1. What are the timing parameters for actuated signal control? Draw a figure to illustrate each parameter [5 points].
There are five timing parameters: yellow change interval, red interval (including all read clearance interval), minimum green (also known as initial interval), the passage time (also called the vehicle interval, extension interval, or unit extension), and the maximum interval. The relationships among these parameters are shown in Figure 1-1.

![Figure 1-1. Relationship among timing parameters for actuated signal control](image)

2. If you are asked to choose single loop detectors for freeway main-lane surveillance, which type of loop (long, short, sequential short) will you choose? Which mode (presence vs. pulse) would you set? Why? [5 points]

I will choose short loops and set them to the presence mode. Both occupancy and volume measurements are essential for freeway main-lane surveillance.

The reason for not choosing long loops is because long loops are more subject to failure and adjacent lane splashover. Additionally, when traffic is congested, two or more vehicles may be on top of a long loop at the same time and, hence, result in wrong measurements. Sequential short loops are generally used to simulate long loops and have similar problems to those of long loops.

Since a loop in pulse mode only counts vehicles and does not output occupancy, it is not appropriate to set a loop in pulse mode for freeway main-lane surveillance.

Therefore, short loops, operating in presence mode, are able to fulfill the freeway main-lane surveillance job.
3. Are there any differences for detecting small vehicles, high-bed vehicles, and regular cars? Show an example loop configuration that is suitable for detecting each of the above vehicle types. [8 points]

There are differences in loops for detecting different types of vehicles. For example, California Type A loops are used for detecting passenger cars, while chevron configurations are used for detecting small vehicles. High-bed trucks have been found best detected with diamond loops with seven turns of wire. California Type D detectors are effective for bicycle detections. Please see Figure 3-1 for the configurations.

(a) California Type A
(b) Chevron loop configuration
(c) Diamond loop configuration
(d) California Type D loop configuration

(Type A loop rotate 45° and add four more turns)

Figure 3-1 Example configurations of loop detectors

4. You are asked to design a semi-actuated signal control for an intersection shown in Figure 4-1. Both northbound and southbound approaches have four lanes (two for each direction). Westbound and eastbound approaches have two lanes (one for each direction) each.). The speed limit for northbound and southbound approaches is 40 mph and that for westbound and eastbound is 25 mph. Table 4-1 shows the average hourly traffic volumes by directions. If you have the money for just two loop detectors (long, sequential short, or short) for this project, what is your design plan? Please specify and justify: (1) which type of loop detectors you will
choose; (2) where to put them; (3) detector mode; and (4) the minimum green and passage time interval lengths you want to use. Make assumptions if necessary. [12 points]

![Figure 4-1 Layout of the intersection.](image)

Table 4-1: Average Hourly Traffic Volumes by Directions

<table>
<thead>
<tr>
<th>from</th>
<th>to</th>
<th>Northbound</th>
<th>Southbound</th>
<th>Westbound</th>
<th>Eastbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northbound</td>
<td>-</td>
<td>800</td>
<td>160</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Southbound</td>
<td>850</td>
<td>-</td>
<td>100</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Westbound</td>
<td>30</td>
<td>30</td>
<td>-</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Eastbound</td>
<td>5</td>
<td>5</td>
<td>80</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

(1) As can be seen in Table 4-1, in westbound and eastbound directions, average hourly traffic volumes are very low comparing to those of in northbound and southbound directions. So northbound and southbound street is the major street and westbound and eastbound street is the minor street for this intersection. Since loop occupancy form of detection is generally used on low speed approaches and this type of operation is most effective when speeds are 25 mph or less, I will design the intersection to be semi-actuated with two 50-foot long loop detectors (or equivalent sequential short loops), each for one direction, on the minor street (east-west).

(2) The locations of the two loop detectors are illustrated in Figure 4-2. Each of the two loop detectors is located immediately upstream of the stop line for each direction.
(3) The loops will be operating in presence mode because presence mode allows the loop to stay on as long as a vehicle is occupying it. This way, the controller continuously extends the green as long as the loop is occupied.

(4) The minimum green and the passage time intervals are generally set to zero or near zero. The long loop operates in presence mode and the controller continuously extends the green as long as the loop is occupied, therefore it is not necessary to preset a minimum green time interval. The passage time interval is timed to permit a vehicle to travel from the detector to the intersection. Since the long loop is located immediately upstream of the stop line, it almost takes no time for the vehicle to travel from the detector to the intersection. So, the minimum green and the passage time intervals are generally set close to zero. However, if pedestrian triggered green and vehicle triggered green for east-west direction are not treated differently, minimum pedestrian crossing time should be set as the minimum green time.

5. What is a dilemma zone? If an intersection approach has a speed limit of 40 mph, yellow time of 3 seconds and red clearance time of 1 seconds, is there a dilemma zone? If yes, how long? Assume that the effective width of the intersection is 55 ft and all vehicles have the same vehicle length of 18 feet. Please use deceleration rate of 10 ft/sec\(^2\) and Gazi’s equation (Equation 68 in Reader 7) for acceleration rate calculation. [10 points]

Let Xc denote the maximum distance from the stop line from which a vehicle is able to clear the intersection, and Xs denote the minimum distance from the stop line where the vehicle can stop completely after the beginning of the yellow interval. If Xc < Xs, then the area from Xs-Xc to Xs is where a vehicle can neither stop nor go if faced with a yellow indication. This area is termed the “dilemma zone”. Please refer to Figure 5-1 for “dilemma Zone” illustration.
Figure 5-1. Dilemma Zone (Xs > Xc)

Given:
- \( V = 40 \) mph = 58.7 ft/sec
- \( Y = 3 \) secs
- \( R = 1 \) sec
- \( W = 55 \) ft
- \( L = 18 \) ft
- \( d = 10 \) ft/sec\(^2\)
- \( a = 16.0 - 0.213 \times V = 16.0 - 0.213 \times 58.7 = 3.504 \) ft/sec\(^2\)

Assume perception/reaction time = 1 sec
Solving for \( Xs \) and \( Xc \).

\[
Xs = Vt + \frac{V^2}{2d} = 58.7 \times 1 + \frac{58.7^2}{2 \times 10} = 230.985 \text{ ft}
\]

\[
Xc = V(Y+R) + \frac{a(Y+R-t)^2}{2} - (W + L) = 58.7 \times (3+1) + 3.504 \times (3+1-1)^2 / 2 - (55 + 18) = 177.568 \text{ ft}
\]

Dilemma zone = \( Xs - Xc \) = 230.985 - 177.568 = 53 ft

Yes, there is a 53 ft long dilemma zone.