BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2019-2020

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

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

The symbols have their usual meanings.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) Define Health System. According to the WHO health System Framework, what are the building blocks of a health system? How do they interact? (16)

   (b) 'They may have more of a desire to serve a greater purpose than to lead' – by this statement, which type of leadership is being described? Explain in brief. (5)

   (c) Among the various types of leadership, which do you find the least and the most preferable for the healthcare system of Bangladesh. Explain your preference with relatable reasons/examples. (14)

2. (a) What are the sources of healthcare financing in Bangladesh? (5)

   (b) What are the sources of financial flows in public sector healthcare financing? (25)

   (c) How the graduation of Bangladesh from the category of 'Least Developed Country (LDC)' will affect its sources of healthcare financing? (5)

3. (a) What secondary functions do hospitals perform? What are the primary functions? (10)

   (b) Classify healthcare organizations by: (25)

   (i) The length of stay

   (ii) Type of service

4. (a) Discuss the key ethical tenets (principles) for biomedical engineers. (15)

   (b) Write down the various categories of professional and personal code of ethics which have been recommended for the biomedical engineers by the biomedical engineering society. (20)

Contd P/2

BME 405

SECTION – B

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

5. (a) What is the key difference between disinfection and sterilization? Which factors may affect the efficacy of sterilization and/or disinfection process of a medical device? (15)

   (b) Which participants/stakeholders are responsible for ensuring the safety of medical devices? Discuss their roles in maintaining device safety. (20)

6. (a) Draw and discuss the framework for medical device regulation (pre-market, market and post-market). (20)

   (b) Draw a diagram showing the various phases in the life span of a medical device. What safety concerns are related to the packaging and labeling of a medical device? (15)

7. (a) Discuss the role of Bangladesh 'Directorate General of Drug Administration (DGDA)' in medical device regulation. (15)

   (b) Write down the steps of pre-market approval and post-market surveillance of medical device in Bangladesh. What safeguard clause does DGDA have in place for medical devices? (20)

8. (a) What are the objectives of establishing a clinical engineering department in a hospital? (5)

   (b) Which key issues may arise while operating a clinical engineering department? How can these issues be managed? (20)

   (c) What are the criteria of an ideal location for a clinical engineering department within a hospital building? (10)

L-4/T-2/BME **Date: 28/3/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2019-2020

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** questions.

Symbols have their usual meanings.

1. (a) Derive the law of Laplace with the assumptions of heart being (i) a thin walled sphere, and (ii) a thick walled sphere. Use appropriate assumptions and diagram where necessary. **(15)**

(b) Normal dimensions of the human heart for live persons can be determined noninvasively using magnetic resonance imaging (MRI) or two dimensional echocardiography (2DE). Suppose, a heart patient has performed 2DE and found that, during systole, the left ventricular cavity has a diameter of about 34 mm and the wall thickness is about 16 mm. If systolic pressure of the patient is 130 mmHg, estimate the wall tension assuming that the wall stress is constant and that the ventricle is sphere of the dimensions given. Also estimate the wall stress. **(10)**

(c) Explain the Frank-Starling law of the heart. **(10)**

2. (a) With the help of appropriate assumptions and diagrams, derive a mathematical expression for determining cardiac output via indicator dilution method. Also mention if this analysis can be applied for the whole heart. **(10)**

(b) For a given cardiac output, the average velocity of blood in a particular category of blood vessel, aorta, arteriole, etc. is inversely proportional to the total cross-sectional area of the vessels in that category. Suppose, the cross-sectional area of the aorta is about 4.5 cm^2 and the total cross-sectional area of the capillaries has been estimated as 4500 cm^2. **(10)**

(i) What is the average velocity of the blood, in cm/s, in the aorta and in the capillaries, when the cardiac output is 90 cm^3s^{-1}?

(ii) If a typical capillary length is taken as 0.5 mm, how long does it typically take for an erythrocyte to pass through? (ignore axial streaming).

(c) Suppose, an athlete is preparing for the Olympics and as part of her preparation, she is undergoing strenuous exercise every day. What effects would this continuous strenuous exercise have on her cardiovascular system? Would the steady-state operating point of her cardiovascular system remain unchanged during exercise? If not, show graphically and comment on the implications of the shift. **(12)**

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BME 407

3. (a) Instead of being closed, alveoli are open to the airways and are connected to each other through the gas within the lungs. According to the law of Laplace, small alveoli should have higher pressure than the large alveoli, and thus the small alveoli should collapse and the large ones grow larger. But why doesn't that happen? **(5)**

(b) The circulating blood volume typically is 7% of body weight. Assume that a person weighs 80 kg and that the hemoglobin concentration is 14.5 g/dL. The person has a hematocrit of 0.40. Now, if the person is infused with 100 mL of 150 mM $NaHCO_3^-$, assuming instant equilibration with the plasma and exchange across the red blood cells is slow before respiratory or renal compensation can occur. What would happen to plasma pH? **(15)**

(c) During exercise Q_{O_2} increases to 2000 $mLmin^{-1}$, and the respiratory quotient remains at 0.8, and that Q_a increases to 18 $Lmin^{-1}$. Assume that P_{aO_2} remains at 95 mmHg and P_{aCO_2} is 40 mmHg and that blood [Hb] = 15 g%. For these conditions, answer the following. **(15)**

(i) What is the total arterial content of O_2 and the venous content O_2?

(ii) What is the Q_{CO_2}?

(iii) Can you determine the total CO_2 content of venous blood and the partial pressure or CO_2 in venous blood?

(iv) Determine the new alveolar ventilation from the alveolar ventilation equation.

(v) Calculate the predicted P_{aO_2} from the alveolar gas equation.

4. (a) Due to some problems with the respiratory system, pulmonologist instructs you to inspire as deeply as possible, and then to exhale as rapidly and completely as possible. After that you see the pulmonologist observing a graph called 'clinical spirogram'. Draw a clinical spirogram approximately in your answer script. Clearly label and explain the clinically useful parameters to be obtained from the spirogram. **(10)**

(b) A pulmonologist advise you to measure the functional residual capacity (FRC) of your lungs using a whole body plethysmograph. Upon inquiring, you get to know the following. **(15)**

The whole body plethysmograph method consists of a refrigerator-sized, air-tight chamber in which the patient can sit comfortably and which is usually transparent so that the patient can see the operator and vice versa. The patient breathes through a tube connected to a pneumotach, which can measure airflow and pressure at the mouthpiece and which is fitted with a shutter. After a normal expiration, the shutter closes and the patient pants against the closed shutter, while simultaneously holding the cheeks in with the hands. The pressure at the mouthpiece is recorded.

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

The pressure goes up and down cyclically due to the panting effort. When the pressure goes up, the gas remaining in the lung is compressed, is volume decreases. The decrease in volume of the thoracic cavity is accompanied by an increase in volume outside the body, in the chamber.

Now, if the volume change measured by the body plethysmograph is 71 mL and the pressure change measured at the mouthpiece was 20 mmHg, what would the FRC be? Note that the vapor pressure of water remains unchanged. Make necessary assumptions if required.

(c) Why is physiological dead space always larger than anatomic dead space? Also, explain the effect of oxygenation on the total CO_2 content of blood with the help of Haldane effect. **(10)**

SECTION – B

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

5. (a) A. V. Hill derived an empirical equation to describe the force-velocity relationship of muscle. **(20)**

He wrote:

$$(T + \alpha)(v + \beta) = (T_o + \alpha)\beta$$

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 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 , $\alpha = \beta = 0.25$.

(b) How different frequencies and loudness of sounds are interpreted at the cochlear by the hair cells? **(15)**

6. (a) How can you measure the GFR, ERPF and RPF of a patient? Explain with illustrations. **(20)**

(b) Explain the renal titration curve for para-amino hippuric acid (PAH). **(15)**

7. (a) A person has TBW = 42 L and ECF = 14 L and a plasma osmolarity of 300 $mOsM.L^{-1}$. He losts 6 g of NaCl and 0.5 in sweat and eats a meal that contains 4 g of NaCl and drinks 2L of isotonic saline (300 $mOsM.L^{-1}$). What is the new ECF and ICF volume and osmolarity? Show the changes in the Darrow-Yannet diagram. **(15)**

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Contd... Q. No.7

(b) To determine the TBW (L) of a person, you infused (IV injection) 628 mg of D_2O in the body through the left hand. Then you sampled the plasma concentration of D_2O from the right hand for 10 hrs (until it reached steady state), and the concentration changes as, $C(t) = 15(1 - e^{-0.5t})$ mg/L. Assume, that the person lost 0.4% of D_2O (via urination) during this time. Find the TBW. **(12)**

(c) Derive the equation for the fraction of water reabsorption in nephron. **(8)**

8. (a) Explain the working principle of Blood-Brain barrier with proper schematic. **(10)**

(b) Consider muscle fibers that are 8 cm long and that develop a maximum of 20 $N.cm^{-2}$ force per unit area. Consider a muscle that has a volume of 20 cm^3 with the fibers aligned with the direction of the tendon ($\theta = 0$). **(15)**

(i) What is maximum force developed by this muscle?

(ii) If partial recruitment results in activation of 10% of the muscle fibers (assuming they are all equal size), how much force could the muscle generate?

(iii) If the muscle fibers contract 15% of their length in 50 ms under no load, what is the maximum muscle velocity?

(c) Explain with illustration, the general mechanism of synaptic transmission of neurotransmitters. **(10)**

L-4/T-2/BME **Date: 03/4/2022**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2019-2020

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** questions.

Symbols have their usual meanings.

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

   (b) Describe the commonly used techniques to characterize bionanomaterials. **(20)**

   (c) Write a short note on aptamer and its application. **(5)**

2. (a) Describe the biological basis of corona formation and how they interact with cells. **(15)**

   (b) What are the components of binanocomposite? With suitable example, write how binanocomposites can be used for vascular tissue engineering? **(20)**

3. (a) Define the term "Artificial Antibodies.' How can epitope imprinting technology be used to manufacture such bionanomaterials? **(20)**

   (b) Describe the importance of solution casting method of synthesize binanocomposites. **(15)**

4. (a) How does extracellular vesicles function as nanocarriers? How can nanomedicines be classified based on endocytosis of particles? **(12)**

   (b) Write the challenges of translating a tissue engineered implant to clinical use. **(13)**

   (c) What are the safety aspects of bionanomaterials? What are the long-term toxicity effects of bionanomaterials? **(10)**

Contd P/2

BME 415

SECTION – B

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

5. (a) Draw a schematic describing the architecture and functionality of aptamer-based thrombin sensor. **(10)**

(b) Describe the mechanism of microbial mediated synthesis of metal nanoparticles. **(15)**

(c) How can we use bio-scaffolds for anti-cancer drug delivery? Explain in brief. **(10)**

6. (a) Give your opinion on using metal nanoparticles for drug delivery. **(8)**

(b)Write down the functions of components of biosensor mechanism. **(12)**

(c) Describe the synthesis procedure of a bionanomaterial using chemical vapour deposition technique. **(15)**

7. (a) Describe the properties of calcium phosphate that are important for biomedical applications. **(20)**

(b) Explain and compare the top down and bottom-up approaches of nanoparticle synthesis. **(15)**

8. (a) Write down the steps involving the formation of hydroxyapatite in biological fluids. **(10)**

(b) Describe the use of bionanomaterials in MRI image quality enhancement. **(15)**

(c) With a schematic, describe the function of gas-generating polymer nanoparticles in ultrasound imaging. **(10)**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2019-2020

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**.

1. (a) What are the two most widely used wired communication modalities used for telemedicine systems? Provide illustration of the required hardware for both. Discuss the advantages and disadvantages of both types of communication. (15)

   (b) With the help of a flow diagram, provide a brief overview of satellite communication-based telemedicine system. Discuss the benefits and limitations of satellite communication for telemedicine. (15)

   (c) Why do we need an arbitration protocol for the BUS network topology? (5)

2. (a) In a large hospital, you are required to propose a method to track medical equipment by attaching a low-cost device to them. The hospital authority requires that the device cannot use any battery to operate but is not willing to use a solution using a bar-code or QR-code. What technology solution would you provide for this scenario? Describe the working principle of your system. (15)

   (b) With illustrations, briefly discuss the working mechanism of frequency-division multiplexing (FDM) and time-division multiplexing (TDM). How do these techniques benefit telemedicine systems? (15)

   (c) Write down five 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 an FDA approved wearable fitness tracker. One patient's fitness tracker was showing incorrect data for the calorie counter due to a calibration error when the user first installed the device. During the patients regular visit to Clinic-1, the doctor provided an incorrect dose of medication to the patient based on the inaccurate information on calories burnt. The medication later caused a severe adverse event. Who is responsible for this situation and why? State any assumptions you make. (10)

   (b) Define HL7 and briefly discuss its functions. (5)

Contd P/2

BME 431

Contd ... Q. No. 3

(c) Consider the following scenario. A large hospital uses a Hospital Information System (HIS) however, its Laboratory Information System (LIS) is outdated and not HL7 compatible. An admitted patient in the ICU needs to perform an arterial blood gas (ABG) analysis every few hours. What will be the main challenge for not having HL7 compatibility in this situation? Discuss how patient care could be improved if HL7 was fully integrated in the hospital. Using a basic HL7 flow diagram, show how the patient's information will be transferred through the various hospital information systems if HL7 was implemented. State any assumptions you make. You do not need to write HL7 messages or codes. (15)

4. (a) What is a Hospital Information System (HIS)? What subsystems does it connect to within a hospital facility? Describe the functions and benefits of an effective HIS. (15)

(b) Consider the following scenario. A teleradiology software transmits medical images in DICOM format to a remote radiologist. The radiologist can view the image in JPG format on the web browser or download the DICOM file directly. During reporting of a chest CT scan, a remote radiologist observed that the browser information panel did not show the radiation does used for imaging. As this information was urgently required, the radiologist called the hospital. However, the medical technologist was unavailable at that time. Can you suggest any ways to help the radiologist? (10)

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

SECTION – B

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

5. (a) What does it mean by adversarial attack in medical image? (5)

(b) Suppose, you want to establish a telemedicine system in remote areas of Bangladesh. What are the main ethical issues that you will have to consider? (20)

(c) How will you classify telemedicine system based on connection types? Explain in brief. (10)

6. (a) What is tele-pharmacy? Discuss its advantages and disadvantages. (15)

(b) What are the functions and benefits of an electronic drug store? Give your opinion on the feasibility of an electronic drug store in Bangladesh. (20)

7. (a) Design a network consisting of wireless body area network (WBAN) and explain its functionality in brief. (15)

(b) Discuss about the challenges that you will face to build up a WBAN. (20)

8. (a) What are the main functions of motes? (5)

(b) Discuss about the functionality and importance of different mobile hardware platforms in mHealth. (15)

(c) Draw a schematic and explain the working mechanism of sensor nodes in hospital environment. (15)

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2019-2020

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**.

1. (a) Suppose you are generating an MRI image of a sample with two different materials A and B having same M_0 = 1 A/m. However, the relaxation times of the materials are different. The relaxation times of material A and B are as follows: **(25)**

   A: T_{1A} = 1.2s and T_{2A} = 80 ms

   B: T_{1B} = 800 ms and T_{2B} = 45 ms

   Assume a 90° excitation. And $\Delta S_{XY}(t) = M_{XY}A(t) - M_{XY}B(t)$ be the difference in transverse magnetization, $\Delta S_Z(t) = M_ZA(t) - M_ZB(t)$ be the difference in longitudinal magnetization.

   (i) Find an expression for the time that maximizes $\Delta S_{XY}(t)$

   (ii) Find an expression for the time that maximizes $\Delta S_Z(t)$

   (iii) Determine the maximum T_2 image contrast of the sample (Hints: use T_R = infinity and T_E = time that maximizes $\Delta S_{XY}(t)$)

   (iv) Determine the maximum T_1 image contrast of the sample (Hints: use T_R = time that maximizes $\Delta S_Z(t)$ and $T_E = 0$)

   (b) Derive the Ernst angle. Why is it important? **(10)**

2. (a) Determine M(t) solving the full Bloch equation (in matrix form) as shown. After 90° excitation, with initial condition, **(20)**

   $M(0) = [M_0\cos\theta, M_0\sin\theta, 0]$;

$$\frac{dM}{dt} = \begin{pmatrix} -1/T_2 & \gamma B_0 & 0 \\ -\gamma B_o & -1/T_2 & 0 \\ 0 & 0 & -1/T_1 \end{pmatrix} M + \begin{pmatrix} 0 \\ 0 \\ \frac{M_0}{T_1} \end{pmatrix}$$

   Hints: Assume $M_{XY}(t) = M_X(t) + iM_Y(t)$.

   (b) Suppose, the k-space is sampled from (0, 0) to (0.5, 0). The units of kx and ky are in cm^{-1}. If $G_X(t)$ = 1.5 Gauss/cm, find the value of the readout time in x-direction. Assume ^{1}H-spins. **(7)**

   (c) Suppose two ^{1}H isochromats is in different locations in a 1.5T static magnetic field having difference in field strength of 20 ppm. What is the phase difference between them at 4 ms after a 90° RF excitation? **(8)**

Contd P/2

BME 443

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

   (b) Describe gradient echo and spin echo MRI imaging techniques, their advantages and disadvantages with diagrams. **(20)**

4. (a) Explain slice-selection in MRI and how can we adjust the thickness of a slice with proper illustration? **(15)**

   (b) What will be the bandwidth ($\Delta\omega$) and central frequency $(\bar{\omega})$ of the RF signal to excite the shown slice (Z_1 = 7 cm to Z_2 = 13 cm) in a 1.5T static magnetic field and $G_Z = \frac{1}{2\pi}$ rad.s^{-1}.cm^{-1} (assume ^{1}H-spin)? **(10)**

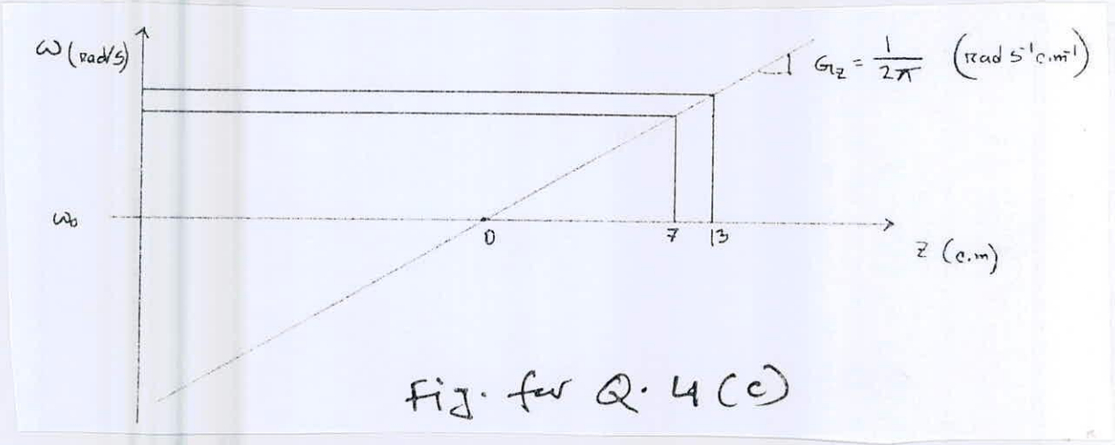

Fig. for Q. 4 (c)

   (c) Suppose, T_R = 33 ms (Repetition time), N_X = 256 (number of readout samples), N_Y = 256 (number of phase encodes) and N_Z = 128 (number of slices). What will be the time to acquire a 3D volume? **(5)**

   (d) Suppose, you want to image 500 × 500 resolution, FOV_X = 10 cm and FOV_Y = 10 cm object. What will be the k-space dimensions (W_{KX}, W_{KY}, ΔK_X, and ΔK_Y)? **(5)**

SECTION – B

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

5. (a) What are the principal mechanisms of proton (^{1}H) relaxation in magnetic resonance (MR) imaging? Discuss the most dominant mechanism in detail. **(15)**

   (b) Differentiate between T_1 and T_2 relaxation time. Discuss the effects of T_1 relaxation on T_2 relaxation. Also explain how the size and motion of the hydrogen residing molecules affect T_1 and T_2 relaxation time in MR imaging. **(20)**

Contd P/3

BME 443

6. (a) Explain the structure of a superconductive MRI magnet. Also, explain how superconductivity can be achieved. Use appropriate diagrams where necessary. **(15)**

   (b) What is Eddy current loss and what are its implications in MR imaging? Discuss different methods to reduce Eddy current loss. **(10)**

   (c) Explain how chemical shift and MR spectroscopy can be used for the assessment of health risks in human. Use suitable examples. **(10)**

7. (a) Suppose, a material has equilibrium magnetization M_0 and relaxation time constants T_1 and T_2. If a 90° excitation is applied, find an expression for $|M(t)|$, the magnitude of the magnetization as a function of time. Also show that if $T_2 < T_1$, $|M(t)|$ can never exceed M_0. **(13)**

   (b) Write short notes on (i) Net magnetization vector, (ii) Field inhomogeneity, (iii) fMRI. **(12)**

   (c) With the help of appropriate diagrams, show how gradients fields are applied along different axes using the gradient coils. **(10)**

8. (a) Suppose you are the chief biomedical engineer in a hospital which is planning on installing a MRI facility. Which international standard would you follow for the basic safety and essential performance of magnetic equipment of your MRI facility? Explain the different operating modes specified by this standard. Also, discuss with proper examples how different items are classified with respect to MRI safety hazards. **(20)**

   (b) Explain different types of coils used in MR imaging. **(10)**

   (c) Suppose, for some MR experiment, you need to flip a proton spin, lying initially along the z-axis, in to the x′-y′ plane by using an appropriate radiofrequency (RF) pulse. If this 90° RF pulse time interval is 1.0 ms, what is the magnitude of the applied RF field, B_1? **(5)**
