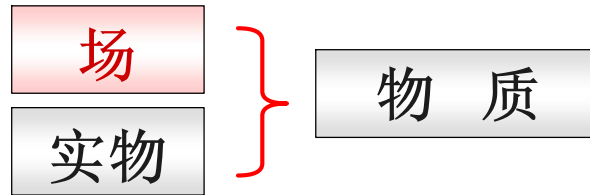


一 静电场



静电场：静止电荷周围存在的电场



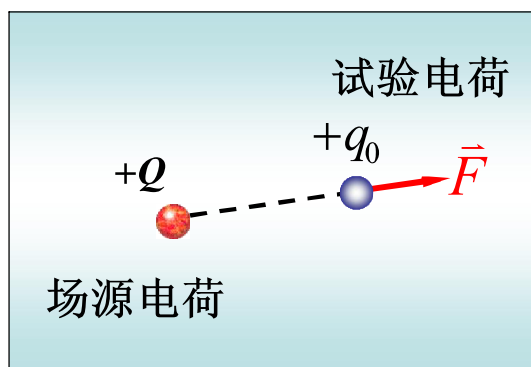
二 电场强度

1 试验电荷

- ◆ 点电荷
- ◆ 电荷足够小

2 电场强度

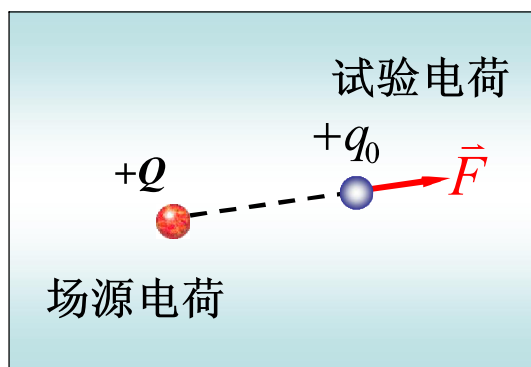
$$\vec{E} = \frac{\vec{F}}{q_0}$$



$$\vec{E} = \frac{\vec{F}}{q_0}$$

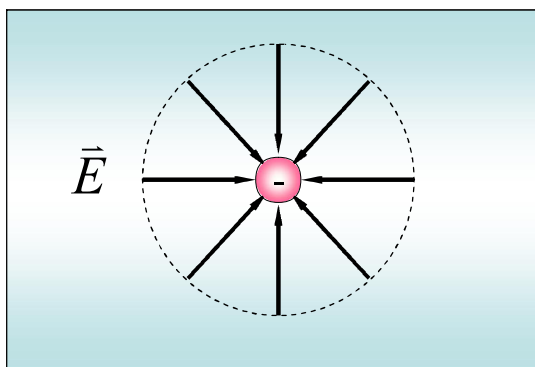
- ◆ 定义：单位正试验电荷所受的电场力
- ◆ 单位： $\text{N}\cdot\text{C}^{-1}, \text{V}\cdot\text{m}^{-1}$
- ◆ 和试验电荷无关
- ◆ 电荷 q 受电场力：

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

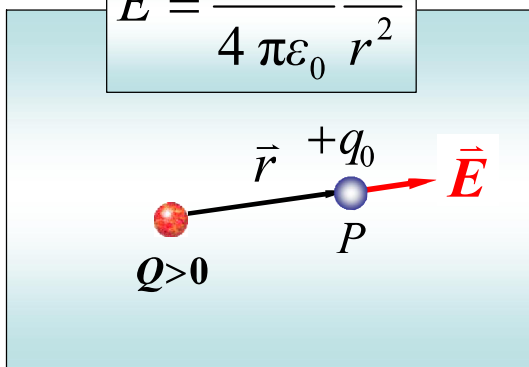


三 点电荷电场强度

$$\vec{F} = \frac{1}{4\pi\epsilon_0} \frac{Qq_0}{r^2} \vec{e}_r \quad \vec{E} = \frac{\vec{F}}{q_0} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \vec{e}_r$$



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



四 电场强度叠加原理

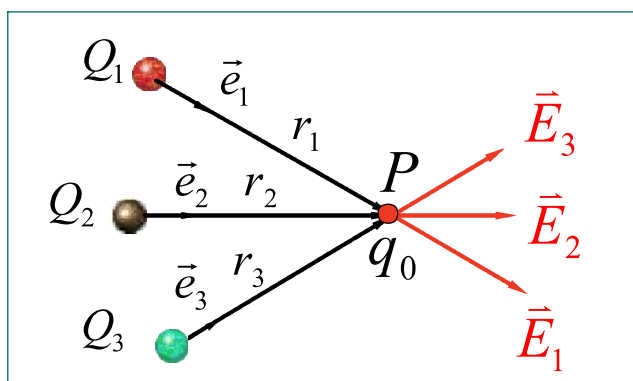
◆ 点电荷系的电场

$$\vec{F}_i = \frac{1}{4\pi\epsilon_0} \frac{q_0 Q_i}{r_i^2} \vec{e}_i$$

$$\vec{E} = \sum_i \vec{E}_i = \frac{1}{4\pi\epsilon_0} \sum_i \frac{Q_i}{r_i^2} \vec{e}_i$$

$$\vec{F} = \sum_i \vec{F}_i$$

$$\vec{E} = \frac{\vec{F}}{q_0} = \sum_i \frac{\vec{F}_i}{q_0}$$

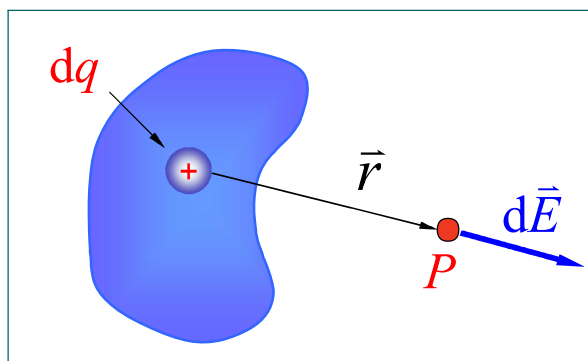


◆ 电荷连续分布的电场

$$d\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} \vec{e}_r \quad \vec{E} = \int d\vec{E} = \int \frac{1}{4\pi\epsilon_0} \frac{\vec{e}_r}{r^2} dq$$

电荷体密度 ρ $dq = \rho dV$

$$\vec{E} = \int_V \frac{1}{4\pi\epsilon_0} \frac{\rho \vec{e}_r}{r^2} dV$$

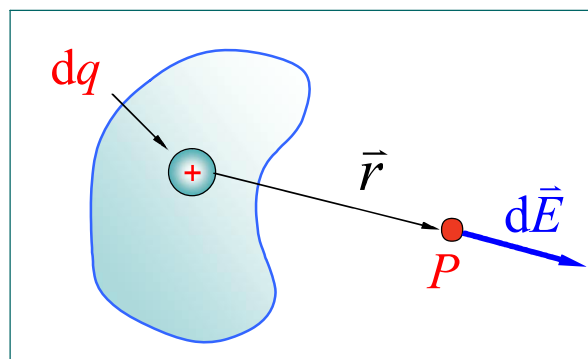


◆ 电荷连续分布的电场

$$d\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} \vec{e}_r \quad \vec{E} = \int d\vec{E} = \int \frac{1}{4\pi\epsilon_0} \frac{\vec{e}_r}{r^2} dq$$

电荷面密度 σ $dq = \sigma dS$

$$\vec{E} = \int_S \frac{1}{4\pi\epsilon_0} \frac{\sigma \vec{e}_r}{r^2} dS$$

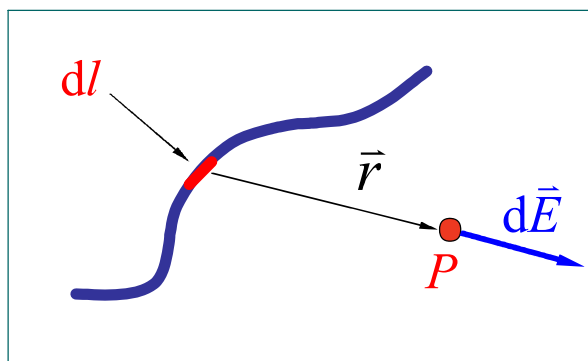


◆ 电荷连续分布的电场

$$d\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{dq}{r^2} \vec{e}_r \quad \vec{E} = \int d\vec{E} = \int \frac{1}{4\pi\epsilon_0} \frac{\vec{e}_r}{r^2} dq$$

电荷线密度 λ $dq = \lambda dl$

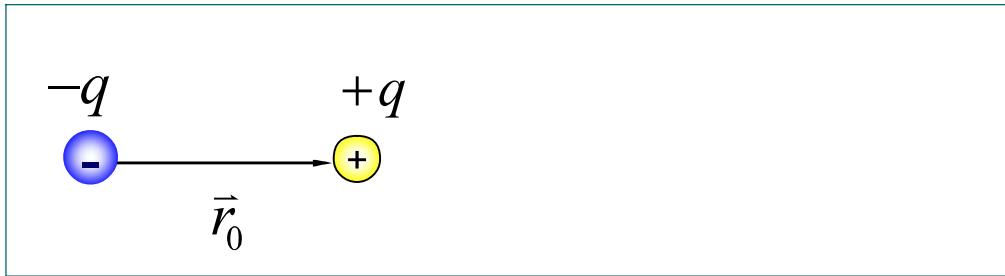
$$\vec{E} = \int \frac{1}{4\pi\epsilon_0} \frac{\lambda \vec{e}_r}{r^2} dl$$



五 电偶极子的电场强度

电偶极子的轴 \vec{r}_0

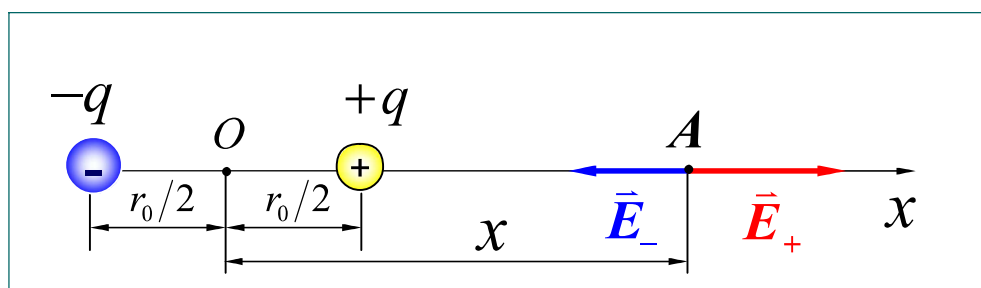
电偶极矩(电矩) $\vec{p} = q\vec{r}_0$



(1) 轴线延长线上一点的电场强度

$$\vec{E}_+ = \frac{1}{4\pi\epsilon_0} \frac{q}{(x-r_0/2)^2} \vec{i} \quad \vec{E}_- = -\frac{1}{4\pi\epsilon_0} \frac{q}{(x+r_0/2)^2} \vec{i}$$

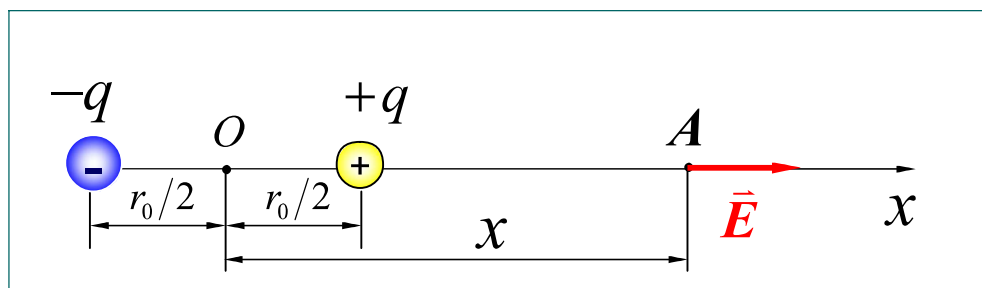
$$\vec{E} = \vec{E}_+ + \vec{E}_- = \frac{q}{4\pi\epsilon_0} \left[\frac{2xr_0}{(x^2 - r_0^2/4)^2} \right] \vec{i}$$



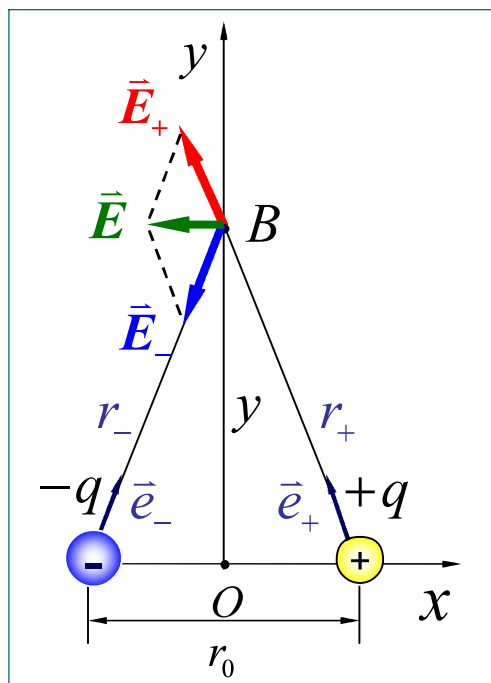
$$\vec{E} = \frac{q}{4\pi\epsilon_0} \left[\frac{2xr_0}{(x^2 - r_0^2/4)^2} \right] \vec{i}$$

$$x \gg r_0$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{2r_0q}{x^3} \vec{i} = \frac{1}{4\pi\epsilon_0} \frac{2\vec{p}}{x^3}$$



(2) 轴线中垂线上一点的电场强度



$$\vec{E}_+ = \frac{1}{4\pi\epsilon_0} \frac{q}{r_+^2} \vec{e}_+$$

$$\vec{E}_- = -\frac{1}{4\pi\epsilon_0} \frac{q}{r_-^2} \vec{e}_-$$

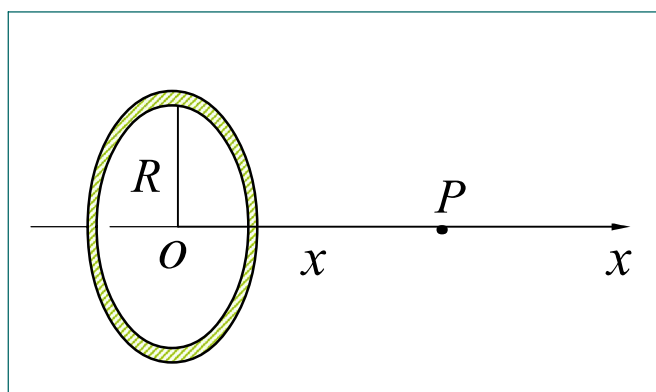
$$r_+ = r_- = r = \sqrt{y^2 + \left(\frac{r_0}{2}\right)^2}$$

$$\vec{E} = \vec{E}_+ + \vec{E}_- = -\frac{1}{4\pi\epsilon_0} \frac{\vec{p}}{r^3}$$

$$y \gg r_0 \quad \vec{E} = -\frac{1}{4\pi\epsilon_0} \frac{\vec{p}}{y^3}$$



例1 正电荷 q 均匀分布在半径为 R 的圆环上. 计算通过环心点 O 并垂直圆环平面的轴线上任一点 P 处的电场强度.

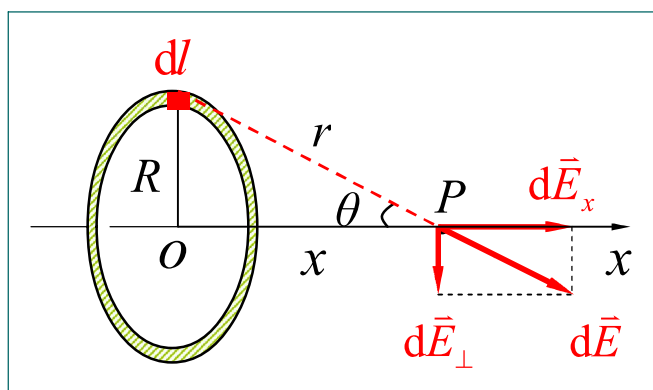


$$\text{解 } \lambda = \frac{q}{2\pi R} \quad dq = \lambda dl \quad dE = \frac{1}{4\pi\epsilon_0} \frac{\lambda dl}{r^2}$$

$$d\vec{E} = d\vec{E}_x + d\vec{E}_\perp \quad \text{由于 } E_\perp = \int dE_\perp = 0$$

$$\text{故 } E = \int dE_x = \int dl \cos\theta$$

$$\begin{aligned} &= \int \frac{\lambda dl}{4\pi\epsilon_0 r^2} \cdot \frac{x}{r} \\ &= \frac{\lambda x}{4\pi\epsilon_0 r^3} \int_0^{2\pi R} dl \\ &= \frac{qx}{4\pi\epsilon_0 (x^2 + R^2)^{3/2}} \end{aligned}$$



讨论

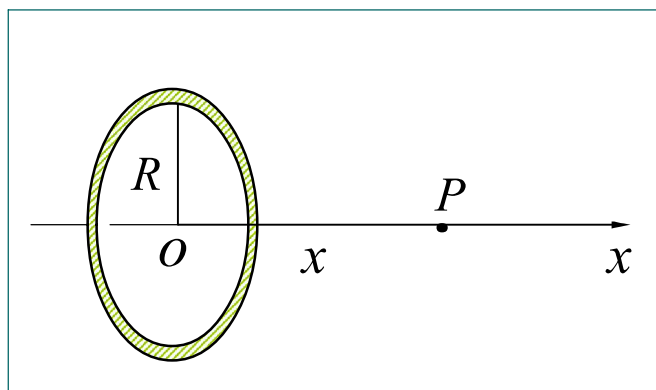
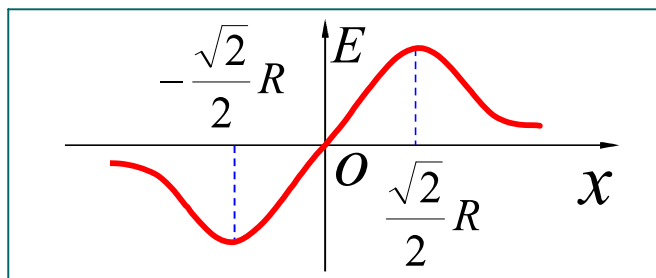
(1) $x \gg R$

(2) $x = 0$

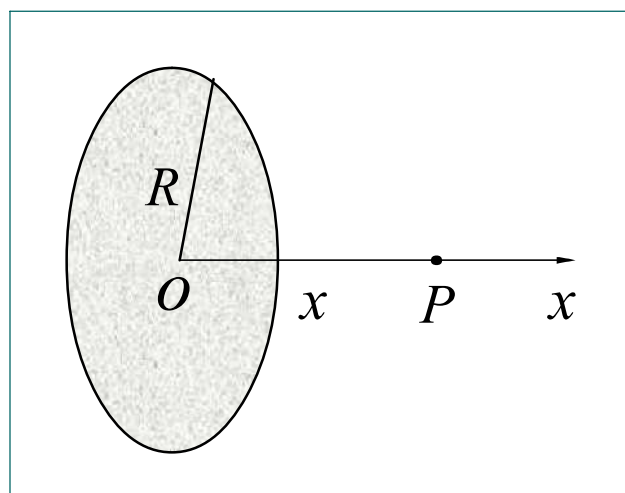
$E_o = 0$

(3) $\frac{dE}{dx} = 0$

$x = \pm \frac{\sqrt{2}}{2} R$



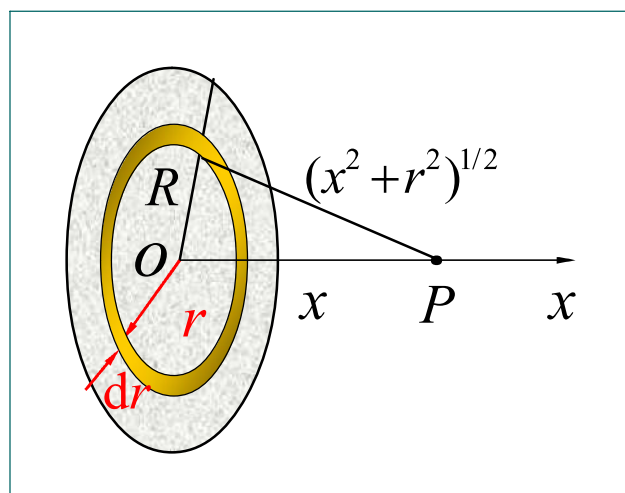
例2 有一半径为 R ，电荷均匀分布的薄圆盘，其电荷面密度为 σ 。求通过盘心且垂直盘面的轴线上任意一点处的电场强度。



解 $\sigma = q / \pi R^2$ $dq = \sigma 2\pi r dr$

$$dE_x = \frac{x dq}{4\pi\epsilon_0 (x^2 + r^2)^{3/2}} = \frac{\sigma}{2\epsilon_0} \frac{x r dr}{(x^2 + r^2)^{3/2}}$$

$$E = \int dE_x$$
$$= \frac{\sigma x}{2\epsilon_0} \left(\frac{1}{\sqrt{x^2}} - \frac{1}{\sqrt{x^2 + R^2}} \right)$$



讨论

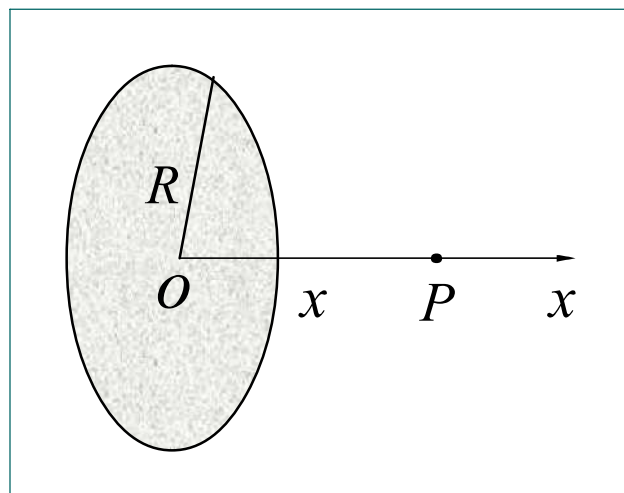
$$E = \frac{\sigma x}{2\epsilon_0} \left(\frac{1}{\sqrt{x^2}} - \frac{1}{\sqrt{x^2 + R^2}} \right)$$

$$x \ll R$$

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

$$x \gg R$$

$$E \approx \frac{q}{4\pi\epsilon_0 x^2}$$



选择进入下一节:

5-2 库仑定律

5-3 电场强度

5-4 电场强度通量 高斯定理

*5-5 密立根测定电子电荷的实验

5-6 静电场的环路定理 电势能

5-7 电势

