

EXAM
TRAFFIC FLOW DYNAMICS

202000083

23 May 2022

8:45-11:45

Room: Sportcentrum SC1

The exam consists of 4 problems. Maximum scores are listed in the table below.

Good luck

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problem	max score
1	20
2	20
3	20
4	30
bonus	10
total	100

1. [20 pts] Four vehicles are traveling between X and Y with their positions observed at any instant in time. The section between X and Y has a length of 28 meters. An observer at point X observes the four vehicles passing point X during a period of 15 seconds. The speeds of the vehicles are measured as 88, 80, 90, and 72 km/h respectively. Calculate the flow, density, time mean speed, and space mean speed of the vehicles. Explain under which conditions these mean speeds can be determined and explain the difference between both types of mean speeds.

Solution

$$q = N \frac{3600}{t_{measured}} = 4 \frac{3600}{15} = 960 \text{ veh/h}$$

$$k = \frac{N}{L} = \frac{4}{0,028} = 142 \text{ veh/km}$$

$$u_{TMS} = u_L = \frac{1}{N} \sum_{i=1}^4 v_i = \frac{1}{4}(72 + 90 + 80 + 88) = 82,5 \text{ km/h}$$

yet, space mean speed is somewhat difficult.

We can only use $u_M = \frac{1}{1/N \sum v_i}$ when there is no acceleration but

that seems not very realistic with such small headways and speed differences. We could use $q = uk$ where $u = u_M$ but this relationship only holds under stationary and homogeneous conditions, which also doesnot apply. Should you have used the first or the second option, no subtraction of points. However, you should have mentioned the assumptions for your chosen approach. finally $u_L \geq u_M$ because of the overrepresentation of fast cars.

2. [20 pts] Suppose for a specific road the fundamental diagram as depicted in figure 1 was derived.
 - (a) [10 points] Copy the figure and depict in your copy as many traffic flow characteristics as possible

Solution

you could have mentioned both types of capacity, i.e. pre-queue maximum flow which in our case is 2400 veh/h and queue discharge flow, which is 2000 veh/h. This yields a capacity drop of

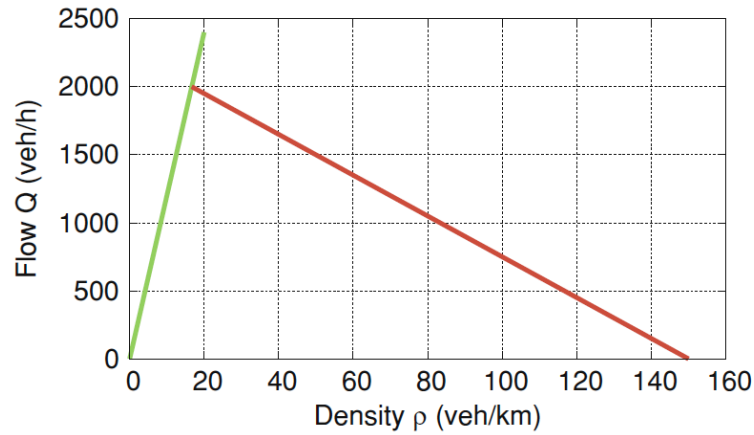


Figure 1: Fundamental diagram

400 veh/h. In the free flow regime speed is $2400/20=120$ km/h. We can see jam density of 150 veh/km, and critical density of 20 veh/km resp $2000/120=16,7$ veh/km. Further for any point in the diagram you could have determined speed as rise over run, or in our case flow over density.

- (b) [10 points] Draw the corresponding speed-flow diagram. Depict the characteristics from (a) also in this diagram.

Solution

the corresponding speed-flow diagram has a free flow part which is a horizontal line ranging from flow is 0 to 2400 with speed is 120 km/h, and a congested part from the origin until the point where speed is 120 km/h and flow is 2000 veh/h. here you can see capacity drop again. Then add an intermediate point from the point in the previous diagram $(k, q)=(80, 1000)$ from which we derive $(q, u)=(1000, 12, 5)$. jam density can be found from the tangent in the origin, and then taking the angle to the speed-axis.

3. [20 pts] Consider the GM-1 carfollowing model as developed by Chandler, Herman and Montroll in 1958.

$$a_{n+1}(t + \Delta t) = \alpha[v_n(t) - v_{n+1}(t)]$$

- (a) [10 pts] Give all drawbacks of this model, and explain how some

of these drawbacks were 'solved' in later versions in the GM-suite of models

Solution

All drawbacks is maybe a little too much, but some are: initially sensitivity was a constant where in later GM-models this was assumed to depend on the speed of the following vehicle and the distance headway. Further drawbacks are that perception error was not included, a stimulus could also be behaviour of cars that drive in front of the car you are following, and a stimulus could be not only speed difference but also deceleration (brake lights)

- (b) [10 pts] Describe the action point model for carfollowing, initially developed by Todosiev and later implemented by Wiedemann, and explain which drawback(s) of the GM-suite of models are overcome by this approach.

Solution

This model was described in some of the slides in the lecture on car following behaviour

4. [30 pts] Consider a two-lane motorway. Assume a triangular fundamental diagram with a free flow speed of 80 km/h, a critical density of 25 veh/km/lane and a jam density of 150 veh/km/lane. The inflow is stationary at 2000 veh/h. Consider a wide vehicle (special transport) driving slowly is entering the road. There are no overtaking possibilities. This creates congestion, of which the tail happens to stay at the same position. After 5 km, the truck leaves the road.
- (a) [11 pts] Draw the fundamental diagram and calculate the capacity of the road stretch.

Solution

Obviously since $q = ku$ it holds that capacity = $25 \cdot 80 = 2000$

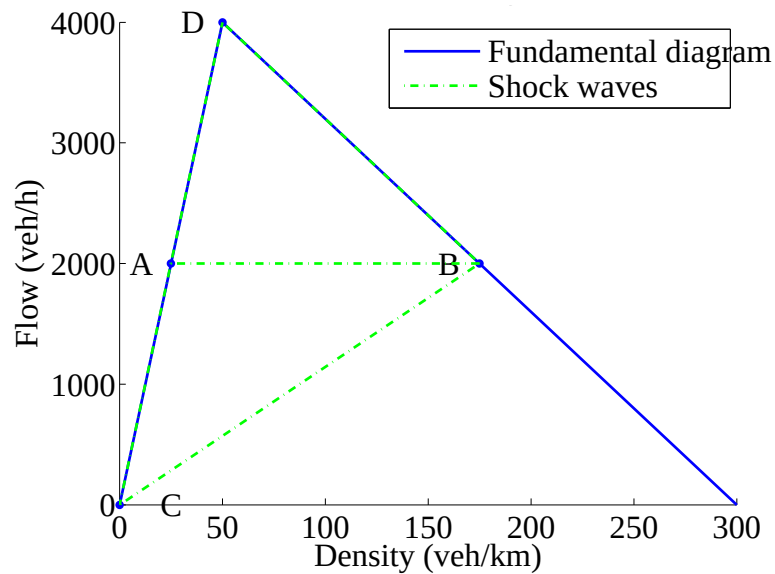


Figure 2: Fundamental diagram

veh/h/lane. There are 2 lanes so capacity is 4000 veh/h

- (b) [10 pts] Sketch the space-time diagram of this situation (with trajectories) from before the moment the truck enters the road to after the moment the traffic situation is stationary.

Solution

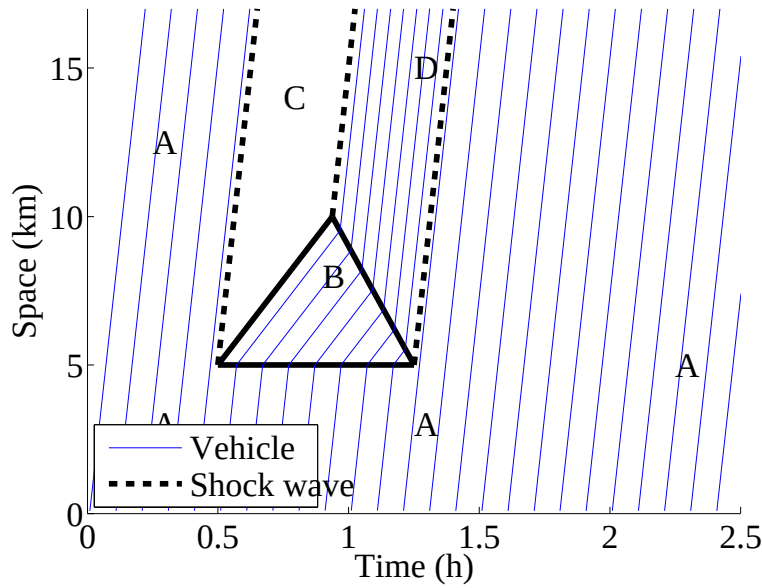


Figure 3: Time space diagram with trajectories

- (c) [3 pts] Calculate the flow in the jam. (Hint: you can use the speed of the shockwave at the tail of the queue)

Solution

Since the tail is at the same place, the flow in the queue should be equal to the inflow, so 2000 veh/h.

- (d) [3 pts] Calculate the density in the jam.

Solution

The fundamental diagram is described by

$$q = C(1 - ((k - k_c)/(k_j - k_c)));$$

use $k_j = 300$; $C = 4000$; $k_c = 50$;

Use the fundamental diagram to find the density at $q=2000$ veh/h.
Solving $q = 1000$ veh/h gives $k = 175$ veh/km

- (e) [3 pts] Calculate the speed of the special transport.

Solution

The speed of the vehicle is equal to the speed in the congested state. Using $q = ku$, gives $v = 2000/175 = 11,4$ km/h