BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
K.K. BIRLA GOA CAMPUS, Semester I, 2022 - 23
Course: INSTR F312 (Transducers and Measurement Systems)

Comprehensive Examination (Regular) **Closed Book** **Date: 24.12.2022**
Max. Marks: 80 **Duration: 3 Hrs**

Name: **ID No:**

PART-A (2×15=30 Marks) Time: 60 Minutes

Write the answers for PART A in the table given below. Write only the final answers. Overwritten answer will not be evaluated.

Q.1		**Q.6**		**Q.11**	
Q.2		**Q.7**		**Q.12**	
Q.3		**Q.8**		**Q.13**	
Q.4		**Q.9**		**Q.14**	
Q.5		**Q.10**		**Q.15**	

Solve the following questions

Q.1 A precision bourdon tube is stated to have an absolute accuracy of ±0.1 percent of full-scale reading of 1MPa. What is the percent accuracy when the gauge is employed for a differential pressure of 40kPa in air at 3 atm and 20°C?

Q.2 A temperature sensor operates as a first-order system and is stated to have a time constant of 0.1 s. If it is initially at a temperature of 100°C and suddenly exposed to an environment temperature of 15°C, how long will it take to indicate a temperature of 17°C?

Q.3 If the temperature sensor of (Q2) is exposed to a harmonic temperature source, for what frequency range will its amplitude response be within 10 percent? What will be the time delay under these circumstances?

Q.4 A certain resistor draws 110.2V and 5.3A. The uncertainties in the measurements are ±0.2V and ±0.06A, respectively. Calculate the power dissipated in the resistor and the uncertainty in the power.

Q.5 A highpass RC filter is to be designed for an attenuation of −3dB at 150Hz. Calculate the required value of the time constant and the attenuation of the filter in dB at 400Hz.

Q.6 A temperature sensor has a transfer function of 25mV/°C and output resistance of 5KΩ. The sensor is connected to an amplifier whose gain is 10 and has input resistance of 10KΩ. What is the amplifier output for a temperature of 60°C?

Q.7 A 4 bit D-A converter has an analog output range of -2 to 4V. Find the analog value corresponding to the input of 1010.

Q.8 A quartz crystal has the dimensions of 2 mm× 2 mm× 1 mm. The charge sensitivity of the crystal is 2.1 pC/N, Young's modulus is 8.6×10^{10} N/m^2 and permittivity is 40.6×10^{-12} F/m. Calculate the charge generated if the crystal is subjected to a strain of 10 micron.

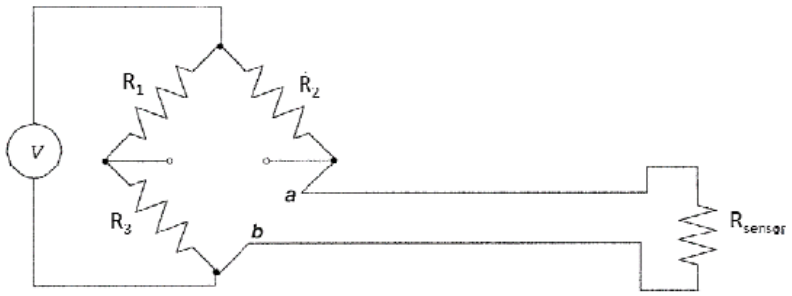
Q.9 In an ultrasonic level gauge, the transmitter and receiver sensors are placed over a liquid tank such that their height from the bottom of the tank is 2 meters. If the time taken by the signal from the transmitting instant to the receiving instant is 2 msec. Find the liquid level height in the tank taking into consideration that the speed of signal is 350 m/sec.

Q.10 An electromagnetic flowmeter is used to measure the average flow rate of a liquid in a pipe of diameter 50 mm. The flux density in the liquid has peak value of 0.1T. The output from the flowmeter is taken to an amplifier of gain 1000 and input impedance of 1MΩ. If the impedance of the liquid between the electrodes is 200kΩ. Calculate the peak value of the amplifier output voltage (V) for an average flow velocity of 20mm/s.

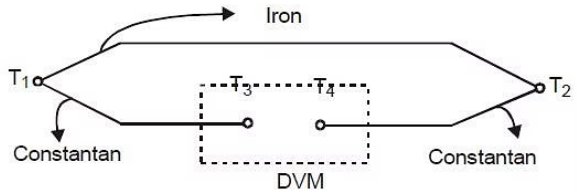
Q.11 A type J thermocouple is used to measure temperature between 0^o C and 300^oC at which it generates 5.268 mV. If the thermal emf is 12.5mV relative to the reference junction at 20^o C. Calculate the measured junction temperature.

Q.12 The power radiated from a hot piece of metal was measured by the radiation pyrometer and the temperature was determined as 820°C, assuming a surface emissivity of 0.75. Later it was found that the accurate value of emissivity was 0.69. Calculate the actual temperature.

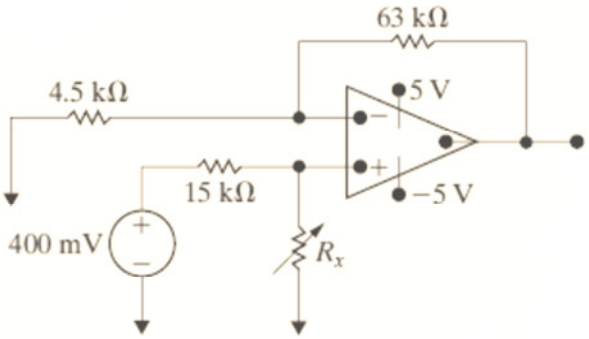
Q.13 A sensor is connected to a bridge circuit through lead wires as shown in figure below. The length of the lead wire is 100 m and the lead wire resistance is 1.45 Ω/m. Calculate the sensor resistance when bridge nulls with R_1 = 3250Ω, R_2 =3450Ω and R_3 = 1560Ω.



Q.14 A iron–constantan thermocouple has a voltage sensitivity of 55 μV/°C. A digital voltmeter is used to measure the voltage as shown in the figure below. Given that: T_1 = 300°C, T_2 = 100°C and T_3 = T_4 = 20°C, what voltage the meter will indicate.



Q.15 Assume that the op amp in the circuit shown below is ideal. Find the output voltage when the variable resistor is set to 60kΩ.



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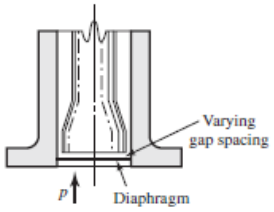
Note: 1. All questions are compulsory. 2. Make Assumptions wherever necessary and justify

PART-B (50 Marks) Time: 2 Hrs

Q.1(a) A capacitance-diaphragm pressure gauge shown in figure below is to be used to measure differential pressure as high as 1000 psi. The diaphragm pressure gauge is constructed of spring steel ($E = 29 \times 10^6$ psi, $\nu = 0.3$) and diameter of the diaphragm is 0.5 inch. Calculate the thickness of the gauge required so that the maximum deflection is one-third this thickness. Estimate the capacitance pressure sensitivity of the device when the gap spacing is 0.01 inch. Assume the dielectric constant is that of air. Take 1m = 39.37 inch. [6M]



(b) A mercury manometer has one arm in the shape of a well and the other as a tube inclined at 30° to the horizontal. The well is 4 cm in diameter and the tube 5mm in diameter. Find the percentage error in measurement if we neglect the area correction factor. [4M]

Q.2(a) A Data acquisition system (DAS) has an ADC of 8 bits with a input range of 0 to 2.5 V. Inputs are temperature from 20° to 100°C scaled at 40 mV/°C, pressure from 1 to 100 psi scaled at 100 mV/psi, and flow from 30 to 90 gal/min scaled at 150mV/(gal/min). Develop the equations required for signal conditioning circuit to interface the temperature, pressure and flow sensor and the ADC. [6M]

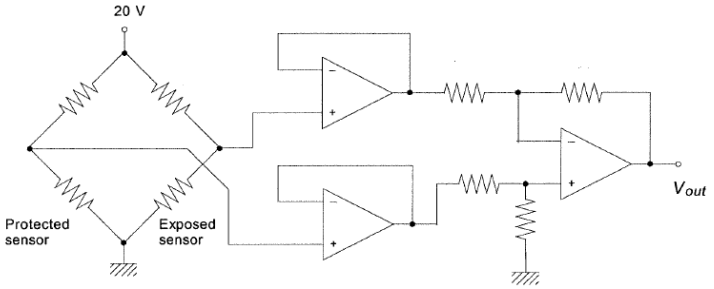
(b) Develop a low-pass RC filter to attenuate 0.5 MHz noise by 97%. Specify the critical frequency, values of R and C, and the attenuation of a 3kHz input signal. [4M]

Q.3 (a) A rotameter calibrated for metering has a scale ranging from 0.014 m^3/min to 0.14 m^3/min. It is intended to use this meter for metering a gas of density 1.3 kg/m^3 with in a flow range of 0.028 m^3/min to 0.28 m^3/min. What should be the density of the new float if the original one has a density of 1900 kg/m^3? Both the floats can be assumed to have the same volume and shape. [5M]

(b) A platinum resistance thermometer is used to measure temperature between 0ºC to 200ºC. Given that the resistance at tºC as $R_t = R_0(1+\alpha t+\beta t^2)$ And $R_0=100\Omega$, $R_{100}= 138.50\ \Omega$ and $R_{200}= 175.83\Omega$, calculate the nonlinearity at 100ºC as a percent of full scale deflection. [5M]

Q.4(a) A thermistor is used to measure wind speed from 0 to 60 mph .It has been experimentally found that the temperature varies with winds speed as given in table below. Obtain the design values of signal conditioning circuit shown below to ensure output of 0 to 6 V for wind speed of 0 mph to 60 mph. The thermistor has a resistance of 2 kΩ at 45°C with a slope of -24 Ω/°C within ± 10°C, and the dissipation constant is 5.4 mW/°C. Consider ambient temperature of 21°C and operating temperature of 45°C. [8M]

Speed (mph)	0	10	20	30	40	50	60
ΔT(°C)	0	-3.0	-4.5	-5.5	-6.3	-7.1	-7.7



Q.4(b) An iron-constantan thermocouple is connected to a potentiometer whose terminals are at 25°C. The potentiometer reading is 3.59 mV. What is the temperature of the thermocouple junction? Refer the temperature table. [4M]

Q.5(a) Draw the circuit diagram of instrumentation amplifier and derive the expression for output voltage, V_{out}. Consider V_1 and V_2 as inputs to the instrumentation amplifier. Assume that no current into op-amp, no voltage across op-amp inputs and no loading of differential amplifier by first stages. [4M]

(b) Draw and explain the functional elements of an ammeter. [4M]

TYPE J: IRON-CONSTANTAN

	0	5	10	15	20	25	30	35	40	45
−150	−6.50	−6.66	−6.82	−6.97	−7.12	−7.27	−7.40	−7.54	−7.66	−7.78
−100	−4.63	−4.83	−5.03	−5.23	−5.42	−5.61	−5.80	−5.98	−6.16	−6.33
−50	−2.43	−2.66	−2.89	−3.12	−3.34	−3.56	−3.78	−4.00	−4.21	−4.42
−0	0.00	−0.25	−0.50	−0.75	−1.00	−1.24	−1.48	−1.72	−1.96	−2.20
+0	0.00	0.25	0.50	0.76	1.02	1.28	1.54	1.80	2.06	2.32
50	2.58	2.85	3.11	3.38	3.65	3.92	4.19	4.46	4.73	5.00
100	5.27	5.54	5.81	6.08	6.36	6.63	6.90	7.18	7.45	7.73
150	8.00	8.28	8.56	8.84	9.11	9.39	9.67	9.95	10.22	10.50

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