NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 2203: INSTRUMENTATION PHYSICS

BSc HONOURS PART II: MAY 2002 DURATION: 3 HOURS

ANSWER ALL PARTS OF QUESTION I IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

SECTION A

1. (a) (i) Define the term uncertainty. [2]

(ii) A resistance arrangement of 50 ohms is desired. Two resistances of 100.0 ± 0.1 ohms and two resistances of 25.0 ± 0.02 ohms are available. Which should be used, a series arrangement with the 25-ohm resistors or a parallel arrangement with the 100-ohm resistors? Calculate the uncertainty for each arrangement. [4]

(b) (i) Define the term resolution. [3]

(ii) If you are using a 10 bit ADC, and wish to read a signal whose range is 2.5 volts, what value of resolution should you expect? [3]

(c) Four temperature sensors have the following input/output characteristics where T(t) is the temperature as a function of time. Which one is linear?

(i) $V(t) = aT(t) + b$

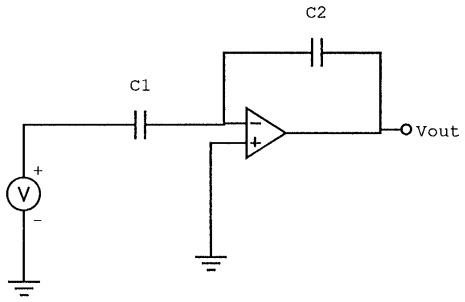
(ii) $V(t) = aT(t - z)$, where z is a constant

(iii) $V(t) = a\dfrac{dT(t)}{dt}$

(iv) $V(t) = e^{aT(t)}$ [4]

(d) Explain what is meant by 'the order of a system'. [4]

(e) A piezoelectric pressure sensor has an input/output relationship $V = gP_{in}$ where V = voltage and P_{in}= pressure. The diagram below is used for signal conditioning for a prezoelectric senior. Find the transfer cunction.



[4]

(f) State four classes of systematic error and give one example of each. [4]

(g) Using well labelled functional diagrams, show how the following instrumentation blocks can be implemented:

(i) voltage-to-frequency converter and [4]

(ii) instrumentation amplifier. [4]

(h) Differentiate between laminar and turbulent flow in a pipe. [4]

SECTION B

2. (a) We are using a thermistor and a PN junction diode in the opamp circuit to measure temperature. The resistance of the thermistor as well as the current-voltage relationship of the PN junction diode are given as follows:

$$R(T) = R_0 e^{B\left(\frac{1}{T}-\frac{1}{T_0}\right)} \text{ and } I = Ae^{\frac{qV-E_g}{kT}}$$

(i) Draw a schematic diagram for the circuit described. [5]

(ii) Find the expression for the output voltage of the circuit in terms of the temperature of the thermistor. When the PN junction diode remains at a fixed temperature of T_0, at all times. [10]

(b) List five advantages and disadvantages of thermistors over other resistance type thermometers [5]

3. (a) Assume that the output voltage of a sensor is given as:

$V_1(T) = \frac{c_1}{T} + c_2$, which is a non-linear relationship.

In the narrow region of interest, T_1 - T_2, it is derived to use the relationship $V_2(t) = K_1 T + K_2$ to approximate the above non-linear relationship. Show the steps to be followed to find the maximum error from this approximation. [10]

(b) Define the Johnson noise density for a resistive element. [3]

(c) If a resistive sensor is connected in a voltage divider circuit, discuss the effect of both the Johnson noise and the supply voltage on the performance of the sensor system. [7]

4. (a) For a system of two semi-circular plates in which the overlapping area alters with angular displacement of a common shaft,

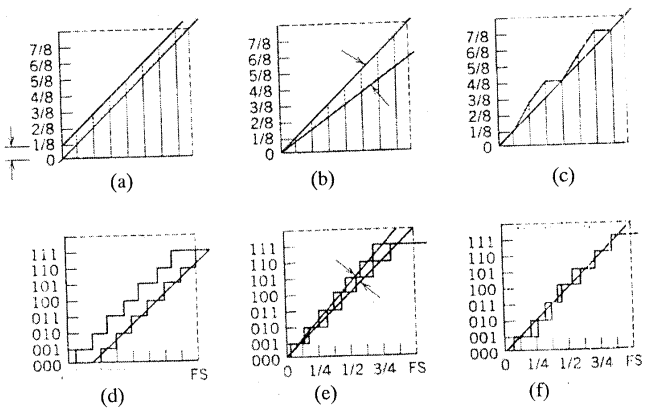
(i) derive the transfer function of the system for any dielectric, [5]

(ii) what is the responsitivity of the system and [3]

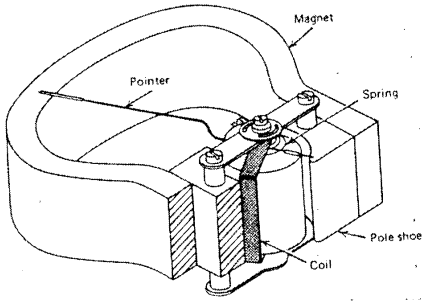
(iii) suggest one method that can be used to increase the responsitivity. [2]

(b) Using diagram where applicable, discuss the following:
(i) auto – correlation, and
(ii) dual sensitivity in load cells. [10]

4. (a) Name the ADC and DAC errors depicted in the calibration curves (a) – (f). Specify which ones are ADC or DAC errors. [6]



(b) Name the instrument below. With the use of appropriate equations, describe how this instrument works. [10]



(c) Calculate the value of the multiplier resistance on the 50-V range of a dc voltmeter that uses a 500-. A meter movement with an internal resistance of 1 K . [4]

6. (a) State the assumptions involved in deriving Bernoulli's equation. [3]

(b) Write down Bernoulli's equation and explain all the terms in the equation. [5]

(c) Using a well labelled diagram, describe any one of the following:

(i) Orifice meter, and [6]

(ii) venturi meter. [5]

- END OF PAPER -