Ref. No. Ex/ PG/IEE/PC/T/111/2025

MT.I.E.E. 1st Yr. 1st Semester Examination, 2025

SUBJECT: - Advanced Sensing Techniques Total Time: Three hours

Time : Three hours Full Marks 100

All Questions are Compulsory. Please read instructions for each Question.

Numericals:Q1 CO1:Q2 CO2: Q3 CO2: Q4 CO3:Q5

Q.No.		Marks
1.	**Answer any 10:** 1.1. (a) What do you mean by minimum detectable signal? If the input noise of a sensor is sinusoidal in nature with a peak-to-peak value of 0.1 mV, what would be the MDS? (b) Define selectivity and specificity. How are they related? 1.2. What are the different types of failures possible in a sensor? How do you define reliability function? If *m* units of produced items have been checked *n* times and the average failure at an instant of time, *t*, is found to be 1%, what is the value of the reliability function? 1.3. (a) How is the output of a potentiometric sensor affected due to shorting of windings by jockey? For a 100 turn potentiometer, if once the 50th wire is only contacted while at the next instant, 50th and the 51st wires are shorted by the jockey, what would be the percent loss in resolution in the second case if the supply voltage is 10 V? 1.4. What is longitudinal piezoresistance coefficient in connection with strain gauges? How does the resistivity of a gauge material having Poisson's ratio 0.4 and gauge factor 2 change with strain? If the Young's modulus of the material is 2 x 106 kg/cm2, what is its longitudinal piezoresistance coefficient? 1.5. What are the different types of inductive sensors? How is displacement measured by such sensors? How does the inductance change in such a system? A core having 20 single-turn coil and a magnetic path length, including an armature of 10 cm, has a cross-section area of 1.2 sq cm. For a displacement to be measured, the gap length changes from 0.1 cm to 0.15 cm. By what percentage does the inductance of the coil change and for what original inductance value? Assume a core permittivity of 10.5. 1.6. Does the sensitivity of an inductive transducer vary? If yes, how does it vary? Calculate the normalized sensitivity of an inductance type transducer formed with a core material of permittivity 10.5 and the 'closed' length of path of 10 cm for a gap length of (i) 0.1 cm and (ii) 0.05 cm. 1.7. How is linearity of input-output relation improved in case of a ferromagnetic plunger type transducer? What material is usually the plunger made of? How does the inductance of the system change for a push-pull type design with a change in position of the plunger, for a plunger permittivity 12.2, coil average diameter 1.1 cm, and plunger diameter 0.86 cm. How does the situation change if the plunger is replaced by short-circuited sleeve over the pair of coils, the sleeve being movable? Discuss with diagram. 1.8. What are the different types of capacitive sensors used for displacement measurement? How do they differ in operating principles? If the air gap between the teeth of the two electrodes of a serrated type capacitive transducer is 0.1 cm and the 'active' tooth length is 1 cm, what is the sensitivity factor of the sensor? Assume constant term as 4.	10x5=50

[Turn over

Q.No.		Marks
	1.9. What type of capacitive sensors are used in pressure transmitters? Explain its operation with appropriate diagrams. If the diaphragm diameter is 2.8 cm (in a diaphragm type capacitive sensor), separation between the fixed and the movable plate is 0.4 cm in normal condition, and the diaphragm is kept taut with a tension of 2 kg/cm, what is the change in the capacitance for an input differential pressure of 1 kg/cm2? 1.10. How does a pyroelectric ceramic work as a thermal sensor? A pyroelectric ceramic of coefficient 7 x 10–8 coul/cm3/K, l x w x t = 10 cm x 4 cm x 2 cm, is placed between a pair of electrodes of size 10 cm x 4 cm. If it is heated at a rate of 0.5°C/s, what would be the change of voltage per unit time across the electrodes? Assume eps = 200. 1.11. What are quantum efficiency and quantum yield? How are they related? If wavelength of a monochromatic radiation incident on a photoemissive surface of a sensor is 546.1nm, calculate the number of electrons that would be released for 1 Watt of incident radiation. 1.12. (a) Why is noise so important in photoconductors? What are the different sources of noise and how are they quantified? Is *NEP* defined taking all such noise into consideration? What is detectivity? How is it related to *NEP*? (b) For an average of N incident photons, what is the probability that their number in a pulse stream be n? Calculate the probability for $N = 20$ and $n = 5$.	
2.	2.1 Describe the principle of spectroscopic thermometry. How are intensities of molecular lines measured and related to temperature? What is coherent anti-stokes Raman spectroscopy? OR How are quartz crystal resonators used as temperature sensors? How is resonant frequency related to temperature? Draw the schematic diagram of a crystal resonator thermometer used in practice. 2.2 What different types of sensor electrodes are known to be used commercially? To which type the first, second, third kinds, and, redox types belong? How are they different— construction-wise and operation-wise? OR Explain the action of a liquid ion exchanger membrane for generating a cell potential. What are the specific types of materials used for such membranes? What is ion exchanger immobilized–in–polyvinylchloride membrane? 2.3 Show the constructional features of a gas-sensing electrode system using a gas-permeable membrane. What are the gases commonly detectable by such types of electrodes? What is an equilibrium constant? What is its function in solving for the output cell voltage? OR Describe the special molecular selective electrode called biomembranes with due reference to materials, construction, functional state equations, and preservation.	3x4=12

Q.No.		Marks
3.	**Answer any 2:** 3.1 (a) Describe the basic principle of a Hall device and show how can it be used as a magnetic field sensor? On what factors and parameters of the sensor does the Hall voltage output depend for a given field condition? (b) How is performance of a Hall sensor evaluated? What are its primary and secondary sensitivities? OR (a) What is the major advantage with SQUID sensor that makes it popular in scientific work but why then, it has limited commercial popularity? (b) What is a Josephson constant? Discuss a SQUID that is used for maintaining voltage standard in terms of frequency? 3.2 Draw the schemes of a simple and a planar semiconductor photoconductor structures. How do they respond to radiation of different wavelengths in terms of penetration depths? Obtain an expression of photocurrent in such a sensor for a monochromatic radiation of frequency n, power P, the sensor material radiation absorption coefficient a, sensor length l, and electric field impressed E. Assume, carrier life time as t, transit time as t, and pair generated per unit volume as h. 3.3 Describe the various principles used for optical fibers as sensors with schematics and naming the corresponding variable measured using the particular principle. OR Compare the performances of organic and inorganic scintillators. How does a scintillator act in radiation energy detection? On what factors does the output of a scintillator depend?	2x4=8
4.	4.1 (a) Describe the principles of a 'smart transmitter'. What and where does it transmit? (b) What are the different deviations that need be compensated in sensor systems? How is a nonlinearity taken care of in a present day smart sensor? OR What are the major processing steps in developing the standard semiconductor microsensor technology? Describe with suitable diagrams. What are the different film deposition processes in this technology and how are they implemented? 4.2 (a) Discuss with suitable diagrams, the techniques of diffusion and ion implantation as are required in microsensor systems. In which stage of the sensor development are these methods of processing used? (b) Describe briefly, the four micromachining techniques and compare their advantages and uses.	2x5=10

Q.No.		Marks
4.	4.2 OR List six commonly used techniques for producing thin film sensors. How are these different from the ones for thick films? Describe with appropriate diagram how does plasma enhanced chemical vapour deposition (PECVD) technique improve with respect to simple chemical vapour deposition technique?	
5.	5.1 How does a photomultiplier work? Sketch a photomultiplier tube having serially arranged dynodes and explain its operation. Compare the spectral response characteristics of cathode surface materials such as Na–Sb, Sb–Cs, and Cs–Cs2O–Ag. In gas-filled photomultipliers, which gases are preferred and at what pressures, and, why? 5.2 What is basically the concept of 'smart sensors'? What are the essential elements in such an unit? Show with the help of a diagram, the arrangement of these elements. OR Show, with the help of diagrams, how the primary sensors are being integrated with signal processing ensembles. What are the essential components in the signal processing unit? What is a ring oscillator? How has it been integrated? Where, in a smart sensor, is it likely to be used? 5.3 Describe three types of oxygen sensors used in automobiles (on-board) comparing their advantages and operations with the help of V–I characteristics. Show that in the range of operation, the limiting current in the device is proportional to concentration of oxygen in the gas. OR How is static pressure measured in aerospace studies? How is it dependent on total pressure, isentropic ratio, and Mach number? Explain with graph. How does misalignment of the probes affect measurement? Show with curves, how the per cent errors change with angle of misalignment for three different types of probes. 5.4 Describe, on what principles do the microsensors work in biomedical systems? Which electromagnetic ranges of frequencies are important for biomedical studies and how are they detected? OR How are environmental hazards spread? Draw a block diagram to explain the same. How has instrumentation improved the studies of ecology? Give a few examples.	4x5=20