Exam 4821

Duration – 3 hours. Points are indicated for each question.
The exam has 5 questions
54 can be obtained. Note that half of the points is not always suffcient for a 6.
Use your time wisely!

Remarks:
– Allowed: calculator (but no smartphones...)
– Not allowed: working with pencil (use a pen instead)
– Put labels at all your graph axes
– For some questions, a indcative number of words is given as guidance for the required level of detail. Your answer may be shorter or longer. It will be judged on the good elements in there, but for all wrong answers points will be deducted.
– Make sure you provide the calculus procedure as well as the result in order to get the maximum points.

1) Short questions (12 points)

A road has a capacity of 2000 veh/h, a free flow speed of 120 km/h, a critical density of 25 veh/km and a jam density of 150 veh/km.

a) Draw a realistic fundamental diagram in the with the above properties, both in the flow-density plane and in the speed-density plane; indicate how speed can be found in the flow-density diagram. (4 pt)

b) Describe briefly (100 words) the assumptions in Daganzo's theory of slugs and rabbits (3 pt)

Slugs stay always in the right lane (1)
Rabbits choose the fastests lane (1)
Free speed of rabbits is higher than the free speed of slugs (1)

c) What are cumulative curves, and how are they constructed? (1 pt)

A count of the number of vehicles over time at one location (1).

d) What is a vertical queing model and how is this related to cumulative curves (2 pt)

A model describing the inflow and outflow of the vehicles, with a restriction on the maximum outflow rate. The queues will not occupy any horizontal space (1). This is basically two cumulative curves, inflow and outflow, at one location, in which the angle of the outflow is maximized at capacity (1).

e) What is higher, the space mean speed of the time mean speed? Why? (1 pt)

Time mean speed, since the faster cars are weighted higher (1)

f) How can the space mean speed be calculated from individual local speed observations v_i. Give an equation. (1pt)

u=1/sum(1/vi)

2) State recognition (9,5 points)

a) What are the phases according to three-phase traffic flow theory? How are they characterised? (2 pt)

1) Free flow => free driving + spee
2) Synchonized flow => equal speeds in both lanes, speeds <70 km/h
3) Wide Moving Jams => backwards travelling waves, v very low.

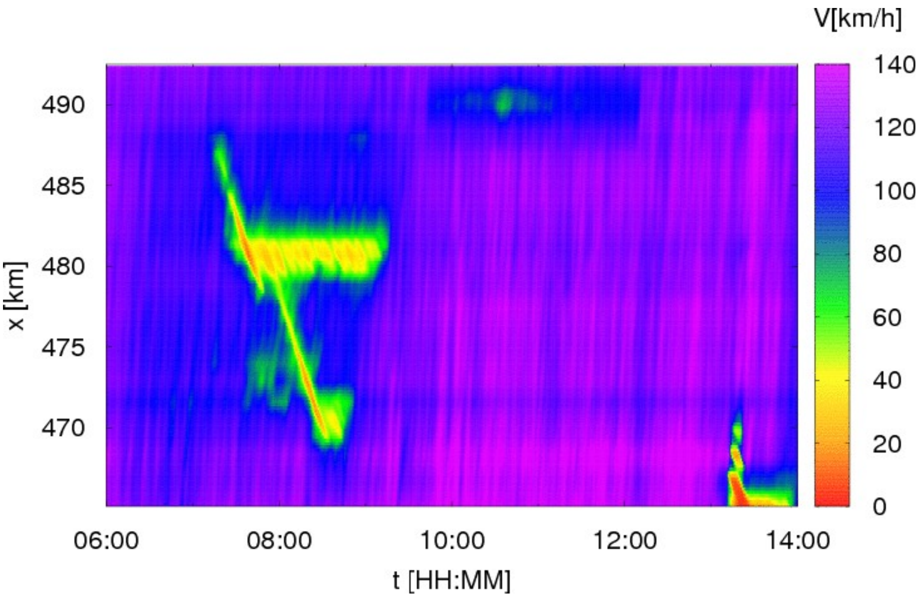
(1 point for names, 1 for definitions)

Below, you find some traffic state figures from www.traffic-states.com. For each figure, indicate:

I) The driving direction (top-down or bottom-up) and *explain why* based on traffic flow theory (0,5pt per figure, spread over b-d) and

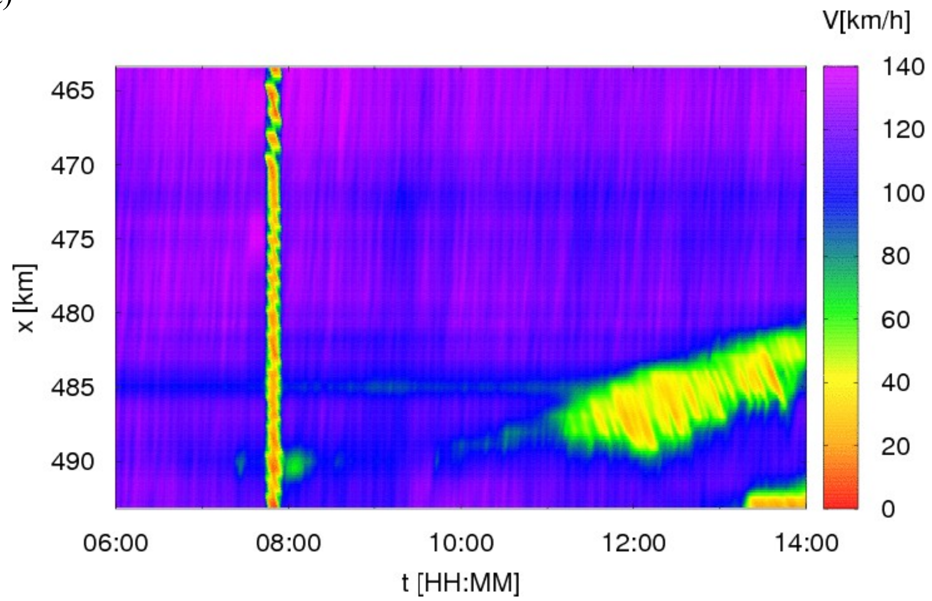
II) the traffic characteristics present, and the most likely causes for these (6 pt, spread over b-d)

b. (up to 10.00 am) (2 pt)



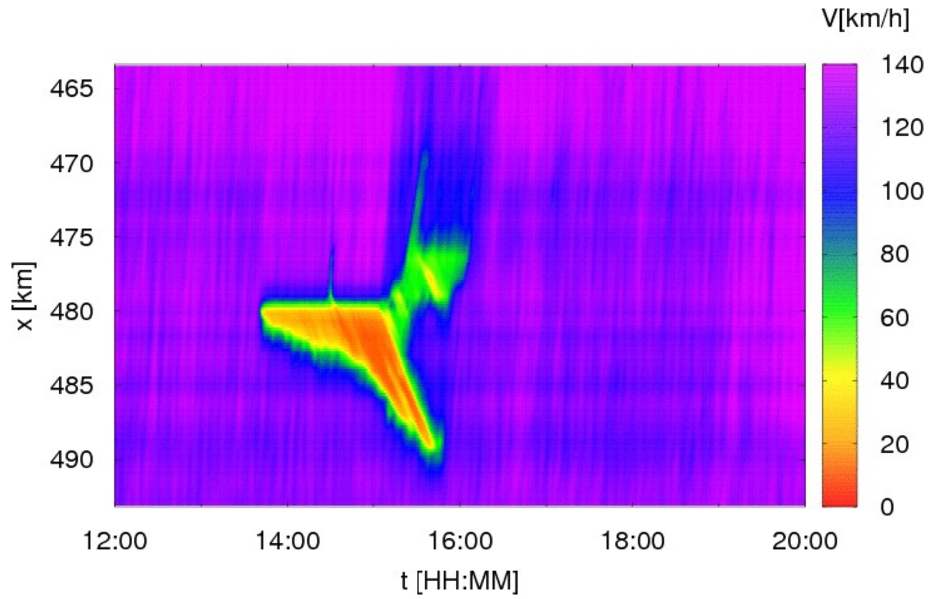
Down-top => stop-and-go wave travelling backwards (0.5)

Stop -and-go wave (0.5) and a local bottleneck at 482 (0.5) causing an area of synchronised flow (congestion) (0.5) c (3 pt)



down-top. Finer structure within the congested part. (0.5)
Moving bottleneck (0.5) => structure moves upstream (1)
Data error at 8am (1)

d (3.5 pt)



down-top, from the shockwave speeds (0.5)
Incident (1)
Synchronized flows (and stop-and-go waves) (1)
Queue outflow at capacity after resolving (1)

3) Simulation model (11 points)

a) Explain briefly (indication: 100 words) Newells car-following model. Also plot a space-time diagram indicating these properties. (3 pt)

Trajectory of vehicle is its leaders' trajectory delayed in time (1) and moved backwards in space (1).

b) Name the three types of (in)stability in traffic flow, and explain briefly their effect (50 words and 1 graph per type) (3 pt)
   1) Follower-leader (local) => overreaction on distirbance in one leader-follower pair
   2) Platoon => disturbance grows in a platoor
   3) Traffic flow => space between platoons is insufficient, so a disturbance in a platoon causes a delay in the next platoon

c) Can multi-anticipation improve stability? Which type and how? (3 pt)
   Yes. Smoothing (1) of distrurbances improves platoon stability (1). Thereby, the amplitudes of a disturbance are reduced (1).

d) How can lane-changing cause a breakdown? (50 words) (1 pt)
   A slower vehicle can merge into another lane, which causes a disturbance, growing to a breakdown (1)

e) How can lane-changing prevent a breakdown? (Hint: use the lane distribution.) (2 pt)
   Now the lane distribution is uneven (1). If vehicles change towards lanes with lower densities, a jam might be prevented (1).

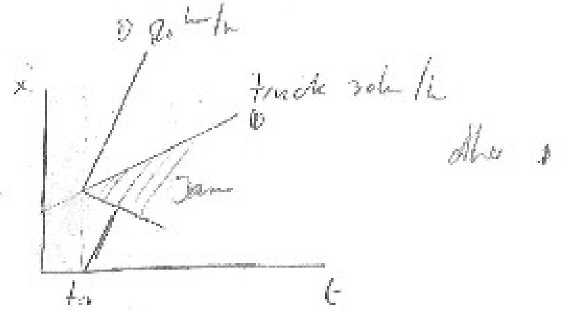
4) Moving bottleneck (12 points)

Imagine a truck drivers strike in France on a 3-lane motorway from time t=t0. For the road you may assume a triangular fundamental diagram with a capacity of 2000 veh/h/lane, a critical density of 25 veh/km/lane and a jam density of 125 veh/h/lane. Suppose there is no traffic jam at t<t0, and a constant demand of 5000 veh/h. Assume the truck drivers drive at 30 km/h, not allowing any vehicle to pass.

a) What is the maximum flow on the road behind the trucks? (3 pt)

Use the triangular fundamental diagram. For the congested branch, the equation is q=2000-2000/100*(k-25). From the speed we q=kv=30k. Solving this set of equations (1), we find k=50, and thus the flow of 30*50 = 1500 veh/h (1)

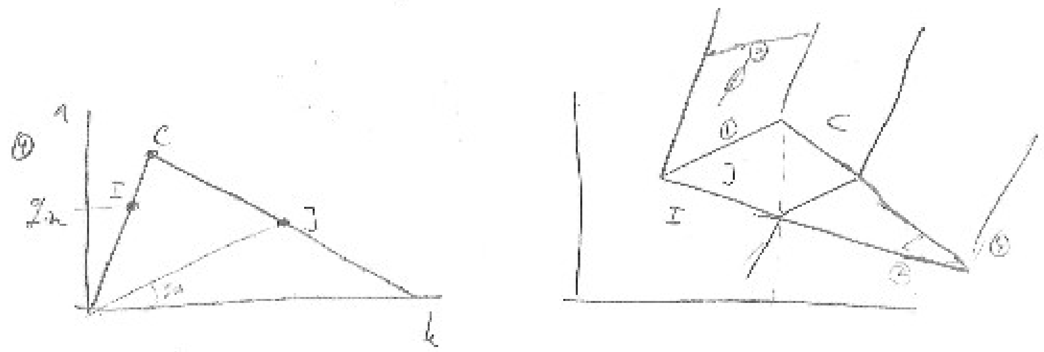
b) Sketch the traffic flow operations in a space-time diagram. Pay attention to the direction of the shockwave, and note the propagation speeds of the other waves. (3 pt)



Starting with shockwave theory can be rewarded with 1 pt.

After a while, the trucks leave the road.

c) Sketch again the traffic operations in the space time diagram. Do this until the traffic jam is solved (if applicable), or until the traffic states propagate linearly if demand does not change. (3 pt)



d) What is the speed at which the tail of the queue propagate backwards? (1 pt)
in I: flow 5000 veh/h, and density 62.5 veh/km, using the equation for the cognested branch used in e (1 point). In J: q=4500 veh/h, k=150 veh/km. Wij=-500/87.5=-5.7. So it moves with 4.7 km/h upstream (1).

e) In the plot of question 2, draw the trajectory of the vehicle arriving at the tail of the queue at the moment the strike ends (Use a different colour or style than the shockwaves). What is the speed of the vehicle in the jam? (2 pt)
See line in c) (1). Speed is equal to the truck speed, 30 km/h. (1)

5) Marathon Delft (9 points)
Imagine a marathon organised in Delft. There are 30.000 participants, starting at a roadway section which is 25 meters wide.

a) Give a realistic estimate for the capacity of the roadway in runners per hour. Base your answer on the width and headway of a runner (3 pt)

Width of a runner 75 cm (1 point for 50-100 cm), headway 1.5 sec (1 point for 0.9 – 2 seconds).
25 meters / 0.75 = 33,3 runners per roadway (both this, and the rounded values are correct).
The capacity is 33,3/0,75 x 3600 = 73,200 pedestrians per hour.

b) How long would it take for all runners to start? (1 pt)
30,000/79,200 * 60 min/h = 23 min. (1)

Suppose the runners have uniform distribution of running times from 2.5 to 4.5 hours, and all run at a constant speed.

c) Given your answer on question 5a, what width of the road is needed halfway the track? For reasons of simplicity, you may assume that they all start at the same moment (instead of your answer at question 5b). (5 pt)

Halfway: 1 hour duration of the passing of all runners (1)
30,000 runners in 1 hour -> 30,000/60 = 500 runners per min. (1)
Assumed earlier: 75 com width, 1.5 second headway → capacity 1/(0.75 * 1.5) = 0,89 ped/m/s = 53 ped/m/min (1)
The required width: 500/53 = 9,4 meters. (1)