Name: Peter Muyang NI Class: AP Physics C ME/EM

姓名：倪沐阳 班级:AP 物理 C 力学/电磁

Want to hear your feedback:

nmypter@sohu.com

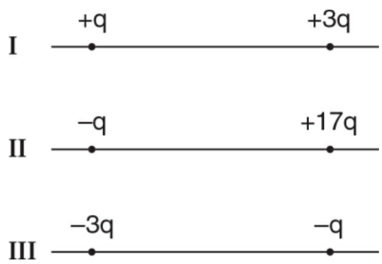
目录

Coulomb's Law 库伦定律

		点电荷	平板电容
库伦力$\vec{F}$		$F = \frac{k\lvert q_1 q_2\rvert}{r^2}$	
电场强度$\vec{E}$	$\vec{E} = \vec{F}/q_0 \ (N/C)$	$\vec{E} = \frac{kq}{r^2}\hat{r}$	
电势V	$dV = -\vec{E}\cdot d\vec{l}$	$V = \frac{kq}{r}$	$V = -Ex$
电势能U	$dU = -\vec{F}\cdot d\vec{l}$	$U_e = q_0 V$	$U = -Fx = q_0 V$

考点 1	● 电荷是分正负的，不同电荷的电场/电势。**Barron Ch11-2,3**

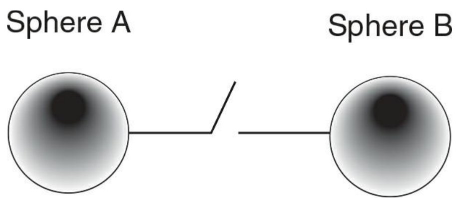
1. Which of the three charge distributions in the right figure has a point or points where the electric field is zero (not counting $\pm\infty$)?
   (A) I (B) II (C) III
   (D) I and II (E) I, II, and III



2. Which of the three distributions in figure above has a point or points where the potential is zero (excluding $\pm\infty$, but assuming that the potential equals zero at these latter points)?
   (A) I (B) II (C) III
   (D) I and II (E) I, II, and III

考点 2	● 电荷是可以流动的。**Barron Ch11-1**

Experiment I: A positively charged rod is brought near sphere A while the switch is closed, the switch is opened, and the rod is then removed.

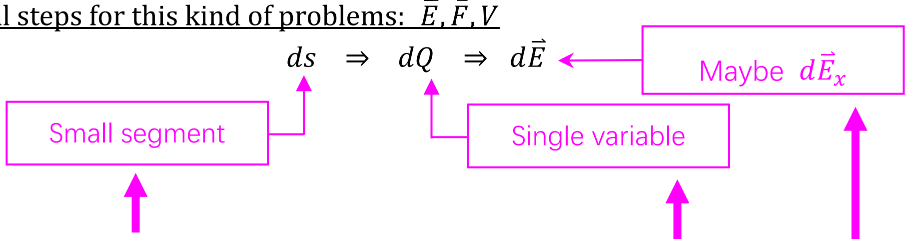


After experiment I
 sphere A is ________negatively charged ________positively charged
 sphere B is ________negatively charged ________positively charged

Experiment II: A positively charged rod is touched to sphere A while the switch is closed, the switch is opened, and the rod is then removed.
After experiment II
 sphere A is ________negatively charged ________positively charged
 sphere B is ________negatively charged ________positively charged

考点 1	1. 答案 E. 各种情况 E=0 的点：I 在两电荷之间，II 在-q 左边，III 在两电荷中间 2. 答案 B. 电势=0 的点在两电荷中间。
考点 2	I: sphere A negatively charged; sphere B positively charged II: sphere A positively charged; sphere B positively charged

General steps for this kind of problems: $\vec{E}, \vec{F}, V$



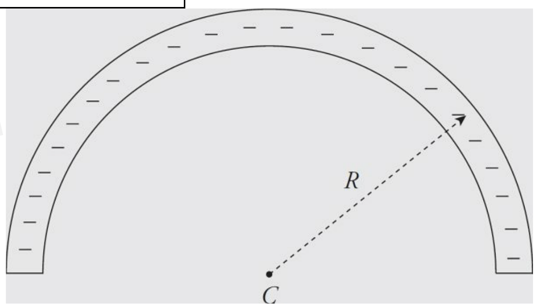
1D	
2D	$dA = 2\pi R dR$ area of a washer
3D	$dV = 4\pi R^2 dR$ volume of a spherical shell

1D	λ	$dQ = \lambda d(length)$
2D	σ	$dQ = \sigma d(area)$
3D	ρ	$dQ = \rho d(volume)$

$d\vec{F} = k\frac{qdQ}{r^2}\vec{r}$	$\begin{cases} d\vec{E}_x = d\vec{E}\cos\theta \\ d\vec{E}_y = d\vec{E}\sin\theta \end{cases}$
$d\vec{E} = \frac{kdQ}{r^2}\vec{r}$	
$dV = \frac{kdQ}{r}$	

考点:	● 注意三个步骤，尤其最后一步$d\vec{E}$可能是只计算$d\vec{E}_x$或者 $d\vec{E}_y$

Example: A thin, nonconducting rod that carries a uniform linear charge Q^- is bent into a semicircle of radius R. Find the electric field at the center of curvature of the semicircle.



Step 1: find ds

λ is the linear charge density:

$\lambda = Q/\pi R$

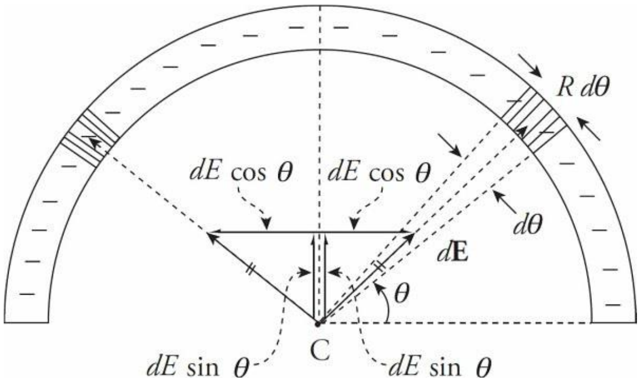
Divide the semicircle into infinitesimal segments ds,

$ds = Rd\theta$

Step 2: $dQ \Rightarrow$ single variable that you integrate with respect to.

The charge in a segment of length ds is dQ

$$dQ = \lambda ds = \frac{Q}{\pi R}Rd\theta = \frac{Q}{\pi}d\theta$$



Step 3: Find the differential function: $d\vec{E}$

As the ring is symmetry, the net field $\vec{E}$ at center of curvature is along the y-axis:

$$\vec{E} = E_y\vec{j}$$

The distance from the segment ds to the center is R:

$$dE_y = dE\sin\theta = \left(\frac{k}{R^2}dQ\right)\sin\theta = \left(\frac{k}{R^2}\frac{Q}{\pi}d\theta\right)\sin\theta$$

Please notice that only θ in the equation is a variable; other factors are all constants. (single variable)

$$E_y = \frac{kQ}{\pi R^2}\int_0^{\pi}\sin\theta\ d\theta = \frac{kQ}{\pi R^2}(-\cos\theta)_0^{\pi} = \frac{2kQ}{\pi R^2}$$

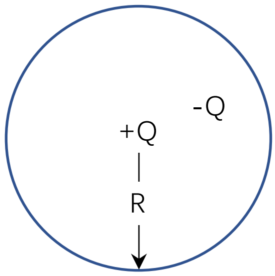
仅仅对E_y进行积分

$$\vec{E} = E_y\vec{j} = \frac{2kQ}{\pi R^2}\vec{j}$$

考点：

- 电荷均匀分布的球体：半径 r 外部的电荷对半径 r 表面电场无影响。

Example(AP-C HW-13-8): A negative charge -Q is distributed throughout the spherical volume of radius R shown by the equation ρ=kr, r<R. A positive point charge +Q is at the center of the sphere. Determine each of the following in terms of the quantities given and fundamental constants.



a. The constant k.

半径为r,厚度为 dr的空心球体积为$dV = 4\pi r^2 dr$,

所含电荷$dQ = \rho dV = (kr)(4\pi r^2 dr) = 4\mathrm{k}\pi r^3 dr$

$$\int_0^R 4k\pi r^3 dr = 4k\pi \frac{R^4}{4} = Q \Rightarrow k = Q/\pi R^4$$

b. The electric field E outside the sphere at a distance r>R from the center

当$\mathrm{r} > \mathrm{R}$时$+Q$产生的电场$\vec{E}_+ = \frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$

当$\mathrm{r} > \mathrm{R}$时$-Q$产生的电场$\vec{E}_- = \frac{-Q}{4\pi\varepsilon_0 r^2}\hat{r}$

当$\mathrm{r} > \mathrm{R}$时$+Q$和$-Q$的电场抵消$\sum \vec{E} = 0$

c. The electric potential V outside the sphere at a distance r>R from the center

当$\mathrm{r} > \mathrm{R}$时$+Q$产生的势能$V_+ = \frac{Q}{4\pi\varepsilon_0 r}$

当$\mathrm{r} > \mathrm{R}$时-Q产生的势能$V_+ = \frac{-Q}{4\pi\varepsilon_0 r}$

当$\mathrm{r} > \mathrm{R}$时$+Q$和$-Q$的势能抵消$\sum V = 0$

d. The electric field E inside the sphere at a distance r<R from the center

当$\mathrm{r} < \mathrm{R}$时$+Q$产生的电场 $\vec{E}_+ = \frac{Q}{4\pi\varepsilon_0 r^2}\hat{r}$

当$\mathrm{r} < \mathrm{R}$时$-Q$的电荷 $dQ = 4\mathrm{k}r^3 dr = 4\frac{Q}{R^4}r^3 dr$

$$\Rightarrow Q_- = \int_0^r 4\frac{Q}{R^4}r^3 dr = 4\frac{Q}{R^4}\left(\frac{r^4}{4}\right) = \frac{r^4}{R^4}Q$$

$$\vec{E}_- = \frac{-Q}{4\pi\varepsilon_0 r^2}\left(\frac{r^4}{R^4}\right)\hat{r}$$

$$\sum \vec{E} = \vec{E}_+ + \vec{E}_- = \frac{Q}{4\pi\varepsilon_0 r^2}\hat{r} - \frac{Q}{4\pi\varepsilon_0 r^2}\left(\frac{r^4}{R^4}\right)\hat{r}$$

$$= \frac{Q}{4\pi\varepsilon_0 r^2}\left(\frac{R^4 - r^4}{R^4}\right)\hat{r}$$

e. The electric potential V inside the sphere at a distance r<R from the center

当$\mathrm{r} < \mathrm{R}$时$+Q$产生的势能$V_+ = \frac{Q}{4\pi\varepsilon_0 r}$

当$\mathrm{r} < \mathrm{R}$时$-Q$的势能$V_- = \frac{-Q}{4\pi\varepsilon_0 r}\frac{r^4}{R^4}$

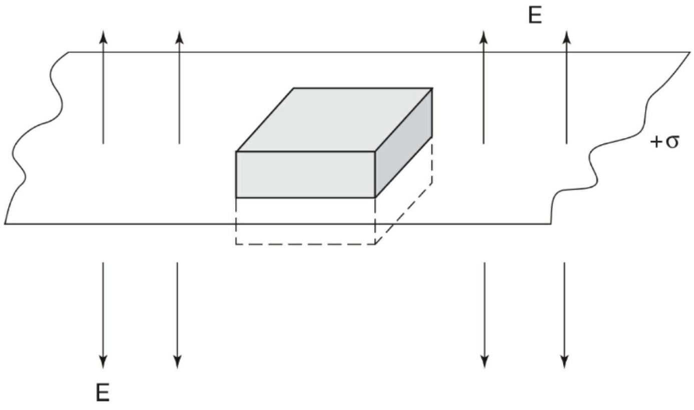
$$\sum V = V_+ + V_- = \frac{Q}{4\pi\varepsilon_0 r} - \frac{Q}{4\pi\varepsilon_0 r}\frac{r^4}{R^4}$$

$$= \frac{Q}{4\pi\varepsilon_0 r}\frac{R^4 - r^4}{R^4}$$

Gauss's Law 高斯定律

Gauss's Law	电通量: Φ_{net}	$\Phi_{net} = \oint_s \vec{E}\cdot\vec{n}dA = \oint_s E_n dA$
	当Φ均匀分布时	$\Phi_{net} = E_n A = \frac{Q_{in}}{\varepsilon_0}$
考点：	● 通量的概念：垂直于某个表面的量称为通量 ⇒ 电通量定义 ● 均匀电场 ⇒ 高斯面上电通量均匀 ⇒ 高斯定律算通量或电场 ● Φ_{net}：穿过高斯表面的净 *flux* ⇒ 和此表面上的电荷注意区分 Q_{in}：高斯面里面的净 *charge*	

Example: (Barron P420)Calculate the electric field produced by an infinitely large sheet of charge with uniform charge density +σ C/m².



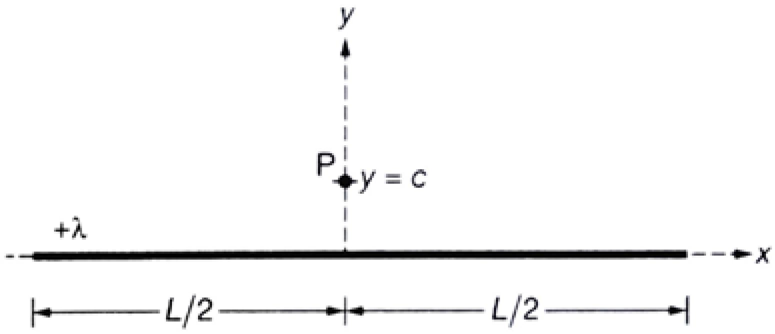
上下各一个 Gaussian surface: $A = x \times y$，总面积 $2A$

The enclosed charge: $Q_{in} = \sigma A$

Gauss's Law: (当Φ均匀分布时) $\Phi_{net} = E_n A = \frac{Q_{in}}{\varepsilon_0}$

$$E_n(2A) = \frac{\sigma A}{\varepsilon_0} \Rightarrow E_n = \frac{\sigma}{2\varepsilon_0}$$

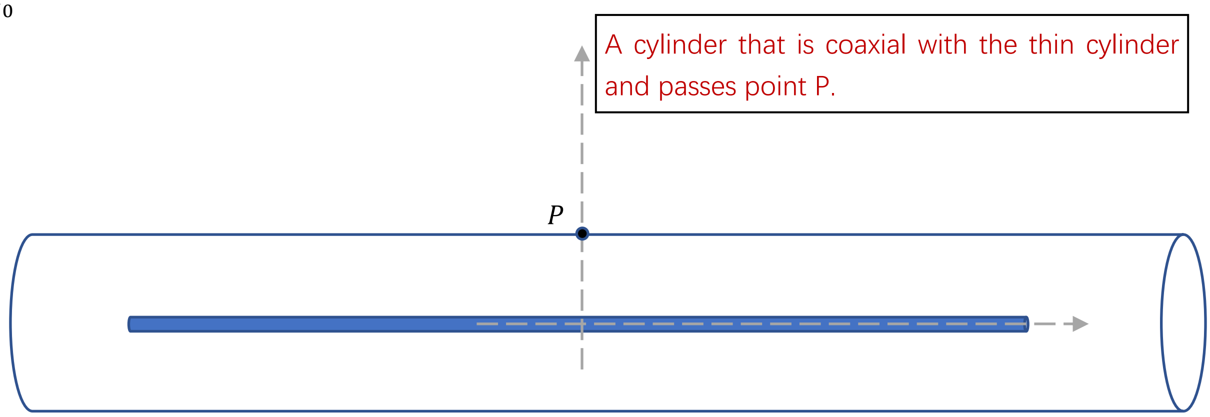
Example: (APC HW13-9) A very long, thing, nonconducting cylinder of length L is centered on the y-axis, as shown. The cylinder has a uniform linear charge density +λ. Point P is located on the y-axis at y=c, where L>>c.
Setup a Gaussian surface and use it to calculate the magnitude of the electric field at point P in terms of λ, c, L and physical constants.



Gauss's law: $\frac{q_{inside}}{\epsilon_0} = \int EdA \Rightarrow \frac{Q}{\epsilon_0} = EA$

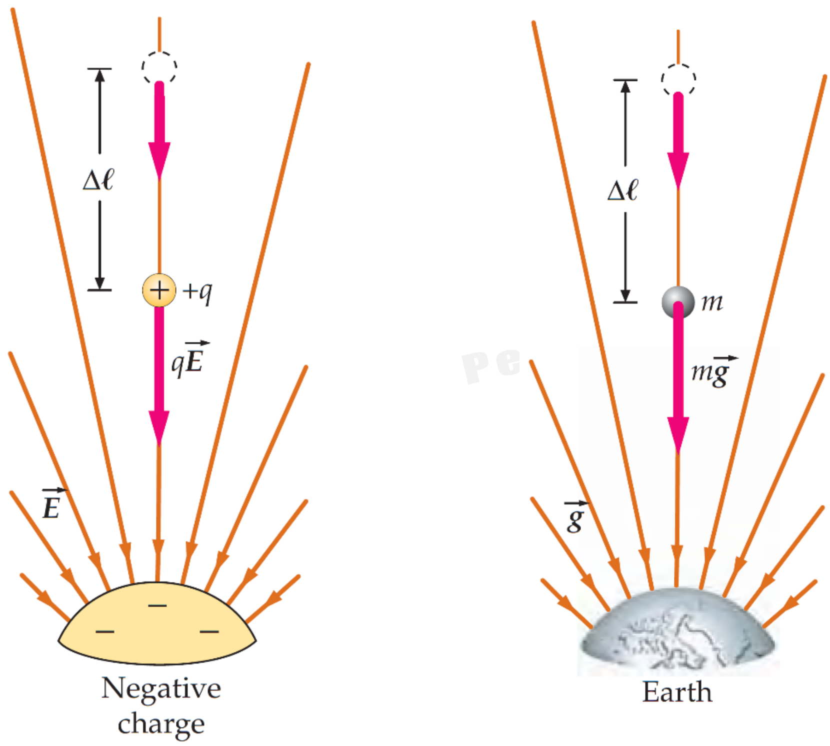
$$\left.\begin{aligned} A &\approx (2\pi c)L \\ Q &= \lambda L \end{aligned}\right\} \Rightarrow \frac{\lambda L}{\epsilon_0} = E(2\pi cL)$$

$$\Rightarrow E = \frac{\lambda}{2\pi c\epsilon_0}$$



Potential and Electric Field 电场和重力场(p765)

Charge q	mass m
Coulomb's Law $F = \frac{k\lvert q_1 q_2 \rvert}{r^2}$ $k = 8.99 \times 10^9\ N \cdot m^2/C^2$	The Universal Gravitation $F_g = \frac{G m_1 m_2}{r^2}$ $G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$
Electric Field $\vec{F} = q\vec{E}$ $E = \frac{kQ}{r^2}$	Gravitational Field $\vec{F} = m\vec{g}$ $g = \frac{GM_e}{r^2}$
Electric Potential Energy $U_e = VQ$	Gravitational Potential Energy $U_m = \text{mgh}$
Potential Difference $V = \frac{U_e}{q} = -\vec{E} \cdot \vec{l}$	Height Difference $h = \frac{U_m}{mg}$



Capacitance 电容

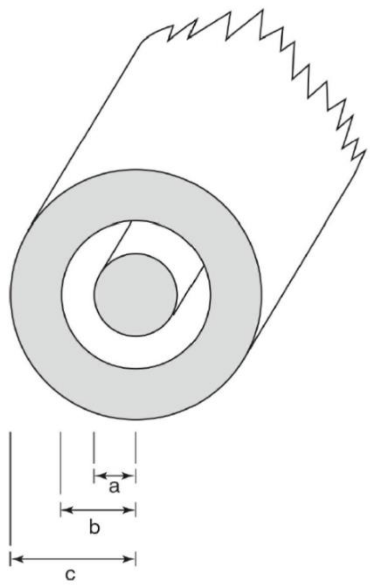
- Capacitance: $C = Q/V$
  Isolated spherical conductor $C = 4\pi\varepsilon_0 R$
  Parallel-plate capacitor $C = \varepsilon_0 A/d$
- Energy in Capacitors: $dU = VdQ = QdQ/C \Rightarrow U = \int \frac{Q}{C} dQ = \frac{Q^2}{2C}$

  $U = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2$
- Dielectrics: $C = kC_0 \quad \varepsilon = k\varepsilon_0$
  $\varepsilon_0 = 8.85 \times 10^{-12}\ F/m$
- Equivalent Capacitance:
  Parallel capacitors $C_{eq} = C_1 + C_2 + C_3 + \cdots$
  Series capacitors $1/C_{eq} = 1/C_1 + 1/C_2 + 1/C_3 + \cdots$

Calculating Capacitance Based on Geometry: $C = Q/\Delta V$

- 计算 E $\Leftarrow$ 当Φ均匀分布时 $\Phi_{net} = EA$
- 计算ΔV $\Leftarrow$ $dV = -\vec{E} \cdot d\vec{l}$
- 计算 C $\Leftarrow$ $C = Q/\Delta V$

Example: Consider the coaxial cable in the right figure, which contains a central cylindrical core of metal (radius a) surrounded by a cylindrical sheath of metal (inner radius b, outer radius c). Charge is moved from the sheath to the inner cylinder, so that charge density is then λ coulombs/length along the inner cylinder and −λ along the sheath.
What is the capacitance of a coaxial cable of length l (ignore edge effects, as in our treatment of a parallel plate capacitor).



Step 1: 计算 E

在 a<r<b 的位置，设置同轴高斯面

$$\Phi_{net} = \oint_s E_n dA \overset{E\perp A}{\Longrightarrow} \Phi_{net} = EA$$

$$\Phi_{net} = E(2\pi r \cdot l) = \frac{Q_{in}}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi r\varepsilon_0}$$

Step 2: 计算ΔV

$$V_b - V_a = \int_a^b dV = -\int_a^b Edr = -\int_a^b \frac{\lambda}{2\pi r\varepsilon_0} dr = \frac{\lambda}{2\pi\varepsilon_0} \ln\frac{a}{b}$$

Step 3: C=Q/ΔV

$$\mathrm{C} = \frac{\mathrm{Q}}{\Delta\mathrm{V}} = \frac{\lambda l}{|V_b - V_a|} = \frac{2\pi\varepsilon_0 l}{\ln\frac{a}{b}}$$