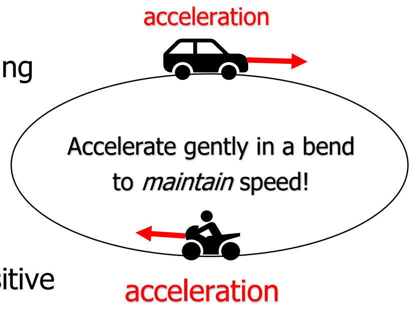
Why should every bend be taken under light acceleration?

Whether driving a car or riding a motorcycle, every bend should be taken under light acceleration.



We tell drivers to 'ease and squeeze': I.E. when 'easing' the steering wheel in to the bend; gently 'squeeze' on the gas pedal!

We tell bikers to 'look, lean and roll': I.E. on approach to a bend, 'look' into the bend; read the Limit Point and apply the Safe Stopping Rule; 'lean' the bike into the bend as you apply Positive Steering; and gently 'roll' on the throttle as you do so!

In each case, a little bit of gas is used in the bend not to ***increase*** speed, but simply to ***maintain*** it!

Why should that be?

Cars and bikes lose speed when travelling round a bend, even if the gas is kept constant throughout.

This raises several questions that need investigation, E.G:

- How do they lose speed if the gas is constant?
- Does this loss of speed affect stability?
- How does light acceleration help the situation when cornering?

Taking these questions in turn:

How do they lose speed if the gas is constant?

A moving vehicle has motion energy, the correct name for which is Kinetic Energy.

The amount of Kinetic Energy is given by a simple formula:

$$\textbf{Kinetic Energy} = \tfrac{1}{2} mV^2$$

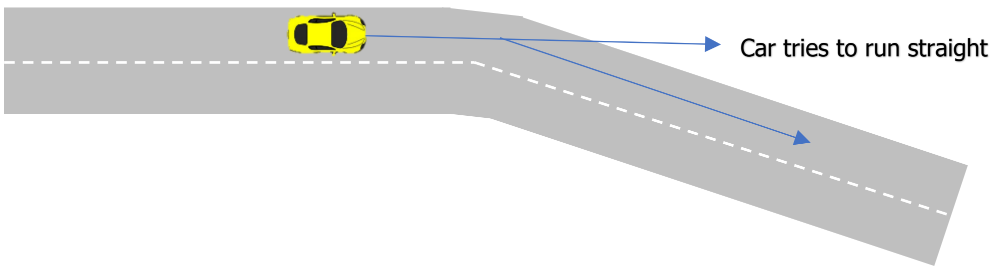
m is the mass of the car or bike in kilograms, this includes the mass of the rider / driver all passengers and contents Etc.

V is the Velocity of the car or bike usually expressed in metres per second.

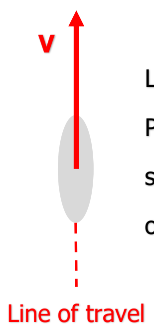
V^2 (pronounced V-squared) is simply **V** times **V**.

The faster the car or bike travels, the more Kinetic Energy it has. E.G. if speed is doubled, Kinetic Energy goes up four times; at three times the speed the vehicle has nine times the Kinetic Energy: as 2 squared is 4; and 3 squared is 9 Etc.

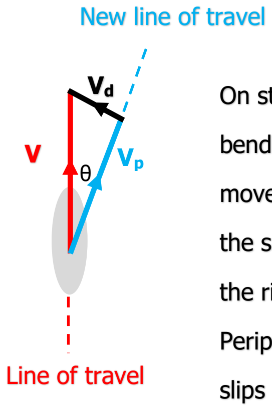
Cars and bikes continually try to run straight and understeer in a bend; but their steering and road friction compels them to follow the angle of the bend.



Consider a simple velocity diagram, which shows the motion of a typical tyre Contact Patch, before and immediately after steering into a right bend.
The diagram on the left shows the Contact Patch before the car or bike enters the bend.
The diagram on the right shows it again, immediately after steering into the bend.

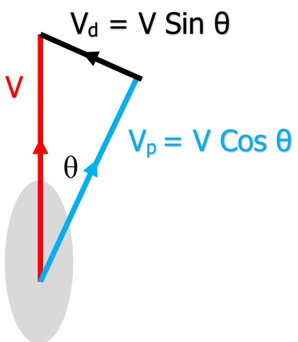


Looking down on a Contact Patch travelling in a straight line at Velocity **V** on approach to a bend.



On steering right to enter a bend, the Contact Patch moves in two directions at the same time. It moves to the right, shown by the Peripheral Velocity $\mathbf{V_p}$ and it slips sideways, shown by the Drift Velocity $\mathbf{V_d}$

In the diagram on the right, the Peripheral Velocity $\mathbf{V_p}$ is the tyres velocity in the new direction of travel and the angle between the Peripheral Velocity $\mathbf{V_p}$ and the Initial Velocity **V** is known as the **Slip Angle**, which is traditionally given the Greek letter Theta (θ).



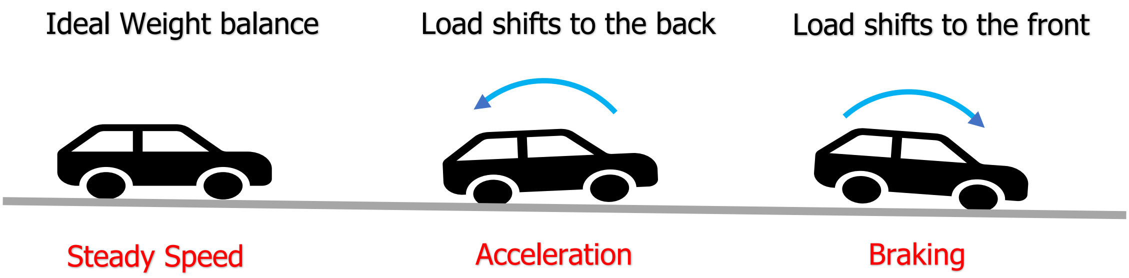
This expanded diagram of the Velocity Triangle shows Peripheral Velocity $\mathbf{V_p}$ is equal to **V** Cos θ.
Slip Angle will be less than 20^0 therefore Cos θ will be less than one, making the Peripheral Velocity V_p less than the Initial Velocity **V**. I.E. ***this is mathematical proof that the car or bike slows down as it steers into a bend!*** It does so because the tyres are trying to 'slip' sideways with Drift Velocity $\mathbf{V_d}$, where $\mathbf{V_d}$ equals **V** Sin θ. This sideways slip is controlled understeer! I.E. a bike or car is constantly trying to Understeer in a bend!

Even without the maths, the Blue arrow is seen to be smaller than the Red arrow, which shows that the car or bike slows down in the bend!

Speed is lost in the bend as the car or bike continually tries to 'slip' sideways towards the outside of the bend. I referred to this as 'controlled understeer' and the term speaks for itself: the car or bike is marginally slipping sideways all the time in the bend, but there is enough Friction opposing this to prevent the car or bike from drifting off the road out of control. If there is insufficient Friction available, perhaps because of ice, gravel or diesel spillage reducing the Coefficient of Friction between the tyres and the road surface, the understeer becomes 'uncontrolled' and the car or bike moves in the direction of the Drift Velocity. In a right bend the vehicle would run wide and possibly come off the road on the nearside, where there are likely to be obstructions such as trees or walls; in a left bend, drifting across the centre line of the road into the path of oncoming traffic is even more hazardous to health.

Does this loss of speed affect stability?

The second question concerns stability and asks if loss of speed in a bend affects the stability of the car or bike. Look at the cars in the diagram below:



A moving car or bike is in its most 'stable' condition when travelling on a straight, flat, road surface at a steady speed; as shown by the diagram on the left.

When Accelerating, 'load' shifts to the back, causing the rear of the car or bike to squat and the front to rise. This redistribution of load affects suspension and tyre Grip: front wheel drive cars lose grip as weight is unloaded from the front contact patches; and rear wheel drives (and motorcycles) gain grip, as weight is loaded on to the rear contact patch / patches.

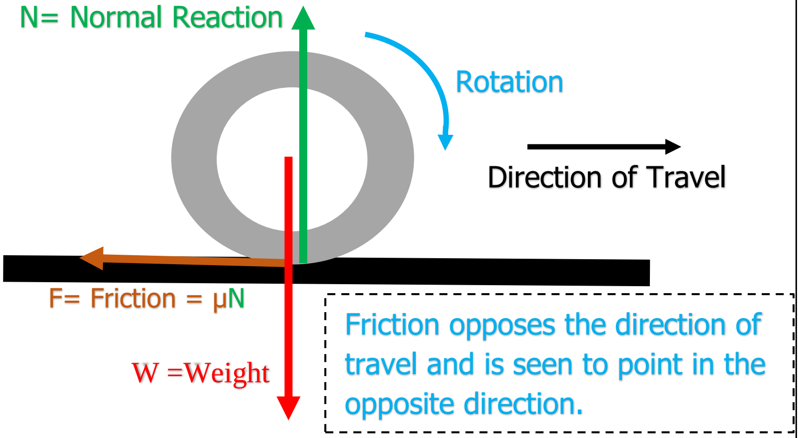
Four-wheel drives also experience load shift, but with four points of contact laying down the drive, they are less likely to be affected.

This load shift also upsets the ideal stability that existed before the car or bike Accelerated: as shown by the centre diagram.

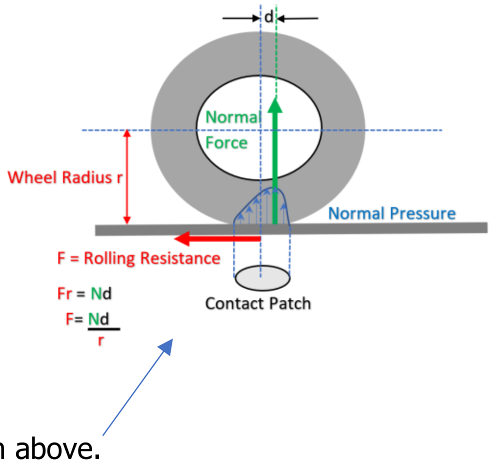
When Braking 'load' shifts to the front, causing the front of the car or bike to squat and the rear to rise. This additional load on the front end increases the Weight (W) on the front Contact Patch / Patches.

The Newton's Third Law equal and opposite Force to the Weight acting down on the Contact Patch, is the Normal Reaction Force (N) acting up:

W = N



Note that the Normal Reaction Force is applied at a point slightly ahead of the centre of the Contact Patch; this is because of the Air Pressure Distribution within the tyre, which has its maximum value slightly ahead of the centre of the patch. The Normal Reaction Force times the small distance to the centre of the patch (d) known as the Rolling Friction Parameter, produces a Torque that is equal and opposite to the Rolling Resistance Force F multiplied by the Radius of the wheel: as shown in the diagram above.



Friction (F) between the Contact Patch and the road surface is given by the formula:
F = μN, where μ (the Greek letter Mu: pronounced '*mew*') is the *Coefficient of Friction* between the road surface and the tyre Contact Patch and N is the Normal Reaction Force. μ is a dimensionless quantity, with a value ranging typically between 0 and 1.4: the bigger the number, the Grippier the surface!

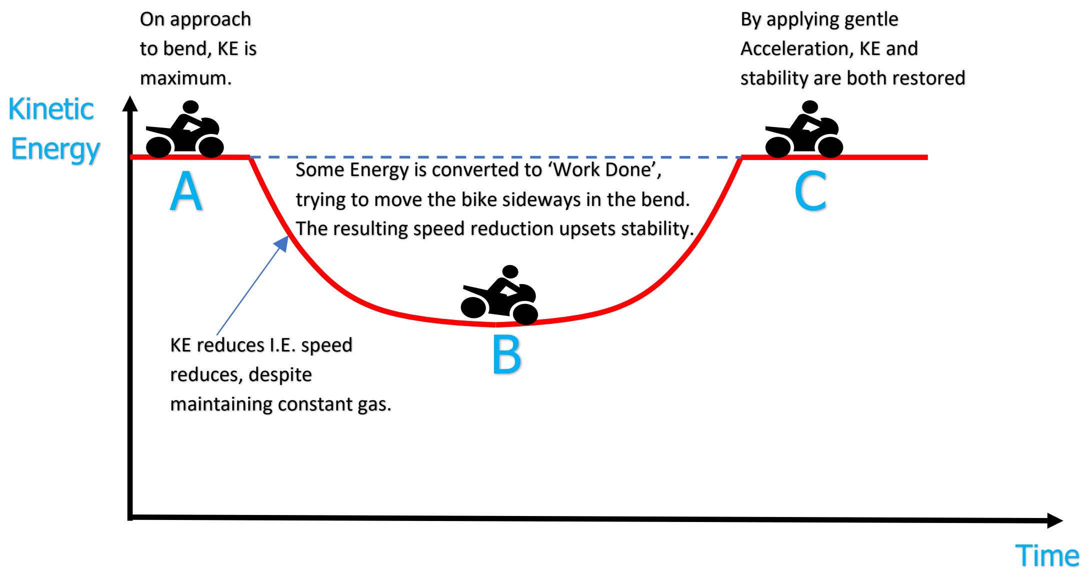
In summary, braking shifts load to the front; which increases both W and N; and this in turn increases Friction F (I.E. Grip) between the Contact Patch and the road surface.
The increased Grip on the front Contact Patches makes front brakes more effective than rear brakes and this is true for both cars and bikes. Have you noticed there is normally more brake dust to clean off your car's front wheels, than off the back wheels? The amount of brake dust produced is related to the amount of work done by the brakes, and as the front brakes work harder when stopping the car or bike, they produce more dust to mess up your

nice shiny front wheels. Load shift to the front also upsets the ideal stability that existed before the car or bike started braking: as shown by the diagram on the right.

How does light acceleration help the situation when cornering?

The final question asks how light Acceleration in the bend helps when cornering. Previously we have shown that cars and bikes slow down in a bend, as speed is lost to controlled understeer.

This speed reduction upsets stability, which is clearly not good when cornering: especially if making progress. We will now consider how light acceleration in a bend helps the situation: car or bike.



At Point A in the diagram above, the rider approaches the bend at a fixed and appropriate Velocity. Kinetic Energy is proportional to the square of the 'Speed' element of the bike's Velocity. For this manoeuvre, we can take this initial Kinetic Energy to be the maximum Kinetic Energy; although the term is purely relative and does not imply an *absolute* maximum value of Kinetic Energy.

On entering the bend, the bike slows as some of the Kinetic Energy of approach is converted to 'Work Done' in trying to slip the bike sideways. I.E. Kinetic Energy reduces on entering the bend.

Note: 'Work Done' is the correct technical term used to describe the situation where Energy of one form or another is converted to work.

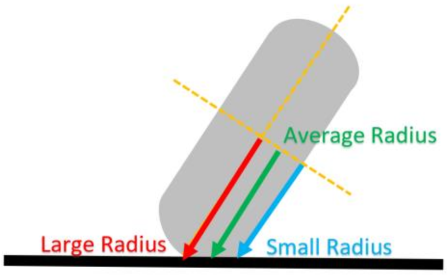
The reduction in Kinetic Energy is shown between Points A and B. The mass of the bike and rider does not change on entering the bend, so the reduction in Kinetic Energy is because of speed reduction, with the associated disadvantage of load shift and departure from ideal stability.

By gently rolling on the throttle in the bend, the engine produces more Power, at the expense of increased fuel consumption. Power is defined as the 'Rate at which Work is Done', therefore the engine does more work to compensate for that lost to controlled understeer. How do know how much throttle to use?

Simple: use just enough gas to maintain speed! If speed is maintained, the approach Kinetic Energy is maintained, which means that just enough extra Work is done by the engine to balance the Work Done to generate controlled understeer.

Ideal stability is also maintained, because there is no reduction in speed and therefore load does not shift!

Note: The story is slightly more complicated for bikes than for cars, owing to the shape of a motorcycle's tyre and the fact that bikes lean into bends! Consequently, the bike slows down in a bend as a result of these factors.



When cornering, the tyre radius effectively reduces and the average radius of the tyre (Green Arrow) lies somewhere between the Large Radius (Red Arrow) and the Small Radius (Blue Arrow).

For any given road speed, the tyre must rotate faster, when leaning, as it is running on a smaller radius. The net result is that when the bike leans off the vertical, the back wheel tries to make the engine turn faster, to match the increased speed demanded by the smaller radius on which it runs. However, Engine Braking resistance prevents any increase and as Engine Braking is greater than before the lean, it slows the bike in the turn.

This is similar to the way Engine Braking Resistance slows the wheels (and the bike) when a lower gear is selected at speed.

Conclusion:

Every bend in the world should be taken under light acceleration: car or bike!

Gentle gas in the bend maintains speed, which provides just enough extra work output by the engine to balance that lost to controlled understeer, maintaining ideal stability.

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