一 静电场

电荷 ⇄ 电 场 ⇄ 电荷

场
实物

物 质

静电场： 静止电荷周围存在的电场

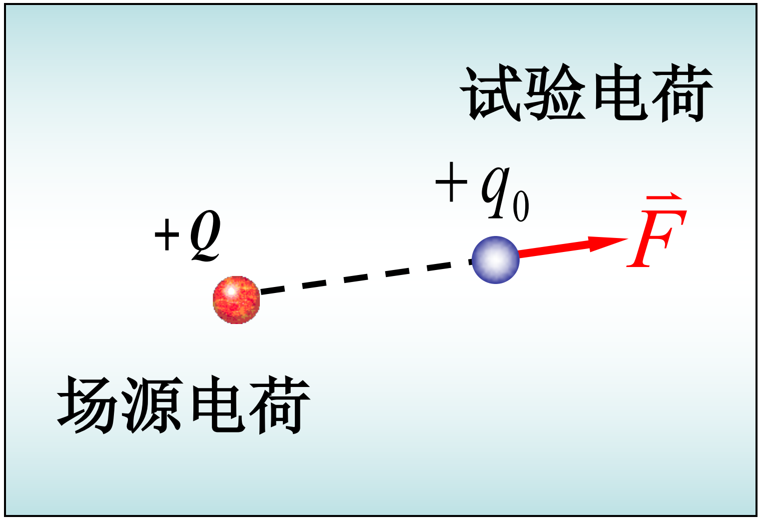
二 电场强度

1 试验电荷

- 点电荷
- 电荷足够小

2 电场强度

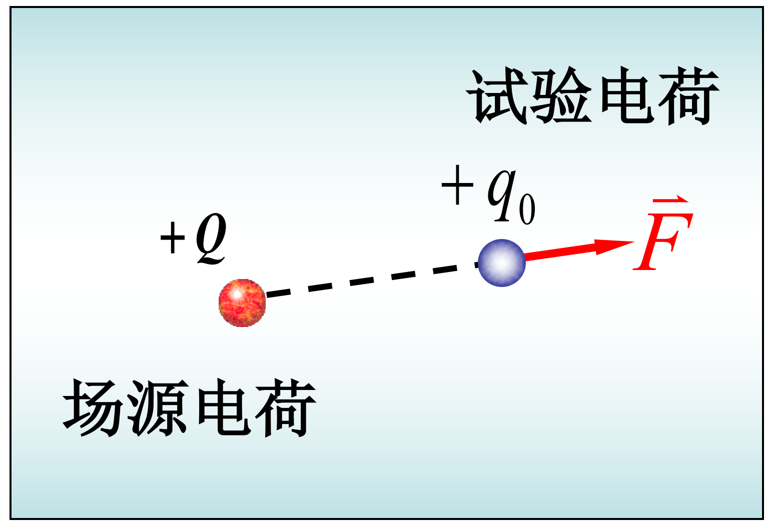
$$\vec{E}=\frac{\vec{F}}{q_0}$$



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

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

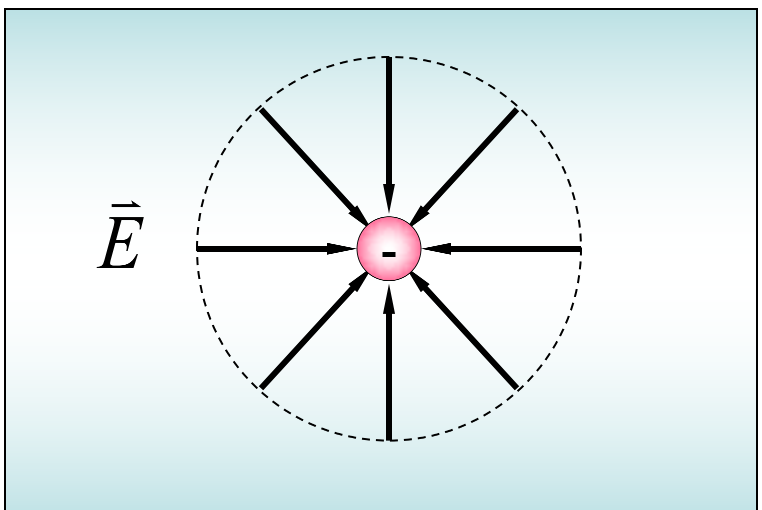
$$\boxed{\vec{F}=q\vec{E}}$$

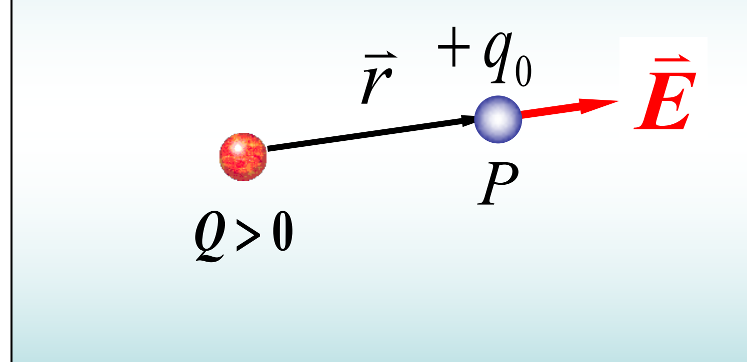


三 点电荷电场强度

$$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{Qq_0}{r^2}\vec{e}_r \qquad \vec{E} = \frac{\vec{F}}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\vec{e}_r$$

$$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}}$$





四　电场强度叠加原理

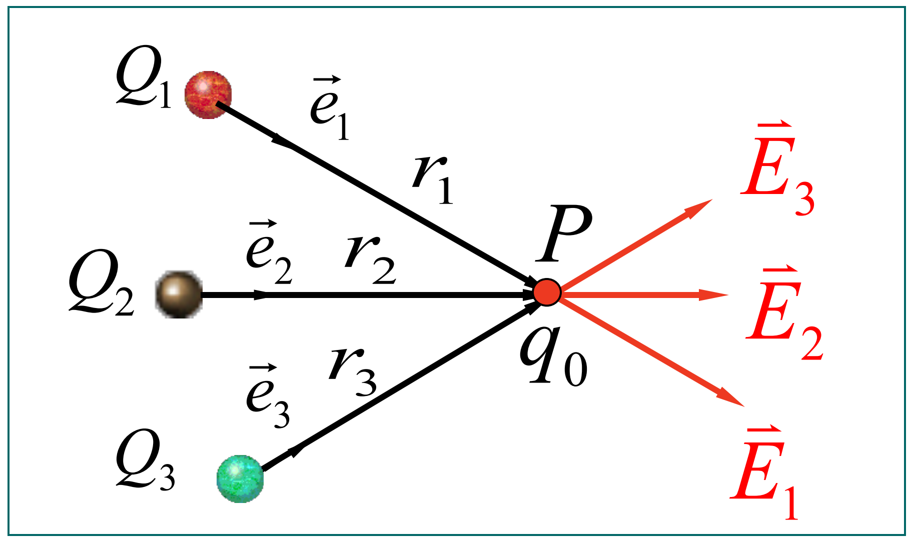
◆ 点电荷系的电场

$$\vec{E} = \sum_i \vec{E}_i = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{Q_i}{r_i^2}\vec{e}_i$$

$$\vec{F}_i = \frac{1}{4\pi\varepsilon_0}\frac{q_0 Q_i}{r_i^2}\vec{e}_i$$

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

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

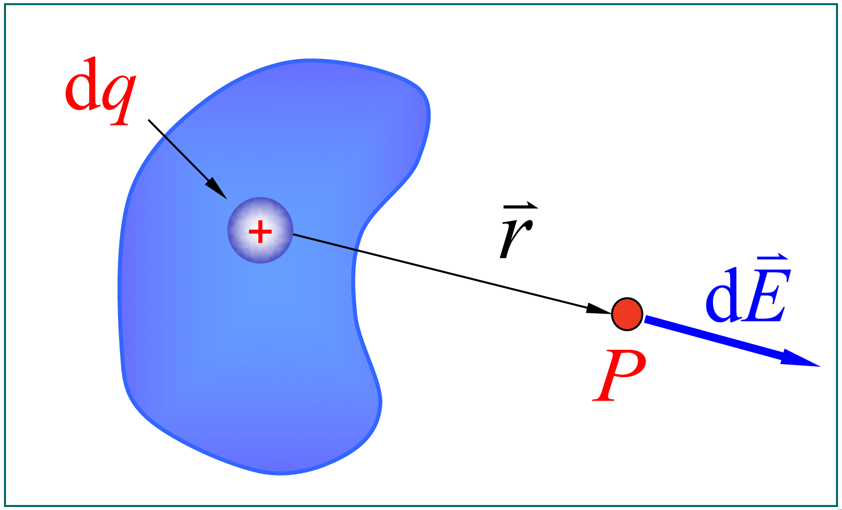


电荷连续分布的电场

$$\mathrm{d}\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{\mathrm{d}q}{r^2}\vec{e}_r \qquad \vec{E} = \int \mathrm{d}\vec{E} = \int \frac{1}{4\pi\varepsilon_0}\frac{\vec{e}_r}{r^2}\mathrm{d}q$$

电荷**体**密度 ρ $\qquad \mathrm{d}q = \rho \mathrm{d}V$

$$\boxed{\vec{E} = \int_V \frac{1}{4\pi\varepsilon_0}\frac{\rho\vec{e}_r}{r^2}\mathrm{d}V}$$

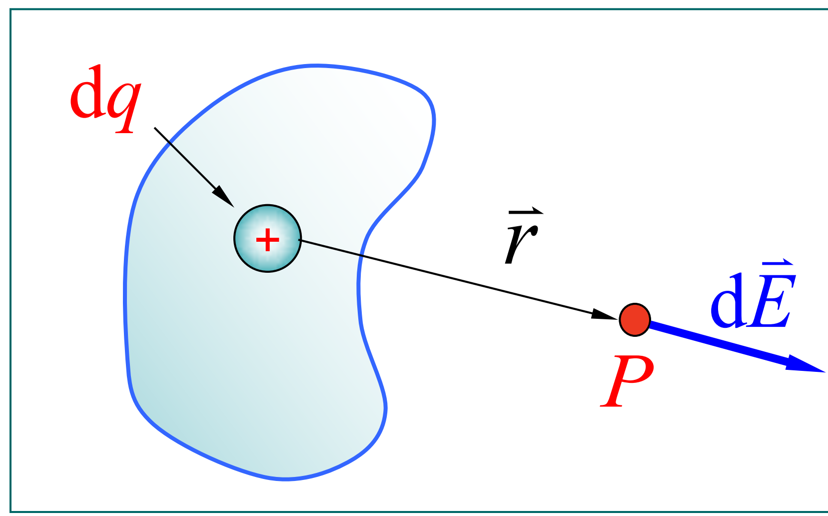


◆ 电荷连续分布的电场

$$\mathrm{d}\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{\mathrm{d}q}{r^2}\vec{e}_r \qquad \vec{E} = \int \mathrm{d}\vec{E} = \int \frac{1}{4\pi\varepsilon_0}\frac{\vec{e}_r}{r^2}\mathrm{d}q$$

电荷**面**密度 σ $\qquad \mathrm{d}q = \sigma \mathrm{d}S$

$$\boxed{\vec{E} = \int_S \frac{1}{4\pi\varepsilon_0}\frac{\sigma\vec{e}_r}{r^2}\mathrm{d}S}$$

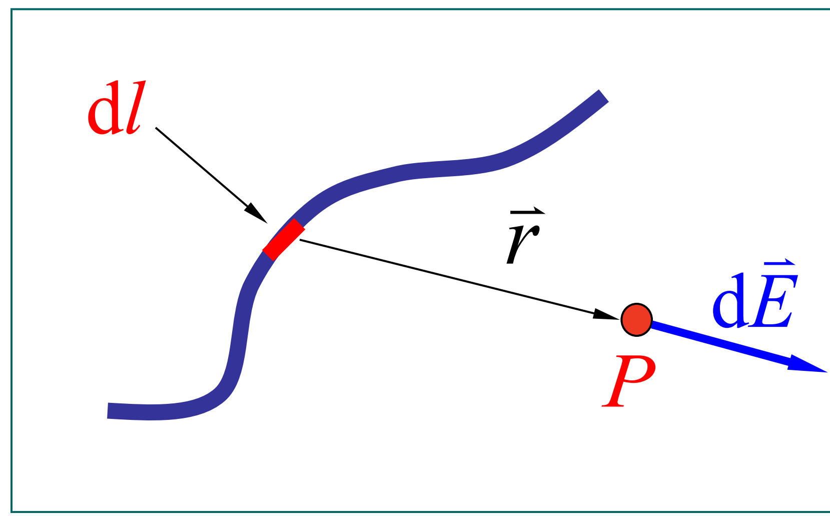


电荷连续分布的电场

$$\mathrm{d}\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{\mathrm{d}q}{r^2}\vec{e}_r \qquad \vec{E} = \int \mathrm{d}\vec{E} = \int \frac{1}{4\pi\varepsilon_0}\frac{\vec{e}_r}{r^2}\mathrm{d}q$$

电荷线密度 λ　　$\mathrm{d}q = \lambda \mathrm{d}l$

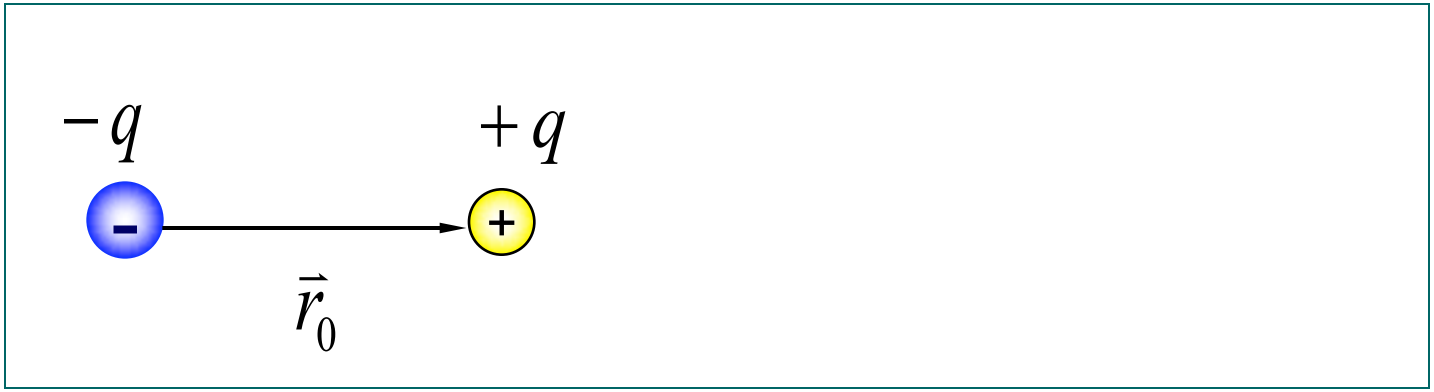
$$\boxed{\vec{E} = \int_l \frac{1}{4\pi\varepsilon_0}\frac{\lambda\vec{e}_r}{r^2}\mathrm{d}l}$$



五　电偶极子的电场强度

电偶极子的轴 $\vec{r}_0$

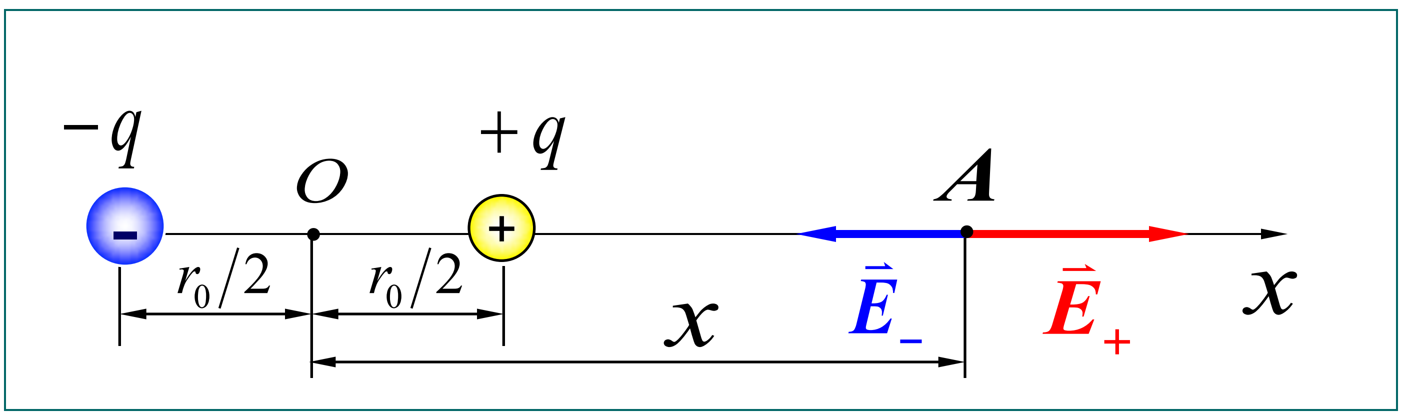
电偶极矩（电矩） $\vec{p}=q\vec{r}_0$



（1）轴线延长线上一点的电场强度

$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(x - r_0/2)^2}\vec{i} \qquad \vec{E}_- = -\frac{1}{4\pi\varepsilon_0}\frac{q}{(x + r_0/2)^2}\vec{i}$$

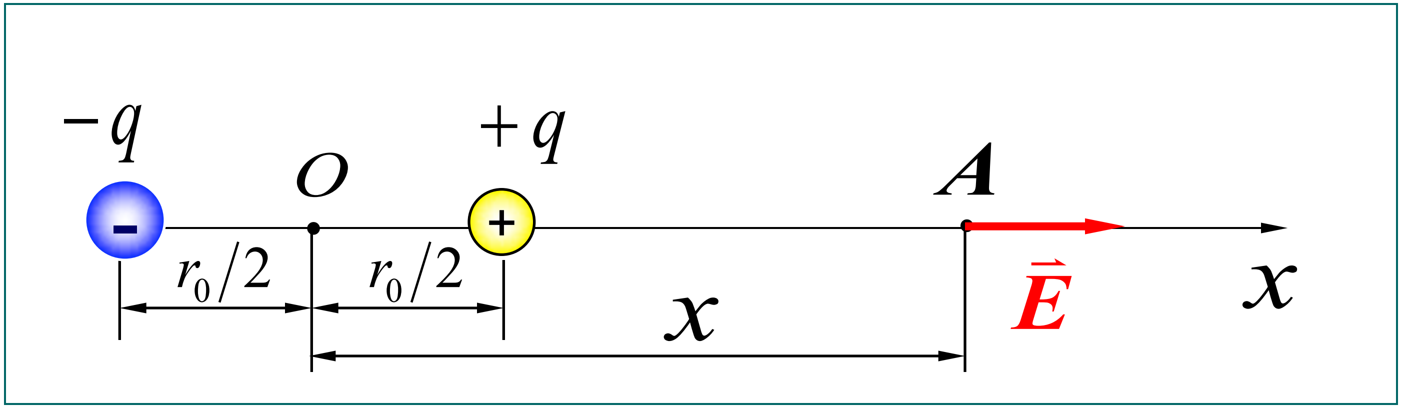
$$\vec{E} = \vec{E}_+ + \vec{E}_- = \frac{q}{4\pi\varepsilon_0}\left[\frac{2xr_0}{(x^2 - r_0^2/4)^2}\right]\vec{i}$$



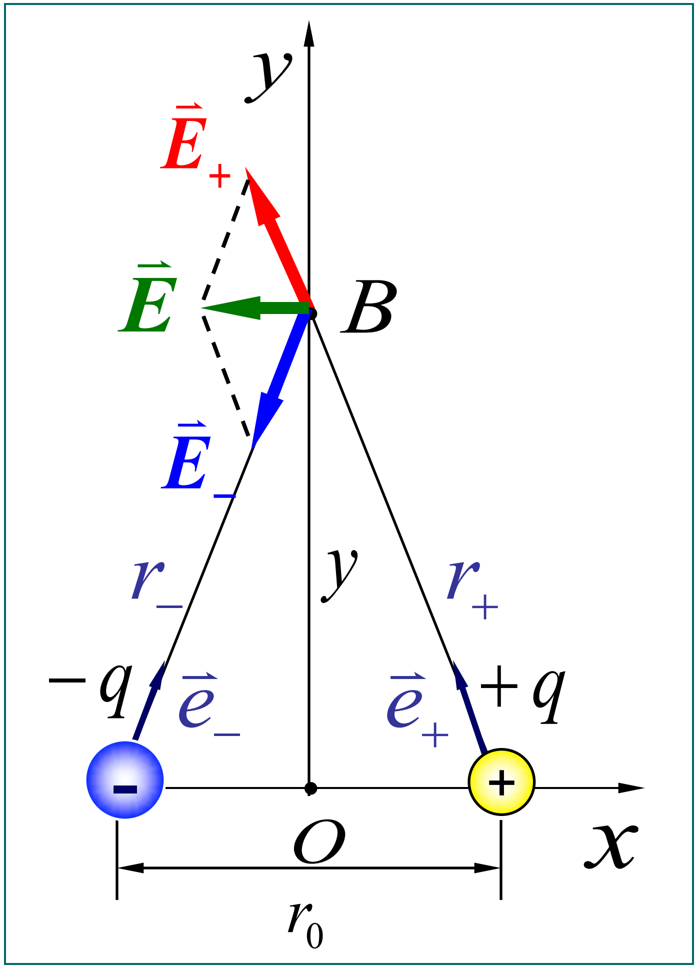
$$\vec{E}=\frac{q}{4\pi\varepsilon_0}\left[\frac{2xr_0}{(x^2-r_0^2/4)^2}\right]\vec{i}$$

$$x>>r_0$$

$$\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{2r_0q}{x^3}\vec{i}=\frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{x^3}$$



（2）轴线中垂线上一点的电场强度



$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_+^2}\vec{e}_+$$

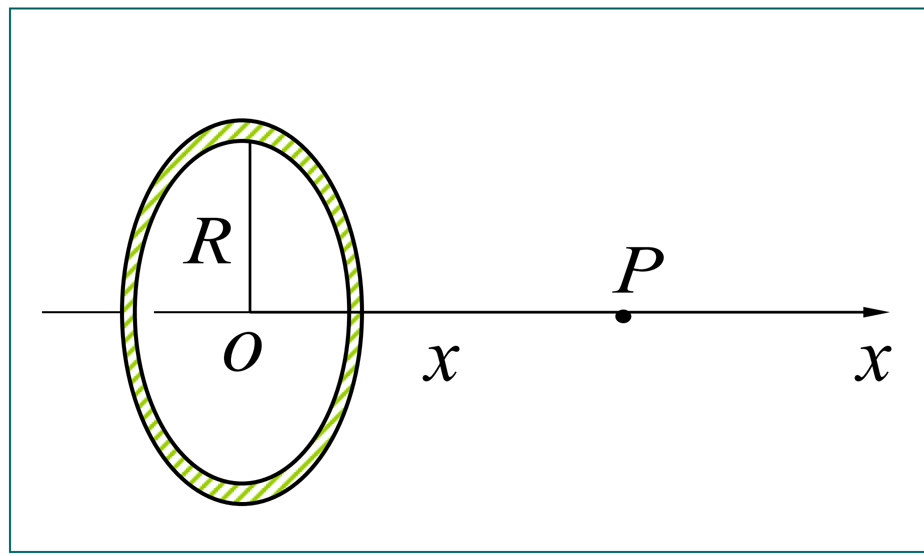
$$\vec{E}_- = -\frac{1}{4\pi\varepsilon_0}\frac{q}{r_-^2}\vec{e}_-$$

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

$$\vec{E} = \vec{E}_+ + \vec{E}_- = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$$

$$y >> r_0 \quad \vec{E} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{y^3}$$

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.



解 $\lambda=\dfrac{q}{2\pi R}$ $\quad \mathrm{d}q=\lambda\mathrm{d}l$ $\quad \mathrm{d}E=\dfrac{1}{4\pi\varepsilon_0}\dfrac{\lambda\mathrm{d}l}{r^2}$

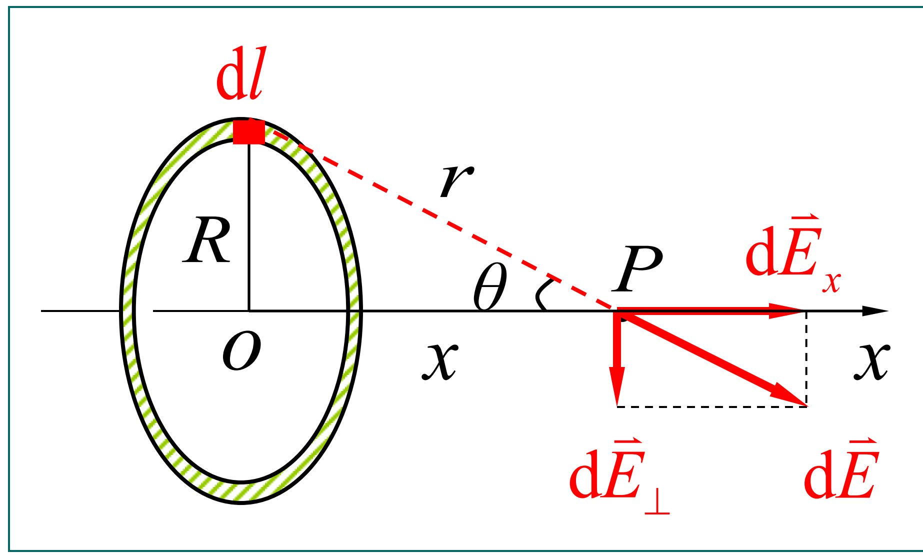
$\mathrm{d}\vec{E}=\mathrm{d}\vec{E}_x+\mathrm{d}\vec{E}_\perp$ 由于 $E_\perp=\int_l \mathrm{d}E_\perp=0$

故 $E=\int_l \mathrm{d}E_x=\int_l \mathrm{d}E\cos\theta$

$$=\int\frac{\lambda\mathrm{d}l}{4\pi\varepsilon_0 r^2}\cdot\frac{x}{r}$$

$$=\frac{\lambda x}{4\pi\varepsilon_0 r^3}\int_0^{2\pi R}\mathrm{d}l$$

$$=\frac{qx}{4\pi\varepsilon_0(x^2+R^2)^{3/2}}$$



讨 论

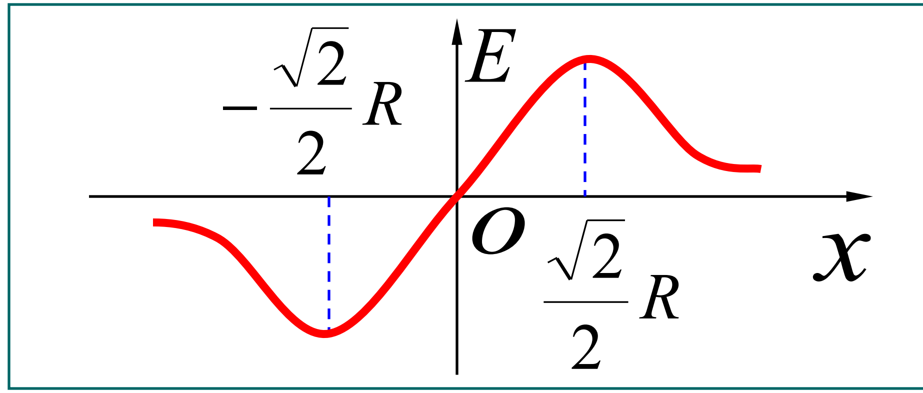
（1） $x >> R$

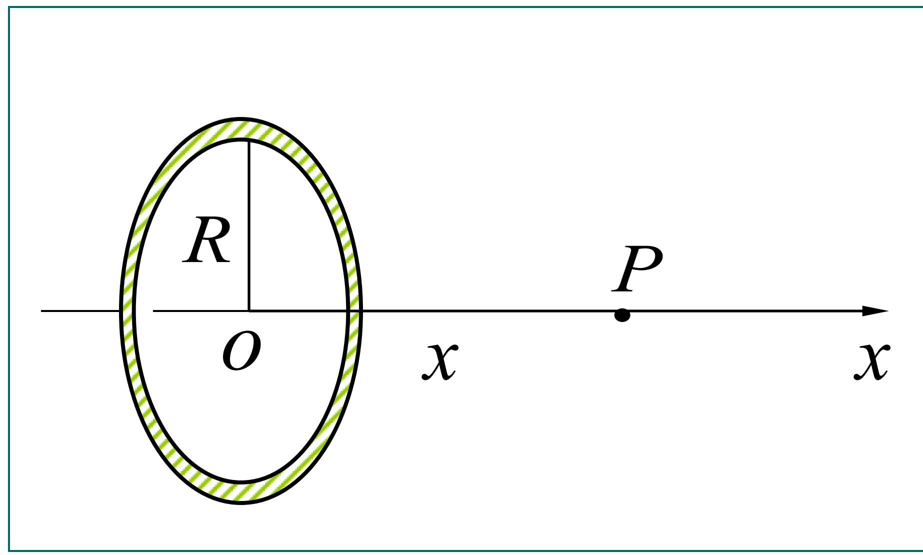
（2） $x = 0$

$E_o = 0$

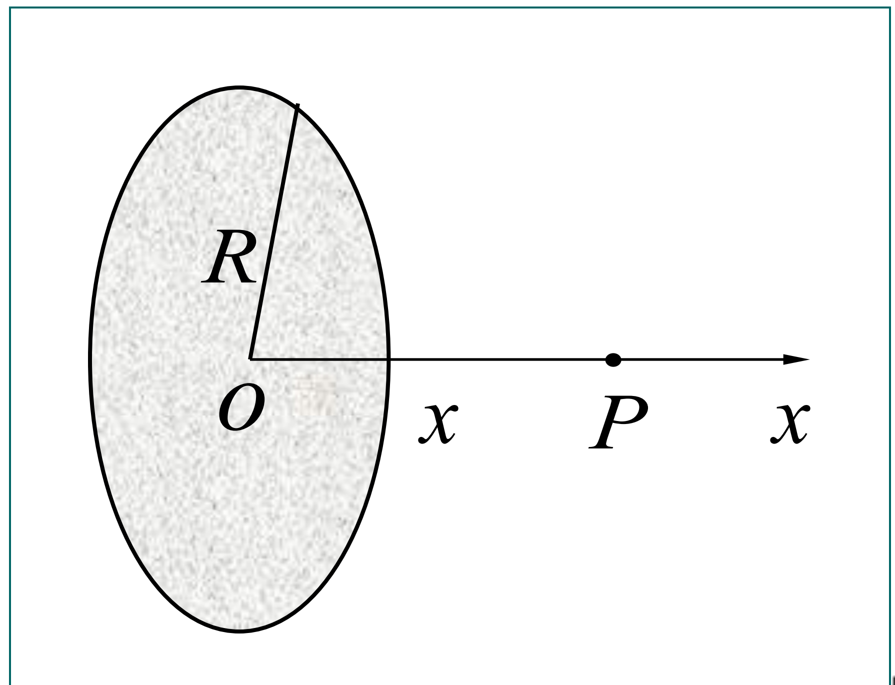
（3） $\dfrac{\mathrm{d}E}{\mathrm{d}x} = 0$

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





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.

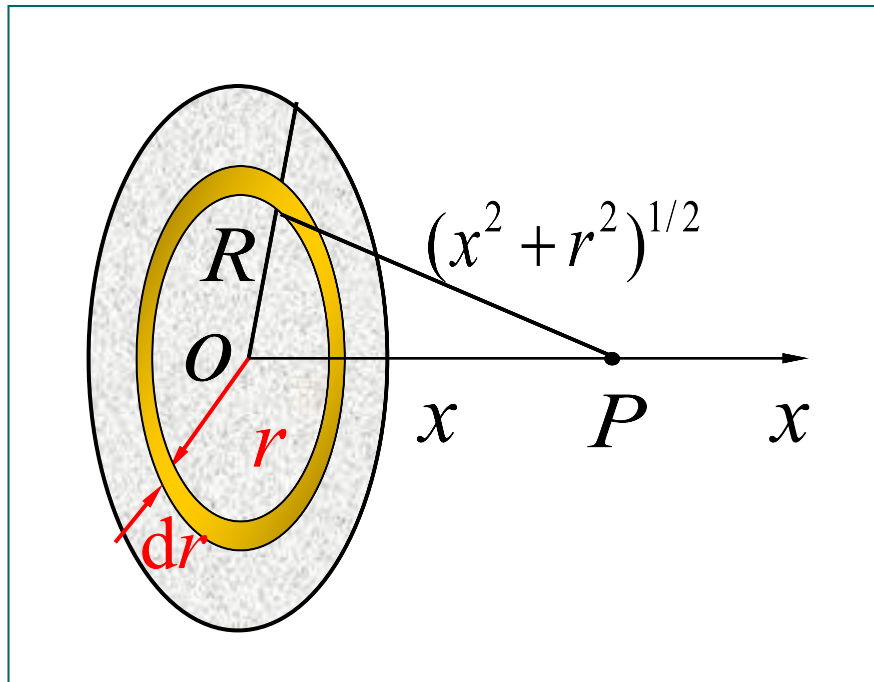


解 $\sigma = q / \pi R^2 \qquad \mathrm{d}q = \sigma 2\pi r \mathrm{d}r$

$$\mathrm{d}E_x = \frac{x\mathrm{d}q}{4\pi\varepsilon_0 (x^2+r^2)^{3/2}} = \frac{\sigma}{2\varepsilon_0}\frac{xr\mathrm{d}r}{(x^2+r^2)^{3/2}}$$

$$E = \int \mathrm{d}E_x$$

$$= \frac{\sigma x}{2\varepsilon_0}\left(\frac{1}{\sqrt{x^2}} - \frac{1}{\sqrt{x^2+R^2}}\right)$$



讨论

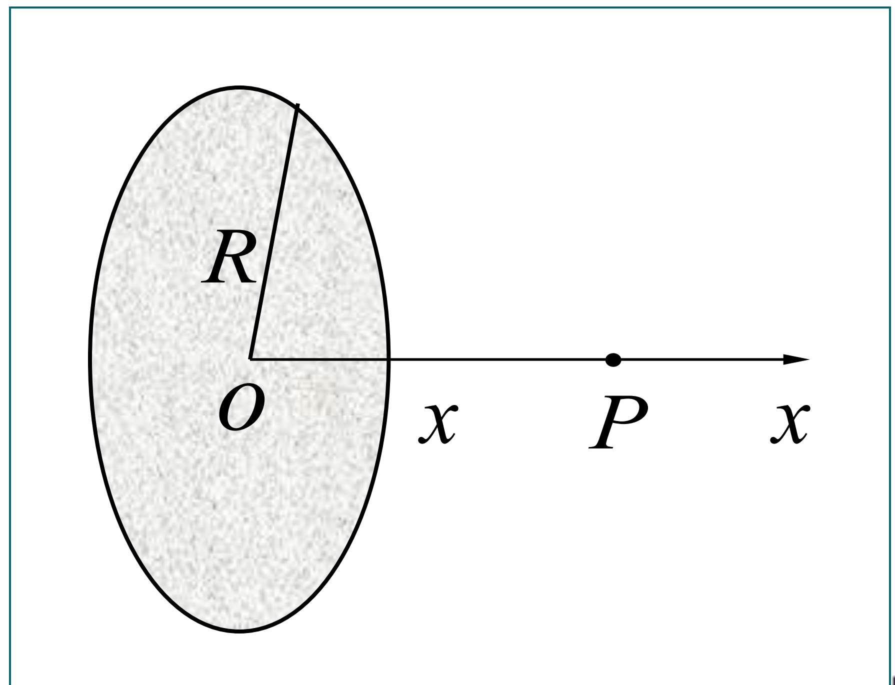
$$E = \frac{\sigma x}{2\varepsilon_0}\left(\frac{1}{\sqrt{x^2}} - \frac{1}{\sqrt{x^2+R^2}}\right)$$

$x << R$

$$E \approx \frac{\sigma}{2\varepsilon_0}$$

$x >> R$

$$E \approx \frac{q}{4\pi\varepsilon_0 x^2}$$



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