Homework: Conservation

5.1, 5.3

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5.1

Table 1 shows vehicle counts from the Lincoln Tunnel's 1.5-mile long south tunnel. The counts are binned by hour over a 24-hour period, and are for both entering and exiting vehicles.

Table 1: Lincoln Tunnel Vehicle Counts

Time	Vehicles Entering	Vehicles Exiting
00:00	0	0
01:00	90	80
02:00	400	390
03:00	900	874
04:00	1,860	1,870
05:00	2,060	2,028
06:00	2,200	2,210
07:00	3,000	2,978
08:00	4,060	4,026
09:00	4,200	4,154
10:00	3,207	3,223
11:00	3,386	3,424
12:00	2,810	2,832

Time	Vehicles Entering	Vehicles Exiting
13:00	3,019	3,029
14:00	3,880	3,838
15:00	3,665	3,637
16:00	4,020	3,980
17:00	4,600	4,634
18:00	4,282	4,316
19:00	3,740	3,772
20:00	3,120	3,138
21:00	1,680	1,706
22:00	408	438
23:00	0	10

The level of service (LOS) of the tunnel is determined by the density, as shown in Table 2.

Table 2: LOS of Highway Segment

LOS	Density (veh/mi/lane)
A	< 11
B	11–18
C	18–26
D	26–35
E	35–45
F	> 45

For each hour, the density is calculated from the number of vehicles in the tunnel. This is given by the difference in cumulative entering vehicles and cumulative exiting vehicles. The tunnel is 1.5 miles in length and has 2 lanes, so the density per lane is given by $k_l = \frac{N_{\text{tunnel}}}{1.5 \times 2}$. Table 3 shows this for each hour.

Table 3: Density and LOS Calculations for Lincoln Tunnel

Time	Cumulative Vehicles Entering	Cumulative Vehicles Exiting	Vehicles In Tunnel (En−Ex)	Density (veh/mi)	Lane Density (veh/mi/lane)	Level of Service
00:00	0	0	0	0.00	0.00	A
01:00	90	80	10	6.67	3.33	A
02:00	490	470	20	13.33	6.67	A
03:00	1,390	1,344	46	30.67	15.33	B
04:00	3,250	3,214	36	24.00	12.00	B
05:00	5,310	5,242	68	45.33	22.67	C
06:00	7,510	7,452	58	38.67	19.33	C
07:00	10,510	10,430	80	53.33	26.67	D
08:00	14,570	14,456	114	76.00	38.00	E
09:00	18,770	18,610	160	106.67	53.33	F
10:00	21,977	21,833	144	96.00	48.00	F
11:00	25,363	25,257	106	70.67	35.33	E
12:00	28,173	28,089	84	56.00	28.00	D
13:00	31,192	31,118	74	49.33	24.67	C
14:00	35,072	34,956	116	77.33	38.67	E
15:00	38,737	38,593	144	96.00	48.00	F
16:00	42,757	42,573	184	122.67	61.33	F
17:00	47,357	47,207	150	100.00	50.00	F
18:00	51,639	51,523	116	77.33	38.67	E
19:00	55,379	55,295	84	56.00	28.00	D
20:00	58,499	58,433	66	44.00	22.00	C
21:00	60,179	60,139	40	26.67	13.33	B
22:00	60,587	60,577	10	6.67	3.33	A
23:00	60,587	60,587	0	0.00	0.00	A

5.3

A crash on Interstate 91 occurred at 08:00 AM, blocking one of the 2 lanes and reducing the discharge rate of the highway segment to 1800 vehicles per hour. The inflow to this segment is 2600 vehicles per hour. Additionally, 2 miles ahead of the crash is an on-ramp with an inflow of 400 vehicles per hour. See Figure 1 for a depiction.

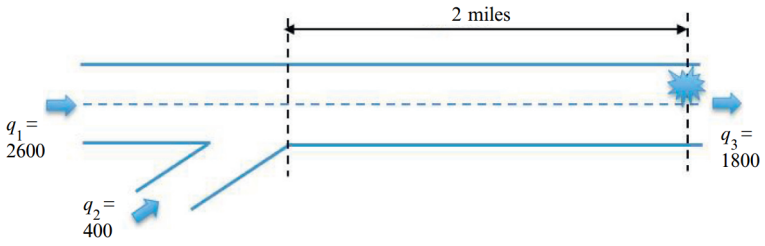

Figure 1: Depiction of the section of I-91 with the crash.

The Massachusetts Department of Transportation wants to avoid vehicles backing up to the on-ramp, which will happen at some point since the inflow is greater than the discharge. Assuming a consistent vehicle spacing (front bumper to front bumper) of 29.3 feet, the 2-mile segment will be backed up when there are 360 vehicles in each lane. Because there are 2 lanes, when 720 vehicles are in this segment the highway will be backed up to the on-ramp. The difference in inflow and discharge is 1200 vehicles per hour, so this will occur in 0.6 hours or 36 minutes. This means that the Department of Transportation has until 08:36 AM to clear the crash before the highway is backed up to the on-ramp.