NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4130 - INDUSTRIAL INSTRUMENTATION

EXAMINATION

BSc HONOURS PART IV: DECEMBER 2004 *DURATION: 3 HOURS*

ANSWER **ALL** PARTS OF SECTION A AND ANY **THREE** IN 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 what this means? [4]

(b) Name two base units of the SI, give their symbols and describe briefly the principles on which their realizations are based. [4]

(c) Briefly explain what calibration is and its purpose. Also explain why a unit under test (UUT) can never have a smaller uncertainty than the standard against which it is calibrated. [6]

(d) Explain the following measurement techniques.
(i) Deflection method
(ii) Substitution method [4]

(e) What is traceability? Explain concisely the significance of each of the components in the traceability ladder using temperature as an example. [8]

(f) What is the difference between repeatability and reproducibility? [4]

(g) Explain three sources of uncertainty in measurement systems. [6]

(h) The resolution of a digital display is 0.001. Calculate the standard deviation due to this resolution. [4]

SECTION B

2 (a) Give in your own words the meaning and interpretation of the word "measurement uncertainty". How does it differ with error? [4]

(b) Explain the difference between type - A and type - B uncertainty evaluation. [4]

(c) Indicate what information should be given in the result of a measurement to enable the reader to fully interpret the measurement result? [4]

(d) Table 1 below shows specifications of a 4½ digit digital multimeter (DMM), stating the worst case deviations for each function as a percentage of range plus a percentage of reading plus a fixed number of digits.

Table 1

Range (at 23 ± 3 °C)	1 month % range + % value + digits	3 month % range + % value + digits	1 year % range + % value + digits
200 mV DC	0 + 0.04 + 3	0 + 0.08 + 4	0 + 0.10 + 5
2 V to 200 V DC	0.02 + 0.03 + 1	0.2 + 0.04 + 2	0.02 + 0.07 + 3
2000 V DC	0 + 0.04 + 2	0 + 0.06 + 3	0 + 0.07 + 4

Suppose the meter was last calibrated ten months ago and was adjusted to be well within specifications, what is the standard uncertainty if the instrument read 7.000 V on the 20 V range. [8]

3 (a) Distinguish between a sensor and a transducer. [2]

(b) Write brief notes on the following sensors including relevant equations in your explanation.
(i) Thermistor
(ii) IC sensor
(iii) RTD [9]

(c) With the aid of circuit diagrams explain how the above sensors can be used to produce voltage signals. [9]

4 A resistor R_x was calibrated at a temperature of 23.2 °C by connecting it in series with a standard resistor R_s and voltage measurements of V_x across R_x and V_s across R_s were taken and tabulated in Table 2 below. The value of the standard resistor Rs at 23.0 °C was given as 10.0001 ± 0.0005 Ω (2σ). Take α for the resistors to be 2.3×10^{-4} .

Table 2

Reading number	V_s / V	V_x / V
1	1.005	1.003
2	1.007	1.004
3	1.003	1.000
4	1.004	0.998
5	1.002	0.999

(a) Derive a model equation relating R_x, R_s and r including influence quantities. [4]

(b) Calculate the sensitivity coefficience for each of the quantities in the model equation. [6]

(c) Draw the uncertainty budget for this calibration and calculate the combined standard uncertainty. [10]

5 (a) How does an electrical signal generated in a thermocouple? [4]

(b) In a particular industrial situation, a chromel - alumel thermocouple with chromel N alumel extension wires is used to measure the temperature of a fluid. In connecting up this system, the instrumentation engineer responsible has inadvertently interchanged the extension wires from the thermocouple. The ends of the extension wires are held at a reference temperature of 0 °C and the output emf measured is 12.1 mV. If the junction between the thermocouple and extension wires is at a temperature of 40 °C, what temperature of fluid is indicated and what is the true fluid temperature? [10]

(c) Explain the Peltier effect including its use in generating temperatures below 0 °C. [6]

6 (a) Describe any two elements of an optical measurement system giving examples in each case. [6]

(b) An optical fibre transmission system consists of a circular LED source, a 2 metre length of optical fibre and a PIN diode detector. Both the source and detector are positioned 100 μm from the ends of the fibre. Detailed data for the source, a glass fibre, a polymer fibre and a detector are given on the sheet provided. Use this data to answer the following questions.

(i) The total power P_s emitted by the source in all directions.
(ii) The numerical aperture and the maximum angle of acceptance of the glass fibre.
(iii) The numerical aperture and the maximum angle of acceptance of the polymer fibre.
(iv) The source and the detector are linked by the glass fibre; calculate the power input to the fibre, fibre transmission factor and power output from the fibre.
(v) The source and detector are now linked by the polymer fibre; calculate the power input to the fibre, fibre transmission factor, and power output from the fibre. [14]

END OF PAPER

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INDUSTRIAL INSTRUMENTATION 1 SPH4130
DATA FOR QUESTION 6

Glass Fibre

- Multimode step index
- Core diameter = 100μm
- Core refractive index = 1.5
- Core- cladding index difference = 0.015
- Attenuation at 810nm = 5dB km^{-1}
- Fibre length = 2m

Polymer fibre

- Multimode step index
- Core diameter = 1.0 mm
- Core refractive index = 1.65
- Core cladding index difference = 0.04
- Attenuation at 810 nm = 500 dB Km^{-1}
- Fibre length = 2m

PIN diode detector

- Diameter = 2.0 mm
- Centre wavelength = 810 nm
- Responsibility at 810 nm = 0.55 A W^{-1}

LED Source

- Brightness = 10 W cm^{-2} sr^{-1}
- Diameter = 200 μm
- Centre Wavelength = 810 nm