Problem 1

Tuesday, April 6, 2021

(1) $80 + 40 = 120\text{ mH}$

$120\text{mH} \parallel 20\text{mH} = \frac{120 \cdot 20}{120+20} = 17.14\text{mH}$

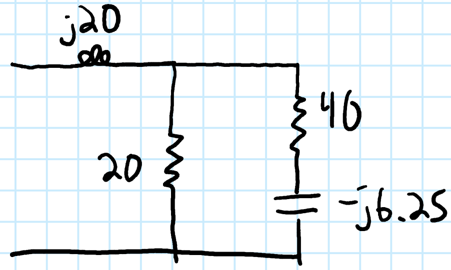
$17.14\text{mH} + 10\text{ mH} = 27.14\text{mH}$

(2) $\frac{40 \cdot 80}{40+80} = 26.67\,\mu\text{F}$

$26.67 + 20 = 46.67\,\mu\text{F}$

$\frac{46.67 \cdot 10}{46.67+10} = 8.235\,\mu\text{F}$

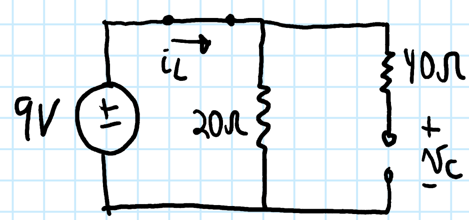
(3) @ 2000 rad/s:



$(40 - j6.25) \parallel 20 = 13.42\angle{-2.934°}$

$13.42\angle{-2.934°} + j20 = 23.51\angle 55.24°\ \Omega = 13.41 + j19.31\ \Omega$

(4) DCSS:



NO CURRENT IN 40Ω!

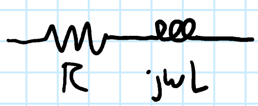
$i_L = \frac{9}{20} = 0.45\text{ A}$ $\quad E = \frac{1}{2}Li^2 = 1.0125\text{ mJ}$

$v_C = 9\text{V}$ $\quad E = \frac{1}{2}Cv^2 = 3.240\text{ mJ}$

$E_R = 0$ ALWAYS!

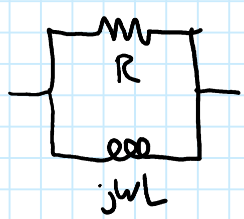
(5) $Z = 700 + j100\ \Omega$ $\quad X > 0$ MEANS INDUCTOR

(a)



$R = 700\Omega$ $\quad \omega L = 100 \Rightarrow L = \frac{100}{5000} = 20\text{mH}$

(b)



$Y = \frac{1}{Z} = 1.4 - 0.2j\text{ m℧} = \frac{1}{R} + \frac{1}{j\omega L}$

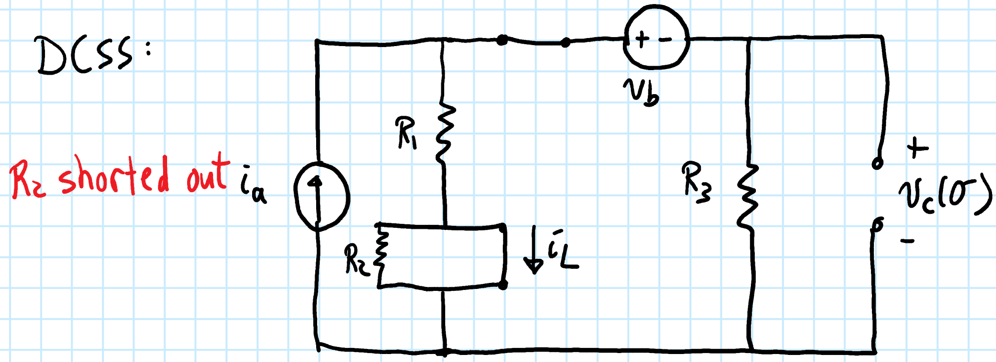
$R = \frac{1}{1.4 \cdot 10^{-3}} = 714.3\ \Omega$

$L = \frac{1}{0.2 \cdot 10^{-3} \cdot 5000} = 1\text{ H}$

Problem 2

Tuesday, April 6, 2021

(1) DCSS:

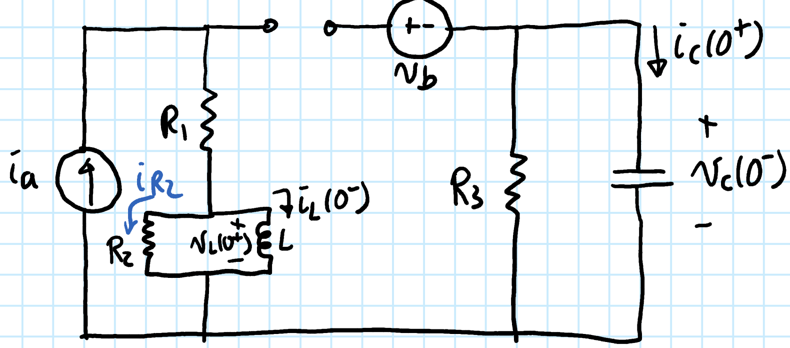


$$v_c(0^-) = i_a(R_1 \| R_3) - \frac{v_b R_3}{R_1 + R_3} = \frac{i_a R_1 R_3 - v_b R_3}{R_1 + R}$$

$i_c(0^-) = 0$ AND $v_L(0^-) = 0$

$$i_L(0^-) = \frac{i_a(R_1 \| R_3)}{R_1} + \frac{v_b}{R_1 + R_3} = \frac{i_a R_3 + v_b}{R_1 + R_3}$$

$t = 0^+$



$v_c(0^+) = v_c(0^-)$ AND $i_L(0^+) = i_L(0^-)$

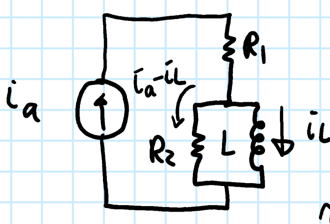
$v_L(0^+) = R_2(i_a - i_L(0^-))$ BCM $\quad i_{R_2} = i_a - i_L(0^-)$

$v_c(0^+) = -R_3 i_c(0^+)$

---

(2) $$i_L(0^-) = \frac{i_a(R_1 \| R_3)}{R_1} + \frac{v_b}{R_1 + R_3} = (4 - 2) = 2\text{ mA}$$

$t > 0$:

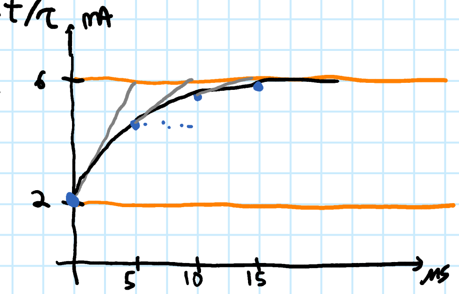


$R_2(i_L - i_a) + L\frac{di_L}{dt} = 0$ KVL, right

$\frac{L}{R_2}\frac{di_L}{dt} + i_L = i_a$

$\tau = \frac{L}{R_2} = 5\,\mu s \quad i_{L,\infty} = i_a = 6\text{ mA}$

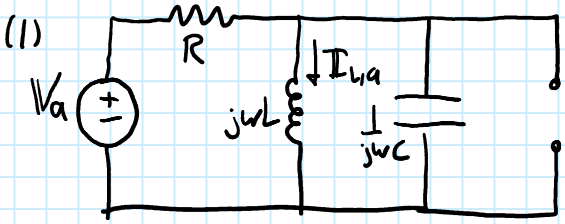
$$i_L(t) = i(\infty) + (i(0) - i(\infty))e^{-t/\tau}$$
$$= (6 - 4e^{-t/5\cdot10^{-6}})\text{ mA}$$



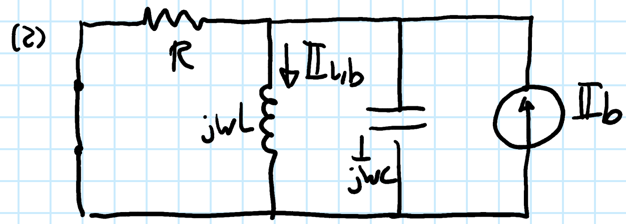
Problem 3

Tuesday, April 6, 2021

(1)



(2)



$$\mathbb{Z}_{LC} = \frac{\frac{j\omega L}{j\omega C}}{j\omega L + \frac{1}{j\omega C}} = \frac{j\omega L}{(j\omega)^2 LC + 1}$$

$$\mathbb{Z}_{LRC} = R \,||\, j\omega L \,||\, \frac{1}{j\omega C} = \frac{1}{\frac{1}{R} + \frac{1}{j\omega L} + j\omega C} = \frac{j\omega L R}{(j\omega)^2 LRC + j\omega L + R}$$

V. DIVISION, OHM'S LAW

$$\mathbb{I}_{L,a} = \frac{\mathbb{Z}_{LC}\mathbb{V}_a}{R + \mathbb{Z}_{LC}} \cdot \frac{1}{j\omega L} = \frac{\frac{j\omega L}{(j\omega)^2 LC + 1}}{R + \frac{j\omega L}{(j\omega)^2 LC + 1}} \frac{\mathbb{V}_a}{j\omega L} = \frac{\mathbb{V}_a}{(j\omega)^2 LRC + j\omega L + R}$$

I. DIVISION

$$\mathbb{I}_{L,b} = \frac{\mathbb{Z}_{LRC}\,\mathbb{I}_b}{j\omega L} = \frac{R\,\mathbb{I}_b}{(j\omega)^2 LRC + j\omega L + R}$$

$$\mathbb{H}_a = \frac{\mathbb{I}_{L,a}}{\mathbb{V}_a} = \frac{1}{(j\omega)^2 LRC + j\omega L + R}$$

$$\mathbb{H}_b = \frac{\mathbb{I}_{L,b}}{\mathbb{I}_b} = \frac{R}{(j\omega)^2 LRC + j\omega L + R}$$

ω	$\mathbb{V}_a$	$\mathbb{H}_a$	$\mathbb{I}_b$	$\mathbb{H}_b$	$\mathbb{I}_L$
0	3	.001	.008	1	.011
8000	$6\angle 19^\circ$	$4.166 \cdot 10^{-4}\angle -89.05^\circ$	0	X	$.002500\angle -70.05^\circ$
20000	0	X	$.005\angle -117^\circ$	$0.128\angle -130^\circ$	$.0006402\angle 113^\circ$

$$i_L(t) = 11 + 2.5\cos(8000t - 70.05^\circ) + 0.6402\cos(20000t + 113^\circ) \quad \text{mA}$$

(4)/(5) LOOKS LIKE LOW; CHECK DAMPING

$$(j\omega)^2 LRC + j\omega L + R \rightarrow (j\omega)^2 + j\omega \frac{1}{RC} + \frac{1}{LC}$$

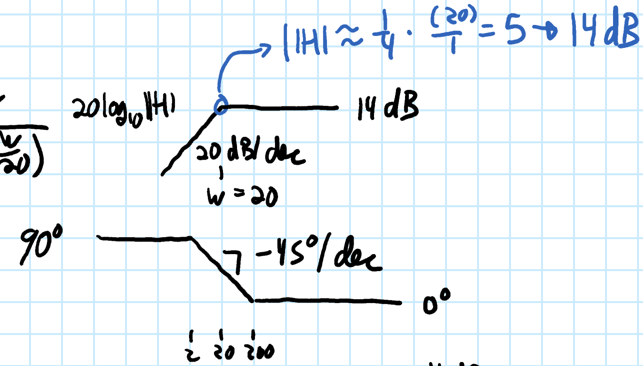
$$\omega_n = \sqrt{\frac{1}{LC}} = 8165 \qquad 2\zeta\omega_n = \frac{1}{RC} \qquad \zeta = \frac{1}{2\omega_n RC} = 1.225$$

OVERDAMPED → LPF!

Problem 4

Tuesday, April 6, 2021

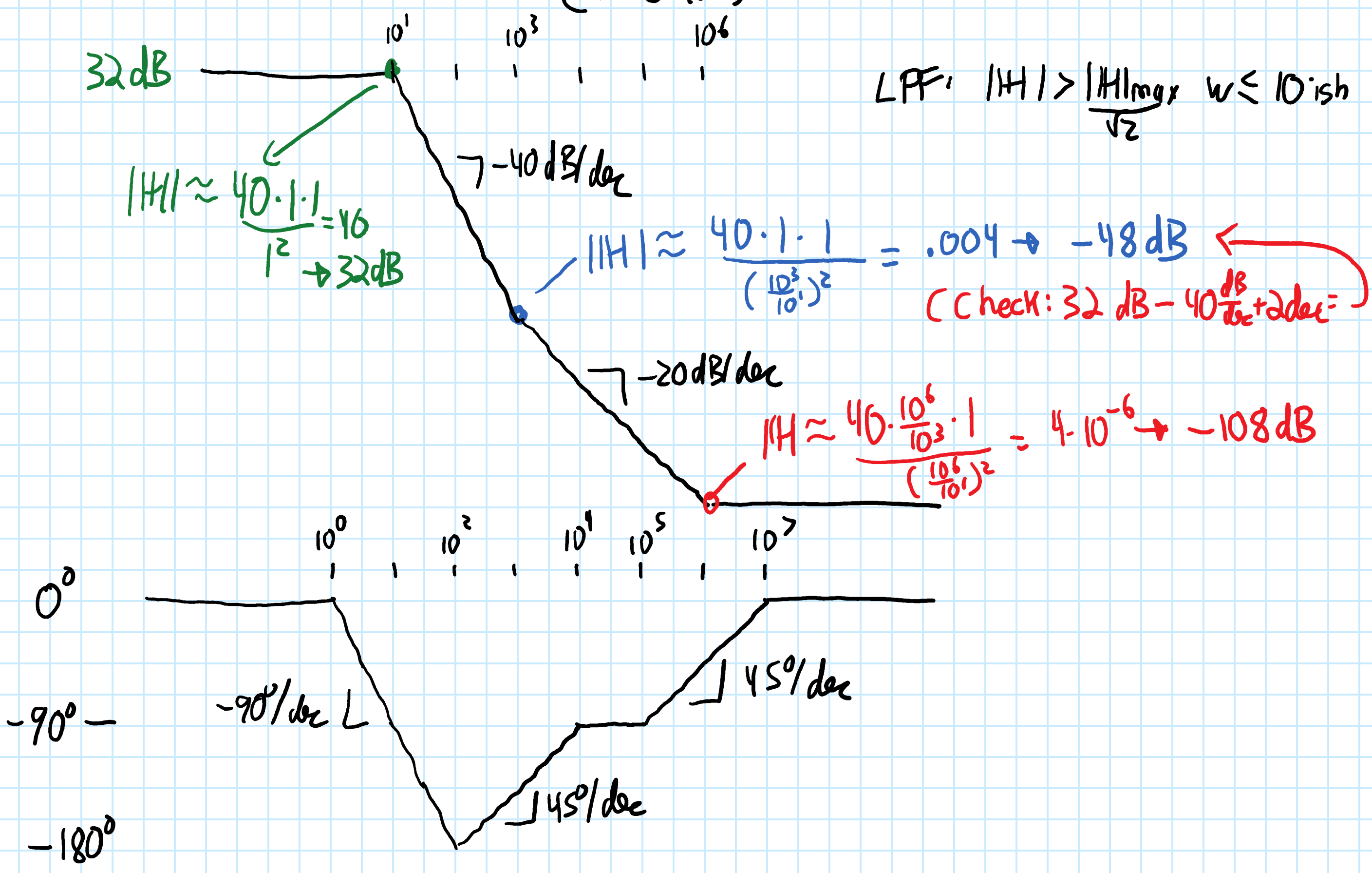
(1) $$\frac{5j\omega}{j\omega+20} = \frac{1}{4}\,\frac{j\omega}{\left(1+j\frac{\omega}{20}\right)}$$



(c) HPF, $|H| > \frac{|H|_{max}}{\sqrt{2}}$ $\omega \geq 20$, MAX GAIN = 5 or 14 dB

(d) $(j\omega+20)V_{out} = 5j\omega V_{in} \to \frac{dV_{out}(t)}{dt} + 20V_{out}(t) = 5\frac{dV_{in}(t)}{dt}$

(2) $$H_2(j\omega) = 40\,\frac{\left(1+j\frac{\omega}{10^3}\right)\left(1+j\frac{\omega}{10^6}\right)}{\left(1+j\frac{\omega}{10^1}\right)^2}$$



(c) LPF, $|H| > \frac{1}{\sqrt{2}}|H|_{MAX}$ FOR $W < 10$ ISH

MAX GAIN = 40 or 32 dB

$(2\cdot 2\cdot 10 \to 6\,dB + 6\,dB + 20\,dB)$