



**SCHOOL OF COMPUTING AND ENGINEERING SCIENCES
BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONICS ENGINEERING
END OF SEMESTER EXAMINATION
BEE 3203 ELECTRICAL MEASUREMENT AND INSTRUMENTATION**

DATE: 11TH MARCH, 2025

TIME: 13:30-16:00 Hours

INSTRUCTIONS:

- i. This paper contains **FIVE** questions.
- ii. You are required to answer **THREE** questions, that is, **QUESTION ONE** which is **COMPULSORY** and any other **TWO** questions.
- iii. All questions carry equal marks i.e. **20 MARKS** each.

QUESTION ONE (20 MARKS).

Your Smartphone Could Soon Measure Your Blood Pressure with Just a Touch



High blood pressure (or hypertension) increases the risk of health problems such as heart or kidney failure but goes undiagnosed in millions of people. A newly developed Android phone app is able to remotely estimate pressure in a person's arteries as their heart squeezes, providing potentially life-saving details on individual health without the need for specialized equipment. Developed by a team led by researchers from the University of Pittsburgh, the app works by taking a variety of readings from the accelerometer, camera, and touch sensors built into modern smartphones. Rather than having to take a trip to the doctor or use a dedicated device, individuals might one day be able to make use of the phone in their pocket, making the innovation particularly important in underserved populations where access to medical care is limited.

- a) With reference to the above cases, briefly critique the author's statement. (4 marks)
- b) Describe any four types of simplex devices that can be used in the smart health monitoring according to the above case. (2 marks)
- c) Briefly, describe the other parameters that the current general smartphone can monitor in the human body. (4 marks)
- d) Based on the above case and the parameters in c) above, develop a proposal on microcontroller-based idea which the health sector can embrace to remain relevant in the current technology era. (4 marks)
- e) Implement the system using Arduino, LCD and a Bluetooth module as minimum. (4 marks)
- f) Assuming, the system in e) above is using a temperature sensor developed from a gold material with length of 60cm and temperature coefficient of $0.0038^{\circ}\text{C}^{-1}$. If its resistance at room temperature is $9.54 \times 10^{-4} \Omega$ determine its new resistance when temperature is increased by 80° . (2 marks)

QUESTION TWO (20 MARKS).

- a) Suppose a pressure measuring instrument consists of a capacitive transducer that uses two quartz diaphragms of area 750 mm^2 separated by a distance of 3.5 mm . When a pressure of 900 kN/m^2 is applied to the top diaphragm it produces a deflection of 0.6 mm . If the capacitance is 370 pF when no pressure is applied to the diaphragms. Find the instruments value of capacitance after the application of a pressure of 900 kN/m^2 . (6 Marks)
- b) If the instrument in a) above is to be used at the toll station along Thika road, develop an Arduino based system to operate a barrier depending on the weights of the different vehicles using this road. (6 Marks)
- c) If the spacing between the diaphragms of the instrument is increased to 4 mm . A pressure of 600 kN/m^2 produces an average deflection of 0.3 mm of the diaphragm of the transducer. The transducer which has a capacitance of 300 pF before application of pressure and is connected in an oscillator circuit having a frequency of 100 kHz . Determine the change frequency of the oscillator after the pressure is applied to the transducer. (4 Marks)
- d) Explain any four factors that need to be considered when choosing the transducer for the system in a) above. (4 Marks)

QUESTION THREE (20 MARKS)

- a) Based on a resistive sensor, an LED and a microcontroller, develop and implement a simple greenhouse monitoring system. (4 marks)
- b) Implement the system in a) above with a remote-control capability, two additional sensors and actuators that are necessary in greenhouse monitoring system to include its wiring diagram and program code indicating the functions of the additional components. (6 marks)
- c) Assuming the system in a) above is a zero-order instrument, describe what you understand by zero-order and develop an algorithm to generate a graph that describes its sensitivity characteristics. (4 Marks)

- d) Suppose a soil moisture measuring instrument consists of a resistive transducer that uses two soil moisture-sensitive electrodes of area 750 mm^2 , separated by a distance of 3.5 mm and initial resistivity of $50 \Omega \cdot \text{mm}$. Determine the instrument's resistance after the soil moisture reaches 35% if the soil's resistivity decreases to $35 \Omega \cdot \text{mm}$. (4 Marks)
- e) Describe two other applications for the system in b) above. (2 marks)

QUESTION FOUR (20 MARKS)

As an engineer, you are tasked with designing and implementing a simple instrument model to improve user awareness through multiple notification mechanisms, especially in highly polluted areas like the Dandora dumping site in Kenya, where air quality poses a significant health risk. The instrument should utilize a sensor-based transducer to detect and monitor airborne particle concentrations in real time. It must also incorporate audio and haptic alerts, a section to display live particle concentration readings, and a communication module for seamless data transmission to a mobile phone, enabling remote monitoring.

- a) Describe the devices you require to implement the system describing their relation to instrumentation and measurements. (4 marks)
- b) Sketch the wiring and schematic diagrams of the system. (4 marks)
- c) Write the code to generate the necessary signals. (4 marks)
- d) Sketch the relation between the possible parameters that affect the design of the haptic alert device. (4 marks)
- e) Describe, with mathematical relations, the type of OP-AMP that can be used to compare two levels of voltage generated by the system in a) above. (4 marks)

QUESTION FIVE (20 MARKS)

- a) With the aid of a diagram describe a sound meter as a sound processing system indicating the corresponding waveforms at each stage of the system. (4 marks)
- b) Given a signal with a combination of frequencies 200Hz , 150Hz and 100Hz with amplitudes of 10, 5 and 20 units respectively. Briefly describe what it possibly represents and simulate it. (4 marks)
- c) Obtain the stream of bits for its 14^{th} to 17^{th} samples based on the optimum resolution. (4 marks)
- d) You have been requested to implement the signal in b) above using Arduino and a buzzer, describe how you could connect the devices together and write an Arduino IDE program to run it effectively. (4 marks)
- e) If the buzzer in d) above has an equivalent circuit consisting of a coil, a resistance and a variable capacitor connected in series and is tuned to resonance using a Q meter. Taking a frequency of operation of 500 Hz , with a resistance of 0.5Ω and the variable capacitor set to 350 pF . Calculate the effective inductance and resistance of the coil, if the Q meter indicates 90. (4 Marks)