NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 2203 – INSTRUMENTATION PHYSICS II

EXAMINATION

BSC HONOURS PART II: MAY 2003 DURATION: 3 HOURS

ANSWER ALL PARTS OF QUESTION 1 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) 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.

   (i) Define the term, uncertainty. [2]

   (ii) Calculate the uncertainty for each arrangement. [4]

   (b) For analog to digital converters: what is differential nonlinearity (DNL) error? [3]

   (c) What are the advantage of RTDs over thermistors? [4]

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

   (e) Discuss the various techniques which are used to reduce noise in:

   (i) electric motors, [4]

   (ii) ignition systems, and [4]

   (iii) RF generators. [3]

   (f) Define the following terms:

   (i) Accuracy, [2]

   (ii) repeatability, [2]

   (iii) measurand, and [2]

   (iv) traceability. [2]

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

(i) orifice plate, [5]

(ii) phosphorescence. [5]

SECTION B

2. You are required to design an electronic instrument which will measure temperature in an oven and numerically display the value. The required temperature range is from 20° to 700 °C with an accuracy of 2%.

a) Draw a block diagram of the instrument, briefly describing the function of each block. [6]

b) Describe the selected temperature sensor. [5]

c) The instrument has been tested by measuring known temperatures. From the results of the testing shown in the following table, discuss the accuracy and precision of the instrument. [9]

Temperature [°C]	Displayed value
20	20.3
40	39.1
60	59.6
100	99.2
150	147.4
200	203.0
250	247.2
300	296.9
400	398.1
500	496.1

3. (a) Define the following terms:

(i) error, and [2]

(ii) non-linearity. [2]

(b) Assume that the output voltage of a sensor is given by the following non-linear relationship:

$V_1(T) = \frac{c_1}{T} + c_2$. In the narrow region of interest, T_1 - T_2, we would like to use the relationship $V_2(t)=K_1T+K_2$, to approximate the non-linear relationship above. Show the steps to be followed to find the maximum error from this approximation. [14]

4. (a) Define the following terms:

(i) first order system, [3]

(ii) step response, and [3]

(iii) settling time. [4]

(b) Derive the transfer function for a liquid-in-glass thermometer. [10]

5. (a) Write down Bernoulli's equation and explain all the terms in the equation [4]

(b) State the assumptions involved in deriving Bernoulli's equation. [4]

(c) Using a well labelled diagram, describe and outline the differences between the following flow meters:

(i) orifice meter, and [6]

(ii) Venturi meter. [6]

6. An ultrasound transducer is applied to the patient's body from outside. Sound which travels from the transducer to the bone, is reflected and returns back to the transducer. The distance between the bone and the transducer is 2.5 cm. Sound impedance of the tissue is given as 1/3 of the sound impedance of the bone.

$P(x) = P_0 e^{-\alpha x}$, where $\alpha = 0.4\ \text{cm}^{-1}$

(a) Describe in brief the physics behind a suitable ultrasound transducer [5]

(b) Describe any transducer that is suitable for use in the 20 Hz to 20 kHz frequency range. [5]

(c) Find the ratio between the received pressure wave, $P^-(0)$, and the wave sent by the transducer, $P^+(0)$. [5]

(d) Using a suitable diagram, explain how an ultrasonic transducer can be used to measure the level of a liquid in a tank. [5]

- END OF EXAMINATION -