ECGR 2254 – Project 1

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Problem 1 A

A: Find the Amplitude of the steady state current.

R1 = 0.1

VS = (480*sqrt(2))

EQ = R1+(Omega*L*j)

Amp = VS/abs(EQ);

Amp = 480*sqrt(2)/abs((R1+(Omega*L*j))

Amp = 480sqrt(2)/(abs(0.1 + 1.6965j))

Amp = 399.4472

The formula, EQ, comes from turning the resistors into phasor domain and multiply the inductor L by Omega and j as well as adding it the whole thing by R1. The magnitude of the steady state is found by multiplying 480 and the square root of 2 together, and dividing the whole thing by the magnitude of the impedance, which is the absolute value of the formula EQ.

B: Differential Equation

Using KVL, the differential equation for the RL circuit would be in this form:

$$Is(t) = \ (R * I) + L\frac{di}{dt}$$

C: Determine an appropriate time step

Omega = 2*pi*60

Tau = L/R1;

T = 2*pi/Omega;

%Time Step

Delta = T/100;

t = [0:Delta:35*Tau];

R2 was not included because, when the switch is open R1 is the only resistor that is connected to the circuit at the time. I choose this as my time step, since the period is much smaller than the Tau in this problem.

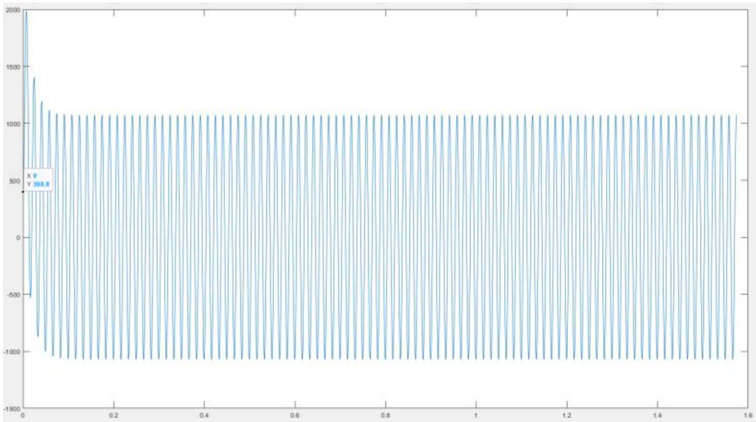
D: Find I(s) with a MATLAB script

```
Phi = 90;

A =T/Delta;

IS= zeros(size(t));

x = (VS*cos(Omega*t-Phi*pi/180))/R1;

Y0 = abs(Amp)*cos((Omega*t) + (deg2rad(Phi - 86.626)));

for U = 1:1:length(t)-1;

    if U==1

       IS(1) = Y0(1);

       IS(U+1) = (x(U) - IS(U) + A*IS(U))/A;

    else

        IS(U+1) = (x(U) - IS(U) + A*IS(U))/A;

    end

end
```

The loop was needed to evaluate the differential equation in section B. After testing different values of Phi with the evaluated differential equation, the current had its maximum peak when Phi was equal to 90 degrees.

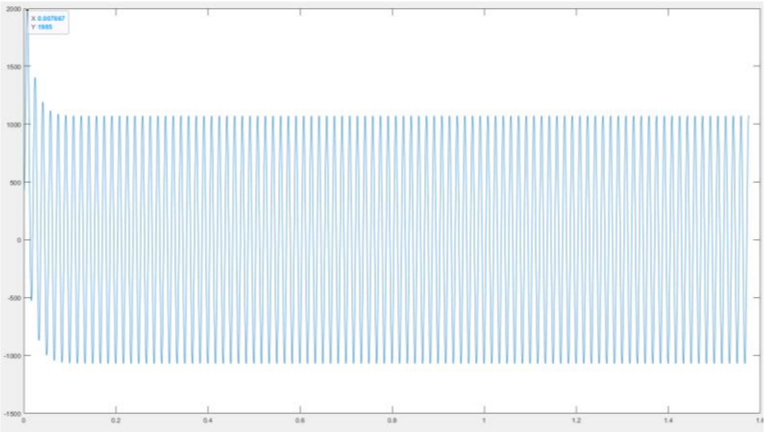
E: Using Phi, find the true value of Is(0)

Using MATLAB, the true value of Is(0) is at 398.8 Amps.



F: What is the peak current?

The peak current is reached at t = 7.667ms with a value of 1985 Amps.



Problem 1A Code:

```
clear all;

%Known Variables

L = 4.5*10^-3

R1 = 0.1;

R2 = 23.04;

%Needed  Variables

Omega = 2*pi*60;

Tau = L/R1;

T = 2*pi/Omega;

%Time Step

Delta = T/100;

t = [0:Delta:35*Tau];

% VS,EQ and B is used to find the Amplitude of the Steady State

VS = (480*sqrt(2))

EQ = R1+(Omega*L*j);

Amp = VS/abs(EQ);

% Phi, A, IS, x, Y0, and the loop is needed in order to find I(s)

Phi = 90;

A =T/Delta;
```

```
IS= zeros(size(t));
x = (VS*cos(Omega*t-Phi*pi/180))/R1;
Y0 = abs(Amp)*cos((Omega*t) + (deg2rad(Phi - 86.626)));
 %Loop
for U = 1:1:length(t)-1;
    if U==1
       IS(1) = Y0(1);
       IS(U+1) = (x(U) - IS(U) + A*IS(U))/A;
    else
        IS(U+1) = (x(U) - IS(U) + A*IS(U))/A;
    end
end
figure(1);
plot(t,IS)
```

Problem 1 B

A: Find the function of the current for Is(0)

$$Is(0) = \frac{Vs * \cos\left(Omega * t - Phi * \frac{pi}{180}\right)}{R1}$$

B: Differential Equation

Using KVL, the differential equation for the RL circuit would be in this form:

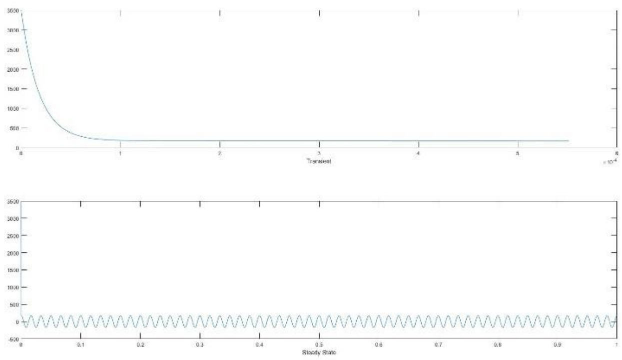
$$Is(t) = (R * I) + L\frac{di}{dt}$$

C: Determine an appropriate time step

```
Omega = 2*pi*60
Tau = L/R1
T = 2*pi/Omega
%Time Step
Delta = 5*Tau/100
t = [0:Delta:60*T]
```

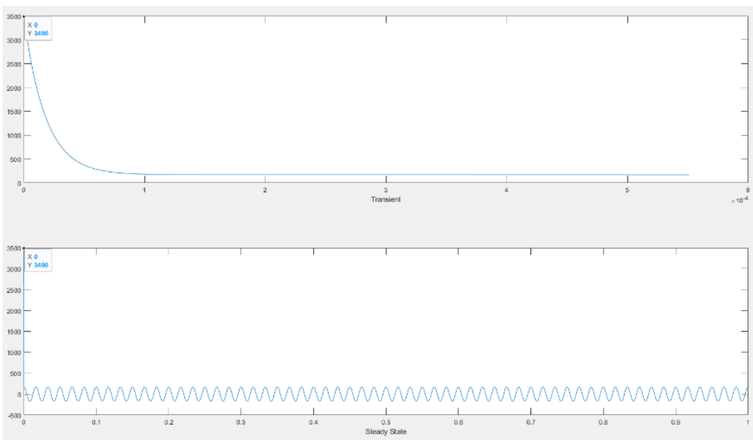
I choose this as my time step, since the tau is much smaller than the period in this problem, and 5Tau/100 for the Delta is about how long it takes for the initial value to go down to 0.

D: Plot the voltage for VL(0)



E: What is the maximum voltage?

The maximum voltage of the circuit is 3490V when t = 0.



Problem 1B Code:

```
clear all;

%Known Variables

L = 2.65*10^-3

R1 = 144;

R2 = 7.2;

%Needed Variables

VS = (480*sqrt(2))

Omega = 2*pi*60;

Tau = L/R1;
```

```
T = 2*pi/Omega;
%Time Step
Delta = 5*Tau/100;
t = [0:Delta:60*T];
% Phi, A, VL, x, Y0,xt, and the loop is needed in order to find VL
Phi = 0;
A =Tau/Delta;
V1 = zeros(size(t));
IS = (VS*cos(Omega*t-Phi*pi/180))/R1;
Y0 = 24.49*cos(Omega*t-8.289*pi/180);
xt = (120*sqrt(2)*cos(Omega*t+Phi*pi/180))/R1;
%Loop
for U = 1:1:length(t)-1;
    if U==1
       V1(1) = Y0(1);
       V1(U+1) = (xt(U) - V1(U) + A*V1(U))/A;
    else
        V1(U+1) = (xt(U) - V1(U) + A*V1(U))/A;
    end
end
VL = R1*V1
figure(1);
subplot (2,1,1)
plot(t(1:600),VL(1:600));
xlabel ('Transient');
subplot (2,1,2 )
plot(t,VL);
xlabel('Steady State');
```

Problem 2

A: What is V_out1 when Vin_1 is equal to at 0V and 5V?

When Vin1 is equal to 0V, Vout is equal 5V and when Vin1 is equal to 5V, Vout is equal to 0V. This is due to the inverter gate causing Vout to always have an inverse relationship with Vin. When Vin is low, Vout is high and vice versa.

B: What is the value of the following?

- Vth = 5V. When the current is high, Vout and the Thevenin voltage are equal.
- Rth = 900 Ohms. The Thevenin resistance is the same as Resistor 1 when Vin is at 0V.
- Vout1 = 5V. The inverter gate will cause the output to be high when the input is low and vice versa.
- Vin2 = 5V. Vin2 and Vout1 are equal.
- IL = 5.56*10^-3 Amps. You need to divide the Thevenin voltage by the Thevenin resistance to get the value of the current.

C: What is the value of the following when Vin1 is high?

- Differential Equation: $V = \frac{Dv^2}{Dt^2} + \frac{R_{TH}}{L_l} * \frac{Dv}{dt} + \frac{v_{TH}}{L_l C_{GS2}}$
- Vin2 =5V. Since Vin1is high, it will cause Vout1 to be low. Vout1 is also inversely proportional to Vin2 which means Vin2 will also be high, which is 5V.
- $\frac{Dv_{in2}(0)}{dt}$ = 0. The current is currently zero, which means that this formula is also equal to zero.
- Vth = 5. Voltage cannot change when a capacitor has been charged, which means that the Thevenin voltage stays at 5V.
- RTH = 90. The resistors in the circuit become parallel whenever the switch is flipped. The value of Thevenin resistance becomes the inverse of (1/R1 +1/R2).

D: Determine an appropriate time step

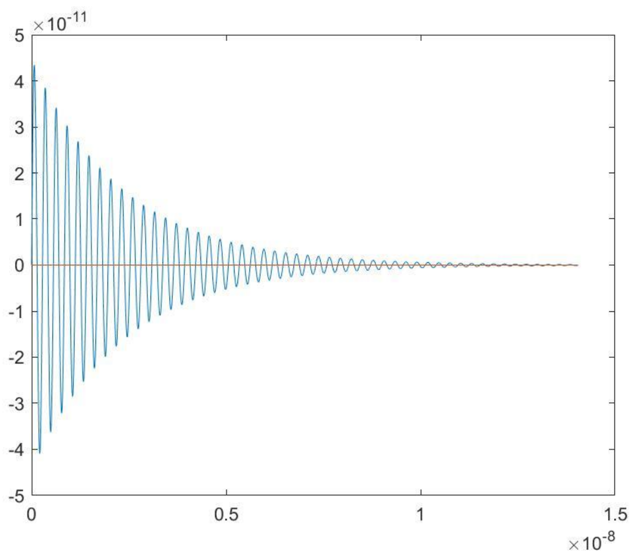
```
B = Rth/L

C = Vth/(L*Cap);

s = roots([ 1 B C]);

Omega = imag(s(1));

Tau = Rth*Cap;

T = 2*pi/Omega

%Time Step

Delta = Tau/1000;

t = [0:Delta:50*T];
```

B and C come from the differential equation stated in Part C. A quadratic equation based on the coefficients of the differential equations can be used to find the roots. Omega is found by taking the imaginary part of the roots. I choose this as my time step, since the period is much smaller than the Tau in this problem.

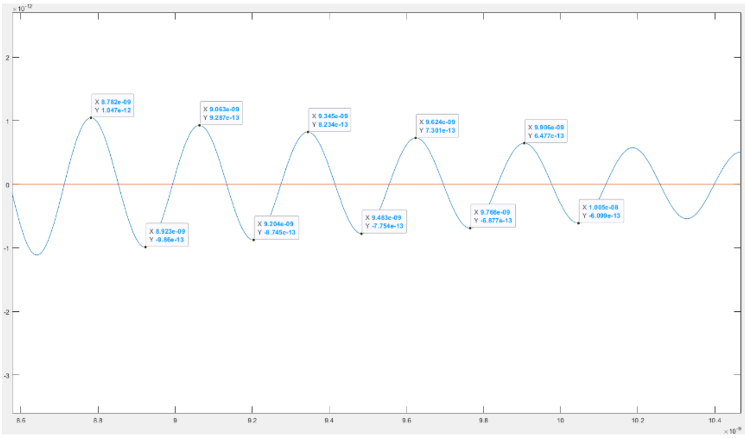
E: Find Vin2(t) with a MATLAB script

```
% y1, y2, and x used to solve Voltage

y1 = zeros(size(t));

y2 = zeros(size(t));

x = ones(size(t));

%Loop

for U = 1:1:length(t)-1;

   if U==1

      y1(1) = Y0(1);

      y2(1) = YPrime(1);

   else

       y1(U+1) = y1(U)+ Delta*y2(U);

       y2(U+1)= Delta*(x(U) - B*y2(U) - C*y1(U))+y2(U);

   end

end
```

The loop was needed to evaluate the differential equation in section C.



F: How long does it take for the voltage to remain below 1V?



Based on the peak values at each interval, the waveform stays below 1 volt at around t = 8.923 *10^-9.

Problem 2 Code:

```
clear all
%Known Variables
L = 100*10^-9;
Cap = 0.1*10^-12;
R1 = 100;
R2 = 900;
Rth = (1/R1 +1/R2)^-1
Y0 = 5;
YPrime = 0;
Vth = 5;
%Needed Variables
B = Rth/L
C = Vth/(L*Cap);
s = roots([ 1 B C]);
Omega = imag(s(1));
Tau = Rth*Cap;
T = 2*pi/Omega
%Time Step
```

```
Delta = Tau/100;
t = [0:Delta:100*T];
% y1, y2, and x used to solve Voltage
y1 = zeros(size(t));
y2 = zeros(size(t));
x = ones(size(t));
%Loop
for U = 1:1:length(t)-1;
    if U==1
       y1(1) = Y0(1);
       y2(1) = YPrime(1);
    else
        y1(U+1) = y1(U)+ Delta*y2(U);
        y2(U+1)= Delta*(x(U) - B*y2(U) - C*y1(U))+y2(U);
    end
end
figure(1);
plot(t,y2,t,x/C)
```

Problem 3

A: Simplify X(t)

Using the double angle formula. X(t) can be rewritten as:

$$X(t) = \frac{X_{audio}}{2 * \cos\,(4\pi f t)}$$

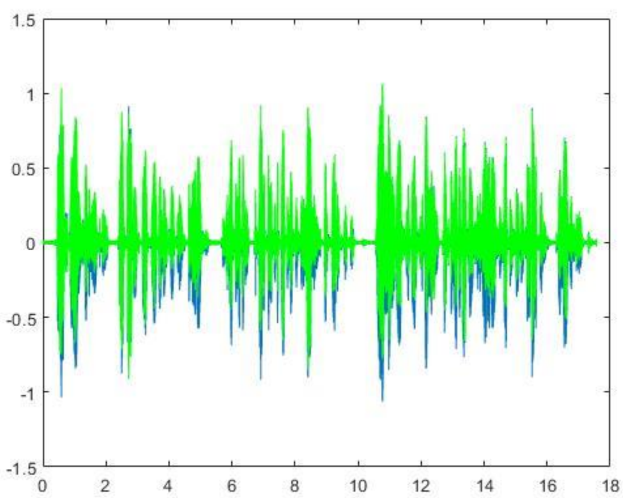
B: Create vectors

```
%Time Step
t = [0:Delta:Delta*(length(x)-1)];


Row = transpose(x);
Out = Row.*(cos(2*pi*frequency*t));


for U = 1:1:length(t)-1
   if U==1
      W(1) = Y0;
      Z(1) = YPrime;
   end
      W(U+1)= W(U) + Delta*Z(U);
      Z(U+1) = Delta*(x(U))+A*W(U)+B*Z(U)+Z(U);
end
```

C: Differential Equation

The circuit requires a second order differential equation for voltage. The form for this would be:

$$V = \frac{Dv^2}{Dt^2} + \frac{1}{RC} * \frac{Dv}{dt} + \frac{X_{Out}}{LC}, \text{ Y(0) = 0, Y'(0) = 0}$$



D: Audio Samples

The sound that is played is the Gettysburg address. Xout is a lot louder compared to Xaudio since Xout is being played at a higher frequency as can be seen in the graph above. When changing the frequency around the audio starts to sound very staticky and at some point, distorted. If you change the frequency too much than the audio will sound nothing like the original audio that is expected to play.

Problem 3 Code:

```
clear all;
clear sound;
%Code from project file to play the sound
fileID = fopen('problem3.bin','r');
x=fread(fileID,'single');
fclose(fileID);
%Known Variables
frequency = 50e3;
Amp = 2.205e6;
L = 253.3*10^-6;
R = 11.254;
C = 1*10^-6;
Delta = 1/Amp;
%Needed Variables
Y0 = 0;
YPrime=0;
A = 1/(R*C);%Diff Eq
B = 1/(L*C);%Diff Eq
%Time Step
t = [0:Delta:Delta*(length(x)-1)];
Row = transpose(x);
```

```
Out = Row.*(cos(2*pi*frequency*t));

%Loop

for U = 1:1:length(t)-1

    if U==1

        W(1) = Y0;

        Z(1) = YPrime;

    end

        W(U+1)= W(U) + Delta*Z(U);

        Z(U+1) = Delta*(x(U))+A*W(U)+B*Z(U)+Z(U);

end

x_audio = downsample(Out,100);

sound (x_audio, 22.053e3);

plot(t,x, t,Out, 'g');
```

Problem 4

A: What is X3?

The form needed for this problem is, X(t) = X_audio*X_3, however the exponent in X(t) needs to be rid of. By making X3 equal the equation below, it will get rid of exponent and allow Xout = X_audio.

$$X_3 = \frac{1}{\mathrm{e}\hat{}(j * 2 * pi * f * t)}$$

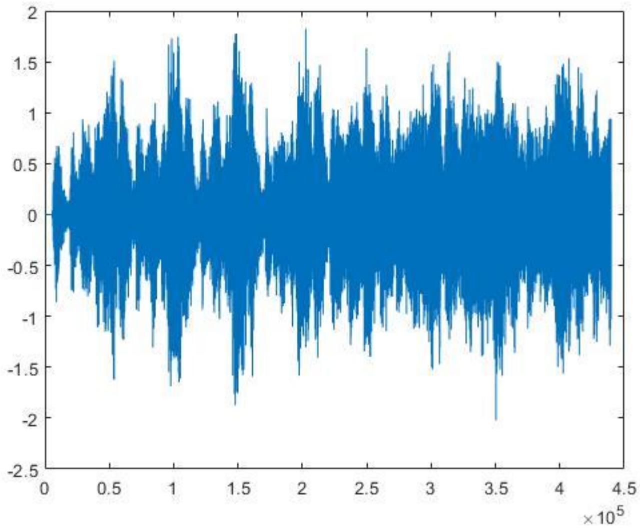
B: Create Vectors

```
%Code from project file to play the sound

fileID = fopen('problem4.bin','r');

XIN=fread(fileID,'single');

fclose(fileID);

%Vectors

x = (XIN(1:2:length(XIN))+j*XIN(2:2:length(XIN)));

t = [0:Delta:Delta*(length(x)-1)];

x_3 = (1./exp(j*2*pi*frequency*t));

Row = transpose(x);
```

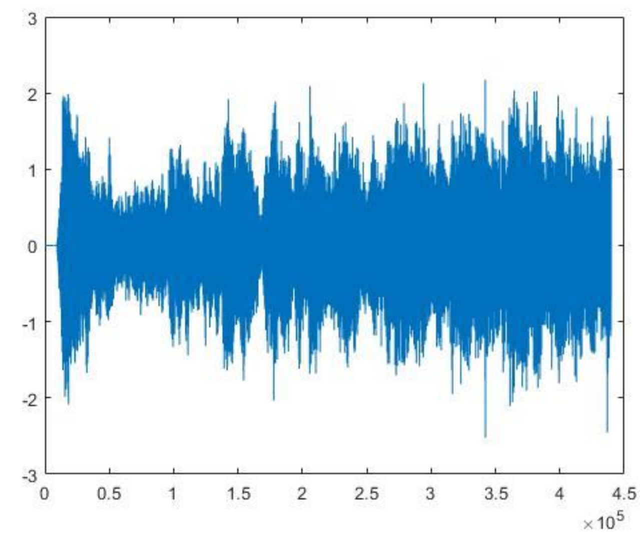
Out = Row .*x_3;

C: Audio Samples

The imaginary sound sample plays the Imperial March.



The real sound sample plays the Star Wars Theme.



Problem 4 Code:

clear all;

clear sound

%Code from project file to play the sound

fileID = fopen('problem4.bin','r');

```
XIN=fread(fileID,'single');
fclose(fileID);
%Known Variables
frequency = 50e3;
amp = 2.205e6;
Delta = 1/amp;
%Vectors
x = (XIN(1:2:length(XIN))+j*XIN(2:2:length(XIN)));
t = [0:Delta:Delta*(length(x)-1)];

x_3 = (1./exp(j*2*pi*frequency*t));

Row = transpose(x);

Out = Row .*x_3;

x_audio = downsample(imag(Out),100);
sound (x_audio, 22.053e3);

plot(x_audio);
```