HUB4045F assignment 2: 25% of final mark

[Solutions to all questions to be submitted on Vula] **[Total Marks: 50]**

Question 1 [8 marks]

Given the table of tissue parameters below, investigate the pulse sequence parameters for T1- and T2-weighted pulse sequences using the relationship: $S = \rho(1 - \exp^{-TR/T1}) \exp^{-TE/T2}$, where S is the MR signal strength, ρ is the spin density, TR the repetition time and TE the echo time.

Tissue	**T1**	**T2**	ρ
Gray matter	1.2 s	70 ms	.89
White matter	800 ms	45 ms	.80

a) To obtain a T1-weighted pulse sequence, what TE would you choose? Think of a TE that will minimize T2-weighting. Using your selected TE, plot (e.g in Matlab/Excel) or sketch by hand the signal strength S vs. TR for a range of TRs from 0 to 2000 ms. Plot gray and white matter on the same axes (clearly labelled) (2)

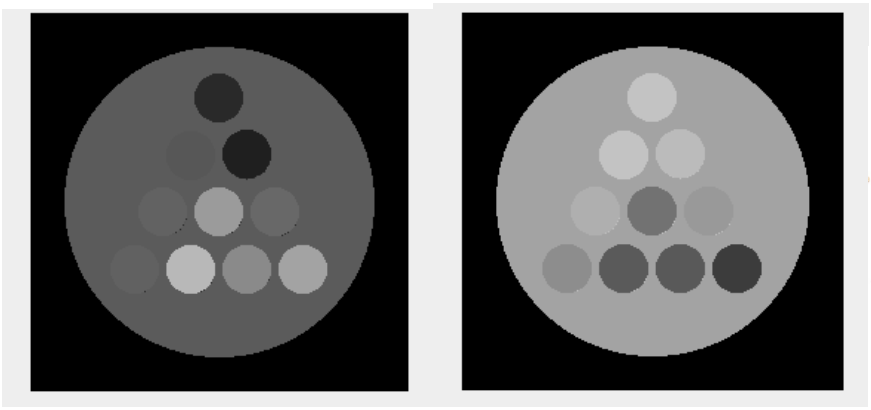
b) In another figure, plot the signal difference between white matter and gray matter. At what TR is this difference maximized? (2)

c) For a T2-weighted pulse sequence, what TR would you choose to remove all T1 weighting? Use your selected TR to plot the signal strength, S, vs. TE for a range of TE s from 0 to 150 ms. Plot gray and white matter on the same axes (clearly labelled). (2)

d) In another figure, plot the signal difference between white matter and gray matter. At what TE is this difference maximized? Set $\rho=1$ for both and determine the optimal TE. How does this relate the tissue T2 s? (2)

Question 2 [8 marks]

The images shown in Figure 1 below were generated by a simulation of the contrasts that would result if a spin echo sequence was used to image a slice through a test object that contains 10 cylindrical tubes arranged in a larger cylinder. The tubes in Fig 3(a) and (b) can be identified using the numbering shown in Fig 3(c). Use the images in Fig 3 and your knowledge of T1-weighting and T2-weighting to answer the following questions:



TR = 2,500ms, TE = 70ms (a)

TR = 600ms, TE = 10ms (b)

(c)

Figure 1

a) Tubes 2 and 3 in the cylindrical test object have the same T1 value. Which tube has the longer T2? Give a reason for your answer. (2)
b) Tubes 4 and 7 in the cylindrical test object have the same T2 value. Which tube has the longer T1? Give a reason for your answer. (2)
c) Do tubes 8 and 9 in the cylindrical test object have the same T1 value or the same T2 value? Why? (2)
d) Which tube in the cylindrical test object has the shortest T1 value and which has the longest T2 value? In each case, give a reason for your answer. (2)

Question 3 [6 marks]

When answering this question refer to figure 2 below:

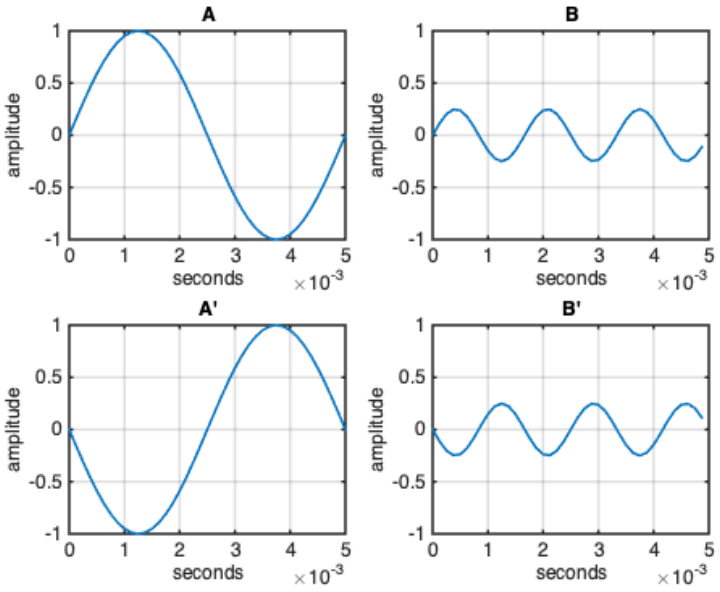
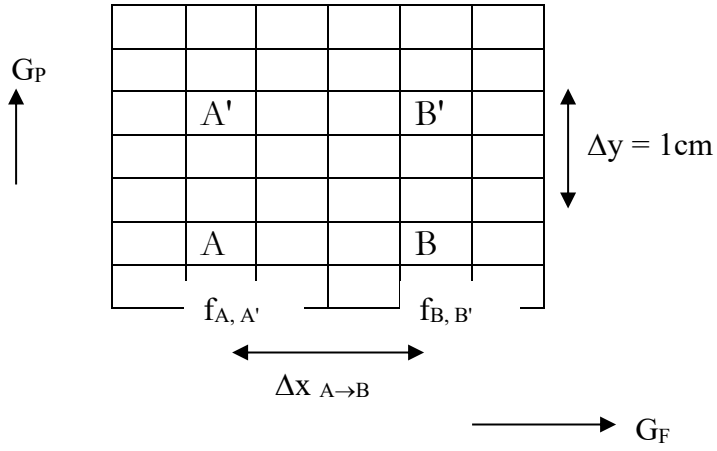


Figure 2

The proton resonance frequencies relative that give the free induction decays (FIDs) from pixels (A) and (B) shown in figure 1 are 200Hz and 600Hz respectively. The FIDs of figures 1A and B resulted from a composite FID of tissue obtained during the application of a frequency-encoding gradient (G_F) of 0.25 G/cm.

a) Calculate the distance of the point in the tissue corresponding to pixel A from the reference point that is assigned the frequency 0Hz. (Recall γ = 42.57 MHz/T for protons. Hint: first convert the frequency-encoding gradient to units of Hz/cm.) (2)
b) What is the distance between tissue structures corresponding to pixel A and pixel B? (1)
c) What is the proton density of pixel (A) relative to pixel (B) in Fig. 1? (1)
d) In Fig. 1, pixel A' is in the same frequency-encoding column as A, and pixel B' is in the same frequency-encoding column as B. A' and B' are in the same phase-encoding row of the image matrix along the y-axis and represent coordinates in the tissue that are 1cm from the AB row. How long would a phase-encoding gradient (G_P) of 0.1 G/cm need to be applied to cause the observed phase changes between pixel A and A' and pixel B and B'? (2)



Question 4 [6 marks]

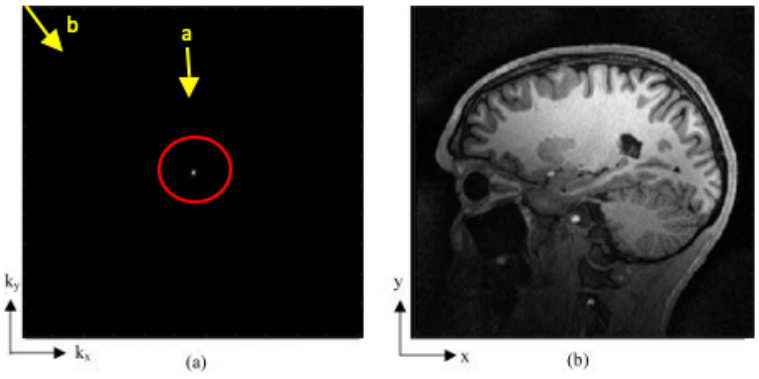


Figure 3

Figure 3 shows the raw k-space data of a sagittal slice through the brain, as well its inverse FT i.e. the brain in image space.

a) Describe what you would see if you discarded the centre of k-space (inside the red circle) before performing the FT and explain why

b) Describe what you would see in the image if there was an RF spike at the arrow position marked a. Comment on the orientation and appearance of the artefact
c) Describe what you would see in the image if there was an RF spike at the arrow position marked b. Explain how and why this artefact differs from position a.

The image is provided for you (brain.dcm). If you have access to Matlab's image processing toolbox you can experiment with Kspace to obtain your answers. Read in the image using dcmread and use fft2 generate Kspace. Note that you need to use fftshift in Matlab to move the zero-frequency component to the centre of Kspace. You can then manipulate Kspace and use ifft2 to see the result on the image. You can include example images of the result for this question if you want to, but accurately describing the effect on the image is sufficient.

Question 5 [4 marks]

Figure 4 shows a 2D spin echo chemical shift imaging sequence for the acquisition of a chemical shift spectrum (used in MR Spectroscopy). Note that both the x- and y-axes are treated as phase encoding axes with gradients applied before the signal is digitized to localise a position in 2D k-space. Note also that each value of G_x is repeated for all possible values of G_y. No imaging gradient is applied during the time when the echo is digitized. Draw the k-space diagram for this sequence. (You should notice that the data for only one point in k-space is acquired with each repetition of the sequence, as opposed to a line of k-space.) Number the points in k-space in order to indicate the order in which they are acquired. You only need to do enough points to indicate the pattern of k-space filling. [4]

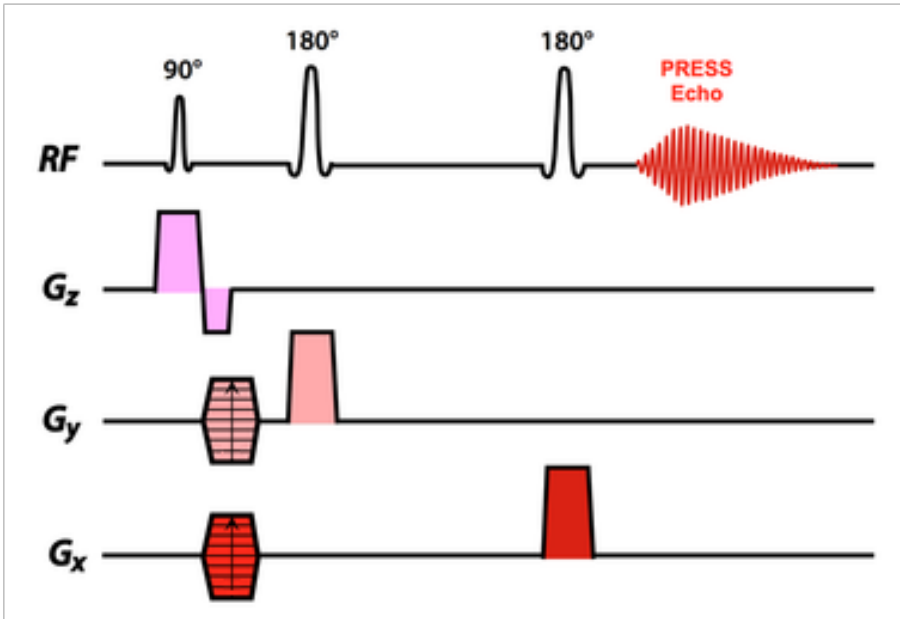


Figure 4

Question 6 [6 marks]

For each of the two pulse sequences shown below:
a) Calculate the total acquisition time (hint: are they 2D or 3D sequences?)
b) Calculate the voxel size
c) Based on the contrast and resolution explain whether you think these are structural or functional images

SEQUENCE ONE

Scanner SIEMENS MAGNETOM TrioTim
Routine
Slab group: 1
Orientation: Sagittal
  Phase encode direction: A >> P
  Readout direction: R >> L
Slices per slab: 160
FoV read: 220 mm
FoV phase: 220 mm
Slice thickness: 1.20 mm
TR: 2300 ms
TE: 2.94 ms
Averages: 1
Contrast
Magnetization preparation: Non-sel. IR
TI: 1100 ms
Flip angle: 9 deg
Reconstruction: Magnitude
Measurements: 1
Resolution
Base resolution: 256
Phase resolution: 192
Slice resolution: 256
PAT mode: GRAPPA
Acceleration factor: PE 2
Geometry
Multi-slice mode: Single shot
Series: Interleaved
Sequence
Bandwidth: 240 Hz/Px
Echo spacing: 7 ms
RF spoiling: On

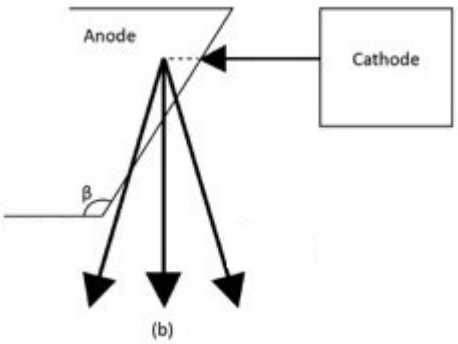
SEQUENCE TWO

Scanner SIEMENS MAGNETOM TrioTim
Routine
Slice group 1
  Slices: 30
  Dist. Factor: 25 %
  Orientation: Transversal
  Phase encode direction: A >> P
  Read encode direction: R >> L
FoV read: 220 mm
FoV phase encode: 220 mm
Slice thickness: 4.0 mm
TR: 2000 ms
TE: 30 ms
Averages: 1
Contrast
MTC: Off
Flip angle: 77 deg
Measurements: 142
Resolution
Base resolution: 64
Phase resolution: 64
PAT mode: None
Matrix Coil Mode: Triple
Geometry
Multi-slice mode: Interleaved
Series: Ascending
Sequence
Bandwidth: 2298 Hz/Px
Free echo spacing: Off
Echo spacing: 0.5 ms
EPI factor: 64
Dummy Scans: 3

Question 7 [4 marks]

Describe the physiological and physical mechanisms behind the BOLD response. What relaxation parameter is responsible?

Question 8 [4x2 marks = 8 marks]



a) Identify what is being shown in the above diagram. Describe what impact this may have on an X-ray image and what could be done to offset this
b) Describe the process of obtaining an image using filtered backprojection
c) How do the PET and CT signal differ. (Hint. The source, energy, quality, etc)
d) True or false: Ultrasound gel is not necessary for clinical ultrasound scanning. Give a reason why

[Total: 50 marks]