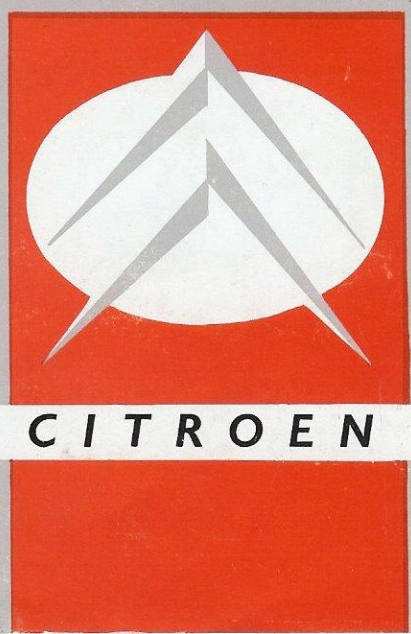
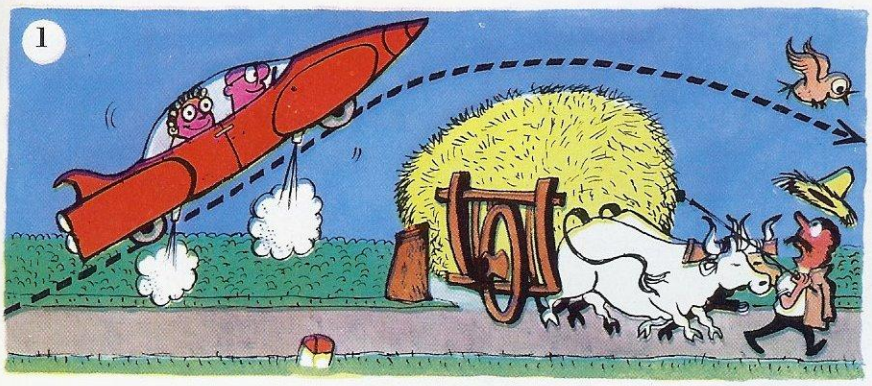
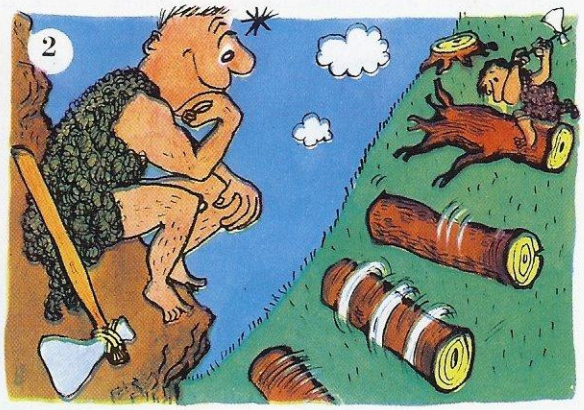
Steering through the ages



STEERING THROUGH THE AGES

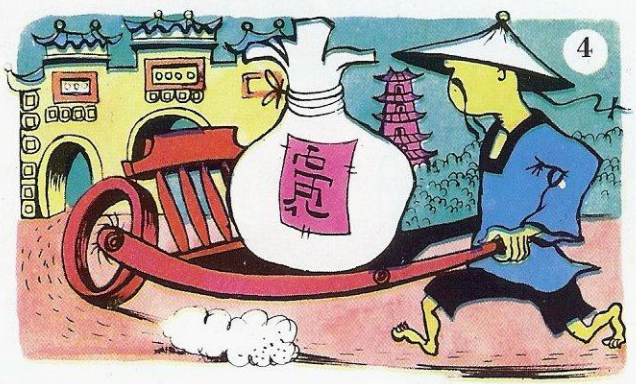
Chapter 1



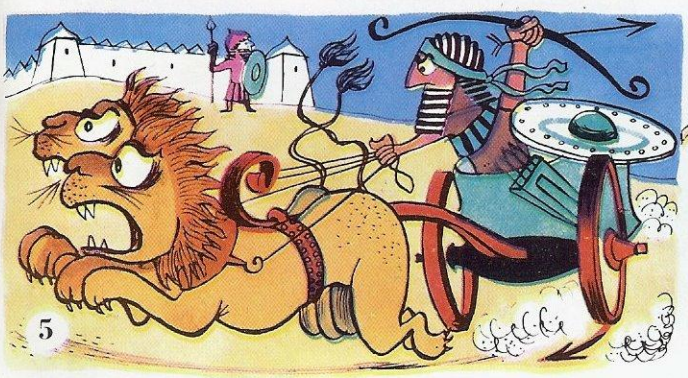


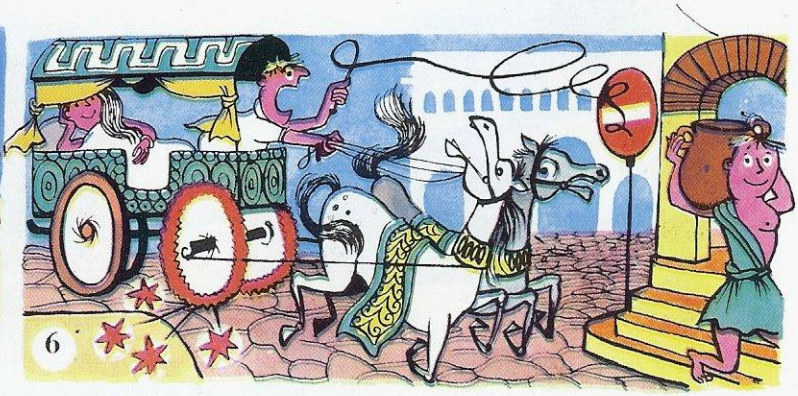
ON a road travelling at 60 m.p.h. an obstruction suddenly appears! There is little choice. Either you stop, or swerve. Science fiction gives us to understand that one of these days we will be able to go over obstacles (1) thanks to antigravity rockets fitted under the car. But whilst we are waiting for this marvel, we have to rely on good brakes and good steering.
Good steering? Easier said than done! Just let's glance at history. Man had to go through countless stages before being able to steer the vehicle he invented.
Thousands of years ago, trunks of trees stripped of their branches no doubt had the same ability, as today, to roll downhill (2).



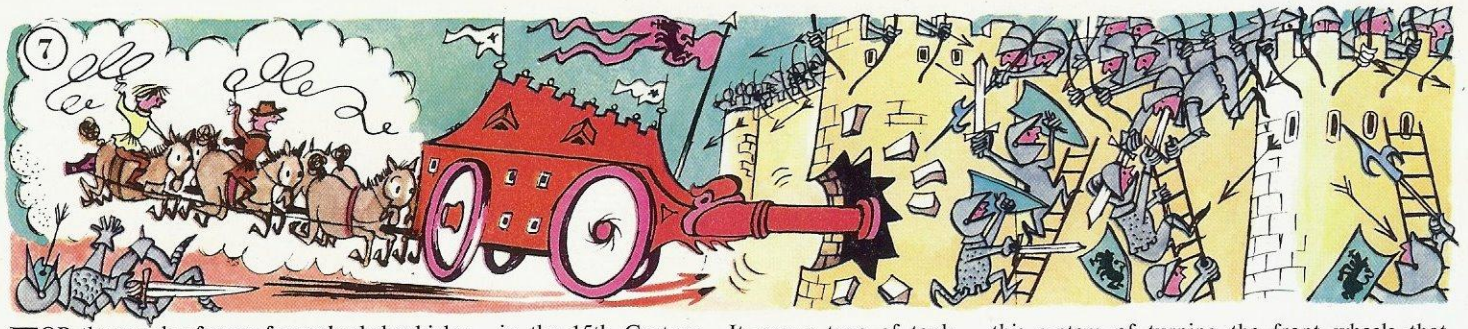


IT is perhaps how prehistoric lumberjacks got the idea of the wheel—by slicing the tree trunks and rolling the roundels (3).
It is mere supposition since one has never found a statue glorifying the person who made this prodigious invention.
In giving wheels to vehicles, human genius brought off a double coup. Not only was he now able to roll along what he had had to drag or carry but he could also manoeuvre (that is direct the course of) what he had previously pushed around.
On one-wheeled vehicles the problem of steering was solved way back in antiquity as instanced by the barrow (4) invented not by BLAISE PASCAL but by the Chinese, 3 centuries B.C.





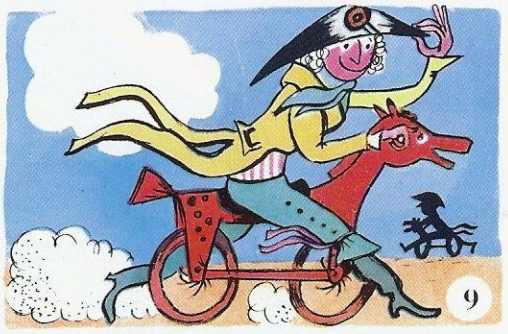
WITH two wheels, one on either side, there is no difficulty either—one wheel pivots, as it were, around the other. A shaft being sufficient to steer the vehicle. It was in this way that the ancient chariots and two-wheeled vehicles were evolved (5).
With three wheels it was not too bad, but four made things complicated. The Roman "RHEDA" (6) for example had four wheels mounted on two fixed axles. In a straight line all was well, but when turning, the horses had to pull obliquely, forcing the wheels to scrape into the required direction.



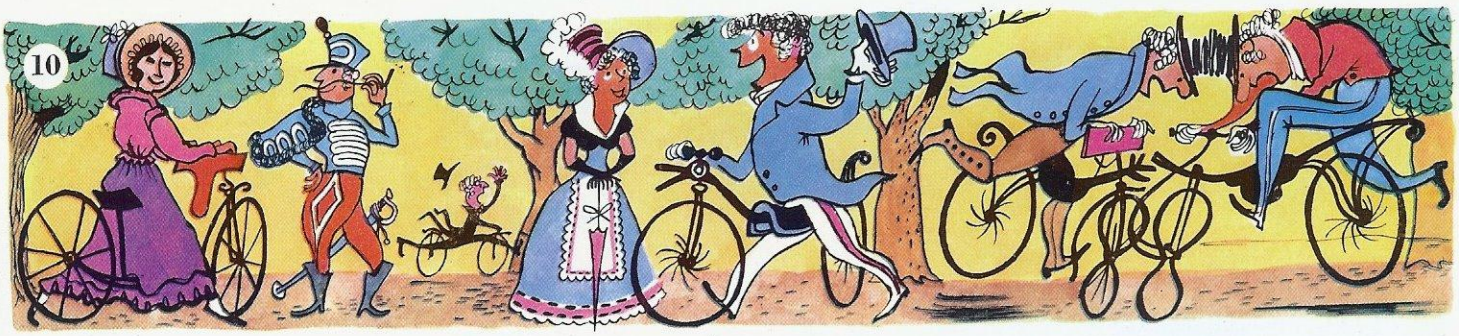
FOR thousands of years four-wheeled vehicles did not possess a suitable steering mechanism.
It would appear that the first front-wheel steering system was invented for a war machine in the 15th Century. It was a type of tank, pushed by six horses, and fitted with a ram to demolish castle walls (7). Inside the tank a rudder post enabled the ram and front wheels to be guided at the same time. It was around this system of turning the front wheels that, through three centuries, the steering of 4-wheeled vehicles was perfected, the front axle pivoting in its entirety on a vertical shaft. It is the "King Pin".



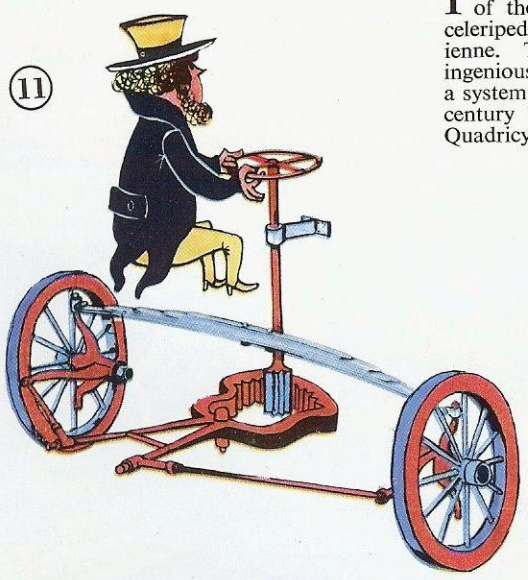
ON the first "four-wheelers", the front wheels were as large as the rear, and consequently when turning they fouled against the coach body. Later the front wheels became smaller so that they could turn under the wheel arch (8).

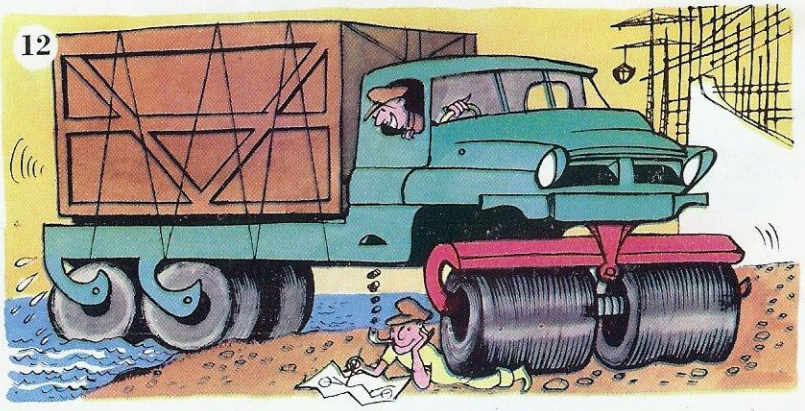


At the turn of the 18th century one could see young bloods riding Celeripedes and Velocipedes (9). These were a type of bicycle made of wood invented in 1791 by Count de Sivrac. The wheels were not on either side but one behind the other—the celeripede only went in a straight line. To turn, one had to pick it up and point it in the required direction.

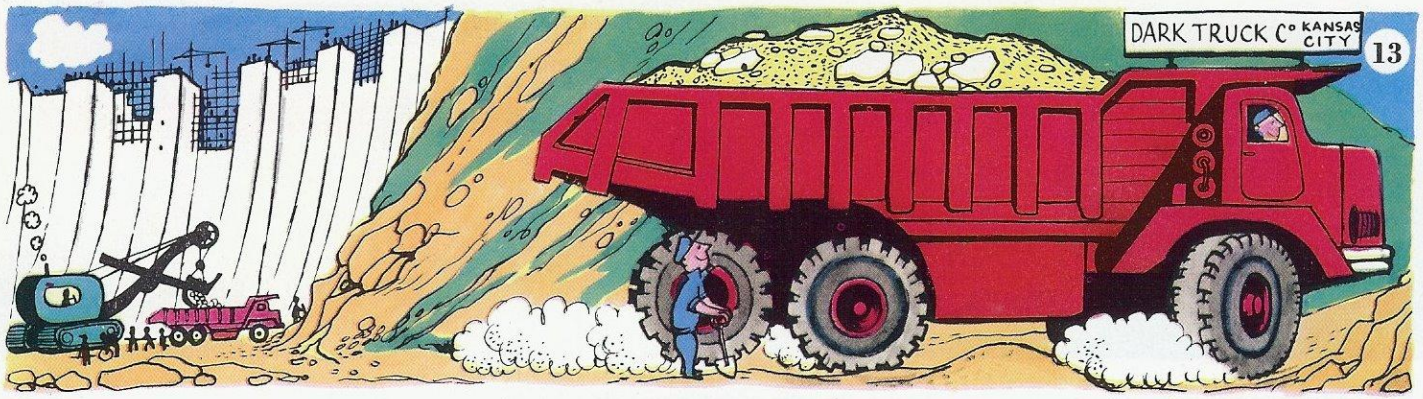


IT is to Baron Drais that we owe the pivoting of the front (10) wheels of bicycles. His celeripede could turn and was called the Draisienne. To make the front wheel pivot was an ingenious idea, it foreshadowed as early as 1818 a system of steering which was to appear half a century later on the first motor cars called Quadricycles (2 bicycles joined together) (Panhard, Peugot, etc.).
On the 28th April, 1873, Amédée Bollée, senior, bell founder at Le Mans, patented at the age of 29 the first 2-pivot steering where the front wheels, connected by a bar, could pivot on themselves. This new revolutionary invention was to open the era to the present day systems of automobile steering.

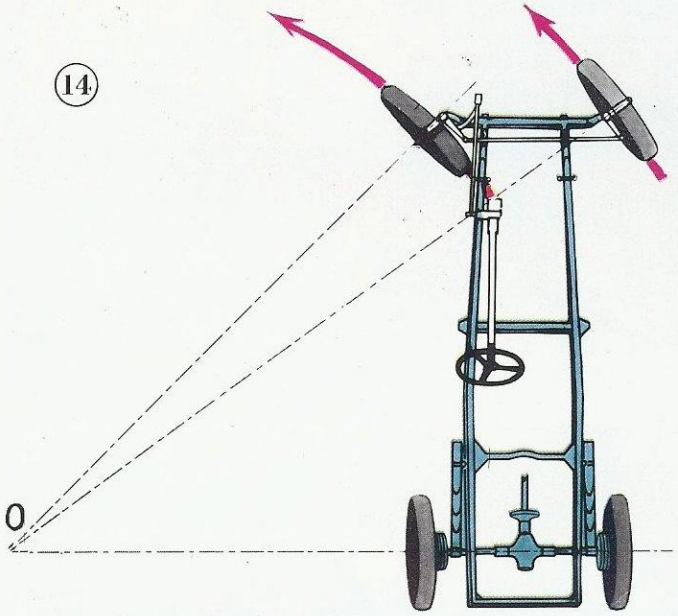


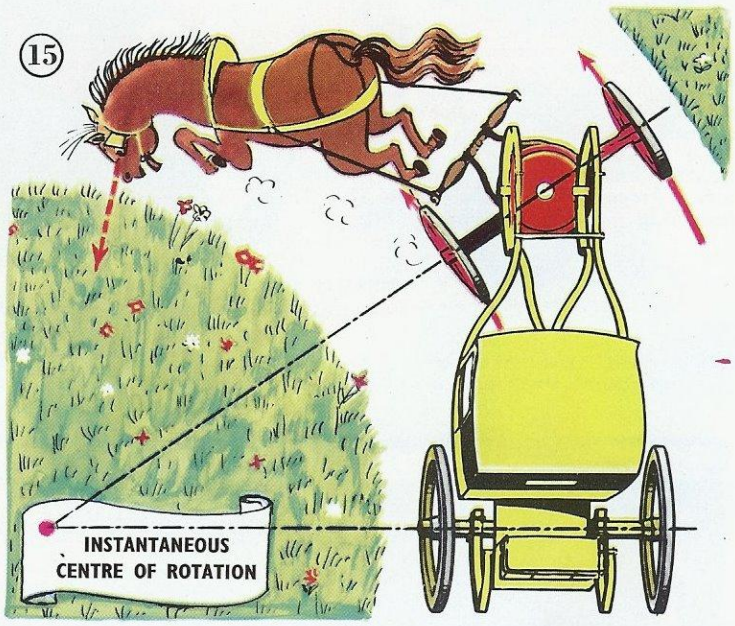


ON the "Mancelle" (1878), another invention of Amédée Bollée, the control of the pivoting of the directional wheels was made by a steering wheel (as today). Through a cog-wheel the steering wheel could make a section controlling the wheels turn to the right or left. This design (11) appears to herald the first rack and pinion steering which some 60 years later, was to be fitted on the mass-produced Citroen.
By an exceptional circle of ideas, the most modern tractors use the King-Pin type of steering. It is the same with the "Albee Rolligan" (12) whose complete front wheel assembly pivots like that of an ordinary heavy roller.

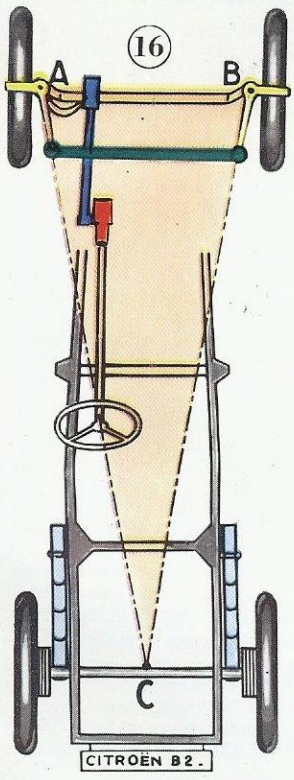


AGAIN the King-Pin system is used on the 54 ton tipper (13) (world's record of useful load) of the Dart Truck Company of Kansas City. The front wheels pivot in their entirety around a vertical shaft, but as the muscles of the driver are not sufficient to manoeuvre this vehicle he has a hydraulic servo-motor to assist him.





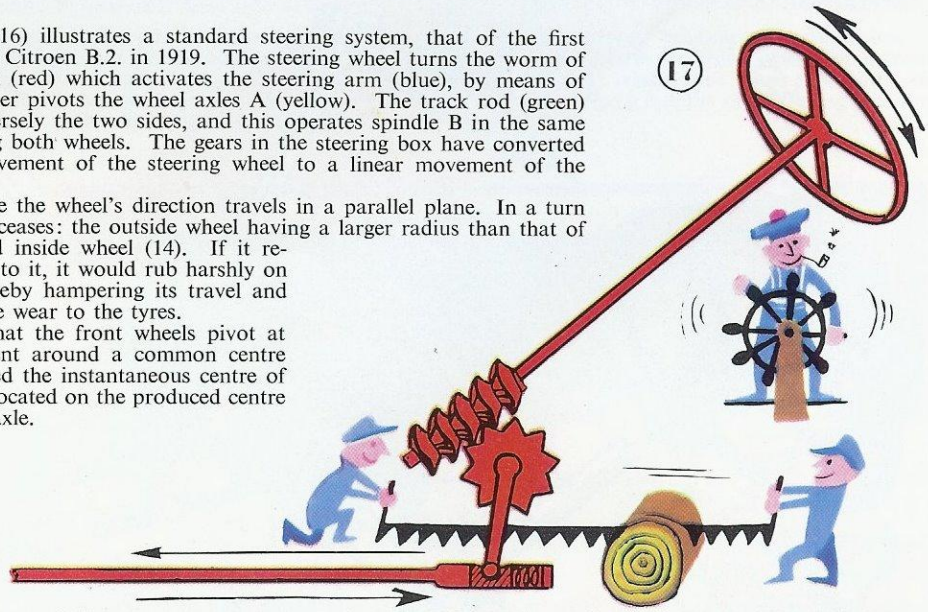
APART from these exceptional cases all automobile steering today is of the "pivoting directional wheel" type (14) in contrast to the "King Pin" (15) system where the directional axle is a single unit pivoting horizontally around a vertical axle.



THE sketch (16) illustrates a standard steering system, that of the first chassis of a Citroen B.2. in 1919. The steering wheel turns the worm of the steering box (red) which activates the steering arm (blue), by means of an arm: the latter pivots the wheel axles A (yellow). The track rod (green) connects transversely the two sides, and this operates spindle B in the same way, so pivoting both wheels. The gears in the steering box have converted the circular movement of the steering wheel to a linear movement of the track rod (17).

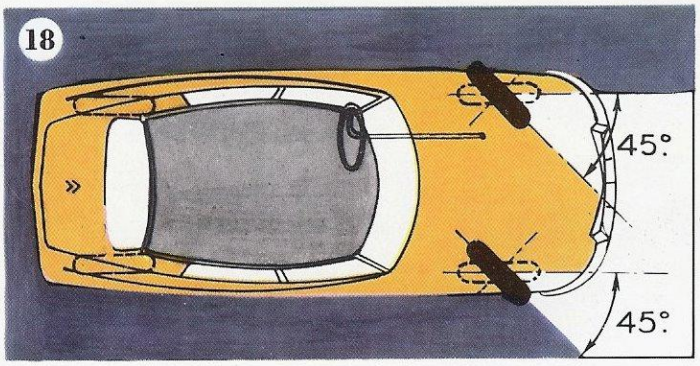
In a straight line the wheel's direction travels in a parallel plane. In a turn this parallelism ceases: the outside wheel having a larger radius than that of its opposite and inside wheel (14). If it remained parallel to it, it would rub harshly on the ground thereby hampering its travel and causing excessive wear to the tyres.

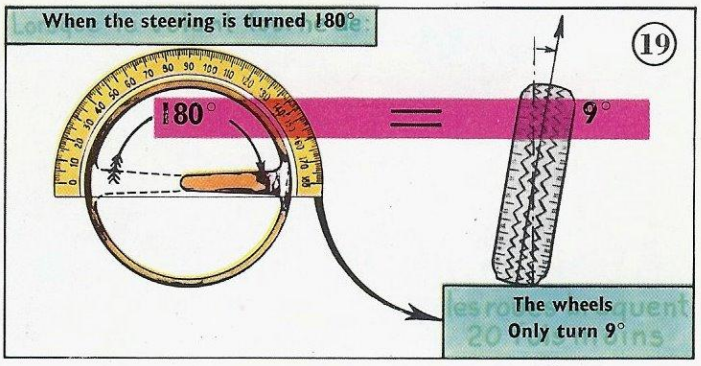
It is essential that the front wheels pivot at the same moment around a common centre O. This is called the instantaneous centre of rotation and is located on the produced centre line of the rear axle.



If, on a bend, each of the wheels is to pivot exactly at the required angle, it is necessary that the steering geometry is absolutely correct.

At the beginning of the century a mechanic named Janteau, gave his name to an experimental system of operating the steering so that it responded to required conditions. It consisted of a design of spindle levers which, when they were projected back, with the front wheels in a straight ahead position met at a point located in the middle of the rear axle (16), Janteau's triangle. This design of Janteau's is only approximate but for many years has been considered as satisfactory.



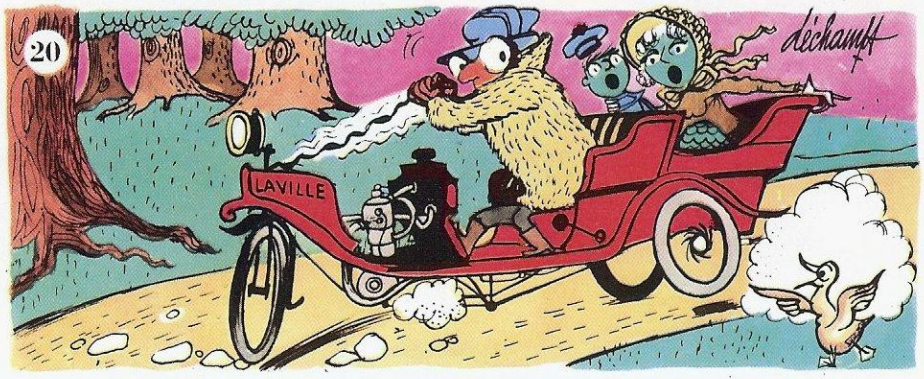


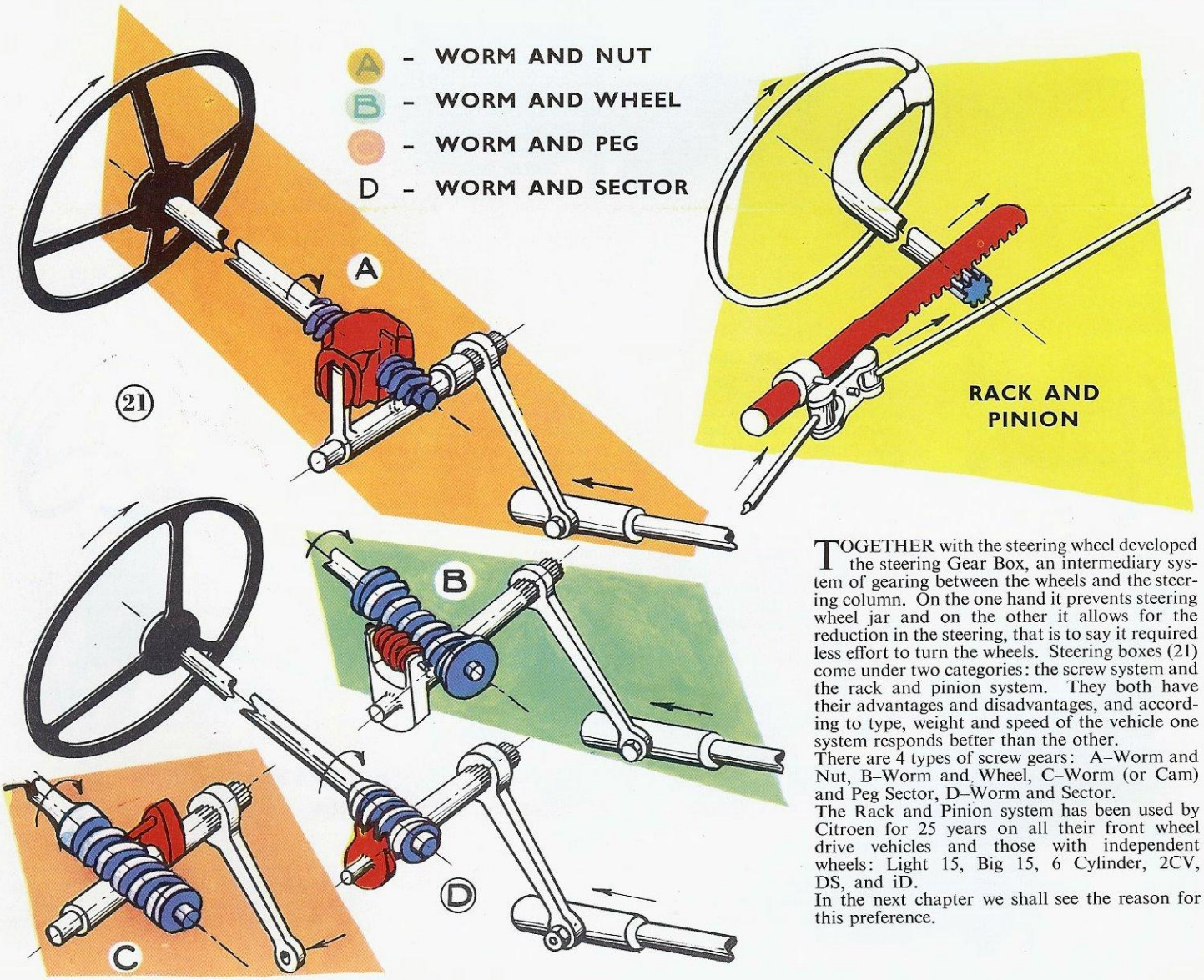
WHAT is the steering lock? It is the maximum angle which the wheels generally on the front can pivot to the right or left of their straight ahead position (18).

What is the ratio of reduction? It is the ratio between the angle of turn by the steering wheel and the angle of turn of the running wheels (19).

For example, if the running wheels turn 9° for half a turn of the steering wheel (180°) one says that the ratio is 180÷9 or 20 to 1.

ORIGINALLY the steering of cars was by a simple tiller bar operating direct to the wheels. Needless to say that one's arms collected all the roughness of the roads (20).
Later on this tiller bar was replaced by the circular steering wheel with 5, 4, 3 or 2 spokes until Citroen introduced the single spoke on their D.S.

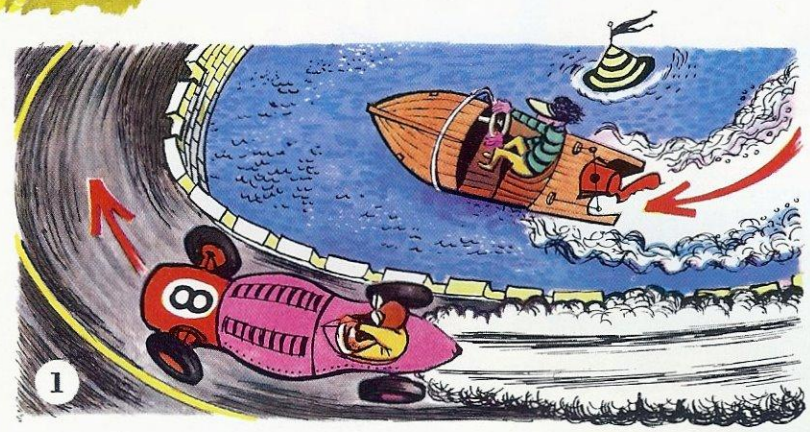




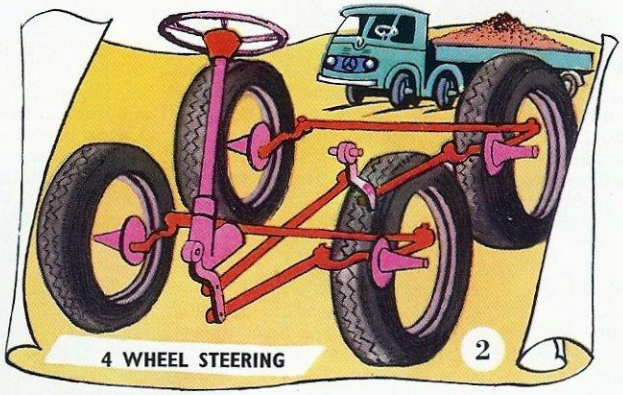
TOGETHER with the steering wheel developed the steering Gear Box, an intermediary system of gearing between the wheels and the steering column. On the one hand it prevents steering wheel jar and on the other it allows for the reduction in the steering, that is to say it required less effort to turn the wheels. Steering boxes (21) come under two categories: the screw system and the rack and pinion system. They both have their advantages and disadvantages, and according to type, weight and speed of the vehicle one system responds better than the other.
There are 4 types of screw gears: A–Worm and Nut, B–Worm and Wheel, C–Worm (or Cam) and Peg Sector, D–Worm and Sector.
The Rack and Pinion system has been used by Citroen for 25 years on all their front wheel drive vehicles and those with independent wheels: Light 15, Big 15, 6 Cylinder, 2CV, DS, and iD.
In the next chapter we shall see the reason for this preference.

STEERING THROUGH THE AGES

Chapter 2



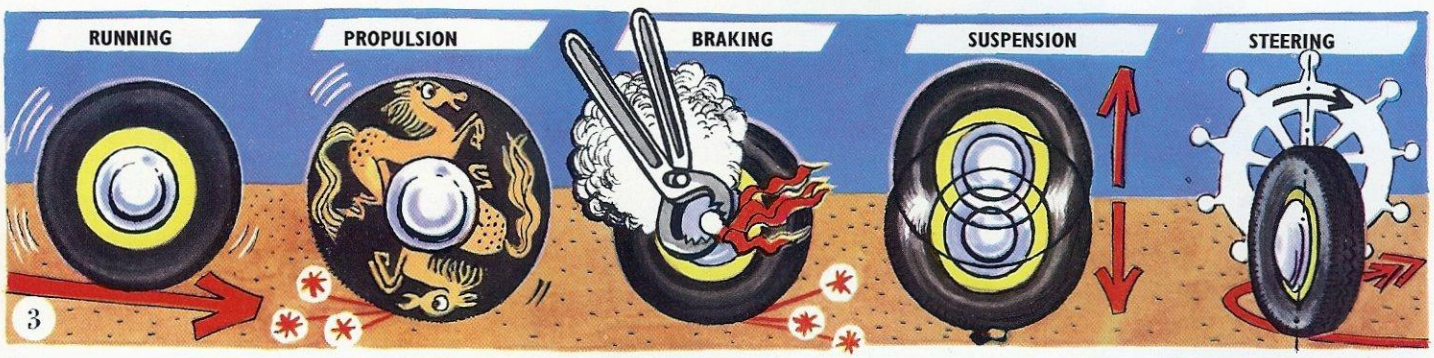
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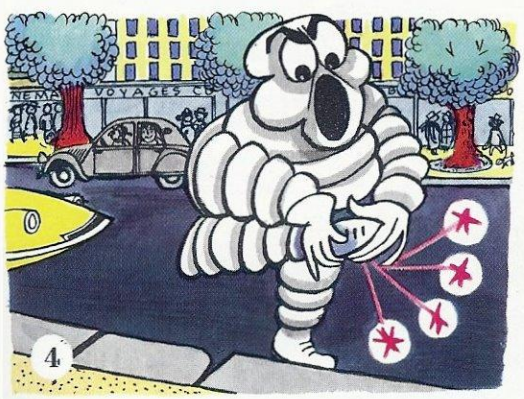
I. On ships the steering is at the rear, on motor-cars it is on the front wheels (1). The rear wheels can also be directional and so can all 4 wheels which would permit a turn almost on the spot.

II. For a long time various makes of British trucks and more recently Daimler Benz in Germany have made very large trucks with the steering acting on four front wheels (2).

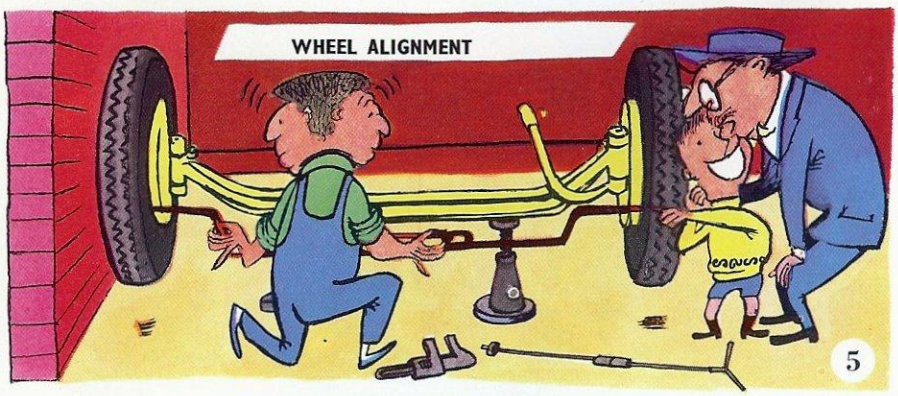


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III. To steer a vehicle the front wheels must turn from left to right and from right to left. But they must also be able, when running, to move up and up and down to ensure suspension. In braking they must be able to halt the forward speed of the vehicle. On front wheel drive vehicles—the Citroen and Panhard for example—the front wheels have, also, to transmit the motor drive which propels the car. When you think of the diversity of all these stresses—running, suspension, braking and propulsion (3) you wonder how the front wheels of a front-wheel drive vehicle can also cope with the steering. What a number of conflicting problems to resolve!



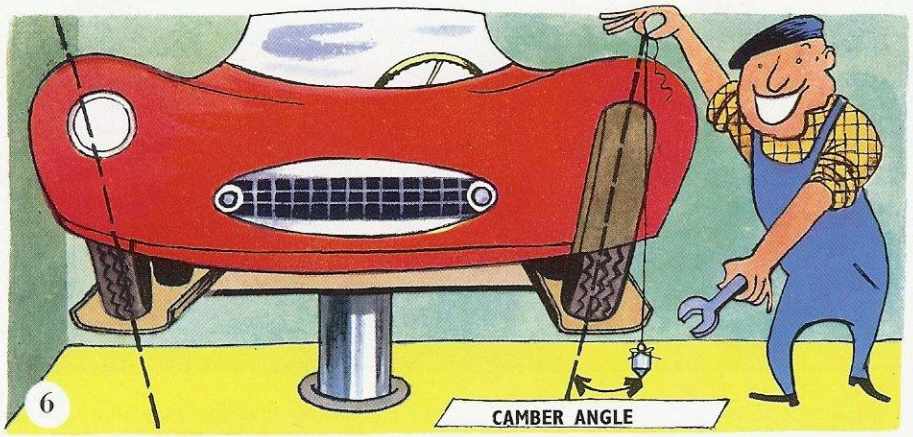
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IV. In the previous chapter we have already mentioned certain aspects of the problem—steering designs, turning angle, steering reduction ratios and the gearing of steering boxes. We still ought to explain, among other things, parallelism or wheel alignment, castor and camber angles, swivel inclination, drift of tyres, etc. This would be far too complicated, so we will stick to the most elementary explanations, such as those which will give us a chance to understand the mechanic when, for example, we have hit a kerb (4) and want him to check the wheel alignment.

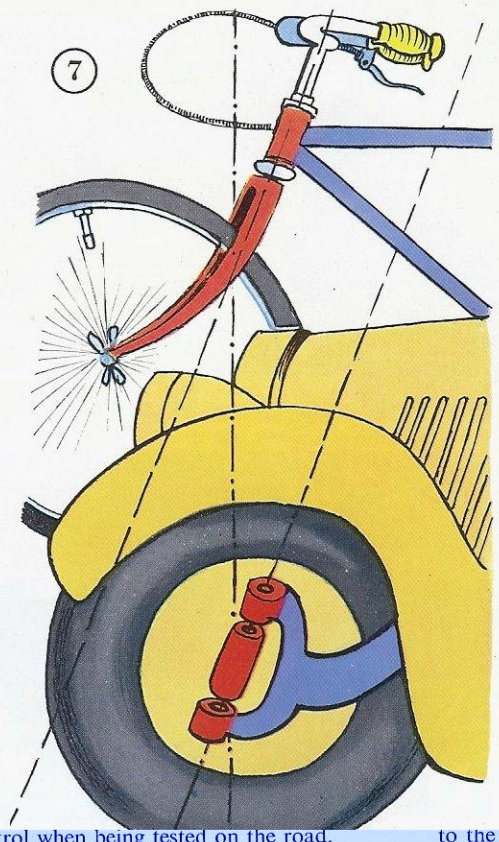
V. Parallelism or alignment is the wrong word because when the front wheels of a car are in a straight line they are only parallel in theory. In practice, it is called "toe-in" when they converge towards the front and "toe-out" when they diverge. Correcting wheel alignment in reality is giving the front wheels the correct toe-in or out as specified by the manufacturers (5). The wheels of the DS must be adjusted to give a slight "toe-in" of 2 to 3 millimetres.

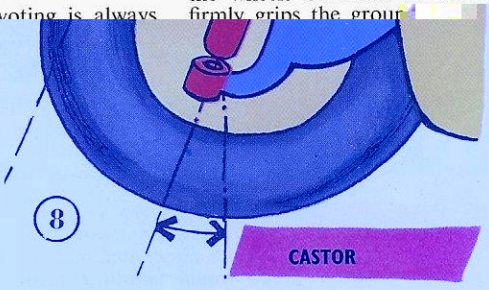


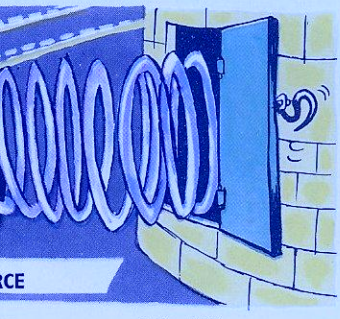
VI. Camber angle is the inclination of the central wheel plane to the vertical, a sort of toe-in or out towards the base. Seen from the front, the wheels are said to be cambered when they are slightly opened up like a capital "V" (6). This again is a question of millimetres or rather minutes of arc. It presents a problem which uses up lots of ink—and lots of petrol when being tested on the road.

VII. To define Castor angle let's make a comparison with the bicycle. The front wheel of a bicycle pivots to the right and left about the axis of the fork (7). The front wheels of an automobile pivot to the right and left about the axis of the king pins.
On the bicycle this axis of pivoting is always more or less inclined towards the front. When one looks at a cycle in profile we can say that the incline of the fork chases the wheel in front of it. On the automobile it is the engineer who calculates, by comparison with the vertical, the angle of castor which will give the best results (8). Castor is one of those factors which contributes to give steering stability, which means that after a turn, without imposing any effort on the arms of the driver, the steering wheel returns by itself to the straight ahead position. It is self centre point steering (20).

VIII. One often speaks of the drift of tyres. How does this affect the steering? When a vehicle enters a turn, the centrifugal force—as in a sling—tends to force the wheels outwards of the curve. The tyre firmly grips the ground but being composed of rubber, both excellent elastic elements, is gradually deformed by the centrifugal force (9). Instead of following their planned medium of rotation the wheels try to go a little sideways—in fact they want to "Crab" (10). This running sideways or drifting is not to be confused with skidding.
Centrifugal force is not alone in provoking drift—drift can also be produced when running along the lower side of a cambered road and, above all, when the wind blows across the car





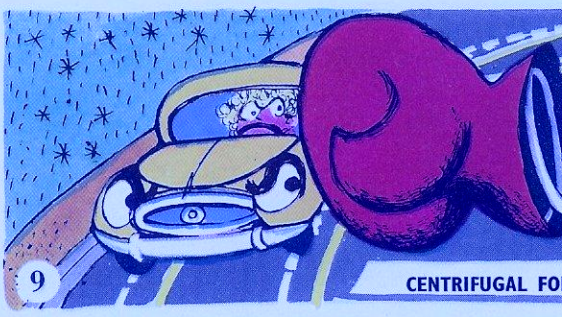


steer very carefully (11).

hat can a driver do to keep a good urse? Naturally—and unconscious- ist turn his wheels, away from the on a bend, the vehicle drifts from the not from the front, there will be a o turn more than is required. This entuated at the rear by the disturbing effect of centrifugal force; one says that it "over-steers". To make up for the deviation the driver may have to turn his steering wheel opposite to the way he wishes to follow. He will thus cancel the over-steering (12).

X. On the other hand, when it is the front wheels which drift and not the rear, it is not so serious. The driver, in effect, when rectifying

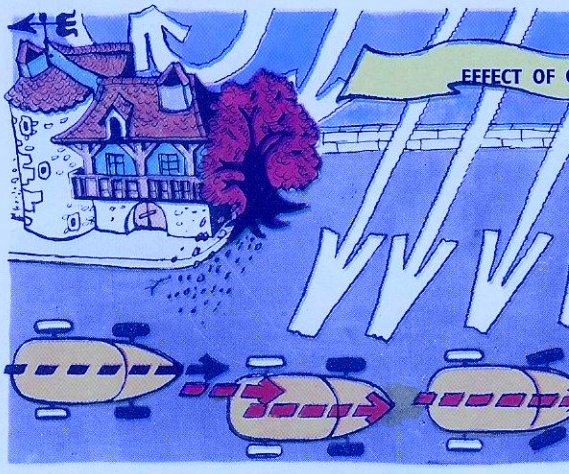




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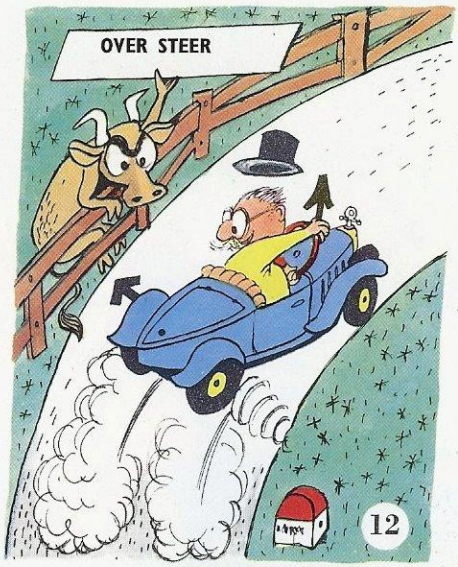


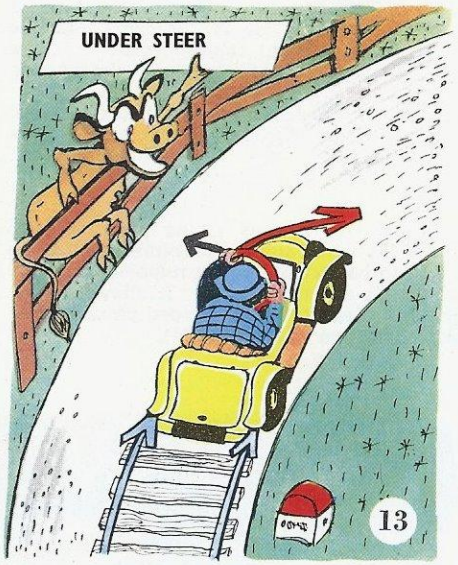


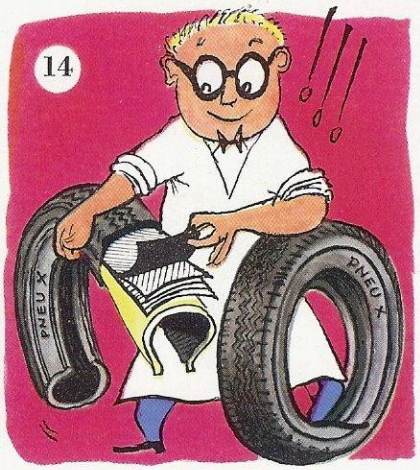
of gravity, the pressure of the front and rear wheels, etc; but the preponderant factor rests in the build of the tyre itself. From this point of view it is not without reason that the DS and ID, both very fast cars, are fitted as standard with "X" tyres which have an outstanding resistance to drift (14). The combination of front-wheel drive and "X" tyres gives these two cars steering precision and road holding that is unsurpassed.

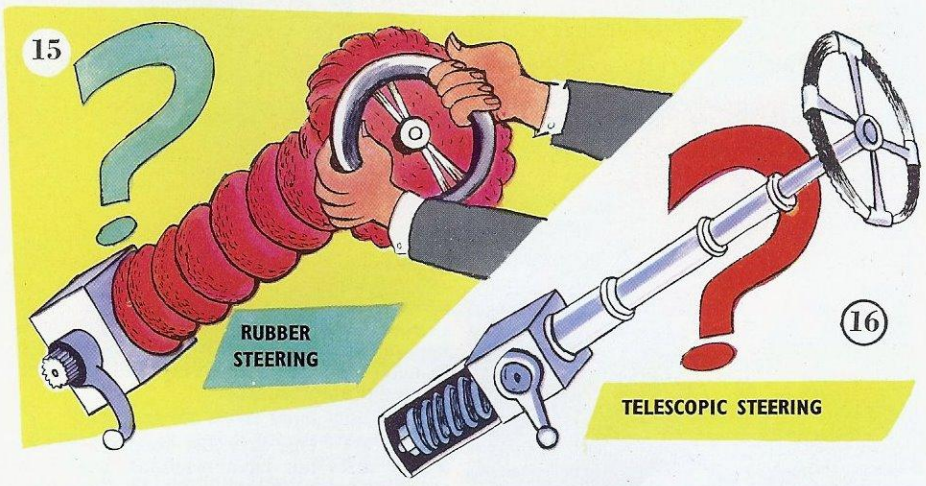
XII. With so many factors the problems of steering can, without doubt, only have compromise solutions. It is not possible to give preference to one quality of steering without sacrificing another. What then are the qualities of ideal steering? The principles are safety, stability, precision, smoothness and absence of reaction. Let's examine them one by one.

XIII. Safety is primarily the strength of materials used and their assembly. On the road our lives depend on the steering.

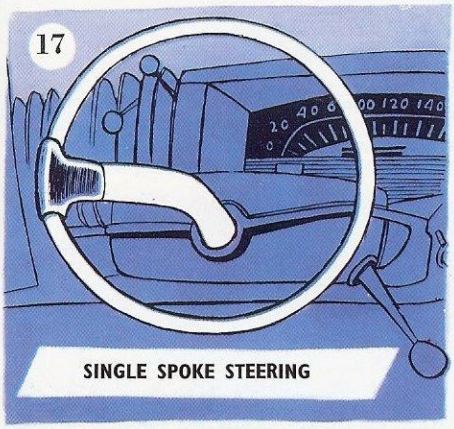


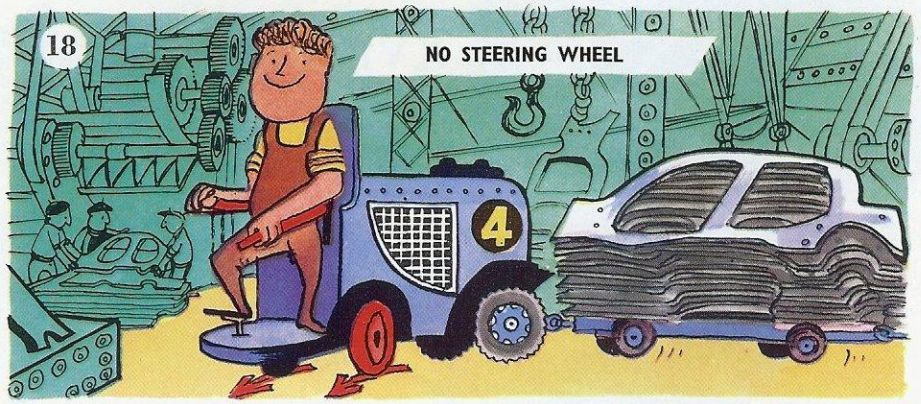


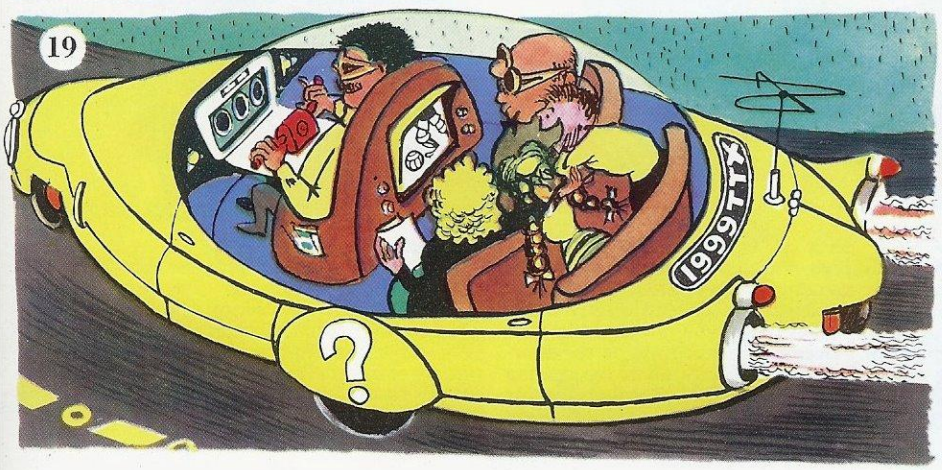




All manufacturers understand this and nowadays we no longer hear of steering breaking. Safety can be understood in another way, for instance from the point of view of the steering wheel. In collisions it is possible that the steering wheel will turn against the driver like an offensive weapon, so one's thoughts turn to a rubber steering wheel (15) or a telescopic steering column in which a spring absorbs the violence of the impact, etc. (16). Citroen has proposed another solution. The steering wheel of the DS (17) has only one flat incurved spoke. The single spoke wheel is less dangerous than the standard steering wheel with a central hub.



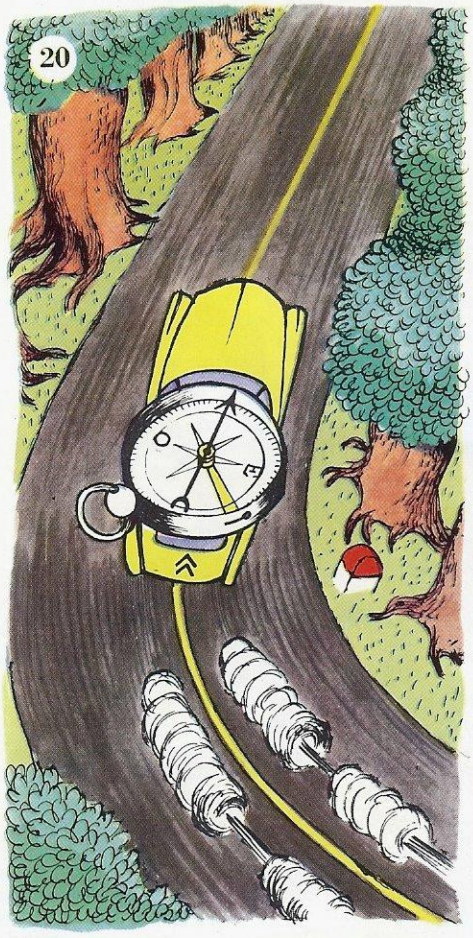


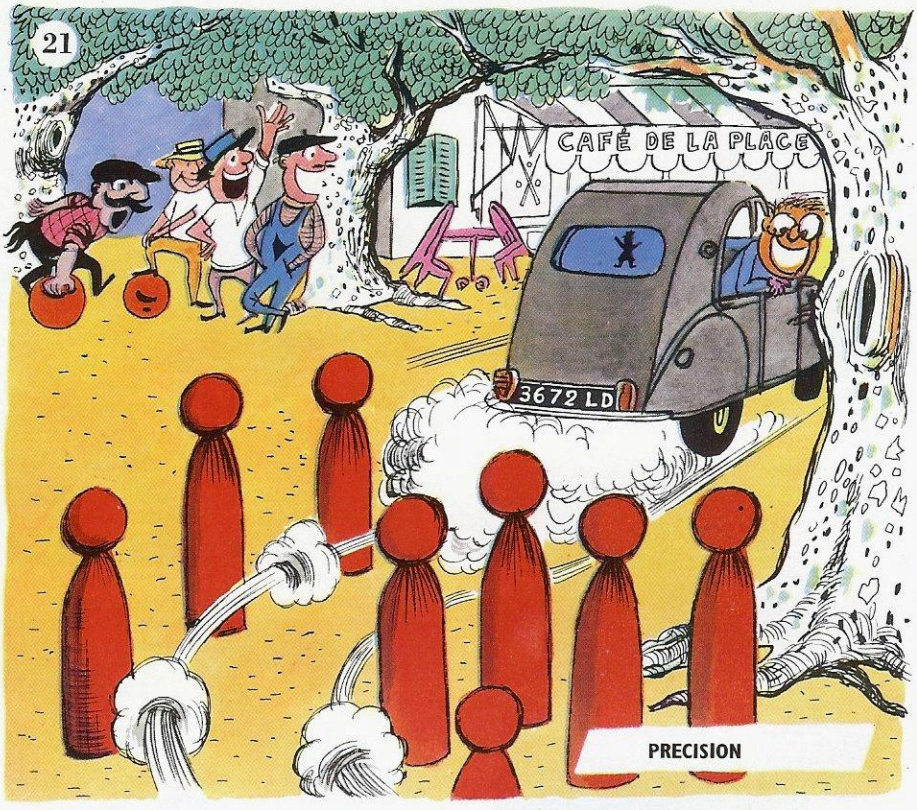


XIV. The best way to obviate the danger of steering wheels would be to do away with them as on the electric 'donkeys' which transport materials within the factories (18). They have not got a steering wheel, only a simple lever. In the car of tomorrow the steering wheel will probably be replaced by two levers, one for each hand, operated from an arm-chair position. A small turn of the wrists would be sufficient to steer the car (19). This is not fantastic, however, for several years now the mass produced DS Citroen has paved the way to assisted mechanisms which had not previously existed.

XV. Stability is the second quality of steering. It is the ability of the directional wheels to centre themselves on a straight line after one has turned the steering wheel (20).
This stability depends on castor angle, swivel angle, flexibility of shock absorbers, etc. It is a problem that Citroen have definitely solved. One says that Citroen cars are "Auto-stable".

XVI. As well as saying precision, one could also say faithfulness. Steering is said to be precise when it responds faithfully to what is demanded of it. It allows, at full speed, to place the car where one pleases to the nearest fraction of an inch (21).





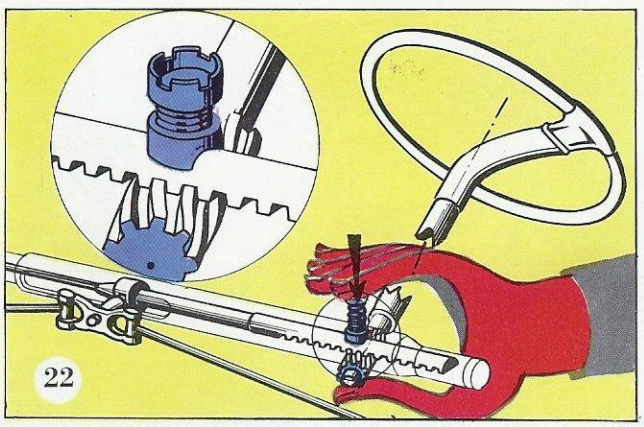
To achieve this accuracy one must reduce the working parts to a minimum. From this point of view the rack and pinion system (used by Citroen for 24 years) is the best. The box contains a spring (22) which holds the pinion permanently on the rack: Play and wear being taken up automatically.

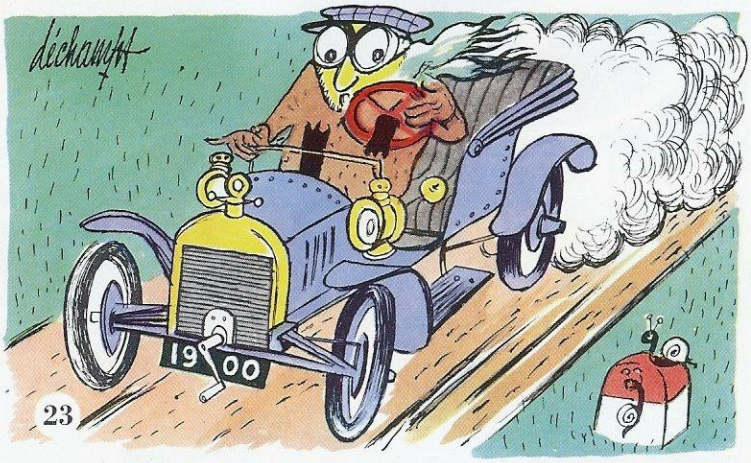
XVII. One says that good steering must not have reactions, but of what reactions are we talking? They are the rebounds caused by the roughness of the roads which can affect the steering wheel steering shaft and linkages or steering gears.

XVIII. The driver must, at will, be able to turn the front wheels of his car for direction. On the other hand the wheels must not, because of some roughness on the roads, turn the steering wheel. That is why in the early days of the motor car they made steering gears with completely irreversible steering which did not transmit reactions. The arms of the driver were spared but gradually the hammerings on the joints and shaft reached a point where at one end or the other the steering broke without warning (23).

XIX. Following this came steering known as semi-reversible. This was a little better but still insufficient.
The day came when front wheel geometry was given proper attention and in particular when it was known how to construct independent wheel suspension, a solution which became standard with Citroen. Without being irreversible, because the steering wheel returns itself (20), steering today does not cause any unpleasant steering wheel reactions.

XX. Smoothness is the most appreciated quality, if not the most important. It alone summarises the pleasures of driving which is itself a mixture of other pleasures that



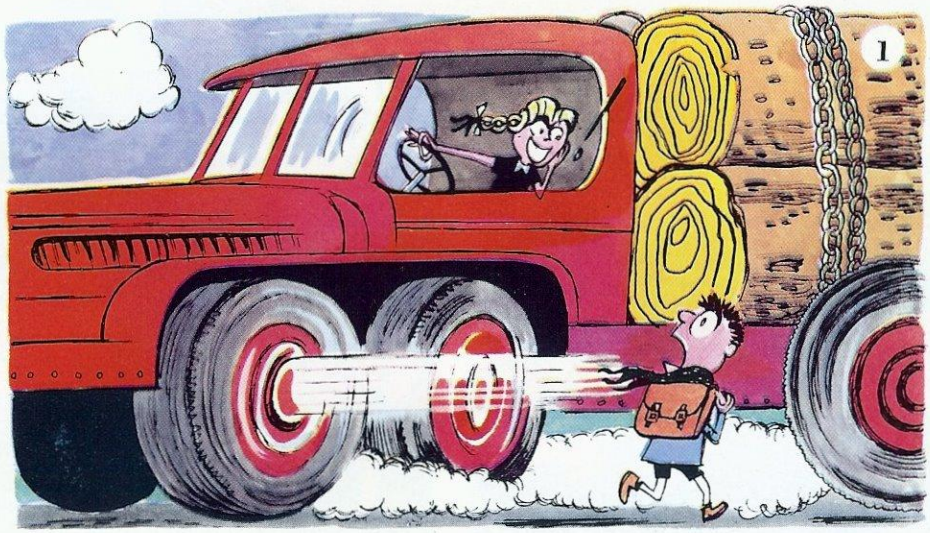


one feels when aiming, throwing, commanding or escaping from time and space. Smoothness of steering depends on two other factors: efficiency and gearing. Steering is a transmission unit. As such it is usual to talk of its efficiency. Steering efficiency is the ratio between the work of the driver to the steering wheel of his car and the work which is necessary to turn the wheels on the ground.

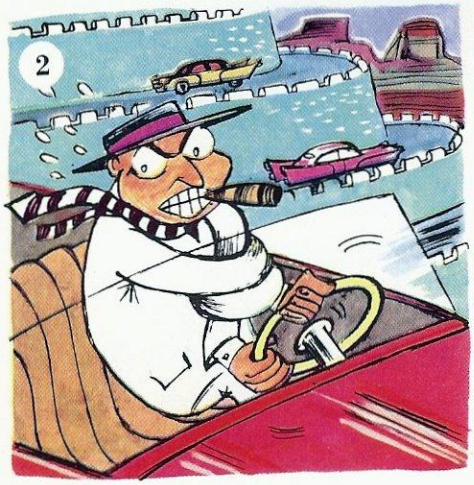
XXI. In a car equipped with steering of high efficiency and judicious gearing, steering is not only done without fatigue, but becomes second nature. You go exactly where your vision takes you; you don't notice the number of movements of the arms to the steering wheel. To reach this point where the steering system has such remarkable sensitivity motor engineers have had to use all their imagination and skill.
The most remarkable progress has been with assisted or servo-steering. The driver requires no effort to turn the steering wheel, it is sufficient for him to give an indication with the tip of his fingers; a little motor—and not the arms of the driver—takes over and turns the wheels. Such is the case with the DS—which is fitted with assisted steering.

Chapter 3

I. Progress makes life easier. Today a small girl would be able to drive the heaviest lorry without fatigue. All steering must be smooth to handle (1).



II. For steering to be smooth it must, as we have seen, have very high reduction gearing, such as some large American cars where to steer a little it is necessary to give



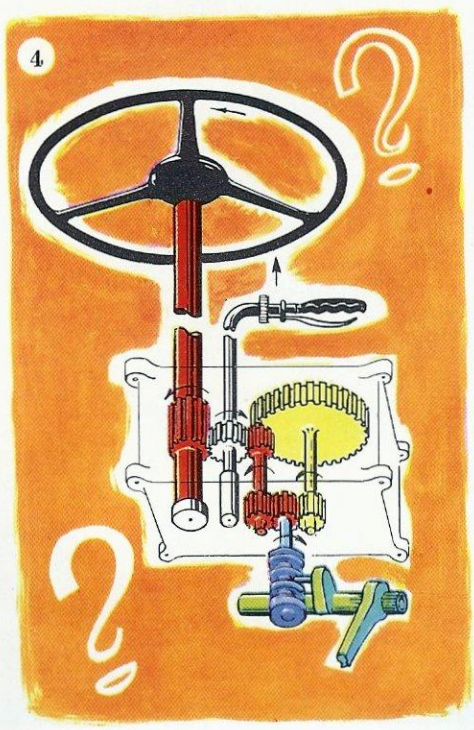
several turns of the steering wheel. What is saved in effort is compensated in movement. The work remains the same. On the winding mountain roads the steering is continually being turned one way or the other (2).

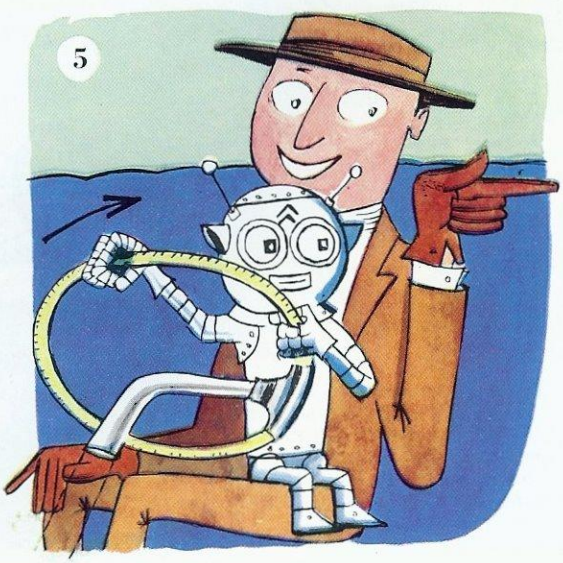
III. When, on the other hand, you have a low gearing system the steering is more positive (3), it is more precise, it responds more quickly. It is useful but is harder to operate.

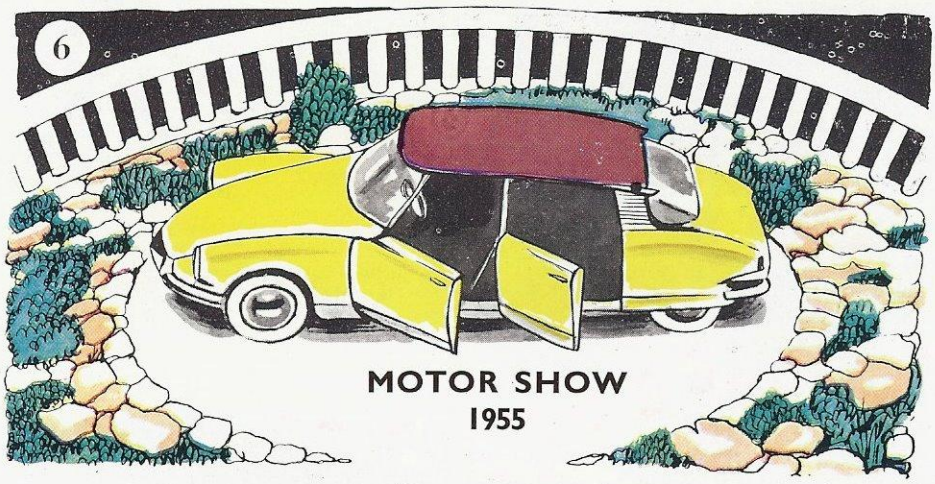


IV. Then how can we combine the advantages of smooth steering and those of positive steering. A steering box with a double ratio of gearing could be considered (4). On the roads when you travel fast the small gear ratio would be used; in towns and for parking a larger one. Needless to say this solution has never been used; it would be dangerous because how could we expect anyone to develop reflexes with conditions of use which change at every moment.

V. Something else had to be found. The idea came of making the steering work by using a small special motor. This is assisted steering; from now on what does it matter about the weight? What does it matter if one travels fast? Or when parking? If, from the moment one touches the steering a robot takes charge and turns the wheels! (5).





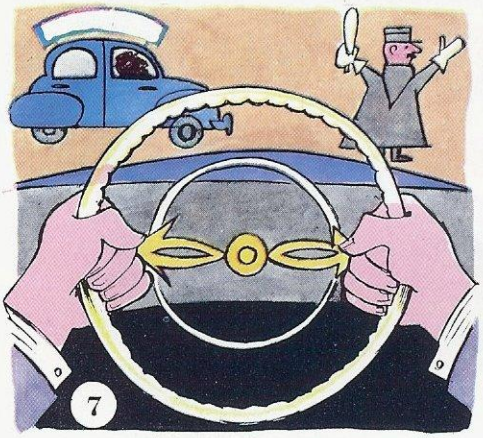


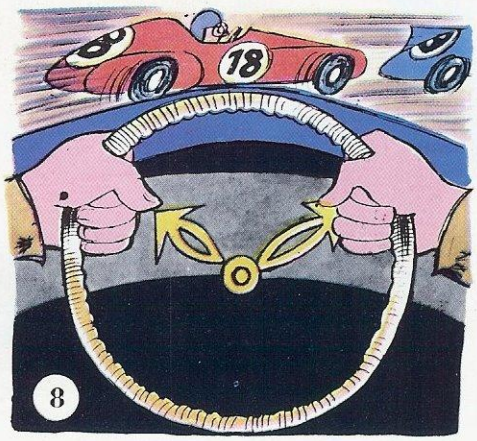
VI. For a long time very big trucks have been fitted with assisted steering. On cars the application is more recent. In France the DS was the first and for 4 years the only mass produced car with servo-steering.

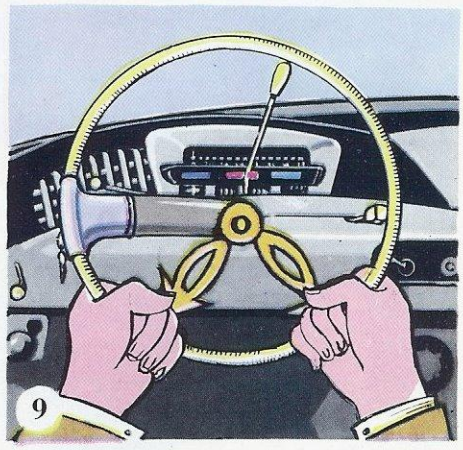
VII. In driving schools you are taught to hold the steering wheel in such a way that you should always be able, in case of an emergency, to turn quickly to the right or left or "swish in" to avoid anything unexpected. You have more force in pulling than pushing and that is why you are advised always to have the hands in opposition, i.e., the left hand at 9 and the right hand at 3 of an imaginary clock (7).

VIII. The favourite position for the racing driver is at 10 past 10 (8); there you are ready for every eventuality. With servo-steering, as on the DS.19, one can drive at 20 past 8, that is to say with the elbows and forearms comfortably relaxed as if they are resting on the arms of an easy chair (9).

IX. The DS. in effect responds to your touch in the most literal sense of the word. It does not much matter if you push or pull the steering wheel. One is as easy as the other, because a simple indication (10) of the fingers is sufficient to turn the wheels. The robot (servo) is there to do the work for you.

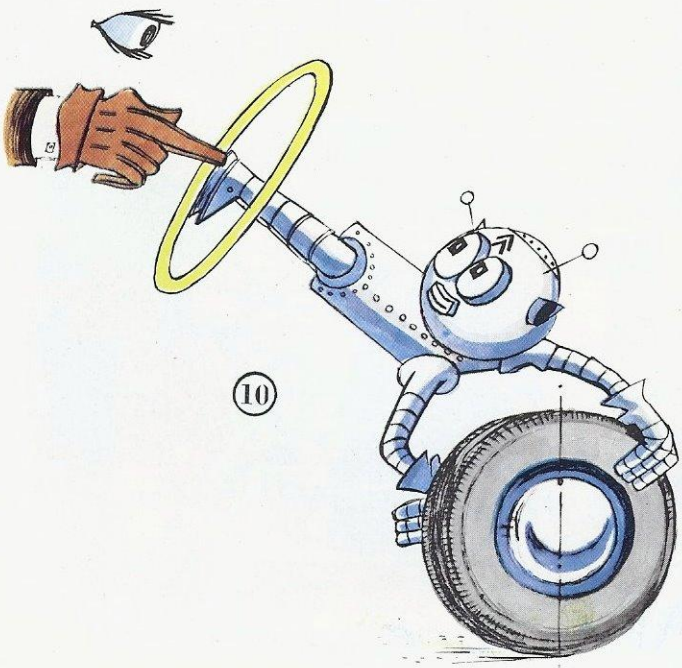


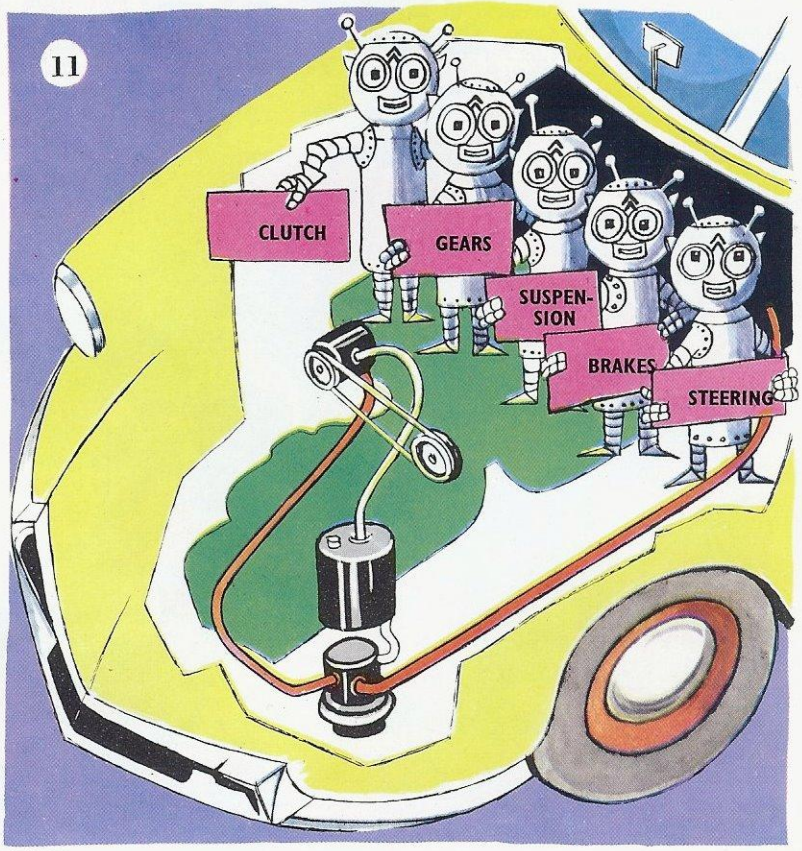




X. Which is this Robot? It is one of those that belong to a hydraulic power station which is found under the bonnet of the Citroen DS. This station consists of a reservoir of liquid, a rotary pump driven by the engine of the car and a pressure accumulator.
The hydraulic energy is distributed throughout the car everywhere it is required, for example, to release the clutch, to change gear, to brake, to correct automatically the suspension and to help you steer (11).

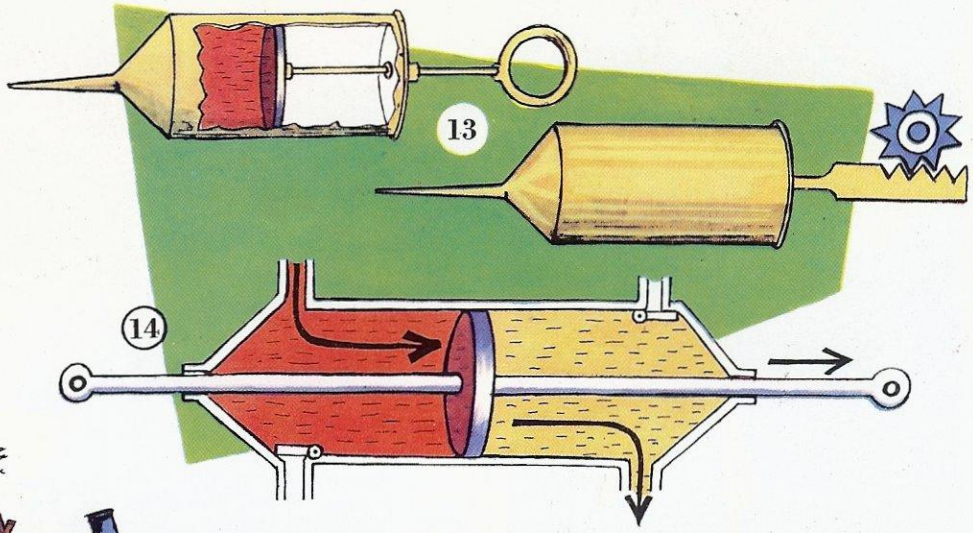
XI. To make it available, the pressure is brought to what is called an hydraulic reservoir; this is a piece of machinery that receives the hydraulic energy (pressure) and converts it to mechanical energy (movement). In the case of the DS these reservoirs are hydraulic jacks. What is an hydraulic jack? It can best be compared to a bicycle pump or a syringe. When pressure is applied to the piston it is displaced and forces the liquid under pres-

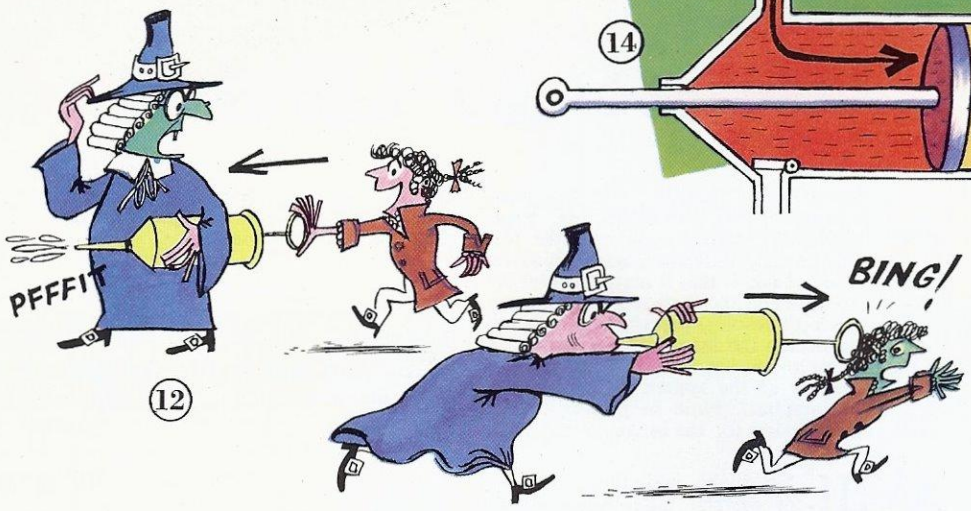




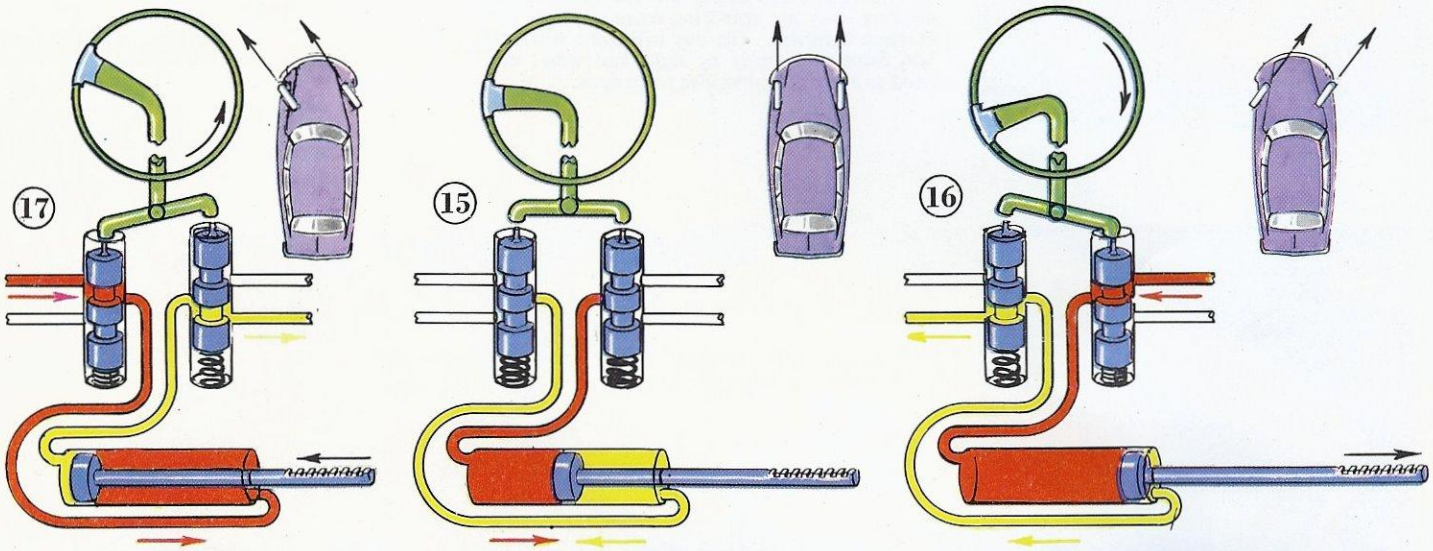
sure out of the syringe. Conversely if the liquid under pressure is injected in the syringe it is the rod of the piston which moves. That is a simple hydraulic jack (12). One way displacement.

XII. To the end of the piston rod let's fix a steering rack (13) which under hydraulic pressure will displace itself and make the wheels of the car turn. The steering system will turn without having to use any force on the steering wheel.



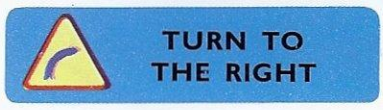


XIII. The piston is located in the centre of the pump and the piston rod projects on both sides. The body of the pump is therefore divided by the central piston into two separate compartments, one on the left, the other on the right (14). Each can, when required, receive the pressure or allow the liquid to escape so that it returns to the central reservoir. That is what is called a double acting servo piston displacement (working in both directions).





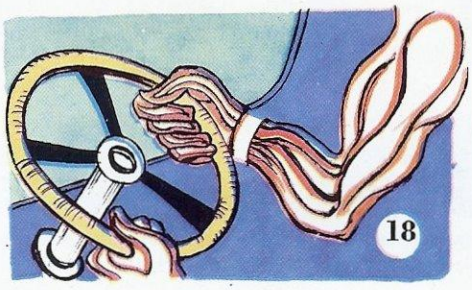


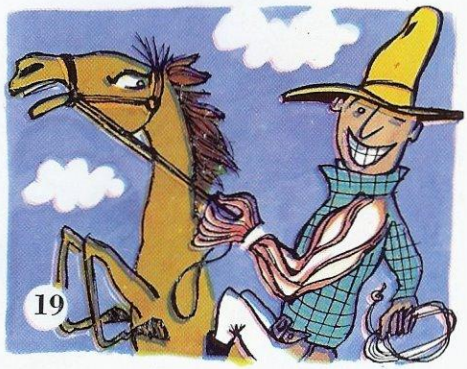


XIV. With the steering wheel in the straight ahead position (15) the pressure distributor and exhaust are closed: the piston remains central and therefore the wheels are kept in the straight ahead position. Only a slight turn on the steering wheel to the right (16) and the distributor allows the pressure (red) to enter the compartment, at the same time the liquid (yellow) escapes to the opposite compartment.
Likewise when the steering wheel is turned to the left (17) the pressure and the exhaust are reversed and the wheels turn the other way.
Each time the steering wheel is moved, however gently, and in any direction, the steering is assisted.

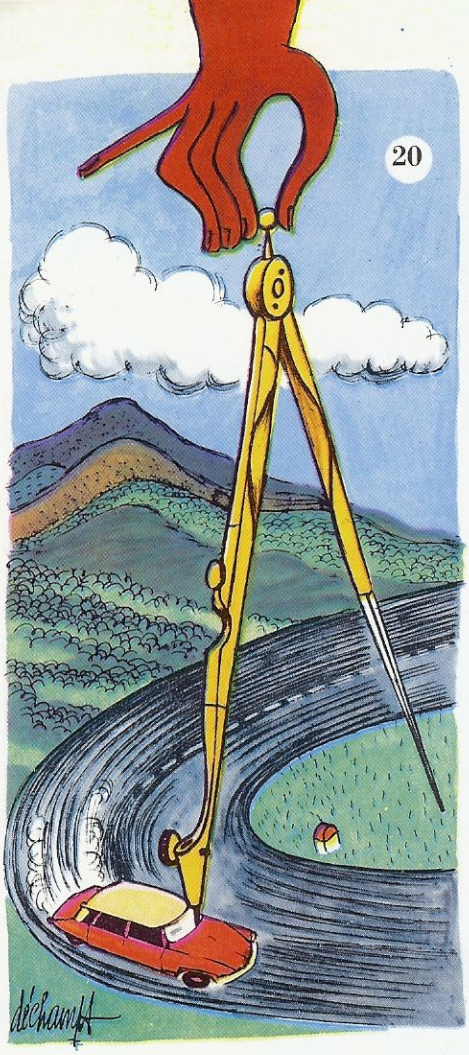
XV. Is it sufficient to prime the rotation of the steering wheel for the hydraulic robot to turn the wheels? In theory—Yes. But in practice it is not quite so because the driver would feel unhappy, he would be frightened if he did not experience a corresponding sensation in his muscles (18); when you operate a rudder, brake or an accelerator you like to feel a muscular sensation. It is your way to measure and apportion an action.

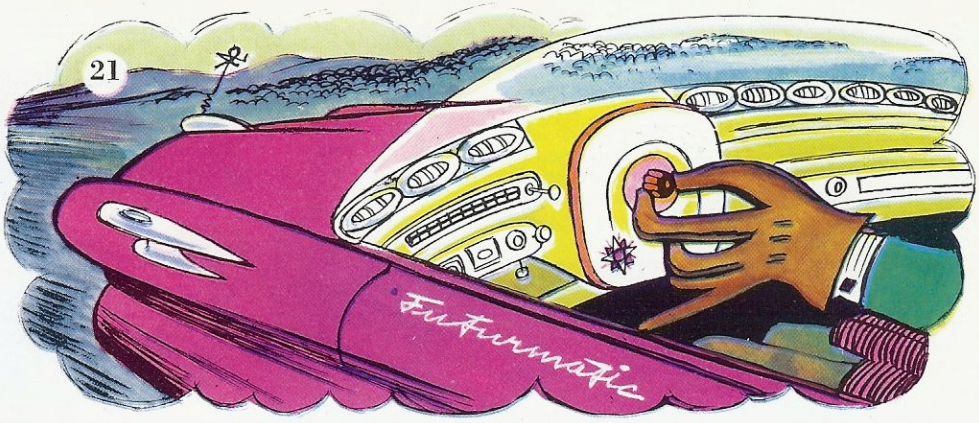
XVI. Thus you have that feeling of being master of your car, just like the rider (19) who with pressure on the reins or the flanks of his horse, adjusts his actions to the reactions of his mount.





XVII. If you are an expert driver you experience the same sensations, the same mastery, with the servo-steering of the DS. Why? Because the system of retroaction allows for the required muscular sensations, resulting in the right amount of servo assistance being applied.

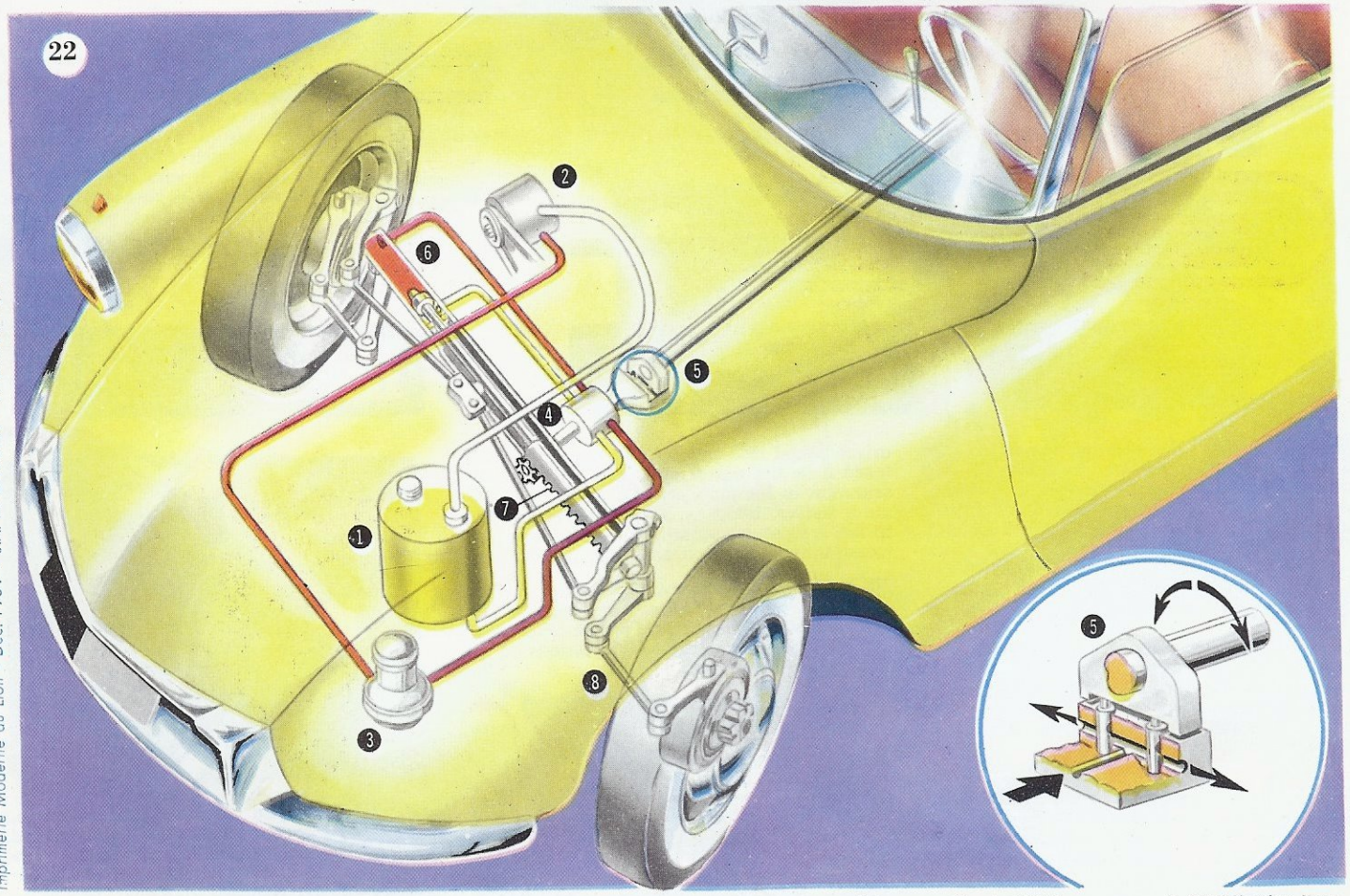




In driving a DS for the first time you have reflexes as those for non-assisted steering. Your wheel is well under control, you have the feel of steering, the only difference, and this is an enormous advantage, is that it requires infinitely less effort to drive and above all, to park. You can take corners with absolute precision (20). Apart from its gentleness the incomparable sensitivity of the DS servo-steering is due in a large way to the ingenuity of the system which registers very slight impulses. (Note in passing that a similar system exists for the brakes of the DS).

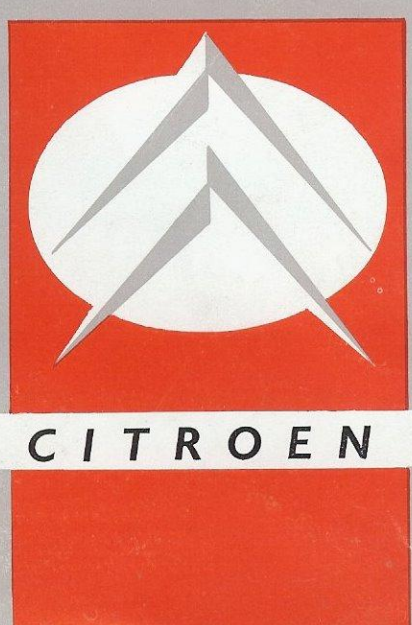
XVIII. No doubt, with time, the style of drivers' tastes will change. In America where nearly all cars have assisted steering, they are searching more and more for extreme lightness. The day will come when one will drive exclusively by sight and won't even need to have any muscular sensations. On that day the steering wheel will disappear and in its place will be a simple knob no bigger than that on a radio set (21).

XIX. An essential quality of servo-mechanism is its ability to continue functioning if by chance the system becomes faulty. With this in mind the end of the steering column of the DS. has the same pinion as that which on 'non-assisted' steerings (on the ID. for example) directly controls the rack. Being constantly engaged, this purely mechanical control instantly replaces the hydraulic system should it be necessary.
The steering of the DS. is, therefore, the classical rack and pinion steering with the added advantage, when the engine is running, of being hydraulically assisted (22).
In all circumstances and whatever happens the steering of the car is absolutely safe.



1. Hydraulic Fluid Reservoir
2. High Pressure Pump
3. Accumulator and Pressure Control Valve
4. Distribution Box
5. Steering Control Valve
6. Hydraulic Cylinder
7. Rack and Pinion
8. Steering Rod

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