General Physics (II) 期中考 I Apr. 10, 2020

試卷請註明、姓名、班級、學號，請遵守考場秩序

I.計算題(50 points) (所有題目必須有計算過程,否則不予計分)

1&2. (20pts) 3 line charge distributions on *x-axis, y-axis, and x-z* plane are shown in Fig. 1. The charge densities are $-\lambda_0$, $\lambda_0(\boldsymbol{x/a})$, and $\lambda_0 \cos\theta$ for the charges on lines ***AO*** and ***DO*** and arc ***BC,*** respectively, where θ is the angle relative to +z-axis, and λ_0 is constant. Find the electric field (***x*-, *y*-,** and ***z***-components) at point ***P*** on the *y*-axis due to (a) (6pts) line charge ***AO***, (b) (7pts) line charge ***DO***, and (c) (7pts) line charge ***BC***. The coordinates of ***O, A, B, C, D,*** and ***P*** are *(0,0,0)*, *(0,-2a,0)*, *(0,0,a)*, *(a,0,0)*, *(2a,0,0)*, and *(0,b,0)*, respectively.

3. (a) (5pts) As shown in Fig. 2(a), an infinitely long uniform cylindrical (圓柱形) charge distribution with axis coincide with the z-axis, the charge density is ρ ($\rho > 0$). Determine the direction and the magnitude of the E-field at point ***P*** at (*R/2,R/2,R/2*).
(b) (10 pts) Now a spherical(球形) portion of radius ***R*** of the charge centered at (*R*,0,0) is removed, as shown in Fig. 2(b), determine the direction and the magnitude of the E-field on the x-axis between (0,0,0) and (4R,0,0).

(If you apply Gauss's law to solve this problem, show your Gaussian surfaces for the calculation).

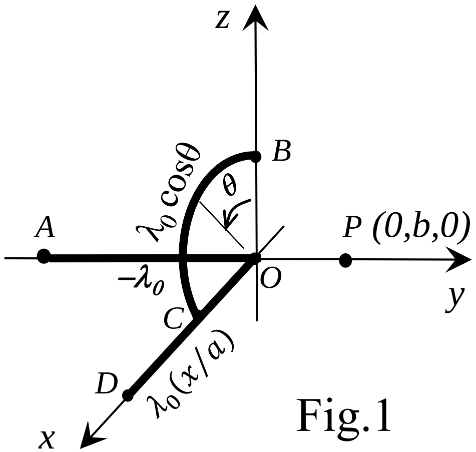


Fig.1

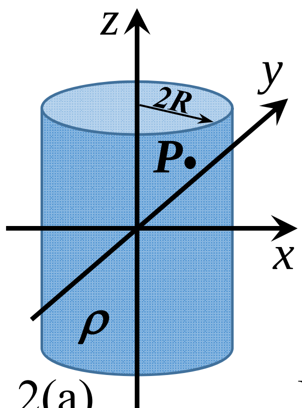


Fig. 2(a)

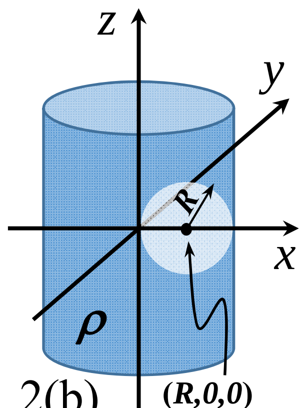


Fig. 2(b)

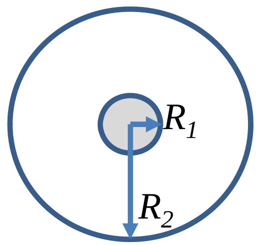


Fig.3(a)

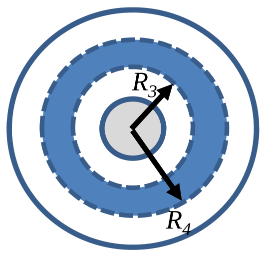


Fig.3(b)

4. (a) (7 pts) Consider a capacitor made of two concentric metal spherical shells with radii $\boldsymbol{R_1}$ and $\boldsymbol{R_2}$ respectively, as shown in Fig. 3(a). The inner shell has total charge **+Q**, the outer shell –**Q**. Determine the electric field $\vec{E}(r)$ for $R_1 < r < R_2$ and the electric potential difference between the two shells? And what is the capacitance of this system?

(b) (8 pts) Now a spherical metallic shell is inserted into this system with inner radius R_3 and outer radius R_4 , as shown in dashed circles in the Fig. 3(b). What are the total charges on the inner and outer metallic shell of radius R_3 and R_4, respectively? What is the capacitance for this new structure?

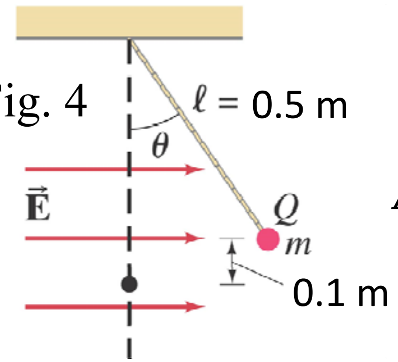
II.選擇題(50 points)

1.(5pts) A point charge with mass of 0.001 kg at the end of an insulating cord of length 0.5 m is observed to be in equilibrium in a uniform horizontal electric field of 15,000 N/C, when the pendulum's position is shown in Fig. 4, with the charge 0.1 m above the lowest position. If the field points to the right, determine the magnitude and sign of the point charge Q with the unit in μC. (A) Q≦-0.4; (B) -0.4<Q≦-0.3; (C) -0.3<Q≦-0.2; (D) -0.2<Q≦-0.1; (E) -0.1<Q≦0.1; (F) 0.1<Q≦0.2; (G) 0.2<Q≦0.3 (H) 0.3<Q≦0.4; (J) 0.4<Q≦0.5; (K) 0.5<Q.

2.(5pts) Two conducting spheres initially have a charge +Q uniformly distributed on each of their surfaces. The radius of sphere A is twice of the radius of sphere B. The two spheres are far away from each other. Now both of them is connected by a conducting wire, After the charge distribution reaches equilibrium, assume the charge on the sphere A is *x**Q. What is *x*?

(A) 1/3 (B) 1/2 (C) 2/3 (D) 1 (E) 4/3 (F) 3/2 (G) 2

Fig. 4



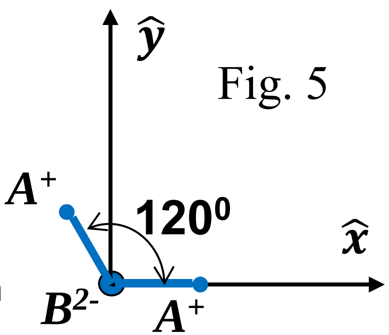


Fig. 5

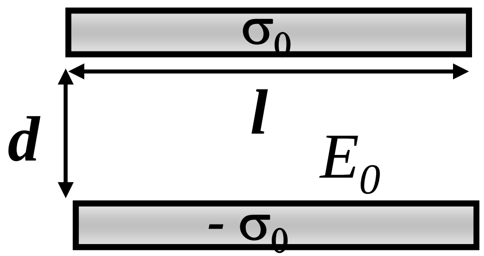


Fig. 6(a)

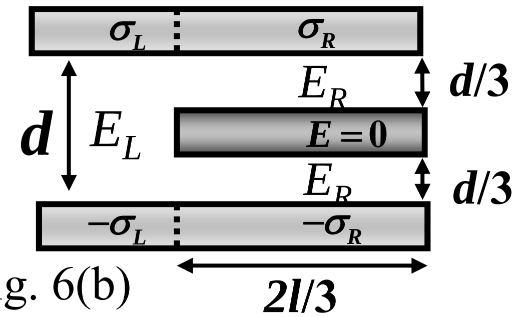


Fig. 6(b)

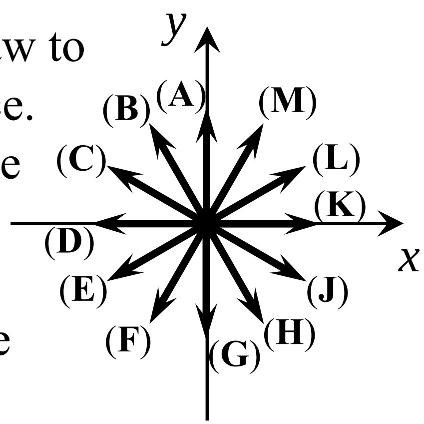
3. (5pts) Consider a polar molecule $\boldsymbol{A_2B}$ each $\boldsymbol{A}$ atom prefers to lose one $\boldsymbol{e}$ becomes $\boldsymbol{A^+}$ and $\boldsymbol{B}$ atom gains $2\boldsymbol{e}$ becomes $\boldsymbol{B^{2-}}$ (Fig. 5). The bond length is $\boldsymbol{a}$**.** This molecule has non-zero electric dipole moment. Now it is placed in a uniform electric field $\vec{\boldsymbol{E}} = \boldsymbol{E_0\hat{y}}$**.** The magnitude of the torque of this molecule is $\boldsymbol{x(eaE_0)}$ right after the electric field is turned on and the electric potential energy loss (decreases) is $\boldsymbol{y(eaE_0)}$ when the molecule is aligned with the electric field. What is **(*x*, *y*)?** (assume the initial positions of the molecule and the orientation of the electric field is shown as in Fig. 5)

(A) $\left(\frac{\sqrt{3}}{4}, \frac{\sqrt{3}}{2}\right)$ **(B)** $\left(\frac{\sqrt{3}}{4}, \frac{1}{2}\right)$ **(C)** $\left(\frac{\sqrt{3}}{4}, 1-\frac{\sqrt{3}}{2}\right)$ **(D)** $\left(\frac{1}{4}, \frac{\sqrt{3}}{2}\right)$ **(E)** $\left(\frac{1}{4}, \frac{1}{2}\right)$ **(F)** $\left(\frac{1}{4}, 1-\frac{\sqrt{3}}{2}\right)$
(G) $\left(\frac{\sqrt{3}}{2}, \frac{\sqrt{3}}{2}\right)$ **(*H*)** $\left(\frac{\sqrt{3}}{2}, \frac{1}{2}\right)$ **(J)** $\left(\frac{\sqrt{3}}{2}, 1-\frac{\sqrt{3}}{2}\right)$ **(K)** $\left(\frac{1}{2}, \frac{\sqrt{3}}{2}\right)$ **(L)** $\left(\frac{1}{2}, \frac{1}{2}\right)$ **(M)** $\left(\frac{1}{2}, 1-\frac{\sqrt{3}}{2}\right)$ **(N) None of above**

4. (5pts) Symmetry of a charge distribution is the key for applying Gauss's law to calculate the E-field distribution resulted from a charge distribution in space. Assume that there is a charged distribution $\rho(x, y, z)$ in space, which can be expressed with the flowing function

$$\rho(x, y, z) = -\frac{2}{(y+1)^2+2},$$

Which of the direction on the right shows the direction of the E-field at the origin?



5. (5 pts) A capacitor, containing two flat square metal plates with area $\boldsymbol{A}$ **(=** $\boldsymbol{l^2}$**)** and a separation $\boldsymbol{d}$ **(*d* << *l*).** This capacitor is charged to store charge $\boldsymbol{Q}$ **(=** $\boldsymbol{\sigma_0 A}$**)** with a battery, then the battery is removed (Fig. 6(a)). The potential difference and electric field in the capacitor are $\boldsymbol{V_0}$ and $\boldsymbol{E_0}$**.** Now an uncharged conducting plate with thickness ***d*/3** places into the capacitor to a depth ***2l/3***, maintaining the same spacing ***d*/3** between the two metal plates of the capacitor (Fig. 6(b)). The potential difference becomes $\boldsymbol{xV_0}$ and the electric fields are $\boldsymbol{E_L = yE_0}$ and $\boldsymbol{E_R = zE_0}$**.** What is true in the following answers? You may neglect edge effects.

(A) $\boldsymbol{x > 1,\ y > 1}$ **(B)** $\boldsymbol{x > 1,\ y = 1}$ **(C)** $\boldsymbol{x > 1,\ y < 1}$ **(D)** $\boldsymbol{x = 1,\ y > 1}$ **(E)** $\boldsymbol{x = y = 1,}$
(F) $\boldsymbol{x = 1,\ y < 1}$ **(G)** $\boldsymbol{x < 1,\ y > 1}$ **(H)** $\boldsymbol{x < 1,\ y = 1}$ **(J)** $\boldsymbol{x < 1,\ y < 1}$

6. (5pts) Same structure and procedures as in **problem 5,** but now the battery is connected to the capacitor all the time. Which of the following is correct?

(A) $y > 1,\ z > 1$ **(B)** $y > 1,\ z = 1$ **(C)** $y > 1,\ z < 1$ **(D)** $y = 1,\ z > 1$ **(E)** $y = z = 1$, **(F)** $y = 1,\ z < 1$ **(G)** $y < 1,\ z > 1$ **(H)** $y < 1,\ z = 1$ **(J)** $y < 1,\ z < 1$

Integration Formula for reference

$$\int \frac{dx}{\sqrt{x^2 \pm b^2}} = \ln\left(x + \sqrt{x^2 \pm b^2}\right) \qquad \int \frac{x^2 dx}{\sqrt{x^2 \pm b^2}} = \frac{x\sqrt{x^2 \pm b^2}}{2} - \frac{b^2}{2}\ln\left(x + \sqrt{x^2 \pm b^2}\right)$$

$$\int \frac{dx}{\left(x^2 \pm b^2\right)^{3/2}} = \frac{\pm x}{b^2\sqrt{x^2 \pm b^2}} \qquad \int \frac{x^2 dx}{\left(x^2 \pm b^2\right)^{3/2}} = \frac{-x}{\sqrt{x^2 \pm b^2}} + \ln\left(x + \sqrt{x^2 \pm b^2}\right)$$

1	2	3	4	5	6	7	8	9	10
J	E	M	G	J	D	M	B	C	B
11	12	13	14	15	16				
D	H	F	F	B	A				

1&2. 3 line charge distributions on *x-axis*, *y-axis*, and x-z plane are shown in Fig. 1. The charge densities are $-\lambda_0$, $\lambda_0(x/a)$, and $\lambda_0\cos\theta$ for the charges on lines ***AO*** and ***DO*** and arc ***BC,*** where θ is the angle relative to +z-axis, and λ_0 is constant. Find the electric field (***x-***, ***y-***, and ***z***-components) at point ***P*** on the *y*-axis due to (a) (6pts) line charge ***AO***, (b) (7pts) line charge ***DO***, and (c) (7pts) line charge ***BC***. The coordinates of ***O, A, B, C, D,*** and ***P*** are *(0,0,0)*, *(0,-2a,0)*, *(0,0,a)*, *(a,0,0)*, *(2a,0,0)*, and *(0,b,0)*, respectively.

(a) line charge ***AO***, $\vec{r}\,' = (0, y, 0)$, $\vec{r}_p = (0, b, 0)$

$\vec{r} = \vec{r}_p - \vec{r}\,' = (0, b - y', 0)$ 1 $\quad d\vec{E} = \dfrac{k(-\lambda_0 dy')(0, b - y', 0)}{|b - y'|^3}$ 1

$E_y = -k\lambda_0 \displaystyle\int_{-2a}^{0} \frac{dy'}{|b - y'|^2} = \frac{-k\lambda_0(2a)}{b(b+2a)}$ 2 $\quad E_x = E_z = 0;$ 2

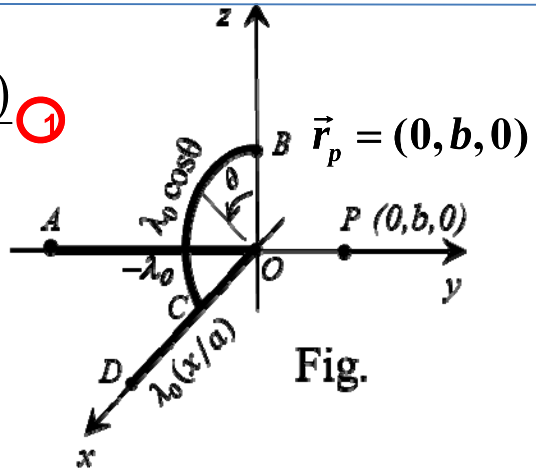


Fig.

(b) line charge ***DO***, $\vec{r}\,' = (x', 0, 0)$, $\vec{r} = \vec{r}_p - \vec{r}\,' = (-x', b, 0)$ 1

$$d\vec{E} = \frac{k\left(\lambda_0 \dfrac{x'}{a} dx'\right)(-x', b, 0)}{\left(b^2 + x'^2\right)^{3/2}}$$ 1

$$E_x = \frac{-k\lambda_0}{a} \int_0^{2a} \frac{x'^2\, dx'}{\left(b^2 + x'^2\right)^{3/2}}$$

$$\boxed{\int \frac{x^2 dx}{\left(x^2 \pm b^2\right)^{3/2}} = \frac{-x}{\sqrt{x^2 \pm b^2}} + \ln\left(x + \sqrt{x^2 \pm b^2}\right)}$$

$$= \frac{-k\lambda_0}{a}\left[\frac{-2a}{\sqrt{4a^2 + b^2}} + \ln\left(\frac{2a + \sqrt{4a^2 + b^2}}{b}\right)\right]$$ 2

$$E_y = \frac{k\lambda_0 b}{a} \int_0^{2a} \frac{x'dx'}{\left(b^2 + x'^2\right)^{3/2}} = \frac{k\lambda_0 b}{a}\left[\frac{1}{b} - \frac{1}{\sqrt{b^2 + 4a^2}}\right]$$ 2

$E_z = 0;$ 1

(c) line charge ***BC***, $\vec{r}\,' = (a\sin\theta, 0, a\cos\theta)$,

$\vec{r} = \vec{r}_p - \vec{r}\,' = (-a\sin\theta, b, -a\cos\theta)$ 1

$$d\vec{E} = \frac{k(\lambda_0 \cos\theta a d\theta)(-a\sin\theta, b, -a\cos\theta)}{\left(b^2 + a^2\right)^{3/2}}$$ 1

$$E_x = \frac{-k\lambda_0 a^2}{\left(b^2 + a^2\right)^{3/2}} \int_0^{\pi/2} \cos\theta \sin\theta d\theta = \frac{-k\lambda_0 a^2}{2\left(b^2 + a^2\right)^{3/2}}$$ 2

$$E_y = \frac{k\lambda_0 ab}{\left(b^2 + a^2\right)^{3/2}} \int_0^{\pi/2} \cos\theta d\theta = \frac{k\lambda_0 ab}{\left(b^2 + a^2\right)^{3/2}}$$ 1

$$E_z = \frac{-k\lambda_0 a^2}{\left(b^2 + a^2\right)^{3/2}} \int_0^{\pi/2} \cos^2\theta d\theta = \frac{-\pi k\lambda_0 a^2}{4\left(b^2 + a^2\right)^{3/2}}$$ 2

3. (a) (5pts) As shown in Fig. 2(a), an infinitely long uniform cylindrical (圓柱形) charge distribution with axis coincide with the z-axis, the charge density is ρ ($\rho > 0$). Determine the direction and the magnitude of the E-field at point **P** at (*R/2*,*R/2*,*R/2*).

(b) (10 pts) Now a spherical(球形) portion of radius ***R*** of the charge centered at (*R*,0,0) is removed, as shown in Fig. 2(b), determine the direction and the magnitude of the E-field on the x-axis between (0,0,0) and (4R,0,0).

(If you apply Gauss's law to solve this problem, show your Gaussian surfaces for the calculation).

(a) Select a cylindrical Gaussian surface *C1* of length ℓ, radius r that passes *P*, and we apply Gauss's Law:

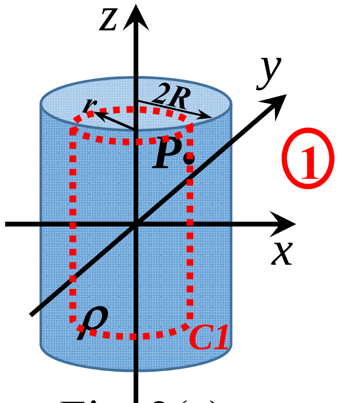


Fig. 2(a)

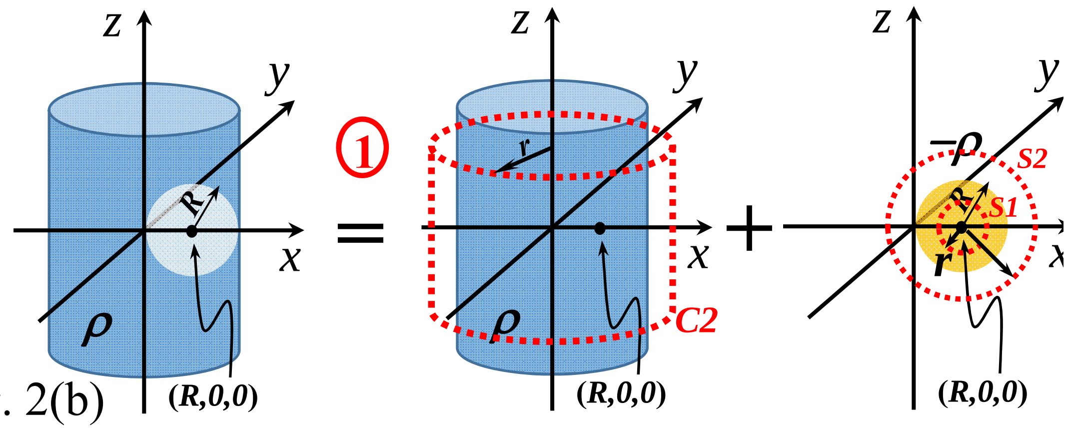


Fig. 2(b)

$$\Phi_E = \iint_{C1} \vec{E}_C \cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0},$$

$$\vec{E}_C(r) = E_C(r)\hat{r},\ d\vec{A} = dA\cdot\hat{r},$$

$$\Rightarrow \Phi_E = \iint_{C1} \vec{E}_C \cdot d\vec{A} = 2\pi r\ell E(r)$$ ①

$$Q_{in} = \rho\pi r^2\ell$$ ①

$$\Rightarrow 2\pi r\ell E_C(r) = \frac{\rho\pi r^2\ell}{\varepsilon_0}$$

$$\Rightarrow E_C(r) = \frac{\rho r}{2\varepsilon_0},\ \vec{E}_C(r) = \frac{\rho\vec{r}}{2\varepsilon_0}$$ ①

For P(R/2,R/2,R/2),

$$\vec{r} = (\frac{R}{2},\frac{R}{2},0)$$

$$\Rightarrow \vec{E}_C(r) = \frac{\rho}{2\varepsilon_0}(\frac{R}{2},\frac{R}{2},0)$$

$$\Rightarrow \vec{E}_C(r) = \frac{R\rho}{4\varepsilon_0}(1,1,0)$$ ①

(b) The charged distribution is equivalent to a uniform infinitely long cylindrical charge distribution of charge density ρ and a uniform spherical charge distribution of density -ρ.

For 0<r≤R, We select a spherical Gaussian surface *S1* concentric with the spherical charge distribution, and apply the Gauss's Law:

$$\Phi_E = \iint_{S1} \vec{E}_S \cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0},$$

$$\vec{E}_S(r) = E_S(r)\hat{r},\ d\vec{A} = dA \cdot \hat{r},$$

$$\Rightarrow \Phi_E = \iint_{S1} \vec{E}_S \cdot d\vec{A} = 4\pi r^2 E(r)$$

$$Q_{in} = -\frac{4\pi r^3 \rho}{3}$$

$$\Rightarrow 4\pi r^2 E_S(r) = -\frac{4\pi r^3 \rho}{3\varepsilon_0}$$

①

$$\Rightarrow E_S(r) = -\frac{\rho r}{3\varepsilon_0},\ \vec{E}_S(r) = -\frac{\rho \vec{r}}{3\varepsilon_0},$$

$$\vec{r} = (x-R, 0, 0)$$

$$\Rightarrow \vec{E}_S(r) = -\frac{\rho(x-R)}{3\varepsilon_0}\hat{i}$$ ①

For the cylindrical charge distribution,

$$\vec{r} = (x,0,0) \Rightarrow \vec{E}_C(r) = \frac{\rho x}{2\varepsilon_0}\hat{i}$$

$$\vec{E}_T = \vec{E}_C + \vec{E}_S$$

$$= \frac{\rho x}{2\varepsilon_0}\hat{i} - \frac{\rho(x-R)}{3\varepsilon_0}\hat{i}$$

$$= \frac{\rho(x+2R)}{6\varepsilon_0}\hat{i}$$ ①

For R<r≤2R,

$$\vec{E}_S(r) = -\frac{\rho \vec{r}}{3\varepsilon_0},\ \vec{r} = (x-R, 0, 0)$$

$$\Rightarrow \vec{E}_S(r) = -\frac{\rho(x-R)}{3\varepsilon_0}\hat{i}$$

$$\vec{E}_C(r) = \frac{\rho x}{2\varepsilon_0}\hat{i},\quad \vec{r} = (x,0,0)$$

$$\vec{E}_T = \vec{E}_C + \vec{E}_S = \frac{\rho(x+2R)}{6\varepsilon_0}\hat{i}$$ ①

For 2R<r,

For the cylindrical charge distribution, we select a cylindrical Gaussian surface *C2* of radius r and length ℓ, and apply Gauss's Law:

$$\Phi_E = \iint_{C2} \vec{E}_C \cdot d\vec{A} = 2\pi r \ell E_C(r)$$

$$Q_{in} = \rho \pi 4R^2 \ell$$

$$\Rightarrow 2\pi r \ell E_C(r) = \frac{\rho \pi 4 R^2 \ell}{\varepsilon_0}$$

$$\Rightarrow \vec{E}_C(r) = \frac{2\rho R^2}{\varepsilon_0 r}\hat{r}$$ ①

$$\vec{r} = (x,0,0)$$

$$\Rightarrow E_C(r) = \frac{2\rho R^2}{\varepsilon_0 x}\hat{i}$$ ①

For the spherical charge distribution, we Gaussian surface *S2* concentric with the spherical charge distribution, and apply the Gauss's Law:

$$\Phi_E = \iint_{S2} \vec{E}_S \cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0},$$

$$\Phi_E = \iint_{S2} \vec{E}_S \cdot d\vec{A} = 4\pi r^2 E(r)$$

$$Q_{in} = -\frac{4\pi R^3 \rho}{3}$$

$$\Rightarrow 4\pi r^2 E_S(r) = -\frac{4\pi R^3 \rho}{3\varepsilon_0}$$

$$\Rightarrow E_S(r) = -\frac{\rho R^3}{3\varepsilon_0 r^2},$$ ①

$$\vec{E}_S(r) = -\frac{\rho R^3}{3\varepsilon_0 r^2}\hat{r},$$

$$\vec{r} = (x-R, 0, 0)$$

$$\Rightarrow \vec{E}_S(r) = -\frac{\rho R^3}{3\varepsilon_0 (x-R)^2}\hat{i}$$ ①

$$\vec{E}_T = \vec{E}_C + \vec{E}_S$$

$$= \frac{2\rho R^2}{\varepsilon_0 x}\hat{i} - \frac{\rho R^3}{3\varepsilon_0 (x-R)^2}\hat{i}$$ ①

3. (a) (7pts) Consider a capacitor is made of two concentric metal spherical shells with radia $\boldsymbol{R_1}$ and $\boldsymbol{R_2}$ respectively, as shown in fig. 1a. The inner shell has total charge **+Q**, the outer shell –**Q**. What are the electric field and electric potential difference between the two shells? And what is the capacitance of this system?

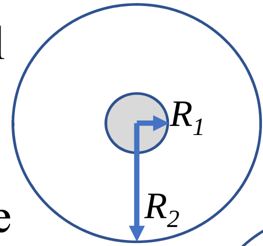


Fig.3a

(b) (8 pts) Now A spherical metallic tube is inserted into this system with radius R_3 and R_4 , as shown in dashed lines in the fig. 1b. First , what are the total charges on the inner and outer metallic shell of radius R_3 and R_4 respectively? What is the capacitance for this new structure?

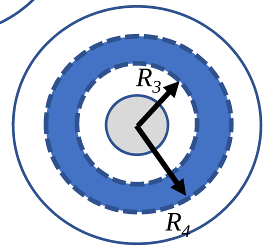


Fig.3b

(a) (i) By using the Gauss's law, calculate the electric field between the two spherical shell:

Choose the concentric spherical Gaussian surface (三維球殼) S_1:

$$\oint_S \vec{E}\cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0} \Rightarrow 4\pi r^2 E_r = \frac{Q}{\varepsilon_0} \Rightarrow \vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r}$$

1 1

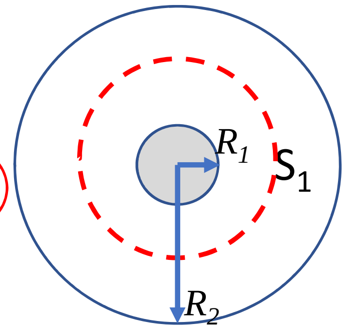


Fig.1a

Calculate the electric potential difference between the two spherical shells:

$$V(R_2) - V(R_1) = -\int \vec{E}\cdot d\vec{S} = -\int E(r)dr$$

1

$$= -\int \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}dr = -\frac{Q}{4\pi\varepsilon_0}\left(-\frac{1}{r}\right)\Bigg|_{R_1}^{R_2} = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{R_2} - \frac{1}{R_1}\right)$$

1

(ii) Calculate the capacitance by using the definition :

$$C = \frac{Q}{|\Delta V|} = \frac{4\pi\varepsilon_0}{\frac{1}{R_1} - \frac{1}{R_2}} = \frac{4\pi\varepsilon_0 R_1 R_2}{(R_2 - R_1)}$$

1 2

(b) (i) The charge in the inner shell at $r=R_3$ and on the outer shell at $r=R_4$:

Take spherical Gaussian surface S_1: $\oint_S \vec{E}\cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0} = 0$

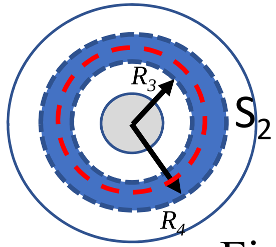


Fig.1b

Since there is no electric field inside the metal.

$\Rightarrow$ The charge $-Q$ in the inner shell at $r=R_3$, and then the charge $=Q$ on the outer shell at $r=R_4$. 2

(ii) Choose the concentric spherical Gaussian surface between $R_4 < r < R_2$: 1

$$\oint_S \vec{E}\cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0} \Rightarrow \vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r} \Rightarrow V(R_2) - V(R_4) = -\int \vec{E}\cdot d\vec{S} = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{R_2} - \frac{1}{R_4}\right)$$

Choose the concentric spherical Gaussian surface between $R_3 < r < R_4$:

$$\oint_S \vec{E}\cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0} = 0 \Rightarrow \vec{E} = 0 \Rightarrow V(R_4) - V(R_3) = 0$$ 1

Choose the concentric spherical Gaussian surface between $R_1 < r < R_3$:

$$\oint_S \vec{E}\cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0} = 0 \Rightarrow \vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r} \Rightarrow V(R_3) - V(R_1) = -\int \vec{E}\cdot d\vec{S} = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{R_3} - \frac{1}{R_1}\right)$$

1

$$\Delta V = V(R_2) - V(R_1) = \{V(R_2) - V(R_4)\} + \{V(R_4) - V(R_3)\} + \{V(R_3) - V(R_1)\}$$

$$= \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{R_2} - \frac{1}{R_4} + \frac{1}{R_3} - \frac{1}{R_1}\right)$$ 1

$$C = \frac{Q}{|\Delta V|} = \frac{4\pi\varepsilon_0}{\frac{1}{R_1} - \frac{1}{R_2} - \frac{1}{R_3} + \frac{1}{R_4}}$$ 2

（b）另一個解法: The charge in the inner shell at r=R_3 and on the outer shell at r=R_4:

Take spherical Gaussian surface S_1:

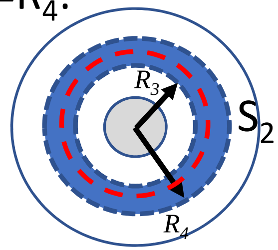
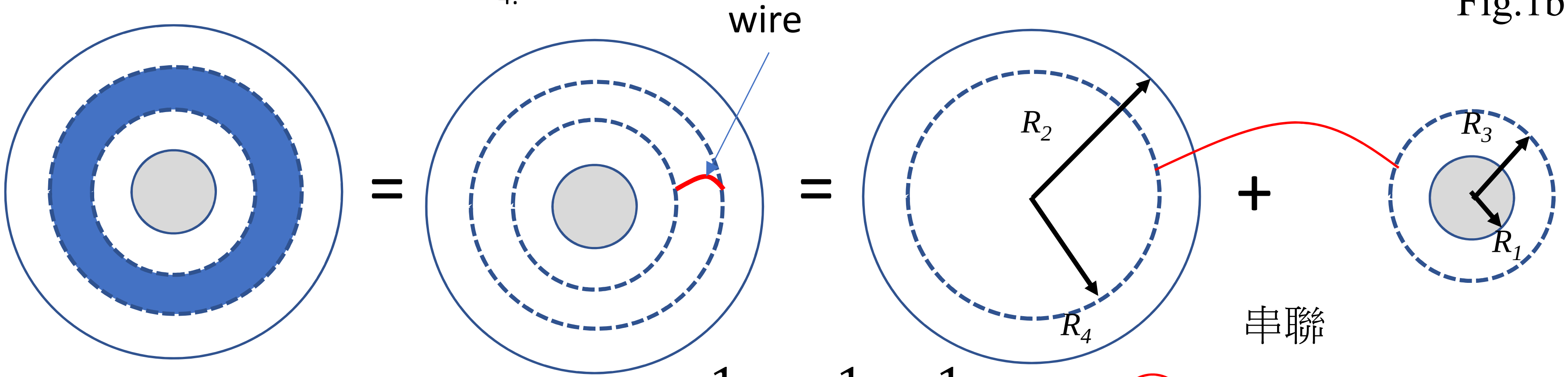


Fig.1b

Since there is no electric field inside the metal.

⇨ The charge –Q in the inner shell at r=R_3, and then the charge =Q on the outer shell at r=R_4. 2



$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$ 2

From the result in (a): $C_1 = \dfrac{4\pi\varepsilon_0}{\dfrac{1}{R_4} - \dfrac{1}{R_2}}$ 1 and $C_2 = \dfrac{4\pi\varepsilon_0}{\dfrac{1}{R_1} - \dfrac{1}{R_3}}$ 1

$$C = \frac{4\pi\varepsilon_0}{\dfrac{1}{R_1} - \dfrac{1}{R_2} - \dfrac{1}{R_3} + \dfrac{1}{R_4}}$$ 2