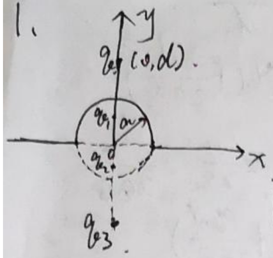
1、



$q_1=-\frac{a}{d}q_e$，位置为 $(0,\frac{a^2}{d})$.

$q_2=\frac{a}{d}q_e$，位置为 $(0,-\frac{a^2}{d})$.

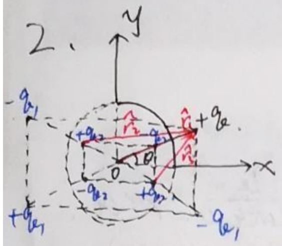
$q_3=-q_e$，位置为 $(0,-d)$.

$$\vec F=\frac{q_e}{4\pi\varepsilon_0}\left[\frac{-\frac{a}{d}q_e}{(d-\frac{a^2}{d})^2}+\frac{-q_e}{(2d)^2}+\frac{\frac{a}{d}q_e}{(d+\frac{a^2}{d})^2}\right]\vec{e_y}$$

$$=\frac{-q_e^2}{4\pi\varepsilon_0}\left[\frac{1}{4d^2}+\frac{4a^3d^3}{(d^4-a^4)^2}\right]\vec{e_y}.$$

(注：课本P353例8.3解答中图(b)的 q_2，q_3 标反了).

2、



$q_1=q_e$，距离原点为 d. $q_2=\frac{a}{d}q_e$，距离原点为 $\frac{a^2}{d}$.

$$\vec F=\frac{\frac{a}{d}q_e^2}{4\pi\varepsilon_0}\left(\frac{\hat r_2}{r_2^2}+\frac{\hat r_3}{r_3^2}\right)$$

$$+\frac{q_e^2}{4\pi\varepsilon_0}\left[\frac{-\frac{a}{d}}{(d-\frac{a^2}{d})^2}\hat r_1+\frac{1}{4d^2}\hat r_1+\frac{-\frac{a}{d}}{(d+\frac{a^2}{d})^2}\hat r_1\right]$$

$$\left[\frac{1}{4d^2}+\frac{-2ad}{(d^2-a^2)^2}\right]\hat r_1.$$

$$+\frac{-q_e^2}{4\pi\varepsilon_0}\frac{1}{4d^2\sin^2\theta}\vec{e_y}$$

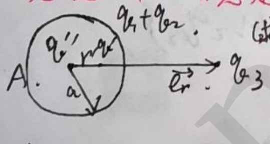
$$+\frac{-q_e^2}{4\pi\varepsilon_0}\frac{1}{4d^2\cos^2\theta}\vec{e_x}.$$

可继续把 $\hat r_1$，$\hat r_2$，$\hat r_3$ 分解成 $\{\vec{e_x},\vec{e_y}\}$ 的线性组合(巨麻烦……)，

也可一开始用极坐标表示(也很麻烦……).

3、(1) $\left\{\begin{array}{l}\text{静电屏蔽}\\ q_1,\ q_2\text{位于空腔正中心}\end{array}\right.\Longrightarrow \vec F_{q_1}=\vec F_{q_2}=0.$

(注：光有静电屏蔽是不够的，q_1，q_2 只有在空腔中心才受力为0，且该平衡态是一个不稳定平衡态).



(求 F_{q_3} 时)等效为A的外表面带电荷量为 q_1+q_2.

引入第一个像电荷 $q'=-\frac{a}{r}q_3$，$r'=\frac{a^2}{r}$ (相当于外表面接地时的情况，此时外表面电势为0).

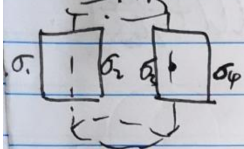
为保证外表面电荷量为 q_1+q_2，引入第二个像电荷 $q''=q_1+q_2-q'=q_1+q_2+\frac{a}{r}q_3$.

为保证A的外表面仍然等势，应将 q'' 置于A的球心处.

$$\vec F_{q_3}=\frac{q_3}{4\pi\varepsilon_0}\left[\frac{-\frac{a}{r}q_3}{(r-\frac{a^2}{r})^2}+\frac{q_1+q_2+\frac{a}{r}q_3}{r^2}\right]\vec{e_r}.\qquad \vec F_A=-\vec F_3.$$

(2) $r\gg a$ 时，$\vec F_{q_1}=\vec F_{q_2}=0$. $\vec F_A=-\frac{q_3}{4\pi\varepsilon_0}\frac{q_1+q_2}{r^2}\vec{e_r}$.

2.3. 解. 2块板的情况. 取如图所示高斯面,由于静电屏蔽,



$\oint \vec{E}\cdot d\vec{S}=0$，故有 $\sum q_i=\sigma_2 S+\sigma_3 S=0 \Rightarrow \sigma_2=-\sigma_3$.

取右金属板内一点, $E=\frac{1}{2\varepsilon_0}(\sigma_1+\sigma_2+\sigma_3-\sigma_4)=0$.

由于 $\sigma_2+\sigma_3=0$，故 $\sigma_1=\sigma_4$

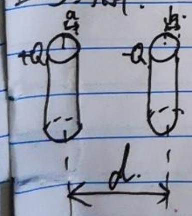
推广到本题,有 $\begin{cases} Q_B+Q_C=0,\ Q_D+Q_E=0,\ Q_F+Q_G=0.\ Q_A=Q_H, \\ Q_A+Q_B=5,\ Q_C+Q_D=1,\ Q_E+Q_F=1,\ Q_G+Q_H=2. \end{cases}$

解得 $\begin{cases} Q_A=4.5C,\ Q_B=0.5C,\ Q_C=-0.5C,\ Q_D=1.5C. \\ Q_E=-1.5C,\ Q_F=2.5C,\ Q_G=-2.5C,\ Q_H=4.5C. \end{cases}$

若用一根导线连接,则有 $\begin{cases} Q_B+Q_C=0,\ Q_F+Q_G=0.\ Q_A=Q_H, \\ Q_A+Q_B=5.\ Q_C+Q_F=2,\ Q_G+Q_H=2. \end{cases}$

解得 $Q_A=4.5C,\ Q_B=0.5C.\ Q_C=-0.5C,\ Q_F=2.5C,\ Q_G=-2.5C,\ Q_H=4.5C$

2.5. 解.



$\varepsilon_0 E_1 2\pi r=Q \Rightarrow E_1=\frac{Q}{2\pi\varepsilon_0 r}$.

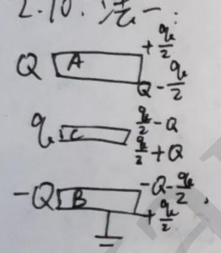
$U_1=\frac{Q}{2\pi\varepsilon_0}\int_a^{d-b}\frac{1}{r}dr=\frac{Q}{2\pi\varepsilon_0}\ln\frac{d-b}{a}$.

$U_2=\frac{-Q}{2\pi\varepsilon_0}\int_b^{d-a}\frac{1}{r}dr=\frac{-Q}{2\pi\varepsilon_0}\ln\frac{d-a}{b}$.

$\Delta U=U_1-U_2=\frac{Q}{2\pi\varepsilon_0}\ln\frac{(d-b)(d-a)}{ab}$.

$$C=\frac{Q}{\Delta U}=\frac{2\pi\varepsilon_0}{\ln\frac{(d-b)(d-a)}{ab}}\approx\frac{2\pi\varepsilon_0}{\ln\frac{d^2}{ab}}$$

2.10. 法一:



(接地处没有电荷).

$C_0=\frac{Q}{U}=\frac{\varepsilon_0 S}{d}$. $C_{AC}=C_{CB}=\frac{\varepsilon_0 S}{\frac{d}{2}}=\frac{2\varepsilon_0 S}{d}$.

$U_C=\frac{Q+\frac{q_0}{2}}{\frac{2\varepsilon_0 S}{d}}=\frac{1}{2}\left[\frac{Q}{C_0}+\frac{q_0 d}{2\varepsilon_0 S}\right]=\frac{1}{2}\left(U+\frac{q_0 d}{2\varepsilon_0 S}\right)$.

法二 (叠加原理) $\sigma=\frac{q_0}{S}$. $E=\frac{\sigma}{2\varepsilon_0}=\frac{q_0}{2\varepsilon_0 S}$.

$U_C=\frac{U}{2}+E\cdot\frac{d}{2}=\frac{U}{2}+\frac{q_0 d}{4\varepsilon_0 S}=\frac{1}{2}\left(U+\frac{q_0 d}{2\varepsilon_0 S}\right)$.

2.6 设$\begin{cases}\text{地球带电} +q \\ \text{月球} \quad -q\end{cases}$，以无穷远为电势零点，

则 $\Delta U = \dfrac{q}{4\pi\varepsilon_0}\left(\dfrac{1}{a}+\dfrac{1}{b}\right)$ 显然

$$C = \frac{q}{\Delta U} = 4\pi\varepsilon_0 \frac{ab}{b+a}.$$

⇒若用细导线连通⇒二者等势⇒并联，

$$C = 4\pi\varepsilon_0(a+b).$$

[若详细推导，

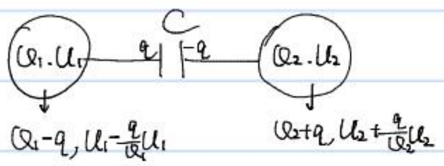
则由等势⇔$\begin{cases}\dfrac{q_1}{4\pi\varepsilon_0 a} = \dfrac{q_2}{4\pi\varepsilon_0 b} = U \\ q_1+q_2 = Q\end{cases}$

解得$\begin{cases}q_1 = \dfrac{a}{a+b}Q \\ q_2 = \dfrac{b}{a+b}Q\end{cases} \Rightarrow U = \dfrac{Q}{4\pi\varepsilon_0(a+b)}$

$\Downarrow$

$C = \dfrac{Q}{U} = \cdots$]

2.14

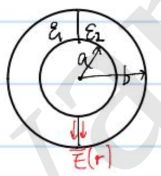


$$\frac{q}{C} = \left(U_1 - \frac{q}{Q_1}U_1\right) - \left(U_2 + \frac{q}{Q_2}U_2\right)$$

即 $q = C(U_1-U_2) - qC\left(\dfrac{U_1}{Q_1}+\dfrac{U_2}{Q_2}\right) \Rightarrow q = \dfrac{C(U_1-U_2)}{1+C\left(\dfrac{U_1}{Q_1}+\dfrac{U_2}{Q_2}\right)}$

此时 $U_C = \dfrac{q}{C} = \dfrac{Q_1Q_2}{Q_1Q_2 + C(U_1Q_2+U_2Q_1)}(U_1-U_2)$

2.21



由于介质和极化电荷的存在，考虑电位移矢量$\vec{D}$.

Gauss: $Q_{tot0} = \oiint_S \vec{D}\cdot d\vec{S}$ (*) ("0"代表自由电荷)

取半径为r的球形Gauss面 $(a<r<b)$，

(*)式化为 $+Q = \varepsilon_1 E_1 \cdot 2\pi r^2 + \varepsilon_2 E_2 \cdot 2\pi r^2$ ①.

由于介质分界面平行于电场方向，由静电场环路定理：$E_1(r) = E_2(r)$ ②

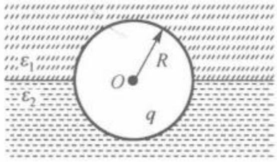
联立①②解得 $E_1 = E_2 \triangleq E = \dfrac{Q}{2\pi(\varepsilon_1+\varepsilon_2)r^2}$.

故 $\Delta U = \int_a^b E(r)\,dr = \dfrac{Q}{2\pi(\varepsilon_1+\varepsilon_2)}\left(\dfrac{1}{a}-\dfrac{1}{b}\right)$.

$$C = \frac{Q}{\Delta U} = 2\pi(\varepsilon_1+\varepsilon_2)\frac{ab}{b-a}.$$

(别忘了写 E 的方向！)

2.19 如习题 2.19 图所示，一导体球外充满两半无限电介质，介电常量分别为 ε_1 和 ε_2，介质界面为通过球心的无限平面. 设导体球半径为 a，总电荷为 q，求空间电场分布和导体球表面的自由面电荷分布.



习题 2.19 图

解 本题属于介质界面与电场线重合的情况，具有对称性的是电场. 取球坐标 (r,θ,ϕ)，原点位于球心，电场沿径向方向，且只与 r 有关. 由高斯定理得

$$2\pi r^2\varepsilon_1 E + 2\pi r^2\varepsilon_2 E = q \quad \Rightarrow \quad \boldsymbol{E} = \frac{q}{2\pi(\varepsilon_1+\varepsilon_2)r^2}\boldsymbol{e}_r$$

据此求得两介质区的电位移矢量如下：

$$\boldsymbol{D}_1 = \varepsilon_1\boldsymbol{E} = \frac{\varepsilon_1 q}{2\pi(\varepsilon_1+\varepsilon_2)r^2}\boldsymbol{e}_r,\quad \boldsymbol{D}_2 = \varepsilon_2\boldsymbol{E} = \frac{\varepsilon_2 q}{2\pi(\varepsilon_1+\varepsilon_2)r^2}\boldsymbol{e}_r$$

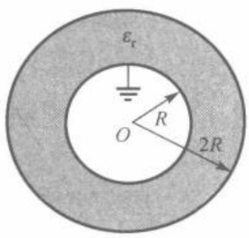
导体球表面的自由面电荷密度为

$$\sigma_1 = D_1(a) = \frac{\varepsilon_1 q}{2\pi(\varepsilon_1+\varepsilon_2)a^2},\quad \sigma_2 = D_2(a) = \frac{\varepsilon_2 q}{2\pi(\varepsilon_1+\varepsilon_2)a^2}$$

2.15 有一半径为 R 的金属球，外面包有一层相对介电常量为 $\varepsilon_r = 2$ 的均匀电介质，壳内外半径分别为 R 和 $2R$，介质内均匀分布着电量为 q_0 的自由电荷，金属球接地. 求介质球壳外表面的电势.

解 金属球接地，如习题 2.15 图所示，其电势 $U=0$. 介质中自由电荷密度为 $3q_0/\{4\pi[(2R)^3-R^3]\}$. 设接地金属球表面的感应电荷总量为 q，由对称性可判断电荷沿金属球表面均匀分布. 运用高斯定理，可求得介质内电场强度

$$4\pi r^2\varepsilon_r\varepsilon_0 E_1 = q + \frac{r^3-R^3}{(2R)^3-R^3}q_0 \quad \Rightarrow \quad E_1 = \frac{1}{8\pi\varepsilon_0}\left(\frac{q}{r^2}+\frac{q_0 r}{7R^3}-\frac{q_0}{7r^2}\right)$$



习题 2.15 图

在介质外的电场强度 $E_2 = (q+q_0)/(4\pi\varepsilon_0 r^2)$. 由金属球和无穷远电势均等于零的条件

$$\int_{2R}^{R} E_1 \mathrm{d}r = \int_{2R}^{\infty} E_2 \mathrm{d}r \qquad \Rightarrow \quad \frac{1}{8\pi\varepsilon_0}\int_{2R}^{R}\left(\frac{q}{r^2}+\frac{q_0 r}{7R^3}-\frac{q_0}{7r^2}\right)\mathrm{d}r = \frac{q+q_0}{4\pi\varepsilon_0}\int_{2R}^{\infty}\frac{\mathrm{d}r}{r^2}$$

可求得 $q=-16q_0/21$. 介质球壳外表面电势为

$$U = \int_{2R}^{\infty} E_2 \mathrm{d}r = \int_{2R}^{\infty}\frac{q+q_0}{4\pi\varepsilon_0 r^2}\mathrm{d}r = \frac{q+q_0}{8\pi\varepsilon_0 R} = \frac{5q_0}{168\pi\varepsilon_0 R}$$

2.28: $r<a$: $D\cdot 4\pi r^2 = q_l \cdot \frac{r^3}{a^3} \Rightarrow \vec{D} = \frac{q_l r}{4\pi a^3}\vec{e_r}$.

$r>a$: $D\cdot 4\pi r^2 = q_l \Rightarrow \vec{D} = \frac{q_l}{4\pi r^2}\vec{e_r}$.

$$\vec{E} = \frac{\vec{D}}{\varepsilon_i} = \begin{cases} \frac{q_l r}{4\pi\varepsilon_r\varepsilon_0 a^3}\vec{e_r}, & r<a \\ \frac{q_l}{4\pi\varepsilon_0 r^2}\vec{e_r}, & r>a \end{cases}$$

法一: $U(\vec{r}) = \int_r^{+\infty} \vec{E}(\vec{r})\cdot d\vec{r} = \frac{q_l}{8\pi\varepsilon_r\varepsilon_0}\left(\frac{1}{a} - \frac{r^2}{a^3}\right) + \frac{q_l}{4\pi\varepsilon_0 a}$, $r<a$.

$\rho = \frac{q_l}{\frac{4}{3}\pi a^3}$. $W = \frac{1}{2}\iiint_{V_0} \rho U \, dV$. (积分区间$V_0$为球, $r<a$部分)

法二: $w = \frac{1}{2}\vec{D}\cdot\vec{E}$. $W = \iiint_V w \, dV = \frac{q_l^2}{8\pi\varepsilon_0 a}\left(1 + \frac{1}{5\varepsilon_r}\right)$. (积分区间$V$为全空间)

2.32 (1) 法一: $V = \frac{q_{l1}}{4\pi\varepsilon_0 R_1} + \frac{q_{l2}}{4\pi\varepsilon_0 R_2} \Rightarrow q_{l1} = 4\pi\varepsilon_0 V R_1 - \frac{R_1}{R_2} q_{l2}$.

法二: 由高斯定理, 可求得 $\vec{E} = \begin{cases} \frac{q_{l1}}{4\pi\varepsilon_0 r^2}\vec{e_r}, & R_1<r<R_2 \\ \frac{q_{l1}+q_{l2}}{4\pi\varepsilon_0 r^2}\vec{e_r}, & r>R_2 \end{cases}$.

$$V = \int \vec{E}\cdot d\vec{r} = \frac{1}{4\pi\varepsilon_0}\left[\int_{R_1}^{R_2} \frac{q_{l1}}{r^2} dr + \int_{R_2}^{+\infty} \frac{q_{l1}+q_{l2}}{r^2} dr\right]$$

$$\Rightarrow q_{l1} = 4\pi\varepsilon_0 V R_1 - \frac{R_1}{R_2} q_{l2}.$$

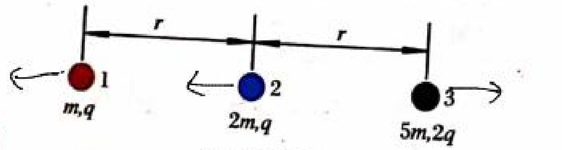
(2) 法一: $V_2 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_{l1}}{R_2} + \frac{q_{l2}}{R_2}\right)$. $W = \frac{1}{2}(V q_{l1} + V_2 q_{l2})$.

法二: $W = \iiint_V \frac{1}{2}\vec{D}\cdot\vec{E} \, dV = \iiint_V \frac{\varepsilon_0}{2} E^2 \, dV$

$$= \frac{\varepsilon_0}{2}\left[\int_{R_1}^{R_2} \left(\frac{q_{l1}}{4\pi\varepsilon_0 r^2}\right)^2 4\pi r^2 dr + \int_{R_2}^{+\infty} \left(\frac{q_{l1}+q_{l2}}{4\pi\varepsilon_0 r^2}\right)^2 4\pi r^2 dr\right]$$

$$= \frac{1}{8\pi\varepsilon_0}\left[(4\pi\varepsilon_0 V)^2 R_1 + \left(\frac{1}{R_2} - \frac{R_1}{R_2^2}\right) q_{l2}^2\right]$$

2.30 3个带正电的粒子分别被固定在如图中相应位置。每个粒子的质量、带电量和相邻粒子间距 r 都已经给出。同时释放3个粒子。求3个粒子彼此离得非常远时它们的动能。假设粒子沿同一直线运动。粒子在图中分别标号为1,2,3。



习题 2.30 图

总静电能 $W_0 = \cancel{W_{\text{自}}} + W_{\text{互}} = \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{r} + \frac{2q^2}{r} + \frac{2q^2}{2r}\right)$

(点电荷近似) $\quad = \frac{q^2}{\pi\varepsilon_0 r}$

"离得很远" $\Rightarrow$ W_0 完全转化为 E_K.

定性分析 $\Rightarrow$ 1、2向左运动，3向右运动.

$$\begin{cases} \text{Momentum: } \sqrt{2mE_{K1}} + \sqrt{4mE_{K2}} = \sqrt{10mE_{K3}} \Rightarrow \sqrt{E_{K1}} + \sqrt{2E_{K2}} = \sqrt{5E_{K3}} & ① \\ \text{Energy: } E_{K1} + E_{K2} + E_{K3} = W_0 & ② \end{cases}$$

还差一个方程. 此时可以分析一下三者的运动过程.

$$m\ddot{x}_1 = \frac{1}{4\pi\varepsilon_0}\left(-\frac{q^2}{r_{12}^2} - \frac{2q^2}{r_{13}^2}\right) \quad (1)$$

$$2m\ddot{x}_2 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q^2}{r_{21}^2} - \frac{2q^2}{r_{23}^2}\right) \quad (2)$$

$$5m\ddot{x}_3 = \frac{1}{4\pi\varepsilon_0}\left(\frac{2q^2}{r_{31}^2} + \frac{2q^2}{r_{32}^2}\right) \quad (3)$$

$t=0$ 时，$\begin{cases} r_{12} = r_{21} = r \\ r_{23} = r_{32} = r \\ r_{13} = r_{31} = 2r \end{cases}$

可知，$\begin{cases} m\ddot{x}_1(0) = -\frac{q^2}{4\pi\varepsilon_0}\frac{3}{2r^2} \\ 2m\ddot{x}_2(0) = -\frac{q^2}{4\pi\varepsilon_0}\frac{1}{r^2} \\ 5m\ddot{x}_3(0) = \frac{q^2}{4\pi\varepsilon_0}\frac{5}{2r^2}. \end{cases}$ (×) $\Rightarrow \ddot{x}_2(0) = \frac{1}{2}\left(\ddot{x}_1(0) + \ddot{x}_3(0)\right)$

两端对时间积分 $\dot{x}_2(dt) - \cancel{\dot{x}_2(0)} = \frac{1}{2}\left[\left(\dot{x}_1(dt) - \cancel{\dot{x}_1(0)}\right) + \left(\dot{x}_3(dt) - \cancel{\dot{x}_3(0)}\right)\right]$

两端对时间积分 $x_2(dt)-\cancel{x_2(0)}=-\frac{1}{2}\left[\left(x_1(dt)-\cancel{x_1(0)}\right)+\left(x_3(dt)-\cancel{x_3(0)}\right)\right]$

$(dt\to 0)$ 得 $\underbrace{x_2(dt)-x_2(0)}_{0}=\frac{1}{2}\left[\left(x_1(dt)-\underbrace{x_1(0)}_{-r}\right)+\left(x_3(dt)-\underbrace{x_3(0)}_{+r}\right)\right]$

即在 dt 时刻
$$\left.\begin{cases} r_{12}(dt)=x_2(dt)-x_1(dt)=\frac{1}{2}[x_3(dt)-x_1(dt)] \\ r_{23}(dt)=x_3(dt)-x_2(dt)=\frac{1}{2}[\quad\quad] \\ r_{13}(dt)=x_3(dt)-x_1(dt)=2r(dt). \end{cases}\right\}\triangleq r(dt)$$

⇒这说明(*)式所示关系在 dt 时也成立，进而在任意 t 时成立。

于是恒有关系：$v_2=\frac{1}{2}(v_1+v_3)$ ⇒ $-2\sqrt{\frac{2E_{k2}}{2m}}=-\sqrt{\frac{2E_{k1}}{m}}+\sqrt{\frac{2E_{k3}}{5m}}$ （方向表现在符号上）

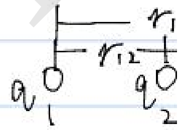
（v_i 带方向）

即 $-\sqrt{2E_{k1}}+2\sqrt{E_{k2}}+\sqrt{\frac{2}{5}E_{k3}}=0$

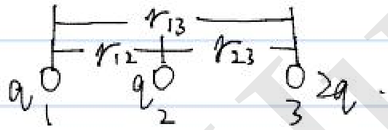
$\sqrt{E_{k1}}=\sqrt{2E_{k2}}+\sqrt{\frac{1}{5}E_{k3}}$ ③

⇒联立①~③解得
$$\begin{cases} E_{k1}=\frac{9q^2}{16\pi\varepsilon_0 r} \\ E_{k2}=\frac{q^2}{8\pi\varepsilon_0 r} \\ E_{k3}=\frac{5q^2}{16\pi\varepsilon_0 r} \end{cases}$$

[法二]：



[法二]：



从初态→末态，三个电磁力做的功转化成了动能。

① 考虑1&2：$E_1=\int_r^{\infty}\frac{q^2}{4\pi\varepsilon_0 r_{12}^2}dr_{12}=\frac{q^2}{4\pi\varepsilon_0 r}$ （为简便起见，不妨记 $E_0\triangleq\frac{q^2}{\pi\varepsilon_0 r}$）

重点在于解构 E_1，理清 E_1 中有多少转化到了1上，又有多少转化到了2上。

$\overleftarrow{m}$ $3dx$ $\overleftarrow{2m}$ dx $\overrightarrow{5m}$ dx

$$\begin{cases} E_{1k_1}=\frac{3}{3+(-1)}E_1=\frac{3}{8}E_0 \\ E_{1k_2}=\frac{-1}{3+(-1)}E_1=-\frac{1}{8}E_0 \end{cases}$$

② 同理考虑2&3：

$E_2=\int_r^{\infty}\frac{2q^2}{4\pi\varepsilon_0 r_{23}^2}dr_{23}=\frac{q^2}{2\pi\varepsilon_0 r}$ ⇒ $\begin{cases} E_{2k_2}=\frac{1}{1+1}E_2=\frac{1}{4}E_0 \\ E_{2k_3}=\frac{1}{1+1}E_2=\frac{1}{4}E_0 \end{cases}$

③ 1&3：

$E_3=\int_{2r}^{\infty}\frac{2q^2}{4\pi\varepsilon_0 r_{13}^2}dr_{13}=\frac{q^2}{4\pi\varepsilon_0 r}$ ⇒ $\begin{cases} E_{3k_1}=\frac{3}{3+1}E_3=\frac{3}{16}E_0 \\ E_{3k_3}=\frac{1}{3+1}E_3=\frac{1}{16}E_0 \end{cases}$

综上，
$$\begin{cases} E_{k_1}=E_{1k_1}+E_{3k_1}=\frac{9}{16}E_0 \\ E_{k_2}=E_{1k_2}+E_{2k_2}=\frac{1}{8}E_0 \\ E_{k_3}=E_{2k_3}+E_{3k_3}=\frac{5}{16}E_0 \end{cases}$$

3.2. 解: $R=\int\frac{dr}{\sigma S}=\frac{1}{\sigma}\int_a^b\frac{1}{4\pi r^2}dr=\frac{1}{4\pi\sigma}\left(\frac{1}{a}-\frac{1}{b}\right)=\frac{b-a}{4\pi\sigma ab}$

3.3. 解 (1) $R=\int\frac{\rho dr}{S}=\rho\int_a^b\frac{1}{2\pi rl}dr=\frac{\rho}{2\pi l}\ln\frac{b}{a}$.

(2) $\varepsilon E\cdot 2\pi rl=Q\Rightarrow\vec{E}=\frac{Q}{2\pi\varepsilon rl}\vec{e_r}$.

$U_{ab}=\int\vec{E}\cdot d\vec{r}=\int_a^b\frac{Q}{2\pi\varepsilon rl}dr=\frac{Q}{2\pi\varepsilon l}\ln\frac{b}{a}$.

$C=\frac{Q}{U_{ab}}=\frac{2\pi\varepsilon l}{\ln\frac{b}{a}}$.

(3) $R\cdot C=\frac{\rho}{2\pi l}\ln\frac{b}{a}\cdot\frac{2\pi\varepsilon l}{\ln\frac{b}{a}}=\rho\varepsilon$.

3.5. 解: $\vec{j}=\frac{I}{2\pi r^2}\vec{e_r}=\sigma\vec{E}=\frac{1}{\rho}\vec{E}\Rightarrow\vec{E}=\frac{\rho I}{2\pi r^2}\vec{e_r}$.

$U=\int_r^{r+\Delta r}\vec{E}\cdot d\vec{r}=\int_r^{r+\Delta r}\frac{\rho I}{2\pi}\cdot\frac{1}{r^2}dr=\frac{\rho I}{2\pi}\left(\frac{1}{r}-\frac{1}{r+\Delta b}\right)$.

$r=1$m时, $U\approx1193.66$V. $r=10$m时, $U\approx18.02$V.