Tune-Up Tuesday for September 9, 2025

% Copy this file into a Matlab script window, add your code and answers to the
% questions as Matlab comments, hit "Publish", and upload the resulting PDF file
% to this page for the tune-up assignment. Please do not submit a link to a file
% but instead upload the file itself. **Late penalty:** 2 points per minute late.

% (a) Copy, paste and run the Matlab code from lecture slide 1-18 to generate a
% cosine signal $x(t) = \cos(2\ \text{pi}\ f_0\ t)$ with $f_0 = 440$ Hz and play it as an audio signal
% for 3s at a sampling rate of $f_s = 8000$ Hz. 440 Hz is an 'A' note on the fourth
% octave on the Western scale. See Piano key frequencies.

```
% (a) 'A' note on Western scale in 4th octave (A4) at 440 Hz
f0 = 440;                % note 'A4'
fs = 8000;               % sampling rate
Ts = 1/fs;               % sampling time
t = 0 : Ts : 3;          % 3 seconds
x = cos(2*pi*f0*t);
sound(x, fs);
pause(3);
```

% (b) Add to the code in (a) to generate a new signal $y(t) = \cos(2\ \text{pi}\ f_0\ t) \cos(2\ \text{pi}\ f_1\ t)$
% with $f_1 = 110$ Hz by using the same sampling rate of $f_s = 8000$ Hz. The code on
% the left side of lecture slide 3-3 might be helpful. Please remember to use the .*
% operator for pointwise multiplication of two vectors.

```
% (b) Multiply cosine at 440 Hz and cosine at 110 Hz
% Modified code from left side of lecture slide 3-3.
f1 = 110;                % 'A' in the second octave
x1 = cos(2*pi*f1*t);
y = x .* x1;
```

% (c) Add to the code in (b) to play $y(t)$ as an audio signal.
%   Describe what you hear.
%   Express y(t) as a sum of two sinusoids.

```
% (c) Play y(t) at a sampling (playback) rate of 8000 Hz.
%     I hear two notes/tones at a lower pitch than 440 Hz.
%     The product can be written as a sum of two cosines.
%     Using lecture slide 3-2,
%     y(t) = 0.5 cos(2 pi 330 t) + 0.5 cos(2 pi 550 t)
%     Tones at 330 Hz (E 4th octave) and 550 Hz (C# 5th octave)
%     are harmonics of 110 Hz. See Piano frequencies.
sound(y, fs);    % soundsc(y, fs) could also have been used.

% Note: The product cos(2*pi*f0*t) cos(2*pi*f1*t) will have
% amplitudes on [-1, 1] because each cosine has amplitudes
% on [-1, 1]. Hence, the sound command can be used without
% clipping amplitude values.

% Note: Playing a tone at 110 Hz may not be audible when
% played back on a laptop.  Many laptop playback systems
% have very low volume outputs for frequencies below 200 Hz.
```

% (d) Plot one period of y(t). We'll first need to find the period of y(t).
% The product of two sinusoids with frequencies f0 and f1 produces
% frequencies at f0+f1 and f0-f1. You could modify the code from the
% bottom right side of lecture slide 3-3.

```
ffund = gcd(f0+f1, f0-f1); % 440 Hz +/- 110 Hz
Tfund = 1/ffund;
n = round(Tfund / Ts);      % Tfund / Ts isn't an integer.
plot( t(1:n), y(1:n) );
```

% See below for the plot. The plot has several artifacts as noted below.