Copyright statement

- The images and the pictures in this lecture are provided by the CDs accompanied by the books
  1. University Physics, Bauer and Westfall, McGraw-Hill, 2011.
  2. Principles of Physics, Halliday, Resnick, and Walker, Wiley, 8th and 9th Ed.
- The rest is made by me.

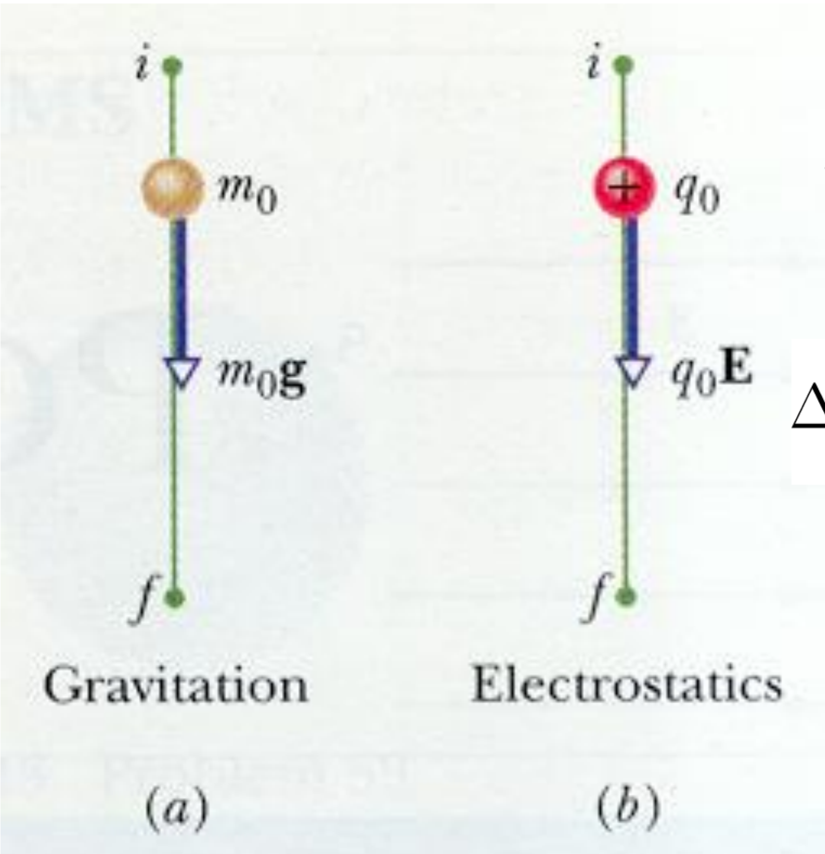
Chap. 23 Electric potential

Electric potential

Electric potential energy

$$\Delta U = U_f - U_i = -W$$

$$U = -W_\infty$$ (infinity as a reference point)



Both forces conservative

Electric potential $$V = \frac{U}{q}$$

$$\Delta V = V_f - V_i = \frac{U_f}{q} - \frac{U_i}{q} = \frac{\Delta U}{q} = -\frac{W}{q}$$

$$V = -\frac{W_\infty}{q}$$

SI unit 1 volt = 1 V = 1 J/C

Electric field $$\frac{\mathrm{N}}{\mathrm{C}} = \frac{\mathrm{N}}{\mathrm{C}}\frac{\mathrm{V}\cdot\mathrm{C}}{\mathrm{J}}\frac{\mathrm{J}}{\mathrm{N}\cdot\mathrm{m}} = \mathrm{V/m}$$

$$1\ \mathrm{eV} = 1.60 \times 10^{-19}\mathrm{J}$$

Work done by an applied force

일과 에너지 정리에 의하면

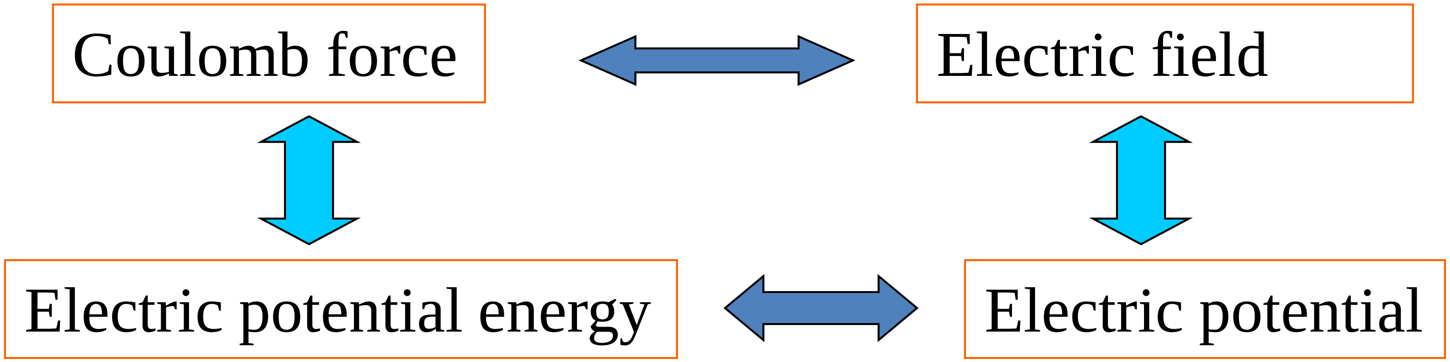
$$\Delta K = K_f - K_i = W_{\text{app}} + W$$

만일 운동 전후의 운동에너지가 같다면 $(K_f = K_i)$

$$W_{\text{app}} = -W$$

$$\Delta U = U_f - U_i = W_{\text{app}} = q\Delta V$$

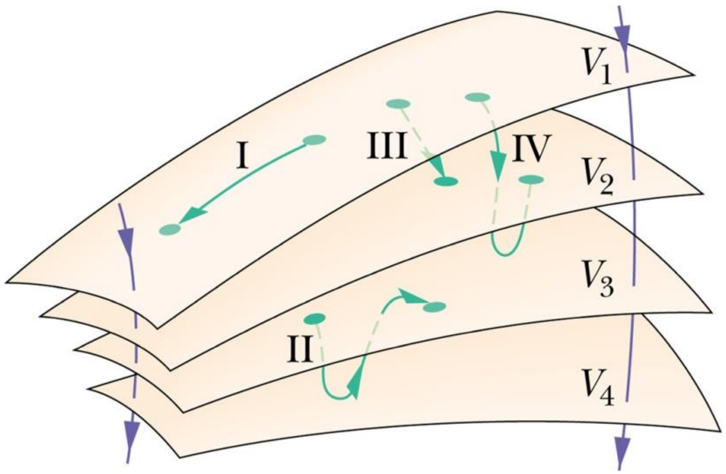
Electric potential energy and electric potential



$$U_C(r) = -\int_{\infty}^{r} \boldsymbol{f}_C(\boldsymbol{r}) \cdot d\,\boldsymbol{s} \qquad V(r) = -\int_{\infty}^{r} \boldsymbol{E}(\boldsymbol{r}) \cdot d\,\boldsymbol{s}$$

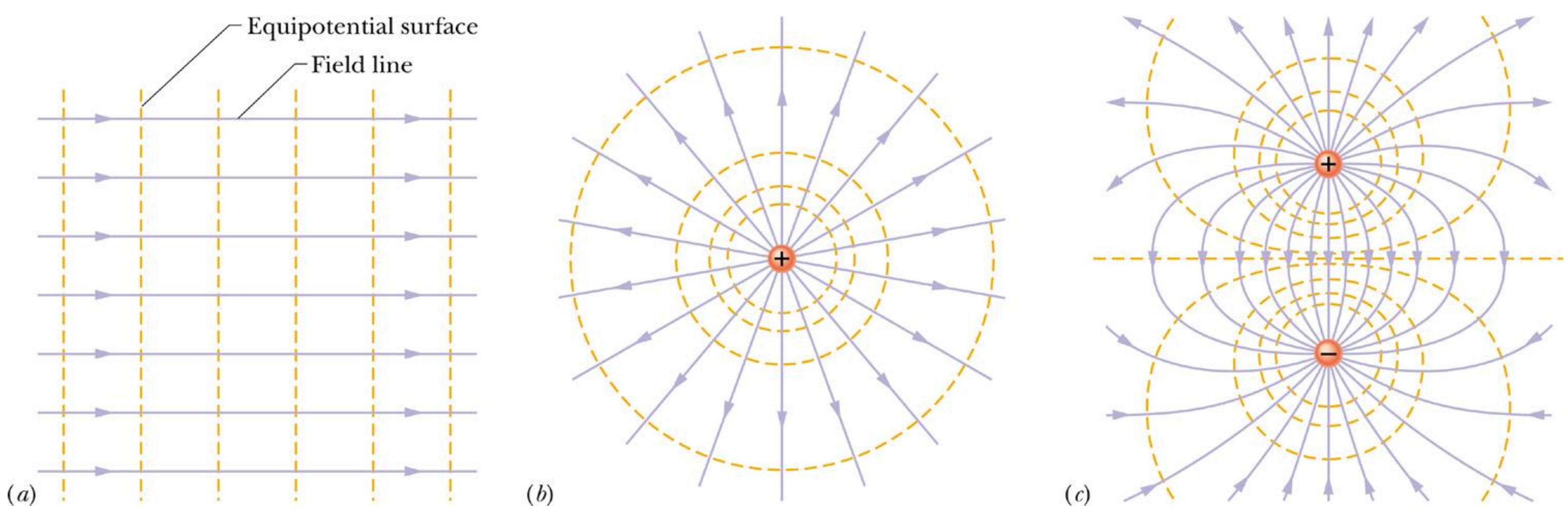
$$U_C(\boldsymbol{r}) = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} \qquad V(\boldsymbol{r}) = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r}$$

Equipotential surface

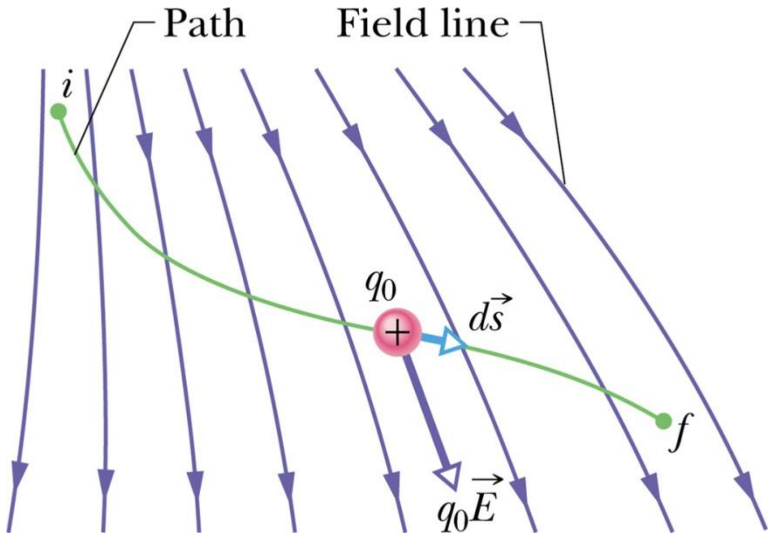


$$V_f - V_i = 0 \longrightarrow -\frac{W_{if}}{q} = 0$$

Equipotential surfaces are normal to the electric field.



Electric potential from electric field

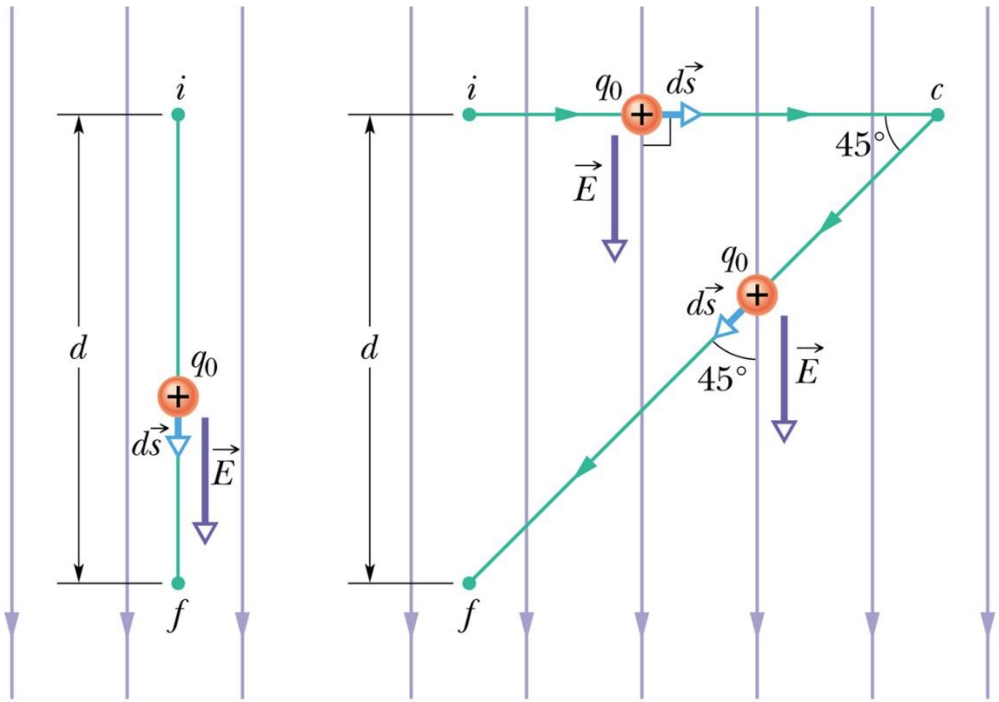


$$dW = \vec{F} \cdot d\vec{s} = q_0 \vec{E} \cdot d\vec{s}$$

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

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

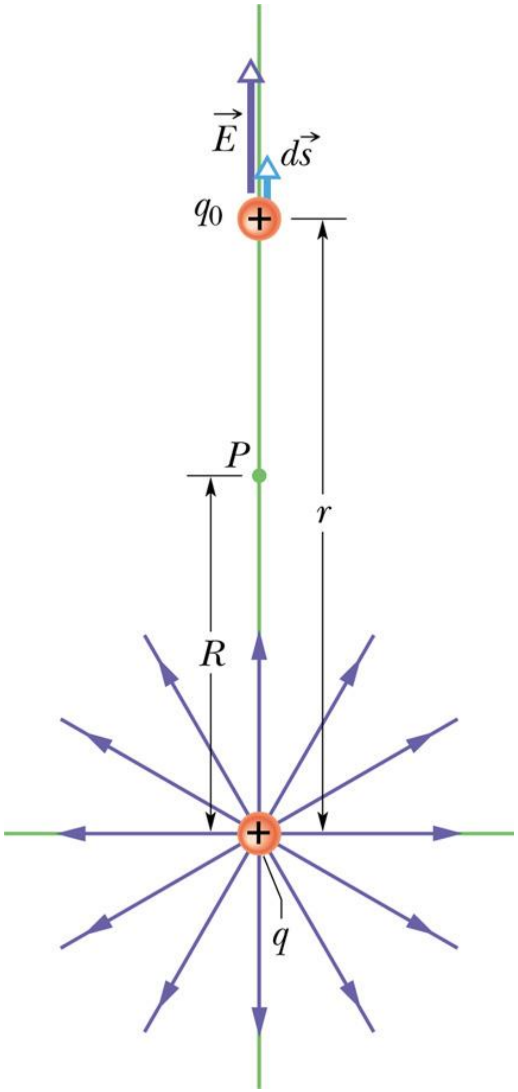
Example



(a) (b)

$$V_f - V_i = -\int_i^f \vec{E} \cdot d\vec{s} = -\int_i^f E ds = -Ed$$

Electric potential by a point charge

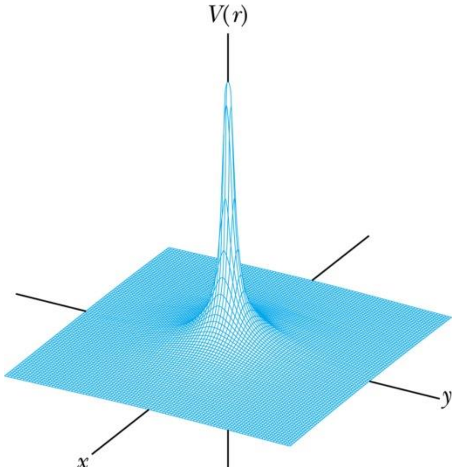


$$\vec{E} \cdot d\vec{s} = E\cos\theta ds = Edr$$

$$V_f - V_i = -\int_R^\infty Edr = -\int_R^\infty \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}dr$$

$$0 - V = -\frac{1}{4\pi\epsilon_0}\frac{1}{R}$$

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



Electric potentials from a point charge, electric dipole, line charge, surface charge, spherical charge (principle of superposition)

1） Point charge q

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

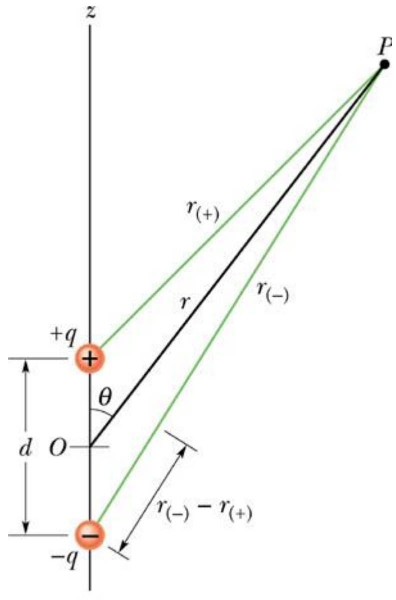
2) Many point charges

$$V = \frac{1}{4\pi\varepsilon_0}\sum_{i}\frac{q_i}{r_i}$$

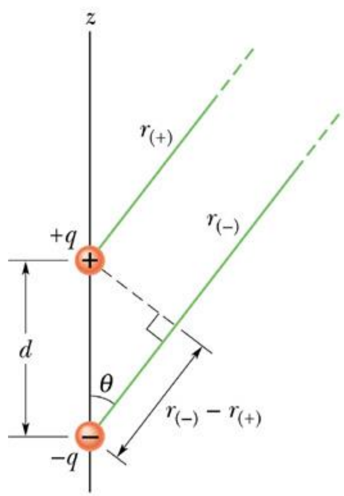
3) Continuous charge distribution

$$V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r}$$

Electric dipole

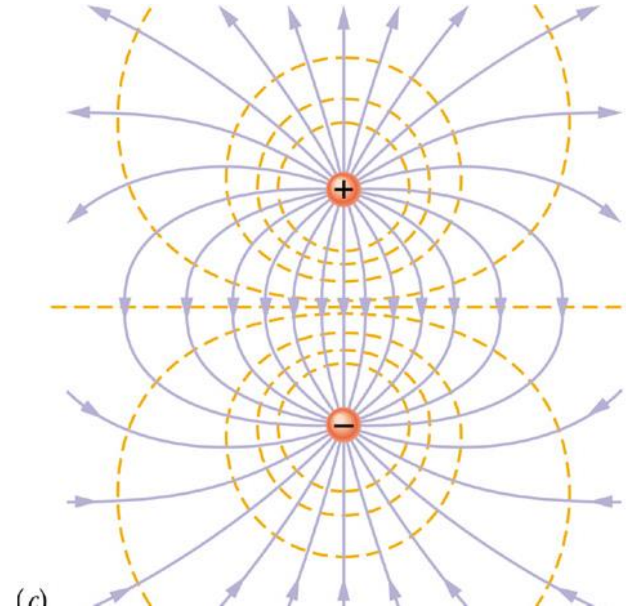


(a)

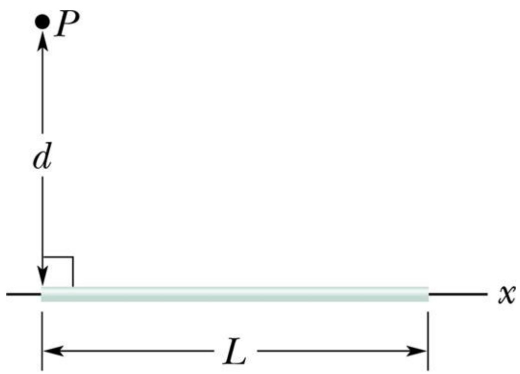


(b)

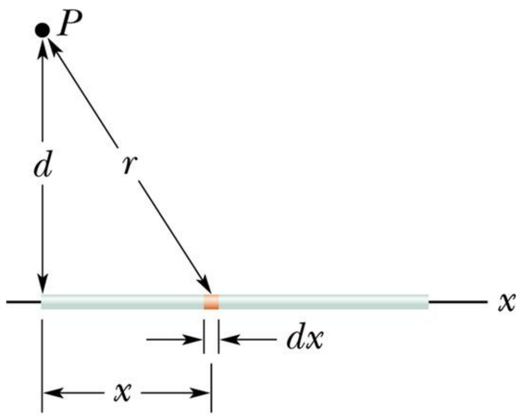
$$V = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2}$$



Line charge



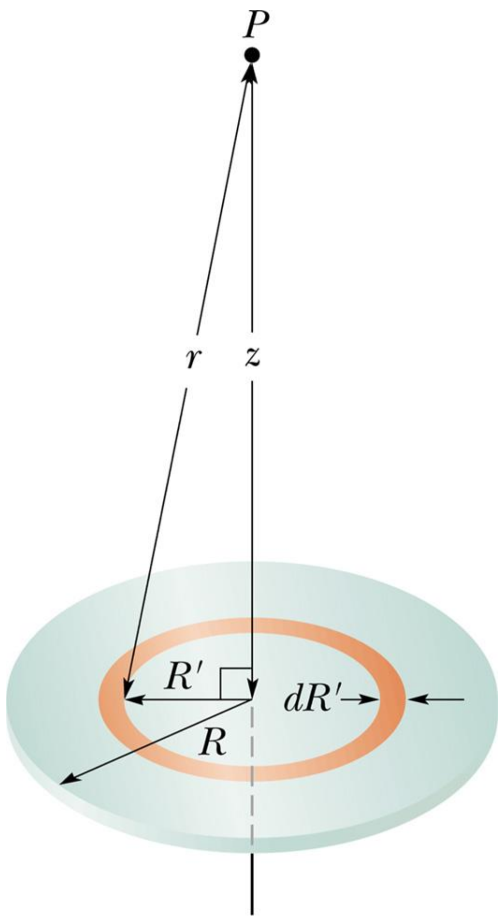
(a)



(b)

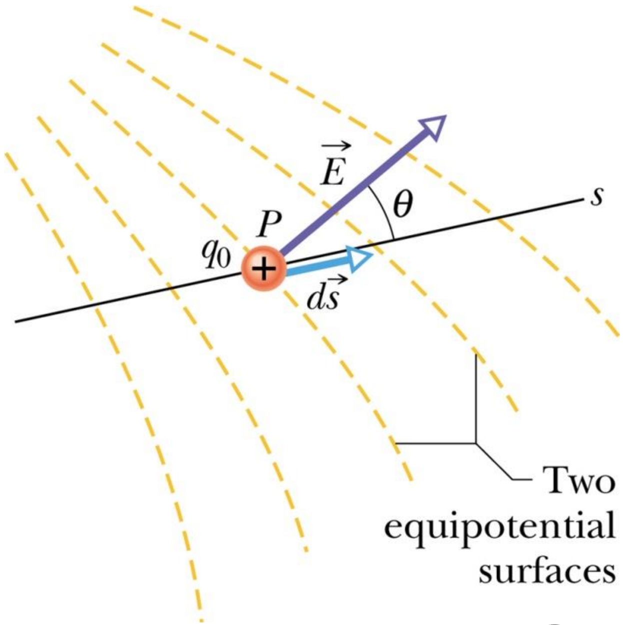
$$V = \frac{\lambda}{4\pi\epsilon_0} \ln \frac{L + \sqrt{L^2 + d^2}}{d}$$

Surface charge



$$V = \frac{\sigma}{2\epsilon_0}\left(\sqrt{z^2 + R^2} - z\right)$$

Electric field from electric potential



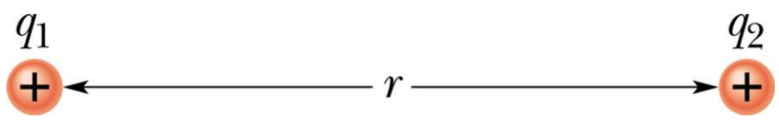
$$-qdV = qE\cos\theta ds \longrightarrow E\cos\theta = -\frac{dV}{ds}$$

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

일반적으로

$$\mathbf{E} = -\nabla V \equiv (-\frac{\partial V}{\partial x}, -\frac{\partial V}{\partial y}, -\frac{\partial V}{\partial z})$$

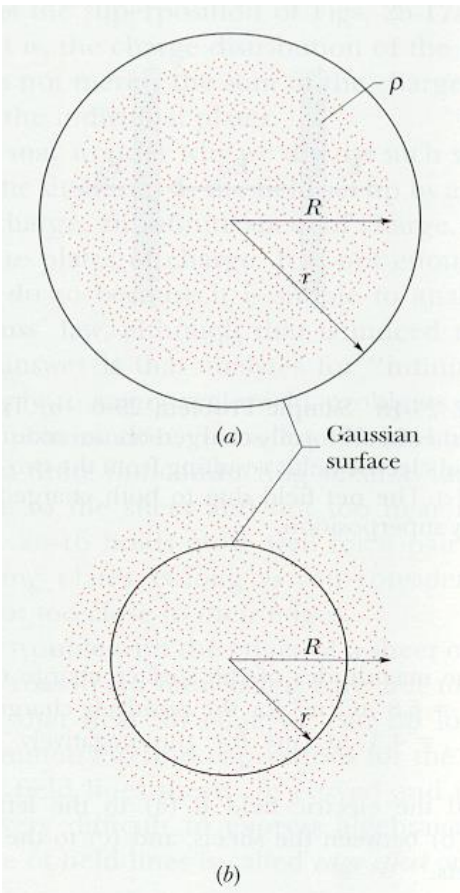
Electric potential energy from point charges

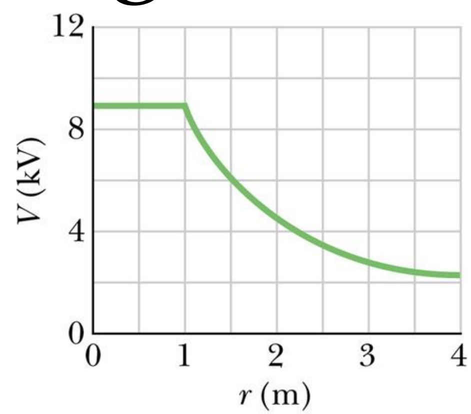


$$V = \frac{1}{4\pi\epsilon_0}\frac{q_1}{r}$$

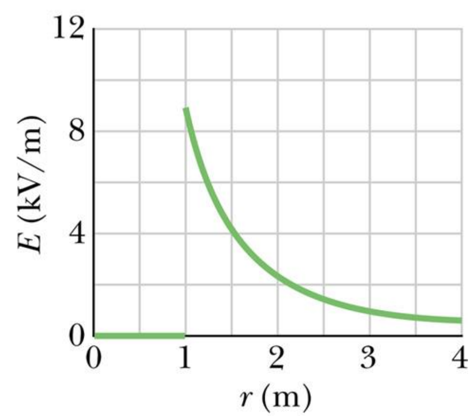
$$U = W = q_2 V = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

Electric potential for an isolated charged conductor





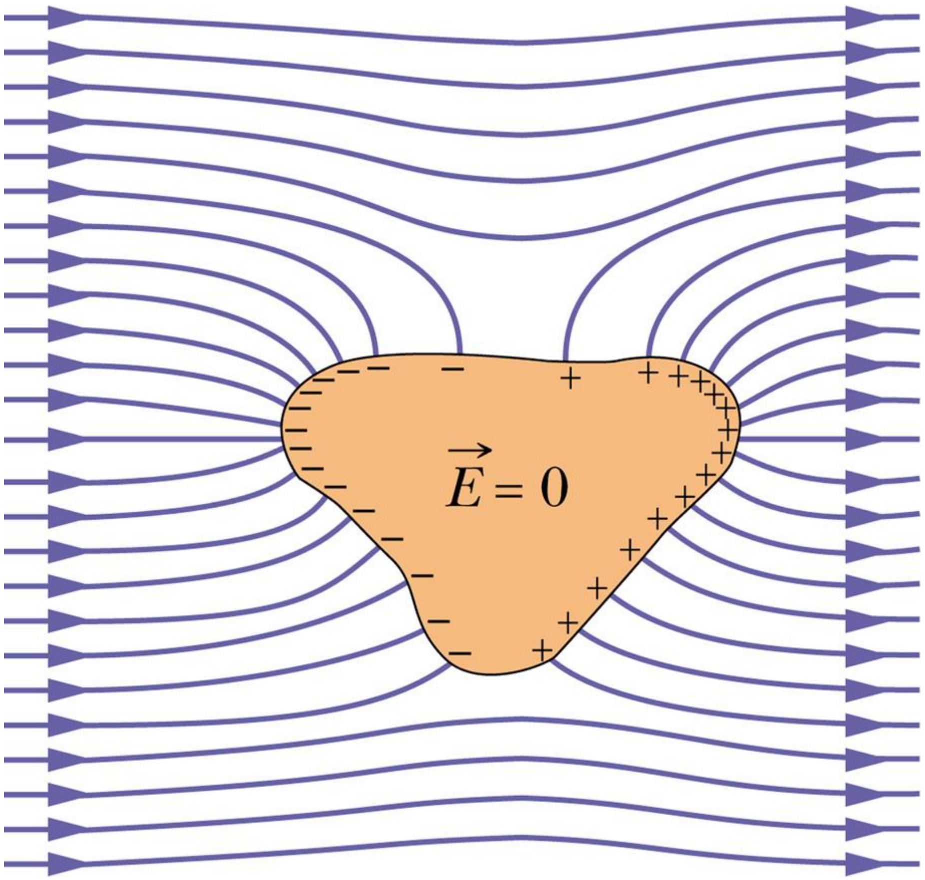
(a)



(b)

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

Isolated conductor in an external E



Surface of a conductor is an equipotential surface, hence normal to the electric field.