Problem 1: Morphology

Apply the opening operation on the image below, using the following structuring element with the origin as the center pixel:

```
1 0 0
1 1 0
1 0 0
```

In the image below, black pixels denote object pixels (value = 1) and white pixels denote background pixels (value = 0).

 Scratch space:  Final result:
Problem 2: Skeleton

In the images below, objects are shown in grey. Mark each pixel with a cross that belongs to the object skeleton, as we defined it in class:

Problem 3: Industry Successes

In class, we talked about companies with computer vision successes, such as, ABB, Adobe, CameraMouse, Cognex, IBM, Microsoft, and Mobileye.

A develops optical character recognition software for understanding document images.
B develops computer vision software for driver assist systems.
C makes vision products for assessing manufacturing processes.
D sells video-based game controllers.

What are the companies?

A is **Adobe**
B is **Mobileye**
C is **IBM**
D is **Microsoft**

Problem 4: Distance between Curves

Draw the two distances most relevant for computing the Hausdorff distance between the two curves.
Problem 5: True or False?

Circle your answer.

1. The Recursive Labeling Algorithm finds the connected components in a binary image in $O(n)$ time where $n$ is the number of pixels in the image.
   True or False?

2. The Sequential Labeling Algorithm finds the connected components in a binary image in $O(n^2)$ time where $n$ is the number of pixels in the image.
   True or False?

3. The Sobel edge detection mask is used in the double-thresholding step of the Canny algorithm.
   True or False?

4. It is better to have high values in the off-diagonal entries of a confusion matrix than low values.
   True or False?

5. The closing morphology operator can be used to fill holes and concavities that are smaller than the structuring element.
   True or False?

6. The second central moments along both $x$ and $y$ direction for an object with a non-zero area in an image are always non-zero and non-negative.
   True or False?

7. The second central moments $a$, $b$, and $c$ of an object in a binary image can be used to compute the object orientation $\theta$ with the equation $\tan 2\theta = \frac{b}{a-c}$. If $b = 0$ and $a = c$, the object is too symmetric to allow us to define the object orientation by the axis of least inertia.
   True or False?

8. Image pyramids are useful for detecting objects at different scales.
   True or False?

9. The pixel values in the axial slices of a computed tomography scan represent the density of the imaged material.
   True or False?
Problem 6: Binary Image Analysis

1. Consider the muscle cell in this phase-contrast microscopy image. Note that the white halo around the cell is an imaging artifact and does not belong to the cell. (a) Draw the axis of least inertia of this cell. (b) What is the orientation of the cell in the image? Write down the approximate angle in degrees. (c) Where approximately in the image is the centroid of the object? Mark it clearly with a cross.

![Image of muscle cell with annotations]

(a). as shown in the figure.
(b). It's approximately 30°.
(c). as shown as the point of the cross.

2. Consider the measures of object shape that we discussed in class. Select the measure for which it is straightforward to determine an approximate value here. What is that approximate value?

3. Sketch an approximate histogram of the gray values of this cell image.

2. Circularity is a good measure for the shape.
   Since the shape is closer to a line than a circle, the value will be close to 0, maybe 0.1 or 0.15.

4. Label the histogram above with the thresholds that were used to create the following binary images of the cells.

![Histogram with thresholds]

4. The thresholds are for the left and right image respectively.

5. Develop an algorithm that could segment the cell from the background. Give a very brief description (at most 3 sentences).

     Use a Gaussian Blur to smooth the image.
     Use a proper kernel to do closing on the image.
     Use a proper threshold to convert into a binary image.
     Use a proper kernel to do closing on the image so that the cell object is connected.
Problem 7: Template Matching

(a) In template matching, if the function that measures the match between template and scene subimage is the sum squared difference, the result is invariant to linear variations in brightness.

True or False?

(b) In template matching, if the function that measures the match between template and scene subimage is the normalized correlation coefficient (NCC), the value of a perfect match is one.

True or False?

(c) Propose an algorithm that uses template matching to track a moving object in a video. Use the NCC to measure a match. Fill in the missing pseudo-code text.

INPUT: Video
1. Initialization: Time $t = 1$; Allocate space $A$ to store locations of object in video;
2. FOR frame $I_t$ of the video:
   DO: ...
   
   frame_dif = $|I_t - I_{t-1}|$
   FOR pixels in frame_dif:
   Find the first positive pixel idex
   Set the template for
   FOR sizes from $1$ to $10$
   crop $I_t$ at idex with size $s$
   match with template and calculate NCC

3. IF not at end of video: $t = t+1$; GO TO 2.

OUTPUT: Location array, where $A[i]$ is location of object in frame $i$