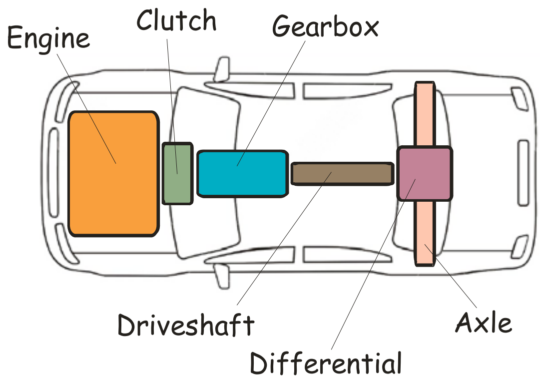
MECHANIC ACTIVITY BADGE

The Mechanic Activity Badge teaches us about mechanical systems and how they work. We are going to focus on the car and the most common type of engine cars use - the internal combustion engine. To keep things relatively simple, we're going to stick to describing a rear-drive car with a manual gearbox and a 4 cylinder engine.

How Does A Car Move?

A car produces power within its **internal combustion engine**, which turns a **flywheel** which connects to the **clutch** via a pressure plate. The clutch is connected to the **gearbox**, which modifies and transfers power to the **drive shaft**. The drive shaft connects to a **differential** on the **rear axle** of the car, which turns the wheels and moves the car. It sounds more complicated than it is!

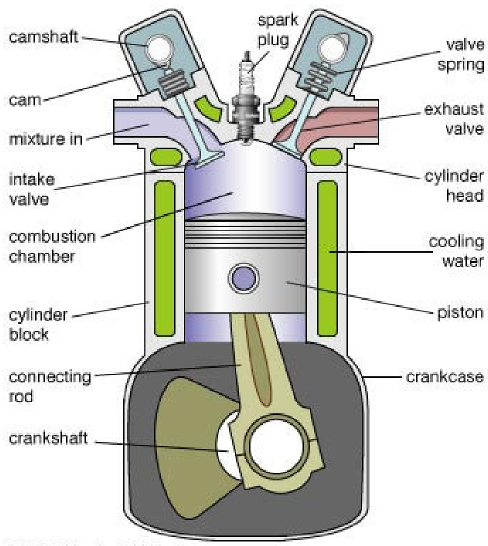


The Internal Combustion Engine

An internal combustion engine is so called because it **combusts** (sets fire to) fuel inside itself (internally). That was easy!

By burning fuel, the engine produces energy. It must then take that energy and convert it into a rotary motion useful for turning a car's wheels. Therefore, an engine must contain:

- A method of bringing fuel into itself
- A method of burning the fuel to produce as much energy as possible
- A method of using that energy to produce rotary motion
- A method of expelling the leftovers from burning fuel (exhaust gasses)



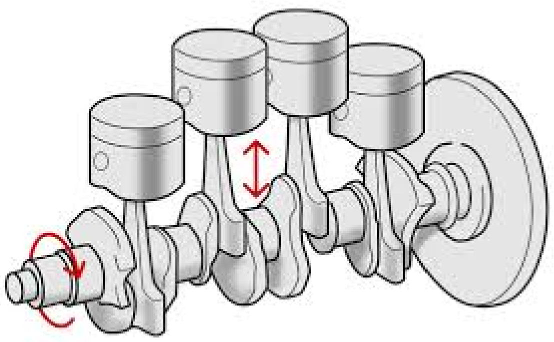
The work for each of these requirements is handled by **valves**, **pistons**, and **spark plugs**. A piston sits in a **cylinder**, so it can slide up and down. The piston fits tightly into the cylinder, so it doesn't rattle about while moving up and down, and won't let fuel, energy, or exhaust gas escape while the engine is in operation. At the top of a cylinder sit two valves - one for letting fuel in (**intake**), the other for letting exhaust gas out (**exhaust**) - and a spark plug, which is a device for introducing a spark into the cylinder to explode fuel.

When in operation, a cylinder goes through four stages:

- **Intake ("Suck"):** The piston is moving down in the cylinder, and the intake valve is open. The movement of the piston sucks fuel in to the cylinder. (Actually, it sucks a mixture of air and fuel in - you know that fire needs air to burn!)
- **Compression ("Squeeze"):** The piston is moving up, and both valves are closed. This squashes (compresses) the fuel into a smaller space, which will produce more power when it explodes.
- **Power ("Bang"):** The piston reaches the top of the cylinder, both valves are closed, and the spark plug ignites the fuel. The fuel explodes, and the explosion forces the piston down.
- **Exhaust ("Blow"):** The piston is moving up, and the exhaust valve is open. This forces the gas left over from the explosion out of the cylinder, into the exhaust pipe, and out of the car.

Remember:

Suck   Squeeze   BANG!   Blow



The piston is connected via a **connecting rod** to the **crankshaft**. The crankshaft is designed in an offset pattern, so when the piston moves up and down in the cylinder it pushes the crankshaft around, producing the rotary movement we need to drive the car.

You can see from this drawing that a car usually has more than one piston (and accompanying cylinders). Having more than one piston means that the engine can have cylinders that are at different stages in the cycle. With four cylinders, you can have all four stages going on at the same time - meaning there is always one explosion happening to keep the engine moving efficiently and consistently. You might have heard of engines named "V8" or even "V16". These engines have even more cylinders (the "V" refers to how they are arranged inside the engine), and can therefore have multiple cylinders going "BANG!" at once, producing more power - and a faster car! Explore what type of engines Formula One racing cars are using, and have used in the past.

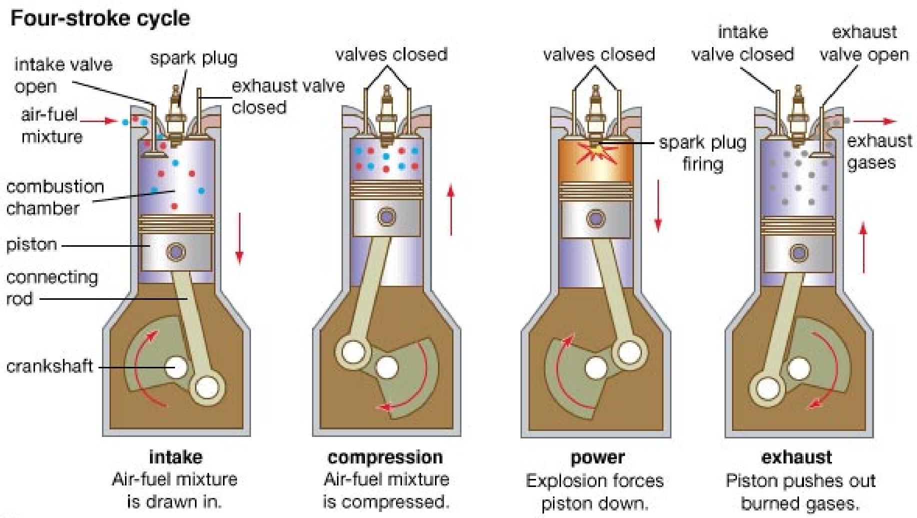
Timing is Everything!

You can see that there is a lot of things that have to happen at set times during an engine's operation. It's no good if the cylinder is read for a BANG, but the spark plug isn't going to fire at the right time - or if the cylinder is in its compression stage, but the exhaust valve is open.

For this reason, all of the bits and pieces of a cylinder need to work at the right time. To help with this, the crankshaft is connected to a **camshaft** via the **timing chain** (or **timing belt**), and it is this that sorts out when the valves open and close. Get the camshaft lined up properly with the crankshaft, and the mechanical side of the engine should be sorted!

But there is an electrical side, too, and that determines when the spark plugs fire. To sort that out, the engine's electrical system is connected to a **distributor**. This is also mechanically driven by the motion of the crank shaft. Inside the distributor is a revolving electrical connection, which connects each spark plug in turn to the car's electrical power. So, by lining the distributor up properly, the spark plugs will fire when they are supposed to.

The entire cycle for a 4-cylinder engine looks like this:



Descriptively:

The piston moves down in the cylinder while the intake valve is open, drawing a mix of fuel and air into the cylinder. As the crank shaft revolves, it moves the piston up in the cylinder and turns the camshaft, with the timing chain, to close the valves. This compresses the fuel mixture. When the piston reaches the top of the cylinder, the distributor connects the spark plug to electrical energy, causing it to fire and explode the fuel mix. The explosion forces the piston down, which turns the crank shaft around. When the piston comes back up, the camshaft opens the exhaust valve and the exhaust gas is forced from the cylinder. When the piston reaches the top, the exhaust valve closes and the intake valve opens, ready to start the whole cycle again.

When you start a car, you use energy from the car's battery to turn the crankshaft. This starts the engine's cycle, and away we go!

The Flywheel said to the Clutch...

When you first start a car, you do not want it suddenly zooming down the road. To give the driver control over this, the engine is not directly connected to the wheels.

The engine actually turns a large disc called a **flywheel**. The driver can press a pedal inside the car to connect or disconnect the flywheel from the wheels by way of a **friction plate**. When the pedal is up, the friction pedal is pressed against the flywheel, and the power from the engine is connected to the wheels. When the pedal is down, the friction plate is lifted away from the flywheel, so the engine cannot turn the wheels. This whole pedal-friction plate mechanism is called the **clutch**.

When you learn to drive, you will learn a lot about clutch operation. For example, if you release the clutch too quickly, suddenly applying the whole weight of the car's drive system to the engine can cause it to stall. You can also hold a car on a hill by balancing the amount of pressure the clutch is applying to the flywheel, to be able to drive a car up or downhill from parked without risk of rolling in the wrong direction first.

Playing with Speed - the Gearbox

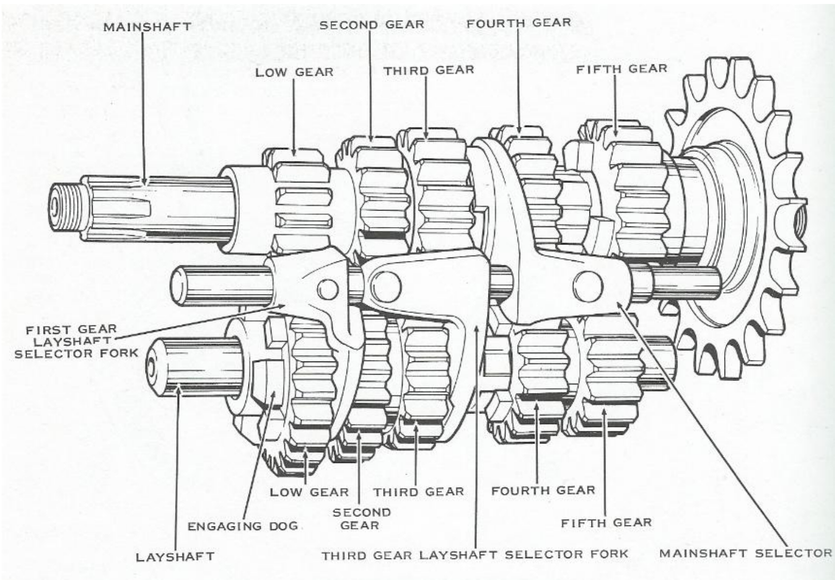
The engine (through the clutch) is not connected *directly* to the wheels. Instead, the power is transferred through a **gearbox**. The gearbox is... a box of gears, aligned so that the rotary speed of the engine can be modified before it is transferred to the wheels. The lower the gear, the slower the wheels move in relation to the speed of the engine. The higher the gear, the closer the wheels will move to the speed the engine is moving at. Usually, the highest gear a car has provides **direct drive**. That is, the wheels move at the same speed as the engine.

Low gears also provide high **torque**. Torque is a twisting force. All that rotary energy provided by the engine can't just be thrown away, just because we are forcing the wheels to turn at a slower speed. Instead, the rest of the energy is converted into torque. We are turning the wheels slower, but we are turning them with more force. This is why we start a car in a low gear, and shift upwards through the gears as we get faster - the car needs more force to get it moving than it does to keep it moving. Experiment by pushing something heavy (not too heavy - do not injure yourself or anyone else!). You'll find that, once you have got it moving, it gets easier to keep it going.

We also use low gears to drive up steep hills, or when towing, or any other situation where we need more force than speed.

Gearboxes have two special settings, too. **Neutral** is where no gear has been selected, so none of the rotary power provided by the engine is being sent to the wheels. **Reverse** is a special gear selection that, as you might guess, turns the wheels in the opposite direction - causing the car to move backwards instead of forwards.

The picture below shows the gears inside a five-speed gearbox. Don't panic! You only have to understand what a gearbox does, not how it does it with all of its collection of cogs and rods!

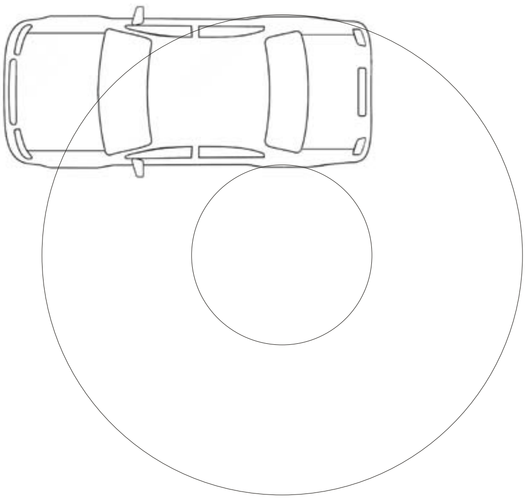


Viva la Differential!

We haven't quite reached the wheels yet, though!

At the moment, we have the engine, producing rotary power, which goes through the clutch and gearbox, to the drive shaft. But this is all in the wrong direction to power the wheels! All of our rotary power is going down the length of the car. We need to somehow turn it 90 degrees. Not only that, but consider what happens when a car turns a corner...

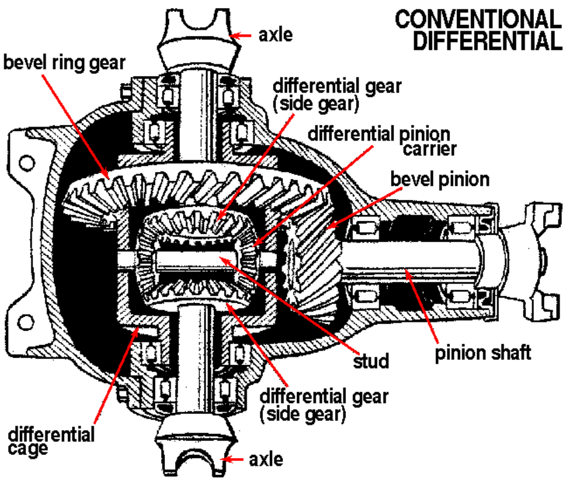
If you draw a circle, and say that this is the path a car's wheel takes when turning a corner - for example, the right-hand wheel when turning left. Now imagine the left hand wheel, and the circle it will draw while the car is turning. You'll end up with something like this:



What do you notice? Now imagine that the left and right hand wheels are travelling at the same speed. What do you think will happen?

The fact is that, when turning, the wheel on the inside of the turn will have to travel less distance than the wheel on the outside - their circles are of significantly different sizes. Because you want both wheels to go into and come out of the turn at the same time, it means the inside wheel has to turn slower than the outside - it must travel less distance in the same time as the outside wheel.

Through a series of gears, a car's **differential** transfers the drive rotation to the wheels, and allows the wheels to travel at different speeds. It's a clever device! As with the gear box, the diagram below shows the inner workings of the differential, but you just need to know what it does.

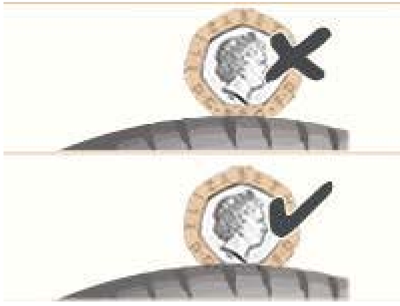


Tyres and Wheels

Finally! We've arrived at the wheels! A car's wheels are round devices designed to bolt onto an axle, and hold tyres. Simple enough. Or is it...

Tyre Tread

A tyre possesses **tread**. These are the lumps and bumps around the surface of a tyre that are designed to give the car grip and disperse water. You might see racing tyres that have no tread - this is because racing tyres are made from extra-sticky rubber designed for the surface of a race track. On normal cars, driving on roads with no tread on your tyres is very, very dangerous.



Because of this, it is illegal to drive on roads with tread that is not very deep. It is important that the depth of tread (which wears down the more you drive) is checked regularly. The easiest way to do this is to put a 20p coin edge down into the tyre's tread. If the band around the edge of the coin doesn't appears over the tread, the tread is OK. There are more sophisticated tools for measuring the depth of tread, too.

Tyre Pressure

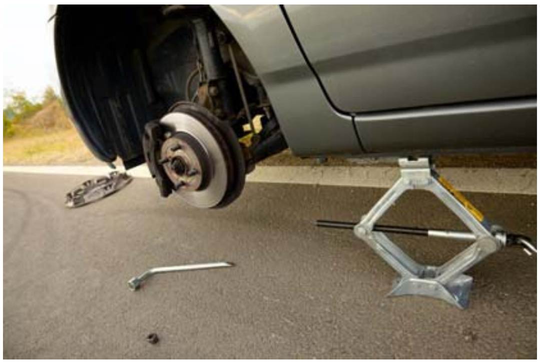
A car's tyres must be inflated - that is, to fill them with air. When you fill something with air, the more air you put in the higher the pressure (the force the air inside is pushing the inside of the tyre with) is. Imagine a balloon. If you do not put enough air into the balloon, the air inside cannot put enough pressure on the balloon to make it nice and round. On the other hand, if you put too much air into the balloon, the pressure becomes too great for the balloon to handle, and it goes POP!

This is the same for tyres. All cars are designed to work with tyres of a given size, inflated to a particular pressure (or, sometimes, range of pressures for different uses or loads being carried). You can find this information on a label or plate, usually inside the driver's door. Next time you're opening the car door, see if you can find it. This gives tyre pressure information in bar, and also in pounds per square inch for us old ones still more used to Imperial measurements.

You can check to see if a tyre matches the correct pressure by using a **pressure gauge**. These are simple devices that you connect to the valve of the tyre. Shown here is an analogue pen gauge, but you can get digital dial versions too. If the tyre doesn't have enough air, you can add more by using a pump.

Car tyre pumps often come with a built-in pressure gauge, but some do not. In either case, you must check the pressure as you go, to make sure you are inflating to the correct pressure. If you keep pumping, but the tyre's pressure does not go up - the chances are you have a puncture, and must change to a spare wheel.

Changing Wheels



Changing a wheel on a car can be **dangerous** if you do not apply common sense and act responsibly!

Every car should carry a spare wheel, a **jack**, and a spanner that fits the nuts which hold the wheels to the car. This is so that a driver has everything he needs to get home safely should his car suffer a puncture. Usually, the jack is a **scissor jack**.

First, find a safe place to do the work. You might need to move the car, if you are on a dangerous section of road. A safe place should be safe for you to work, and have a flat, strong, level (not on a hill!) surface on which to place the jack. You are going to be lifting the car with the jack - it **must** be stable **at all times**!

Second, locate the jacking point for the wheel you are going to be working on. All cars have special strong points near the wheels that are designed for the jack to fit onto. If you lift a car away from these special points, you can damage the car's bodywork or floor. Once you have located this strong point, raise the jack by turning its screw, just so that the top of the jack slots onto the jacking point.

Third, use the spanner to loosen the wheel nuts. Do not take them off! We do this before actually lifting the car, because sometimes it takes a bit of brute force and effort to get them to undo. **You do not want to be doing anything involving brute force while the car is in the air!!!**

Fourth, raise the car by turning the jack's screw. Keep going until the tyre you are working on leaves the ground. Remember that you will be putting an inflated tyre onto the wheel, having taken a punctured and deflated tyre off - leave enough room, but don't go mad.

Fifth, remove the nuts with the spanner, and gently ease the wheel off the axle. Remember - **no brute force while the car is in the air**. As you remove the nuts, put them in a safe place so you don't lose any.

Sixth, locate the new wheel's holes onto the axle's bolts, and put the nuts back on. Don't tighten the nuts at first - just put them on enough to hold the wheel and make sure everything's straight.

Seventh, tighten the nuts a little. Not fully! Again, remember the rule - **no brute force in the air**!

Eighth, clear everything out of the way, and lower the car by turning the jack's screw in the opposite direction to that used to lift. Lower until the jack comes free from the jacking point, and the car is fully on the ground.

Ninth, now the car is on the ground, you can use the spanner to tighten the bolts. They need to be fairly tight - you do not want the wheel to fall off while you're driving!

Finally, drive home. While you are driving, be wary of anything that feels wrong through the steering - it just might be that new wheel about to fall off!

Tyre Construction

Not all tyres are created equally. The two most widespread types of construction are **radial** and **cross-ply**.

Cross-ply tyres have rigid walls (the edges of the tyre). They are generally more robust and cheaper to manufacture (and to buy). A lot of budget tyres will be cross-ply, as will tyres made for tough environments.

Radial tyres are made to be more flexible. This gives the driver more control, as the tyres end up working with him (the tyre's flexibility allows the wheel to move where the driver wants), rather than against him (the tyre's inflexibility fighting against the driver's will). Consequently, radial tyres are a lot safer. They are also more expensive.

Because radial tyres flex and cross-ply tyres do not, it is **very** dangerous to mix them on a car. Imagine trying to turn a corner, where one wheel is saying "yes, cool - go for it!", and the other is saying "no way, I want to go *this* way instead!". The result is potentially disastrous. At the very least, you should never mix radial and cross-ply tyres on the same axle of a car. At the very best, you should never mix them on a car full stop - always make sure all of the tyres on your car are of the same type. Just, do not do it - it will kill you.

Ongoing Maintenance

Beyond putting petrol in them and making sure the tyres aren't going to murder you, there are all sorts of little odd jobs that need doing to make sure a car is safe and happy. You don't need to know everything, but the following are within the scope of the Mechanic Badge:

- **Windscreen wash:** To keep the windscreen clean and safe, all cars have washers that squirt a water/cleaner mix onto the windscreen. This liquid is stored in a tank under the bonnet of the car. You need to know how to find it, how to check it, and how to fill it - especially without accidentally pouring windscreen wash into the brake fluid reservoir!!!!
- **Radiator:** Cars pump water around the engine to keep it cool (not an easy job, with all those explosions going on!). The water is passed through a **radiator** to cool it down. Unlike the radiators in your house, which give off heat to keep you warm, a car's radiator gives off heat to keep the water going through it cool. The level of water in the radiator needs checking periodically, because a car without enough water will quickly overheat and damage itself. The water put into a car is mixed with antifreeze, to stop it freezing inside the car. Water expands when it freezes - this would be a bad thing to happen inside a car's engine!
- **Windscreen wipers:** These are rubber blades that move across a car's windscreen to keep it clear from rain and other things that would obscure the driver's vision. They can wear out or become damaged, and must be replaced.
- **Lights:** Last but not least, a car has several lights - headlights, braking lights, reversing lights, indicators... All of them must be kept in working order. Just like the lights in your house, car lights have bulbs that can blow, and must be replaced. As an exercise, see how many cars you can spot that do not have properly working lights - a lot more than you would think!

The MOT

Every year, every vehicle (cars, trucks, motorbikes - all of them) registered in the United Kingdom that is 3 years of age or older must undergo a series of safety checks known as an MOT test (taking its name from the Ministry of Transport). It is illegal to drive such a vehicle without having a valid MOT.

The purpose of the MOT is to make sure vehicles being driven on the UK's roads are safe. It tests tyres, suspension, brakes, seats, seatbelts, and many other aspects of a vehicle that, if not properly maintained or damaged, could make the vehicle unsafe.

MOT tests are carried out by establishments licensed to do them. The symbol shown is used to display that an establishment holds a licence. On your travels, take a look around - see how many times you see this symbol.

In general, the MOT tests:

- Bodywork, for excessive corrosion and jagged edges
- The bonnet, to make sure it shuts and latches properly
- The doors, to make sure they close and latch properly
- Windscreen, for damage that might obscure the driver's view or render the windscreen unsafe
- Windscreen wipers and washers, to make sure they work
- Steering and suspension, to make sure it is not damaged and works properly
- Tyres and wheels, for safety (tread depth and damage, for example)
- Brakes, to make sure they work properly
- Exhaust system, to make sure it's complete and secure
- Exhaust emissions, to check for excessive pollution
- Seats, to make sure they're secure
- Fuel system, to make sure the lines carrying fuel to the engine are not damaged or leaking, and the system is secured with a key to the petrol tank
- Seat belts, that they are present and secure
- Mirrors, to make sure they are secure and in good condition
- Boot, to make sure it closes and latches properly
- Registration number plates, to make sure they are present and legal
- Lights, to make sure they are working and are in good condition
- Horn, to make sure it's working
- Identification number, to make sure it matches the vehicle

Think about each point above, and why it is necessary to include within an annual safety test for cars. Do you think it should include anything else?

Why do you think an annual test for cars 3 or more years old is needed?

Why do you think cars younger than 3 years do not need to be tested?