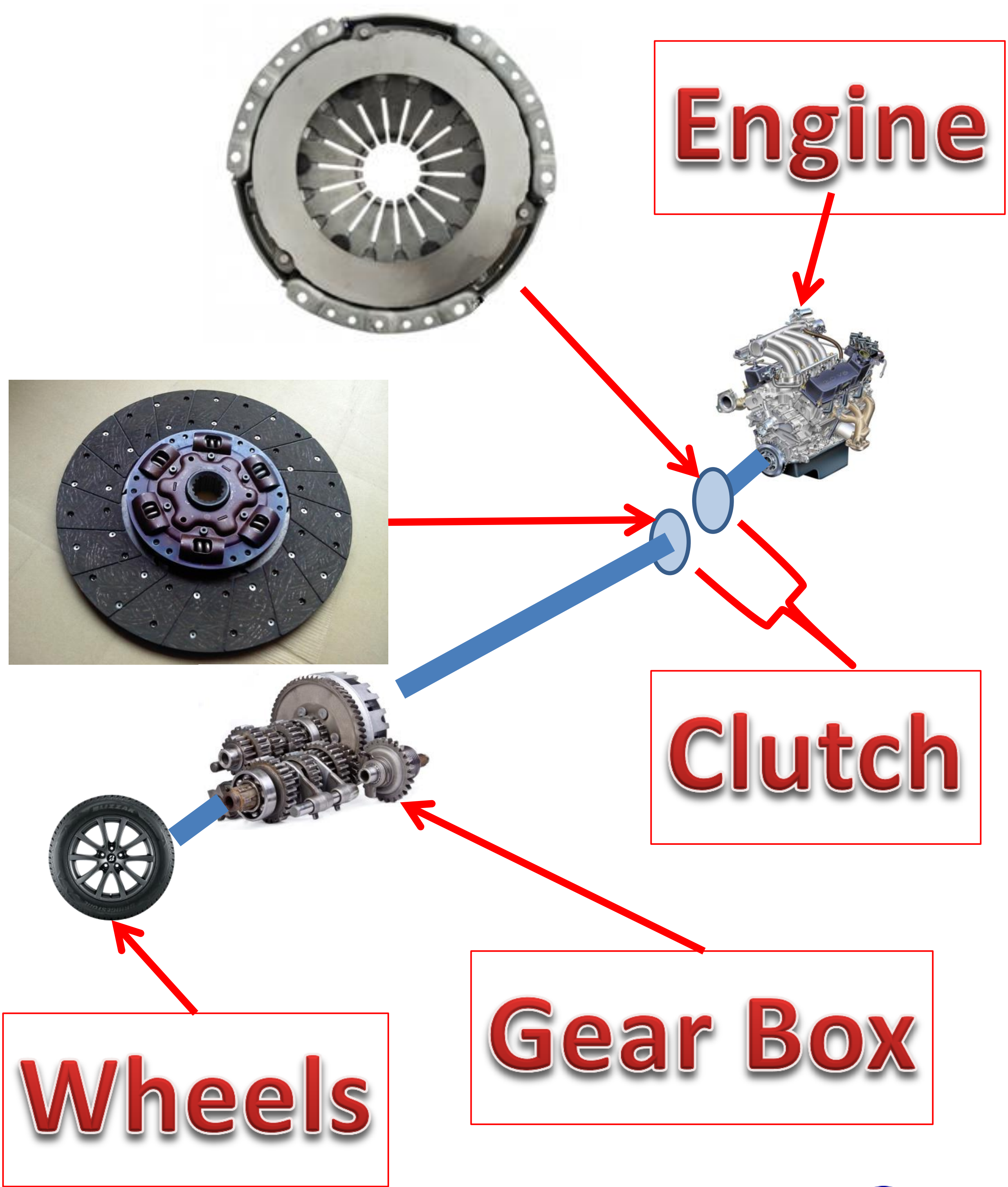
How a car works



Contents

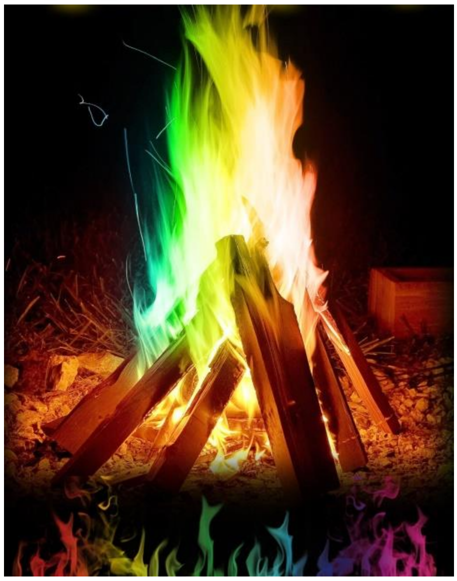
It’s really important that you separate an engine from the car.

Sure, the car comes with an engine but you don’t have to use it to move the car; you could:
Get out and push,
You could roll it down a hill,
You could pull it behind another car.

Here is a car, which has a place to sit, steering, brakes and in this picture is powered by a friend. In a normal car, you are supplied with an engine and we used a clutch to join the engine to the car and in doing so propell the car down the road.

You see that the steering and brakes are all part of the car and have nothing to do with the engine.

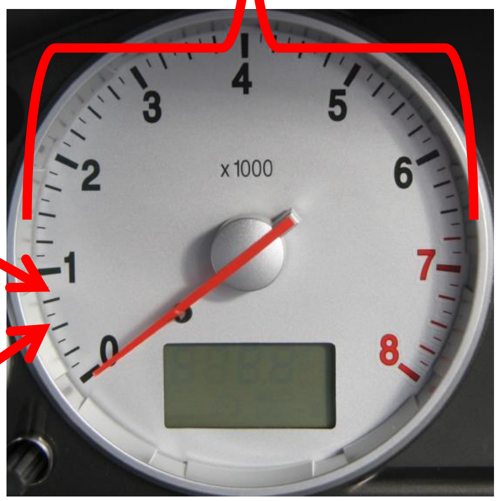
The Engine



> 800 rpm = resource/power

Driver

Jeeves



800 rpm = idle

600 rpm = stall

Now, remember that the engine has nothing to do with a car as such; it's just a useful tool that comes with a car to help us move it around.

You could remove an engine from a car, put the engine on the pavement and you'd still have a car that you could roll down a hill and brake and steer.

An engine is separate to a car, like a cyclist is separate to a bike! Both can be used for propulsion but aren't actually the machine itself.

An engine consists of many metal parts that go up and down and ultimately cause something to spin very quickly (half of a clutch actually); think of an orbital sander (or a drill!) for example; it has a disc (or drill bit) that can spin between nothing and very fast.

If you look at the diagram on the previous page, you will see a dial for a petrol car. It displays speeds between zero and 8000 RPM (Revolutions Per Minute or Revs).

At around 6800 RPM the dial starts to show red and this is because the engine would be getting near its maximum speed – try to stay out of this area.

There is a minimum speed of 600 RPM (not exact but about 600) and if the engine gets this slow, it switches off (known as stalling).

There is also a point where the engine idles (called idling) at 800 RPM (varies from car to car but it's about 800). You will have seen drivers get out of a car but leave the engine running, the engine is idling at this point (more on that in a moment).

This is a rev counter for a diesel car (my car is diesel).

You can see that diesels don't rev as high as petrols but the principle is the same; stay out of the red bit!

Max speed = 8000rpm / 6000rpm
Danger = 6800rpm / 4500rpm
Idle = 800ish rpm
Stall = 600ish rpm or less

An Engine is like a fireplace

You can think of an engine like a fireplace at home.

Start a fire: put some kindling in the fireplace, get a lighter, and start a fire.
Do nothing more: Fire would eventually go out.
Put more wood on a burning fire: fire keeps going until you stop adding fuel to it.
Put a lot of wood on a fire: you get a big fire.
Stop adding wood: fire gets smaller and eventually goes out unless you add more fuel.

In a car, we use diesel or petrol instead of wood. Because this is a liquid rather than a solid, the fire gets big quickly but also burns through the fuel quickly and so the size of the fire is more 'on demand' (like a gas hob for cooking on).

Only one pedal operates the engine and that is the accelerator (the pedal on the right). You can think of this like a Super Soaker and the more you press the pedal, the more fuel enters the engine and so we get a big fire. Imagine if this little darling was firing petrol rather than water with his Super Soaker – geesh!

Jeeves saves the day!

The problem comes when we take our foot off the accelerator; no fuel is going into the engine and so the fire would go out. But it doesn't! We all know that an engine can keep running when we are stationary. You may have seen people start an engine then get out and do something in the boot of the car, all the time the engine keeps running and this is known as idle, the engine is idling.

We can therefore work out that some fuel must be entering the engine to stop it from switching off. This is the job of the idle valve and I like to think of mine as a butler that I call Jeeves. In my mind, he wears a suit, has a water pistol full of diesel and thinks he looks like James Bond.

I employ Jeeves to keep the engine running at 800 RPM. If, (through driver error normally), the revs get below 800 RPM, Jeeves squirts faster on the pistol to try and raise the revs back up to 800 RPM. If we really force the issue and allow the revs to get to 600 RPM, Jeeves gets cramp in his finger, swears quite a lot, throws a tantrum and walks off complaining about working conditions and so the engine stops working because no fuel is going in.

When the driver raises the revs above 800 RPM, Jeeves sits down and reads a book; he only works at 800 RPM or less. So if the driver raises the revs high and takes their foot off the pedal, neither Jeeves nor the driver supply fuel until it hits 800 RPM and so it's FREE motoring!!! Bargain!

Moment to reflect!!

'Learn' this stuff, don't just 'read' it!

Engine summary:

1. You put fuel into an engine using the accelerator (pedal on the right which is operated by the right foot only).
2. Jeeves keeps the engine running at 800rpm if you do nothing.
3. Minimum speed is 600rpm, go below this and the engine stalls.
4. Maximum speed depends on car; in my car 4500rpm is the maximum you should go for any length of time.
5. Go above 6000rpm and you run the risk of blowing up the engine and making all the internal components become external components – don't do this!!!!

The Gearbox

MPH Gear RPM(revs)

MPH		Gear		RPM(revs)
5	←	1	←	800
10	←	2	←	800
15	←	3	←	800

Revs	Gear 1	Gear 2	Gear 3
0	0	0	0
400	2.5	5	7.5
800	5	10	15
1600	10	20	30
3200	20	40	60

(mph)

Gear				
1 (revs)	0	400	800	1200
1 (mph)	0	2.5	5	7.5

Cont.... →

Gearbox, input and output

Firstly, let discuss why we even need a gearbox.

The point of a gearbox is to take an input speed and output a different speed; one speed in, different speed out.

Take a piece of flexible wire 10cm in length.

Bend it around to make a wheel: 

The circumference of the wheel would be 10cm. By this we mean that for one rotation of the wheel, it would have travelled 10cm.

Now, let's take another piece of wire 10cm and do the same. We now have two wheels each with a circumference of 10cm.

Let's pretend that these are actually cogs with teeth that intermingle. When you turn one of the cogs, it would turn the other cog. Because the circumference is the same, each cog would turn the same amount. So one complete turn of cog A would result in one complete turn of cog B.

What if they were different sized cogs though?

Assume cog A is 10cm and cog B is 20cm:
For one rotation of cog A, cog B would only turn a half turn (it needs to travel 20cm for a complete turn but it's only gone 10, hence a half turn).

Now assume cog A is 10cm and cog B is 5cm:
For one rotation of cog A, cog B would turn twice (it needs to travel 5cm for a complete turn but it's travelled 10, hence a double rotation).

This table demonstrates different cog sizes and number of resulting turns; I hope you get the idea (fingers crossed).

Cog A size	Travels	#Turns	Cog B size	Cog A forces B to travel	#Turns
10cm	10cm	1	10cm	10cm	1
			20cm	10cm	0.5
			5cm	10cm	2
			2cm	10cm	5
20cm	20cm	1	10cm	20cm	2
			20cm	20cm	1
			5cm	20cm	4
			2cm	20cm	10

Real world example

So now, let's put this into some real world situation:

Before we get going I just want to point out that the figures I am about to produce are for demonstration purposes only and bear no relation to the real world.

We want to get a car capable of doing 135mph (I know the maximum speed limit is 70mph in England but there's more to this than meets the eye and there are reasons why manufacturers want cars capable of more than 70mph which is beyond this document, ask me in a lesson).

Let us pretend that we want the wheels of the car rotating at 135,000rpm to get 135mph (1000rpm for 1mph).

On a diesel car, the maximum working speed of the engine is 4,500rpm; we will therefore assume we have attached the engine to cog A and the wheels of the car cog B.

Our requirements

135,000rpm is 30 times faster than 4,500rpm; we need cog B to be a 30th in size than cog A, therefore:

Cog A could be 30cm and cog B 1cm,
Cog A could be 60cm and cog B 2cm etc.

The problem

The problem is that the bigger the multiplier, the harder it is to actually take the energy from cog A to cog B. What we need to do is take it all in steps; it is much easier to ask an engine to increase speed by 2 than 30 for example.

The solution

If you've ever ridden a bicycle, pulling off in 1st is much easier that 21st, you might not even have enough leg strength to pull away in 21st. On a bike, your legs have a maximum speed they are prepared to rotate, so you start off in a low gear to break inertia, get the bike going and once it's moving you try a higher gear to attain the higher speeds.

Same thing in a car; my car is a 6 speed car so I could do the following:
1st gear 5x multiplier,
2nd gear 10x multiplier
3rd gear 15x multiplier
4th gear 20x multiplier
5th gear 25x multiplier
6th gear 30x multiplier

Facts

Behind the scenes in a car, you have the wheels of the car joined to a gearbox and on the other side of the gear box we have half of the clutch (one half connected to the gear box, the other half is connected to the engine). See the picture on page 1.

In my car, if the clutch is spinning at 800RPM, the wheels of the car are rotating at 5MPH times the gear number. So in 1st gear 5MPH, 2nd gear 10MPH etc.

My car:
At 800rpm, your speed will be 5mph times the gear number. e.g. 3rd gear = 15mph @ 800rpm

Because the clutch and the wheels are joined together via the gear box, each side must reflect the speed of the other. So if one side is stationary, so is the other.

You can see from the diagram on page 9 how doubling the speed of the clutch also doubles the speed of the wheels. You can also see that if we were to double the speed of the wheels, they in turn would double the speed of the clutch.

All a gear box does, is change the speed that comes out based upon the speed that goes in.

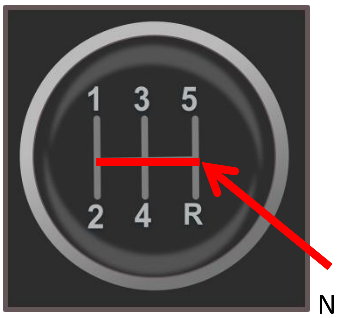
Just like on a pedal cycle, you could think of the clutch as the pedals on your bike. If your legs were to rotate at 10 RPM then maybe in 1st gear you are doing 1MPH, but in 21st gear maybe you are doing 20 MPH. Your legs are still rotating at the same speed but the gears change how fast the wheels on the cycle go round.

Assuming that you are in a gear, it's the speed of the clutch and gear box that actually relates to the speed of the car.

You could stand behind a car and push it in 1st gear and in the background the clutch would start rotating. If you ran at 5MPH, the clutch would be spinning at 800RPM.

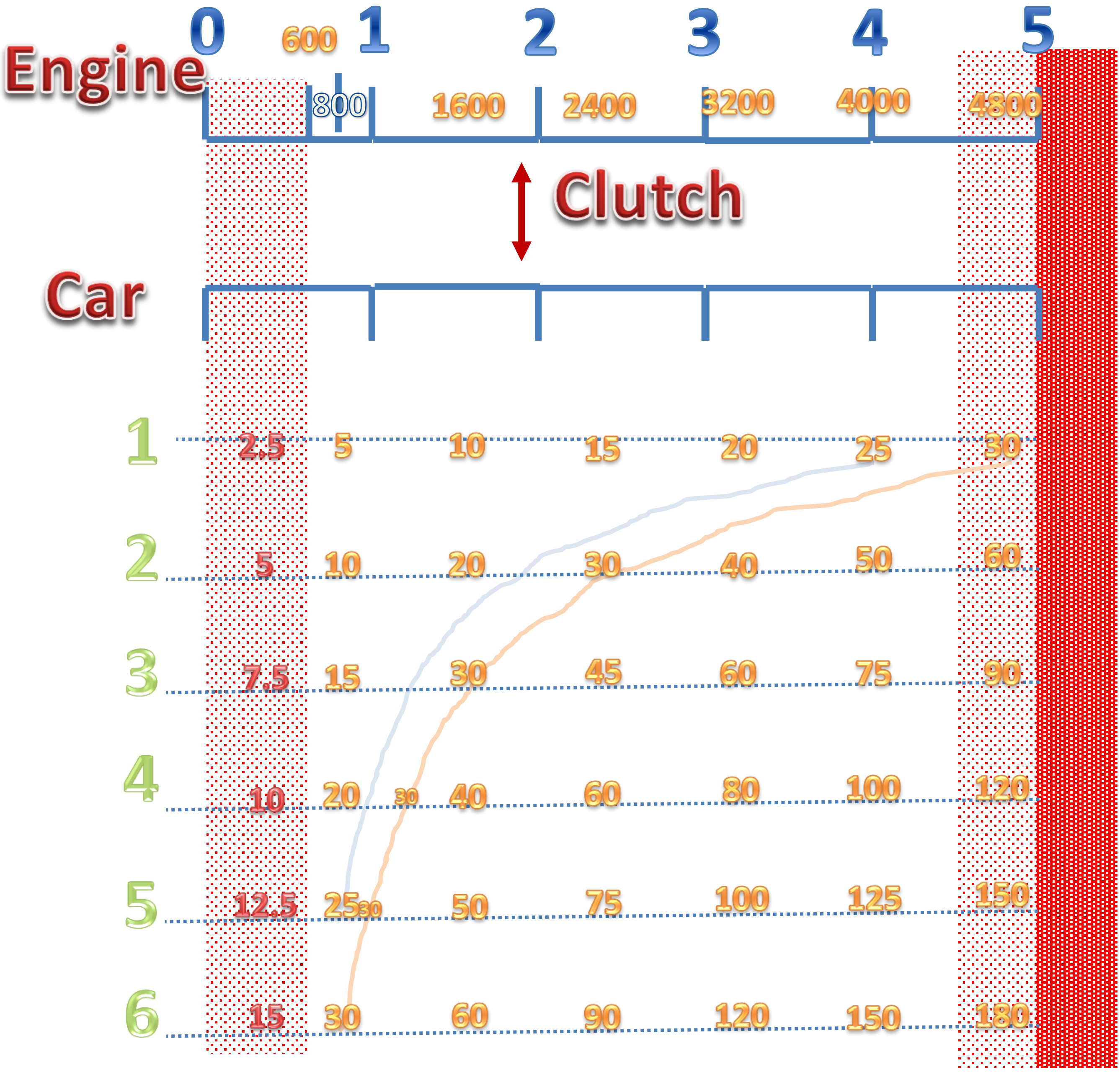
It's worth pointing out that the brakes are mounted to the car as well so when you brake, you slow the wheels (just like on a pedal cycle).

There is also a 'nothing' gear called neutral and it lives anywhere on the centre line between the odd and even numbered gears; this is effectively gear zero. We use this when we want to have a gap between the wheels and the clutch.



Neutral gear

Engine vs Gear speed



Look at the diagram above:
The engine has a stalling area below 600rpm and a danger area above 4500rpm, (idle is at 800rpm).
The clutch joins the engine to the car and so the engine would reflect the same speed as the gearbox when joined.

My car will be doing 5mph times the gear number at 800rpm hence 5mph in 1st, 10mph in 2nd etc.
You can also see that when the gearbox is travelling 5 times faster, so is the car, hence 25mph at 4000rpm in 1st (800rpm x 5 = 4000rpm therefore 5mph x 5 = 25mph).

Moment to reflect!!

'Learn' this stuff, don't just 'read' it!

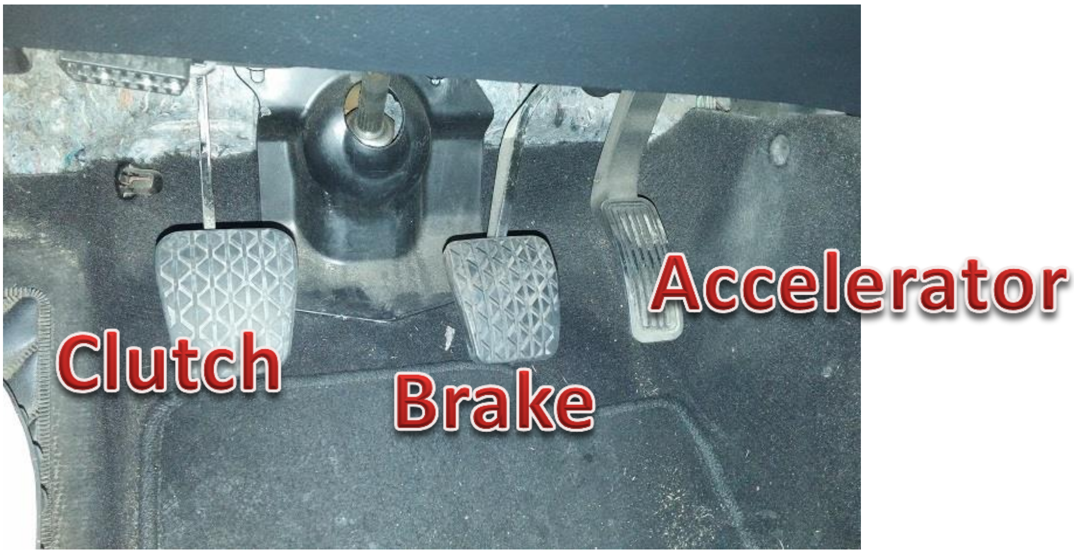
Gearbox summary:

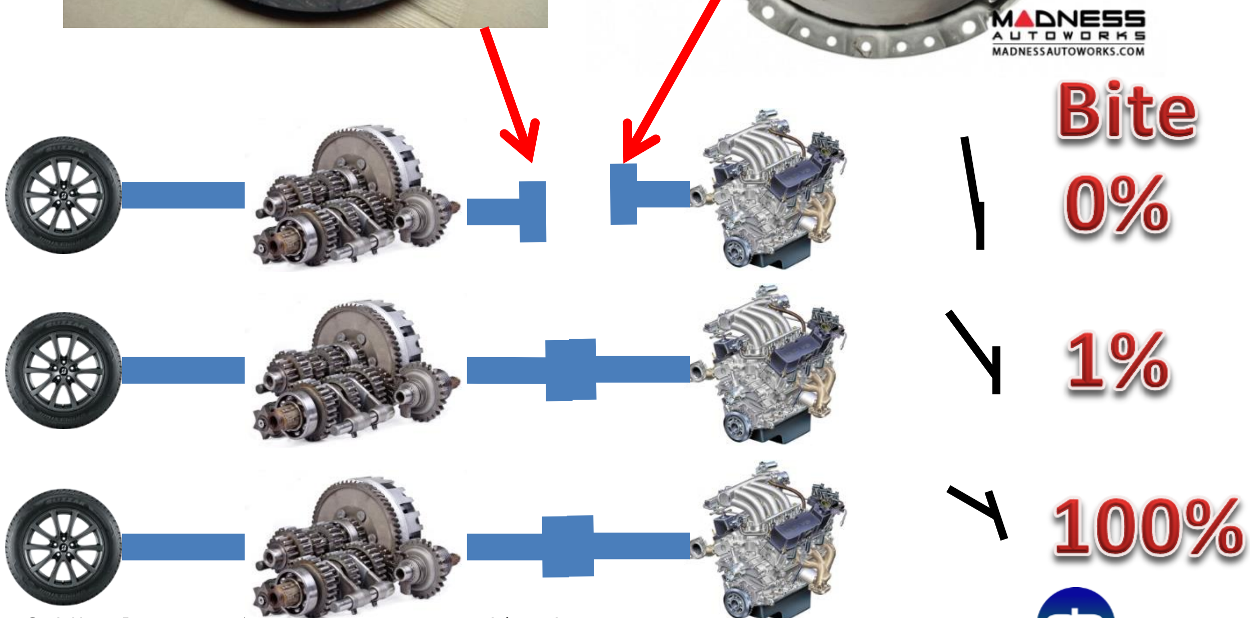
(This has nothing to do with the engine remember)

1. A gearbox takes a rotational speed in and changes the rotational speed coming back out again.
2. In my car, you will be travelling at 5mph times the gear number at 800rpm so 5mph in 1st, 10mph in 2nd, 15mph in 3rd etc, all at 800rpm.
3. We use lower gears to get moving and then go up gears to help us build speed.
4. Neutral is a nothing gear or gear zero. We use this when we want to take our foot off the clutch but still have a gap between the engine and the wheels of the car.
5. You can go from any gear to any gear up or down (more on this later) but normally you will go up gears one after the other and come down by missing gears out (this is called 'block changing').

Gavin House Instructor

The Clutch



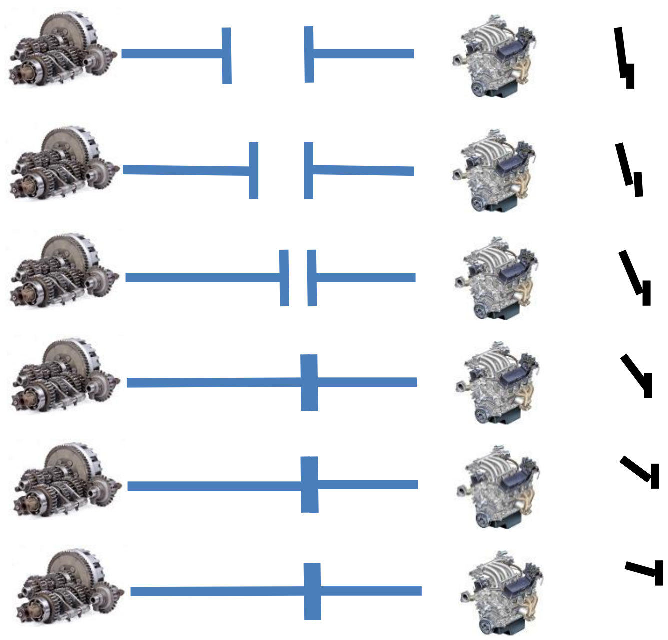


The clutch pedal is a percentage pedal

There's lots of misinformation about the clutch. In my opinion, it's the most important pedal to master and the one pedal that causes the most problems for people. It's incredibly sensitive and requires a deft touch to operate properly; it causes a lot of concentration faces in the car I can tell you!

Lots of parents teach you to push the accelerator down as you bring the clutch up; **<u>this is incorrect</u>**; well, I say that, you can do that if you want, but you don't <u>have</u> to; let me explain:

1. The clutch pedal separates the two clutch plates.
2. When you're not touching the pedal the plates are touching; when you push the pedal down, you separate the plates.
3. When the plates touch, this is known as a bite or getting a bite.
4. You can have anything between zero and a 100% bite.



Pedal all the way down, 0% bite

Bring pedal up a bit, 0% bite

Bring pedal up a bit more, 0% bite

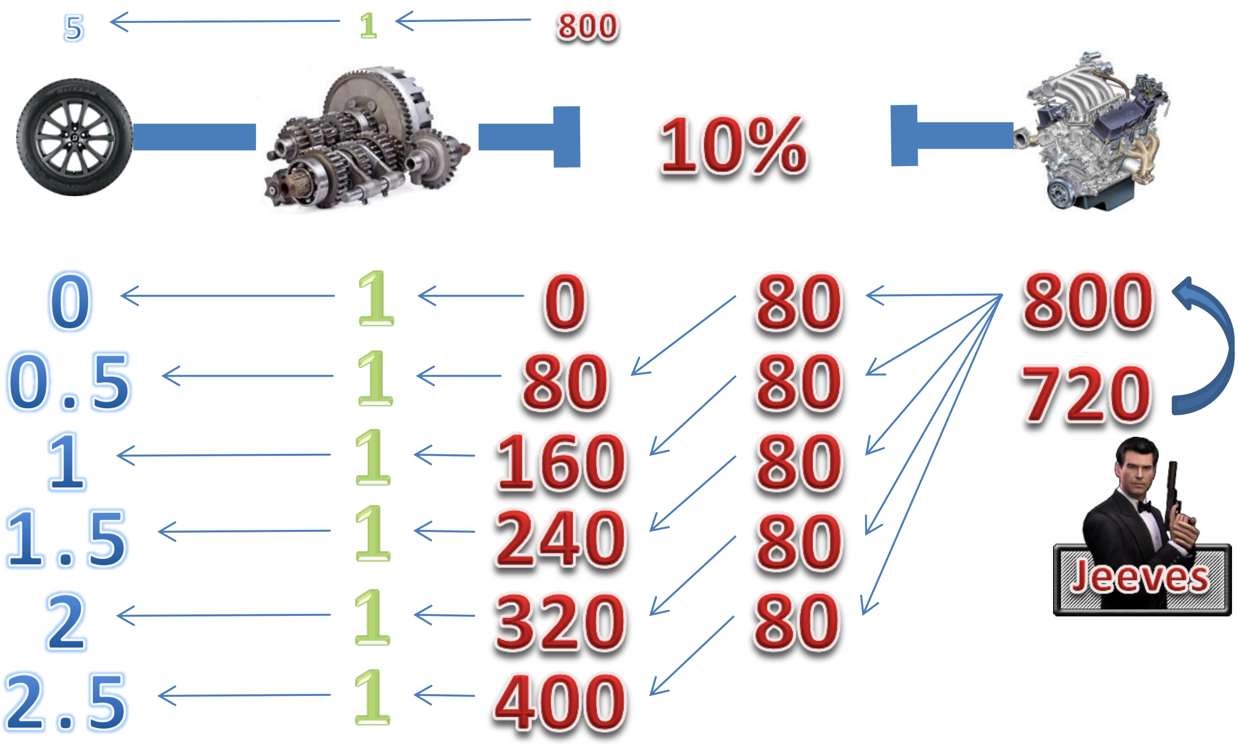
Bring pedal up a bit more, 1% bite

Bring pedal up a bit more, anywhere between 1 and 99% bite

Foot off pedal, 100% bite

Ok, so now you understand that the height of the pedal equates to the size of the bite; let's see what this means to us in the real world.

Bite = percentage of difference



Above I show in small text a reminder that if the clutch is spinning at 800rpm in 1st, you're doing 5mph.

This is the simple version to aid understanding. Above we have a 10% bite; this means that we transfer 10% of the engine speed across to the gearbox.

10% of 800rpm is 80rpm and so the gearbox starts to rotate at 80rpm which means that the wheels of the car are now rotating at 0.5mph (80rpm is 10% of 800rpm therefore 0.5mph is 10% of 5mph).

If you take 80rpm from the engine then it would slow to 720rpm but because of my hero Jeeves, he fires more fuel in to keep the engine at 800rpm – WHAT A STAR HE IS! I LOVE JEEVES!!!!!

Keep your foot at 10% and you will get another 80rpm, and another, and another, and another, therefore the car slowly gets faster 0.5mph at a time. When you get the gearbox travelling at the same speed as the engine, you can fully take your foot off the pedal thus joining the gearbox to the engine; both sides will now spin at the same speed. In theory this means that the car can get faster than the engine; it can't. Let's see what actually happens…..

What actually happens is that the clutch moves across 10% of the difference between the two sides. This means that the gearbox doesn't get faster than the engine; it just increases speed until it matches the engine speed and then stops getting faster.

How do we know when they're at the same speed? Option 1: if you're not touching the accelerator, the car stops increasing in speed; option 2: if you are using the accelerator at the same time, the speed of the engine drops when the two speeds are close to matching and then increases again when they match speed, a sort of 'dip and climb on the rev counter'.

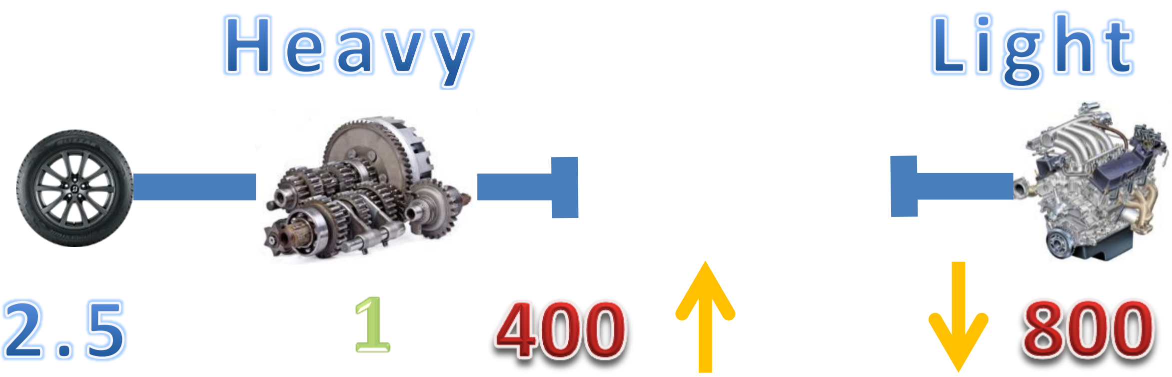
Look for the car to stop accelerating or for the engine revs to drop and then climb again.

Because we've got the engine at 800rpm in this example, the gearbox will go to 800rpm and so we'll do 5mph.

However, if we pressed the accelerator and set the engine speed to 1600rpm, the gearbox would increase by 10% until it got to 1600rpm and so we'd being doing 10mph (double 800rpm and so double 5mph).

Set the engine to 4000rpm and the gearbox would go to 4000rpm and therefore 25mph.

Issues (off clutch too soon)



100% bite = car and engine joined so they must be the same speed

OK, one of the issues that loads of people have with getting the car moving is taking their foot off the clutch too soon; now this is just physics at play here.

Relatively speaking, the car is heavy when compared to the engine.

PHYSICS SAYS, JOIN SOMETHING HEAVY TO SOMETHING LIGHT, THE HEAVY THING WINS

Try running at a Sumo Wrestler and see who wins!

So if the gearbox side is rotating at 400rpm and the engine is rotating at 800rpm and we join them together we have a problem.

Option 1 Car goes up to engine speed

ISSUE: CAN'T ACCELERATE THE CAR THAT FAST BECAUSE OPTION 2 IS EASIER:

Option 2 Engine goes down to car speed

ISSUE: SPEED NOW BELOW 600RPM = STALL

SOLUTION: WAIT FOR BOTH SIDES TO MATCH SPEED, THEN RELEASE THE CLUTCH

As you can see, if you get a 10% bite, you will need to wait for 10 lots of 10% to happen before you can remove your foot from the clutch.

If you had a 25% bite, you'd have to wait for 4 lots of 25% to happen before you can remove your foot.

What if I want to drive less than 5mph?

Good question!

From what we have been talking about, when you get a bite, the car goes to 5mph (if the engine is at 800rpm). If you recall however, the speed of the gearbox is most closely related to the speed of the car.

If the gearbox gives 5mph at 800rpm, then you'd get 2.5mph at 400rpm and therefore 1mph at 160rpm. So how do you get the gearbox rotating at 160rpm?

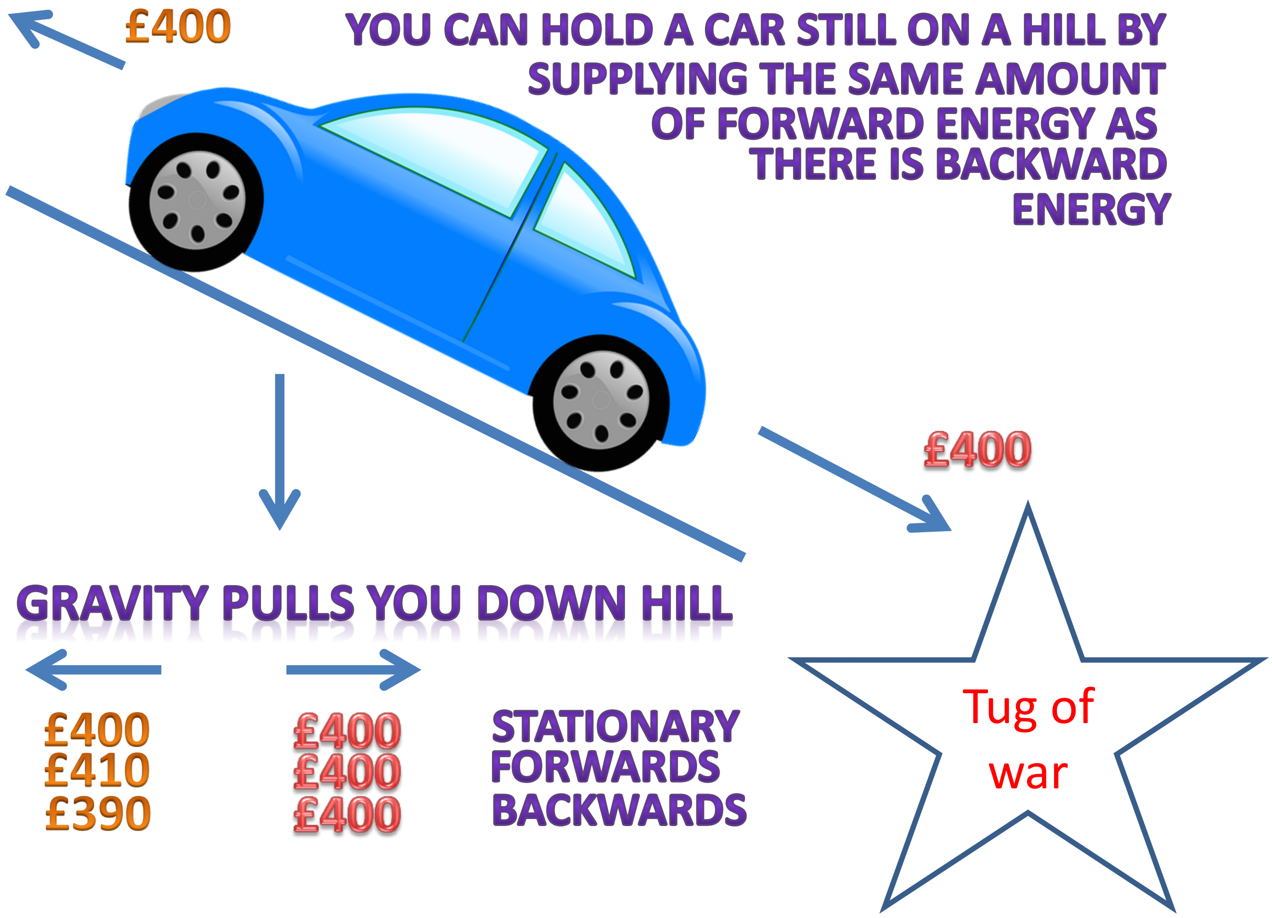
1. Get a small bite to transfer energy from the engine to the gearbox
2. Wait for the car to accelerate to the speed you want
3. Push the clutch back down a bit to stop transferring energy across from the engine
4. The car will roll a bit and possibly slow down
5. Get a small bite again to rebuild speed
6. Connect and disconnect from the engine as required to maintain the speed you want

Well this all sounds straight forward but you also need to consider that you can't get too big a bite and a good way to think about this is in monetary terms.

At the end of the day, power from an engine is just a resource that you use as required. Money is a resource that we all use as required; you could therefore think of an engine like a bank account.

Bank Account

Think of the engine revs as money in a bank account



Now all I'm doing in this example is replacing revs for pounds. Don't jump ahead and think about how to do this yet; just wait a little bit and read the next bit!!!

As a driver, we are constantly deploying energy (£'s) to combat or enhance the world around us.

In the example above, the car is on a hill and gravity is pulling the car down and therefore backwards; in this example we're saying that it's spending £400 to pull us backwards. Just like a game of tug-of-war, if you have the same amount of energy/money/power (however you want to think of it) pulling in opposite directions, they will cancel each other out and neither side will win.

So if we spend £400 of forward motion, it will cancel out the £400 of rearward motion from gravity and the car will remain stationary on the hill without need for any brakes – cool huh!
Spend less than £400 and the car will go backwards, spend more than £400 and we go forward. The more each side wins by the faster the car will accelerate in that direction.

Ok, so how do I do this then?

Wife = Clutch

Can't spend £400 but can ask for a percentage of the account

NEED TO SPEND £400?

50% of £800? No, you take £400, you leave £400 which is less than £600 and so the engine would stall

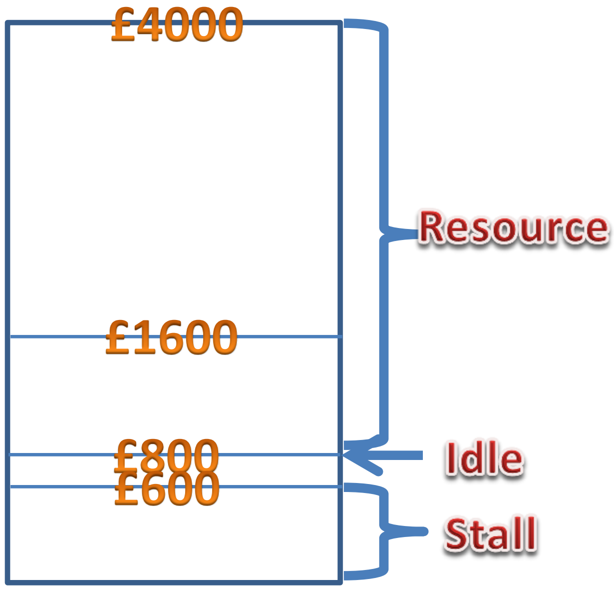
25% of £1600? Sounds good!

10% of £4000? Sounds good!

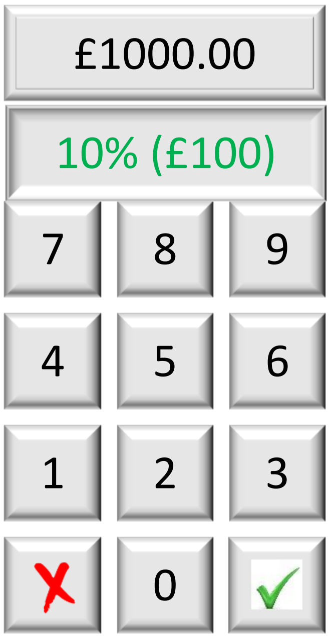
JUST MAKE SURE YOU LEAVE AT LEAST £600 (IDEALLY >£800) IN THE ACCOUNT AFTER A BITE!

Me = Accelerator

I EARN MONEY, REVS = MONEY IN ACCOUNT



I go to work and I earn money, I put this money in the bank account by pushing the accelerator. The amount of engine revs represents the amount of money in there.



I have an agreement with the bank manager that I will never get below £600 in the account or something bad will happen, like he shoots my cat for example.

Jeeves has agreed that he will keep me at £800 to cover direct debits and will try to keep it above £600 for me (told you he was a good lad!)

My wife is the clutch pedal and she can gain access to the bank account by spending a percentage of it. The cash point she uses doesn't allow you to withdraw a specific amount though. It only shows the account balance and allows her to ask for a percentage of it so she can't spend £100 but she can spend 10% of £1000 for example.

Now, my wife needs to spend £400, between us we could have:

Balance (accelerator)	Percentage (clutch)	Get	Leave	Thoughts
£800	50%	£400	£400	Bad – Dead cat
£1600	25%	£400	£1200	Good – we have more than £600 left, happy cat!
£2400	16.66667%	£400	£2000	Good – happy cat!
£4000	10%	£400	£3600	Good – happy cat!

Applying it all

How to pull away

If you don't touch the accelerator and keep your revs at 800rpm, this means:

1. You are only 200 rpm away from stalling speed so you need to be very good with your clutch pedal.
2. If you are on a hill, you are likely to stall because you need a big bite to combat the hill. A big bite means you will move a lot of revs over and so they will drop below 600rpm and you'll stall.
3. The maximum speed the car can get to is 5mph; not recommended if you are moving out into traffic.

To pull away, raise your revs a bit, like anything between 1500 and 2000 rpm. At the same time get a small bite to give you the rate of acceleration that you want.

When your revs 'drop and climb' then you can take your foot off the clutch and you are driving! Keep pushing the accelerator to build speed.

How to creep

Same as we mentioned previously about driving slowly, here it is again just to be nice to you.

1. Get a small bite to transfer energy from the engine to the gearbox
2. Wait for the car to accelerate to the speed you want
3. Push the clutch back down a bit to stop transferring energy across from the engine
4. The car will roll a bit and possibly slow down
5. Get a small bite again to rebuild speed
6. Connect and disconnect from the engine as required to maintain the speed you want

How to gear change

You can only change gear when you have pushed the clutch all the way down, so:

1. Put your hand on the gear lever
2. Remove your right foot from the accelerator
3. Push the clutch pedal to the floor with your left foot
4. Move the gear from your current gear to the new gear (1 to 2 in this example)
5. Get a bite by bringing the clutch back up and hold your foot still for half a second then remove the foot from the pedal
6. Press the accelerator again
7. If you are still accelerating and will do another gear change soon, keep your hand on the gear lever, repeat steps 2 to 7. If you're done gear changing, hand back on steering wheel.

The Automatic

For a lot of people, the thought of a manual car is too much or frankly far too complicated to even consider. As cars go over to electric, the requirement for a manual car will disappear anyway so in my opinion, the manual cars days are numbered. I do also think that this won't fully happen until about 2040 so in the meantime, the requirements for a manual will still exist.

You could well plan to only drive automatic cars and that's fine but, if you hire a car and order an automatic but when you get there they only have manuals, what are you going to do? If you have a manual licence you can drive either automatic **or** manual but an automatic licence will limit you to automatics only – just something to consider….

Automatics are generally more expensive to buy which may also affect your insurance premiums; new drivers beware!

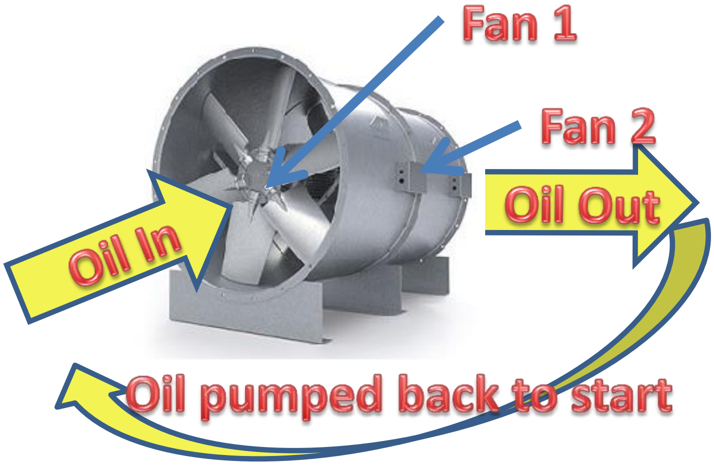
So how does an automatic work then?

The engine operates in exactly the same way as previously described; go to the front of the document for more information.

How does the engine join to the gearbox?

Think of a desk fan, in fact, think of 2 desk fans and some oil.

With a desk fan, when you turn it on, the fan spins and air blows in your face. When the fan is off and you start blowing it yourself, you can make the fan spin backwards. So if we put two fans face together and turned one on, fan 1 would spin fan 2 backwards.



So, now put the fans in a tunnel and fill the tunnel with oil (just imagine there are two fans in this tunnel; once the oil has passed through, it loops back to the start.

Obviously, the setup pictured would not work in the real world, so there's lots of clever engineering going on the background in a real car but you get the idea.

The engine outputs power to a fan and so when the engine revs increase, the speed of the fan increases.

The gearbox has the second fan connected to it. The faster the engine spins, the more the oil pressure increases and spins the gearbox.

There is no physical connection between the engine and the gearbox, therefore , you can stop the wheels of the car and still have the engine running without stalling the engine.

The gearbox

The gearbox in an automatic is a massively complicated piece of engineering that is beyond the scope of this document. It still performs the same task and operates under the same principles as the manual gearbox as it needs to do the same job; it's just how it goes about doing it that's different. I suggest going on YouTube if you want more information from an engineering point of view.

However, I will tell you how to operate one!

You have different modes in an automatic. Theres normally a button that you would press to allow you to change mode. Depending on the car, sometimes you may also need your foot on the brake pedal before they will allow you to change mode.

Driving Modes

P – Park
This should only be used when the car is stationary. A metal clamp locks the gearbox in place so that the gearbox can't phyically rotate. If the gearbox can't rotate, neither can the wheels of the car. You should still use the handbrake as well though to secure a car.

R – Reverse
This makes you go backwards.

N – Neutral
This should be used if you are being towed or pushed. It allows free movement regardless of if the engine is running or not.

D – Drive
This is the normal position for driving. Select this and let the car worry about which gear it wants to select.

S – Sport
Use this if you want the car to perform in a more sporty manner. A usual sport mode will keep the gearbox in a lower gear than normal (thus raising revs of the engine); it will also change down gears sooner than normal. (See the section Gears/Why/When).

M(+/-) – Manual up or down
You can manually select gears and the display will normally show the gear you have selected for example, M3 for manual mode, 3rd gear. A good example would be if you're preparing to perform an overtake and need more power or maybe you want to pull away in 2nd gear because you are on snow and want to reduce wheel spin; some automatics have a snowflake button for this very situation though.

How to drive an automatic
You only use your right foot to operate the pedals – never left foot brake. Your left foot should stay on the foot rest and your right foot does all the work, after all, you either want to stop or go, never both, therefore you only need to operate one pedal at a time.

When you get into the car, the gear lever should be left in Park.

Assuming you have started the car, put your seatbelt on etc, you put your foot on the brake and then select the gear that you want, Drive, Reverse etc.

Now, thinking about the 2 fans that make the car move, the engine fan is trying to spin the gearbox fan but can't because you have your foot on the brake so as soon as you release the pressure on the brakes, the car is likely to start creeping in that direction – useful for parking or moving in slow traffic.

If you are on a hill you might need a bit of accelerator just to help it creep.

Now, press the accelerator to raise your revs and you will now set a rate of acceleration. The car will now continue to accelerate at that rate and as it builds speed it just does gear changing for you. You do not take your foot off the accelerator to aid gear changing like you do in a manual – just leave gears to the car.

When you reach the speed you wish to travel at, decrease the pressure on the accelerator so that you can maintain that speed. If you take your foot off the accelerator, the car will start to slow down.

To stop the car, take your foot off the accelerator, use the brakes to help you stop at the location you want. When the car is stationary put the car in Park if you plan on turning the engine off or keep it in Drive if you are just about to pull away again.

Kick down

Kick down is a feature to enable faster acceleration. By default a gearbox is designed to produce optimum revs to do the job at hand but it's biased towards fuel economy.

The short version is that higher revs = higher power and therefore better acceleration. A gearbox will try to keep your revs low for fuel economy but if you want to accelerate quickly you need high revs.

To do this, you press the accelerator quickly and hard whilst driving, even all the way down to the floor. This action tells the computer that we want to accelerate quickly, it then changes down a gear or two, your revs then increase dramatically and you have lots of power to accelerate.

You might want to read 'Horses, gears, why, when' which explains gearing in more depth.

The different types of automatic gearboxes

Conventional

This the normal type of transmission, you find this everywhere.

Continuously Variable Transmissions (CVT)

CVT's are popular in hybrid cars such as the Toyota Prius. A CVT is a belt driven system and does away with cogs. There is only 1 gear ration but it's permanently changing to try and always be in the most efficient state. This means you get a very smooth drive as there's no gear changing.

The downside is slower acceleration than other automatic gearboxes; they also sound horrible if you try to accelerate them hard. There is a feeling of being 'disconnected' from the car which some people find disconcerting.

Dual Clutch

Similar to a conventional gearbox but this time there are two clutches which you switch between. The clutch you're not using tries to anticipate the gear you will want next and gets it ready for you, then you swap almost imperceptibly to the different clutch and thus new gear. The car gets your next gear prepared and you just swap to it; very fast.

Automated Manual Gearboxes

These aren't as popular as they used to be but can be found in cheaper cars such as Skoda Citigo.

These are like a manual car but a computer operates the clutch when you change gear; there is therefore a delay as they have to react to your input and they can sometimes be a bit jerky.

Pros and Cons of automatics?

Although automatic gearboxes traditionally have a reputation for being high maintenance, they are more reliable than they used to be.

They also reduce the chance of parts going wrong - for example, if your clutch control isn't perfect, you won't wear out the clutch in an automatic car.

As well as being easier to drive, in some cases automatic versions of cars can actually be more efficient than their manual counterparts.

They can be faster, too - many dual-clutch transmissions in particular can change gears quicker than humans can, shaving crucial tenths of a second off the 0-62mph time.

Automatic cars are, however, usually more expensive to buy, which will not help your cause if you're a new driver already facing high insurance premiums.

Engine, Foot and Terrain Braking

What is Engine braking?

Engine braking is when you're driving down a road and take your foot off the accelerator.

The engine will naturally start slowing down to 800rpm (0.8 in the picture).

If your clutch is up and you are in gear, then you have joined the engine to the car and so a by-product of the engine slowing is that it also slows the car to a degree. This is quite a subtle brake but very important and useful.

You should be aware that the more revs you have, the more engine braking you have. You will lose speed quicker between 6000rpm and 4000rpm than you will between 3000rpm and 1000rpm for instance.

When you get to 800rpm, the car will pull you along the road so you have no engine braking at all; get below 800rpm and the car will try to accelerate you back up to 800rpm.

What is Foot braking?

This is a no brainer, the more you push the brake pedal, the quicker the car stops.

What is Terrain braking?

This could also be known as World Braking I suppose; it's how the world around us affects the car.

Going uphill will slow down quicker than on a flat; you might even pick up speed going downhill.

Driving on gravel will slow you quicker than concrete, ice will not be as effective as concrete.

Head wind will slow you more than a tail wind.

The Situation

Assuming that you are driving a manual car, when we want to drive off we want our feet on the clutch and accelerator.

We want this so that we can raise our revs just prior to pulling away to lessen the chances of stalling the car as we bring the clutch up a bit.

The clutch basically moves revs from the engine into the gearbox to give us motion. If we don't raise the revs, the bite on the clutch could drop the engine revs below minimum speed and stall us; the fix for this is to raise the revs away from idle prior to using the clutch.

The Problem

The world is not flat and so there's a very good chance that you will be on a hill when you get to a junction.

If you approach an up-hill junction on a brake pedal and stop, when you take your foot off the brake to drive off, you are very likely to roll backwards into whomever is walking behind the car – this is bad!

You will have to perform a hill start at this point which means putting the handbrake on, getting your feet on the correct pedals, getting a bite and raising revs before slowly lowering the handbrake to move off.

Now, I do hill starts all day long and there's nothing wrong with them, they're very useful!

However, if I drive in such a manner that I force myself into a hill start at every junction, then I am incorporating delays that just don't need to be there. Wouldn't it be better to 'arrive ready to drive' and if there's a hole in the traffic, just drive into it? Of course it would be!

So therefore, if I can get my feet on the clutch and accelerator prior to arriving at the junction then I'm in a good position to just flow out into traffic.

I want you to think of the brake pedal as a pedal we use to top up the deficiencies in the other two brakes: engine and terrain.

In theory, given enough road, you could take your foot off the accelerator, the car would slow, clutch down around 1000rpm (to avoid being pulled along the road) and the car would roll to a stop in due course.

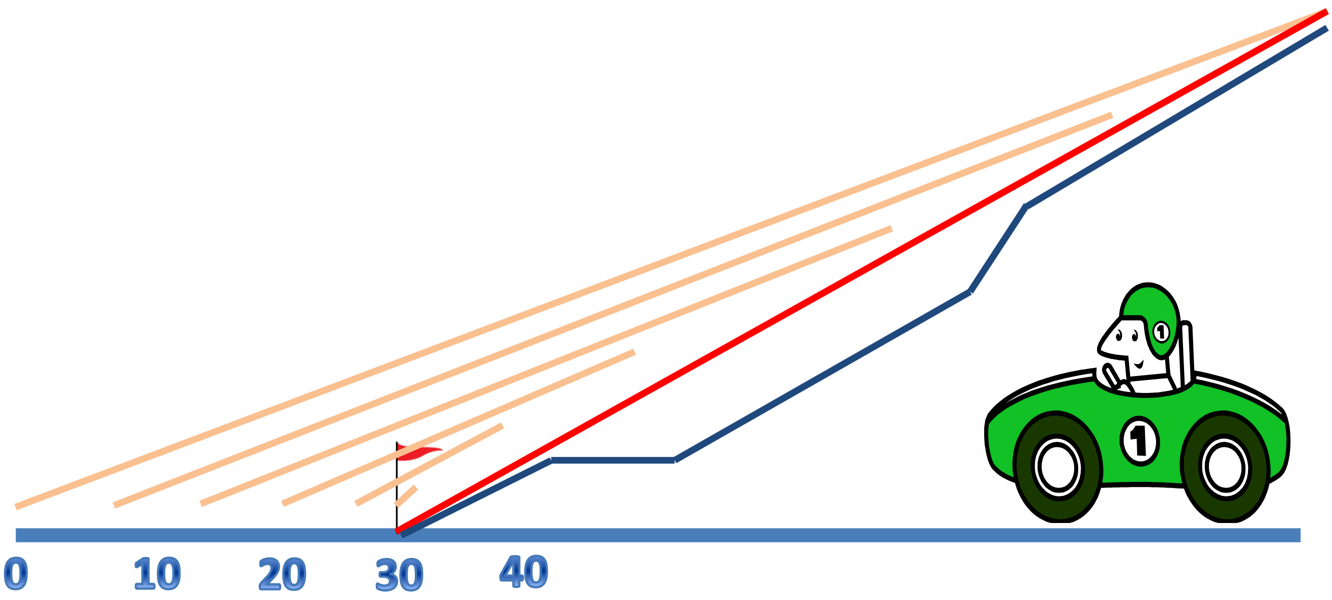
You would need a lot of road for this, so what we do is speed up the slowing process by supplying additional braking half way through. I still want to let terrain braking do the last little bit if I can though because I want my right foot on the accelerator when I get to the junction.

Now, most learners think that you brake for the place you want to get to (see red line in diagram on next page), you don't. If you apply brakes to stop at a place and half way through braking you suddenly go up hill (blue line on the diagram over), you'll end up stopping too soon, then you'll have to drive along a bit more and that will confuse everyone behind you.

You want to let engine and terrain braking do the work and then top up with foot brake when it looks like you're going to overshoot your stopping point. At the last moment you get off the brake pedal if terrain can do the last little bit for you.

Engine + Foot + Terrain = Total

Engine	Foot	Terrain	Total		
5		2	7	7	23
4		-3	1	8	22
3		1	4	12	18
2		3	5	17	13
1	1	1	3	20	10
0	2	1	3	23	7
0	1	1	2	25	5
0	3	1	4	29	1
0	0	1	1	30	0



You need to supply 30 lots of braking to stop at the flag; supply too little and you'll overshoot, supply too much and you'll stop early.

1. Foot off the pedals, you initially get 5 engine and 2 terrain totalling 7 braking; you are projected to stop at 7.
2. As you slow, your revs drop and so the amount of engine braking you get reduces.
3. Now you get 4 engine and this time we go down hill so you get 3 terrain <u>accelerating</u> totalling 1 braking so you are projected to stop at 8.
4. Then you get 3 engine and 1 terrain, projected to finish at 12.

5. Then you get 2 and 3 projected to finish at 17 but you're getting close to your finishing point and it looks like you're going to overshoot, you'd better start thinking about adding a bit of foot brake.
6. 1,1 and 1 gives an extra 3 so now you're projected to finish at 20.
7. You've now got so slow that you have to push the clutch down to avoid stalling the engine, you have now lost engine braking. Now it's just foot and terrain braking so you need to supply the brake pedal to top up the braking where it's lacking.
8. You can see that you might need to increase or decrease the pressure on the pedal to vary the amount of braking.
9. When you are a few car lengths away from your finishing point, slip the car into 1st gear and get ready to hold the car still using the clutch.
10. Finally, at the last moment, remove your foot from the brake pedal and let the car roll to a stop by way of terrain braking.

You should now catch the car with the clutch pedal. The clutch bite will stop the car rolling backwards; the hill will stop the car rolling forwards. If you have good clutch control they will cancel each other out and you can hold the car still on the hill.

Crucially, your right foot is over the accelerator so if you can go, you just raise your revs, slightly bigger bite and you're away!!!

Remember that if you are pointing downhill, you will need to still use the brake pedal. This is not a problem, because when you take your foot off the pedal, the car will roll forwards and this is what we want anyway.

Just a word of caution, having a bite for a long period of time generates a lot of friction in the clutch plates. This in turn generates a lot of heat and you can smell burning sometimes, keep burning the clutch and you could shatter the flywheel and basically lose your gearbox – not good; very expensive to fix.

However, there's a big benefit of using the clutch for short periods of time before you try to set fire to your car because your driving style will be so much smoother and fluid.

Summary:

1. We use the brake pedal to top up deficiencies in the engine and terrain braking.
2. Always 'aim short, 1st gear, creep'.
3. If 'a pause becomes a await' i.e you're going to be held up for a while, by all means put the handbrake on and wait with the clutch down (to avoid burning the clutch). We are trying to avoid driving in a manner that <u>forces</u> us to do a hill start every time; there's nothing wrong with doing a hill start when you actually need one.

Horses, Gears, Why, When

Please note I am talking concepts here and figures used are purely for demonstration purposes to get the concept across; don't try to relate these figures to anything else I have said.

In the days before cars, people used to travel around by horse and carriage.

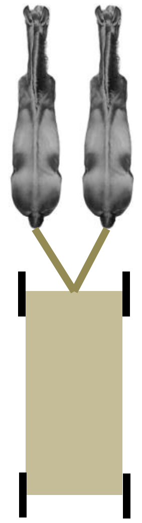
The Internal Combustion Engine was invented (just like petrol and diesel engines in today's cars) and the 'Horseless Carriage' (later shortened to car) was invented.

To sell this new mode of transport, people needed to know what they were buying.

Invented by James Watt, horsepower originally measured the amount of work that a horse lifting coal out of a coal mine could do in a minute. Back then, one HP equated to 33,000 foot-pounds. Not important but today, you can easily convert HP into different units, like 1 HP that equates to 746 Watts.

The car manufacturer could now tell people that this car has a 2hp engine and does the same amount of work as 2 horses; the engine now did the job that the horses used to.

Obviously, the more horses you have at the front of the carriage, the easier the carriage will initially move and the faster it will accelerate.



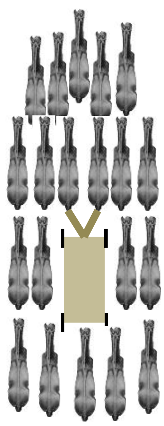
Think of my engine as being capable of outputting the same amount of power as 100 horses and the rest of the car as a carriage like you get in Cowboys and Indians movies. Here's a 2HP carriage but think of my car as a 100HP carriage.

HP is a calculation based on the turning force of the engine (known as torque) multiplied by the number of Revs of an engine (also known as Revolutions or RPM – Revolutions Per Minute, because the internals of an engine go round).

HP = REVS X TORQUE

Simply, the higher the revs from the engine the more HP (or horses!) you have access to (up to a maximum limit).

Revs = Horses



We all know that an engine rises in revs as we accelerate and as we slow down, those revs drop.

Because HP is a calculation based on revs, as the revs climb we get access to more horses.

We could imagine a scene where there's a carriage in a field and the number of horses tied to that carriage are the same number that correspond to the revs of the engine (they can be tied anywhere on the carriage, not just in front). 20HP

So at 1000rpm you have 20 horses available to you; as the revs climb more horses just appear like magic next to the car (if the revs dropped then the horses would start to disappear). 2000rpm will give you 40 horses, 3000rpm gives 60, 4000rpm gives 80 and 5000 gives 100 and everything in-between i.e 1500rpm = 30hp.

Now diesel and petrol engines behave slightly differently and because my car is a diesel, I'll talk about that.

If you raise your revs above 5000rpm however, you still only have 100 horses but it's like they're running down-hill too fast and some of them are falling over. So whilst you may still have 100, the amount of useable power from them gets less as more fall over.

Revs	Horses/HP	Good?
1000	20	Good
2000	40	Good
3000	60	Good
4000	80	Good
5000	100	Good
>5000	Some of the 100 are falling over	Bad

There's no getting away from it, when driving, the revs of the engine relate to how many horses you have brought with you.

Pros and Cons

Don't forget that there are good and bad points to having horses though.

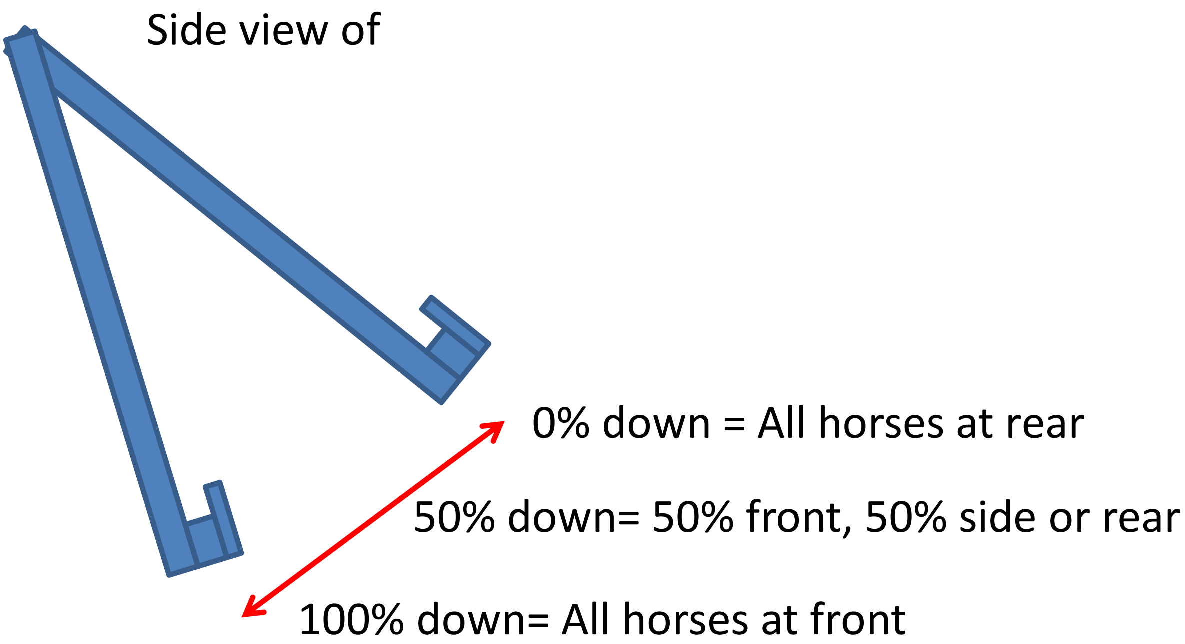
A horse equals power and that's good, but having a horse also means:

1. You need to feed it fuel (diesel for a car, hay for a horse), so it's expensive!
2. Horses fart and cars emit pollution, so more emissions.
3. Horses talk to each other and make noise and high revs are noisy, so noise pollution.

So that's 1 positive to 3 negatives! Really, we only want to bring horses when we need them, otherwise it's wasteful and bad for the environment.

The accelerator

The accelerator decides where the horses are positioned on a car like this:



So if the engine is at 1000rpm; we have access to 20 horses. If we push the accelerator down 50%, 10 horses are tied to the front and 10 are on the side or rear.

To summarise so far

Revs = horses. The more horses you have, the more power you have access to.
If you go into 5000rpm or higher, then your horses start falling over and the amount of power you have access to starts to drop.
The accelerator decides how you place the horses around the car, foot to the floor = maximum acceleration as 100% of the horses are used at the front. Take your foot off the accelerator and 100% of the horses go to the back of the car and you start to slow down.
You can move the horses around the car depending on how hard you push the accelerator.

Choose the right Gear to choose the right rev

Fact:
The higher the gear, the lower the rev
The lower the gear, the higher the rev

I know this might sounds crazy, but make the sound of a car accelerating and going up through the gears. Every time you go up a gear you drop the sound of the engine.

When you do a gear change you are at the same speed, it's just that you changed the gear, i.e:

1. Accelerate to 10mph,
2. Change from 1st to 2nd, you're still doing 10mph at this point.
3. Now accelerate again to raise to a different speed.

What's happened is that the revs have dropped so that you can build them again, but when you changed the revs you were doing 10mph.

We can therefore say that changing gears changes revs!

So how do we use this knowledge then?

The world around us is acting upon the car and forces are there trying to slow us down or accelerate us. We want to move the car but we need to take these forces into account.

There are two factors we need to account for:

1. The number of horses we are bringing and therefore potentially the number of horses we're not utilising and wasting and
2. How hard we are pressing the accelerator.

As a general guide, the lighter you press the accelerator, the less fuel is being pushed into the engine and so the more efficient the engine is.

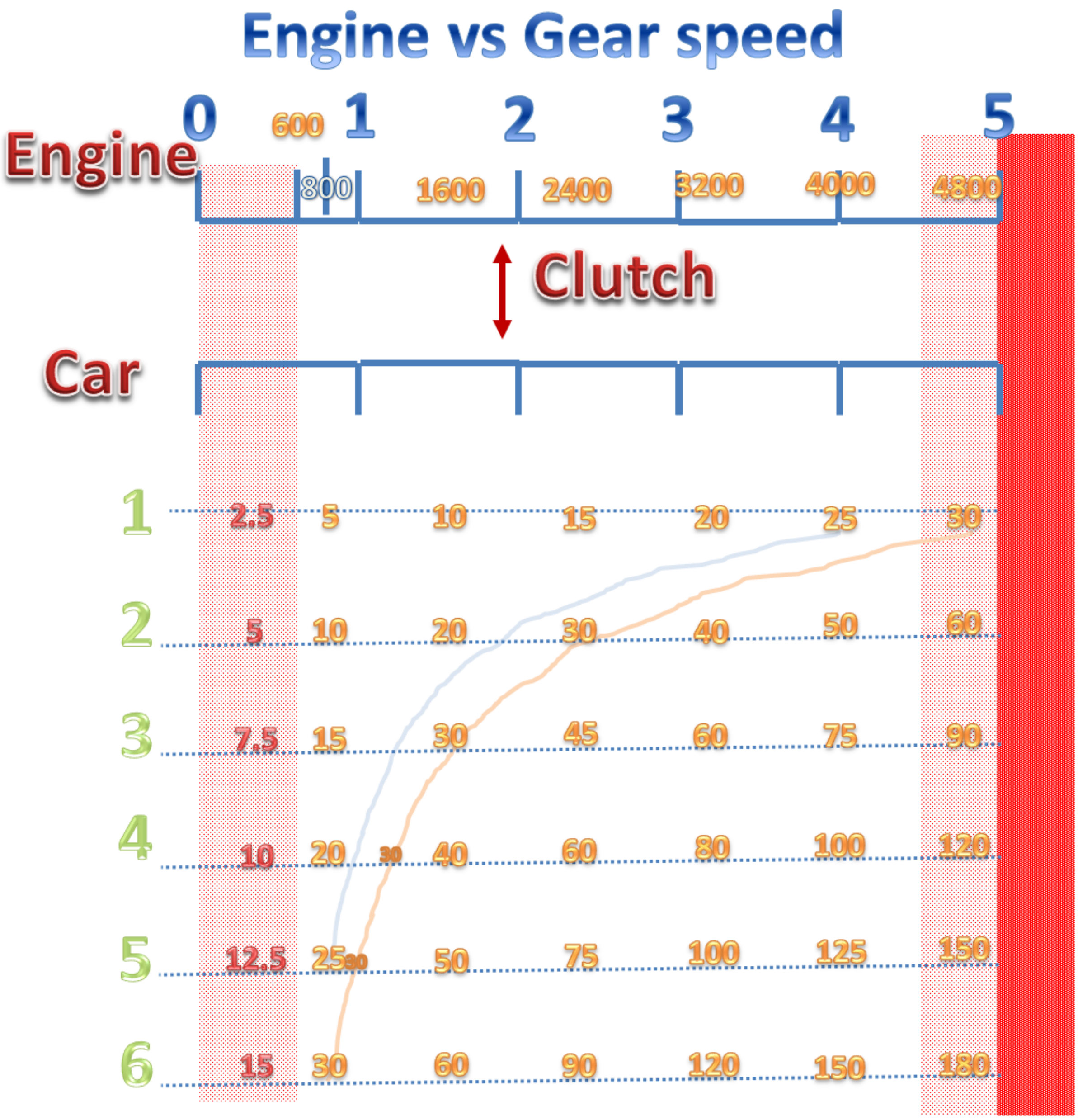
However, the lower the revs of an engine, the less work the engine does in the same period of time – which is also economical.

WHAT WE'RE LOOKING FOR IS THE IDEAL SITUATION WHEREBY WE CAN HAVE LOW REVS AND LIGHTLY PRESS THE ACCELERATOR

It might be more economical to lightly use a higher revving engine than have to push hard on a low revving engine. You will get a feel for it as you drive more.

Gear choice

The gear you pick changes the revs of the engine, the rev you have changes the number of horses. This is my actual car gearing and how it behaves.



Assuming a 100hp engine at 5000rpm, the diagram shows that **at 30mph** my car would be doing this:

Gear	Rev	Horses
1	4800	96
2	2400	48
3	1600	32
4	1200	24
5	960	19.2
6	800	16

Scenario 1

We are driving along a flat road with very little wind against the car doing 30mph. Taking into account all forces acting against the car, we have a combined resistance of 10HP.

10HP slowing

So, just to maintain our current speed we have to produce 10 horses tied to the front of the car. If we supply less than 10 we will slow down, if we produce more than 10, we will accelerate.

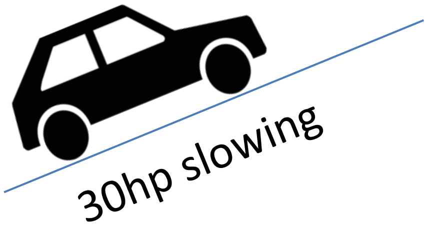
These are the options:

Gear	Rev	Horses	Accelerator %	Used horses	Good?	Comment
6	800	16	62.5	10	Good ish	Only 6 horses unused, quite hard on the accelerator though. It'll work though.
5	960	19.2	52	10	Good	9.2 horses wasted but accelerator only half way down, not much wastage and light on the pedal – I like it!
4	1200	24	41.7	10	Good	12 horses wasted but only 42% down – probably the most efficient
3	1600	32	31.25	10	Good ish	22 horses wasted but 31% down, a bit wasteful…
2	2400	48	20.8	10	Bad	38 horses too many, starting to sound loud
1	4800	96	10.4	10	Bad	86 horses too many, you sound like a boy racer and are polluting the world – stop it!!

As you can see, often there isn't one good gear, there are multiples and you need to pick the one you feel is best at the time.

Scenario 2

We are driving up a hill; there is a combined resistance of 30HP



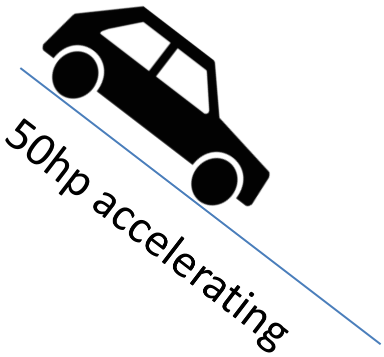
We need 30HP to maintain our current speed, anything less than 30 horses tied to the front and we will slow down, tie more to the front and we will accelerate.

These are the options:

Gear	Rev	Horses	Accelerator %	Used horses	Good?	Comment
6	800	16	100	16	Bad	We need 30 horses and can only supply 16. The car will get slower and stall.
5	960	19.2	100	19.2	Bad	We need 30 horses and can only supply 19.2. The car will get slower and stall.
4	1200	24	100	24	Bad	We need 30 horses and can only supply 24. The car will get slower and stall.
3	1600	32	93.75	30	Good ish	2 horses wasted but 94% down, very little scope for improving performance if you want it…
2	2400	48	62.5	30	Good	18 horses wasted, 62% down, you will have some acceleration if you want it, starting to sound loud
1	4800	96	31.25	30	Good ish / Bad	66 horses too many, good scope for acceleration if you plan on doing so soon but very wasteful if you're not planning on accelerating. You sound like a boy racer and are polluting the world.

Scenario 3

We are driving down a steep hill and the hill is trying to accelerate us with the force of 50 horses.



We need 50HP to maintain our current speed but his time tied to the back of the car, anything less than 50 horses tied to the back and we will accelerate down hill; tie more to the back and we will slow down. Remember, that the more you win by the more you will act in that direction. I.e. winning by 25 in any direction will have a greater affect than winning by 5.

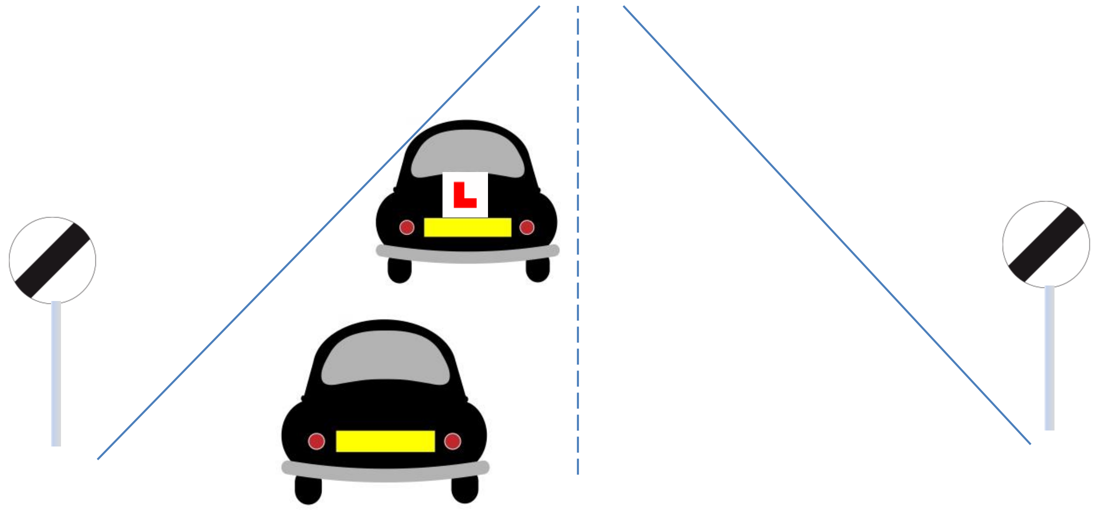
These are the options:

Gear	Rev	Horses	Accelerator %	Used horses	Good?	Comment
6	800	16	0	16	Bad	We need 50 horses and can only supply 16. The car will speed up.
5	960	19.2	0	19.2	Bad	We need 50 horses and can only supply 19.2. The car will speed up.
4	1200	24	0	24	Bad	We need 50 horses and can only supply 24. The car will speed up.
3	1600	32	0	32	Bad	We need 50 horses and can only supply 32. The car will speed up.
2	2400	48	0	48	Bad	We need 50 horses and can only supply 48. The car will speed up.
1	4800	96	48	50	Good	The only gear we can use. Push the accelerator down half way to reduce the impact of engine braking and you can control the speed of the car.

Let's not forget that if you are on a small hill, using the brake pedal is more efficient than going into 1st gear and solely using engine braking. I am trying to demonstrate how changing gears can enhance car control in these examples.

Scenario 4

We are stuck behind one of those bloody learner drivers who doesn't use their eyes. They've gone from a 30 into a national speed limit (60 on this road). We need to overtake them.



The road has a resistance of 10 horses so all the time we were in the 30 zone I would behave as per scenario 1.

As we approach the national speed limit, I would prepare the car and drive at 30 but with extra horses. We do this because as soon as we get into the 60 zone, we need to blast passed the learner and get up to 60 before we get stuck behind them if other traffic arrives.

These are the options:

Gear	Rev	Horses	Accelerator %	Used horses	Good?	Comment
6	800	16	62.5	10	Bad	Only 6 horses unused, good for economy but we need power! We need horses!
5	960	19.2	52	10	Bad	Only 9.2 horses in reserve when we hit the accelerator; we can do better.
4	1200	24	41.7	10	Bad	Only 12 horses in reserve when we hit the accelerator; we can do better.
3	1600	32	31.25	10	Good ish	22 horses in reserve, getting better, we'd have a luke-warm level of acceleration.
2	2400	48	20.8	10	Good	38 horses in reserve – good! We'll have loads of power and the revs can climb a long way before we need to change gear.
1	4800	96	10.4	10	Bad	86 horses is an excellent amount of horses to aid with acceleration, but we have to gear change when we

						increase revs by just 200rpm, so you'd have to change into 2nd as soon as you hit the accelerator. You may as well just start in 2nd.

Now we have the correct gear selected, as soon as the opportunity arises, put the accelerator on the floor and go for it; don't muck about, really go for it. The longer you take to overtake something, the longer you are in the path of potential oncoming traffic and therefore there's a real chance of a head on collision – not nice!

According to the earlier diagram, 2nd gear can get you to 60mph. I would therefore accelerate from 30 to 60 in 2nd gear and then do a block change from 2nd into 6th. I do this because my priorities have changed from 'accelerate' to 'cruise'.