2016

שאלה 1

$$GH(s) = \frac{K}{s(s+2)(s+4)}$$

א) 1)

$$\beta = \frac{(2h+1)180}{n-m} = \frac{(2h+1)180}{3}$$

$$\boxed{\beta = 60°, 180°, 300°}$$

$$\sigma_0 = \frac{0+(-2)+(-4)}{3} = -2$$

$$\boxed{\sigma_0 = -2}$$

2) חיתוך עם ציר x

$$\frac{1}{b} + \frac{1}{b+2} + \frac{1}{b+4} = 0$$

$$3b^2 + 12b + 8 = 0$$

$$b = \begin{cases} -0{,}845 \\ -3{,}15 \end{cases}$$

$$\boxed{b = -0{,}845}$$

חיתוך עם ציר y

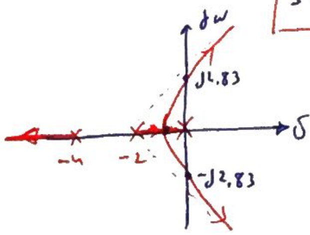
$$P(s) = s^3 + 6s^2 + 8s + K$$

$$s^3 + 8s = 0 \Rightarrow s^2 + 8 = 0$$

$$s = \pm j\sqrt{8}$$

$$\boxed{s = \pm j2{,}83}$$

3)



ב)

s^3	1	8
s^2	6	K
s^1	$\frac{48-K}{6}$	
s^0	K	

$$\frac{48-K}{6} > 0$$

$$\left.\begin{matrix} K < 48 \\ K > 0 \end{matrix}\right\} \quad \boxed{0 < K < 48}$$

שאלה 2

$$\frac{C}{R} = \frac{s+2}{s^2+2s+5}$$

א)

$$\boxed{C(s) = \frac{s+2}{s(s^2+2s+5)}}$$

$$C(s) = \frac{s+2}{s(s^2+2s+5)} = \frac{A}{s} + \frac{Bs+C}{s^2+2s+5}$$

$$A(s^2+2s+5) + (Bs+C)s = s+2$$

$$s=0 \Rightarrow A \cdot 5 = 2 \Rightarrow \boxed{A = 2/5}$$

$$s=1 \Rightarrow \frac{2}{5}8 + B + C = 3 \Rightarrow B + C = -1/5$$

$$s=-1 \Rightarrow \frac{2}{5} \cdot 4 + (B+C)(-1) = 1 \Rightarrow B - C = -3/5$$

$$2B = -4/5 \Rightarrow \boxed{B = -\frac{2}{5}}$$

$$\boxed{C = 1/5}$$

ב)

$$C(s) = \frac{0{,}4}{s} + \frac{-0{,}4s + 0{,}2}{s^2+2s+5} = \frac{0{,}4}{s} - 0{,}4\frac{s-0{,}5}{(s+1)^2+2^2}$$

$$c(t) = 0{,}4 - \frac{0{,}4\sqrt{(-1{,}5)^2+4}}{2} e^{-t} \sin(2t+\phi) \qquad \begin{matrix} a=1 \\ b=2 \\ \alpha=-0{,}5 \end{matrix}$$

$$\phi = \tan^{-1}\frac{2}{-1{,}5} = 180 - 53 = 127°$$

$$\boxed{c(t) = 0{,}4 - 0{,}5e^{-t}\sin(2t+127°)}$$ או $0{,}4 - 0{,}4e^{-t}\cos 2t + 0{,}3e^{-t}\sin 2t$

2,2 rad

ג)

$$t = 0{,}5 \Rightarrow \boxed{C = 0{,}42}$$

שאלה 3

א)

$$GH = \frac{K(s+1)^2}{(s+10)^2}$$

$$20\log\frac{K \cdot 1^2}{10^2} = 8 \Rightarrow K = 251$$

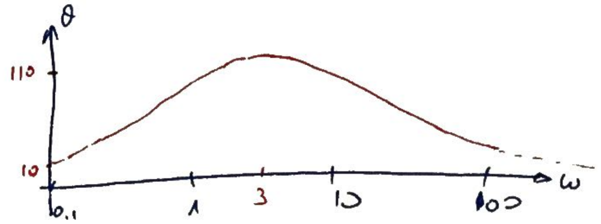
$$\boxed{GH = \frac{251(s+1)^2}{(s+10)^2}} = \boxed{\frac{2{,}51(1+s/1)^2}{(1+s/10)^2}}$$

ב) kd

ג)

$$\theta = 2\tan^{-1}\frac{\omega}{1} - 2\tan^{-1}\frac{\omega}{10}$$

ω	0	0,1	0,3	1	3	10	30	100	∞
θ	0	10°	30°	79°	110°	79°	33°	10°	0



שאלה 4

$$GH(s) = \frac{8(s+6)}{s^2(s+8)}$$

א)

$$\boxed{3 = \text{סוג המערכת}}$$

ב) סוג 2

$$\boxed{K_p = \infty} \quad -1$$

$$\boxed{K_v = \infty} \quad -2$$

$$K_a = \lim_{s\to 0} s^2 \frac{8(s+6)}{s^2(s+8)} = 6$$

$$\boxed{K_a = 6} \quad -3$$

ג)

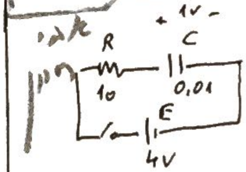
עבור $R(s) = \frac{5}{s^2}$

$$e_{ss} = \frac{5}{K_v} = \frac{5}{\infty} = 0$$

$$\boxed{e_{ss} = 0}$$

2015

שאלה 1



א) $E(t) = R\cdot I(t) + \frac{1}{C}\int I\,dt$

$E'(t) = R\,I'(t) + \frac{1}{C} I(t)$

$R I'(t) + \frac{1}{C} I(t) = 0$

$10 I'(t) + 100 I(t) = 0$

$\boxed{I'(t) + 10 I(t) = 0}$ משוואה דיפרנציאלית

ב) $I(0) = \frac{E - V_C(0)}{R} = \frac{4-1}{10}$

$\boxed{I(0) = 0{,}3\ A}$

ג) $S I(s) - I(0) + 10 I(s) = 0$

$I(s)(S+10) = 0{,}3$

$I(s) = \frac{0{,}3}{s+10}$

$\boxed{I(t) = 0{,}3\, e^{-10t}}$

שאלה 2

$GH = \frac{K}{s(s+1)(s+3)(s+4)}$

א)

$S_1 = 0$	$S_2 = -1$	$S_3 = -3$	$S_4 = -4$

ב) $\sigma_0 = \frac{\sum Re(P_i) - \sum Re(Z_i)}{n-m} = \frac{0+(-1)+(-3)+(-4)}{4}$

$\boxed{\sigma_0 = -2}$ מרכז אסימפטוטות

$\beta = \frac{(2k+1)180}{4} = \boxed{45^\circ, 135^\circ, 225^\circ, 315^\circ}$

ג) משוואה אופיינית —

$P(s) = s(s+1)(s+3)(s+4) + K$

$P(s) = s^4 + 8s^3 + 19s^2 + 12s + K$

s^4	1	19	K
s^3	8	12	0
s^2	17.5	K	
s^1	$\frac{210-8K}{17.5}$		
s^0	K		

1) $210 - 8K > 0$

$K < 26.25$

2) $K > 0$

$0 < K < 26{,}25$

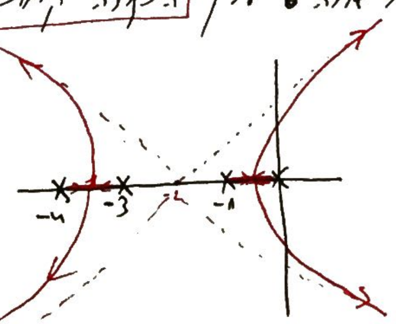
$\boxed{K = 26{,}25 \quad , \quad K = 0}$ — נק' חיתוך

ד) $s = -3.5$ נק' זו במקום $K = \frac{35}{16}$ —

$(-3.5)^4 + 8(-3.5)^3 + 19(-3.5)^2 + 12(-3.5) + \frac{35}{16} = 0$

נקודה זו היא לכן $\boxed{\text{הנקודה היא על } RL}$

ה) 2ע

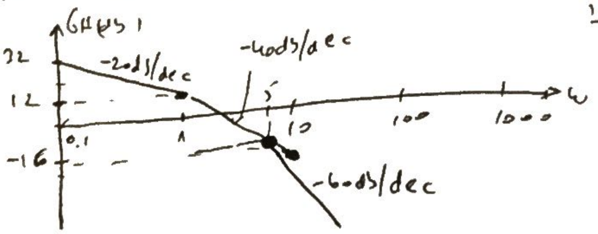


שאלה 3

$GH(s) = \frac{20(s+5)}{s(s+1)(s^2+10s+25)} = \frac{20(s+5)}{s(s+1)(s+5)^2}$

$GH(s) = \frac{20}{s(s+1)(s+5)} \overset{\omega}{\equiv} \frac{20}{j\omega(1+j\omega)(5+j\omega)}$

גובה



$20\log\frac{20}{0.1\cdot1\cdot5} = 32\,db \quad \leftarrow \quad \omega = 0.1$

פאזה

$\theta = -90^\circ - tg^{-1}\frac{\omega}{1} - tg^{-1}\frac{\omega}{5}$

ω	0.1	0.2	0.5	1	2	5	10	20	50	100	1000
θ	-97	-104	-122	-146	-175	-216	-238	-253	-263	-267	-269,7

ב)

$\omega \to 0$	$GH(db) = \infty\ db$
$\omega \to \infty$	$\theta = -270^\circ$

ג) מהגרף המקורב ←

$\boxed{GM = 2db \quad PM = 5^\circ}$ סעיף 3' — מרווח הגבר, מרווח פאזה

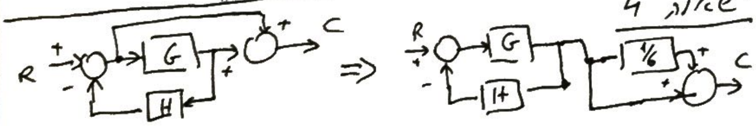
באופן חישובי מדויק

$\omega_\pi = \sqrt{5} \to GH(db) = -1.25db \to \underline{GM = 1.25db}$

$\omega_c = 2.3265 \to \theta = -182.6 \to \underline{PM = -2.6^\circ}$

סעיף 3' ד'

שאלה 4



א) $\frac{C}{R} = \left(\frac{1}{G}+1\right)\frac{G}{1+GH} = \frac{1+G}{G}\cdot\frac{G}{1+GH}$

$\boxed{\frac{C}{R} = \frac{G+1}{1+GH}}$

ב) $\frac{C}{R} = 1 \Leftarrow H = 1$

$\boxed{C(t) = t}$

ג) $\frac{C}{R} = \frac{\frac{K}{s(s+10)^2}+1}{1+\frac{K}{s(s+10)^2}\cdot(s+40)} = \frac{K + s(s+10)^2}{s(s+10)^2 + K(s+40)}$

$P(s) = s^3 + 20s^2 + 100s + Ks + 40K$

s^3	1	100+K
s^2	20	40K
s^1	a	
s^0	40K	

$a = \frac{20(100+K) - 40K}{20} = \frac{2000-20K}{20}$

1) $K < 100$

2) $K > 0$

$\boxed{0 < K < 100}$

(3

$G=\frac{2K}{(S+1)S(S+2)(S+4)}$ $H=2S+1$

$\frac{C}{R}=\frac{2K}{S(S+1)(S+2)(S+4)+2K(2S+1)}=\frac{}{S^4+7S^3+14S^2+(8+4K)S+2K}$

$S^4+7S^3+14S^2+(8+4K)S+2K$ (א

S^4	1	14	2K
S^3	7	8+4K	0
S^2	$\frac{90-4K}{7}$	2K	
S^1	a		
S^0	2K		

$a=\frac{\frac{(90-4K)}{7}(8+4K)-14K}{\frac{90-4K}{7}}$

$a=\frac{-16K^2+230K+720}{90-4K}$

(1 $\boxed{K<22.5} \Leftarrow 90-4K>0$

(2 $-16K^2+230K+720>0$ $\boxed{-2.64<K<17}$

(3 $2K>0 \Rightarrow \boxed{K>0}$

-2.64, 0, 17, 22.5

$\boxed{0<K<17}$ (ב

(ג $K_p=\lim_{s\to 0} GH=\frac{2\cdot 10\cdot(2S+1)}{S(S+1)(S+2)(S+4)}=\infty \Leftarrow K=10$

$\boxed{e_{ss}=0}$

$e_{ss} = R-C_{ss}(2S+1) = R-C_{ss}$ ($s\to 0$)

$\boxed{C_{ss}=R=1}$

(4

$GH_{(s)}=\frac{K(S+1)}{S(S+2)^3}$

(א $S_1=0$ $S_2=-2$, $S_3=-2$, $S_4=-2$ קטבים

$S=-1$ אפסים

(ב $\sigma_0=\frac{\sum Re(P_i)-\sum Re(Z_i)}{n-m}=\frac{0(-2)+(-2)+(-2)-(-1)}{4-1}$

$\boxed{\sigma_0=-1.67}$

$\beta=\frac{(2h+1)180°}{n-m}=60°, 180°, 300°$

(ג $P_{(s)}=S(S+2)^3+K(S+1)=S^4+6S^3+12S^2+(8+K)S+K$

S^4	1	12	K
S^3	6	8+K	0
S^2	$\frac{64-K}{6}$	K	0
S^1	a		
S^0	K		

$a=\frac{\frac{64-K}{6}(8+K)-6K}{\frac{64-K}{6}}$

$a=\frac{-K^2+20K+512}{64-K}>0$

1) $64-K>0$ $\boxed{K<64}$

2) $-14.7<K<34.74$

3) $K>0$

-14.7, 0, 34.74, 64

$\boxed{0<K<34.74}$

2014

(1

$\frac{V_c}{V_i}=\frac{1}{S^2LC+SCR+1}=\frac{\frac{1}{LC}}{S^2+S\frac{R}{L}+\frac{1}{LC}}=\frac{10^8}{S^2+10^4S+10^8}$ (א

$V_c=\frac{\frac{1}{SC}}{R+SL+\frac{1}{SC}}$

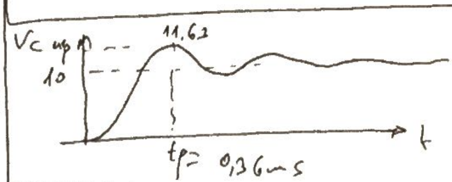
1K, 0.1H, 0.1μF, V_i, V_c

(ב $\boxed{V_c''(t)+10^4V_c'(t)+10^8V_{c(t)}=10^8V_{i(t)}}$

(ג $V_{c(s)}=\frac{10^8}{S(S^2+10^4S+10^8)}$ $V_i=\frac{10}{S}$

$\boxed{V_{c(t)}=10-11.547e^{-5000t}\sin(8.66\cdot10^3t+60)}$ $\omega_n=10^4$, $\zeta=0.5$

(ד



(2

$\boxed{GH_{(s)}=\frac{K_1(S+30)}{(S+1)(S+100)^3}}$ $\boxed{K=40}$

(א $20\log\frac{K_1\cdot 30}{1\cdot 100^3}=32 \Rightarrow \boxed{K_1=1.33\cdot10^6}$

(ב $\theta=tg^{-1}\frac{\omega}{30}-tg^{-1}\frac{\omega}{1}-3tg^{-1}\frac{\omega}{100}$

ω	0.1	0.2	0.5	1	2	5	10	20	50	100	200	500	1000
θ	-6	-11°	-26	-45	-63	-78	-83	-87	-110	-151	-199	-239	-255

(ג $PM=-160°+180=20°$

$GM=8db$

מחשב: $\omega_\pi=150.5$, $GM=12.8db$, $\omega_1=56$, $PM=65°$

(ד $8db \Leftarrow 35db$

$20\log K^*=-27$

$K^*=0.0446$

$K_2=K_1\cdot K^*=1.33\cdot10^6\cdot0.0446$

$\boxed{K_2=59\cdot10^3}$

$K_2=1.77$

$\omega=0$

$32-27=5db$

$20\log\frac{K_2\cdot 30}{1\cdot 100^3}=5$

$K_2=59\cdot10^3$

(ד

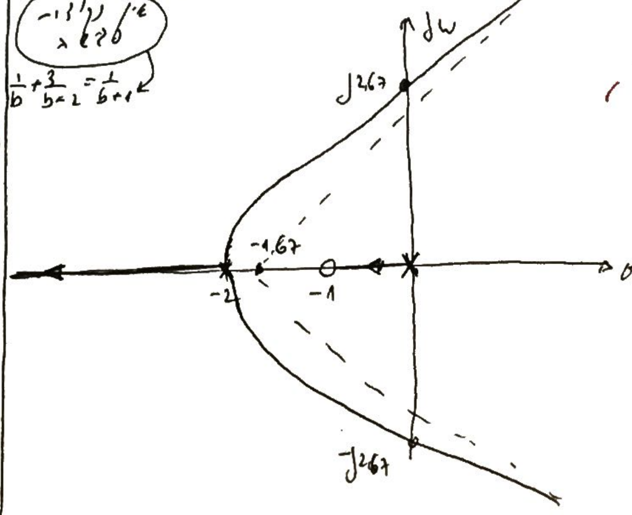
$6S^3+(8+K)S=0$

$S(6S^2+8+34.74)=0$

$\boxed{S=\pm j2.67}$

$\frac{1}{b}+\frac{3}{b+2}=\frac{1}{b+1}$

(ה



K013

שאלה 3

$$GH(s)=\frac{1}{10}\cdot\frac{(1+25\cdot10^{-3}s)}{2\cdot10^{-3}s}\cdot\frac{K}{s}\cdot\frac{1}{20}$$

$$=\frac{0.0625K(s+40)}{s^2}$$

א) קטבים: $s_1=0,\ s_2=0$

אפסים: $s=-40$

ב)
$$\frac{1}{b}+\frac{1}{b}-\frac{1}{b+40}=0$$

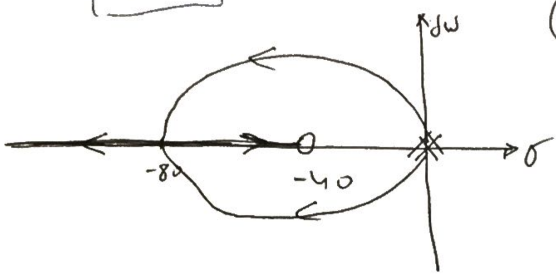
$$2(b+40)-b=0$$

$$b+80=0$$

$b_1=-80$ — נק' חיתוך ציר x

$b_2=0$

ג)



שאלה 4

$$GH=\frac{20}{s(s+1)(s+2)}$$

א)
$$K_p=\lim_{s\to0}\frac{20}{s(s+1)(s+2)}=\infty$$

$$K_v=\lim_{s\to0}s\frac{20}{s(s+1)(s+2)}=10$$

$$K_a=\lim_{s\to0}s^2\frac{20}{s(s+1)(s+2)}=0$$

ב)
מדרגה יחידה $e_{ss}=\frac{1}{1+K_p}=\frac{1}{1+\infty}=0$

שיפוע $e_{ss}=\frac{1}{K_v}=\frac{1}{10}=0.1$

$$e_{ss}=\frac{1}{K_a}=\frac{1}{0}=\infty$$

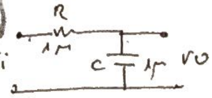
ג) עבור מדרגה נקבל שגיאה 0 לכן מתאים לבקרה מלאה, $e_{ss}=0$

הערה – המצב לא יציבה

$$s^3+3s^2+2s+20$$

s^3	1	2	0
s^2	3	20	
s^1	$\frac{6-20}{3}=\left(-\frac{14}{3}\right)$		
s^0	20		

שאלה 1



$V_i=5e^{-t}$

$V_{C(0)}=1V$

א)
$$V_o=V_c=\frac{1}{C}\int I\,dt\Rightarrow I(t)=C\,V_o'(t)$$

$$V_{in}(t)=IR+V_o(t)$$

$$V_{in}(t)=RC\,V_o'(t)+V_o(t)$$

ב)
$$V_i(t)=5e^{-t}\to V_i(s)=\frac{5}{s+1}$$

$$RC\left(sV_o(s)-V_o(0)\right)+V_o(s)=\frac{5}{s+1}$$

$$sV_o(s)-1+V_o(s)=\frac{5}{s+1}$$

$$(s+1)V_o(s)=1+\frac{5}{s+1}$$

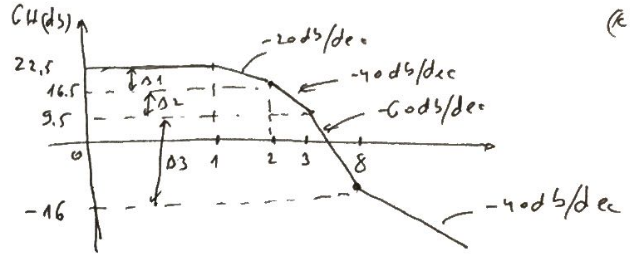
$$V_o(s)=\frac{1}{s+1}+\frac{5}{(s+1)^2}$$

$$V_o(t)=e^{-t}+5te^{-t}$$

שאלה 2

$$GH(s)=\frac{10(s+8)}{(s+1)(s+2)(s+3)}$$

א)



הגבר $\Rightarrow GH=20\log\frac{80}{1\cdot2\cdot3}=22.5db$

$$\Delta1=-20\log\frac{2}{1}=-6db$$

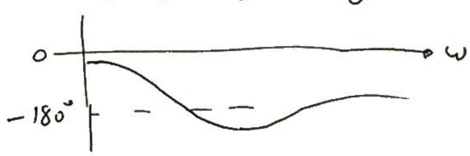
$$\Delta2=-40\log\frac{3}{2}=-7db$$

$$\Delta3=-60\log\frac{8}{3}=-25.6db$$

מופע

ω	0	0.1	0.2	0.3	0.5	1	2	3	8	10	∞
θ	0°	-10°	-19°	-29°	-46°	-83°	-128	-152	-183°	-184°	-180

$$\theta=tg^{-1}\frac{\omega}{8}-tg^{-1}\frac{\omega}{1}-tg^{-1}\frac{\omega}{2}-tg^{-1}\frac{\omega}{3}$$



ב)
$\omega=0\Rightarrow GH=22.5db$

$\omega\to\infty\Rightarrow\theta=-180°$

ג) מהגרף

$\omega_1\Rightarrow\theta=-168°\Rightarrow PM=180+-168$

$PM=12°$ עודף מופע

$\omega_\pi\Rightarrow GH=-10db\Rightarrow GM=10db$ עודף מופע

$GM=9.5db$

$PM=15°$

מצוין