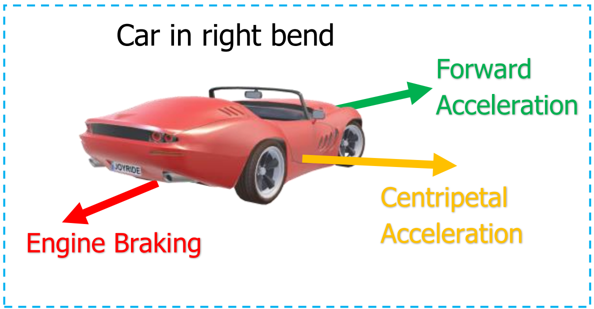
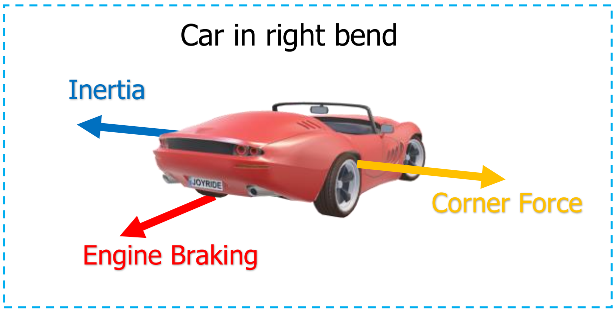
Does changing down on approach to a bend reduces the risk of understeer?

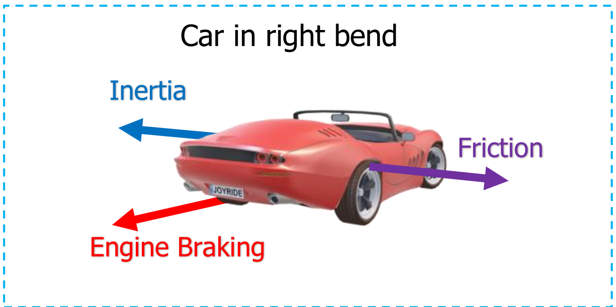


A moving conventional vehicle experiences Engine Braking Force, which always opposes motion (I.E. it tries to slow the car!)
On steering into a bend, the car also begins to accelerate 'Centripetally', that is it accelerates towards the centre of the bend. (Centripetal literally mean 'centre facing').
This acceleration occurs even if the car's linear speed along the road surface remains constant, because **Centripetal Acceleration** results from the rate of change of the 'direction' element of car's Velocity and not the 'speed' element of Velocity; therefore, Centripetal Acceleration exists even if speed through the bend is constant, simply because the car's ***direction*** is constantly changing: which is contrary to the way most of us think of acceleration.



Acceleration is always caused by an associated net Force (Newton's Second Law). Both the Acceleration and the associated Force responsible for it are quantities that have size and direction: they are Vector quantities. It is a fact that the direction in which the Force acts and that of the resulting Acceleration are the ***same***, as such, the **Centripetal Force** associated with **Centripetal Acceleration** also acts towards the centre of the bend: in driving terms, we call this Centripetal Force, the **Corner Force.**

Every Force has an equal and opposite Reaction Force (Newton's Third Law). Inertia is that property which resists any change in a body's state of rest or uniform motion. Mass is a measure of Inertia. The more massive a body is, the more Inertia it has and the harder it is to get it moving; or to stop it moving once it has started. Even if the speed in a bend is constant, Inertia opposes Centripetal Acceleration and the associated Corner Force.
Inertia is therefore the Newton's Third Law **'equal and opposite Force'** to the Corner Force, hence why the Blue arrow points in the opposite direction to the Corner Force.
If the forces that contribute to the Corner Force equal the Inertia Force, the car will be stable in a bend; but if Inertia is greater than the forces that contribute to the Corner Force, the car will understeer and possibly leave the road.



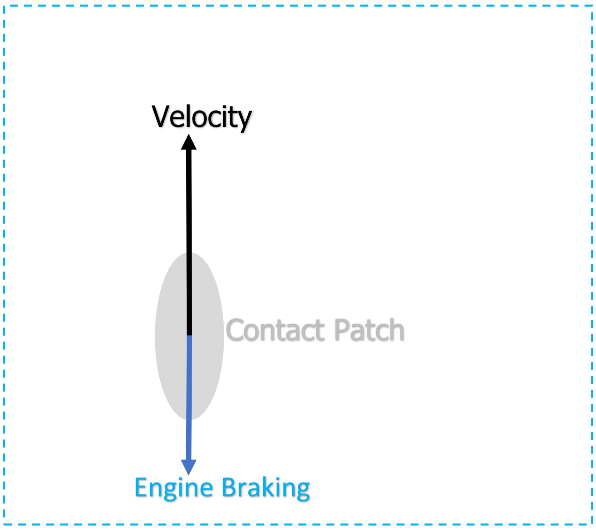
For convenience, Friction is shown as one Force, however, it acts at all four tyre contact patches.

When a car steers through a bend it continually tries to 'slip' sideways towards the outside of the bend, under the influence of its Inertia, the only thing stopping it sliding off the road is Friction between the tyres and the road surface. I.E. if cornering on ice, where Friction is low, Inertia is likely to be greater than the opposing Friction Force, causing the car to understeer and slip sideways off the road.

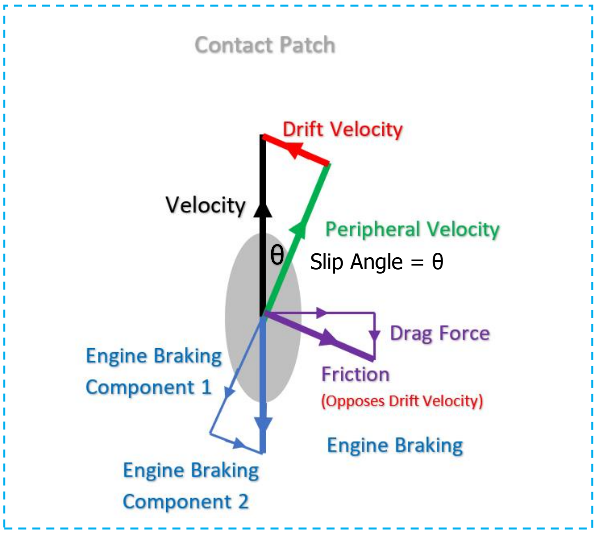
Friction opposes sideways 'slip', so it must therefore point towards the centre of the bend, as this is the opposite direction to the sideways motion; this is not surprising as it is this Friction Force that meets the demand of the Corner Force and to do that it must point in the same direction as the Corner Force!

We have also said that Engine Braking opposes motion. The diagram on the left below is looking down on one of the tyre contact patches, with the car in a straight line on approach to a bend. Note how the Engine Braking Force oppose forward Velocity.

The Diagram on the right shows the Velocities and Engine Braking Forces acting on the Contact Patch at the instant the driver steers to the right, in to the bend.



Plan view looking DOWN on tyre Contact patch before steering into a right bend.



On steering into the bend to the right, the Contact Patch essentially continues to point forward, but the tyre walls twist and deform, pointing into the bend.

In the Diagram above on the right, the Contact Patch tries to move to the right in the direction of the Peripheral Velocity (I.E. the direction the tyre points into the bend), whilst at the same time slipping to the left, as shown by the Drift Velocity. This sideways slip is controlled Understeer and every car does it. Front wheel drive; rear wheel drive or four-wheel drive: they all Understeer in a bend! The angle between the original Velocity and the Peripheral Velocity is known as the Angle of Slip: or simply, Slip. Typically, if Slip exceeds about 20^0, you would lose it in the bend!

It takes a lot of energy for the car to slip sideways like this and that energy comes from the cars initial motion energy, also known as its Kinetic Energy. If Kinetic Energy is reduced during Understeer as it is converted in to Work Done in pushing the car sideways, the car slows down in the bend, ***even if the gas pedal is kept constant throughout!***

Looking at it another way, Friction opposes the Drift Velocity and the Friction Force is shown by the purple arrow. For convenience, this Friction Force can be resolved into its horizontal and vertical components, where the vertical component -the Drag Force- is responsible for the car slowing down as it negotiates the bend. I.E. the car slows because the Drag Force opposes forward Velocity!

If you are mathematically inclined, you will note that Peripheral velocity is 'V Cos θ'; with θ being somewhere between 0^0 and 20^0, 'Cos θ' is less than 1; therefore, 'V Cos θ' is less than V: which also confirms that the car slows down on steering into the bend!

On slowing down in the bend, load shifts to the front of the car, which upsets the ideal stability. To redress the load shift, regain stability and put back the energy lost to this sideways slip, the driver must gently squeeze on the gas as they ease the wheel round and glide the car into the bend; hence the term: **Ease and Squeeze**! Hence, to maximise stability, every bend in the world should be taken under light acceleration.

You will also see from the Diagram above on the right, that **Friction** opposes the **Drift Velocity**. If the car was cornering on ice, this Friction would be very small, and the car is far more likely to Understeer out of control and slip off the road to the left in a right bend; or slip towards oncoming traffic in a left bend!

The Friction Force can be seen to act towards the centre of the bend, and it is this Friction that is mainly responsible for meeting the demand of the Corner Force!

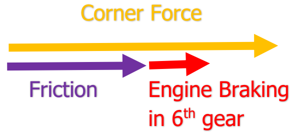
Engine Braking (blue arrow) opposes the car's velocity (black arrow). The Engine Braking force can be resolved into two components: Engine Braking Component 1 and Engine Braking Component 2 (both shown by thin blue arrows).

Engine Braking Component 1 opposes Peripheral Velocity and Engine Braking Component 2 opposes Drift Velocity. Engine Braking Component 2 also acts in the same direction as the Friction Force, so they can be added together so that their combined effect meets the demand of the Corner Force.

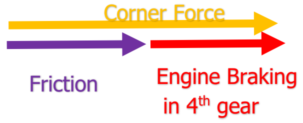
To put it another way, if Friction plus Engine Braking Component 2 can add together and cancel out the effect of the Inertia Force, the car remains stable with a controlled amount of understeer and this is what normally happens when we drive through a bend under control.

However, the maximum Friction Force available is finite and when driving normally there is always Friction in reserve; you don't use all the available Friction in any given bend unless you are pushing the car to the limit.

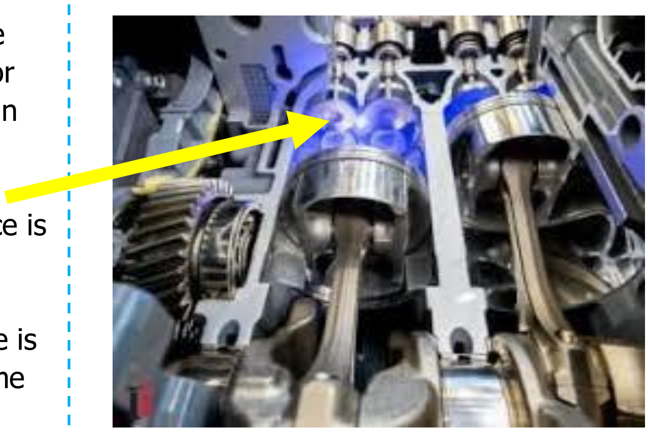
With an Engine Braking Component helping to meet the demand of the Corner Force, ***less*** of the maximum Friction Force is needed to meet this demand, leaving more Friction in reserve to cope with understeer. See how these Forces look on the simple Force diagrams shown below:



In the diagram on the left, the Corner Force ***demand*** exceeds the sum of Friction plus Engine Braking Force in 6th gear and the car experiences uncontrolled Understeer!



In the diagram on the right, the Corner Force ***demand*** is met by Friction plus the bigger Engine Braking Force in 4th gear and the car does not Understeer: it remains stable in the bend!



Experience tells us that the Engine Braking Force increases, if a lower gear is selected at speed: for example, dropping from 6th to 4th. This because in the lower gear, the pistons experience more gas resistance as they try and move up and down in their cylinders with increased RPM: this resistance is the main cause of Engine Braking!

The argument developed above shows that there is a component of Engine Braking acting in the same direction as the Friction Force between the tyre contact patches and the road; this component of Engine Braking therefore helps meet the demand of Corner Force. You could equally say that this component of Engine Braking plus the Friction Force add up to oppose the Inertia Force, which is trying to make the car Understeer: it's simply another way of looking at the same issue.

In the lower gear, the Engine Braking component increases, therefore making it more likely to meet the Corner Force demand and conversely, less likely that the car will experience uncontrolled Understeer.

This agrees perfectly with our driving experience, as most drivers will know that taking a sharp bend in a high gear, is likely to result in uncontrolled Understeer with the car running dangerously wide in the bend; whereas changing down to a lower gear fractionally before entering the bend, lets the car hold its line beautifully with a controlled (I.E. a normal) amount of Understeer that feels perfectly stable in the bend: it does not run wide.

It is wrong to say that changing to a lower gear for a bend gives more grip: it cannot!

What we can say is that changing to a lower gear for a bend **reduces the demand for grip**, as some of the Corner Force demand is met by an increased Engine Braking component provided by the lower gear. This lower demand for grip is effectively the same as having increased grip, as there is more grip in reserve if the car inadvertently tries to increase Understeer, usually because of too much speed into the bend.

To summarise, the lower gear does not ***increase grip***, it simply ***reduces the demand for grip***: which amounts to the same thing, hence why we change down on approach to a bend, as it reduces the ***demand*** for grip, making the car feel more stable; less prone to understeer and more able to deal with understeer as there is more Friction Force in reserve!

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