CEE 320 Midterm Examination II (50 minutes)

- Please write your name on this cover.
- Please write you last name on all other exam pages

- This examination is open-book, open-note.
- There are 5 questions worth a total of 200 points.
- Each question lists the point value for that question.

- Please work quietly and respect other people's space.
- Carefully read each question and ensure that you answer what is asked.
- If you need additional workspace, use the back of the page or the blank page included at the end of the examination.
- If you need to unstaple pages, I have a stapler to restaple them at the end of the examination.

Name (first, last): ____

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

The space mean speed is the average speed of all vehicles on a particular segment of freeway, measured at an instant in time.

True

The time mean speed can be easily measured by radar.

True

Average vehicle spacing is the inverse of vehicle density.

True

According to traffic flow theory, when free flow speeds are observed, the freeway is operating at capacity.

False

When a bottleneck is active, downstream flow is less than the arrival rate.

True

Question 2: Short Questions (5 points each)

Using traffic flow theory, if the jam density of a particular roadway is 250 vehicles/mile, what is the density at capacity?

Page 143 in the text shows the following relationship: $k_{cap} = \frac{k_j}{2}$

Therefore, $k_{cap} = \frac{250}{2} = 125 \;\; vehicles/mile$

What speed estimation parameter (g) should be used if you are trying to estimate speed using a single loop detector (6 ft long) for a 40 ft long bus?

$$g = \frac{5{,}280}{EVL \times 100}$$

EVL = vehicle length + detector length = 40 + 6 = 46 feet

$$g = \frac{5{,}280}{46 \times 100} = 1.15$$

List one Intelligent Transportation System technology and describe how it improves the transportation system.

Traffic Systems Management Center
Variable message signs
Weather monitoring stations
Traffic maps on web, PDA
511 traffic information service
Trafficgauge devices
Traffic cameras
Ramp metering
Weigh-in-motion stations
There are many more

What is the capacity (in terms of passenger cars per lane per hour) of a freeway whose measured free flow speed (FFS) is 65 mph?

2350 pc/ln/hr

3 points for the number, 2 points for the correct units

Which of the following is a linear relationship? (circle one)

1. Speed vs. Density
2. Flow vs. Density
3. Speed vs. Flow

Question 3 (25 points)

A signal is being retimed so that its associated intersection will operate at 80% capacity. Assume a lost time of 4 seconds per phase. The intersection operates in 2 phases:

- Phase 1: eastbound and westbound traffic go at the same time.
- Phase 2: northbound and southbound traffic go at the same time.

The calculated saturation flow and measure flows are shown below.

Phase	Lane Group	Saturation Flow	Measured Flow
1	Eastbound	1000 veh/hr	100 veh/hr
	Westbound	1000 veh/hr	200 veh/hr
2	Northbound	1800 veh/hr	600 veh/hr
	Southbound	1600 veh/hr	600 veh/hr

Report the following:

1. The critical lane group for phase 1 and phase 2.
2. The minimum necessary cycle length (rounded up to the nearest 5 seconds).
3. The optimal cycle length using Webster's practical C_{opt} equation (rounded up to the nearest 5 seconds).

Critical Lane Groups

These are simply the lane groups in each phase with the highest v/s ratios

Critical lane groups are **westbound** and **southbound**

C_{min}

$$C_{\min} = \frac{8 \times 0.80}{0.80 - \left(\frac{200}{1000} + \frac{600}{1600}\right)} = 28 \ s$$

Or C_{min} = 30 seconds (rounded up to the nearest 5 seconds)

C_{opt}

$$C_{opt} = \frac{1.5(8) + 5}{1 - \left(\frac{200}{1000} + \frac{600}{1600}\right)} = 40 \ s$$

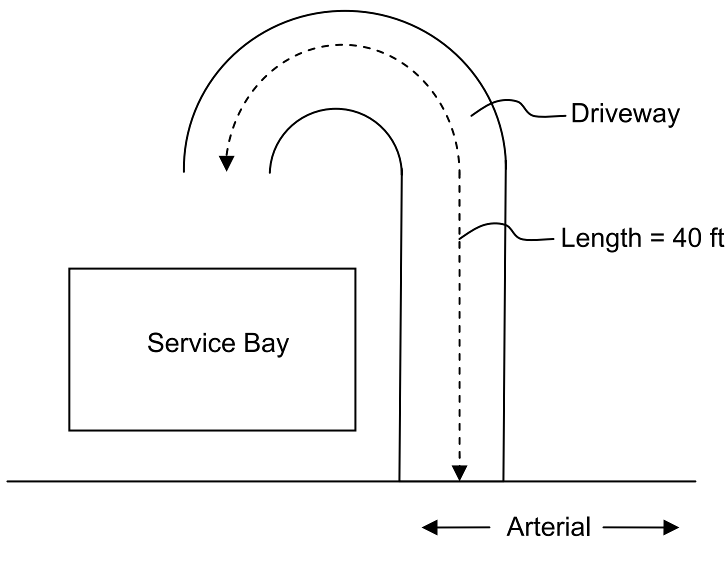
Or C_{opt} = 40 seconds (rounded up to the nearest 5 seconds)

Problem 4 (30 points)

A Jiffy-lube owner wants to build a new store in Lynnwood, WA. This store will have two service bays and a single driveway (one lane) with a centerline length of 40 ft. Customers must wait in line for the next available bay in this driveway.

The city of Lynnwood wants to know the probability that there will be enough waiting customers such that the line will back up onto the arterial during the peak hour of business?

- On average, a waiting vehicle takes up 20 ft of centerline driveway length.
- Each vehicle spends an average of 10 minutes in the service bay.
- Average arrival rate is 5 vehicles/hour.



This is a straight-up M/M/N queuing problem. You know that if more than 4 vehicles in the system (two on the driveway and two in the service bays), the queue will extend into the street. So really the problem is asking what the probability of having more than 4 vehicles in the system.

Determine the arrival and departure rates
Arrival rate = 5 vehicles/hr Departure rate = 10 minutes/vehicle = 6 vehicles/hr

Then, determine ρ: $\rho = \frac{\lambda}{\mu} = \frac{5}{6} = 0.833$

Determine P(0)
You know that there are 2 service channels so N = 2 .

$$P_0 = \frac{1}{\sum_{n_c=0}^{N-1} \frac{\rho^{n_c}}{n_c!} + \frac{\rho^N}{N!(1-\rho/N)}} = \frac{1}{\frac{0.833^0}{0!} + \frac{0.833^1}{1!} + \frac{0.833^2}{2!\left(1-\frac{0.833}{2}\right)}} = 0.412$$

Determine P_1 through P_4

We are concerned about the situation when there are more than 4 vehicles in the system so we need to calculate the probability of zero, one, two, three, and four vehicles in the SYSTEM and then subtract them all from one.

$$P_1 = \frac{\rho^n P_0}{n!} = \frac{0.833^1(0.412)}{1!} = 0.343$$

$$P_2 = \frac{\rho^n P_0}{n!} = \frac{0.833^2(0.412)}{2!} = 0.143 \text{ OR } P_2 = \frac{\rho^n P_0}{N^{n-N} N!} = \frac{0.833^2(0.412)}{2^{2-2} \times 2!} = 0.143$$

$$P_3 = \frac{\rho^n P_0}{N^{n-N} N!} = \frac{0.833^3(0.412)}{2^{3-2} \times 2!} = 0.060$$

$$P_4 = \frac{\rho^n P_0}{N^{n-N} N!} = \frac{0.833^4(0.412)}{2^{4-2} \times 2!} = 0.025$$

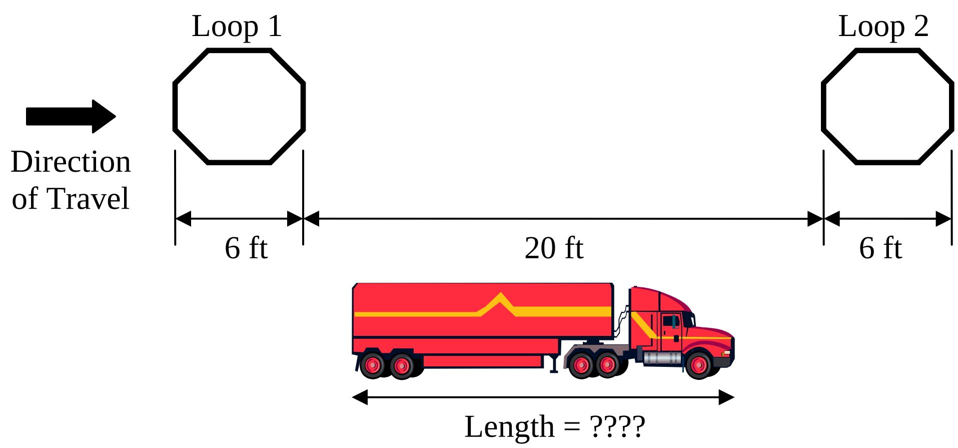
Determine P(n>4)

$$P(n>4) = 1-(P(0)+P(1)+P(2)+P(3)+P(4)) = 1-0.412-0.343-0.143-0.060-0.025 = 0.017$$

There is a 1.7% probability that the queue will extend into the street

Question 5 (7 points)

A semi-tractor trailer crosses a set of dual loop detectors with the geometry shown below. The on-time for loop 1 is 0.83 seconds and the on-time for loop 2 is 0.91 seconds. The truck triggers loop 2 at 0.33 seconds after loop 1. How long is the truck and trailer combination?



Use the dual loop equations for determining speed and length on slide 31 of the traffic detection lecture notes.

$$Speed = \frac{l_{dist}}{t_2 - t_1} = \frac{(20+6)}{0.33} = 78.79 \quad \frac{ft}{\text{sec}}$$

$$L_{truck} = \frac{Speed(ot_1 + ot_2)}{2} = \frac{78.79(0.83+0.91)}{2} = 68.55 \quad ft$$

Question 6 (8 points)

A signal approach has a saturation flow rate of 1800 vehicles/hour. During one 80-second cycle, there are 4 vehicles queued at the beginning of the cycle (the start of the effective red) and 2 vehicles queued at the end of the cycle (the end of the effective green). At the beginning of the effective green there are 10 vehicles in the queue. The arrival rate is constant and the process is D/D/1. If the effective red is known to be less than 40 seconds, what is the total vehicle delay during this 80 second signal cycle?

Solve for r and λ, with 2 equations and 2 unknowns.

$$4 + 80\lambda = \frac{(80 - r)}{3600}1800 + 2$$
$$4 + \lambda r = 10$$

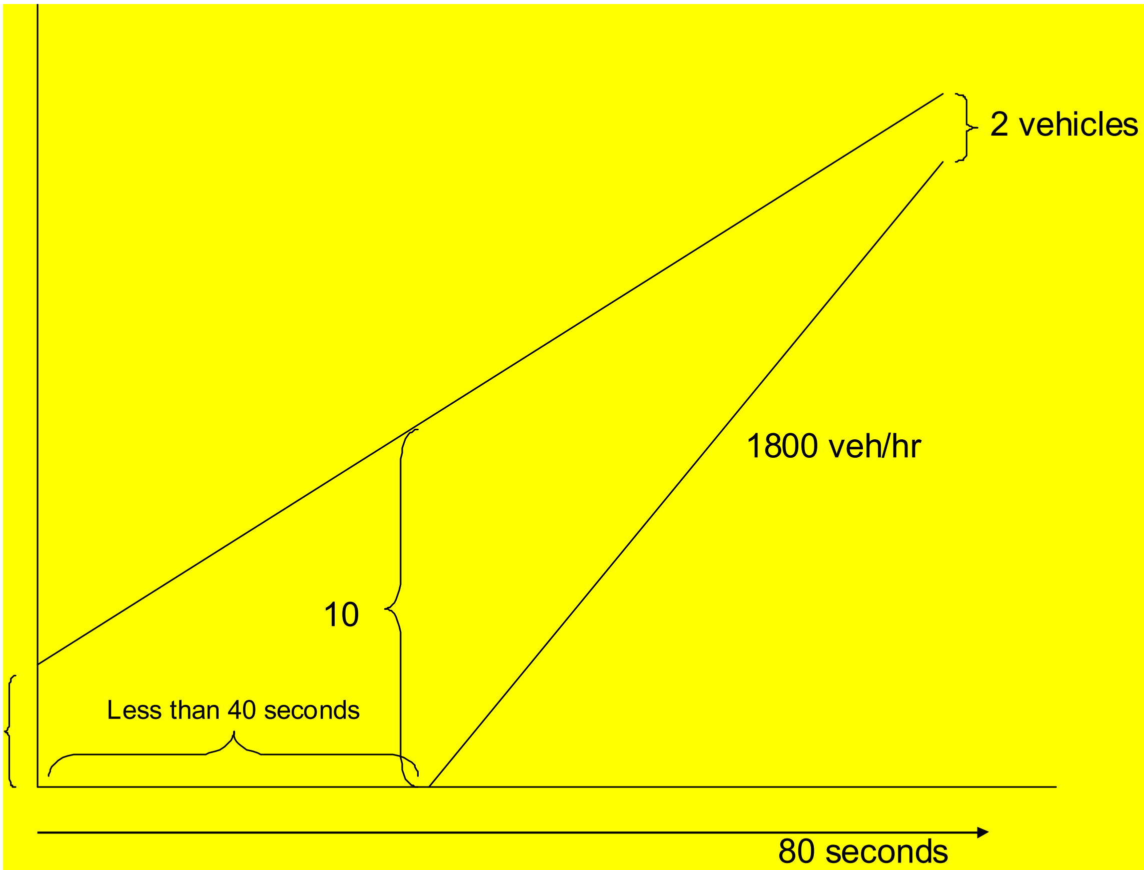
$$4 + 80\frac{6}{r} = \frac{80 - r}{3600}1800 + 2$$
$$r^2 - 76r + 960 = 0$$
$$r = 16,60$$

We were told r was less than 40 seconds, so r=16 seconds, and λ=0.375 vehicles/second.

Total delay:

$$\int_0^{80}(4 + .375t)dt - \frac{1}{2}(64)(32) = 320 + 1200 - 1024 = 496$$ vehicle-seconds

Draw a time versus cumulative number of vehicles diagram to represent the queuing during this 80 second cycle.


2 vehicles
1800 veh/hr
10
Less than 40 seconds
80 seconds