National Exams December 2015

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)(2 marks) Why are sensitivity and selectivity often conflicting objectives in the design of a sensor system?

b)(2 marks) How should an instrument calibration procedure be adapted to assess the selectivity of an instrument?

c)(2 marks) What information is revealed by repeating a calibration several times?

d)(2 marks) How should hysteresis be evaluated in a calibration process?

e)(2 marks) What parameters describe the dynamic response of an instrument?

f)(2 marks) Why is the subtraction of a measured baseline from a measured signal a problem?

g)(2 marks) Why is the RMS value of the calibration error a good indication of the success of the calibration?

h)(2 marks) Why should derivatives be avoided in measurement calculations?

i)(2 marks) How long does an instrument take to approach a final response value?

j)(2 marks) Why must a calibration curve be monotonic?

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)(2 marks) What are aliasing errors?

b)(2 marks) What is an internal standard?

c)(2 marks) What is the origin of shot noise?

d)(2 marks) Describe the operation of a reference electrode.

e)(2 marks) What is an isolation amplifier?

f)(2 marks) Why is frequency modulation a good method of transmitting data over long distances?

g)(2 marks) What is the difference between noise and electrical interference?

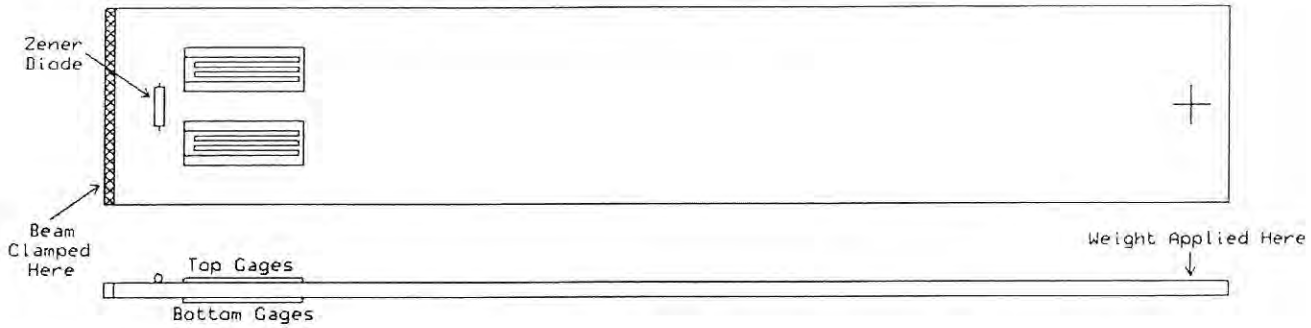
h)(2 marks) Why should the input impedance of a measuring instrument be very much higher than the source impedance of the sensor?

i)(2 marks) Why is fluorescence better than absorbance in measuring the concentration of a substance?

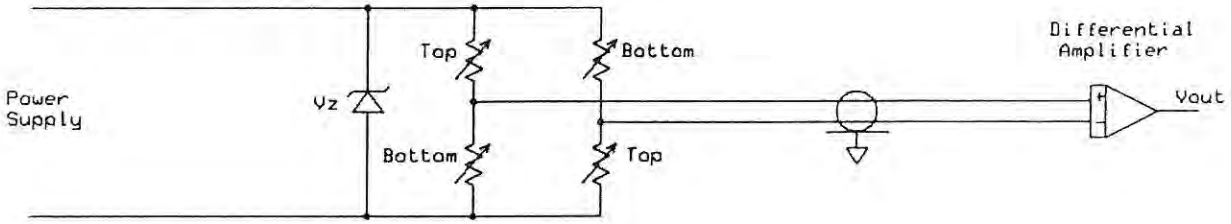
j)(2 marks) In taking X-ray images, what trade-off is required in determining the exposure time?

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

The deformation of a beam is used to measure applied loads. The configuration shown here has four gages, two on top of the beam and two on the bottom. The beam is rigidly clamped at one end and the load applied at the other.



a)(8 marks) From the electrical schematic shown here, derive an equation giving the output voltage, Vout, in terms of the strain gage resistances under load. Assume the four gages are identical when not under load.



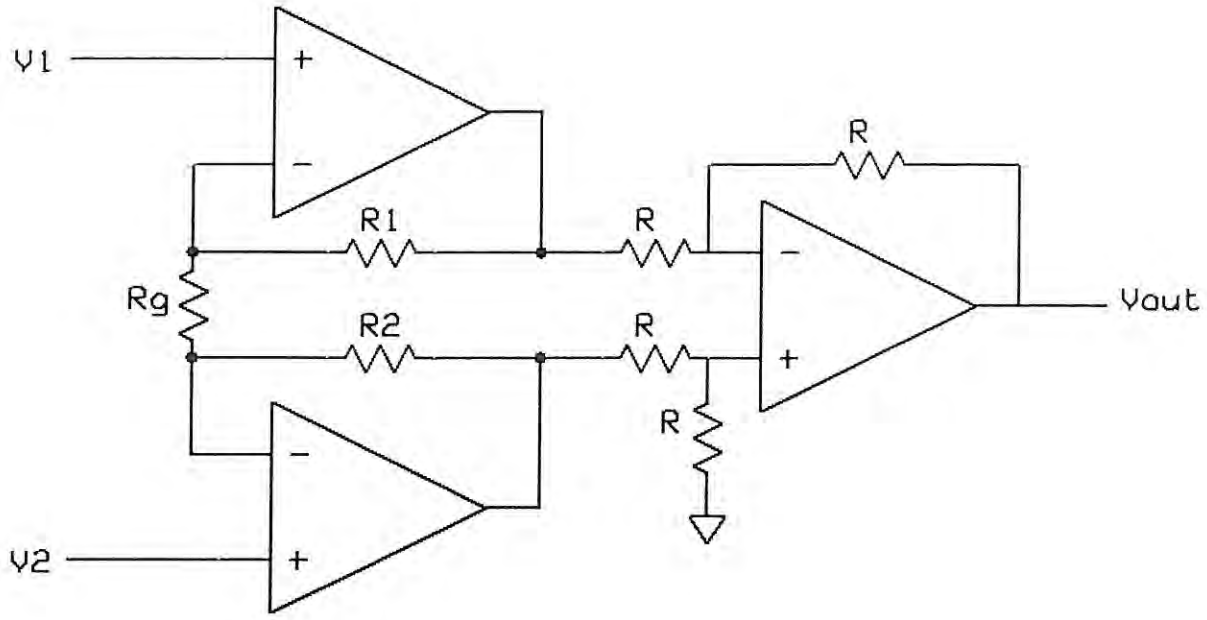
b)(2 marks) What are two advantages of using this configuration rather than using a single gage?

c)(3 marks) If the gages are located far from the electronics, explain why the Zener diode is useful.

d)(3 marks) The signal leads are shown as a shielded twisted pair cable. Why should the shield be grounded only at one end?

e)(4 marks) Why should the excitation voltage for a strain gage bridge be low?
Why should the excitation voltage for a strain gage bridge be high?

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



The schematic diagram describes a typical instrumentation amplifier.

a)(8 marks) Derive an equation giving the output voltage in terms of the two input voltages, V1 and V2.

b)(2 marks) What are two advantages of this type of amplifier?

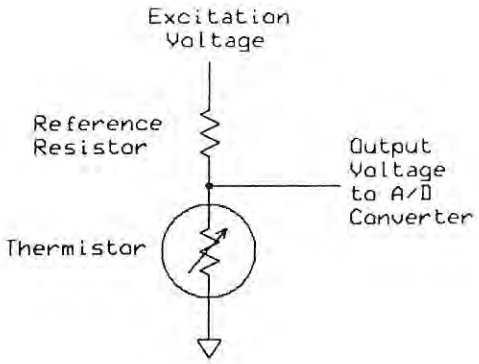
c)(3 marks) The four resistors labelled R in the final stage must have identical values. What is the consequence of mismatches in their value?

d)(3 marks) Explain (briefly) why the first stage resistors R1 and R2 need not have identical values.

e)(4 marks) Why are amplifier noise and offset critical considerations in the first stage of an instrument system?

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

A thermistor with the following calibration data is connected in a measuring circuit as shown:



Temperature (^{O}C)	Resistance (Ohm)
10	201700
20	125500
21	119800
30	80000
37	59190
40	52190
50	34780

a)(4 marks) What is the best value of the reference resistor for measuring temperature on a warm day at 30^{O}C?

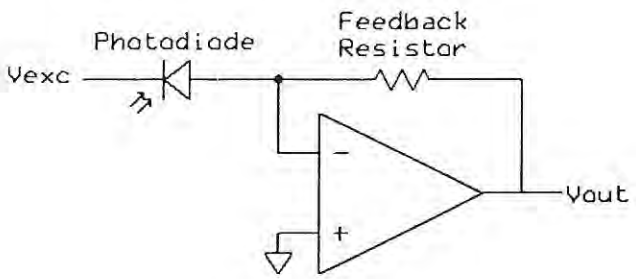
b)(6 marks) If the reference resistor is 100000 Ohms and the excitation is 5 volts, what is the approximate sensitivity of the measurement at 20.5^{O}C?

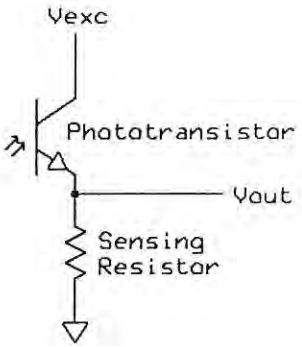
c)(6 marks) If an average temperature is required when the temperature varies by 20^{O}C, why does using an average resistance or an average output voltage result in an incorrect value?

d)(4 marks) How would you solve the averaging problem pointed out in part c?

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

The following schematic diagrams show photodiode and phototransistor light intensity measuring circuits:





Vexc is a positive excitation voltage.

a)(2 marks) Why is there a reverse bias current through a photodiode exposed to light?

b)(2 marks) Why is there a reverse bias current through a photodiode in complete darkness?

c)(2 marks) How can the 'dark current' be reduced?

d)(2 marks) Why is a phototransistor more sensitive to light than a photodiode?

e)(2 marks) How is the sensitivity changed by changing the excitation voltage?

f)(3 marks) Why does the sensitivity of a photodetector depend on the wavelength of the light?

g)(4 marks) Briefly explain the operation of a photomultiplier tube.

h)(3 marks) A CCD camera uses charge coupled devices as photodetectors. Under very low light levels, detector noise is a problem. How does this noise affect the pictures taken?

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

An orifice meter is used to measure the flow through a 10 cm inside diameter pipeline. The orifice opening diameter is 7 cm. The density of the fuel flowing through the line is 800 kg/m^3. The viscosity of the fuel is 15 kg/(m sec).

a)(8 marks) What is the flow rate if the measured pressure drop is 65 pascals?

b)(4 marks) What assumptions did you make in doing the calculation of part a?

c)(2 marks) Why is a venturi flow meter more efficient than an orifice flow meter?

d)(3 marks) Does the flow orientation of an orifice flow meter have to be horizontal? Explain your answer briefly.

e)(3 marks) What is the effect of an upstream flow obstruction such as an elbow on an orifice flow meter.