A. Theme: Image processing fundamentals and filtering.

a. How would you set up a camera to capture images that are silhouettes of shapes without using reflected light? [20 points]

Transmitted light through a diffusing screen is an alternative to reflected light. The obstruction of the transmitted light by objects placed on a light table creates a strong contrast between object and background.

b. A square image is to reliably represent a shape with a minimum width of 10 cms in the real world. The image will cover 10m*10m in the plane of the shape. What is the lowest resolution that the square image can have when the number of pixels on each side must be a power of two? [20 points]

The criterion to be used is that the minimum width of the region shall be root(2) times the side of the pixel. All calculations can be made by projecting the measurements into the real world.

A minimum width of 10cms. implies a pixel side of 10/root(2) cms.

Thus the number of pixels on the side of the image is 10*100/(10/root(2))=100*root(2)
=141.4
The number of pixels rounded up to the appropriate power of 2 is 256.

c. What is meant by the term pseudo-colour? [20 points]

Pseudo-colour is the term given to the allocation of colour based on grey level so that a monochrome image is represented by a colour image. The purpose is to use the human's
greater ability to separate colour tones than separation of grey levels. With training and under the right conditions, there is a greater perception of detail.

d. Give a mathematical statement of a theorem that relates filtering in the space domain to filtering in the frequency domain. [20 points]

Let f(x,y) be an image, F(u,v) be its Fopurier transform.
Let g(x,y) be a convolution kernel and G(u,v) be its Fourier transform.

The convolution theorem states that

$$T(f*g(x,y)) = F(u,v)\ G(u,v)$$

where T represents the calculation of the Fourier transform and f*g is the convolution of f and g.

e. Assuming that the Fourier transform of f(x,y) is F(u,v), write down the expression for the power spectrum. Comment on the dynamic range of the values in the Fourier transform F(u,v) when the values of f(x,y) lie between 0 and 255. [20 points]

$$P(u,v) = sqr(\ |F(u,v)|\ ) = sqr(Re(F(u,v))) + sqr(Im(F(u,v)))$$

The pixel values of a real image in the range 0..255 lead to very large values in the components of the Fourier transform, both real and imaginary. Fidelity in the calculations involving Fourier transforms requires high precision in combination of large numbers to create accurate small numbers.

B. Theme: Segmentation, description and recognition.

a. What is meant by 'edge based segmentation'? [20 points]

Edge based segmentation seeks to identify transitions in a property of the pixels, usually brightness, such that the various closed paths in the set of edges partition the image into fragments that can be associated with understandable components.

The different methods of edge based segmentation lead to different edge paths. For example, DoG leads to edges that can only be simple closed paths without branches; sobel+threshold leads to possibilities of T junctions.

Construction of a completely accurate set of edges is highly unlikely. Correction of edges by model direction or heuristics is usually necessary.

b. Consider the expression

$$y = A \sin(ws*t) + B \sin(wn*t).$$

Assume that ws is an angular frequency that is associated with a signal and that wn is an angular frequency associated with noise. Assume wn >> ws. Use the expression to reason that edge enhancement involving differentiation tends to magnify noise. [20 points]

Edge enhancement based on differencing can be examined by differentiating the expression

$$dy/dt = ws\ A \cos(ws*t) + wn\ B \cos(wn*t)$$

$$d2y/dt2 = -ws**2\ A \sin(ws*t) - wn**2\ B \sin(wn*t)$$

Two methods of identifying edges are (1) locate the maximum of |dy/dt| and (2) locate the zero crossings of d2y/dt2.

Both these methods are affected by the noise frequency magnifying the noise term. Given that wn >> ws it can be seen that the noise term tends to dominate. This is especially true for d2y/dt2.

c. How does the Laplacian of Gaussian edge detector resist the effects of noise in locating an edge as the zero crossing of the second derivative? [20 points]

The Laplachian of Gaussian edge detector applies the Laplachian operator to give access to the zero crossings of the second derivative, but the image data is smoothed by convolving the image data with a Gasussian of chosen width.

d. What is the Euler number of a shape? [20 points]

The Euler number of a shape is E=C-H

Where C is the number of connected components and H is the number of holes.

e. What technique can be used to match shape numbers? [20 points]

A shape number is the minimum numerical value obtained by rolling around the string, representing the differences in heading for a chain code representation of the shape.

The shape number is an attempt at normalisation of the starting point for the string. The taking of differences is an attempt to make the shape orientation independant. The size of the shape is not normalised. If the shapes are of the same size then a spelling corrector can match the strings. If the shapes are of different sizes, then an attempt to rescale is required before spelling correction.