CS 111: Digital Image Processing
Spring 2019
Midterm Exam 1: May 08, 2019

Time: 1½ hours   Total Points: 90

Name (in BLOCK LETTERS): _____

Seat Assignment: _____

Pledge: I neither received nor gave any help from or to anyone in this exam.

Signature: _____

Useful Tips

1. All questions are multiple choice questions. Please indicate your answers clearly. You may circle them or write out the exact choice. If your choice is unclear or ambiguous, you will not receive credit for your answer.
2. Use the blank pages as your worksheet. Put the question number when working out the steps in the worksheet. Do your work clearly. This will help in awarding partial credit. Answer the questions you are most comfortable with first.
3. **Points are indicative of the time in minutes you should spend on the question.**
4. Please ask for extra sheets if you need more.
5. Staple all your worksheets together with the paper when submitting at the end of the exam. If pages of your exam are missing since you took them apart, we are not responsible for putting them together.
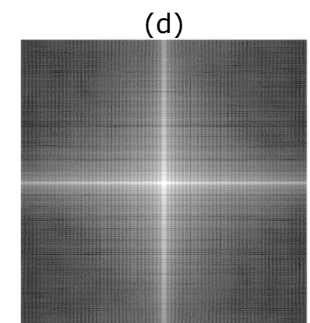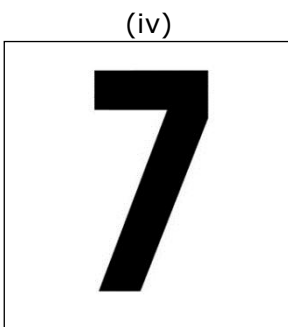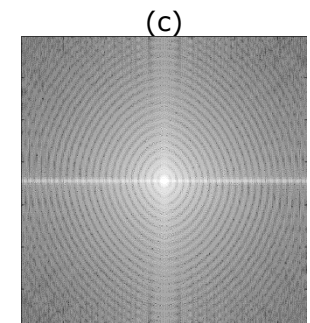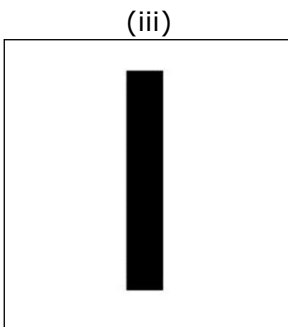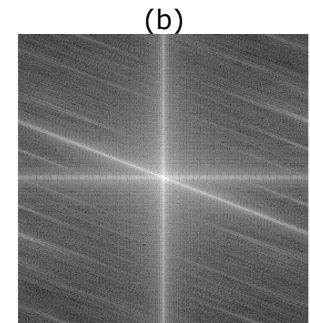
Do not enter anything in the table below

Q #	Maximum Points	Points Received
1)	8	
2)	7	
3)	6	
4)	6	
5)	8	
6)	6	
7)	12	
8)	4	
9)	3	
10)	6	
11)	3	
12)	4	
13)	10	
14)	7	
Total	90	

1) **[4x2=8]** Match the images in left column to the magnitude plot of their DFT in right column.

(i)

(a)

(ii)

(b)

(iii)

(c)

(iv)

(d)
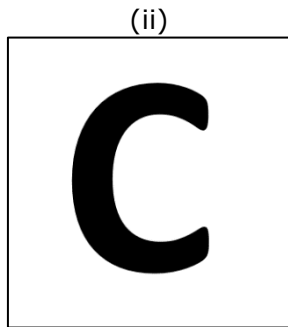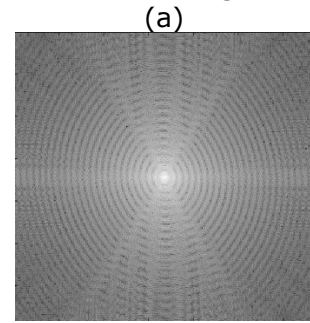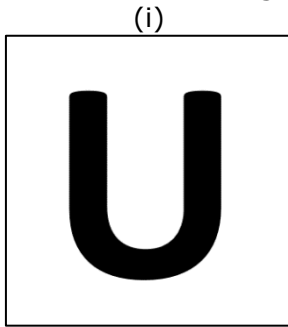
2) **[1+2+1+1+2=7]** Consider a 256x256 image and its Gaussian Pyramid. The original image is considered as level-0 of the pyramid.

    a. What is the highest level in the pyramid?
        i. Level 0
        ii. Level 1
        iii. Level 8
        iv. Level 9

    b. Level *i* of this pyramid can be achieved in which of the following ways?
        i. By convolving level $i-1$ image with a Gaussian and subsampling
        ii. By convolving level $i-1$ image with a Gaussian and upsampling
        iii. By convolving level $i+1$ image with a Gaussian and subsampling
        iv. By convolving level $i+1$ image with a Gaussian and upsampling

    c. We can reduce the image size of each level by a:
        i. Factor of 2
        ii. Factor of 3
        iii. Factor of 4

    d. This is possible because:
        i. Each level reduces the frequency content by an octave
        ii. Some of the pixels become zero due to the processing
        iii. Nyquist sampling requirement goes down with each level

    e. Convolving with a box kernel in the spatial domain is equivalent to:
        i. Multiplication with a sinc in frequency domain
        ii. Convolution with a box in frequency domain
        iii. Multiplication with a gaussian in frequency domain
        iv. Convolution with a sinc in frequency domain

3) **[3+3=6]** Consider $g[n]$, a 1-D discrete signal of length K and $h[n]$, the impulse response of a system with length L. The output of this system with input $g[n]$ is denoted as $y[n]$.

    a. The length of $y[n]$ is
        i. L
        ii. $K + L - 1$
        iii. $K + L$
        iv. $K + L + 1$

    b. Assuming $K \geq L$, what is number of samples in $y[n]$ that are fully immersed?
        i. L
        ii. $K - L$
        iii. $K - L + 1$
        iv. K

4) **[2+2+2=6]** Let $f(x,y)$ denote an image and $f_G(x,y)$ denote the image obtained by applying the Gaussian filter $g(x,y)$ to $f(x,y)$. In the photography industry, an operation called *high boost filtering* generates an image $f_B(x,y) = af(x,y) - f_G(x,y)$, where $a \geq 1$.

    a. You are asked to use one filter to achieve the high boost filtering. The filter you should use is:
        i. $\delta(x,y) - g(x,y)$
        ii. $1 - g(x,y)$
        iii. $a\,\delta(x,y) - g(x,y)$
        iv. $a - g(x,y)$

    b. If $G(k,l)$ is the frequency domain response of $g(x,y)$, the frequency response of this filter is given by:
        i. $\delta(k,l) - G(k,l)$
        ii. $a - G(k,l)$
        iii. $a\,\delta(k,l) - G(k,l)$
        iv. $1 - G(k,l)$

    c. The shape of this filter in the frequency domain is similar to a:
        i.   Low-pass filter
        ii.   High-pass filter
        iii.   Band-pass filter


5) **[2+2+2+2=8]** Consider the case of sampling during image capture and reconstruction during image display. The image considered for capture and subsequent display has a bandwidth of 50Hz. The sampling function in the spatial domain is a comb function whose frequency domain response, *C*, is also a comb function.

    a. The frequency interval between of the spikes of *C* is
        i. 50Hz
        ii. 100Hz
        iii. 25 Hz

    b. Consider a point spread function or reconstruction kernel of bandwidth 70Hz in frequency domain. This would result in:
        i. Blurring
        ii. Pixelization
        iii. Correct reconstruction

    c. Consider a point spread function or reconstruction kernel of bandwidth 30Hz in frequency domain. This would result in:
        i. Blurring
        ii. Pixelization
        iii. Correct reconstruction

    d. Consider a point spread function or reconstruction kernel of bandwidth 50Hz in frequency domain. This would result in:
        i. Blurring
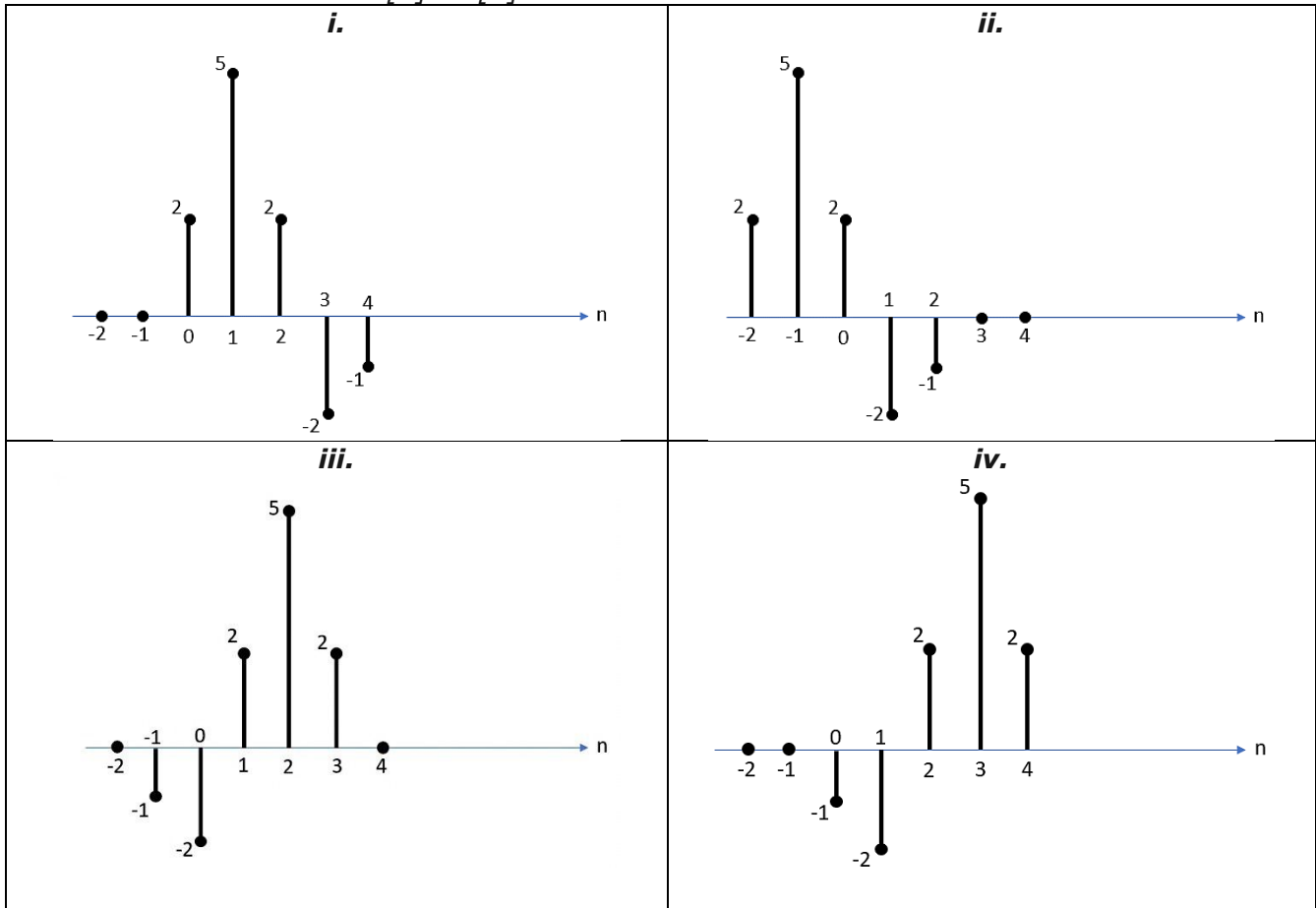   *ii.* Pixelization
        iii. Correct reconstruction

6) **[6]** Consider the 1-D signal $x_1[n]$ and an impulse response, $h[n]$ shown below:

$X_1[n]$

$h[n]$
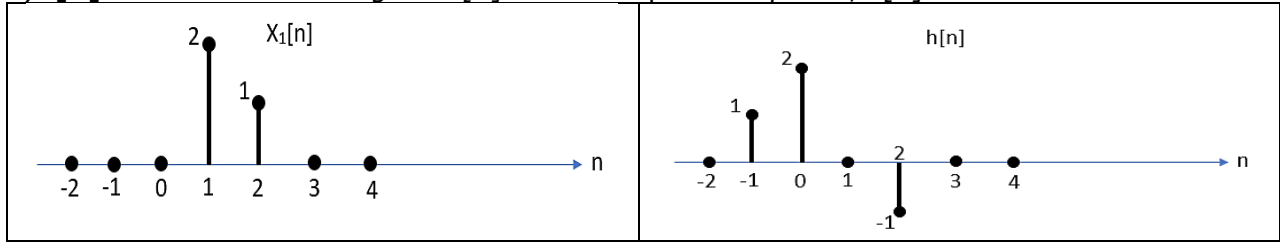
a. The value of $x_1[n] * h[n]$ is:

i.

ii.

iii.

iv.

6

7) **[2+4+4+2=12]** Consider a signal of 8 samples given by:
$$x[n] = -A + Bcos\left(\frac{\pi n}{4}\right) + Csin\left(\frac{\pi n}{4}\right) - Dcos\left(\frac{\pi n}{2}\right).$$
Where A, B, C & D are non-zero, real numbers.

    a. The DC component of this signal is:
        i.   A
        ii.   -A
        iii. -A/8
        iv. A/8

    b. The array **Xc** is given by:
        i. [-A, B, -D, 0, 0]
        ii. [0, B, D, 0, 0]
        iii. [-A, 0, B, 0, -D]
        iv. [0, 0, B, 0, -D]

    c. The array **Xs** is given by:
        i. [-A, C, 0, 0, 0]
        ii. [0, C, 0, 0, 0]
        iii. [-A, 0, C, 0, 0]
        iv. [0, 0, C, 0, -D]

    d. What is the amplitude of the sinusoidal wave that makes 4 cycles within the 8 samples?
        i. 0 (zero)
        ii. B
        iii. C
        iv. D

8) **[2+1+1=4]** Consider amplitude modulation of audio signals whose bandwidth is limited to 40Hz. The carrier frequencies range from 300Hz-660Hz (**both ends included**), the first carrier frequency being 300Hz.

    a. How many radio stations can be transmitted?
        i. 4
        ii. 5
        iii. 9
        iv. 10

    b. How will the number of stations change if the range is moved by 100Hz (i.e. 200Hz-560Hz)? It will:
        i. Remain the same
        ii. Increase
        iii. Decrease

    c. How will the number of stations change if the range is doubled (i.e. 600Hz-1320Hz)? It will:
        i. Remain the same
        ii. Double
        iii. Halve

9) **[1+1+1=3]** Correlation is considered as a convolution with the flipped kernel.

    a. It is used for:
        i. Removing noise
        ii. Pattern matching
        iii. Band pass filtering
        iv. Removing Outliers

    b. It is used in DFT for:
        i. Analysis
        ii. Synthesis

    c. Consider an image with repetitive patterns (e.g. waves, grass, sand, pebbles). Can correlation be used to detect the frequency of repetitions?
        i. Yes
        ii. No

10) **[1+1+1+2+1=6]** Consider the Laplacian filter.

    a. It provides which of the following at any pixel in an image?
        i. Gradient in x direction
        ii. Gradient in y direction
        iii. Curvature
        iv. Strength and direction of edges

    b. Consider an image on which the Laplacian filter has been applied for edge detection. An edge in the image corresponds to which of the following in the filtered image?
        i. Zero
        ii. Zero Crossings
        iii. Maxima
        iv. Minima

    c. If the image is noisy, what kind of filter should be applied to the image before applying the Laplacian filter?
        i. A low-pass filter
        ii. A high-pass filter
        iii. A gradient filter

    d. The operation in (c) will degrade which of the following properties of a good edge detector?
        i. Detection
        ii. Localization
        iii. Single Response

    e. By changing the size of this preprocessing filter, we can detect edges of:
        i. Different lengths
        ii. Different resolutions
        iii. Different contrasts

11) **[1+1+1=3]** Consider the Canny edge detector.

- *a.* The Canny edge detector depends on a:
    - *i.* Gradient based operator
    - *ii.* Curvature based operator

- *b.* The Canny edge detector removes spurious edges by:
    - *i.* Hysteresis
    - *ii.* Non-maxima Suppression
    - *iii.* Low pass filtering
    - *iv.* Finding zero crossings

- *c.* The Canny edge detector removes streaking or broken edges by:
    - *i.* Hysteresis
    - *ii.* Non-maxima Suppression
    - *iii.* Low pass filtering
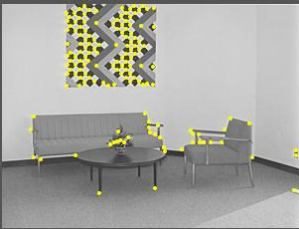   - *iv.* Finding zero crossings

12) **[4]** Consider the following 1-D signals:
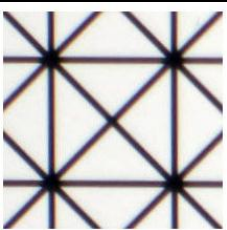
$x[n] = \delta[n-1] + 2\delta[n+1]$	$h[n] = \delta[n] + \delta[n-1] + \delta[n+1]$

- *a.* The value of *x[n] * h[n]* is:
    - *i.* $2\delta[n-2] + 2\delta[n-1] + 3\delta[n] + \delta[n+1] + \delta[n+2]$
    - *ii.* $2\delta[n+1] + \delta[n-1]$
    - *iii.* $3\delta[n+1] + \delta[n] + 2\delta[n-1]$
    - *iv.* $\delta[n-2] + \delta[n-1] + 3\delta[n] + 2\delta[n+1] + 2\delta[n+2]$

13) **[5x2=10]** Consider the pairs of images shown below. The left image in each pair is before applying a filter and the right one is after applying the filter on that image. The right column shows the names of different operations. Match each image pair to the operation that corresponds to what was performed on that pair.

	Before filtering	After filtering
i		
ii		
iii		
iv		
v		

Filter type
a) Laplacian Filter
b) Median Filter
c) Low-pass Filter
d) Corner Detector
e) Edge Detector

14) **[2+3+2=7]** We want to use the Hough transform to identify the presence of different types of conics (e.g. parabolas, hyperbolas, ellipses) in an edge image.

    a. Consider a parabola given by the equation $y = ax^2+bx+c$. The Hough space for identifying parabolas is:
-     *i.*   One-dimensional
-     *ii.*   Two-dimensional
-     *iii.*   Three-dimensional

    b. Each pixel of the parabola in image space corresponds to which of the following in Hough space?
-     *i.*   Parabola
-     *ii.*   Sphere
-     *iii.*   Plane

    c. The general equation of the entity corresponding to the parabola in the Hough space is given by:
-     *i.* $ax + by = c$
-     *ii.* $ax + by + z = c$
-     *iii.* $y^2 = 4ax$
-     *iv.* $x^2 + y^2 + z^2 = 1$