Department of Electrical Engineering
Indian Institute of Technology Kharagpur

Medical Image Analysis (EE61008)

End-Semester Examination **Spring, 2016-17**

Credits: 4 Full Marks: 100 Duration of Examination: 3 hours

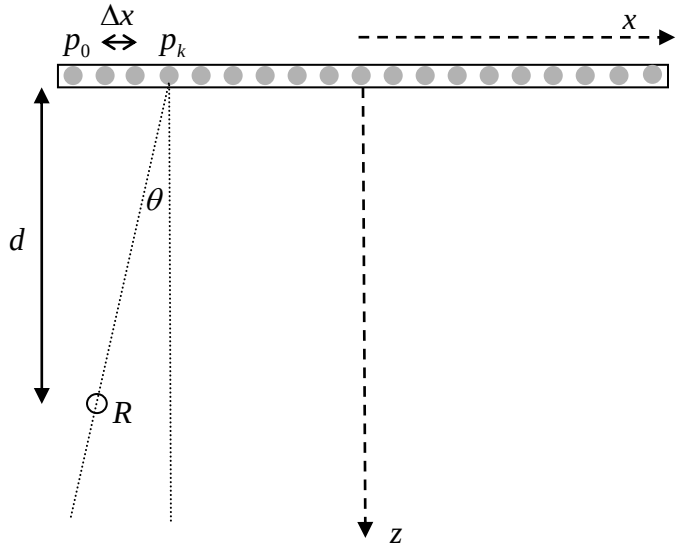
Date: Monday, 24 April 2017, 2-5 PM

Instructions:

1. All questions are compulsory. Marks are indicated in parentheses.
2. Please write your name, roll number, subject name and code, date and time of examination on the answer script before attempting any solution.
3. Use of only electronic calculators is permitted.
4. No extra resources viz. graph papers, log-tables, trigonometric tables would be required.

Question 1:

A linear geometry ultrasound transducer has the elements arranged as per the following configuration. The velocity of sound in the media it propagated through it is c and the frequency of the transducer is f.



Let $t_{k,R}$ be the time taken by the ultrasonic pulse originating at the transducer element p_k to reach the point marked as R. Similarly the time taken by the ultrasonic pulse echoed from R to reach the transducer element p_k be $t_{R,k}$. Please answer the following.

(a) Prove that $t_{k,R} = t_{R,k}$ under the specified conditions. (5 marks)

(b) Find the transmit beamformer triggering sequence for each of the transducer elements p_j where $j \in [0, N-1]$ such that the pulses from all of the elements arrive at the focus point R on the scanline corresponding to element p_k and oriented at an angle θ to the normal from the plane of transducer elements? (10 marks)

(c) If P_k^0 is the power of the ultrasonic pulse emitted at p_k, then what is the power of the echo pulse received at p_{k+1}? (10 marks)

(d) What will be the change in the pressure of the received echo pulse at p_{k+1} if the operating frequency is changed from 10MHz to 40MHz? (5 marks)

Question 2:

A standard 1.5 T MRI machine has an effective imaging dimension of 60 cm x 60 cm slices along the transverse section and a length of 200 cm. The slice encode gradient is of 40 mT/m and the frequency encode gradient is of 40 μT/m. Compute the following: (3 + 2 + 5 marks)

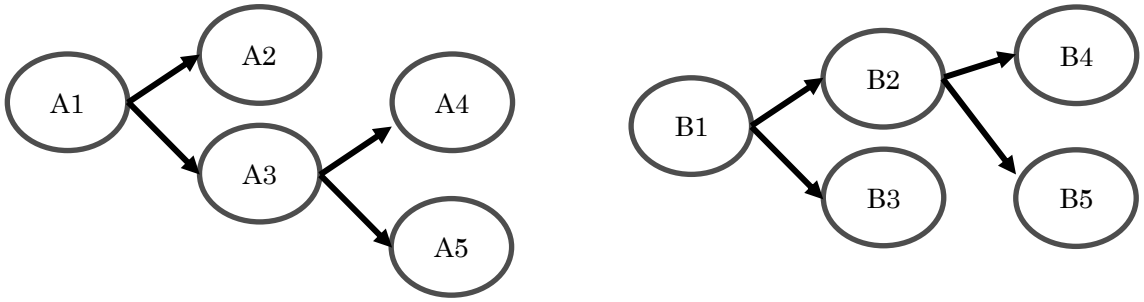
a. Range of magnetic field strength to be experienced within the effective imaging volume?
b. Range of Larmor frequencies to be experienced within the effective imaging volume by a hydrogen atom with a gyromagnetic ratio of $\gamma = 42.58$ MHz/T ?
c. Consider that the voxel resolution of the MRI imaging device is 1 mm x 1 mm x 1mm. What is the minimum frequency hop between two neighboring voxels in the volume?

Question 3:

Consider a vector $\mathbf{x}$ to be the input to a perceptron model such that it produces a vector $\hat{\mathbf{y}}$ as the output. They are related as $\hat{\mathbf{y}} = f_{\text{NL}}(\mathbf{w}.[\mathbf{x}; 1])$, and the non-linear activation function is $f_{\text{NL}}(z) = \frac{1}{1+e^{-z}}$, and $\mathbf{w}$ is termed as the connection weights relating the input to the output. Say that during training of the network using the gradient descent rule, for a set of given inputs $\{\mathbf{x}_i, \mathbf{y}_i\}$ the error between the observed as the predicted is written as the cost function of the learning rule as $J(\mathbf{w}) = \frac{1}{N}\sum_{i=1}^{N}\|\hat{\mathbf{y}}_i - \mathbf{y}_i\|$ then derive the analytical form of $\frac{\partial J(\mathbf{w})}{\partial \mathbf{w}}$? (10 marks)

Question 4:

Consider the following two trees (A and B) in a decision forest and answer the following.



Node	$\|\omega_0\|$	$\|\omega_1\|$	Node	$\|\omega_0\|$	$\|\omega_1\|$
A1	50	56	B1	45	55
A2	20	0	B2	45	20
A3	30	56	B3	0	35
A4	0	56	B4	2	20
A5	30	0	B5	43	0

a. Compute the entropy at each node for each of the trees A and B? (10 marks)
b. Identify the leaf nodes for the trees A and B? Justify your reason. (10 marks)
c. Calculate the posterior probability of decision at each leaf node? (5 marks)
d. Calculate the information gain at each decision node of the tress A and B? (5 marks)

Question 5:

Compute the TP, FP, TN, FN, Precision, Recall, Sensitivity, Specificity, F-Score, Accuracy for the following RGB color image segmentation problem of optical microscopic histology I and its ground truth M. Perform segmentation with nearest neighbor search using the following class seeds $1 = \{(1,1,3)\}$ and $0 = \{(10,3,9)\}$ (20 marks)

$$I = \begin{bmatrix} (1,1,2) & (1,1,1) & (0,0,1) & (10,2,4) \\ (0,1,2) & (1,3,4) & (10,1,2) & (1,3,1) \\ (0,0,0) & (9,9,9) & (9,8,9) & (10,2,10) \\ (1,1,1) & (1,2,1) & (9,10,11) & (10,11,10) \end{bmatrix} \quad M = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \end{bmatrix}$$