Medical Imaging, ECE 491 | **Final Exam** | **Total Grade=50 Points** | **January 9th, 2018**

Mansoura University	Faculty of Engineering	Biomedical Engineering (BME) Program Time allowed: 120 min Exam is 2 pages Assume any missing data **Include and name all steps**

Question # 1: [5 points] Sketch a typical arrangement for a formation of a plain x-ray image. List one advantage and one disadvantage of x-ray imaging. How computed tomography (CT) imaging is different?

Question # 2: [5 points] Sketch the main components of an MRI scanner, showing their places on the scanner. Describe the job of each component in producing the MRI image.

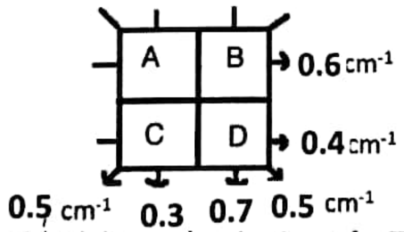
Question # 3: [5 points] For the following Matlab code:

```
Image=[0 1 2 3;3 2 1 0;1 1 1 1;2 2 3 3];  % input image
pdf=0;                                     % initialization of pdf variable
cdf=0;                                     % initialization of cdf variable
For i=0:3                                  % computation loop for pdf and cdf variables
  [x y]=find(Image==i);
  pdf_Im(i+1)=length(y)/16;
  cdf(i+1)= sum(pdf_Im(1 : i+1));
end                                        % end of computation loop
[x1  y1]= find(cdf>0.5);                   % find threshold position
Seg_Image=Image<cdf(x1(1),y1(1));          % Compute the segmented image
```

(a) Compute the values of the variables x, y, pdf, and cdf when the loop index i=0 **[3 points]**

(b) Compute the values of the variables x1,y1, and Seg_Image after the execution of the code **[2 points]**

Question # 4: [5 points] If the linear attenuation coefficient of water is 0.2 cm^{-1}. Reconstruct the image values in **Fig. 1** **using the iterative arithmetic reconstruction technique** [i.e., compute the linear attenuation coefficient at each pixel of the image (i.e., the values A, B, C, and D)]. Compute the Hounsfield unit (CT number) at each pixel. Use the table given to determine the location of each pixel in the body.



Vertical, horizontal, and diagonal projections of a CT image

Hounsfield units in the body

Bone	+400 → +1000
Soft tissue	+40 → +80
Water	0
Fat	−60 → −100
Lung	−400 → −600
Air	−1000

Fig. 1 A CT image projections (left) and CT numbers in body (right)

Question # 5: [5 points] A Doppler shift ultrasound scanner transmits an ultrasound wave with a frequency of **1.5MHz**. The scanner receives an echo from a moving blood cell with a frequency of **1.48MHz**. If the ultrasound velocity is 1500 m/s. Compute the velocity of the blood cell and determine whether it approaches or travel away from the transducer

Question # 6: [15 points, each is 3 points] Explain the following:

(a) How the isotope half life and half value layer is selected in nuclear imaging.
(b) How positron (positive-Beta or anti-electron) emission images are produced.
(c) How Lamor frequency is selected in magnetic resonance imaging.
(d) How functional MRI is acquired.
(e) How A-mode ultrasound is performed

Question # 7: [5 points] Given the following four manually segmented registered training images, where the object label is "1" and the background label is "0":

Training Image 1

0	0	0	0
0	1	1	0
0	0	1	0
0	0	1	0

Training Image 2

0	0	0	0
0	1	1	0
0	1	1	0
0	0	1	0

Training Image 3

0	0	0	0
0	0	1	0
0	1	1	0
0	0	1	0

Training Image 4

0	0	1	0
0	1	1	0
0	1	1	0
0	0	0	0

(a) Build the probabilistic shape prior map **[3 points]**
(b) Use this model to classify the following image, which has Q=10 grey levels **[2 points]**

Test Image

8	2	0	9
3	2	1	7
4	1	7	8
5	5	6	8

Question # 8: [5 points] If the intensity model of the object versus the back ground, where the object label is "1" and the background label is "0", is computed as follow:

Grey level, q	0	1	2	3	4	5	6	7	8	9
p(q,x=0)	0	0.025	0.025	0.025	0.04	?	0.05	0.06	0.1	0.125
p(q,x=1)	0.12	0.105	0.055	0.05	0.05	?	0.025	0.025	0.025	0

Assuming equal prior probabilities of the object and the background. Compute the marginal distribution of the grey level image p(y=q). Classify the following test image using the Bayes classifier.

Test Image

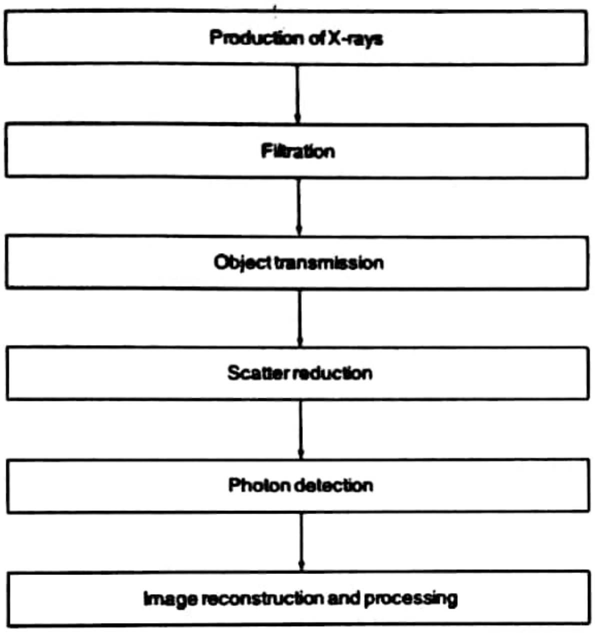
8	2	0	9
3	2	1	7
4	1	0	8
5	5	3	8

د. أحمد النقيب   خالص امنياتى بالتوفيق   تمت الاسئلة

Mansoura University	Faculty of Engineering	Biomedical Engineering (BME) Program Time allowed: 120 min Exam is 2 pages Assume any missing data **Include and name all steps**

<u>Question # 1:</u> [5 points] Sketch a typical arrangement for a formation of a plain x-ray image. List one advantage and one disadvantage of x-ray imaging. How computed tomography (CT) imaging is different?

Sol.

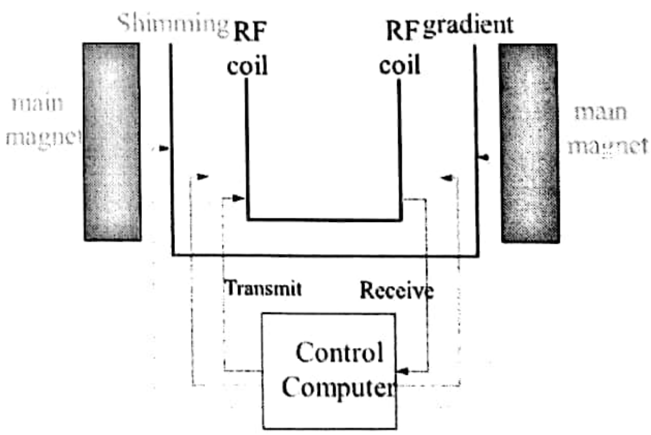


<u>Adv.</u>	**<u>Dis.</u>**
Excellent in imaging bones and air (lungs), cheap	2D, can not image the 3D details of the object, harmful radiation
CT: 3D, The object is scanned using X-rays from a number of different angles and then a cross-sectional image of it can be computed	

<u>Question # 2:</u> [5 points] Sketch the main components of an MRI scanner, showing their places on the scanner. Describe the job of each component in producing the MRI image.

Sol. The major components of an **MRI** scanner are:

- Main magnet, which polarizes the sample
- Shim **coils** for correcting inhomogeneities in the main magnetic field
- **Gradient** system which is used to localize the MR signal
- RF system, which excites the sample and detects the resulting NMR signal
- A control system to manage the whole system



Question # 3: [5 points] For the following Matlab code:

```
Image=[0 1 2 3;3 2 1 0;1 1 1 1;2 2 3 3];  % input image
pdf=0;                                     % initialization of pdf variable
cdf=0;                                     % initialization of cdf variable
For i=0:3                                  % computation loop for pdf and cdf variables
  [x y]=find(Image==i);
  pdf_Im(i+1)=length(y)/16;
  cdf(i+1)= sum(pdf_Im(1 : i+1));
end                                        % end of computation loop
[x1 y1]= find(cdf>0.5);                    % find threshold position
Seg_Image=Image<cdf(x1(1),y1(1));          % Compute the segmented image
```

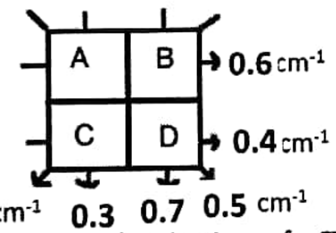
(a) Compute the values of the variables x, y, pdf, and cdf when the loop index i=0 **[3 points]**

Sol. x=[1 2]; y=[1 4], pdf=0.125

(b) Compute the values of the variables x1,y1, and Seg_Image after the execution of the code **[2 points]**

Sol. cdf=[0.125 0.5 0.75 1];x1=[1 1]; y1=[3 4];Seg_Image=[1 0 0 0;0 0 0 1;0 0 0 0;0 0 0 0]

Question # 4: [5 points] If the linear attenuation coefficient of water is 0.2 cm^{-1}. Reconstruct the image values in **Fig. 1** **using the iterative arithmetic reconstruction technique** [i.e., compute the linear attenuation coefficient at each pixel of the image (i.e., the values A, B, C, and D)]. Compute the Hounsfield unit (CT number) at each pixel. Use the table given to determine the location of each pixel in the body.



Vertical, horizontal, and diagonal projections of a CT image

Hounsfield units in the body

Bone	+400 → +1000
Soft tissue	+40 → +80
Water	0
Fat	−60 → −100
Lung	−400 → −600
Air	−1000

Fig. 1 A CT image projections (left) and CT numbers in body (right)

Sol. Initial

0	0
0	0

vertical

0.15	0.35	0.5
0.15	0.35	0.5

Horizontal

0.2	0.4	0.5
0.1	0.3	0.5

Diagonal

0.2	0.4
0.1	0.3

$1000 * (Mu - 0.2)/0.2$

0 water	1000 bone
-500 Lung	500

Question # 5: [5 points] A Doppler shift ultrasound scanner transmits an ultrasound wave with a frequency of **1.5MHz**. The scanner receives an echo from a moving blood cell with a frequency of **1.48MHz**. If the ultrasound velocity is 1500 m/s. Compute the velocity of the blood cell and determine whether it approaches or travel away from the transducer

Sol. fr=1.48 MHz: c+u=ft c/fr ➔ u=[1.5/1.48*1500]-1500= 20.27 m/s (away)

Question # 6: **[15 points, each is 3 points]** Explain the following:

(a) How the isotope half life and half value layer is selected in nuclear imaging.

half life: the time required for the radioactivity to drop to half of its current value

half-value layer: thickness of tissue that absorbs one-half of the radioactivity produced

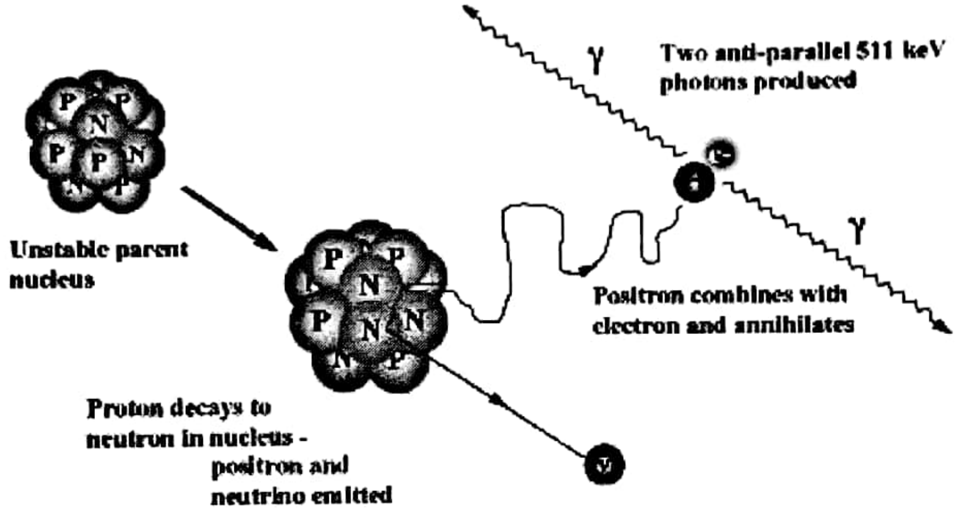
- In nuclear imaging half life should be large enough (in terms of hours) in order to capture the image, half-value layer should be large enough (in terms cm, larger than the body thickness) in order to penetrate the human and reach the detector

(b) How positron (positive-Beta or anti-electron) emission images are produced

- As the radioisotope undergoes positron emission decay, it emits a positron, an antiparticle of the electron with opposite charge

- The emitted positron travels in the tissue for a short distance (typically less than 1 mm depending on the isotope) then it is annihilated with an electron in the tissue

- After the positron is annihilated, it results in a formation of two gamma-rays that are detected using gamma-ray detectors and produce better image quality than other radioactive decay mechanisms



(c) How Lamor frequency is selected in magnetic resonance imaging

- In magnetic resonance, only protons with that preceeds with a Lamor frequency of the same as the RF pulse will respond
- Lamor frequency is selected by changing the applied magnetic field B0 using the gradient coils;

$$\omega 0 = \gamma \, B0(x,y,z)$$

ω0 is the angular frequency (radian per second)

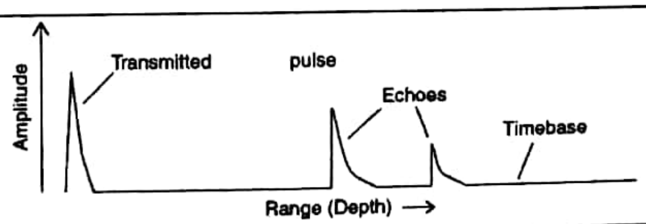
B0 is the magnitude of the applied magnetic field (tesla)

(d) How functional MRI is acquired

- Record two images one at rest and one during activating the brain with a certain stimulus
- Record the difference between the two images

(e) How A-mode ultrasound is performed

- To acquire an A-mode scan, short pulses are transmitted along a US probe, and the A-mode scan represents the amplitude of the pulse echoes versus the time of arrival



Question # 7: [5 points] Given the following four manually segmented registered training images, where the object label is "1" and the background label is "0":

Training Image 1

0	0	0	0
0	1	1	0
0	0	1	0
0	0	1	0

Training Image 2

0	0	0	0
0	1	1	0
0	1	1	0
0	0	1	0

Training Image 3

0	0	0	0
0	0	1	0
0	1	1	0
0	0	1	0

Training Image 4

0	0	1	0
0	1	1	0
0	1	1	0
0	0	0	0

(a) Build the probabilistic shape prior map **[3 points]**

Object shape prior

0	0	0.25	0
0	0.75	1	0
0	0.75	1	0
0	0	0.75	0

background shape prior

1	1	0.75	1
1	0.25	0	1
1	0.25	0	1
1	1	0.25	1

(b) Use this model to classify the following image, which has Q=10 grey levels **[2 points]**

Classification

0	0	0	0
0	1	1	0
0	1	1	0
0	0	1	0

Question # 8: [5 points] Assuming equal prior probabilities of the object and the background. Compute the marginal distribution of the grey level image p(y=q). Classify the following test image using Bayes

Sol.

Grey level, q	0	1	2	3	4	5	6	7	8	9
p(q,x=0)	0	0.025	0.025	0.025	0.04	**0.05**	0.05	0.06	0.1	0.125
p(q,x=1)	0.12	0.105	0.055	0.05	0.05	**0.045**	0.025	0.025	0.025	0
p(q)	0.12	0.125	0.08	0.075	0.09	0.095	0.075	0.085	0.125	0.125

Bayes classifier: If $p(x=0|y) \geq p(x=1|y)$ then decide $(X=0)$, Otherwise decide $(X=1)$.

Thus Class x=0 :$p(x=0|y)p(y) \geq p(x=1|y)p(y) \rightarrow P(Y,X=0) \geq P(Y,X=1) \rightarrow$ Levels $q=5,6,7,8,$ and 9

Test Image

8	2	0	9
3	2	1	7
4	1	0	8
5	5	3	8

classification

0	1	1	0
1	1	1	0
1	1	1	0
0	0	1	0