GX655

OLLSCOIL NA hÉIREANN
The National University of Ireland

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Trinity Examinations, 2000/01

Second Year Mechanical Engineering Examination

INSTRUMENTATION

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Attempt *Five* Questions.
Time Allowed: *3 Hrs.*

Graph paper, Laplace Transforms, and Equations for Least Square Method are available.

1 (a) Define *gauge factor* for a strain gauge. ***(5)***

(b) A foil strain gauge with a gauge factor specified as 2.04 ± 1% is installed on a test specimen of length 50 mm for tensile testing. Under zero load, the gauge resistance is measured as 120 to an accuracy of ± 0.3%. When the instrumented specimen is under load, the gauge resistance increases by 0.36 ± 0.005 Ω.

Calculate the change in length of the specimen and the uncertainty in this result. ***(15)***

2 An instrument has one time-varying input $x(t)$ and one time-varying output $y(t)$. The input and output signals are related by this differential equation:

$$\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + 100y - \frac{dx}{dt} - 100x = 0$$

(a) Give the transfer function $T(s) = Y(s)/X(s)$ of this instrument. ***(5)***

(b) Using the transfer function to determine the approximate frequency response of the instrument, sketch a plot of gain as a function of frequency response on log-log axes. ***(15)***

Note: Useful formulas are given on page 6

3 It is required to measure unsteady air pressures in a system where fluctuations at frequencies of at least 1 kHz are expected. A transducer with acceptable frequency response characteristics to over 15 kHz is available, but it is too large to install in the confined space at the measurement location. It is suggested that the transducer be connected to the measurement site by a tube of 0.5 mm diameter and 1 m length. At the transducer end of the tube there will be a cylindrical dead volume of 10 mm diameter and 10 mm length, as shown in **Figure 3**. At the relevant operating conditions, the viscosity of air is 1.78×10^{-5} Pa s, the density of air is 1.226 kg/m^3 and the speed of sound in air is 340 m/s.

(a) Calculate the damping ratio ξ and natural frequency ω_n of this installation. *(10)*

(b) What is the highest frequency (in Hz) of pressure oscillation at the measurement location for which pressure measured at the transducer will be within 10% of the true pressure? *(8)*

(c) Do you recommend use of this installation? Why? (max 20 words) *(2)*

Note: Useful formulas are given on page 5

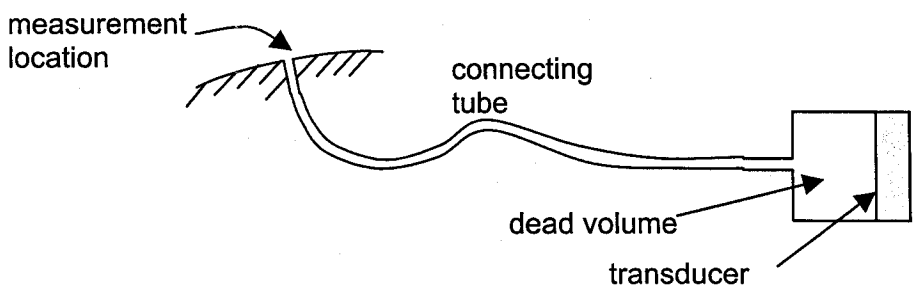

Figure 3 Arrangement of pressure transducer.

4(a) What name is given to the amplifier circuit shown below, where V_i is the input voltage and V_o is the output voltage? What is its purpose? (max 20 words) *(5)*

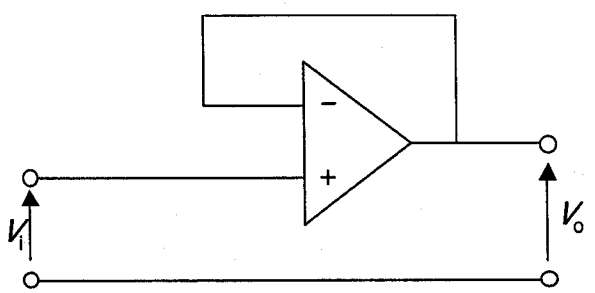

Figure 4(a) Amplifier circuit.

(b) Briefly describe the construction, physical principle and application(s) of a Bridgman gauge (max 50 words). *(5)*

(c) From the following set of data, obtain y as a linear function of x using the method of least squares. *(5)*

y_i	x_i
1.1	0.9
1.2	1.0
2.0	1.6
3.6	4.5
3.7	5.2

Note: Useful formulas are given on page 7.

(d) Draw a schematic of an angular digital displacement transducer. *(5)*

5(a) Define a transducer. *(2)*

(b) Describe three different transducers suitable for measuring displacement. Discuss each of these transducers in terms of accuracy, input requirements and possible sources of error. *(12)*

(c) Five 1cm^2 square plates are arranged as shown in Figure 5(c). The plate spacings are 0.01 cm. The arrangement is to be used for a displacement transducer by observing that the change in capacitance with the distance x. Calculate the sensitivity of the device in pF/cm. Assume the plates are separated by air (Dielectric constant for air = 1.0006). *(6)*

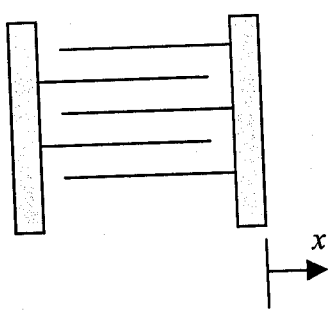

Figure 5(c)

6(a) Describe what is meant by the term thermoelectric effect, and how it is used in modern thermocouples for temperature measurement. State the laws of intermediate metals and intermediate temperatures. *(12)*

(b) You are asked to use a thermocouple to measure the temperature of a water bath. After submersion in the water bath, the thermocouple output is 1.79 mV with the reference junction held at 25°C. Calculate the temperature of the bath and state the thermocouple law that allows the calculation. The calibration table for the thermocouple is given below. *(8)*

Calibration table for Thermocouple (reference junction at 0 °C)

Temperature (°C)	E (mV)
0	0.15
25	0.71
38	1.94
66	2.26
72	2.50
80	2.62

7(a) Discuss each of the following particulate sampling techniques for air-pollution measurement:

(i) Settling and Sedimentation.
(ii) Mechanical Collection
(iii) Filtration Techniques
(iv) Impingement and Precipitator collectors.

(8)

(b) Discuss the importance of isokinetic sampling. *(4)*

(c) A sample is collected at a rate of 50 in^3/s for a period of 1hr through a filter area having a diameter of 1.4 in. As a result of the sample collection, the light transmission of the filter paper is reduced from 80 to 40%. Calculate the value of the Coh/1000ft. *(8)*