DUBLIN CITY UNIVERSITY

Semester Two Examinations 2003

COURSE:	B.Sc. in APPLIED PHYSICS B.Sc. in PHYSICS/LANGUAGE
YEAR:	4
EXAMINATION:	PS410 Sensors
EXAMINERS:	Prof. R. W. McCullough Dr. G.O'Sullivan Dr V. Ruddy Dr B. Lawless
DURATION:	2 hours
INSTRUCTIONS:	Attempt THREE questions

Question 1. A particular type of pressure sensor has a linear response to the pressure stimulus. However individual sensors have different sensitivities and offsets, exhibit temperature dependence and have temperature dependant offsets.

(a) Describe and explain, with the aid of circuit diagrams, the operation of analogue electronic circuits which will deliver a calibrated, temperature independent output signal which is free from offsets. Explain the procedure for calibrating such a sensor and circuit combination. (17)

(b) Explain how the variable resistors used in the calibration adjustment of the analogue circuit can be replaced by digitally stored calibration coefficients. Describe the operation of the circuits used in this digital version. What are the advantages of this digital approach to sensor calibration? (16)

Question 2. (a) Explain the operation of a Nernstian Zirconia type oxygen sensor and discuss some applications of the sensor. (8)

(b) Give an account of the physical and chemical mechanisms which determine the characteristics of ZnO resistive type flammable gas sensors. Why must oxygen be present for the successful operation of these sensors? (8)

(c) Explain why the conductivity of these metal oxide gas sensors can be described by an equation of the form:

$$\sigma = \sigma_0 p(O_2)^{-\beta} \left(1 + k_1[CH_4] + k_2[H_2O] + k_3[H_2][CO] + k_4[H_2O][CO_2]^2\right)^{\beta}$$

and explain the significance of the terms and exponents in this equation. (9)

(d) Explain the features in the construction of a flammable gas sensor which prevent the sensor from causing ignition of any flammable gas present. (8)

Question 3.

(a) Explain why it is not always possible to obtain an equation relating the output signals from a multi sensor array and the concentrations of the analytes presented to the array for analysis. (8)

(b) Discuss the advantages of using neural networks for processing the signals from either multi sensor arrays or for processing the signals from a small number of sensors when a wide range of substances may be presented for analysis. (8)

(c) Discuss the use of the Delta Rule in supervised training of neural networks. (8)

(d) Discuss the use of back-propagation and competition in the unsupervised training of neural networks. (9)

Question 4.

(a) Outline the principle of operation of the *Total Radiation Pyrometer.* What type of radiation detector is suitable for use in such an instrument? (11)

(b) Why does the correct use of a Total Radiation Pyrometer require an emissivity correction? Does the transparency of the atmosphere between the target an objective lens of the pyrometer affect the indicated temperature? (11)

(c) Express the magnitude of the emissivity correction to a measurement in which a Total Radiation Pyrometer indicates a blackbody temperature of 1310 °C if the emissivity of the radiating object is 0.74. Take the effective wavelength of the bandpass filter in the instrument to be 680 nm. The second radiation constant $C_2(=hc/k)$ is 1.439×10^4 μm.K (12)

Question 5.

(a) What is the physical origin of the Seebeck effect? How may it be used to measure differential temperature with a pair of dissimilar metals or alloys? (11)

(b) A Platinum/Platinum-Rhodium type R thermocouple has a range of -50 to +1350 °C with a sensitivity of approximately 6 μV/°C and a nominal inaccuracy of 0.25%. If the resistance of such a thermocouple is 15 Ω and its EMF is measured by a millivoltmeter of bandwidth 10 MHz, what is the Johnson noise of the device expressed as a percentage of the EMF developed. (22)