National Exams May 2010

04-Agric-A5, Principles of Instrumentation

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. Questions 1, 2 and any other three (3) questions constitute a complete exam paper.
   Only questions 1, 2 and the first three (3) other questions as they appear in your answer book will be marked.

4. All questions are of equal value.

Question 1. (20 marks)(You must answer this question. Each part is worth 2 marks.)

Answer the following short answer questions very briefly. Point form, graphs or sketches may be used as appropriate.

a) What is the difference between accuracy and precision?

b) Why is transmitting a 4-20 mA signal more reliable than using a 0-10 volt signal?

c) Why can thermal noise never be removed from a signal?

d) What makes digital data transmission very reliable?

e) How can data be transferred from an instrument without direct contact with the instrument?

f) Electrical filters are used to remove unwanted frequency components of a signal. What is the most used type of filter in instrumentation applications?

g) Why is hysteresis a problem in measurement applications?

h) Why should the shield on a twisted pair cable be grounded only at one end?

i) Why is the direct measurement of a difference better than subtracting two absolute measurements?

j) What is meant by the terms 'zero' and 'span'?

Question 2. (20 marks)(You must answer this question. Each part is worth 2 marks.)

Answer the following short answer questions very briefly. Point form, graphs or sketches may be used as appropriate.

a) Why does a pH electrode require a very high impedance preamplifier?

b) What are self heating errors in thermistor or RTD temperature sensors?

c) Why do phototransistors produce more signal at a given light level than photodiodes?

d) Why is cold junction compensation required when using thermocouples?

e) Why do strain gages need temperature compensation?

f) What is a reference electrode?

g) Why does a triple point cell (water, ice and water vapour in equilibrium) provide a good temperature reference?

h) What parameters describe the dynamic response of a mass and spring type of load sensor?

i) Why is electrical capacitance used to measure moisture content?

j) How can instruments be made explosion proof?

Question 3. (20 marks)(You only have to do three questions from questions 3 to 7.)

Thermistors are a popular temperature sensor because they produce a large signal but their output is a non-linear function of the temperature. Like other thermometers, thermistors do not react to temperature changes instantaneously, but respond with a characteristic time constant.

a)(7 marks) What is the time constant for a small spherical thermocouple 0.5 mm in diameter measuring air temperatures? The thermocouple has the following characteristics:

Density	9000 kg/m^3
Heat Capacity	378 J/(kg °C)
Heat Transfer Coefficient	8.56 J/(sec m^2 °C)

b)(6 marks) What would the temperature reading be if the measurement was recorded 20 seconds after a sudden temperature change of from 25°C to 0°C?

c)(7 marks) If the thermistor is a thin disc, would increasing its diameter but keeping its mass the same decrease its time constant?

Question 4. (20 marks)(You only have to do three questions from questions 3 to 7.)

The simple differential amplifier (made of only 1 operational amplifier) has two major difficulties: it has a low input impedance and it has a rather poor common mode rejection ratio.

a)(5 marks) Draw a schematic diagram of this amplifier.

b)(3 marks) What causes this circuit to have a poor common mode rejection ratio?

c)(2 marks) Why is common mode rejection an essential feature in a differential amplifier?

The instrumentation amplifier (made of 3 operational amplifiers) substantially solves these problems.

d)(5 marks) Draw a schematic diagram of this amplifier system.

c)(5 marks) Explain its high common mode rejection ratio and its high input impedance.

Question 5. (20 marks)(You only have to do three questions from questions 3 to 7.)

Strain gauges are used to measure the deformation of metal members by changing their resistance as they deform with the metal. This resistance change with the elastic stress-strain relations provides a measure of the forces acting on the member. This requires a rigid attachment between the gage and the member. This attachment is most often a polymer type glue and backing material.

a)(7 marks) Strain gauges are usually electrically connected in a Wheatstone bridge configuration where the centre of each arm is connected to a differential amplifier. Why is this circuit used?

b)(6 marks) The use of dummy or non-strained gauges in the Wheatstone bridge provides temperature compensation. Explain how this works.

c)(7 marks) If the polymer used to bond the gauge to the metal member creeps (it slowly flows when it deforms), explain how this will affect the strain measurement as the member is loaded and then unloaded.

Question 6. (20 marks)(You only have to do three questions from questions 3 to 7.)

Many flow meters are based on the measurement of the velocity head of the moving fluid. The result is of the form:

$$Q = k\,\Delta P^{0.5}$$

where Q is the flow rate, ΔP is the measured velocity head in pressure units, and k is a constant of proportionality.

a)(4 marks) List several types of flow meter based on this principle.

a)(7 marks) What factors are included in the proportionality constant k?

b)(6 marks) An orifice meter is used to measure the flow of water (density = 1000 kg/m^3) through a 10 cm diameter pipeline. The orifice diameter is 7 cm. What is the flowrate if the pressure drop across the orifice is 5.4 Pascals?

c)(3 marks) Pressure drop measurements in liquids are made with the tubing connecting the measurement to the pressure transducer full of the liquid. Why must the tubing be completely full of the liquid?

Question 7. (20 marks)(You only have to do three questions from questions 3 to 7.)

An LED (light emitting diode) light source produces monochromatic light over a small wavelength range. Unfortunately only a few fixed wavelengths are available.

a)(4 marks) What determines the emission wavelength of a LED?

b)(4 marks) How is the colour of an object represented as measured data?

c)(4 marks) How are these colour values measured?

c)(4 marks) How would you calibrate this type of instrument?

d)(4 marks) Why is calibration required?