The **ScienceMath**-project: **Modelling Things in Traffic**

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Teaching Material

Worksheets and tasks (see next pages)

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Modeling things in traffic

1. What is a safe duration of the yellow light?

You probably know why most traffic signals have a yellow light which is turned on just before the red light switches to green, and just before the green light switches to red. Do you know why there is a yellow light in each case? In the following assignments you are going to discuss the best duration of yellow light when the signal switches from green to red.

Assignment 1.1: Try to get an overview of which factors should play a role in your decision on the duration of the yellow light before the signal changes to red. List these factors. You might want to draw some sketches of different situations in order to decide which factors are important.

Assignment 1.2: Based on the factors above, formulate in as simple terms as possible a *verbal model* or rule of thumb about the duration of the yellow light.

Stopping a car: The stopping distance of a car is determined by many factors including (1) the velocity of the car, (2) weight of the car, (3) the ability of the car's brakes, (4) the conditions of the tires, (5) the condition of the road's surface and (6) the reaction time of the driver.

Assignment 1.3: Discuss how changes in each of the mentioned factors influence the stopping distance of a car. During your discussion you can draw force arrows and other features that are at play in situation when a driver applies the brakes on a car. You can use the picture below.

Assumptions to a simple model

When we try to make models of systems such as a car which is put to a halt, we often need to simplify matters a bit. We do this by choosing to focus on some factors in the system. The factors we choose to focus on are factors which can vary and the factors which we choose not to focus on are assumed to be constant.

A simple model helps us to understand the system better. But we must always remember to choose our factors with great care. Always ask yourself why we should choose to focus on this factor rather than other factors. And remember: The simple model we produce can always be made more complex (and more "realistic") so that it includes more factors.

Before the next assignments we will make some assumptions so that the models you are going to make will be simple enough to understand but complex enough to get a good sense of the situations.

We propose that you focus on the following factors as variable: (A) the velocity of the car and (B) the condition of the road. This means that we propose that you should proceed as if all the other factors are constant. So we propose that you begin by treating all cars as having roughly the same weight, ability of brakes and tire condition, and that each driver has the same reaction time. Remember, when you later want to make your model more complex you can begin to think about how to include e.g. the weight of the cars as a variable factor.

You must always be reflective about the factors you choose to be constant. Here we will ask you to work with two of the mentioned factors.

Reaction time: The reaction time of the driver is a very important factor when we want to calculate the stopping distance. The reaction time $\mathbf{t_r}$ is given by the time elapsed between receiving a sensory stimulus (such as seeing the lights change) and the appropriate response (e.g. applying the brakes of a car).

Test it yourself 1.1: Try to search for "Online Reaction Time Test" on the internet and use different sites to test your reaction time. You can enter the results in a spreadsheet and find you average reaction time. But remember that your reaction time in front of the computer will be significantly shorter than if you were in traffic.

Deceleration: When we talk about the *braking ability* of a car we refer to how fast it is able to decelerate its velocity to 0 km/h. The braking ability varies considerably from car to car and depends very much on the surface and tire conditions. On wet or icy surfaces a car will decelerate much slower. The unit for deceleration is – as for acceleration – meters per second squared. Can you explain why this is so?

Test it yourself 1.2: You can make this test in two ways: Either with your bike (with a cycle computer which measures speed) or with a car on a private road. If it is possible you can video record the test. Try to move the car/bike at a constant speed and then apply the brakes when you pass a designated mark e.g. a tree or signpost. Measure your *stopping distance* at different velocities. If you record the test on video you can analyze the situation in detail. If you assume that the deceleration was constant, you can calculate the deceleration of your bike/car at different velocities. Draw some graphs of your findings.

Friction: As mentioned, a car will have a much longer braking distance on wet or icy surfaces. Why is this so?

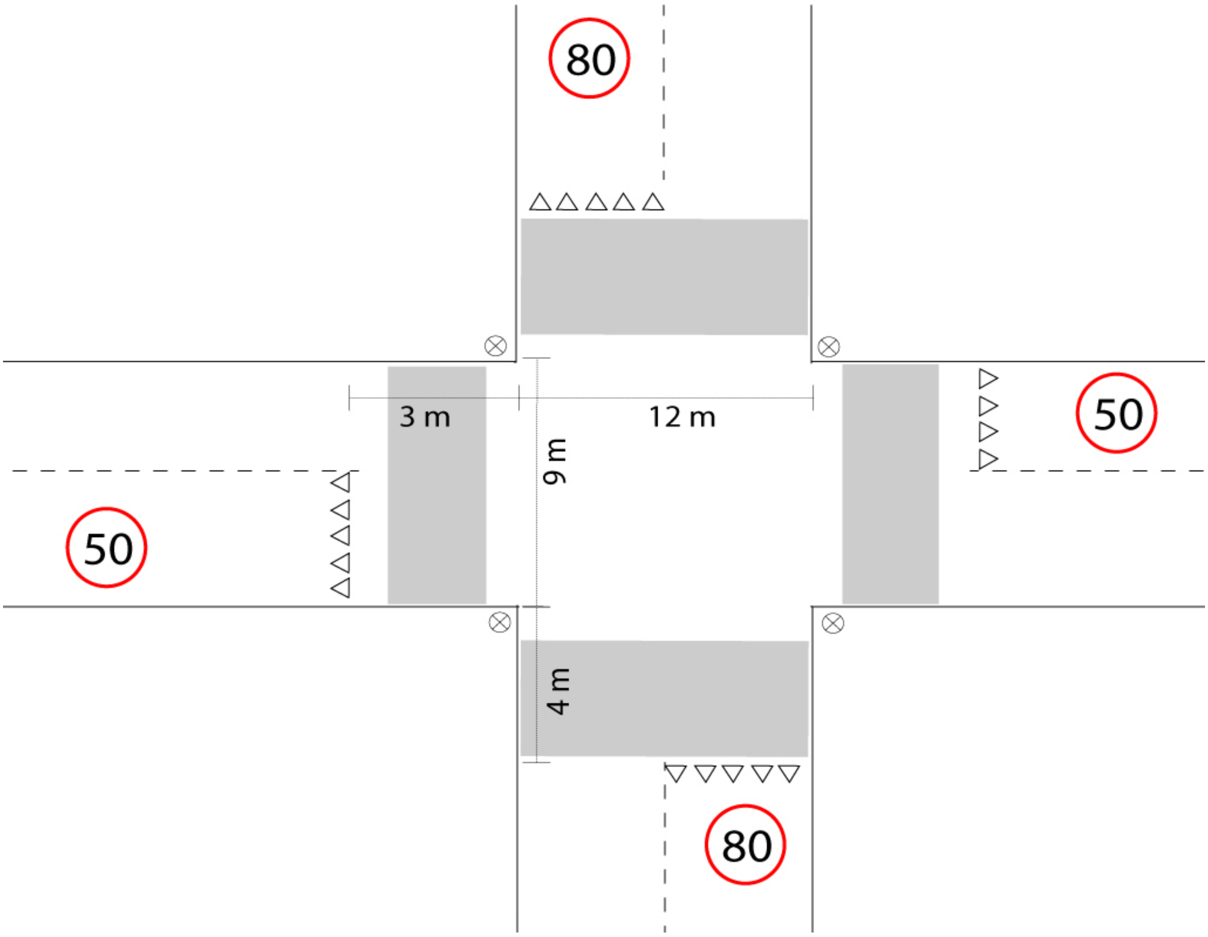
Test it yourself 1.3: There are a number of ways you can test this. Take for instance a heavy and rectangular metal block and slide it on a level dry surface such as your table. Measure how long it travelled from the point where you let it go to the point where it stopped. Now do the same with water on the table, and with vegetable oil on the table. (If it is freezing outside you can try to do it on an icy puddle as well). Remember to slide it at a relatively even velocity. Record your findings in a table.

We are now ready to prepare for our simple model. We will assume, for the sake of the simple model, that the following is true for each vehicle passing a traffic signal

(1) The driver's *reaction time* is constant at 0,6 seconds
(2) The cars do not travel faster than the prescribed maximum velocity
(3) The *deceleration* of a car when the brakes are applied is constant at
   a) $-8\ m/s^2$ when the roads are dry.
   b) $-4\ m/s^2$ when the roads are wet.
   c) $-2\ m/s^2$ when the roads are icy.

The values of theses constants are somewhat standard values for average drivers of average SUVs. But you should briefly discuss how these values correspond to your findings above. If there is a significant difference try to explain that difference. Were your tests good tests? What could be improved?

Assignment 1.4: You have to decide the duration of the yellow light in the crossing sketched below. (The maximum velocities are given in km/h).



Assignment 1.5: For this assignment you need a long measuring cord and a stopwatch. Go to a crossing near your school and measure the width of the intersection. Then draw a picture like the one above of that crossing. Now measure the duration of the yellow light. Is that an appropriate duration?

2. What is the safe velocity in a bend?

For the next series of assignments you need to do some preparations. You must find a road with a relatively sharp bend. Now you have to model the bend. You must first simplify the bend and consider it as part of a circle so that the middle of the road constitutes a part of the circumference of that circle. Give an estimate of the radius of that circle.

Assignment 2.1: Consider a bend like the one on the sketch below. The driver's vision is cut off by a tall sound screen (hedge). Needless to say, it is imperative that the driver has ample time to brake her car if someone in front of her brakes. In bends like the one sketched below the visibility of the driver plays a huge role. Use the data from your preparation and imagine that the bend you have modeled is installed with a tall hedge. What is the maximum safe velocity for a car to drive in that bend?