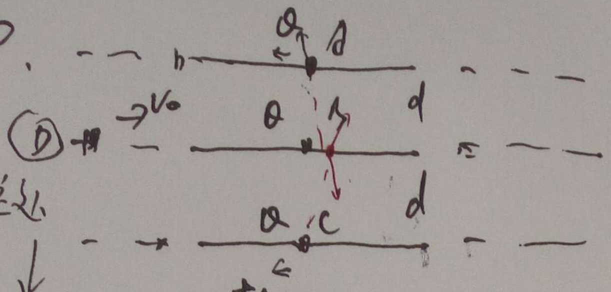
10.



飞过去 → 扰动　　整体 M, Q

B不稳定平衡态

阶段1, 由于D的扰动

A,B,C 相互作用, D不参与

引起动量守恒. 能量守恒

$mv_B - 2mv_A = 0$　　($v_A = v_D$)　　$v_A = u$　　$v_B = 2u$

初始

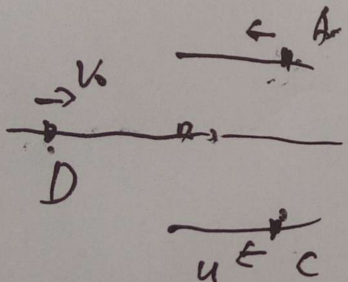
能量

$\frac{1}{2}\left[Q\left(k\frac{Q}{d} + k\frac{Q}{2d}\right)\times 2 + Q\,k\frac{Q}{d}\times 2\right] = \frac{5kQ^2}{2d}$　> 相等

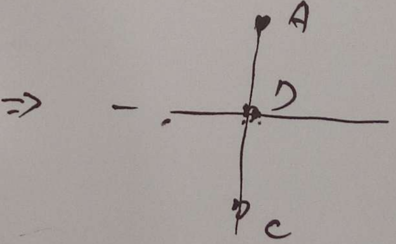
$k\frac{Q^2}{2d} + \frac{1}{2}mv_B^2 + 2\times\frac{1}{2}mv_A^2$　⇒ 势能改变 $E = \frac{2kQ^2}{d}$

$\Rightarrow u = \sqrt{\frac{2kQ^2}{3md}}$

阶段二 D和A,C相互作用. 讨论D刚好穿过A,C



⇒



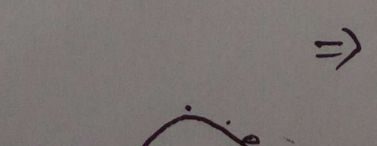
$mv_D - 2mu = 3mv$

$\frac{1}{2}mv_D^2 + \frac{1}{2}\times 2mu^2 - \frac{1}{2}3mv^2 = E$

$\Rightarrow v_D = 2u$

弹性碰撞 $\begin{cases} m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2' \\ \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 = \frac{1}{2}m_1v_1'^2 + \frac{1}{2}m_2v_2'^2 \end{cases}$ △

$\Rightarrow \begin{cases} v_1' = v_1 \\ v_2' = v_2 \end{cases}$ (初态)　$\begin{cases} v_1' = ? \\ v_2' = ? \end{cases} > e = \frac{v_2' - v_1'}{v_1 - v_2} = 1$ △



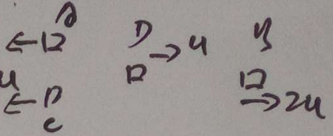
⇓ 穿过 A先减速后加速

未穿过 A减速　　能退上

$V_0 > 2u$ 飞越后三者同速度保持不变.

A、C 各以 u 向左运动　<u>D以 2u 向右</u>

阶段三 D与B作用 交换速度

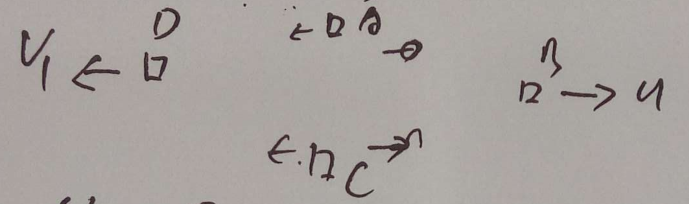


$V_0 < 2u$　D穿不过

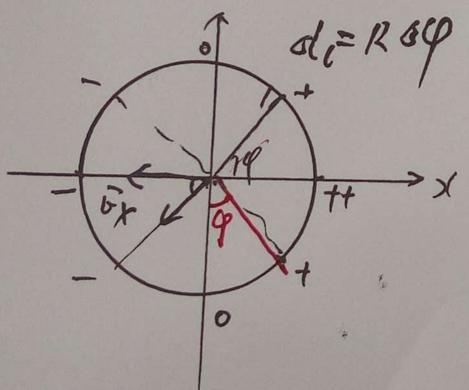
$$MV_0 - 2Mu = MV_1 + 2MV_2$$

$$\frac{1}{2}MV_0^2 + \frac{1}{2}2Mu^2 = \frac{1}{2}MV_1^2 + \frac{1}{2}2MV_2^2$$

$$V_1 = -\frac{4u+V_0}{3} \qquad V_2 = \frac{2V_0-u}{3} < u$$



15、微元累加



$dl = R\Delta\varphi$

$$E_{ix} = k\cdot\frac{\lambda_0\cos\varphi\cdot R\Delta\varphi}{R^2}\cos\varphi$$

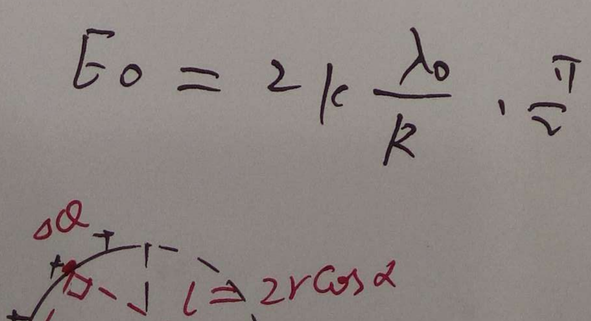
$$= k\frac{\lambda_0\cos^2\varphi}{R}\Delta\varphi$$

$$E_{ix}' = k\frac{\lambda_0\sin^2\varphi}{R}\cdot\Delta\varphi$$

$$E_{ix} + E_{ix}' = k\frac{\lambda_0}{R}\Delta\varphi.$$

$$E_0 = 2k\frac{\lambda_0}{R}\cdot\frac{\pi}{2} = \frac{\pi k\lambda_0}{R}$$

14.



$$\frac{V_B}{V_B} = \eta$$

$$\frac{a_B}{a_B} = ?$$

$$\Delta U_B = k\frac{\Delta Q}{l} = \frac{k\Delta Q}{2r\cos\alpha}$$

$$\Delta E_{Bx} = k\frac{\Delta Q}{l^2}\cos\alpha = k\frac{\Delta Q}{(2r\cos\alpha)^2}\cdot\cos\alpha = k\frac{\Delta Q}{4r^2\cos\alpha}$$

$$= \frac{\Delta U_B}{2r}$$

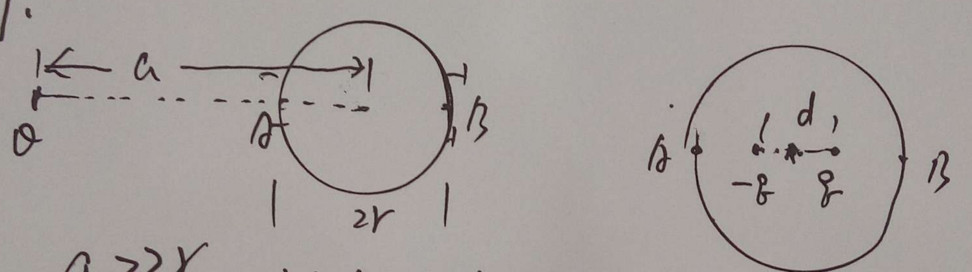
$$\Rightarrow E_B = \frac{U_B}{2r}$$

$$U_A = k\frac{Q}{r} \quad E_A = k\frac{2Q}{\pi r^2} = \frac{2U_A}{\pi r}$$

$$\frac{E_A}{E_B} = \frac{4U_A}{\pi U_B} = \frac{a_A}{a_B}$$

$$qU = \frac{1}{2}mv^2 \qquad \frac{a_A}{a_B} = \frac{4}{\pi}\eta^2$$

19.



$a \gg r$ +Q处场处 $U_{AB} = k\cdot\frac{Q}{a^2}\cdot 2r$

$$U_{AB} = k\frac{Q}{a-r} - k\frac{Q}{a+r} = k\frac{2rQ}{a^2-r^2}$$

电偶极子在A、B处电势分别为

$$U_A = k\frac{-q}{r-\frac{d}{2}} + k\frac{q}{r+\frac{d}{2}}$$

$$U_B = k\frac{q}{r-\frac{d}{2}} + k\frac{-q}{r+\frac{d}{2}}$$

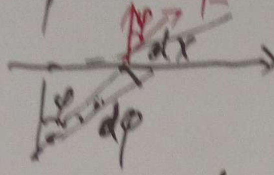
$$U_{AB} = 2k\frac{qd}{r^2} = 2k\frac{Qr}{a^2} \Rightarrow qd = Q\frac{r^3}{a^2}$$

对偶极子的作用力为

$$F = -k\frac{Qq}{(a-\frac{d}{2})^2} + k\frac{Qq}{(a+\frac{d}{2})^2} = -2k\frac{Qqd}{a^3} = -2k\frac{Q^2r^3}{a^5}$$

冲-3 a增加一倍, $\frac{1}{32}$ $\sqrt[3]{32} = 3.17$倍

20. 高斯面R处 $E\cdot\Delta l\cdot 2\pi R = 4\pi k\cdot q\cdot\Delta l \Rightarrow E = 2k\frac{q}{R}$



$$F = eE = \frac{2kqe}{R}$$

$$F_y = F\cos\varphi = \frac{2kqe}{R}\cos\varphi = ma_y = m\frac{dv_y}{dt}$$

$$dt = \frac{dx}{v_x} = \frac{R\,d\varphi}{v_x\cos\varphi} \Rightarrow \text{代入}$$

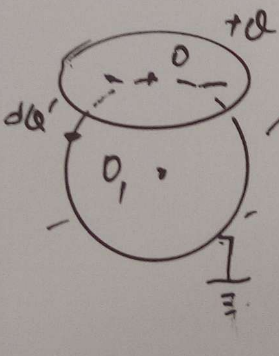
$$dv_y = \frac{2keq\,d\varphi}{mv_x} = \frac{mkeq\,d\varphi}{E_k}$$

$$v_y = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}}\frac{kv_x eq}{E_k}d\varphi = \frac{\pi keqv_x}{E_k}$$

$$\alpha \doteq \tan\alpha = \frac{v_y}{v_x} = \frac{\pi keq}{E_k}$$

24. 五. 静电平衡和电像法

21 $U_0 = k\frac{Q}{a} \Rightarrow Q = \frac{U_0 a}{k}$



球为等势体

取O_1点 为使球面上

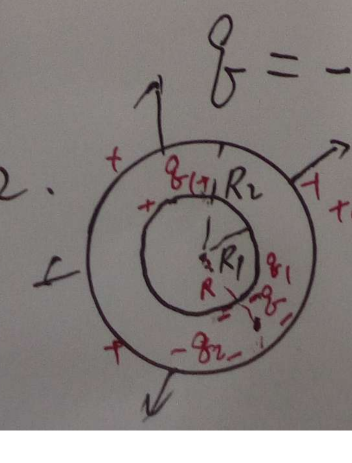
电荷分布不均匀，而O_1点距离相等

$$\Delta U_{O_1} = k\frac{\Delta Q'}{b}$$

$$U_{O_1} = 0 = k\cdot\frac{Q}{\sqrt{a^2+b^2}} + k\frac{q}{b}$$

$$q = -\frac{abU_0}{kQ\sqrt{a^2+b^2}}$$

22.



$+q_2$ 内球表面

均匀分布

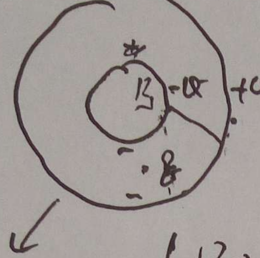
孤立

$n\varphi-\varphi$

$U_内 = k\frac{q}{R}$ $U_外 = \frac{kq}{R_2}$

$U_内 - U_外 = kq\cdot\left(\frac{1}{R} - \frac{1}{R_2}\right)$

(2) 内球外球用导线连接后



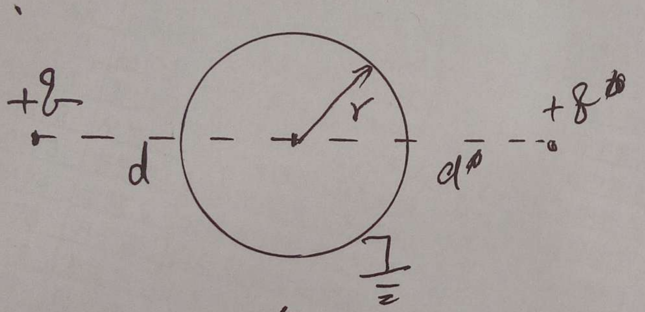
$U_球' = k\left(\frac{q}{R} - \frac{Q}{R_1} + \frac{Q}{R_2}\right)$

$U_壳 = k\frac{q}{R_2}$

$U_球 = U_壳 \Rightarrow Q = \frac{q\cdot\left(\frac{R_2}{R} - 1\right)}{\frac{R_2}{R_1} - 1}$

球壳外面q的分布

25、



球面上像电荷 $q_2 = q_1 = -\frac{r}{d}q$

分别位于 $x = \pm a$，$a = \frac{r^2}{d}$

$F_e = k\cdot\frac{q^2}{(2d)^2} - k\frac{\frac{r^2}{d}q^2}{(d-a)^2} - k\frac{\frac{r^2}{d}q^2}{(d+a)^2} = 0$

$r_0^8 - 8d^3r_0^5 - 2d^4r_0^4 - 8d^7r_0 + d^8 = 0$

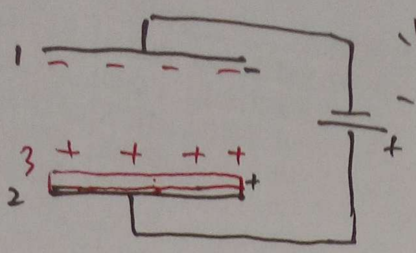
$U_0 = k\cdot\frac{Q + 2\cdot\frac{r_0}{d}q}{r_0} \Rightarrow Q = \frac{1}{k}\left(r_0U_0 - \frac{2r_0q}{d}\right)$

$F_e' = k\cdot\left[\frac{q^2}{4d^2} + \frac{q\left(\frac{2r}{d}q + Q\right)}{d^2} - \frac{q\cdot\frac{r}{d}q}{(d-a)^2} - \frac{q\cdot\frac{r}{d}q}{(d+a)^2}\right.$

$= k\cdot\frac{q\left(\frac{2r}{d}q + Q\right)}{d^2} = \frac{qr_0U_0}{d^2}$

六、电容器

27. (1) $E = \frac{U}{d}$



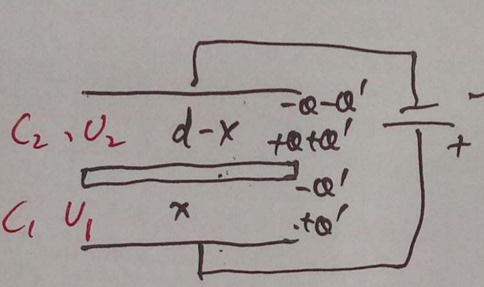
极3带电去 $Q = CU = \frac{SU}{4\pi k d}$

极3时将离开

$Q\frac{E}{2} > mg$

$$U_{min} = \sqrt{\frac{8\pi k m g d^2}{S}}$$

(2) $QU_{min} - mgd = \frac{1}{2}mv^2$



$$\frac{Q'}{C_1} + \frac{Q+Q'}{C_2} = U$$

$$C_1 = \frac{S}{4\pi k \cancel{d} x}, \quad C_2 = \frac{S}{4\pi k(d-x)}$$

$$\Rightarrow Q' = \frac{SxU}{4\pi k d^2} = \frac{x}{d}Q$$

3板受到的电场力

$$F = (Q+Q')\frac{1}{2}\cdot\frac{Q+Q'}{C_2(d-x)} - Q'\frac{1}{2}\cdot\frac{Q'}{C_1 x}$$

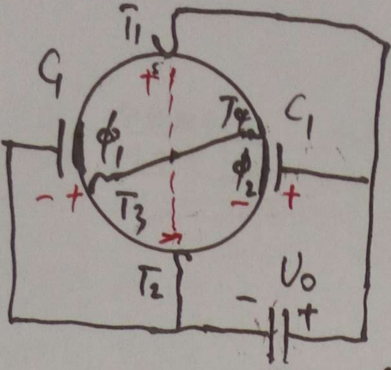
$$= \frac{U}{2d}(Q+2Q') = \frac{QU}{2d}\left(1+\frac{2x}{d}\right)$$

电场力做功 $W = \int_0^d F\,dx = QU$

28. $\frac{10EQ}{81L} = F$

29.

29.



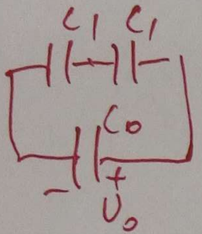
图中为起始位置

每只电容器上的电压 $\frac{U_0}{2}$

电荷 $q = \frac{1}{2} C_1 U_0$

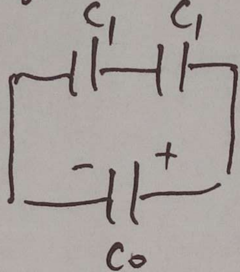
当转过180°后 电容器C_0上的电荷量

如图



$$q' = C_0 U_0 + \frac{1}{2} C_1 U_0 + \frac{1}{2} C_1 U_0 = (C_0 + C_1) U_0$$

再转过180°



$$C_{等效} = C_0 + \frac{1}{2} C_1$$

$$U'_{等效} = \frac{q'}{C_{等效}} = \frac{(C_0+C_1)U_0}{(C_0+\frac{1}{2}C_1)}$$

转了半周 电压从 $U_0 \to \frac{C_0+C_1}{C_0+\frac{1}{2}C_1} U_0$

转了N周 $U_N = \left(\frac{C_0+C_1}{C_0+\frac{1}{2}C_1}\right)^{2N} U_0$