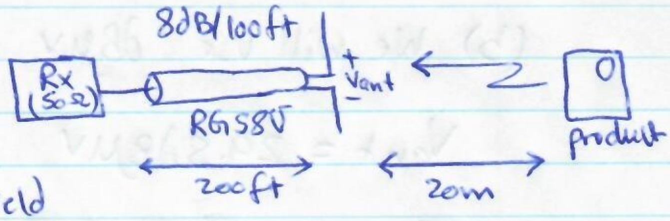
HW1 Solution

$\boxed{Q1}$ $f_0 = 220$ MHz

$P_{RX} = -93.5$ dBm

Ant provids 1.5V/ 1V/m E-field



(a)

5 pts

$$-93.5\text{ dBm} \Rightarrow P|_{mW} = 10^{\frac{-93.5}{10}} = 4.467 \times 10^{-10} \text{ mW}$$

$$P_W = 0.4467 \times 10^{-12} \text{ W}$$

$$V_{rec}|_{50\Omega} = \sqrt{50 \times P_W} = 4.726 \times 10^{-6} \text{ V}$$

$$\rightarrow V_{rec}|_{\mu V} = 20\log_{10}\left(\frac{4.726 \times 10^{-6}}{10^{-6}}\right) = \boxed{13.49 \text{ dB}\mu\text{V}}$$

or $$V_{rec}|_{mV} = 20\log_{10}\left(\frac{4.726 \times 10^{-6}}{10^{-3}}\right) = \boxed{-46.51 \text{ dBmV}}$$

now, @ the Base of the antenna, add the Cable loss,

$$\therefore V_{ant} = V_{rec}|_{dBmV} + 8 \times \frac{200\text{ ft}}{100\text{ ft}} = -46.51 + 16$$

$$= -30.51 \text{ dBmV}$$

or $$V_{ant} = V_{rec}|_{dB\mu V} + 8 \times \frac{200}{100} = 13.49 \text{ dB}\mu\text{V} + 16$$

$$= \boxed{29.45 \text{ dB}\mu\text{V}}$$

Note an important relationship:

$$\boxed{\text{Value in dBm} + 107 \text{ dB} = \text{Value in dB}\mu\text{V}}$$

(b) We will use dBμV since standards are in this unit.

5 pts

$V_{ant} = 29.5\, dB\mu V$

E_{ant}: 1 V/m ⟶ 1.5 V @ ant output terminals

$E_{ant} \longrightarrow 29.5\, dB\mu V$

$E_{ant} \longleftrightarrow 29.854\, \mu V$

$\rightsquigarrow 1.5\, E_{ant} = 29.854\, \mu V/m$

$$E_{ant} = \frac{29.854}{1.5}\, \mu V/m = \boxed{19.903\, \mu V/m}$$

$$\rightarrow E_{ant}\big|_{dB\mu V} = 20 \log_{10} 19.903$$

$$\boxed{E_{ant} = 25.98\, dB\mu V}$$

@ 220 MHz.

FCC Class B @ 3m is 46 dBμV/m

translate to 20 m, level becomes

$$46\, dB\mu V/m + 20\log_{10}\left(\frac{3}{20}\right) \approx \underline{29.52\, dB\mu V/m}$$

Thus, the measured field is (29.52 − 25.98) 3.54 dBμV/m Below FCC requirement ⟶ Device passes FCC

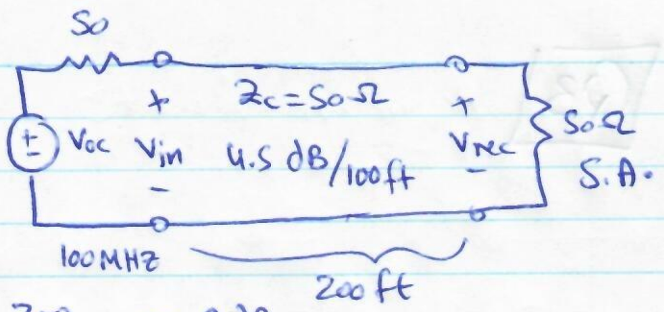
For CISPR 32 (or 22), class B, limit @ 10m is 30 dBμV/m.

translate to 20 m, $30\, dB\mu V/m + 20\log\left(\frac{10}{20}\right)$

$$= \underline{23.98\, dB\mu V/m}$$

measured field is 2 dB above CISPR22 ⟹ Fails.

$\boxed{Q2}$



$V_{rec} = 56.5\ dB\mu V$

(a) Cable loss $= 4.5 * \frac{200}{100} = \underline{9\,dB}$

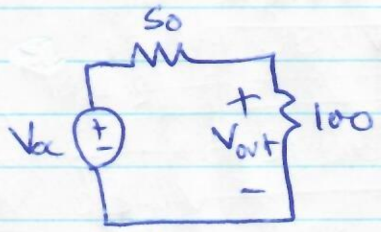
7 pts

$V_{rec} = V_{in} - 9\ dB \rightarrow V_{in} = 56.5 + 9 = \underline{65.5\ dB\mu V}$

$V_{in} = \frac{V_{oc}}{2} \rightarrow V_{oc} = V_{in} + 20\log_{10}(2)$

$V_{oc} = 65.5 + 6 = \boxed{71.5\ dB\mu V}$

Now, we have the circuit



$V_{out} = V_{oc} * \frac{100}{150}$

in dB $\quad V_{out,dB\mu V} = V_{oc,dB\mu V} + 20\log_{10}\left(\frac{2}{3}\right)$

$= 71.5\ dB\mu V - 3.522\ dB\mu V$

$\boxed{V_{out} = 67.98\ dB\mu V}$

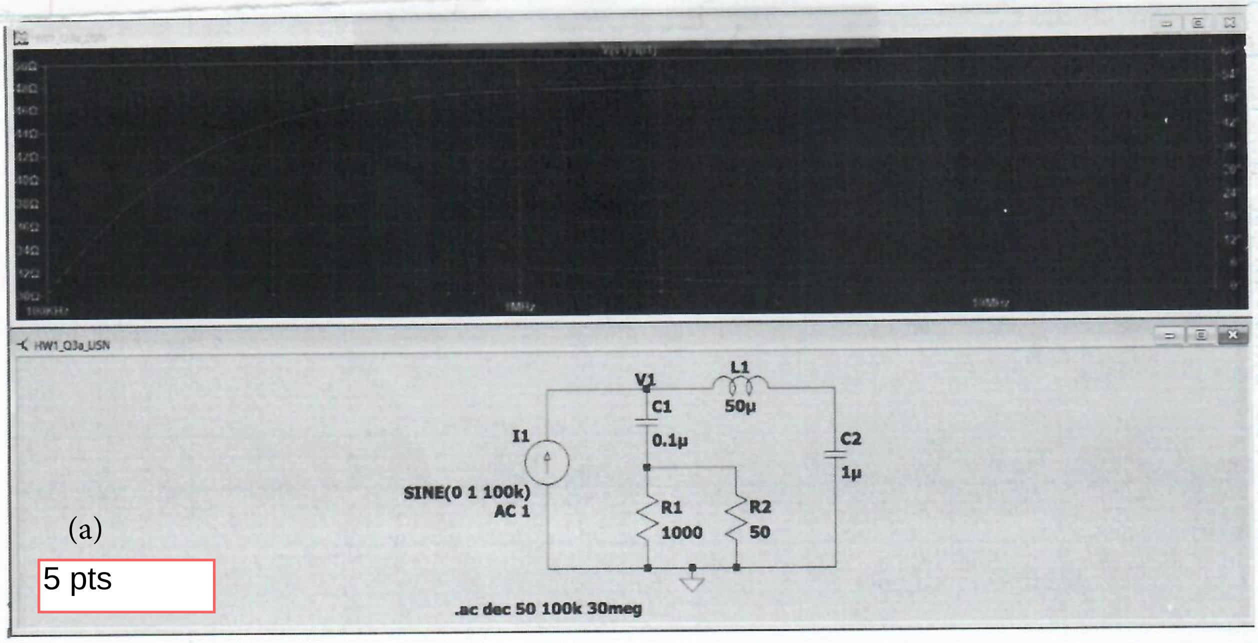
(b) The meter assumes 50 Ω load across it, hence its reading does not change when 100 Ω is placed across it. i.e. the 100 Ω will not load the meter, thus it reads

3 pts

67.98 - 107 = -39.02 dBm

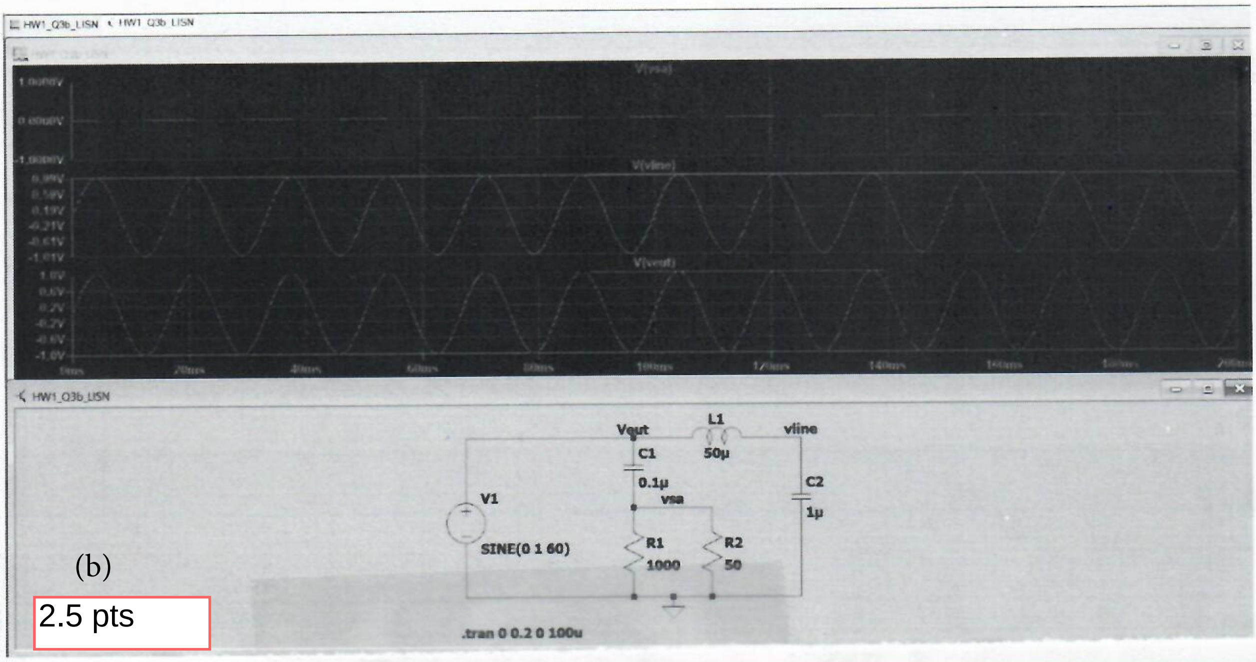
Here we used our note from Q1!!
→ or you can do it the long way :) !

$\boxed{Q3}$



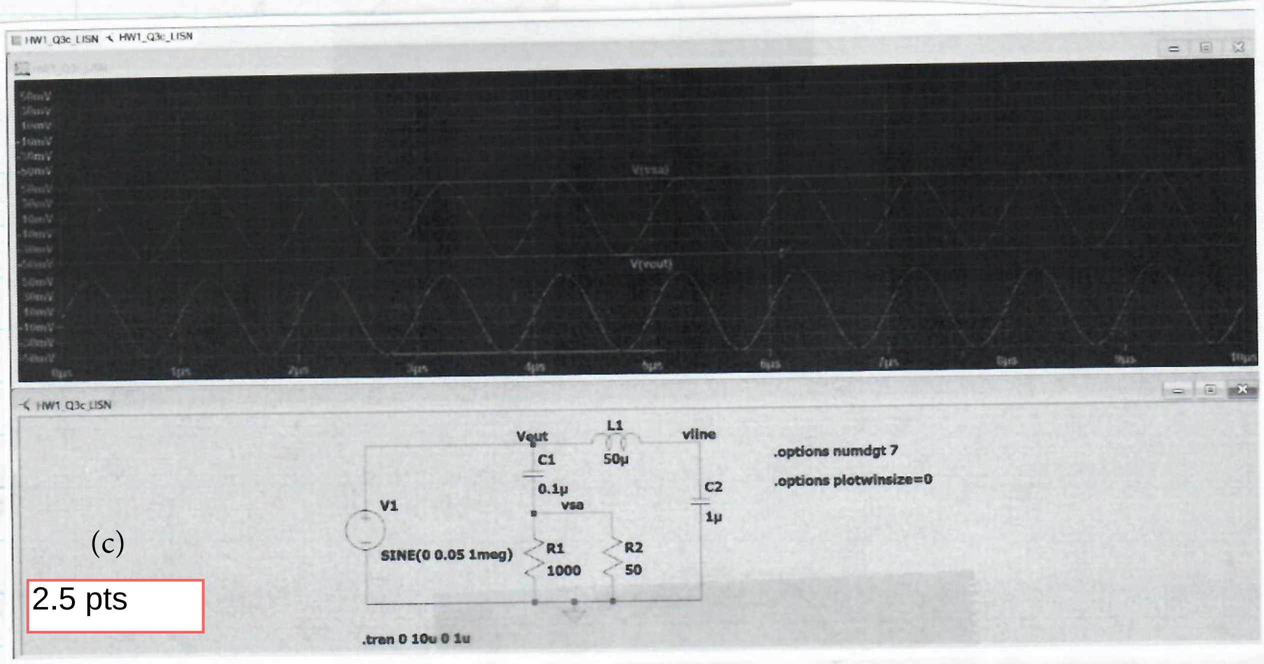
(a)

5 pts



(b)

2.5 pts

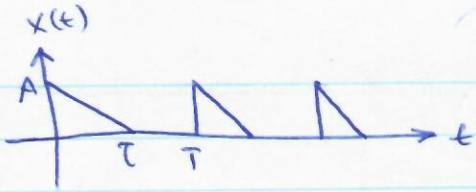

HW1_Q3c_LISN
V(vsa)
V(vout)
Vout
L1
50µ
vline
C1
0.1µ
vsa
C2
1µ
V1
SINE(0 0.05 1meg)
R1
1000
R2
50
.options numdgt 7
.options plotwinsize=0
.tran 0 10u 0 1u

(c)

2.5 pts

5 pts

Q4 let $A = 1\,V$, $\tau = 0.5$ @ 10 MHz



(a) $$T_0\Big|_{10MHz} = \frac{1}{10*10^6} = 0.1\ \mu Sec$$

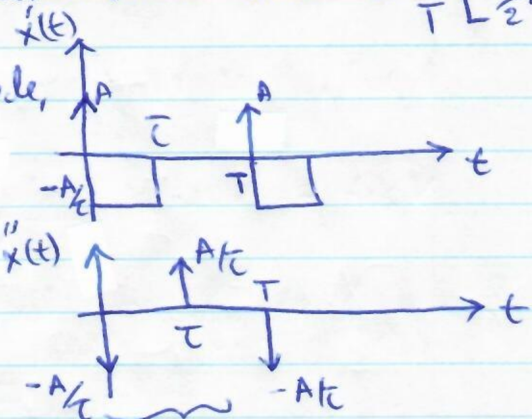
The DC component

$$C_0 = \frac{1}{T}\int_0^T x(t)\,dt = \frac{1}{T}\int_0^T \overbrace{\left[\left(-\frac{A}{\tau}\right)t + A\right]}^{x(t)} dt$$

$$= \frac{1}{T}\left[\left(-\frac{A}{\tau}\right)\frac{t^2}{2} + At\right]_0^\tau = \frac{A\tau}{2T}$$

or $$C_0 = \frac{1}{T}\int_0^T x(t)\,dt = \text{area under curve} = \frac{1}{T}\left[\frac{1}{2}A\tau\right]$$

now, two impulses in one period,



$$C_n^{(1)} = \frac{1}{T}(A) = \frac{A}{T}$$

$$C_n^{(2)} = \left(-\frac{A}{\tau}\right)\frac{1}{T} + \left(\frac{A}{\tau}\right)\frac{1}{T}e^{-jw_0 n\tau}$$

Thus,

$$C_n = \frac{1}{jnw_0}\left(\frac{A}{T}\right) - \frac{1}{(jnw_0)^2}\frac{A}{T\tau}\left[1 - e^{-jnw_0\tau}\right]$$

$$\boxed{w_0 = \frac{2\pi}{T}}$$

$$\overset{C_n^{(1)}}{=} -j\frac{A}{2\pi n}\left[1 - \frac{1}{jnw_0\tau}e^{-jnw_0\frac{\tau}{2}}\underbrace{\left(e^{jnw_0\tau/2} - e^{-jnw_0\tau/2}\right)}_{2j\sin(nw_0\tau/2)}\right]$$

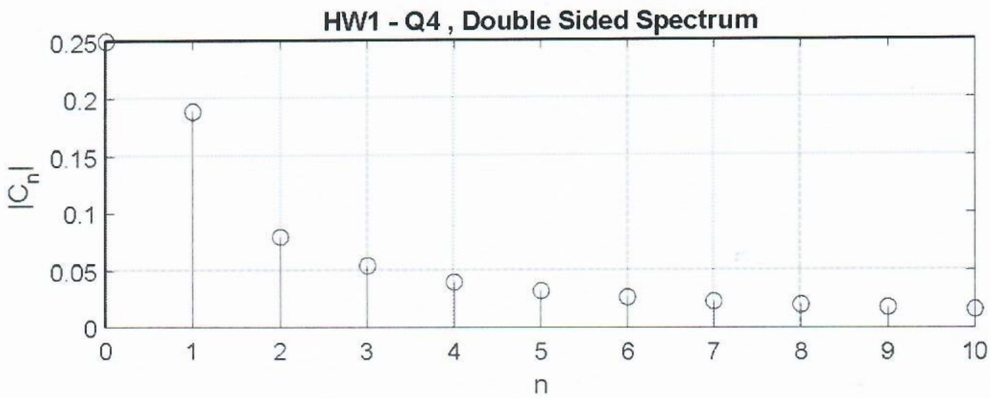
$$C_n = -j\frac{A}{2\pi n}\left[1 - e^{-jn\pi\frac{\tau}{T}}\frac{\sin\left(\frac{n\pi\tau}{T}\right)}{\left(n\pi\tau/T\right)}\right]$$

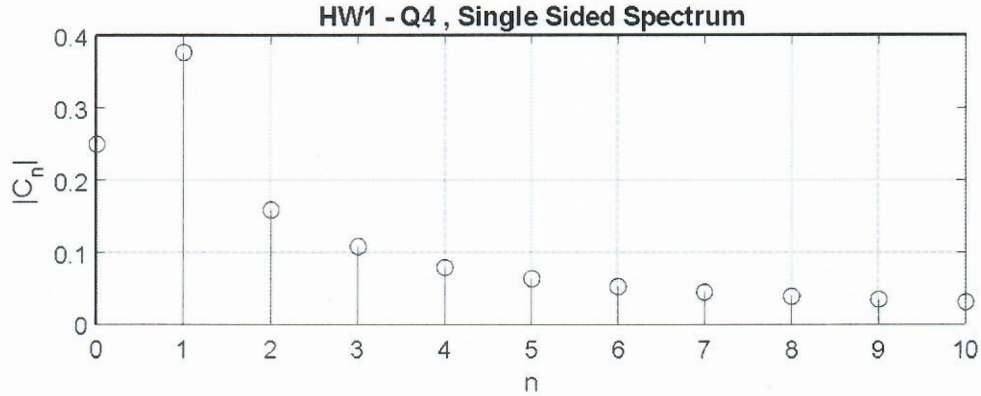
note that this is double sided Spectrum!
For single sided $2|C_n|$! (needed to compare with LTSPICE)

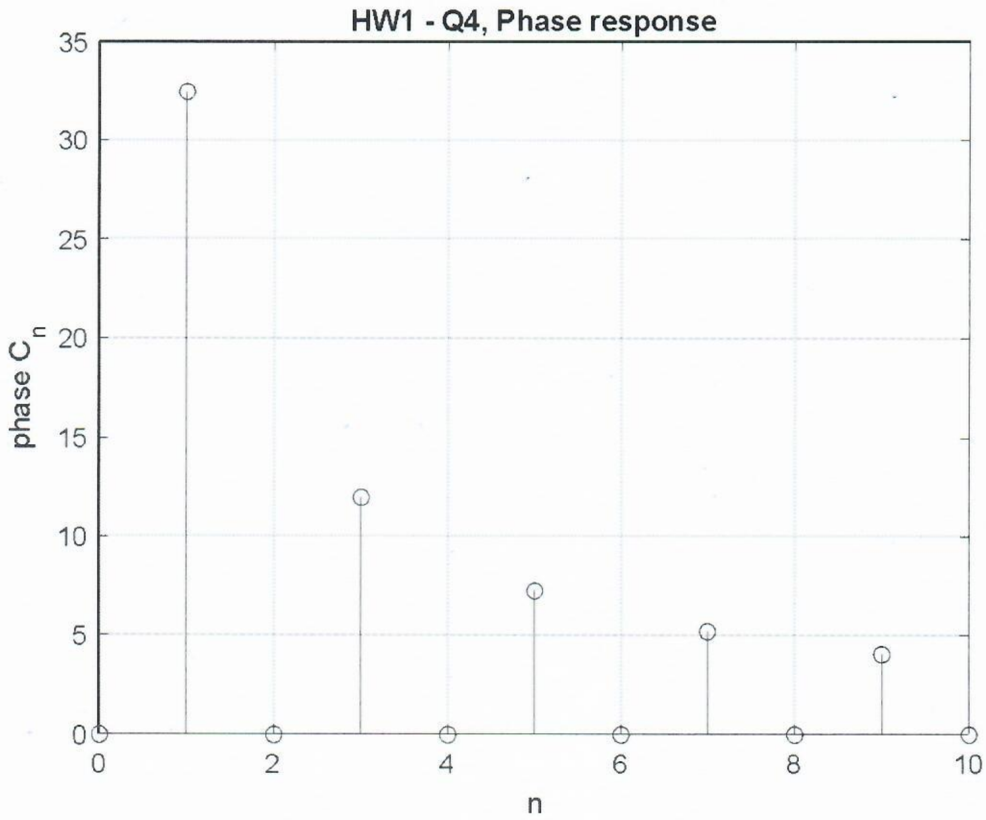
5 pts

Possible MATLAB code for HW1 Q4

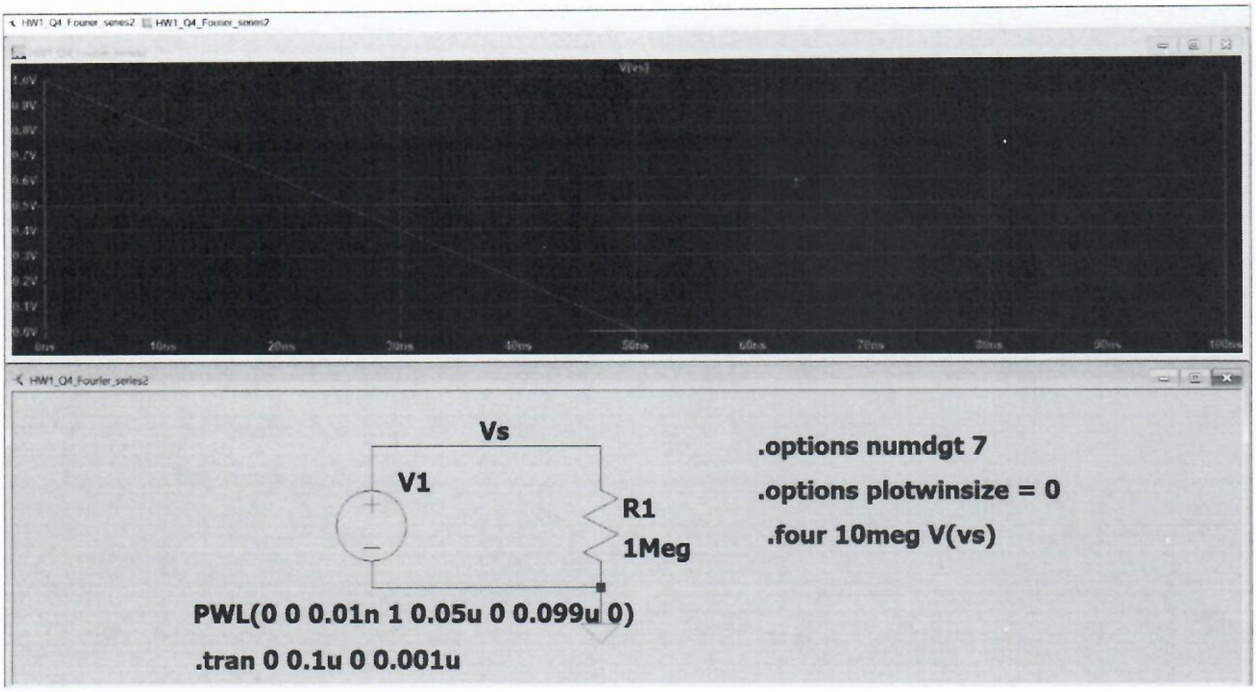
```
%%**********
%% HW 1 Q4
%%**********
clc
clear all
close all
% define parameters
A = 1;
f0 = 10e6;
T0 = 1/f0;
tau = 0.5*T0;
n_harmonics = 10;
nvec = (0:1:10);

% Fourier Coefficients
% DC
c0 = A*tau/(2*T0);
% Cn
Cn = [];
for n=1:n_harmonics
    Cn(n)=
(-i*A)/(2*pi*n)*(1-exp(-i*n*pi*tau/T0)*((sin(n*pi*tau/T0))/(n*pi*tau/T0)));
end
Cn_mag=cat(2,c0,abs(Cn))
Cn_1sided_mag=cat(2,c0,2*abs(Cn))
Cn_phase=cat(2,angle(c0),angle(Cn)+(pi/2)).*180/pi  % note that I subtracted 90deg
subplot(211)
stem(nvec,Cn_mag)
grid on
title('HW1 - Q4 , Double Sided Spectrum')
ylabel('|C_n|')
xlabel('n')
subplot(212)
stem(nvec,Cn_1sided_mag)
grid on
title('HW1 - Q4 , Single Sided Spectrum')
ylabel('|C_n|')
xlabel('n')
figure(2)
stem(nvec,Cn_phase)
grid on
title('HW1 - Q4, Phase response')
ylabel('phase C_n')
xlabel('n')
```


HW1 - Q4 , Double Sided Spectrum
$|C_n|$
n
0.25
0.2
0.15
0.1
0.05
0
0 1 2 3 4 5 6 7 8 9 10


HW1 - Q4 , Single Sided Spectrum
$|C_n|$
n
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10


HW1 - Q4, Phase response
phase C_n
n
35
30
25
20
15
10
5
0
0 2 4 6 8 10

LTSPICE for Q4



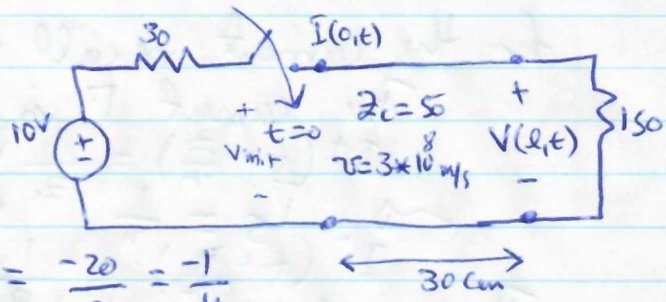
SPICE Error Log: C:\Users\p111849\Google Drive\2023_Sabbatical_Leave\OU\courses\EMC\LTSPICE_examples\HW1_Q4_Fourier_series2.log

```
Circuit: * C:\Users\p111849\Google Drive\2023_Sabbatical_Leave\OU\courses\EMC\LTSPICE_examples\HW1_Q4_Fourier_series2.asc

.OP point found by inspection.
N-Period=1
Fourier components of V(vs)
DC component:0.25

Harmonic     Frequency     Fourier       Normalized     Phase       Normalized
 Number        [Hz]        Component      Component    [degree]     Phase [deg]
    1        1.000e+07     3.774e-01     1.000e+00      32.47°         0.00°
    2        2.000e+07     1.592e-01     4.218e-01      -0.04°       -32.50°
    3        3.000e+07     1.085e-01     2.874e-01      11.93°       -20.54°
    4        4.000e+07     7.959e-02     2.109e-01      -0.07°       -32.54°
    5        5.000e+07     6.418e-02     1.701e-01       7.17°       -25.30°
    6        6.000e+07     5.306e-02     1.406e-01      -0.11°       -32.58°
    7        7.000e+07     4.566e-02     1.210e-01       5.07°       -27.40°
    8        8.000e+07     3.980e-02     1.055e-01      -0.14°       -32.61°
    9        9.000e+07     3.546e-02     9.396e-02       3.88°       -28.59°
Total Harmonic Distortion: 62.317908%(68.043813%)


Date: Tue Jan 24 10:23:57 2023
Total elapsed time: 0.061 seconds.

tnom = 27
temp = 27
method = modified trap
totiter = 254
traniter = 254
tranpoints = 128
accept = 128
rejected = 0
matrix size = 2
fillins = 0
solver = Normal
Matrix Compiler1: off  [0.0]/0.0/0.0
Matrix Compiler2: off  [0.0]/0.0/0.0
```

7 pts

Q5

One way $T_D = \frac{L}{v} = 1\ \text{nsec}$

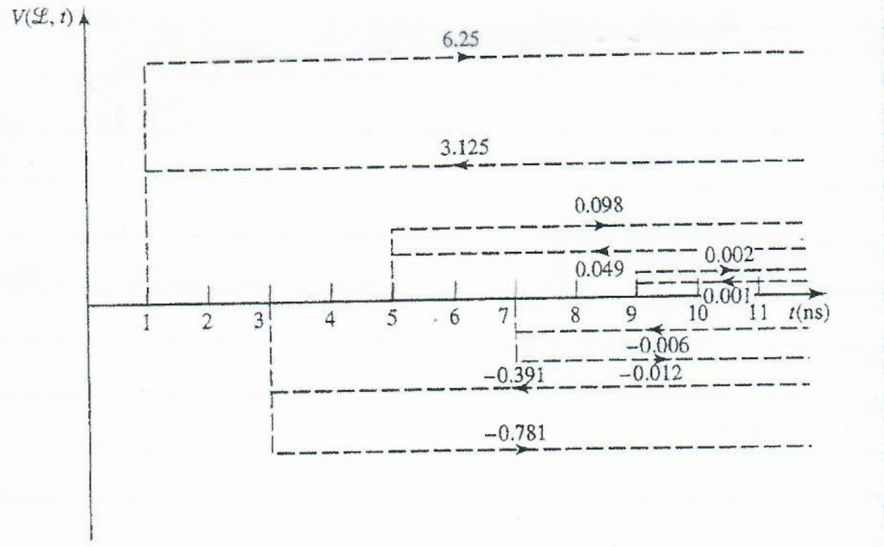


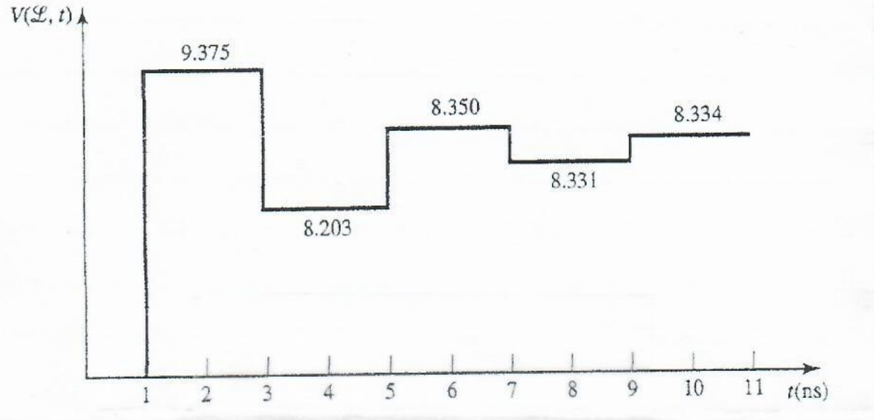
$$\Gamma_s = \frac{Z_s - Z_c}{Z_s + Z_c} = \frac{30-50}{80} = \frac{-20}{80} = \frac{-1}{4}$$

$$\Gamma_L = \frac{Z_L - Z_c}{Z_L + Z_c} = \frac{150-50}{150+50} = \frac{100}{200} = \frac{1}{2}$$

$$V_{init} = 10 * \frac{50}{30+50} = 6.25\ V$$

voltage sketch



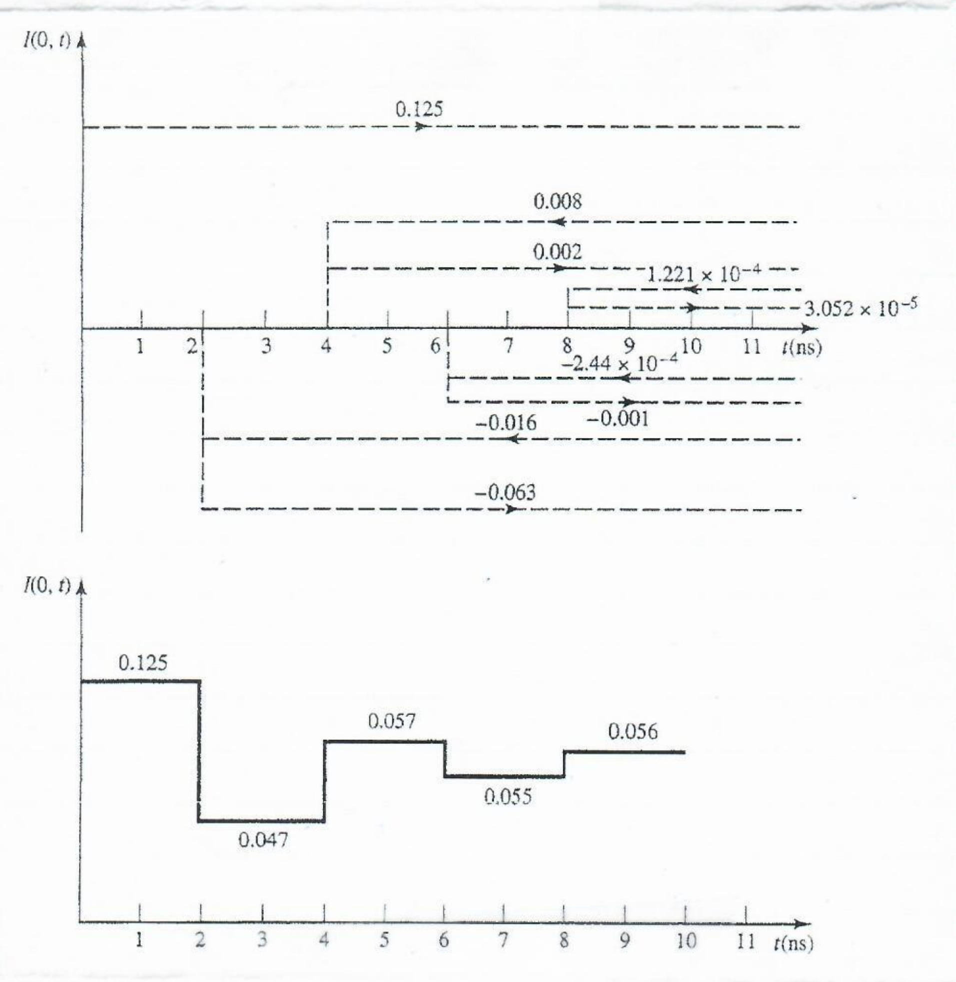


for the current, recall that,

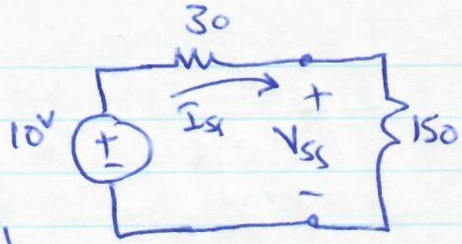
The current Γ is opposite (-ve) of voltage Γ

$\leadsto \Gamma_S = \frac{1}{4}$ & $\Gamma_L = -\frac{1}{2}$

Thus current sketch is



for steady state values, we have the circuit



$$V_{ss} = 10 * \frac{150}{150+30} = \boxed{8.33\,V}$$

$$I_{ss} = \frac{10}{150+30} = \boxed{0.056\,A}$$

LTSPICE Solution:

3 pts