Figure 1. Ideal Filter Characteristics

Use the following answer for the next 4 questions

    a) high pass filter
    b) low pass filter
    c) notch filter
    d) band pass filter

1) Figure 1 (a) characterizes an ideal

2) Figure 1 (b) characterizes an ideal

3) Figure 1 (c) characterizes an ideal

4) Figure 1 (d) characterizes an ideal

Figure 2. Single Pole Passive Filter Circuit

5) The single pole passive filter drawn in Figure 2 is a

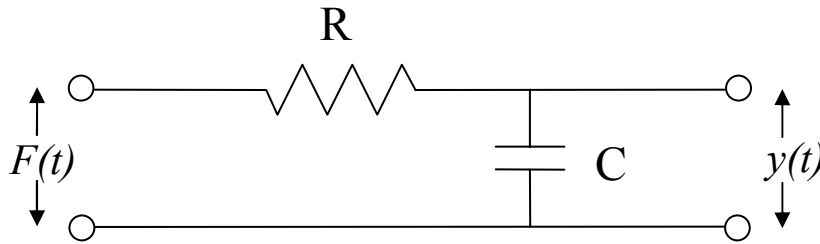   **a) low pass filter**
   b) high pass filter
   c) band pass filter
   d) notch filter
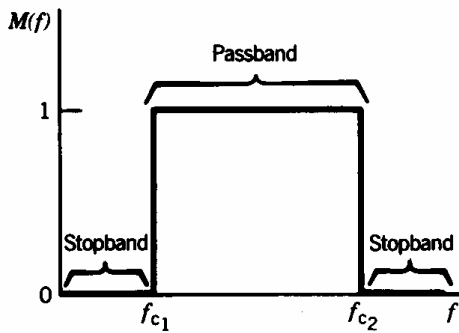
6) The single pole passive filter drawn in Figure 2 has a cutoff frequency of

   a) $f_c=RC$
   b) $f_c=1/RC$
   c) $f_c=2\pi/RC$
   d) $f_c=1/2\pi RC$

7) The output, $y(t)$, from the single pole passive filter in Figure 2 will

   a) always lag a dynamic input signal $F(t)$.
   b) slightly amplify the input signal $F(t)$.
   c) have a phase lag of 90 degrees at the cutoff frequency.

8) What would the time constant of a single pole Butterworth low pass filter built with a 1000 ohm resistor, R, and a 100 uF capacitor, C, be?

   a) $2\pi RC$ seconds
   b) $1/2\pi RC$ seconds
   c) 10^{-1} seconds $= \tau = RC = 1000 * 100 * 10^{-6}$
   d) 1 seconds
   e) 10^5 seconds

9) Which low pass filter type has the steepest magnitude ratio roll off?

   a) Bessel
   b) Butterworth
   c) Chebyshev
   d) Elliptic

10) Which low pass filter type has a linear phase shift?

    a) Bessel
    b) Butterworth
    c) Chebyshev
    d) Elliptic

11) The transfer function of the low pass filter tested in lab 5 is a complex valued function?

    a) true
    b) false

12) Both the magnitude ratio and phase lag vs. frequency *can* be obtained using the sine wave sweep method of determining the transfer function

    a) true
    b) false

13) At the filter cutoff frequency a 4 pole passive Butterworth low pass filter will attenuate the input signal

    a) -3 dB
    b) -4 dB
    c) -12 dB
    d) None of the above

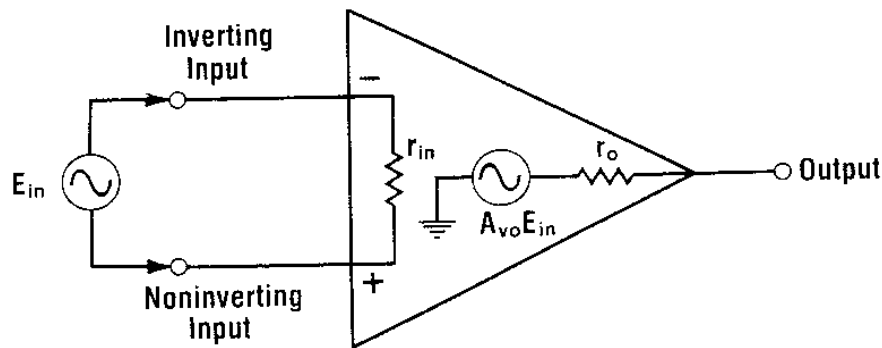**Figure 3. The equivalent circuit of an ideal operational amplifier.**

14) For the ideal operational amplifier in Figure 3

    a) $r_{in} = 0$, $r_o = \infty$, $A_{vo} = \infty$
    b) $r_{in} = 0$, $r_o = 0$, $A_{vo} = \infty$
    c) $r_{in} = \infty$, $r_o = \infty$, $A_{vo} = \infty$
    d) $r_{in} = \infty$, $r_o = 0$, $A_{vo} = \infty$
    e) $r_{in} = \infty$, $r_o = 0$, $A_{vo} = 1$

15) For the ideal operational amplifier in Figure 3 the bandwidth is not assumed to be infinite.

    a) true
    b) false

16) For the ideal operational amplifier in Figure 3 the output is zero if the input is zero.

    a) true
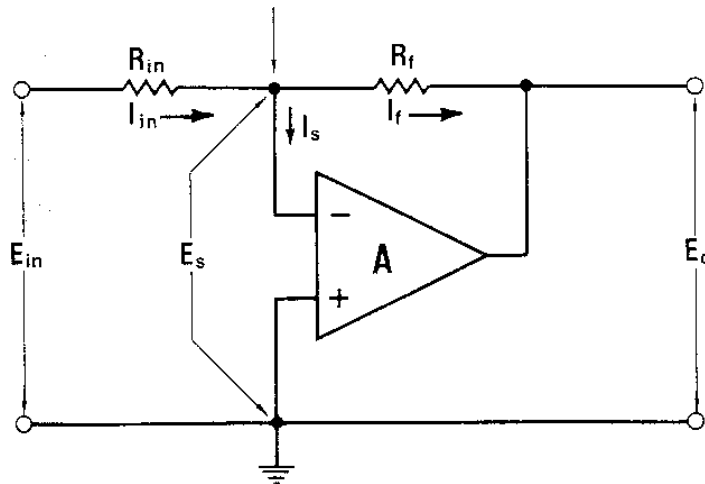   b) false

Figure 4. Basic Operational Amplifier Circuit 1

17) The basic operational amplifier circuit in Figure 4 is

    a) an inverting amplifier
    b) an integrating amplifier
    c) a differentiating amplifier
    d) a non-inverting amplifier

18) For the basic operational amplifier circuit in Figure 4,

    a) $I_{in} = I_f$, $E_{in} = E_s$, $I_s = 0$, Gain = $-R_f/R_{in}$
    b) $I_{in} = I_f$, $E_{in} = I_{in}R_{in}$, Gain = R_f/R_{in}
    c) $I_{in} \neq I_f$, $E_s = 0$, $I_s = 0$, Gain = $-R_f/R_{in}$
    d) $I_{in} = E_{in}/R_{in}$, $E_s = 0$, $I_s = 0$, Gain = $-R_f/R_{in}$

Use the following answers for the next 5 questions
    a) Integrator
    b) Non-inverting Amplifier
    c) Differential Amplifier
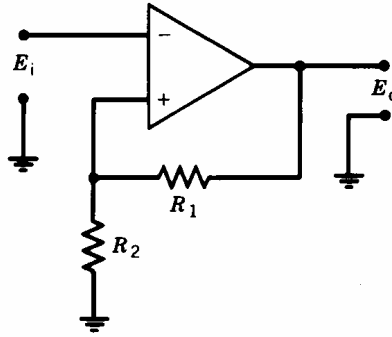   d) Differentiator
    e) Inverting Amplifier

Figure 5. Op-Amp Circuit

19) Figure 5 is a **inverting amplifier (note that E_i is attached to the negative input)**
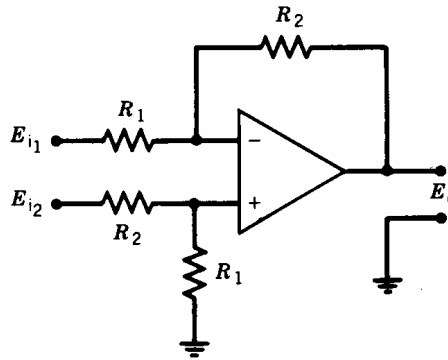

Figure 6. Op-Amp Circuit

20) Figure 6 is a **differential amplifier**
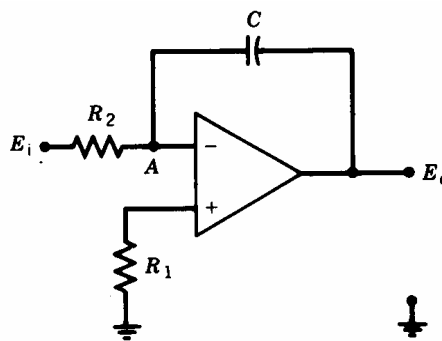
Figure 7. Op-Amp Circuit

21) Figure 7 is an **integrator**
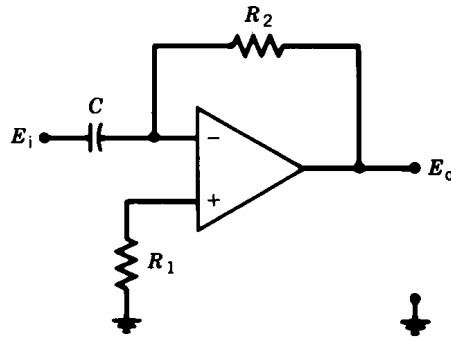
Figure 8. Op-Amp Circuit

22) Figure 8 is a **differentiator**
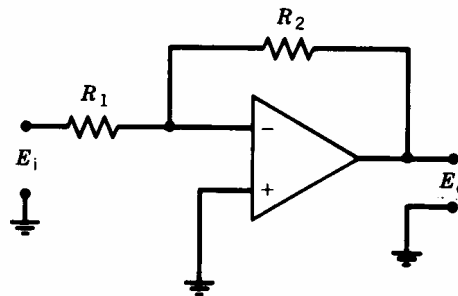
Figure 9. Op-Amp Circuit

23) Figure 9 is a **inverting amplifier**

24) The gain of the amplifier circuit in Figure 9 is
   a) $-R_1R_2$
   b) $-R_1/R_2$
   c) R_1R_2
   d) R_2/R_1
   e) **$-R_2/R_1$**

25) To avoid voltage measurement loading errors the input resistance of the measuring meter
   a) should be about the same as the sensor output resistance.
   b) should be much less than the sensor output resistance.
   c) **should be much greater than the sensor output resistance.**

26) For flow variables, the input impedance of the measurement instrument should be much greater than the output impedance of the sensor.
   a) true
   b) **false**

27) Temperature is

   a) an effort variable
   b) a flow variable

28) Temperature should be measured with a high input impedance sensor.

   a) true
   b) false

29) Heat Flux is

   a) an effort variable
   b) a flow variable

30) Heat flux should be measured with a high input impedance sensor.

   a) true
   b) false

31) If you would like to resolve the daily, weekly, monthly and summer seasonal (June 21st to September 21st) temperature fluctuations at your summer home what is the least amount of data you must collect?

   a) once a day for one week
   b) once a day for 3 months
   c) twice a day for 6 months
   d) twice a day for 3 months
   e) ten times a day for 3 months

32) If you need to present a reasonable graph of the temperature fluctuations in the previous question (31) what is the least amount of data you must collect?

   a) 4 times a day for 6 months
   b) 10 times a day for one and a half months
   c) 30 times a day for 3 months
   d) 10 times a day for 3 months
   e) twice a day for 3 months

33) Given the ADC hardware and thermocouple used in lab 2 this semester, what is the highest frequency air temperature fluctuation you could accurately track?

   a) approximately 1 Hz.
   b) approximately 45 Hz.
   c) approximately 0.1 Hz.
   d) approximately 0.001 Hz., $\tau \approx$ minutes, therefore maximum tracking frequency is 1/minutes

34) Given the ADC and thermocouple hardware used in the lab this semester to regulate your spa water temperature. How small of a temperature change would you be able to detect assuming there was no electronic noise. (The ADC full scale range is 10 volts, the maximum gain is 100 and the thermocouple static sensitivity is 25,000 degrees C/Volt)

    a) approximately 6 degrees C
    b) approximately 1 degree C = 10/100/4096*25,000 = 0.6 degrees
    c) approximately 60 degrees C
    d) approximately 0.04 degree C
    e) None of the above (will be accepted)

35) The binary representation of 5 is:

    a) 0101
    b) 1010
    c) 0110
    d) 1100
    e) None of the above

36) The 4 bit 2's complement representation of -2 is:

    a) 1000
    b) 0010
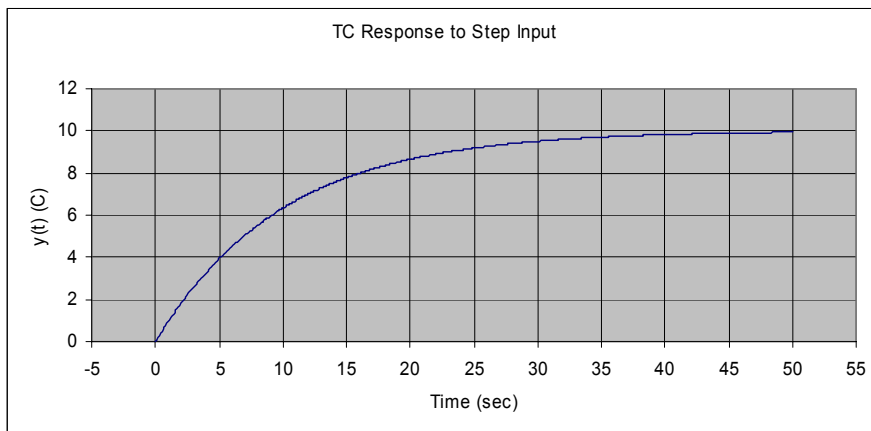   c) 1111
    d) 1110
    e) None of the above

Figure 10. Thermocouple Step Input Response Function.

37) The time constant, τ, of the thermocouple response plotted in Figure 10 is approximately:

    a) 5 seconds
    b) 10 seconds
    c) 15 seconds
    d) 20 seconds
    e) 50 seconds

38) To estimate the 95% confidence interval for a linear curve fit of 15 data points you would use the formula

a) $C.I. = \pm t_{15,95} S_{xy}$

b) $C.I. = \pm t_{13,95} S_{x}$

c) $C.I. = \pm t_{13,95} S_{\bar{x}}$

d) $C.I. = \pm t_{13,95} S_{xy}$

e) None of the above

39) To estimate the 90% confidence interval of the sample mean value about the true mean value from a 50 point normally distributed data set you would use the formula

a) $C.I. = \pm t_{50,90} S_{x}$

b) $C.I. = \pm t_{49,90} S_{x}$

c) $C.I. = \pm t_{48,90} S_{\bar{x}}$

d) $C.I. = \pm t_{49,90} \dfrac{S_x}{N^{1/2}}$

e) None of the above

40) Given a 50 point normally distributed data set. If a 51st data point where taken, there is a 95% probability that its value would lie within what confidence interval of the mean.

a) $C.I. = \pm t_{50,90} S_{x}$

b) $C.I. = \pm t_{49,90} S_{x}$

c) $C.I. = \pm t_{48,90} S_{\bar{x}}$

d) $C.I. = \pm t_{49,90} \dfrac{S_x}{N^{1/2}}$

e) None of the above

41) If the Nyquist sampling criteria was satisfied for an input signal with a frequency of 100 Hz, what was the sampling rate?

a) 1 kHz

b) 200 Hz

c) 2 kHz

d) None of the above

42) The time constant (τ) of a thermocouple can be effected by the following factor(s)?

a) size of the temperature step

b) the direction of the temperature change

c) the medium around the thermocouple

d) all of the above

e) a) and c) only
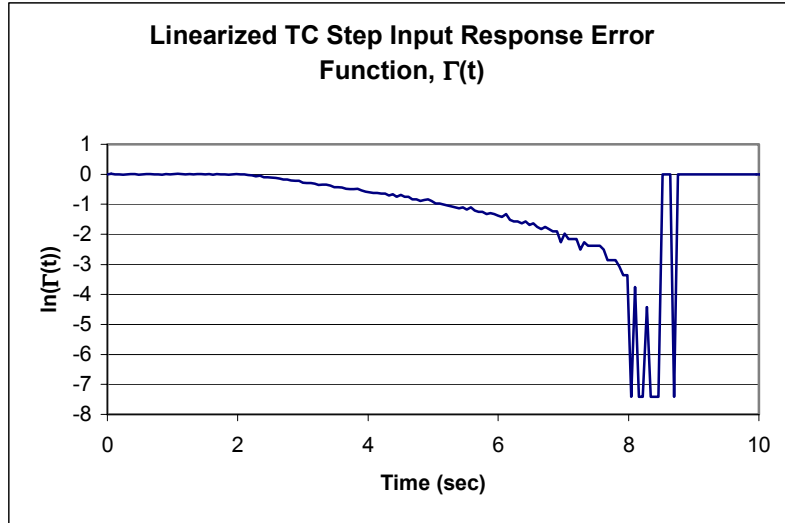
Figure 11. Linearized step input response error function.

43) While linearizing the dynamic calibration data taken during lab #2 report using equation: $\ln\{[(T-T_0)/(T_f-T_0)]\}=-t/\tau$ you obtain a curve like the one in Figure 11. This plot is indicative of

    a) a well collected, properly processed data set with quantization error at the end of the record.

    b) a truncated data set or a poor estimation of T_f.

    c) a data set with too much noise to properly analyze.

    d) none of the above
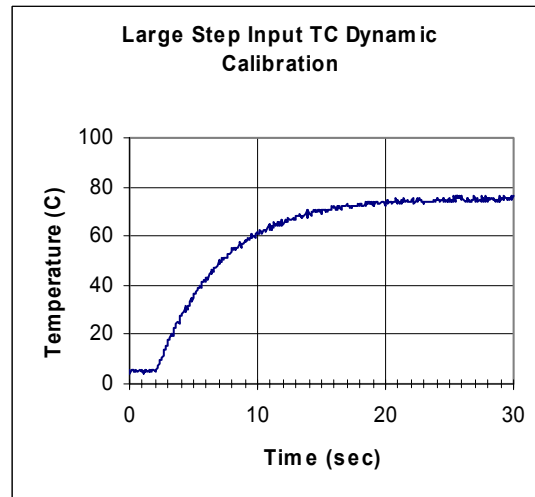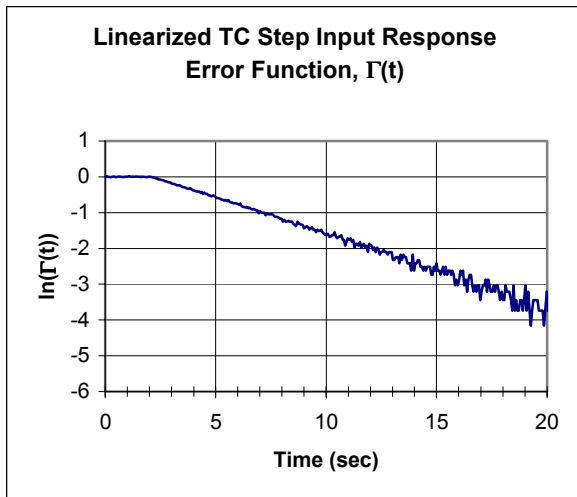
44) The two data sets plotted above are taken with thermocouples that have significantly different time constants.

    a) true

    b) false, exactly the same data, -1/slope of left curve = 2/3 rise time of right curve

45) In lab #3 you assumed that $(T - T_f)/(T_0 - T_f) = e^{-t/\tau}$ for constant work input. You *should* have assumed that:

a) **T_0, is the lab air temperature**
b) T_0, is the drum temperature at start of data collection run.
c) T_f, is the drum temperature at the end of the data collection run.
d) b) and c) are both correct
e) a) and c) are both correct

46) If the convective heat transfer coefficient used in lab #3 where truly constant then after performing a linear regression on temperature vs time for drum turning, you would find that the difference between the value of dT/dt predicted by dT/dt=P/C and the measured value from the data set would _____ as the speed of the drum increases. Here T is temperature, P is input power, and C is heat capacity of the calorimeter.

a) get bigger
b) get smaller
c) **remain the same**

47) Which of the following properties are generally desirable in a transducer?

a) Large time constant
b) Low natural frequency
c) **Linearity**
d) A, B & C <u>are all</u> desirable
e) B & C <u>are both</u> desirable

48) A manometer's static sensitivity is proportional to the specific gravity of the manometer fluid.

a) **true**
b) false

49) Which of the following is an indication the static sensitivity?

a) The correlation coefficient, R
b) **Slope of the regression line**
c) The 95% confidence interval
d) Standard error of the fit, S_{xy}

50) The Bourdon Tube forms the basic element of most dial pressure gauges.

a) **true**
b) false

51) The input impedance of a deflection type pressure transducer is proportional to the static sensitivity of the transducer.

a) true
b) **false, inversely proportional to**

FIGURE 10.3   Operating principle for a Vernier scale.
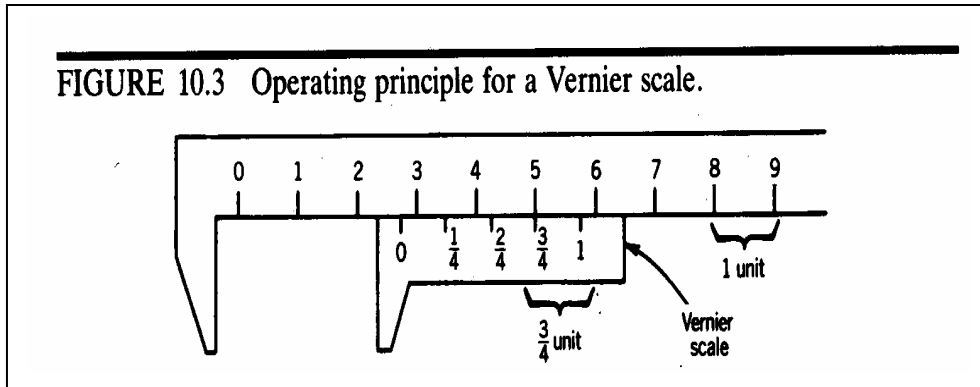
52) The reading of the vernier scale from your text in Figure 10.3 above is

   a) 2
   b) 2.25
   c) 2.5
   d) 2.75
   e) 3

53) In lab #4 you used different pressure step sizes to estimate the dynamic response characteristics of the pressure system. Which of these characteristics depends on the size the step?

   a) Gain or Static Sensitivity (K)
   b) Damping ratio (ξ)
   c) Natural frequency of the transducer (ω_n)
   d) The steady state value, (y_∞)
   e) none of the above

54) The natural frequency (ω_n) listed on the Entran web site of the pressure transducer used in lab 4 is?

   a) 100,000 Hz
   b) 300 Hz
   c) 150,000 Hz
   d) 10,000 Hz
   e) 15,000 Hz

55) If the damping ratio, ξ, of the pressure transducer is less than 1 the system would be considered:

   a) **Under damped**
   b) Over damped
   c) Critically damped
   d) None of the above

FIGURE 3.13 Second-order system response to a step function input.
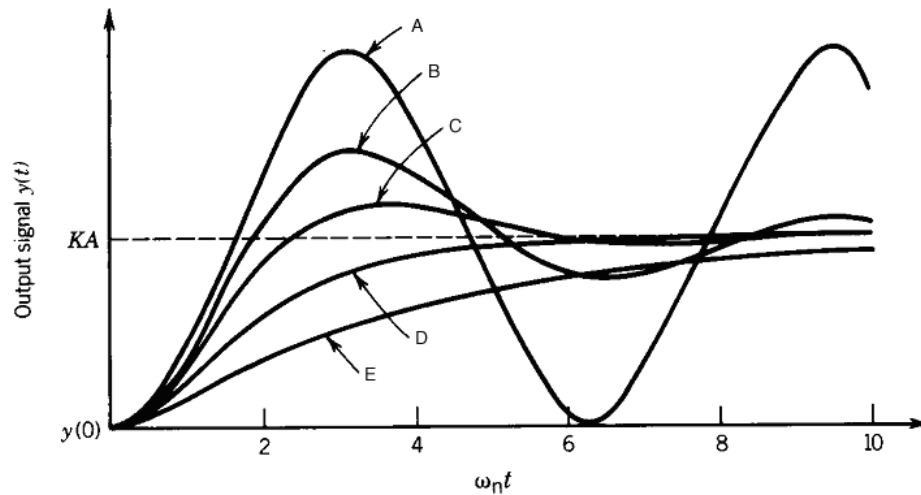
56) In the figure above (Figure 3.13 from your text) **A; ξ=0, B; ξ=.25, C; ξ=.5, D; ξ=1, E; ξ=2**

57) In the figure above (Figure 3.13 from your text) **B** has a damping ratio, ξ, of 0.25

58) Your text gives the homogeneous solution to an under damped second order system as:

$$Y(t) = KA - KA \cdot e^{-\xi\omega_n t} \left[\frac{\xi}{(1-\xi^2)} \sin(\omega_n \sqrt{1-\xi^2} t) + \cos(\omega_n \sqrt{1-\xi^2} t) \right]$$

In lab #4 you found what term to be missing from the equation?
a) **The starting value, y(0)**
b) The gain value, G
c) The steady state value, $y(\infty)$
d) None of the above

59) A deflection device or sensor has an infinite input impedance.

a) true
b) **false**

60) In lab#5 you performed a Fourier analysis on voltage vs. time step input response data. Can this analysis be applied to a nondeterministic signal?

a) **Yes**
b) No

61) The linear potentiometer is a resistance potentiometer (a rheostat or variable resistor). Is the voltage output of the potentiometer proportional to the extension length?

   a) Yes
   b) No

62) A histogram of repeated measurements of a static input value

   a) provides an indication of the instrument precision error.
   b) should be normally distributed.
   c) neither A or B are correct.
   d) both A and B are correct.

63) Most temperature transducers exhibit dynamic behavior typical of _____ systems.

   a) zeroeth order
   b) first order
   c) second order

64) The complete Fourier series representation of the step input function, u(t), will have _____ non-zero terms.

   a) 1
   b) 10
   c) no
   d) infinite
   e) none of the above

65) The area under the delta function, $\delta(0)$ or $\delta(t)$, is 1 by definition.

   a) true
   b) false

66) A 102 Hz sine wave sampled at 100 Hz will result in a sampled data set with what frequency

   a) 100 Hz
   b) 102 Hz
   c) 2 Hz
   d) none of the above

67) The quantization error in an A/D conversion depends on:

   a) the speed of the A/D conversion.
   b) the number of bits of the A/D converter.
   c) the amplitude of the input signal relative to the full range of the A/D converter.
   d) both A, B and C are all correct.
   e) both B and C are correct.

68) Precision is the ability to represent a true (known) value.

   a) true
   b) false (accuracy is…)

69) The width of the probability density function of a normally distributed variable is proportional to the variance.

   a) true
   b) false

70) The standard deviation is the square root of the variance.

   a) true
   b) false

71) The sample variance is defined as: $S_x^2 = \dfrac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2$, should be $S_x^2 = \dfrac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2$

   a) true
   b) false

72) When performing discrete time series analysis on a data set the highest resolvable frequency is

   a) (record length)$^{-1}$
   b) (record length)/(number of data points)
   c) (sampling frequency)/2
   d) sampling frequency

73) When performing discrete time series analysis on a data set the lowest resolvable frequency is

   a) (record length)$^{-1}$
   b) (record length)/(number of data points)
   c) (sampling frequency)/2
   d) sampling frequency

74) When performing discrete time series analysis on a data set the frequency resolution is

   a) (record length)$^{-1}$
   b) (number of data points)/(record length)
   c) (sampling frequency)/2
   d) sampling frequency

75) The phenomenon known as leakage occurs when performing discrete time series analysis on a data set with a frequency component which is not an integer multiple of the frequency resolution

   a) true
   b) false

Example 5.x from your text book: A voltmeter is to be used to measure the output from a pressure transducer that outputs an electrical signal. The nominal pressure expected will be about 3 psi (3 lb/in.^{2}). Estimate the design-stage uncertainty in this combination. The following information is available:

Voltmeter
        Resolution: 10 µV
        Accuracy: within 0.001% of reading

Transducer
        Range: ± 5 psi
        Sensitivity: 1 V/psi
        Input power: 10 VDC ± 1%
        Output: ± 5 V
        Linearity: within 2.5 mV/psi over range
        Repeatability: within 2 mV/psi over range
        Resolution: negligible

KNOWN
        Instrument specification

Assumptions
        Values representative of instrument at 95% probability

Find
        u_o for each device and u_d for the measurement system

76) The interpolation error $(u_0)_E$ of the voltmeter is?

  a) ± 5 µV (95%)
  b) ± 10 µV (95%)
  c) ± $\sqrt{10}$ µV (95%)
  d) ± $\sqrt{5}$ µV (95%)

77) The instrument error $(u_c)_E$ will be

  a) ± (3 V x 0.001%) = 30 µV (95%)
  b) ± $\sqrt{3}$ V x 0.001% = $30^{1/2}$ µV (95%)
  c) ± (1 V x 0.001%) = 1 µV (95%)
  d) none of the above

78) The design stage uncertainty, $(u_d)_E$, in the voltmeter is

  a) $\pm\sqrt{5^2 + 30^2} = 30.4\mu V$ (95%)
  b) $\pm\sqrt{10^2 + 30^2} = 31.6\mu V$ (95%)
  c) $\pm\sqrt{5 + 30} = 5.9\mu V$ (95%)
  d) none of the above

79) The uncertainty in the pressure transducer output at the design stage. $(u_c)_p =$
$\pm\sqrt{(2.5\text{mV/psi x 3 psi})^2 + (2\text{mV/psi x 3 psi})^2} = \pm 9.61$ mV (95%)

a) true
b) false

80) Gauge pressure refers to the pressure relative to atmospheric pressure

a) true
b) false

81) The interferometer works by measuring the light and dark fringes produced by interference of two light beams.

a) true
b) false

82) The LVDT has better position resolution but a smaller range than the linear potentiometer.

a) true
b) false

83) A data set sample mean is $\bar{y} = \dfrac{1}{N-1}\sum\limits_{i=1}^{N} y_i$

a) true
b) false

84) The D'Arsonval meter is based on the principle that, when voltage is applied to a wire placed in a magnetic filed, a force is produced on the wire.

a) true
b) false, …when a current flows in a wire…

85) Careful calibration of an instrument

a) requires constant values of extraneous variables.
b) can minimize the effect of precision error.
c) can eliminate the effect of bias error.
d) both A and C are correct.
e) both B and C are correct.

86) The quantization error in a data set could be reduced by first

a) increasing the speed of the electronics.
b) increasing the number of bits in the ADC
c) amplifying the input signal
d) both B and C are correct.
e) A, B and C are all correct.

Representative values of the Student-t estimator are as follows:

ν	$t_{\nu,50}$ %	$t_{\nu,90}$ %	$t_{\nu,95}$ %	$t_{\nu,99}$ %
2	0.816	2.920	4.103	9.925
5	0.727	2.015	2.371	4.032
10	0.700	1.812	2.082	3.169
20	0.687	1.725	2.010	2.845
50	0.680	1.679	1.961	2.679
∞	0.674	1.645	1.884	2.576

87) Given a data set with 20 degrees of freedom, a sample mean of 1.0 and a sample standard deviation of 0.5. Approximately 95% of the data points will lie in the range of

   a) 0 to 2, $\pm t_{20,95}S_x = 1 \pm 2.010*0.5 = 1 \pm 1.0$ (remember significant digits!)
   b) 0.5 to 1.5
   c) 1.0 to 1.5
   d) 1.0 to 2.0
   e) none of the above

88) Given a data set with 20 degrees of freedom, a sample mean of 1.0 and a sample standard deviation of 0.5. The sample mean is within what range of the true mean with a 50% probability?

   a) $x' = \bar{x} \pm 0.687 \dfrac{S_{\bar{x}}}{N^{1/2}}$

   b) $x' = \bar{x} \pm 0.687 S_{\bar{x}}$

   c) $x' = \bar{x} \pm 0.687 \dfrac{S_x}{N^{1/2}}$ **b) and c) are the same! either answer is accepted.**

   d) none of the above

89) Given a calibration data set, y_i, with N points and a standard deviation of σ. A 3rd order polynomial is fit to the data set. At each y_i the polynomial is evaluated giving a y_{ci}. The *standard error of the fit* for this data set is defined as **b)**

   a) $S_{yx} = \sqrt{\dfrac{\sigma^2}{N^{1/2}}}$

   c) $S_{yx} = \sqrt{\dfrac{\sigma^2}{\nu}}$

   b) $S_{yx} = \sqrt{\dfrac{\sum\limits_{i=1}^{N}(y_i - y_{ci})^2}{\nu}}$

   d) $S_{yx} = \sqrt{\dfrac{\sigma^2}{(N-4)}}$

90) Given a calibration data set with 20 points being fit with the equation, $y_{ci} = a_0 + a_1 \exp^{a_2}$, how many degrees of freedom are there in the fit?

a) 16
b) 17, 20 - 3 unknowns!
c) 18
d) 19
e) 20

91) If the precision error in a measurement is limited by instrument resolution, the effect of this error can be reduced by

a) carefully calibrating the instrument.
b) repeating the measurement several times and averaging the results.
c) both A and B are correct.
d) neither A or B are correct.

92) The 90% confidence limits on a linear regression line will lie _____ from the line than the 95% confidence limits.

a) a greater distance
b) the same distance
c) a smaller distance

93) Amplitude ambiguity will occur during a Fourier transformation if

a) the individual data points are too sparsely spaced.
b) the period chosen for transformation does not contain an integral multiple of the dominant frequency of the signal being analyzed.
c) the signal being analyzed has too low a frequency.
d) there are too many discontinuities in the signal being analyzed.

94) In a design-stage uncertainty analysis, the zero-order uncertainty estimate for each component of the instrument system is estimated from

a) preliminary measurements using the component.
b) the manufacturer's estimates of instrument error.
c) the instrument resolution.
d) a combination of A and C.
e) a combination of B and C.

95) The coefficients in a regression equation are chosen to minimize the _____ between the measured and calculated dependent variable for each value of the independent variable.

a) square of the sum of the differences
b) the sum of the squares of the differences
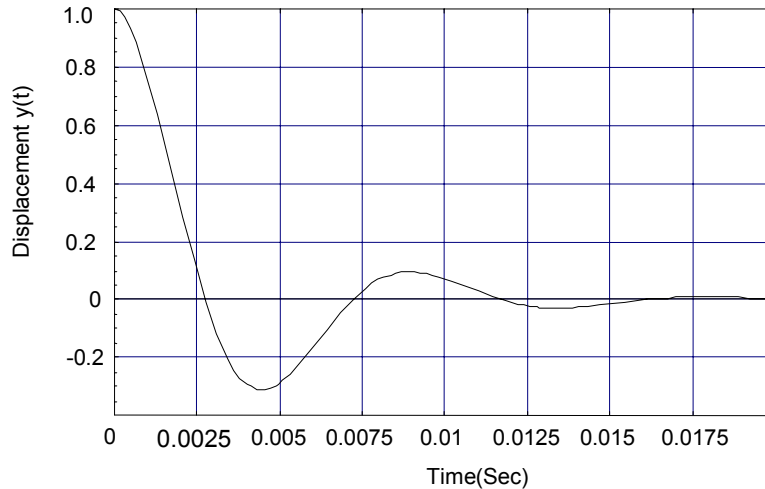c) the sum of the differences

Figure 12. A sample unit step response function of a second order system.

96) Using Figure 12 the ringing period is approximately 0.0045 seconds

    a) true
    b) false

97) Using Figure 12 estimate the value of the rise time

    a) 0.0025 sec
    b) 0.0045 sec
    c) 0.0075 sec
    d) 0.0175 sec
    e) none of the above

98) The natural frequency of a second order system is 1/ringing period

    a) true
    b) false

99) The time constant, τ, of the system plotted in Figure 12 is approximately 0.002 seconds

    a) true
    b) false, this is a second order system, τ is for first order systems only!

100)   This test is worth 20% of your course grade.

    a) true
    b) false