DUBLIN CITY UNIVERSITY

SEMESTER TWO EXAMINATIONS 2001

COURSE:	B.Sc. in Applied Physics B.Sc. in Physics with a Language
YEAR:	4
SUBJECT/MODULE:	PS410 Sensors
EXAMINERS:	Prof. R. W. McCullough Dr. G. O'Sullivan Dr V. Ruddy Dr B. Lawless
TIME ALLOWED:	2 hours
INSTRUCTIONS:	Attempt THREE questions

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Question 1

(a) Describe the silicon diaphragm piezoresistive pressure sensor and explain clearly how it may be used to measure the differential pressure across the diaphragm.

(b) A diaphragm has four piezoresistors diffused into one surface, two of which are sensitive to tangential strain, the others to radial strain. Two are n-type silicon with gauge factors of -153, the others are of p-type with gauge factors of +173. Show, with the aid of a clearly labelled Wheatstone Bridge Circuit, how the four gauges might be wired to detect the differential pressure across the diaphragm. You may assume that the higher pressure is applied to the side of the diaphragm in which the piezoresistors are located.

If the bridge is powered by a 10V dc supply and balanced at zero differential pressure (the piezoresistors having approximately equal unstrained resistance) what bridge output is obtained when the diaphragm experiences a differential pressure which causes a tangential strain of +100 microstrain and a radial strain of -50 microstrain?

How is automatic temperature compensation achieved in such a system?

Question 2

(a) Outline the principle of operation of the "Two Colour Pyrometer". Explain why such an instrument does not require an emissivity correction. Show briefly how the operating principle of the pyrometer was adapted in the fibre optic "Accufibre" thermometer probe.

(b) Radiation from a viewing port in a furnace is focused by a convex lens onto a photodiode detector operating in photoconductive mode in a Two Colour Pyrometer located approximately 3 meters from the furnace. Two passband optical filters with central wavelengths of 500 and 510 nm and FWHM values of 5 nm are placed alternatively in the radiation beam as it enters the photodiode. The photodiode current is measured and found to vary from 0.121 mA to 0.145 mA when the 500 nm filter is replaced by the 510 nm one. What is the furnace temperature if the second radiation constant (C_2) in the Planck Distribution Law has a value of 14,398 μm K. (Planck's Distribution Law $M_\lambda = \frac{C_1}{\lambda^5}\left[\exp(\frac{C_2}{\lambda T}) - 1\right]$

Question 3

Describe a flue gas analyser that may be used to detect the concentration of carbon monoxide (CO) and carbon dioxide (CO_2) in the exhaust gases of a combustion process using the absorption bands of CO at 4.61 microns and of CO_2 at 4.25 microns. Details of suitable light source, optical components, detector and signal processing electronics should be included.

Question 4

Describe the principle of operation of analog electronic circuits which allow the signal from a single sensor to be adjusted so as to compensate for offset, gain, temperature dependent offset and temperature dependent gain.

Explain how these circuits can then be adapted so that the variable resistors used for adjustment and compensation can be replaced by digitally switched circuits with the coefficients stored in eprom memory.

Explain the advantages of changing to this digital system.

Use circuit diagrams to illustrate your discussion where appropriate.

Question 5

Explain, with the aid of circuit diagrams, the principles of the methods used in:

(a) the conversion of a current to a voltage when a photodiode or photomultipler is used as the primary sensor. Explain how the gain of the I-V converter can be increased without using resistor values greater than a few MegOhms. Why should the use of high value resistors be avoided, if possible, in amplifier circuits?

(b) the measurement of small capacitances such as those associated with a diode junction e.g. the Boonton capacitance meter. How can DC bias voltages be applied to the component under test?

Question 6

Explain, with the aid of diagrams, the construction of hot wire anemometer sensors. What differences are there between hot wire sensors for use in air and those for use in water.

Discuss the derivation of the relationship between the current in the hot wire and the velocity of the fluid.

Explain the practical differences between constant current and constant temperature modes of operation of the sensor.

What is meant by the term "Overheat Ratio"?

Discuss the problems which arise due to variations in the temperature of the fluid.

How can the hot wire anemometer be calibrated at low air flows and at high air flows?

How can the hot wire anemometer be used to measure the direction of the air flow?