CEE 320 Midterm Examination (50 minutes)

Fall 2009

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

- This exam is NOT open book, but you are allowed to use one 8.5x11 sheet of notes and a calculator
- There are 6 questions worth a total of 80 points.
- Each question lists the point value for that question.

- Please work quietly and respect other people's space. You may leave the exam room quietly if you are finished before the end of the exam period.
- 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)

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

True

B. The time mean speed can be easily measured by radar.

True

C. Average vehicle spacing is the inverse of vehicle density.

True

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

False

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

True

Question 2: Short Questions (5 points each)

A. 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, $k_{cap} = \frac{250}{2} = 125 \ \ vehicles/mile$

B. 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

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

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

D. If drivers arrive at a single toll booth at the average rate of 1 vehicle every 10 seconds, and the arrivals can be modeled as a poisson process. What is the probability of 2 vehicles arriving in 12 seconds?

P(2)=(6/5)^2*e^(-6/5)/2!=.2169 or 22%

E. 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	505
4:15–4:30	615
4:30–4:45	505
4:45–5:00	555

$PHF = \frac{V}{V_{15} \times 4} = \frac{2{,}180}{615 \times 4} = 0.8862$ (2 significant digits if fine too: 0.89)

Question 3: 15 points

The entry plaza to a new sea port is being designed. It is expected that 115 semi-trucks (hauling cargo containers) will arrive during the peak hour of demand. The mean service rate at each entry booth is such that one truck can be processed every 30 seconds.

Determine the following:

1. Average queue length, average time waiting in the queue, and average time spent in the system. Assume just one processing booth is open, and that truck arrivals are Poisson distributed and booth service times are exponentially distributed.

2. Whether 3 booths will keep the average time waiting in the queue less than 1 minute, if the arrival rate doubles and the service time increases by 10 seconds. Assume that both arrival and departure headways are exponentially distributed.

$$\lambda = \frac{115\_trucks}{60\_\min} = 1.917\_trucks/\min$$

$$\mu = \frac{1\_trucks}{30\_\sec s} x \frac{60\_\sec s}{1\_\min} = 2\_trucks/\min$$

$$\rho = \frac{\lambda}{\mu} = 0.958$$

M/M/1 queueing system

Average queue length: $\bar{Q} = \frac{\rho^2}{(1-\rho)} = 22.042\_vehicles$

Average time waiting in the queue: $\bar{w} = \frac{\lambda}{\mu(\mu-\lambda)} = 11.5\_\min/vehicle$

Average time in the system: $\bar{t} = \frac{1}{\mu-\lambda} = 12\_\min/vehicle$

M/M/N queueing system

$$\lambda = \frac{230\_trucks}{60\_\min} = 3.833\_trucks/\min$$

$$\mu = \frac{1\_trucks}{40\_\sec s} x \frac{60\_\sec s}{1\_\min} = 1.5\_trucks/\min$$

$$\rho = \frac{\lambda}{\mu} = 2.556$$

If N>2 then we can apply the following equations:

$$P_0 = \frac{1}{1 + \frac{\rho}{1!} + \frac{\rho^2}{2!} + \frac{\rho^3}{3!\left(1 - \frac{\rho}{N}\right)}} = 0.039$$

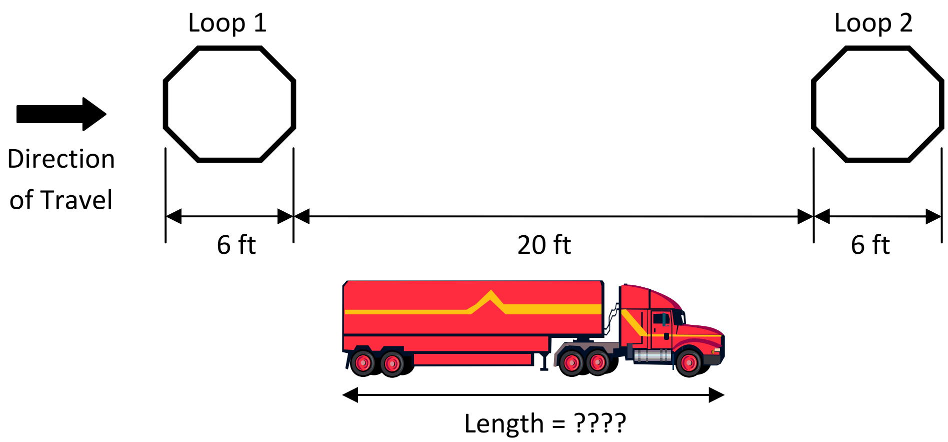
$$\overline{Q} = \frac{P_0 \rho^{N+1}}{N \times N}\left[\frac{1}{\left(1 - \frac{\rho}{N}\right)^2}\right] = 4.218\_veh$$

$$\overline{w} = \frac{\rho + \overline{Q}}{\lambda} - \frac{1}{\mu} = 1.1003\_\min/veh = 66.017\_\sec/veh$$

No, 3 booths will not keep the average time waiting in queue to less than 1 minute.

Question 4: 10 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. 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.

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

$$L_{truck} = Speed(ot_1) = 78.79(0.83) = 65.40 \ \ ft$$

Question 5: 10 points

The formation of a queue at a single toll booth is represented in the figure below. Please describe the features identified by the letters on the figure below. Indicate the units for each.

a) queue length at time t_1, in number of vehicles

b) maximum queue length, in number of vehicles

c) maximum wait time, in time (e.g. minutes)

d) departure rate when queue present, in vehicles per time

Question 6: 15 points

A new segment of freeway is being built to connect two existing parallel freeway facilities, in an urban area. The following traffic and roadway characteristics are expected:

Traffic Characteristics:

- AADT = 85000 veh/day
- K = 11%
- D = 55%
- PHF = 0.92
- 6% trucks and buses
- 2% RVs
- Primarily commuters

Roadway Characteristics:

- Rolling terrain
- Interchange density = 1 per mile
- Lane widths = 12 ft
- Shoulder widths = 4 ft

Determine whether 4 lanes will ensure that this new freeway segment will operate at no worse than LOS D during the peak hour in the peak direction. Recall the BFFS for an urban freeway is 70 mph. Necessary tables are included on the following pages.

DDHV=5143

f_p=1.00, P_T=0.06, P_R=0.02

E_T=2.5, E_R=2.0 (Table 6.7)

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} = 0.90$$

BFFS=70, f_{LW}=0, f_{ID}=2.5

If N=4,

f_{LC}=0.4 and f_N=1.5

FFS=BFFS- f_{LW} - f_{ID} - f_{LC} - f_N=65.6 mph

$$v_p = \frac{DDHV}{PHF \times f_{HV} \times N \times f_p} = 1553$$

S=65.5 mph

$D=v_p/S=24$ pc/mi/ln

LOS C

Yes, this will ensure better than LOS D.

Criteria	LOS				
	A	B	C	D	E
FFS = 75 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	75.0	74.8	70.6	62.2	53.3
Maximum v/c	0.34	0.56	0.76	0.90	1.00
Maximum service flow rate (pc/h/ln)	820	1350	1830	2170	2400
FFS = 70 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	70.0	70.0	68.2	61.5	53.3
Maximum v/c	0.32	0.53	0.74	0.90	1.00
Maximum service flow rate (pc/h/ln)	770	1260	1770	2150	2400
FFS = 65 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	65.0	65.0	64.6	59.7	52.2
Maximum v/c	0.30	0.50	0.71	0.89	1.00
Maximum service flow rate (pc/h/ln)	710	1170	1680	2090	2350
FFS = 60 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	60.0	60.0	60.0	57.6	51.1
Maximum v/c	0.29	0.47	0.68	0.88	1.00
Maximum service flow rate (pc/h/ln)	660	1080	1560	2020	2300
FFS = 55 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	55.0	55.0	55.0	54.7	50.0
Maximum v/c	0.27	0.44	0.64	0.85	1.00
Maximum service flow rate (pc/h/ln)	600	990	1430	1910	2250

Note:
The exact mathematical relationship between density and v/c has not always been maintained at LOS boundaries because of the use of rounded values. Density is the primary determinant of LOS. The speed criterion is the speed at maximum density for a given LOS.

EXHIBIT 23-3. SPEED-FLOW CURVES AND LOS FOR BASIC FREEWAY SEGMENTS

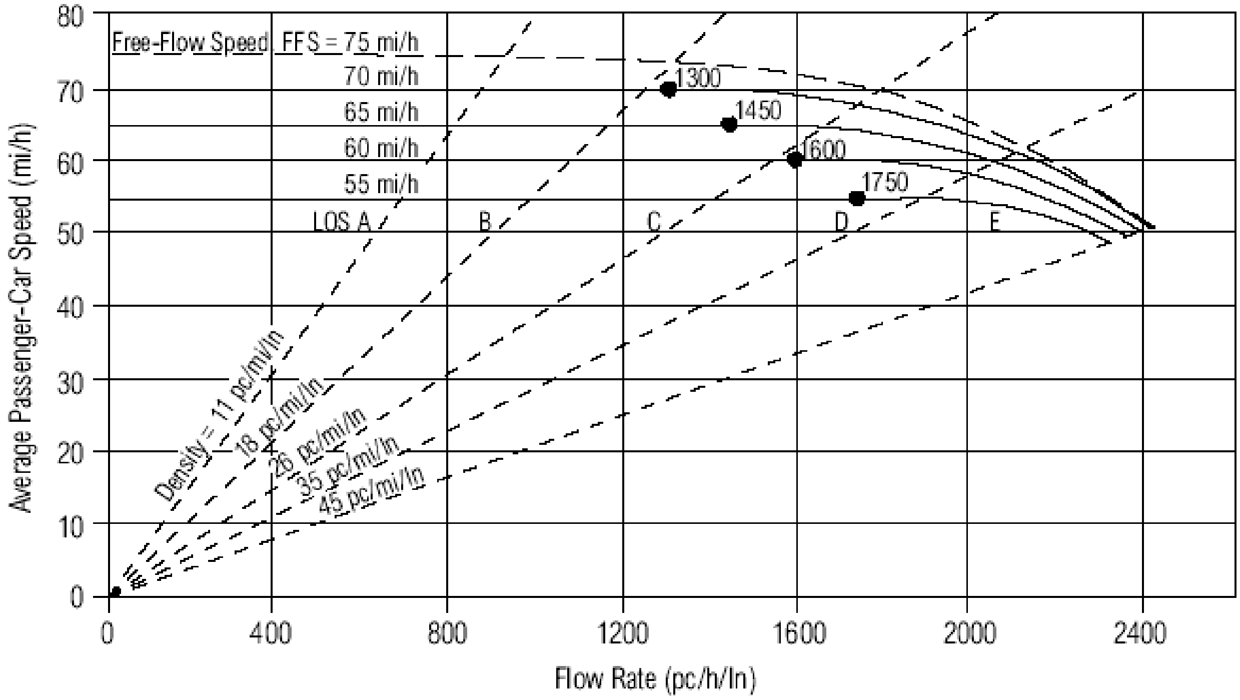


EXHIBIT 23-4. ADJUSTMENTS FOR LANE WIDTH

Lane Width (ft)	Reduction in Free-Flow Speed, f_{LW} (mi/h)
12	0.0
11	1.9
10	6.6

EXHIBIT 23-5. ADJUSTMENTS FOR RIGHT-SHOULDER LATERAL CLEARANCE

Right-Shoulder Lateral Clearance (ft)	Reduction in Free-Flow Speed, f_{LC} (mi/h)			
	Lanes in One Direction			
	2	3	4	≥ 5
≥ 6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	3.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

EXHIBIT 23-8. PASSENGER-CAR EQUIVALENTS ON EXTENDED FREEWAY SEGMENTS

Factor	Type of Terrain		
	Level	Rolling	Mountainous
E_T (trucks and buses)	1.5	2.5	4.5
E_R (RVs)	1.2	2.0	4.0

EXHIBIT 23-6. ADJUSTMENTS FOR NUMBER OF LANES

Number of Lanes (One Direction)	Reduction in Free-Flow Speed, f_N (mi/h)
≥ 5	0.0
4	1.5
3	3.0
2	4.5

Note: For all rural freeway segments, f_N is 0.0.

EXHIBIT 23-7. ADJUSTMENTS FOR INTERCHANGE DENSITY

Interchanges per Mile	Reduction in Free-Flow Speed, f_{ID} (mi/h)
0.50	0.0
0.75	1.3
1.00	2.5
1.25	3.7
1.50	5.0
1.75	6.3
2.00	7.5