Department of Mechanical and Aerospace Engineering
MAE334 - Introduction to Instrumentation and Computers

Midterm Examination

October 19, 2005

- **Closed Book and Notes**
- **Fill in your name** on your scoring sheet
- **Fill in your 8-digit person number** on your scoring sheet.
- For each question, choose **THE BEST ANSWER** and mark the corresponding answer on the scoring sheet.
- **The student-t table is on the last page of the exam**

<u>Fill in circle 1 under GRADE OR EDUCATION</u> on your scoring sheet. This is your test number! You will receive a ZERO if you do not indicate your test number.

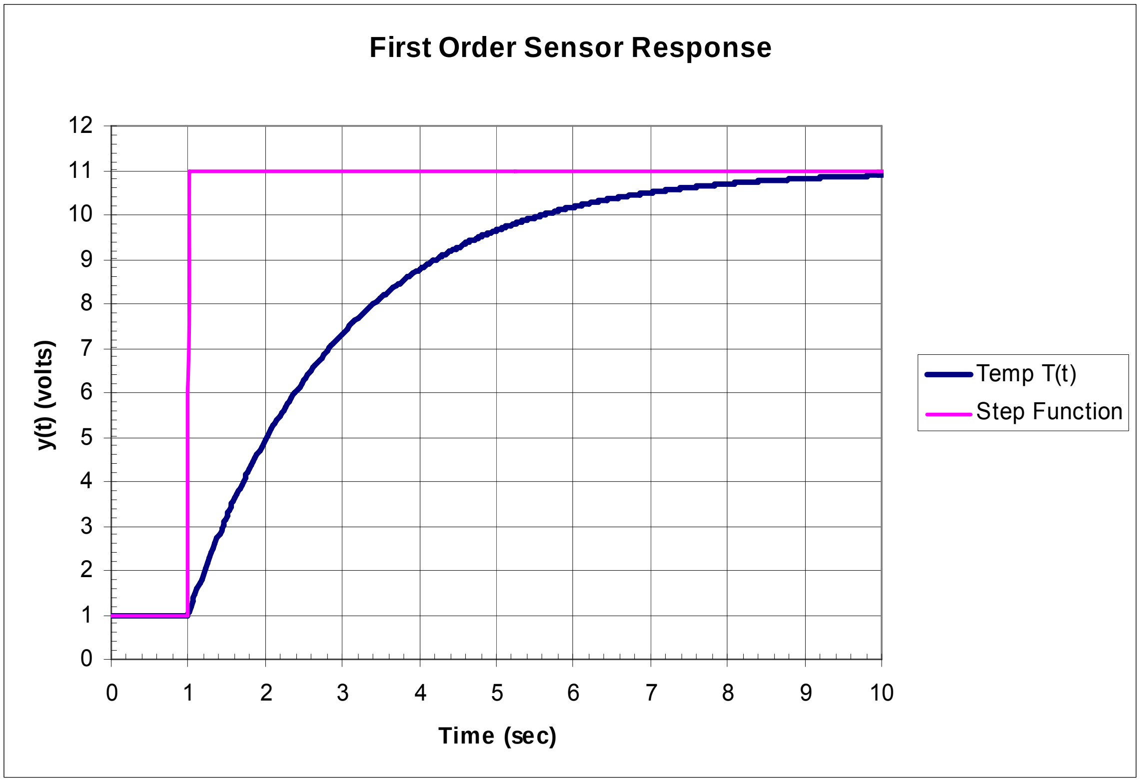

Figure 1. Time response output of a first order system subjected to a step input function.

1. What is the approximate time constant of the first order system plotted in Figure 1?
    a. 2
    b. 3
    c. 4.5
    d. >10
    e. None of the above

2. If the time constant of the thermocouple used in Lab 2 had changed from 2 seconds for the water-to-water experiments to 200 seconds for the water-to-air experiments what would explain the difference?
    a. The convective heat transfer coefficient increased by a factor of 100.
    b. The convective heat transfer coefficient decreased by a factor of 100.
    c. The thermal capacity of the thermocouple is 100 times greater in air.
    d. The specific heat of air is 100 times larger than water.
    e. None of the above.

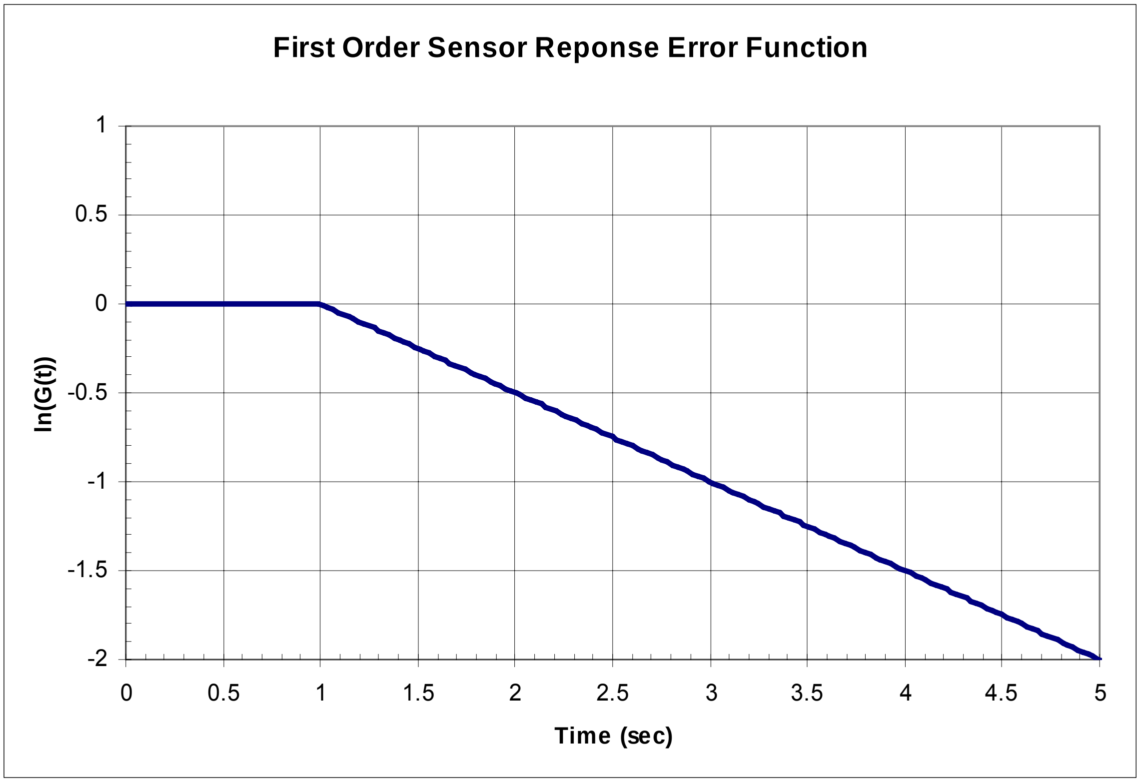

Figure 2. Linearized error function of a first order system subjected to a step input function.

3. The data from Figure 1 was used to obtain Figure 2?
    a. True
    b. False
4. If the static sensitivity of the thermocouple was less, the time constant would be smaller.
    a. True
    b. False
5. If the thermocouple used to obtain Figure 2 was subjected to a 5 Hz temperature fluctuation you would expect
    a. A minimal amplitude reduction and phase lag of the output signal
    b. A moderate amplitude reduction and phase lag of the output signal
    c. A major amplitude reduction and phase lag of the output signal
    d. The moon to be made of cheese
6. The MicroSoft Excel function used to obtain the student-t table value, $t_{99\%,108}$ would be
    a. =TINV(99%,108)
    b. =TINV(1%,108)
    c. =1/TINV(99%,108)
    d. None of the above

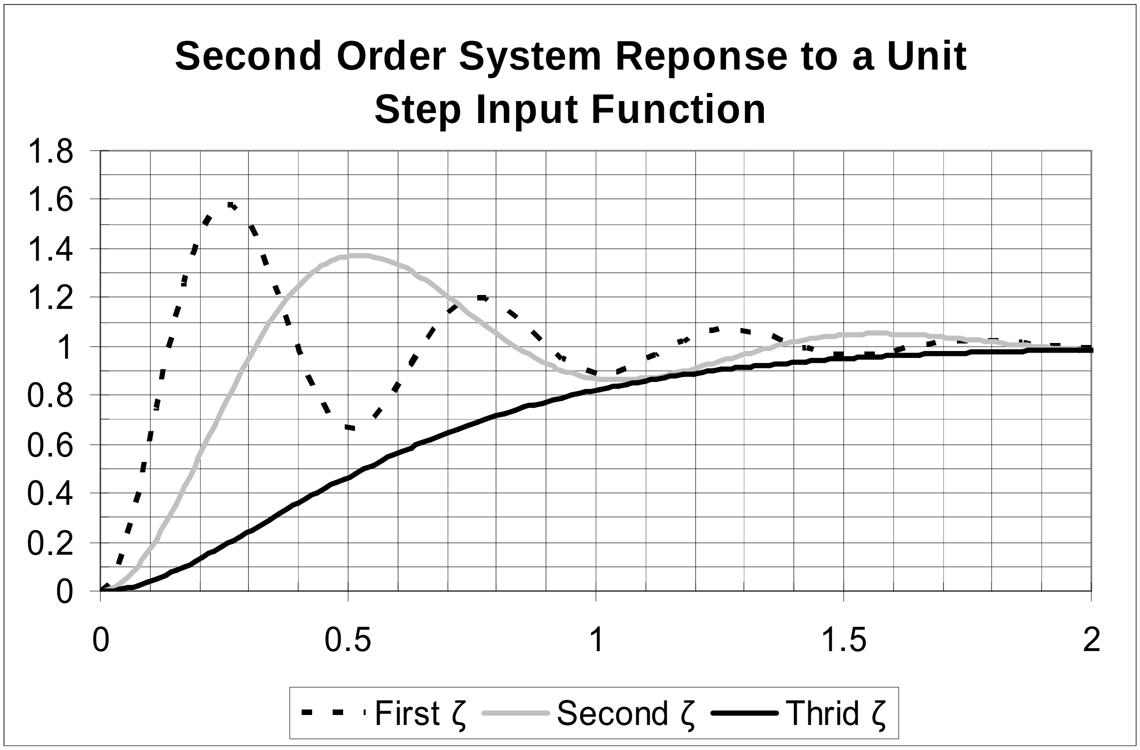

Figure 3. Response of a second order system to a step input function.

7. Which system response in Figure 3 has the shortest settling time?
   a. First
   b. Second
   c. Third
   d. The second and third are approximately equal
   e. The first and third are approximately equal

8. What is the approximate natural frequency of the first system in Figure 3?
   a. 0.5 Hz
   b. 5 Hz
   c. 2 Hz
   d. 1 Hz
   e. It can not be determined from the graph

9. To correctly enter the LINEST array function in MicroSoft Excel you could
   a. Type in the function in a cell and press Cntl+Shift+Enter
   b. Type in the function in a cell, then drag the cell to a 2 column by 5 row array
   c. Select a 2 column by 5 row array, type in the function and then press Cntl+Shift+Enter
   d. None of the above

10. If you have an uncalibrated instrument its bias error can be reduced by randomizing your data collection, taking a large quantity of data and repeating the experiment numerous times.
    a. True
    b. False

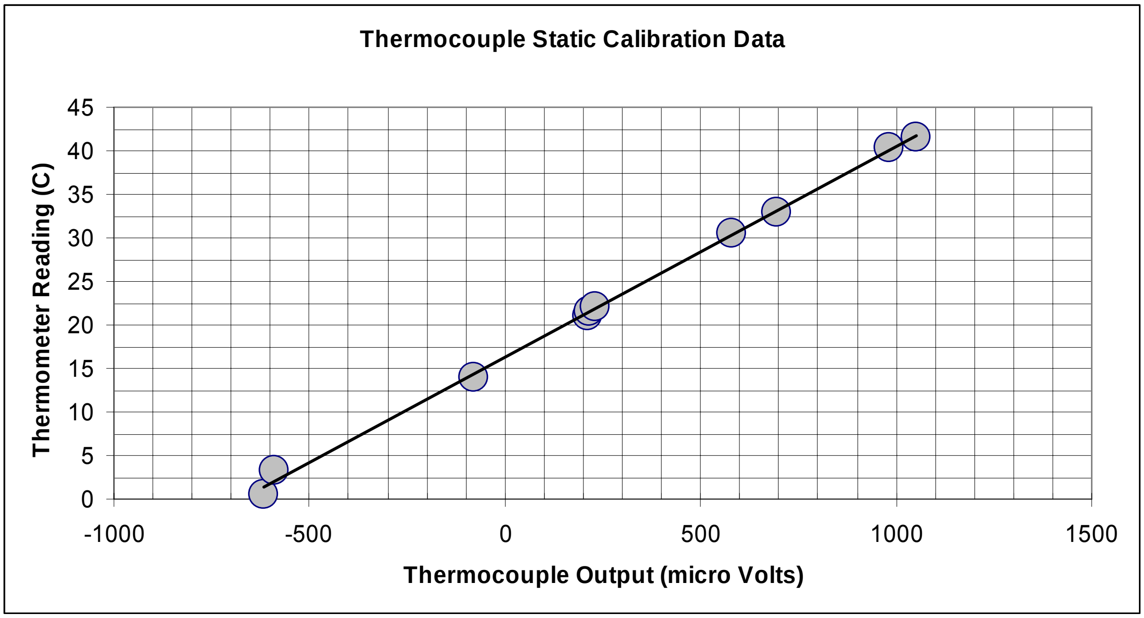

Figure 4. Thermocouple static calibration plot of data from Table 1 with a linear trend line fit to the data.

11. The linear trend line in Figure 4 has how many degrees of freedom?
    a. 11
    b. 10
    c. 9
    d. 8

12. For the μV vs. Temperature (°C) data in table 1, S_x=5x(10^{-4}), S_{yx}=0.5, R^2=0.98. What is the confidence interval for a second order fit with 90% certainty?
    a. ±(1.833 x 0.5)
    b. ±(1.812 x 0.98)
    c. ±(1.833 x 5x(10^{-4}))
    d. ±(1.860 x 5x(10^{-4}))
    e. None of the above

Point Number	Thermometer Reading [C]	DMM Value (uV)
1	0.50	-616.0
2	21.00	213.0
3	41.50	1050.0
4	30.50	580.0
5	33.00	695.0
6	21.50	217.0
7	3.20	-590.0
8	40.30	984.0
9	22.00	229.0
10	14.00	-79.0
11	4.5	-533.0

Table 1. Lab 2 thermocouple static calibration data plotted in Figure 4.

13. If the static sensitivity of a thermocouple was found to be 8192 °C/V and a bi-polar 12 bit ADC with a full scale range of 25 volts and an input signal gain of 50 was used to record the thermocouple output, what would the quantization level in °C be?
    a. 1 °C
    b. 2 °C
    c. none of the above

14. If you have a calibrated instrument its precision error can be minimized by randomizing your data collection, taking a large quantity of data and repeating the experiment numerous times.
    a. True
    b. False

15. A 4 bit ADC with a 16 volt input signal range has a finer resolution than a 8 bit ADC with a 200 volt input signal range.
    a. True
    b. False

16. The ADC used in the lab would output what binary value corresponding to -3?
    a. 111111111101
    b. 100000000011
    c. 000000000011
    d. 111111111100
    e. None of the above

17. Unlike a thermocouple a resistance temperature device, RTD, behaves very close to a zero order system?
    a. True
    b. False

18. Interference is considered to be a deterministic extraneous variable in an experiment?
    a. True
    b. False

19. If your static calibration data is best fit with the equation $y = 4x^2 + 4x + 4$, then the static sensitivity is 4.
    a. True
    b. False

20. How does $\overline{x}$ relate to x' for a normally distributed data set?
    a. $\overline{x} = x' \pm t_{\nu,P\%} S_x$
    b. $x' = \overline{x} \pm t_{\nu,P\%} S_x$
    c. $x' = \overline{x} \pm t_{\nu,P\%} \frac{S_x}{N^{1/2}}$
    d. None of the above

21. A manometer will behave as a first order system?
    a. True
    b. False

22. The regression analysis *goodness of the fit* is inversely proportional to the number of degrees of freedom?
    a. True
    b. False

23. If you sample the function sin(198πt) at 100 samples per second the data record will have frequency content at
    a. 198 Hz
    b. 99 Hz
    c. 49 Hz
    d. 2 Hz
    e. 1 Hz
24. The error function of a thermocouple subjected to a step input in the second lab function will vary from
    a. 1 to 0
    b. 0 to -∞
    c. T_0 to T_∞
    d. -1 to 0
    e. None of the above

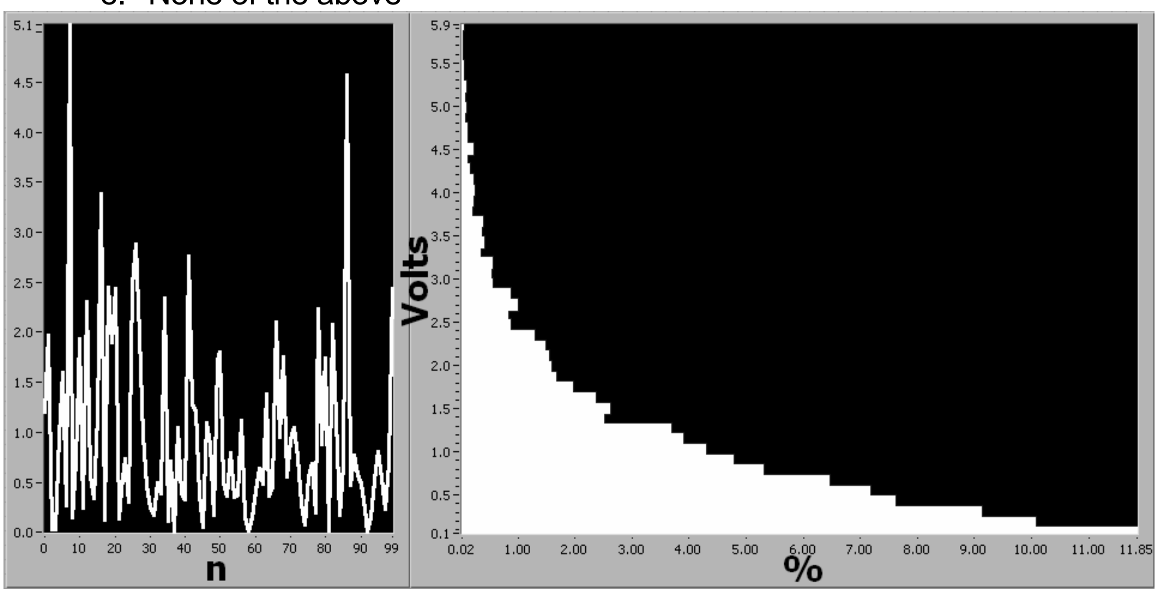

Figure 5. Gamma Noise signal (left) and the corresponding histogram (right).

25. From Figure 5 it can be determined that the gamma noise signal spends approximately 99% of the time below 2.5 volts.
    a. True
    b. False

Table 2. Student's t-distribution table.

	Student-t Distribution			
ν	50%	90%	95%	99%
1	1.000	6.314	12.706	63.656
2	0.816	2.920	4.303	9.925
4	0.741	2.132	2.776	4.604
5	0.727	2.015	2.571	4.032
6	0.718	1.943	2.447	3.707
7	0.711	1.895	2.365	3.499
8	0.706	1.860	2.306	3.355
9	0.703	1.833	2.262	3.250
10	0.700	1.812	2.228	3.169
11	0.697	1.796	2.201	3.106
12	0.695	1.782	2.179	3.055
13	0.694	1.771	2.160	3.012
14	0.692	1.761	2.145	2.977
15	0.691	1.753	2.131	2.947
16	0.690	1.746	2.120	2.921
17	0.689	1.740	2.110	2.898
18	0.688	1.734	2.101	2.878
19	0.688	1.729	2.093	2.861
20	0.687	1.725	2.086	2.845