Question 1: True/False Questions (1 point each)

Average signal delay is always longer when delay due to randomness in the arrival rate is considered.

True

The actual green phase of a traffic signal is always longer than the effective green time.

False

Intersection Level of Service is based on estimated signal delay per vehicle.

True

The passage of a vehicle over a loop is identified by an increase in inductance.

False

Question 2: Short Questions (5 points each)

Calculate the saturation flow rate if saturation headways are 2 seconds.

3600/2=1800 vehicles/hour

Estimate freeway speed for a 40 foot long vehicle that spends 1.5 seconds occupying a 6 foot radius, approximately circular loop.

(40+12)/1.5 = 34.7 feet per second

What is the most popular type of traffic detector at new ATMS sites today?

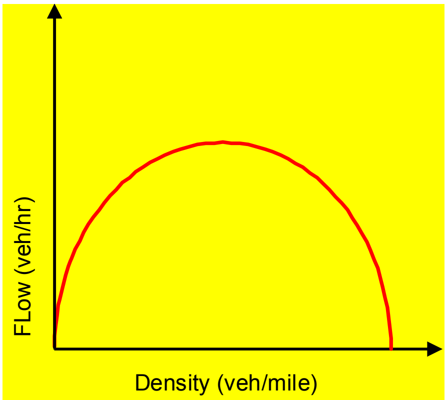
Loop detectors

Given the following traffic counts, what is the peak hour factor for 4:00pm to 5:00pm?

Time Period	Volume (vehicles)
4:00–4:15	525
4:15–4:30	600
4:30–4:45	550
4:45–5:00	575

$$PHF = \frac{V}{V_{15} \times 4} = \frac{2{,}250}{600 \times 4} = 0.9375$$ (2 significant digits if fine too: 0.94)

Draw the form of the flow-density relationship assumed in traffic flow theory.



Question 3 (25 points)

I-90 crosses the Snoqualmie River at about milepost 47.5. Here, the eastbound portion of the Interstate has the following characteristics:

- Rural freeway classification
- No HOV lanes
- 12 ft lane width
- 10 ft right-side shoulders
- 4 lanes (there are 3 lanes going westbound for a total of 7 lanes)
- 0.80 interchanges per mile
- Volume = 2,800 vehicles/hour
- Peak hour factor = 0.98
- 18% trucks and buses
- 2% recreational vehicles
- 4% upgrade for 0.80 miles
- Driver population adjustment factor = 1.0

Report the following:

1. Free flow speed for this section of freeway (to the nearest mile per hour).
2. The 15-minute passenger-car equivalent flow rate (v_p in pcplph).
3. The freeway section level of service (LOS).

Find FFS

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID}$$

- BFFS = 75 mph because it is a rural freeway and no other information is given
- f_{LW} = 0 from Table 6.3 because lane width = 12 ft
- f_{LC} = 0 from Table 6.4 because right-shoulder clearance > 6 ft
- f_N = 0 from Table 6.5 because it is always 0 for rural freeway segments

- f_{ID} = 1.54 interpolating from Table 6.6 – NOTE: must interpolate for credit

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID} = 75 - 0 - 0 - 0 - 1.54 = 73.46 = 73 \ \ mph$$

Note: must be to the nearest mph and not 73.46 to get full credit

Calculate f_{HV}

- Table 6.8 gives E_T = 2.0 for a 4% upgrade for 0.80 miles
- Table 6.9 gives E_R = 3.0 for a 4% upgrade for 0.80 miles

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} = \frac{1}{1 + (0.18)(2-1) + (0.02)(3-1)} = 0.8197$$

Find v_p

$$v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}$$

- PHF = 0.98
- N = 2
- f_{HV} = 0.8197
- f_p = 1.0

$$v_p = \frac{2{,}800}{0.98 \times 4 \times 0.8197 \times 1} = 871.43 \ \ pcplph$$

Find LOS

From Figure 6.2, speed (S) = 73 mph

$$D = \frac{v_p}{S} = \frac{871.43}{73} = 12.44 \ \ pcplpm$$

From Table 6.1, **LOS B**

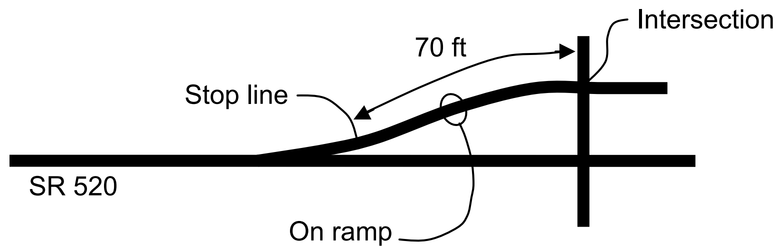
Problem 4 (20 points)

A new freeway ramp meter will be installed on the Medina onramp to westbound SR 520. There is 70 ft from the ramp meter stop line back to the nearest intersection, and each stopped vehicle takes up an average of 20 ft. The desired meter rate is one vehicle every 10 seconds, while the arrival rate averages one vehicle arrival every 11 seconds.

Using M/D/1 queue analysis answer the following questions:

- What is the average queue length?
- Will the average queue length extend into the intersection?

- What is the average time spent in the system (in seconds)?
- What meter rate (in terms of time between vehicles), calculated to the nearest whole second, will result in an average queue length of less than 1 vehicle?



$$\rho = \frac{\lambda}{\mu} = \frac{5.45 \frac{vehicles}{\min}}{6 \frac{vehicles}{\min}} = 0.9083$$

$$\overline{Q} = \frac{\rho^2}{2(1-\rho)} = \frac{(0.9083)^2}{2(1-0.9083)} = 4.5 \ \ vehicles$$ (using ρ = 0.9 gives 4.05 vehicles, OK)

Therefore, at 20 ft/vehicle your queue length (on average) is:

$4.5 \times 20 = 90 \ \ ft$ Realistically, this means the queue on average is either 4 or 5 vehicles long (80 or 100 ft) – both lengths are over the 70 ft provided and thus the queue would extend into the intersection.

$$\overline{w} = \frac{1}{2\mu}\left(\frac{\rho}{1-\rho}\right) = \frac{1}{2(6)}\left(\frac{0.9083}{1-0.9083}\right) = 0.825 \ \ \min = 49.5 \ \ \sec$$

$$\bar{t} = \frac{1}{2\mu}\left(\frac{2-\rho}{1-\rho}\right) = \frac{1}{2(6)}\left(\frac{2-0.9083}{1-0.9083}\right) = 1.0 \ \ \min$$

About 1 minute = average time spent in the system.

For the adjusted meter rate, you want to solve the "average length of queue" equation so Q-bar ≤ 1.0

$$\overline{Q} = \frac{\rho^2}{2(1-\rho)} = \frac{(\rho)^2}{2(1-\rho)} = 1 \ \ vehicle$$

$$2 - 2\rho = \rho^2 \quad \Rightarrow \quad \rho^2 + 2\rho - 2 = 0 \quad \Rightarrow \quad \rho = 0.7321 \ \ or \ \ -2.7321$$

Obviously, you can't have a negative number for ρ so choose 0.7321. Now, enter this into the equation for ρ to get arrival rate:

$$\rho = \frac{\lambda}{\mu} = \frac{5.45 \frac{vehicles}{\min}}{\mu} = 0.7321 \quad \Rightarrow \quad \mu = 7.44 \ \frac{vehicles}{\min} = 8.06 \ \frac{\sec}{vehicle}$$

Problem 5 (15 points)

An approach to a signalized intersection has a saturation flow rate of 2640 veh/h. For one cycle, the approach has 3 vehicles in queue at the beginning of an effective red, and vehicles arrive at 1064 veh/h. The signal for the approach is timed such that the effective green starts 8 seconds after the approach's vehicle queue reaches 10 vehicles, and lasts 15 seconds. What is the total delay for this signal?

$$\lambda = \frac{1064}{3600} = 0.296 \text{ vehicles/second}$$

$$s = 2640 \text{ vehicles/hour}$$

$$\mu = \frac{s}{3600} = .733 \text{ vehicles/second}$$

Solving for t

$$3 + \lambda t = 10$$

$$t = \frac{7}{\lambda} = 23.7 \text{ seconds}$$

Solving for effective red

$$r = t + 8$$

$$r = 31.7 \text{ seconds}$$

$$g = 15 \text{ seconds (given)}$$

$$C = r + g = 46.7$$

Notice that the queue will not dissipate before the end of the cycle. With 3 vehicles in queue at the beginning of the red phase, and an additional 46.7*.296=13.8 vehicles arriving during the cycle, we will have 16.8 vehicles that would like to pass through the intersection during the cycle. However, we can only get .733*15=10.995 vehicles through the intersection. There will still be 16.8-10.99=5.82 vehicles waiting at the end of the cycle.

$$D_t = 3(t+8) + \frac{(t+8)\lambda(t+8)}{2} + \int_0^{15} (\lambda(t+8) + \lambda t)dt - \frac{15^2 \mu}{2} = 379.6 \text{ vehicle-seconds}$$