DUBLIN CITY UNIVERSITY

SEMESTER TWO EXAMINATIONS 2000

COURSE: B.Sc. in Applied Physics

B.Sc. in Physics with a Language

YEAR: 4

SUBJECT / MODULE: PS410 - Sensors

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TIME ALLOWED: 2 hours

INSTRUCTIONS: Attempt three questions.

PLEASE DO NOT TURN OVER THIS PAGE UNTIL YOU ARE TOLD TO DO SO

This booklet contains 5 pages, including cover sheet.

Question 1:

Either

a. What is meant by an emissivity correction in the context of temperature measurement using a pyrometer?
b. Discuss, in detail, the design of the *Two Colour Pyrometer*.
c. How is the output of the detector in the pyrometer at the two measurement wavelengths related to the temperature of the radiating object?

Plancks equation for the emittance M_λ at a wavelength λ of an object at a Kelvin temperature T is:

$$M_\lambda = \frac{c_1}{\lambda^5\left[\exp\left(c_2 / \lambda T\right) - 1\right]}$$

The constants c_1 and c_2 have values of 3.7×10^8 W m^{-2} μm^{-1} and 1.439×10^4 $\mu m.K$

Or

Describe with the aid of a diagram the design of the Accufibre temperature sensor. Outline the principle of operation of the device and show how the temperature of the fibre tip is related to the output currents from the photodetectors.

Discuss briefly how such a pyrometer might be calibrated.

Question 2:

Either

Explain clearly, with the aid of a diagram, the design of a gas analyser for a chemical which has an absorption band in the mid infrared. What photoconductive devices are suitable to detect such an absorption?

What factors determine the minimum detectable concentration MDC of such an analyser? Derive an expression for the MDC in terms of the parameters listed.

Or

Show how a two dimensional array of photoconductive infrared detectors or pixels, may be used to create an infrared image of an object. What is meant by the minimum detectable temperature (MDTD) difference of such a camera system and discuss why the MDTD depends upon the following: pixel area, total number of pixels and the array scanning frequency.

The emittance of an object at a temperature T (Kelvin) is quoted at the end of Question 1 above.

Question 3:

Either

Discuss how the density of liquid in a pipe may be determined using a nuclear radiation transmission system. What type of radiation is used and how is the radiation flux detected? Why does the random nature of radioactive source decay place an upper limit on the fluid flowrate if a minimum detectable density variation is required?

Or

Give an account of the use of :

i. Bridge Circuits.
ii. Current to voltage converters

In measuring the resistance of sensors where the response is a resistance change in response to the primary stimulus.

Your account should include the following sub headings:

a. Supply voltage normalisation
b. Temperature compensation
c. Circuits for use with high resistance sensors
d. Circuits for use with low resistance sensors
e. Instrumentation amplifiers and common mode rejection
f. Circuits which generate an output voltage proportional to the sensor resistance change
g. Circuits which allow compensation for cross sensitivity effects

Question 4.

Either

Explain the principles of operation of each of the following types of A/D converters:

(i) Feedback A/D converters utilising R-2R ladder DACs/

(ii) Sigma Delta type A/D converters

Discuss how these converters are incorporated into Smart Sensors. Explain the advantages and disadvantages of each type of converter. Explain how modifications of these converters can be used to set calibration coefficients in Smart Sensors.

Or

Discuss the Progressive polynomial calibration method for sensors with particular reference to:

(i) The algorithm used in the method

(ii) The advantages of the Progressive Polynomial method over other methods and procedures

i. The operation of the method in the calibration of sensors on a production line
ii. Sensor characterisation responses which limit the use of the method.

Question 5.

Either

Give an account of the operation of neural networks under the following headings:

a. Neurons
b. Thresholding
c. Squashing function
d. Hidden layers
e. Supervised and Unsupervised learning

Explain why neural networks are used with sensor arrays in situations where the sensor response matrix is not easily invertible.

Or

Some solid state flammable gas sensors have responses of the form:

$$\theta = \theta_0 P(O_2)^{-\beta}\left[1 + k_1[CH_4] + k_2[H_2O] + k_3[H_2] + k_4[H_2O][CO] + k_5[H_2O][CO]^2\right]^{\beta}$$

a. Explain the origin of this sensor response
b. Explain why such non specific sensor responses or cross sensitivities cause difficulties in analysing a gas sample
c. Discuss how arrays of sensors having different response coefficients, k_n , can be used for gas analysis
d. Explain how neutral nets can be used to overcome the problem of the non invertability of the sensor response matrix
e. Explain how such a neural set and sensor array combination can be trained.

Quantity Symbol Value Units

Speed of light in vacuum c 2.998 x 10^{8} ms^{-1}

Acceleration due to gravity g 9.81 ms^{-2}

Gravitational constant G 6.67 x 10^{-11} Nm ^{2} kg^{-2}

Avagadro?s Number N_A 6.02 x 10^{23} mol^{-1}

Boltzmann?s Constant k 1.38 x 10^{-23} JK^{-1}

Stefan-Boltzmann Constant s 5.67 x 10^{-8} Wm^{-2} K^{-4}

Molar Gas constant R 8.31 J mol^{-1} K^{-1}

Rydberg constant R_h 1.1 x 10^{7} m^{-1}

Electron charge e 1.6 x 10^{-19} C

Electron mass m_e 9.1 x 10^{-31} kg

Permittivity of free space e_0 8.85 x 10^{-12} Fm^{-1}

Permeability of free space m_0 4p x 10^{-7} Hm^{-1}

Planck?s constant h 6.63 x 10^{-34} Js

Bohr magneton m_B 9.27 x 10^{-24} JT^{-1}

Atomic mass unit u 1.66 x 10^{-27} kg