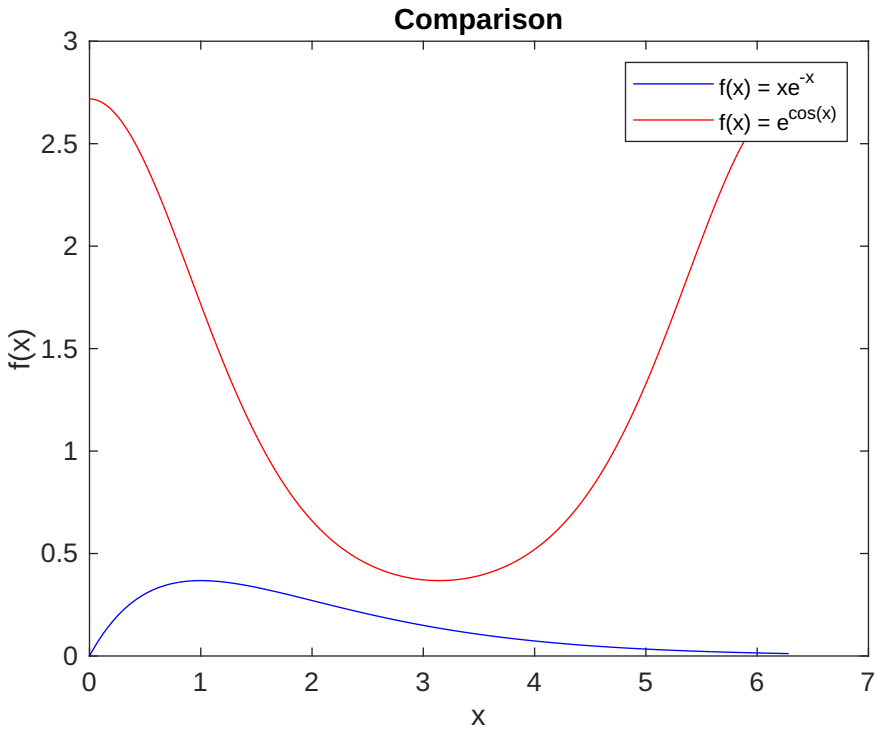
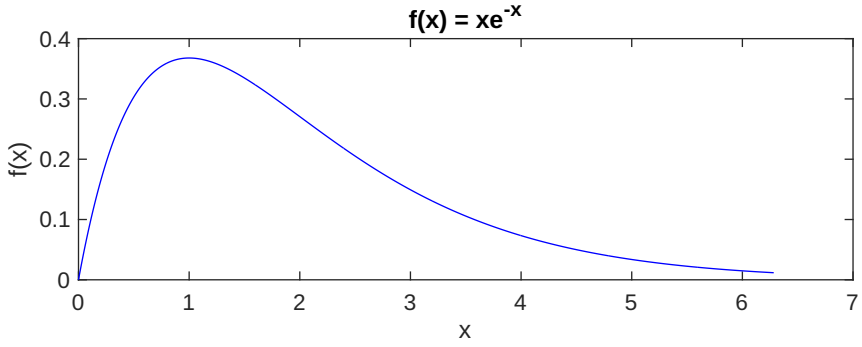
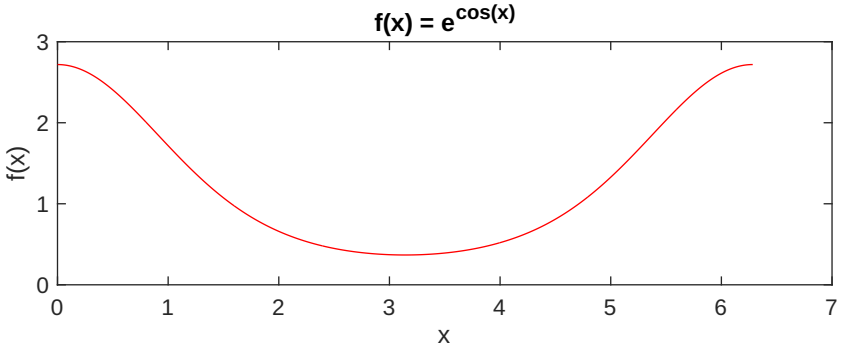
Question 1:

```
x = linspace(0,2*pi,1000);

figure(1);
y1 = x .* exp(-x);
y2 = exp(cos(x));

plot(x, y1, 'b', x, y2, 'r');
xlabel('x');
ylabel('f(x)');
title('Comparison');


legend('f(x) = xe^{-x}' , 'f(x) = e^{cos(x)}');

figure(2);
subplot(2,1,1)
plot(x,y1,'b');
xlabel('x');
ylabel('f(x)');
title('f(x) = xe^{-x}')


subplot(2,1,2)
plot(x,y2,'r');
xlabel('x');
ylabel('f(x)');
title('f(x) = e^{cos(x)}')
```

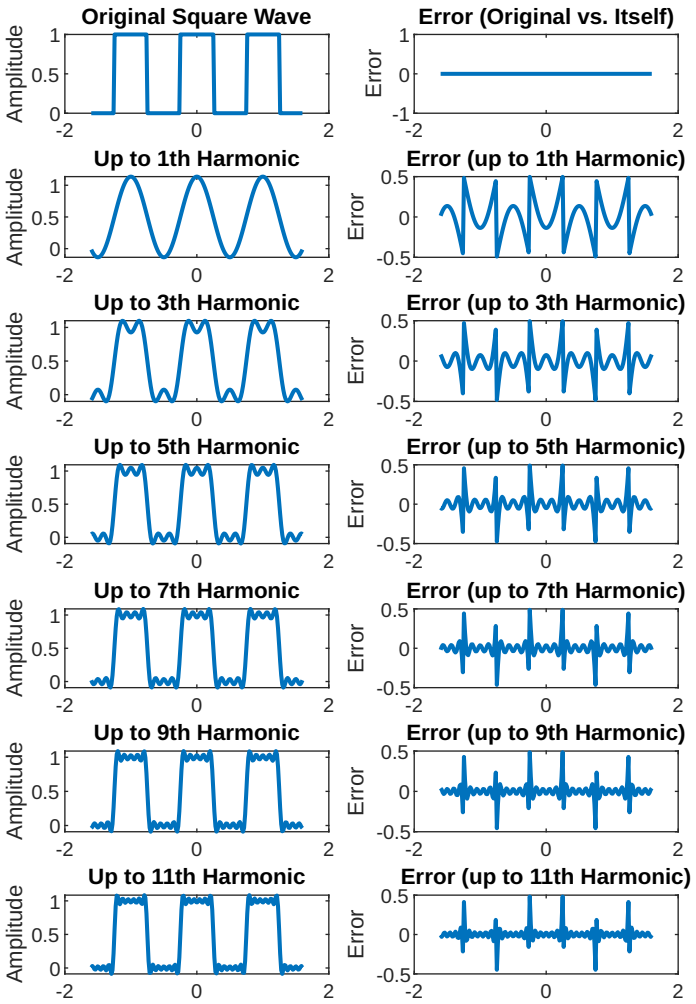






```
Question 2:
t = linspace(-1.6, 1.6, 200);

T = 1.0;
w0 = 6.2839;
x = zeros(size(t));
for i = 1:length(t)
    mod_t = mod(t(i) + T/2, T) - T/2;
    if abs(mod_t) < 0.25
        x(i) = 1.0;
    else
        x(i) = 0.0;
    end
end

a0 = 0.5;
a1 = 0.31831;
a3 = -0.1061;
a5 = 0.06366;
a7 = -0.0455;
a9 = 0.03537;
a11 = -0.0289;

x_approx = zeros(7, length(t));
x_approx(1,:) = a0 * ones(size(t));
x_approx(2,:) = x_approx(1,:) + a1 * 2 * cos(1*w0*t);
x_approx(3,:) = x_approx(2,:) + a3 * 2 * cos(3*w0*t);
x_approx(4,:) = x_approx(3,:) + a5 * 2 * cos(5*w0*t);
x_approx(5,:) = x_approx(4,:) + a7 * 2 * cos(7*w0*t);
x_approx(6,:) = x_approx(5,:) + a9 * 2 * cos(9*w0*t);
x_approx(7,:) = x_approx(6,:) + a11 * 2 * cos(11*w0*t);

errors = zeros(1, 7);
for k = 1:7
    errors(k) = mean(abs(x - x_approx(k,:)));
end

figure;
set(gcf, 'Position', [100, 100, 800, 1200]);

subplot(7, 2, 1);
plot(t, x, 'LineWidth', 1.5);
title('Original Square Wave');
ylabel('Amplitude');

subplot(7, 2, 2);
plot(t, zeros(size(t)), 'LineWidth', 1.5);
title('Error (Original vs. Itself)');
ylabel('Error');

harmonic_steps = [1, 3, 5, 7, 9, 11];
for k = 1:6
    subplot(7, 2, 2*k+1);
    plot(t, x_approx(k+1,:), 'LineWidth', 1.5);
    title(sprintf('Up to %dth Harmonic', harmonic_steps(k)));
    ylabel('Amplitude');

    subplot(7, 2, 2*k+2);
    plot(t, x - x_approx(k+1,:), 'LineWidth', 1.5);
    title(sprintf('Error (up to %dth Harmonic)', harmonic_steps(k)));
```

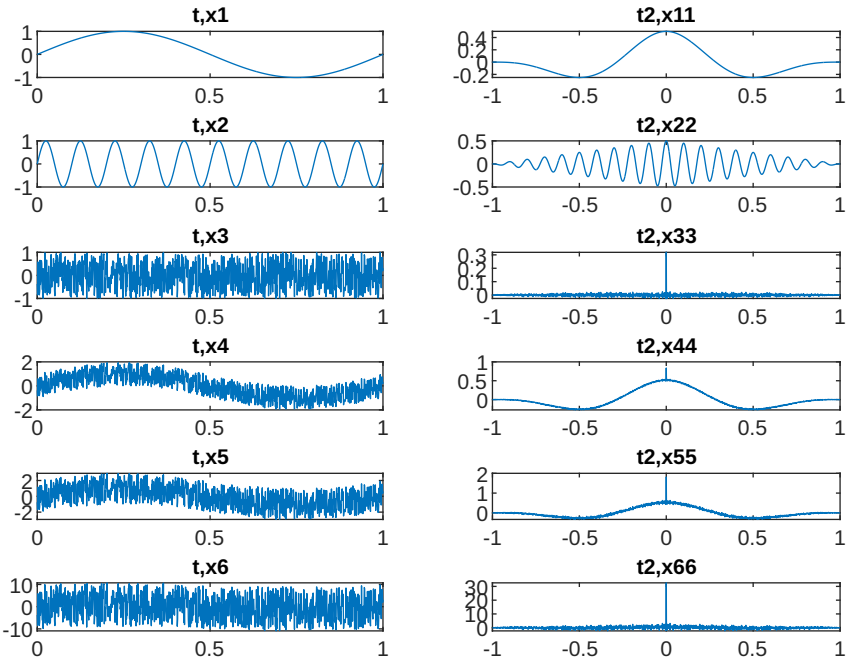
```
    ylabel('Error');
end

errors = zeros(1, 7);
for k = 1:7
    errors(k) = mean(abs(x - x_approx(k,:))) * 100;
end

required_harmonics = find(errors < 5, 1);

if isempty(required_harmonics)
    disp('More than 11 harmonics needed for <5% error.');
else
    harmonic_order = [0, 1, 3, 5, 7, 9, 11];
    fprintf('Number of harmonics needed for <5%% error: %d (i.e., up to %dth harmonic)
\n',required_harmonics, harmonic_order(required_harmonics));
end
```



Question 3:

```
t = linspace(0.0 , 1.0 , 1001);
N1 = length(t);

w0 = 2*pi;
x1 = sin(w0*t);

x11 = xcorr(x1,x1,'biased');
t2 = linspace(-1, 1 , length(x11));

x2 = sin(10*w0*t);
x22 = xcorr(x2 , x2 , 'biased');

x3 = 2 * rand(1,N1)-1;
x33 = xcorr(x3 , x3 , 'biased');

x4 = x1 + x3;
x44 = xcorr(x4 , x4 , 'biased');

x5 = x1 + 2*x3;
x55 = xcorr(x5 , x5 , 'biased');

x6 = x1 + 10*x3;
x66 = xcorr(x6 , x6 , 'biased');

figure;

subplot(6,2,1);
plot(t,x1);
title ('t,x1');

subplot(6,2,2);
plot(t2,x11);
title ('t2,x11');

subplot(6,2,3);
plot(t,x2);
title ('t,x2');

subplot(6,2,4);
plot(t2,x22);
title('t2,x22');

subplot(6,2,5);
plot(t,x3);
title('t,x3')

subplot(6,2,6);
plot(t2,x33);
title('t2,x33');

subplot(6,2,7);
plot(t,x4);
title('t,x4')

subplot(6,2,8);
plot(t2,x44);
title('t2,x44');

subplot(6,2,9);
```

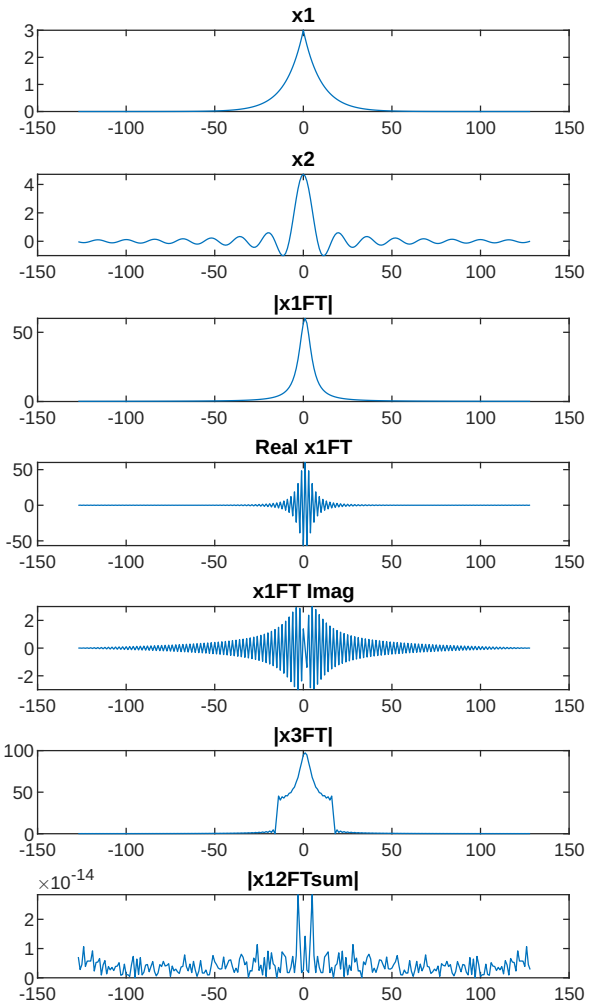
```
plot(t,x5);
title('t,x5');

subplot(6,2,10);
plot(t2,x55);
title('t2,x55');

subplot(6,2,11);
plot(t,x6);
title('t,x6')

subplot(6,2,12);
plot(t2,x66);
title('t2,x66');


%(x1):
% -Clean periodic autocorrelation peaks at 1s intervals.
%-Shows perfect repetition.
%(x2):
%-Tighter peaks at 0.1s intervals.
%-Higher frequency = closer peaks.
%(x3):
%-Single spike at center.
%-No pattern.
%(x4):
%-Peaks visible but noisy base
%(x5):
%-Peaks weaker, noise stronger.
%(x6):
%-Peaks nearly gone, noise dominates.
%Comparison:
%Autocorrelation clearly distinguishes periodic signals from noise.
%While sinusoids produce predictable peaks, noise corrupts this pattern proportionally to its amplitude.
```



Question 4:

```
t = -127:128;

A1 = 3;
C = 10;
x1 = A1*exp(-abs(t)/C);

A2 = 12;
w0 = 2*pi/16;
x2 = A2 * sin(w0*t) ./ t;

x2(t==0) = A2 * w0;

x1FT = fftshift(fft(x1));

x2FT = fftshift(fft(x2));

x3 = x1 + x2;

x3FT = fftshift(fft(x3));

x12FTsum = x1FT + x2FT;

x12FTdif = x3FT - x12FTsum;

figure;
subplot(7,2,1);
plot(t,x1);
title('x1');

subplot(7,2,2);
plot(t,angle(x1FT));
title('Phase of x1FT');

subplot(7,2,3);
plot(t,x2);
title('x2');

subplot(7,2,4);
plot(t,angle(x2FT));
title('Phase of x2FT');

subplot(7,2,5);
plot(t,abs(x1FT));
title('|x1FT|');

subplot(7,2,6);
plot(t,abs(x2FT));
title('|x2FT');

subplot(7,2,7);
plot(t,real(x1FT));
title('Real x1FT');

subplot(7,2,8);
plot(t,real(x2FT));
title('Real x2FT');

subplot(7,2,9);
```

```
plot(t,imag(x1FT));
title('x1FT Imag');

subplot(7,2,10);
plot(t,imag(x2FT));
title('2xFT Imag');

subplot(7,2,11);
plot(t,abs(x3FT));
title('|x3FT|');

subplot(7,2,12);
plot(t,abs(x12FTsum));
title('|x12FTsum|');

subplot(7,2,13);
plot(t,abs(x12FTdif));
title('|x12FTsum|');

subplot(7,2,14);
plot(t,angle(x12FTdif));
title('Pahse of x12FTdif');
```


x1
x2
|x1FT|
Real x1FT
x1FT Imag
|x3FT|
|x12FTsum|
×10-14
Phase of x1FT
Phase of x2FT
|x2FT
Real x2FT
2xFT Imag
|x12FTsum|
Pahse of x12FTdif