

Analysis and significance of Pembrey Test results

Basic Definitions

$$\text{Overall Steering Ratio} = \frac{\text{Steering Wheel Angle}}{\text{Road Wheel Angle}}$$

So

$$\text{Road Wheel Angle} = \frac{\text{Steering Wheel Angle}}{\text{Overall Steering Ratio}}$$

Neutral Steer

The SAE defines neutral steer as :

A vehicle is neutral steer at a given trim if the ratio of the steering wheel angle to the overall steering ratio [ie the actual steered wheel angle] equates to the Ackerman steering angle for a given radius of turn.

Ackerman Steering

Ackerman steering angle δ (*delta*) is the geometric steered wheel angle required for a car of wheelbase L to track round a turn of radius R at low speeds where the external forces due to accelerations are negligible so $\delta = L / R$ for small angles.

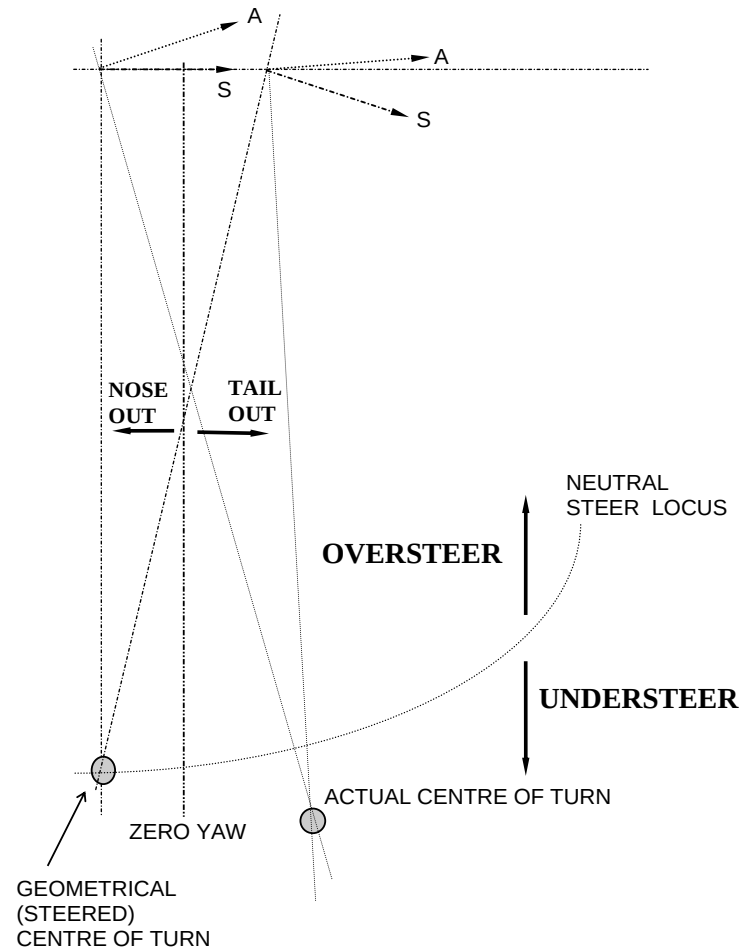
Understeer

A vehicle is understeer at a given trim if the ratio of the steering wheel angle to the overall steering ratio is greater than the Ackerman steering angle for a given radius of turn

Oversteer

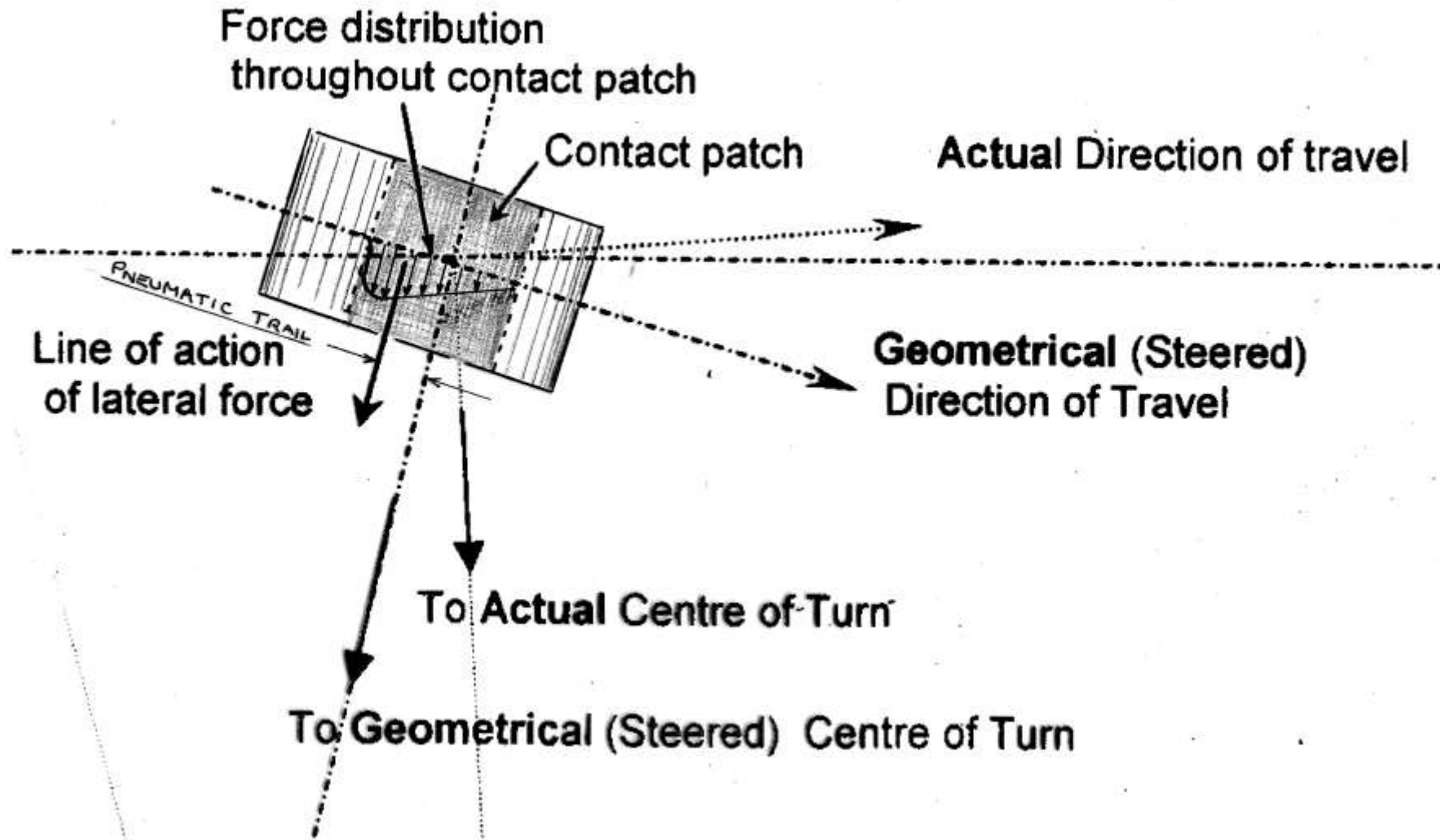
A vehicle is oversteer at a given trim if the ratio of the steering wheel angle to the overall steering ratio is less than the Ackerman steering angle for a given radius of turn

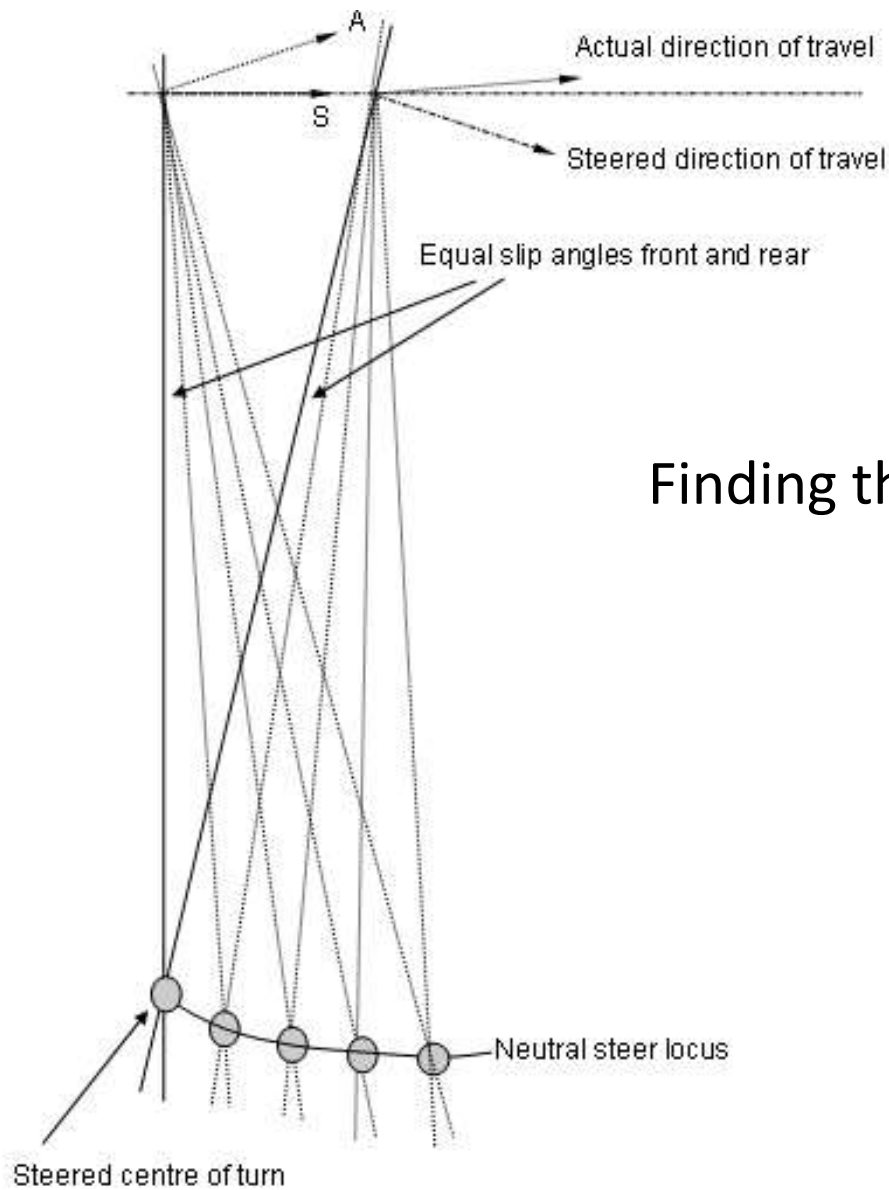
Geometrical method of demonstrating oversteer and understeer



If the centre of turn is closer to the car than the neutral steer locus the car will be oversteer and if it is beyond the locus it is understeer .

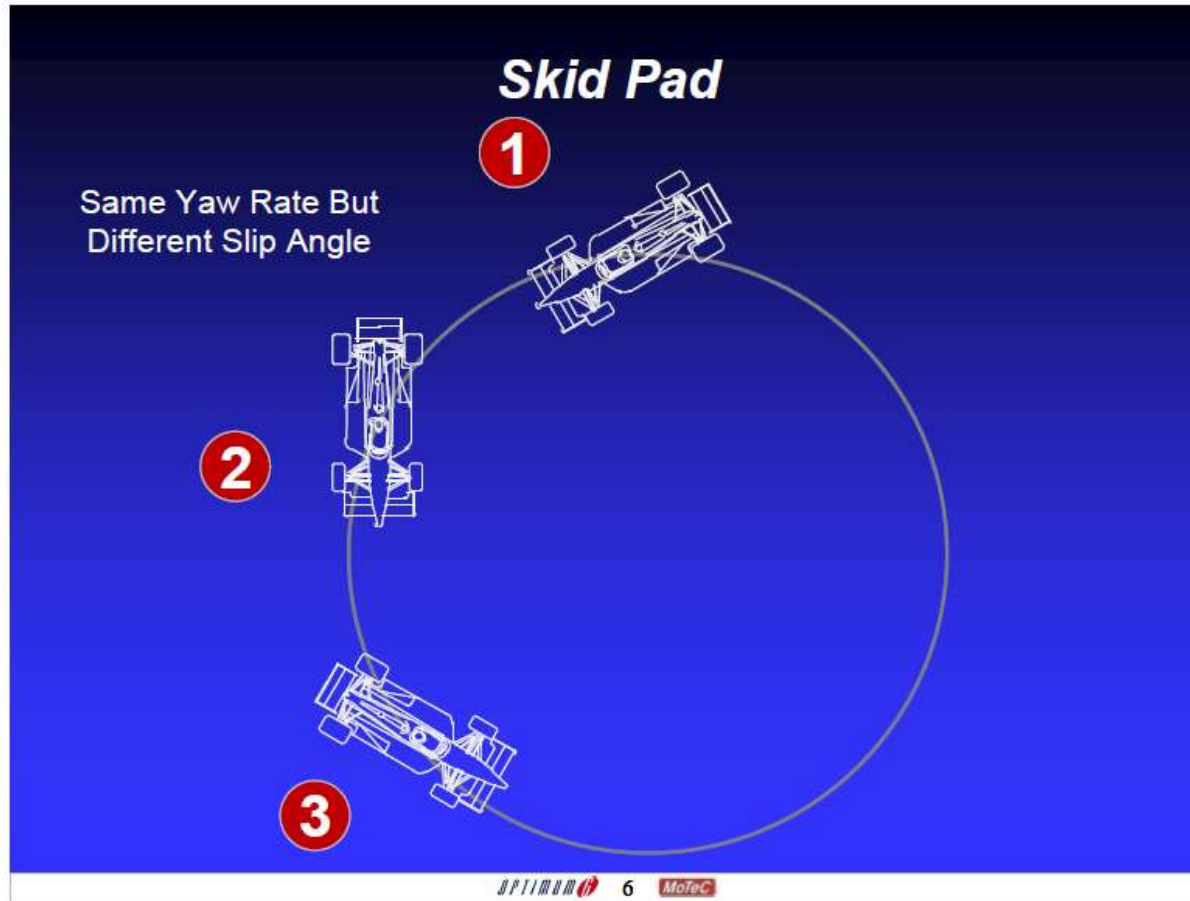
So the car shown is understeer with tail out attitude.





Finding the neutral steer locus

Tail out cornering on the skid pad

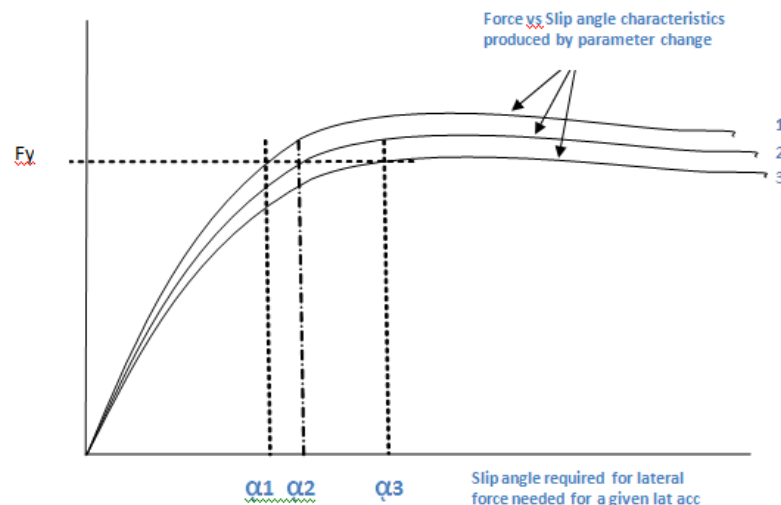


Assignment aim

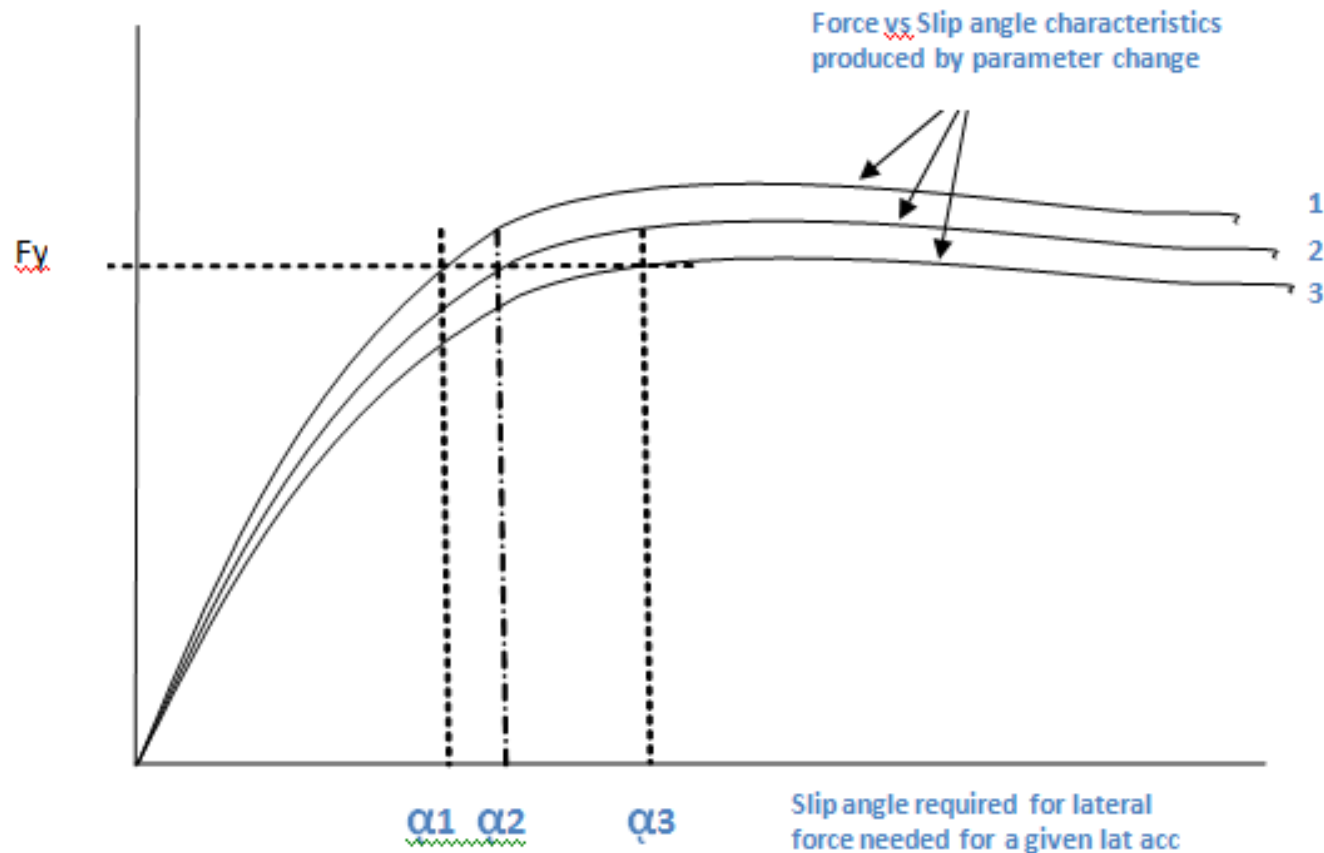
The aim of the assignment is to demonstrate the change in vehicle behaviour produced by the change in parameter that you are adjusting - tyre pressure or damper setting

Using the steer angle to demonstrate changes in grip

If something is done to the front axle of a car that increases the grip characteristic from Level 3 to Level 1 the slip angle required to produce the force required for specific lateral acceleration will change from α_3 to α_2



Slip Angle vs lateral force characteristics for a range of parameter values



Using Steer Angle in Place of Slip Angle

If the steer angle is used rather than slip angle (as an easier parameter to measure) the parameter value that give the maximum grip can be found.

By finding the steer angle required to enable a car to achieve 0.6g lateral acceleration for each of a range of parameter values – eg 10 to 30 psi tyre pressure, the way grip changes with the parameter can be highlighted.

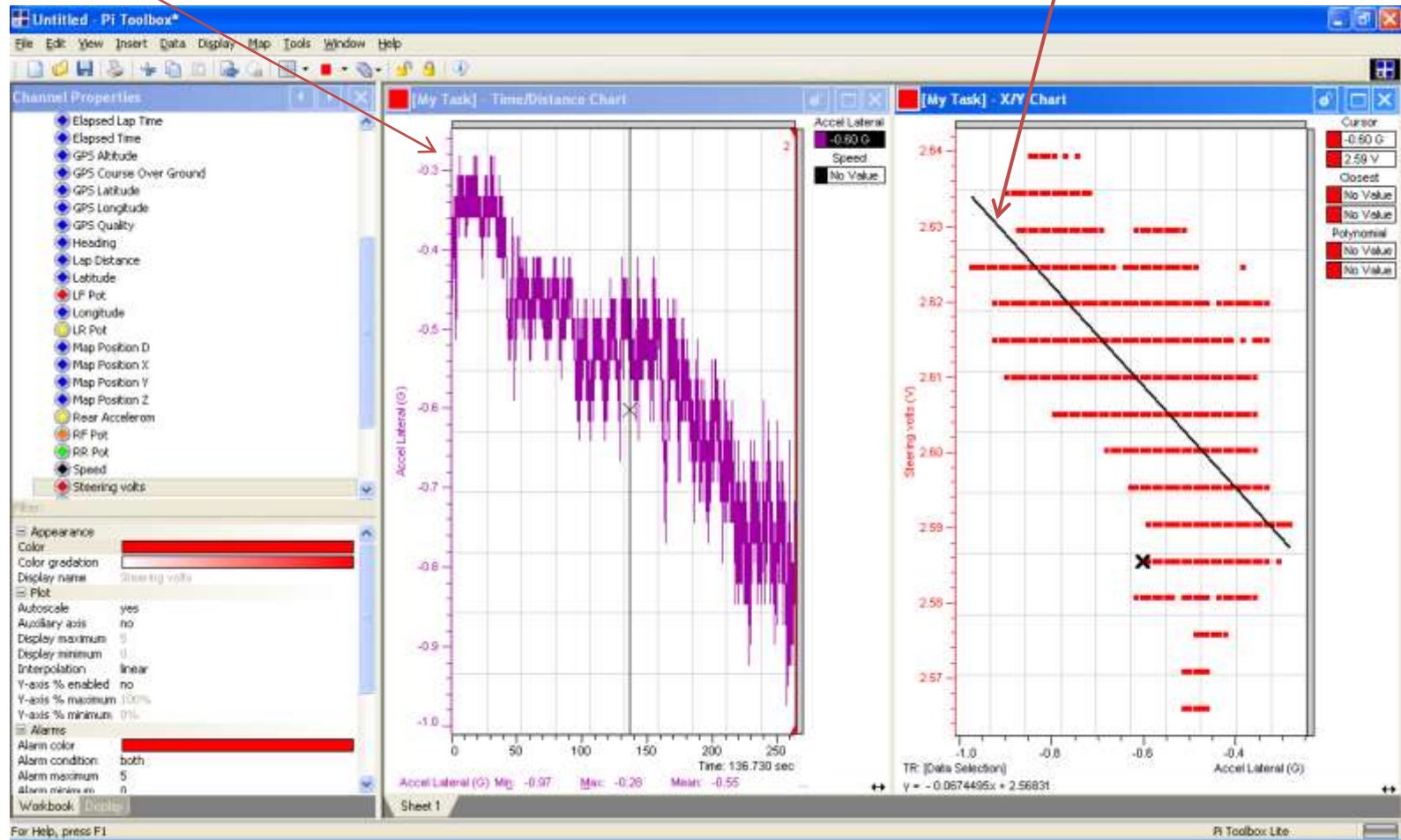
Obtaining a valid steer angle vs lateral acceleration value

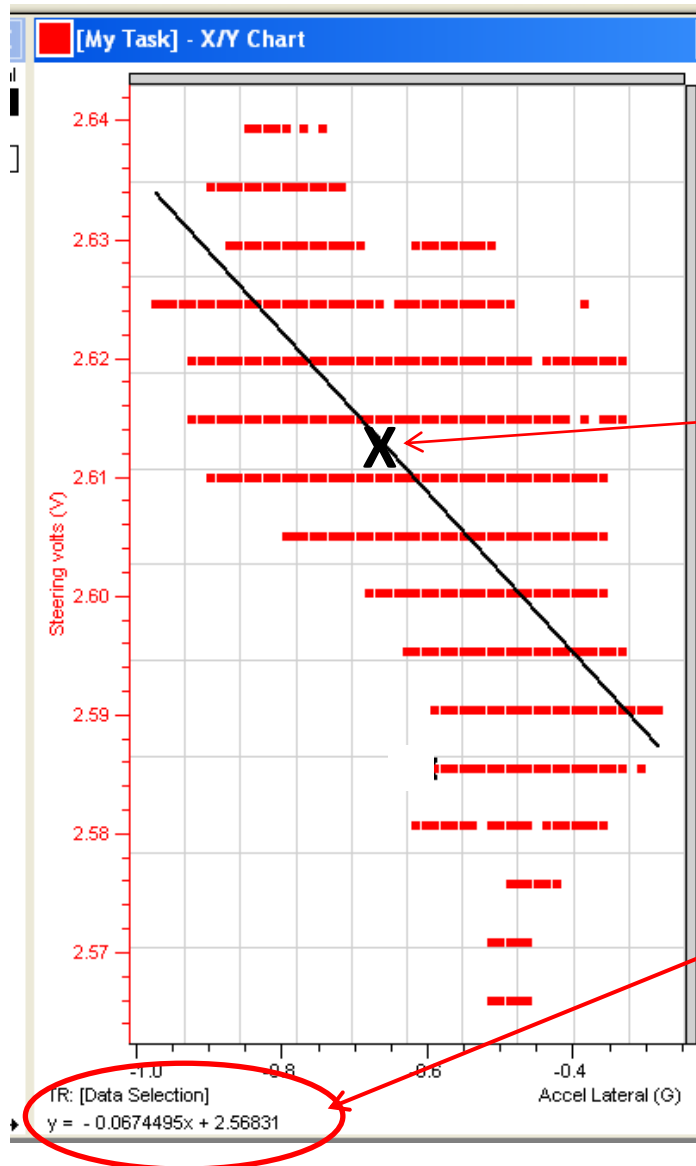
In the assignment you will be measuring the steer angle as the car travels round the steering pad. There is a great deal of 'noise' in the data and it would be hard to obtain a valid value for steer angle by looking at one instant in time.

By measuring thousands of points in a full test run, however, a mean value can be found by plotting a trendline that represents all those points to give a valid value for the steer angle at a particular lateral acceleration

Select a series of laps with a constant change of lat acc

Insert an XY plot in the work sheet and add a linear trendline



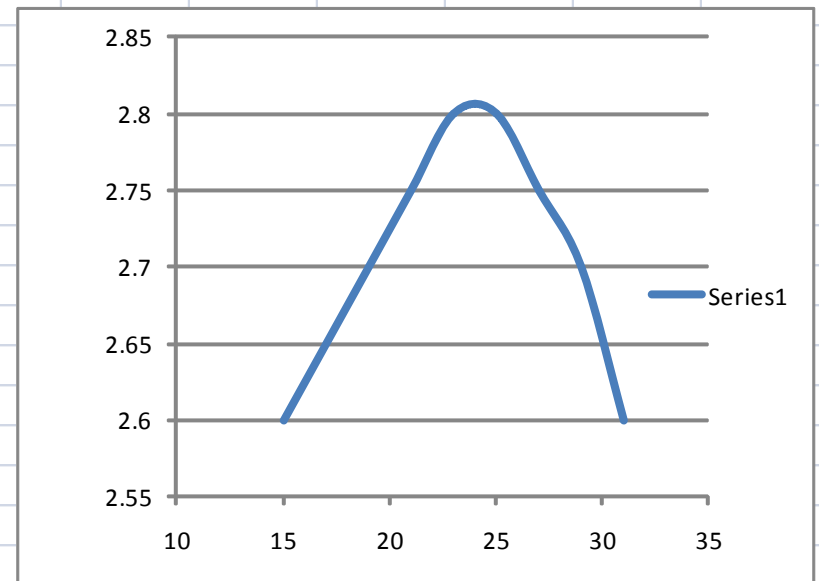


Find the value of the steering angle at a relatively high lateral acceleration so that the parameter has a significant impact on the handling balance. You can either do this by moving the cursor on the trendline to the chosen lateral acceleration and then noting the steering volts.

or
Put the lateral acceleration into the equation of the trendline

Repeat this exercise for each parameter value and then plot parameter value against steering volts. The example shows the effect of front tyre pressure with the peak steering voltage indicating the minimum steering angle and hence where maximum grip is occurring at around 25psi

Tyre Pressure	Steering Volts
15	2.6
17	2.65
19	2.7
21	2.75
23	2.8
25	2.8
27	2.75
29	2.7
31	2.6



Summary of effect of change made to front axle

The steer angle increases because the front axle grip has reduced

The steer angle reduces because the front axle grip has increased

Summary of effect of change made to rear axle

The steer angle increases because the rear axle grip has increased

The steer angle reduces because the rear axle grip has reduced

Ackerman Steering Geometry and Ackerman Steering Angle - A Clarification

For the assignment you need to find the **ackerman steering angle**. If the road wheel steering angle is greater than this then you have understeer and if it is less you have oversteer.

The **ackerman steering geometry** is the arrangement of the steering system which is designed so that both inner and outer steered wheels have the correct steered angle so that they both drive round the same turn centre. In line with the rear axle.

Ackerman Steering

The SAE defines ackerman steering as the angle of the steering wheel that is required with zero front and rear slip angles where both front and rear wheels track around the same centre.

Although the SAE definition of under , neutral and over steer talks in terms of steering wheel angle compared with ackerman steering angle we can simplify it by using the measured outer road wheel angle - the conversion to steering wheel angle is just the steering ratio of steering wheel to road wheel angle.

Ackerman Steering Angle

Both inner and outer wheels will have an influence on the steering wheel angle that is finally produced. We assume that the outer wheel is the most influential in cornering as it is the most heavily laden.

The ackerman steering angle is most easily found by driving round a corner at very low speed when no slip angles will be produced. You have plotted the graph for the conversion from steering wheel sensor volts to road wheel angle and so the road wheel angle for ackerman steering can be found. .

Ackerman Steering Angle

You can also calculate the ackerman steering angle (in radians) of the outer front wheel by dividing the wheel base by the radius of turn (which is 21.5 m in the case of the Pembrey test)

You can compare the road wheel angle found by calculation with the road wheel angle measured during a low speed turn.

Further work

Look at the value of the trendline for different polynomial orders to see if that shows the trend more accurately – for example as speed increases the balance may change and this would not be demonstrated by a 1st order trendline

Check that the trendline really does represent the trend of data points and is not just a mathematically accurate but irrelevant line