1 True or False, 5p

a) True

b) True

c) False

d) False

e) False

f) True

g) False

h) True

i) False

j) False

2 Local neighborhood operations, 5p

a) Assuming a standard representation of the gray levels: $0, \ldots (K-1)$, we need $\lceil(\log_2(K))\rceil = \lceil\log_2(9+1)\rceil = 4$ bits per pixel.

b) median filtering:

0	0	0	0	0	0
0	6	6	5	3	0
0	6	6	6	4	0
0	5	6	5	0	0
0	0	0	0	0	0
0	0	0	0	0	0

mean filtering:

1	1	2	2	1	1
2	4	5	4	3	1
3	5	7	6	4	1
2	4	5	4	3	1
2	2	2	2	1	0
1	1	0	0	0	0

Then you should add some comments to compare the two results, e.g. that the mean filtering smears out and blur the image while the median filter removes outliers (which could infact be important aspects of the image). General comments on the difference between the two filters should be ok, even though all effects are not visible in this toy example.

c) image patch:

i_{11}	i_{12}	i_{13}
i_{21}	i_{22}	i_{23}
i_{31}	i_{32}	i_{33}

filter kernel:

p_{11}	p_{12}	p_{13}
p_{21}	p_{22}	p_{23}
p_{31}	p_{32}	p_{33}

Then order your image patch and filter kernel in any systematic way into a vector, $\mathbf{i} = [i_{11}, \ldots i_{33}]^{\mathrm{T}}$, $\mathbf{p} = [p_{11}, \ldots p_{33}]^{\mathrm{T}}$. Then convolution in this neighborhood is described by $\mathbf{p}^{\mathrm{T}}\mathbf{i}$.

3 Object description 5p

a) Find the set of all black pixels that are reachable from the white background by a up, down, left or right step.

b) Indicate what directions and what codes you are using. Then you make a code sequence, e.g. [2, 2, 2, 2, 5, 4, 5, 6, 7, 6, 0, 1].

c) First compute difference encoding, [0 0 0 6 6 2 6 0 7 0 5 0], then compute minimum magnitude integer encoding (MMI) of this [0 0 0 0 6 6 2 6 0 7 0 5].

d) E.g. take all $k \times 90$ degree steps times 1 and all $45 + k \times 90$ degree steps times $\sqrt{2}$ and sum up, $8 + 4\sqrt{2}$.

4 Morphology and Distances 5p

a)

0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0
0	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	0	0

b)

1	1	0	0	0	1	1	0	0
1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	0
1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	0

c) E.g. opening followed by closing.

d) We replace the object with 0s (distance is 0).

0	3	0	0	0	0	0	0	0
0	3	0	3	0	0	3	3	0
0	3	3	3	0	0	0	0	0
0	3	6	3	0	0	0	3	0
0	3	6	3	0	0	0	0	0

5 Coding and compression, 5p

a) left: (8,1), (7, 1), (6, 1), (5, 3), (4, 2), (3, 1), (2, 1), (1, 1), (0, 1), (2, 2), (1, 1), (0,1) and right: (8, 1), (-1, 3), (0,2), (-1, 1), (0,1), (-1, 4), (2, 1), (0, 1), (-1, 2).

b) Compression would be more efficient for the difference encoded image, because that histogram has a few peaks. We can use entropy to measure the lower bound of the number of bits per pixel needed.

c) The shortest code Huffman can represent is 1 bit so there is no gain compared to plain binary coding even if the statistics of 0s and 1s is extremely skew. One have to encode the binary image into blocks, e.g. 4 pixel blocks, that then translates to numbers from 0 to 15. Then, in this new rather trivial encoding, Huffman encoding can again be efficient.

6 Segmentation, 5p

a) Watershed segmentation is explained in the lecture notes. The image is divided into 3 regions separated by pixel idices 11 and 18.

b) In seeded watersheds one can avoid that all local minimas generate a new segment.

c) You can merge them based on some critera of similarity.

7 Clustering 5p

a) K-means clustering is explained in the lecture slides.

b) This can result in different clusterings, just follow the algorithm and many answers can be correct. Please explain every step so that it is easy to follow how it works and how you are thinking.

c) E.g. an application of OCR, where you discover different characters and then afterwards add knowledge about what character each cluster is. Many answers would be correct, be creative...

8 The Wiener Filter 5p

a) That the observed signal can be described as $y = x + e$, where e is the noise component. If you add noise like this instead, $y = x(1 + e)$ it is an example of non-additive noise.

b) There will be wrap around effects, caused by the cyclic nature of the DFT. Use padding.

c) Estimate the point spread function based on the speed and direction, ideally by observing how a small dot is transformed or by prior knowledge about the speed and direction. Estimate the noise spectrum and the image spectrum. Use the Wiener filter to reconstruct the non-distorted image.

d) The background will be destroyed (not blurred) in the restored image. There will be edge effects as well, on border of the moving parts and the still background. The Wiener model is actually only valid on the moving plate and not for the rest of the image.