1)1-i, 2-h, 3-f, 4-c, 5-a

2a) Sorted elements =
[0 0 0 0 0 0 0 0 0 32 38 39 39 41
45 45 47 48 49 50 52 55 58 59 65 75 99] → Median = 41

2b)

$$\log_2(x) = \log_e(x)/\log_e(2)$$

$$Y = e^{\log_2(x)} = e^{\log_e(x)/\log_e(2)} = x^{1/\log_e(2)} \approx x^{1.44}$$

$$x^{1.44} < x \quad for\ x \in (0,1)$$ → image will be **darker**

2c) $H(u, v) = 2 + 2j \cdot sin(u - v)$

2d) For Sobel filter: gradient magnitude= $2.8 \approx 3$, gradient orientation = $135°$

```
%-----------------------------
hSobel = fspecial('sobel')              % horizontal Sobel filter
vSobel = hSobel'                        % vertical   Sobel filter
gradientY = imfilter(I,vSobel);
gradientX = imfilter(I,hSobel);
gradientMagnitude   = sqrt(gradientY.^2 + gradientX.^2);
gradientDirection   = atan2(gradientY, gradientX);
answer = [ gradientMagnitude(3,3) gradientDirection(3,3)*180/pi]
```

3a) GLCM size: 2 x 2

3b) GCLM

	0	1
0	P(0,0)	P(0,1)
1	P(1,0)=P(0,1)	P(1,1)

The only possibility that entropy=0 is when P(0,0)=1 xor P(1,1)=1.

GLCM solution #1:

	0	1
0	1	0
1	0	0

Image: all pixels = 0

GLCM solution #2:

	0	1
0	0	0
1	0	1

Image: all pixels = 1

3c)

GLCM

	3	4
3	0	10
4	10	0

GLCM normalized

	3	4
3	0	1/2
4	1/2	0

Contrast = $(-1)^2 \cdot \frac{1}{2} + (1)^2 \cdot \frac{1}{2} = 1$

3d) *Unsupervised* classification: do not use/require training data.
Supervised classification: use information from training data.

4a) When rotating an object by some degrees, the radius (distance to the origo) is preserved: $r^2 = x^2 + y^2 = (x')^2 + (y')^2 = (r')^2$. Here, x',y' are coordinates of the rotated object → $\sum_{x,y}(x^2 + y^2)f(x,y) = \sum_{x,y} r^2 f(x,y) = \sum_{x',y'}(r')^2 f(x',y')$

4b) M = NCOLS = number of layers
n = NROWS = number of nodes in a layer

Ratio between number of paths to evaluate in DP and Exhaustive computation:
$R = n^M/(n^2(M-1)+n)$ → DP ca R times faster.

4c) *sensitivity* = probability of classifying object's pixels as object
specificity = probability of classifying backgroud's pixels as background

4d) The mean shift filtering is a part of the mean shift segmentation algorithm.

4e) The constant λ controls the smoothness of the resulting velocity field. A large lambda corrensponds to small changes in the velocity field for the neighboring pixels.

4f) A live-wire is a piecewise-boundary detection technique, and less automatic than snake. A snake requires an initialization only, the live-wire requires the user intervention for every piece of the boundary.

4g) 1p.

5a) See the textbook, Hough transform for circular objects.

5b) A vote matrix with only one vote for every angle/parameter value.

6a) The optimal threshold corresponds to the intersection of the histograms/pdfs:

$$\begin{cases} y = -x + 120 \\ y = -\frac{3}{2}x - 150 \end{cases} \Longrightarrow$$

$x = T_{opt}$ = 108 (optimal threshold value) $y_{opt} = 12$

A1 = Area Triangle #1 = 60*60, A2= Area Triangle #2 = 0.5* 50*30,
E = Area of Error triangles = 10*12
Error rate = E / (A1+ A2) = (10*12/(60*60+0.5*50*30)) = **0.0276** (2.76%)

6b) Cumulative costs:

	1	2	3
1	20	20	19
2	12	11	14
3	6	12	14
4	6	10	15
5	4	8	15
6	4	10	18

Three minimal paths (with cost =14):
4-10-14; path = (1,5)→(2,4)→(3,3)
6-12-14: path = (1,4)→(2,3)→(3,2)
6-11-14: path = (1,3)→(2,2)→(3,2)