L-3/T-II/BME Date: 20/01/2021

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-II B.Sc. Engineering Examination 2018-19 (January 2020 Term)

Sub: **BME 305** (Physiological Control Systems)

Full Marks: 180 Time 2 Hours

The Figures in the margin indicate full marks.

All the symbols have their usual meanings.

Assume reasonable values for missing data.

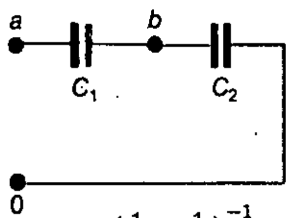
USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

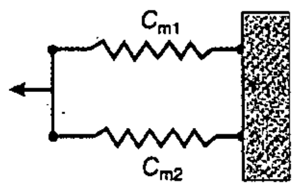
1. (a) With appropriate diagrams and formulations, show how the generalized property of storage can be applicable in electrical, mechanical, fluidic, thermal and chemical systems. **(20)**

   (b) In the figures below, Fig 1(a) shows two series capacitors while Fig 1(b) shows two parallel springs. Using the concept of generalized property of the storage element, explain briefly why the equivalent storage element for both systems turn out to have the same expression. **(10)**



$$C = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)^{-1}$$

Fig 1(a)



$$C = \left(\frac{1}{C_{m1}} + \frac{1}{C_{m2}}\right)^{-1}$$

Fig 1(b)

2. (a) A schematic representation of the processes involved in the regulation of glucose and insulin is shown in Fig. 2. Assuming that x and y represent glucose and insulin concentration in the plasma, respectively, derive the equations relating the steady-state level of x and y. You may use mass balance equations of blood glucose and insulin to derive the equations. **(25)**

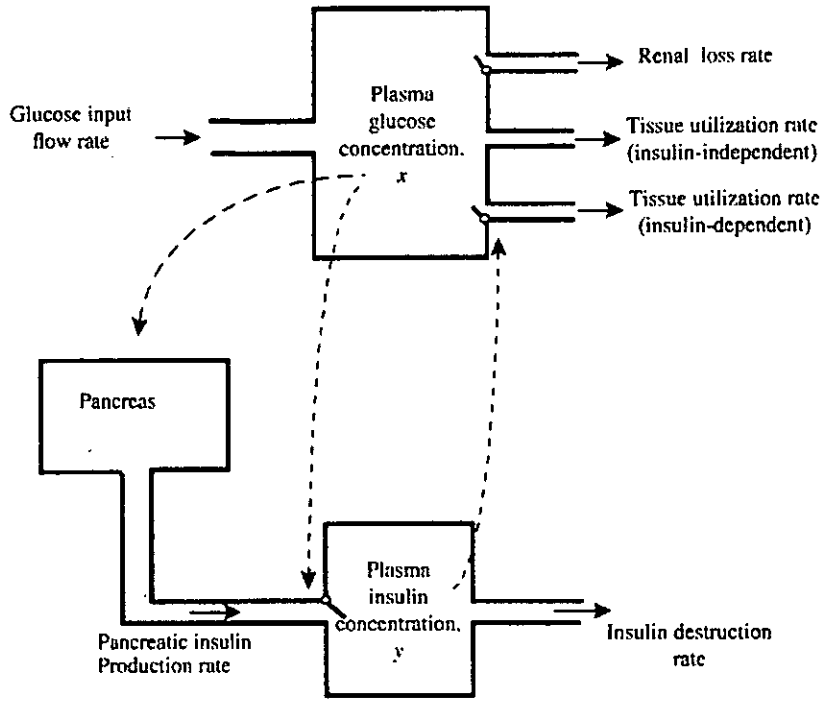


Fig. 2.

(b) Using the glucose regulation model derived in the previous part, illustrate how the steady state operating point changes for normal condition, type-1 and type-2 diabetes. **(5)**

3. (a) A second order lung mechanics model is shown in Fig. 3(a) where the symbols have usual meaning. Derive its transfer function in the closed-loop condition with a loop gain of *k*. For this system, assume that the input is P_{ao} and the output is P_A. **(20)**

(b) Derive the generalized impulse response of the second-order system in Fig. 3(a). For what condition will this system provide an underdamped response? Derive the impulse response for this condition. You may use the Laplace transform pairs provided below. **(10)**

$$e^{-at}\cos\omega t \overset{\mathcal{L}}{\Leftrightarrow} \frac{s+a}{(s+a)^2+\omega^2}$$

$$e^{-at}\sin\omega t \overset{\mathcal{L}}{\Leftrightarrow} \frac{\omega}{(s+a)^2+\omega^2}$$

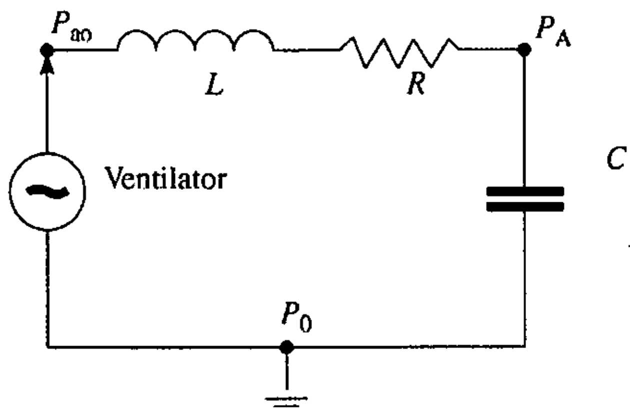


Fig. 3(a)

4 (a) Consider the simplified model of eye movement control shown in Fig. 4(a). Assuming that G/J = 14,400 rad²s², B/J = 24 rad s⁻¹, and k_v = 0.01, compute the frequency response for this model. Display the magnitude and phase components of the frequency response in the form of a Bode plot. You may approximate the plot by showing magnitude and phase of the response for the following frequencies: 10^0, 10^1, 10^2, 10^3 and 10^4 by using a logarithmic scale. **(20)**

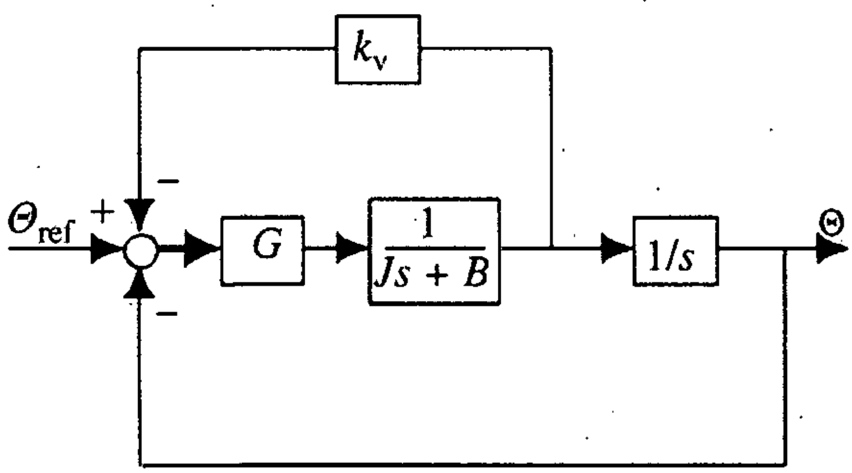


Fig. 4(a)

(b) What is relative stability? Draw the Nichols chart for two different stable systems where one of them has higher gain margin than the other, but both systems have the same phase margin. **(10)**

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. (a) Viscoelastic behaviour of cells can be modelled as Maxwell bodies consisting a spring and a dashpot connected as shown in Fig. for Q. no. 5(a). If $x(t)$ is the relative displacement of the two terminals in response to the force $F(t)$, find the transfer function $X(s)/F(s)$. Calculate and sketch the displacement if a constant force, F_0 is suddenly applied to the cell. **(15)**

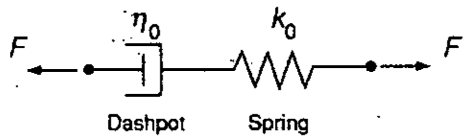


Fig. for Q. no. 5(a)

(b) A muscle hanging from a beam is shown in Fig. for Q. no. 5(b). The α-motor neuron can be used to electrically stimulate the muscle to contract and pull the mass, m, which under static conditions causes the muscle to stretch. An equivalent mechanical system to this setup is shown in the same figure. The force F_{iso} will be exerted when the muscle contracts. Find an expression for the displacement $X_1(s)$ in terms of $F_1(s)$ and $F_{iso}(s)$. **(15)**

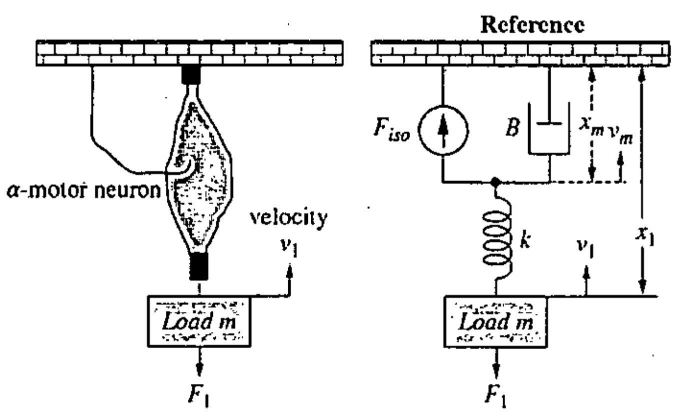


Fig. for Q. no. 5 (b)

6. (a) Type-1 diabetes patients had to inject themselves with insulin a few times a day. New delayed-action insulin analogues such as insulin Glargine require a single **(15)**

daily dose. A model has been developed for the concentration-time evolution of plasma for insulin Glargine. For a specific patient, state-space model matrices are given by:

$$\mathbf{A} = \begin{bmatrix} -0.435 & 0.209 & 0.02 \\ 0.268 & -0.394 & 0 \\ 0.227 & 0 & -0.02 \end{bmatrix}; \quad \mathbf{B} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix};$$

$$\mathbf{C} = \begin{bmatrix} 0.0003 & 0 & 0 \end{bmatrix}; \quad \mathbf{D} = 0$$

where the state vector is given by:

$$\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}.$$

The state variables are

x_1 = insulin amount in plasma compartment

x_2 = insulin amount in liver compartment

x_3 = insulin amount in interstitial (in body tissue) compartment

The system's input is u, external insulin flow. The system's output is y, plasma insulin concentration. Find the system's transfer function.

(b) Using Mason's rule, find the transfer function, $T(s) = C(s)/R(s)$, for the system represented in Fig. for Q. no. 6(b). **(15)**

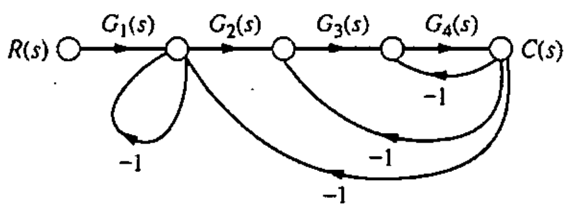


Fig. for Q no. 6(b)

7. (a) Given the system shown in Fig. for Q. no. 7(a), find J and D to yield 20% overshoot and a settling time of 2 seconds for a step input of torque $T(t)$. **(15)**

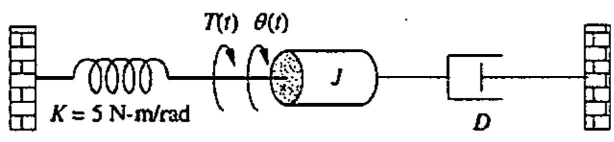


Fig. for Q. no. 7(a)

(b) A linearized HIV infection model can be shown to have the transfer function **(15)**

$$P(s) = \frac{Y(s)}{U_1(s)} = \frac{-520s - 10.3844}{s^3 + 2.6817s^2 + 0.11s + 0.0126}$$

It is desired to develop a policy for drug delivery to maintain the virus count at prescribed levels. For the purpose of obtaining an appropriate $u_1(t)$, feedback will be used as shown in Fig. for Q. no. 7(b). As a first approach, consider $G(s) = K$, a constant to be selected. Use the Routh-Hurwitz criteria to find the range of K for which the system is closed-loop stable.

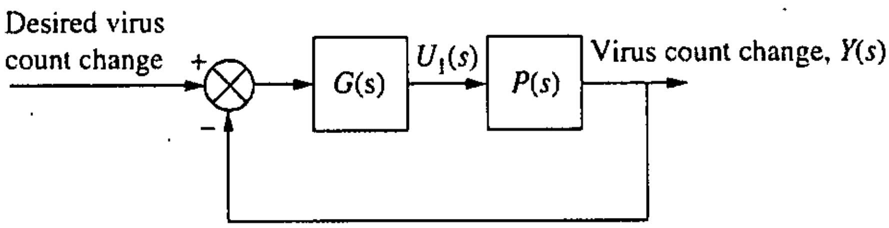


Fig. for Q. no. 7 (b)

8 (a) For the system shown in Fig. for Q. no. 8(a), find the sensitivity of the steady-state error for changes in K_1 and in K_2, when $K_1 = 100$ and $K_2 = 0.1$. Assume step inputs for both the input and the disturbance. **(15)**

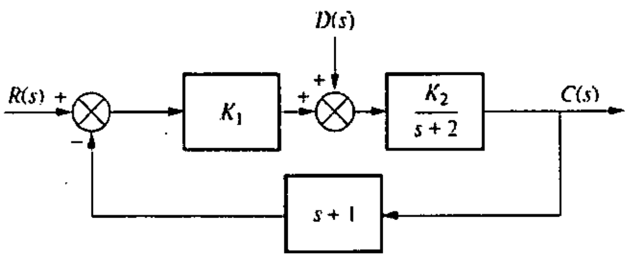


Fig. for Q. no. 8(a)

(b) For each of the root loci shown in Fig. for Q. no. 8(b), write whether or not the sketch can be a root locus. If the sketch cannot be a root locus, explain why. Give all reasons. **(15)**

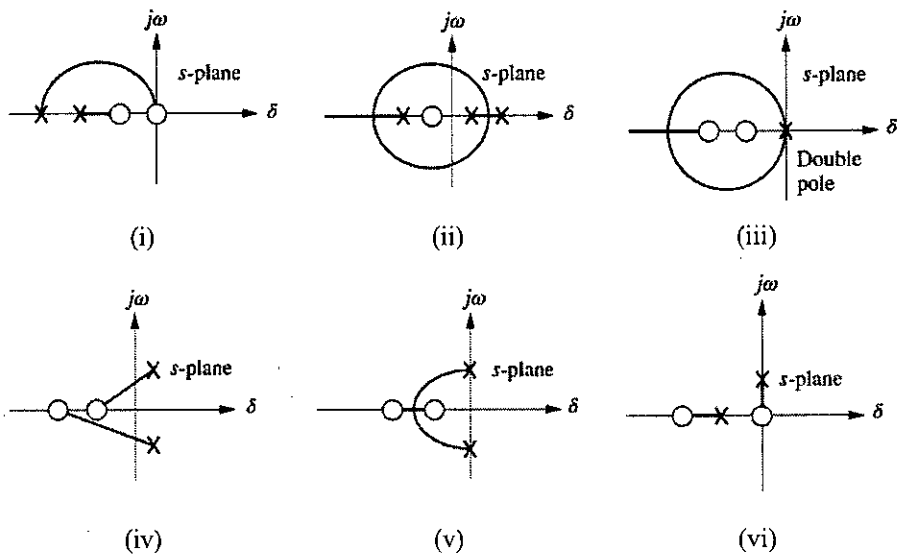


Fig. for Q. no. 8(b)

L-3/T-II/BME **Date: 24/01/2021**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-II B.Sc. Engineering Examination 2018-19 (January 2020 Term)

Sub: **BME 307** (Biomedical Transport Fundamentals)

Full Marks: 180 Time 2 Hours

The Figures in the margin indicate full marks. All the symbols have their usual meanings.

Assume reasonable values for missing data.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) In micropipette systems that measure membrane and cortical tension, the pressure difference $\Delta p = p_p - p_0$ is produced by a column of fluid. Where, p_p is suction pressure and p_0 is the external pressure in the bath. Thus, $\Delta p = \rho g h$. The fluid is water and the minimum column height that can be maintained is 2.5 μm. **(15)**

   i. Determine the minimum pressure that can be generated.

   ii. For a cell of radius 6 μm and a micropipette radius of 1.5 μm, determine the smallest cortical tension that can be measured.

   (b) Angular flow of a fluid between two concentric cylinders can be used to measure fluid viscosity by calculating the torque required to maintain the outer cylinder at a constant rotational speed. Derive an expression for the required torque for a Newtonian fluid. **(15)**

2. (a) In postcapillary venules, leukocytes are close to the vessel wall, rolling or moving more slowly than the average fluid velocity v_f, as shown in Fig. for Q. no. 2(a). At sites of injury or infection, the leukocyte velocity v_c slows further, and the cells stop and migrate into the surrounding tissue. The slower leukocyte velocity is a result of specific interactions between the endothelial cells of the vessel wall and the leukocytes. These interactions produce a force F_b on the cells that slows them down. The force depends upon the plasma density and viscosity, the hematocrit, as well as on the fluid velocity, the leukocyte velocity, the leukocyte diameter, d_c, and **(15)**

the vessel diameter, d_t. Use the Buckingham Pi theorem to identify the appropriate dimensionless groups.

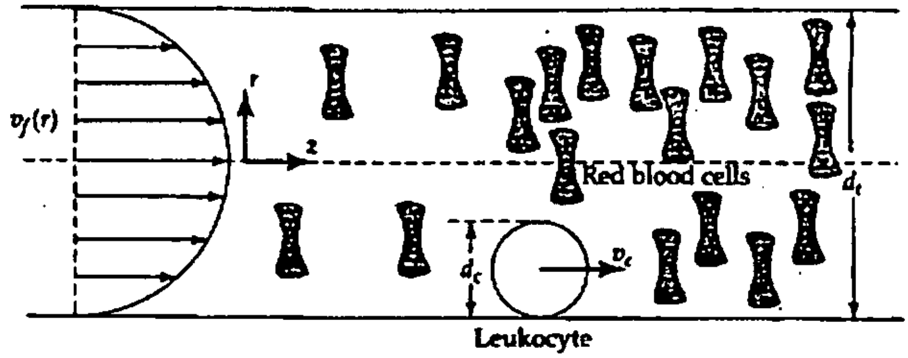


Fig. for Q. no. 2(a)

(b) Determine the terminal velocity and the time that is required to reach steady state for a leukocyte (density= 1.077 g/cm^3 and radius 7 μm) that is settling in a tissue culture medium (density= 1.01 g/cm^3 and viscosity= 0.0085 g/cm.s). **(15)**

3. (a) In modeling a skin burn from an oven, approximate the skin and tissue layer to be infinitely thick compared to the damaged layer. The temperature throughout the entire skin and tissue layer is uniform at 33°C before contact with oven, and the surface layer of skin increases to the temperature of the oven, 200°C, instantaneously upon contact. Consider that skin becomes damaged when it reaches 62°C. The thermal diffusivity of skin is 2.5×10^{-7} m^2/s. Find the depth of the damaged layer of skin after 2 seconds of exposure to the oven temperature. **(15)**

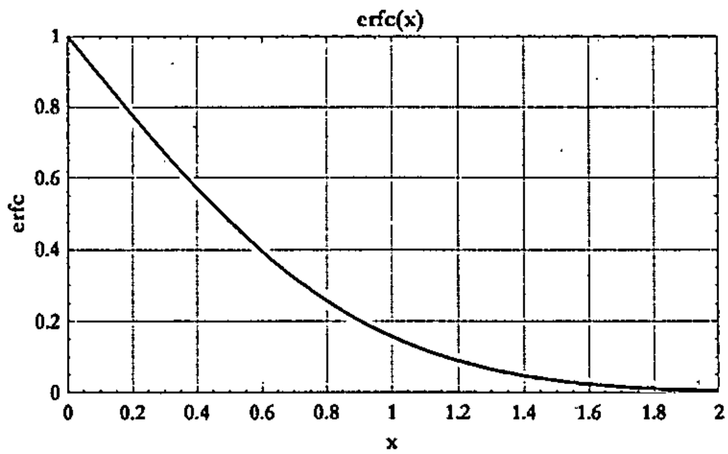


Fig. for Q. no. 3(a)

(b) Consider the entrance region of a cylindrical tube of radius R. The inlet velocity profile is uniform, with velocity U_0. The fluid is Newtonian and the flow is steady. Within the entrance region, the velocity field is two dimensional. Downstream, the velocity field is fully developed and depends on r only. Use the integral forms of the conservation of linear momentum and mass for steady flow to relate the drag force exerted by the fluid on the walls of the tube to the pressure drop in the entrance region. **(15)**

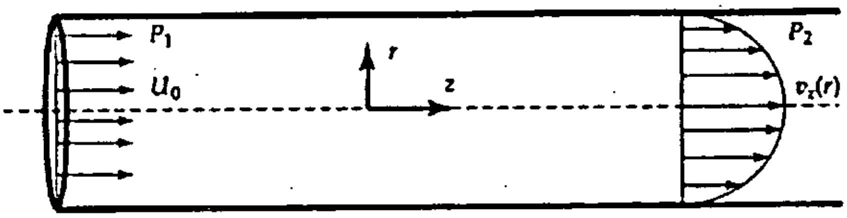


Fig. for Q. no. 3(b)

4 (a) Derive the laminar boundary layer equations for steady two dimensional flow from the nondimensional form of the Navier-Stokes equation using appropriate scaling. **(15)**

(b) Pulmonary valve stenosis is suspected in an infant with poor blood oxygenation. The right ventricle is underdeveloped, with a maximum cross-sectional area of 2 cm^2. From echocardiography, the velocities in the right ventricle and across the pulmonary valve are 0.5 m/s and 1.3 m/s, respectively. Estimate the pressure drop across the valve the cross sectional area of the valve. **(15)**

Table 1: Integral forms of the conservation equations

Conservation of mass	$\frac{\partial}{\partial t}\int_V \rho dV + \int_S \rho\vec{v}\cdot\vec{n}dS = 0$
Conservation of momentum	$\frac{\partial}{\partial t}\int_V \rho\vec{v}dV + \int_S \rho\vec{v}\left(\vec{v}\cdot\vec{n}\right)dS = -\int_S P\vec{n}dS + \int_S \tau_{ij}\cdot\vec{n}dS + m\vec{g}$

Table 2: Navier-Stokes equation for incompressible Newtonian fluid

$$\rho\left(\frac{\partial\vec{v}}{\partial t} + \vec{v}\cdot\nabla\vec{v}\right) = -\nabla P + \mu\nabla^2\vec{v} + \rho\vec{g}$$

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE.**

5. (a) What effects do competitive and noncompetitive inhibition have on the kinetics of enzyme reactions? **(10)**

(b) Consider steady-state diffusion through two media arranged parallel to each other (Fig. for Q. no. 5(b)). Assume that diffusion is one-dimensional. At x = 0, $C_1 = \phi_1 C_0$ and $C_2 = \phi_1 C_0$. At x = L, $C_1 = \phi_1 C_L$ and $C_2 = \phi_1 C_L$. Develop an expression for the steady state flux across the two media. Show that the diffusive resistances act in parallel. **(20)**

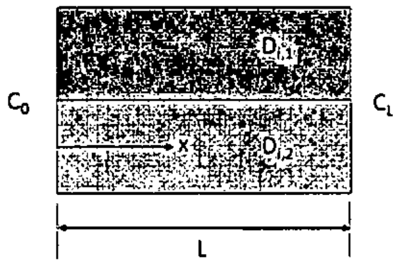


Fig. for Q. no. 5(b)

6. (a) The 'invertase' enzyme catalyzes the hydrolysis of sucrose into two monomers of glucose and fructose. The inhibition of this enzyme reaction occurs at high substrate concentration, which is called 'substrate inhibition' it can be modeled by the following scheme of reactions: **(20)**

$$E + S \underset{k_{-1}}{\overset{k_{+1}}{\rightleftharpoons}} ES \xrightarrow{k_{+2}} P$$

$$ES + S \underset{K_s}{\rightleftharpoons} ESS$$

Where $K_S = \frac{[ES][S]}{[ESS]}$ = Equilibrium constant

Derive the reaction rate equation for the product formation using appropriate assumptions.

(b) What are the possible scenarios that can cause the molecule dependent available volume fraction smaller than the porosity in porous media? **(10)**

7. (a) Oxygen is passing through a one-dimensional cellular layer of thickness L. The constant filtration velocity is v_f acting as the same direction of the concentration gradient. Oxygen is not metabolized in this cellular layer. The partition coefficient of the oxygen in the cellular layer is ϕ. The oxygen concentration at the entrance is ϕC_0 and at the exit is ϕC_L where C_0 and C_L are the bulk concentration outside of the cellular layer near the entrance and exit, respectively. Determine the expression for concentration at any point inside the domain. **(20)**

(b) What dimensionless group describes the relative importance of convection versus diffusion? Explain the physical basis of this group. **(10)**

8. (a) Consider a two-layer model of an artery (Fig. for Q. no. 8(a)). The layers are of thickness R_0-R_I and R_I-R_i. The inner layer has the diffusion coefficient of D_i and the outer layer has the diffusion coefficient of D_0. The solute concentration in the lumen ($0 < r < R$) is C_i, and the concentration at R_0 is C_0. Calculate the effective diffusion coefficient. **(25)**

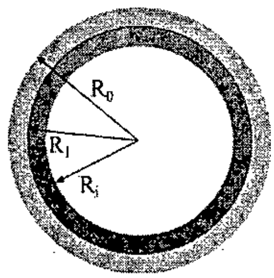


Fig. for Q. no. 8(a)

(b) Explain how measurements of receptor-ligand binding at equilibrium can be used to determine whether a binding is a simple bimolecular reaction or not. **(5)**

Table 1: Equations of continuity in various coordinate systems

Rectangular	$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x}(\rho v_x)+\frac{\partial}{\partial y}(\rho v_y)+\frac{\partial}{\partial z}(\rho v_z)=0$
Cylindrical	$\frac{\partial \rho}{\partial t}+\frac{1}{r}\frac{\partial}{\partial r}(\rho r v_r)+\frac{1}{r}\frac{\partial}{\partial \theta}(\rho v_\theta)+\frac{\partial}{\partial z}(\rho v_z)=0$
Spherical	$\frac{\partial \rho}{\partial t}+\frac{1}{r^2}\frac{\partial}{\partial r}(\rho r^2 v_r)+\frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(\rho \sin\theta\, v_\theta)+\frac{1}{r\sin\theta}\frac{\partial}{\partial \emptyset}(\rho v_\emptyset)=0$

Table 2: Mass conservation relations for dilute solutions in various coordinate systems

Rectangular	$\frac{\partial C_i}{\partial t}+v_x\frac{\partial C_i}{\partial x}+v_y\frac{\partial C_i}{\partial y}+v_z\frac{\partial C_i}{\partial z}=D_{ij}\left(\frac{\partial^2 C_i}{\partial x^2}+\frac{\partial^2 C_i}{\partial y^2}+\frac{\partial^2 C_i}{\partial z^2}\right)+R_i$
Cylindrical	$\frac{\partial C_i}{\partial t}+v_r\frac{\partial C_i}{\partial r}+\frac{v_\theta}{r}\frac{\partial C_i}{\partial \theta}+v_z\frac{\partial C_i}{\partial z}=D_{ij}\left(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial C_i}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 C_i}{\partial \theta^2}+\frac{\partial^2 C_i}{\partial z^2}\right)+R_i$
Spherical	$\frac{\partial C_i}{\partial t}+v_r\frac{\partial C_i}{\partial r}+\frac{v_\theta}{r}\frac{\partial C_i}{\partial \theta}+\frac{v_\emptyset}{r\sin\emptyset}\frac{\partial C_i}{\partial \emptyset}$ $=D_{ij}\left(\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial C_i}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial C_i}{\partial \theta}\right)\right.$ $\left.+\frac{1}{r^2\sin^2\theta}\frac{\partial^2 C_i}{\partial \emptyset^2}\right)+R_i$

Table 3: Governing equations for heat conduction in various coordinate systems

Rectangular	$\frac{\partial T}{\partial t}=\frac{k}{\rho c_p}\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)+\frac{\dot{q}_{met}}{\rho c_p}$
Cylindrical	$\frac{\partial T}{\partial t}=\frac{k}{\rho c_p}\left(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 T}{\partial \theta^2}+\frac{\partial^2 T}{\partial z^2}\right)+\frac{\dot{q}_{met}}{\rho c_p}$
Spherical	$\frac{\partial C_i}{\partial t}=\frac{k}{\rho c_p}\left(\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial T}{\partial \theta}\right)+\frac{1}{r^2\sin^2\theta}\frac{\partial^2 T}{\partial \emptyset^2}\right)$ $+\frac{\dot{q}_{met}}{\rho c_p}$

L-3/T-2/BME **Date: 13/01/2021**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2018-2019

Sub: **CHE 471** (Biochemistry)

Full Marks: 180 Time: 2 Hours

The figures in the margin indicate full marks.

Symbols used have their usual meaning and interpretation.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION A

There are **THREE** questions in this section. Answer any **TWO**.

1. (a) Explain with a suitable example how variations in amino acid sequence of haemoglobin may lead to a hereditary human disease. **(20)**

(b) With a proper diagram, show how carbohydrate can be synthesized from different precursors. Differentiate among the processes for animals and plants. **(15)**

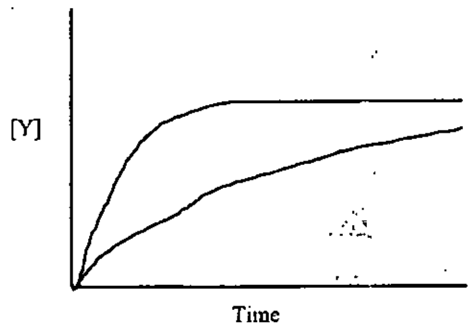
(c) Mention a few electron transporter proteins that take part in Oxidative Phosphorylation. Write about the function of ATP synthase enzymes. **(4+6=10)**

2. (a) Draw formation of α-D-fructopyranose and α-D-fructofuranose from D-fructose. **(12)**

(b) (i) At what substrate concentration would an enzyme with a k_{cat} of 30.0 s^{-1} and a K_m of 0.005 M operate at one-quarter of its maximum rate?

(ii) Determine the fraction of V_{max} that would be obtained at the following substrate concentrations: $[S] = 10K_m$.

(iii) An enzyme that catalyzes the reaction $X \rightleftharpoons Y$ is isolated from two bacterial species. The enzymes have the same V_{max} but different K_m values for the substrate X. Enzyme A has a K_m of 2 μM while enzyme B has a K_m of 0.5 μM. The plot below shows the kinetics of reactions carried out with the same concentration of each enzyme and with [X] = 1 μM. Which curve corresponds to which enzyme and why?



(7+7+10 =24)

(c) Differentiate between reversible and irreversible inhibition. **(9)**

3. (a) How do archaebacteria manage to survive in extreme conditions like low pH or high temperatures? **(10)**

(b) Write short notes on different types of steroids found in human body or used as drugs. **(15)**

(c) "Individual lipid molecules can move laterally in the plane of the membrane by changing places with neighboring lipid molecules"- describe a technique to prove it. **(20)**

SECTION B

There are **THREE** questions in this section. Answer any **TWO**.

4. (a) With the help of a properly labelled titration curve for a weak acid, HA having pKa=5.86, calculate the pH range within which this acid shows optimum buffering capacity. (show your working). Explain in your own words why this is the optimum pH range for buffering. **(20)**

(b) Comparing two amino acids: aspartic acid and tryptophan - **(18)**

(i) which would be more soluble in water and why?

(ii) would either of them show absorbance in UV spectra, why or why not?

(iii) which would show positive hydropathic index and why?

(c) Draw the structure of a typical pyrimidine and purine. **(7)**

ChE 471

5. (a) The below DNA sequence is part of the DNA coding sequence, what is the corresponding mRNA sequence? **(10)**

5' TTATGTGGCACAGAGAA 3'

(b) Use the codon chart, find the start codon, ignore everything before the start codon. Use the correct reading frame to write down the correct peptide sequence in one letter code. **(15)**

(c) Explain ANY TWO rules of DNA replication with appropriate diagrams **(20)**

6. Explain with appropriate schematics/diagrams what do you understand by the following statements **(any five)** : **(9×5 = 45)**

(i) Planar nature of peptide bonds gives rise to dihedral angles (φ and ψ)

(ii) α-helices are stabilized by hydrogen bonds.

(iii) β-sheets are stabilized by hydrogen bonds.

(iv) The pI of all amino acids is not $\frac{pK_1+pK_2}{2}$.

(v) pK_a values for the ionizable groups in glycine are lower than those for simple, methyl-substituted amino and carboxyl groups.

(vi) The enzyme DNA polymerase catalyzes the addition of dNTP to a DNA chain.

(vii) The formation of the micelle is governed by the change of entropy in the system.

mRNA Codon Chart

	U	C	A	G	
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	stop	stop	A
	Leu	Ser	stop	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G

Amino Acid Properties

Amino acid name	Molecular weight amino acid	Molecular weight residue	pK_1	pK_2	pK_R
Alanine	89.10	71.08	2.34	9.69	
Arginine	174.20	156.18	2.17	9.04	12.48
Asparagine	132.12	114.10	2.02	8.80	
Aspartic Acid	133.11	115.09	1.88	9.60	3.65
Cysteine	121.16	103.14	1.96	10.28	8.18
Glutamic Acid	147.13	129.11	2.19	9.67	4.25
Glutamine	146.15	128.13	2.17	9.13	
Glycine	75.07	57.05	2.34	9.60	
Histidine	155.16	137.14	1.82	9.17	6.00
Hydroxyproline	131.13	113.11	1.82	9.65	
Isoleucine	131.18	113.16	2.36	9.60	
Leucine	131.18	113.16	2.36	9.60	
Lysine	146.19	128.17	2.18	8.95	10.53
Methionine	149.21	131.19	2.28	9.21	
Phenylalanine	165.19	147.17	1.83	9.13	
Proline	115.13	97.11	1.99	10.60	
Serine	105.09	87.07	2.21	9.15	
Threonine	119.12	101.10	2.09	9.10	
Tryptophan	204.23	186.21	2.83	9.39	
Tyrosine	181.19	163.17	2.20	9.11	10.07
Valine	117.15	99.13	2.32	9.62	

L-3/T-2/BME **Date: 10/01/2021**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-II B.Sc. Engineering Examination 2018-2019 (January 2020 Term)

Sub: **EEE 375** (Digital Signal Processing)

Full Marks: 180 Time 2 Hours

`The Figures in the margin indicate full marks.

All the symbols have their usual meanings.

Assume reasonable values for missing data.

USE SEPARATE SCRIPTS FOR EACH SECTION

There are 4 pages in this question paper.

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**

1. (a) Consider the linear constant coefficient difference equation (10)

$$y(n) - \frac{1}{4}y(n-2) = \delta(n), \qquad n \geq 0$$

Find a set of initial conditions on $y(n)$ for $n < 0$ so that y(n) = 0 for $n \geq 0$.

(b) A causal linear time-invariant system has a system function (20)

$$H(z) = \frac{1 + z^{-1}}{1 - \frac{1}{2}z^{-1}}$$

Find the z-transform of the input, x(n), that will produce the output

$$y(n) = \frac{1}{3}\left(\frac{1}{4}\right)^n u(n) - \frac{4}{3}(2)^n u(-n-1)$$

2. Consider the following system shown in **Fig. for Q.2** for processing a continuous-time signal with a discrete-time system: (30)

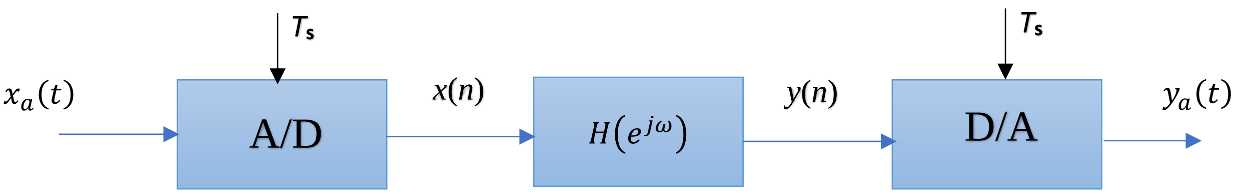


Fig. for Q.2.

The frequency response of the discrete-time filter is

$$H(e^{j\omega}) = \frac{2(\frac{1}{3} - e^{-j\omega})}{1 - \frac{1}{3}e^{-j\omega}}$$

If F_s = 2 kHz and $x_a(t) = \sin(1000\pi t)$, find the output $y_a(t)$.

3. (a) Consider the system in Fig. for Q.3(a) with $h(n) = a^n u(n),\ -1 < a < 1.$ (22)

Determine the response $y(n)$ of the system to the excitation

$$x(n) = u(n+5) - u(n-10)$$

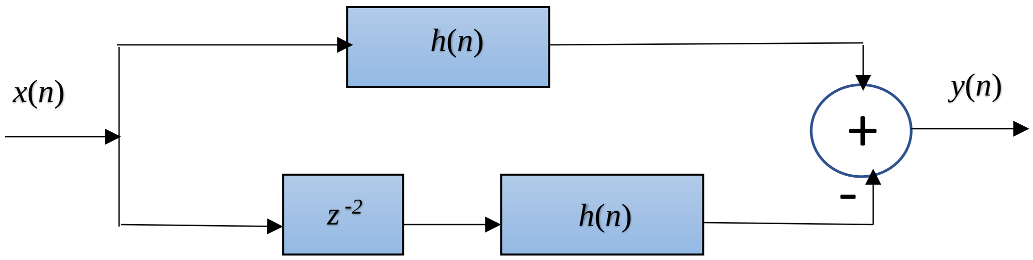


Fig. for Q.3(a).

(b) Consider the system described by the difference equation (8)

$$y(n) = ay(n-1) + bx(n)$$

Determine b in terms of a so that $\sum_{n=-\infty}^{\infty} h(n) = 1$, where $h(n)$ is the impulse response of the system.

4. (a) Compute the cross-correlation sequence $r_{xy}(l)$ for the following signal sequences: 15

$$x(n) = \begin{cases} 1, n_0 - N \le n \le n_0 + N \\ 0, \qquad \qquad otherwise \end{cases}$$

$$y(n) = \begin{cases} 1, -N \le n \le N \\ 0, \quad otherwise \end{cases}$$

(b) An analog signal $x_a(t) = \sin(480\pi t) + 3\sin(720\pi t)$ is sampled 600 times per second. 15

i) Determine the Nyquist sampling rate for $x_a(t)$.

ii) Determine the folding frequency.

iii) What are the frequencies, in radians, in the resulting discrete-time signal $x(n)$?

iv) If $x(n)$ is passed through an ideal D/A converter, what is the reconstructed signal $y_a(t)$.

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.

5. Consider a discrete-time LTI system that is described by the following difference equation **(30)**

$$y(n) = x(n) - x(n-8)$$

(i) Plot the magnitude and phase of the frequency response of the system

(ii) A discrete-time input signal $x(n)$ is obtained by sampling an analog signal $x_a(t) = T_s\left[\frac{sin(10t)}{\pi t}\right]$ with a sampling rate of $T_s = \frac{2\pi}{40}$. Plot the magnitude spectrum of the DTFT of the sampled signal $x(n)$.

(iii) Plot the magnitude spectrum of the DTFT of the corresponding output signal $y(n)$

(iv) Determine the numerical value of $\int_{-\infty}^{+\infty}|y(n)|^2$ using Parseval's relation.

6. (a) Consider the sequences $x_1(n) = \{\mathbf{1}, 2, 3, 4\}$ and $y(n) = \{\mathbf{1}, 0, 0, 0\}$ **(15)**
Determine the sequence $x_2(n)$ such that $Y(k) = X_1(k)X_2(k)$ where $X_1(k)$ and $X_2(k)$ are the 4-point DFTs.

(b) Determine the Fourier transform $X(\omega)$ of the signal $x(n) = \{1, 2, \mathbf{3}, 2, 1, 0\}$. **(15)**
Using the expression of $X(\omega)$, compute the 6-point DFT $V(k)$ of the sequence $v(n) = \{\mathbf{3}, 2, 1, 0, 1, 2\}$.

7. Using Kaiser window method, a discrete-time filter with generalized linear phase has to be designed that meets the specification of the following form: **(30)**

$$\begin{array}{lll} & \left|H\left(e^{j\omega}\right) \le 0.01\right| & 0 \le |\omega| \le 0.25\pi \\ 0.95 \le & \left|H\left(e^{j\omega}\right) \le 1.05\right| & 0.35\pi \le |\omega| \le 0.60\pi \\ & \left|H\left(e^{j\omega}\right) \le 0.01\right| & 0.65\pi \le |\omega| \le \pi \end{array}$$

(i) Determine the minimum length of the impulse response and the value of the Kaiser window parameter β for the filter.

(ii) What is the delay of the filter?

(iii) Find the ideal impulse responses $h_d(n)$ and the actual response $h(n)$ of the filter.

8. (a) Determine the transfer function of the digital equivalent of a resistive-capacitive (RC) low-pass filter using impulse invariance method. Assume a sampling frequency of 150 Hz and a cut-off frequency of 30 Hz. **(10)**

(b) A digital filter is required to remove baseline wander and artefacts due to body movement in a certain biomedical application. The filter is required to meet the following requirements: **(20)**

passband	:	1-128 Hz
stopband	:	0-0.5 Hz
passband ripple	:	$\leq$ 3 dB
stopband attenuation	:	$\geq$ 20 dB
sampling frequency	:	256 Hz

Determine the order of a suitable IIR filter and its transfer function $H(z)$. The transfer function of prototype low-pass filter is given by

order 1 : $H(s) = \frac{1}{s+1}$

order 2 : $H(s) = \frac{1}{s^2+\sqrt{2}s+1}$

order 3 : $H(s) = \frac{1}{(s+1)(s^2+s+1)}$

L-3/T-2/BME **Date: 17/01/21**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-II B.Sc. Engineering Examination Session: January 2020

Sub: **EEE 377** (Random Signal and Processes)

Full Marks: 180 Time 2 Hours

The Figures in the margin indicate full marks

USE SEPARATE SCRIPTS FOR EACH SECTION

There are 4 page(s) in this question paper.

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**

All the symbols have their usual meanings

Assume reasonable values for missing data.

1. (a) The joint PDF of two continuous random variables X and Y is given by $f_{XY}(x, y) = kx$ for $0 < y \leq x < 1$ and 0 otherwise. Find: (i) the value of the constant k, (ii) the marginal PDFs of X and Y, (iii) $P(0 < X \leq 0.5, 0 < Y \leq 0.25)$. (15)

   (b) Two independent random variables X and Y are exponential with parameters λ and γ. Find the pdfs of $Z= XY$ and $W=X/Y$. (15)

2. (a) A system consists of two components A and B where the lifetime of A is exponentially distributed with a mean of 200 hours and the lifetime of B is exponentially distributed with a mean of 400 hours. What is the expected value of W, the time to failure of the system if (i) the components are connected in series and (ii) in parallel. Assume that A and B are independent. (15)

   (b) Find the characteristic function of Y which is a sum of n independent and identically distributed Cauchy random variables. Comment on your result in relation to the Central Limit Theorem. (15)

3. (a) A random process $Y(t)$ is given by $Y(t) = A\text{Cos}(\omega t + \theta)$ where ω is a constant, and A and θ are independent random variables. The random variable A has a mean of 3 and a variance of 9, and phase θ is uniformly distributed between $-\pi/2$ and $\pi/2$. Is the process wide-sense stationary (WSS)? Verify. (15)

(b) For the process described in 3(a), find if it is mean-ergodic and correlation-ergodic? (15)

4 (a)Justify whether the following functions can be the valid power spectrum density (PSD) of a WSS process: (15)

(i) $\frac{Cos\,3\omega}{1+\omega^2+\omega^4}$ (ii) $2\omega + \frac{3\omega^4}{(1+\omega^2)^2}$ (iii) $\frac{1}{\sqrt{1-3\omega^2}}$ (iv) $\frac{|\omega|+2\omega}{1+2\omega+3\omega^2}$

(b) A WSS process $X(t)$ has the autocorrelation function given by $R_{XX}(\tau) = Cos(\omega_0\tau)$. The process is provided as input to a system with the transfer function $H(\omega)$ where $|H(\omega)|^2 = \frac{64}{(16+\omega^2)^2}$. What is the PSD of the output process? If the output process is sampled at 20s sampling period, find the PSD of the sampled process. Comment on your result. (15)

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**

All the symbols have their usual meanings

Assume reasonable values for missing data.

5. (a) Three car brands A, B, C , have all the market share in a certain city. Brand A has 20% of the market share, brand B has 30%, brand C has 50%. The probability that a brand A car needs a major repair during the first year of purchase is 0.05, the probability that a brand B car needs a major repair during the first year of purchase is 0.10, and the probability that a brand C car needs a major repair during the first year of purchase is 0.15. (18)

(i) What is the probability that a randomly selected car in the city needs a major repair during its first year of purchase?

(ii) If a car in the city needs a major repair during its first year of purchase, what is the probability that it is a brand A car?

(b) A university has twice as many undergraduate students as graduate students. Twenty five percent of the graduate students live on campus, and 10% of the undergraduate students live on campus. (12)

i) If a student is chosen at random from the student population, what is the probability that the student is an undergraduate student living on campus?

ii) If a student living on campus is chosen at random, what is the probability that the student is a graduate student?

6. (a) A biased four-sided die has faces labeled 1,2,3 and 4. Let the random variable X denote the outcome of a roll of the die. Extensive testing of the die shows that the PMF of X is given by (12)

$$p_X(x) = \begin{cases} 0.4 & x=1 \\ 0.2 & x=2 \\ 0.3 & x=3 \\ 0.1 & x=4 \end{cases}$$

(i) Find the CDF of X.

(ii) What is the probability that a number less than 3 appears on a roll of the die?

(iii)What is the probability of obtaining a number whose value is at least 3 on a roll of the die?

(b) A random variable X has the following PDF, where K>0: (18)

$$f_X(x) = \begin{cases} 0 & x<1 \\ K(x-1) & 1 \le x \le 2 \\ K(3-x) & 2 \le x \le 3 \\ 0 & x>3 \end{cases}$$

(i) What is the value of K? (ii) Sketch $f_X(x)$. (iii) What is the CDF of X?

(iv)What is P$(1 \le X \le 2)$?

7. (a) Assume that the length of phone calls made at a particular telephone booth is exponentially distributed with a mean of 3 minutes. If you arrive at the (18)

telephone booth just as Chris was about to make a call, find the following:

(i) The probability that you will wait more than 5 minutes before Chris is done with the call.

(ii) The probability that Chris' call will last between 2 minutes to 6 minutes.

(b) A random variable X has a mean of 4 and a variance of 2. Use the Chebyshev inequality to obtain an upper bound for $P(|X-4|\geq 2)$. (12)

8. (a)If $Y=aX^2$, $a>0$ is a constant and the mean and other moments of X are known, determine the following in terms of the moments of X: (18)

(i) the mean of Y

(ii) the variance of Y

(b) Assume that $U=\min(X, Y)$, where X and Y are independent random variables with the respective PDFs (12)

$$f_X(x) = \lambda e^{-\lambda x} \quad x \geq 0$$

$$f_Y(y) = \mu e^{-\mu y} \quad y \geq 0$$

where $\lambda>0$ and $\mu>0$. What is the PDF of U?