(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER EXAMINATIONS

FOR THE DEGREE
OF
BACHELOR OF TECHNOLOGY EDUCATION
IN
ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE CODE: TEE 414

COURSE TITLE: MEASUREMENT AND INSTRUMENTATION

DATE: FRIDAY, APRIL 22ND, 2022.   **TIME: 3:00 – 5:00 PM**

INSTRUCTIONS TO CANDIDATES

ANSWER QUESTION ONE AND ANY OTHER TWO QUESTIONS.
QUESTION ONE CARRIES 30 MARKS AND ALL OTHERS 20 MARKS EACH.

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

(a) Differentiate the following terms as used in measurement: **(5marks)**
   (i)   Digital and Analogue instruments
   (ii)   Accuracy and Precision
   (iii)   Range and Span
   (iv)   Repeatability and Reproducibility
   (v)   Tolerance and Threshold

(b) The width of a room is measured 10 times by an ultrasonic rule and the following measurements are obtained (units of meters): 5.381, 5.379, 5.378, 5.382, 5.380, 5.383, 5.379, 5.377, 5.380, and 5.381. The width of the same room is then measured by a calibrated steel tape that gives a reading of 5.374 m, which can be taken as the correct value for the width of the room.**(5marks)**
   (i) What is the measurement precision of the ultrasonic rule?
   (ii) What is the maximum measurement inaccuracy of the ultrasonic rule?

(c) A balloon is equipped with temperature and altitude measuring instruments and has radio equipment that can transmit the output readings of these instruments back to ground. The balloon is initially anchored to the ground with the instrument output readings in steady state. The altitude measuring instrument is approximately zero order and the temperature transducer first order with a time constant of 15s. The temperature on the ground, $T0$, is 10^0C and the temperature T_x at an altitude of x meters is given by the relation: **(8marks)**

$$Tx = T_0 - 0.01x$$

   (i)   If the balloon is released at time zero, and thereafter rises upwards at a velocity of 5m/s, draw a table showing the temperature and altitude measurements reported at intervals of 10s over the first 50s of travel. Show also in the table the error in each temperature reading.
   (ii)   What temperature does the balloon report at an altitude of 5000m?

(d) Suppose that the components of the circuit shown in Figure 1 have the following values: $R1=400$ ohms; $R2 =600$ ohms; $R3=1000$ ohms; $R4 =500$ ohms; $R5 =1000$ ohms. The voltage across AB is measured by a voltmeter, whose internal resistance is 9500 ohms. What is the measurement error caused by the resistance of the measuring instrument?   **(5marks)**
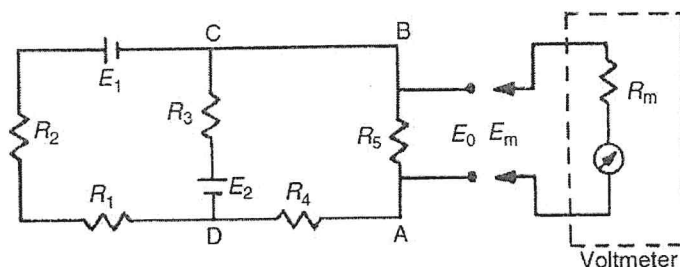
Figure 1

(e) In a practical exercise to determine the freezing point of a metal alloy, the following measurements of the freezing point temperature were obtained: 519.5, 521.7, 518.9, 520.3, 521.4, 520.1, 519.8, 520.2, 518.6, and 521.5. Express the mean value and the error boundaries expressed to **(7marks)**
  (i)   68% confidence limits,
  (ii)   95.4% confidence limits, and
  (iii) 99.7% confidence limits.

QUESTION TWO   20MKS

(a) Explain the meaning of instrument calibration   **(2marks)**
(b) Explain the following terms: **(3marks)**
  (i)   calibration chain
  (ii)   traceability
  (iii) standards laboratory
(c) What pieces of equipment used are used for calibrating mass-measuring instruments and explain their mode of operation? Sketch a beam balance and a weigh beam and briefly discuss their mode of operation.   **(6marks)**
(d) Discuss how the following are calibrated: translational displacement transducers and linear-motion accelerometers?   **(4marks)**
(e) Briefly discuss the procedures involved in the following: rotational displacement sensors, rotational velocity sensors, and rotational acceleration sensors.   **(5marks)**

QUESTION THREE   20MKS

(a) A certain type of pressure transducer, designed to measure pressures in the range of 0 – 10 bar, consists of a diaphragm with a strain gauge cemented to it to detect diaphragm deflections. The strain gauge has a nominal resistance of 120 ohms and forms one arm of a Wheatstone bridge circuit, with the other three arms each having a resistance of 120 ohms. The bridge output is measured by an instrument whose input impedance can be assumed infinite. If, in order to limit heating effects, the maximum permissible gauge current is 30 mA, calculate the maximum permissible bridge excitation voltage. If the sensitivity of the strain gauge is 338 milliohms/bar and the maximum bridge excitation voltage is used, calculate the bridge output voltage when measuring a pressure of 10 bar.   **(5marks)**

(b) A bridge circuit, as shown in Figure 2, is used to measure the value of the unknown resistance Ru of a strain gauge of nominal value 500 ohms. The output voltage measured across points DB in the bridge is measured by a voltmeter. Calculate the measurement sensitivity in volts/ohm change in Ru if   **(5marks)**
  (i)   the resistance Rm of the measuring instrument is neglected and
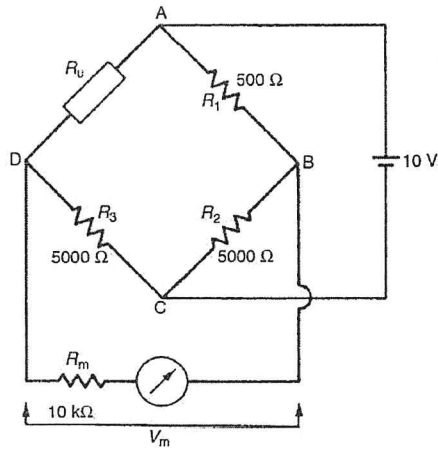 (ii)   account is taken of the value of Rm.

Figure 2

(c) Calculate the reading that would be observed on a moving iron ammeter when it is measuring the current in the circuit shown in Figure 3. **(5marks)**
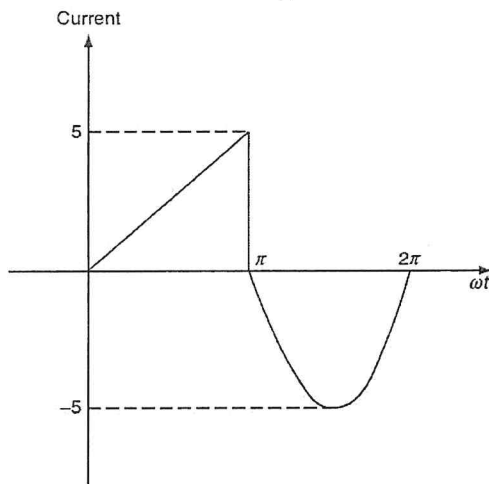

Figure 3

(d) Sketch a block diagram showing the main components in a digital storage oscilloscope and explain the mode of operation of the instrument. **(5marks)**

QUESTION FOUR   20MKS

(a) Explain the principal components in the computational element contained within an intelligent instrument. **(5marks)**

(b) What are the two main types of computer memory? Which type is predominantly used in intelligent instruments and why? **(5marks)**

(c) How does an intelligent instrument correct for environmentally induced errors in measurements? What preconditions must be satisfied to allow an intelligent instrument to correct for such errors? How are these preconditions satisfied? **(5marks)**

(d) Describe the typical function of devices known as smart sensors. **(5marks)**

QUESTION FIVE   20MKS

(a) Define electrical transducers? **(2marks)**

(b) A strain gauge has a gauge factor of 4. If the strain gauge is attached to a metal bar that stretches from 0.25 m to 0.255 m when strained. What is the percentage change in resistance? If the unstrained value of gauge is 120 ohms what is resistance value of gauge after application of strain? **(6marks)**

(c) An 8-plate transducer has plates of dimensions 25 mm × 25 mm and a separation of 0.2 mm between the plates. The arrangement is to be used for displacement measurement. Determine the sensitivity of the arrangement for air medium. **(5marks)**

(d) An accelerometer output is 0.5mV/m with a $\pm$ 20mm core displacement. The spring constant is 400 N/m and the core mass is 60g. Determine the natural frequency, maximum measurable acceleration and accelerometer sensitivity. **(7marks)**