BIEE, 2nd Year 1st Semester Examination, 2019
SUBJECT: Fundamentals of Instrumentation

Time: Three hours | Full Marks 100

All questions are compulsory.

Q.No.			Marks
1.	i)	Answer any 2: a) What are the uses of a variable manipulation element and a data presentation element in an instrument? Give examples. b) What are interfering and modifying inputs in a measuring system? Specify their effects on zero and sensitivity of the instrument c) State the functional representations of a step input and an impulse input. Which of these are usable in practical systems and how? d) What are the typical electrical sensing elements used with load cells? What is the placement of these sensors on the load cells? Why are they so placed?	5
	ii)	Derive the expression for the amplitude modulated signal when a sinusoidal carrier signal is modulated by a sinusoidal modulating signal, stating assumptions if any. Draw the typical frequency responses of the modulating signal and the DSBSC signal. OR Derive from 1st principles the condition for balance in a Wheatstone Bridge circuit and the general expression for the unbalanced voltage in this W.B. circuit. Discuss the placement of the gages and the performance of a W.B. when i) one arm has an active strain gage ii) the bridge has one active and one dummy gage iii) bridge has two active gages and iv) all four arms have active gages.	10
	iii)	Write notes on (any one) i) Through and across variables ii) Electrical equivalents of mechanical systems	5
2.	i)	A voltmeter has range of [4V, 20V] and resolution is 1mV. Determine its dynamic range in dB. Differentiate between threshold and resolution. OR A non-linear pressure sensor has an input range of 0 to 10 bar and an output range of 0 to 5 V. The output voltage at 4 bar is 2.20 V. Calculate the non-linearity in volts and as a percentage of span. Describe linearity and sensitivity.	2+4
	ii)	Define precision and accuracy. Compare these parameters in the analog and digital modes of operation.	4

Q.No.			Marks
2.	iii)	The following results were obtained when a (linear) pressure transducer was tested in a laboratory under the 3 following conditions: I Nominal: Ambient temperature T_a =20 °C, supply voltage V_s= 10 V; II T_a =20 °C, V_s=12 V; III T_a =25 °C, V_s=10 V Input (barg) 0 2 4 6 8 10 Output I 4 7.2 10.4 13.6 16.8 20 (mA) II 4 8.4 12.8 17.2 21.6 28 III 6 9.2 12.4 15.6 18.8 22 (a)Justify and determine the values of K_M, K_I, a and K associated with the generalised model equation $O = (K + K_M I_M)I + a + K_I I_I$. b) Predict an output value when the input is 5 barg, V_S = 12 V and ambient temperature is 25 °C. OR Write notes on (any two) a) Ramp response of an underdamped second order system b) Static characteristics of a system c) Dynamic range and Bandwidth of a system	10
	iv)	A platinum resistance sensor, which measures temperatures within 0 to 200℃, follows the relation $R_T=R_0(1+\alpha T+\beta T^2)$, where R_0=100.0 Ω, R_{100}=138.50 Ω and R_{200}=175.83 Ω. Calculate α and β; and the non-linearity at 100℃ as % fsd. OR The resistance R(Ω) of a thermistor varies with temperature T(K) as: R=0.0585 exp(3260/T). Design a deflection bridge for this element for: input range 0 to 50℃, output range 0 to 1.0V and an approximately linear input-output relationship.	5
3.	i)	A capacitor of (1.0±0.1)μF is charged to a voltage of (20±1)V, where errors are standard deviations. What is the charge on the capacitor?	3
	ii)	A sample of 100 dry cells, tested to find the length of the life, produced the following results: mean = 12 hours, standard deviation σ = 3 hours. Assuming that the data are normally distributed, what % of battery cells are expected to have life i) more than 15 hours, ii) less than 6 hours? What is the 50% expectancy range of battery life? OR For a rectangular rod, the measurement of its dimensions (in inches) yield the following: a) length: mean=2.0, s.d=0.005 b) breadth: mean=0.5, s.d=0.002 and c) height: mean=16.5, s.d=0.40. Find the nominal volume and its standard probable error.	7
	iii)	Test the goodness of fit of the data given using chi square test. Height(m) | 1.52-1.56 | 1.57-1.61 | 1.62-1.66 | 1.67-1.71 | 1.72-1.76 No. of students | 5 | 18 | 42 | 27 | 8 Given $\chi^2_{0.95}$=5.99; $\chi^2_{0.05}$=0.103.	10

Q.No.		Marks
4. i)	Derive the output voltage of an actual potentiometric transducer in response to an input displacement. Express the % nonlinearity N(x) considering $x = R_x / R$ and $m = R / R_L$. If $e_0 / e_i = 0.5$ and $m = 1$, then determine the value of x.	6
ii)	Draw, derive and compare the outputs of a 3 lead vs. 2 lead wire systems in terms of signal loss factor and temperature compensation in a double strain gage W.B. circuit. OR Compare a bonded wire strain gage and a semiconductor strain gage in terms of construction, gage factor, gage characteristics, accuracy, precision, linearity, sensitivity and stability.	6
iii)	Draw and describe a capacitive proximity sensor. Derive the relation of the displacement to the output voltage considering an op-amp based charge amplifier. OR Derive the output transfer function of a loaded LVDT from first principles. Determine and comment on the gain and phase of this system.	6
iv)	A variable dielectric capacitive displacement sensor consists of two square metal plates of length 5 cm, separated by a gap of 1 mm. A sheet of dielectric material, also 1 mm thick and of the same area as the plates can be slid between them edgewise. Given that $\varepsilon_0 = 8.85\times10{-}12$ F/m, $\varepsilon_{air}=1$, $\varepsilon_{dielectric}=4$, calculate the capacitance of the sensor when the edgewise input displacement of the dielectric x = 0.0, 2.5 and 5.0 cm. Express the sensitivity of the sensor as a function of the input displacement and state values. Comment on the linearity of the sensor. OR Explain the working principle of a Hall effect transducer with diagram. A Hall probe of thickness 2mm, carrying a current of 300mA is placed in a magnetic field of 0.5T. If the probe output is 0.5V, what will be the Hall coefficient?	5
v)	Draw the standard axis system and define the g, d and h constants of a piezoelectric transducer. Derive the relation between these three constants.	4
vi)	Explain the principle of operation of a pyroelectric detector stating all assumptions. Discuss its suitability for dynamic measurement. OR Explain the principle of operation of an optical pyrometer with diagram. What are the functions of a) absorption filter, b) red filter in it? OR Write notes on (any two) i) Eddy current type displacement transducer ii) Comparison of wirewound and conductive plastic potentiometers iii) SQUID Magnetometer iv) Differential pressure pick up	8

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998
3.5	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998
3.6	0.9998	0.9998	0.9999							