Lab Assignment

Imports, Functions and Variables

You, 3 minutes ago | 1 author (You)

```
#Lab1 ELE532
#Jahmil Ally (501045419)

#Imports
import os
import time
import numpy as np
import sympy as sp
import scipy.io as sci
import matplotlib.pyplot as plt
import sounddevice as sd        You, 2 weeks ago • Create lab2main.py
import matlab.engine

#Variable Declaration
color="g"
eng = matlab.engine.start_matlab()

#Defining a generic function for plotting
def plot(f_t, t, newGraph=True, figsize=(12.0, 6.0), title="", functionLabel="", xLabel="t", yLabel="f(t)"):
    global color
    if newGraph:
        plt.figure(figsize=figsize)
        color="g"

    #Configure Colour
    if  color == "g" and  newGraph==False:
        color="r"
    elif color == "r" and  newGraph==False:
        color="y"
    elif color == "y" and  newGraph==False:
        color="b"
    elif color == "b" and  newGraph==False:
        color="o"
    elif color == "o" and  newGraph==False:
        color="p"

    #Configurable titles/ Labels
    plt.plot(t, f_t, color=color, label=functionLabel)
    if title !="":
        plt.title(title)
    if xLabel !="":
        plt.xlabel(xLabel)
    if yLabel !="":
        plt.ylabel(yLabel)

    #Visuals
    plt.grid(True)
    plt.legend()
    plt.tight_layout()
```

A. Impulse Response

- **Problem A.1**

  Code:

```
#Part A:
#Problem A.1
#Define values
R = [1e4, 1e4, 1e4]
C = [1e-6, 1e-6]

#Coefficients for the characteristic equation
A1 = [1, (1/R[0] + 1/R[1] + 1/R[2]) / C[1], 1 / (R[0] * R[1] * C[0] * C[1])]

#Characteristic roots
lambda_values = np.roots(A1)

print("\nA.1) Roots:" + str(lambda_values[0]) + "," + str(lambda_values[1]) + "\n")
```

  Results:

```
A.1) Roots:-261.8033988749895,-38.19660112501052
```

- **Problem A.2**

  Code:

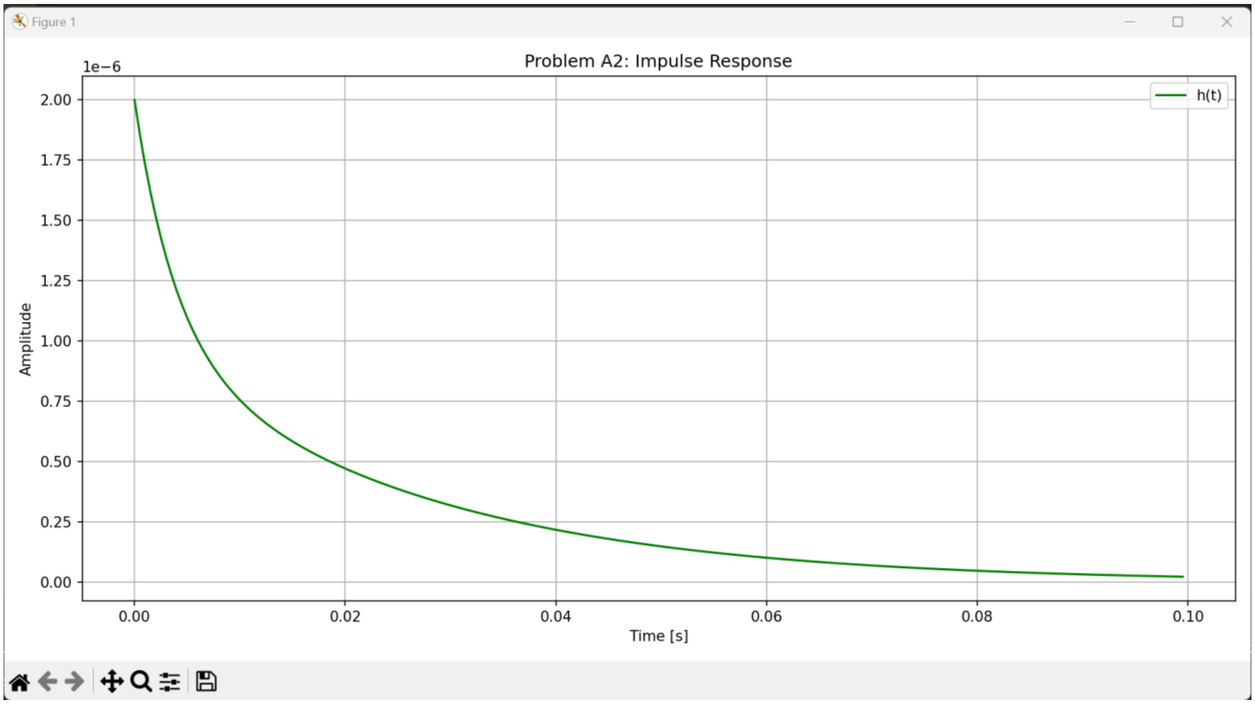
```
#Problem A.2
#Time vector
t = np.arange(0, 0.1, 0.0005)

#Unit step function: u(t)
u = lambda t: 1.0 * (t >= 0)

#h(t) using the characteristic roots
h = lambda t: (C[0] * np.exp(lambda_values[0] * t) + C[1] * np.exp(lambda_values[1] * t)) * (u(t))

#h(t) Plotted
plot(h(t), t, title="Problem A2: Impulse Response", functionLabel="h(t)", xLabel="Time [s]", yLabel="Amplitude")
```

  Results:



- **Problem A.3**

  Code:

```
#Problem A.3
def CH2MP2(R, C):
    #Coefficients for the characteristic equation
    A = [1, (1/R[0] + 1/R[1] + 1/R[2]) / C[1], 1 / (R[0] * R[1] * C[0] * C[1])]

    #Characteristic roots
    roots = np.roots(A)

    return roots

lambda_ = CH2MP2([1e4, 1e4, 1e4],[1e-9, 1e-6])

print("\nA.3) Roots:" + str(lambda_[0]) + "," + str(lambda_[1]) + "\n")

plt.show()
```

  Results:

```
A.3) Roots:(-150.00000000000006+3158.7180944174174j),(-150.00000000000006-3158.7180944174174j)
```

B. Convolution.

- **Problem B.1**

  Code:

```python
#Part B:
#Problem B.1
#Specify the primary and alternate file paths
primary_script_path = "/Users/jah/Documents/GitHub/ELE532/lab2/CH2MP4.m"
alternate_script_path = "C:\\Users\\Jahmil\\Desktop\\Coding_Projects\\ELE532\\lab2\\CH2MP4.m"

#Check if the file exists in the primary location
if os.path.exists(primary_script_path):
    script_path = primary_script_path
else:
    #If not, use the alternate location
    script_path = alternate_script_path

eng = matlab.engine.start_matlab()
eng.eval(f"run('{script_path}')", nargout=0)
```

lab2 > CH2MP4.m

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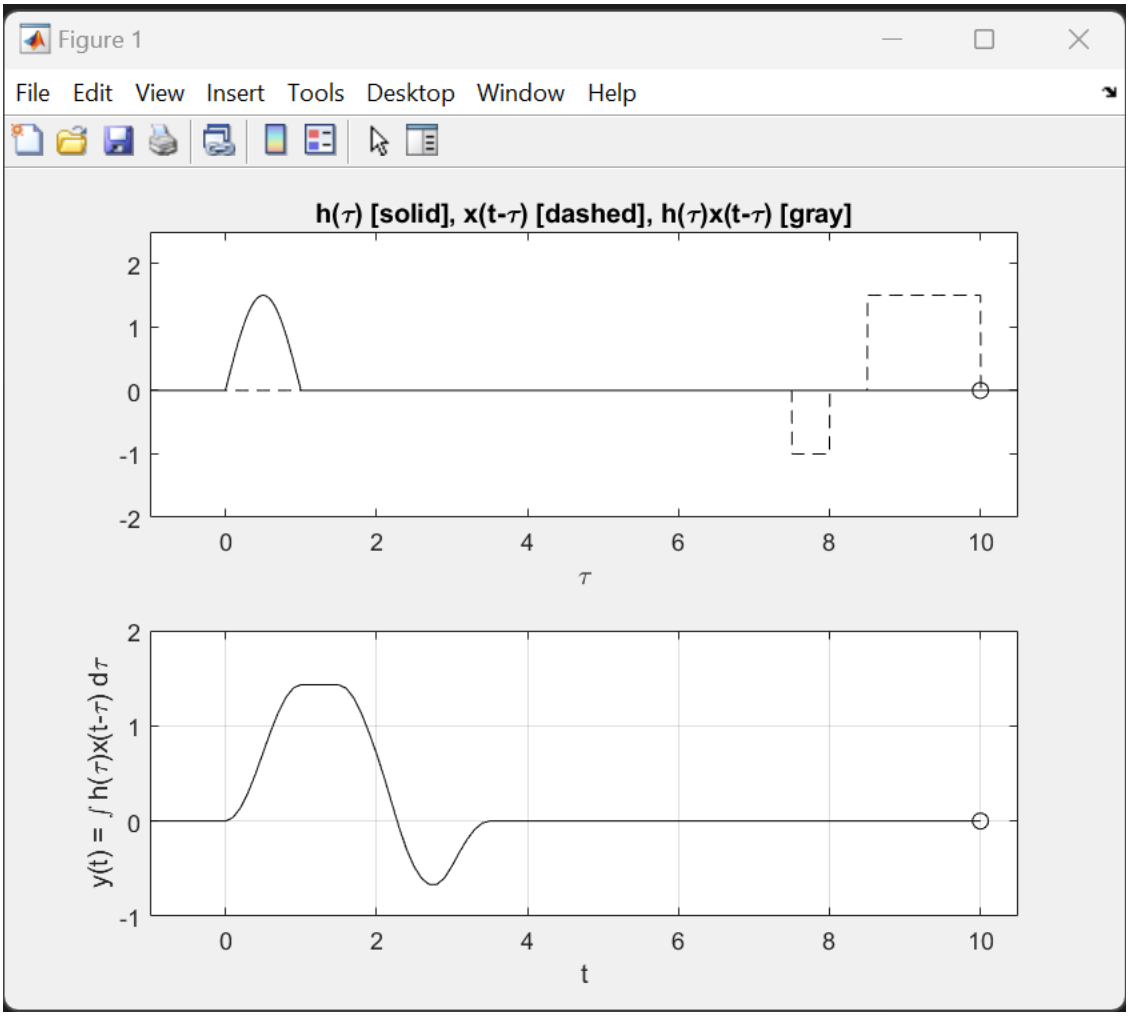
```matlab
% CH2MP4.m : Chapter 2, MATLAB Program 4
% Script M-file graphically demonstrates the convolution process.figure(1)
% Create figure window and make visible on screen
u = @(t) 1.0*(t>=0);
x = @(t) 1.5*(u(t)-u(t-1.5))-u(t-2)+u(t-2.5);
h = @(t) 1.5*sin(pi*t).*(u(t)-u(t-1));
dtau = 0.005;
tau = -1:dtau:10.5;ti = 0;
tvec = -1:.1:10; y = NaN*zeros(1,length(tvec));

% Pre-allocate memory        You, 2 weeks ago • Lab2
for t = tvec,
    ti = ti+1; % Time index
    xh = x(t-tau).*h(tau);
    lxh = length(xh);
    y(ti) = sum(xh.*dtau);
    % Trapezoidal approximation of convolution integral
    subplot(2,1,1),plot(tau,h(tau),"k-",tau,x(t-tau),"k--",t,0,"ok");
    axis([tau(1) tau(end) -2.0 2.5]);
    patch([tau(1:end-1);tau(1:end-1);tau(2:end);tau(2:end)],...
        [zeros(1,lxh-1);xh(1:end-1);xh(2:end);zeros(1,lxh-1)],...
        [.8 .8 .8],"edgecolor","none");
    xlabel("\tau"); title("h(\tau) [solid], x(t-\tau) [dashed], h(\tau)x(t-\tau) [gray]");
    c = get(gca,'children'); set(gca,'children',[c(2);c(3);c(4);c(1)]);
    subplot(2,1,2),plot(tvec,y,"k",tvec(ti),y(ti),"ok");
    xlabel("t"); ylabel("y(t) = \int h(\tau)x(t-\tau) d\tau");
    axis([tau(1) tau(end) -1.0 2.0]); grid;

    if abs(t - 2.25) < 0.01 % Check if t is close to 2.25
        pause; % Pause at t = 2.25
    else
        pause(0.001); % Pause for other time points
    end
end
```

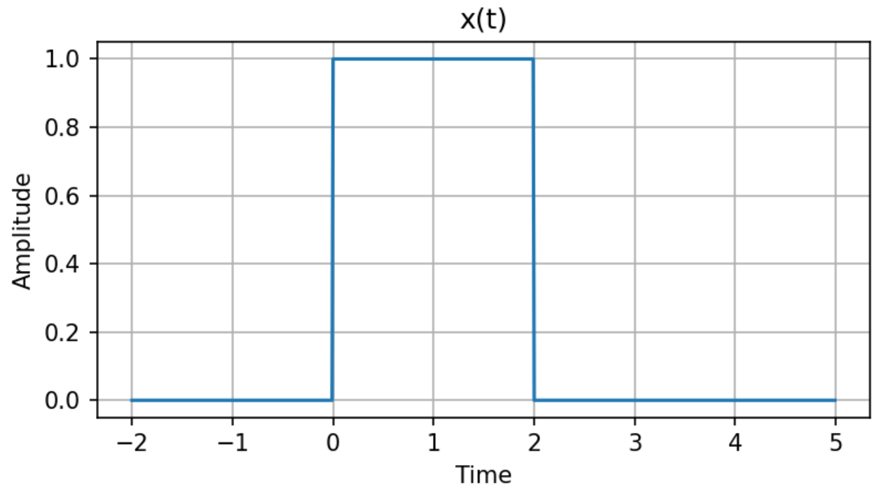
Results:

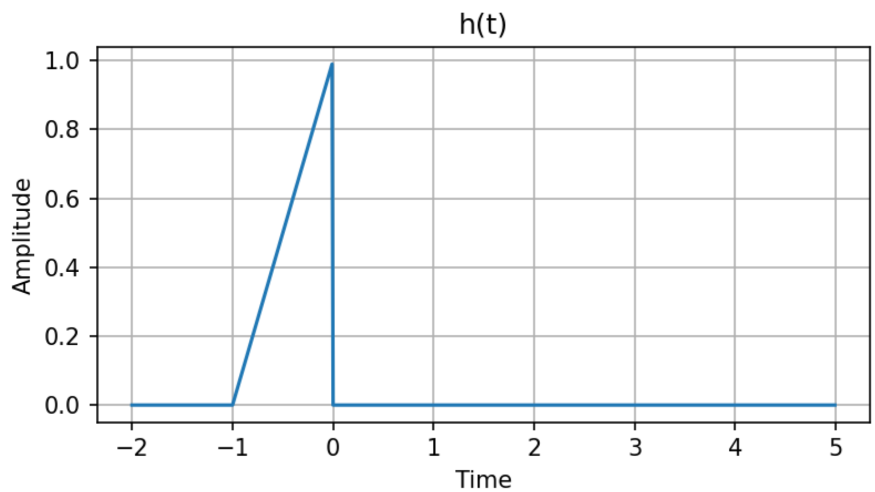


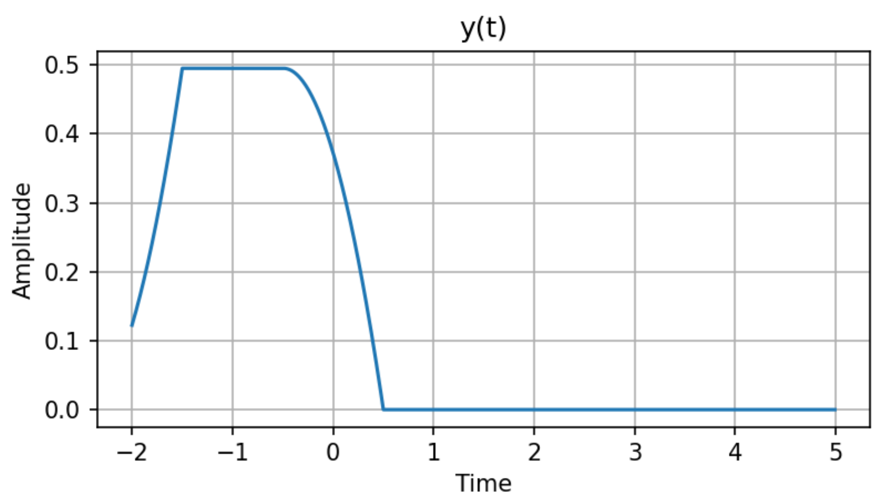
- **Problem B.2**
  Code:

```
#Problem B.2
#Defining functions
x = lambda t: np.heaviside(t , 1) - np.heaviside(t - 2, 1)
h = lambda t: (t+1) * (np.heaviside(t + 1, 1) - np.heaviside(t, 1))

#Defining time vector
t = np.arange(-2, 5, 0.01)

x_t = x(t)
h_t = h(t)

y_t = np.convolve(x_t, h_t, "same") * 0.01

plt.figure(figsize=(6, 14))

#Subplot for x(t)
plt.subplot(3, 1, 1)
plt.plot(t, x_t, label="x(t)")
plt.title("x(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

#Subplot for h(t)
plt.subplot(3, 1, 2)
plt.plot(t, h_t, label="h(t)")
plt.title("h(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

#Subplot for y(t)
plt.subplot(3, 1, 3)
plt.plot(t, y_t)
plt.title("y(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

plt.subplots_adjust(hspace=0.5)

plt.show()
```

Results:


x(t)
Amplitude
1.0
0.8
0.6
0.4
0.2
0.0
−2
−1
0
1
2
3
4
5
Time


h(t)
Amplitude
1.0
0.8
0.6
0.4
0.2
0.0
−2
−1
0
1
2
3
4
5
Time


y(t)
Amplitude
0.5
0.4
0.3
0.2
0.1
0.0
−2
−1
0
1
2
3
4
5
Time

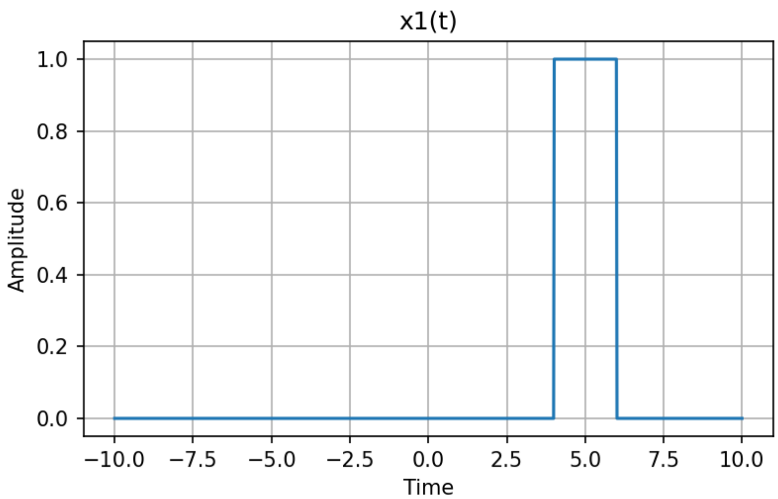
- **Problem B.3**

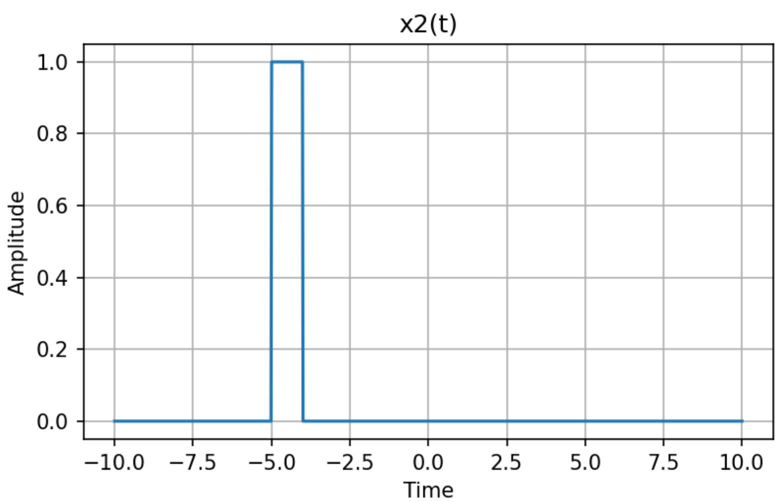
  Part A:

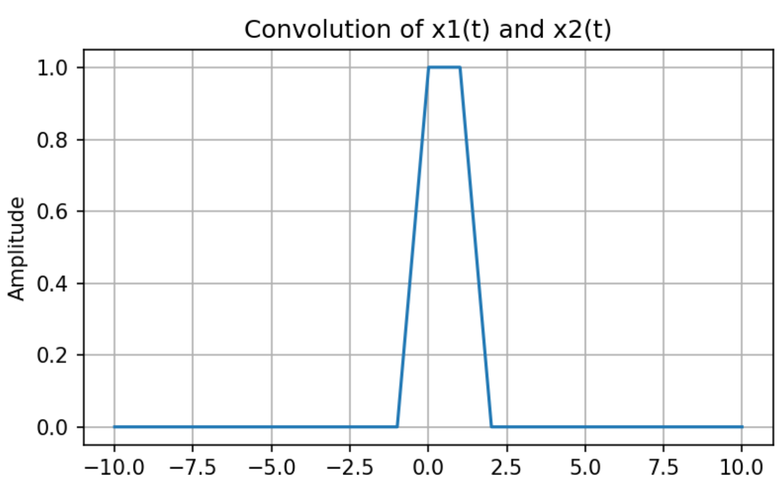
  Code:

```
#Problem B.3
#Part a)
t = np.linspace(-10, 10, 1000)
x1 = lambda t: (np.heaviside(t - 4, 0.5) - np.heaviside(t - 6, 0.5))
x2 = lambda t: (np.heaviside(t + 5, 0.5) - np.heaviside(t + 4, 0.5))

x1_t = x1(t)
x2_t = x2(t)

convolution = np.convolve(x1_t, x2_t, "same") * (t[1]-t[0])  # Multiply by dt for integration

plt.figure(figsize=(6, 14))

#Subplot for x1(t)
plt.subplot(3, 1, 1)
plt.plot(t, x1_t)
plt.title("x1(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

#Subplot for x2(t)
plt.subplot(3, 1, 2)
plt.plot(t, x2_t)
plt.title("x2(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

#Subplot for convolution
plt.subplot(3, 1, 3)
plt.plot(t, convolution)
plt.title("Convolution of x1(t) and x2(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

plt.subplots_adjust(hspace=0.5)
```

  Results:


x1(t)
Amplitude
1.0
0.8
0.6
0.4
0.2
0.0
−10.0 −7.5 −5.0 −2.5 0.0 2.5 5.0 7.5 10.0
Time

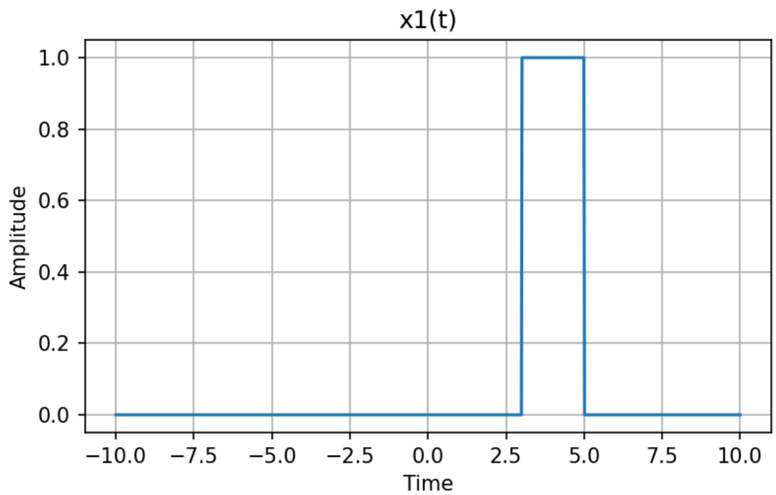

x2(t)
Amplitude
1.0
0.8
0.6
0.4
0.2
0.0
−10.0 −7.5 −5.0 −2.5 0.0 2.5 5.0 7.5 10.0
Time

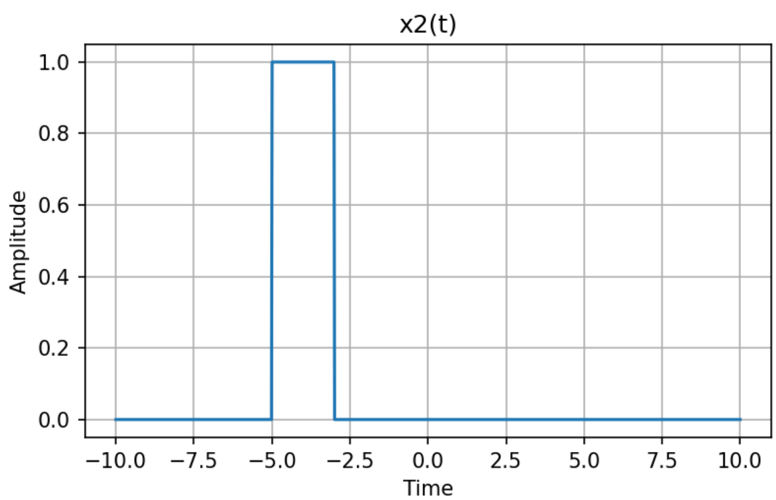

Convolution of x1(t) and x2(t)
Amplitude
1.0
0.8
0.6
0.4
0.2
0.0
−10.0 −7.5 −5.0 −2.5 0.0 2.5 5.0 7.5 10.0
Time

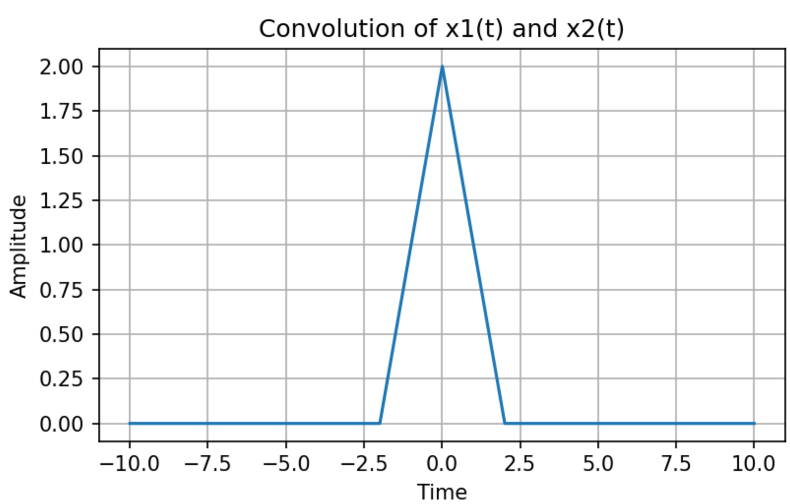
Part B:
Code:

```
#Part b)
t = np.linspace(-10, 10, 1000)
x1 = lambda t: (np.heaviside(t - 3, 0.5) - np.heaviside(t - 5, 0.5))
x2 = lambda t: (np.heaviside(t + 5, 0.5) - np.heaviside(t + 3, 0.5))

x1_t = x1(t)
x2_t = x2(t)

convolution = np.convolve(x1_t, x2_t, "same") * (t[1]-t[0])  # Multiply by dt for integration

plt.figure(figsize=(6, 14))

#Subplot for x1(t)
plt.subplot(3, 1, 1)
plt.plot(t, x1_t)
plt.title("x1(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

#Subplot for x2(t)
plt.subplot(3, 1, 2)
plt.plot(t, x2_t)
plt.title("x2(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

#Subplot for convolution
plt.subplot(3, 1, 3)
plt.plot(t, convolution)
plt.title("Convolution of x1(t) and x2(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)
plt.subplots_adjust(hspace=0.5)
```

Results:


x1(t)
Amplitude
Time
1.0
0.8
0.6
0.4
0.2
0.0
−10.0 −7.5 −5.0 −2.5 0.0 2.5 5.0 7.5 10.0

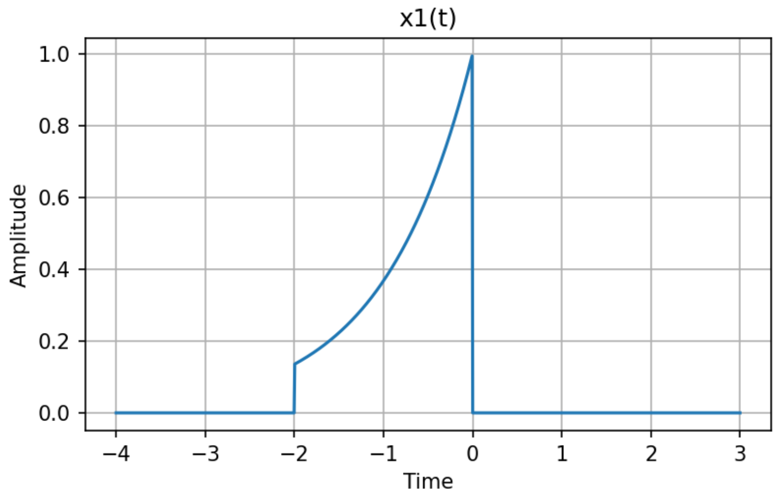

x2(t)
Amplitude
Time
1.0
0.8
0.6
0.4
0.2
0.0
−10.0 −7.5 −5.0 −2.5 0.0 2.5 5.0 7.5 10.0

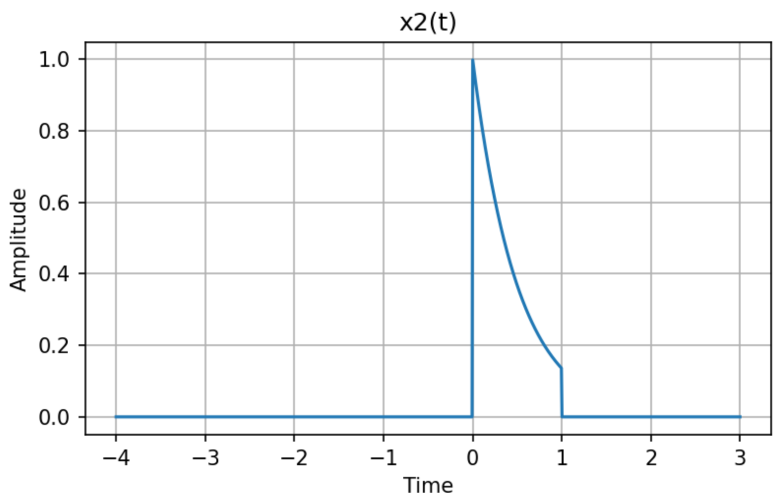

Convolution of x1(t) and x2(t)
Amplitude
Time
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
−10.0 −7.5 −5.0 −2.5 0.0 2.5 5.0 7.5 10.0

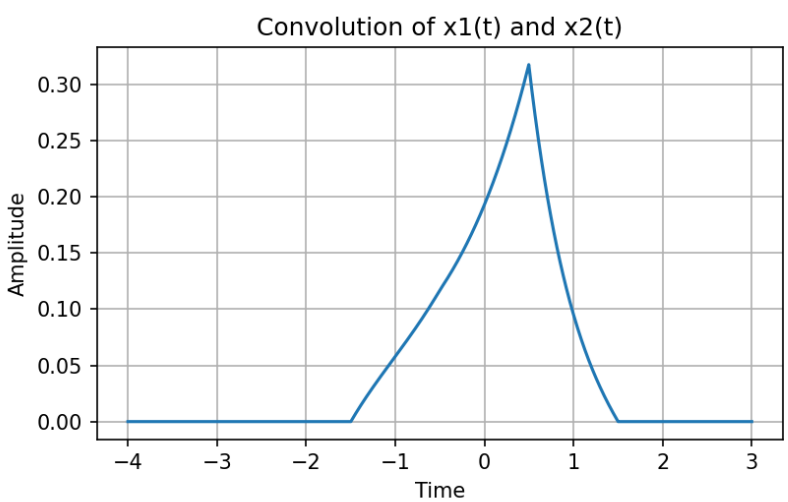
Part H:
Code:

```
#Part h)
t = np.linspace(-4, 3, 1000)  #Extended to capture both functions
x1 = lambda t: np.exp(t) * (np.heaviside(t + 2, 0.5) - np.heaviside(t, 0.5))
x2 = lambda t: np.exp(-2 * t) * (np.heaviside(t, 0.5) - np.heaviside(t - 1, 0.5))

x1_t = x1(t)
x2_t = x2(t)

convolution = np.convolve(x1_t, x2_t, "same") * (t[1]-t[0])  # Multiply by dt for integration

plt.figure(figsize=(6, 14))

# Subplot for x1(t)
plt.subplot(3, 1, 1)
plt.plot(t, x1_t)
plt.title("x1(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

# Subplot for x2(t)
plt.subplot(3, 1, 2)
plt.plot(t, x2_t)
plt.title("x2(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

# Subplot for convolution
plt.subplot(3, 1, 3)
plt.plot(t, convolution)
plt.title("Convolution of x1(t) and x2(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)
plt.subplots_adjust(hspace=0.5)

plt.show()
```

Results:


x1(t)
Amplitude
Time
1.0
0.8
0.6
0.4
0.2
0.0
−4
−3
−2
−1
0
1
2
3


x2(t)
Amplitude
Time
1.0
0.8
0.6
0.4
0.2
0.0
−4
−3
−2
−1
0
1
2
3


Convolution of x1(t) and x2(t)
Amplitude
Time
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−4
−3
−2
−1
0
1
2
3

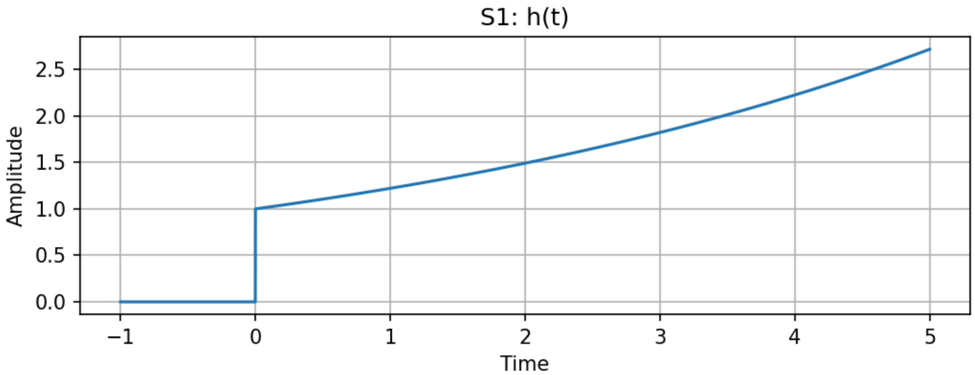
C. System Behavior and Stability.

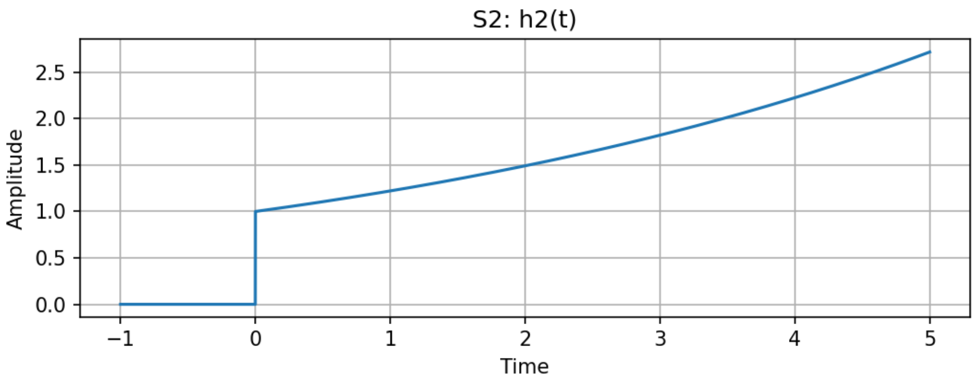
- **Problem C.1**

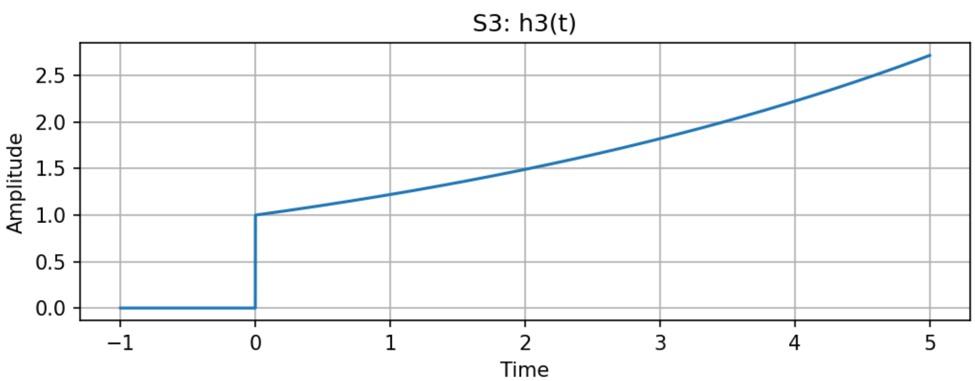
  Code:

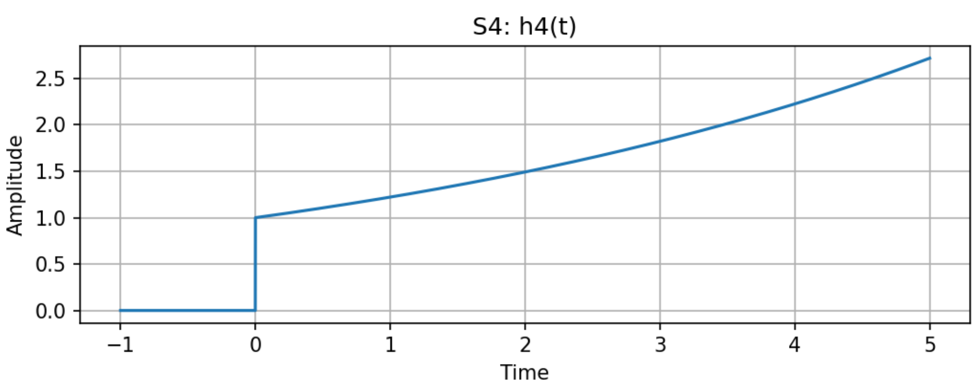
```
#Part C:
#Problem C.1
#Defining Functions
t = np.arange(-1, 5, 0.001)
h1 = lambda t: np.exp(t/5) * np.heaviside(t, 1)
h2 = lambda t: 4*np.exp(-t/5) * np.heaviside(t, 1)
h3 = lambda t: 4*np.exp(-t) * np.heaviside(t, 1)
h4 = lambda t: 4*(np.exp(-t/5) - np.exp(-t)) * np.heaviside(t, 1)


h1_t= h1(t)
h2_t= h1(t)
h3_t= h1(t)
h4_t= h1(t)


plt.figure(figsize=(8, 16))

# Subplot for h1(t)
plt.subplot(4, 1, 1)
plt.plot(t, h1_t, label="e^(t/5) * u(t)")
plt.title("S1: h(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

# Subplot for h2(t)
plt.subplot(4, 1, 2)
plt.plot(t, h2_t, label="4e^(-t/5) * u(t)")
plt.title("S2: h2(t)")
plt.xlabel("Time")          You, 9 minutes ago • Uncommitted changes
plt.ylabel("Amplitude")
plt.grid(True)

# Subplot for h3(t)
plt.subplot(4, 1, 3)
plt.plot(t, h3_t, label="4e^-t * u(t)")
plt.title("S3: h3(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

# Subplot for h4(t)
plt.subplot(4, 1, 4)
plt.plot(t, h4_t, label="4(e^(-t/5) - e^(-t)) * u(t)")
plt.title("S4: h4(t)")
plt.xlabel("Time")
plt.ylabel("Amplitude")
plt.grid(True)

plt.subplots_adjust(hspace=0.5)

plt.show()
```

Results:


S1: h(t)
Amplitude
Time
2.5
2.0
1.5
1.0
0.5
0.0
−1
0
1
2
3
4
5


S2: h2(t)
Amplitude
Time
2.5
2.0
1.5
1.0
0.5
0.0
−1
0
1
2
3
4
5


S3: h3(t)
Amplitude
Time
2.5
2.0
1.5
1.0
0.5
0.0
−1
0
1
2
3
4
5


S4: h4(t)
Amplitude
Time
2.5
2.0
1.5
1.0
0.5
0.0
−1
0
1
2
3
4
5

- **Problem C.2**
  Results:

```
#Problem C.2
#S1:
eigenvalue_1 = 1/5

#S2:
eigenvalue_2 = -(1/5)

#S3:
eigenvalue_3 = -1

#S4:
eigenvalue_4a = -(1/5)
eigenvalue_4b = -1
```

- **Problem C.3**
  Code:

```
#Problem C.3
#Specify the primary and alternate file paths
primary_script_path = "/Users/jah/Documents/GitHub/ELE532/lab2/C3.m"
alternate_script_path = "C:\\Users\\Jahmil\\Desktop\\Coding_Projects\\ELE532\\lab2\\C3.m"

#Check if the file exists in the primary location
if os.path.exists(primary_script_path):
    script_path = primary_script_path
else:
    #If not, use the alternate location
    script_path = alternate_script_path

eng = matlab.engine.start_matlab()
eng.eval(f"run('{script_path}')", nargout=0)
```

C3.m U ×

lab2 > C3.m

```matlab
%Define the u(t) function
u = @(t) 1.0.* (t>=0);

%Define the x(t) function.
x = @(t) sin(5*t).*(u(t) - u(t - 3));

%Truncate each impluse response funtion.
h1 = @(t) exp(t/5).*(u(t)-u(t-20));
h2 = @(t) 4*exp(-t/5).*(u(t)-u(t-20));
h3 = @(t) 4*exp(-t).*(u(t)-u(t-20));
h4 = @(t) 4*(exp(-t/5)-exp(-t)).*(u(t)-u(t-20));

%Modified CH2MP4 from B.1
dtau = 0.005;
tau = 0:dtau:20; ti = 0;
tvec = 0:.1:20; y = NaN*zeros(1,length(tvec));


%Change This to see Each Function
h=h1;

% Pre-allocate memory
for t = tvec,
    ti = ti+1; % Time index
    xh = x(t-tau).*h(tau);
    lxh = length(xh);
    y(ti) = sum(xh.*dtau);
    % Trapezoidal approximation of convolution integral
    subplot(2,1,1),plot(tau,h(tau),"k-",tau,x(t-tau),"k--",t,0,"ok");
    axis([tau(1) tau(end) -2.0 2.5]);
    patch([tau(1:end-1);tau(1:end-1);tau(2:end);tau(2:end)],...
        [zeros(1,lxh-1);xh(1:end-1);xh(2:end);zeros(1,lxh-1)],...
        [.8 .8 .8],"edgecolor","none");
    xlabel("\tau"); title("h(\tau) [solid], x(t-\tau) [dashed], h(\tau)x(t-\tau) [gray]");
    c = get(gca,'children'); set(gca,'children',[c(2);c(3);c(4);c(1)]);
    subplot(2,1,2),plot(tvec,y,"k",tvec(ti),y(ti),"ok");
    xlabel("t"); ylabel("y(t) = \int h(\tau)x(t-\tau) d\tau");
    axis([tau(1) tau(end) -1.0 2.0]); grid;

    drawnow;
end
```

Results:

h1:

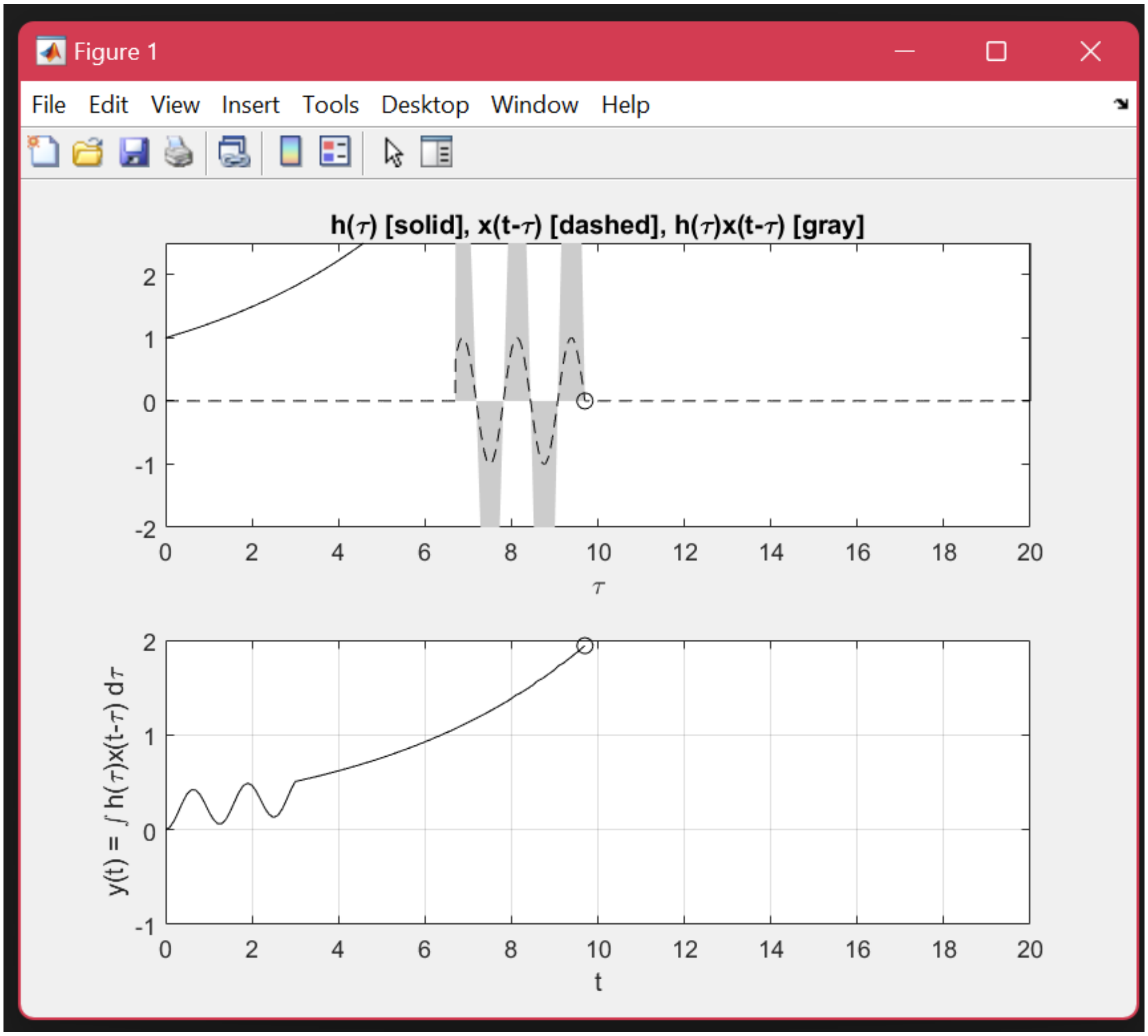


Figure 1
File Edit View Insert Tools Desktop Window Help
h(τ) [solid], x(t-τ) [dashed], h(τ)x(t-τ) [gray]
2
1
0
-1
-2
0 2 4 6 8 10 12 14 16 18 20
τ
y(t) = ∫ h(τ)x(t-τ) dτ
2
1
0
-1
0 2 4 6 8 10 12 14 16 18 20
t

h2:

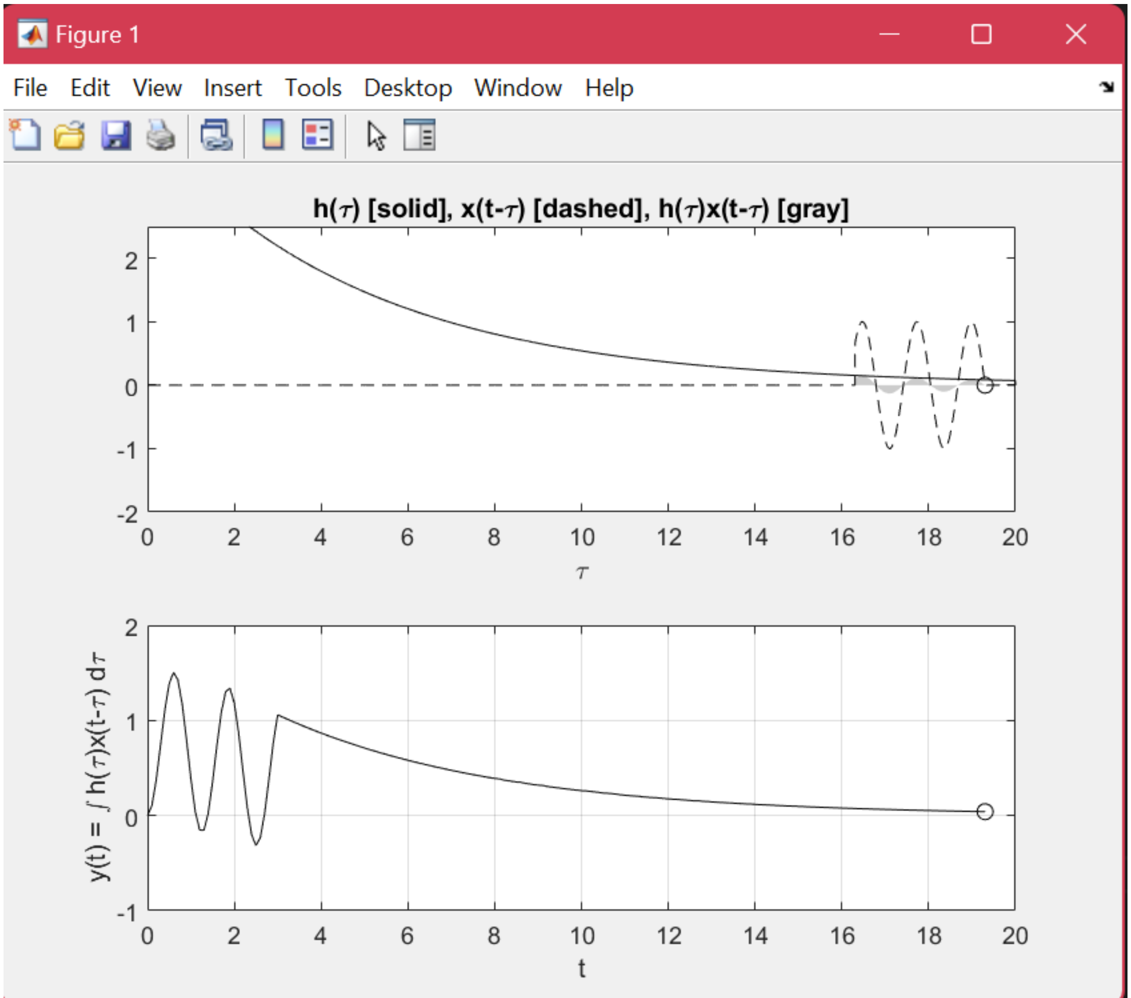


Figure 1
File Edit View Insert Tools Desktop Window Help
h(τ) [solid], x(t-τ) [dashed], h(τ)x(t-τ) [gray]
τ
y(t) = ∫ h(τ)x(t-τ) dτ
t

h3:

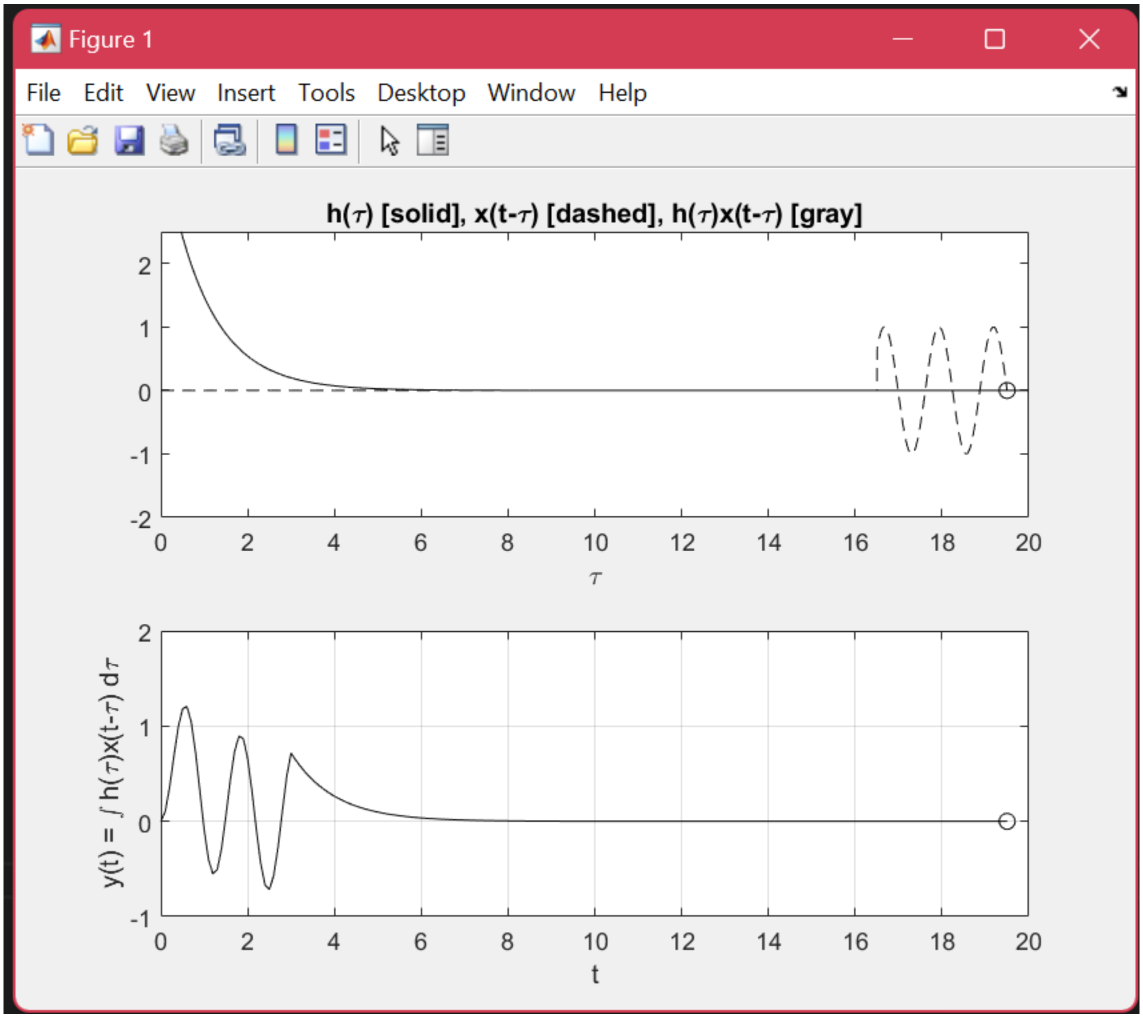
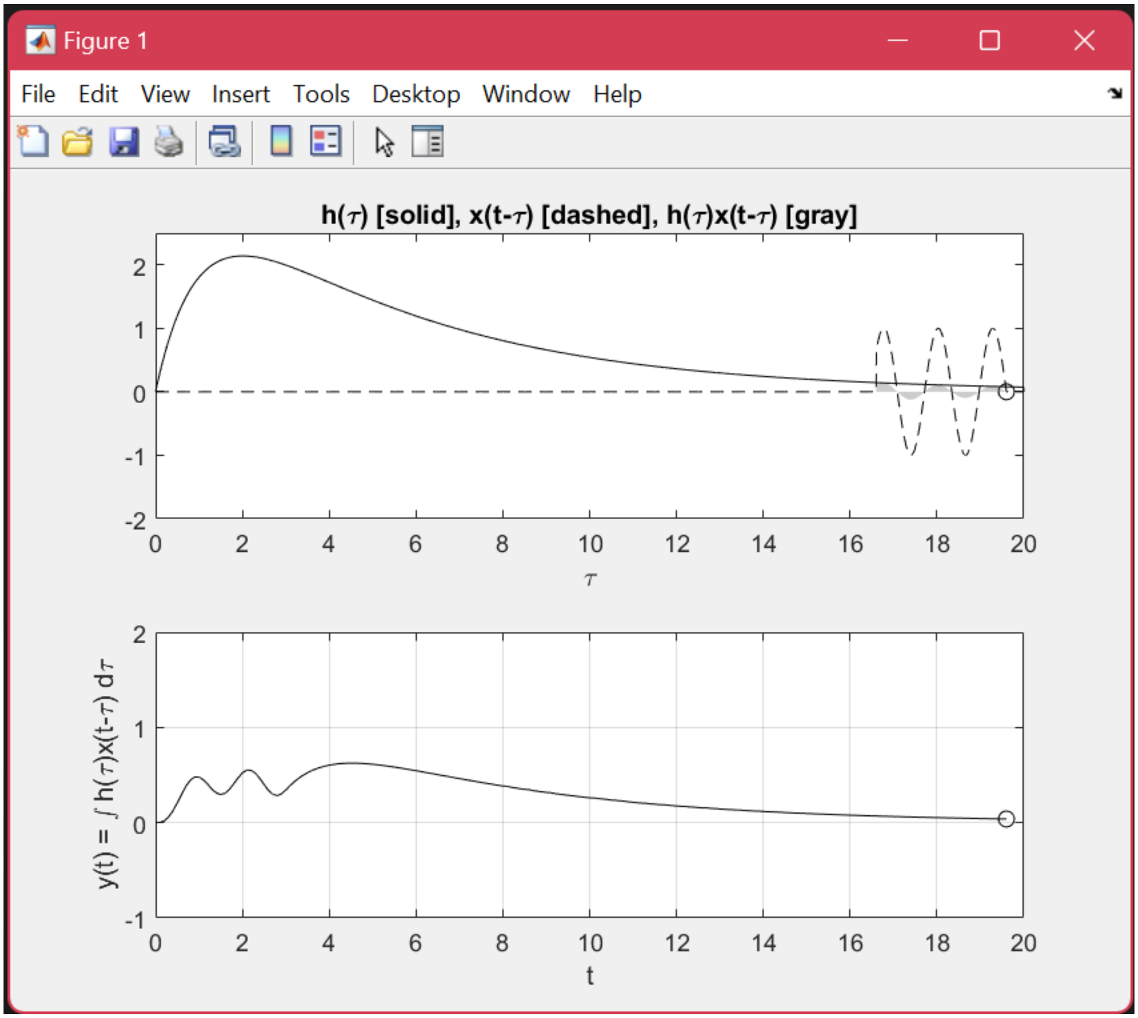


Figure 1
File Edit View Insert Tools Desktop Window Help
h(τ) [solid], x(t-τ) [dashed], h(τ)x(t-τ) [gray]
τ
y(t) = ∫ h(τ)x(t-τ) dτ
t

h4:



D. Discussion.

- **Problem D.2**
  Results: When two signals are convolved, the resulting signal's duration is equal to the sum of the durations of the original functions.