MichiganTech

Spring 2001

BE 3600 BioInstrumentation

Final Exam: 11 May 2001, Friday, 10 AM

ACTUALLY ADMINISTERED **IN CLASS**

This exam:

- Consists of 12 questions,
- Score from this exam will determine 25-30 % of your grade,
- You will have 2 hours to complete the exam,
- Closed books, closed notes, but use of calculators is allowed,
- Please mark your answers on the COVER SHEET,
- Do not forget to write your name.

TEST FORM CODE:

YOUR NAME:_____

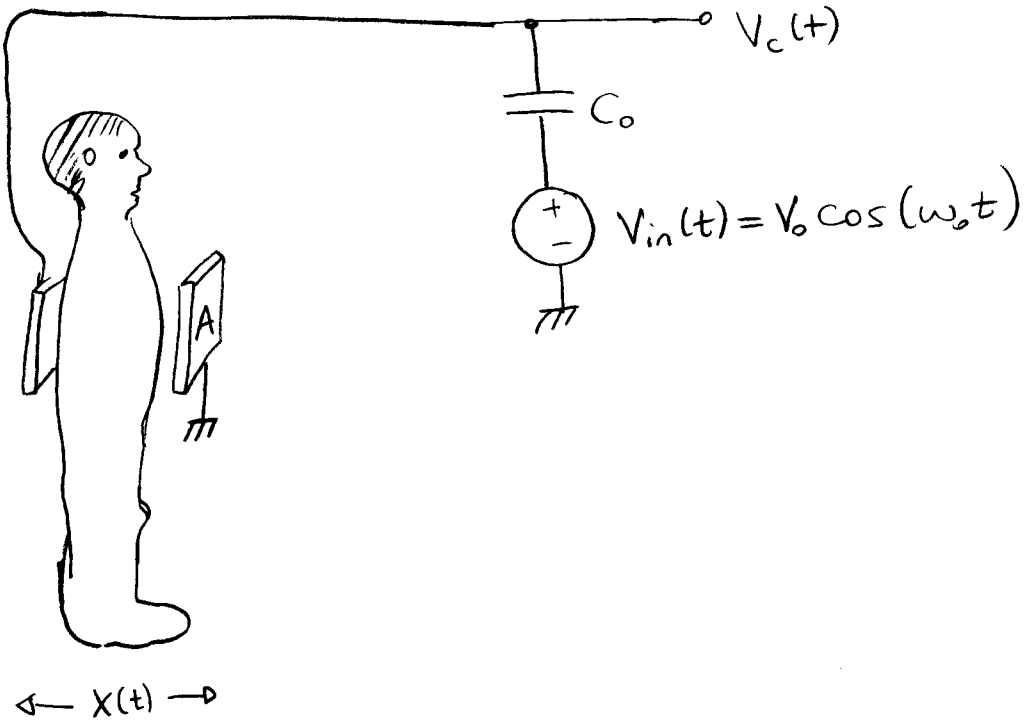
GOOD LUCK!

ANSWERS:

1. ___	5. ___	9. ___
2. ___	6. ___	10. ___
3. ___	7. ___	11. ___
4. ___	8. ___	12. ___

QUESTION 1

A capacitive sensor is being used to measure the thoracic depth to monitor the respiratory activity. A circuitry is formed as shown below where the x is the distance between the plates of the capacitor, hence the thoracic depth. Determine the equation for the output voltage, V_C.



ANSWER:

A) $V_C = V_{in}\dfrac{C_0 X}{\varepsilon A}$

B) $V_C = V_{in}\dfrac{C_0}{X + \varepsilon A}$

C) $V_C = V_{in}\dfrac{C_0 X}{C_0 X + \varepsilon A}$

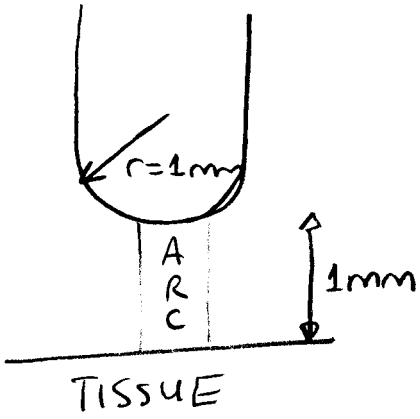
D) $V_C = V_{in}\dfrac{X}{X + \varepsilon A}$

E) $V_C = V_{in}\dfrac{C_0 X + \varepsilon A}{C_0 X}$

CORRECT ANSWER IS "C"

QUESTION 2

Tip of an electrocautery instrument has a radius of curvature of $r = 1\ mm$. It is specified that the electrical arc to cut the tissue will be obtained with 300 Volts, when the tip is 1 mm away from the tissue. If the current flowing through the device is 5 nano amps, what is the cross sectional area of the arc current? (You can assume that it takes 100 nano-seconds for electrons to cross the gap).



ANSWER:

A) 0.377 mm^2

B) 0.753 mm^2

C) 1.130 mm^2

D) 1.507 mm^2

E) 1.883 mm^2 CORRECT ANSWER

QUESTION 3

Input / output relationship of a sensor is given as follows:

y[k] = (0.5) y[k-1] + u[k],

where u[k] is the input, and y[k] is the output.

If the input u[k] is a unit step, determine the output y[k]

ANSWER:

A) $y[k]=\left(\frac{1}{2}\right)^k$, for k≥0

B) $y[k]=2-\left(\frac{1}{2}\right)^k$, for k≥0 CORRECT ANSWER

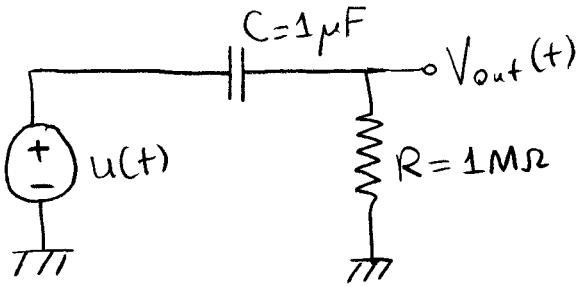
C) $y[k]=2+\left(\frac{1}{2}\right)^k$, for k≥0

D) $y[k]=1-\left(\frac{1}{2}\right)^k$, for k≥0

E) $y[k]=1+\left(\frac{1}{2}\right)^k$, for k≥0

QUESTION 4

A capacitive pressure transducer is setup as shown below



Where u(t) is a step function, R = 1 MΩ, C=1μF (fixed during the test)

If we sample the system with ΔT = 1 milli-sec time steps, what is the discrete time output of this system ($V_{out}[k]$)

ANSWER:

A) $V_{OUT}[k] = e^{-k}$, for k≥0

B) $V_{OUT}[k] = e^{-\frac{k}{1000}}$, for k≥0 CORRECT ANSWER

C) $V_{OUT}[k] = 1 - e^{-k}$, for k≥0

D) $V_{OUT}[k] = 1 - e^{-\frac{k}{1000}}$, for k≥0

E) $V_{OUT}[k] = 1 + e^{-\frac{k}{1000}}$, for k≥0

QUESTION 5

Impulse response of a sensor is given as follows:

$$h(t)=\begin{cases}2, |t|<1\\ 0, |t|\geq 1\end{cases}$$

When an unknown signal *x(t)* is applied to the input, following output was observed:

$$y(t)=\begin{cases}4(1-\frac{|t|}{2}), |t|<2\\ 0, |t|\geq 2\end{cases}$$

Determine *x(t)*

ANSWER:

A) $x(t)=\begin{cases}2, |t|<1\\ 0, |t|\geq 1\end{cases}$

B) $x(t)=\begin{cases}1, |t|<2\\ 0, |t|\geq 2\end{cases}$

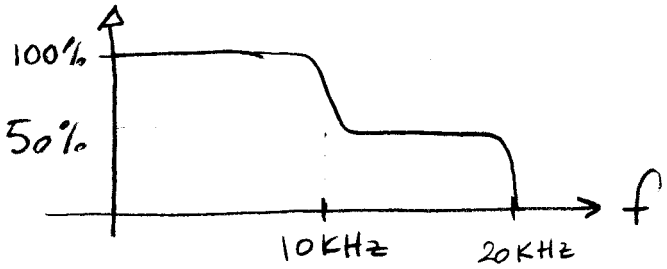
C) $x(t)=\begin{cases}2, |t|<2\\ 0, |t|\geq 2\end{cases}$

D) $x(t)=\begin{cases}1, |t|<1\\ 0, |t|\geq 1\end{cases}$ CORRECT ANSWER

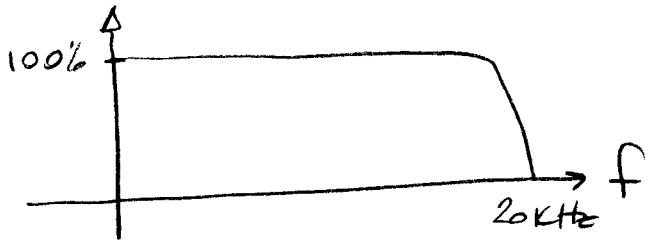
E) $x(t)=\begin{cases}4, |t|<2\\ 0, |t|\geq 2\end{cases}$

QUESTION 6

A patient's audiology report shows the response of her ear is follows:



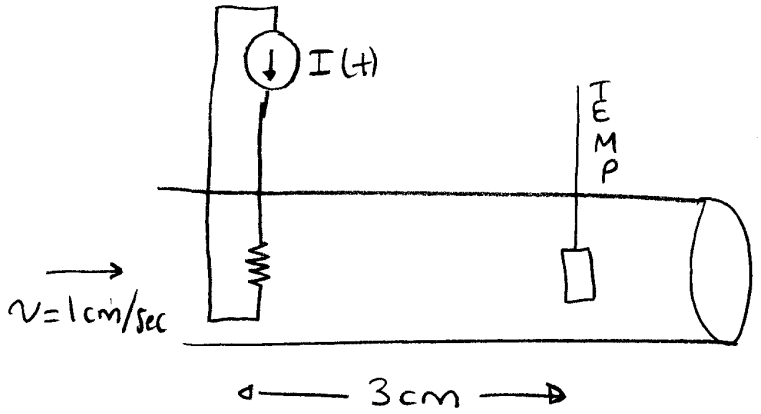
Which filter shown below would restore her hearing to a flat spectrum?



CORRECT ANSWER IS "C"

QUESTION 7

A flow sensor was designed using the principles of thermo-dilution method. Its output is sampled at ΔT = 1 second time steps. Incoming blood is at 37 °C, and has a density of 1 gram / cm^3, and specific heat of 1 cal / °C - grams. If the flow is at 1 cm / sec, heating element has a resistance of 1 Ω, the distance between the heater and the temperature sensor is 3 cm, and the cross sectional area of the artery is 1 cm^2, find the relationship between the output temperature and the current on the heating element (note that 1 calorie = 4.2 Watts).



ANSWER:

A) $Temp[k] = 37^\circ C + \frac{I^2[k-3]}{4.2} x100$

B) $Temp[k] = 37^\circ C + \frac{I^2[k-3]}{4.2}$ CORRECT ANSWER

C) $Temp[k] = 37^\circ C + \frac{I^2[k-300]}{4.2} x100$

D) $Temp[k] = 37^\circ C + \frac{I^2[k-300]}{4.2}$

E) $Temp[k] = 37^\circ C + \frac{I^2[k]}{4.2} x100$

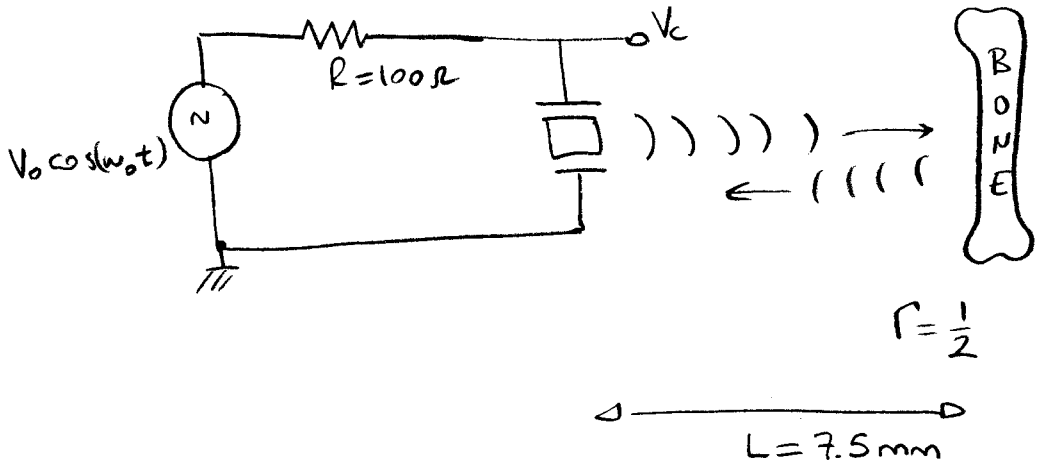
QUESTION 8

A piezo-electric transducer works with the following equation

$V = g\,P$, where V is the voltage on the transducer, P is the pressure, and g is a constant and equal to 1.

This transducer is used for ultrasound imaging and can simply be modeled as a capacitor, C = 1 μF. If the entire system is configured as shown below, what is the peak amplitude of the voltage on the transducer, V_C

(You can neglect the attenuation in the tissue. Reflection coefficient for the tissue-bone interface is given as $\Gamma = 0.5$. Voltage source generates a voltage of $V_0 \cos(\omega t)$, where f = 100 KHz, and $V_0 = 10\ Volts$. Distance between the transducer and the bone is *7.5 mm*. Assume that the speed of sound in tissue is 1,000 meters per second.)



ANSWER:

A) 297.5 mV

B) 318 mV

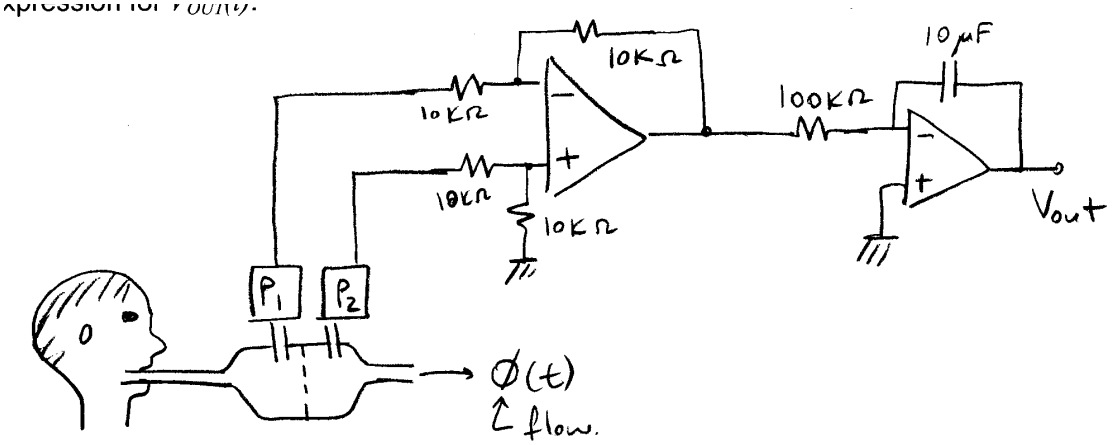
C) 238.5 mV

D) 159 mV

E) 79.5 mV CORRECT ANSWER

QUESTION 9

A pneumotachograph is an instrument to measure the respiration of a patient and shown in the diagram below. Pressure sensors P_1 and P_2 have gain of 1, i.e. $V=P$ (voltage output is equal to pressure input). These two transducers are placed on either side of a fine mesh with resistance to flow R. Determine the expression for $V_{OUT}(t)$.



ANSWER:

A) V_{OUT} = *Ramp*

B) V_{OUT} = *Unit Step*

C) $V_{OUT} = -(P_2-P_1)$

D) $V_{OUT} = \Phi(t)$

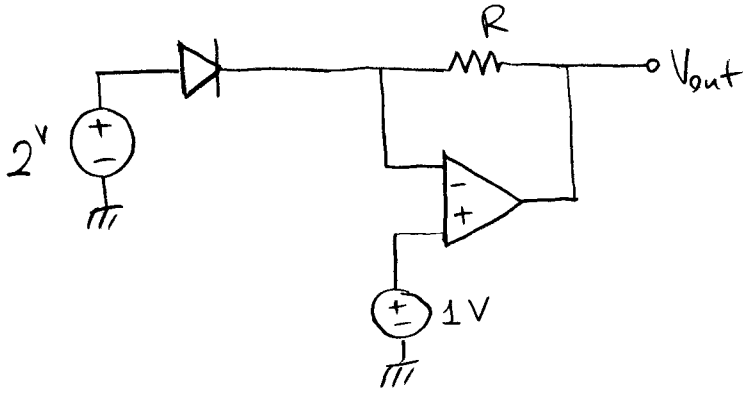
E) V_{OUT} = *Respiratory Volume* (CORRECT ANSWER)

QUESTION 10

A diode can be used as a temperature sensor. Relationship between the current and voltage is given as follows:

$I = Ae^{\frac{qV - E_g}{kT}}$ where I is the current, V is the voltage, E_g and k are constants and T is the temperature.

Find the output of the circuit shown below.



ANSWER:

A) $V_{OUT} = 1 + A\mathrm{Re}^{\left(\frac{q-E_g}{kT}\right)}$ CORRECT ANSWER

B) $V_{OUT} = \frac{1}{q}\left(kt\ln\left(\frac{V}{RA}\right) + E_g\right)$

C) $V_{OUT} = 2 + A\mathrm{Re}^{\left(\frac{q-E_g}{kT}\right)}$

D) $V_{OUT} = \frac{2}{q}\left(kt\ln\left(\frac{V}{RA}\right) + E_g\right)$

E) $V_{OUT} = \frac{2}{q}\left(kt\ln\left(\frac{V}{RA}\right) + E_g + 1\right)$

QUESTION 11

Filter shown below is running with input signal sampled at ΔT = 1 milli-second time steps. What frequencies are removed from the input signal.

$y[n] = \sum_{k=0}^{7} x[n-k]$ where x is the input, and y is the output.

ANSWER:

A) 50 Hz and 60 Hz

B) 125 Hz and 250 Hz CORRECT ANSWER

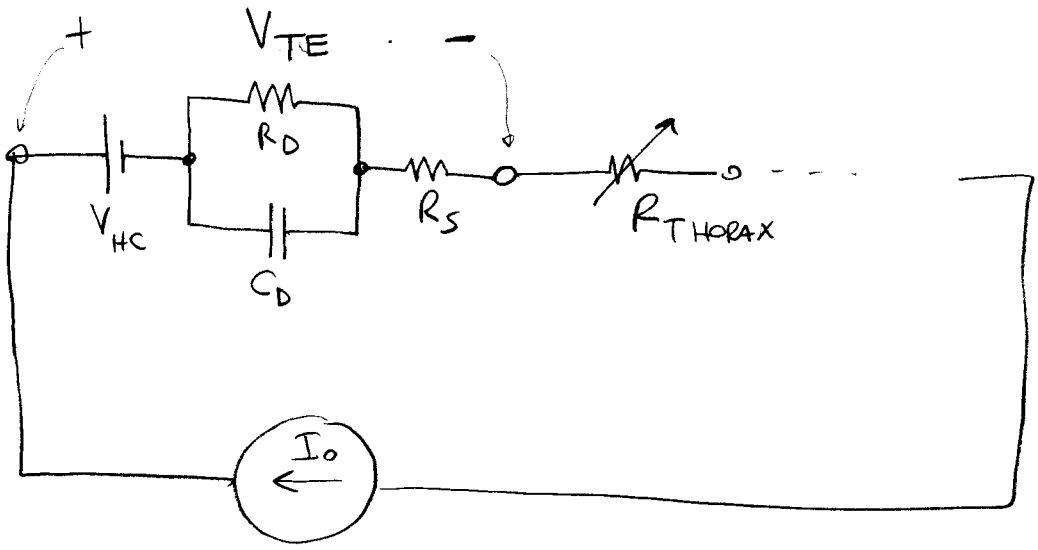
C) 50 Hz

D) 60 Hz

E) 60 Hz and 180 Hz

QUESTION 12

A transthoracic impedance monitor utilizes DC excitation to measure the chest impedance. Find out the voltage drop on one of the electrode-electrolyte interfaces (V_{TE}) if the excitation is I_0.



ANSWER:

A) $V_{TE} = V_{HC} + I_0(C_D + R_D + R_S)$

B) $V_{TE} = V_{HC} + I_0(1/C_D + R_D + R_S)$

C) $V_{TE} = V_{HC} + I_0(j/C_D + R_D + R_S)$ *where* $j^2 = -1$

D) $V_{TE} = V_{HC} + I_0(R_D + R_S)$ CORRECT ANSWER

E) $V_{TE} = \infty$