

NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 2203 – INSTRUMENTATION PHYSICS

BSc. HONOURS PART II: MAY 2006

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) An instrument can be *precise* but not *accurate*. Explain. [4]
- (b) List and explain four possible sources of errors in measurement instruments. [4]
- (c) Explain what is meant by traceability ladder when applied to a measurement system used by a calibration company. [4]
- (d) A system is specified as being first order with a time constant of 10 s and a steady state value of 5. How will the output of the system vary with time when subjected to a step input? [4]
- (e) (i) Define Johnson noise for a resistive sensor. [3]
(ii) Calculate Johnson noise for a resistive sensor whose resistance is 65.2Ω at 22.3°C . The frequency range of the input signal is from 100 kHz to 120 kHz. [3]
- (f) Draw diagrams for the following thermocouple junction configurations:
(i) insulated junction
(ii) grounded junction
(iii) exposed junction
Give one advantage or disadvantage of each configuration. [6]
- (f) Explain the principle of operation of a linear variable differential transformer (LVDT). [4]
- (g) Explain the conservation of volume flow rate? Include a relevant equation and assumptions made. [4]
- (h) With the aid of a well-labeled diagram explain how an ionization chamber can be used to measure radiation. [4]

SECTION B

- 2 (a) Distinguish between deterministic and random signals. [2]
- (b) Name four sources of noise in measurement systems. [4]
- (c) 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. [6]
- (d) Figure 1 below shows a balanced differential receiver/transmitter pair interconnected by a wire connection over a straight path covering a distance of 100 m. The transmission path is subjected to a magnetic interference caused by high power machine switching transients. An instrument engineer has one of the four choices for the type of interconnecting cables:
- parallel pair (unshielded),
 - parallel pair (shielded),
 - twisted pair (unshielded),
 - twisted pair (shielded).
- (i) For each of the four cases listed, explain the mechanism by which the magnetic field generated by the high power machines generates a noise voltage at the receiver input. [4]
- (ii) Suggest a ranking of the listed options in terms of their magnetically induced noise rejection properties. [4]

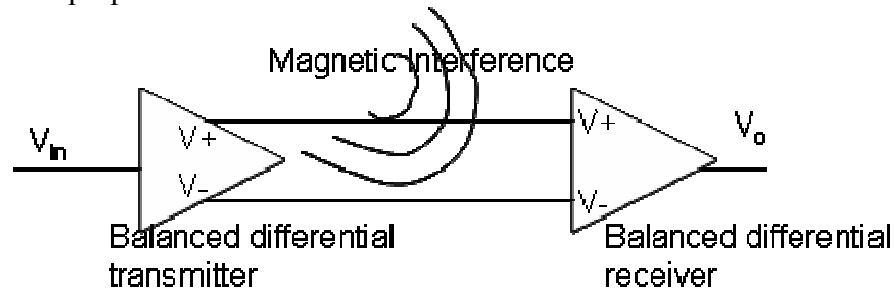


Figure 1. Balanced differential receiver/transmitter

- 3 (a) Design a reactive deflection bridge that incorporates a variable reluctance push pull displacement sensor. [4]
- (b) 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, μ_r is equal to $1.3 \times 10^7 \text{ H}^{-1}$ and the permeability of free space is equal to $4\pi \times 10^{-7} \text{ Hm}^{-1}$. The sensor is incorporated into the deflection bridge of question 3(a) with V_s equal to 15 V.
- (i) Calculate the constants k and α for the sensor. [4]
- (ii) Calculate E_{TH} if the measured displacement is 2 cm. [3]
- (c) Write explanatory notes on the following data presentation elements:
- (i) analogue chart recorders,
 - (ii) light emitting diodes,
 - (iii) liquid crystal displays. [9]

- 4 (a) What is the difference between a sensor and a transducer? [4]
- (b) Draw and explain a circuit diagram that will enable you to get a voltage signal when a strain gauge is used to measure mechanical strain. Include temperature compensation. [6]
- (c) A thermometer originally indicates a temperature of 20°C and is then suddenly inserted into a liquid at 45°C . The thermometer has a time constant of 2 s.
Derive a differential equation showing how a thermometer reading is related to the temperature input.
Give its solution showing how the thermometer reading varies with time. [10]
- 5 (a) What do you understand by Reynolds number in flow measurement. [2]
- (b) For what range of Reynolds number do you regard a fluid flow to be
(i) turbulent and
(ii) laminar? [4]
- (c) (i) Describe the principle of operation of an electromagnetic flowmeter. [5]
(ii) What are the five main features of this type of flowmeter? [5]
(iii) An electromagnetic flow meter is used to measure the volume flow rate of a conducting fluid in a circular pipe of radius 0.10 m. Calculate the average velocity of the fluid if the magnetic field is 0.15 T and the voltage appearing across the measurement electrodes is 0.8 V. [4]
- 6 Write explanatory notes on the following radiation detectors:
- (a) semiconductor detector, [5]
- (b) proportional counter, [5]
- (c) Geiger – Muller counter, [5]
- (d) scintillation detector. [5]

- END OF EXAMINATION -