49/60

1a.

$$\tau_{th} = \frac{K}{Ls+R} V$$

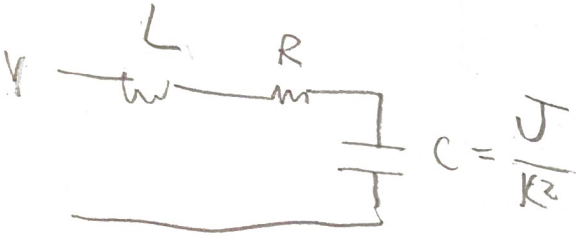
$$Z_{th} = \frac{\tau}{\omega} \quad \tau = \frac{K^2}{Ls+R} \qquad \tau = \tau_{ext}$$

$$k_{th} = \frac{K^2}{L}$$

$$b_{th} = \frac{K^2}{R} + b$$

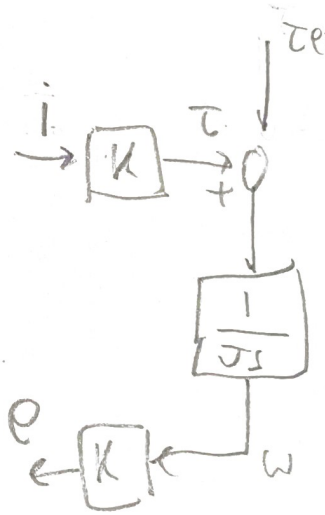
Missing 'b'

-1



$$Z_{eq} = Ls + R + \frac{K^2}{Js}$$

b $\quad i = V/Z_{eq} \rightarrow V = \frac{1}{s}$



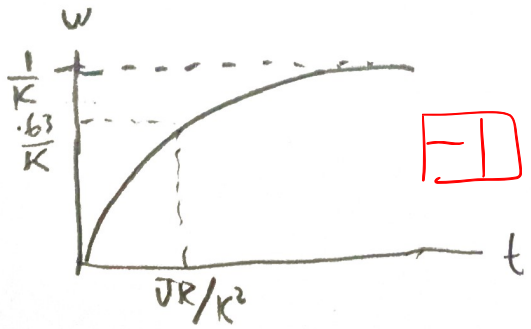
τ_{ext} = 0 since ω & τ_{ext} are constant

$$\omega(s) = \frac{K}{Js}\left(\frac{V}{Ls + R + \frac{K^2}{Js}}\right)$$

$$= \left(\frac{K}{sJR + K^2}\right)\left(\frac{1}{s}\right)$$

$$= \left(\frac{-1/K}{s + K^2/JR}\right) + \left(\frac{1/K}{s}\right)$$

$$\omega(t) = \frac{-1}{K} e^{-K^2/JR\, t} + \frac{1}{K} = \frac{1}{K}\left(-e^{-K^2/JR\, t} + 1\right)$$



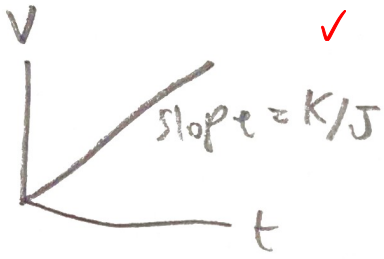
-1

Missing 'b'

c. open → $V = e$ → $i = 0$ ✓

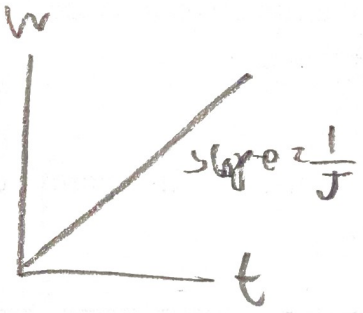
$\tau = \tau_{ext}$ → $\theta = \frac{K}{Js}\tau$

$V(s) = \frac{K/J}{s^2}$



✓ −1 Missing b

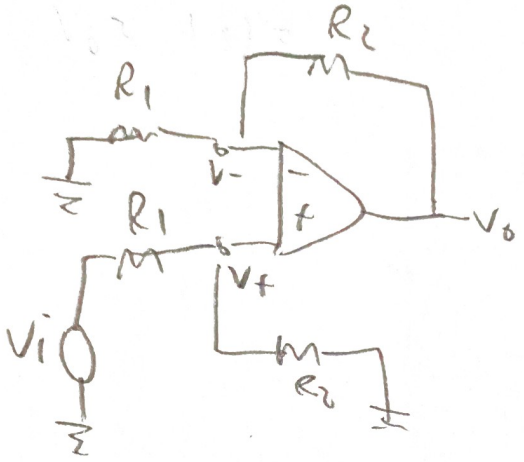
d. $w = \frac{1}{Js}\tau_{ext} = \frac{1}{Js^2}$



−3

Expect steady-state speed.

2a.



Op Amp

$V_o = A(s)(V_+ - V_-)$

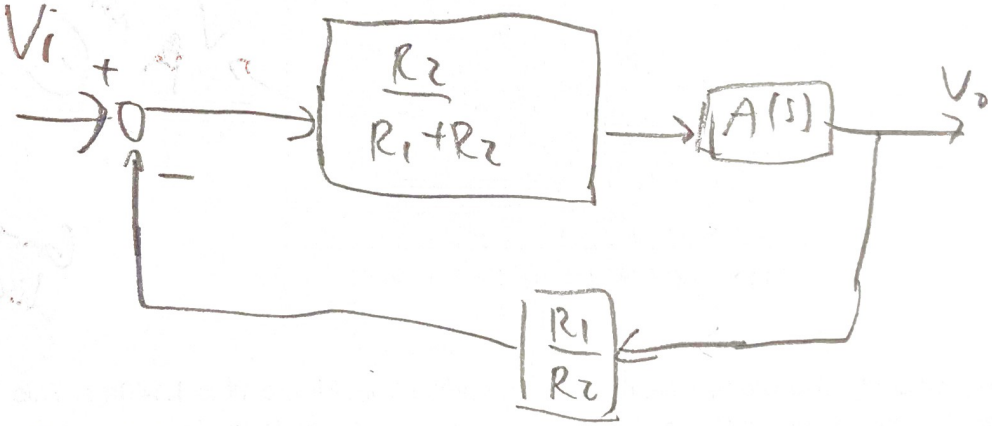
KCL

$0 = \frac{V_- - V_o}{R_2} + \frac{V_- - 0}{R_1} \rightarrow V_- = \left(\frac{R_1}{R_1+R_2}\right) V_o$

$0 = \frac{V_+ - 0}{R_2} + \frac{V_+ - V_i}{R_1} \rightarrow V_+ = \left(\frac{R_2}{R_1+R_2}\right) V_i$

$V_o = A(s)\left(\frac{R_2}{R_1+R_2} V_i - \frac{R_1}{R_1+R_2} V_o\right)$

$= A(s)\left(\frac{R_2}{R_1+R_2}\right)\left(V_i - \frac{R_1}{R_2} V_o\right)$



✓

b. $L(s) = \left(\frac{R_2}{R_1+R_2}\right) A(s) \frac{R_1}{R_2} = \frac{R_1}{R_1+R_2} A(s) = f A(s)$ ✓

$f = \frac{R_1}{R_1+R_2}$

c. $f = \frac{1k}{1k+1k} = \frac{1}{2}$

$|L(j\omega_c)| = 1 \rightarrow |A(j\omega_c)| = 2 \rightarrow \omega_c = 5 \times 10^6$ Hz ✓

$= 2 \times 10^0$

$\phi_m = -105^\circ + 180^\circ = 75^\circ$

d. $G(s) \neq \frac{L(s)}{1+L(s)}$

$[10K = 10^4]$

$|G(jw)|_{10KHz} = -3dB = \frac{1}{\sqrt{2}}$

$\frac{1}{\sqrt{2}} = \left| \frac{FA(jw)|_{10KHz}}{1+FA(jw)|_{10KHz}} \right| = \left| \frac{f(10^3 \angle -90^\circ)}{1+f(10^3 \angle 90^\circ)} \right|$

$\frac{1}{\sqrt{2}} = \left| \frac{f(-j10^3)}{1+f(-j10^3)} \right| \rightarrow f = \frac{1}{1000} = 10^{-3}$

$f = \frac{R_1}{R_1+R_2} \rightarrow R_2 = 999K\Omega$ ✓

e. $|G(jw)|_{w=0} \neq \frac{FA(jw)|_{w=0}}{1+FA(jw)|_{w=0}} = \frac{10^6/10^3}{1+10^6/10^3} = 0.999 \approx 1$

-2

f. $w = 2\pi \times 10^7$ rad/s $= 10^7$ Hz

✓ $|A(jw)|_{w=10^7} = 1$

$\angle A(jw)|_{w=10^7} = -120^\circ$

$A(jw)|_{w=10^7} = 1 \angle -120^\circ$

$= -.5 - j.866$

$G(jw)|_{w=10^7} \neq \frac{FA}{1+FA} = \frac{(-.5-j.866)/1000}{1010+(-.5-j.866)/1000}$

$= -.005024 - j8.748 \times 10^{-4}$

$M_0 = |G|_{w=10^7} = \sqrt{.005^2 + (8.7 \times 10^{-4})^2}$

$= .0051$

$\phi_0 = \angle G_{w=10^7} = -\tan^{-1}\left(\frac{.005}{8.7 \times 10^{-4}}\right) - 90^\circ$

$= -170^\circ$

-3