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。

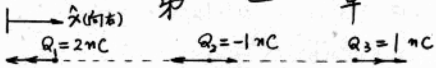
有鑒於此，曉園出版社特地聘請了許多在本科上具有相當研究與成就的人士，精心出版了一系列的題解叢書，為各該科目的研習，作一番介紹與舖路的工作。

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

第 一 章

1.



(a) $$\vec{F}_1 = \frac{Q_1 Q_2}{4\pi\epsilon_0 r_{12}^2}(-\hat{x}) + \frac{Q_1 Q_3}{4\pi\epsilon_0 r_{13}^2}(-\hat{x})$$

$$= \frac{Q_1}{4\pi\epsilon_0}\left(\frac{Q_2}{r_{12}^2} + \frac{Q_3}{r_{13}^2}\right)(-\hat{x})$$

$$= \frac{2\times10^{-9}}{4\pi\times8.854\times10^{-12}}\left(\frac{-1\times10^{-9}}{1^2} + \frac{1\times10^{-9}}{2^2}\right)(-\hat{x})$$

$$= 1.35\times10^{-8}(\hat{x})N \quad \triangle$$

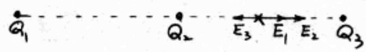
$$\vec{F}_2 = \frac{Q_2 Q_3}{4\pi\epsilon_0 r_{23}^2}(-\hat{x}) + \frac{Q_2 Q_1}{4\pi\epsilon_0 r_{12}^2}(\hat{x})$$

$$= 9\times10^{-9}(-\hat{x})\ N \quad \triangle$$

$$\vec{F}_3 = \frac{Q_3 Q_1}{4\pi\epsilon_0 r_{13}^2}(\hat{x}) + \frac{Q_3 Q_2}{4\pi\epsilon_0 r_{23}^2}(\hat{x})$$

$$= 4.5\times10^{-9}(\hat{x})\ N \quad \triangle$$

(b)



$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$$

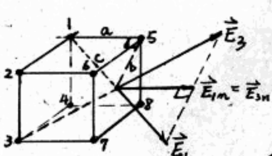
$$= \frac{Q_1}{4\pi\epsilon_0 r_1^2}(\hat{x}) + \frac{Q_2}{4\pi\epsilon_0 r_2^2}(\hat{x}) + \frac{Q_3}{4\pi\epsilon_0 r_3^2}(-\hat{x})$$

$$= \frac{1}{4\pi\epsilon_0}\left(\frac{Q_1}{r_1^2} + \frac{Q_2}{r_2^2} - \frac{Q_3}{r_3^2}\right)(\hat{x})$$

$$= \frac{10^{-9}}{4\pi\times8.854\times10^{-12}}\left(\frac{2}{1.5^2} + \frac{-1}{0.5^2} - \frac{1}{0.5^2}\right)(\hat{x})$$

$$= -64(\hat{x})N/C = 64(-\hat{x})\ N/C \quad \triangle$$

2.



由於向量对称
5.6.7.8 完全抵消
1.2.3.4. 僅存法线分量

$E = 4E_{1n}$ （垂直向外）

如图中之直角三角形 abc，$a = 10cm = 0.1m$

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

$E_1 = \frac{Q}{4\pi\epsilon_0 c^2} = \frac{4\times10^{-9}}{4\times3.14\times8.854\times10^{-12}\times(\frac{\sqrt{6}}{2}\times0.1)^2} = 2400$ nt/C

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

$E = 4E_{1n} = 4\times1960 = 7840$ nt/C （垂直向外）

3. (a) $V_{21} = \frac{Q}{4\pi\epsilon_0 r_2} - \frac{Q}{4\pi\epsilon_0 r_1} = \frac{Q}{4\pi\epsilon_0}(\frac{1}{r_2}-\frac{1}{r_1})$

$= \frac{-5\times10^{-9}}{4\times3.14\times8.854\times10^{-12}}(\frac{1}{3}-\frac{1}{1}) = 30$ Volt.

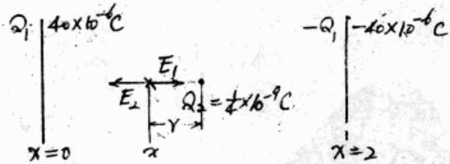
$W = eV = 1.6\times10^{-19}\times30 = 4.8\times10^{-18}$ 焦

(b) $V_{21} = -\int_1^2 E_L\, dL$

$= -\int_{10}^{4}\frac{12}{x}dx = -12\ln x\Big|_{10}^{4} = 12\ln2.5 = 18$ volt

$W = eV = 1.6\times10^{-19}\times18 = 2.88\times10^{-18}$ 焦

4.



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

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

$r = \sqrt{\frac{AQ_2}{4\pi Q_1}} = \sqrt{\frac{100\times10^{-4}\times4\times10^{-9}}{4\pi\times40\times10^{-6}}} = 7.05\times10^{-5}$ m

$= 0.07$ mm

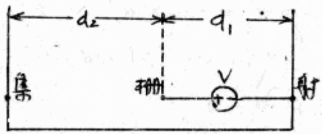
故 $x=1-r=1-0.07=0.93$ mm ←

(b) 將 -4×10^{-9}C 置於 $+4\times10^{-9}$C 之左方，使電場≒E_1

則不受力，此恰與(a)之解同

故亦置於 $x=0.93$ mm 處 ←

5.



(a) 由於能量不滅，而射極與集極等電位，故亦以零速度射入集極 ←

(b) $\frac{1}{2}mu^2=eV$, $u=\sqrt{\frac{2eV}{m}}=5.93\times10^5\sqrt{V}$ m/s ←

(c) 於 d_1 間， $F_1=ma_1=e\frac{V}{d}$, $a_1=\frac{eV}{md_1}$

$d_1=\frac{1}{2}a_1t_1^2$, ∴ $t_1=\sqrt{\frac{2d_1}{a_1}}=\sqrt{\frac{2m}{eV}}\,d_1$

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

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

6. (a) $u_1=10$ m/sec , $u_2=30$ m/sec

$\frac{1}{2}mu_2^2-\frac{1}{2}mu_1^2=qV$

$V=\frac{m}{2q}(u_2^2-u_1^2)=\frac{4\times10^{-16}\times(30^2-10^2)}{2\times8\times10^{-19}}=2\times10^{-5}$ Volt ←

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

平衡時 $F_e=F_g$ $qV/d=mg$

∴ $V=mgd/q=\frac{4\times10^{-16}\times9.8\times0.01}{8\times10^{-19}}=49$ Volt ←

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

$\frac{1}{2} m u_0^2 = eV_0$

$V_0 = \frac{m u_0^2}{2e} = \frac{9.11 \times 10^{-31} \times 26.8^2}{2 \times 1.6 \times 10^{-19}} = 2.11 \times 10^{-9}$ volt ←

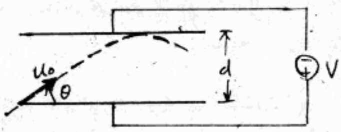
(b) $\frac{m}{m_0} = 1.01$

$eV = K.E. = mc^2 - m_0 c^2 = 0.01\, m_0 c^2$

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

$= 5.3 \times 10^3$ Volt ←

8.



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

在最高点 $u =$ 水平初速 $= u_0 \cos\theta$

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

$eV = \frac{1}{2} m u_0^2 \sin^2\theta = eV_0 \sin^2\theta$

$\therefore \sin\theta = \sqrt{V/V_0}$ ←

9. 電子束作圆周運動，半径为 r，則电场並未作功

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

向心力 $\frac{mu^2}{r} = eE_r = \frac{eV}{r \ln 5/4}$

$\therefore u = \sqrt{\frac{eV}{m \ln 5/4}} = 0.888 \times 10^6 \sqrt{V}$ (m/s) ←

10. (a) 平衡时 $F_g = F_e = q\frac{V}{d}$

$32\times10^{-12} = q\frac{1000}{0.5}$, $q = 1.6\times10^{-14}\ C$

电子数 $= \frac{1.6\times10^{-14}}{1.6\times10^{-19}} = 10^5$ 個

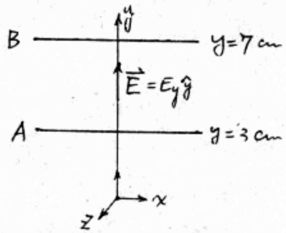
(b) 加速度 $a = \frac{F}{m} = \frac{eE}{m} = \frac{eV}{md}$

自中央 $\frac{d}{2} = \frac{1}{2}at^2$

$t = \sqrt{\frac{d}{a}} = \sqrt{\frac{d}{eV/md}} = \sqrt{\frac{m}{eV}}\cdot d = \sqrt{\frac{(32\times10^{-12}/9.8)}{1.6\times10^{-19}\times1000}}\times 0.5$

$= 71.4$ sec

11.



(a) $\rho_s = 2\times10^{-9}\ C/cm^2 = 2\times10^{-9}\times10^4\ C/m^2$

$E_y = \frac{Q}{\epsilon_0 A} = \frac{\rho_s}{\epsilon_0} = \frac{2\times10^{-9}\times10^4}{8.854\times10^{-12}} = 2.26\times10^6\ V/m$

(b) $V_{AB} = -E_y(y_A - y_B) = -2.26\times10^6(0.03-0.07)$

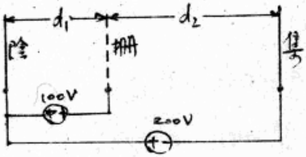
$= 9.04\times10^4$ Volts

(c) $W = qV_{21} = -qE_y(y_2-y_1) = -8\times2.26\times10^6(0.06-0.04)$

$= -3.62\times10^5$ joules

(負号表示此电荷獲得動能)

12.

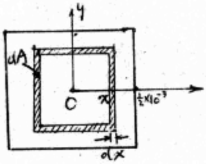


(a) $F = eE = eV/d = 1.6\times10^{-19}\times100/2\times10^{-3} = 8\times10^{-15}\ nt$
(向栅极)

(b) $u_0 = \sqrt{\frac{2eV_0}{m}} = 5.93\times10^5\sqrt{V_0}$
$= 5.93\times10^5\sqrt{100} = 5.93\times10^6\ m/sec$

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

13.



因线性分佈电流

设 $J(x) = 10^5\left(1 - \frac{x}{\frac{1}{2}\times10^{-3}}\right)$

$dI = J(x)\,dA$
$= 10^5\left(1-\frac{x}{\frac{1}{2}\times10^{-3}}\right)\cdot 8x\,dx$
$= \left[(8\times10^5)x - (16\times10^8)x^2\right]dx$

总电流 $I = \int dI$
$= \int_0^{\frac{1}{2}\times10^{-3}}\left(8\times10^5\,x - 16\times10^8\,x^2\right)dx$
$= \left(4\times10^5\,x^2 - \frac{16}{3}\times10^8\,x^3\right)\Big|_0^{\frac{1}{2}\times10^{-3}}$
$= 0.1 - 0.066$
$= 0.033$ Amp

14. (a) $Q = \int i\,dt = \int_{-\frac{1}{2}}^{0} 10e^{-20t}dt + \int_{0}^{\frac{1}{2}} 10e^{20t}dt$

$= -\frac{1}{2}e^{-20t}\Big|_{-\frac{1}{2}}^{0} + \frac{1}{2}e^{+20t}\Big|_{0}^{\frac{1}{2}}$

$= (-\frac{1}{2}+\frac{1}{2}e^{10}) + (\frac{1}{2}e^{10}-\frac{1}{2})$

$= e^{10}-1$ ←

(b) $q(t) = \frac{e^{10}-1}{2} + \int_0^t 10e^{20\tau}d\tau = \frac{e^{10}-1}{2} + \frac{1}{2}e^{20\tau}\Big|_0^t$

$= \frac{e^{10}-1}{2} + \frac{1}{2}(e^{20t}-1)$ ←

15. (a) $i = (A\rho)u = (10^{11}\times1.6\times10^{-19})\times3\times10^{7} = 0.48$ Amp ←

(b) $\frac{1}{2}mu^2 = eV$, $V = \frac{mu^2}{2e} = \frac{9.11\times10^{-31}\times(3\times10^{7})^2}{2\times1.6\times10^{-19}} = 2560$ Volts ←

(c) 每一电子傳熱 $\frac{1}{2}mu^2 = \frac{1}{2}\times9.11\times10^{-31}\times(3\times10^{7})^2$

$= 4.12\times10^{-16}$ joules

W = 所有之电子数 × 每個电子之傳熱

$= \frac{10^{11}\times3\times10^{7}\times(2\times3600)\times4.12\times10^{-16}}{3600\times1000}$ 仟瓦小時

$= 2.47$ 仟瓦小时 ←

(另法) $W = iVt = 0.48\times2570\times2\times10^{-3} = 2.47$ 仟瓦小時 ←

16. (a) $E = \frac{V}{d} \rightarrow \frac{V}{d/2} = 2E$，變為2倍 ←

(b) $u_0 = \sqrt{\frac{2eV_0}{m}}$ 不變

$t = l_p/u_0 \rightarrow \frac{1}{2}l_p/u_0 = \frac{1}{2}t$ 變為$\frac{1}{2}$倍 ←

(c) $u_y = \frac{eE_L}{m}\cdot\frac{l_p}{u_0} \rightarrow \frac{e(2E_L)}{m}\frac{(\frac{1}{2}l_p)}{u_0} = u_y$

$u = \sqrt{u_0^2+u_y^2}$ 不變 ←

(d) $d_s = \frac{u_y}{u_0}\cdot l_{f} \rightarrow \frac{u_y}{u_0}(\frac{1}{2}l_{f}) = \frac{1}{2}d_s$ 變為$\frac{1}{2}$倍 ←

17. (a) $eV = 1.6\times10^{-19}\times 2000 = 3.2\times10^{-16}$ joule

(b) $\frac{1}{2}mu_x^2 = eV$, $u_x = \sqrt{\frac{2eV}{m}} = 5.93\times10^5\sqrt{2000} = 2.65\times10^7$ m/sec

(c) $t_p = l_p/u_x = 2\times10^{-2}/2.65\times10^7 = 0.755\times10^{-9}$ sec

(d) $t_{ps} = l_{ps}/u_x = 25\times10^{-2}/2.65\times10^7 = 9.44\times10^{-9}$ sec

(e) $E_d = V_d/d_p = 100/2\times10^{-2} = 2\times10^4$ V/m

(f) $F_d = eE_d = 1.6\times10^{-19}\times2\times10^4 = 3.2\times10^{-15}$ nt,(向正板)

(g) $a_y = F_d/m = 3.2\times10^{-15}/9.11\times10^{-31} = 3.51\times10^{15}$ m/sec^2

(h) $u_y = a_y t_p = 3.51\times10^{15}\times0.755\times10^{-9} = 2.65\times10^6$ m/sec

(i) $\Delta y = u_y t_{ps} = 2.65\times10^6\times9.4\times10^{-9} = 2.5\times10^{-2}$ m

(j) 脈波改变之时间不可小於电子束穿过垂直偏向板所需之时间,故 $\tau_{min} = t_p = 0.755\times10^{-9}$ sec

示波器图示:

(只有尖端之点得完全加速)

18.

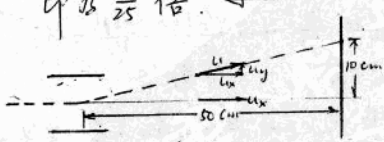
由图中可知 $\frac{u_y}{u_x} = \frac{10}{50}$ $\therefore u_y = \frac{1}{5}u_x$

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

中心部位之电子速率仅为 u_x

其亮度比 $\frac{26}{25}u_x^2 : u_x^2 = \frac{26}{25} : 1$

即为 $\frac{26}{25}$ 倍.



19. 由(29)式 $d_s = \frac{v_d l_p l_{ps}}{2V_0 d_p}$

$$V_0 = \frac{v_d}{2}\frac{l_p l_{ps}}{d_p d_s} = \frac{50\times3\times20}{2\times2\times1} = 750 \text{ Volts}$$ A

20. (a) $i = ne = 10^{15}\times0.9\times1.6\times10^{-19} = 1.44\times10^{-4}$ Amp A

(b) (29)式 $d_s = \frac{v_d l_p l_{ps}}{2V_0 d_p} = \frac{(2.6-2.4)\times2\times16}{2\times2.5\times1} = 1.28$ cm A (向下)

動能增加百分率:

$$\frac{\frac{1}{2}mu_y^2}{\frac{1}{2}mu_x^2} = \left(\frac{u_y}{u_x}\right)^2 = \left(\frac{d_s}{l_{ps}}\right)^2 = \left(\frac{1.28}{16}\right)^2 = 0.08^2$$

$$= 0.0064 = 64\%$$ A

21. (a) $u = 5.93\times10^5\sqrt{1000} = 1.88\times10^6$ m/sec

自陽極至螢幕需時 $t = \frac{0.5}{1.88\times10^6} = 2.66\times10^{-7}$ sec

二電子因靜电力排斥,而有分離速率 v

能量不減 $2\cdot\frac{1}{2}mv^2 + \frac{e^2}{4\pi\epsilon_0 r} = \frac{e^2}{4\pi\epsilon_0 d}$

其中 r 為兩电荷距離 $d = 50\,\mu m$

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

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

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

$$\int_d^r \frac{dr}{\sqrt{1-\frac{d}{r}}} = \sqrt{\frac{e^2}{\pi\epsilon_0 dm}}\int_0^t dt$$

積分得 $d\sqrt{\frac{r^2}{d^2}-\frac{r}{d}} + \frac{d}{2}\ln\left(\frac{2r}{d}-1+2\sqrt{\frac{r^2}{d^2}-\frac{r}{d}}\right) = \sqrt{\frac{e^2}{\pi\epsilon_0 dm}}\,t$

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

右方 $\frac{2e}{d}\frac{t}{\sqrt{\pi\epsilon_0 dm}}=\frac{2\times1.6\times10^{-19}}{50\times10^{-6}}\frac{t}{\sqrt{\pi\times8.854\times10^{-12}\times50\times10^{-6}\times9.11\times10^{-31}}}$

$=1.84\times10^{8}t$ ——①

此處 $=1.84\times10^{8}\times2.66\times10^{-7}=49$

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

试误法 得 $x\simeq22.8$

故 $r=xd=22.8\times50\times10^{-6}=1.14\times10^{-3}\,m=1.14\,mm$

(b) 相对質量比静止質量多10%

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

解 $v=0.418c=0.418\times3\times10^{8}=1.25\times10^{8}\,m/sec$

过渡时间 $t=\frac{0.5}{1.25\times10^{8}}=4\times10^{-9}\,sec$

故 $2\sqrt{x^2-x}+\ln(2x-1+2\sqrt{x^2-x})=1.84\times10^{8}\times4\times10^{-9}=0.736$

解之 $x\simeq1.033$

故 $r=xd=1.033\times50\times10^{-6}=51.65\times10^{-6}=51.65\,\mu m$

(C) 过渡时间 (a) $t=2.66\times10^{-7}\,sec$

(b) $t=4\times10^{-9}\,sec$

(b) 另解：由於 $t\to0$，故 $F\simeq const.$

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

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

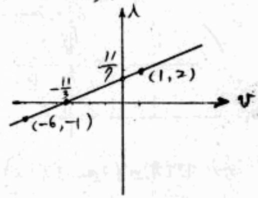
$$=\frac{(1.6\times10^{-19})^2(4\times10^{-9})^2}{4\pi\times8.854\times10^{-12}\times(50\times10^{-6})^2\times9.11\times10^{-31}}=1.62\times10^{-6}\,m$$

故 $r=d+\Delta d=50\times10^{-6}+1.62\times10^{-6}=51.62\times10^{-6}\,m$

第 二 章

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

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



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

v 截距 $i=0,\ v=-\frac{11}{3}$

i 截距 $v=0,\ i=\frac{11}{7}$

(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

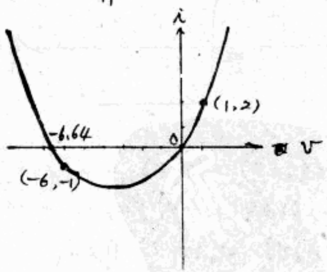
$\therefore$ v-i 曲线必需过原点 $(0,0)$，$(1,2)$，$(-6,-1)$

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

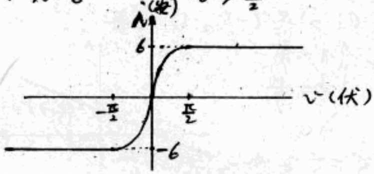
$i=\frac{11}{42}v^2+\frac{73}{42}v$

其截距需在 $|v|<6.5$ 之外

$i=0,\ v=-\frac{73}{11}=-6.64<-6.5$ 故合所求

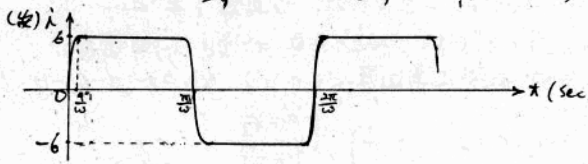


2. $\begin{cases} i = 6\sin v & |v| \le \frac{\pi}{2} \\ i = -6 & v < -\frac{\pi}{2} \\ i = 6 & v > \frac{\pi}{2} \end{cases}$



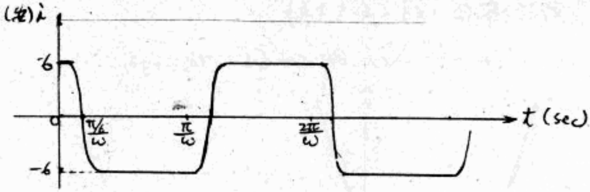
(a) $v(t) = 10\sin 377t$

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



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

$= 10\sin(377t + 150^\circ)$ 較(a)領先150°



B. 曲線坐標 (0, 0), (1, 1.8), (2, 3), (3, 4.1), (4, 5)
(5, 5.8), (6, 6.7), (7, 7.4)

$i = a_0 + a_1 v + a_2 v^2 + a_3 v^3$ 之形式

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

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

$i = 1.876v - 0.22v^2 + 0.016v^3$

(b) $v = 1$, $i = 1.672$, $\Delta i = 1.672 - 1.8 = -0.138$

$v = 3$, $i = 4.38$, $\Delta i = 4.38 - 4.1 = 0.28$

$v = 5$, $i = 5.88$, $\Delta i = 5.88 - 5.8 = 0.08$

$v = 7$, $i = 7.84$, $\Delta i = 7.84 - 7.4 = 0.44$

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

利用 trial and error

$T = 1060^\circ K$

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

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

$\therefore i = 0.8\,(A) = ne$

$$n = \frac{0.8}{e} = \frac{0.8}{1.6\times10^{-19}} = 5\times10^{18}\ \text{electrons/sec}$$

(b) 由附录B10, $V(x) = \left(\frac{x}{d}\right)^{4/3} V$

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

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

$$Q = A\int_0^d \rho(x)dx = A\int_0^d -\frac{4}{9}\frac{\epsilon_0 V}{d^{4/3}}x^{-2/3}dx$$

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

由B-10 $i(V) = 2.34\times10^{-6}\frac{A}{d^2}V^{3/2}$

$$\therefore \frac{V}{d}A = \frac{id}{2.34\times10^{-6}V^{1/2}} = \frac{0.8\times10^{-3}}{2.34\times10^{-6}\cdot\sqrt{400}} = 17.1$$

代入 $Q = -\frac{4}{3}\times8.854\times10^{-12}\times17.1 = -2.02\times10^{-10}\ C$

6. (a) 由图2-5，光通量为 0.08 lm，200V

$i_b = 4\,\mu A$

$$N = \frac{i_b t}{e} = 4\times10^{-6}\times10^{-3}/1.6\times10^{-19} = 2.5\times10^{10}\ \text{electrons}$$

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

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

(c) $W_1 = i_1 V t = 4\times10^{-6}\times200\times10^{-3} = 8\times10^{-7}$ joules

(d) $P_1 = i_1 V = 4\times10^{-6}\times200 = 8\times10^{-4}$ W

$P_2 = i_2 V = 1\times10^{-6}\times200 = 2\times10^{-4}$ W