Electromechanical Systems
ASE 375

Lecture 26: Review for Test 2

Test Info

- 2pm-2:45pm, in Class, May 1^{st}, Wed.
- Test is Closed book: That means no books, notes, laptops, tablets or phones. Calculators are allowed. No scratch paper. Use the backside of your test booklet.
- Test will be worth 15 pts. Your first test score will be assumed to be out of 15 pts, i.e., you are getting a chance to score an additional point.
- Any equations needed that you are not expected to remember are provided.
- Ask for clarification if the meaning of a question is unclear to you.

Overview

- Accelerometers, Impulse and Frequency Response
- Shakers, Hydraulic/Pneumatic, Electromagnetic, Piezoelectric
- Optical Measurements
  - Semiconductors, P-N Junction Diodes, Photodiodes, Optical Whole Field Measurements
- Acoustics

Overall note: no need to remember any equations, but if shown an equation, you need to know what the different terms mean

Dynamic Measurements, Accelerometers, Impulse and Frequency Response, Shakers

- Fundamental principle behind accelerometers
- Different types of accelerometers : mechanical, capacitive, piezoelectric
- Fourier Transform
  - Representation of waves in time and frequency domains
- Different types of inputs/forcing
- Single degree of freedom spring mass system
  - Response of SDOF system
  - Natural frequency, damped natural frequency, damping factor
- Electromagnetic Shaker principle
- Pascal’s Law: Hydraulics and Pneumatics

Optical Measurements

- Semiconductor Principles
  - Conductors, Insulators, Semiconductors
  - P-type, N-type Semiconductors
  - Valence band and conduction band physics
  - P-N Junction Diodes, LEDs, Photodiodes, Laser Vibrometer, Doppler effect, Scanning Laser Vibrometer
- Digital Image Correlation : Whole field measurements, components required in DIC for 2D and 3D

Acoustics

- Fundamentals of acoustics – what is sound, what is speed of sound, sound propagation
- Sound power (W) – Sound energy per unit time,
- Intensity, $I = \frac{p^2}{\rho c}$, (W/sq.m) - Sound power per unit area
- Sound pressure – local variation in pressure (N/sq.m)
- Threshold intensity – Sound level or Loudness in dB is 0, $L = 10 \log_{10}(I/I_0)$, $I_0 = 10^{-12}$ W/sq.m
- $SPL = 20 \log_{10}(p/p_{ref})$, $p_{ref} = 10^{-6}$ N/sq.m
- Sound measurement principle – its like measuring pressure, except the pressure levels are very low and unsteady
- Sound pressure > Diaphragm motion > Current/Voltage
- Capacitive and electromagnetic are commonly used

Problem 1

- For a spring mass system, $m\ddot{x} + c\dot{x} + kx = f(t)$ you are given the following relations.
- $\omega_n = \sqrt{\frac{k}{m}}, \omega_d = \omega_n(\sqrt{(1-\zeta^2)}, \zeta = \frac{c}{\sqrt{2km}}$.
- Given stiffness = 0.01, damping = 1 , and mass = 100, is the system overdamped or underdamped?
- If so, what is the damped natural frequency

- Solution
  - Calculate, $\zeta = \frac{1}{\sqrt{2*0.01*100}}$ = 0.7 < 1, so system is underdamped
  - $\omega_d = \sqrt{\frac{k}{m}}(\sqrt{(1-\zeta^2)}$ = $\sqrt{\frac{0.01}{100}}(\sqrt{(1-.7^2)}$ = 0.1*0.714/10 = 0.714e-2 rad/s

Problem 2

- What is the force required on a piston of 0.1sq.m area, if the piston is used to lift a 600N load on 1sq.m surface.

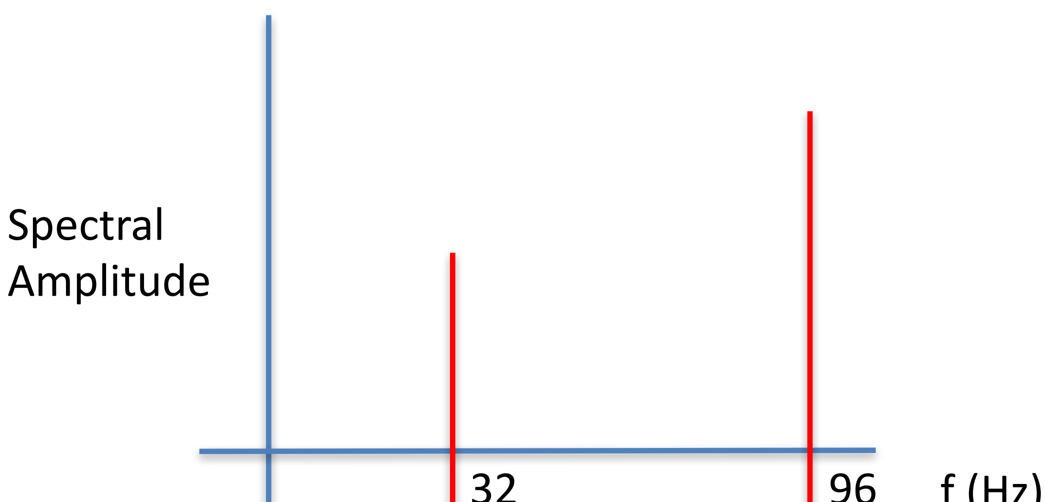
- Pascals Law:
  - $F1/A1 = F2/A2$,
  - $F1=A1 \times F2/A2 = 0.1*600/1 = 60N$

Problem 3

- A time domain signal is written as 3 sin(200t)+ 6 sin(600t). Show the frequency domain representation of this signal with correct labels, values and units.
- You are not required to calculate the exact spectral amplitudes, just show them in relation to each other (i.e. which one is bigger)

Problem 3 - Solution

- A time domain signal is written as 3 sin(200t)+ 6 sin(600t). Show the frequency domain representation of this signal with correct labels, values and units.
- First component has a frequency given by $2\pi f = 200, or\ f = 32Hz$
- The second component is three times that, or 96Hz. The second component also has a higher amplitude, so it will have a bigger peak in the frequency domain.



Problem 4

- A motor system has two resonances, f1=13kHz and f2=50kHz. When the motor bearing fails, a third resonance occurs at 25kHz. What is the minimum sampling rate needed for the system?

Problem 4 Solution

- A motor system has two resonances, f1=13kHz and f2=50kHz. When the motor bearing fails, a third resonance occurs at 25kHz. What is the minimum sampling rate needed for the system?

- The largest frequency determines the Nyquist Frequency and the sampling rate has to be at least 2 times Nyquist, so in this case $2f_2$=100kHz

Problem 5

- If the input range of a signal is 25.6V, what is the resolution of the measurement system for an 8-bit A/D board

Problem 5 solution

- If the input range of a signal is 25.6V, what is the resolution of the measurement system for an 8-bit A/D board

Solution
An 8 bit A/D board has 256 digital states, (2^8)
Breaking up the input range in 256 states, we get,
25.6/256 = 0.1V resolution

Problem 6

- A measurement system with an input voltage range of 0-10V has to have a resolution of 0.1V or better. If one of the bits is always used for an on-off switch (or trigger) what is the smallest bit A/D board required for this application? What is the actual resolution of the board?

Problem 6 Solution

- A measurement system with an input voltage range of 0-10V has to have a resolution of 0.1V or better. If one of the bits is always used for an on-off switch (or trigger) what is the smallest bit A/D board required for this application? What is the actual resolution of the board?
- Solution: If the resolution has to be 0.1V, then the number of digital levels (states) needed for a range of 10V is
  - 10/0.1 =100
- An n bit board can have 2^n states
  - A 6 bit board can have 64 states, while a 7 bit board can have 128 states, which means we need at least a 7 bit board to achieve the 0.1 V resolution or better.
  - Since we need to add a bit for the trigger (switch), we need an 8 bit board.
- The actual resolution achieved is 10/128 = 0.078V