Exam CIE-4821-09
Traffic Flow Theory and Simulation

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The exam has 6 questions. 43 points can be obtained, which are specified per question and subquestion. Some questions might require more time than others, so *use your time wisely*! The total time available for this exam is 3 hours.

Remarks:

- Allowed: calculator (but no smartphones...), self-made equation sheet (1 double sided A4 max)
- Put labels at all your graph axes.
- If a *sketch* is asked, there is no need for an exact drawing. Do make sure, though, that it is clear whether points lie higher or lower or on one line, and that this is correct.
- Your answer will be judged on the good elements in there, but for all wrong answers points will be deducted.
- For some questions, an indicative number of words is given as guidance for the required level of detail. Your answer may be shorter or longer.
- Make sure you provide the calculus procedure as well as the result in order to get the maximum points.

Question	Points
1	5
2	8
3	3
4	9
5	13
6	5
Total:	43

1. Short questions

Total for Question 1: 5

(a) **What does a Macroscopic Fundamental Diagram describe? Make sure your answer shows clearly the differences between an MFD and a fundamental diagram.** (2)

(b) **What is qualitatively the effect of inhomogeneity in the network on the MFD? (No explanation needed)** (1)

(c) **In Lagrangian coordinates, the fundamental diagram is often expressed in spacing (horizontal) - speed (vertical) form. Sketch a fundamental diagram in the spacing-speed plane** (2)

2. From car-following to a fundamental diagram

Total for Question 2: 8

The optimal velocity model is a car-following model specifying the acceleration a as follows:

$$a = a_0(v^* - v) \tag{1}$$

In this equation, v is the speed of the vehicle, and a_0 a reference acceleration (tunable parameter, constant for a specific vehicle-driver combination). v^* is determined as follows:

$$v* = 16.8(\tanh(0.086(\Delta x - 25) + 0.913)) \tag{2}$$

In this equation, Δx is the distance (in meters) between the vehicle and its leader.

(a) **Explain qualitatively the working of this car-following model; i.e. comment on these two equations.** (2)

(b) **What are the conditions for which a fundamental diagram holds?** (1)

(c) **Derive the expression a fundamental diagram (flow as function of density) for these conditions using the OVM model** (4)

(d) **What are the values capacity, free speed and jam density (either derive the value or use you graphical calculator to determine this – you may round numbers to the precision of your liking...)** (1)

3. MOBIL lane change model

Total for Question 3: 3

Consider the mobil lane change model. A driver c has several options: change lanes to the left, to the right or stay in his current lane. For each of the options a total utility (denoted U_{tot}) can be calculated.

$$U_{\text{tot}} = U_c + p \sum_{i \in \text{other drivers}} U_i \tag{6}$$

The utility for the driver i U_i is assumed to be its instantaneous acceleration, as computed using a car-following model (the Intelligent Driver Model – although the specific model is not relevant for the question). The driver is assumed to take the option with the highest utility.

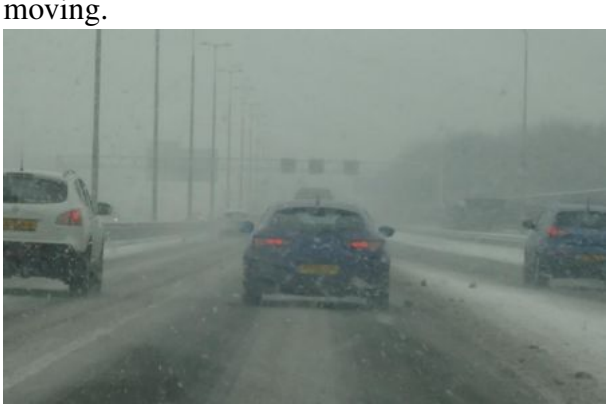
(a) **Explain the working of the model in words** (2)

(b) **What value for p can be expected** (1)

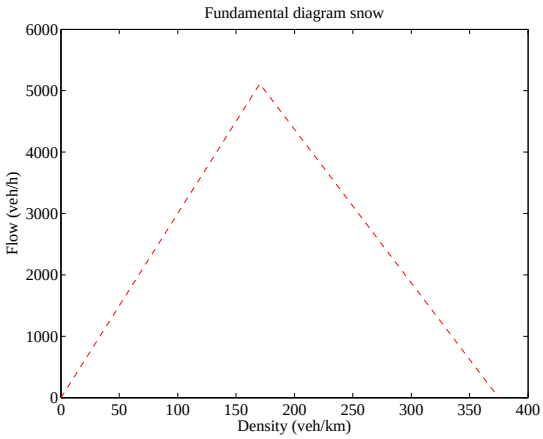
4. Snow plow

Total for Question 4: 9

During a winter night, a 30 cm snow covered a three lane motorway fell. Traffic is still moving.



This changes the traffic operations. Assume a triangular fundamental diagram. The free flow speed reduces to 30 km/h, the jam density to 125 veh/km/lane. The capacity is 5000 veh/h.



A truck spins and cannot move further, thereby blocking the road completely, not allowing other vehicles to pass. This leads to a traffic jam. The inflow is 1000 veh/h.

(a) **Draw the resulting traffic operations in a space time plot and in the fundamental diagram. Calculate all shock wave speeds.** (4)

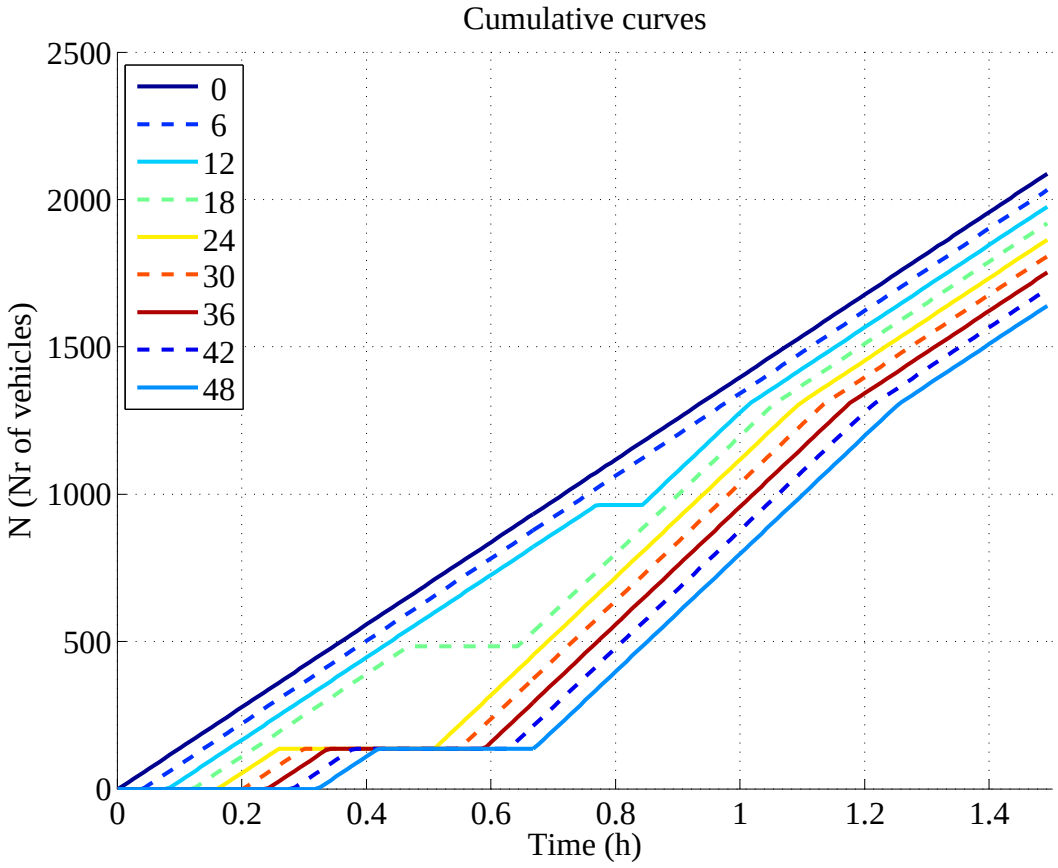
A snow plow comes to free the vehicles that are stuck. After freeing the vehicles, the snow plows clear two of the three lanes of the motorway. Thereby, they drive at 5 km/h on the motorway. The capacity of vehicles passing the snow plough on the left lane is 2000 veh/h. The inflow on the road is 1000 veh/h.

(b) **Sketch the traffic operations in a space-time plot and in the fundamental diagram. Explain how you construct the graphs. (No point given here for the beginning, discussed in question b)** (5)

5. Cumulative curves

Total for Question 5: 13

The graphs show cumulative curves for different locations along the road. The legends shows the distances in km from the beginning (i.e., upstream end) of a road. For the remainder of the question, reasoning is more important than exact readouts from the graph. When using graph readouts, please state so explicitly and *note the values you read from the graph*.



(a) **Explain the traffic state, mention a possible cause (e.g., "different speed limits for different sections", "peak hour jam") and explain why** (3)

(b) **Estimate is the total delay encountered here** (3)

(c) **Sketch the traffic situation in space-time (shock waves – no trajectories needed).** (3)
Estimate the the location of changes in traffic states.

Assume a triangular fundamental diagram.

(d) **Estimate, from the given curves, give the free speed, capacity, critical density and jam density** (4)

6. Crown jewels in the tower

Total for Question 6: 5

We consider an exhibition with the most important piece an object in a small glass show case in the middle of the room. Visitors do not have a preference to see a particular side of the piece. The room is 15 meters long and 6 meters wide.

(a) **Explain why a larger glass show case can increase the capacity of the exhibition room, in terms of visitors per unit of time** (2)

An alternative design is considered. Instead of the visitors walking by the art, the visitors can stand on a moving walkway (like in the airport), which is constructed at each side of the glass. Visitors step at the moving walkway at the beginning of the room, and step off at the end. They are not allowed to walk backwards on the moving walkway.

(b) **What is the capacity of the room in this case. Base your answer on (explicitly stated) reasonable assumptions on distance and speed.** (3)