Name:	First name:	Matrikel number:

Exam to the Lecture Traffic Dynamics and Simulation SS 2022

Total 120 points

Problem 1 (20 points)

(a) Describe, in one sentence, the difference between microscopic and macroscopic traffic flow models. Give the main dynamical variables of each model class.

(b) Determine if, in following situations, microscopic or macroscopic models are better suited. Justify your decisions in a few words.

(i) Generating the surrounding traffic in driving simulators,

(ii) traffic state estimation and short-term prediction,

(iii) determining the efects of speed limits on the traffic flow,

(iv) real-time traffic-dependent navigation,

(v) determining the efects of assisted or autonomous vehicles on the surrounding traffic flow.

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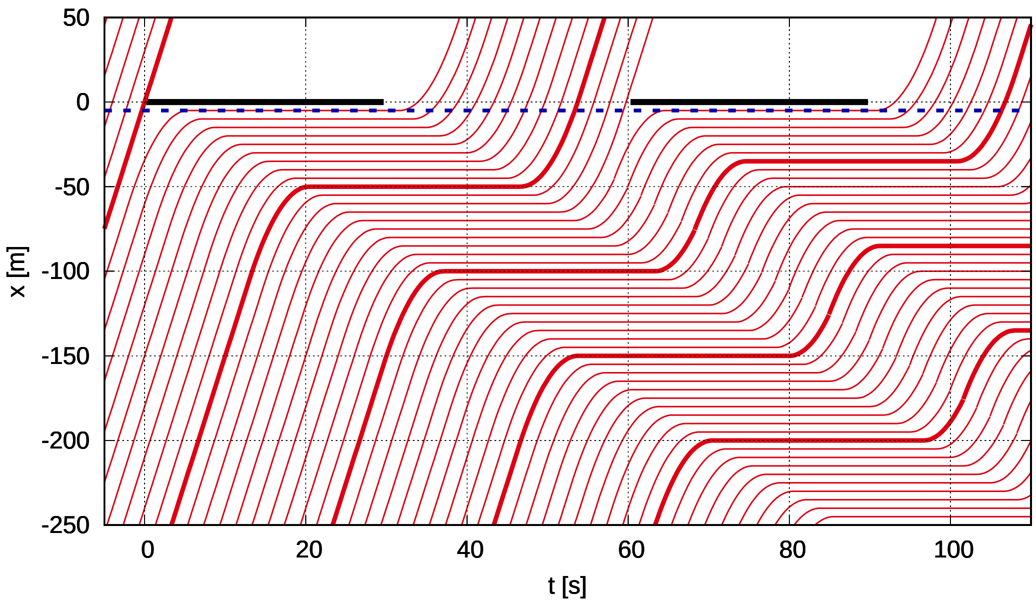
Problem 2 (40 points)
Given are trajectories of cars near a signalized intersection with the traffic light at $x = 0$ (red for the times where the thick black lines appear). Every 10^{th} trajectory is drawn as a thicker line.



(a) Determine the maximum density ρ_{max} during the queuing phases and the maximum outflow $Q_{\text{max}} = Q_{\text{out}}$ at $x = 50\,\text{m}$ during the green phases.

(b) Determine, for $x < -100\,\text{m}$ and $t < 20\,\text{s}$, the flow, density, and (free-flow) speed v_0.

(c) Determine the cycle-average capacity of the signalied intersection. Is this capacity sufficient for the actual demand?

(d) Determine the wave velocity w of the congested $\to$ free transitions.

(e) Draw the fundamental corresponding to these trajectories assuming it is tridiagonal.

(f) The cross section detector near the stopping line (blue dotted line) records following data during one cycle of 60 s:

Time [s]	34	38	40	42	44	46	48	50	52	55	56	58	60
Speed [km/h]	3	14	26	35	41	46	50	51	51	51	51	51	51

Assuming an aggregation time interval of 1 min, determine the point $(\rho_{\text{data}}, Q_{\text{data}})$ obtained from the data when using the arithmetic mean speed V and estimating the density by $\rho_{\text{data}} = Q_{\text{data}}/V$. Draw this point into the fundamental diagram (FD) and discuss why this point does not lie on the FD.

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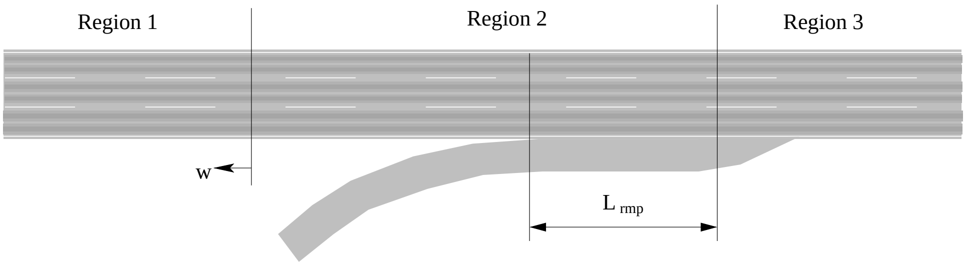
Problem 3 (40 points)

Given is a three-lane freeway section with an onramp:

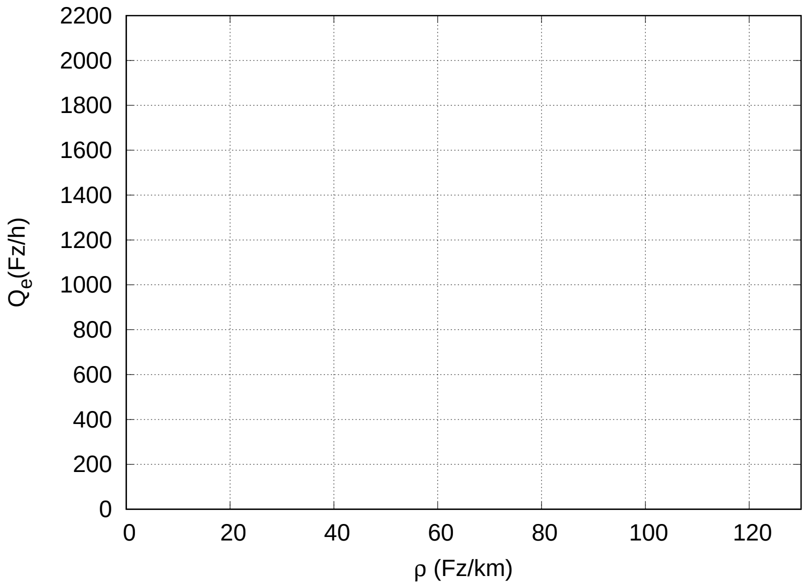


Traffic flow is described by a LWR model with the tridiagonal fundamental diagram

$$Q_e(\rho) = \min\left[V_0\rho, \frac{1}{T}\left(1 - l_{\text{eff}}\rho\right)\right].$$

(a) On the main road, there is a constant total demand of 3 600 veh/h, and on the onramp 1 200 veh/h. Give the ramp term of the continuity equation for the lane-averaged quantities in the merging section ($L_{\text{rmp}} = 300\,\text{m}$).

(b) During normal weather, the tridiagonal FD parameters are given by $v_0 = 126\,\text{km/h}$, $T = 1.5\,\text{s}$ und $l_{\text{eff}} = 8\,\text{m}$. Plot the fundamental relation for the lane-averaged quantities into following diagram:



(c) Determine if the infrastructure can take the demand during normal weather, i.e., the capacity in all regions is higher than the demand.

(d) During a strong thunderstorm, people drive more defensively resulting in parameter changes to $v_0 = 72\,\text{km/h}$ and $T = 2.1\,\text{s}$ (the effective length is unchanged). Draw the changed fundamental diagram in the above diagram as well.

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(e) Show that, during the thunderstorm, the infrastructure can no longer satisfy the unchanged demand, so a traffic breakdown happens on the main road (we assume no jam on the onramp). Determine the flow (per lane) and density (per lane) in the congested region and calculate the propagation velocity of the upstream jam front free $\rightarrow$ congested.

Problem 4 (20 points)

Consider the decision situation where the driver of a stopped vehicle wants to enter a priority road at an unsignalized intersection.

(a) Formulate the safety and incentive criteria and argue that the incentive criterion is always satisfied for this type of decision.

(b) In order to safely enter, arriving vehicles on the priority road may need to brake by at most a critical deceleration $b_{\text{safe}} = 2\,\text{m/s}^2$. Determine the minimum gap to an arriving main-road vehicle as a function of its speed v using the IDM+ with the parameters $a = b = b_{\text{safe}}$

Hint: The IDM+ with acceleration $\dot{v} = \min(a_{\text{free}}, a_{\text{int}})$ only leads to decelerations if $v > v_0$ (not assumed), or if the minimum function selects the interacting part $a_{\text{int}} = -a(s^*/s)^2$.