Final Exam
June 14, 2006

ECE 223: Signals & Systems II
Dr. McNames

- Keep your exam flat during the entire exam.
- If you have to leave the exam temporarily, close the exam and leave it face down while you are out of the room.
- Turn off cell phones.
- Do not open the exam until instructed to do so.
- Do not use separate scratch paper. If you need more space, use the backs of the exam pages and write a note directing my attention to these pages.
- You will have 100 minutes to complete the exam.
- If you have extra time, double check your answers.
- Include units with each of your answers.
- Show all of your work for full credit.

Problem 1: _____ / 18
Problem 2: _____ / 14
Problem 3: _____ / 10
Problem 4: _____ / 8

Total: _____ / 50
1. **Key Concepts (18 pts)**

The following abbreviations are used throughout this exam: FT = Fourier Transform, FS = Fourier Series, DT = Discrete-Time, and CT = Continuous-Time. Unless specified otherwise, you may assume the signal is real-valued for all of these questions.

a. (4 pts) What are the following components of the signal \( x[n] = 17 \exp(-j1.7\pi n) \)?

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>( \angle {x[n]} = \frac{\pi}{2} )</td>
</tr>
<tr>
<td>Imaginary part</td>
<td>( \text{Im}{x[n]} = -17 )</td>
</tr>
<tr>
<td>Fundamental frequency</td>
<td>( \Omega = 1.7\pi )</td>
</tr>
<tr>
<td>Fundamental period</td>
<td>( N = 2 )</td>
</tr>
</tbody>
</table>

b. (1 pt) What types of signals can be represented as sums of sinusoids?

- Energy
- Power
- Periodic
- Nonperiodic

c. (1 pt) Which types of signals can be represented as integrals of complex sinusoids?

- Energy
- Power
- Periodic
- Nonperiodic

d. (2 pts) If a sinusoidal signal \( x(t) = A \cos(\omega t + \theta) \) is applied to an LTI system, how is the output of the system related to the input signal and the system’s impulse response \( h(t) \)?

e. (2 pts) If a sinusoidal signal \( x[n] = A \cos(\Omega n + \theta) \) is applied to an LTI system, how is the output of the system related to the input signal and the system’s impulse response \( h[n] \)?

f. (1 pt) Why is Parseval’s theorem important?

g. (1 pt) What is the difference between the DFT and the FFT?

h. (1 pt) Which of the following transforms can be calculated with a computer exactly, ignoring finite precision effects?

- DTFT
- DTFS
- CTFT
- CTFS

i. (1 pt) Which of the following transforms can be estimated with the FFT?

- DTFT
- DTFS
- CTFT
- CTFS
1. **Key Concepts Continued (18 pts)**
   
j. (1 pt) What is the purpose of zero padding?

k. (1 pt) What is the consequence of windowing a signal when estimating the CTFT?

l. (1 pt) Why is windowing almost always applied in the estimation of the CTFT?

m. (1 pt) What is Gibb’s phenomenon?
2. DT Systems (14 pts)

The frequency response of a discrete-time system is shown below. The phase of the response at \( \Omega = 0 \) is \( 0^\circ \).

---

a. (1 pt) What type of filter is this?
- Lowpass
- Highpass
- Bandpass
- Bandstop
- None

b. (1 pt) What type of filter is this?
- Elliptic
- Chebyshev Type I
- Chebyshev Type II
- Butterworth

c. (1 pt) Suppose the minimum gain in the passband is 1.90. What are the approximate passband frequencies? Include units with your answer.

d. (1 pt) Suppose the maximum gain in the stopband is 0.10. What are the approximate stopband frequencies? Include units with your answer.

---

e. (3 pts) Evaluate the frequency response at the following frequencies.

\[
|H(e^{j2\pi})| = \quad \text{angle } \{H(e^{j2\pi})\} = \\
|H(e^{j33.1\pi})| = \quad \text{angle } \{H(e^{j33.1\pi})\} = \\
|H(e^{-j0.4\pi})| = \quad \text{angle } \{H(e^{-j0.4\pi})\} = 
\]

f. (7 pts) Suppose the following input signal is applied to this system. What is the output of the system? Hint: use the symmetry and periodic properties of the DTFT.

\[x[n] = 3 + 30 \sin(0.3\pi n + 12^\circ) + 100 \cos(4.8\pi n - 170^\circ) + 80 \cos(-0.4\pi n + 120^\circ)\]
3. **Sampling Applications (10 points)**
An intern at NOAA is given the task of designing the instrumentation for a bouy that will be located 100 miles off the coast of Cannon Beach. Among other tasks, an analog sensor on the bouy continuously measures the wave height. The wave height must be transmitted to a base station located in Cannon Beach. The period between the waves is expected to range from 5 to 25 seconds. Express all frequencies in units of Hz.

a. (1 pt) The intern decides to assume the waves are sinusoidal. What is the highest frequency component of the signal?
   \[ f_{\text{max}} = \]

b. (1 pt) What is the lowest frequency component of the signal?
   \[ f_{\text{min}} = \]

c. (1 pt) If the intern decides to sample this signal, what is the minimum sample rate she could use without causing aliasing?
   \[ f_s = \]

Suppose a supervising engineer informs the intern that the wave height is not sinusoidal and has significant power in up to 4 harmonics. Use this model of the signal to answer the remaining questions.

d. (1 pt) What is the highest frequency component of the signal given this revised model?
   \[ f_{\text{max}} = \]

e. (1 pt) What is the minimum sample rate she must use?
   \[ f_s = \]

f. (1 pt) Suppose the intern is concerned about high frequency noise that may be picked up by the sensor. What type of filter should she use to limit the bandwidth from 0 to \( f_{\text{max}} \)?
   Lowpass  Highpass  Bandpass  Bandstop  Notch

g. (1 pt) Suppose the filter must have a transition band that is at least 50% as wide as the passband. What is the passband frequency range of this filter?

h. (1 pt) What is the stopband frequency range of this filter?

i. (1 pt) If this filter is also to be used as an anti-aliasing filter, what is the minimum sample rate that could be used with this filter?
   \[ f_s = \]

j. (1 pt) What is the highest frequency component in the passband of the resulting discrete-time signal. Express your answer in units of radians per sample
   \[ \Omega_{\text{max}} = \]
4. **Communications Concepts (8 pts)**

Suppose a speech signal is to be transmitted across campus using amplitude modulation techniques. You are allocated a bandwidth from 100 kHz to 110 kHz and limited to a transmission power of 100 watts.

a. (1 pt) If you use single sideband modulation, what is the maximum bandwidth of your baseband signal?

\[ f_{\text{max}} = \]

b. (1 pt) If you use double sideband modulation, what is the maximum bandwidth of your baseband signal?

\[ f_{\text{max}} = \]

c. (1 pt) What type of filter must you apply to the speech signal to ensure the bandwidth of the baseband signal is within this range?

- Lowpass
- Highpass
- Bandpass
- Bandstop
- Notch

\[ \]

d. (2 pts) What specifications would you use for this filter, assuming that you use double sideband modulation? Specify some reasonable passband and stopband frequencies and attenuation specifications? Note that there are many acceptable answers to this problem.

\[ \]

\[ \]

e. (1 pt) If you wished to minimize the cost of the receiver, would you use synchronous amplitude modulation (SAM) or asynchronous amplitude modulation (AAM)? Explain.

- SAM
- AAM

\[ \text{Explanation:} \]

\[ \]

\[ \]

f. (1 pt) If you wished to maximize the quality of the received signal, would you use synchronous or asynchronous amplitude modulation? Explain.

- SAM
- AAM

\[ \text{Explanation:} \]

\[ \]

\[ \]

g. (1 pt) What would the frequency of your carrier signal be?

\[ f = \]