Instructions:

Open readings and notes. No other internet. No collaboration.

Write your answers on separate pages and show all work (where applicable).

Keep your answers concise and to the point (I will not read overly-lengthy answers).

No time limit, but be wise and do not let this exam take over your life. You can probably finish Parts I and II in ~3 hours at most.

Due: Mon., May 9 by 5pm (hardcopy only, except for Part III which will be submitted via email)

Part I: 10 points each (70 points total)

Answer each question with no more than a paragraph. Illustrations may help.

1. What does it mean for an image to be "digital"? There are two parts to this answer (explain both).
2. We have seen how MATLAB is a powerful tool for digital image processing. Explain how linear algebra concepts such as vectors, matrices, matrix multiplication, etc. can be applied to images.
3. In the context of geometrically transforming an image, explain the concepts of spatial resampling and pixel value (intensity) interpolation.
4. What does a gamma-correction do? What does this have to do with a power-law contrast stretch?
5. Explain in qualitative and quantitative terms what happens when you do a principal components transformation to a multispectral image. How is this useful?
6. Explain the morphological operations of erosion and dilation.
7. What is aliasing? How can it be avoided?

Part II: 4 points each (40 points total)

Answer each part with no more than a couple of sentences. Illustrations may help.

8. Fourier Analysis and Convolutions: Define and explain the following. Include equations where appropriate. Items in parenthesis are hints to things you might want to mention in your answers.

(a) convolution and the correlation functions,

(b) spatial domain vs. frequency domain,

(c) spatial frequency,

(d) Fourier theorem (what is the idea behind Fourier analysis?),

(e) the Fourier transform and the Fast Fourier Transform,

(f) frequency spectrum and the Fourier transform image (what are they?),

(g) Fourier convolution theorem (why does this make Fourier so useful?),

(h) stationary periodic noise (what is it and how can you get rid of it in the spatial doman and in the frequency domain?),

(i) why is "padding" needed when doing an FFT of an image?

(j) what is the Fourier shift theorem?

Part III: 50 points

9. MATLAB: At the link on the class website from which you downloaded the final exam there is a folder called "Mars". In there are four JPEG format images. These are images taken by the Curiosity rover using a unique capability it has on the microscopic imager (http://themeridianijournal.com/2013/01/curiosity-takes-first-nighttime-and-black-light-photos/). The microscopic imager has two sets of LEDs that allow it to take images at night! One set illuminates the scene using white, visible light. One set illuminates the scene using ultraviolet (UV) light. The images you have were taken in Jan. 2013 (on Sol 165 of the mission) and were the first nighttime images taken at the surface of Mars. Two are photos of the outcrop where Curiosity drilled its first hole on Mars. One of these photos was taken using visible illumination and the other using UV illumination. The other two images are calibration images, one of the night sky (with no illumination) and the other of a calibration target on the rover (illuminated with low-intensity UV light). Note that the night sky and the UV image of the outcrop are both 1632x1200 pixels, while the visible image of the outcrop and the UV calibration target image are both 1088x800 pixels. Write a MATLAB code to do the following with these images:

   (a) Read in the images and display them.

(b) A number of the bright spots in the images are due to thermal noise in the microscopic imager's sensor and are not "real" data. Generate an image that only contains this noise and output it to a JPEG file.

(c) Based on your estimate of the location of the noisy pixels, remove the noise from the night sky image to make an image map that just shows the stars. Output this as a JPEG file.

(d) Based on your estimate of the location of the noisy pixels, remove the noise from the UV and visible images of the outcrop. Save the noise-removed UV and visible images to JPEG files.

(e) Compare the cleaned-up UV and cleaned-up visible images of the outcrop. In the UV image the brightest pixels will be where the surface material is fluorescing under UV light and probably indicates the presence of gypsum or other fluorescent minerals. Gypsum is bright white under visible light, too, but other minerals that fluoresce may not be (as) bright under visible light. Do some image processing to make an image map that shows where the most fluorescent material is. Also do some image processing to make an image map that shows the locations of material that is dark under visible light but fluoresces under UV light. Save your resulting image maps to JPEG files.

<u>Turn in your MATLAB code ONLY (no images) via email</u>. I have the input images already. The `.m` file(s) should work with no modification needed (i.e. I should be able to execute your program from the command line and it should work). Be sure to adequately comment your code so I can follow what it does.