NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 2203 – INSTRUMENTATION PHYSICS

BSc. HONOURS PART II: MAY 2005 DURATION: 3 HOURS

ANSWER ALL QUESTIONS FROM SECTION A AND ANY 3 QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

SECTION A

1 (a) What is a
(i) Signal processing element and a
(ii) Data presentation element.
Give examples in each case. [4]

(b) Define and distinguish the terms *span* and *range*. [4]

(c) Explain two types of environmental inputs that affect the output of a measurement system. [4]

(d) What is a strain gauge? Draw a clearly labelled diagram that shows how a strain gauge can be used to produce a voltage signal when a force is applied to it. [4]

(e) With the aid of clearly labelled diagrams explain two thermocouple junction configurations. What are the advantages and disadvantages of each configuration? [4]

(f) What is an IC sensor? What are the advantages of using an IC sensor to measure temperature in the range 0 – 100 °C over an RTD and a thermocouple? [4]

(g) What do you understand by
(i) Mass flow rate and
(ii) Volume flow rate.
Include relevant equations where possible. [4]

(h) An electromagnetic flow meter is used to measure the volume flow rate of conducting fluid in a circular pipe of radius 0.10 m. Calculate the average velocity of the fluid if the magnetic field is 0.15T and the voltage appearing across the measurement electrodes is 0.8 V. [4]

(i) With the aid of a well-labelled diagram explain how a semiconductor detector is used to measure radiation. [4]

(j) The 4 – 20 mA current loop is a popular medium for industrial signal transmission. Suggest two reasons for its popularity. Explain how it is possible for a two-wire current loop system to utilize the signal wire pair to supply power to sensors.

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 400 °C to 1600 °C.

(a) Draw the block diagram of the instrument, briefly describing the function of each block. [8]

(b) Give a detailed explanation of the selected temperature sensor including how the sensor measures temperature. [6]

(c) Explain another temperature sensor that should be used for cold junction compensation. [3]

(d) What are the three possible sources of errors when using your instrument to measure temperature? [3]

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

(b) Design a reactive deflection bridge that incorporates a variable reluctance push pull displacement sensor. [6]

(c) A variable reluctance push pull displacement sensor is used to measure displacement . The total distance between the two ferromagnetic cores is 5 cm, the radius of each core is 4 cm, $\mathcal{R}_o$ is equal to $1.3 \times 10^{7}\ H^{-1}$ and the permeability of free space is equal to $4\pi \times 10^{-7}\ Hm^{-1}$. The sensor is incorporated into the deflection bridge of question 3 (b) with V_s equal to 15 V.
(i) Calculate the constants k and $\propto$ for the sensor. [4]
(ii) Calculate E_{TH} if the measured displacement is 2 cm. [3]
(iii) Explain why the relationship between E_{TH} and x is linear but the relationship between L_1 (or L_2) and x is non linear. [3]

4 (a) Describe concisely the principle of operation of a piezoelectric transducer. [6]

(b) What are the industrial applications of piezoelectric transducers. [4]

(c) What are the main sources of errors in piezoelectric transducers? [5]

(d) A voltage follower circuit driven by a piezoelectric transducer is given in Figure 1 below. Show that in this circuit, the voltage sensitivity of the piezo is $S_v = S_q/C$. [5]

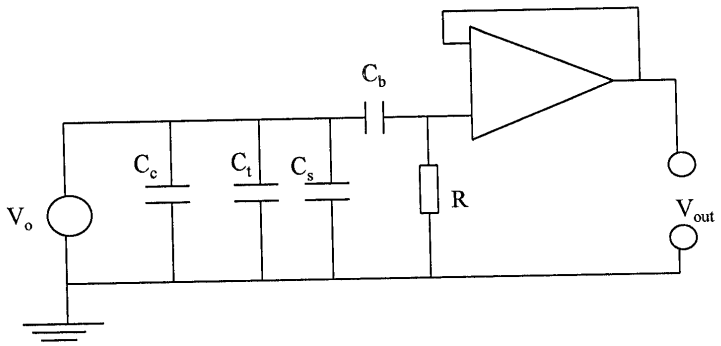

Figure 1: Voltage follower circuit

5 (a) What do you understand by Bernoulli's equation? State assumption involved in deriving this equation. [5]

(b) Differentiate between laminar and turbulent flow in a pipe. [5]

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

6 Write explanatory notes on the following radiation detectors.
(a) Ionisation chamber. [5]
(b) Proportional counter. [5]
(c) Geiger – Muller counter. [5]
(d) Scintillation detector. [5]

- END OF EXAMINATION -