Phase 2

Trade of Motor Mechanic

Module 7

Unit 3

Steering, Alignment & Geometry

Produced by

SOLAS

An tSeirbhís Oideachais Leanúnaigh agus Scileanna
Further Education and Training Authority

In cooperation with:

Subject Matter Experts

Martin McMahon

&

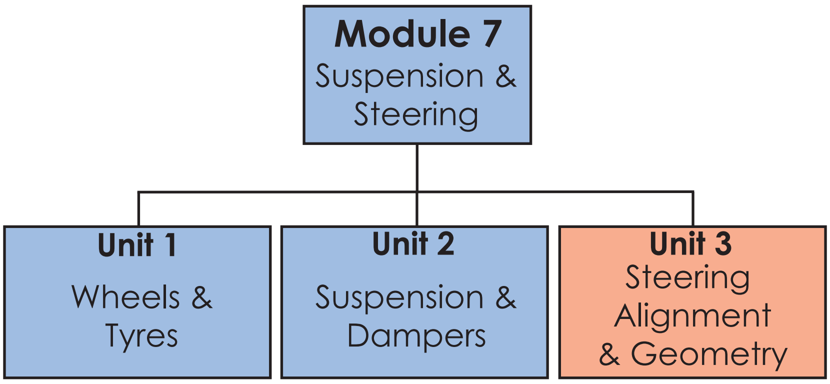
CDX Global

Curriculum Revision 2.2 16-01-07

Table of Contents

Introduction

There are 3 Units in Module 7. This Unit 3 focuses on Steering, Alignment and Geometry.



The steering system must provide control over the direction of travel of the vehicle; good manoeuvrability for parking the vehicle; smooth recovery from turns as the driver releases the steering wheel (self cantering action), minimum transmission of road shocks from the road surface and road wheel feed back.

This unit will cover the key components associated with the Steering, Alignment and Geometry section and the relevant environment, health and safety.

Unit Objective

By the end of this unit each apprentice will be able to:

- Describe the function and basic technical requirements of the steering system.
- Describe the Ackermann theory and explain its relevance in the design and operation of steering systems
- Describe the basic principle of wheel alignment setting/adjustment
- Describe the basic operation and identify the components of a rack and pinion type steering system
- Describe the health, safety and environmental awareness issues related to Suspension and Steering systems dismantling, reassembling and used components disposal/recycling procedures
- Remove/replace/refit ball joints and gaiters on steering racks
- Align the steering system
- Describe the purpose of and identify the main design/component structural angles in steering 'geometry'
- Locate relevant manufacturer's data of training vehicle/unit, steering geometry settings
- Measure the Camber angle and record and compare to manufacturer's settings

1.0 Health, Safety and Environmental Procedures

Key Learning Points

- Health, safety and environmental issues e.g. danger of serious/ deadly road accident if manufacturer's recommendations on tightening/torqueing of all bolts/ nuts are not strictly adhered to, used components collected, separated for recycling
- Steering wheel airbag system intrusion/accidental deployment or system technical damage, wearing of safety glasses/goggles; use of taper joint breaker tools/hammer activity - damage to seals/threads, road wheels/steering components working loose/falling off

1.1 Health, Safety and Recycling

If the proper safety procedures are not adhered when working on Steering, Alignment and Geometry this could lead to serious injury / health problems to personnel.

Instruction is given in the proper safety precautions applicable to working on Steering, Alignment and Geometry, include the following:

- Danger of serious auto–accidents if all steering and suspension bolts are not torqued to original manufacture's recommendations.
- Used components disposed off/recycled in accordance with environmental regulations.
- Steering wheel air bags systems (intrusion / accidental deployment or system technical damage. Manufacturer's specifications and procedures adhered to at all times.
- Use of tapered joint breaker tools / hammer, etc.
- Use of Personal Protective Equipment (PPE).

Refer to motor risk assessments, Environmental policy and Material Safety Data Sheets (MSDS)

2.0 Technical Requirements of the Steering System

Key Learning Points

- Driver vehicle control, steering ratio, steering behaviour; self centering action, road wheel feedback, basic oversteer/understeer characteristics

2.1 Principles of Steering

The steering system must provide control over the direction of travel of the vehicle; good manoeuvrability for parking the vehicle; smooth recovery from turns as the driver releases the steering wheel (self centering action), minimum transmission of road shocks from the road surface and road wheel feed back.

The effort by the driver is transferred from the steering wheel, down the steering column, to a steering box. The steering box converts the rotary motion of the steering wheel, to the linear motion needed to steer the vehicle. It also gives the driver a mechanical advantage.

The linear motion from the steering box is then transferred by tie-rods, to the steering arms at the front wheels. The tie rods have ball joints that allow steering movement and movement of the suspension. The steering-arm ball-joints are arranged so that movement in the suspension does not affect steering operation.

2.2 Steering Systems

The direction of motion of a motor vehicle is controlled by a steering system. A basic steering system has 3 main parts:

- A steering box connected to the steering wheel.
- The linkage connecting the steering box to the wheel assemblies at the front wheels.
- The front suspension parts to let the wheel assembly's pivot.

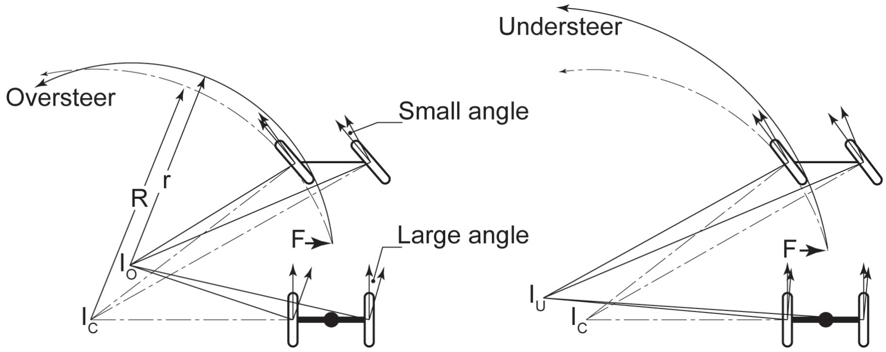
When the driver turns the steering wheel, a shaft from the steering column turns a steering gear. The steering gear moves tie rods that connect to the front wheels. The tie rods move the front wheels to turn the vehicle right or left.

There are 2 basic types of steering boxes - those with rack-and-pinion gearing and those with worm gearing. In both cases, the gearing in the steering box makes it easier for the driver to turn the steering wheel and hence, the wheels.

A rack-and-pinion steering system has a steering wheel, a main-shaft, universal joints and an intermediate shaft. When the steering is turned, movement is transferred by the shafts to the pinion. The pinion is meshed with the teeth of the rack, so pinion rotation moves the rack from side to side. This type of steering is used on passenger vehicles because it is light and direct.

2.3 Oversteer/Understeer

Oversteer is the tendency for a vehicle to turn into a corner more than necessary due to a loss of traction at the rear wheels. It is best described as a feeling that the rear of the vehicle wants to "swing out". Oversteer can be caused by a number of reasons such as excessively worn rear tyres, incorrect tyre pressures, vehicle drive train (rear wheel drive cars have a tendency towards oversteer) and vehicle weight balance (front to rear).



Understeer, also known as "push" or "pushing" is best described as the situation that occurs when the vehicle fails to sufficiently respond to the drivers steering input. It occurs when the front tyres do not have sufficient grip to carry out the cornering manoeuvre asked of them. Main cause of understeer include excessive cornering speed, wet / icy road conditions, incorrect tyre pressures and poor tyre condition (tread depth etc.).

Understeer is as the term suggests the opposite of oversteer and it is generally accepted as preferable to oversteer for the average motorist. Most motorists will experience understeer at some point whilst driving and as opposed to oversteer it is fairly predictable and relatively easy to overcome.

3.0 The Ackermann Theory Explained

Key Learning Points

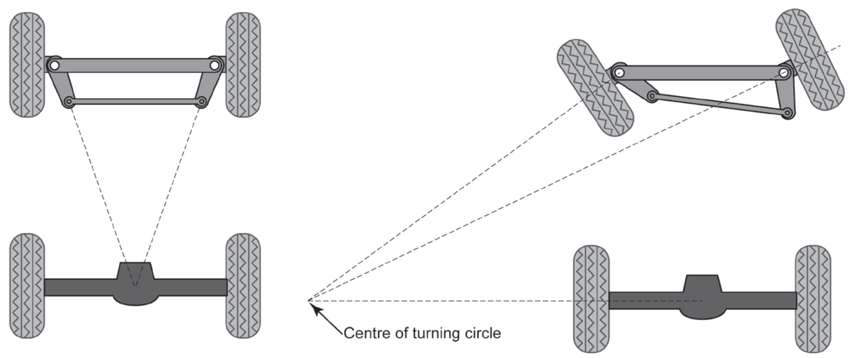
- Ackermann theory; wheels following vehicle instantaneous centre point of rotation, toe out on turns, body track and wheel base

3.1 Toe-Out on Turns (Ackermann Angle)

Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radii as shown in following pictures.

Toe-out on turns is the relative toe setting of the front wheels, as they turn to left, or right.

When a vehicle makes a turn, each wheel should rotate with true rolling motion that is free from tyre scrub.



True rolling motion is only obtained when each wheel is at 90 degrees to a line drawn between the swivel axis and the centre of turn.

Because the rear wheels are fixed, the centre of turn will lie somewhere along the centreline of the rear axle, depending on how far the steering wheel is turned from the straight-ahead position.

To provide true rolling motion, the inner wheel must be turned through a greater angle than the outer wheel. This allows the inner wheel to turn through a smaller turning radius than the outer wheel.

This automatically correct alignment is obtained by use of the Ackerman principle and layout. With the steering linkage at the rear of the wheels, the distance across the tie-rod ends (body track) at the steering arm joints is made shorter than the distance across the steering axis swivels (see picture). This forces the inner wheel to turn through a larger angle when the steering is turned.

The Ackerman angle is the angle the steering arms make with the swivels, on the centreline of the vehicle, at or near the centre of the rear axle.

4.0 Principle of Wheel Alignment Setting/Adjustment

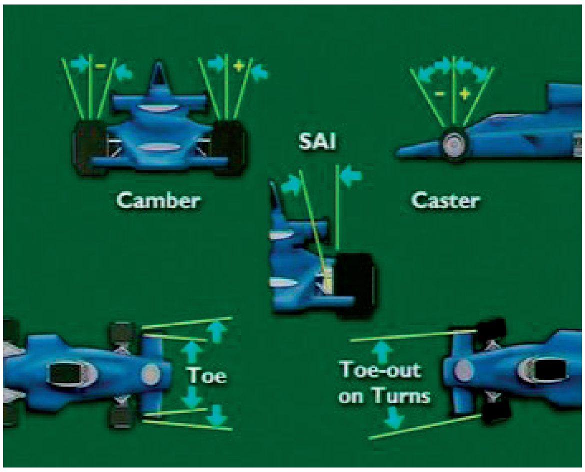
Key Learning Points

- Wheel alignment; linear measurement, forces acting on front wheels (FWD/RWD) toe in - toe out

4.1 Basic Principles of Wheel Alignment

All wheels of a vehicle must be correctly positioned, with the vehicle and with each other, for the vehicle to drive and steer properly.

A driver should not need to keep manipulating the steering wheel to maintain the vehicle in a straight-ahead position on straight level roads. Similarly little effort should be needed to turn the vehicle into curves or to let it return to the straight-ahead position when the curve has been negotiated. Wheels are installed on the suspension units at certain angles to provide for these factors. These angles taken together are called wheel alignment.

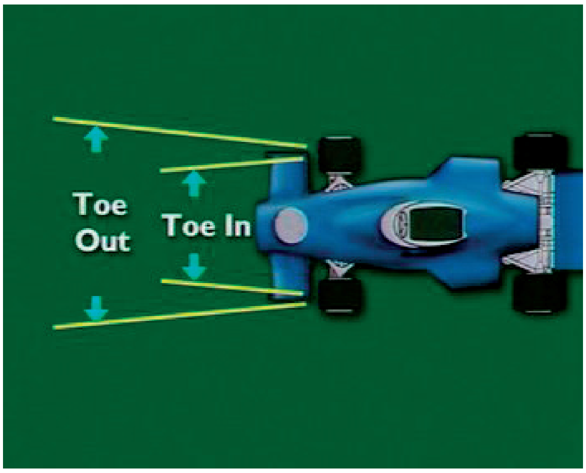


The factors that affect wheel alignment are:

- Camber
- Caster
- Steering axis inclination
- Toe-in and toe-out
- Toe-out on turns

4.2 Toe-In & Toe-Out

When the fronts of the wheels, as looking down upon the vehicle, are closer together than the rear of the wheels, it is called toe-in. The opposite arrangement is called toe-out.



The static toe setting is designed to compensate for slight wear in steering connections which may cause the wheels to splay outwards or inwards. This setting depends on front wheel drive or rear wheel drive layout and the vehicle manufacture. The result achieved is that wheels will be parallel when the vehicle is in motion, which avoids tyre scrub.

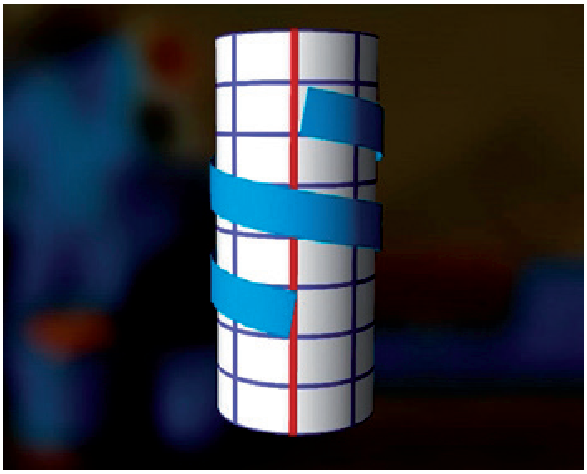
5.0 Rack and Pinion Type Steering System

Key Learning Points

- Rack and pinion; gear housing, pinion moving rack, ball joints, gaiters etc.

5.1 Helix

If an inclined plane is wrapped around a cylinder, the edge of the plane forms a shape called a helix.



Rotation of the cylinder causes a point on the helix to move, along the surface of the cylinder. The distance the point moves in one revolution of the cylinder is called the pitch.

The helix shape is commonly used as a thread on nuts and bolts and also for teeth in steering gears and transmissions.

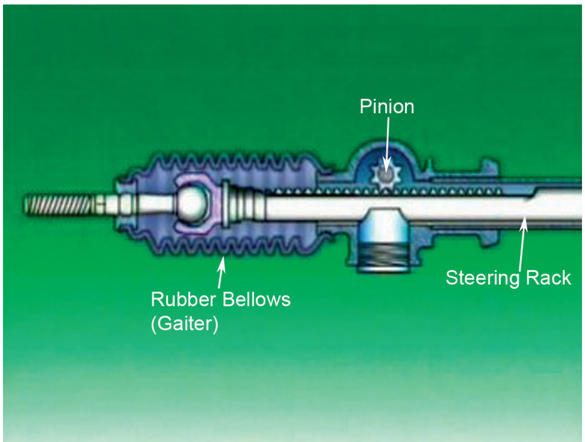
5.2 Rack-and-Pinion Steering

The steering rack is supported at the pinion end, by being sandwiched between the pinion and a spring-loaded, rack guide yoke. This spring-loaded yoke ensures free play is eliminated between the gears, while still allowing for relative movement.

The rack is supported at the other end in the rack housing or tube by a bush normally of nylon. Nylon is used because it has a low coefficient of friction and is hard wearing. The pinion is supported by 2 bearings in the rack housing.

These bearings are pre-loaded to keep the pinion in the correct position relative to the rack and to eliminate free play.

A rack-and-pinion steering box is normally lubricated by grease. Each end of the rack is protected from dirt and water by a flexible synthetic rubber bellows (gaiter) attached to the rack housing and to the tie rod. The bellows extends and collapses as the tie-rods move away from and towards the housing, as the rack moves.



On some vehicles, both bellows are interconnected by a tube so that as the steering wheel is moved from side to side, air is transferred from the collapsing bellows side to the expanding bellows side.

Rack-and-pinion type steering gears are used because their construction makes them compact and light-weight. Their steering response is very sharp because the rack operates directly on the steering knuckle. And there is very little sliding and rotation resistance, which gives lighter operation.

5.3 Rack-and-Pinion Gearbox

The rack-and-pinion steering gear box has a pinion, connected to the steering column. This pinion runs in mesh with a rack that is connected to the steering tie rods. This gives more direct operation. Both the pinion and the rack teeth are helical gears. Helical gearing gives smoother and quieter operation for the driver.

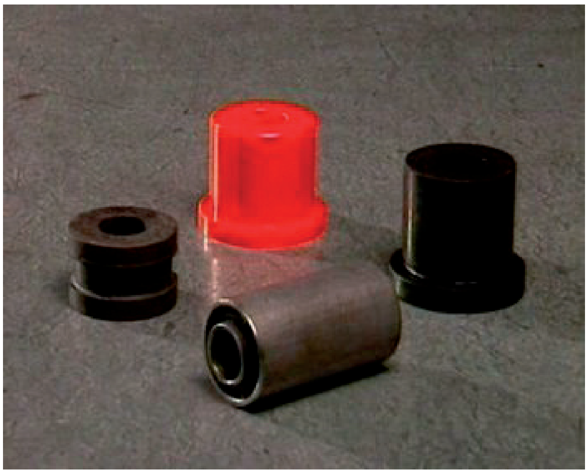
Turning the steering wheel rotates the pinion and moves the rack from side to side. Ball joints at the end of the rack locate the tie-rods and allow movement in the steering and suspension.

Mechanical advantage is gained by the reduction ratio. The value of this ratio depends on the size of the pinion.

A small pinion gives light steering, but it requires many turns of the steering wheel to travel from lock to lock. A large pinion means the number of turns of the steering column is reduced, but the steering is heavier to turn. Ratios vary, depending on the type of vehicle. But in each case the ratio is the same for all positions of the wheels. It is a fixed ratio.

5.4 Bushes/Bushings

Bushes or bushings act as bearings at suspension fulcrum points to allow for movement of the component while maintaining its alignment.



They can be metallic or made of rubber, nylon, or urethane. In commercial vehicles metallic bushes are commonly used as shackle bushes for leaf springs. Any force applied to the bush acts through it to the body of the vehicle, which results in a harsher ride. The mounting pin on a metallic bush is usually drilled to allow for lubricating the bushes.

5.5 Joints

Ball joints are swivel connections mounted in the outer ends of the front control arms and on the steering track rods and tie-rods. They allow the control arms to move up and down with suspension deflection and also let the wheel and hub assembly turn for steering.

The ball joint can be a sealed self-contained unit fastened to the control arm in a number of ways.

6.0 Servicing Joints and Gaiters on Steering Racks

Key Learning Points

- Remove/replace/refit ball joints and gaiters

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

7.0 Aligning the Steering System

Key Learning Points

- Wheel alignment; measurement/adjustment procedures (equal on both sides where applicable), equal lock on both sides, steering wheel position central, (steering wheel/ airbag not interfered with), final setting to manufacturer's recommendations
- Use of Camber gauge to measure and record camber angle

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

8.0 Steering 'Geometry'

Key Learning Points

- Steering ratio; use of protractor and turntables
- Steering geometry; Camber, K.P.I. (S.A.I.) included angle, castor

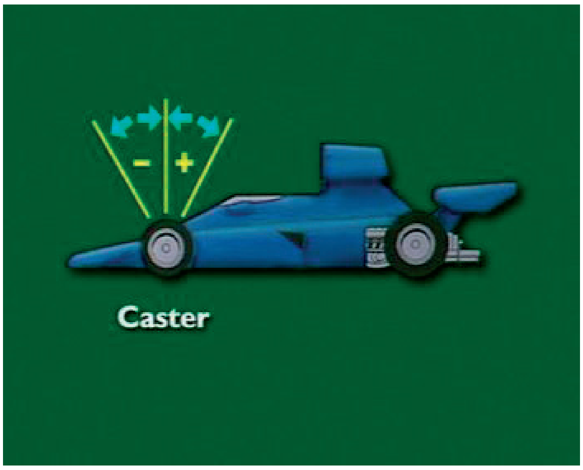
8.1 Steering Ratio

The steering ratio is the ratio of how far you turn the steering wheel to how far the wheels turn. For instance, if one complete revolution (360 degrees) of the steering wheel results in the wheels of the car turning 20 degrees, then the steering ratio is 360 divided by 20, or 18:1. (This can be measured using a protractor that is mounted on turntables). A higher ratio means that you have to turn the steering wheel more to get the wheels to turn a given distance. However, less effort is required because of the higher gear ratio.

Some cars have variable-ratio steering, which uses a rack-and-pinion gearset that has a different tooth pitch (number of teeth per centimetre) in the centre than it has on the outside. This makes the car respond quickly when starting a turn (the rack is near the centre) and also reduces effort near the wheel's turning limits.

8.2 Caster

Seen from the side of the vehicle, the steering axis centreline is normally tilted from the vertical. Caster is the angle formed by this line and a line drawn vertically through the centre of the wheel. Backward tilt from the vertical is positive caster. Forward tilt is negative caster.



When a vehicle has positive caster a line drawn through the steering axis centreline meets the road surface ahead of the centreline of the wheel. The tyre contact point is behind the steering axis. When the wheel is turned to the right the tyre contact point is moved to the left of the direction of travel and similarly for turning to the left.

In forward motion, this generates a self-cantering force which helps return the wheels to the neutral position when the steering wheel is released. The effects of positive caster can be seen in the motion of this furniture wheel. When it is acted on by a forward-moving force its pivot point ahead of the wheel ensures the wheel always trails behind.

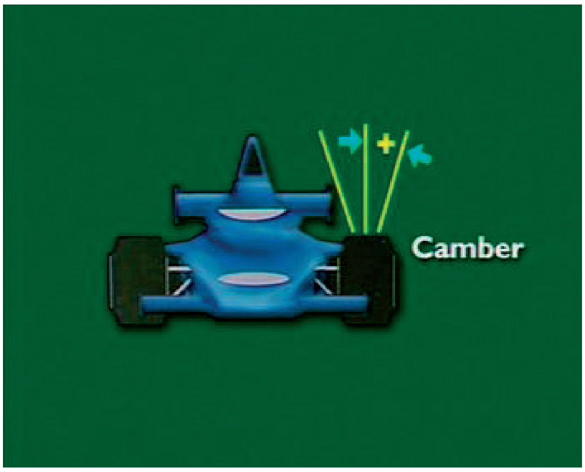
Most cars have positive caster because it makes it easier to travel in a straight line with minimal driver action. But as positive caster increases more and more effort is needed to turn the steering wheel.

Some vehicles have by design an amount of negative caster. Generally such vehicles would only operate at low speeds as vehicles with negative caster can become unstable as speed increases.

In all cases, the manufacturer's specification should be followed.

8.3 Camber

Camber is viewed from the front of the vehicle and it is the angle of tilt of the wheel from the vertical.



A wheel that leans away from the vehicle at the top is said to have positive camber. A wheel that leans towards the vehicle is said to have negative camber.

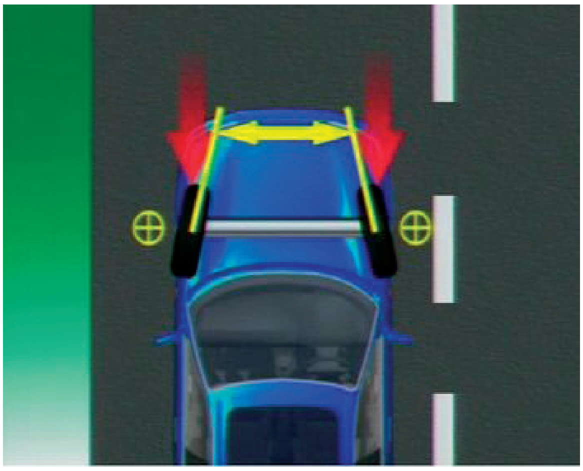
On modern vehicles tyres are wider but they are generally smaller in diameter and large camber angles would produce excessive wear on the outer edges of the tyres. The amount of camber is now reduced, so that most cars have what is called zero average camber to give long tyre life.

This is because when a vehicle is in motion, zero camber is difficult to maintain. Changes in running camber can be caused by road irregularities and load variations.

8.4 Scrub Radius

Scrub radius is also known as steering offset and scrub geometry. It is the distance between 2 imaginary points on the road surface. I – the point of centre contact between the road surface and the tyre. II the point where the steering-axis centre-line contacts the road surface.

If these two points intersect at the centre of the tyre at the road surface then the scrub radius is zero. If they intersect below the road surface, scrub radius is positive. If they intersect above the road surface scrub radius is negative.



The effect of scrub radius – positive or negative – is to provide a turning moment which attempts to turn the wheel away from the central position, when the vehicle is in motion.

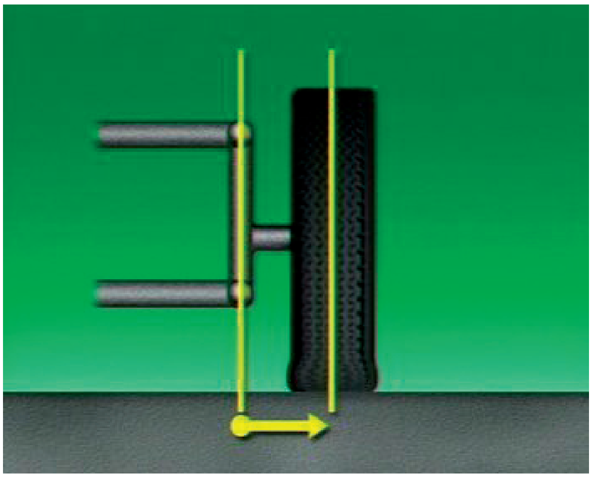
If it has negative scrub radius, the front wheels again tend to move back, but this time, they toe-in. On front-wheel-drive vehicles, the opposite occurs. Positive scrub radius causes toe-in and negative causes toe-out.

During braking, on any type of drive, if braking effort is greater on one side of the vehicle than the other, positive scrub radius will cause the vehicle to veer towards the side with the greater effort. Negative scrub radius will cause the vehicle to veer away from the side of greatest effort. How much it veers depends on the size of the scrub radius.

This is why, vehicles with a diagonal-split brake system have negative scrub radius built into the steering geometry. If one half of the brake system fails, then the vehicle will tend to pull up in a straight line. Since the offset of the wheel rim determines where the centreline of the tyre meets the road surface, it is important that the offset is not changed if wheels are being replaced.

8.5 Steering Axis Inclination (SAI)

The axis around which the wheel assembly swivels as it turns to the right or left is called the steering axis. It is formed by drawing a line through the upper and lower pivot points of the suspension assembly. Seen from the front of the car it is tilted inward.



The angle formed between this line and the vertical provides steering axis inclination angles. Steering axis inclination acts with caster to provide a self-centring of the front wheels.

When the wheels are in the straight-ahead position the ends of the stub axles are almost horizontal. When the wheels turn to either side the effect of steering axis inclination is to make the ends of the stub axle tend to move downward, but this is prevented by the wheel. The stub axle carrier then must move up which raises the front of the vehicle.

When the steering wheel is released, the mass of the vehicle forces the stub carrier back down, which pushes the wheels back to a central position.

With a vertical steering axis, no self-centring would occur. The wheel would pivot on a radius with the steering axis as its centre. This would introduce a turning moment on the wheel, road shocks would be transmitted back to the steering wheel and steering would be difficult to control. Steering axis inclination brings the pivot point close to the centre of the tyre contact patch at the road surface. It intersects with the camber line drawn through the tyre and the wheel.

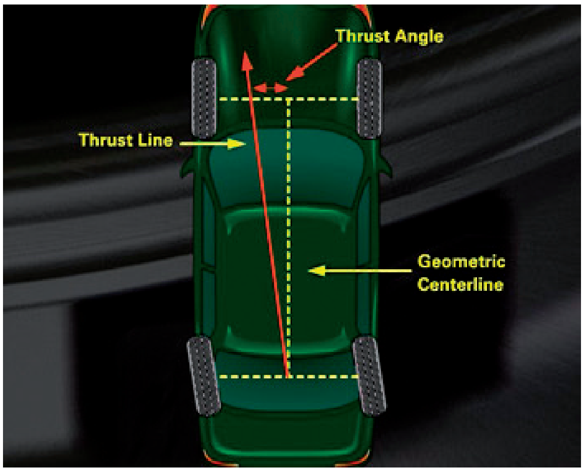
If these 2 lines intersect at the centre of the tyre, at the road surface, then the vehicle is said to have zero offset or zero scrub radius. If they intersect below the road surface, then it has positive offset or scrub radius. If they intersect above the road surface then it has negative offset or scrub radius.

The angle between the steering axis inclination and the camber line is called the included angle. It is a diagnostic angle.

Since the steering axis inclination is not adjustable, if the camber angle is correct, then the steering axis inclination should also be correct, that is it should match the specification. SAI is also referred to as KPI (King Pin Inclination) on trucks and old cars with king pins instead of ball joints.

8.6 Thrust Angle & Centrelines

On a vehicle with Independent Rear Suspension undertaking a front-wheel-only alignment is considered to be an inadequate procedure.



The thrust angle refers to all four wheels and their relationship to each other in addition to their relationship to an imaginary centreline that runs from each pair of wheels down the centre of the vehicle. The term "thrust line" refers to the direction in which the rear wheels are pointing. The thrust angle can be adjusted on vehicles with adjustable rear suspensions.

The thrust line may be in the same position as the vehicle's geometric "centreline"; however there are variations to this. Ideally the thrust line and the vehicle's geometric centreline should line up closely.

The "centreline" is drawn through point's midway between each pair of wheels; however the thrust line is normally in the perpendicular position of the rear axle on solid axle cars, or, with IRS, is a line derived by splitting the toe angle of the rear wheels on the vehicle.

For instance, if the rear wheel on the right rear wheel side of the vehicle is toed-in six degrees and the rear wheel on the left is at zero degrees, the thrust line will veer off three degrees to the left of the vehicle centreline at the rear wheels when the vehicle is moving forward.

An ideal situation is where the thrust and centrelines coincide. Given the size of a vehicle the tolerances during manufacture, operational stresses and component wear; it's rare that they do. If the deviation is very small then remedial action is normally unnecessary. A large deviation can cause considerable concern when the vehicle is being driven. And the cause of this condition needs to be identified and corrected.

Under such conditions the rear wheels are steering the car away from its centreline and the driver has to turn the steering wheel to one side to keep the car going in a straight line. In extreme circumstances the tracks the rear tyres make are beside those of the front. This condition is known as "crabbing" and can cause diagonal tyre pattern wear as well as vehicle instability in some driving conditions.

Summary

The thrust angle refers to all four wheels and their relationship to each other and to an imaginary centreline that runs from each pair of wheels down the centre of the vehicle. The term "thrust line" refers to the direction in which the rear wheels are pointing.

9.0 Locating Manufacturer's Data on Steering Geometry Settings

Key Learning Points

- Sourcing of relevant manufacturer's data on task procedures and Tolerances

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

10.0 Camber Angle Measurement and Recording

Key Learning Points

- Manufacturers nut locking (self locking), tightening procedures adhered to. Road wheel retainer nuts torqued to manufacturer's specifications
- Convert linear measurement to angular

Practical Task

This is a practical task. Please refer to your instructor for additional information, which is available from the automotive technical manuals.

10.1 Conversion from Degrees to Millimetres

Degrees & Mins	Wheel Rim Size (Inches)						
	10"	12"	13"	14"	15"	16"	17"
0°01′	0,1	0,1	0,1	0,1	0,1	0,1	0,1
0°02′	0,1	0,2	0,2	0,2	0,2	0,2	0,3
0°03′	0,2	0,3	0,3	0,3	0,3	0,4	0,4
0°04′	0,3	0,4	0,4	0,4	0,4	0,5	0,5
0°05′	0,4	0,4	0,5	0,5	0,6	0,6	0,6
0°06′	0,4	0,5	0,6	0,6	0,7	0,7	0,8
0°07′	0,5	0,6	0,7	0,7	0,8	0,8	0,9
0°08′	0,6	0,7	0,8	0,8	0,9	0,9	1,0
0°09′	0,7	0,8	0,9	0,9	1,0	1,1	1,1
0°10′	0,7	0,9	1,0	1,0	1,1	1,2	1,3
0°11′	0,8	1,0	1,1	1,1	1,2	1,3	1,4
0°12′	0,9	1,1	1,2	1,2	1,3	1,4	1,5
0°13′	1,0	1,2	1,2	1,3	1,4	1,5	1,6
0°14′	1,0	1,2	1,3	1,4	1,6	1,7	1,8
0°15′	1,1	1,3	1,4	1,6	1,7	1,8	1,9
0°16′	1,2	1,4	1,5	1,7	1,8	1,9	2,0
0°17′	1,3	1,5	1,6	1,8	1,9	2,0	2,1
0°18′	1,3	1,6	1,7	1,9	2,0	2,1	2,3
0°19′	1,4	1,7	1,8	2,0	2,1	2,2	2,4
0°20′	1,5	1,8	1,9	2,1	2,2	2,4	2,5
0°21′	1,6	1,9	2,0	2,2	2,3	2,5	2,6
0°22′	1,6	2,0	2,1	2,3	2,4	2,6	2,8
0°23′	1,7	2,0	2,2	2,4	2,5	2,7	2,9
0°24′	1,8	2,1	2,3	2,5	2,7	2,8	3,0
0°25′	1,8	2,2	2,4	2,6	2,8	3,0	3,1
0°26′	1,9	2,3	2,5	2,7	2,9	3,1	3,3
0°27′	2,0	2,4	2,6	2,8	3,0	3,2	3,4
0°28′	2,1	2,5	2,7	2,9	3,1	3,3	3,5
0°29′	2,1	2,6	2,8	3,0	3,2	3,4	3,6
0°30′	2,2	2,7	2,9	3,1	3,3	3,5	3,8
	Dimension in mm						

Degrees & Mins	Wheel Rim Size (Inches)						
	10"	12"	13"	14"	15"	16"	17"
0°31′	2,3	2,7	3,0	3,2	3,4	3,7	3,9
0°32′	2,4	2,8	3,1	3,3	3,5	3,8	4,0
0°33′	2,4	2,9	3,2	3,4	3,7	3,9	4,1
0°34′	2,5	3,0	3,3	3,5	3,8	4,0	4,3
0°35′	2,6	3,1	3,4	3,6	3,9	4,1	4,4
0°36′	2,7	3,2	3,5	3,7	4,0	4,3	4,5
0°37′	2,7	3,3	3,6	3,8	4,1	4,4	4,6
0°38′	2,8	3,4	3,7	3,9	4,2	4,5	4,8
0°39′	2,9	3,5	3,7	4,0	4,3	4,6	4,9
0°40′	3,0	3,5	3,8	4,1	4,4	4,7	5,0
0°41′	3,0	3,6	3,9	4,2	4,5	4,8	5,1
0°42′	3,1	3,7	4,0	4,3	4,7	5,0	5,3
0°43′	3,2	3,8	4,1	4,4	4,8	5,1	5,4
0°44′	3,3	3,9	4,2	4,6	4,9	5,2	5,5
0°45′	3,3	4,0	4,3	4,7	5,0	5,3	5,7
0°46′	3,4	4,1	4,4	4,8	5,1	5,4	5,8
0°47′	3,5	4,2	4,5	4,9	5,2	5,6	5,9
0°48′	3,5	4,3	4,6	5,0	5,3	5,7	6,0
0°49′	3,6	4,3	4,7	5,1	5,4	5,8	6,2
0°50′	3,7	4,4	4,8	5,2	5,5	5,9	6,3
0°51′	3,8	4,5	4,9	5,3	5,7	6,0	6,4
0°52′	3,8	4,6	5,0	5,4	5,8	6,1	6,5
0°53′	3,9	4,7	5,1	5,5	5,9	6,3	6,7
0°54′	4,0	4,8	5,2	5,6	6,0	6,4	6,8
0°55′	4,1	4,9	5,3	5,7	6,1	6,5	6,9
0°56′	4,1	5,0	5,4	5,8	6,2	6,6	7,0
0°57′	4,2	5,1	5,5	5,9	6,3	6,7	7,2
0°58′	4,3	5,1	5,6	6,0	6,4	6,9	7,3
0°59′	4,4	5,2	5,7	6,1	6,5	7,0	7,4
1°00′	4,4	5,3	5,8	6,2	6,6	7,1	7,5
	Dimension in mm						

Self Assessment

Q1: In the 'rack and pinion' system, the pinion rotation moves the: (Tick one box only)

❑ 1. Rack from side to side

❑ 2. Steering shaft from side to side

❑ 3. Rack in and out

❑ 4. Steering shaft in and out

Q2: A 'rack and pinion' steering system is used on: (Tick one box only)

❑ 1. Heavy-duty commercial vehicles

❑ 2. Medium-duty commercial vehicles

❑ 3. Transit buses

❑ 4. Light passenger vehicles

Q3: The purpose of the 'rack and pinion' bellow is: (Tick one box only)

❑ 1. To protect the internal components from dirt; to contain the lubrication grease in the steering component

❑ 2. To protect the internal components from dirt; to contain the lubrication grease in the steering component; to assist with the steering effort

Q4: The rack in a 'rack and pinion' system is held in contact with the pinion by a: (Tick one box only)

❑ 1. Roller bearing

❑ 2. Nylon bush

❑ 3. Spring-loaded yoke

❑ 4. Rubber stop

Q5: In a 'rack and pinion' system, the smaller the pinion gear, the heavier the steering. (Tick one box only)

❑ 1. True

❑ 2. False

Q6: The rack and pinion steering is an integral part of the: (Tick one box only)

- ❑ 1. Steering linkage
- ❑ 2. Vehicle frame
- ❑ 3. Steering box
- ❑ 4. None of these

Q7: In a variable ratio rack and pinion system, as it come towards the end of the travel, its: (Tick one box only)

- ❑ 1. Ratio remains the same
- ❑ 2. Ratio changes
- ❑ 3 Steering angles are varied

Q8: The 'included angle' is a combination of: (Tick one box only)

- ❑ 1. Camber and steering axis inclination
- ❑ 2. Turning radius and Ackerman angle
- ❑ 3. Caster and camber
- ❑ 4. Toe-in and toe-out

Q9: Positive camber can be increased by moving the upper ball joint inward toward the frame of the vehicle. (Tick one box only

- ❑ 1. True
- ❑ 2. False

Q10: Positive caster can be increased by moving the upper ball joint toward the front of the vehicle. (Tick one box only)

- ❑ 1. True
- ❑ 2. False

Q11: The toe-in adjustment is normally made after the camber and caster adjustments are made. (Tick one box only)

- ❑ 1. True
- ❑ 2. False

Q12: Which of the following factors do NOT affect wheel alignment? (Tick only one box)

- ❑ 1. Camber
- ❑ 2. Steering axis inclination
- ❑ 3. Toe-in & toe-out
- ❑ 4. Tyre width

Q13: What is toe-in? (Tick only one box)

- ❑ 1. When the front of the wheels are closer together than the rear of the wheels
- ❑ 2. When the rear of the wheels are closer together than the front of the wheels
- ❑ 3. When the front of the wheels have worn more than the rear of the wheels
- ❑ 4. When the front wheels have worn more than the rear wheels

Suggested Exercises

- Use an electronic data facility to procure manufacturer's appropriate data for use with practical exercises
- Replace track rod ends and gaiters on rack and pinion units
- Measure and adjust front wheel alignment to manufacturer's recommendations
- Measure steering geometry on training vehicles and compare findings to manufacturer's specifications
- Measure and calculate the steering ratio

Training Resources

- Technical information in book/electronic form on basic automotive steering systems and basic steering system kinematics (i.e. road wheel-surface feedback etc.)
- Relevant manufacturer's data on steering geometry of training vehicles/units
- Training vehicles/unit for practical exercises
- Wheel alignment and steering geometry gauges
- Suitable automobile lifting equipment
- Torque spanner

Suggested Further Reading

- Advanced Automotive Diagnosis. Tom Denton. ISBN 0340741236
- Automobile Electrical and Electronic Systems (3rd Edition). Tom Denton. ISBN 0750662190
- Automotive Mechanics (10th Edition). William H. Crouse and Donald L. Anglin. ISBN 0028009436
- Bosch Automotive Electrics Automotive Electronics: Systems and Components (4th Edition). Robert Bosch. ISBN 0837610508
- Bosch Automotive Handbook (6th Edition). Robert Bosch. ISBN 1860584748
- Bosch Automotive Technology Technical Instruction booklet series (numerous titles)
- Hillier's Fundamentals of Motor Vehicle Technology: Book One (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780823
- Hillier's Fundamentals of Motor Vehicle Technology: Book Two (5th Edition). V.A.W. Hillier and Peter Coombes. ISBN 0748780998
- Modern Automotive Technology. James E. Duffy. ISBN 1566376106
- Motor Vehicle Craft Studies - Principles. F.K. Sully. ISBN 040800133X
- National Car Test (NCT) Manual (Department of Transport, Vehicle Testers Manual - DoT VTM). Department of Transport
- Transmission, Chassis and Related Systems (Vehicle Maintenance and Repair Series: Level 3) (3rd Edition) John Whipp and Roy Brooks. ISBN 186152806X
- Vehicle and Engine Technology (2nd Edition). Heinz Heisler. ISBN 0340691867
- http://www.cdxglobal.com/
- http://auto.howstuffworks.com/
- http://www.autoshop101.com/
- http://www.cdxetextbook.com/
- Automotive Encyclopedia and Text Book Resource (CD version of e-textbook), Available from your instructor.

Notes

SOLAS

An tSeirbhís Oideachais Leanúnaigh agus Scileanna
Further Education and Training Authority

27-33 Upper Baggot Street
Dublin 4