L-4/T-II/BME **Date : 27/03/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-II B. Sc. Engineering Examinations 2020-2021

Sub : **BME 405** (Healthcare System Management)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

Symbols carry their usual meaning. Assume reasonable values for any missing data.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. **Answer all questions**.

1. (a) Which leadership style is best suited to enhance the quality of service delivery at a District Hospital in Bangladesh and why? Give your opinion in brief. **(15)**

   (b) What is the major difference between leadership and management? How do management and leadership contribute together to improve service delivery in the healthcare sector of Bangladesh? **(20)**

2. (a) What is a hospital? Explain the major functions of a hospital. **(15)**

   (b) According to WHO, what are the six stages of national level healthcare planning? Give your opinion on the current national level healthcare planning of Bangladesh. **(20)**

3. (a) Compare the healthcare financing sources of Canada (Fig. for Q. No. 3(a) with Bangladesh and give your suggestions to improve the healthcare financing policy of Bangladesh. **(20)**

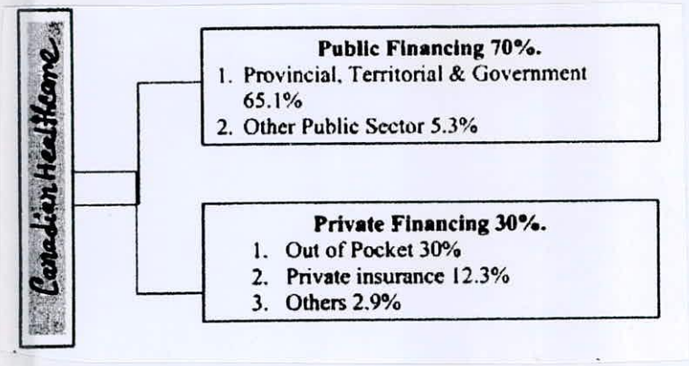

Figure for Q. No. 3(a) Canadian Health Care Public vs Private Financing (2020)

(b) What are the challenges towards achieving UHC (Universal Health Coverage) in the coming decade for Bangladesh? What are your recommendations regarding financial protection schemes to achieve UHC in Bangladesh?

4. (a) What are the major ethical issues in healthcare management system? Write down the "CODE of ETHICS" for Biomedical Engineering Society (BMES). **(20)**

Contd P/2

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Contd. Q. No. 4

(b) Suppose, you are designing a portable hemodialysis machine as a biomedical engineer. What are your responsibilities while designing this technology to solve a major healthcare problem? Explain in brief. **(15)**

SECTION – B

There are **FOUR** questions in this section. Answer all the questions.

The symbols have their usual meanings.

5. (a) What is the classification of medical devices according to DGDA guidelines? What is the role of DGDA to regulate medical device circulation in Bangladesh? **(12)**

   (b) Write the functions of a clinical engineering department in a hospital. How can a clinical engineer work synergistically to ensure the safety and reliability of medical devices? Mention the specific parties that the clinical engineer needs to interact with to accomplish this goal. **(18)**

   (c) What are the types of cleaning that can be performed to decontaminate medical devices? **(5)**

6. (a) Write the names of the responsible parties to ensure the safety of medical devices. Describe the role of each participant in maintaining device safety. **(20)**

   (b) Suppose you are employed as a biomedical engineer in a hospital. You have observed a technical problem with an MRI machine that may compromise patient safety. What should you do in that case? Does this incident fall under the SMDA? If so, why? **(15)**

7. (a) How can medical devices be categorized for decontamination? Describe them. Is it permissible to re-use single use medical devices? What are the FDA guidelines in this regard? **(17)**

   (b) Mention and describe the fundamental required to maintain a clinical engineering department.

8. (a) Suppose you have founded a start-up company of an innovative medical device in Bangladesh and you want to put your device in the market. What are the requirements that are necessary to be met for placing your device in Bangladeshi market? What shall be your responsibility after your device has reached at the hands of the local users?

   (b) What are the stages of regulatory control of a medical device? Mention the critical elements for device regulation. What do you mean by GHTF? What are their principles for safety and performance of medical devices? **(22)**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-II B. Sc. Engineering Examinations 2020-2021

Sub : **BME 407** (Quantitative Physiology)

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**.

The Symbols have their usual meanings.

1. (a) Analyze the graph shown in figure 1(a) to approximately draw the corresponding clinical spirogram in your answer script. Assess whether airway resistance of the person is normal or not. **(5+5)**

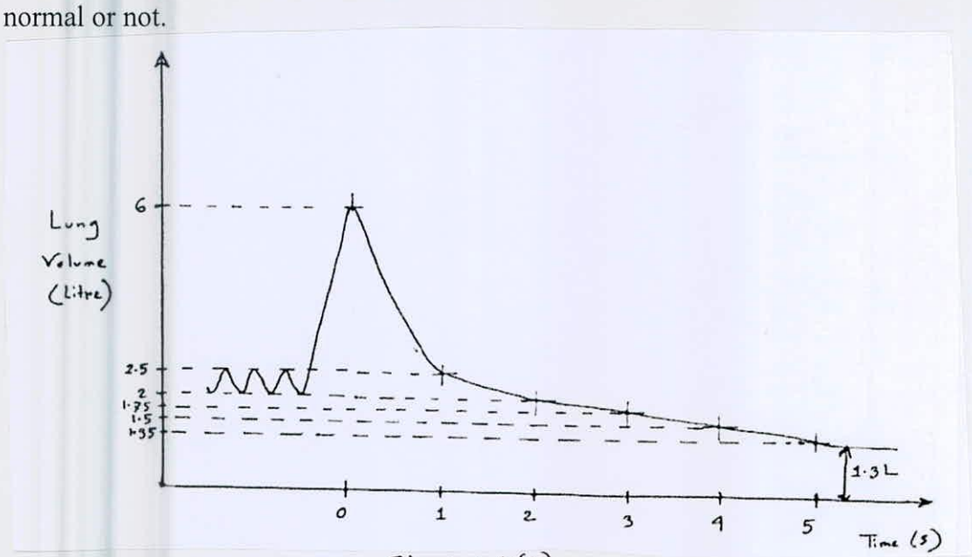

Figure 1(a)

(b) During a hot summer day, a football player weighing 100 kg lost 5 L of hypotonic sweat. His hematocrit (Hct) before the workout was 45% and RBC count was 5×10^6 mm^{-3}. During the workout, he drank 1.5 L of water which had been absorbed into the blood from the gastrointestinal (GI) tract. Assume that the blood mass is 8% of his body mass and that the density of blood is 1.05 g cm^{-3}. Further assume that the fluids lost from his body were distributed proportionately from the extracellular volume and intracellular volume, which make up 20% and 40% of the body mass, respectively (assume the density of the fluids is 1.0 g cm^{-3}). Now determine the followings using the provided data. **(15)**

(i) Volume of fluid the player lost

(ii) The amount of lost volume that came from the extracellular and intracellular fluid compartment respectively.

(iii) The mean cell volume (MCV) before the workout

(iv) The MCV after the workout

(v) Hematocrit after the workout

Make necessary assumptions where needed, and use nominal values of parameters if not specified otherwise.

Contd P/2

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Contd...Q. No. 1

(c) Explain why surfactant (i) lowers surface tension, (ii) reduces the work of breathing, (iii) helps stabilize alveoli size, and (iv) prevents low interstitial fluid pressures. **(10)**

2. (a) Figure 2(a) shows a rapid injection indicator dilution curve used to measure cardiac output. Suppose, the concentrations at times C and D are given as $C(t_0)$ and $C(t_1)$ respectively. Now determine the shaded area under the dotted curve between time C and E in terms of $C(t_0)$, $C(t_1)$ and t_1. Assume that the decaying portion of the curve in between time C and E to be an exponential decay with time constant τ and that time E tends to infinity. **(15)**

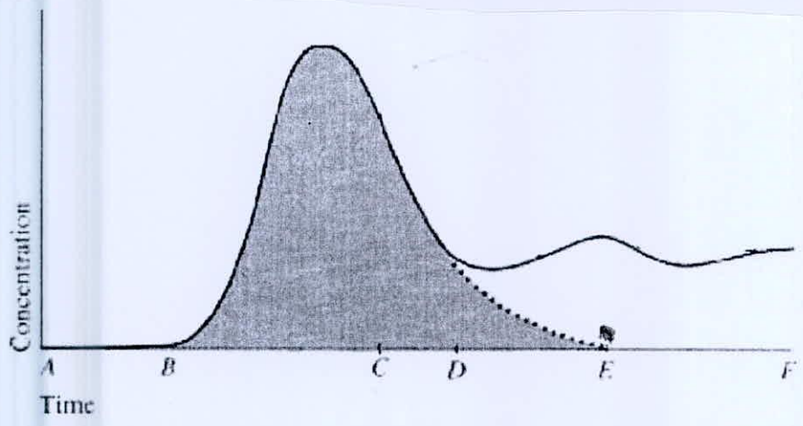

Figure 2(a)

(b) Explain mathematically why large, multi-cellular organisms require complicated circulatory systems for their existence. **(5)**

(c) What are the effects of the following cases on O2 dissociation curve compared to the normal condition? Explain the reasons behind the effects as well. **(15)**

(i) Addition of acid and base (ii) Effect of CO_2 (iii) Effect of temperature

3. (a) Suppose the radius of the aorta in a test subject determined by MRI is 12 cm. At rest, his end diastolic volume is 140 mL and his end systolic volume is 55 mL. His diastolic pressure is 70 mmHg and his systolic pressure is 115 mmHg. If the start of the cardiac cycle is taken at the time of opening of the mitral valve, the aortic valve in this person opens at 0.55 s and closes at 0.9 s. The entire cycle lasts 1.1 s in this person. Density of blood is 1.055 g mL^{-1} and its viscosity is 3.0×10^{-3} Pa s. Using this information, determine the following. **(15)**

(i) Cardiac output (ii) Average velocity of blood in the aorta

(iii) Reynolds number for blood during ejection (iv) Nature of blood flow in the aorta.

(v) Pressure-volume work done during ejection

Use nominal values of parameters if not specified otherwise.

Contd P/3

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Contd...Q. No. 3

(b) Figure 3(b) shows the steady-state operating point of the cardiovascular system in a normal condition. In your answer script, approximately illustrate what changes the following situations would bring to the steady-state operation of the cardiovascular system while compared to the normal condition. Explain the reasonings behind the changes as well. **(15)**

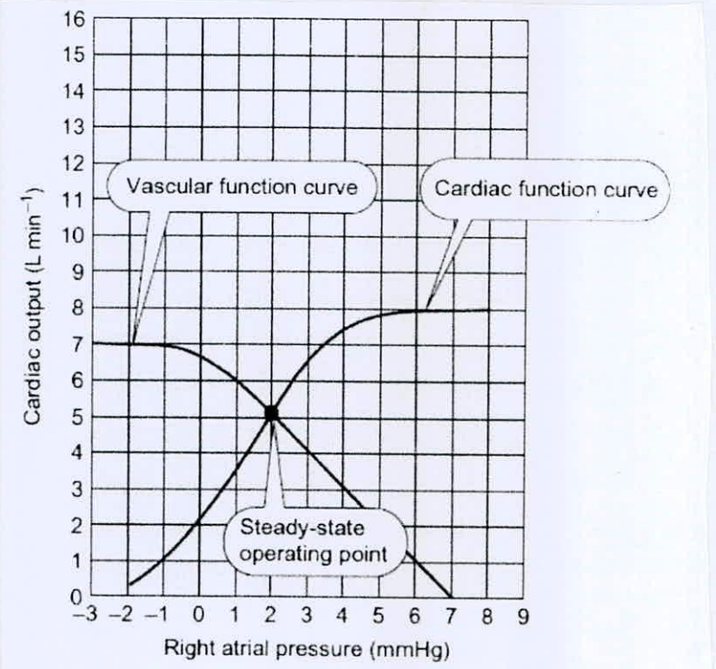

Figure 3(b)

(i) Oral uptake of the drug 'benazepril' which dilates the resistance vessels of your circulatory system

(ii) Increased release of dopamine in your body constricts the resistance vessels

(iii) Injection of the drug 'dobutamine' which increases contractility of heart muscles

(iv) Occurrence of myocardial ischemia which decreases cardiac contractility.

(c) There is no rigid structural connection between the lungs and the chest wall, and the lung mostly 'float' in the thoracic cavity. Explain how lings can still follow the chest wall during respiration as if they are attached. **(5)**

4. (a) With appropriate assumptions, derive the Henderson-Hasselbalch equation for the HCO_3^- buffer system in terms of partial pressure of CO_2. Using the Hendarson-Hasselbalch equation, explain how hypoventilation can cause respiratory acidosis. **(15)**

(b) The typical diameter of an alveolus is 0.3 mm, and the surface tension of water is about 70 dyne cm^{-1}. **(20)**

(i) Assume that no surfactant is present at mechanical equilibrium. Calculate the pressure within this alveolus in this scenario.

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Contd...Q. No. 4(b)

(ii) Presence of surfactant lowers the surface tension to about 28 dyne cm^{-1}. What would the pressure be in the alveolus when surfactant is present? Note that 1 dyne = 10^{-5} N.

(iii) Determine the amount of work necessary to expand all the alveoli of a single lung in a normal tidal volume of 0.5 L when the functional residual capacity (FRC) is 2.3L, dead space volume is 150 mL, and total number of alveoli in the two lungs is 300×10^6. Assume that surface surfactant is present.

(iv) During normal tidal breathing, the airflow is about 0.5 L s^{-1} and the pressure driving airflow is about 1 mmHg. Calculate the overall airway resistance, and estimate the energy required to overcome this airway resistance for a tidal volume of 0.5 L.

(v) The amount of work asked to calculate in (iii) was the work required per breath just to expand the alveoli of a single lung. The work of breathing includes the work to overcome airway resistance and to expand the chest wall. Assume that the work of expanding the chest wall is about one-half of the work of expanding a lung. If the resting metabolism is 5200 J min^{-1}, what fraction of resting metabolism is used in the work of breathing? If breathing is 8% efficient, about what fraction of resting metabolism is used for breathing?

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.
The Symbols indicate their usual meanings.

5. (a) Suppose you want to determine the ECF (L) of a person. So, you infused inulin in the body at a constant rate (i.e. Rate of infusion = Rate of excretion) to reach steady-state plasma inulin concentration as shown in Figure 5(a). You maintained the plasma inulin concentration at steady state until the person urinated and emptied his bladder (after 2 hours). Immediately you stopped infusion and the plasma inulin concentration decreased as $c(t) = Co(1-\frac{1}{10}t)$ mg/L. As inulin is freely filtered by kidney, we can assume [Pin] = [Uin]. And also assume, the flow rate of urine, Qu = 2.8 L/hr and the steady-state concentration of inulin, Co = 20 mg/L. Now, determine the ECF (L) of the person. **(12)**

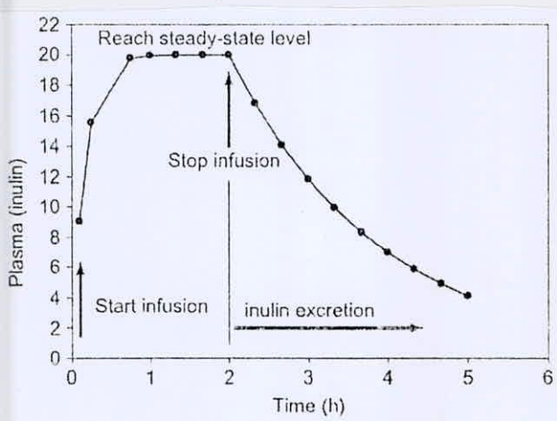

Figure for Question 5(a)

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Contd...Q. No. 5

(b) Suppose a person is infused with 0.9% normal saline (NaCL) at a constant rate of 150 mL/hour. During this session, the person loses 2.5 L of fluid (urine) containing 1% (NaCL) through urination. What will be the ECF, ICF and plasma osmotic pressure after 24 hours of infusion? Show using Darrow-Yannet diagram. Assume, the initial TBW = 42 L, ECF = 14 L and the plasma osmotic pressure = 300 mOsM. **(13)**

(c) Why the clearance of inulin is equal to the GFR? Explain with proper illustration. **(10)**

6. Kidneys are one of the most important organs in the human body, responsible for filtering waste products and excess fluids from the blood to maintain a healthy balance of electrolytes and fluids. One of the key indicators of kidney function is the GFR, which measures the rate at which blood is filtered through the glomeruli in the kidneys. Doctors often use the clearance of para-amino hippuric acid (PAH) to determine renal plasma flow (REP) and GFR, a substance that is freely filtered by the glomeruli.

(a) The filtration and secretion rate of PAH are as follows: **(13)**

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

Plot the titration curve and clearance of PAH with respect to the plasma PAH concentration ($mgdL^{-1}$).

(b) Assume the glomerular hydrostatic pressure P_{GC} = (60 – 10z) mmHg, the glomerular oncotic pressure, π_{GC} = 25 + 10(1–e^{-50z}) mmHg and the Bowman's capsule hydrostatic pressure P_{BS} = 20 mmHg. Assume the distance from the afferent arteriole to the efferent arteriole is 0.2 cm. Now, plot the Starling force as a function of distance from the afferent arteriole to the efferent arteriole. **(10)**

(c) Suppose the following test results were obtained from a patient over a 24-hour period. **(12)**

Urine volume = 1.5 L

Urine [inulin] = 100 mg%

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

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

Plasma [inulin] = 2 mg%

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

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

Calculate the following values:

(i) Clearance of C_{inulin}, C_{urea}, C_{PAH}. (ii) ERPF

(iii) The rate of PAH filtration, excretion, and secretion.

7. (a) Derive an expression for glomerular capillary hydrostatic pressure and explain the mechanisms responsible for autoregulation of renal blood flow and GFR with proper illustration? **(20)**

Contd P/6

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(b) Suppose the ratio of concentrations TF/P (tubular fluid/plasma) for inulin = 4.0 Now, derive the relation for fraction of water reabsorption and determine the value. **(15)**

8. (a) An excitable cell has the following conditions: **(15)**

$[Na^+]_o = 145$ mM; $[Na^+]_i = 10$ mM;

$[K^+]_o = 4$ mM; $[K^+]_i = 150$ mM;

After passing a number of action potentials in a short time, the following changes occurred:

$[Na^+]_o = 140$ mM; $[Na^+]_i = 15$ mM;

$[K^+]_o = 7$ mM; $[K^+]_i = 145$ mM;

Calculate E_{Na} and E_K for the two conditions. If at rest $g_K = 10\ g_{Na}$, calculate the resting membrane potential for both sets of ionic composition. What effect would this have on action potentials?

(b) A. V. Hill derived an empirical equation to describe the force-velocity relationship of muscle as follows: **(20)**

$$(T+\alpha)\ (v+\beta) = (T_0+\alpha)\beta.$$

Here, T is the tension or force, v is the velocity, and T_o is the force at which v=0, the isometric tension.

(i) Derive an expression for the maximum velocity in terms of T_o, α and β.

(ii) Derive an expression of power (T*v) in terms of v, T_o, α and β.

(iii) What will be the value of maximum power delivered by the muscle? If $T_o = 1$, and $\alpha=\beta=0.25$.

L-4/T-II/BME **Date : 03/04/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-II B. Sc. Engineering Examinations 2020-2021

Sub : **BME 415** (Bionanomaterials)

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**.

The symbols have their usual meanings.

1. (a) What are bionanomatrials? What are their advantages compared to biomaterials? **(10)**

   (b) Nanoemulsions can be prepared using the heterogeneous dispersions of two immiscible liquid phases with a mean droplet size in range of 20-200 m. Describe the method that produces nanoemulsions in the dispersion medium. How can these particles be used for drug delivery? What are the techniques that can be used to characterize the types of particles? **(17)**

   (c) Are there any safety issues when it comes to using bionanomaterials long-term? Explain. Why? **(8)**

2. (a) What are the processing techniques that can be used to synthesize bionanocomposities? Discuss their comparative advantages and disadvantages. **(18)**

   (b) How the concept of nanomedicine can be used for cancer treatment? Mention different types of nanocarriers and discuss how each of them can be used for cancer treatment. Is there any particular carrier that you think is the most suitable one? **(17)**

3. (a) Aritficial antibodies are a wonder of modern biotechnology and medical science. Among the different types of methods to manufacture artificial antibodies, which method do you think is the most efficient and versatile? Justify your answer. **(18)**

   (b) You have been asked to design a combination of nanomaterials for targeted antiviral therapeutic delivery using molecular imprinting methods. However, a major challenge in targeting viruses arises due to their comparatively large dimensions, fragile architecture and poor stability in organic solvents. Because of these issues, selective virus recognition becomes a problem. What improvements can you suggest to solve this problem so that virus detection is enhanced? **(12)**

   (c) Write short notes on intercalated and exfoliated nanocomposites. **(5)**

4. (a) Polymeric nanometerials play an important role in tissue engineering applications. With suitable examples, discuss how polymeric nanomaterials can contribute to the field of tissue engineering.. What is the advantage of using nano sized polymeric materials? Include both synthetic and natural polymers in your discussion. **(25)**

   (b) Discuss the classification of bionanomaterials based on their size and persistency. **(10)**

Contd P/2

BME 415

SECTION – B

There are **NINE** questions in this section. Answer any **SEVEN**.

The symbols have their usual meanings.

5. (a) If a cube with a 1 mm edge is milled to crate cubes with 10 mm, then calculate how many times the surface area will increase. **(15)**

   (b) How can we incorporate hydrophilic and hydropholic drugs inside lipsomes? Explain with a schematic. **(15)**

6. (a) What is Aptamer? Explain the concept of GC content. **(15)**

   (b) Using schematic, explain the concept of competitive protein adsorption. Use time plot if necessary.

7. Describe the chemical reduction method for synthesizing nanomaterial. How does this method help in biological synthesis of nanoparticles? **(15)**

8. (a) Describe how bioactive glass induce bone tissue growth with necessary schematic and reactions. **(15)**

   (b) Why strontium is doped in the bioglass formation?

9. (a) What is the main difference between cell penetrating peptide and pore forming peptide? **(15)**

   (b) Why antibacterial peptides are cationic? Explain the pore-forming Barrel-Stave model of Magainin-2.

10. (a) Describe how chitosan-gum nanoparticle can be synthesized in the lab. **(15)**

    (b) How can we obtain cryogel, aerogel, or zerogel through sol-synthesis method?

11. (a) What information can we obtain from PDI (plydispersity index)? **(15)**

    (b) Why TGA curves usually have three distinct regions?

    (c) How can we get crystallinity percentage information from a XRD curve?

12. What is shape memory effect? How can we observe this effect thermally and mechanically? Explain with appropriate diagrams. **(15)**

13. (a) Why decreasing grain size increases the yield strength of nanostructured steel? **(15)**

    (b) Suppose there are two transparent vials. In one vial, there is silver nanoparticles solution of 10 nm range, and in the other one there is silver nanoparticles solution of 50 nm. Do you think both the solutions will have same color appearance? Explain your reasoning.

L- 4/T-II/BME **Date : 03/05/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L- 4/T-II B. Sc. Engineering Examinations 2020-2021

Sub : **BME 431** (Telemedicine 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**.

The symbols have their usual meanings.

1. (a) What are the benefits and limitations of telemedicine? How does telemedicine affect the cost of healthcare? **(15)**

   (b) Provide a brief overview of satellite communication-based telemedicine system. Show an appropriate flow diagram. Discuss the benefits and limitations of satellite communication for telemedicine. **(15)**

   (c) Explain the need for using an arbitration protocol for certain network topologies. Give an example. **(5)**

2. (a) How does electromagnetic interference (EMF) affect a wireless telemedicine system? Discuss its potential sources and possible solutions. **(10)**

   (b) What are the functions of an EMR? Briefly discuss the relationship among EMR, HER and PHR, and highlight their differences. **(20)**

   (c) Explain the differences between circuit and packet switching. **(5)**

3. (a) Consider the following scenario. Hospital-1, Hospital-2 and Clinic-1 use their own EMRs. A 3rd party company developed an EHR solution by integrating these EMRs along with patients who use a wearable heartrate monitor. The device was approved by the US FDA for non-diagnostic personal use only. However, one of the patient's device was showing an increased average heart-rate due to a calibration error when the user first installed the device. During the patient's regular visit to Clinic-1, the doctor prescribed a beta-blocker-based medication based on the inaccurate information on average heart rate. The medication later caused an unwanted side effect. Who is responsible for this situation and why? State any assumptions you make. **(15)**

   (b) You are designing a wireless monitoring system for a tele-ICU. The frequency content of physiological signals to be transmitted are provided below: **(15)**

   (i) Phonocardiogram (PCG) 20-500 Hz

   (ii) Electrocardiogram (ECG) 0.5-150 Hz

   (iii) Electromyogram (EMG) 0 – 500 Hz

   The wireless transmission channel signal-to-noise-ratio (SNR) is 10dB. Where SNR is defend as:

Contd P/2

$$\text{SNR } (dB) = 20 \log_{10}\left(\frac{S}{N}\right)$$

where, S = maximum peak signal power level.

N = Channel noise power level.

What is the required bandwidth if all of the physiological signals are needed to be transmitted faithfully for this tele-ICU system? What is the maximum bit-rate that can be achieved in the given scenario?

(c) What are the different types of information sources in a telemedicine system? **(5)**

4. (a) What is medical grade broadband? How is multiprotocol label switching (MPLS) used to achieve a higher quality of service? Explain the differences between traditional IP switching and MPLS. **(15)**

(b) Explain the benefits and potential risks associated with Clinical Decision Support Systems (CDSS). **(10)**

A CDSS is used to predict if an ICU patient's condition will deteriorate or not with a sensitivity of 95% and specificity of 60%. For one patient, the system predicted that the patient will not deteriorate at a specific night. Based on this result, what should the nurse do next?

(c) What is PACS? Using an illustration, briefly describe its components. **(10)**

SECTION – B

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

Assume any reasonable value of missing data.

5. (a) What do you think is the current "state-of-the–art" and the privacy & usability challenges of mHealth in Bangladesh? **(20)**

(b) In 203, rescarchers' pilot tested iMHere, a web-based m-Health portal system used by wellness coordinators to be linked with smartphone apps used by spina bifida patients. The program delivered consistent reminders to patients related to self-care activities like catheterization, medication taking and self-skin examination for pressure ulcers that may have originated from the use of orthoses or limited weight shifting from wheelchair. Give your opinion on the possible impact of mHealth, using the example of iMHere for the advancement of rehabilitation services. **(15)**

6. (a) **(25)**

(i) What are three tiers mentional in Figure: Question 6(a)? Also, explain the wireless communication system among the three tiers.

(ii) What do you think about the challenges, security and privacy requirements of Wireless Body Are Networks (WBANs).

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BME 431

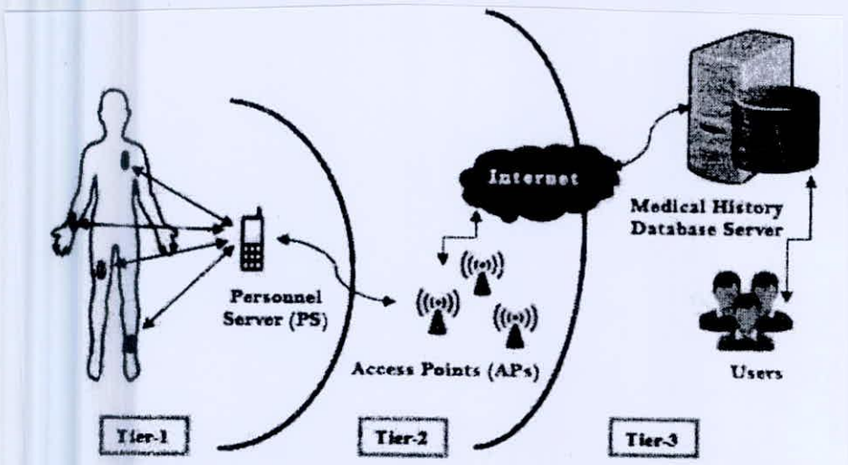

Figure: Question 6 (a)

(c) Describe the major advantages and disadvantages of Tele-pharmacy in developed countries. **(10)**

7. (a) Explain the main ethical concerns that need to be addressed in a telemedicine system. **(15)**
   (b) Propose a blockchain based telemedicine solution to address "Breast Cancer Awareness" issue. Also, explain the features of your proposed solution in brief. **(20)**

8. (a) The **Mindshift** app is the best mental health apps in North America which is geared to those who are using cognitive behavior therapy to address mental health issue. Its features include sets of relaxation, visualization and mindfulness strategies, check-in tools to monitor physical and mental symptoms, and many other tools utilizing a cognitive behavioural therapy approach. Within the first couple of weeks of its release, Canada saw over 40,000 daily users of the mobile app. Explain the factors behind the success of Mindshift. **(25)**
   (b) Describe the major confidentially threats and factors affecting confidentiality issues within the health system. **(10)**

L-4/T-II/BME **Date : 29/04/2023**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-II B. Sc. Engineering Examinations 2020-2021

Sub : **BME 443** (Magnetic Resonance Imaging)

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**.

The Symbols have their usual meanings.

1. (a) Magnetic Resonance Imaging (MRI) is a widely used diagnostic tool which uses the principle of nuclear magnetic resonance (NMR) to produce detailed image of the internal structures of the body. The Bloch equation is a fundamental equation that describes the behavior of magnetic spins in a magnetic field and forms the basis of MRI. **(15)**

   Given the full Bloch equation, find the magnetization response M(t) after $\alpha°$ RF excitation. [Hints: $M(0) = M_o\sin\alpha, M_o\cos\alpha$]]

$$\frac{dM}{dt} = \begin{pmatrix} -1/T_2 & \gamma B_0 & 0 \\ -\gamma B_0 & -1/T_2 & 0 \\ 0 & 0 & -1/T_1 \end{pmatrix} M + \begin{pmatrix} 0 \\ 0 \\ \underline{M} \end{pmatrix}$$

   (b) Suppose you accidently tip the magnetization to 150°. How much additional time will be needed until it relaxes back to 90° (X-Yplane)? Express in terms of variables. **(10)**

   (c) Suppose you tip the magnetization M(t) to $(90 + \alpha)^o$ and let it relax to $(90 - \alpha)°$. Will the magnetization intensity [Mxy(t)| (in the X – Y plane) be the same at $(90 + \alpha°)$ and $(90 - \alpha)°$. Explain with mathematical proof. **(10)**

2. It is important to understand different types of MRI imaging techniques used in clinical practice. T_1, T_2, and proton density (PD) are commonly used MRI imaging sequences that provide different types of information about the tissue being imaged. T_1-weighted images provide information about the anatomical structure and composition of tissues; T_2-weighted images are sensitive to the water content and provide information about the tissue architecture and pathology, while PD-weighted images provide information about the density of protons in the tissue.

   Now, as a biomedical engineer you want to generate an MRI image of a sample with two different materials A and B having proton M_{AO}= 1 A/m and M_{BO}=2.5 A/m. The relaxation times of material A and B are as follows: **(10)**

   A: T_{1A} = 12 s and T_{2A} = 200 ms

   B: T_{1B} = 1.1 s and T_{2B} = 900 ms

Contd P/2

BME 443

Contd...Q. No. 2

(a) Identify the type of imaging technique that will give the maximum contrast of the sample and determine the contrast. Explain your result with mathematical support (in terms T_R, T_E). **(20)**

[Hints: Contrast, C= ($I_B - I_A$), I=Amplitude]

(b) Compute the ideal local contrast for a PD-weighted image of the sample? Is it same, better or worse than the contrast you obtained in 2(a)? Briefly explain. **(8)**

(c) What are the factors affecting T_1, and T_2 relaxations? Why do we get T_2^* instead of T_2? - Briefly explain. **(7)**

3. MRI signal data is represented in a mathematical space known as k-space. This space gives a distinctive representation of the spatial frequency information of the signal. To transform the k-space data into an image of a specific slice of the body, a process called Slice Selection is used. Understanding these concepts is crucial for obtaining high-quality MRI images.

(a) Show that the samples of the MRI signals are the samples of the 2-D Fourier transform of the body being scanned. Consider a 2-D plane and a rotating frame. **(15)**

(b) What will be the bandwidth ($\Delta\omega$) and central frequency (ϖ) of the RF signal to excite a slice thickness of 1mm (ΔZ) at –7cm $(\overline{Z})$ from the origin in a 1.5T static magnetic field and $G_Z = \frac{1}{2\pi}\text{rad}'^{-1}\,\text{cm}^{-1}\left(\text{assume}^1\text{H}-\text{spin}\right)$? **(8)**

(c) Suppose, the k-space is sampled from (–0.5,0) to (0.5,0). The units of k_x and k_y and k_y are in cm^{-1}. IF $G_x(t)$ = 2.0 Gauss/cm, find the value of the readout time (Tread). Assume ^{1}H-spins. **(7)**

(d) Suppose, T_R = 4 ms (Repetition time), N_X = 512 (number of readout samples), N_Y = 512 (number of phase encodes) and N_Z = 256 (number of slices). What will be the time to acquire a 3D volume? **(5)**

4. Magnetic Resonance Imaging (MRI) uses different pulse sequences to generate images of the human body. Spin warp, spin echo, and projection are some of the commonly used pulse sequences in MRI imaging. Understanding the principles and applications of these pulse sequences is essential for producing high-quality as well as time-efficient MRI images.

(a) Describe the spin-wrap pulse sequence technique with an illustration. Do you think it is better than 2-sided projection pulse sequence technique? Explain your answer. **(15)**

(b) Suppose, you are scanning a 1D object m(x) = rect(x/W). Explain the pulse sequence for the 1D imaging along with k-space values and the received signal. Use proper illustrations. **(10)**

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(c) Explain aliasing in MRI imaging, and how it affects the quality of the acquired images. What measure can be taken to mitigate these effects on image quality? **(10)**

SECTION – B

There are **FOUR** questions in this section. Answer any **THREE**.
The Symbols indicate their usual meanings.

5. (a) Explain how the American College of Radiology (ACR) expert panel on MR safety recommends the designation of various zones for ensuring safe practice in MR units, and how the ACR designates personnel into different categories. **(15)**

(b) Figure 5(b) shows a spin-echo (SE) T_2-weighted (T_2w) image of a patient with multiple sclerosis on left and inversion recovery curves showing the range of null points for fat tissue, white matter (WM), grey matter (GM), and cerebrospinal fluid (CSF) on the right. However, the lesions in the SE T_2w image cannot be seen clearly due to very high signal of CSF in brain T_2w images. Identify a method that you can use to suppress the CSF signal in order to observe the lesions more clearly in your image. Draw the pulse sequence diagram of your prescribed contrast method. Use the inversion recovery curves to make numerical inference for timing parameters. Remember that CSF has long spin-lattice relaxation time (T_1) which is greater than 3000 ms. **(10)**

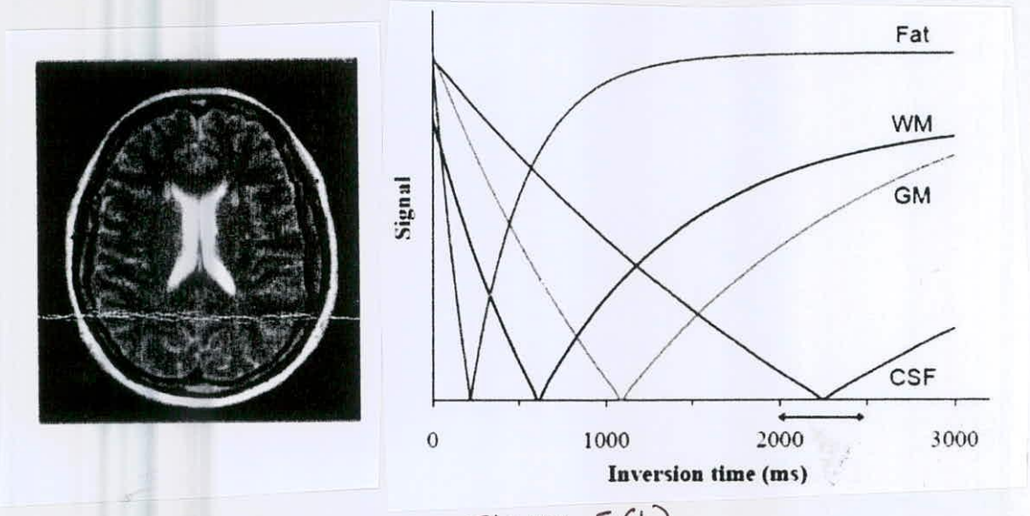

Figure 5(b)

(c) Explain the Time-of-Flight (TOF) effect in MRI. **(10)**

6. Write short notes to explain the following. **(15)**

(i) Magnet quenching (ii) MR elastography (iii) RF shielding

(b) What are the effects of poor magnet homogeneity in MR images? Determine the in homogeneity of a 1.5 T magnet which has a maximum variation of 7.5 μT over a 40 cm DSV **(10)**

(c) Explain the Bloembergen-Purcell-Pound (BPP) theory of relaxation for body tissue. **(10)**

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7. (a) Construct an equation for Ernst angle in terms of repetition time (TR) and T_1 relaxation time and comment on its significance. Evaluate the Ernst angle for a spoiled gradient echo sequence in the brain where T_1 = 800 ms and TR = 3000 ms. **(15)**

   (b) Explain with the help of a diagram how gradient field non-linearly can cause geometric distortions in MR images. Draw a schematic of a birdcage coil in low pass configuration, and show how you can optimize the number of elements so that the current distribution over the surface of the coil varies sinusoidally. **(5+7)**

   (c) List four methods by which you can improve SNR of your MR images without affecting scan time. Also, list the most common causes of artefacts encountered in MRI? **(8)**

8. (a) Suppose you are the chief biomedical engineer of a reputed hospital in your locality. Your hospital has just procured and installed an MRI machine. For when patients, will you contraindicate the use of MRI examinations? **(3+7)**

   Some Gadolinium (Gd) based contrast agents were procured at the same time. In which cases would you recommend not to use the Gd agents? Also explain how the Gd based agents can be used to enhance contrast without harming the human body despite Gd being toxic in its elemental state.

   (b) Suppose you are performing T_1-weighted (T_1w) imaging of liver and fat tissue. Using the table for question 8(b), infer which tissue will appear brighter and which will appear darker in your image, and justify your inference with proper explanation. **(5+5+3)**

Tissue	T1 (msec)	T2(msec)
Liver	500	40
Fat	250	70

Table 8(b)

   Also, draw appropriate T_1 relaxation curves for the two types of tissue in your answer script on the same time-scale. Assuming that maximum value M_0 is same for both tissues, explain and show the T_1 properties determine the particular value of repetition time (TR) that you need to set in order to maximize the contrast between the tissue types.

   (c) Explain how gadolinium (Gd) enhances contrast of a tissue in T_1-weighted (T_1w) imaging. Suppose you are acquitting T1w images of liver tissue, and to enhance contrast, you have injected 0.1 mmol Gd per kg body weight in the vasculature of the subject. If the relaxivity for longitudinal and transverse relaxation rates for Gd are 4 and 5 $mmol^{-1}$ s^{-1}, respectively, determine the new relaxation times of liver tissue after the injection of Gd. From the new relaxation times, comment on the effect of Gd on T_1 and T_2 relaxation rates. Note that normal T_1 and T_2 values for liver tissue are 500 ms and 40 ms, respectively. **(4+6+2)**
