Answer any seven (7) of the ten (10) questions from this exam paper.
Each question is equally weighted.
Answer in the script book provided.
(Please observe that there is a Formula sheet on the last page.)

Question 1.

(a) Give the names, and the symbols, for the metric prefixes for ten to the powers of:
(1) Nine.
(2) Minus Nine.
(3) Twelve.
(4) Minus Twelve.

(b) Distinguish between the following pairs of concepts:

(1) Accuracy and precision.
(2) Error and mistake.

(c) Give the value of each of these constants:

(1) Electron charge.
(2) Speed of light in vacuo.
(3) Boltzmann's constant.
(4) Planck's constant.
(5) The electric permittivity of the vacuum.

(d) An inductance doesn't have a Q factor, so why does an inductor have one?

(e) The following figure shows a Wheatstone bridge with $R_1 = 2500\,\Omega$, $R_2 = 1000\,\Omega$, R_3 is the variable resistance, and R_X is the unknown resistance. R_3 varies from $2000\,\Omega$ to $20\,\mathrm{k}\Omega$. Calculate the range of the unknown resistance that the bridge can measure.

Question 2.

(a) Name the kinds of **AC bridge** suitable for measuring:

(1) capacitance;
(2) low-Q inductors;
(3) high-Q inductors.

(b) (i) *Draw* a simple **inverting** amplifier's circuit.
(ii) *Derive* the expression for its voltage gain.

(c) For each of the following properties, in your script-book write "yes" or "no" to whether an **ideal** op-amp has that property.

(1) infinite open loop gain.
(2) non-zero output impedance.
(3) infinite bandwidth.
(4) infinite output impedance.
(5) non-zero noise generation.

(d) *Draw* the circuit for an **op-amp differentiator**.

Question 3.

(a) When making measurements of a patient's heart during **cardiac surgery**, is it better to *ground* the *sensor*, or not? Justify your answer.

(b) Write the formula for the sensitivity S of a **strain gauge** in terms of the resistance R and the length L of a conductive bar under longitudinal compression.

(c) A **comparator** is shown below. Assume that the maximum and minimum **output** voltages are 12 V and -12 V. Determine the maximum and minimum **input** voltages.

(d) Prove that the input-output relationship for the following **instrumentation amplifier** is

$V_o = (V_1 - V_2)(1 + \frac{2R}{R_A})$.

Question 4.

(a) What is most often the *cause* of **voltage drift** in an op-amp?

(b) For a **thermocouple**, what is the *name* of the effect whereby a *voltage* applied across the junctions generates a *temperature* difference?

(c) State the **sampling theorem**.

(d) Using a 74LS163 and logic gates of your choice, design a **counter** that counts up from 3 to 12 then repeats.

Question 5.

(a) Quote the **Barkhausen criterion** for oscillation in a feedback circuit.

(b) In a **CRO**, what is the purpose of **blanking**?

(c) (1) **Semiconductor temperature transducers** contain two identical transistors for which the difference in their base-emitter voltages depends on temperature. *Write the formula* for that difference voltage ΔV_{be} in terms of temperature T, Boltzmann's constant k, the electron charge q, and the two transistors' emitter currents $I_1$and I_2.

(2) Calculate the value of ΔV_{be} at a temperature of 300 K, if the emitter currents are 1 mA and 2 mA.

(d) For the following block diagram of a **pulse** generator, name all the numbered *blocks*, *inputs*, and *outputs*.

Question 6.

(a) Name two common types of *inherent error* in a **frequency counter**, and describe what causes them.

(b) In the context of oscilloscope *probes*, what is **flashover**?

(c) *Sketch* the distorted waveforms that result from feeding a *square* wave to:
(i) a **low** pass filter;
(ii) a **high** pass filter;
(iii) a **band** pass filter.

(d) For the following block diagram of a **digital storage oscilloscope**, name all the numbered *inputs*, *outputs*, and *blocks*.

Question 7.

(a) If a **DAC** has a *minimum* voltage of 0 volts, a *maximum* voltage of 5.08 volts, and a *resolution* of 40 millivolts, then how many **bits** does it have?

(b) (i) What is a **ground fault**?
(ii) How does a **ground fault interrupter (GFI)** work?

(c) Define **total harmonic distortion**.

(d) Name the numbered *blocks* in the following block diagram of a **Fourier analyser**.

Question 8.

(a) Define the **input sensitivity rating** of an amplifier.

(b) A **fluid pressure** transducer with a sensitivity of 3 μV/V/mmHg is excited by a +15 V dc source. Find the *output voltage* if a pressure of 60 mmHg is applied.

(c) State the formula for the total *impedance* of a **series RLC** resonant tank circuit.

(d) For the following block diagram of an **RF signal generator**, name all numbered *blocks*, *inputs*, and *outputs*.

Question 9.

(a) Draw a picture showing how you would make a **bandstop** filter from a lowpass and a high-pass filter.

(b) (1) Name the five (5) principal subsystems of an **oscilloscope**.
(2) Very briefly, describe the purpose of each of those subsystems.

(c) What causes **shot noise**?

(d) (1) Give the formula for the angular frequency ω_s above which a **times-one probe** suffers severe attenuation and phase shift in the following circuit. [*Hints:* Think *time constant*. The relevant resistance is $R_s||R_i$ and the total capacitance is $C_c + C_i$.]

(2) Calculate ω_s for a source resistance of $400\,\Omega$, a cable capacitance of 100 pF, an oscilloscope input capacitance of 30 pF, and an oscilloscope input resistance of 1 MΩ.

Question 10.

(a) The **GPIB** standard has what five (5) requirements for the *cables* connecting the instruments?

(b) **Magnetically** coupled interference voltage decreases with what two (2) quantities?

(c) If an **electric shield** has an opening in the shape of a cylinder with a diameter of 4 cm and a sleeve of length 8 cm, then what is the *attenuation* of a sinusoidal interference waveform with a wavelength of 64 cm that enters that opening?

(d) Here is the block diagram for a **successive approximation ADC**. *Name* each numbered

block.

OVER/

FORMULAS

$L_4 = R_2R_3C_1$

$P = 4kT.\Delta f$

$V^2_{RMS} = P.R$

$\lambda_c = \pi r$

Attenuation = $54.5(\frac{L}{\lambda_c})\sqrt{1-(\frac{\lambda c}{\lambda})^2}$ (dB)

$k = 1.38 \times 10^{-23} W.Hz^{-1}K^{-1}$

$e = 1.609 \times 10^{-19} C$

$\varepsilon_0 = 8.85 \times 10^{-12} F.m^{-1}$

$\mu_0 = 4\pi \times 10^{-7} H.m^{-1}$

$h = 6.626 \times 10^{-34} J.s$

$c = 2.9979 \times 10^{8} m.s^{-1}$

$\pi = 3.141592654$

$0^oC = 273.15K$