NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 2203 - INSTRUMENTATION PHYSICS

BSc HONOURS PART II: JUNE 2004 DURATION: 3 HOURS

ANSWER **ALL** PARTS OF SECTION A AND ANY **THREE** IN SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS

SECTION A

1. (a) Describe any two elements of a measurement system. [4]

   (b) What is the difference between precision and accuracy. [4]

   (c) List four sources of possible errors in measurement instruments. [4]

   (d) Explain concisely the significance of each of the components in the traceability ladder using pressure as an example. [6]

   (e) Distinguish between noise and interference and describe two methods used to reduce noise in a measurement system. [6]

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

   (i) Voltage to frequency converter [4]
   (ii) Instrumentation amplifier [4]

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

   (h) Describe concisely the principle of operation of a piezo electric transducer. [4]

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 10^0C to 100°C with an accuracy of 1%.

   (a) Draw a block diagram of the instrument, briefly describing the function of each block. [7]

   (b) Describe the selected temperature sensor. [5]

(c) The instrument has been tested by measuring known temperatures. The results of the testing are shown in the table below. Discuss the accuracy and precision of the instrument. [8]

Temperature °C	Displayed Value
11	11.3
15	14.1
30	29.6
45	44.2
50	47.4
61	64.0
68	66.2
72	70.3
81	79.6
93	91.1
100	96.1

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

(b) State the assumptions involved in deriving Bernoulli's equation. [5]

(c) Using a well labelled diagram, describe and outline the differences between the following flow meters.
(i) Orifice meter and
(ii) Venturi meter. [10]

4. (a) What is a
(i) signal conditioning element and a
(ii) deflection bridge [4]

(b) Design a Reactive Deflection Bridge that incorporates a capacitance level sensor. [6]

(c) A capacitance level transducer is used to measure the depth h of liquid in a tank between 0 and 7m. The total length l of the transducer is 8m and the ratio b/a of the diameter of the concentric cylinders is 2.0. The dielectric constant ε of the liquid is 2.4 and the permitivity of free space ε_o is 8.85×10^{-12} Fm^{-1}. The transducer is incorporated into the deflection bridge of question 4 (b) with
$R_2 = 100\Omega$,
$R_3 = 10k\Omega$ and $V_s = 15V$.

(i) Calculate the value of C_o so that the amplitude E_{TH} is zero when the tank is empty. [3]
(ii) Using C_o calculate E_{TH} at maximum level. [3]
(iii) Explain why the relationship between E_{TH} and h is non-linear and calculate the non linearity at h = 3.5m as a percentage of full scale deflection. [4]

5. (a) Explain the thermoelectric effect. [3]

(b) List the five thermocouple laws. [5]

(c) An ion Vs constantan thermocouple is to be used to measure temperatures between 0 and 300°C. The emf values are given below.

$E_{100.0} = 5268\mu V$

$E_{200.0} = 10777\mu V$

$E_{300.0} = 16325\mu V$

(i) Find the non-linearity at 100°C and 200°C as a percentage of full scale. [4]

(ii) Between 100°C and 300°C the thermocouple *emf* is given by $E_T = a_1 T + a_2 T^2$
Calculate a_1 and a_2. [4]

(iii) The emf is $12500\mu V$ relative to a reference junction of 20°C and the corresponding reference junction current voltage is $1000\mu V$. Use the result of (ii) to estimate the measured junction temperature. [4]

6. (a) Explain briefly what is meant by nuclear magnetic resonance (NMR)? [4]

(b) How is the technique of nuclear resonance absorption used to extract information about the interior of solids. [9]

(c) Discuss NMR imaging with respect to the planar tissue model. [7]