**Benha University**
**High Institute of Technology**
**Hospital Instrumentations (E472)**
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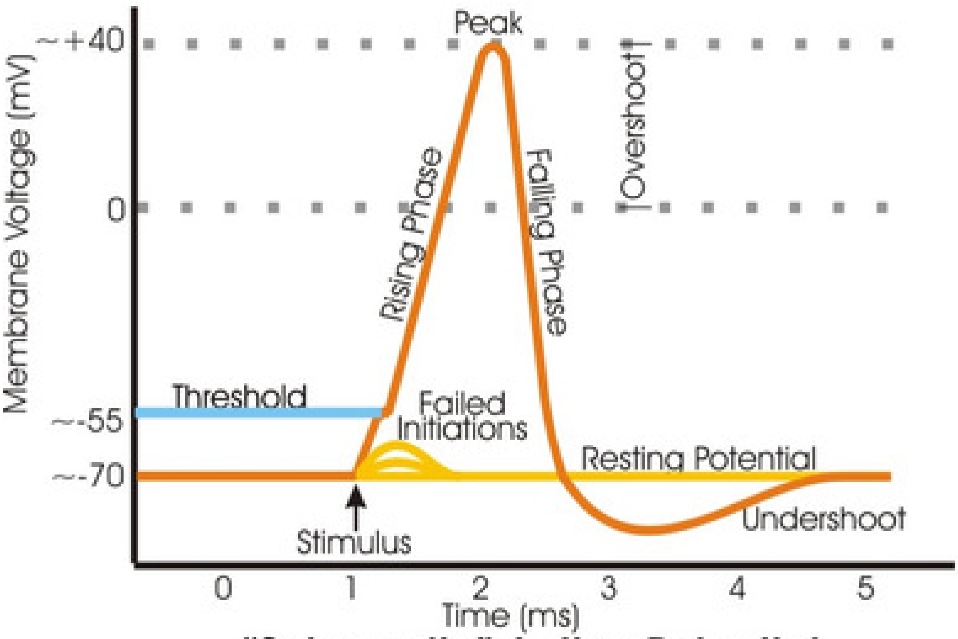
**Electrical Department**
**4Th year (control)**
**Time: 3 Hrs**

# Exam With Model Answer

***Answer the following questions with the aid of drawing if possible.***

**Question (1):** **[15 Marks]**

a) **Draw the action potential and explain its main parts**




**"Schematic" Action Potential**

The action potential is an electrical event occurring when a stimulus of sufficient intensity is applied to a neuron or muscle cell, allowing sodium to move into the cell and reverse the polarity.

Normally neurones (neurons, or nerve cells) maintain a resting potential of -70mV across their membrane by the active pumping of $3Na^+$ ions out of the cell for every 2 $K^+$ ions pumped into the cell by a $Na^+/K^+$ pump. When the neurone is stimulated, sodium ion channels open in the membrane and sodium ions flood in to the cell down an electrochemical gradient by diffusion, increasing the potential of the cell to +40mV. This is called depolarization. At this point the sodium channels close, and potassium ion channels open. Potassium ions flood out of the cell down their electrochemical gradient, decreasing the cell's membrane potential. This is called repolarisation. There is a slight overshoot where too many potassium ions diffuse out of the cell, and there is hyper-polarization where the cell's membrane potential falls below its normal -70mV, but this is corrected and the resting potential is once again restored. This is the sequence of events that makes up a single action potential. Action potentials are transmitted by salutatory conduction in the neurone, and impulses jump from node to node along the axon of the neurone.

### b) Differentiate between the rest potential obtained by Nernst and Goldman equation

The Nernst equation has a physiological application when used to calculate the potential of an ion of charge $z$ across a membrane. This potential is determined using the concentration of the ion both inside and outside the cell:

$$E = \frac{RT}{zF} \ln \frac{[\text{ion outside cell}]}{[\text{ion inside cell}]} = 2.303 \frac{RT}{zF} \log_{10} \frac{[\text{ion outside cell}]}{[\text{ion inside cell}]}.$$

When the membrane is in thermodynamic equilibrium (i.e., no net flux of ions), the membrane potential must be equal to the Nernst potential. However, in physiology, due to active ion pumps, the inside and outside of a cell are not in equilibrium. In this case, the resting potential can be determined from the Goldman equation:

$$E_m = \frac{RT}{F} \ln \left( \frac{\sum_i^N P_{M_i^+}[M_i^+]_{\text{out}} + \sum_j^M P_{A_j^-}[A_j^-]_{\text{in}}}{\sum_i^N P_{M_i^+}[M_i^+]_{\text{in}} + \sum_j^M P_{A_j^-}[A_j^-]_{\text{out}}} \right)$$

- $E_m$ = The membrane potential (in volts, equivalent to joules per coulomb)
- $P_{\text{ion}}$ = the permeability for that ion (in meters per second)
- $[ion]_{\text{out}}$ = the extracellular concentration of that ion (in moles per cubic meter, to match the other SI units, though the units strictly don't matter, as the ion concentration terms become a dimensionless ratio)
- $[ion]_{\text{in}}$ = the intracellular concentration of that ion (in moles per cubic meter)
- $R$ = The ideal gas constant (joules per kelvin per mole)
- $T$ = The temperature in kelvin
- $F$ = Faraday's constant (coulombs per mole)

The potential across the cell membrane that exactly opposes net diffusion of a particular ion through the membrane is called the Nernst potential for that ion. As seen above, the magnitude of the Nernst potential is determined by the ratio of the concentrations of that specific ion on the two sides of the membrane. The greater this ratio the greater the tendency for the ion to diffuse in one direction, and therefore the greater the Nernst potential required to prevent the diffusion.

### c) List the possible causes of the CMV.

The common-mode voltage is comprised of two parts:

1) 50- or 60-Hz interferences.
2) DC electrode offset potential.
3) Any other voltage that may be applied to both electrodes simultaneously.

### d) List types of damage that can result from defibrillator used with ECG.

1) Damage for one terminal of the amplifier (the ECG signal is distorted).
2) Damage for both terminals of the amplifier (no ECG signal out).

### e) List the basic maintenance procedures for ECG machine.

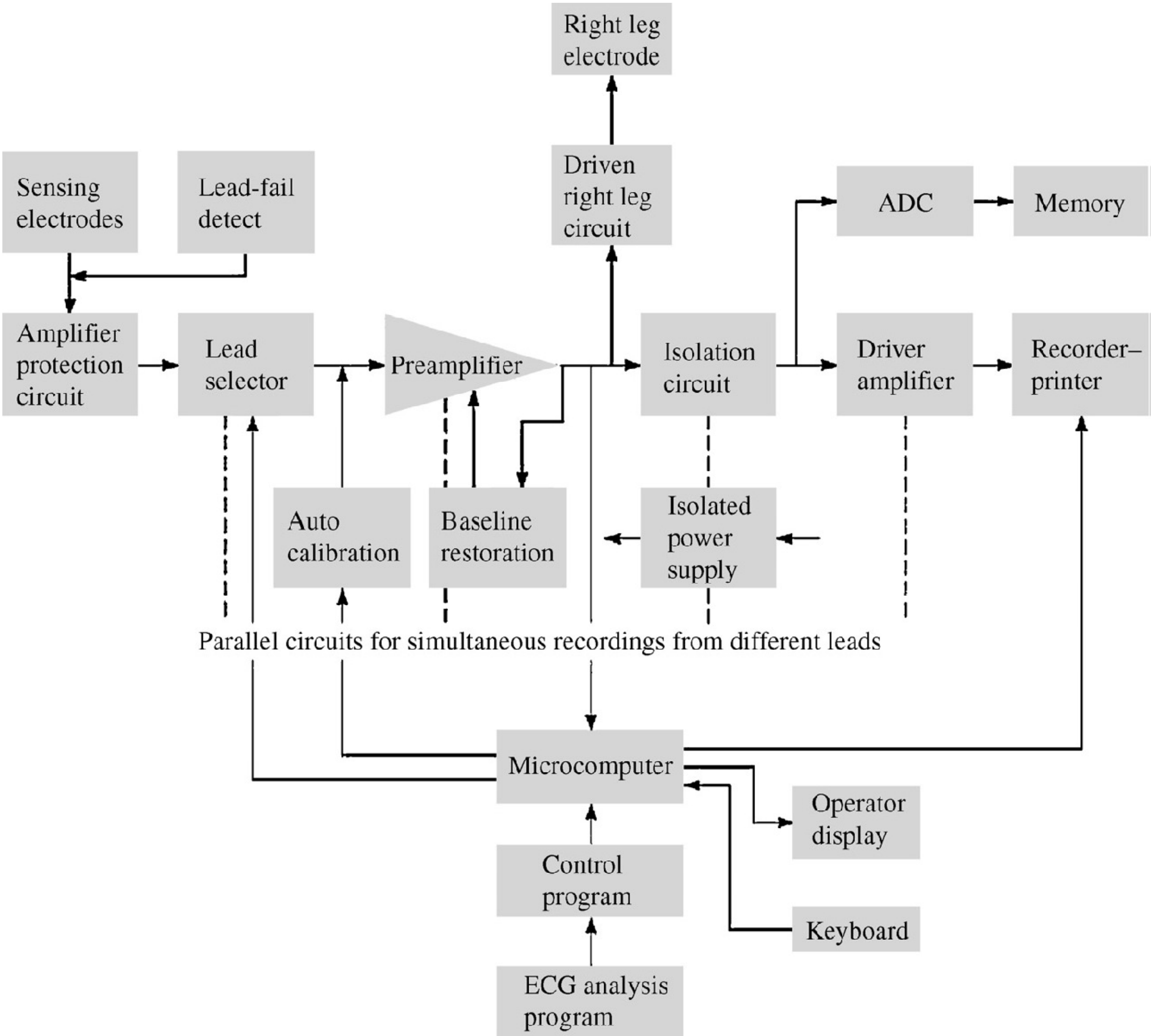
See the book

**Question (2):** **[15 Marks]**

a) **Differentiate between the unipolar and bipolar limb leads**

See the book

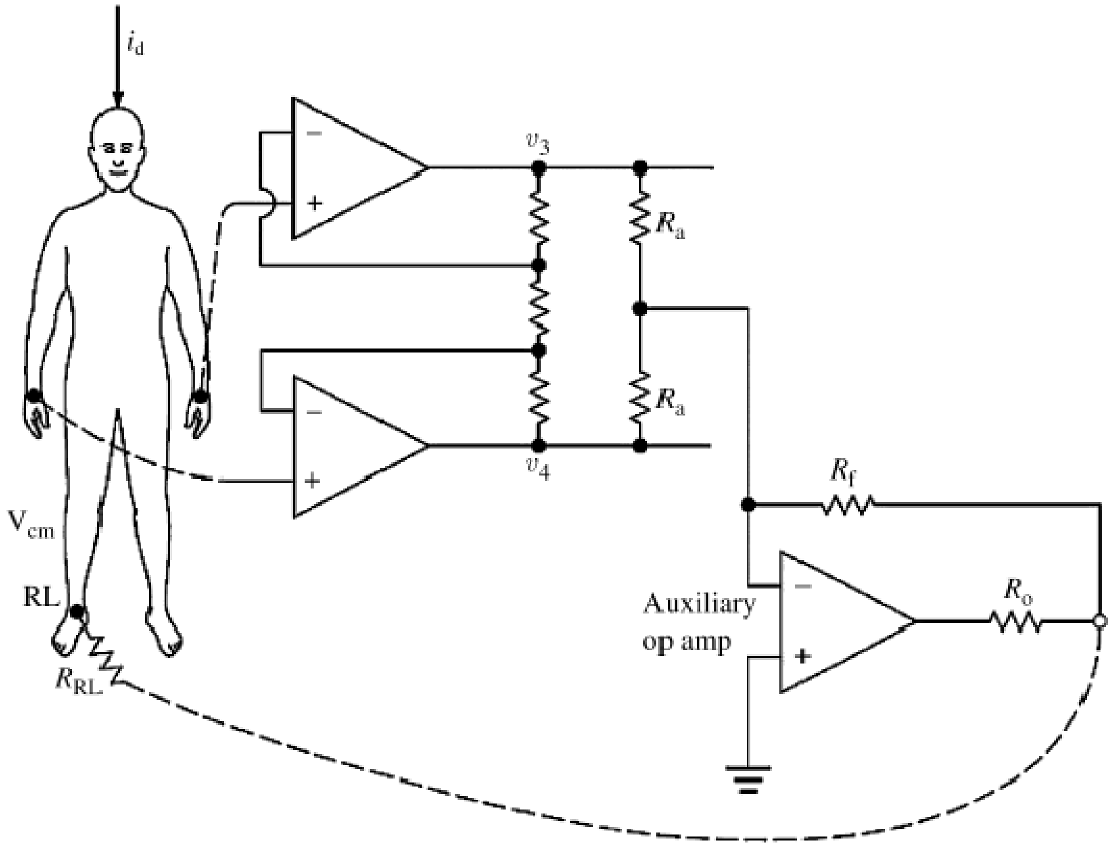
b) **Draw the block diagram of a basic ECG machine.**




c) **Describe the meaning of right leg drive and why it is used**

In most modern electrocardiographic systems, the patient is not grounded at all. Instead, the right-leg electrode is connected (as shown in Figure below) to the output of an auxiliary op amp. The common-mode voltage on the body is sensed by the two averaging resistors $R_a$, inverted, amplified, and fed back to the right leg. This negative feedback drives the common-mode voltage to a low value. The body's displacement current flows not to ground but rather to the op-amp output circuit. This reduces the interference as far as the ECG amplifier is concerned and effectively grounds the patient.

The circuit can also provide some electric safety. If an abnormally high voltage should appear between the patient and ground as a result of electric leakage or other cause, the auxiliary op amp in Figure below saturates. This effectively ungrounds the patient, because the amplifier can no longer drive the right leg. Now the parallel resistances $R_f$ and $R_o$ are between the patient and ground. They can be several megohms in value—large enough to limit the current. These resistances do not protect the patient, however, because 120 V on the patient would break down the op-amp transistors of the ECG amplifier, and large currents would flow to ground.



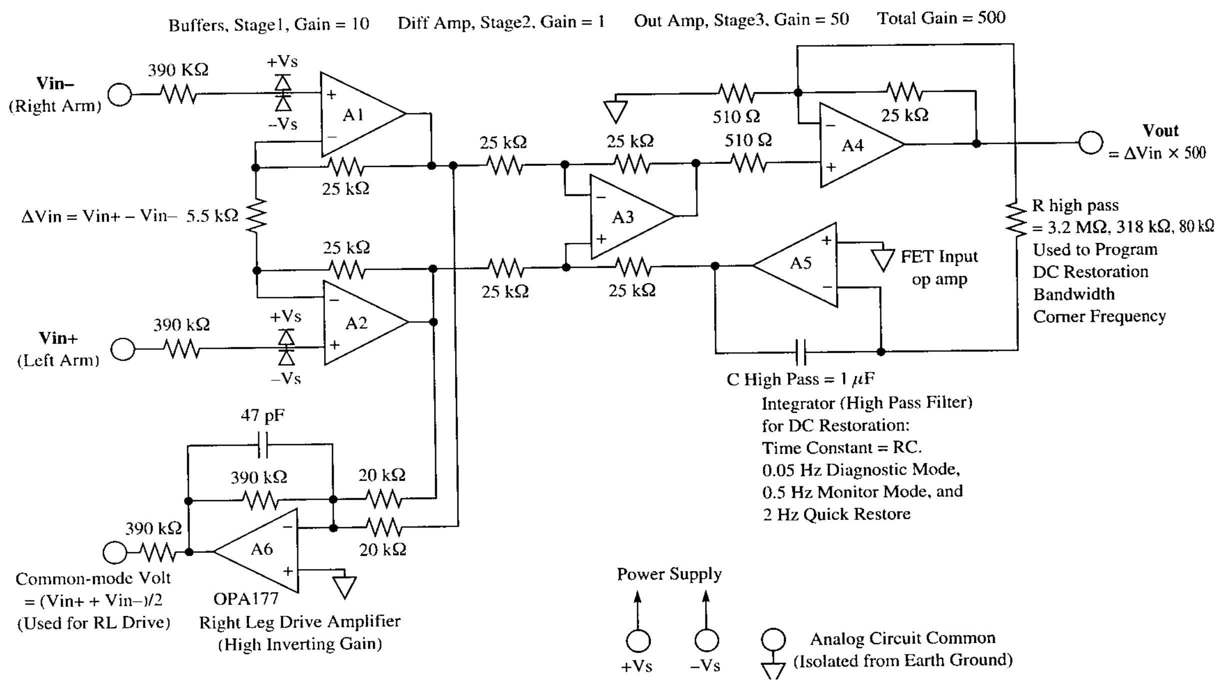

**d) Mention the purpose of the Electosurgery unit (ESU) interference filter. And how it is connected with both the defibrillator protection circuit and the ECG Amp.**

Solved exactly in sections.

**e) List the types of pacemakers and explain their principle of operation.**

See the book

**<u>Question (3):</u>** For the circuit shown below: **[15 Marks]**



a) **Explain the function of the circuit.**

ECG amplifier with common mode voltage cancelation via right leg driven and dc offset voltage cancelation via the use of a DC restorator.

b) **Verify the gain values mentioned for the buffers stage, differential amplifier stage, and the out Amplifier stage.**

Just write the equation of each stage and get the values.

c) **Calculate the output voltage if the input was 1 mVp-p ECG + 300 mV dc offset. [mention the effect of using the integrator A5 (DC restorator)]**

The 300 mV dc offset voltage is canceled via the dc restorator and the 1 mV will be amplified with the gain of 500 (which is the total gain of the circuit) and give an output of 500 mV (0.5 V) peak-to-peak.

## Question (4): [15 Marks]

a) **List the types of defibrillator circuits and explain their principle of operation.**

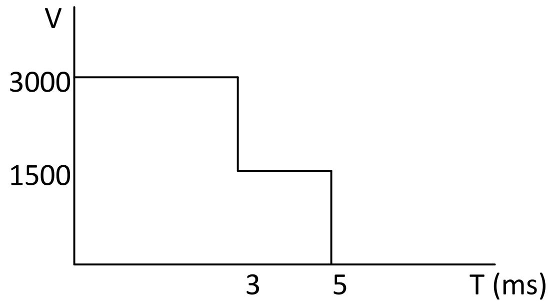
See the book

b) **Differentiate between the defibrillator circuit and the defibrillator protection circuit for the ECG amplifier.**

The defibrillator circuit is a high voltage impulse signal generator that is used to defibrillate the heart fibrillation problem.

The defibrillator protection circuit is a circuit used to protect the ECG amplifier from damage when the defibrillator is used in patient with ECG leads connected.

c) **The voltage pulse delivered to defibrillator paddles attached to a patient is given in the shown figure below. The thorax resistance RT= 50 Ω, what must be the skin-electrode resistance in order that 110J of energy will be delivered to the thorax of the patient? Assume that RD= 10 Ω.**




Solved exactly in sheets

*With best wishes*