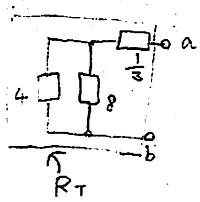
問1

(1) $E_T = 10 - \frac{4}{8+4}\cdot 16 + \frac{8\cdot 4}{8+4}\cdot\frac{1}{2}$

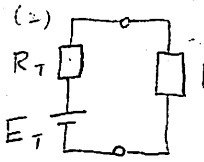
$= 6$ V



$R_T = \frac{4\cdot 8}{4+8} + \frac{1}{3}$

$= 3\ \Omega$

(2)



$P_R = \frac{1}{R}\cdot\left(\frac{RE_T}{R_T+R}\right)^2$

$= R\cdot\frac{36}{(R+3)^2}$

(3) $P_R = \frac{36}{\left(\sqrt{R}+\frac{3}{\sqrt{R}}\right)^2}$

最小値の定理から

$\sqrt{R} = \frac{3}{\sqrt{R}}$

⇔ $R = 3$ のとき P_R は最大値

$P_{Rmax} = 3$ W

問2

2013
電気回路

(1) $E = L\frac{di(t)}{dt} + v(t)$

$v(t) = \frac{1}{C}\int i(t)\,dt$ より

$i(t) = C\frac{dv(t)}{dt}$

よって

$E = LC\frac{d^2v(t)}{dt^2} + v(t)$ … ①

(2) $v(0) = -E$ [V] … ②

$\left.\frac{dv(t)}{dt}\right|_{t=0} = \frac{i(0)}{C} = 0$ … ③

(3) ①をラプラス変換して

$\frac{E}{s} = LC\{s^2V(s) - sv(0) - v'(0)\} + V(s)$

$= (1+LCs^2)V(s) + LCEs$ (∵ ②, ③)

$V(s) = \frac{\frac{E}{s} - LCEs}{LCs^2+1}$

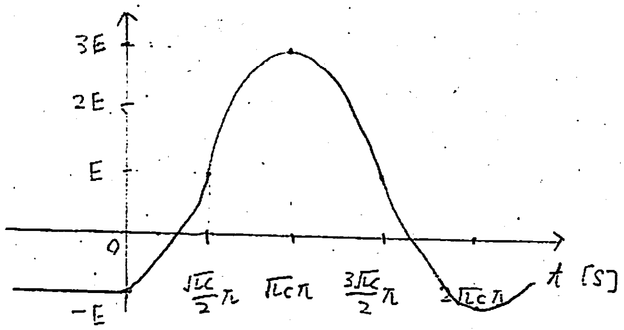
$= \frac{E}{\sqrt{LC}}\frac{1}{s}\cdot\frac{\frac{1}{\sqrt{LC}}}{s^2+\frac{1}{LC}} - E\cdot\frac{s}{s^2+\frac{1}{LC}}$

$v(t) = \frac{E}{\sqrt{LC}}\int_0^t u(t-\tau)\sin\frac{\tau}{\sqrt{LC}}d\tau - E\cos\frac{t}{\sqrt{LC}}$

$= \frac{E}{\sqrt{LC}}\int_0^t \sin\frac{\tau}{\sqrt{LC}}d\tau - E\cos\frac{t}{\sqrt{LC}}$

$= E\left\{1-\cos\frac{t}{\sqrt{LC}}\right\} - E\cos\frac{t}{\sqrt{LC}}$

$= E - 2E\cos\frac{t}{\sqrt{LC}}$



(5) $i(t) = C\frac{dv(t)}{dt}$

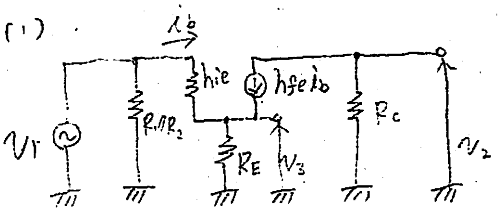
$= -2CE\left(-\frac{1}{\sqrt{LC}}\sin\frac{t}{\sqrt{LC}}\right)$

$= 2E\sqrt{\frac{C}{L}}\sin\frac{t}{\sqrt{LC}}$

$|I| = \frac{2E\sqrt{\frac{C}{L}}}{\sqrt{2}} = \sqrt{\frac{2C}{L}}\,E$

問1

(1)



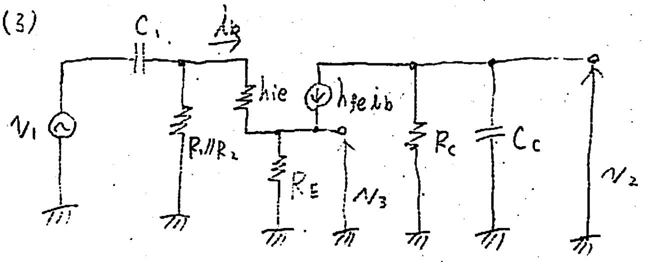
(2)
$$\begin{cases} v_1 = \{h_{ie} + R_E(1+h_{fe})\} i_b \\ v_3 = R_E(1+h_{fe}) i_b \end{cases}$$

$$A_{a2} = \frac{R_E(1+h_{fe})}{h_{ie} + R_E(1+h_{fe})}$$

$$v_2 = -h_{fe} R_C i_b$$

$$A_{a1} = \frac{-h_{fe} R_C}{h_{ie} + R_E(1+h_{fe})}$$

(3)



(4)
$$\begin{cases} \dfrac{R_1/\!/R_2}{R_1/\!/R_2 + \frac{1}{j\omega C_1}} v_1 = \{h_{ie} + R_E(1+h_{fe})\} i_b \\ v_3 = R_E(1+h_{fe}) i_b \\ v_2 = -h_{fe}\left(R_C /\!/ \frac{1}{j\omega C_C}\right) i_b \end{cases}$$

$$A_{b1} = -h_{fe}\left(R_C /\!/ \frac{1}{j\omega C_C}\right) \cdot \frac{R_1/\!/R_2}{\left(R_1/\!/R_2 + \frac{1}{j\omega C_1}\right)\{h_{ie}+R_E(1+h_{fe})\}}$$

$$= \frac{-h_{fe}(R_1/\!/R_2)}{h_{ie}+R_E(1+h_{fe})} \cdot \frac{1}{\frac{1}{R_C}(R_1/\!/R_2) + \frac{C_C}{C_1} + j\left\{\omega C_C(R_1/\!/R_2) - \frac{1}{\omega C_1 R_C}\right\}}$$

$$A_{b2} = \frac{R_E(R_1/\!/R_2)(1+h_{fe})}{h_{ie}+R_E(1+h_{fe})} \cdot \frac{1}{(R_1/\!/R_2) - j\frac{1}{\omega C_1}}$$

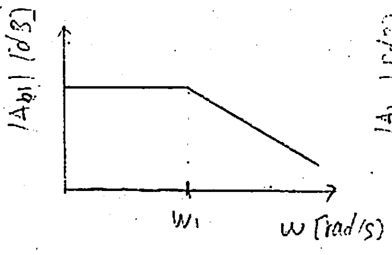
(5)
$$20\log|A_{b1}| = 20\log\left\{\frac{h_{fe}(R_1/\!/R_2)}{h_{ie}+R_E(1+h_{fe})}\right\}$$
$$-10\log\left\{\left(\frac{1}{R}(R_1/\!/R_2)+\frac{C_C}{C_1}\right)^2 + \left(\omega C_C(R_1/\!/R_2) - \frac{1}{\omega C_1 R_C}\right)^2\right\}$$

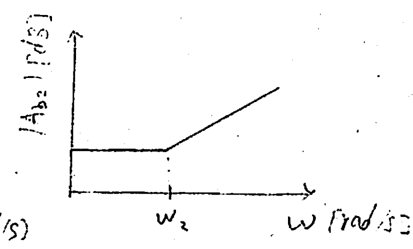
$$\left(\frac{1}{R}(R_1/\!/R_2)+\frac{C_C}{C_1}\right)^2 > \left(\omega_1 C_C(R_1/\!/R_2) - \frac{1}{\omega_1 C_1 R_C}\right)^2$$

のとき、傾き20で減衰

$$20\log|A_{b2}| = 20\log\left\{\frac{R_E(R_1/\!/R_2)(1+h_{fe})}{h_{ie}+R_E(1+h_{fe})}\right\}$$
$$-10\log\left\{(R_1/\!/R_2)^2 + \left(\frac{1}{\omega C_1}\right)^2\right\}$$

$$\omega_2 = \frac{1}{C_1(R_1/\!/R_2)}$$ 以上のとき 傾き20で上昇





問2

2013
電子回路

(1)
$$v_o = v_i$$
$$G_1 = 1$$

(2)
$$v_i = e + v_o$$
$$v_o = A_d e$$
$$v_i = \left(\frac{1}{A_d} + 1\right) v_o$$
$$G_F = \frac{A_d}{A_d + 1}$$

(3)
$$G_F = \frac{10000}{10001}$$
$$E_r = \frac{\frac{10000}{10001} - 1}{1} \times 100$$
$$= -\frac{1}{10001} \times 100$$
$$= -0.01\ \%$$

2013 電気磁気学

問1

(1) 内導体に単位長さ当たり $\lambda\,[C/m]$ の電荷を考える。

$0 \le r < a$

$$E = 0 \quad [V/m]$$

$a \le r < b$

$$\iint_S E \cdot dS = \frac{\lambda l}{\varepsilon}$$

$$E = \frac{\lambda l}{2\pi\varepsilon r l} = \frac{\lambda}{2\pi\varepsilon r} \quad [V/m] \quad \cdots ①$$

$$V_{ab} = -\int_b^a \frac{\lambda}{2\pi\varepsilon r}\,dr = \frac{\lambda}{2\pi\varepsilon}\ln\frac{b}{a} \quad [V]$$

$V_{ab} = V$ より

$$\lambda = \frac{2\pi\varepsilon}{\ln\frac{b}{a}} V$$

①に代入して

$$E = \frac{V}{\left(\ln\frac{b}{a}\right) r} \quad [V/m]$$

(2)

$$C = \frac{\lambda}{V_{ab}} = \frac{2\pi\varepsilon}{\ln\frac{b}{a}} \quad [F/m]$$

(3)

$$U = \frac{1}{2}CV^2 = \frac{\pi\varepsilon}{\ln\frac{b}{a}} V^2$$

(4)

$$F = \lambda E(a) = \frac{\lambda^2}{2\pi\varepsilon a} = \frac{2\pi\varepsilon}{a\left(\ln\frac{b}{a}\right)^2} V^2 \quad [N/m^2]$$

(5)

$t = \ln\frac{b}{a} > 0$ とおくと

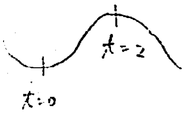
$$a = b\varepsilon^{-t}$$

$$F = \frac{2\pi\varepsilon}{b t^2 \varepsilon^{-t}} V^2 = \frac{2\pi\varepsilon}{b} V^2 \cdot \frac{1}{f(t)}$$

$f(t) = t^2\varepsilon^{-t}$ が最大になればよい

$$f'(t) = 2t\varepsilon^{-t} - t^2\varepsilon^{-t} = t\varepsilon^{-t}(2-t) = 0,\quad t = 2$$

よって $f(t)$ は $t = 2$ のとき最大



$$2 = \ln\frac{b}{a}$$

よって

$$a = \frac{b}{\varepsilon^2}$$

問2

(1)

$$H = \frac{I_1}{2\pi r} - \frac{I_1}{2\pi\{r-(b+c+d)\}} \quad [A/m]$$

(2)

$$d\Phi = \mu_0 H(r)\, l\, dr$$

$$\Phi = \int_a^{b+c+d-a} \mu_0 H(r)\, l\, dr$$

$$= \frac{\mu_0 l I_1}{2\pi}\left[\ln\left\{\frac{r}{r-(b+c+d)}\right\}\right]_a^{b+c+d-a}$$

$$= \frac{\mu_0 l I_1}{2\pi}\ln\left\{\frac{b+c+d-a}{-a}\cdot\frac{a-(b+c+d)}{a}\right\}$$

$$= \frac{\mu_0 l I_1}{\pi}\ln\left\{\frac{b+c+d-a}{a}\right\} \quad [Wb]$$

$$L_i = \frac{\Phi}{l I_1} = \frac{\mu_0}{\pi}\ln\left\{\frac{b+c+d-a}{a}\right\} \quad [H]$$

(3)

$$d\Phi_{21} = \mu_0 H(r)\, c\, dr$$

$$\Phi_{21} = \int_b^{b+c} \mu_0 c H(r)\, dr$$

$$= \frac{\mu_0 c I_1}{2\pi}\left[\ln\left\{\frac{r}{r-(b+c+d)}\right\}\right]_b^{b+c}$$

$$= \frac{\mu_0 c I_1}{2\pi}\ln\left\{\frac{b+c}{-d}\cdot\frac{-c-d}{b}\right\}$$

$$= \frac{\mu_0 c I_1}{2\pi}\ln\left\{\frac{(b+c)(c+d)}{bd}\right\} \quad [Wb]$$

$$M = \Phi_{21}/I_1 = \frac{\mu_0 c}{2\pi}\ln\left\{\frac{(b+c)(c+d)}{bd}\right\} \quad [H]$$

(4)

$$\Phi_{21} = \frac{\mu_0 c}{2\pi}\ln\left\{\frac{(b+c)(c+d)}{bd}\right\} I_0\cos\omega t$$

$$v = -\frac{d\Phi_{21}}{dt} = \frac{\mu_0 c I_0 \omega}{2\pi}\ln\left\{\frac{(b+c)(c+d)}{bd}\right\}\sin\omega t$$

(5)

$$F = I_2\mu_0\sin\frac{\pi}{2}\left(H(b+c) - H(b)\right)$$

$$= \frac{\mu_0 I_1 I_2}{2\pi}\left\{\frac{1}{b+c} + \frac{1}{d} - \frac{1}{b} - \frac{1}{c+d}\right\}$$

$$= \frac{\mu_0 I_1 I_2}{2\pi}\cdot\frac{-c(d-b)(b+c+d)}{bd(b+c)(c+d)} \quad [N] < 0$$

向き：左

大きさ：

$$F = \frac{\mu_0 I_1 I_2 c(d-b)(b+c+d)}{2\pi bd(b+c)(c+d)} \quad [N]$$