L-3/T-1/BME Date : 06/11/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **BME 301** (Bioelectricity)

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**.

1. (a) Describe the factors in details that lead to a reversible condition in which a muscle is no longer able to generate or sustain the expected power output. **(15)**

   (b) As a side effect of a drug, the Ca^{2+} channels of the cardiac muscle are blocked. Qualitatively draw the transmembrane potential profile of the cardiac muscle after a stimulation and explain the profile. **(10)**

   (c) Using a hypothetical two compartment concentration cell, explain, with suitable illustrations, how the Nernst equilibrium is reached across a cellular membrance. **(10)**

2. (a) To measure the membrance resistance, a cell pair is connected to a voltage-clamp circuit via a patch electrode in the whole-cell configuration. Separate voltages V_1, V_2 are applied to each cell and the resulting currents, I_1, I_2, measured (subscripts 1 and 2 refer to cell 1 and cell 2). For adult rat myocyte, the junctional (nexal) resistance is measured as 15 MΩ, and the access (pipette) resistances are insignificant. Calculate the lumped sarcolemmal membrane resistances of each cell when symmetric pulse of 27 mV (relative to the holding potential of -42 mV) is applied for 200 ms. The measured current I_1 and I_2 are 0.5 nA and 5nA respectively. **(10)**

   (b) "Too much or too little overlap of thick and thin filaments in resting muscle results in decreased tension": explain these phenomena with appropriate diagram. **(15)**

   (c) What are the clinical significances of an electrocardiogram? **(10)**

3. (a) Consider a short segment of an unmyelinated nerve. Each nerve segment has a circular cross-section with diameter d and length L. The temperature is 300K, and the membrane capacitance is 1.2 $\mu F/cm^2$. There is no variation of membrane potential along the axial coordinate. Membrane conductances for different ions are: g_K = 0.375 mS/cm^2, g_{Na} = 0.01 mS/cm^2, g_{Cl} =0.57 mS/cm^2. The ionic concentrations are given below: **(6+5+6+5+3=25)**

Concentration (mM)		
Ion	Intra	Extra
K^+	280	10
Na^+	50	437
Cl^-	51	485

Contd P/3

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Contd..... Q. No. 3

(i) Find E_k, E_{Na}, E_{Cl}

(ii) Find the resting potential.

(iii) Find I_K, I_{Na}, I_{Cl}

(iv) Draw the equivalent circuit for the parallel conductance model. Clearly label all the components and show their values on your drawing. Also, give the values of all the potentials, with correct polarities, and all the currents, with correct directions.

(v) Based on your calculations, explain whether there is a net influx or efflux of each of the ions involved.

(b) Why is it important to operate an electrode in the capacitive region? What will happen if an electrode made of platinum is operated outside of the capacitive region? **(10)**

4. (a) The quantitative dependence of transmiter release on external calcium concentration ([Ca]) has been studied at the frog neuromuscular junction, using intracellular recording and taking the amplitude of the end-plate potential (EPP) as an index of the number of packets released. The experimental values are given below: **(25)**

[Ca] mM	EPP mV
0.201543	0.14336
0.251706	0.302864
0.299822	0.598495
0.351374	0.98744
0.400594	1.670208
0.449466	2.546511
0.501811	3.494624

The basic assumption is that on the nerve terminal two parallel reactions occur (having equal dissociation constant of 1.1 mM) where Ca^{2+} and Mg^{2+} bind to a presynaptic structure. Assuming the proportionality constant that relates between the EPP and measure of the facilitation of transmitter release of 0.1 mV, calculate the amount of total presynaptic structure

(b) What are the important considerations for selecting the material of an electrode for functional electrical stimulation application? **(10)**

SECTION – B

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

5. (a) With a long stimulus, the lowest stimulus current that would produce an action potential had magnitude $10\mu A/cm^2$, and the transmembrane voltage at the end of that stimulus was 20 millivolts. Moreover, the membrane was found to have a time constant of 2.4 msec. Using shorter stimuli, the investigator set a stimulus duration and then

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Contd..... Q. No. 5(a)

carefully tried stimuli of different current magnitudes until the current was found that produced (at the end of the stimulus) the threshold voltage for an action potential. What stimulus current is needed for a stimulus duration of 0.2 msec, if other results are as shown in the table below? Also, find the rheobase and chronaxie. Give numerical answers, in μA/cm^2. **(15)**

duration (msec)	current ($\mu A/cm^2$)
1	29.346
3	14.015

(b) For an impulse stimulus to an excitable tissue under subthreshold conditions, fine the steady-state response using the cylindrical fiber model. **(20)**

6. Given the table below for HH membrane and Environmental Parameters: **(35)**

$\bar{g}_K$	36	mS/cm^2	maximum K^+conductivity
$\bar{g}_{Na}$	120	mS/cm^2	maximum Na^+ conductivity
g_L	0.3	mS/cm^2	leakage conductivity
C_m	1.0	μF/cm^2	membrane capacitance
E_K	-72.1	mV	K^+ Nernst potential
E_{Na}	52.4	mV	Na^+ Nernst potential
E_L	-49.2	mV	leakage Nernst potential
V_r	-60	mV	resting potential
I_s	0	μA/cm^2	stimulus current
I_m	0	μA/cm^2	total membrane current for patch if no stimulus

and HH state variables:

V_m	-11.5	mV	transmembrane potential
n	0.378	—	gating probability n
m	0.417	—	gating probability m
h	0.477	—	gating probability h

Find V_m^2 for a time step of 100 μs.

Assume n^0=n, m^0=m, and h^0=h.

Also,

$$\alpha_n = \frac{0.01(10 - v_m)}{\left[\exp\left(\frac{10-v_m}{10}\right) - 1\right]} \qquad \alpha_m = \frac{0.1(25 - v_m)}{\exp[0.1(25 - v_m)] - 1} \qquad \beta_m = 4\exp\left(-\frac{v_m}{18}\right)$$

$$\beta_n = 0.125\exp\left(\frac{-v_m}{80}\right) \qquad \alpha_h = 0.07\exp\left(-\frac{v_m}{20}\right) \qquad \beta_h = \left\{\exp\left[\frac{(30 - v_m)}{10}\right] + 1\right\}^{-1}$$

7. Using the core-conductor model, derive **(10+10+15)**

(i) the relationship between axial currents and voltage across the membrane,

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(ii) the process of obtaining the membrane current if only the voltage across the membrane is known.

(iii) the voltage-divider relationship between the intracellular voltage, the extracellular voltage, and the voltage across the membrane.

8. (a) What is a voltage clamp? Explain how voltage-clamp methods enable the investigation of electrically active membranes. **(3+7)**

(b) Explain, using Einstein's equation, why an experiment conducted to measure the bioelectric potential of cells and tissues at room temperature will give inaccurate results for human as well as squids. **(5)**

(c) Two chambers numbered 1 and 2 have the following dimensions (see the Figure for Q. 8(c)). Dimension L is 100 microns, and W 100 microns. Height H (out of surface) is 100 microns. The dotted lines show the edge of a boundary layer that has a thickness of 40°A. (The dotted lines identify the position of a transition region, not a physical boundary.) The temperature is 300 degrees Kelvin, and the diffusion coefficient D_k is 1.96×10^{-5} cm^2/sec. Within either chamber the concentration and electric potential are uniform, though different between chambers. The K+ concentrations are K_1 in chamber 1 and K_2 in chamber 2. A linear change occurs in concentration and potential across the transition region. The potential difference is the voltage V, where $V = \varphi_1 - \varphi_2$. Note the polarity, i.e. a positive value for V occurs when the potential in chamber 1 is the higher. Concentration K_1 is 0.22 mM, K_2 is 0.02 mM, and V is -0.04 Volts. **(5+5+5+5)**

(i) At x = 0, what is the potassium current along x due to diffusion?

(ii) At x = 0, what is the potassium current along x due to electric field?

(iii) What is concentration K_1 in $moles/cm^3$?

Iiv) How many K+ ions are then in volume 1?

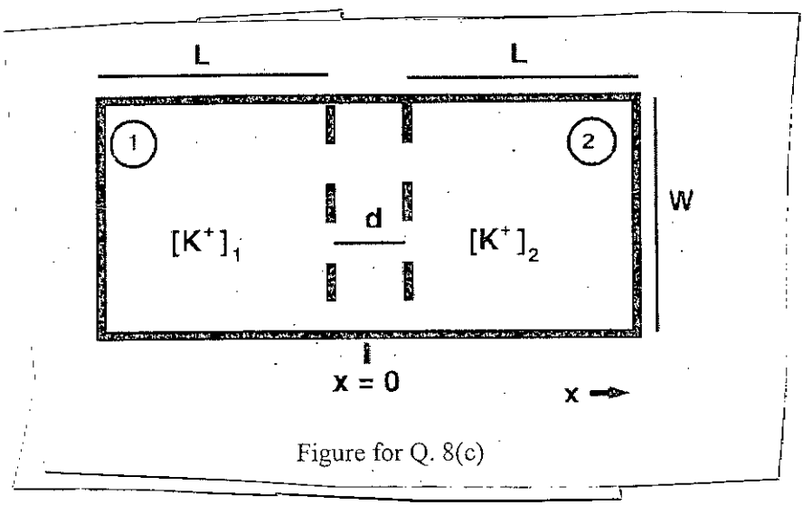

Figure for Q. 8(c)

L-3/T-1/BME **Date : 24/10/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

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

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**.

1. (a) What is electroneurogram (ENG)? Illustrate with appropriate figures how ENG can be used to measure neural conduction velocity. **(15)**

(b) A prototype cuff-less blood pressure measurement system simultaneously acquires the ECG and PPG signals from a patient and calculates the systolic BP using the relation: $BP = \frac{A}{PTT^2} + B$ where, PTT (Pulse Transit Time) is the time difference between ECG and PPG peaks, A and B are constants. The designer used linear regression to find the constant values: A = 1.15 and B = 110. To test this prototype, a subject's systolic BP is measured using an accurate BP machine and found to be 120 mmHg. The cuff-less BP system is used five times on this subject and the following PTT readings were obtained: **(20)**

Measurement No.	**1**	**2**	**3**	**4**	**5**
PTT (seconds)	0.45	0.41	0.39	0.412	0.40

Assuming that the systolic BP value of he subject did not change during these measurements, calculate the following for the cuff-less BP measurement system:

(i) The average error in the measurement of systolic BP.

(ii) The average accuracy of this system.

(iii) The precision of this system (use a deviation measure of your choice).

2. (a) How does the AC power line interfere with the ECG instrumentation system? Explain using neat diagrams and discuss possible solutions in reducing the interferences. **(15)**

(b) How is it possible to measure blood pressure directly? Describe the instrumentation and working principles of intravascular and extravascular BP measurement systems. **(15)**

(c) What are flexible electrodes and why are they beneficial? Describe one type of flexible electrode. **(5)**

3. (a) With appropriate diagrams discuss the origin of surface electroencephalogram (EEG). **(15)**

(b) You are required to design a single-lead EEG measurement system for a sleep study. The available electrodes have an impedance of 2500 Ω. Due to various reasons, it is observed that the electrode impedances change with time. You may assume that the electrode impedances may differ by a maximum 1000 Ω while the ground impedance remains unchanged. The power-line displacement current was measured to be 400 nA while the patients EEG signal has a maximum amplitude of 12 μV. **(20)**

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Contd….. Q. No. 3(b)

(i) Find the CMMR required for the EEG system so that the signal-to-common-mode-noise ratio is at least 120/1 at the output.

(ii) Find the required input impedance of the EEG amplifier so that the change in electrode impedance does not cause a power-line interference signal of greater than 1μV in the output.

4. (a) With appropriate diagrams, explain the equivalent circuit model of the electrode-skin interface. Using this model discuss the effects of skin preparation and sweat glands. **(15)**

(b) Write short notes on the following: **(15)**

(i) Brain computer interfaces,

(ii) Photoplethysmography,

(iii) Ag/AgCl Electrode.

(c) What are the properties of a good biopotential electrode? **(5)**

SECTION – B

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

Symbols carry their usual meaning. Reasonably assume any missing data

5. (a) How does Ultrasound transducers achieve beam focusing and beam steering without any moving parts? **(8)**

(b) For a piezoelectric sensor plus cable that has 1 nF capacitance, design a voltage amplifier by using only one noninverting amplifier that has a gain of 10. It should handle a charge of 1 μC generated by the carotid pulse without saturation. It should have a frequency response from 0.05 Hz to 100 Hz. Add the minimal number of extra components to achieve design specifications. **(15)**

(c) Design and sketch a circuit to measure physiological temperatures with a thermistor. Necessary data are given in Table for Q no. 5(c). **(12)**

Parameter	Value	Unit
Resistance value at 25 °C	10000	Ω
$\beta_{25/85}$ value	3977	K

Table for Q no. 5(c)

6. (a) For the LVDT shown in Fig. for Q no. 6(a), sketch the voltages c-e, d-e, and c-d as the core is displaced through its normal range. How can you determine the direction of displacement? **(10)**

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Contd..... Q. No. 6

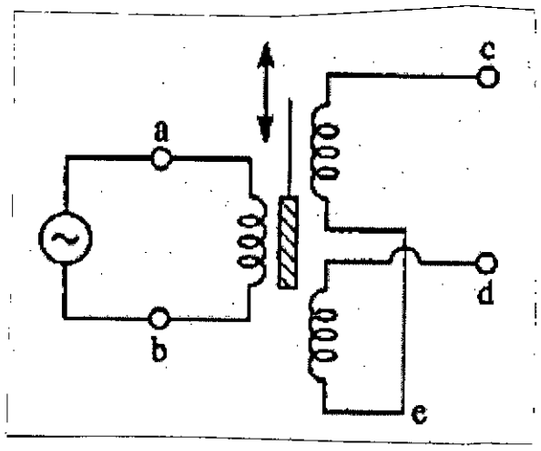

Fig. for Q no. 6(a)

(b) Explain the principles behind electrical impedance plethysmography. **(10)**

(c) How does blood pressure monitoring devices measure blood pressure without using Korotkoff sound? **(8)**

(d) Calculate the approximate area of the aortic valve for the patient with the aortic and left ventricular pressure shown in Fig. for Q no. 6(d). The patient's cardiac output was measured by thermodilution as 6400 ml/min and the heart rate as 78 bpm. **(7)**

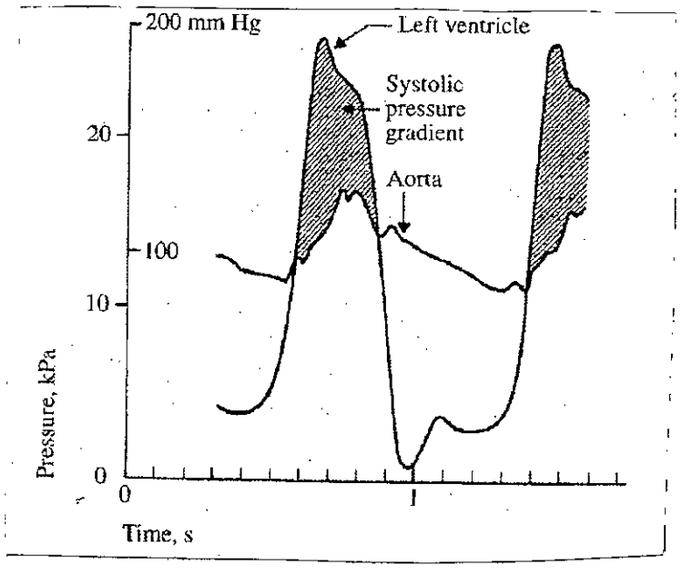

Fig. for Q no. 6(d)

7. (a) Imagine you have been tasked with selecting a device for administering drug flow from an infusion pump. What sensor technology will you pick? Explain the reasons behind your choice. **(7)**

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Contd..... Q. No. 7

(b) Explain how consistent dosing is maintained from a metered dose inhaler throughout the use. **(6)**

(c) With suitable diagrams explain how an atrial synchronus pacemaker works. Does this pacemaker replicate the function of the heart of a physiologically intact person? If the answer is no, design a system that closely replicate an intact heart. **(12)**

(d) A Fleisch pneumotachometer has 100 capillary tubes, each with a diameter of 1 mm and a length of 5 cm. What pressure drop occurs for peak flow as shown in Fig. for Q no. 7(d)? **(10)**

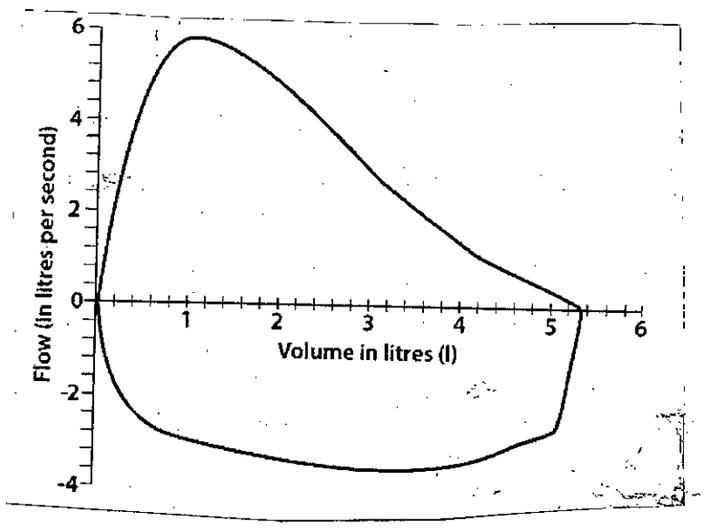

Fig. for Q no. 7(d)

8. (a) With suitable diagram, describe the Helium-dilution estimate of lung volume. **(10)**

(b) In a He-dilution experiment, a spirometer is preloaded with 10 liters of 5% He at room temperature, 25°C. After the patient has rebreathed, the He concentration in the spirometer is 4% with temperature 32°C. What is the FRC? **(7)**

(c) Describe the sources of microshock hazard. **(10)**

(d) A person receives a lethal macroshock while standing in water and simulataneously touching the ungrounded metal casing on a high voltage 50 Hz power transformer. Assume that the resistance of the skin on the person's hand is 100 kΩ and that the resistance of the skin on the person's feet is negligible. A capacitance of 25 nF is measured between the transformer casing and the high voltage conductors. Find the minimal value of the high voltage, assuming that 75 mA is the minimal fibrillating macroshock. Draw an equivalent circuit. **(8)**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

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. Answer any **THREE**.

1. (a) The figure blow shows a rudimentary approximation of one cycle of an ECG signal, e(t). Express $e(t)$ in terms of the unit step and ramp functions. **(5)**

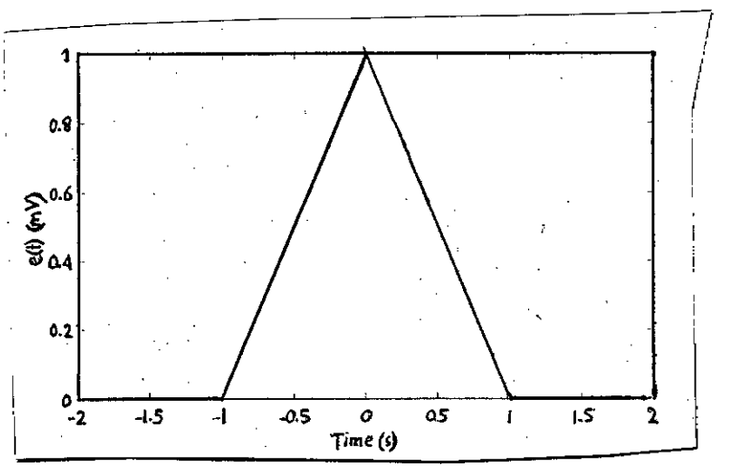

Figure for Q.1(a)

(b) $e(t)$ is passed through the following system: **(5+5)**

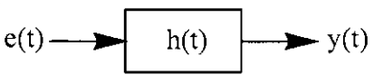

Figure for Q.1(b)

Sketch y(t) if:

(i) $h(t) = \delta(t - 4n)$.

(ii) $h(t) = \delta(t - 1.5n)$.

where, $n = 0, \pm1, \pm2, \pm3, \ldots\ldots$

(c) Determine whether the following systems are **(10+10)**

- linear or non-linear
- time-invariant or time-variant
- causal or non-causal
- memoryless or with memory
- stable or unstable

(i) $y(t) = \int_{-\infty}^{2t-3} x(\tau)d\tau$

(ii) $y(t) = \frac{1}{2}|x(t)| - \pi t$ for all t.

2. (a) A simplistic model of an ultrasound field equation may be given by the following differential equation: **(10+15)**

$$p'''(t) + 3p''(t) - p'(t) - 2p(t) = 3v''(t) - v(t),$$

where $p(t)$ and $v(t)$ are the ultrasound pressure and velocity fields, respectively.

Contd P/2

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Contd ... Q. No. 2

(i) Draw the Direct Form-I and Direct Form-II realizations of the system.

(ii) Considering the system initially relaxed, evaluate the impulse response of the system.

(b) Evaluate the following: **(10)**

(i) $\int_{-\infty}^{\infty} f(\tau)\delta(t-\tau)d\tau$

(ii) $\int_{-\infty}^{\infty} e^{(t-1)} \sin\left\{\frac{\pi}{2}(t-5)\right\}\delta(t+3)dt$

(iii) $\int_{-\infty}^{\infty} (t^2+3t+2)\delta(-1-t)dt$

(iv) $\left(\frac{jw+2}{w^2+9}\right)\delta(w)$

(v) $\left(\frac{1}{jw+2}\right)\delta\left(w+\frac{j}{2}\right)$

3. (a) An electrical membrane under subthreshold conditions can be modeled by a parallel combination of resistor and a capacitor as shown below. The input to the membrane is a stimulating current, i, and the output is taken to be the transmembrane voltage, V_m. **(15)**

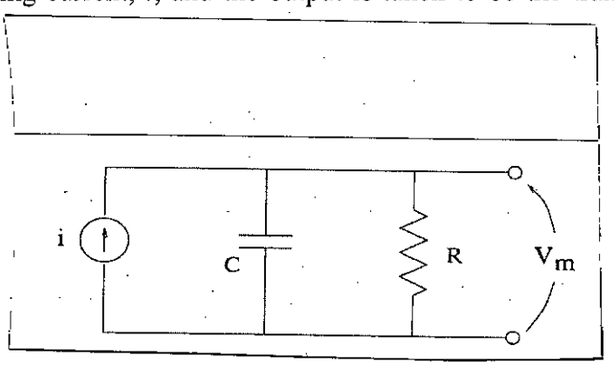

Figure for Q.3(a)

The waveform of the stimulating current is shown below:

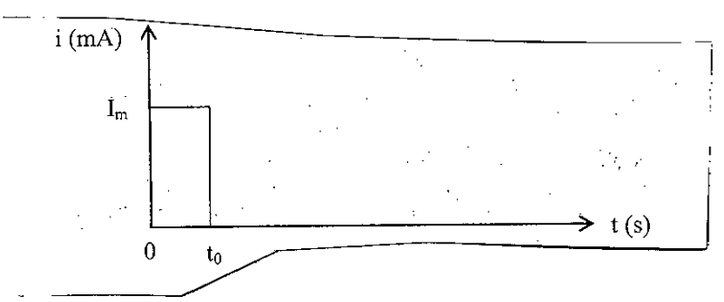

Figure for Q.3(a)

The capacitor is initially charged to a voltage V_C. Find the zero-input response of the membrane to the stimulating current.

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Contd ... Q. No. 3

(b) Consider the system defined below: **(20)**

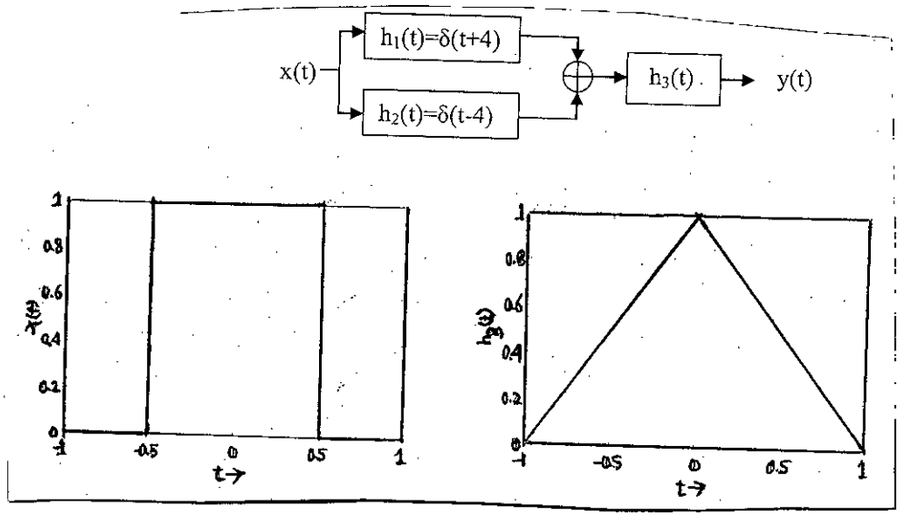

Figure for Q.3(b)

Using the graphical interpretation of convolution, find the analytical expression of $y(t)$. Also, sketch $y(t)$.

4. (a) The unit impulse response of an LTI system is given by **(20)**

$$h(t) = \{e^{-3t} - e^{-2t}\}u(t)$$

Find the zero-state responses of the system for inputs

(i) $u(t)$

(ii) $e^{-t}u(t)$

(b) A typical biphasic signal which is given input to a transcutaneous electrical nerve stimulator (TENS) unit, $x(t)$, is shown below: **(5+5+5)**

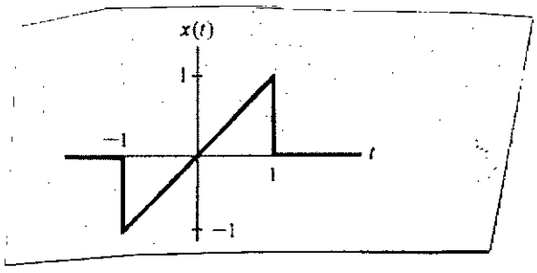

Figure for Q.4(b)

(i) Write the analytical form of $x(t)$ in terms of unit step and ramp functions.

(ii) If $y(t) = x(-2t - 2)$, sketch $y(t)$ and write the analytical form of $y(t)$.

(iii) Write the analytical forms of the odd and even parts of the signal $x(t)$.

SECTION – B

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

5. (a) Electrical stimulation of tissue is often performed using a periodic square-wave voltage source. Due to the capacitive effect of the electrode, the observed current wave shape is distorted as shown in the figure below. Find the trigonometric Fourier series in the compact form for the current waveform $f(t)$ and draw its magnitude and phase spectra. The function $f(t)$ is given by: **(20)**

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$$f(t)=\begin{cases} e^{-\frac{t}{2}} & 0<t<\pi \\ -e^{-\frac{t}{2}} & \pi<t<2\pi \end{cases}$$

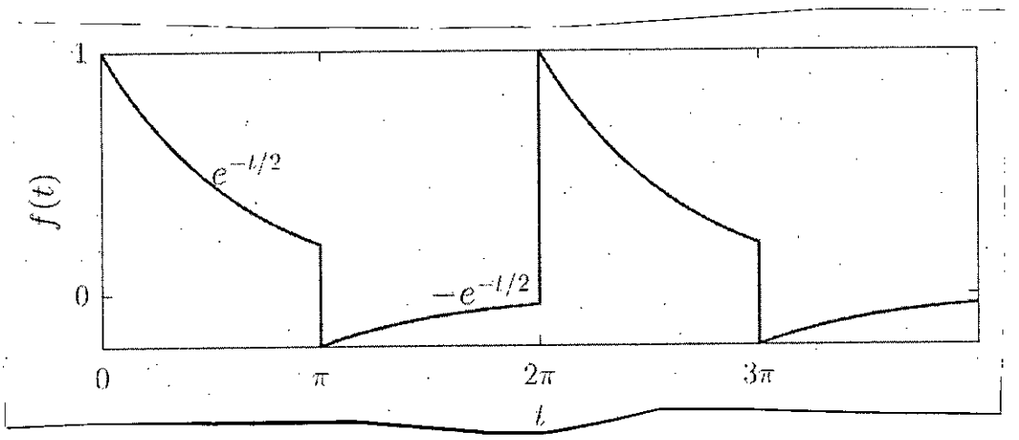

Figure for Q.5(a)

(b) Derive the relationship between the complex coefficients D_n of the exponential Fourier series and the coefficients C_n and θ_n of the trigonometric Fourier series. Use this relation to sketch the exponential Fourier spectra of the current waveform in questions 1(a) above. **(15)**

6. (a) Suppose an ECG signal is high-pass filtered to remove the baseline drift. The filter transfer function is provided below: **(20)**

$$|H(\omega)|=\begin{cases} 0 & \omega \le \frac{\pi}{2} \\ 1 & \omega > \frac{\pi}{2} \end{cases} \qquad \angle H(\omega)=\begin{cases} -\omega & -20\pi < \omega \le 20\pi \\ -\frac{\omega}{2} & \text{otherwise} \end{cases}$$

Plot the transfer function. Notice that the filter has an ideal magnitude response and a non-linear phase response. By observing the Fourier power spectrum of ECG signals, $|x(\omega)|^2$, (for a heart-rate of 150bpm) provided in the Fogure below, discuss how this filter will affect the various components (P-T waves, QRS complex, etc.) of the ECG signal, $x(t)$.

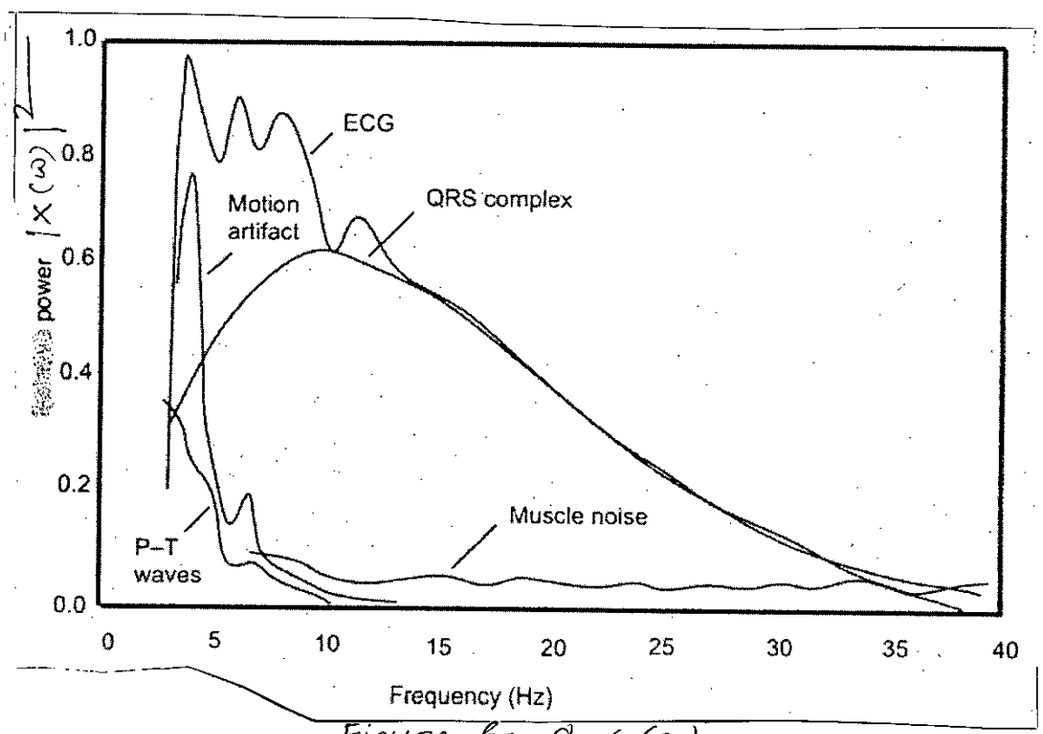

Figure for Q.6(a)

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Contd ... Q. No. 6

Fig. 6(a):

Fourier power spectrum of the QRS complex, P and T waves, muscle noise and motion artifacts based on ECG signals of 150 beats/minute heart rate. Use this spectrum as an approximate indicator for which different ECG components dominate which frequency components in the Fourier domain.

(b) State the time and frequency convolution properties of the Fourier transform. Prove the time-convolution property. **(15)**

7. (a) What are the limitations of Fourier series analysis? How does the Fourier transform overcome the limitations? **(5)**

(b) Prove the initial and final value theorem of the Laplace transform. **(18)**

(c) If $f(t) \Leftrightarrow F(\omega)$ then show that: **(6+6)**

(i) $f(t+T)+f(t-T) \Leftrightarrow 2F(\omega)\cos T\omega$

(ii) $-jtf(t) \Leftrightarrow \dfrac{d}{d\omega}F(\omega)$

8. (a) Using the Lapalce transform, solve the differential equation below: **(11)**

$$\left(D^2+4D+4\right)y(t)=(D+1)f(t)$$

Given $y(0^-)=2$ and $\dot{y}(0^-)-1$ and $f(t)=e^{-t}u(t)$

(b) Find the inverse Laplace transform of the following functions: **(12+12)**

(i) $\dfrac{(2s+5)e^{-2s}}{s^2+5s+6}$

(ii) $\dfrac{2s+1}{(s+1)(s^2+2s+2)}$

Useful Formulas:

$$\int e^{ax}\sin bx dx=\frac{e^{ax}}{a^2+b^2}[a\sin bx-b\cos bx]+C$$

$$\int e^{ax}\cos bx dx=\frac{e^{ax}}{a^2+b^2}[a\cos bx+b\sin bx]+C$$

L-3/T-1/BME Date : 02/11/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **MATH 313** (Probability and Statistics)

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**.

1. (a) Fluid median, third quartile, second decile, seventieth percentile from the table. Draw a suitable diagram and locate them. **(18)**

Age (years)	under 25	25-29	30-34	35-44	45-54	55-64	65-74
Number (million)	2.3	4.1	5.3	10.6	9.7	6.8	4.4

(b) First 4 moments about the value 4 of a variable are -1.5, 17, -30 and 108. Calculate mean and SD. If Mode is 3, find Karl Pearson's coefficient of Skewness and Kurtosis. Represent them graphically and comment on the nature of distribution. **(17)**

2. (a) The shareholder Research Bureau of Bangladesh conducted recently a research study on the price (Tk) behavior of three leading industrial shares X, Y, Z for the period 2014 to 2017, the results of which are published as following in the quarterly journal: **(18)**

Share	Average Price	Standard Deviation	Current Selling Price
X:	1800	5.40	36.00
Y:	2250	4.50	34.75
Z:	2400	6.00	39.00

Which share in your opinion appears to be more stable in value?

(b) A study is made on the amount of converted sugar in a certain process at various temperatures. The data are coded and recorded as follows:

Temperature X	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
Converted Y	8.1	7.8	8.5	9.8	9.5	8.9	8.6	10.2	9.3	9.2	10.5

(i) Find the equations of both regression lines. **(17)**

(ii) Estimate the amount of converted sugar produced when the coded temperature is 1.75

(iii) Find the value of correlation coefficient.

3. (a) A product developer is interested in reducing the drying time of a primer paint. Two formulations of the paint are tested; formulation-1 is the standard chemistry, and formulation-2 has a new drying ingredient that should reduce the drying time. From experience, it is known that the standard deviation of drying time is 8 minutes, and

Contd P/2

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Contd..... Q. No. 3(a)

this inherent variability should be unaffected by the addition of the new ingredient. Ten specimens are painted with formulation-1, and another 10 specimens are painted with formulation-2. The two sample average drying times are $\bar{x}1 = 121$ minutes and $\bar{x}2 = 112$ minutes, respectively. What conclusions can the product developer draw about the effectiveness of the new ingredient, using $\alpha = 0.05$? **(18)**

(Given that $z = 1.645$ at 5% level of significance)

(b) Memory capacity of 9 students is tested before and after training. State whether the training is effective or not from the following scores: **(17)**

Students:	1	2	3	4	5	6	7	8	9
Before Training:	10	15	9	3	7	12	16	17	4
After Training:	12	17	8	5	6	11	18	20	3

(Given that for 8 degrees of freedom $t_{0.05} = 2.31$)

4. (a) As head of a department of a consumer's research organization, you have the responsibility for testing and comparing lifetimes of four brands of electric bulbs. Suppose you test the lifetime of three electric bulbs of each of the four brands. The data is shown below, each entry representing the lifetime of an electric bulb, measured in hundreds of hours: **(18)**

Brand

Brand A	Brand B	Brand C	Brand D
20	25	24	23
19	23	20	20
21	21	22	20

Can you infer that the mean lifetime of the four brands of electric bulbs are equal with 5% level of significance? (Given that $f_{0.05,3,8} = 4.07$)

(b) The following data gives the number of units produced by 4 different workers using 3 different machines: **(17)**

Machine Type

Workers	A	B	C
1	20	28	26
2	22	30	32
3	26	32	10
4	32	24	24

Test whether (a) the four workers differ with respect to mean productivity?

(b) the mean productivity is same for the different machine type?

Use 1% level of significance, (Given that $f_{0.01,3,6} = 9.78$ and $f_{0.01,2,6} = 10.92$)

Contd P/3

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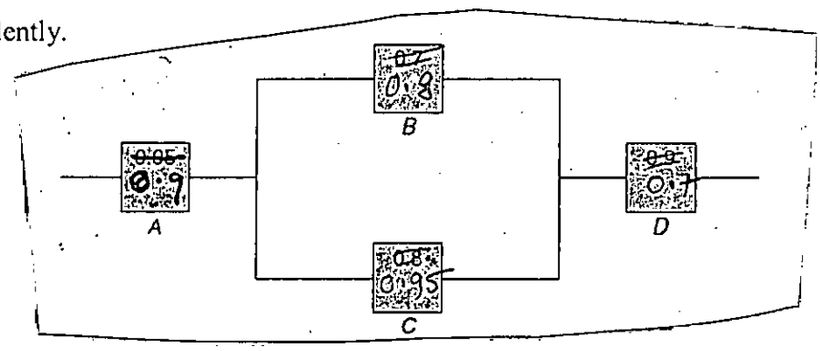
SECTION – B

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

5. (a) An electrical system consists of four components as illustrated in following figure. The reliability (probability of working) of each component is also shown in figure. Find the probability that (i) the entire system works and (ii) Given that the system works, what is the probability that the component B is not working. Assume that the four components work independently. **(10)**



(b) A firm is accustomed to training operators who do certain tasks on a production line. Those operators who attend the training course are known to be able to meet their production quotas 90% of the time. New operators who do not take the training course only meet their quotas 65% of the time. Fifty percent of new operators attend the course. Given that a new operator meets her production quota, what is the probability that she attended the program? **(10)**

(c) Number of CD4+T (or T cell) is very crucial for the progression of AIDS infection. Consider the following data on patients with suspected AIDS reported by Marylanders metropolitan Hospital, USA during 1990-2000. Notice that there was a considerable overlap in T cell values among two different types of patients: Primary phase (infected for 3-4 weeks), Chronic Phase (infected for 3-4 years). Further, the lower the T-cell value, the more likely the patients are to be progressed towards AIDS. **(15)**

Table: HIV patient's diagnostic test

No of T cells (10^6/ml)	During Primary Phase	During Chronic Phase
<15	474	20
15-34	175	79
35-64	82	171
65-94	30	188
94>	48	1332

Contd P/4

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Contd..... Q. No. 5(c)

Answer the following questions:

i. How a given test result affects the likelihood of disease during Chronic and Primary Phase, use the likelihood ratios (LR) to estimate the results?

ii. Compute sensitivity and specificity for above data to construct Receiver Operating Characteristic (ROC) curve.

iii. Based on the ROC curve, give proper interpretation for the diagnostic patients using the term like Area under the curve (AUC), relation between AUC and LR.

6. (a) A U-shaped component is to be formed from the three parts A, B, and C. The picture is shown below. The length of A is normally distributed with a mean of 10 millimeters and a standard deviation 0.1 millimeter. The thickness of parts B and C is normally distributed with a mean of 2 millimeters and a standard deviation of 0.05 millimeter. Assume all dimensions are independent. Determine the mean and standard deviation of the length of the gap D. **(5)**

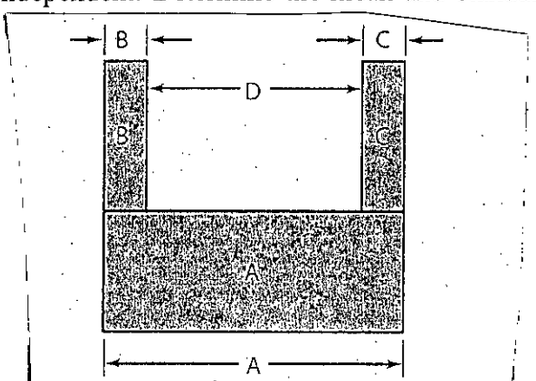

Figure: The U-shaped component

(b) Show that Poisson distribution is the limiting case of binomial distribution. **(12)**

(c) Show that for X and Y continuous random variables with covariance σ_{xy}, the correlation coefficient ρ_{xy} lies between -1 to 1.The fraction X of male runners and the fraction Y of female runners who compete in marathon races are described by the joint density function **(18)**

$$f(x,y)=\begin{cases}8xy, & 0\le y\le x\le 1\\ 0, & elsewhere\end{cases}$$

Find the correlation coefficient and interpret your result.

7. (a) A soft-drink machine is regulated so that it discharges an average of 200 milliliters per cup. If the amount of drink is normally distributed with a standard deviation equal to 15 milliliters, **(10)**

i. What fraction of the cups will contain more than 224 milliliters?

ii. What is the probability that a cup contains between 191 and 209 milliliters?

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Contd..... Q. No. 7(a)

iii. How many cups will probably overflow if 230-milliliters cups are used for the next 1000 drinks?

iv. Below what value do we get the smallest 25% of the drinks?

(Necessary table attached)

(b) An exponential distribution has a density function given by **(17)**

$$f(x,\beta)=\begin{cases}\frac{1}{\beta}e^{-\frac{x}{\beta}}, & x>0\\ 0, & elsewhere\end{cases}$$

Find expected mean, variance and discuss the memory less property of the above distribution. The length of time between breakdowns of an essential piece of equipment is important in the decisions of the use of auxiliary equipment. An engineer thinks that the best model for time between breakdowns of a generator is the exponential distribution with a mean of 15 days. (i) If the generator has just broken down, what is the probability that it will break down in the next 21 days? (ii) What is the probability that the generator will operate for 30 days without a breakdown?

(c) Using he definition of moment generating function, find the rth moment about the origin of the Exponential distribution. **(8)**

8. (a) Let X be a random variable having moment generating function $M_X(t)$ with E[X] = 0 and Var(X) = 1, show that **(10)**

$$\lim_{n\to\infty}\left[M_X\left(\frac{t}{\sqrt{n}}\right)\right]^n=\exp\left(\frac{t^2}{2}\right)$$

(b) Show how to select 20 random samples of 3 students each (with and without replacement) from the following table by using random numbers. (Necessary table attached) **(25)**

Height (in)	Frequency
10-15	10
15-20	20
20-25	35
25-30	23
30-35	12

Find the mean of the sampling distribution of means in both cases and Compare the results, explaining discrepancies (if any).

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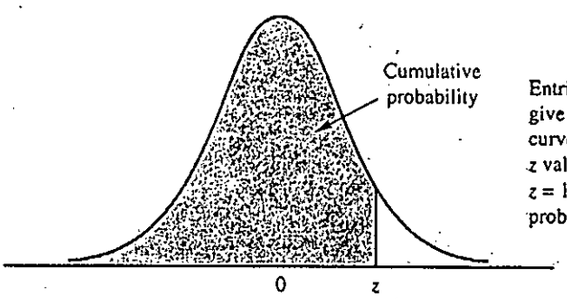
Table for Q7(a)

CUMULATIVE PROBABILITIES FOR THE STANDARD NORMAL DISTRIBUTION



Entries in the table give the area under the curve to the left of the z value. For example, for $z = 1.25$, the cumulative probability is .8944.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990

L-3/T-1/BME Date : 29/10/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **CSE 391** (Embedded Systems and Interfacing)

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**.
*Find the Pin Configuration of ATmega32 MCU and its different register configurations at the end of the questions.
*If configuration for any of the required registers are missing, just assume configuration and clearly mention your assumption. If you believe any control word/bit configuration is missing in the question paper, just assume a pattern of your choice and clearly mention your assumption.

1. (a) Suppose the Code Segment Register has a value 3100 and the Instruction Pointer Register has a value 1208. What will be the address where the next instruction will be fetched from? All the numbers are given in hexadecimal format. **(5)**

(b) Define Computer Bus. What do you understand by an n-bit microprocessor? In a microprocessor system, the address bus 32-bit wide and the memory is byte addressable. What is the maximum allowable address that can be addressed? **(3+3+4=10)**

(c) What does pre-fetching and pipelining means in a microprocessor system? How prefetching is done in 8086 architecture? **(5+5=10)**

(d) Define Harvard and Von Neumann Architecture. In case of 8086, which architecture is used? Discuss its advantage(s) and disadvantage(s) over the other one. **(3+3+4=10)**

2. (a) What are the advantages of interrupt over polling? What are the steps does the CPU follow to handle an interrupt? **(4+8=12)**

(b) Describe with example(s) the necessity of using "volatile" variables in a C program in the context of ATmega32 interrupts. **(5)**

(c) Suppose for an 8086 architecture, we have the following instruction set.

Instruction Type	Description of Instruction	OP Code
ADD A, B	$A = A + B$	90
ADD A, immediate	$A = A + immediate$	91
SUB B, [address]	$A = B - memory[address]$	92
MOV A, immediate	$A = immediate$	93
OR A, B	$A = A$ OR B	94
JMP [address]	The next instruction to be executed is the one written at $memory[address]$	95

Now consider the following Assembly code.

```
MOV A, 25H
ADD A, B
ADD A, 36H
SUB B, [X]
OR A, B
JMP 1887H
MOV A, 255H
ADD A, 511H
ADD A, B
JMP 1996H
```

Contd P/2

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Contd..... Q. No. 3(c)

You have to write the machine code related to the above assembly code in the 1MB main memory of 8086 in tabular form as shown below. The Instruction (right) column should contain the machine code to be written while the Address (left) column should contain the address of the main memory where you are writing the corresponding code. Your table should have row(s) for each of the given 10 assembly instructions. The values of Code Segment Resister and Data Segment Register are 1800H and 9000H respectively and both of the segments are 64KB of size. Remember that the memory of 8086 is byte addressable and the data bus is 16-bit wide. Give a probable value of the variable 'X' of the 4th assembly instruction and justify your value picking. **(10×1.5+3=18)**

Address	Instruction

3. (a) Consider that you have configured the ATmega32 ADC with a reference voltage of 4V and ADLAR = 1. What is the step size when **(3×3=9)**

   i) You are only reading ADCH?

   ii) You are reading ADCL first and then ADCH?

   iii) You are reading ADCH first and then ADCL?

   (b) Suppose you are using an 8-bit ADC. The reference voltage is set to 3.56V. Calculate the digital values is binary format when the analog input is **(2×3=6)**

   1. 1.7V
   2. 3.2V

   (c) Consider the following scenario:

   You are using a temperature sensor which produces an output voltage of 0V to 4V for 0 degree to 100 degree Celsius linearly. The sensor is connected to the ADC0 pin of ATMega32 and you are using a pre scalar of 4. Your setup has two push buttons A and B which are connected to INT1 and INT2 pins, respectively.

   Now write a C code to use ADC of ATmega32 MCU in interrupt mode so that when the button A is pressed, the microcontroller will read the sensor value and determine the temperature and then dump the temperature value on Port B. Upon pressing the button B, port B will be reset to the room temperature value (assume to be 25 degree Celcius). keep in mind that you have to choose the ADC reference voltage in a way so that the precision is not compromised. The buttons bounce a lot. Do necessary steps in your code so that debouncing is achieved.

Contd P/3

CSE 391

Contd.... Q. No 3(c)

The codes for external interrupt events of INT0 and INT1 are as following:

Code	Interrupt Triggering Events
00	Low Level
01	Any Logical Change
10	Falling Edge
11	Rising Edge

The codes for external interrupt events of external INT2 are as following:

Code	Interrupt Triggering Events
0	Falling Edge
1	Rising Edge

4. (a) Distinguish between a microprocessor and a microcontroller. **(8)**

(b) Discuss the following data addressing modes with their usage. **(3×3=9)**

(i) Base-plus-index addressing

(ii) Register relative addressing

(iii) Base-relative-plus-index addressing

(c) Suppose, 8086 is reading data bytes from a type writer through Port A of the 8255 using strobed input mode (mode 1). The timing diagram for one byte of data transfer is given below:

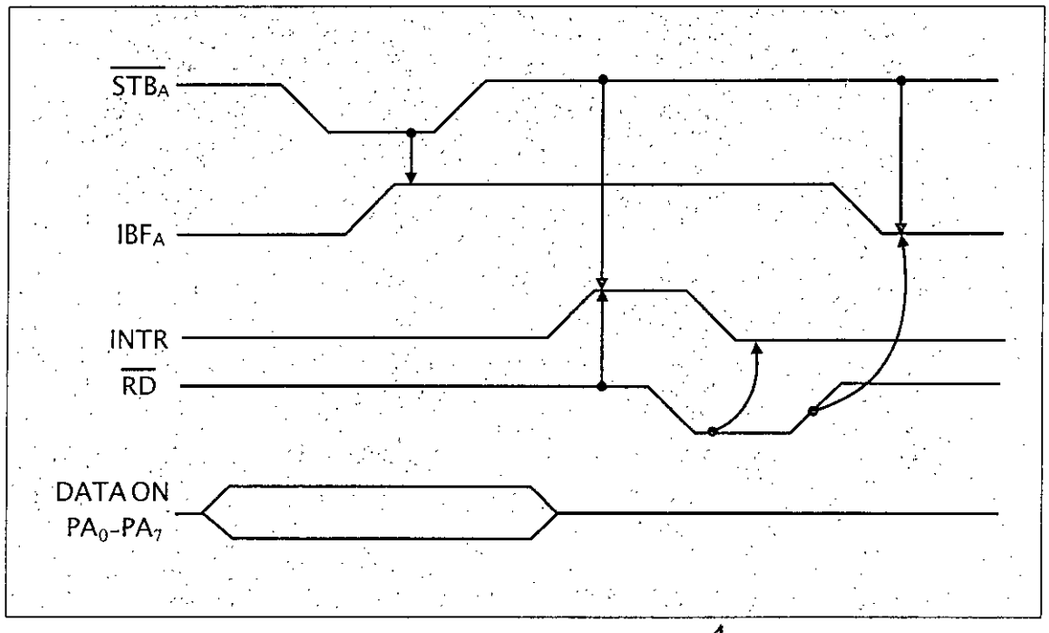


Figure 1: 8255 Timing Diagram for Q.4(c)

Now redraw the same timing diagram in your answer script and mark the first occurrence of each of the following events with the corresponding event ID surrounded by a circle on the timing diagram. **(2×9=18)**

Contd P/3

CSE 391
Contd.... Q. No. 4(c)

Event ID	Event Description
1	8255 loads data into its input latch
2	The typewriter indicates that data is no more valid
3	The typewriter sends data to port's data line
4	8255 forbids the typewriter to send next data
5	8255 lowers prevents a second interrupt for the same data
6	CPU starts reading the data
7	Data transfer complete
8	8255 informs CPU about the data by generating interrupt signal
9	Read Complete

SECTION – B

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

5. John Doe is passionate about embedded system. Currently he is working on a project where he needs to interface LM35 (temperature sensor) with Arduino Uno. LM 35 is a *voltage-producing sensor*. His circuit diagram for reading the ADC value is given in Fig. for Q. 5. But he finds out that he is always reading a constant value. So he is thinking about replacing the LM35 with a resistive sensor.

   (a) What is the allowable reference voltage range for ADC in John's project? How John can properly utilize this range? **(2+3)**

   (b) Where is the problem in John's circuitry and how can it be solved? Write appropriate code so that John's work is done. **(3+4+8)**

   (c) "John can construct two different circuits if he switches to a resistive sensor"- do you agree? Justify your answer with necessary diagrams. **(10)**

   (d) After solving the problem with your suggestion, John finds out that the temperature reading is 27°C. What value was read by the analogRead(ADC PIN) function? **(5)**

6. Steve Smith needs to design an alarm to protect Bangladesh National Museum. He is thinking about sonar sensors to detect unwanted presence of a person. These sensors will be activated after closing the museum. The alarm(s) should be triggered when a person is detected by the sonar-sensor(s). However, once an alarm starts, it should continue even after the person moves away from the front of the sensor.

CSE 391

Contd..... Q. No. 6

(a) In Smith's design, which switching element should be attached with the alarm? With proper schematic diagram, discuss the self-repeating characteristics of his chosen switching element. **(2+8)**

(b) Help Smith by constructing a circuit diagram to measure the distance of an obstacle using Arduino Uno and HC-SR04 (sonar sensor). Write down the corresponding code to implement this. **(7+10)**

(c) "The microcontroller of Arduino Uno has Harvard Architecture" - do you agree? Justify your answer. **(8)**

7. Andrew Russell is using Raspberry Pi for smartly controlling his home. For this, he needs to interface ADC0804 to his Pi. ADC0804 is an 8-bit, single channel, parallel output ADC. But he has only 2 digital I/O pins left for interfacing ADC0804. He is also facing difficulty to execute his program at startup. He is also annoyed to see a *Runtime-Warning*, saying something along the lines *"channels already in use"* whenever he runs his program more than once.

(a) How can Russell ensure execution of his program at startup? **(7)**

(b) What is the simple mechanism that Russell can use to interface ADC0804 with his Pi? Discuss with connecting diagram. **(10)**

(c) Explain the concept of *Priority-Inversion* and *chain-blocking* and how these problems are solved in RTOS with proper diagram. **(10)**

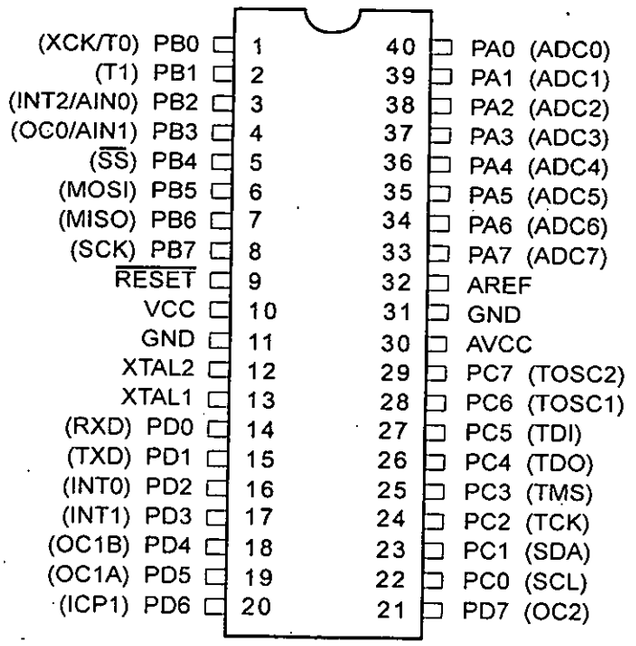
(d) Explain the concept of dual-kernels showing the diagram of its implementation. **(8)**

8. (a) Briefly describe the concept of channels and pipes in NRF24L01 module. **(6)**

(b) Is asynchronous communication really asynchronous as the name suggests? If not, then write down some basic mechanisms that can be undertaken to co-ordinate such communication among devices. **(5)**

(c) "SPI communication can be conceptually modeled as the interaction between two shift registers" - do you agree with this statement. Justify your answer. **(10)**

(d) Briefly explain the *repeated start condition* and *clock stretching* of TWI protocol. **(7+7)**



ATMega32 Pin Out for Section A

Register Name	Configuration							
GICR	INTF1	INTF0	INTF2	-	-	-	-	-
GIFR	INTF1	INTF0	INTF2	-	-	-	-	-
MCUCR	SE	SM2	SM1	SM0	ISC11	ISC10	ISC01	ISC00
MCUCSR	JTD	ISC2	-	JTRF	WDRF	BORF	EXTRF	PORF
TCCR1A	COM1A1	COM1A0	COM1B1	COM1B0	FOC1A	FOC1B	WGM11	WGM10
TCCR1B	ICNC1	ICES1	-	WGM13	WGM12	CS12	CS11	CS10
TIMSK	OCIE2	TOIE2	TICIE1	OCIE1A	OCIE1B	TOIE1	OCIE0	TOIE0
TIFR	OCF2	TOV2	ICF1	OCF1A	OCF1B	TOV1	OCF0	TOV0
UCSRA	RXC	TXC	UDRE	FE	DOR	PE	U2X	MPCM
UCSRB	RXCIE	TXCIE	UDRIE	RXEN	TXEN	UCSZ2	RXB8	TXB8
UCSRC	URSEL	UMSEL	UPM1	UPM0	USBS	UCSZ1	UCSZ0	UCPOL
SPCR	SPIE	SPE	DORD	MSTR	CPOL	CPHA	SPR1	SPR1
SPSR	SPIF	WCOL	-	-	-	-	-	SPI2X
ADMUX	REFS1	REFS0	ADLAR	MUX4	MUX3	MUX2	MUX1	MUX0
ADCCSRA	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0
EEARH	-	-	-	-	-	-	EEAR9	EEAR8
EEARL	EEAR7							EEAR0
EEDR	MSB							LSB
EECR	-	-	-	-	EERIE	EEMWE	EEWE	EERE

List of Registers of ATMega32 for Section A

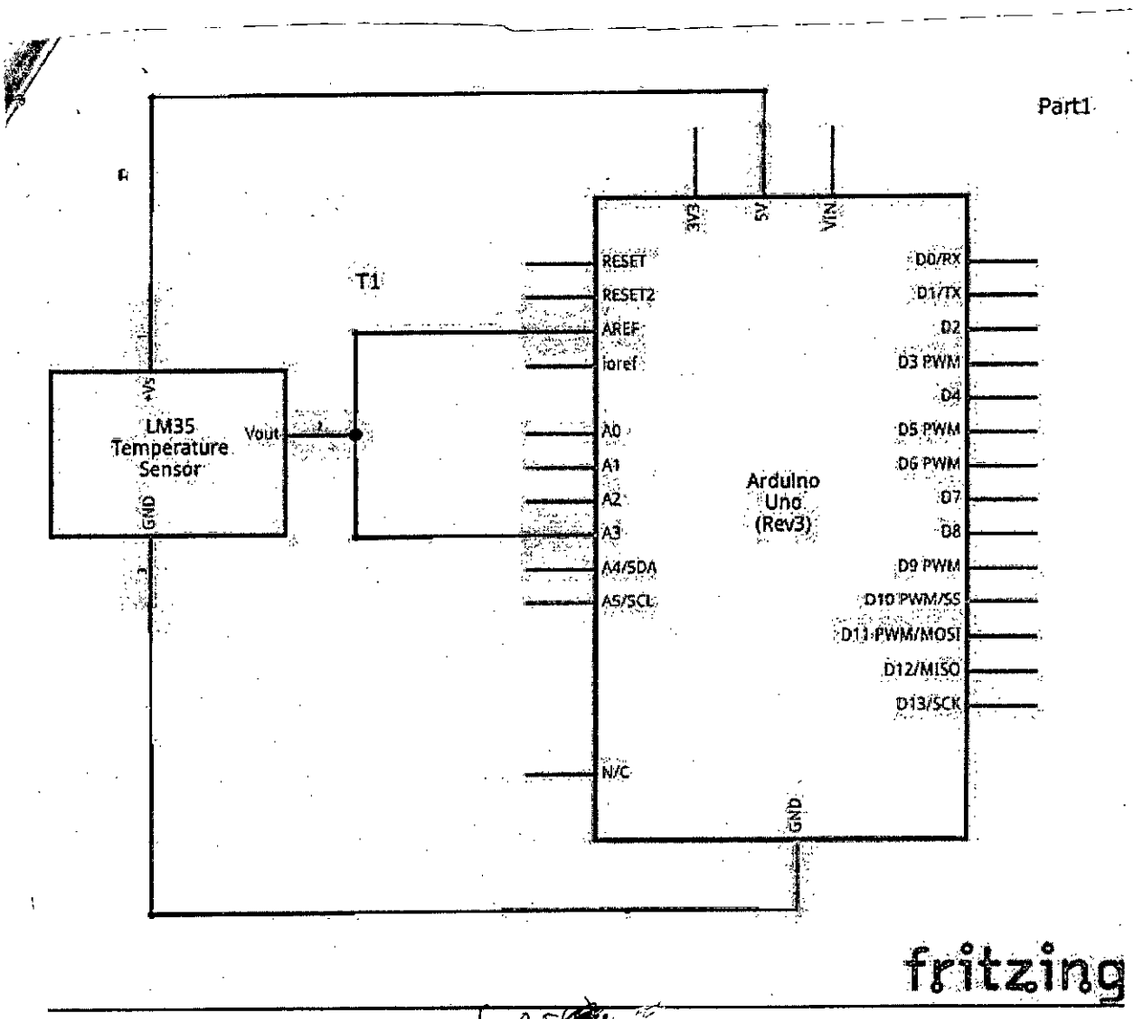


Figure 1: John's circuit