

1. Coulomb's law

$$F = \frac{kq_1q_2}{r^2}$$

- $(k \approx 9 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)$

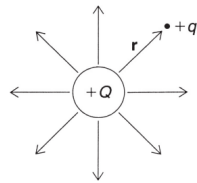
$$k = \frac{1}{4\pi\epsilon_0}$$

- where ϵ_0 represents vacuum

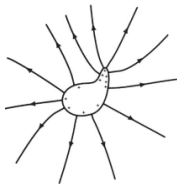
2. Electric field(E)

$$\vec{E} = \frac{\vec{F}}{q}$$

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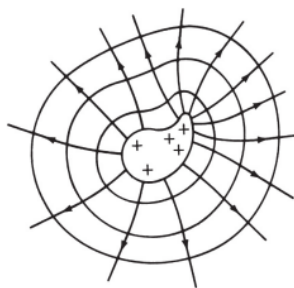
- **Figure 1.5 Drawing Electric Field Lines** (-Q 方向向里)



- 电场线的密集程度与曲率半径正相关 (curvature)

3. Electric potential (V)

- $V = kQ/r$



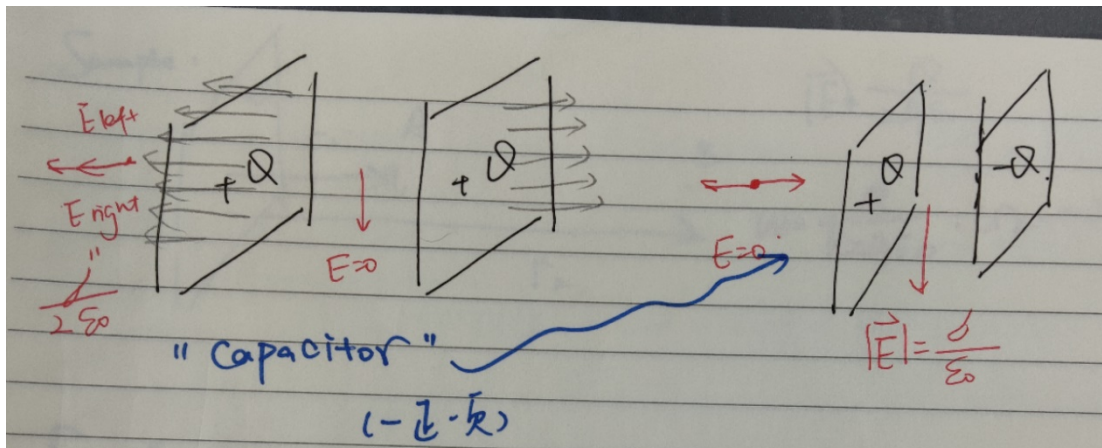
- Equipotential: the line is perpendicular to the electric field line

4. Work & Energy (J)

- $W = -q\Delta V = -\Delta PE$
- Similarities in uniform gravitational and electrical formulas:

	Gravitational	Electrical
Forces	mg	qE
Potential Energy Differences	$mg\Delta h$	$qE\Delta x$

5. Capacitor (two plates that are oppositely charged)



fringe effect: the electric field loses its uniformity near the edges of the plates.

6. formulas

- 静电力 F (N)

$$F = \frac{kQq}{r^2} \quad \rightarrow \quad F = \frac{E}{\pm q}$$

- 电场 E (N/C)

$$E = \frac{kQ}{r^2}$$

- 电势 V (Nm/C) $\rightarrow E = -\frac{\Delta V}{d}$

$$V = \frac{kQ}{r}$$

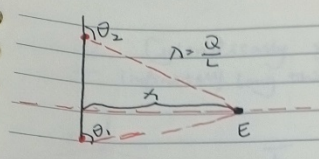
- 电势能 U_e (J) $\rightarrow U_e = \pm q\Delta V$

$$U_e = \frac{kQq}{r}$$

- 功 W (J) $\rightarrow W = -U_e = \pm qEd$

$$W = Fd = \Delta k$$

6. Applications of Gauss's law

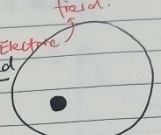


 $\lambda = \frac{Q}{L}$

a charged thin spherical shell

Gauss's Law. \rightarrow 用 Gauss's Law 来推 Electric field.

Electric Flux $\Phi = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enclosed}}}{\epsilon_0}$


 point charge

$\Phi = \oint \vec{E} \cdot d\vec{A}$

 $= E \cdot 4\pi r^2 = \frac{Q}{\epsilon_0}$

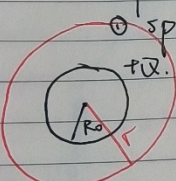
 $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{r^2} = k \frac{Q}{r^2}$

 actually k

Application of Gauss's Law.

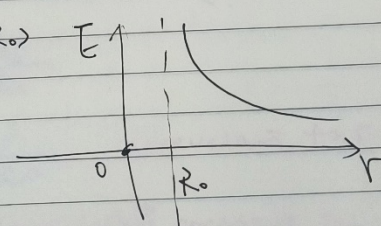
Spherically symmetric field.

① spherical thin shell with $+Q$, R_0 .



 sphere charge.

$E = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{r^2} \quad (r > R_0)$



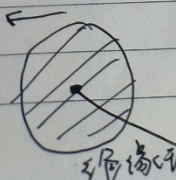
$r > R_0$

$E \cdot 4\pi r^2 = \frac{q_{\text{enclosed}}}{\epsilon_0}$

 $E_{\text{inside}} = 0 \rightarrow$ net charge 算出来的.

② Solid insulated sphere with $+Q$, R_0

(Q distributes on the whole sphere uniformly).



 均匀分布

$E_{\text{outer}} \times 4\pi r^2 = \frac{Q}{\epsilon_0}$

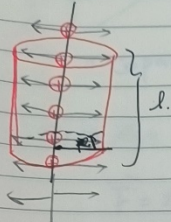
 $E_{\text{inner}} \times 4\pi r^2 = \frac{q}{\epsilon_0} = \frac{\frac{Q}{\frac{4}{3}\pi R_0^3} \times \frac{4}{3}\pi r^3}{\epsilon_0}$

 $E_{\text{inner}} = \frac{1}{3} \frac{Q}{\pi R_0^3} \frac{r}{\epsilon_0}$

 $= k \frac{Q r}{R_0^3}$

2. Cylindrically symmetric field.

— infinitely long thin stick with +ve (uniformly distributed) on the stick with a constant λ .

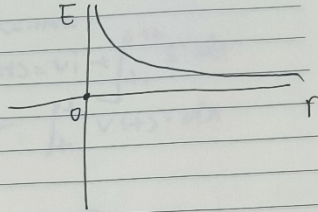


$$\Phi_{\text{bottoms}} + \Phi_{\text{side.}}$$

↓
因为上下是无限的所以为0 (无电通量).

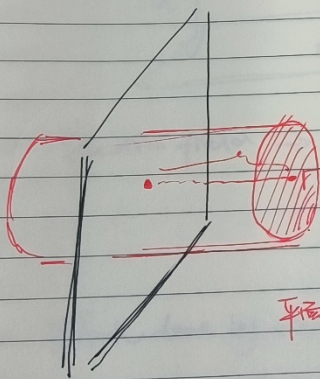
$$E \cdot 2\pi r \cdot l = \frac{\lambda l}{\epsilon_0}$$

$$E = \frac{\lambda}{2\pi\epsilon_0} \cdot \frac{1}{r}$$



3. planarly symmetric field.

infinitely large surface with constant planar density σ .



$$\Phi = \Phi_{\text{bottoms}} + \Phi_{\text{side.}}$$

$$2EA = \frac{\sigma A}{\epsilon_0}$$

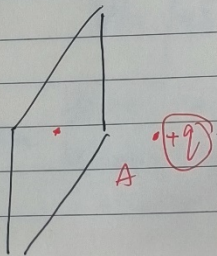
$$E = \frac{\sigma}{2\epsilon_0}$$

irrelevant to r !

平面周围 ~~任意~~ 点均可知场强是 constant σ .

↓
匀强场.

(uniform field).



在那一地方受到的力都相同

7. Work & energy in the uniform electric field

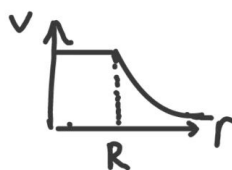
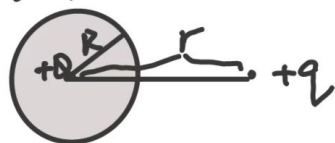
沿电场线做功电势能减小

For a positive charge, 电势和电势能一致

For a negative charge, 电势和电势能不一致

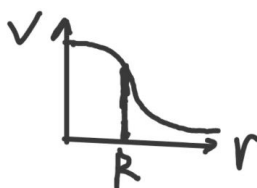
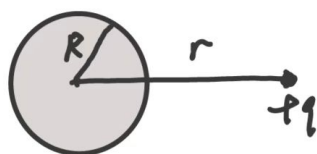
8. 带点球壳/实心球的电势

带点球壳



inside: $V = \frac{kQ}{R}$
 outside: $V = \frac{kQ}{r}$

带电实心球



inside:
$$W_{\infty \rightarrow r} = \int_{r_0}^R \frac{kQr}{R^2} \cdot q \cdot dr + \int_R^{\infty} \dots$$

实心球壳 (见高斯那章)

$$= \dots$$

$$= \frac{1}{2} \frac{kQq}{R^2} (R^2 - r^2) + \frac{kQq}{R}$$

= 常数

outside: $\frac{kQ}{r}$

9. Capacitor (A device that can store energy and charge) & capacitance

- Capacitance C (F)

$$C = Q/V = \epsilon_0 A/d$$

- Potential energy: $U = 1/2 QV$

$Q_e \rightarrow E = \frac{Q}{A\epsilon_0} \rightarrow V = \frac{Qd}{A\epsilon_0} \rightarrow C = \frac{A\epsilon_0}{d}$ (常量)