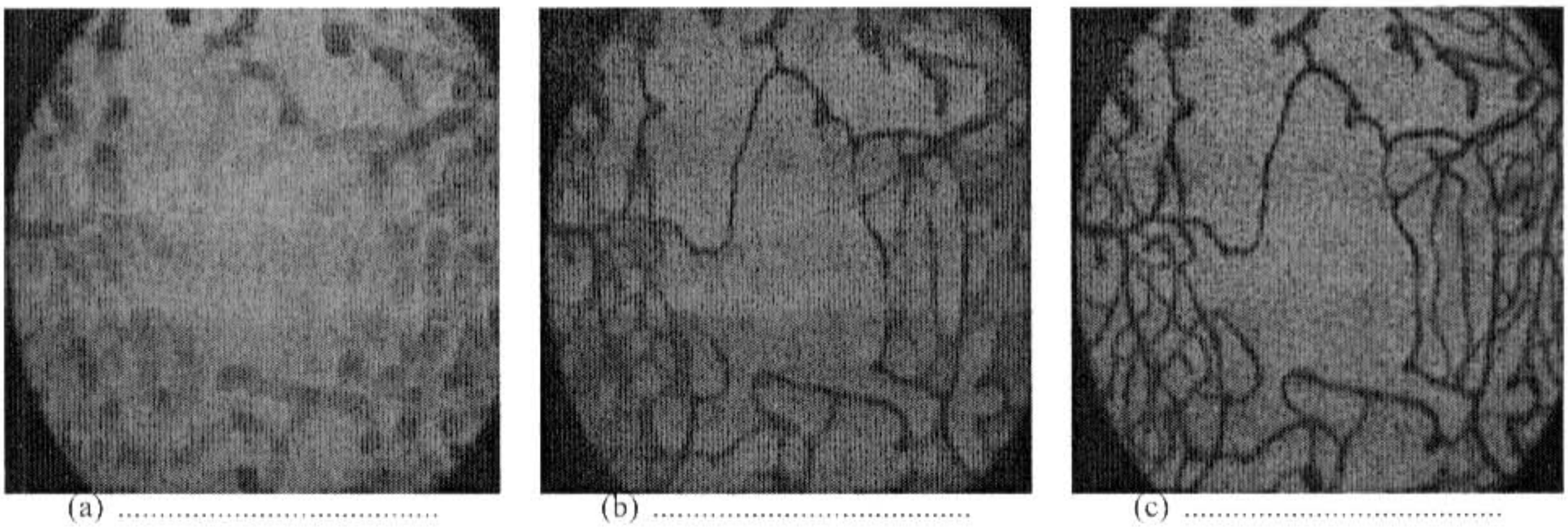
21 November 2006	**Image Understanding Exam**	10.00 – 11.30
Matr.Nummer: Kennzahl:	Nachname (Last Name): Vorname (First Name):	

The maximum number of points that can be obtained is 30. Please use the space provided for answering questions. The answers should be short but comprehensive. You may answer in English or German.

Bei der vorliegenden Prüfung können Sie eine maximale Anzahl von 30 Punkten erreichen. Bitte verwenden Sie den für die Beantwortung der Frage vorgesehen Platz und beantworten Sie die folgenden Fragen kurz aber aussagekräftig. Sie können die Fragen auf Englisch oder Deutsch beantworten.

1 Mathematical Morphology

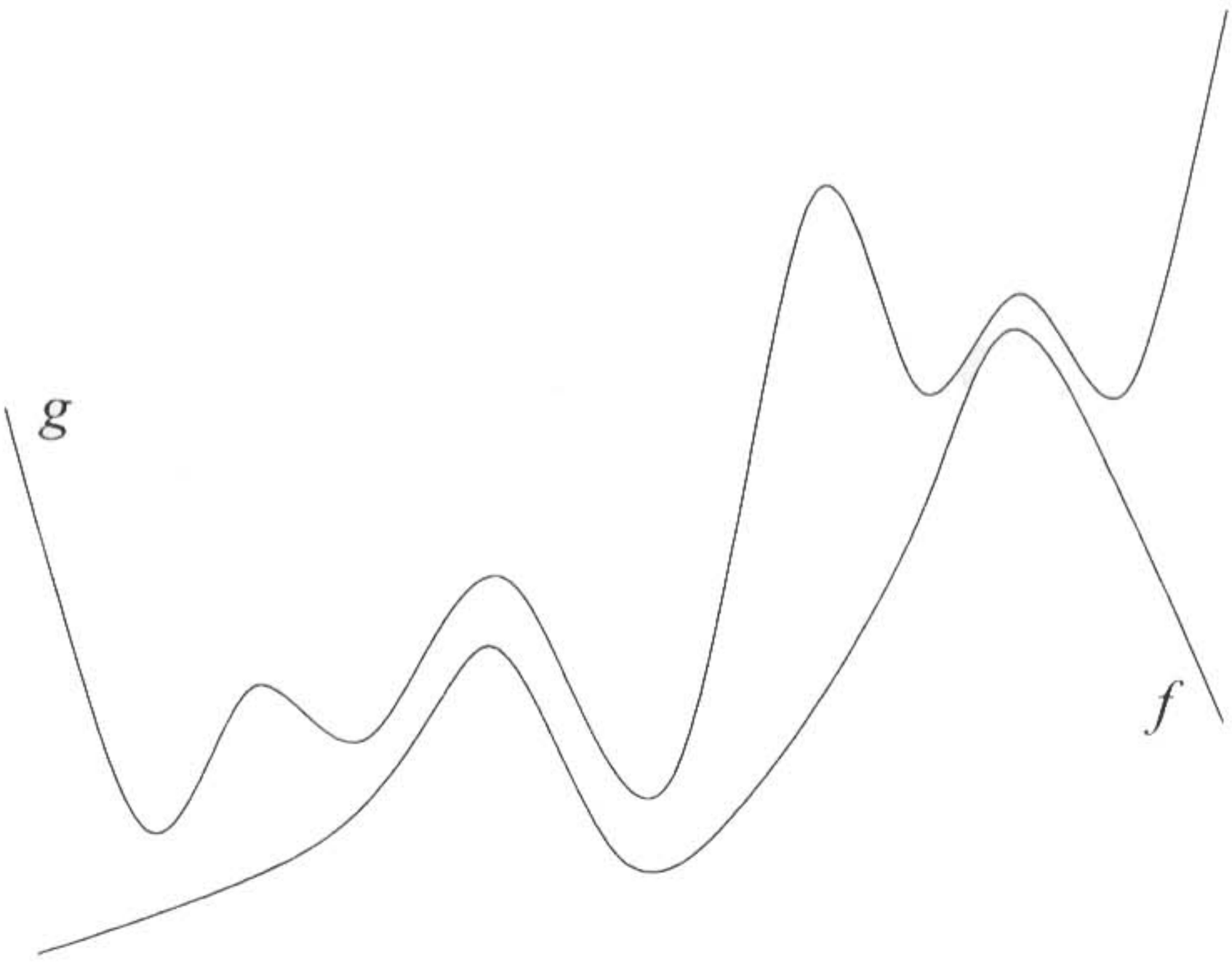
- Below are three greylevel images. One is the original image (size 256×256 pixels), one is the opening of the original image and the other is the closing of the original image. Both of these are done with a square structuring element of size 3. Write in the labels *original*, *opening* and *closing* below the images. (1 point)



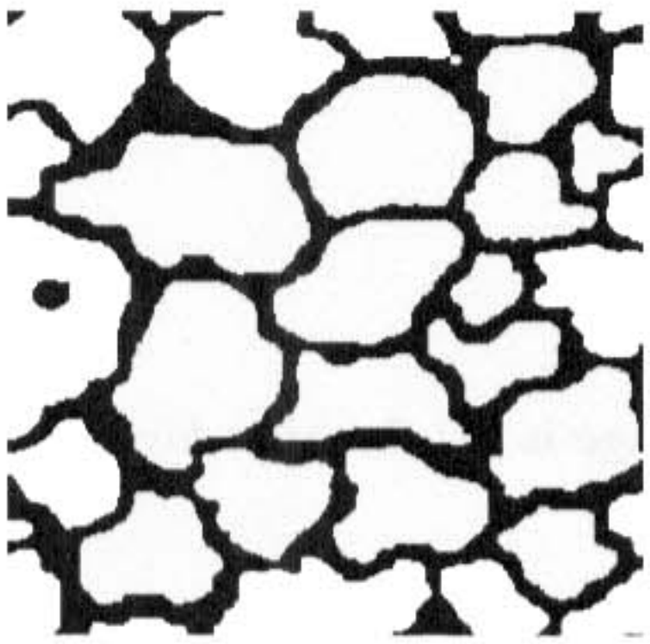
(a) ..... (b) ..... (c) .....

- Write the definitions of both the *white top-hat* and *black top-hat*. Why is it guaranteed that the pixel values in the results of these operators are always greater than or equal to zero? (1 point)

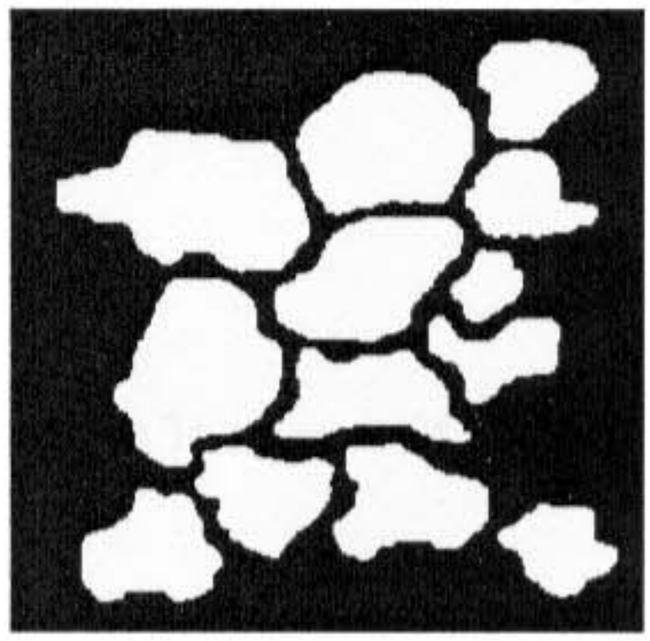
- Explain the morphological *reconstruction by dilation* algorithm. What are the roles of the *marker* and *mask* images? For the functions of one dimension below, show the result of a morphological reconstruction by dilation of marker f inside mask g, i.e. $R_g(f)$. (2 points)



- Describe how you would produce binary image (e) below from binary image (d) below by making use of mathematical morphology. In other words, how would you remove the connected components touching the border of a binary image? (2 points)



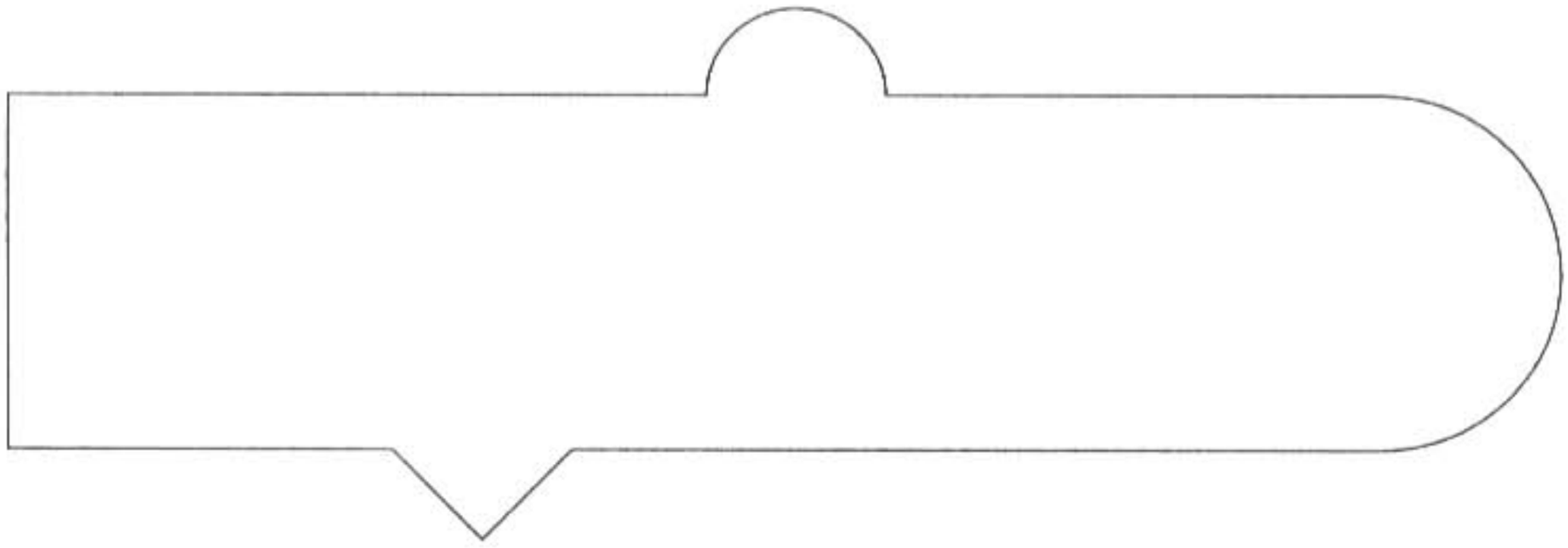
(d)



(e)

2 Skeletons

- Draw the Euclidean skeleton of the following shape (1 point):



- Which digital skeletonisation algorithm is guaranteed to produce a skeleton which is homotopic to the original shape? (Give only its name) (1 point)

3 Greyscale image processing

- Write down any 3×3 convolution kernel which can be used to detect vertical edges in an image. (1 point)

- Explain why the histogram of a discrete image is not flat after *histogram equalisation*? (1 point)

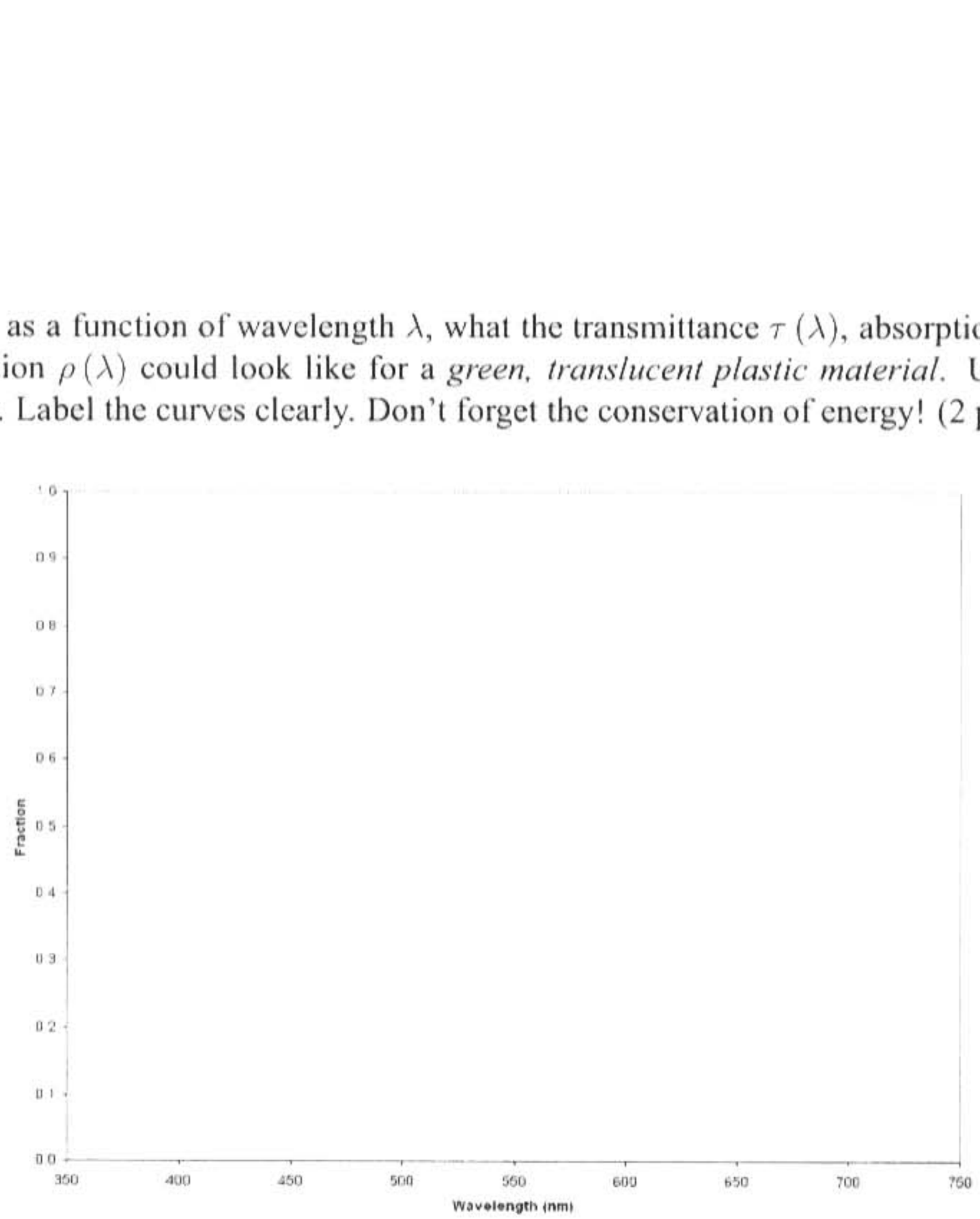
4 Colour

- What are *false colours* in the result of a colour image processing operation? Under what conditions could false colours appear? (1 point)

- An electromagnetic signal in the visible light range with a spectral power distribution $\Phi(\lambda)$ arrives at the eye. Describe the information that is extracted from the signal by the cone receptors in the eye. (1 point)

- What is *computational colour constancy*? Describe how and why computational colour constancy could play an important role in algorithms for the automatic recognition of objects in colour images. (2 points)

- Draw, as a function of wavelength λ, what the transmittance $\tau(\lambda)$, absorption $\alpha(\lambda)$ and reflection $\rho(\lambda)$ could look like for a *green, translucent plastic material*. Use the axes below. Label the curves clearly. Don't forget the conservation of energy! (2 points)



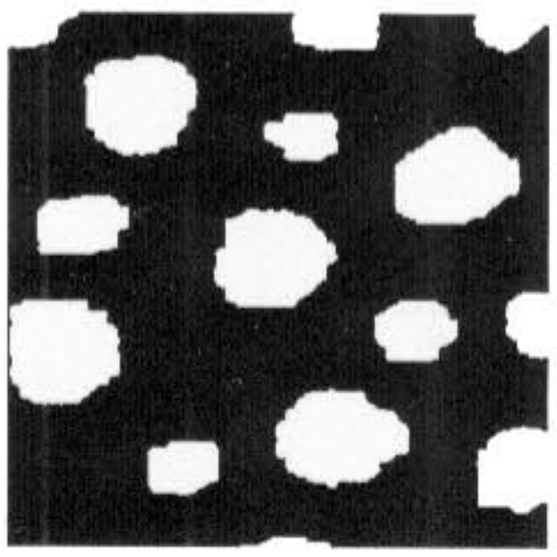
- Give the name of any colour space other then RGB. (1 point)

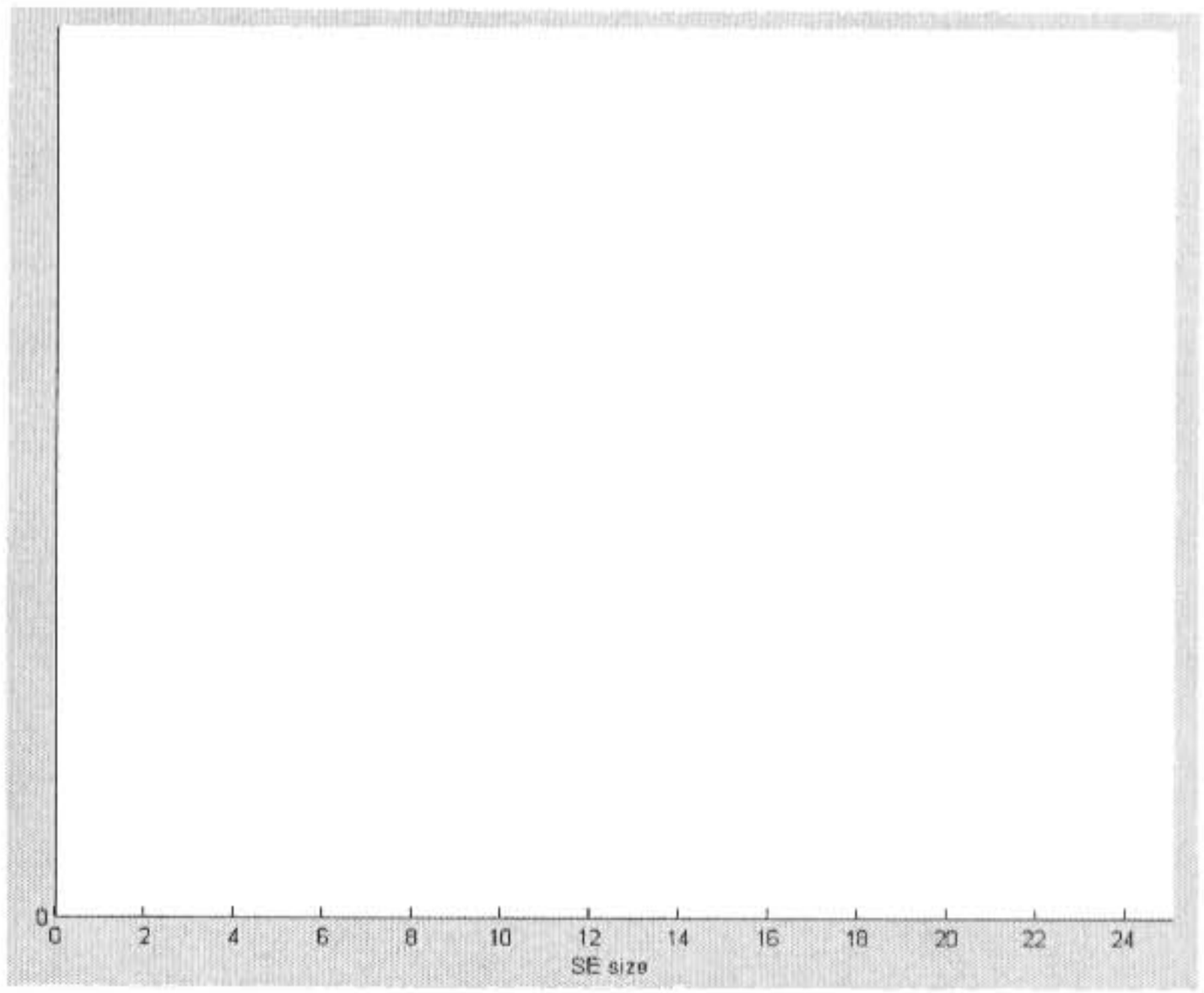
5 Texture

- Calculate the co-occurrence matrix $P_{0°,1}$ for the following 4×4 image containing 4 greylevels ($0°$ indicates the horizontal direction.) (2 points)

2	0	0	2
2	0	3	1
1	3	3	2
1	2	3	3

- Sketch an estimate on the axes provided of what the *pattern spectrum* of a granulometry by opening with a disc-shaped structuring element of the following binary image looks like. The radius of the structuring element is given on the x-axis. To help you out, the image is of size 256×256 pixels and the black line to the right of the image has length 30 pixels. (1 point)





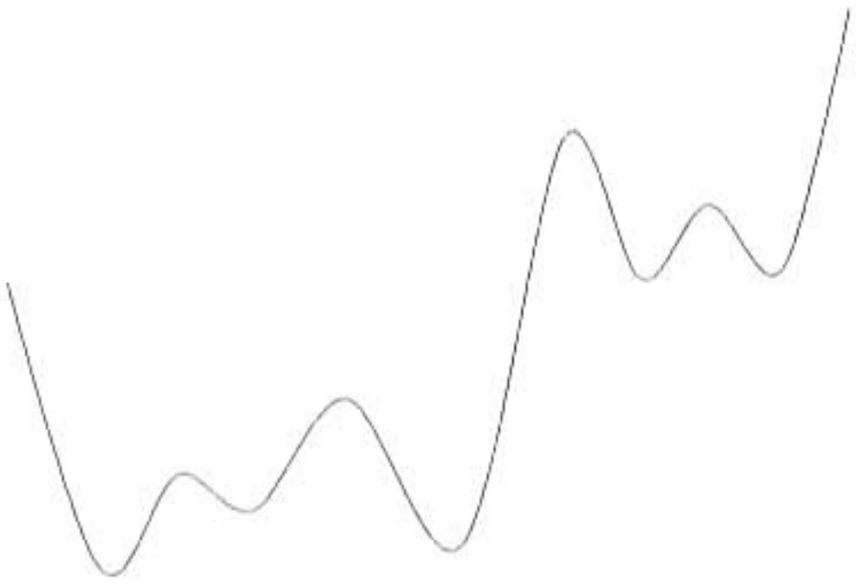
- Give the name of any texture analysis algorithm, except the co-occurrence matrix. (1 point)

6 Hough Transformation

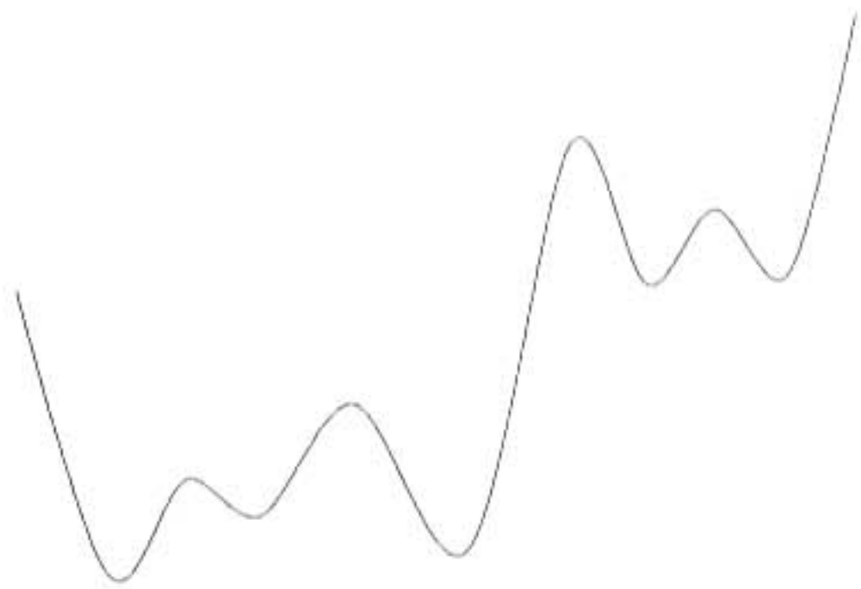
- Using a polar representation (i.e. s and θ), explain the concept of the Hough transformation for line detection. Draw several lines in the image space (i.e., the x, y space) and sketch the corresponding Hough transformations in the parameter space. Label all important points, lines and axes. (3 points)

7 Segmentation

- Describe the criterion used to discard watershed lines in the construction of a hierarchy based on the *Waterfall*. In the functions of one variable below, indicate the extent of the regions resulting from a Watershed segmentation of this function (on the left) and a segmentation at the first level of the Waterfall hierarchy (on the right). (2 points)



(f) Watershed segmentation



(g) Waterfall level 1 segmentation

- The Watershed is well known for producing an over-segmentation if directly applied to a greyscale image. Briefly describe a method to reduce the number of regions produced by a Watershed segmentation (except for the Waterfall). (1 point)

8 CBIR and Object Recognition

- What is the *Semantic Gap* and why does it exist? (1 point)

- What are *narrow image domains* and *broad image domains*? Give an example of each. (2 points)