V_B - V_A$, (ii) $V_C - V_A$, and (iii) $U_C - U_B$?



Q:

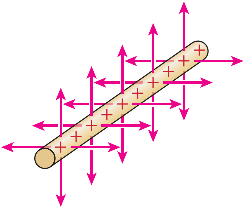


- Which point, A or B, has a larger electric potential?
- What is the potential difference between A and B?

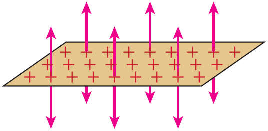
Looking at the Big Picture: Where We Are Now

$$\begin{tikzcd}[column sep=huge, row sep=huge]
\textbf{Acts locally} & \vec{F} \arrow[r, leftrightarrow, "-\int_i^f \vec{F}\cdot d\vec{r}"] \arrow[d, leftrightarrow, "\frac{F}{q_0}"'] & U_{\text{elec}} \arrow[d, leftrightarrow, "\frac{U}{q_0}"] & \textbf{Observer dependent} \\
\textbf{Acts everywhere} & \vec{E} \arrow[r, leftrightarrow, "-\int_i^f \vec{E}\cdot d\vec{r}"'] & V_{\text{elec}} & \textbf{Source dependent}
\end{tikzcd}$$

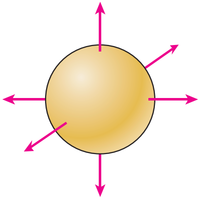
Cylindrical symmetry



Planar symmetry



Spherical symmetry



Potentials of 3 Key $\vec{E}$ Field Sources: Continuous

Line	**Surface**	**Volume**
$\vec{E} = \left(\frac{\lambda}{2\pi\epsilon_0 r}\right)\hat{r}$	$\vec{E} = \left(\frac{\sigma}{2\epsilon_0}\right)\hat{n}$	$\vec{E} = \left(\frac{\rho r}{3\epsilon_0}\right)\hat{r}$
$V = -\int_i^f \vec{E} \cdot d\vec{r}$	$V = -\int_i^f \vec{E} \cdot d\vec{r}$	$V = -\int_i^f \vec{E} \cdot d\vec{r}$
$V = -\left(\frac{\lambda}{2\pi\epsilon_0}\right)\int_i^f \frac{1}{r} dr$	$V = -\left(\frac{\sigma}{2\epsilon_0}\right)\int_i^f dr$	$V = -\left(\frac{\rho}{3\epsilon_0}\right)\int_i^f r dr$
$V = -\left(\frac{\lambda}{2\pi\epsilon_0}\right)\left[\ln r\right]_i^f$	$V = -\left(\frac{\sigma}{2\epsilon_0}\right)\left[r\right]_i^f$	$V = -\left(\frac{\rho}{3\epsilon_0}\right)\left[\frac{r^2}{2}\right]_i^f$
$V = -\left(\frac{\lambda}{2\pi\epsilon_0}\right)\ln r - V_0$	$V = -\left(\frac{\sigma}{2\epsilon_0}\right) r - V_0$	$V = -\left(\frac{\rho}{6\epsilon_0}\right) r^2 - V_0$