L-3/T-1/BME

Date: ~~18/04/2024~~ 19/05/2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **BME 101** (Introduction to Biomedical Engineering)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Question No. 1 is **MANDATORY**. Answer any **TWO** of the remaining **THREE** questions.

1. (a) Briefly explain how one can control gene expression. **(15)**

(b) Describe the various stages of the cardiac cycle and illustrate how pressure and volume changes take place. **(15)**

(c) Consider a patient undergoing a renal clearance test for substance Y. During the test, the patient's urine flow rate is measured to be 2 mL/min. The concentration of substance Y in the patient's plasma is 10 mg/dL, and the concentration of substance Y in the patient's urine is 5 mg/dL. Calculate the renal clearance of substance Y for this patient. **(15)**

2. (a) Explain the basic principle of fluorescence microscope with schematic. **(12)**

(b) Which one is the most important component of x-ray imaging system? With schematic describe the working principal of that. **(13)**

(c) Write down the clinical applications of ultrasound imaging. **(5)**

3. (a) Molecular docking is an important step in drug discovery. How do you quantitatively calculate the affinity of a drug with a protein based on experiments? Include all necessary derivations. **(15)**

(b) A cylindrical blood vessel with a length of 10 cm and a radius of 0.1 cm has a flow rate of 5 mL/s. The viscosity of blood is 0.04 poise. Calculate the pressure drop across the blood vessel **(15)**

4. (a) Briefly describe different pathological conditions where gas exchange in the alveoli is affected, and provide the underlying cause of why the gas exchange is affected. **(15)**

(b) Briefly describe the different features of the innate and adaptive immune systems. **(15)**

Contd P/2

SECTION – B

There are **FOUR** questions in this section. Question No. 5 is **MANDATORY**.

Answer any **TWO** of the remaining **THREE** questions.

5. (a) The tibia is the major weight-bearing bone in the lower extremity. If 88% of body mass is proximal to the knee joint, how much compressive force acts on each tibia when a 500 N person stands on only on his/her right leg? How much compressive force acts on each tibia if the person holds a 20 N sack of groceries? **(16)**

   (b) Discuss the comparative advantage and disadvantage of synthetic and natural polymer. **(9)**

   (c) Explain the working principal of pulse oxiometer? **(11)**

   (d) What is the difference between PET and SPECT scan? **(9)**

6. (a) Explain the stages of wound healing with appropriate schematic. **(12)**

   (b) Draw a schematic of wetspinning setup. **(6)**

   (c) With example, write short notes on the classes of medical devices. **(12)**

7. (a) What is the clinical significance of neutral buoyancy? **(9)**

   (b) Is blood a Newtonian fluid? Draw shear stress vs shear rate graph of blood, plasma and water. **(12)**

   (c) What defines a stem cell? **(9)**

8. (a) What are the 12 leads of ECG? How 10 electrodes are used to measure ECG signals? **(16)**

   (b) With schematic mention what are the sensors involved in a dialysis machine? **(14)**

L-3/T-1/BME Date: ~~20/04/2024~~ 13/05/2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **BME 303** (Biomedical Instrumentation and Measurements)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

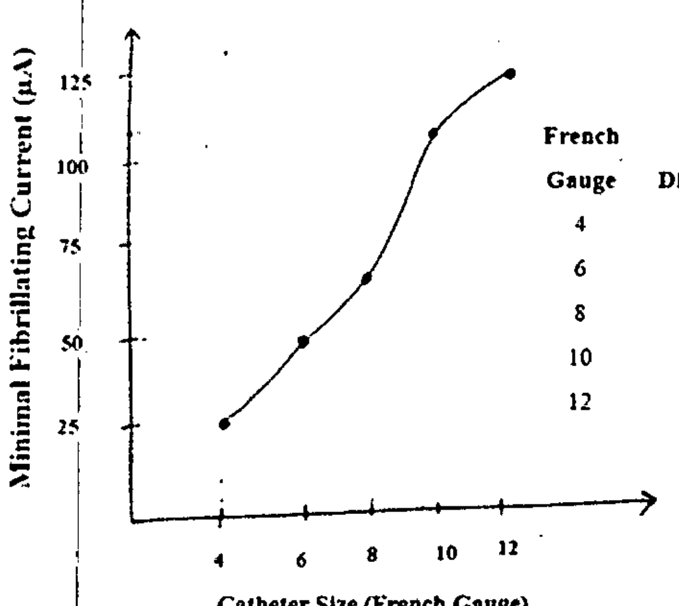
USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Question No. 1 is **MANDATORY**.
Answer any **TWO** of the remaining **THREE** questions.

1. (a) For a piezoelectric sensor plus cable system that has 1 nF capacitance, design a voltage amplifier by using only one non-inverting amplifier that has a gain of 10. It should handle a charge of 1 μC generated by the carotid pulse. It should not drift into saturation because of bias currents, and it should have a frequency response from 0.05 Hz to 100 Hz. The amplifier enters saturation when output voltage exceeds 15 Volts. Add minimal number of extra components to achieve the design specifications. **(15)**

(b) Determine the resistivity of the liquid necessary for safe operation of a liquid-filled catheter that is 1.5 m long, and has an outer diameter of 2 mm. Use the data provided in Figure: Question 1(b). Assume that the patient is grounded and that a 120 V fault develops at the sensor. **(15)**



French Gauge	Inner Diameter (mm)	Outer Diameter (mm)
4	1	1.333
6	1.5	2
8	2.25	2.667
10	3	3.333
12	3.75	4

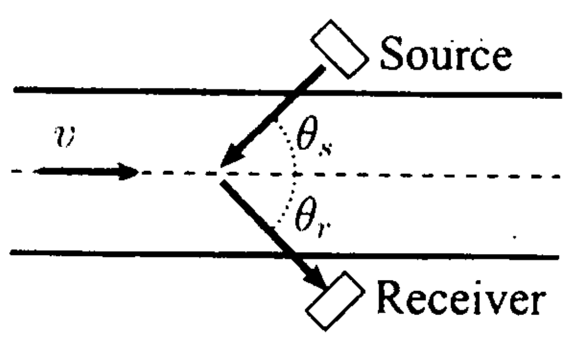
Figure: Question 1(b)

(c) With appropriate diagrams, explain the origin of Korotkoff sounds, and how a doctor can determine systole and diastole systole blood pressure based on these sounds. Also mention the disadvantages of using catheter-tip sensors to measure blood pressure. **(15)**

2. (a) **(15)**

i. To assess the cardiovascular health of a patient, a doctor asks you to determine the cardiac output of a patient. So, you apply a 0.5 T magnetic field across the diameter (1.6 cm) of a blood vessel. As a result, a voltage potential of 30 mV forms across the vessel diameter, perpendicular to the magnetic field. From this information, calculate the volumetric blood flow rate of the patient through the vessel.

ii. The above-mentioned method was invasive in nature. To determine cardiac output in a much less invasive method, you decide to involve a 1 MHz ultrasonic transceiver on another blood vessel of the patient the cross-sectional area of which is 2 cm^2, as shown in <u>Figure: Question 2(a)</u>. With $\theta_r = \theta_s = 30^\circ$, you detect a frequency shift of 1200 Hz. Assuming speed of sound in blood to be 1500 m/s, what would be the calculated volumetric blood flow rate through the vessel in this method?



<u>Figure: Question 2(a)</u>

iii. Next, the doctor wants to know the partial pressure of CO_2 in the patient's blood. So, you submerge a pH electrode, and a P_{CO2} electrode into the patient's blood sample. Blood pH is found to be 6.9. Previously, you had calibrated the carbon dioxide electrode to 40 mmHg at blood pH of 7.4. What would the doctor now find the partial pressure of CO_2 to be in the patient's blood sample?

(b) Explain the working mechanism of pneumotachometers. Discuss the trade-offs that exist in the design and use of these sensors. **(15)**

3. (a) Consider the temperature transducer shown in <u>Figure: Question 3(a)</u>, with constant supply voltage $V_s = 1$ V, a first thermistor R_1 with nominal resistance R_{nom} and temperature coefficient α_1, a second thermistor R_2 with same nominal resistance but with complementary temperature coefficient $\alpha_2 = -\alpha_1$, and two identical resistors $R_3 = R_4 = R$. The transducer produces a differential output voltage V_o in response to temperature T acting on both thermistors. **(15)**

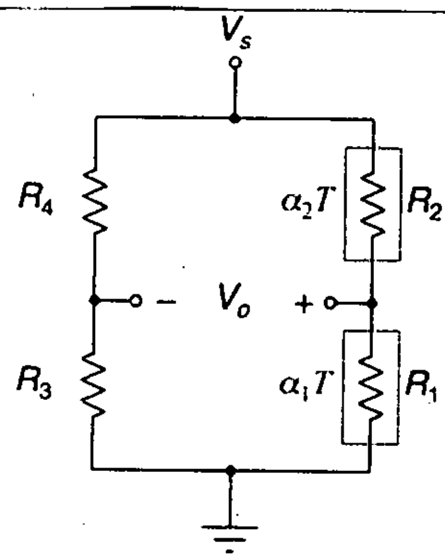


Figure: Question 3(a)

i. Find the output voltage V_o as a function of temperature T.

ii. Suppose the transducer is flexible and mounted on the skin of a patient to monitor body temperature. Due to stretching during movement, the thermistors and resistors are all subject to the same strain ε. If all four resistances have the same strain gauge factor G, show that the voltage response of the transducer is insensitive to strain.

iii. The wearable sensor is powered by a lithium-ion battery which is subject to voltage variations. How do the offset and sensitivity change for a 10% drop in the voltage supplied by the battery? Explain.

(b) Mathematically show how helium (He) dilution method is used to estimate functional residual capacity (FRC) of lung. Suppose, in an He-dilution experiment, a 10-liter spirometer is preloaded with 5% He at room temperature (25°C). After the patient has rebreathed, the He concentration in spirometer is found to be 4% at 305 K. Now calculate FRC of the subject. **(15)**

4. (a) With mathematical analysis, explain how physicians can assess valvular stenosis by measuring the pressure gradient across the valve of interest and flow through it. Suppose, a patient's cardiac output and heart rate are measured to be 6 L/min, and 65 bpm, respectively. Calculate the approximate area of the aortic valve for the patient if average pressure drops by 50 mmHg during the ejection period of 0.25 seconds. Assume that blood density is 1050 kg/m^3, and discharge coefficient for semilunar valves is 0.85. **(15)**

(b) Name the basic safety and essential performance standard for medical electrical equipment. How does this standard classify medical electrical equipment according to the used method of protection against electric shock? Provide example of each class. **(15)**

SECTION – B

There are **FOUR** questions in this section. Question No. 5 is **MANDATORY**.

Answer any **TWO** of the remaining **THREE** questions.

5. (a) Describe the fabrication process of Parylene-based neural electrodes. How do these neural probes differ from conventional neural microelectrodes in terms of efficiency, lifetime and biocompatibility? **(15)**

(b) How can you apply your understanding of biosensor fabrication techniques to develop a sensor that accurately measures blood pH levels? **(15)**

(c) Figure for Question 5(c) demonstrates a block diagram of a cardiac pacemaker. Are there any limitations associated with this particular type of pacemaker? If so, how can these limitations be addressed or overcome? **(15)**

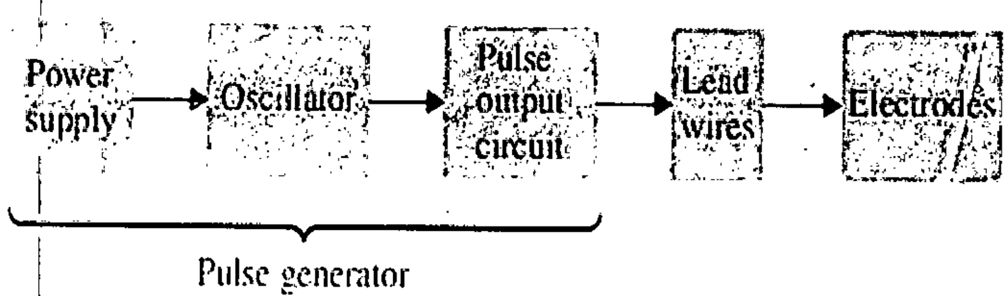


Figure: Question 5(c)

6. (a) Illustrate a block diagram of a basic arrhythmia monitoring system. Explain how this system detects Ventricular Fibrillation. **(10)**

(b) A cardiac pacemaker delivers 5V pulses of 2 ms duration to bipolar electrodes that can be approximated as being a 2 kΩ resistive load. The mean pulse rate of the pacemaker is 70 per minute. The pulses represent 25% of the energy consumed by the pacemaker. The pacemaker is powered by two Lithium cells connected in series to give a voltage of 5.6 volts. What is the minimally acceptable capacity for each cell or continuous operation lasting 20 years? **(10)**

(c) Consider the following amplifier circuit with resistances R1 = 1 kΩ, R2 = R3 = 10 kΩ, R4 = 1 MΩ, R5 = 100 kΩ, and R6 = 1 kΩ. You may assume that the op-amp is ideal and not saturated. Find the output voltage V_{out} as a function of input voltage V_{in}. **(10)**

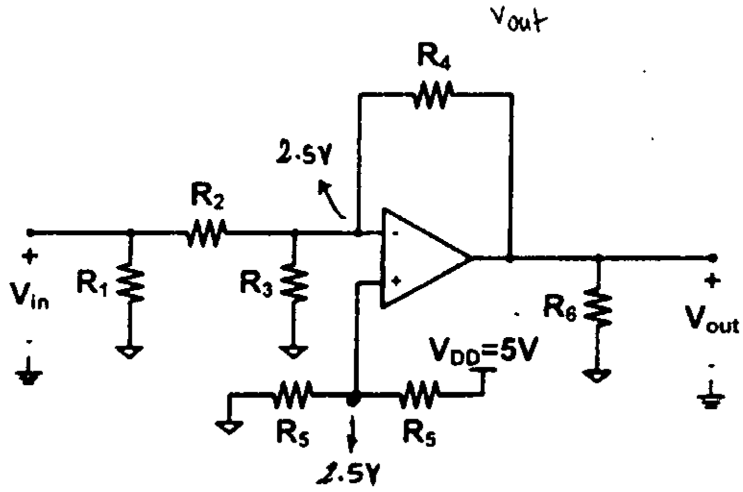


Figure: Question 6(c)

7. (a) You just landed an internship at a major bio-instrumentation company. Your first assignment is to design an infant ECG device with the following specifications: **(20)**
   - Band-pass filtering between 0.1 Hz and 1 kHz corner frequencies.
   - Amplification of the 1 mVpp ECG differential signal by 60 dB.
   - Level-crossing detection to produce a square wave output signal at the

heartbeat frequency.

You have two electrodes, a single 2.5 V battery, ideal op-amps, and any required resistors and capacitors. Be sure to label all components, inputs, outputs, and needed values.

(b) You are given a biomedical instrument that measures strain and produces a digital reading on an output display. The instrument transduces the strain into a voltage, and digitizes this voltage by a 10-bit analog-to-digital converter (ADC). The transducer voltage as a function of strain is shown in the graph below, and the ADC full-scale voltage range is from 0 V to 1 V. **(10)**

(i) Find the sensitivity of the strain-to-voltage transducer and the range of strain over which it operates.
(ii) Find the resolution of the instrument and the range of strain over which it produces a valid digital reading.
(iii) The transducer for known strain values produces a voltage that on average is 0.05V lower than expected and with a standard deviation of 0.01V. Find the relative accuracy and precision of the instrument.

8. (a) Which cable configuration, as depicted in Figure for Question 8(a), would be more advantageous for an ECG acquisition system, and what are the reasons for this preference? **(10)**

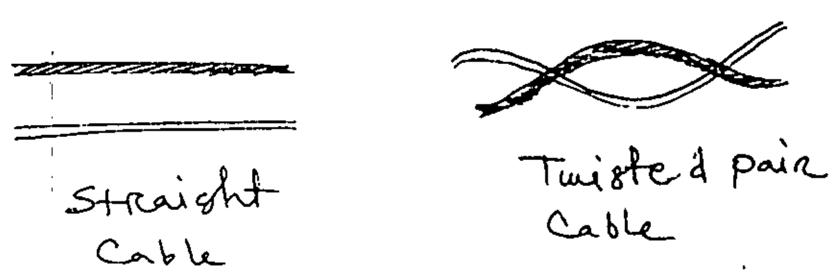


Figure: Question 8(a)

(b) A typical EMG bio-amplifier circuit is given below. You may assume that the op-amps are ideal and not saturated. **(20)**

(i) Find the transfer function $H(jw) = V_{out}(jw) / V_{in}(jw)$.
(ii) Find the maximum gain, low cut-off frequency, and high cut-off frequency of the filter response for $R_1 = R_1' = 10$ kΩ, $R_f = R'_f = 1$ MΩ, $R = 1$ MΩ, $R' = 10$ kΩ, $R_L = 100$ kΩ, and $C = C' = 100$ nF. Sketch the Bode plot (log amplitude and phase as a function of log frequency).

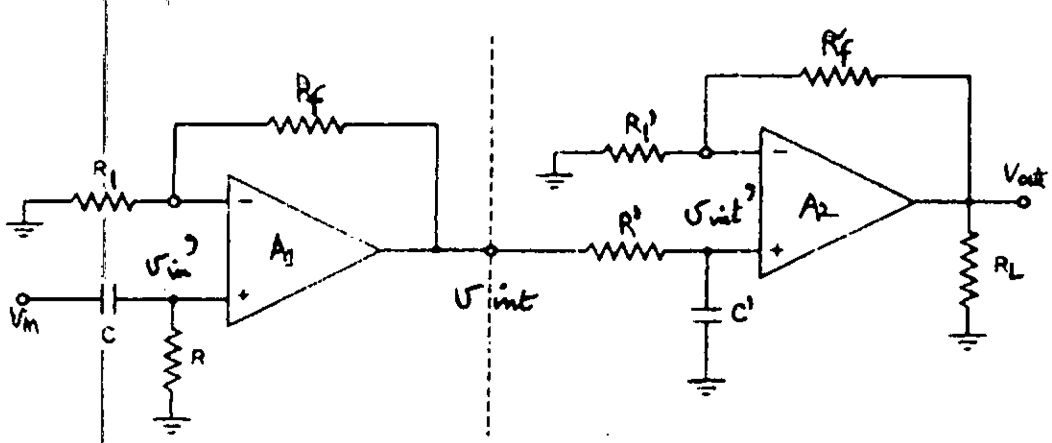


Figure: Question 8(b)

L-3/T-1/BME **Date : ~~25/04/2024~~** 26/5/24

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub : **BME 309** (Quantitative Physiology)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

Question 1 is **MANDATORY**. Answer any **TWO** of the remaining **THREE** questions.

1 (a) During respiration, given the normal value of CO_2 production rate, Q_{CO_2} = 200 mL.min^{-1} (STPD), tidal volume, V_T = 510 mL (BTPS), anatomic dead space, V_D = 150 mL (BTPS), and respiratory rate, V_R = 12 min^{-1}. During exercise, Q_{CO_2} increased to 1000 mL.min^{-1} (STPD), and V_R increased to 20 min^{-1}. **15**

i. What would V_T be if P_{ACO_2} did not change?

ii. If R = 0.8 calculate P_{AO_2} (assuming that P_{ACO_2} = 40 mmHg).

(b) The filtration and secretion rate of PAH are as follows: **15**

$$R_F = 1.2 * [P_{PAH}] \qquad R_s = \begin{cases} 4.8 * [P_{PAH}] & R_s \leq 80 \\ 80 & otherwise \end{cases}$$

Explain the titration and clearance plots of PAH with respect to the plasma PAH concentration (mg.dL^{-1}).

(c) Identify the status of various points in the $pH - HCO_3^-$ diagram as shown in Figure: Question 1(b) and how the body responds to partially and completely compensate each of them. **15**

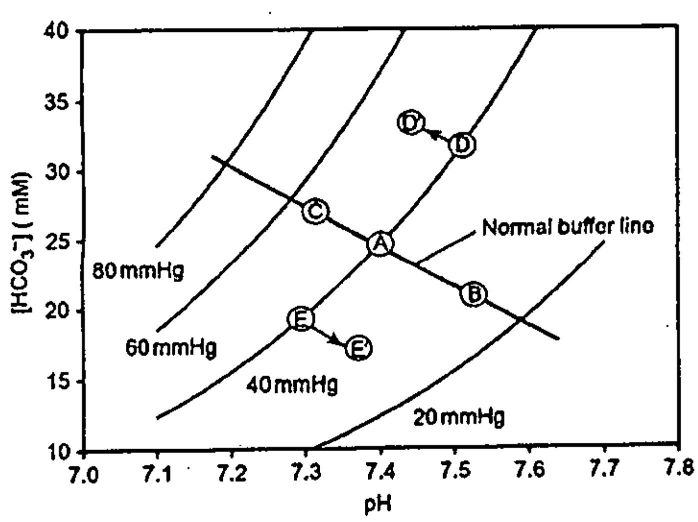


Figure: Question 1(b)

2 (a) To determine the extracellular fluid (ECF) of a person, you infused inulin in the body at a constant rate (i.e., Rate of infusion = Rate of excretion). The profile of the plasma inulin concentration is shown in Figure: Question 2(a). You maintained the plasma inulin concentration at steady state until the person urinated and emptied his bladder (after 2 hours). Immediately you stopped infusion and the plasma inulin concentration decreased as $C(t) = C_o(1 - \frac{1}{10}t)$ mg/L. As inulin is freely filtered by kidney, we can assume plasma inulin concentration, $[P_{in}]$ = urine inulin concentration, $[Ui_n]$. The flow rate of urine, Q_u = 2.8 L/hr and the steady-state concentration of inulin, C_o = 20 mg/L. Determine the ECF (L) of the person? **15**

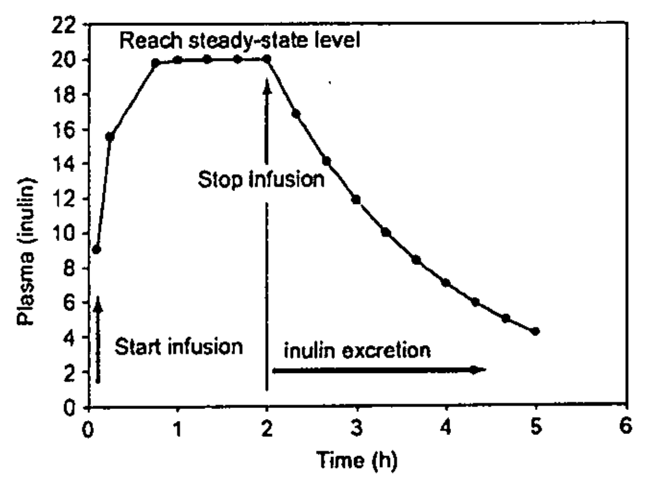


Figure: Question 2 (a)

(b) What are the effects of the following cases on O_2 dissociation curve compared to the normal condition? Explain the reasons behind the effects as well. **15**

(i) Effect of $[H^+]$ (ii) Effect of CO_2 (iii) Effect of body temperature

3 (a) In light of gas transport in respiratory physiology, explain the statement "Haldane effect is the converse of the Bohr effect." **15**

(b) Derive the Gibbs-Donnan equilibrium ratio and determine the potential across the capillaries. Here, R = 8.314 J.mol^{-1}K^{-1}. **15**

4 (a) Explain mathematically why is physiological dead space always larger than anatomic dead space? **10**

(b) At rest, the rate of CO_2 production is about 200 mL.min^{-1}, STPD; tidal volume is 0.51 L, anatomic dead space is about 150 mL, and respiratory rate is about 12 min^{-1}. Calculate the partial pressure of oxygen at alveoli, P_{AO_2}. **8**

(c) Suppose the following test results were obtained from a patient over a 24 hours period: **12**

Contd P/3

Urine volume = 1.5 L

Urine [inulin] = 100 mg%

Urine [urea] = 215 $mmolL^{-1}$

Urine [PAH] = 70 $mgmL^{-1}$

Plasma [inulin] = 2 mg%

Plasma [urea] = 5 $mmolL^{-1}$

Plasma [PAH] = 0.2 $mgmL^{-1}$

Calculate the following values:

i. Clearance of C_{inulin}, C_{urea}, C_{PAH}.

ii. ERPF

iii. The rate of PAH filtration, excretion, and secretion?

BME 309

SECTION - B

Question 5 is **MANDATORY**. Answer any **TWO** of the remaining **THREE** questions.

5. (a) Describe the three-element Windkessel model of the heart, outlining its components and what they represent. Subsequently, establish the corresponding mathematical relationship between pressure and flow. **(10)**

(b) Discuss the limitations of using indicator dilution method for estimating cardiac output. To circumvent the problems of indicator dilution method, suppose a physician is using the rapid-injection thermodilution method of finding a patient's cardiac output. Compute the cardiac output from the following data. **(10)**

$$V_i = 10\,\text{ml},\ \Delta T_i = -30\,\text{K}$$
$$\rho_i = 1005\,\text{kg/m}^3,\ c_i = 4170\,\text{J/(kg}\cdot\text{K)}$$
$$\rho_b = 1060\,\text{kg/m}^3,\ c_b = 3640\,\text{J/(kg}\cdot\text{K)}$$
$$\int_0^{t_1} \Delta T_b dt = -5.0\,\text{s}\cdot\text{K}$$

(c) Determine if either of the subjects of Figure: Question 5(c) have lung disease or not. If yes, is it obstructive or destructive? **(10)**

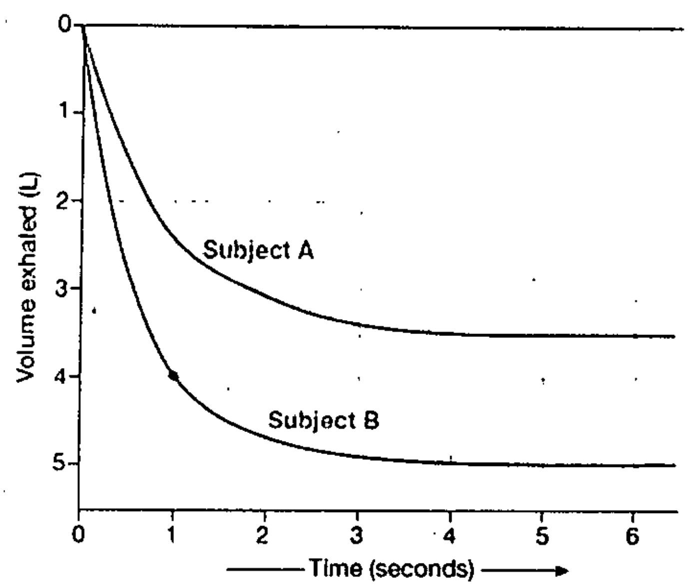


Figure: Question 5(c)

(d) Answer the following questions. **(15)**

i. Suppose the last time you gave blood, your Hct was 40% and your hemoglobin was 14 g%. That was about 3 months ago. In the blood bank, they determined you are type A negative. Suppose you have been in an accident and your doctors suspect internal bleeding. They took a sample of your blood and found a Hct of 25%. What would you expect your hemoglobin to be now?

ii. During exercise, an athlete consumed 1.0 L of O_2 per min. Arterial content of O_2 was 20.5 mL% and mixed venous blood had 12.5 mL%. What is the athlete's cardiac output during exercise?

iii. A normal individual experiences a deep cut that severs the radial artery near the elbow. Ignoring air resistance, approximately how high will the blood

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spurt? Assume that specific gravity of blood is 1.050 g cm^{-3} and the specific gravity of mercury is 13.6 g cm^{-3}).

6. (a) With appropriate assumptions and diagrams, derive the law of Laplace with the assumptions of heart being (i) a thin walled sphere, and (ii) a thick walled sphere. Using the Law of Laplace, mathematically show that dilated hearts get hypertrophied, i.e., they develop thicker walls. **(20)**

   (b) From the lung parameter values given below, calculate inspiratory reserve volume (IRV), expiratory reserve volume (ERV), residual volume (RV), and draw an approximate spirometry trace in your answer script. Also label the various lung volumes and capacities. **(10)**

   Tidal volume = 450 mL; Functional residual capacity = 2350 mL;
   Vital capacity = 4750 mL; Total lung capacity = 5900 mL.

7. (a) Figure: Question 7(a) shows lung volume vs. transpulmonary pressure graphs for three different conditions. What can you determine from these graphs? What might the conditions A and B be? Explain your answer. **(12)**

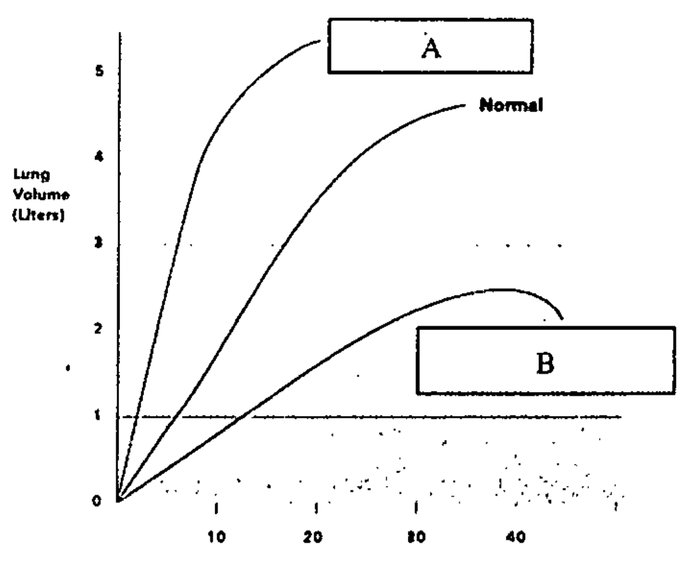

Figure: Question 7(a)

   (b) Suppose the following values are obtained for a specimen of venous blood: mean cell volume (MCV) = 90 μm^3, hematocrit (Hct) = 40%, and mean corpuscular hemoglobin content = 30 pg. Compute the red blood cell (RBC) count, and mean corpuscular hemoglobin concentration (MCHC). Comment on the characteristics of RBCs. **(10)**

   (c) Identify the heart's contractile events in the Wigger diagram shown in Figure: Question 7(c). **(8)**

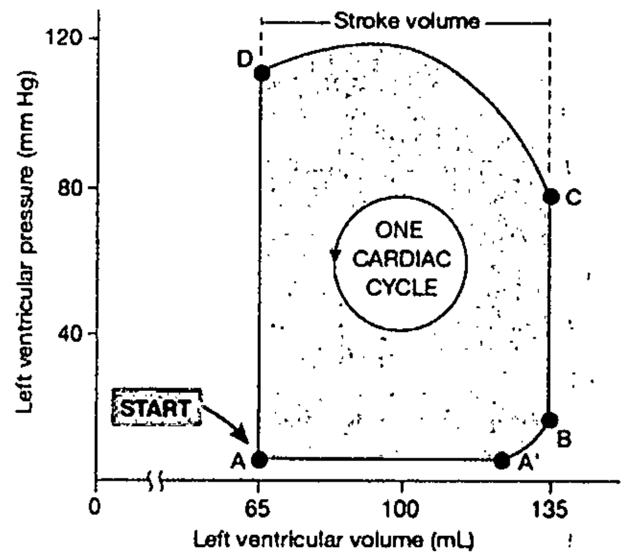

Figure: Question 7(c)

8. (a) A pulmonologist advises you to measure the functional residual capacity (FRC) of your lungs using a whole body plethysmograph. Upon inquiring, you get to know the following. The whole body plethysmograph method consists of a refrigerator-sized, air-tight chamber in which the patient can sit comfortably and which is usually transparent so that the patient can see the operator and vice versa. The patient breathes through a tube connected to a pneumotach, which can measure airflow and pressure at the mouthpiece and which is fitted with a shutter. After a normal expiration, the shutter closes and the patient pants against the closed shutter, while simultaneously holding the cheeks in with the hands. The pressure at the mouthpiece is recorded. **(15)**
The pressure goes up and down cyclically due to the panting effort. When the pressure goes up, the gas remaining in the lung is compressed and volume is decreased. The decrease in volume of the thoracic cavity is accompanied by an increase in volume outside the body, in the chamber. Now, if the volume change measured by the body plethysmograph is 71 mL and the pressure change measured at the mouthpiece was 20 mmHg, what would the FRC be? Note that the vapor pressure of water remains unchanged. Make necessary assumptions if required.

(b) Assume a ~~normal~~ healthy female has a resting tidal volume of 400 mL, a respiratory rate of 13 breaths/min, and an anatomic dead space of 125 mL. When she exercises, which of the following scenarios would be most efficient for increasing her oxygen delivery to the lungs? Explain the outcome of each scenario to reach your verdict. **(10)**

i. Increase of respiratory rate to 20 breaths/min but no change in tidal volume
ii. Increase of tidal volume to 550 mL but no change in respiratory rate
iii. Increase of tidal volume to 500 mL and respiratory rate to 15 breaths/min

Which of these scenarios is most likely to occur during exercise in real life?

(c) With appropriate diagrams, explain how sympathetic stimulation accelerates heart rate via positive chronotropic effect. **(5)**

L-3/T-1/BME Date: ~~31/03/2024~~ 20|05|2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **BME 311** (Biomedical Signals and Systems)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Question No. 1 is **MANDATORY**. Answer any **TWO** of the remaining **THREE** questions.

1. (a) If the two halves of one period of a periodic signal are identical in shape except that one is the negative of the other, the periodic signal is known to have a half-wave symmetry. If a periodic signal $f(t)$ with a period of T_o is half-wave symmetric, then $f\left(t-\frac{T_0}{2}\right) = -f(t)$. **(20)**

(i) In this case, show that all the even numbered harmonics vanish, and the odd numbered harmonics are given by:

$$a_n = \frac{4}{T_0}\int_0^{\frac{T_0}{2}} f(t)\cos(n\omega_0 t)\,dt \qquad \text{and} \qquad b = \frac{4}{T_0}\int_0^{\frac{T_0}{2}} f(t)\sin(n\omega_0 t)\,dt$$

(ii) For the biphasic signal $f(t)$ defined below within the time window $[0,\ 2\pi]$, first draw its waveform and determine if its half-wave symmetric.

$$f(t) = \begin{cases} \exp\left(-\frac{t}{10}\right); & 0 \le t \le \pi \\ -\exp\left(-\frac{t-\pi}{10}\right); & \pi < t \le 2\pi. \\ 0; & \text{Otherwise} \end{cases}$$

(iii) If the signal is half-wave symmetric, then using the results obtained in part (i) above, find the trigonometric Fourier series coefficients of $f(t)$.

(b) A bioinstrumentation system uses the following passive filter circuit with input $f(t)$ and output $y(t)$ as shown in Figure: Question 1(b). (i) Using Laplace transform, find its zero-state response if the input voltage is $f(t) = 5te^{-t}u(t)$. (ii) Find the transfer function relating the output $y(t)$ to the input $f(t)$. **(15)**

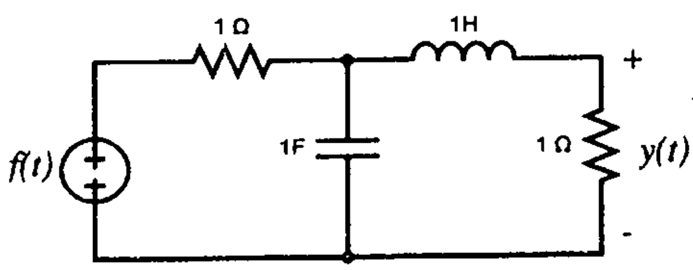

Figure: Question 1(b)

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(c) The Figure: Question 1(c) below shows the time and frequency domain representations of a photoplethysmography (PPG) signal. It can be seen from the bottom plot that frequency components present in PPG signal are heart rate (HR) component and motion artefact (MA) noise component. Design an ideal bandpass filter to be applied to the PPG signal so that only the HR components remain after filtering. Write down the magnitude and phase response expressions of the filter and show their plots. Your filter should facilitate a distortion-less transmission. Note that the plot of Figure: Question 1(c) is shown in linear frequency (f in Hz) while your filter expressions should be in angular frequency (ω in rad/sec). You may estimate frequency values from the plot. **(10)**

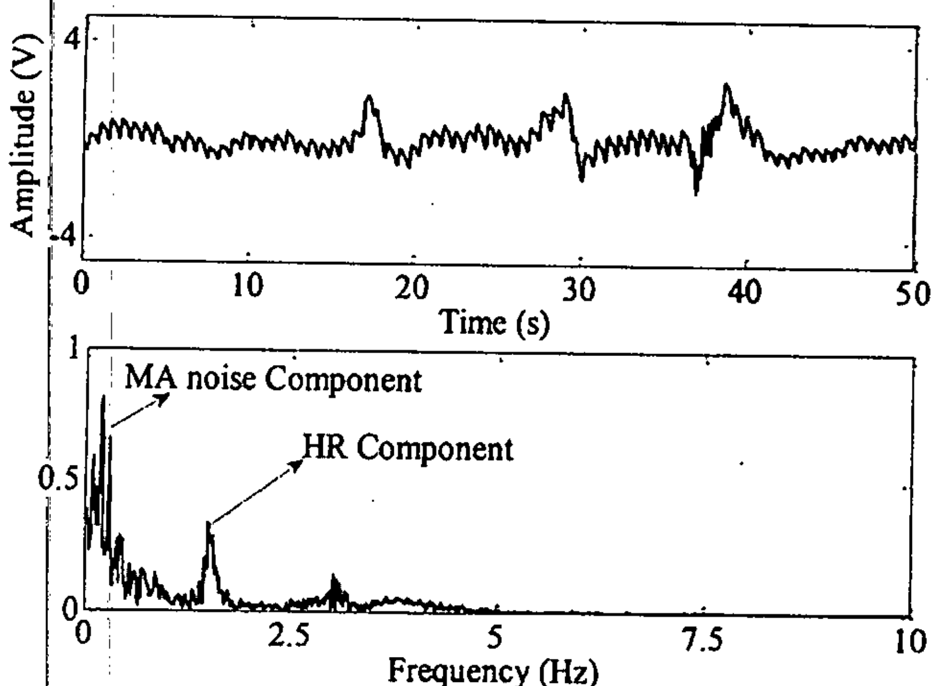

Figure: Question 1(c)

2. (a) Prove the frequency differentiation property of the Fourier transform (dual of the time differentiation property) which is given by: **(15)**

$$-jtf(t) \underset{\mathcal{F}}{\Leftrightarrow} \frac{d}{d\omega} F(\omega)$$

Using this property determine the Fourier transform of $f(t) = te^{-at}u(t)$.

(b) Determine the Fourier transform of the following signal: **(10)**

$$f(t) = \frac{1}{2}\left[\delta(t) + \frac{j}{\pi t}\right] e^{j4t}$$

(c) Using the Laplace transform of the signal $e^{-at}u(t)$ explain the concept of region of convergence (ROC) in the s-plane. **(5)**

3. (a) Determine the Fourier transform of the signal in Figure: Question 3(a). **(11)**

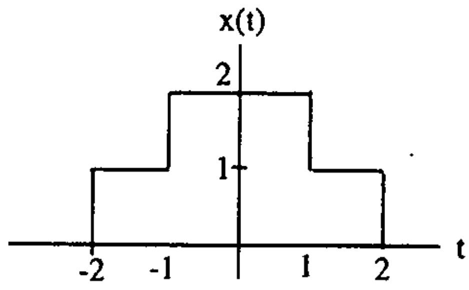

Figure: Question 3(a)

(b) Calculate the initial and final value of the zero-state response of a system with transfer function $H(s)$: **(11)**

$$H(s) = \frac{6s^2 + 3s + 10}{2s^2 + 6s + 5}$$

Assume that input to the system is (i) $u(t)$ and (ii) $e^{-t}u(t)$.

(c) Derive the scaling property of the Fourier transform. Using this property, illustrate what happens to the Fourier transform of a rect(t) function when its width is increased towards infinity and decreased to near zero. **(8)**

4. (a) A full-wave rectifier is used to obtain a DC signal from a sinusoidal input signal sin(t). The rectified signal $f(t)$, depicted in Fig. 3.18, is applied to the input of a low-pass RC filter, which suppresses the time-varying component and yields a, DC component with some residual ripple. Find the filter output $y(t)$. **(12)**

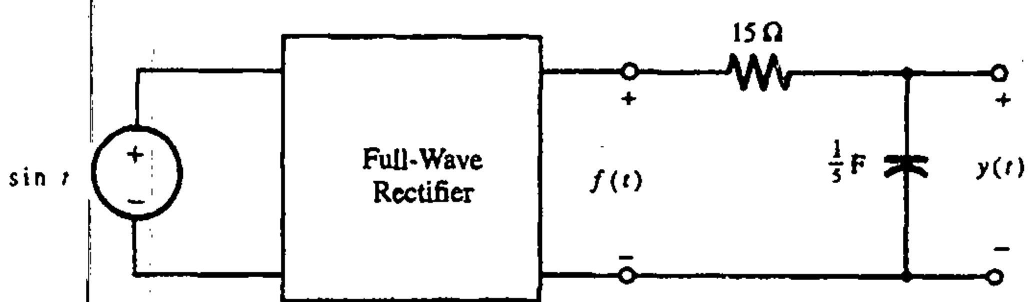

Figure: Question 4(a)

(b) Using the Laplace transform solve the following differential equation: **(10)**

$$(D^2 + 3D + 2)y(t) = Df(t)$$

Assume: $y(0^-) = \dot{y}(0^-) = 0$ and $f(t) = u(t)$.

(b) Calculate the inverse Laplace transform of: **(8)**

$$F(s) = \frac{e^{-s} + e^{-2s} + 1}{s^2 + 3s + 2}$$

SECTION – B

There are **FOUR** questions in this section. Question No. 5 is **MANDATORY**.
Answer any **TWO** of the remaining **THREE** questions.

5. (a) The figure below is an approximation of one cycle of ECG signal. **(15)**

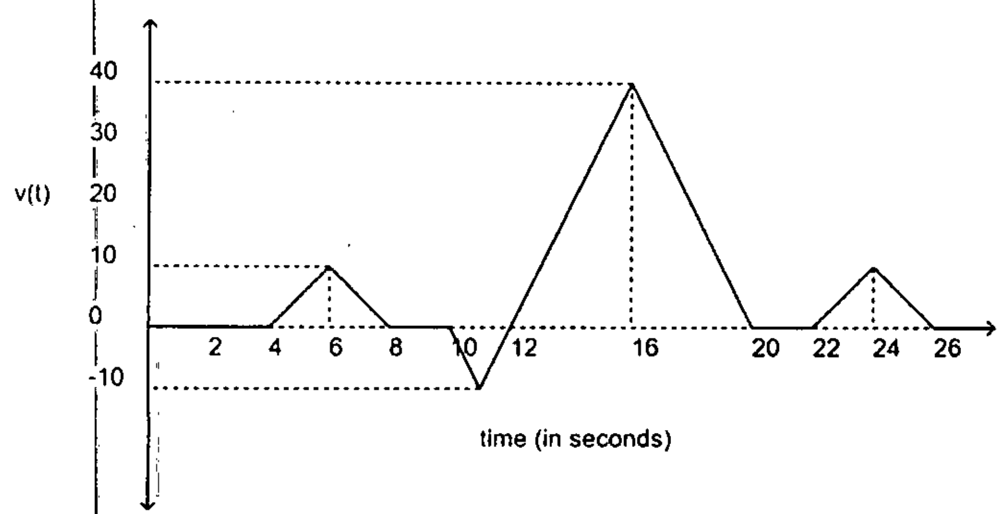

Figure for Q. 5(a)

i. Express v(t) in terms of the unit step and ramp functions.

ii. Find v(30-t).

(b) For diabetes management, a basic model for blood glucose dynamics can be described by the following differential equation: **(20)**

$$(D^2 + 6D + 25)y(t) = (D + 3)x(t)$$

Where y(t) is the glucose concentration and x(t) is insulin infusion rate. Get the complete response of the system for a step increase of 5 units in insulin infusion rate. Consider $y(0^+) = 0; y'(0^+) = 2$.

(c) When analyzing sleep pattern, a basic model for respiratory effort can be represented by the following equation: **(10)**

$$Q'''(t) + 2Q''(t) - 2Q(t) = X'(t) - 7X(t)$$

Where Q(t) and X(t) denote the respiratory effort signals and change in airflow, respectively. Draw the Direct Form-I and Direct Form-II realizations of the system.

6. (a) While calibrating a pressure sensor, following input-output was observed **(15)**

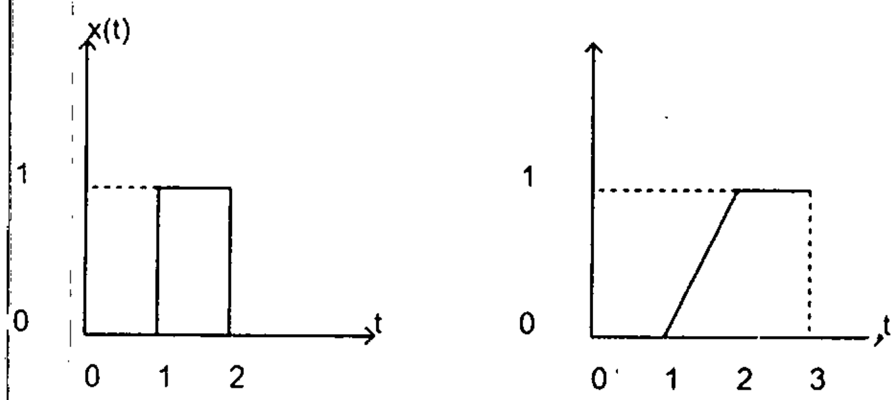

Figure for Q. 6(a)

Where output $y(t)$ is recorded for 3 seconds. Determine whether the system is causal, time-invariant and memoryless. Also, find the output of the system for input

$x_1(t) = u(t) + u(t-1) - 2u(t-2)$

(b) Graphically determine the convolution of the following two signals: **(15)**

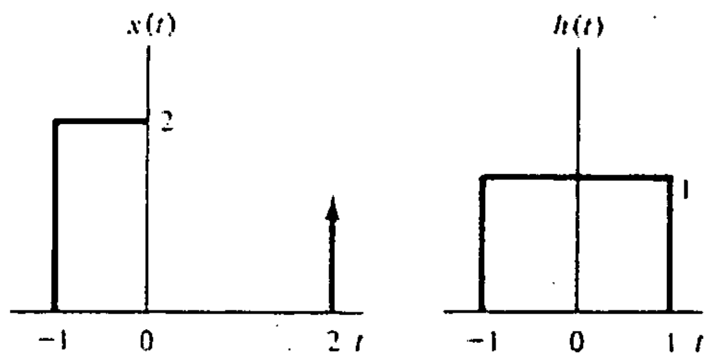

Figure for Q. 6(b)

7. (a) Mechanical analog of electrical circuit model of respiratory mechanics is shown in the figure below. **(15)**

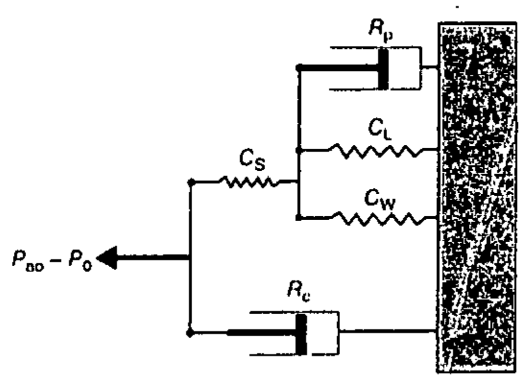

Figure for Q. 7(a)

i. Draw the analogous electrical system.

ii. In certain situations, chest-wall stiffness might increase. How will it affect the model? Discuss.

(b) Find the impulse response of an integrator, i.e. $y(t) = \int_{-\infty}^{t} x(\tau)d\tau$ **(7)**

(c) Determine whether the signal $x(t) = \cos\left(100\,\pi t + \frac{\pi}{3}\right) + \sin\left(40\pi t + \frac{2\pi}{3}\right)$ is periodic or not. If periodic, find the fundamental period of the signal. **(8)**

8. (a) Determine if the following systems are inertible. If invertible, find the inverse system. **(8)**
   i. $h(t) = u(t)$
   ii. $h(t) = e^{-t}u(t)$

(b) In a simulation model of electromyography, muscle electrical activity is formulated as follows: **(15)**

$$y''(t) + 11y'(t) + 24y(t) = x''(t) - 2x'(t) + 3x(t)$$

Where a relation between the EMG signal and motor neuron firing rate is established. Use state variable technique to find the impulse response.

(c) State and prove the commutative property of convolution. **(7)**