



## **DUBLIN CITY UNIVERSITY**

### **Semester Two Examinations 2004**

**COURSE:** B.Sc. in APPLIED PHYSICS  
B.Sc. in PHYSICS with a LANGUAGE

**YEAR:** 4

**EXAMINATION:** PS410 Sensors

**EXAMINERS:** Prof. M. Mansfield  
Prof. G.O'Sullivan  
Dr V. Ruddy  
Dr B. Lawless

**DURATION:** 2 hours

**INSTRUCTIONS:** Attempt THREE questions

**Question 1.** (a) Outline the principle of operation of the *Two Colour Pyrometer*. Does the transparency of the atmosphere between the radiation source and the pyrometer affect the precision of the temperature measurement?  
What optical detector is used in this instrument and why is it chosen for the application? [17]

(b) Describe how the two colour technique is modified in the Acufiber Thermometer to measure temperature. [16]  
The Planck Distribution Law for blackbody radiation given by:

$$M_{\lambda} = C_1/\lambda^5 \{\exp(C_2/\lambda T) - 1\}$$

where  $C_1$  and  $C_2$  are constants.

**Question 2.** (a) Explain the principle of operation of the infrared sensitive photoconductor (such as the PbS quantum device). Show, with the aid of a circuit diagram, how the photon generated current is converted to a voltage using an operational amplifier circuit. [11]

(b) Why is it necessary to cool such detectors? Describe briefly how a Peltier cooler may be used for this purpose. [11]

(c) Describe with the aid of diagrams how a PbS infrared photoconductor is used in a sensor to measure moisture content of a powder or granular material. Water has a strong absorption band at 1.9 microns. [11]

**Question 3.** Discuss how *differential pressure* may be measured using a Silicon Diaphragm in which semiconductor strain gauges are diffused. Details of a bridge circuit to convert strain to voltage should be included.

Show how the output of the bridge circuit is related to the strain in all four strain gauges. Explain clearly why a bridge circuit configuration gives an output which is insensitive to temperature changes while maintaining strain sensitivity. [33]

**Question 4.** Write a detailed proposal for an instrumentation system which will monitor the pressure fluctuations due to wind acting on a 20 m high, 10 m diameter dome top flammable liquid storage silo.

Your proposal should contain an introduction which describes the causes of the pressure fluctuations which will occur due to wind speeds up to 40 m/s (strong gale). Account should be taken of the expected fluctuations in the wind speeds and of pressure fluctuations due to vortex shedding. [11]

Your proposal should specify the pressures sensors to be used, the locations of the sensors, the signal transmission methods, the data logging system together with reasoned arguments for your choices. [11]

You should also provide numerical estimates of expected pressure fluctuations and the frequency spectra of the fluctuations. You should also address any possible safety aspects of the installation and the response of the monitoring system to environmental effects such as temperature and snow or ice. [11]

**Question 5.** Many sensor elements exhibit offset, nonlinear responses and temperature dependencies. Discuss, with the aid of appropriate circuit diagrams, the analogue circuits which can be used to condition the sensor signal so as to remove the offsets, linearise the response and compensate for temperature effects. [13]

How can these analogue circuits be replaced by digital circuits in which the potentiometer settings of the analogue circuits are replaced by coefficients stored in digital memory? [13]

What are the manufacturing and operational advantages of replacing the analogue circuits by digital circuits? [10]

- Question 6.**
- (a) Give an account of the principle of operation of the Hall effect magnetic sensor. Explain why Hall sensors using n-type doped semiconductor materials give the largest response. What limits the sensitivity of the Hall magnetic sensor? [10]
  - (b) Explain the operation of the Anisotropic Magnetic Resistor (AMR) magnetic sensor. How does the Barber Pole structure permit the fabrication of a linear magnetic field sensor. How does the Set/Reset technique of magnetisation reversal permit the removal of zero offsets? [13]
  - (c) Explain the balance of forces on a simple magnetic compass. Why is such a compass only suitable for use in specific regions of the Earth? Why is it necessary to use a three axis detection system when AMRs are being used to implement an electronic compass which is to be used for accurate navigation purposes? [10]