Queen's University
CISC 457
Test 3 - SOLUTIONS

November 16, 2015
11:30am
Duration: 50 minutes

Closed book

Initial of Family Name: ____

Student Number: ______________________
(Write this at the top of every page.)

There are 5 questions and 20 marks total.

Answer all questions.

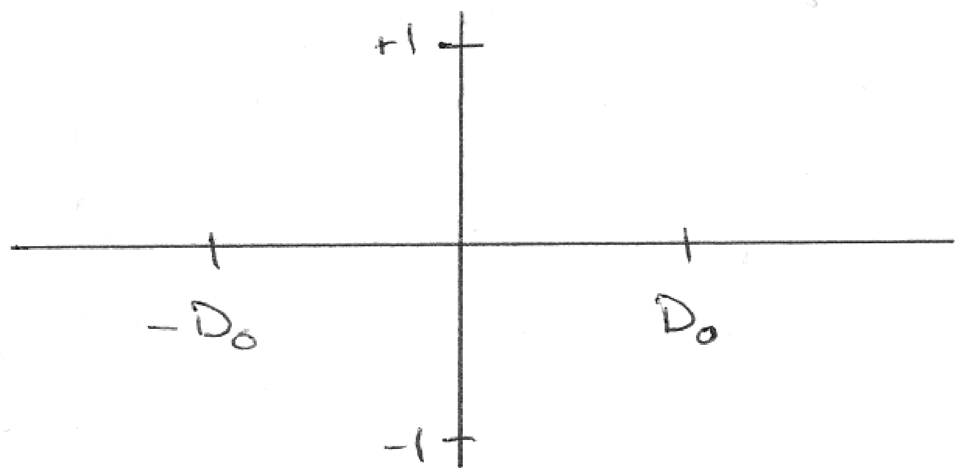
This exam paper should have 7 pages,
including this cover page.

1 – Filters	/ 4
2 – CT Imaging	/ 5
3 – Point and Edge Detection	/ 4
4 – Hough Transform	/ 3
5 – Segmentation	/ 4
Total	/ 20

The candidate is urged to submit with the answer paper a clear statement of any assumptions made if doubt exists as to the interpretations of any question that requires a written answer.

1 Filters — 4 points

Part A — 2 points Draw on the frequency domain axes below a one-dimensional high-pass Butterworth filter with $n = 1$ and with D_0 as shown on the horizontal axis.




```
[1 mark] =0 at origin, symmetric about origin, goes to 1 a bit after D0

[1 mark] crosses the point ( D0, 0.5), smooth transitions
```

Part B — 2 points Ringing occurs with the ideal low-pass filter. What is the symptom of ringing in this case? Why does ringing occur?

```
[1 mark] Get periodic bright (and dark) spots radiating around
bright pixels.

[1 mark] Occurs because the ideal low-pass *spatial* filter is the
sync function, which oscillates sinusoidally, so spreads the effect
of bright pixels.  Or any similar answer that indicates that they
understand.
```

2 CT Imaging — 5 points

Part A — 1 point The Radon Transform is

$$\int_y \int_x f(x,y)\ \delta(x\cos\theta + y\sin\theta - \rho)\ dx\ dy$$

where $f(x,y)$ is the x-ray absorption at (x,y). Explain why the Radon transform is equal to the total x-ray absorption along the line $L(\rho,\theta)$: $x\cos\theta + y\sin\theta = \rho$.

```
[1 mark] Because the double integral is non-zero only on when the
delta function is non-zero, which is when (x,y) is on the line L
(i.e.  when x cos theta + y sin theta = rho).
```

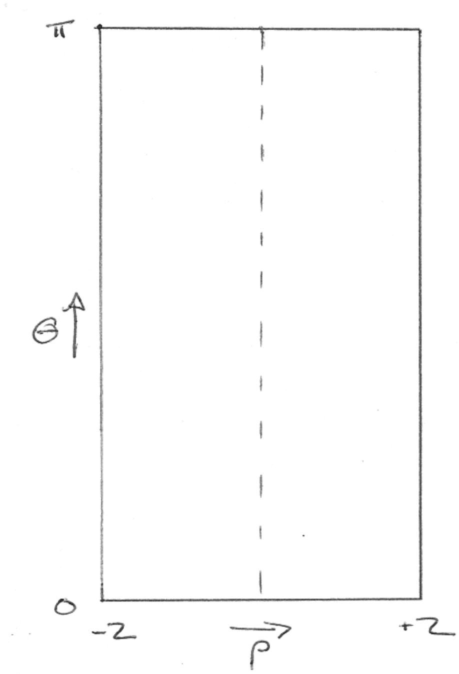
Part B — 2 points What is the ideal filter for a "filtered backprojection" as a function of frequency ω? What kind of filter is used in practice, and why?

```
[1 mark] abs(omega).  Should realy say that it's truncated, but no
marks lost if they don't say so.

[1 mark] Multiply abs(omega) by Hamming filter (or other similar
filter) to reduce ringing in the reconstruction (i.e. so that the
sharp edges of the truncated abs(omega) are smoothed).
```

... continued

Part C — 2 points Draw the sinogram in the range $[-2, 2] \times [0, \pi]$ of a small circular object at location $(1, 0)$.



[1 mark] half a period of a vertical sinusoid

[1 mark] max or min (only one should appear, as it's half a period) in rho axis should be about +/- 1.

3 Point and Edge Detection — 4 points

Part A — 1 point What does the "Difference of Gaussians" filter do?

```
[1 mark] Detects edges
```

Part B — 1 point What is the Laplacian of $f(x, y)$, written in terms of finite differences of $f(x, y)$?

```
[1 mark] =   f(x+1,y) - 2 f(x,y) + f(x-1,y)
           + f(x,y+1) - 2 f(x,y) + f(x,y-1)
```

Part C — 1 point Why do derivative filters enhance noise?

```
[1 mark] Because noise introduces very quick changes in value
(i.e. high derivatives), which are detected by the derivative
filter.
```

Part D — 1 point With Canny Edge Detection, under what conditions will a potential edge pixel (which is a pixel with a gradient magnitude between the low and high Canny thresholds) become a real edge pixel?

```
[1 mark] When connected to a real edge pixel through a chain of
adjacent potential edge pixels.
```

4 Hough Transform — 3 points

Part A — 1 point For the Hough Transform, if lines are described as $y = mx + b$ and the parameter space is (m, b), what bins in the parameter space are incremented for the pixel at (2,3)?

```
[1 mark] Those bins intersected by the line 3 = 2 m + b.
```

Part B — 1 point Why is the $y = mx + b$ line parameterization bad for detecting edges with the Hough Transform?

```
[1 mark] Because near-vertical (or vertical) lines have a very large
m (or infinite m) in the parameter space, requiring a very wide
range of bins in the m direction.
```

Part C — 1 point In detection of circles of radius r with the Hough Transform, what bins are incremented for the pixel at (x, y)?

```
[1 mark] All bins at (u,v) such that |(u,v) - (x,y)| = r.
```

... continued

5 Segmentation — 4 points

Part A — 1 point In terms of the image histogram, explain why noise makes segmentation difficult.

```
[1 mark] noise spreads out pixels values, sometimes causing values
from foreground and background pixels to overlap.
```

Part B — 2 points Explain why Otsu's method finds a globally optimal threshold. What measure does Otsu's method seek to minimize?

```
[1 mark] Yes.  It tests all possible values of the threshold.

[1 mark] It minimizes the within-class sum of squares (or maximizes
the square of the differences of the class means).
```

Part C — 1 point Using a summed area table in which SAT[x,y] $= \sum_0^x \sum_0^y f(x,y)$, how would you find $\sum_3^{10} f(x,5)$?

```
[1 mark] = SAT[10,5] - SAT[2,5] - SAT[10,4] + SAT[2,4]

It's okay if their indices are off by one in any of the last three
terms.  They need to have the idea that it's SAT[10,5] minus two
things and plus one thing.
```