

電工學導論詳解

INTRODUCTION TO ELECTRICAL ENGINEERING

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前 言

研習理工的同學，都有一種認識，那就是：一本書的習題往往是該書的精華所在，藉着習題的印證，才能對書中的原理原則澈底的吸收與瞭解。

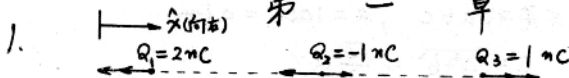
有鑒於此，曉園出版社特地聘請了許多在本科上具有相當研究與成就的人士，精心出版了一系列的題解叢書，為各該科目的研習，作一番介紹與鋪路的工作。

一個問題的解答方法，常因思惟的角度而異。曉園題解叢書，毫無疑問的都是經過一番精微的思考與分析而得。其目的在提供對各該科目研讀時的參考與比較；而對於一般的自修者，則有啓發與提示的作用。希望讀者能藉着這一系列題解叢書的幫助，而在本身的學問進程上有更上層樓的成就。

電工學導論題解

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第一章

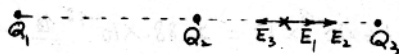


$$\begin{aligned} (a) \quad \vec{F}_1 &= \frac{Q_1 Q_2}{4\pi\epsilon_0 r_{12}^2} (-\hat{x}) + \frac{Q_1 Q_3}{4\pi\epsilon_0 r_{13}^2} (-\hat{x}) \\ &= \frac{Q_1}{4\pi\epsilon_0} \left(\frac{Q_2}{r_{12}^2} + \frac{Q_3}{r_{13}^2} \right) (-\hat{x}) \\ &= \frac{2 \times 10^{-9}}{4\pi \times 8.85 \times 10^{-12}} \left(\frac{-1 \times 10^{-9}}{1^2} + \frac{1 \times 10^{-9}}{2^2} \right) (-\hat{x}) \\ &= 1.35 \times 10^{-8} (\hat{x}) N \quad \triangle \end{aligned}$$

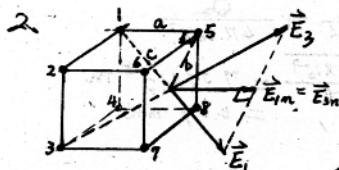
$$\begin{aligned} \vec{F}_2 &= \frac{Q_2 Q_3}{4\pi\epsilon_0 r_{23}^2} (-\hat{x}) + \frac{Q_2 Q_1}{4\pi\epsilon_0 r_{12}^2} (\hat{x}) \\ &= 9 \times 10^{-9} (-\hat{x}) N \quad \triangle \end{aligned}$$

$$\begin{aligned} \vec{F}_3 &= \frac{Q_3 Q_1}{4\pi\epsilon_0 r_{13}^2} (\hat{x}) + \frac{Q_3 Q_2}{4\pi\epsilon_0 r_{23}^2} (\hat{x}) \\ &= 4.5 \times 10^{-9} (\hat{x}) N \quad \triangle \end{aligned}$$

(b)



$$\begin{aligned} \vec{E} &= \vec{E}_1 + \vec{E}_2 + \vec{E}_3 \\ &= \frac{Q_1}{4\pi\epsilon_0 r_1^2} (\hat{x}) + \frac{Q_2}{4\pi\epsilon_0 r_2^2} (-\hat{x}) + \frac{Q_3}{4\pi\epsilon_0 r_3^2} (\hat{x}) \\ &= \frac{1}{4\pi\epsilon_0} \left(\frac{Q_1}{r_1^2} + \frac{Q_2}{r_2^2} - \frac{Q_3}{r_3^2} \right) (\hat{x}) \\ &= \frac{10^{-9}}{4\pi \times 8.85 \times 10^{-12}} \left(\frac{2}{1.5^2} + \frac{-1}{0.5^2} - \frac{1}{0.5^2} \right) (\hat{x}) \\ &= -64 N/C = 64 (-\hat{x}) N/C \quad \triangle \end{aligned}$$



由於向量對稱
5, 6, 7, 8 完全抵消
1, 2, 3, 4 僅存在法線分量

<1>

$$E = 4E_{1n} \text{ (垂直向外)}$$

如图中之直角三角形 abc , $a = 10\text{cm} = 0.1\text{m}$

$$b = \frac{\sqrt{2}}{2}a \quad c = \sqrt{a^2 + b^2} = \frac{\sqrt{6}}{2}a$$

$$E_1 = \frac{Q}{4\pi\epsilon_0 c^2} = \frac{4 \times 10^{-9}}{4 \times 3.14 \times 8.854 \times 10^{-12} \times (\frac{\sqrt{6}}{2} \times 0.1)^2} = 2400 \text{ nt/c}$$

$$E_{1n} = E_1 \frac{a}{c} = 2400 \times \frac{2}{\sqrt{6}} = 1960 \text{ nt/c}$$

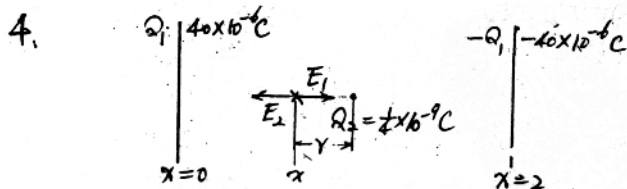
$$E = 4E_{1n} = 4 \times 1960 = 7840 \text{ nt/c (垂直向外)} \quad 4$$

$$\begin{aligned} 3. (a) V_{21} &= \frac{Q}{4\pi\epsilon_0 r_2} - \frac{Q}{4\pi\epsilon_0 r_1} = \frac{Q}{4\pi\epsilon_0} \left(\frac{1}{r_2} - \frac{1}{r_1} \right) \\ &= \frac{-5 \times 10^{-9}}{4 \times 3.14 \times 8.854 \times 10^{-12}} \left(\frac{1}{3} - \frac{1}{1} \right) = 30 \text{ Volt} \end{aligned}$$

$$W = eV = 1.6 \times 10^{-19} \times 30 = 4.8 \times 10^{-18} \text{ 焦} \quad 4$$

$$\begin{aligned} (b) V_{21} &= - \int_1^2 E_L dL \\ &= - \int_{10}^4 \frac{12}{x} dx = -12 \ln x \Big|_{10}^4 = 12 \ln 2.5 = 18 \text{ volt} \end{aligned}$$

$$W = eV = 1.6 \times 10^{-19} \times 18 = 2.88 \times 10^{-18} \text{ 焦} \quad 4$$



$$E_1 = \frac{Q_1}{\epsilon_0 A} \quad E_2 = \frac{Q_2}{4\pi\epsilon_0 r^2}$$

$$E=0 \text{ 時}, E_1 = E_2 \quad \frac{Q_1}{\epsilon_0 A} = \frac{Q_2}{4\pi\epsilon_0 r^2}$$

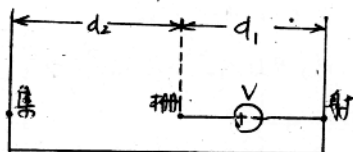
$$r = \sqrt{\frac{AQ_2}{4\pi Q_1}} = \sqrt{\frac{100 \times 10^{-4} \times 1 \times 10^{-9}}{4\pi \times 40 \times 10^{-6}}} = 7.05 \times 10^{-5} \text{ m} = 0.07 \text{ mm}$$

<2>

故 $x = 1 - r = 1 - 0.07 = 0.93 \text{ mm}$ 4

- (b) 将 $-1 \times 10^{-9} \text{ C}$ 置于 $+1 \times 10^{-9} \text{ C}$ 之左方. 使电场 $= E$,
 则不受力. 以恰与 (a) 之解同
 故亦置于 $x = 0.93 \text{ mm}$ 处 4

5



- (a) 由於能量不減. 而射極與集極等電位. 故亦以
 零速度射入集極 4

(b) $\frac{1}{2} m u^2 = eV$, $u = \sqrt{\frac{2eV}{m}} = 5.93 \times 10^5 \text{ m/s}$ 4

(c) 在 d_1 間, $F_1 = ma_1 = e \frac{V}{d}$, $a_1 = \frac{eV}{md}$

$d_1 = \frac{1}{2} a_1 t_1^2$, $\therefore t_1 = \sqrt{\frac{2d_1}{a_1}} = \sqrt{\frac{2m}{eV}} d_1$

同理在 d_2 間, $t_2 = \sqrt{\frac{2m}{eV}} d_2$

$t = t_1 + t_2 = \sqrt{\frac{2m}{eV}} (d_1 + d_2)$ 4

6. (a) $u_1 = 10 \text{ m/sec}$, $u_2 = 30 \text{ m/sec}$

$\frac{1}{2} m u_2^2 - \frac{1}{2} m u_1^2 = qV$

$V = \frac{m}{2q} (u_2^2 - u_1^2) = \frac{4 \times 10^{-16} \times (30^2 - 10^2)}{2 \times 8 \times 10^{-19}} = 2 \times 10^{-5} \text{ Volt}$ 4

(b) $F_e = qE = q \frac{V}{d}$, $F_g = mg$

平衡時 $F_e = F_g$, $qV/d = mg$

$\therefore V = mgd/q = \frac{4 \times 10^{-16} \times 9.8 \times 0.01}{8 \times 10^{-19}} = 49 \text{ Volt}$ 4

<3>

7. (a) $u_0 = 60 \text{ mile/hr} = 60 \times 1609 / 3600 = 26.8 \text{ m/sec}$

$$\frac{1}{2} m u_0^2 = e V_0$$

$$V_0 = \frac{m u_0^2}{2e} = \frac{9.11 \times 10^{-31} \times 26.8^2}{2 \times 1.6 \times 10^{-19}} = 2.1 \times 10^{-9} \text{ volt} \quad \text{---}$$

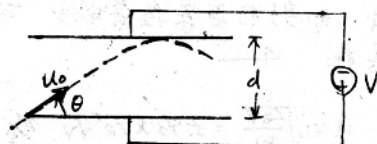
(b) $\frac{m}{m_0} = 1.01$

$$eV = K.E. = m c^2 - m_0 c^2 = 0.01 m_0 c^2$$

$$V = 0.01 m_0 c^2 / e = 0.01 \times 9.11 \times 10^{-31} \times (3 \times 10^8)^2 / 1.6 \times 10^{-19}$$

$$= 5.3 \times 10^3 \text{ Volt} \quad \text{---}$$

8.



$$\frac{1}{2} m u_0^2 = e V_0, \quad u_0 = \sqrt{\frac{2eV_0}{m}}$$

在最高處 $u = \text{水平初速} = u_0 \cos \theta$

$$\text{若恰擦過, } \frac{1}{2} m (u_0 \cos \theta)^2 + eV = \frac{1}{2} m u_0^2$$

$$eV = \frac{1}{2} m u_0^2 \sin^2 \theta = e V_0 \sin^2 \theta$$

$$\therefore \sin \theta = \sqrt{V/V_0} \quad \text{---}$$

9. 電子束作圓周運動. 半徑為 r , 則電場並未做功.

$$u_{\text{out}} = u_{\text{in}} = u$$

$$\text{向心力 } \frac{m u^2}{r} = e E r = \frac{e V}{r \ln 5/4}$$

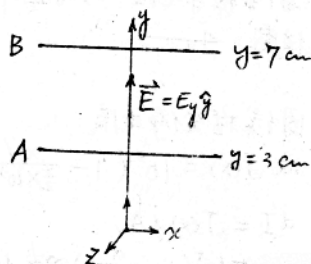
$$\therefore u = \sqrt{\frac{e V}{m \ln 5/4}} = 0.888 \times 10^6 \text{ m/s} \quad \text{---}$$

10. (a) 平衡时 $F_g = F_e = q \frac{V}{d}$
 $32 \times 10^{-12} = q \frac{1000}{0.5}$, $q = 1.6 \times 10^{-14} \text{ C}$
 电子数 $= \frac{1.6 \times 10^{-14}}{1.6 \times 10^{-19}} = 10^5 \text{ 个}$ 4

(b) 加速度 $a = \frac{F}{m} = \frac{eE}{m} = \frac{eV}{md}$
 自中求 $\frac{d}{2} = \frac{1}{2} a t^2$

$t = \sqrt{\frac{d}{a}} = \sqrt{\frac{d}{eV/md}} = \sqrt{\frac{m}{eV}} \cdot d = \sqrt{\frac{(32 \times 10^{-12} / 9.8)}{1.6 \times 10^{-19} \times 1000}} \times 0.5$
 $= 71.4 \text{ sec}$ 4

11.

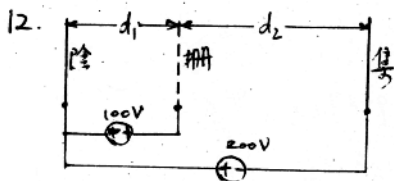


(a) $P_s = 2 \times 10^{-9} \text{ C/cm}^2 = 2 \times 10^{-9} \times 10^4 \text{ C/m}^2$

$E_y = \frac{Q}{\epsilon_0 A} = \frac{P_s}{\epsilon_0} = \frac{2 \times 10^{-9} \times 10^4}{8.854 \times 10^{-12}} = 2.26 \times 10^6 \text{ V/m}$ 4

(b) $V_{AB} = -E_y (y_A - y_B) = -2.26 \times 10^6 (0.03 - 0.07)$
 $= 9.04 \times 10^4 \text{ Volts}$ 4

(c) $W = q V_{AB} = -q E_y (y_2 - y_1) = -8 \times 2.26 \times 10^6 (0.06 - 0.04)$
 $= -3.62 \times 10^5 \text{ joules}$ 4
 (负号表示此电荷获得动能)

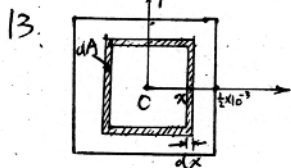


(a) $F = eE = eV/d = 1.6 \times 10^{-19} \times 100 / 2 \times 10^{-3} = 8 \times 10^{-15} \text{ N}$ 4

(向栅极)

(b) $u_0 = \sqrt{\frac{2eV_0}{m}} = 5.93 \times 10^5 \sqrt{V_0}$
 $= 5.93 \times 10^5 \sqrt{100} = 5.93 \times 10^6 \text{ m/sec}$ 4

(c) 栅极与阴极间之电位差为 $100 + 200 = 300 \text{ Volts}$, 在 100 Volts 处之电位差时, 与阴极等电位, 此时速率为 0, 由此
 $\frac{100}{300} d_2 = \frac{1}{3} d_2$ 之位处 4



因线性分布电流

故 $J(x) = 10^5 \left(1 - \frac{x}{\frac{1}{2} \times 10^{-3}} \right)$

$dI = J(x) dA$

$= 10^5 \left(1 - \frac{x}{\frac{1}{2} \times 10^{-3}} \right) \cdot 8\pi dx$

$= \left[(8 \times 10^5)x - (16 \times 10^8)x^2 \right] dx$

总电流 $I = \int dI$

$= \int_0^{\frac{1}{2} \times 10^{-3}} (8 \times 10^5 x - 16 \times 10^8 x^2) dx$

$= \left(4 \times 10^5 x^2 - \frac{16}{3} \times 10^8 x^3 \right) \Big|_0^{\frac{1}{2} \times 10^{-3}}$

$= 0.1 - 0.066$

$= 0.033 \text{ Amp}$ 4

$$\begin{aligned}
 14. (a) \quad Q &= \int i \, dt = \int_{-\frac{1}{2}}^0 10e^{-20t} dt + \int_0^{\frac{1}{2}} 10e^{20t} dt \\
 &= -\frac{1}{2}e^{-20t} \Big|_{-\frac{1}{2}}^0 + \frac{1}{2}e^{20t} \Big|_0^{\frac{1}{2}} \\
 &= \left(-\frac{1}{2} + \frac{1}{2}e^{10}\right) + \left(\frac{1}{2}e^{10} - \frac{1}{2}\right) \\
 &= e^{10} - 1 \quad 4
 \end{aligned}$$

$$\begin{aligned}
 (b) \quad q(t) &= \frac{e^0 - 1}{2} + \int_0^t 10e^{20\tau} d\tau = \frac{e^0 - 1}{2} + \frac{1}{2}e^{20t} \Big|_0^t \\
 &= \frac{e^0 - 1}{2} + \frac{1}{2}(e^{20t} - 1) \quad 4
 \end{aligned}$$

$$15. (a) \quad i = (A/P)u = (10^{11} \times 1.6 \times 10^{-19}) \times 3 \times 10^7 = 0.48 \text{ Amp} \quad 4$$

$$(b) \quad \frac{1}{2}mu^2 = eV, \quad V = \frac{mu^2}{2e} = \frac{9.11 \times 10^{-31} \times (3 \times 10^7)^2}{2 \times 1.6 \times 10^{-19}} = 560 \text{ Volts}$$

$$(c) \quad \text{电子传热} \quad \frac{1}{2}mu^2 = \frac{1}{2} \times 9.11 \times 10^{-31} \times (3 \times 10^7)^2 = 4.12 \times 10^{-16} \text{ joules}$$

W = 所有电子数 $\times$ 每个电子之传热

$$= \frac{10^{11} \times 3 \times 10^7 \times (2 \times 3600) \times 4.12 \times 10^{-16}}{3600 \times 1000}$$

19瓦时

$$= 2.47 \text{ 19瓦时} \quad 4$$

$$(另法) \quad W = iVt = 0.48 \times 2570 \times 2 \times 10^{-3} = 2.47 \text{ 19瓦时} \quad 4$$

$$16. (a) \quad E = \frac{V}{d} \rightarrow \frac{V}{d/2} = 2E, \text{ 变为 2 倍} \quad 4$$

$$(b) \quad u_0 = \sqrt{\frac{2eV_0}{m}} \text{ 不变}$$

$$t = l_p / u_0 \rightarrow \frac{1}{2}l_p / u_0 = \frac{1}{2}t \text{ 变为 } \frac{1}{2} \text{ 倍} \quad 4$$

$$(c) \quad u_y = \frac{eEL}{m} \cdot \frac{l_p}{u_0} \rightarrow \frac{e(2EL)}{m} \cdot \frac{(\frac{1}{2}l_p)}{u_0} = u_y$$

$$u = \sqrt{u_0^2 + u_y^2} \quad \text{不变} \quad 4$$

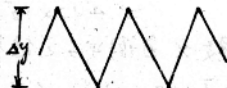
$$(d) \quad d_s = \frac{u_y}{u_0} \cdot l_p \rightarrow \frac{u_y}{u_0} \left(\frac{1}{2}l_p\right) = \frac{1}{2}d_s \text{ 变为 } \frac{1}{2} \text{ 倍} \quad 4$$

<7>

17. (a) $eV = 1.6 \times 10^{-19} \times 2000 = 3.2 \times 10^{-16} \text{ joule}$ 4—
 (b) $\frac{1}{2} m u_x^2 = eV$, $u_x = \sqrt{\frac{2eV}{m}} = 5.93 \times 10^5 \sqrt{2000} = 2.65 \times 10^7 \text{ m/sec}$ 4—
 (c) $t_p = l_p / u_x = 2 \times 10^{-2} / 2.65 \times 10^7 = 0.755 \times 10^{-9} \text{ sec}$ 4—
 (d) $t_{ps} = l_{ps} / u_x = 25 \times 10^{-2} / 2.65 \times 10^7 = 9.44 \times 10^{-9} \text{ sec}$ 4—
 (e) $E_d = V_d / d_p = 100 / 2 \times 10^{-2} = 2 \times 10^4 \text{ V/m}$ 4—
 (f) $F_d = e E_d = 1.6 \times 10^{-19} \times 2 \times 10^4 = 3.2 \times 10^{-15} \text{ nt (向正板)}$ 4—
 (g) $a_y = F_d / m = 3.2 \times 10^{-15} / 9.11 \times 10^{-31} = 3.51 \times 10^{15} \text{ m/sec}^2$ 4—
 (h) $u_y = a_y t_p = 3.51 \times 10^{15} \times 0.755 \times 10^{-9} = 2.65 \times 10^6 \text{ m/sec}$ 4—
 (i) $\Delta y = u_y t_{ps} = 2.65 \times 10^6 \times 9.44 \times 10^{-9} = 2.5 \times 10^{-2} \text{ m}$ 4—
 (j) 脈波改變之時間不可小於電子束穿過垂直偏向板所需之時間, 故 $\tau_{min} = t_p = 0.755 \times 10^{-9} \text{ sec}$ 4—

示波器圖示:

(只有尖端之束
得完全加速)



18.

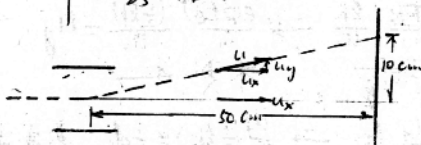
由圖中可知 $\frac{u_y}{u_x} = \frac{10}{50}$ $\therefore u_y = \frac{1}{5} u_x$

$$u^2 = u_x^2 + u_y^2 = u_x^2 + \left(\frac{1}{5} u_x\right)^2 = \frac{26}{25} u_x^2$$

中心部位之電子速率僅為 u_x

$$\text{其速度比 } \frac{\frac{26}{25} u_x^2}{u_x^2} = \frac{26}{25} = 1$$

即為 $\frac{26}{25}$ 倍。 ←



< S >

19. 由(29)式 $d_s = \frac{V_d l_p l_p}{2 V_0 d_p}$
 $V_0 = \frac{V_d l_p l_p}{2 d_p d_s} = \frac{50 \times 3 \times 20}{2 \times 2 \times 1} = 750 \text{ Volts. } \underline{A}$

20. (a) $i = ne = 10^{15} \times 0.9 \times 1.6 \times 10^{-19} = 1.44 \times 10^{-4} \text{ Amp } \underline{A}$

(b) (29)式 $d_s = \frac{V_d l_p l_p}{2 V_0 d_p} = \frac{(2.6-2.4) \times 2 \times 16}{2 \times 2.5 \times 1} = 1.28 \text{ cm } \underline{A}$
 (向下)

动能增加百分比:

$$\frac{\frac{1}{2} m u_y^2}{\frac{1}{2} m u_x^2} = \left(\frac{u_y}{u_x} \right)^2 = \left(\frac{d_c}{l_p} \right)^2 = \left(\frac{1.28}{16} \right)^2 = 0.08^2$$

$$= 0.0064 = 64\% \quad \underline{A}$$

21. (a) $u = 5.93 \times 10^5 \sqrt{1000} = 1.88 \times 10^6 \text{ m/sec}$

自阴极至屏幕需时 $t = \frac{0.5}{1.88 \times 10^6} = 2.66 \times 10^{-7} \text{ sec}$

= 电子因电场排斥, 而有分离速率 v

能量守恒 $2 \cdot \frac{1}{2} m v^2 + \frac{e^2}{4\pi\epsilon_0 r} = \frac{e^2}{4\pi\epsilon_0 d}$

其中 r 为两电荷距离 $d = 50 \mu\text{m}$

$$v = \frac{d(\frac{1}{2}r)}{dt} = \frac{1}{2} \frac{dr}{dt}$$

$$\therefore \frac{1}{4} m \left(\frac{dr}{dt} \right)^2 = \frac{e^2}{4\pi\epsilon_0 d} \left(1 - \frac{d}{r} \right)$$

$$\frac{dr}{dt} = \sqrt{\frac{e^2}{\pi\epsilon_0 d m}} \sqrt{1 - \frac{d}{r}}$$

$$\int_d^r \frac{dr}{\sqrt{1 - \frac{d}{r}}} = \sqrt{\frac{e^2}{\pi\epsilon_0 d m}} \int_0^x dx$$

积分得 $d \sqrt{\frac{r^2}{d^2} - \frac{r}{d}} + \frac{d}{2} \ln \left(\frac{2r}{d} - 1 + 2\sqrt{\frac{r^2}{d^2} - \frac{r}{d}} \right) = \sqrt{\frac{e^2}{\pi\epsilon_0 d m}} x$

令 $x = \frac{r}{d}$ 则 $2\sqrt{x^2 - x} + \ln(2x - 1 + 2\sqrt{x^2 - x}) = \frac{2e}{d} \frac{\pi}{\sqrt{\pi\epsilon_0 d m}}$

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$$\text{右方 } \frac{2e}{d} \frac{t}{\sqrt{\pi \epsilon_0 d m}} = \frac{2 \times 1.6 \times 10^{-19}}{50 \times 10^{-6}} \frac{t}{\sqrt{\pi \times 8.854 \times 10^{-12} \times 50 \times 10^{-6} \times 9.11 \times 10^{-31}}}$$

$$= 1.84 \times 10^8 t \quad \text{--- ①}$$

$$\text{由题} \quad = 1.84 \times 10^8 \times 2.66 \times 10^{-7} = 49$$

$$\text{解 } 2\sqrt{x^2-x} + \ln(2x-1+2\sqrt{x^2-x}) = 49$$

$$\text{试读法得 } x \approx 22.8$$

$$\text{故 } r = xd = 22.8 \times 50 \times 10^{-6} = 1.14 \times 10^{-3} \text{ m} = 1.14 \text{ mm} \quad \Delta$$

(b) 相对质量比静止质量多 10%

$$\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = 1.1$$

$$\text{解 } v = 0.418c = 0.418 \times 3 \times 10^8 = 1.25 \times 10^8 \text{ m/sec}$$

$$\text{过渡时间 } t = \frac{0.5}{1.25 \times 10^8} = 4 \times 10^{-9} \text{ sec}$$

$$\text{故 } 2\sqrt{x^2-x} + \ln(2x-1+2\sqrt{x^2-x}) = 1.84 \times 10^8 \times 4 \times 10^{-9} = 0.736$$

$$\text{解 } x \approx 1.033$$

$$\text{故 } r = xd = 1.033 \times 50 \times 10^{-6} = 51.65 \times 10^{-6} = 51.65 \mu\text{m} \quad \Delta$$

(c) 过渡时间 (a) $t = 2.66 \times 10^{-7} \text{ sec} \quad \Delta$

$$(b) t = 4 \times 10^{-9} \text{ sec} \quad \Delta$$

(b) 另解: 由 $t \rightarrow 0$, 故 $F \approx \text{const.}$

$$a = F/m = \frac{e^2}{4\pi\epsilon_0 d^2 m}$$

$$\Delta d = 2 \times \frac{1}{2} at^2 = \frac{e^2 t^2}{4\pi\epsilon_0 d^2 m}$$

$$= \frac{(1.6 \times 10^{-19})^2 (4 \times 10^{-9})^2}{4\pi \times 8.854 \times 10^{-12} \times (50 \times 10^{-6})^2 \times 9.11 \times 10^{-31}} = 1.62 \times 10^{-6} \text{ m}$$

$$\text{故 } r = d + \Delta d = 50 \times 10^{-6} + 1.62 \times 10^{-6} = 51.62 \times 10^{-6} \text{ m} \quad \Delta$$

第二章

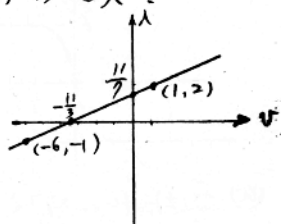
1. (a) 线性 $i = av + b$ 过 $(1, 2)$ 及 $(-6, -1)$ 两点

$$\begin{cases} a+b=2 \\ -6a+b=-1 \end{cases} \quad \text{解} \quad \begin{cases} a=\frac{3}{7} \\ b=\frac{11}{7} \end{cases}$$

$$\therefore i = \frac{3}{7}v + \frac{11}{7}$$

$$v \text{ 截距 } i=0, v = -\frac{11}{3} \text{ A}$$

$$i \text{ 截距 } v=0, i = \frac{11}{7} \text{ A}$$



(b) $i = av^2 + bv + c$, 三未知数 故再需 1 点

当 $|v| < 6.5 \text{ V}$ 功率不为负 故通过 I, III 象限

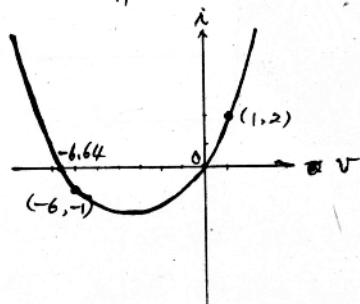
$\therefore v-i$ 曲线必需过原点 $(0, 0)$, $(1, 2)$, $(-6, -1)$

$$\begin{cases} c=0 \\ a+b+c=2 \\ 36a-6b+c=-1 \end{cases} \quad \text{解} \quad \begin{cases} a=\frac{11}{42} \\ b=\frac{73}{42} \\ c=0 \end{cases}$$

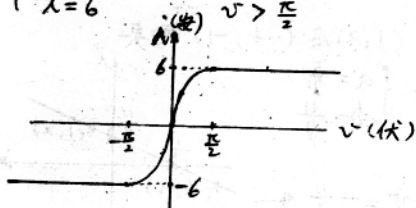
$$i = \frac{11}{42}v^2 + \frac{73}{42}v$$

其截距需在 $|v| < 6.5$ 之外

$$i=0, v = -\frac{73}{11} = -6.64 < -6.5 \text{ 故舍所求}$$

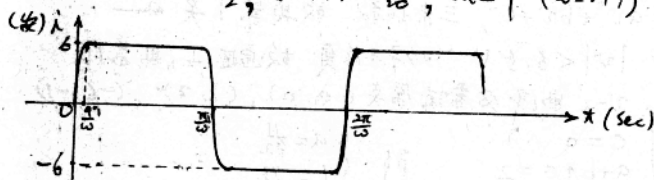


$$2. \begin{cases} \dot{\lambda} = 6 \sin v & |v| \leq \frac{\pi}{2} \\ \dot{\lambda} = -6 & v < -\frac{\pi}{2} \\ \dot{\lambda} = 6 & v > \frac{\pi}{2} \end{cases}$$



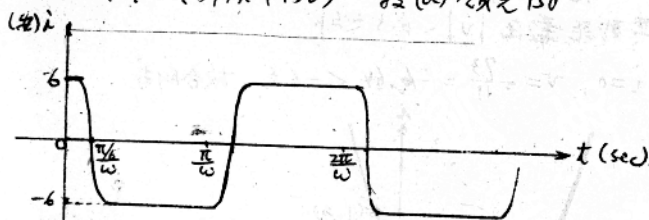
(a) $v(t) = 10 \sin 377t$

当 $10 \sin 377t = \frac{\pi}{2}$, $\sin 377t = \frac{\pi}{20}$, $\omega t \approx 9^\circ$ ($\omega = 377$)



(b) $v(t) = 10 \cos(377t + 60^\circ)$

$= 10 \sin(377t + 150^\circ)$ 较(a) 领先 150°



B. 曲线坐标 $(0, 0), (1, 1.8), (2, 3), (3, 4.1), (4, 5), (5, 5.8), (6, 6.7), (7, 7.4)$

$i = a_0 + a_1 v + a_2 v^2 + a_3 v^3$ 之方程

$$(a) \begin{cases} a_0 = 0 \\ x_0 + 2a_1 + 4a_2 + 8a_3 = 3 \\ x_0 + 4a_1 + 16a_2 + 64a_3 = 5 \\ x_0 + 6a_1 + 36a_2 + 216a_3 = 6.7 \end{cases}$$

解之 $a_1 = 1.876$, $a_2 = -0.22$, $a_3 = 0.016$

$$\lambda = 1.876v - 0.22v^2 + 0.016v^3 \quad \underline{\quad}$$

$$(b) \quad v=1, \lambda=1.672, \Delta\lambda=1.672-1.8=-0.138 \quad \underline{\quad}$$

$$v=3, \lambda=4.38, \Delta\lambda=4.38-4.1=0.28 \quad \underline{\quad}$$

$$v=5, \lambda=5.88, \Delta\lambda=5.88-5.8=0.08 \quad \underline{\quad}$$

$$v=7, \lambda=7.84, \Delta\lambda=7.84-7.4=0.44 \quad \underline{\quad}$$

$$4. \quad 0.2 = 10^{-2} T^2 e^{-11600/T}$$

利用 trial and error

$$T = 1060^\circ K \quad \underline{\quad}$$

$$5. (a) \quad i \propto V^{3/2}$$

$$\frac{i}{0.1} = \left(\frac{400}{100}\right)^{3/2} = 8$$

$$\therefore i = 0.8 \text{ A} = 71 \text{ e}$$

$$n = \frac{0.8}{e} = \frac{0.8}{1.6 \times 10^{-19}} = 5 \times 10^{18} \text{ electrons/sec} \quad \underline{4}$$

$$(b) \text{ 由附录 B5, } V(x) = \left(\frac{x}{a}\right)^{4/3} V$$

$$\text{而 } \frac{d^2 V(x)}{dx^2} = -\frac{\rho(x)}{\epsilon_0}$$

$$\therefore \rho(x) = -\epsilon_0 \frac{d^2 V(x)}{dx^2} = -\epsilon_0 \frac{V}{a^{4/3}} \cdot \frac{4}{3} \cdot \frac{1}{3} x^{-7/3} = -\frac{4}{9} \frac{\epsilon_0 V}{a^{4/3}} x^{-7/3}$$

$$Q = A \int_0^d \rho(x) dx = A \int_0^d -\frac{4}{9} \frac{\epsilon_0 V}{a^{4/3}} x^{-7/3} dx$$

$$= -\frac{4}{3} \frac{\epsilon_0 V}{a^{4/3}} x^{1/3} A \Big|_0^d = -\frac{4}{3} \epsilon_0 \left(\frac{V}{a} A\right)$$

$$\text{由 B-10, } i(V) = 2.34 \times 10^{-6} \frac{A}{a^2} V^{3/2}$$

$$\therefore \frac{V}{a} A = \frac{id}{2.34 \times 10^{-6} \sqrt{V}} = \frac{0.8 \times 10^{-3}}{2.34 \times 10^{-6} \sqrt{200}} = 17.1$$

$$\text{代入 } Q = -\frac{4}{3} \times 8.854 \times 10^{-12} \times 17.1 = -2.02 \times 10^{-10} \text{ C} \quad \underline{4}$$

$$6. (a) \text{ 由图 2-5, 光通量为 } 0.08 \text{ lm, } 200 \text{ V}$$

$$i_b = 4 \mu\text{A}$$

$$N = \frac{i_b t}{e} = 4 \times 10^{-6} \times 10^{-3} / 1.6 \times 10^{-19} = 2.5 \times 10^{10} \text{ electrons} \quad \underline{4}$$

$$(b) \begin{cases} 0.08 \text{ lm, } 200 \text{ V, } i_b = 4 \mu\text{A} \\ 0.02 \text{ lm, } 200 \text{ V, } i_b = 1 \mu\text{A} \end{cases}$$

$$\text{平均电流 } \bar{i}_b = \frac{4+1}{2} = 2.5 \mu\text{A} \quad \underline{4}$$

$$(c) W_1 = i_1 V t = 4 \times 10^{-6} \times 200 \times 10^{-3} = 8 \times 10^{-7} \text{ joules} \quad \underline{4}$$

$$(d) P_1 = i_1 V = 4 \times 10^{-6} \times 200 = 8 \times 10^{-6} \text{ W}$$

$$P_2 = i_2 V = 1 \times 10^{-6} \times 200 = 2 \times 10^{-6} \text{ W}$$

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