# NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY FACULTY OF INDUSTRIAL TECHNOLOGY BACHELOR OF ENGINEERING (HONS) DEGREE 

Final Examination May 2011

TEE 1241
Electrical Measurements
3 hours only
Instructions to candidates:

1. Answer any FIVE questions only.
2. Each question carries 20 marks
3. Show all your steps clearly in any calculation.
4. Start the answers for each question on a fresh page.

## Question 1

a) It is required to produce a voltage which is the composite of three voltages, $\mathrm{V}_{1}, \mathrm{~V}_{2}, \mathrm{~V}_{3}$ according to the equation: $\mathrm{V}_{\text {out }}=-2 \mathrm{~V}_{1}-5 \mathrm{~V}_{2}-2 \mathrm{~V}_{3}$. Design a circuit using operational amplifiers to achieve this, giving realistic values for any resistors used.
b) Making electrical measurements is vital in engineering. How would you define the process of making measurements?
c) List various ways of classifying measurement systems.
d) Which aspects of these classifications describe the following; a speed trap meter, a d'Arsonval DC ammeter, and a soil pH data logger connected to a computer?

## Question 2

a) Describe the mechanical construction of the d'Arsonval meter movement, using a fully labelled diagram.
b) A dynamometer movement produces a full-scale deflection when the product of the currents in the two coils is $10^{-3} \mathrm{~A}^{2}$. If a load of 100 Ohms across a supply voltage of 50 volts produces a half-scale deflection, what is the value of the series resistance in the series resistance in the voltage-measuring part of the circuit?
c) A meter has an internal resistance of 500 Ohms and a full-scale deflection of 1 mA . Design suitable circuits to make this into
i. A voltmeter reading from $0-10$ volts, and
ii. An ammeter to read 0-2 amps.

## Question 3

a) Define a transducer.
[1]
b) Describe a transducer which can be used to measure rotation in the range of 0 to $180^{\circ}$, and indicate in what sort of circuit it could be used.
c) Two strain gauges are fastened to the upper and lower faces of a cantilevered beam. The gauges have sensitivity factor of 2 and initial resistance of 150 Ohms . When the free end of the beam is loaded, both gauges change their resistance by 1 Ohm . What is the radius of curvature on the centreline of the bent beam at the point where the gauges are fixed, if the depth of the beam is 100 mm ?
d) Four strain gauges are used to measure the bending of a beam. The mechanical arrangement and the electrical connections are shown below. The supply voltage across the bridge is 12 volts. The gauges have sensitivity factors of 2.5 . What would be the voltage $\mathrm{V}_{0}$ at the centre of the bridge when all the gauges are mechanically strained by $3 \%$. Indicate which gauges are in tension and which under compression.


## Question 4

a) A platinum resistive temperature transducer has resistance of 150 Ohms at the reference temperature of $20^{\circ} \mathrm{C}$, and temperature coefficient of 0.00392 . It is connected in series with a resistor of 375 Ohms across a 12 volt supply. If the temperature rises to $220^{\circ} \mathrm{C}$, what would be the voltage across the transducer?
[10]
b) State at least 6 terms that describe measurement errors which can occur in measurement systems, indicating briefly how these can be reduced in each case.
c) The expected value of the voltage across a resistor is 5.5 V . However, measurement yields a value of 5.2 V . Calculate:
i. The absolute error
ii. The percent of error
iii. The relative error
iv. The percent of accuracy

## Question 5


a) For the A-D converter circuit shown above, it is found that an input voltage, $\mathrm{V}_{\text {in }}$ of 5 volts produces a binary output of 11111 . What input voltage would produce 01011 ?
b) Explain why the five latches are needed at the binary outputs, and what causes them to change their values.
[6]
c) If the signal at G is a square wave of frequency 50 Hz , sketch the waveform produced at the output of the integrator (point X), showing the time and voltage information.
[8]

## Question 6

a) Describe briefly with the aid of a diagram the operation of a stepper motor.
b) Describe the construction of a dot-matrix printer, and show the connections needed for data transfer and control signals. Explain the purpose of each line and the direction of information flow on it.
c) An Ohmmeter uses a 1.5 volt battery and a d'Arsonval meter movement with a resistance of 200 Ohms. The variable series resistor of the Ohmmeter is adjusted to 1053 Ohms to cause a full-scale deflection when the probes are shorted together. When the probes are placed across a test resistor, the deflection is $64 \%$ of full scale. What is the value of this test resistor?

## Question 7

a) Describe briefly three types of transducers for measuring light intensity.
b) Describe briefly three types of transducers for measuring temperature.
c) A photo-transistor having the characteristics shown in Figure Q7 is connected in series with a load of 2.5 kOhms across a supply of voltage of 25 volts. What would be the voltages across the transistor when the light intensities are 100,200 , and $400 \mathrm{~W} / \mathrm{m}^{2}$ ? Mark the load line and the operating points on the Figure Q7 in page 5.

GRAPH OF FIGURE Q7 SHOULD BE ATTACHED TO YOUR ANSWER BOOK.

## Question 8

a) Describe with the aid of a diagram the construction of an oscilloscope.
b) Explain why a Schmidt Trigger is needed in an oscilloscope timebase circuit to ensure a stable image on the screen
c) Two signals of the same frequency are applied to the X and Y plates of an oscilloscope. Sketch the Lissajous figures that would result when the X input lags the Y input by the following phase shifts: $0^{\circ}, 90^{\circ}, 180^{\circ}, 45^{\circ}, 120^{\circ}$.
d) A 4-bit A-D converter is connected through a decoder to a common-anode 7-segment display. If the actual input voltage to the converter is 2.7 volts and the maximum input is limited to 8 volts, what will be the binary input to the decoder and the binary number out of the decoder to display the equivalent of 2.7 volts.

The Graph for Question 7 - It must be attached to the answer book if this question is attempted.

Student No.


Figure Q7

