ME 361: Instrumentation and Measurement

Assignment 01

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1. Identify the measurement system stages for the following systems:
   (a) Thermocouple based temperature measurement system.
   (b) Air-conditioning system thermostat.
   (c) Automotive odometer.
   (d) Temperature chart-recorder.
   (e) Diesel engine speed control mechanism.
2. A certain pressure transducer has a natural frequency of 5000 Hz and a damping ratio c/c_c of 0.4. Estimate the resonance frequency and amplitude response and phase shift at a frequency of 2000 Hz.
3. Determine the rise time for a critically damped second-order system subjected to a step input when the natural frequency of the system is (a) 10 Hz, (b) 100 kHz, (c) 50 MHz.
4. A thermometer has a time constant of 10 s and behaves as a first-order system. It is initially at a temperature 30°C and then suddenly subjected to a surrounding temperature of 120°C. Calculate the 90% rise time and the time to attain 99% of the steady-state temperature. If the thermometer is subjected to a harmonic temperature variation having an amplitude of 20°C and a frequency of 0.01 Hz. Determine the phase lag and time lag of the thermometer, and the amplitude attenuation.
5. A pressure transducer operates as a second-order system having a natural frequency of 10,000 Hz. For damping ratios c/c_c of 0.3 and 0.4, determine the resonance frequencies. For the transducer, determine the amplitude response and dynamic error for frequencies of 2000 and 4000 Hz. Also, determine the phase lag for these frequencies.
6. A certain resistor draws 110.2 V and 5.3 A. The uncertainties in the measurements are ± 0.2 V and ± 0.06 A, respectively. Calculate the power dissipated in the resistor and the uncertainty in the power.
7. Twelve pressure measurements are made of a certain source giving the following results in kPa: 125, 128, 129, 122, 126, 125, 125, 130, 126, 127, 124, and 123. Obtain the mean value and set the limits for 90 and 95 percent confidence levels. Also, determine the possible value of thirteenth reading with 95% confidence.
8. The density of air is to be determined by measuring its pressure and temperature for insertion in the ideal-gas equation of state; that is, $P = \rho RT$.The value of R for air is 287.1 J/kg-K and may be assumed exact for this calculation. The temperature and pressure are measured as T = 25 $\pm$ 0.4°C, and P = 125 $\pm$ 0.5 kPa. Determine the nominal value for the density in kg/m^3 and its uncertainty.
9. A first-order sensor is to be installed into a reactor vessel to monitor temperature. If a sudden rise in temperature greater than 100°C should occur, shut-down of the reactor will need to begin within 5 s after reaching 100°C. Determine the maximum allowable time constant for the sensor.
10. Based on 51 measurements of a time-dependent electrical signal, the standard deviation is 1.52 V. Find the 95% confidence interval in its true mean value. How many more measurements would be required to provide a 95% confidence interval in the true mean to within ± 0.28 V?