Name:________________________

Person Number:______________________

Department of Mechanical and Aerospace Engineering

MAE334 - Introduction to Instrumentation and Computers

Midterm Examination

October 18, 2001

Closed Book and Notes

For each question, choose the **best** answer and place a mark corresponding to that answer on the machine scoring form. Be sure you put your name and 8-digit person number on both the questionnaire and the scoring sheet.

Failure to turn in this questionnaire with your name and student number on it along with the answer sheet will result in a grade of ZERO.

0. Fill in circle 1 under GRADE OR EDUCATION on side two of your answer sheet (and fill in your name, person number).

1. Waveforms can be broadly classified into these 3 types:
    a. Periodic, aperiodic and static
    b. Stationary, ergodic and nondeterministic
    c. Static, dynamic and nondeterministic
    d. None of the above

See Table 2.1 Classification of Waveforms pg 39

2. The slope of the static calibration curve is known as the:
    a. Response function
    b. Time constant
    c. Static sensitivity
    d. None of the above

See Page 14 section **"Static Sensitivity"**

3. The degree of conformity of a measure to a standard is know as the:
    a. Precision
    b. Accuracy
    c. Sensitivity
    d. Resolution

See page 15 section **"Accuracy"**

4. The average error in a series of repeated measurements of the same static input will quantify the:
    a. Sensitivity error.
    b. Resolution error.
    c. Bias error.
    d. Standard deviation.

See page 15 section **"Precision and Bias Errors"**

5. When sampling a complex periodic signal, the length of the data record should be an integral multiple of the period:
    a. to be able to Fourier transform and inverse transform the signal.
    b. to be able to determine the exact period of the signal.
    c. to avoid leakage in the Fourier transform.
    d. to avoid signal aliasing.

See page 241 section **“Amplitude Ambiguity”** and figure 7.4

6. The Fourier transform of a continuous signal:
    a. Maps the time domain to the frequency domain.
    b. Provides frequency amplitude and phase angle information.
    c. Is a continuous function.
    d. All of the above.

See sections 2.4 – 2.5 **“SIGNAL AMPLITUDE AND FREQUENCY” – “FOURIER TRANSFORM AND THE FREQUENCY SPECTRUM”**

7. A discrete digital representation of a signal is always less precise than the original input signal.
    a. True
    b. False

8. Quantization refers to
    a. the fact that A/D conversion process requires a finite amount of time.
    b. the fact that the number representing an analog signal has a finite precision.
    c. Both (a) and (b) are correct.
    d. Neither (a) or (b) are correct.

See page 249 **“Quantization Error”**

9. The Nyquist or (folding) frequency is:
    a. twice the highest frequency in the signal
    b. half the highest frequency in the signal
    c. half the sampling frequency of the signal
    d. none of the above

See page 238 equation 7.8

10. When frequencies in a signal are aliased, the sampled signal will appear to have a frequency content which is greater than that of the input signal.
    a. true
    b. false

See page 239 Figure 7.3

11. The minimum sampling frequency necessary to avoid aliasing a waveform containing frequencies of 25, 75, 100 and 200 Hz is
    a. 200 samples/sec.
    b. 400 samples/sec.
    c. 1000 samples/sec.
    d. 2000 samples/sec.

See page 236-9 **"Sample Rate"**

12. The National Instruments LAB PC-1200/AI hardware used in the laboratory has a pre-amplification gain setting of 1:
    a. when the input range is 0.2 Volts total.
    b. when the input range is 10 Volts total.
    c. which is independent of the input range.
    d. none of the above.

See lab 1 – did you verify the quantization step size with the manual posted on the MAE 334 home page?

13. The best signal to noise ratio one can expect from a 12 bit analog to digital converter is:
    a. 24 dB.
    b. 48 dB.
    c. 72 dB.
    d. 96 dB.

See page 249 **“Quantization Error”** in particular eq. 7.15

14. Linear response instruments:
    a. Have a better dynamic response than nonlinear instruments.
    b. Are easier to calibrate.
    c. Have a constant static sensitivity over their range.
    d. All of the above are correct.
    e. Only (b) and (c) are correct.

a. could be true. In general the static response is not directly related the dynamic response.

15. The first moment is also know as
    a. The variance
    b. The mean
    c. The time constant
    d. The standard deviation

From class notes! First moment – mean, second – variance, third – skewness, fourth – kurtosis…

16. A precision error
    a. introduces scatter into a series of measurements of the same input.
    b. can be minimized by careful static calibration.
    c. can be minimized by repeating the measurement of the same input many times and averaging the results.
    d. Both (a) and (c) are correct.

See page 15 **"Precision and Bias Errors"**

17. The time constant of a first order system
    a. is independent of the input signal waveform.
    b. is a measure of the speed of response to a change in input.
    c. is inversely related to the size of an applied step input.
    d. All of the above are correct.
    e. both (a) and (b) are correct.

See lab 2

18. The dynamic response of a first order sensor will tend to:
    a. attenuate higher frequencies more than lower ones.
    b. overshoot the actual signal in response to a step input.
    c. be linear.
    d. none of the above.

See page 85, Figure 3.12

19. The thermocouple is considered a first order instrument because
    a. it has only one sensing element.
    b. its static behavior is described by a first order differential equation.
    c. its dynamic behavior is described by a first order differential equation.
    d. both (a) and (c) are correct.
    e. both (b) and (c) are correct.

See page 76, **“First-Order Systems”**

20. A reference junction for the thermocouple used in Experiment 2:
    a. Is not needed for the type of thermocouple used.
    b. Is a solid-state temperature sensor on the ADC input board.
    c. Is a solid-state temperature sensor in the probe itself.
    d. Is the room temperature junction where the thermocouple is connected to the ADC.
    e. (a), (b) & (d) are correct.

21. It is important that the leads of a thermocouple between the measurement junction and the reference junction be held at a constant temperature.
    a. True
    b. False

See Background section of lab 2 and figure 1

Sample of Random Variable **x**			
i	**x_i**	**i**	**x_i**
1	0.98000	11	1.0200
2	1.0700	12	1.2600
3	0.86000	13	1.0800
4	1.1600	14	1.0200
5	0.96000	15	0.94000
6	0.68000	16	1.1100
7	1.3400	17	0.99000
8	1.0400	18	0.78000
9	1.2100	19	1.0600
10	0.86000	20	0.96000

Table 1. Sample data set with a Gaussian distribution, a mean value of 1.0190 and a standard deviation of 0.15768.
This is Example 4.4 on page 124

22. Given the data set in table 1, the number of degrees of freedom, ν, of the standard deviation, S_x, is:
    a. $\nu = 17$
    b. $\nu = 18$
    c. $\nu = 19$
    d. $\nu = 20$

23. Given the data set in table 1, estimate the interval of values over which 95% of the measurements of **x** should be expected to lie.
    a. 1.0190 +/- 0.14979
    b. 1.0190 +/- 0.32891
    c. 1.0190 +/- 0.15768
    d. 1.0190 +/- 0.33002 (1.0190 +/- $t_{19,95}S_x$)

24. Given the data set in table 1, the uncertainty in the mean value could be reduced by:

a. decreasing the sensitivity of the measuring instrument.
b. increasing the total number of measurements.
c. improving the precision of the measuring instrument.
d. both (a) and (b) are correct.
e. both (b) and (c) are correct.

25. Estimate the true mean value of the measurand to within 95% probability based on this finite data set.

a. 1.0190 +/- 0.073795 ($1.0190 \pm t_{19,95} S_{\bar{x}}$ **where** $S_{\bar{x}} = S_x / N^{1/2}$**)**
b. 1.0190 +/- 0.073546
c. 1.0190 +/- 0.33002
d. 1.0190 +/- 0.32891
e. 1.0190 +/- 0.15768

n	Temperature	TC emf output
1	0	0.282441649
2	25	0.288858135
3	50	0.293613655
4	75	0.297277782
5	100	0.300188165
6	125	0.302555125
7	150	0.30451736
8	175	0.306170366
9	200	0.307582925
10	225	0.308803353
11	250	0.309867462
12	275	0.310805379
13	300	0.311636429
14	325	0.312378804
15	350	0.313045578

Table 2. Sample thermocouple calibration data set.

26. A linear regression analysis done on the data set in table 2 yields the following result:

$$T_c = 11445\,emf - 3296$$

The correlation coefficient, $r = 0.943$ and the standard error of the fit, $S_{xy} = 38.5$ What percentage of the variance in T is accounted for by the fit, T_c.

a. 88.9%
b. 94.3%
c. 36.3%
d. none of these

See example 4.9 page 136

27. Given the calibration data set in table 2 the number of degrees of freedom, ν, of a second order regression fit would be:

a. $\boldsymbol{\nu = 12}$
b. $\nu = 13$
c. $\nu = 14$
d. $\nu = 15$

See page 134 $\nu = N - (m+1)$ where m = 2 for a second order equation!

28. Two random variables have the same sample mean; variable X has a sample variance twice as large as variable Y. In order to obtain an estimate of the true mean for each variable with 95% confidence,

a. we will need to make more measurements of X than of Y.
b. we will need to make more measurements of Y than of X.
c. the same number of measurements of each will be required.
d. We will need to switch major from mechanical engineering.

29. A certain measurement has been shown to follow a Gaussian distribution. As the number of repeated measurements increases

a. the sample mean will approach the true mean.
b. the sample standard deviation will approach the true standard deviation.
c. the sample standard deviation will approach zero.
d. both (a) and (b) are true.
e. (a), (b) and (c) are all true.

30. The slope of the natural log of the error function of a first order system, $\ln(\Gamma(t))$, versus time found by analyzing the response to a step input function is:

a. The time constant
b. One over the time constant
c. Minus one over the time constant
d. Minus one times the dynamic sensitivity
e. The distance between the earth and the moon

See example 3.5 page 82

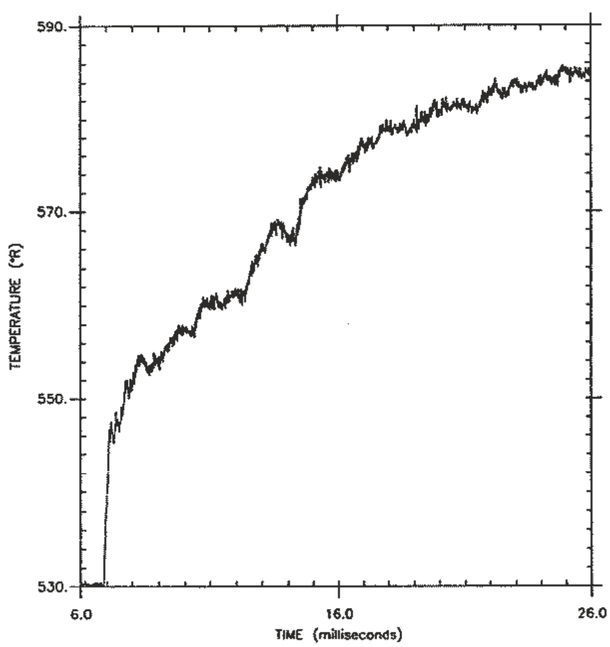

Figure 2. A plot used numerous times during class.

31. Bonus: The plot shown above, which was used several times in class, is of:

a. a typical first order response of a thermocouple to a step input function.
b. a typical surface temperature measurement on a turbine rotor in a shock tunnel.
c. a typical exhaust gas temperature measurement at the exit of a valve in an internal combustion engine.
d. a typical fried brain wave pattern after a MAE 334 midterm exam.

	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
3	0.765	2.353	3.182	5.841
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

Table 3. The Student-t Distribution based on the number of degrees of freedom and percent probability.