L-3/T-2/BME Date : 28/03/2022

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2019-2020

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

Full Marks : 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

The symbols have their usual meanings.

SECTION – A

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

1. (a) Given a simplified version of the linearized lung mechanics model (Figure 1(a)). Consider P_A (alveolar pressure) and Q (air-flow) as outputs, convert the system to a state-space model and determine the state-space representation (SIMO). **(15)**

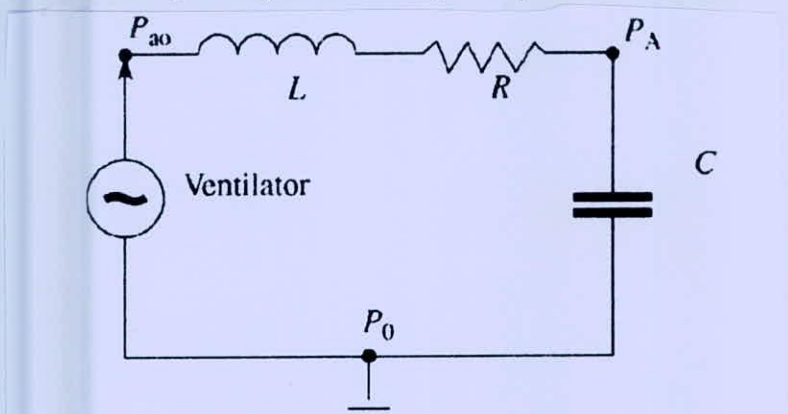


Figure for Question 1(a)

Here, the resistance (R) represents the overall mechanical resistive property, and the compliance (C) element represents, the overall storage property of the respiratory system. The inductance element (L) represents fluid inertance in the airways.

Here, L = 0.1 $cmH_2Os^2L^{-1}$, R = 1 cmH_2OsL^{-1} and C = 0.1 cmH_2O^{-1}

(b) Find the transfer function $G(s) = X_2(s)/F(s)$ of the system (Figure 1(b)) and draw the state-space equivalent block diagram. **(20)**

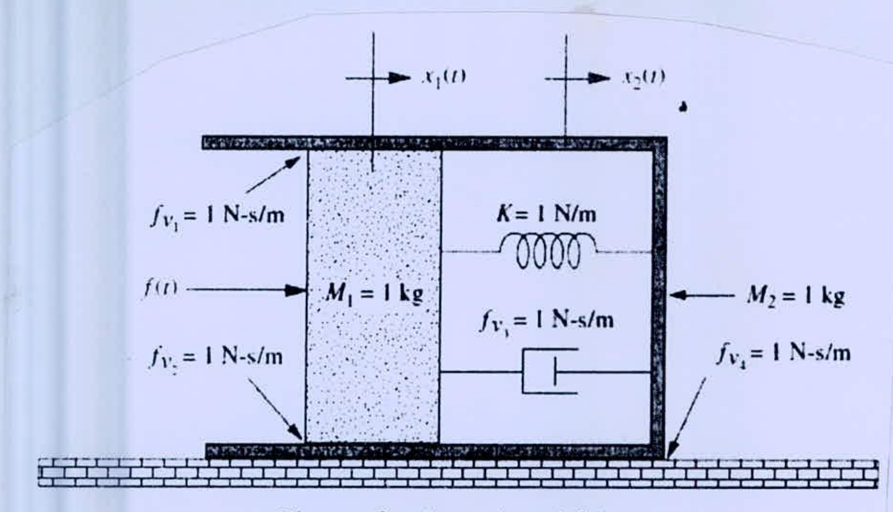


Figure for Question 1(b)

Contd P/2

BME 305

2. (a) Given a generalized solution of a second-order system for a step input. **(20)**

$$c(t) = 1 - e^{-\xi\omega_n t}\left(\cos\omega_n\sqrt{1-\xi^2}\,t + \frac{\xi}{\sqrt{1-\xi^2}}\sin\omega_n\sqrt{1-\xi^2}\,t\right)$$
$$= 1 - \frac{1}{\sqrt{1-\xi^2}}e^{-\xi\omega_n t}\cos\left(\omega_n\sqrt{1-\xi^2}\,t - \phi\right)$$

(i) Derive the equations of peak time (T_p), % OS, and settling time (T_s).

(ii) Comment on T_p, %OS, and Ts for all types of second-order systems.

(b) Design the value of gain K, for the feedback control system (Figure 2(b)) so that the system will respond with a 10% overshoot. **(15)**

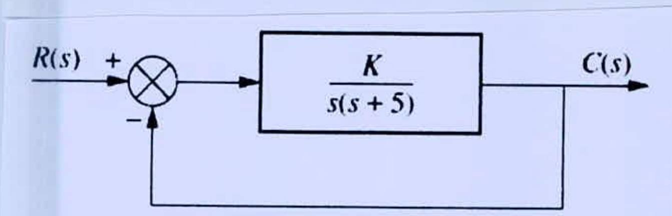


Figure for Question 2(b)

3. (a) Using Mason's rule find the transfer function T(s) = C(s)/R(s), of the system (Figure 3(a)). **(10)**

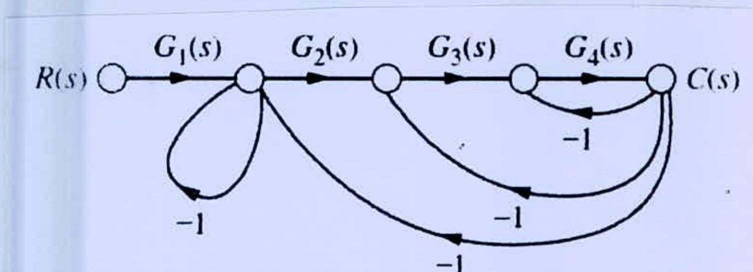
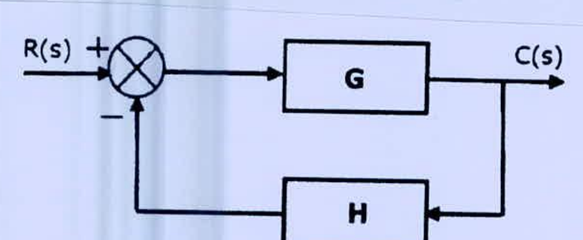


Figure for Question 3(a)

(b) Given a closed loop feedback system (Figure 3(b)). Use the Routh-Hurwitz criterion to find the location of the poles. **(10)**



$$G(s) = \frac{s^3 + 7s^2 - 21s + 10}{s^6 + s^5 - 6s^4 - s^3 - 8s^2 + 20s - 4}$$
$$H(s) = 1$$

Figure for Question 3(b)

BME 305

Contd…Q.No. 3

(c) Find the range of gain K, for the system (Figure 3(c)) that will cause the system to be stable, unstable, and marginally stable, Assume K > 0. **(15)**

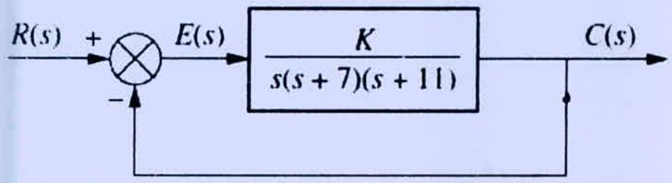


Figure for Question 3(c)

4. (a) Given the control system (Figure 4(a)), find the value of K so that there is 10% error in the steady state. **(10)**

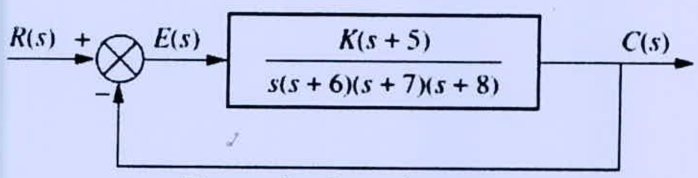


Figure for Question 4(a)

(b) Find the sensitivity of the steady-state error to changes in K for given (Figure 4(b)). **(12)**

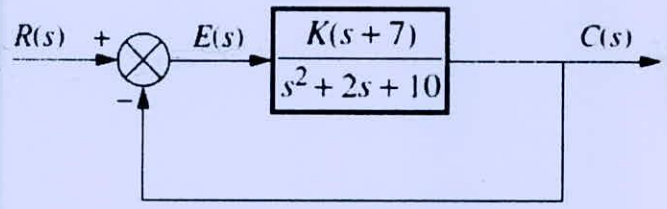


Figure for Question 4(b)

(c) Sketch the root locus and its asymptotes for a unity feedback system that has the forward transfer function. **(13)**

$$G(s) = \frac{K}{(s+2)(s+4)(s+6)} \cdot$$

SECTION – B

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

5. (a) Describe the key differences between engineering control system and physiological control system. **(15)**

(b) Derive a mathematical expression between open loop gain and closed loop gain to show that incorporation of negative feedback into a control system leads to a reduction of the effect of disturbances on the system. You may use any generalized control system block diagram for the analysis. **(20)**

Contd P/4

BME 305

6. (a) Suppose, you have just experienced a fall in your arterial blood pressure. As a result, there is a reduction in the stimulation of the baroreceptors located in your aortic arch and the carotid sinus, which lowers the rate at which neural impulses are sent along the glossopharyngeal and vagal afferents to the autonomic centers in the medulla. Consequently, your sympathetic neural outflow is increased, leading to an increase in heart rate and cardiac contractility, as well as vasoconstriction of the peripheral vascular system. Simultaneously, a decreased parasympathetic outflow aids in the increase in your heart rate. These factors can act together to raise your arterial pressure back to normal again.

Now construct a block diagram to represent the major control mechanism involved in this physiological reflex system. Clearly identify the physiological correlates of the controller, the plant, and the feedback element, as well as the controlling, controlled, and feedback variables. Describe whether it is a positive or negative feedback system and how the feedback mechanism is achieved. **(20)**

(b) Figure 6(b) shows the steady-state model of chemical regulation of ventilation. **(15)**

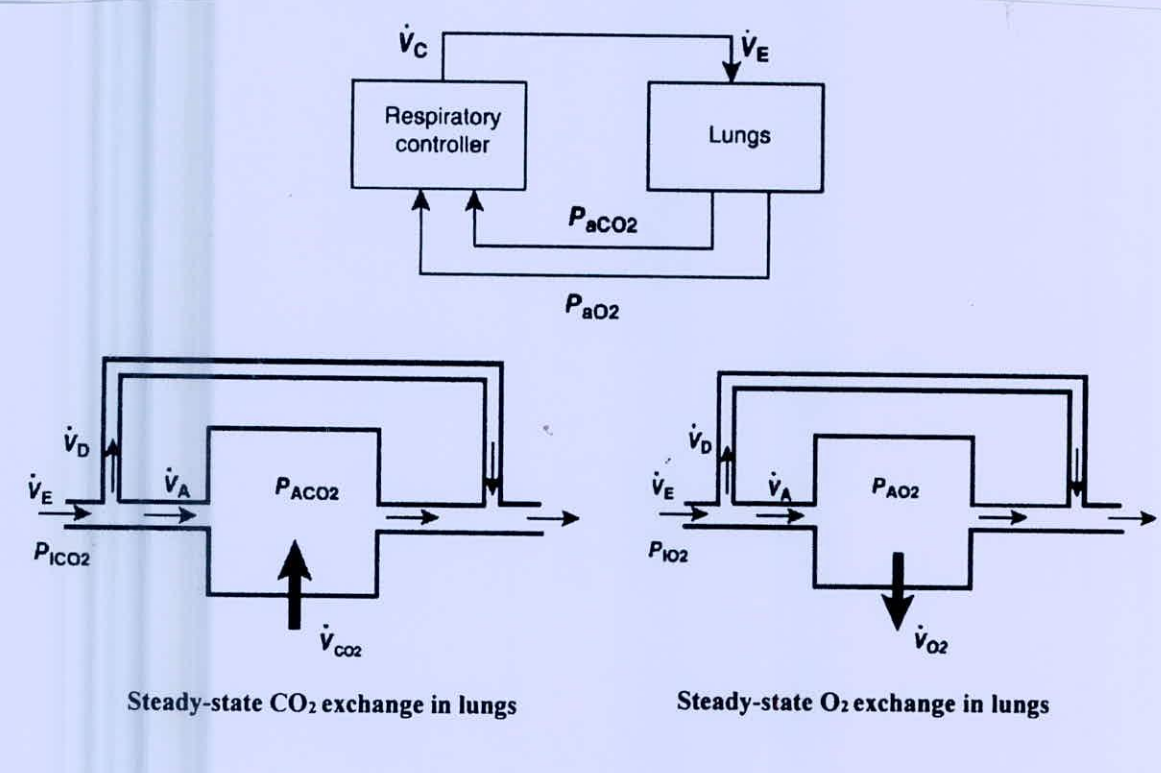


Figure for Question 6(b)

Here, P_{aCO2} and P_{aO2} represent the partial pressure of CO_2 and O_2 in arterial blood respectively while P_{ACO2} and P_{AO2} are the partial pressure of CO_2 and O_2 in alveolar compartment respectively. $\dot{V}_E$ is the total ventilation, $\dot{V}_A$ is the alveolar ventilation, $\dot{V}_D$ is the dead-space ventilation, $\dot{V}_{CO_2}$ is the metabolic CO_2 production rate and $\dot{V}_{O_2}$ is the metabolic O_2 consumption rate.

Derive the mathematical relationship between P_{ACO2} and $\dot{V}_A$, other wisely known as the metabolic hyperbola. Make necessary assumptions where required.

(c) Now suppose, the steady-state ventilator response to CO_2 is given by the following equation. **(10)**

$$\dot{V}_C = \left(1.46 + \frac{32}{P_{aO_2} - 38.6}\right)\left(P_{aCO_2} - 37\right),\ P_{aCO_2} > 37,\ \dot{V}_C = 0,\ P_{aCO_2} \leq 37$$

If the steady-state CO_2 production rate is 200 mLmin^{-1}, the inspired CO_2 concentration is 0, dead-space ventilation rate of 1 Lmin^{-1} and P_{aO2} is 100 mmHg, then,

(i) What are the steady-state values of ventilation and P_{aCO2}?

(ii) If the onset of sleep shifts the CO_2 response curve to the right, so that the apneic threshold is increased from 37 to 42 mmHg, how would the change affect the steady-state values of ventilation and P_{aCO2}? Show the change graphically in your answer script.

7. (a) The following figure 7(a) shows the lumped-parameter mechanical model of a block of blood tissue extracted from a cancerous mass (mass m_m) which is placed on an elastic platform (platform has mass m_t). **(10)**

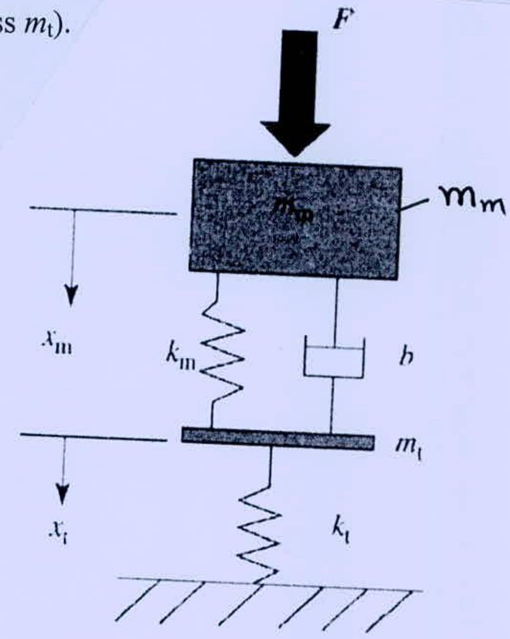


Figure for Question 7(a)

Here, the cancerous tissue is being tested for its mechanical response to a variable F applied to it. k_m and b represent the elastic stiffness and viscous damping, respectively, of the tissue, whereas k_t represents the elastic stiffness of the platform, x_m and x_t repressent the vibrational displacements of the tissue and platform, respectively, in response to F. Note: stiffness = 1/compliance, and ignore the effect of gravity.

Draw the equivalent electrical model. Label each of the elements in the electrical model.

(b) The following figure 7(b) shows a linearized model of the papillary light reflux. **(25)**

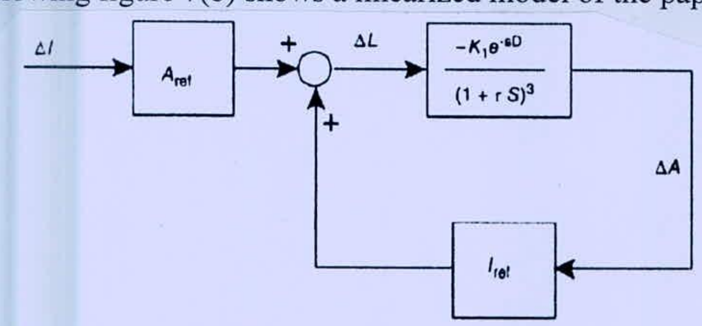


Figure for Question 7(b)

BME 305
Contd...Q.No. 7(b)

Here, ΔI represents a small change in light intensity from the reference intensity level, I_{ref}, while ΔA represents the corresponding change in pupil area from the reference value A_{ref} and ΔL is the change in total light flux reaching the retina. τ is a time constant, D is the pure time delay and K is the steady-state loop gain.

The characteristic equation for the closed loop model is given by the following equation.

$$1+\frac{Ke^{-sD}}{(1+\tau s)^3}=0$$

If the delay D assumes a first-order approximation as following,

$$e^{-sD}=\frac{1-(Ds/2)}{1+(Ds/2)}$$

Find the value of the steady-state loop gain K that would lead to the production of self-sustained oscillations in pupil diameter according to both Routh-Hurwitz and Nyquist stability analysis. Take $\tau = 0.1$ s and $D = 0.18$ s.

8. (a) Humans are able to stand on two legs through a complex feedback system that includes several sensory inputs, equilibrium and visual along with muscle actuation. In order to gain a better understanding of the workings of the postural feedback mechanism, an individual is asked to stand on a platform to which sensors are attached at the base. Vibration actuators are attached with straps to the individual's calves. As the vibration actuators are stimulated, the individual sways and movements are recorded. It is hypothesized that the human postural dynamics are analogous to those of a cart with a balancing standing pole attached (inverted pendulum). In that case, the dynamics can be described by the following two equations.

$$J\frac{d^2\theta}{dt^2}=mgl\sin\theta(t)+T_{bal}+T_d(t)$$

$$T_{bal}(t)=-mgl\sin\theta(t)+k\,J\theta(t)-\eta\,J\,\dot{\theta}(t)-\rho\,J\int_0^t\theta(t)dt$$

Where m is the individual's mass, l is the height of the individual's center of gravity, g is the gravitational constant. J is the individual's equivalent moment of inertia, η, ρ and k are constants given by the body's postural control system, $\theta(t)$ is the individual's angle with respect to a vertical line. $T_{bal}(t)$ is the torque generated by the body muscles to maintain balance, and $T_d(t)$ is the external torque input disturbance. Find the transfer function, $\frac{\theta(s)}{T_d(s)}$. **(10)**

(b) For the following linear lung mechanic model (Figure 8(b)) with integral feedback, derive the equivalent transfer function. **(20)**

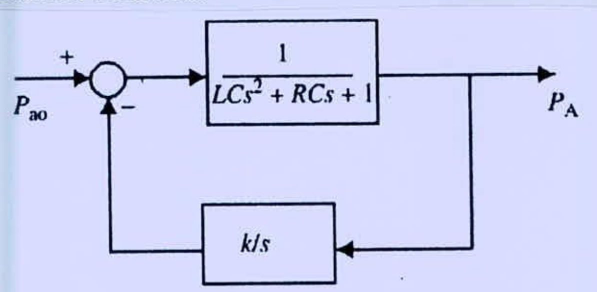


Figure for Question 8(b)

BME 305

Contd...Q.No. 8(b)

From the equivalent transfer function, approximately draw its root locus plot in your answer script and comment on the stability of the system. Also, show if using a proportional feedback could have increased the stability of the system.

(c) What are the possible advantages or disadvantages of using lumped-parameter models instead of distributed-parameter models? **(5)**

L-3/T-2/BME **Date: 22/03/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2019-2020

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

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. Answer any **THREE** questions.

Use Tables 1 and 2 where necessary.

1. (a) Using the following data for skin, fat, bone, and muscle layers, determine the effects of a layer of fat on the heat flux (% change) from the body. Assume same temperature drop for all cases. **(15)**

Table for question 1(a)

Tissue	Thickness (cm)	Thermal conductivity (W m^{-1} K^{-1})
Skin	0.25	0.442
Fat	1.0	0.21
Muscle	2.0	0.42
Bone	0.75	0.50

(b) In an enzyme-catalyzed reactions of glycolysis, accumulation phospheoenol is catalyzed by pyruvate kinase into pyruvate. Alanine is an amino acid which is synthesized from pyruvate binds with the phosphoenol - pyruvate kinase complex and inhibits the enzyme pyruvate kinase during glycolysis. With proper assumption show that addition in Alanine concentration affects both the affinity and maximum reaction rates. **(20)**

2. (a) A novel method of treating pain is to direct an electrical current to the tissue that is the source of the signal. This therapy is accomplished by inducing a small electrical current through tissue for times that are long enough for the system to reach steady state. The energy generation per unit volume by electrical dissipation for a current of 15 mA is 5.7×10^3 W m^3. If the thermal conductivity of muscle is 0.52 W m^{-1} K^{-1}. What is the maximum temperature difference that can be achieved by the system? Derive necessary equations and state the assumptions. **(15)**

(b) Derive the following equation for a dialysis system, where both the blood and dialysate are flowing in the same direction. **(20)**

$$E = \frac{1}{1+Z}\{1 - \exp[-FR(1+Z)]\}$$

Contd P/2

3. (a) The general equation for the receptor-ligand binding kinetics can be given as: **(25)**

$$N_C = N_{CO} \exp\left[-k_{-1}\left(1+\frac{C_{LO}}{K_D}\right)t\right] + \frac{C_{LO}N_{R_T}}{C_{LO}+K_D}\left\{1-\exp\left[-k_{-1}\left(1+\frac{C_{LO}}{K_D}\right)t\right]\right\}$$

In order to determine the association and dissociation rate coefficients, steady-state experiments were performed at various values of the constant initial ligand concentration when no complex is present. Show that the results support the idea that binding is a bimolecular interaction and determine the equilibrium dissociation constant.

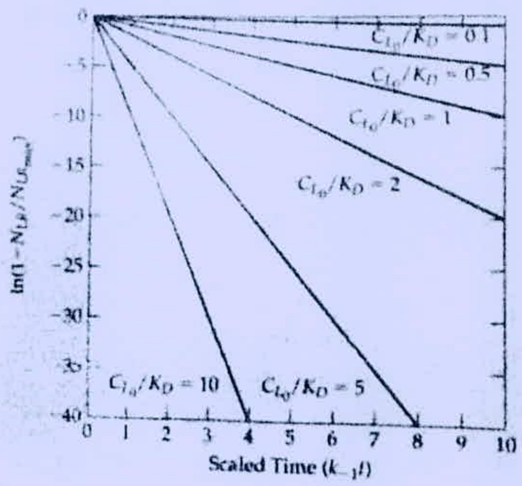


Figure for question 3(a)

(b) A new tissue-engineered scaffold having a volume of 2 mm^3 has been synthesized where 5,203 solid spheres are present. The diameter of each solid sphere is 0.02 mm. Calculate the fraction of the pore volumes compare to the total volumes. **(10)**

4. (a) Derive the general form of conservation of mass for a porous spherical polymer contains a drug to treat brain cancer. Mention the appropriate assumptions. **(15)**

(b) For the following hypothetical reactions, calculate the maximum amount of X_2Y_2 that can be present during the reaction. State your assumptions clearly. **(15)**

$$2XY \xrightarrow{K_1} X_2Y_2$$
$$X_2Y_2 \xrightarrow{K_2} X_2 + Y_2$$

(c) What is the differences between Darcy's Law and Brinkman equation for fluid flow through the porous medium? **(5)**

Contd P/3

BME 307

SECTION – B

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

5. (a) The pressure drop in a curved blood vessel is affected by the curvature of the vessel. Consider a Newtonian fluid of density ρ and viscosity μ flowing at an average velocity υ through a curved segment of radius *a* length L and a radius of curvature R. **(20)**

   (i) Use Buckingham Pi theorem to Identify the dimensionless groups that affect the pressure drop in curved vessels.

   (ii) Sketch and explain the velocity profiles in different sections in a curved blood vessel.

   (b) For a white cell of radius of 5 μm and a cortical tension of 0.03 mN/m, determine the pressure difference needed to draw the cell into a micropipette of radius 1 μm. Mention the assumptions behind the model you are using for pressure calculation. **(15)**

6. (a) A parallel plate flow chamber is being designed to study the adhesion of leukocytes to endothelium. Derive an expression for wall shear stress for pressure driven flow through the chamber. Mention necessary assumptions. **(20)**

   (b) Determine the channel height that can be used in the parallel plate flow chamber to generate wall shear stress as high as 2 Pa with flow rates less than 2 cm^3/s. The viscosity of the tissue culture medium is 0.00087 Pa-s. **(15)**

7. (a) A patient is being examined by echocardiography for possible mitral valve stenosis. The left atrial velocity averaged 0.5 m/s while the valve was open. The maximum velocity through the valve was 1.8 m/s. The cross-sectional diameter in the left atrium where the velocity was recorded was 1.5 cm. **(15)**

   (i) Determine the pressure drop between the left atrium and the valve.

   (ii) Calculate the cross-sectional open area of the mitral valve.

   (b) Use an integral analysis to examine the effect of tapering on the pressure drop in a blood vessel of length L. Assume that the outlet radius R_2 is related to the inlet radius by $R_2 = ER_1$, where $E < 1$. **(20)**

Contd P/4

BME 307

8. (a) The velocity field surrounding a cell of radius R moving at a velocity U_0 through a culture medium of viscosity μ is given by, **(15)**

$$v_r = \frac{U_0}{2}\cos\theta\left(\frac{R}{r}\right)^2\left(\frac{3r}{R}-\frac{R}{r}\right) \quad \text{and} \quad v_\theta = -\frac{U_0}{4}\sin\theta\left(\frac{R}{r}\right)\left(\left(\frac{R}{r}\right)^2+3\right)$$

Calculate the drag force on the cell due to viscous effects.

(b) Give short description of the transport processes in two major organ systems of the body. **(10)**

(c) Both RBC aggregation and RBC deformation contribute to the rheology of blood. How can you demonstrate this experimentally? **(10)**

Table 1: Integral forms of the conservation equations

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

Table 2: Navier-Stokes equation for incompressible Newtonian fluid

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

L-3/T-2/BME **Date: 10/04/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2019-2020

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

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. Answer any **THREE** questions.

1. (a) Consider an LTI system with input $x(n)$ and output $y(n)$. When the input to the system is **(20)**

$$x(n) = 5\frac{sin(0.4\pi n)}{\pi n} + 10\,cos(0.5\pi n),$$

the corresponding output is

$$y(n) = 10\frac{[0.3\pi(n-10)]}{\pi(n-10)}$$

Determine the frequency response $H(e^{j\omega})$ and the impulse $h(n)$ for the LTI system.

(b) A causal LTI discrete-time system has system function **(15)**

$$H(z) = \frac{(1-0.5z^{-1})(1+4z^{-2})}{(1-0.64z^{-2})}$$

Find expressions for a minimum-phase system $H_1(z)$ and an all-pass system $H_{ap}(z)$ such that $H(z) = H_1(z)H_{ap}(z)$.

2. (a) Determine the digital transfer function of the IIR filter obtained by transforming the following causal analog transfer function using the impulse invariance method. Assume $T = 0.2$ sec. **(20)**

$$H_a(s) = \frac{16(s+2)}{(s+3)(s^2+2s+5)}$$

(b) Determine the 3-dB bandwidth of the filters $(0 < a < 1)$ **(15)**

$$H_1(z) = \frac{1-a}{1-az^{-1}}$$

$$H_2(z) = \frac{1-a}{2}\frac{1+z^{-1}}{1-az^{-1}}$$

Which is a better lowpass filter? Justify your answer.

3. (a) Design a linear phase lowpass FIR filter using the window-based approach that satisfies the following specification: $\omega_p = 0.47\pi, \omega_s = 0.59\pi, \delta_p = 0.001, \delta_s = 0.007$. Use the Hamming window. Describe only the details of calculating the antisymmetric impulse response coefficients of the desired FIR filler. **(20)**

(b) Design a linear phase lowpass FIR filter of 7 coefficients using the frequency sampling method. Let the cutoff frequency be 1200 Hz and assume a sampling frequency of 8000 Hz. **(15)**

Contd P/2

EEE 375

4. (a) Consider a finite-duration sequence **(15)**

$$x(n) = \{0, 1, 2, 3, 4\}$$
$$\uparrow$$

(i) Sketch the sequence $s(n)$ with 6-point DFT

$$S(k) = W_2^k X(k), \qquad k = 0, 1, \cdots\cdots, 6$$

(ii) Determine the sequence $y(n)$ with 6-point DFT $Y(k) = \text{real}(X(k))$

(b) Let $x(n)$ be an N-point sequence with an N-point DFT $X(k)$, where N is even. **(20)**

(i) Consider the time-aliased sequence

$$y(n) = \begin{cases} \sum_{l=-\infty}^{\infty} x(n + lM), & 0 \le n \le M-1 \\ 0, & elsewhere \end{cases}$$

what is the relationship between the M-point DFT $Y(k)$ of $y(n)$ and the Fourier transform $X(\omega)$ of $x(n)$?

(ii) Let

$$y(n) = \begin{cases} x(n) + x\left(n + \frac{N}{2}\right), & 0 \le n \le N-1 \\ 0, & elsewhere \end{cases}$$

and

$$y(n) \underset{\frac{N}{2}}{\overset{DFT}{\longleftrightarrow}} Y(k)$$

Find $Y\left(\frac{k}{2}\right)$, $k = 2, 4, \cdots \cdots, N-2$ in terms of $X(k)$.

SECTION – B

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

Symbols and Abbreviations have their usual meanings.

5. (a) Determine if the following discrete-time signals are periodic or not. If periodic, find the fundamental period. You must justify your answers. **(20)**

(i) $x(n) = cos(\pi n/4) sin(n/8)$

(ii) $x(n) = cos(\pi n/12) + sin(n\pi/36)$

(iii) $x(n) = tan(\pi + 0.2n)$

If a periodic, can you suggest necessary modification to make the corresponding signal periodic.

(b) The analog signal $x_a(t) = sin(480\pi t) + 3\,sin(720\pi t) + 5\,sin(1600\pi t)$. Find the Nyquist rate and folding frequency. If the signal is sampled at 800 Hz, develop the analytic expression of the signal reconstructed from the sampled version. **(15)**

Contd P/3

6. (a) Find if the following systems are causal, stable, linear and time-invariant. Justify your answers. **(20)**

   (i) $y(n) = x(n) + nx(n+1) + n^2x(n-1)$

   (ii) $y(n) = x(n)u(n) + x(n)sin\,\omega_o n$

   (iii) $y(n) = \text{floor}\left[x(n)\right]$

   (b) Find the sketch the convolution of $x(a)$ and $h(n)$ where **(15)**

$$x(n) = \frac{1}{3}n; \quad 0 \le n \le 7$$
$$= 0; \quad \text{otherwise}$$
$$h(n) = 1; \quad -4 \le n \le 2$$

   both analytically and graphically. Compare your results.

7. (a) Determine the impulse response and step response of the system described by the following difference equation: **(20)**

$$y(n) = 0.8y(n-1) + 0.1y(n-2) + 0.2y(n-3) + x(n)$$

   Use time-domain approach.

   Explain why we need to obtain the step response.

   (b) Develop the Direct Form I and Direct Form II structures of the following system: **(15)**

$$y(n) = x(n) - x(n-1) + 2x(n-2) + 3x(n-4)$$

   Among the two structures, which one is more advantageous and why?

8. (a) Consider the Z-transforms of the causal signals $x(n)$ and $y(n)$, given below **(20)**

$$X(z) = \frac{1}{1 + 1.5z^{-1} - 0.5z^{-2}}$$

$$Y(z) = \frac{1}{1 - 0.5z^{-1} + 0.6z^{-2}}$$

   Find $x(n)$ and $y(n)$. Partially check your results by calculating x(0), $x(1)$, $x(\propto)$, $y(0)$, $y(1)$ and $y(\propto)$ alternatively.

   (b) Consider the following systems: **(15)**

   (i) $y(n) = 0.75y(n-1) - 0.125y(n-2) + x(n)$

   (ii) $y(n) = y(n-1) + 0.5y(n-2) + x(n) + x(n-1)$

   Are the two systems equivalent? Using the impulse response of the two systems, verify if the systems are stable or not. If not stable, how can you make it stable? Explain.

L-3/T-2/BME **Date: 18/4/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2019-2020

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

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. Answer any **THREE** questions.

Symbols and abbreviations have their usual meanings. You can make reasonable assumptions if necessary.

1. (a) Let $Y = \sqrt{12/n}\sum_{i=1}^{n} X_i$,where X_i represents i.i.d. Poisson random variables. Find the pdf of Y for n = 2, 10 and 20. Comment on your results in relation to Central Limit Theorem. **(20)**

(b) A student uses pens whose lifetime is an exponential random variable with a mean of 1 week. Using the Central Limit Theorem, find the minimum number of pens he should buy at the beginning of 15-week long semester so that he does not ran out of pens during the semester with a probability of 0.90 and 0.95, respectively. Comment on your results. **(15)**

2. (a) Let $h(t) = b\, e^{-at} u(t)$ where a and b are arbitrary constants. X(t) is a white noise process where $R_{xx}(\tau) = q\delta(\tau)$. **(20)**

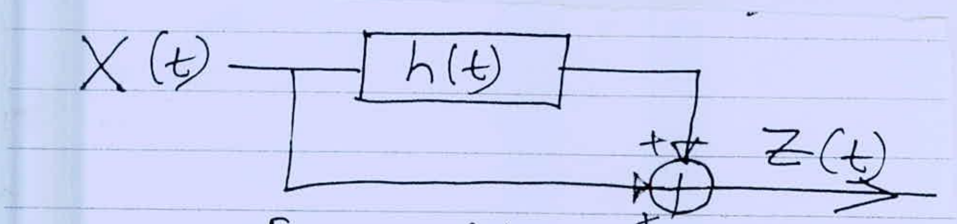


Figure 2(a)

h(t) is the impulse response of an LTI system. For the system shown in Fig. 2(a) find $S_{xz}(w)$ and $S_{zz}(w)$. Then, determine σ_z^2.

(b) Briefly explain mean-ergodicity and correlation- ergodicity of a random process. Comment on the mean-ergodicity and correlation- ergodicity of the process z(t) in Q. 2(a). **(15)**

3. (a) Consider a random process $X(t) = b \cos(wt + \theta)$ where $\theta \sim u(0, \pi/2)$. Is the process a WSS process? If not WSS, give the condition necessary to make it WSS. Justify your answer. Also, comment on the strict-sense stationarity of the process. **(20)**

(b) What will be the PSD of the process Y(n) where $Y(n) = X(n\, T_s)$ where $X(t) = A \sin(2\pi 100t + \theta)$,and $\theta \sim u(0, 2\pi)$, for T_s = 10 ms and 20 ms, respectively. Comment on your results. **(15)**

Contd P/2

4. (a) A pair random variables (X,Y) has the joint pdf given by **(20)**

$$f_{x,y}(x,y)=\frac{1}{8\pi}e^{-\frac{(x-1)^2+(y+1)^2}{8}}$$

Find the probability that (i) X > 2, Y < 0 and (ii) Y > X.

(b) The discrete time real processes X and Y have zero mean where $R_{xx}(k)=\frac{1}{2}k$ and $R_{yy}(k)=\frac{1}{3}k$. X and Y are statistically independent. Let $Z(n)=X(n)-Y(n)$. **(15)**

(i) Find $R_{zz}(k)$ and $S_{xz}(\Omega)$.

(ii) What will be the auto correlation of Z if X and Y are not statistically independent but uncorrelated? Explain.

SECTION – B

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

All the symbols have their usual meanings. Assume reasonable values for missing data.

5. (a) An airline in a small city has five departures each day. It is known that any given flight has a probability of 0.25 of departing late. For any given day find the probabilities that: (i) no flight departs late, and (ii) all flights depart late, and (iii) three or more depart on time. **(15)**

(b) For a certain binary nonsymmetric channel as shown in Fig. for Ques. No. 5(b), it is given that $p_{y|x}(0|1)=0.2$ and $p_{y|x}(1|0)=0.3$ where x is the transmitted bit and y is the received bit. If $p_x(0)$ = 0.4, determine $p_y(0)$, $p_y(1)$, p(error), $p_{x|y}(0|1)$ and $p_{x|y}(1|0)$. **(20)**

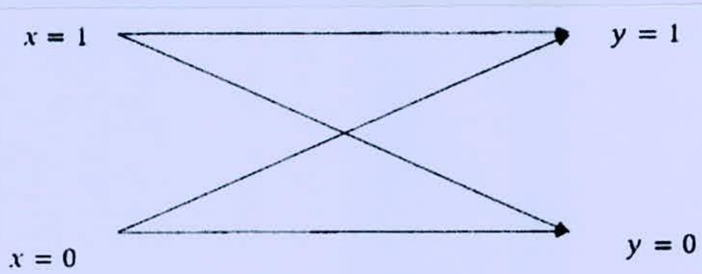


Fig. for Ques. No. 5(b)

6. (a) A random variable X has the probability density function **(15)**

$$f_X(x)=\begin{cases}\left(\frac{3}{32}\right)\left(-x^2+8x-12\right), & 2\le x\le 6\\ 0, & elsewhere\end{cases}$$

Determine the mean and variance of *X* and (-4*X* + 3).

Contd P/3

Contd... Q. No. 6

(b) A random variable X has a probability density function as **(20)**

$$f_X(x) = \begin{cases} \left(\pi/16\right)\cos\left(\pi x/8\right), & -4 \le x \le 4 \\ 0, & elsewhere \end{cases}$$

Find the density function of $g(X) = 5X^2$.

7. (a) In a communication system as shown in Fig. for Ques. No. 7(b), given the probabilities of the repeaters failing independently are $p_1 = P(R_1) = 0.005$, $p_2 = P(R_2) = P(R_3) = P(R_4) = 0.01$, $p_3 = P(R_5) = P(R_6) = 0.05$. Compute the probability that the signal will not arrive at point b. **(15)**

(b) The lifetime of a system expressed in weeks is a Rayleigh random variable X for which **(20)**

$$f_X(x) = \begin{cases} \dfrac{x}{200}\exp\left[-\dfrac{x^2}{400}\right], & 0 \le x \\ 0, & x < 0 \end{cases}.$$

(i) What is the probability that the system will not last a week? (ii) What is the probability that the system lifetime will exceed one year?

8. (a) Assume that automobile arrivals at a gasoline station are Poisson distributed and occur at an average rate 50/hour. The station has only one gasoline pump. If all automobiles are assumed to require three minutes to obtain fuel, what is the probability that a waiting line will occur at the station? **(15)**

(b) Two random variables X and Y are defines by $\overline{X} = 1$, $\overline{Y} = -2$, $\overline{X^2} = 3$, $\overline{Y^2} = 5$, $R_{XY} = -1$. Two new random variables W and U are: **(20)**

$$W = 5X + 2Y$$
$$U = -X - 3Y$$

Find $\overline{W}, \overline{U}, \overline{W^2}, \overline{U^2}, R_{WU}, \sigma_X^2, \sigma_Y^2$. Also explain whether W and U orthogonal or not.

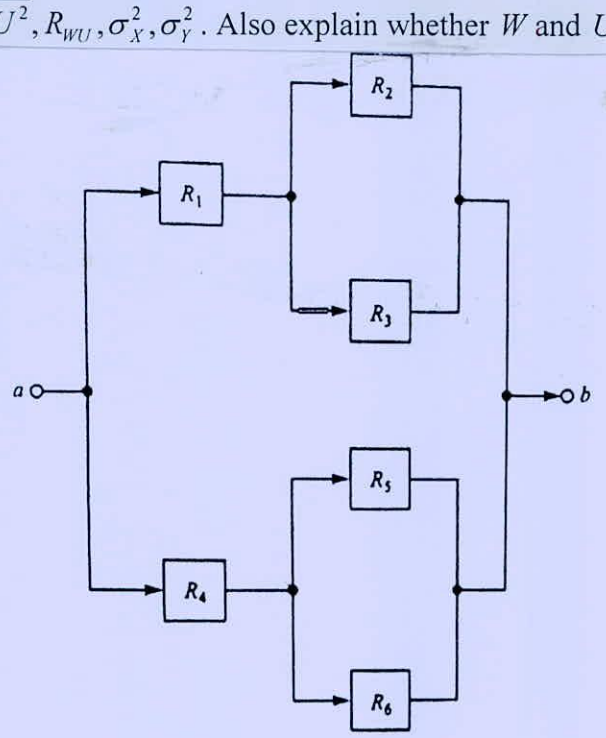


Fig. for Ques. No. 7(b)

Table of Q-Function $Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-t^2/2}\,dt$

Table 1: Values of $Q(x)$ for $0 \le x \le 9$

x	$Q(x)$	x	$Q(x)$	x	$Q(x)$	x	$Q(x)$
0.00	0.5	2.30	0.010724	4.55	2.6823×10^{-6}	6.80	5.231×10^{-12}
0.05	0.48006	2.35	0.0093867	4.60	2.1125×10^{-6}	6.85	3.6925×10^{-12}
0.10	0.46017	2.40	0.0081975	4.65	1.6597×10^{-6}	6.90	2.6001×10^{-12}
0.15	0.44038	2.45	0.0071428	4.70	1.3008×10^{-6}	6.95	1.8264×10^{-12}
0.20	0.42074	2.50	0.0062097	4.75	1.0171×10^{-6}	7.00	1.2798×10^{-12}
0.25	0.40129	2.55	0.0053861	4.80	7.9333×10^{-7}	7.05	8.9459×10^{-13}
0.30	0.38209	2.60	0.0046612	4.85	6.1731×10^{-7}	7.10	6.2378×10^{-13}
0.35	0.36317	2.65	0.0040246	4.90	4.7918×10^{-7}	7.15	4.3389×10^{-13}
0.40	0.34458	2.70	0.003467	4.95	3.7107×10^{-7}	7.20	3.0106×10^{-13}
0.45	0.32636	2.75	0.0029798	5.00	2.8665×10^{-7}	7.25	2.0839×10^{-13}
0.50	0.30854	2.80	0.0025551	5.05	2.2091×10^{-7}	7.30	1.4388×10^{-13}
0.55	0.29116	2.85	0.002186	5.10	1.6983×10^{-7}	7.35	9.9103×10^{-14}
0.60	0.27425	2.90	0.0018658	5.15	1.3024×10^{-7}	7.40	6.8092×10^{-14}
0.65	0.25785	2.95	0.0015889	5.20	9.9644×10^{-8}	7.45	4.667×10^{-14}
0.70	0.24196	3.00	0.0013499	5.25	7.605×10^{-8}	7.50	3.1909×10^{-14}
0.75	0.22663	3.05	0.0011442	5.30	5.7901×10^{-8}	7.55	2.1763×10^{-14}
0.80	0.21186	3.10	0.0009676	5.35	4.3977×10^{-8}	7.60	1.4807×10^{-14}
0.85	0.19766	3.15	0.00081635	5.40	3.332×10^{-8}	7.65	1.0049×10^{-14}
0.90	0.18406	3.20	0.00068714	5.45	2.5185×10^{-8}	7.70	6.8033×10^{-15}
0.95	0.17106	3.25	0.00057703	5.50	1.899×10^{-8}	7.75	4.5946×10^{-15}
1.00	0.15866	3.30	0.00048342	5.55	1.4283×10^{-8}	7.80	3.0954×10^{-15}
1.05	0.14686	3.35	0.00040406	5.60	1.0718×10^{-8}	7.85	2.0802×10^{-15}
1.10	0.13567	3.40	0.00033693	5.65	8.0224×10^{-9}	7.90	1.3945×10^{-15}
1.15	0.12507	3.45	0.00028029	5.70	5.9904×10^{-9}	7.95	9.3256×10^{-16}
1.20	0.11507	3.50	0.00023263	5.75	4.4622×10^{-9}	8.00	6.221×10^{-16}
1.25	0.10565	3.55	0.00019262	5.80	3.3157×10^{-9}	8.05	4.1397×10^{-16}
1.30	0.0968	3.60	0.00015911	5.85	2.4579×10^{-9}	8.10	2.748×10^{-16}
1.35	0.088508	3.65	0.00013112	5.90	1.8175×10^{-9}	8.15	1.8196×10^{-16}
1.40	0.080757	3.70	0.0001078	5.95	1.3407×10^{-9}	8.20	1.2019×10^{-16}
1.45	0.073529	3.75	8.8417×10^{-5}	6.00	9.8659×10^{-10}	8.25	7.9197×10^{-17}
1.50	0.066807	3.80	7.2348×10^{-5}	6.05	7.2423×10^{-10}	8.30	5.2056×10^{-17}
1.55	0.060571	3.85	5.9059×10^{-5}	6.10	5.3034×10^{-10}	8.35	3.4131×10^{-17}
1.60	0.054799	3.90	4.8096×10^{-5}	6.15	3.8741×10^{-10}	8.40	2.2324×10^{-17}
1.65	0.049471	3.95	3.9076×10^{-5}	6.20	2.8232×10^{-10}	8.45	1.4565×10^{-17}
1.70	0.044565	4.00	3.1671×10^{-5}	6.25	2.0523×10^{-10}	8.50	9.4795×10^{-18}
1.75	0.040059	4.05	2.5609×10^{-5}	6.30	1.4882×10^{-10}	8.55	6.1544×10^{-18}
1.80	0.03593	4.10	2.0658×10^{-5}	6.35	1.0766×10^{-10}	8.60	3.9858×10^{-18}
1.85	0.032157	4.15	1.6624×10^{-5}	6.40	7.7688×10^{-11}	8.65	2.575×10^{-18}
1.90	0.028717	4.20	1.3346×10^{-5}	6.45	5.5925×10^{-11}	8.70	1.6594×10^{-18}
1.95	0.025588	4.25	1.0689×10^{-5}	6.50	4.016×10^{-11}	8.75	1.0668×10^{-18}
2.00	0.02275	4.30	8.5399×10^{-6}	6.55	2.8769×10^{-11}	8.80	6.8408×10^{-19}
2.05	0.020182	4.35	6.8069×10^{-6}	6.60	2.0558×10^{-11}	8.85	4.376×10^{-19}
2.10	0.017864	4.40	5.4125×10^{-6}	6.65	1.4655×10^{-11}	8.90	2.7923×10^{-19}
2.15	0.015778	4.45	4.2935×10^{-6}	6.70	1.0421×10^{-11}	8.95	1.7774×10^{-19}
2.20	0.013903	4.50	3.3977×10^{-6}	6.75	7.3923×10^{-12}	9.00	1.1286×10^{-19}
2.25	0.012224						

Table of Error Function

z	erf(z)	z	erf(z)	z	erf(z)
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

L-3/T-2/BME **Date: 02/04/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2019-2020

Sub: **CHE 471** (Biochemistry)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks

SECTION – A

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

1. (a) Describe with diagrams the structure and stability considerations of parallel and antiparallel β-sheets. **(8)**

(b) What are the factor that make proteins stable? Describe with appropriate sketches. **(17)**

(c) Draw the fully protonated structure of any two polar amino acids. Mention the name, the one letter and three letter codes of these. Also calculate the pI of each. **(10)**

2. (a) Describe in detail one characterization technique for Proteins and one for Nucleic acids. Include appropriate diagrams if needed. **(15)**

(b) Given the following DNA template sequence write down the corresponding DNA coding strand and the corresponding m RNA sequence. Finally write down the sequence of amino acids that are coded by the sequence given using the chart given. Choose the correct reading frame based on the start codon (NOTE: the start codon is present within the first 6 bases thus you should ignore all bases coming before that) **(20)**

DNA TEMPLATE sequence:

5′ TGTGAAACCCCTTAAAGAGTTTACATATGGACGTA 3’

3. (a) Draw the general structure of pyrimidine and purine and state examples of each. **(8)**

(b) With the help of a schematic diagram describe in detail the structure of a DNA double helix. In your diagram mark the width and the rise of the helix. **(12)**

(c) With the aid of appropriate diagrams explain the rules of DNA replication. **(15)**

4. (a) Draw the *fully protonated* structure and the titration curve for the pentapeptide

CREAK.

Write down the peptide name in three letter code. What is the charge on this pentapeptide at pH 2, 6 and 13? Show the corresponding **schematic** diagrams at these pHs. What is the pI and the molecular weight of this pentapeptide? **(20)**

(b) Calculate the pH of a buffer solution made from 0.30 M hydrofluoric acid and 0.70 M siodium fluoride after the addition of 0.04 mol of HCl to 1 L of this solution. Assume no change in volume. Ka = 7.1×10^{-4} **(10)**

Contd …… P/2

CHE 471

Contd... Q. No. 4

(c) If the same mixture of acid and salt as in (b) was used but 1 M hydrofluoric acid and 1 M sodium fluoride were used, what would be effect on the buffering? Explain. **(5)**

SECTION – B

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

5. (a) Discuss the types of isomerism commonly observed in biochemicals. With examples, discuss the impacts these isomeric forms have on biological processes. **(15)**

(b) Human reduction blood cells (RBCs) are approximately 7.5 to 8.7 μm in diameter, whereas platelets have diameter that are about 20% less. Suggest a reason for this difference. How would you separate RBCs from platelets? **(4+6)**

(c) The densities of microsomal membranes differ from each other. For example, the removal of Mg^{2+} causes the density of endoplasmic reticulum membrances (ER) to reduce as ribosomes become detached. Based on this information, describe a technique to separate ER membrances from those of other organelles. **(10)**

6. (a) Describe how different inhibitors affect enzymatic reactions. **(10)**

(b) Fumarase follows Michaelis-Menten Kinetics, and its reaction can be describe as follows: **(16+9=25)**

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_2} P + E$$

For the substrate fumarate, it is given that $k_1 = 10^9\ M^{-1}s^{-1}$, $k_{-1} = 4.4 \times 10^4 s^{-1}$ and $k_2 = 10^3 s^{-1}$.

Considering $[E]_0 = 10^{-6}$ M, determine the following:

i) The value of K_m

ii) The initial rate of product formation when $[s]_0 = 10^{-3}$ M

iii) The value of V_{max}

iv) The specificity constant

If the turnover number and specificity constant of fumarase for malate are 900 and 5×10^{-6} respectively, what can you conclude about the difference in fumarase's association with fumarate and malate?

Contd P/3

CHE 471

7. (a) What are the purposes of lectins? Discuss specific examples. **(8)**

(b) Draw the formation of α-D-ribofuranose and β-D-ribofuranose from D ribose (5C). **(6)**

(c) Discuss the role of NADH and $FADH_2$ in supporting the processes occurring in the electron transport chain. **(8)**

(d) Describe the payoff phase of glycolysis. Why is this phase so critical? **(13)**

8. (a) Distinguish between glycerophosholipids and sphingolipids. **(8)**

(b) Describe the several types of integral proteins. Some integral proteins are barrel-shaped, in other words, their β -sheets fold to form an inner cylindrical channel. Discuss specifically how this shape supports membrane transport processes. **(10)**

(c) Gastric juice (phosphorus 1.5) is produced by pumping HCl from blood plasma (phosphorus 7.4) into the stomach. **(17)**

i) Calculate the amount of free energy required to concentrate the H^+ in 1 L of gastric juice at 37 °C.

ii) Under cellular condition, how many moles of ATP must be hydrolyzed to provide this amount of free energy? The free-energy change for ATP hydrolysis under cellular conditions is about 58 kJ/mol. Assume transmembrane electrical potential has no effect on transport.

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	

mRNA Codon Chart

First base	U	C	A	G	Third base
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