CE 455: TRAFFIC ENGINEERING AND MANAGEMENT
LECTURE 2B: MATH PROBLEMS ON TRAFFIC OPERATION

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- Maximum capacity of a road segment is 4000 vph and optimum operating speed = 100 mph. At a scenario, traffic demand is 3000 vph. Suppose that a stalled vehicle suddenly blocks one lane such that the road capacity at the stalled vehicle's location drops to 2000 vph. The vehicle is removed after 30 minutes, at which time the road capacity is fully restored.

i) Determine the speed of the resulting back of queue, and sketch the queue's evolution (i.e. its formation and dissipation) on a time-space diagram.

ii) Calculate the duration of time over which the queue persists.

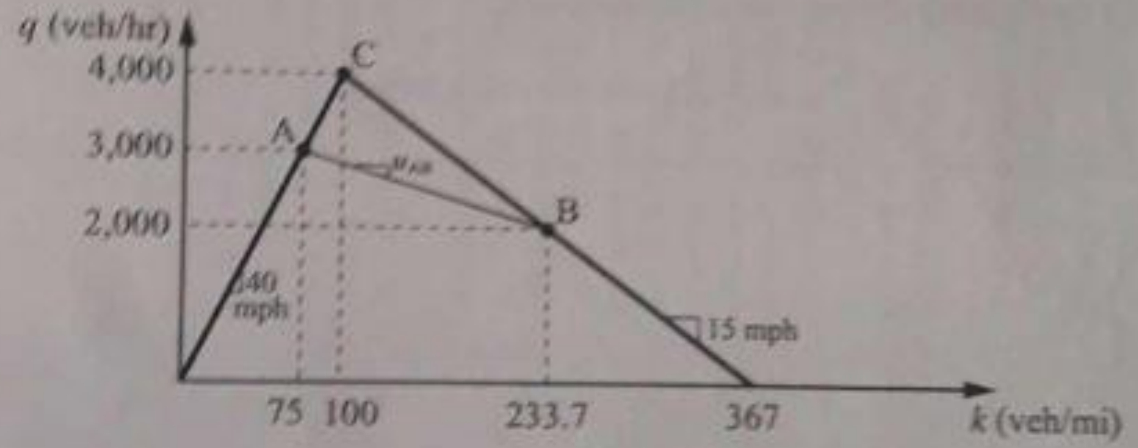
iii) Determine how far upstream of the stalled vehicle the queue reaches.

The fundamental diagram for a long multilane road segment is given below. The traffic demand is 3,000 vph. Suppose that a stalled vehicle suddenly blocks one lane such that the road capacity at the stalled vehicle's location drops to 2,000 vph. The vehicle is removed after 30 minutes, at which time the road capacity is fully restored.

a. Determine the speed of the resulting back of queue, and sketch the queue's evolution (i.e., its formation and dissipation) on a time-space diagram.

Solution 1a

First, identify the traffic states on the fundamental diagram.



$$k_B = 367\ veh/mi - \frac{2{,}000\ veh/hr}{15\ mi/hr} = 233.7\ veh/mi$$

Back of queue $$u_{AB} = \frac{3{,}000\ veh/hr - 2{,}000\ veh/hr}{(233.7\ veh/mi - 75\ veh/mi)} = \mathbf{6.3\ mi/hr}$$

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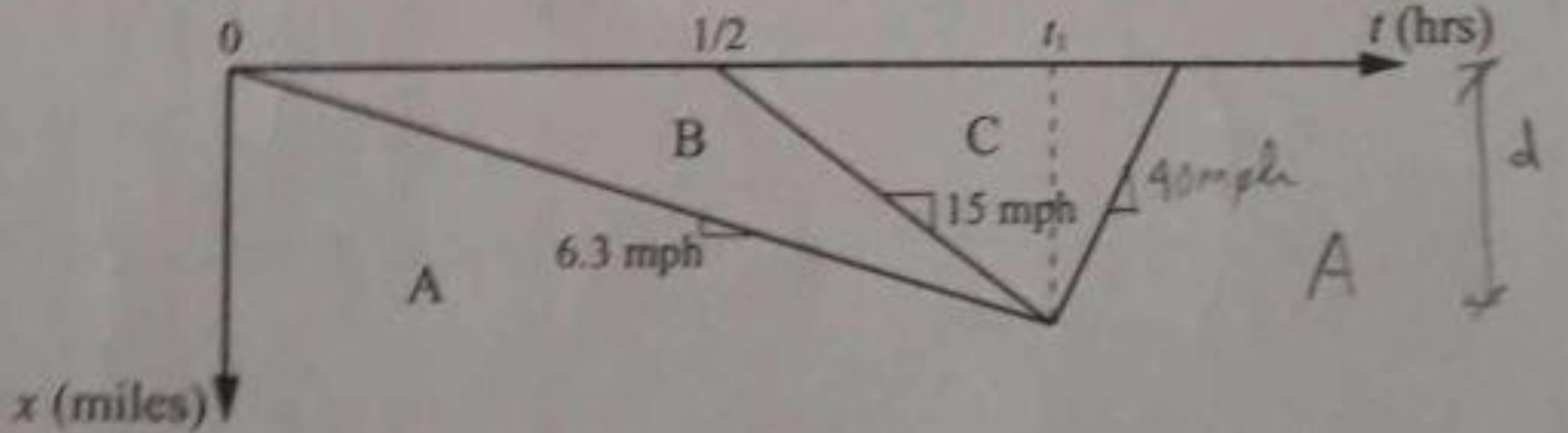

b. Calculate the duration of time over which the queue persists.

Solution 1b

Queue stops growing at time t_1 when the front of the queue reaches the back of the queue.

$$6.3t_1 = 15\,(t_1 - 0.5)$$

$$\mathbf{t_1 = 0.86\ \mathit{hrs}}$$

c. Determine how far upstream of the stalled vehicle the queue reaches.

Solution 1c

This happens at distance d from the stalled vehicle.

$$d = 6.3 \times 0.86 = \mathbf{5.4\ \mathit{miles}}$$

- On a multilane freeway, a roadside observer measures a flow of cars of 2250 cars/hr and a flow of trucks of 500 trucks/hr. the observer also determines that cars travel at 60 mph and trucks 40 mph. (i) Determine the total vehicle density, (ii) Determine the number of cars queued behind each truck in the one-lane section, (iii) Determine the space-mean speed and the time-mean speed on the freeway in the multi-lane section upstream.

Lecture 1: Example 2, Mixed Traffic Stream

Suppose that, on a multiple lane freeway, a roadside observer measures a flow of cars (passing a point) of 2,250 cars/hr and a flow of trucks of 500 trucks/hr. The observer also determines that cars travel at 60 mph and trucks at 40 mph.

a. Determine the total vehicle density.

Solution 2a

Recall the relationship between flow, speed, and density:

$$q = kv \quad \Rightarrow \quad k = \frac{q}{v}$$

The density of each vehicle class (Car, Truck):

$$k_C = \frac{2{,}250 \text{ car/hr}}{60 \text{ mi/car}} = 37.5 \text{ car/mi}$$

$$k_T = \frac{500 \text{ truck/hr}}{40 \text{ mi/truck}} = 12.5 \text{ truck/mi}$$

Total vehicle density is the sum of the density of each vehicle class.

$$\mathbf{k = 50} \ \textit{veh/mi}$$

Now suppose that the multilane highway section narrows to single lane at some downstream location. Cars and trucks enter the one-lane section without delay, but within this section cars catch up trucks and follow in queue.

b. Determine the number of cars queued behind each truck in the one-lane section.

Solution 2b

Simply determine the ratio of cars to trucks that pass the entry point to the one-lane section of the freeway. Since we are interested in vehicles passing a point in space (over time), we use flows:

$$\frac{q_C}{q_T} = \frac{2{,}250\ car/hr}{500\ truck/hr} = \mathbf{4.5\ car/truck}$$

c. Determine the space-mean speed and the time-mean speed on the freeway in the multi-lane section upstream.

Solution 2c

Space mean speed (v_s) is the average weighted by density, time mean speed (v_t) is weighted by flow:

$$v_s = \frac{37.5 \text{ veh/mi} \times 60 \text{ mi/hr} + 12.5 \text{ veh/mi} \times 40 \text{ mi/hr}}{50 \text{ veh/mi}} = \mathbf{55 \text{ mi/hr}}$$

$$v_t = \frac{2,250 \text{ veh/hr} \times 60 \text{ mi/hr} + 500 \text{ veh/hr} \times 40 \text{ mi/hr}}{2,750 \text{ veh/hr}} = \mathbf{56.4 \text{ mi/hr}}$$

$$V_s = \frac{\Sigma K_i V_i}{\Sigma K_i}$$

$$V_t = \frac{\Sigma N_i V_i}{\Sigma N_i}$$