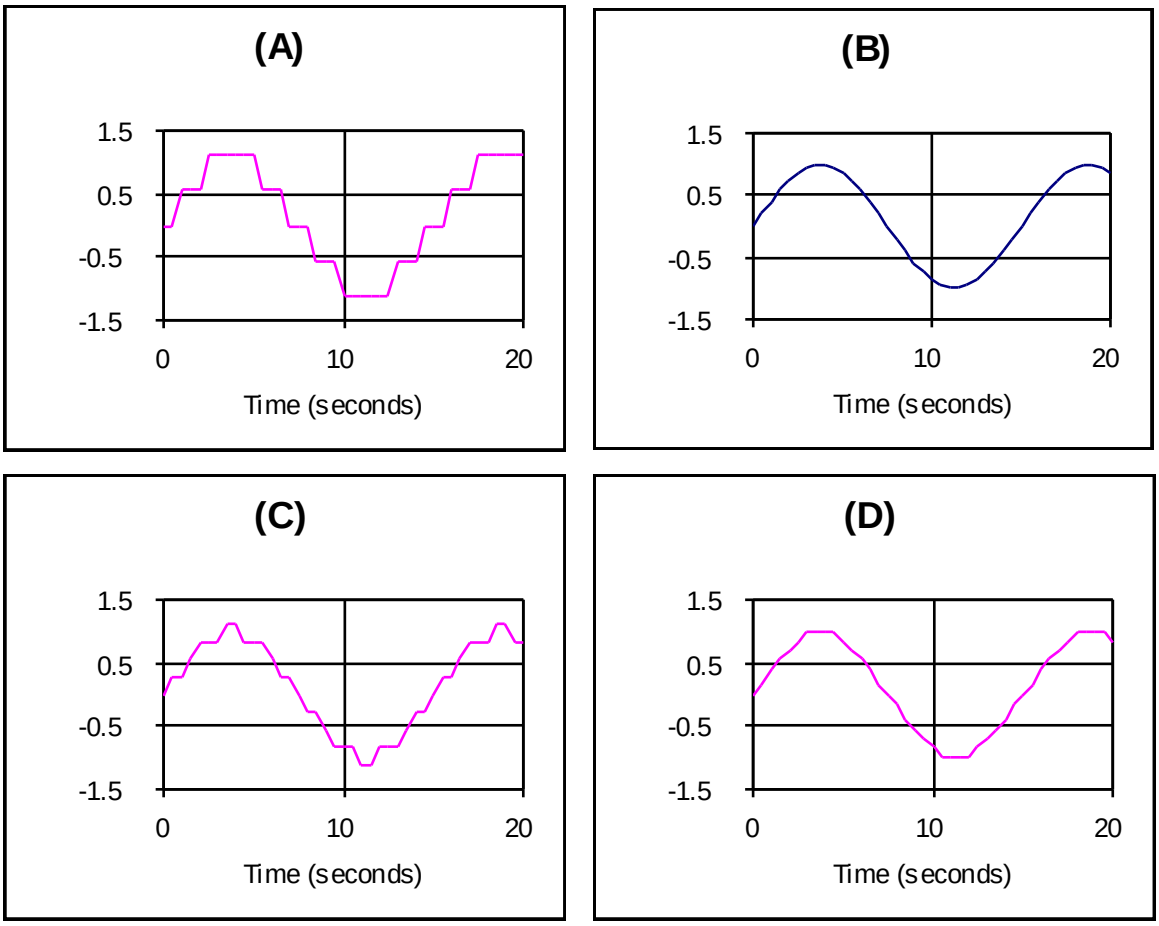
Reminder:
Lab #1 : Limitations of A/D conversion
Lab #2 : Thermocouple, static and dynamic calibration
Lab #3 : Conversion of work into heat
Lab #4 : Pressure transducer, static and dynamic calibration
Lab #5 : Pressure-volume measurements

1) While sampling a sinusoidal signal, we got the following pictures. Choose the output signal that contains the largest quatization error: Largest A, Least B



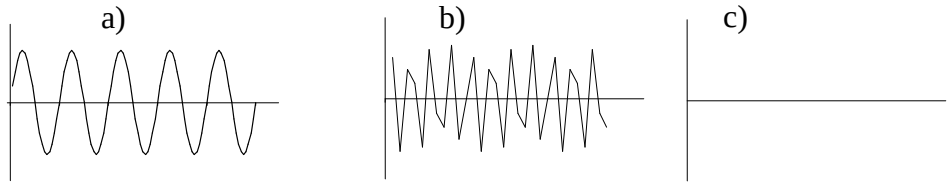
2) The sine wave in the above graphs has a frequency of

a) 15 Hertz
b) .15 Hertz
c) 2π/15 Radians/Second
d) 30π Radians/Second
e) 15π Radians/Second

3) The following equation is used to simulate a digitized sinusoidal signal.

$$Y=sin(2\pi fn/f_s)$$

Where f is signal frequency; f_s is sampling frequency; n=1,2,3,…500. If f = 100 Hz and f_s = 200 Hz what will the output signal looked like? C)



4) Same question as 2 above but now f_s = 2000 Hz? A)

5) While performing Lab #1, Mr. Simpson insisted on setting the sampling frequency to an integer. This was necessary;

a) to avoid aliasing
b) to avoid amplitude ambiguity
c) to resolve the waveform
d) none of the above

6) Suppose the voltage range of your 8 bit ADC is +/- 5 Volts and the input signal gain is 5. What is the minimum voltage difference that can be detected with the A/D converter?

a) 0.0078V
b) 0.0039V
c) 0.0195V
d) 0.0039V

7) Which of the following <u>never</u> depends on the sampling rate?

a) Frequency of the sampled signal
b) Magnitude of the sampled signal
c) Nyquist frequency of the input signal
d) Shape of the sampled signal

8) If the Nyquist sampling criteria was satisfied for an input signal with a frequency of 1kHz, what was the sampling rate?

a) 1kHz
b) 200Hz
c) 2kHz
d) None of the above

9) In Lab #1, the sample rate was held constant while the input signal frequency was increased. If the sample rate is set at 100 samples/sec., what is the maximum resolvable input frequency?

a) 100Hz
b) 200Hz
c) 10Hz
d) 50Hz

10) 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

11) While working on the dynamic calibration during lab #2 report, you suddenly realize your data record stopped well before steady state was achieved and you have no information beyond that time point. You assume it doesn't matter and proceed to use the equation: $-\ln\{1-[(T-T_0)/(T_f-T_0)]\}=(1/\tau)*t$ to calculate the time constant (τ) where T_0 is the initial temperature and T_f is the final temperature.

a) The value of τ will not be effected
b) The value of τ will become smaller
c) The value of τ will become larger
d) Only T_f will be effected

12) When performing static calibration of the thermocouple, you had five water cups of various temperatures. It was suggested to sample them randomly.

a) To torment the students
b) To prevent hysteresis.
c) To minimize the standard error
d) to minimize the effect of extraneous variables.

13) What type of thermocouple did we use in the lab?

a) K-type Chomel-Aluminum
b) J-type Iron-Constantan
c) c) T-type Copper-Constantan
d) G-type Tungsten-Rhodium

14) Which of the following will <u>not</u> affect the system properties in Lab #2?

a) Medium (air or water)
b) Temperature step
c) Heat transfer coefficient
d) Thermocouple type

15) Which of the following is not true based on the thermocouple we used?

a) The thermocouple has a large time constant in air
b) The Thermocouple properties depend on the experimental apparatus.
c) If the room temperature rises, the reference junction temperature will also rise.
d) The thermocouple has a finite mass

16) In Lab #2 we performed a static and dynamic calibration on a thermocouple. What was the main purpose for the dynamic calibration?

a) To see the second order response of the thermocouple
b) To determine the value of the time constant (τ)
c) To determine the damping ratio
d) Both A and B
e) Both B and C

17) What effect did the change of medium from water to air have on the value of the time constant (τ) in lab #2?

a) **Increased τ**
b) Decreased τ
c) Remained the same
d) None of the above

18) The static calibration in lab #2 was conducted with what assumption regarding a cold junction compensator?

a) It was not necessary since all the junctions were at room temperature.
b) It was necessary and the results were skewed as a result of not incorporating a cold junction in the experiment.
c) It was not necessary because the computer comes with cold junction compensation circuitry.
d) Cold junctions are not necessary due to the advancements made in thermocouple technology.
e) **None of the above**

19) You arrived to lab #3 a little late. Your partner is madly turning the drum trying to translate mechanical work into heat. The weight is of 5kg mass, the gravitational acceleration is $9.81 m*s^{-2}$, and the diameter of the drum is 0.0465m. Your partner is turning the drum at a constant rate of 150 turns per minute. Can you help your partner calculate the rate of work done?

a) 171.06 watts
b) **17.90 watts**
c) 7.81 watts
d) 5.70 watts

20) After performing a linear regression on temperature vs time for drum turning in lab #3, you found that the difference between the value of dT/dt predicted by dT/dt=P/C and the measured value is getting _____ as the speed of the drum increases. Here T is temperature, P is input power, and C is heat capacity of the calorimeter.

a) bigger
b) smaller
c) almost same

21) Which of the following properties are generally not desirable in a transducer?

a) Large time constant
b) High natural frequency
c) Linearity
d) A, B & C are all desirable
e) A, B & C are not desirable

22) Which of the following does not indicate the linearity of a static calibration?

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

23) When can we assume that the heat losses are negligible in lab #3?

a) When the temperature difference between the surroundings and the drum is large.
b) When the drum turning rate is large.
c) When the convective heat transfer coefficient is large.
d) **When the rate of temperature change is close to P/C.**

24) Which of the following is not true regarding Lab #3?

a) The drum temperature will reach steady state for an infinite turning of drum.
b) The time constant turned out to depend on drum turning speed.
c) **A thermocouple is good enough to measure temperature transients.**
d) Faster drum speed results in a lager value of dT/dt.

25) What does the time constant (τ) tell us about a 1^{st} order system?

a) How fast the system responds to a step input
b) The time it takes from the start of a step until the system reaches steady state
c) Approximately 2/3 of the total rise time of the system
d) **a & c are correct**

26) In lab #4, was the natural frequency of the system or the natural frequency of the pressure transducer measured?

a) System
b) Transducer
c) Neither

27) In lab #4 you used different pressure step sizes to estimating the dynamic response characteristics of the pressure system. Which of these characteristics does not depend on the size of the step?

a) Gain or Static Sensitivity (K)
b) Damping ratio (ξ)
c) Natural frequency of the transducer (ω_n)
d) **All of the above**

28) What kind of elastic element was used in the pressure transducer of our experiment #4.

a) a foil bonded to the diaphragm
b) a stretched wire
c) a piezoresistive semiconductor
d) none of the above

29) Which of the following does <u>not</u> represent the dynamic characteristics of the pressure transducer system used in lab 4 and 5?

a) Behaves like 2^{nd} order system.
b) Its natural frequency (ω_n) is high.
c) **It has an overdamped damping ratio (ξ)**
d) It is a deflection rather than a null device.

30) Why is a diaphragm type pressure transducer modeled with a second order differential equation?

a) **The transducer has mass which yields inertia**
b) The transducer never resonates in response to a step input
c) The transducer voltage output is very low
d) It isn't modeled with a 2^{nd} order differential equation but with a 1^{st} order equation.

31) If the damping ratio, ξ, of the pressure transducer was greater than 1 the system would be considered:

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

32) If the pressure transducer's natural frequency, ω_n = 150KHz what would you expect its maximum measurable pressure frequency to be?

a) 100% of ω_n
b) 75% of ω_n
c) **50% of ω_n**
d) 20% of ω_n

33) In lab #4 the second order model:

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

was used to simulate the response of the pressure transducer to a change in pressure. What does KA (the static gain) represent?

a) The initial step value
b) **The steady state value**
c) The rise time
d) Both A and C
e) None of the above

(Hint: What does Y(t) equal at t=0 and t=∞)

34) Regarding lab #4 and the equation in the problem above, if the damping ratio (ξ) was equal to 0 what would you expect the time response of the system to look like?

a) **The system will oscillate indefinitely**
b) The system will exponentially decay to the steady state value with no oscillations
c) The response will be a damped sinusoid, which decays to the final step value.
d) It doesn't have any effect on the steady state value of the system
e) None of the above

35) To analyze the pressure-volume relationship in lab #5, we model the process as:

a) a linear process
b) **a polytropic process**
c) a first order process
d) a second order process

36) This is what one of your fellow students wrote in his report for lab #5. "DISCUSSION: …… I measured the pressure and volume in the system simultaneously and obtained the following data: pressure = 5.25 psig , volume = 4 in^3 . Under the assumption of isothermal compression, when the pressure is increased to 7 psig, the volume in the system will decrease to 3 in^3. Further, ……". This statement is:

a) **True**
b) False

37) Which of the following is true based on lab #5?

a) We used gage pressure instead of absolute pressure to find n.
b) We can neglect the volume inside the tube.
c) **We assumed ideal gas for air in the system.**
d) The process was reversible.

38) What characterizes a deflection device as oppose to a null device?

a) **The deflection device changes the system it is measuring and a null device doesn't.**
b) It deflects while a null device doesn't move
c) The deflection device is characterized by a first order system while the null device is 0 order.
d) None of the above

39) In lab#5 you performed a Fourier analysis on pressure vs. time and volume vs. time data. Can this analysis be applied to any nondeterministic signal?

a) Yes
b) **No**

40) From the Entran web page the natural frequency (ω_n) of the pressure transducer is 15KHz. Was the transducer capable of measuring the pressure fluctuations of the system in lab #4?

a) **Yes**
b) No

41) 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

42) A histogram of repeated measurements of a variable

a) is useful for determining if the measurements are randomly distributed.
b) provides an approximation to the probability density distribution of the variable.
c) neither A or B are correct.
d) **both A and B are correct.**

43) The *static sensitivity* of an instrument

a) is the slope of the static calibration curve.
b) is dependent on the value of the input for linear instruments.
c) may vary due to changes in extraneous variables like temperature.
d) **both A and C are correct.**
e) A, B and C are all correct.

44) The number of different values that can be discretized by a 12 bit ADC is:

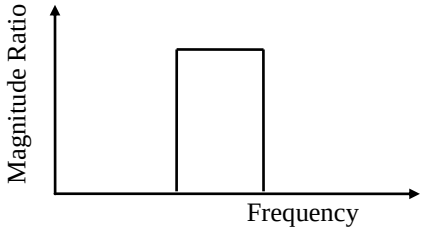
a) **4096**
b) 2048
c) 1024
d) 256
e) 512

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

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

46) The plot of magnitude ratio vs frequency at right is typical of a

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

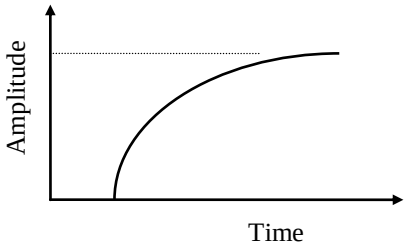


47) An instrument has an output which is proportional to the square root of the input. The *static sensitivity* of the instrument will

a) **decrease as the input increases.**
b) be independent of the magnitude of the input.
c) increase as the input increases.

48) The plot shown at right is typical of the step response of

a) **a first order system.**
b) an overdamped first order system.
c) an underdamped first order system.
d) a critically damped second order system.



49) The Fourier series representation of the function given by:

$$f(t) = 5 + 3 \sin t + 7 \sin 3t + 6 \sin 7t + 5 \sin 10t$$

will have _____ non-zero terms.

a) 21
b) 10
c) **5**
d) 4

50) The step response is a useful measure of system frequency response because:

a) it is independent of step size.
b) it provides enough information to determine the complete frequency response of the system.
c) it can be described by a single parameter regardless of the order of the system.
d) **both A and B are correct**
e) A, B and C are all correct.

51) 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.**

52) The time constant of a temperature sensor can be decreased by

a) decreasing its thermal capacity and decreasing the heat transfer between the sensor and the fluid.
b) increasing its thermal capacity and increasing the heat transfer between the sensor and the fluid.
c) **decreasing its thermal capacity and increasing the heat transfer between the sensor and the fluid.**
d) increasing its thermal capacity and decreasing the heat transfer between the sensor and the fluid.

53) In order to avoid aliasing of an analog signal whose highest frequency component is 100 KHz, sampled with a A/D converter with maximum sampling rate of 100 KHz the anti aliasing filter should be set at::

a) 10 KHz
b) **50 KHz**
c) 100KHz
d) 200 KHz.

54) Which of the following is not characteristic of operational amplifiers?

a) very high open loop gain.
b) **very low input impedance.**
c) very low output impedance.
d) A, B and C are all characteristic of operational amplifiers.

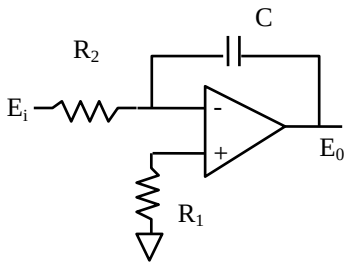
55) The primary advantage of analog filters compared to digital filters is

a) they can be used to prevent aliasing.
b) they take up less memory.
c) **they have a sharper frequency cutoff.**

56) The primary disadvantage of digital filters compared to analog filters is

a) they take up more memory.
b) their frequency cutoff is not as sharp..
c) **they are slower.**

57) The operational amplifier circuit shown at the right could be used as an active



a) Low pass filter.
b) High pass filter.
c) **Integrator.**
d) Differentiator.

58) A transducer being used to measure vibrations with a frequency range of 10-500 Hz is very sensitive to noise from electrical motors running at 500-1000 RPM. The effect of the noise can be minimized by passing the output through a

a) low pass filter
b) high pass filter
c) notch filter
d) bandpass filter.

59) 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.

60) 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.

61) Repeating a measurement of a steady state variable several times and averaging the individual measurements

a) improves the estimate of the true value of the variable.
b) can minimize the effect of uncontrolled extraneous variables.
c) can minimize the effect of bias error on the measurement.
d) both A and B are correct.
e) both A and C are correct.

62) 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

For 5 degrees of freedom, the sample mean is given by: $x_i = 6.54 \pm 1.2$ (90%). To improve the certainty of estimates of the true mean from 90% to 95% probability, assuming the sample standard deviation remains about the same, it is necessary to increase the degrees of freedom from 5 to approximately

a) 10
b) **20**
c) 50

63) 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.

64) 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

65) 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.

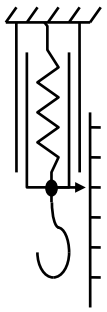
66) In order to accurately follow a time varying signal, a transducer which has a second order dynamic behavior should be:

a) **underdamped.**
b) overdamped.
c) critically damped.
d) it makes no difference.

67) When the input voltage to an A/D converter exceeds its range,

a) it cannot be accurately sampled.
b) the A/D converter could be damaged.
c) the digital output will be saturated.
d) **A,B and C are all correct.**

68) The device shown in the sketch is an old fish scale (mechanical force transducer). Increasing the stiffness of the spring will have the effect of



a) increasing its static sensitivity and increasing its input impedance.
b) decreasing its static sensitivity and increasing its input impedance.
c) **increasing its static sensitivity and decreasing its input impedance.**
d) decreasing its static sensitivity and decreasing its input impedance.

69) If the output impedance of an ideal amplifier is zero it is an infinite source of power.

a) True
b) False

70) An ideal voltmeter has an infinite input impedance.

a) True
b) False

71) The use of manometers to measure fluid pressure is limited because

a) they tend to integrate pressure changes with respect to time.
b) **the tubes are too thin, thus, they low pass filter the pressure changes.**
c) they tend to be very expensive.
d) both A and B are correct.
e) A, B and C are all correct.

72) If the 60 Hz signal from nearby electrical devices is creating measurement system interference errors these errors can be reduced by:

a) shielding the cables
b) using a notch filter
c) Using a band pass filter

d) Both a & b
e) Both a & c

73) 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.

74) Aliasing describes the phenomena

a) in which signal frequency appears higher than the actual value due to inadequate sampling rate.
b) **in which signal frequency appears lower than the actual value due to inadequate sampling rate.**
c) in which signal waveform appears distorted.

75) In order to minimize the effect of ground loops, a data acquisition system should be configured

a) with as many ground connections as possible
b) **with a single low resistance ground connection**
c) with floating reference inputs
d) both B and C.

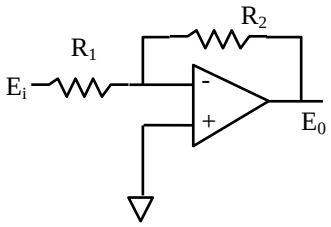
76) In the dynamic calibration of the pressure transducer we used an external trigger to begin the A/D conversion because

a) **the transient response was so fast that automatic triggering was required to capture the data reliably.**
b) the Wheatstone bridge circuit on the transducer could only be activated briefly without overheating.
c) the sampling rate of the A/D converter was too slow for manual triggering.
d) both A and B are correct.
e) both B and C are correct.

77) 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.

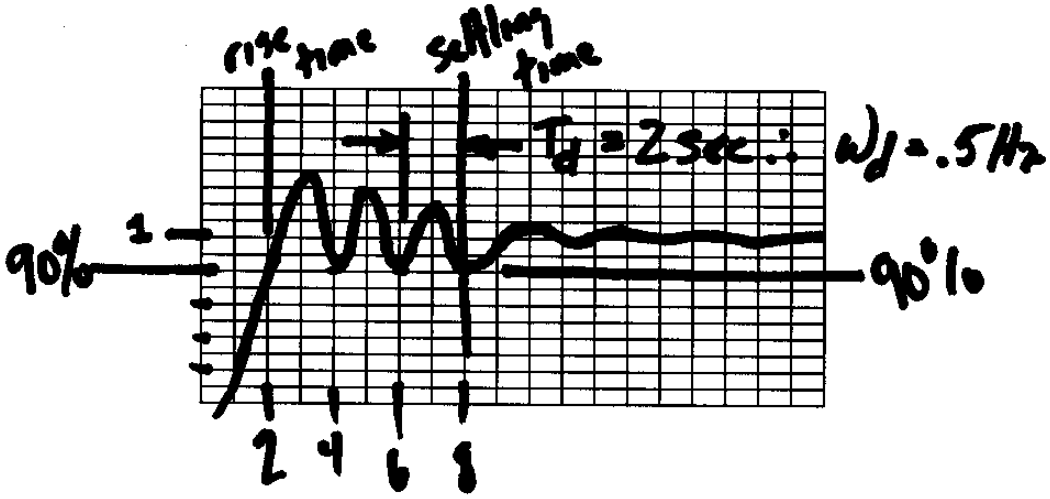
a) square of the sum of the differences
b) **the sum of the squares of the differences**
c) the sum of the differences

78) The operational amplifier shown in the sketch will produce an output voltage, the magnitude of which is …… the input.

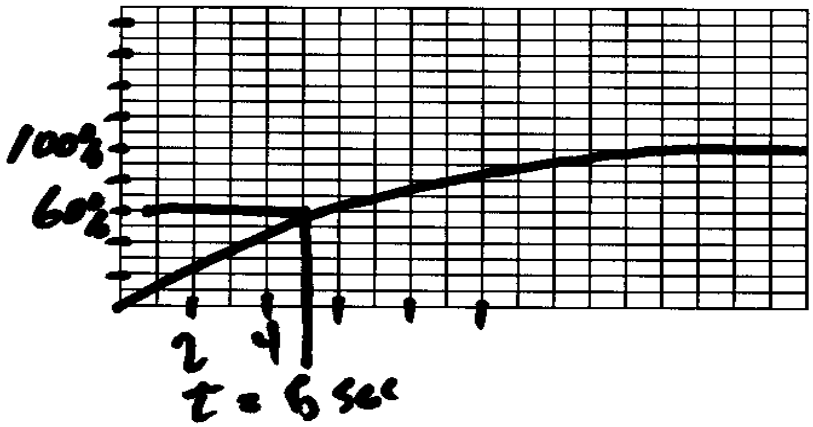


a) **proportional to**
b) the integral of
c) the derivative of
d) none of the above.

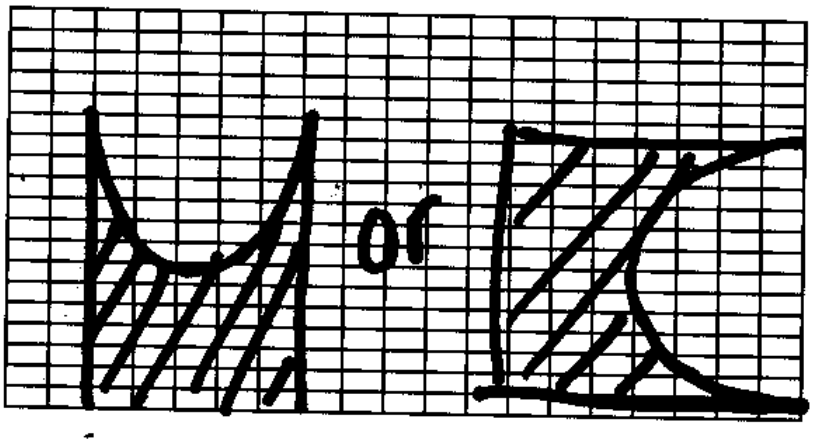
79) Sketch a typical underdamped 2nd order system response to a step input of magnitude 1, a rise time of 2 seconds, a settling time of 8 seconds and a ringing frequency of 0.5 Hertz. The step input is applied at time = 0. Label the Y axis values corresponding to the X axis time values of 2 seconds and 8 seconds



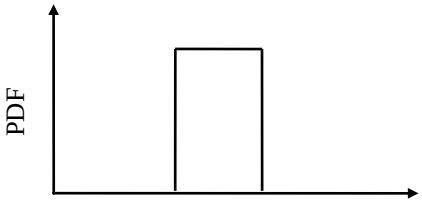
80) Sketch a typical 1st order system response to a step input of magnitude 1 and the time constant is 5 seconds. The step input is applied at time = 0. Label the Y axis values corresponding to 5 seconds and the steady state value.

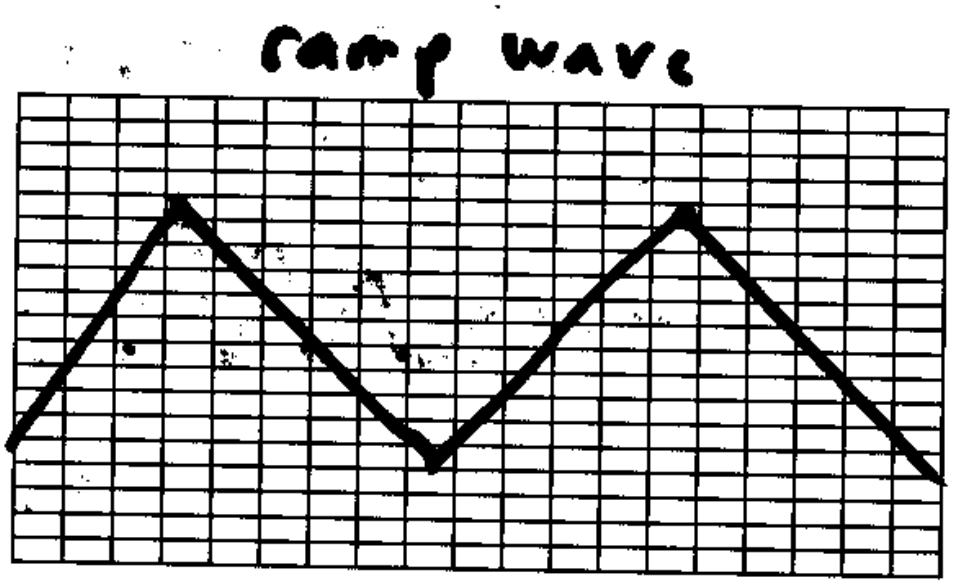


81) Sketch the histogram (Probability Density Function) of a sine wave.

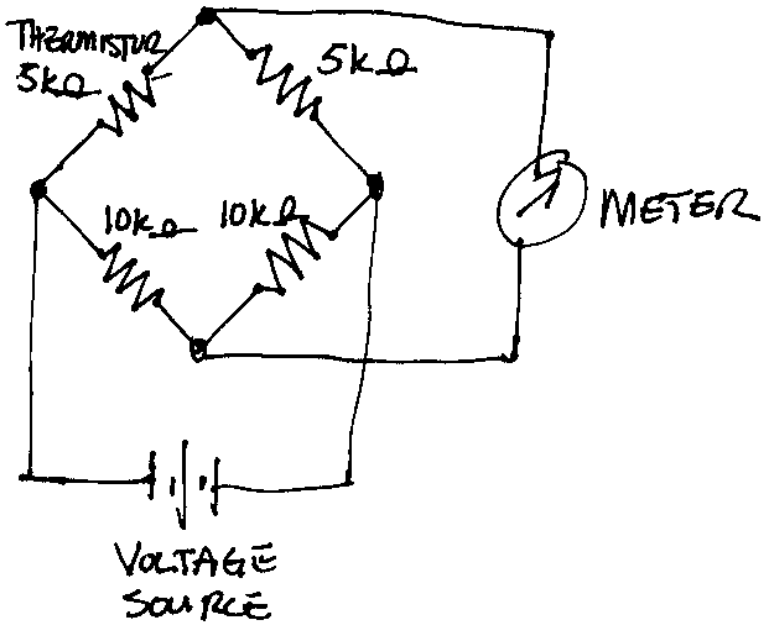


82) Sketch a wave form that would have a histogram like the one shone in the figure to the right.

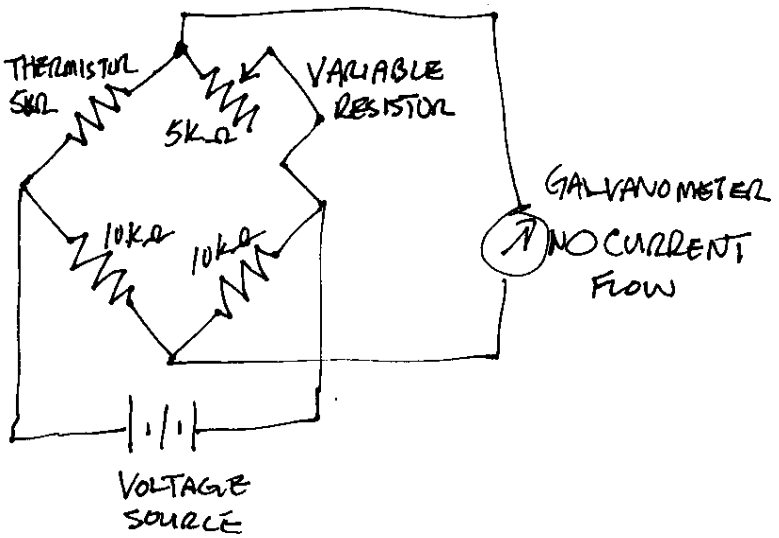




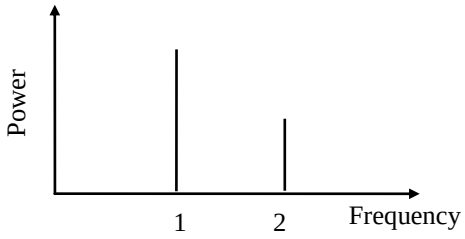
83) Draw a balanced wheatstone bridge with a bridge ratio of 1:2 with a 5,000 ohm thermistor as the active component. Label the thermistor and the voltage input and measurement points, include the voltmeter and the resistor values.

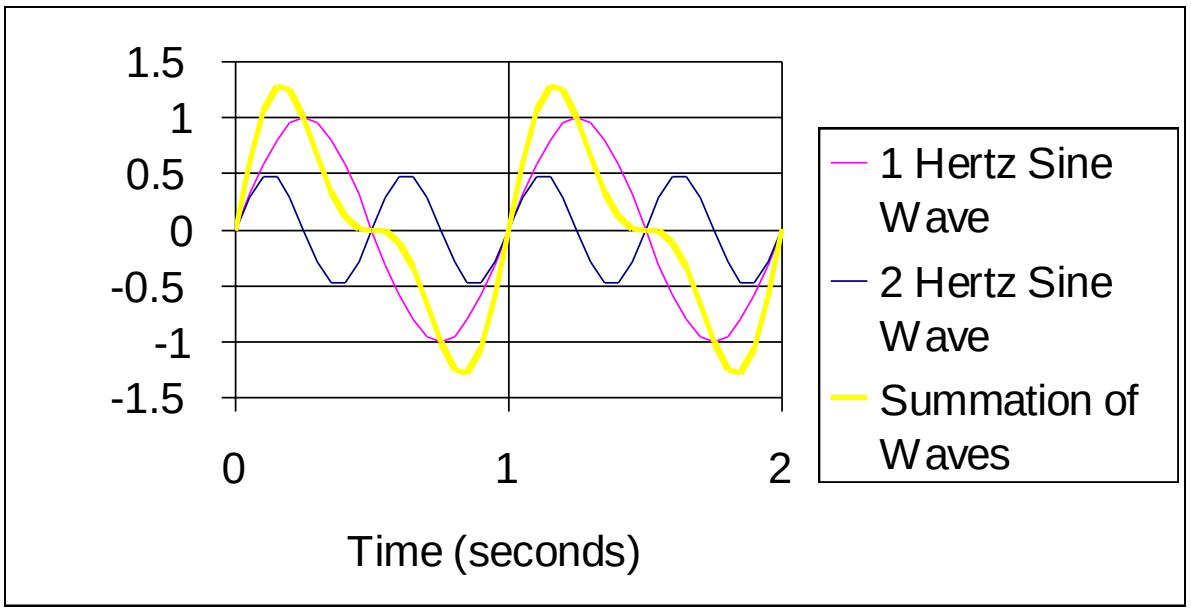


84) Redraw this bridge to include a null measurement output instead of a voltmeter. Indicate clearly what is different from the previous sketch.



85) Sketch a possible waveform which would have a frequency spectra like the one drawn here. Be sure to clearly label your time axis





86) The second order ordinary differential equation $a_2y''+a_1y'+a_0y=F(t)$ is often used as a model to analyze system behavior. The model uses a spring, mass and dashpot elements. For the purpose of vibration analysis, a building like Furans Hall can be modeled as a second order ordinary differential equation, especially in the underdamped situation. Following questions will be assumed the underdamped system solution is of the form:

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

a) Determine the natural frequency and damping ratio in terms of the original coefficients of the equation (a_0,a_1,a_2).

Proceeding from Eq. 3.12 in your text book, the 2nd order ODE can be written as

$$a_2y''(t) + a_1y'(t) + a_0y(t) = F(t)$$

dividing by a_0

$$\frac{a_2}{a_0}y''(t) + \frac{a_1}{a_0}y'(t) + y(t) = \frac{1}{a_0}F(t)$$

This equation can be rewritten in terms of the physical parameters used to describe the system as:

$$\frac{1}{\omega_n^2}y''(t) + \frac{2\zeta}{\omega_n}y'(t) + y(t) = KF(t).$$

Therefore, the natural frequency and damping ratio can be found to be:

$$\frac{1}{\omega_n} = \sqrt{\frac{a_2}{a_0}}$$

$$\omega_n = \sqrt{\frac{a_0}{a_2}}$$

and

$$\zeta = \frac{a_1}{a_0 2\omega_n} = \frac{a_1}{a_0 2\sqrt{a_2/a_0}}$$

$$\zeta = \frac{a_1}{2\sqrt{a_0a_2}}$$

b) We wish to use the model to predict if Furans Hall will survive a strong wind that will cause a formation of vortices around the building at a frequency 45Hz. A sample unit step response function of Furans Hall is shown in Fig.1.

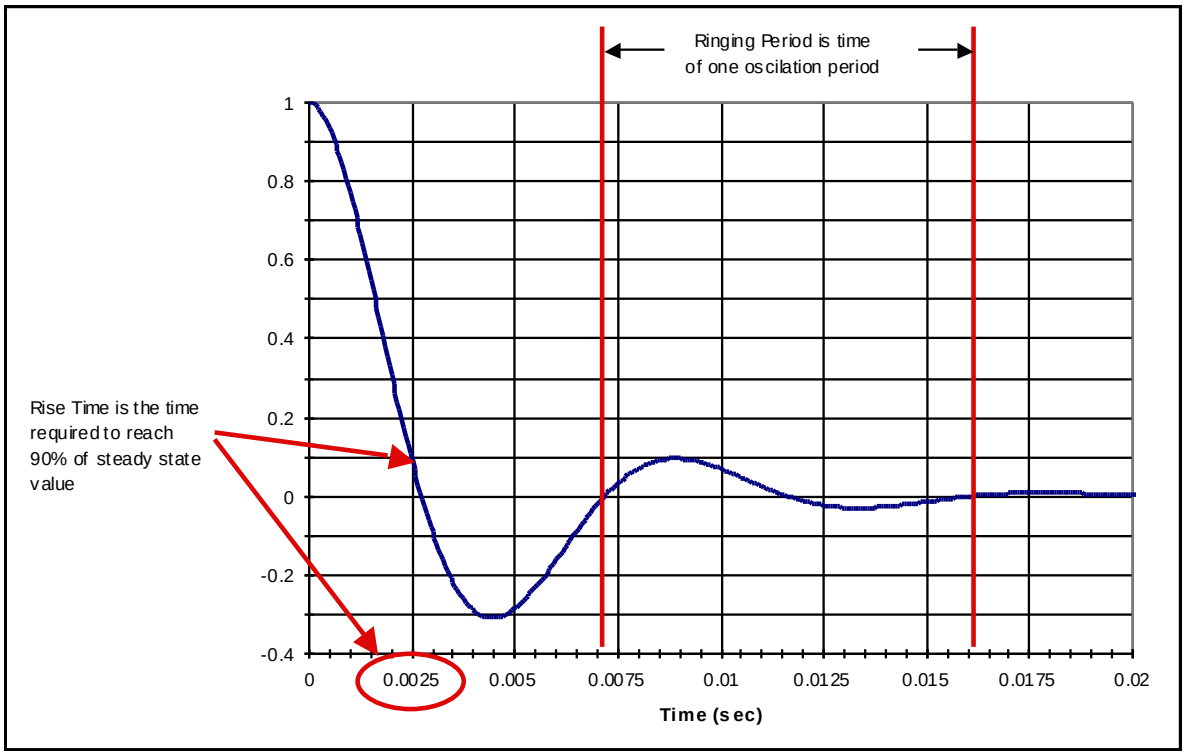


Fig.1: The response of "Furans Hall" subjected to a unit step function.

Estimate the values of ringing period, ringing frequency, rising time, natural frequency, and damping ratio. Is Furans Hall safe under the wind attack?

The rising time, T_r, and ringing period, T_d, can be measured from Fig. 1, which are approximately 0.0025 sec and 0.009 sec respectively (worth 2 points each).

The ringing frequency is the inverse of the ringing period, $1/T_d = 111$ *Hertz* (worth 2 points).

If you estimated the natural frequency to be slightly above the ringing frequency you are correct (worth 1point).

If you estimated the damping ratio to be below 1 that is worth 1 point, below .5 is worth 2 points.

So, the natural frequency is large enough to avoid the resonance. (1 point)