THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND COMMUNICATIONS ENGINEERING

FIRST SEMESTER EXAMINATION – 2022

EE312: ELECTRICAL MEASUREMENT & INSTRUMENTATION

BEEC3 and BEEP3

TIME ALLOWED: 3 HOURS,

INFORMATIONS FOR STUDENTS

1. You have **TEN [10] MINUTES** to read through the paper. You must not begin writing during this time.
2. Answer **FIVE QUESTIONS**. Attend to all the Examination Questions **in any order**.
3. All Answers must be written in the **ANSWER BOOK** supplied.
4. Make sure that you have a data sheet at the final page of the Exam Paper.
5. **COMPLETE THE DETAILS REQUIRED ON THE FRONT COVER OF YOUR ANSWERBOOK – DO THIS NOW.**
6. Only the drawing instruments and the calculators are permitted on your desk. Text books and notebooks are **NOT** permitted.
7. If you are found cheating in the Examination, the penalties specified by the University shall apply.
8. **TURN OFF** all **Mobile Phones** and place them on the floor under your seat before the start of Examination.

QUESTION1 [20 Marks]

Attend to the following **TRUE OR FALSE** statements and answer them. Write on your answer sheet **True** if the statement is true or **False** if you think otherwise.

(a) In moving coil and moving iron instruments damping torque is significant for suppressing pointer oscillations.
(b) Electrodynamometer instruments are calibrated using DC source and operated on AC supply and are called transfer type instruments.
(c) Primarily, three torques encountered in moving iron and moving coil instruments are damping torque, control torque and breaking torque.
(d) Torque responsible for moving pointer over the scale of a moving coil instrument is called control Torque.
(e) Systematic error influences accuracy.
(f) Random error influences precision of the instrument.
(g) Zero error and calibration error can be classified as types of random errors.
(h) Springs used to control motion of coil resulting in deflection is called hair spring and they are spirally wound, phosphor-bronze springs.
(i) PMMC Instrument can have only dc supply to the stationary coil.
(j) Shifting the histogram away from the expected value is an indication of low precision.
(k) Instrument Amplifiers are not preferred over OP Amps in sensitive applications to stop resistance of bridge to interfere with amplifier gain.
(l) If the independent errors propagate linearly and are added linearly.
(m) Passive transducers require external excitation supply.
(n) Resistance temperature detector used for temperature measurement is an example of active transducer.
(o) Strain gage can be arranged in Wheatstone bridge so that the effect of disturbance introduced by environment temperature fluctuations can be nullified.
(p) If output voltage of a Wheatstone bridge is non-zero under null condition it can be zeroed by implementing an offset adjust circuit.
(q) In AC Bridges Reactance are not used for calibration, but quality factors.
(r) Impedance of an AC Bridge Arm in series does not have an equivalent parallel arrangement.
(s) Eddie current circulating through coil former contributes to damping by Lenz's Law.
(t) Sensitivity of a bridge is formulated under balanced condition.

QUESTION2 [20 Marks]

Perform the following analysis described in **(a)** and **(b**) respectively. Question2 **(a)** ia based on **figure 1** and question 2 **(b)** is based on **figure 2**.

(a) Two strain gages are used to measure mechanical stress in a physical system. The transducers (**figure 1a**) are connected to DC bridge by configuration presented in **figure 1 (b)**. Perform the following analysis.

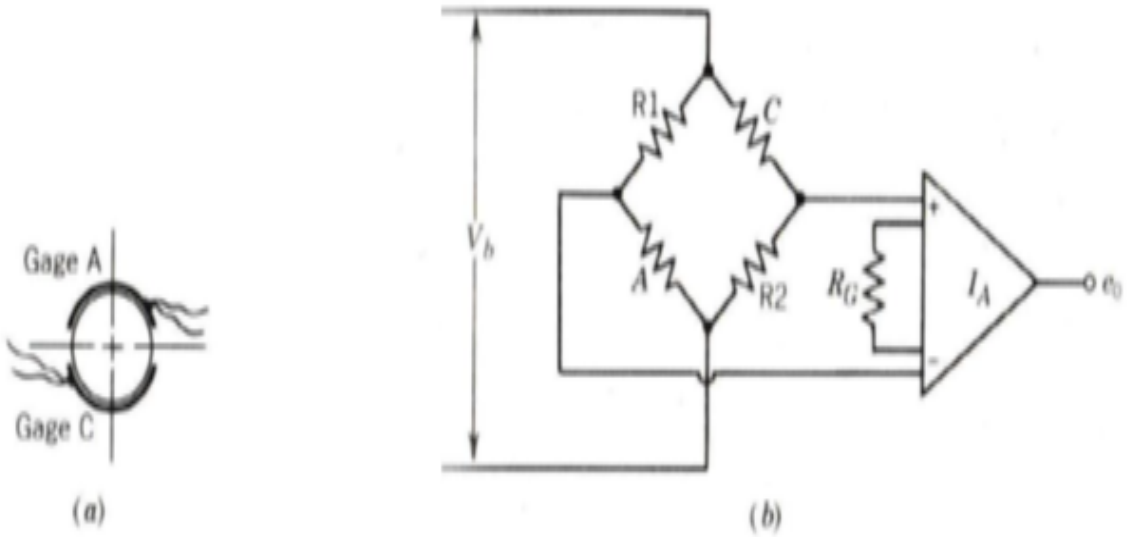

Figure1: For Question 2 (a)

(i) State the mathematical relationship between stress, the change in length, length, the resistance and change in resistance of the elastic material.

(ii) If V_B is supplied to the bridge, with bridge elements R_1, R_2, A and C; derive the unbalanced voltage equation of the bridge.

(iii) Express bridge arm resistance relationships from the null condition by making R1 the subject.

(iv) From **(ii)**, let $A = C = R$. If A undergoes a change of ΔR, simplify the unbalanced voltage equation. What is the value of gauge factor (GF)?

(b) Derive necessary equations that summarize the conversion of measured differential pressure to differential voltage ΔE as depicted in schematic diagram of **figure 2**. Express $\Delta E = E_2 - E_1$ in terms of C_1, C_2, d, and x under unbalanced condition.

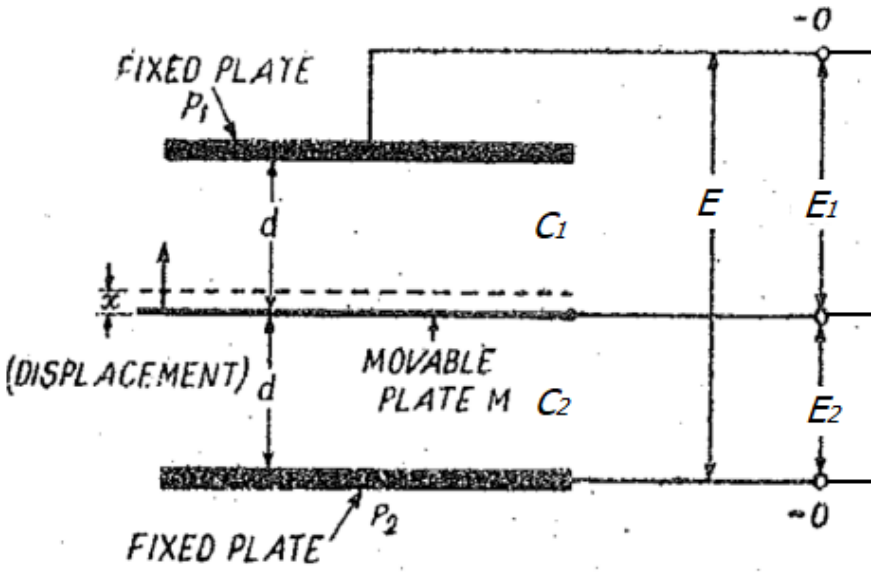

Figure2: For Question 2(b)

QUESTION3 [20 Marks]

This question has parts **(a)**, **(b)** and **(c)**. All Parts are based on differential capacitive pressure transducers depicted in **figure 3**.

(a) A capacitive transducer uses two quartz diaphragms of area 750 mm² Upper and lower fixed plates are separated by a distance of 3.5 mm from the centre plate. A pressure of 900KN/m² when applied to the top diaphragm produces a deflection of 0.6mm with respect to the centre diaphragm. The capacitance is 370pF when no pressure is applied to the diaphragms.

Evaluate the following based on the differential capacitive transducer of **figure 3** after the application of a pressure of 900KN/m2.

(i) Calculate the relative permittivity of dielectric material used in the capacitor transducer.
(ii) Calculate effective value of capacitance C_{1x}
(iii) Calculate effective value of capacitance C_{2x}

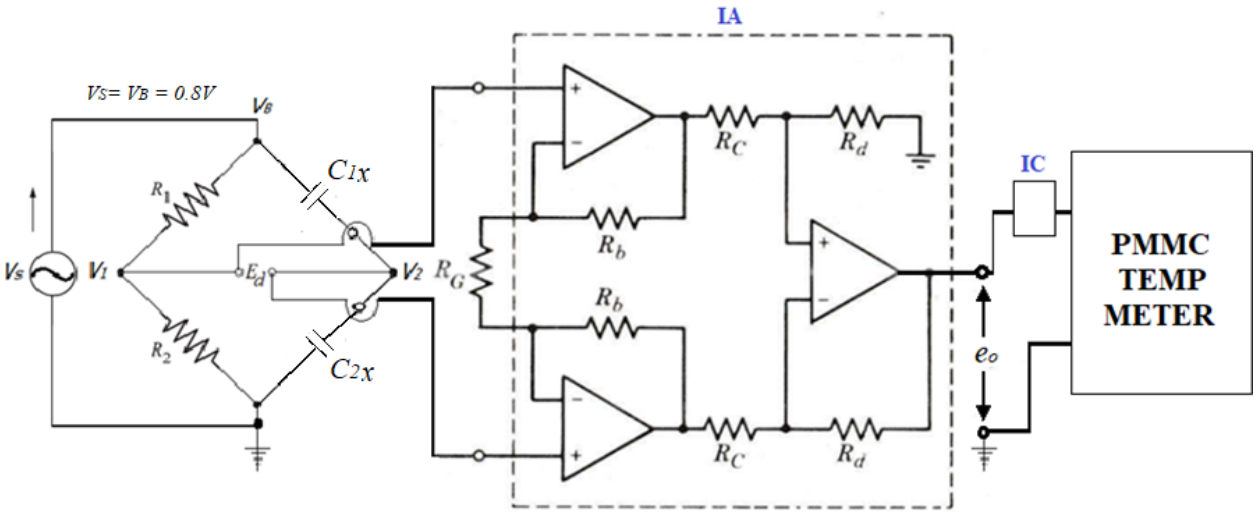

Figure3: For Question 3.

(b) The differential capacitor is connected to a Wheatstone bridge and difference amplifier as shown in **figure 3**. An AC supply of Vs = 0.8 V is used to drive the bridge at a frequency of 50 kHz and the resistance of the bridge are $R_1 = R_2$ = 2500 Ω. The precision Instrument Amplifier (IA) used in the **figure 3** has the following resistance rating. The resistances are RG = 500 Ω, Rb = 1500 Ω, RC = 100 Ω, and Rd = 1000 Ω.

(i) Write the expression for the unbalanced voltage equation of the Wheatstone bridge part of the circuit in **figure 3**.
(ii) Establish the relationship between the bridge arms elements at null (balanced) condition.
(iii) Calculate effective value of output voltage V_o when a pressure of 900KN/m² is imposed on the transducer.

(c) The voltage to current converter located between the IA and the meter has output current, $I = e_o\,(10/R)$, where R = 500Ω. The temperature meter provided is a PMMC instrument and has a coil of dimensions 15 mm × 12 mm. The flux density in the air gap is 1.8×10^{-3} wb/m² and the spring constant is 0.14×10^{-6} N-m/rad. The scale for indication is to be calibrated at 1.5°C/1°. Determine the number of turns required to produce an angular deflection for 150°C temperature reading.

QUESTION4 [20 Marks]

A four-arm ac "parallel inductance bridge" is shown in **figure 4**. The bridge operated at 1 kHz, is at null. The bridge impedance are; Z_{DA} = 1500 Ω, Z_{BC} = 1 000 Ω, Z_{CD} = 10 + 1 / jw10^{-7} Ω and Z_{AB} = 1/R_X + 1/jX_X. Resistance R_X is the equivalent parallel resistance and X_X is equivalent parallel Reactance.

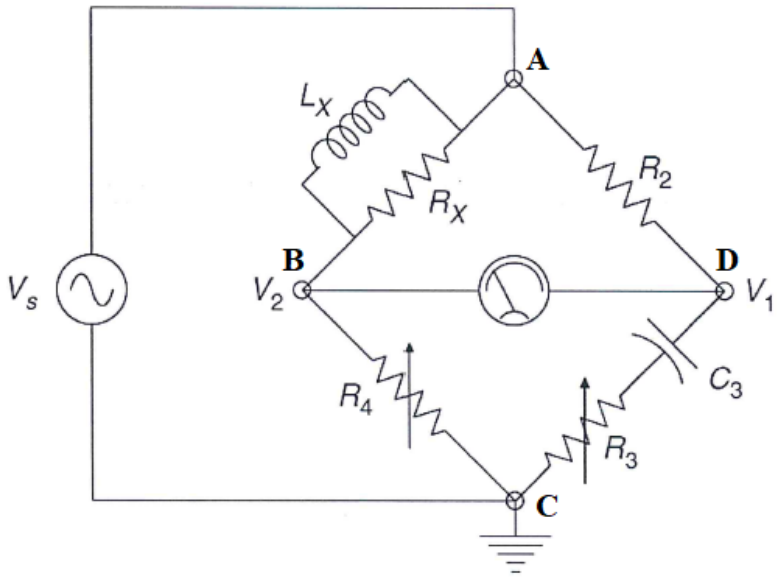

Figure 4: For Question 4

Perform the following analysis based on the above information.

(a) Without substituting the numerical values, establish the expression for resistance R_X and the expression for reactance X_X at null.

(b) Derive the expression for the effective Inductance L_X.

(c) Derive the expression for the Quality Factor (Q_p) for the bridge of **figure4**.

(d) Calculate the value for Quality factor (Q_p) at Null.

(e) Calculate the effective value of inductance L_X at null.

(f) Calculate the effective resistance value for resistor R_X at null.

QUESTION5 [20 Marks]

An electrodynamometer Wattmeter shown in **figure 5** is used to measure power in an AC electrical circuit. The load voltage is 200 V and the instrument has total resistance of the voltage coil circuit as 9300 Ω. The inductance of the voltage coil is 25mH. The mutual inductance changes uniformly from -250 μH at zero deflection to +250 μH at full scale. A current of 25 Amps with a lagging power factor of 0.75 flows through the load. When subject to maximum load current the angle of full scale deflection being 120°.

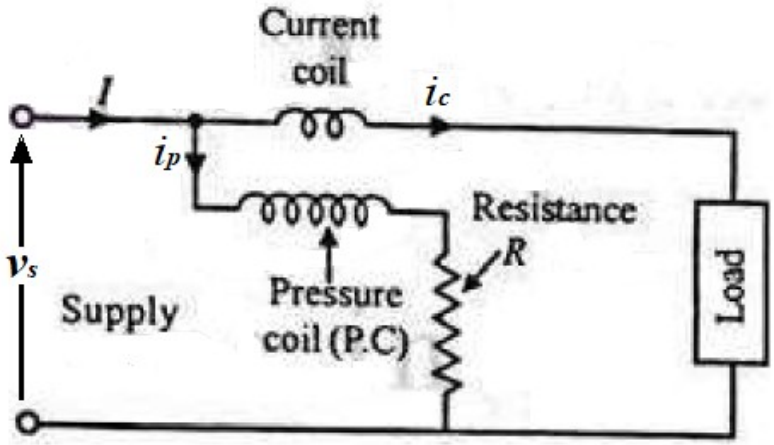

Figure 5: For Question 5.

The resistance of current coil is negligible in comparison to resistance *R*. A pair of hair spring with elastic constant of 4.63×10^{-6} N-m/rad is used to control the instrument's deflection.

Perform the following calculations;

(a) Calculate the current flowing through voltage coil and express your answer as rms current.

(b) Calculate the deflection torque when 25 Amps of alternating current flows through the load.

(c) Determine the angle of deflection when 25 Amp of current is drawn by the load.

(d) What could the value for the maximum rating in Amps of the scale be?

FINAL PAGE OF EXAMINATION QUESTION