ME323 Mechanical measurements

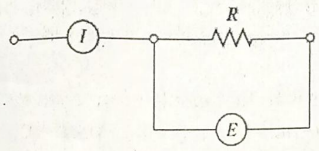
Mid Sem Examination **28 Feb 2023**

Total time: 2 Hours **Total Marks: 50**

Answer all the questions| Make appropriate assumptions, if needed. **(Closed Book Exam)**

Que.1) (a) A resistor has a nominal stated value of 10 Ω ± 1 percent. A voltage is impressed on the resistor, and the power dissipation is to be calculated in two different ways: (1) from $P = E^2/R$ *and* (2) from $P = EI$. In (1) only a voltage measurement will be made, while both current and voltage will be measured in (2). Calculate the uncertainty in the power determination in each case when the measured values of E and I are:

$$E = 100\ V \pm 1\% \text{ (for both cases)}$$
$$I = 10\ A \pm 1\%$$



What uncertainty in the resistance for the first part is necessary to produce the same uncertainty in power determination as results from the current and voltage measurements? [6]

(b) Reynolds number for pipe flow may be expressed as

$$Re = \frac{4\dot{m}/\pi d}{\mu}$$

Where,
ṁ = mass flow, kg/s
d = pipe diameter, m
μ = viscosity, kg/m.s

In a certain system the flow rate is 12 lbm/min, ± 0.5 %, through a 0.5-inch diameter (±0.005-inch) pipe. The viscosity is 44.64×10^{-4} lbm/h.ft, ± 1 %. Calculate the value of the Reynolds number and its uncertainty. [4]

Que.2) A certain thermometer has a time constant of 15 sec and is subjected to a very slow harmonic disturbance having a frequency of 0.01 Hz. What is the time delay in the response of the thermometer and how much does the steady-state amplitude response decrease? Estimate any dynamic error that could be result. [5]

Que.3) A first order pressure sensor must meet the following dynamic response specification:
(a) At least 95 percent accuracy within 0.05s after a step input
(b) Steady-state error of no more than 14kPa for a ramp input of 0.7 Mpa/s
(c) Amplitude accuracy no worse than 90% for a sine wave input of frequency 20 Hz
Find the largest allowable time constant for this sensor [6]

Que.4) A second order pressure sensor has an un-damped natural frequency of 300 $\mathbf{rad/s}$, damping ratio of 0.1 and static sensitivity of $\mathbf{10^{-6}\ V/N/m^2}$. Its output is connected to another second order recording device having an un-damped natural frequency of 400 $\mathbf{rad/s}$, damping ratio of 0.5 and static sensitivity of $\mathbf{5\ mm/mV}$. The input is harmonic pressure signal of amplitude $\mathbf{1000\ N/m^2}$ and frequency $\mathbf{30}$ Hz. Find the value of output amplitude recorded and the phase difference. [5]

Que.5) A pressure transducer operating as a second-order system is to be used to measure a signal at $\mathbf{500\ Hz}$. To select the transducer, we shall choose one with a natural frequency of $\mathbf{1500\ Hz}$. What damping ratio $\mathbf{C/C_c}$ must be selected so that the dynamic error of the amplitude response is less than $\mathbf{2}$ percent? [5]

Que.6) 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 5s after reaching 100°C. Determine the maximum allowable time constant for the sensor. [5]

Que.7) Draw sketches to illustrate the dynamic characteristics of the following: (a) zero-order instrument (b) first-order instrument (c) second-order instrument
In the case of a second-order instrument, indicate the effect of different degrees of damping on the time response. [3+2]

Que.8) A dynamic measurement device operating as a second-order system is to be designed to measure an input frequency of 60 Hz with an amplitude error of no greater than 5 percent. Determine appropriate design parameters which would accomplish this objective. Many answers are possible, so discuss what factors influenced your selection. [3]

Que.9) Distinguish between static characteristics [2+2]
a) Resolution and Threshold
b) Accuracy and Precision

Que.10) What are the elements in a general measurement system? [2]

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