INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY

Date: 3 May, 2023 Time: 3 Hours Total Marks: **100** No. of Students: 86

Code: **AV222**, Course Name: INSTRUMENTATION AND MEASUREMENT, End-Sem Exam

2nd year B. Tech **ECE and Engg. Physics** Students

PART – A (20 Marks)

Answer all Questions

QUESTION: 1: (10 Marks)

Fill in the blanks. Show the calculations in the answer script, wherever required.

(a) Standard deviation of a particular set of 1 kΩ resistors is specified as 10 Ω. The standard deviation of the parallel combination of the two such resistors will be _____

(b) Bandwidth of a voltage-follower circuit that uses an OPAMP of open-loop bandwidth of 10 Hz and open-loop gain of 10^5 is _____

(c) Thermal noise of resistors is an example of _____ error, while the loading effect due to internal resistance of meters is _____ error.

(d) Hall Effect sensor and Photodiode are used to measure _____ and _____, respectively.

(e) Power consumed by a typical opamp depends on its load current, _____ current, and _____ current.

QUESTION: 2 (10 Marks)

Briefly justify the following phrases.

(a) Ramp-response of first-order instruments exhibits an error in the steady-state.

(b) Digital multimeter in AC mode exhibit higher error than in DC mode

(c) Precision is a pre-requisite for accuracy, but do not guarantee accuracy.

(d) The power consumption of a Dual-Slope ADC remains almost a constant with number (n) of bits, while its conversion time increases with n.

PART – B

(Answer any FOUR out of 5 questions, Each question carries 20 marks)

QUESTION: 3 **(9 + 5 + 6 = 20 Marks)**

(a) Consider the circuit in Fig. 1. Assume opamp supply voltages as ± 5 V.

(i) Show that the frequency of the signal, V_B is proportional to the input voltage, V_{IN}. Find the proportionality constant. Make suitable assumptions, if required.

(ii) Draw the (approximate) waveforms of the voltages V_A and V_B when V_{IN} = + 1 V. Mark the amplitude and relevant time-durations of these waveforms.

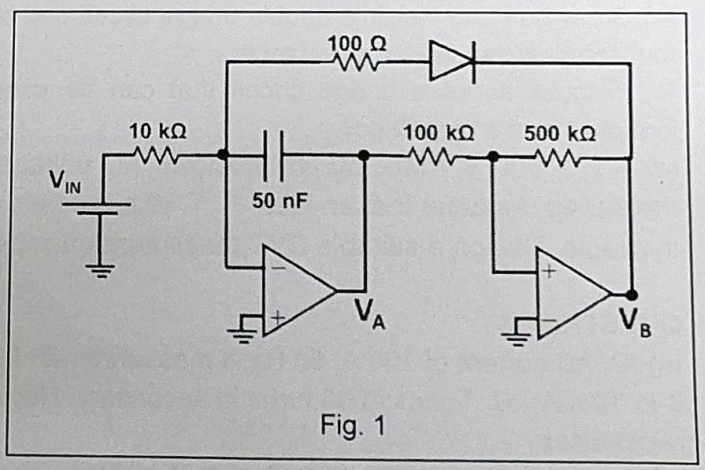

Fig. 1

(b) A frequency meter M can display a maximum count of 1,9999,9999. *What is the typical name of this meter?* A signal v_x of frequency 12.345678 MHz is applied to the meter. What will be the meter reading if the ON time of its standard signal is 10 ms.

(c) Develop a resistance-to-digital converter circuit for a resistive sensor (say, R_X). Assume R_X can vary from 1 kΩ to 1.5 kΩ.

QUESTION: 4 **(5 + 4 + 5 + 6 = 20 Marks)**

The bending force (say, P) experienced by a cantilever beam (see Fig. 2) is measured using four strain gauges (1, 2, 3, 4) of gauge factor 2 and nominal resistance 100Ω. Placement of gauges and beam dimensions are depicted. Young modulus of the beam is 1,00,000 MN/m^2.

(a) Derive and obtain the expression for gauge factor of a strain gauge.

(b) Show how the 4 strain gauges can be connected in wheatstone-bridge form for linear measurement of P.

(c) Determine the *resistance of the gauges* and the *differential output of the bridge* when a force (P) of 10 N is applied. Assume that bridge is excited by a 10 V DC battery.

(d) Now, assume the above beam is at a remote location such that long wires are required to connect the strain-gauge bridge to the battery and voltage measurement unit. Describe a measurement scheme that will render the final output independent of the wire resistances.

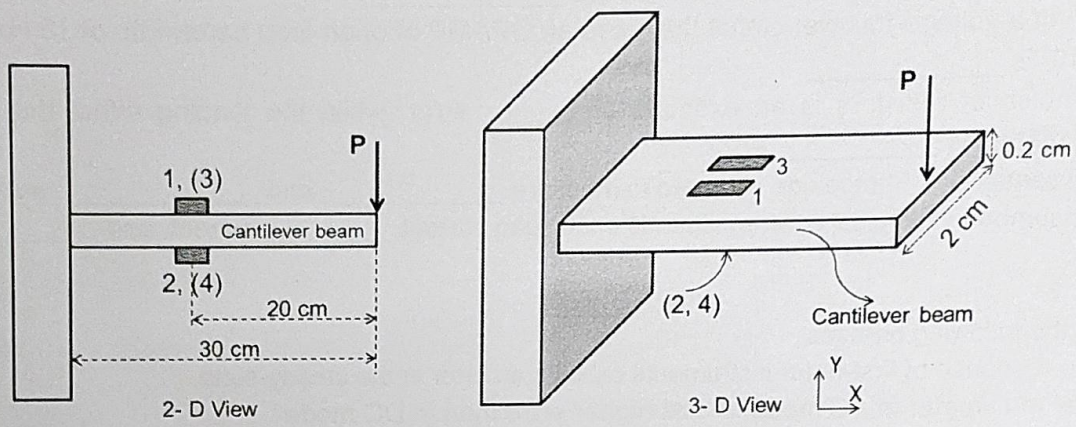

Fig. 2. Strain gauges (1, 2, 3, 4) on a beam. Strain axis of gauges is along the length of the beam (X axis).

QUESTION: 5 **(5 + 5 + 5 + 5 = 20 Marks)**

(a) Resistance (say, R_X) of a cylindrical slab of an insulator is measured using the circuit in Fig. 3. Front view of insulator is shown in figure. Voltmeter V and micro-ammeter μA are ideal. Propose suitable modifications to the circuit (without altering the meter locations) to reduce the effect of leakage current flowing through the surface of the insulator on the measurement of R_X.

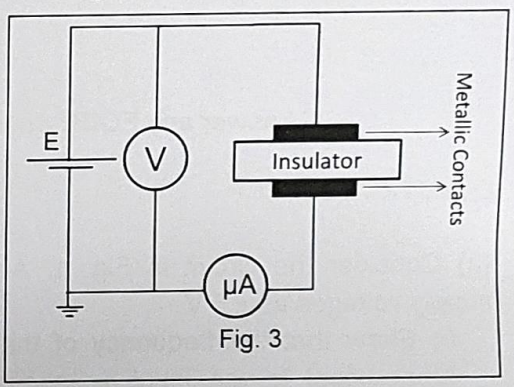

Fig. 3

(b) Show how the Kelvin's double bridge circuit can be used with a four-terminal low-valued resistance.

(c) Discuss about a bridge circuit that can be used to measure inductance of a high-Q coil.

(d) A 0 – 500 V RMS, 50 Hz unknown AC voltage needs to be measured. Assume that an ideal P. T. of turns-ratio 100, 0 – 1 V AC voltmeter, a set of 2 μF capacitors are available. Design a suitable CVT measurement scheme to measure the unknown voltage.

QUESTION: 6 **(9 + 6 + 5 = 20 Marks)**

(a) An AC current of 100 A, 50 Hz is measured with the help of a bar-type C. T. and electrodynamometer (100 Ω, 0 to 10 mA). C. T. has 1000 turns in secondary. Neglect the primary and secondary leakage losses and winding resistances.

Determine (i) shunt resistance (R_{SH}) that needs to be used in the secondary of C. T., (ii) Flux (Φ) in the core, (iii) If loss current of above C. T. is 100 mA, estimate the number of turns (say, m) which could be reduced in secondary winding to get minimum ratio error.

(b) Draw a charge amplifier circuit that can be used to interface push-pull-capacitive displacement sensors. Show how the circuit can nullify the effect of parasitic capacitances. Obtain the output expression of the circuit.

(c) A second order force transducer has a mass of 0.5 kg, stiffness of 200 N/m and a damping constant of 6 Ns/m. Output quantity of this transducer is displacement. Calculate the natural frequency and damping ratio of the transducer. Also, compute the time that will be taken by the transducer to settle within 1 % of its final value (when it is exposed to a step force input).

QUESTION: 7 **(6 + 5 + 5 + 4 = 20 Marks)**

(a) Consider the circuit in Fig. 4. Estimate the readings shown in the meters V1, V2 and A.
E is a voltage source of value E = 100 + 100×sin(1000t), V1 is a (basic) PMMC-based voltmeter, V2 is electrodynamometer-type voltmeter, A is electrodynamometer-based ammeter.

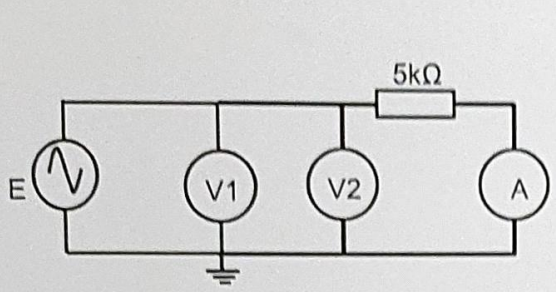

Fig. 4

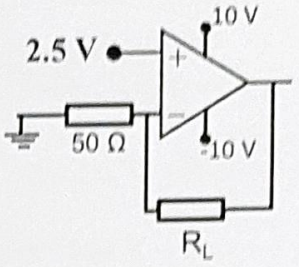

Fig. 5

(b) Assuming an ideal opamp, show that the circuit in Fig. 5 can be used to pass a constant-current of 50 mA through the load resistance R_L, which can vary between 40 Ω and 60 Ω.
Now, consider that opamp in Fig. 5 can source or sink a maximum output current of 35 mA. Show that the circuit can provide the desired current of 50 mA through R_L, by using an additional resistor in the circuit.
(c) With the help of schematic, discuss how a 3-opamp Instrumentation Amplifier (IA) can be used for ECG signal acquisition. Comment on whether IA can reduce the effect of difference-mode and common-mode interferences.
(d) Design a suitable filter circuit to reject the component of power-line interferences in the output of the IA.

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