Model Answer

Answer the following questions with the aid of drawing and equations as possible.

Question (1): [16 Marks] ***Differentiate between***

a) Bonded and un-bonded strain gauges.

- Draw each of them as seen in your text book.
- Unbonded strain gauges can be constructed so that they are linear over a wide range of applied force but are very delicate.
- The bonded strain gauge is generally more rugged but is linear over a smaller range of forces.

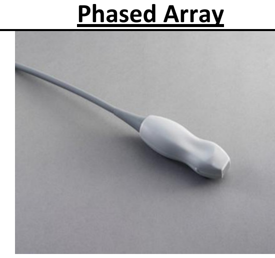
b) Mechanical and electrical ultrasound scanner.

Solve by yourself tacking into consideration that the mechanical scanners are slower than the electrical ones (array of transducers).

c) IMR and CMR.

Solve by yourself taking into consideration the difference between the instrumentation and isolation amplifier.

d) Linear, Phased and Curved ultrasound array of transducers.

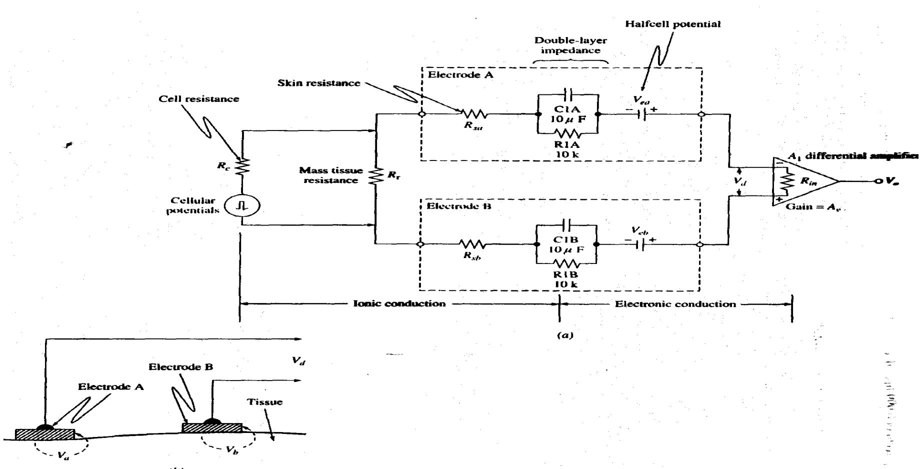
	Linear Array	Curved Array	Phased Array
Shape			
No. of elements	Large	Large	Small
Image shape	Rectangle	Sector	Sector
Imaging range	Small	Large	Large
Resolution	Very good	Very good at near area but at far area it is bad	Very good
Circuit complexity	Simple	Simple	Complex (beamforming)

Question (2): [12 Marks]

1) Solving for the action potential using Nernst and Goldman equations result different values. (true or false and why?).

False → Goldman and Nernst equations are used to solve for the rest potential, not the action potential.

2) Draw the circuit model for two biomedical electrodes produce a differential voltage and attached to a differential amplifier.



3) Draw the glass metal electrode and its equivalent circuit. Explain, why it is used for low frequency signals only? and how to cure this problem.

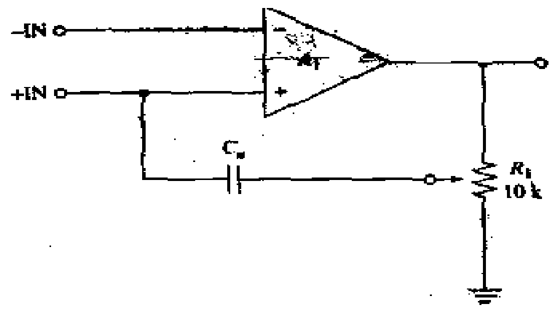
Draw as seen in your text book.

Microelectrodes have very high impedance, so the capacitance with the high impedance makes a low pass filter (LPF); so this electrode is suitable for low frequency bio-signal measurements only.

f=1/2πRC; as R and C increase → f decrease.

Method used for neutralizing the capacitance of the microelectrode and associated circuitry. A neutralization capacitance, C_n is in the positive feedback path along with a potentiometer voltage divider. The value of this capacitance is: $C_n = \frac{C}{A-1}$

Where C_n is the neutralization capacitance
C is the total input capacitance
A is the gain of the amplifier



Capacitance nulling circuit.

Question (3): [12 Marks]

a) Explain how the ultrasound phased array is used to image a sector using the beamforming technique.

Solved exactly in the last lecture.

b) Why ultrasound couldn't be used to image lungs and skeletal system? (Explain with equations)

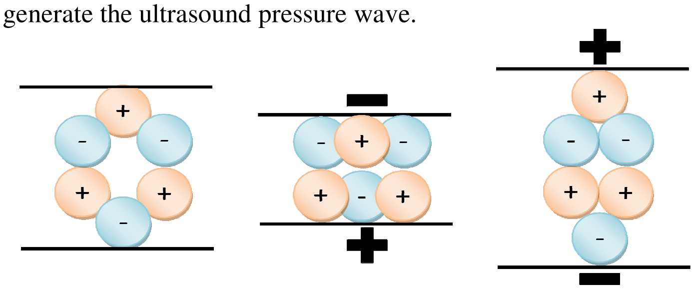
The percentage of energy that is reflected (coefficient of reflection) Γ in the boundary between air and tissue or between bone and tissue is very large (approximately 99.9%) where the difference in acoustic impedance between them is very large;

$$\Gamma = \left(\frac{Z_1 - Z_2}{Z_1 + Z_2}\right)^2$$

So the whole ultrasound beam is approximately reflected and no image is presented.

c) Describe how ultrasound wave is generated, and show how piezoelectric material differ from the piezoresistive one. (give an example of each)

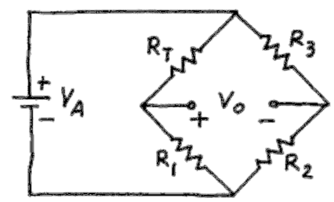
Generation of ultrasound:
The piezoelectric transducer under compression and tension will generate an electric alternating wave and the reverse operation will generate the ultrasound pressure wave.



(a) at rest (b) Compression (c) Tension

Piezoelectric	**Piezoresistive**
Convert electric signal into acoustical wave and vice versa	Convert compression and tension into resistance change
Example: Crystal oscillator (Quartz)	Example: Strain gauges

<u>Question (4):</u> [20 Marks]



1) A thermistor R_T is placed in the Wheatstone bridge as shown. The constant $\beta = 4000\ ^oK$. The resistance of the thermistor is 10 Ω at 37 °C.
   a) Calculate the voltage V_o at 39 °C.
   b) Compute the sensitivity $S = \Delta V_o / \Delta T$ in $V / {}^oC$.

$V_A = 10\ V$, $R_1 = 10\ \Omega$, $R_2 = R_3 = 1000\ \Omega$ and $R_T = R_o e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)}$

T and T_o are in Kelvin, where $T(^oK) = T(^oC) + 273$

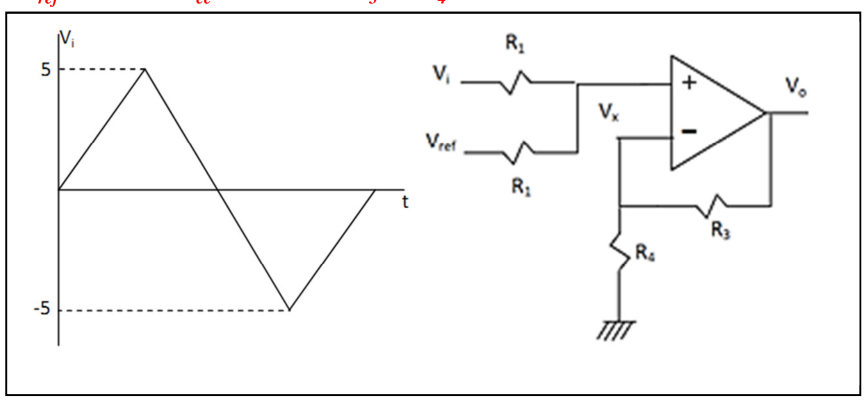
a) $R_T = 10 \cdot e^{4000\left(\frac{1}{273+39} - \frac{1}{273+37}\right)} \simeq 9{,}206\ \Omega$

$V_o = \frac{10}{9{,}206 + 10} \cdot 10 - \frac{10}{2} \simeq \boxed{0{,}207\ V}$

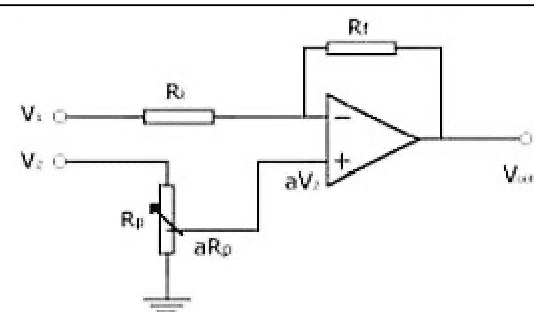
b) $S \simeq \frac{\Delta V_o}{\Delta T} \simeq \frac{0{,}207}{2} \simeq \boxed{0{,}103\ V/^oC}$

2) For the circuit below, draw the output waveform if $V_{ref} = -2V$ and $V_{cc} = \pm 15V$ and $R_3 = 2R_4$.

Draw it by yourself taking into consideration that the feedback is in the -ve terminal, so this is a non-inverting summer where two voltages are summed on the non-inverting terminal. [But take care from saturation].



3) The $CMRR$ is defined as: $\frac{|V_{out}|\ when\ V_2\ is\ grounded}{|V_{out}|\ when\ V_1 = V_2}$
   a) With respect to the amplifier shown drive an expression for the $CMRR$ in terms of R_f and R_i and a.
   b) Find $CMRR$ if $R_f = a\ R_p$ and $R_i = (1 - a)\ R_p$.



$CMRR = \frac{G_D}{G_C}$; $\frac{Differential\ gain}{Common\ mode\ gain}$

When V_2 grounded ➔ inverting amplifier ➔ $G_D = \frac{-R_f}{R_i}$

When $V_1 = V_2$ ➔ $V_+ = aV_2 = aV_1$ ➔ $V_o = \frac{-R_f}{R_i} V_1 + \left(1 + \frac{R_f}{R_i}\right) aV_1$

$$V_o = \frac{-R_f}{R_i} V_1 \left(1 - a\left(1 + \frac{R_i}{R_f}\right)\right)$$

$$G_C = \frac{-R_f}{R_i} \left(1 - a\left(1 + \frac{R_i}{R_f}\right)\right)$$

$$CMRR = \frac{G_D}{G_C} = \frac{1}{1 - a\left(1 + \frac{R_i}{R_f}\right)}$$

if $R_f = a\ R_p$ and $R_i = (1 - a)\ R_p$ then CMRR = 1/0 = ∞