**Instructions**: **1)** Provide neat diagrams and necessary steps with detailed justifications in all applicable places. **2)** Answer every question in a new page and answer all sub-parts of a question together. **3)** Any assumptions made in a question should be mentioned in the answer sheet. **4)** Enclose all numerical answers in a box.

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1 An amplifier meant for amplifying speech signals has a 10 cm^2 air-cored parallel plate capacitive sensor at its input and has an input resistance of 10 MΩ. With the input stage becoming a 1st order system and the minimum input frequency being 20 Hz, calculate x, the plate spacing of the sensor required to pass sound frequencies above this value.   (2 marks)

2 The concentration of Cl- ions for a certain cell membrane was 120 millimoles/litre outside and 4 millimoles/litre inside the membrane. Calculate the external equilibrium potential of these ions with respect to the internal medium at 20 °C. R = 8.314 J/K/mol and F = 96500 C/mol.   (2 marks)

3 Which of the following ECG machines is more precise – Machine A reading peak values 5 mV, 4.5 mV, 4.75 mV, 4.5 mV & 4.25 mV or Machine B reading peak values 4 mV, 4.25 mV, 4.25 mV, 4 mV & 4.25 mV? Support your answer analytically.   (2 marks)

4 Suppose if you are about to make a medical measurement, can you identify at least two constraints that you are likely to encounter during the measurement?   (2 marks)

5 What could be the reason that the sensory system in living organisms cannot respond to inputs that repeat in very short intervals?   (2 marks)

6 A piezoelectric sensor and its cable have a capacitance of 1 nF and its output is being fed to an ideal opamp whose gain = 5. Condition the input stage of the opamp such that it is able to amplify the voltage corresponding to a charge of 1 μC generated by a carotid pulse.   (2 marks)

7 A researcher found out that a certain disease condition can be identified by examining the relative permittivity ε_r of blood. So to measure ε_r, he designs a circuit with the following – a step voltage generator with a known internal resistance, a capacitive cell inside which the blood sample can be placed and a high input impedance Digital Storage Oscilloscope (DSO) with voltage probes. Note: DSO can display stored waveforms.

a How would this measurement circuit look like according to your idea?   (1 mark)
b If you where this researcher, what logic would you have used to measure ε_r using this circuit?   (2 marks)
c Provide necessary equations to support the logic.   (1 mark)

[PTO]

8   The waveform of aortic pressure of a person is obtained as follows. Design a circuit using at the most two ideal bipolar opamps to estimate the approximate time period T of this waveform. Draw the output of each opamp w.r.t to the input, one below the other in the same time scale and briefly explain the logic of your circuit. If in case you are using any assumption, mention the same in the explanation and indicate its effect in the waveforms.
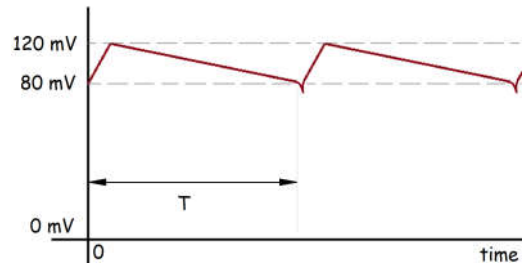
(6 marks)

Note: DO NOT use any counters / timers / microcontrollers / block diagrams in the circuit.

9   An Instrumentation Amplifier (IA) is used to amplify a 3 mV peak ECG signal by a gain of 101.
a   If all the internal resistors are equal and have a value = 25 kΩ, what is the value of the external gain-resistor R_G used?   (2 marks)
b   What is the maximum value of current flowing through this R_G?   (1 mark)
c   If this ECG machine uses a waveform recorder whose input impedance = 1 kΩ, what is the maximum current sourced by the IA while measuring this ECG signal?   (1 mark)
d   It was observed that the IA had an offset voltage V_{os} of 50 mV at its output when the gain was 10. To eliminate this V_{os}, what value of mitigation voltage is needed?   (2 marks)
e   For what value of R_G does the IA saturate at an output value of 6 V, when the same ECG signal is being measured?   (2 marks)