Phase 2

Trade of Motor Mechanic

Module 7

Unit 2

Suspension & Dampers

Produced by

SOLAS

An tSeirbhís Oideachais Leanúnaigh agus Scileanna
Further Education and Training Authority

In cooperation with:

Subject Matter Experts

Martin McMahon

&

CDX Global

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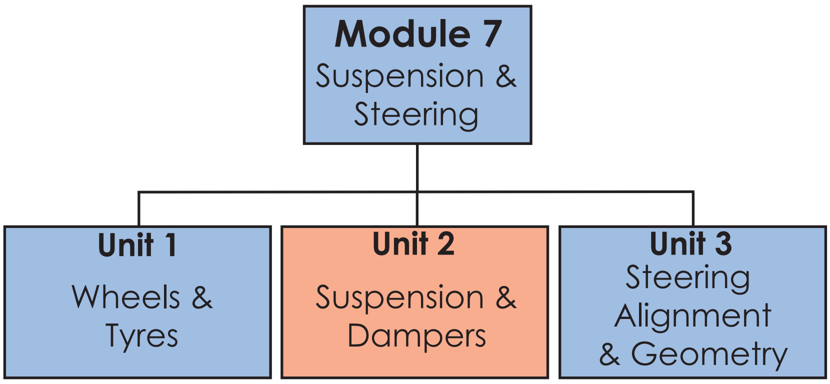
Introduction

There are 3 Units in Module 7. This Unit 2 focuses on Suspension and Dampers.



The purpose of the complete suspension system is to isolate the vehicle body from road shocks and vibrations which would otherwise be transferred to the passengers and load. It must also keep the tyres in contact with the road regardless of road surface. A basic suspension system consists of springs, axles, shock absorbers, arms, rods and ball joints.

This unit will cover the key components associated with the Suspension and the relevant environment, health and safety.

Unit Objective

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

- Describe the function of automobile suspension systems
- Identify the main components and describe the basic operation of coil, torsion bar and leaf type automobile suspension springing systems
- State the advantages of independent suspension systems over non independent types
- Describe the function and operation of tubular hydraulic dampers/shock absorbers
- Describe the procedure used to evaluate the damping action of individual shock absorbers
- Write a procedural work flow chart on the removal/refitting of individual major components of the front/rear independent suspension/steering system
- Remove/refit the major suspension/steering system components/units/shock absorbers etc.
- Describe the NCT/DoT VTM regulations for Bodywork and Chassis/Underbody systems
- Diagnose wear in individual chassis, bracket/suspension/ swivel axle, ball joints/bushes on the front and rear suspensions systems

1.0 Health and Safety

Key Learning Points

- Danger of serious/deadly auto-accident if all steering and suspension bolts are not torqued to original manufacturer's recommendations
- Danger of explosion of gas filled shock absorbers if pressure is not released (i.e. drilled appropriately) before crushing. Appropriate facial - eye protection worn if drilling, possible high pressure gas release
- Precautions with body height adjustment systems, wearing of safety glasses/goggles, safe use of taper joint breakers/ coil spring, coil spring clamping equipment. Safe vehicle body support system/methods during suspension system removal/refitting

1.1 Health and Safety

If the proper safety procedures are not adhered when working on Suspensions and Dampers this could lead to serious injury / health problems to personnel.

Instruction is given in the proper safety precautions applicable to working on Suspensions and Dampers include the following:

- Danger of explosion of gas filled shock absorbers (disposed off in accordance with environmental regulations)
- Body height adjustment
- Use of tapered joint breakers / coil spring
- Coil spring clamping equipment
- Body support system / method during suspension system removal
- Danger of serious auto–accidents if all steering and suspension bolts are not torqued to original manufacture's recommendations
- Use of Personal Protective Equipment (PPE)

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

2.0 The Function of Automobile Suspension Systems

Key Learning Points

- Support of vehicle body and its load, wheel movement without body movement, relevance of suspension/steering system design to vehicle dynamics/stability

2.1 Principles of Suspension

The suspension system isolates the body from road shocks and vibrations which would otherwise be transferred to the passengers and load.

It also must keep the tyres in contact with the road. When a tyre hits an obstruction, there is a reaction force. The size of this reaction force depends on the unsprung mass at each wheel assembly.

The sprung mass is that part of the vehicle supported by the springs - such as the body, frame, engine and associated parts.

Unsprung mass includes the components that follow the road contours, such as wheels, tyres, brake assemblies and any part of the steering and suspension not supported by the springs. Vehicle ride and handling can be improved by keeping unsprung mass as low as possible. When large and heavy wheel assemblies encounter a bump or pothole, they experience a larger reaction force, sometimes large enough to make the tyre lose contact with the road surface.

Wheel and brake units that are small and light, follow road contours without a large effect on the rest of the vehicle. At the same time, a suspension system must be strong enough to withstand loads imposed by vehicle mass during cornering, accelerating, braking and uneven road surfaces.

3.0 Types of Suspension Systems

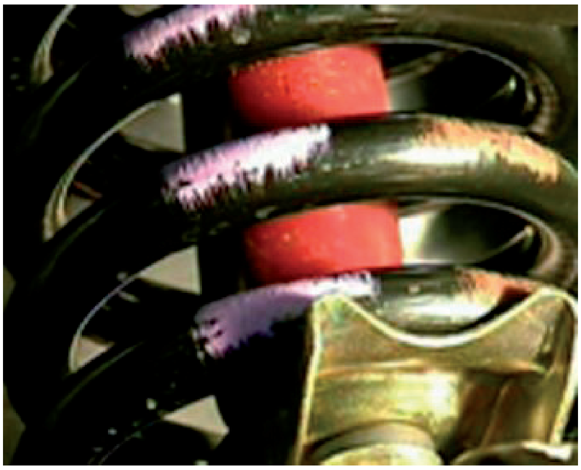
Key Learning Points

- Coil spring, torsion bar, leaf spring, independent/non-independent (beam axle) track control arms/wishbones, anti-roll bars etc.

3.1 Suspension Systems

The purpose of the complete suspension system is to isolate the vehicle body from road shocks and vibrations which would otherwise be transferred to the passengers and load. It must also keep the tyres in contact with the road regardless of road surface. A basic suspension system consists of springs, axles, shock absorbers, arms, rods and ball joints.

The spring is the flexible component of the suspension. Basic types are leaf springs, coil springs and torsion bars. Modern passenger vehicles usually use light coil springs. Light commercial vehicles have heavier springs than passenger vehicles and can have coil springs at the front and leaf springs at the rear. Heavy commercial vehicles usually use leaf springs or air suspension.



Solid or beam axles connect the wheels on each side of the vehicle. This means the movement of a wheel on one side of the vehicle is transferred to the wheel on the other side. With independent suspension, the wheels can move independently of each other, which reduce body movement. This prevents the other wheel being affected by movement of the wheel on the opposite side and this reduces body movement.

When a wheel strikes a bump, there is a reaction force and energy is transferred to the spring which makes it oscillate. Oscillations left uncontrolled can cause loss of traction between the wheel and the road surface.

Shock absorbers dampen spring oscillations by forcing oil through small holes. The oil heats up, as it absorbs the energy of the motion. This heat is then transferred through the body of the shock absorber to the air. When a vehicle hits an obstruction, the size of the reaction force depends on how much unsprung mass is at each wheel assembly.

Sprung mass refers to those parts of the vehicle supported on the springs. This includes the body, the frame, the engine and associated parts. Unsprung mass includes the wheels, tyres, brake assemblies and suspension parts not supported by the springs.

Vehicle ride and handling is improved by keeping unsprung mass as low as possible. Wheel and brake units that are small and light follow the road contours without a large effect on the rest of the vehicle.

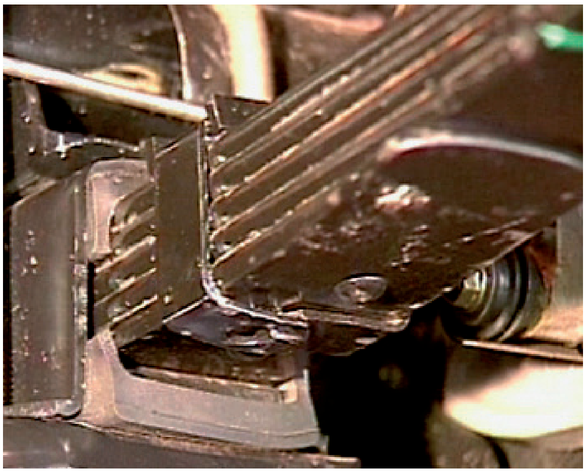
3.2 Coil Springs

Coil springs are used on the front suspension of most modern light vehicles and in many cases, they have replaced leaf springs in the rear suspension. A coil spring is made from a single length of special wire, which is heated and wound on a former, to produce the required shape. The load-carrying ability of the spring depends on the diameter of the wire, the overall diameter of the spring, its shape and the spacing of the coils.

A light commercial vehicle has springs that are robust and fairly stiff. On a small passenger car, they are lighter and more flexible. The coils may be evenly spaced, or of uniform pitch, or unevenly spaced. The wire can be the same thickness throughout, or it may taper towards the end of the spring.

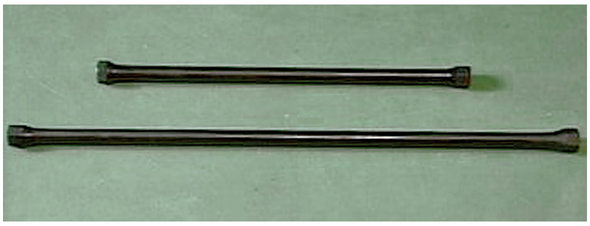
3.3 Leaf Springs

The leaf spring is one of the oldest forms of springing. It is usually used on rear-wheel-drive vehicles because its simplicity. They can be mounted longitudinally. Leaf springs consist of one or more flat springs, made of tempered steel. A number of leaves of different length are used to form a multi-leaf spring. They are held together by a centre bolt that passes through a hole in the centre of each leaf. It is also used to locate the axle on the spring. The axle is then clamped to the spring by U-bolts that wrap around the axle housing and through a spring plate underneath the spring.



Rebound clips are formed at intervals around the leaves. They prevent excessive flexing of the main leaf during rebound and also keep the leaves in alignment. The longest leaf called the main leaf is rolled at both ends to form eyes. These eyes are used to mount the spring to the frame of the vehicle. Some springs have the ends of the second leaf rolled around the eyes of the main leaf, as reinforcement. This leaf is called the wrap leaf. The front of the spring is attached to a rigid spring hanger on the vehicle frame. The rear is connected to the frame by a swinging shackle, which provides a link between the spring eye and a bracket on the subframe.

3.4 Torsion Bars



A torsion bar is a long, alloy-steel bar, fixed rigidly to the chassis or sub-frame, at one end and to the suspension control arm at the other. The bar is fitted to the control arm in the unloaded condition and as the control arm is raised, the bar twists around its centre, which places it under a torsional load.

When the vehicle is placed on the road, with the control arm connected to the suspension assembly, the bar supports the vehicle load and twists around its centre, to provide the springing action. Spring rate depends on the length of the bar and its diameter. The shorter and thicker the bar, the stiffer its spring rate.

Torsion bars can be used across the chassis frame on the same principle, in a trailing arm suspension, or as part of the connecting link between 2 axle assemblies, on a semi-rigid axle beam. After a lot of use, a torsion bar can sag. On many vehicles, it can be adjusted to allow for this. It is used in light vehicles as a stabilizer, or anti-roll bar, connected between each side of the suspension on the front and sometimes the rear.

When the vehicle is turning, centrifugal force acts on the body and tends to make it lean outwards. The anti-roll bar, or stabilizer, tries to use its connections to each side of the suspension, to resist this roll tendency.

3.5 Rubber Springs

Rubber is used in most suspension systems as bump and rebound stops. If the suspension reaches its limit of travel, these stops prevent direct metal-to-metal contact, which reduces jarring of the body of the vehicle. The stops can also be shaped to provide an auxiliary springing function, increasing their resistance progressively with suspension contact.

4.0 Independent Suspension over Non-Independent

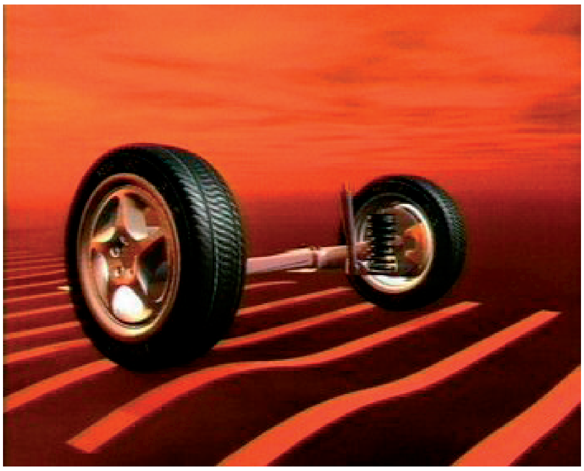
Key Learning Points

- Independent suspension - individual wheel movement, not directly affecting other wheels

4.1 Independent Suspension

One of the main benefits claimed for independent suspension is that unsprung mass can be kept low. Also if a wheel on one side hits a road irregularity it won't upset the wheel on the other side on the same axle. When provided for by the manufacturer it allows wheel camber to be adjusted individually.

One of the simplest and most common independent suspension systems are the McPherson strut type. It can be used on the front and rear of the vehicle.



It consists of a spring and shock absorber unit called a strut. The lower end of the strut is located by a ball joint, fitted to the end of the suspension control arm. Its upper end is located in a moulded rubber mounting. If the unit is on the front, the upper mounting includes a bearing to allow the complete strut to rotate with the steering.

A tension rod, or stay bar, extends from the body sub-frame, to the outer end of the control arm. This maintains the location of the control arm during braking and accelerating. In this front-wheel-drive suspension, the control arm is a wishbone shape with 2 widely-spaced mounting points. This prevents backward and forward movement, so a tension rod is not needed. Wishbones can also be used in a parallel link system. They can be used in pairs with the coil spring between the lower wishbone and the suspension cross-member. Alternatively, the upper link may be a wishbone, with the coil spring mounted above, combined with a single-pivot lower link, located by a tension rod. On some vehicles, a torsion bar provides the springing medium. The torsion bar is attached at the inner fulcrum point of the wishbone, or control arm. As the suspension is deflected, it twists around its centre.

It can be fitted to the upper, or the lower link, depending on the type of vehicle. The upper link is shorter than the lower one – irrespective of the springing method used. When the suspension is deflected, the unequal lengths allow the track of the vehicle to be maintained near constant, but with some changes to camber angle.

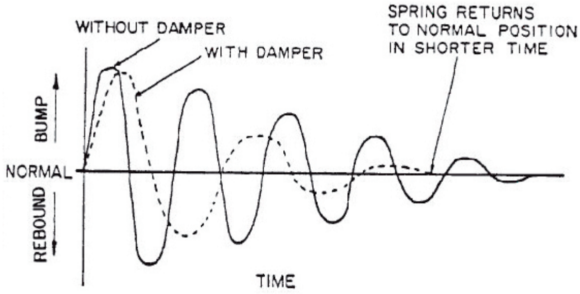
Generally, when the car leans during cornering, the inner wheel leans outwards at the top and the outer wheel leans inwards. This helps to maintain maximum tyre contact with the road surface.

5.0 Tubular Hydraulic Dampers/ Shock Absorbers

Key Learning Points

- Shock absorbers/dampers; dissipate energy out of the suspension system, conventional and gas-charged, maintain wheel in contact with the road, help directional stability etc.

5.1 Damper Action



Spring oscillation curves

When the wheel strikes a bump, energy is given to the spring, which is deflected. When the bump is passed, rebound or release of the stored energy will take place and will carry the spring past the normal position to set up an oscillating motion. This action is similar to the movement of a pendulum. A freely suspended pendulum will oscillate for a considerable time after being struck. In order to give a comfortable ride, some device must be fitted to absorb the energy stored in the spring and so reduce the number of oscillations occurring between the initial bump and the return of the spring to the rest position. This is the duty performed by the damper, also called shock absorber.

5.2 Hydraulic Shock Absorbers

The most widely-used hydraulic shock absorber is the direct-acting telescopic type. It can be fitted as a self-contained unit, or combined with a suspension strut. The strut type uses the same principle of operation but it is considerably larger. The hydraulic shock absorber provides its dampening action by transferring oil, under pressure, through valves which restrict the oil flow.

The twin-tube type is the most common. The outer tube is normally attached to the suspension member at its base and the inner tube provides a working cylinder for a piston which is attached to a piston rod. The piston rod is connected to the frame at its outer end and a bearing at the top of the outer tube keeps the rod in alignment as it moves in and out of the shock absorber, with suspension action.

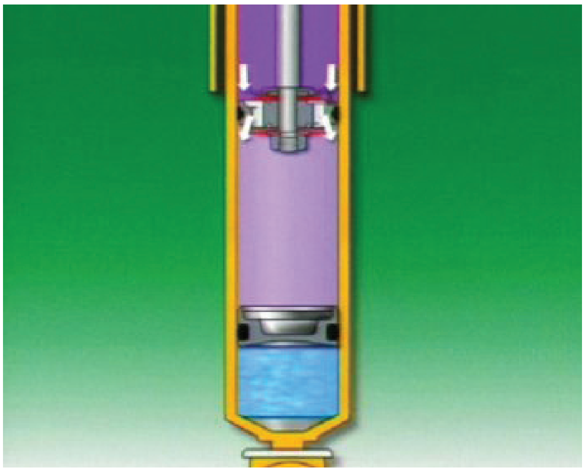
A seal above the bearing prevents oil leakage. It also keeps out dirt and moisture. A shroud protects the rod from damage. During bumps, or compression, the rod and its piston move into the shock absorber. In rebound, or extension, the rod and piston move out of the shock absorber.

For dampening to be effective, resistance is needed in both directions. This is provided by the oil and by disc valves attached to the piston and the base of the inner tube. Oil fills the inner tube and surrounds its outer surface to a level which allows a free space or reservoir to exist above it, between the inner and outer tubes.

5.3 Gas-Pressurised Shock Absorbers

In a hydraulic shock absorber, the oil heats up as the energy of motion of the suspension is dampened. The rapid piston movement as the vehicle moves over the road causes the hydraulic fluid to aerate. This reduces the dampening effect and the shock absorber's performance very quickly deteriorates. This condition is called shock absorber Dissolve. It can be reduced substantially by pressurizing the fluid with gas, usually nitrogen.

In this mono-tube design, fluid fills the chambers above and below the piston. As the piston moves in the cylinder, valves control the movement of oil from one chamber to the other. Pressure on the oil is provided by nitrogen gas at the base of the cylinder, acting on a free-floating separation piston which separates the gas from the oil.



On bump, the piston moves downwards and the penetration of the piston rod displaces a quantity of oil equal to its volume. The separation piston is displaced accordingly and gas pressure increases. On rebound, the piston and rod move upwards and gas pressure reduces as the separation piston follows the movement. Pressure on the oil is maintained, even when the piston and rod are at the top of their stroke.

Disposal of gas pressurised shocks, like all other used units must be disposed in accordance with current law and legislation.

6.0 The Damping Action of Individual Shock Absorbers

Key Learning Points

- Shock absorbers checked for leaks, knocks etc. and Rebound action evaluated to manufacturer's recommendations

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 Work Flow Charts on Suspension Systems

Key Learning Points

- Work flow chart describes the dismantling and reassembly procedures of the prescribed task in a safe, technically logical and correct order

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 Component Servicing

Key Learning Points

- Location, review and recording with the use of, relevant manufacturer's cited terminology and recommended task procedure on suspension/steering assemblies/components
- Dismantling and reassembling to manufacturer's recommended procedures e.g. correct tools, support and care of drives, seals, gaiters etc., torqueing-tightening locking procedures, height adjustment not disturbed. N.B. for safety reasons, do not dismantle McPherson strut units

Practical Task

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

9.0 NCT/DoT VTM Regulations

Key Learning Points

- NCT/DoT VTM regulations for Bodywork and Chassis/ Underbody systems

9.1 NCT Requirements

Please refer to item 42 to 46 and 48 of NCT manual 2004.

10.0 Diagnosing Chassis/ Suspension Components

Key Learning Points

- Examination of Bodywork Chassis/Underbody to NCT/ DoT VTM/ manufacturer's recommended procedures, Primary and Secondary Structures for corrosion/alterations, diagnosis of excessive wear in suspension/ball- joints/ bushes

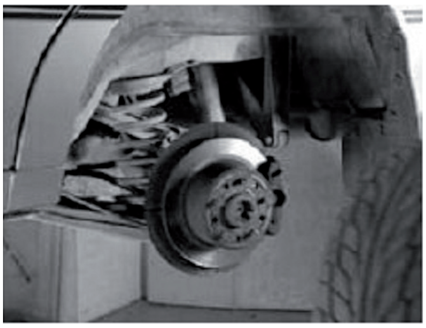
Practical Task

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

10.1 Checking Coil Spring

Note: Design a Work flow chart that describes the dismantling and reassembly procedures for major suspension system components/units (McPherson strut, coil springs, track control wishbone/arms etc.) and to manufacturer recommended procedures.

1. Check coil spring



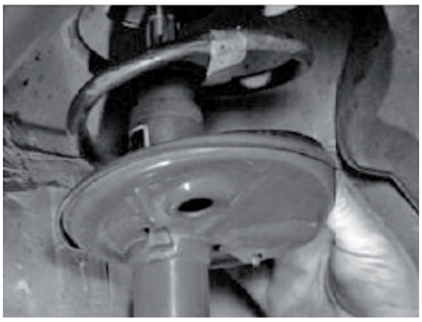
Remove the tyre and wheel assembly to gain better working access.

Check the coils for any signs of cracks or fatigue, such as nicks or scores on any of the coils

Also check the insulating block between the top of the spring and the vehicle body for signs of splitting and chaffing. Any deterioration should be reported.

2. Check McPherson strut upper mounting point

Check the upper mounting point of the McPherson strut for tightness.



Ensure the spring insulator is in position.

3. Check leaf spring

Check the condition of the bushes or mountings and spring shackles.

You can check these by putting a lever in between them and levering against the spring.

4. Check the suspension to body mountings

Inspect the bushes or rubber mountings for any signs of deterioration, swelling or crushing.

Check the tightness of the bolts. Report any loose mounting bolts or retainers to your supervisor. These joints can also be a source of body noise that can be difficult to diagnose.

5. Check the vehicle height

Replace the wheels and lower the vehicle.

Check that the tyre air pressures are correct

Check the vehicle height (continued)

and then measure from the bottom of each wheel rim to the centre of each wheel arch or opening.

Record your readings.

After you have completed measuring both sides and front to rear, compare the readings to the manufacturers specifications.

If there are any differences in height, you will need to consult the shop manual for the allowable tolerances.

Any major differences in the readings could indicate that the suspension springs are worn and have sagged. Report the findings to your supervisor.

Self Assessment

Q1: A rear suspension 'dead' axle in a front-wheel drive vehicle: (Tick one box only)

- ❑ 1. Supports the vehicle and assists in transmitting the drive
- ❑ 2. Only supports the vehicle
- ❑ 3. Is an independent suspension assembly

Q2: A rear suspension U-bolt: (Tick one box only)

- ❑ 1. Adjusts the spring tension
- ❑ 2. Clamps the leaf spring to the chassis
- ❑ 3. Separates each leaf of the spring
- ❑ 4. Clamps the leaf spring to the axle housing

Q3: The longest spring leaf in a spring pack is normally referred to as the: (Tick one box only)

- ❑ 1. Support leaf
- ❑ 2. Main leaf
- ❑ 3. Integral Leaf
- ❑ 4. Primary leaf

Q4: The spring rate of a torsion bar suspension is dependent on: (Tick one box only)

- ❑ 1. Length of the bar
- ❑ 2. The location of the mounting brackets
- ❑ 3. Size or diameter of the bar
- ❑ 4. The length and diameter or size of the bar

Q5: The forces that cause a wheel and tire to bounce are created by the: (Tick one box only)

- ❑ 1. Suspension movement
- ❑ 2. Strut assembly
- ❑ 3. Shock absorber

Q6: The gas used in many gas-pressurised shock absorbers is: (Tick one box only)

- ❑ 1. Hydrogen gas
- ❑ 2. Inert gas
- ❑ 3. Compressed gas
- ❑ 4. Nitrogen gas

Q7: The coils must always be evenly spaced in a coil spring suspension. (Tick one box only)

- ❑ 1. True
- ❑ 2. False

Q8: A shock absorber that can be adjusted for dampening effect is called: (Tick one box only)

- ❑ 1. Adjustable-rate
- ❑ 2. Constant rate
- ❑ 3. Gas-pressurized
- ❑ 4. Air-adjustable

Q9: A coil spring in which the wire diameter decreases towards the end is a: (Tick one box only)

- ❑ 1. Controlled rate spring
- ❑ 2. Adjustable rate spring
- ❑ 3. Progressive rate spring
- ❑ 4. Constant rate spring

Q10: The centre bolt on leaf springs can be used to: (Tick one box only)

- ❑ 1. Clamp the spring to the axle
- ❑ 2. Ensure all leaves carry the same load
- ❑ 3. Maintain leaf alignment
- ❑ 4. Locate the axle relative to the spring

Q11: A torsion bar used as a suspension spring, provides its springing action by: (Tick one box only)

❑ 1. Twisting around its centre

❑ 2. An integrated shock absorber

❑ 3. Changing its length

❑ 4. Transferring load to the opposite wheel

Q12: The purpose of the complete suspension system is to isolate the vehicle body from: (Tick one box only)

❑ 1. Vibrations

❑ 2. Road shocks

❑ 3. Road shocks and vibration

❑ 4. The road

Q13: The stiffness of a coil spring can be increased by: (Tick one box only)

❑ 1. Stretching the spring

❑ 2. Reducing the diameter of the wire

❑ 3. Reducing the weight of the spring

❑ 4. Increasing the diameter of the wire

Q14: A standard hydraulic shock absorber is designed to: (Tick one box only)

❑ 1. Permit use of coil springs instead of leaf springs

❑ 2. Improve rigidity of spring mountings

❑ 3. Dampen spring oscillations

❑ 4. Support part of vehicle mass

Q15: The sprung mass of a vehicle refers to: (Tick one box only)

❑ 1. The mass of the suspension

❑ 2. The mass supported by the springs

❑ 3. The mass of the wheel and brake assemblies

❑ 4. The mass of the springs

Q16: Some vehicles have rubber springs attached to their coil spring suspensions. What is the purpose of the rubber springs? (Tick one box only)

- ❑ 1. To further increase the load ratings of colour coded coil springs
- ❑ 2. To prevent metal-to-metal contact of the suspension parts when the coil springs are compressed
- ❑ 3. To stop suspension noises being transferred to the driver via the chassis composition

Suggested Exercises

1. Use an electronic data facility to procure manufacturer's appropriate data for use with practical exercises
2. Remove, refit/replace the major suspension system components/units (McPherson strut, coil springs, track control wishbone/arms etc.) using manufacturer recommended procedures
3. Remove, refit/replace ball joints
4. Have experience/exposure to the use of dedicated automotive suspension/steering system test equipment and procedures, NCT/DoT VTM regulations

Training Resources

- Technical information in book/electronic form on automotive suspension systems, the basic technical design and structure of the most common variants
- Training vehicles/units with relevant manufacturer's data on procedures/settings of suspension/steering systems for practical exercises
- Suitable automotive workshop facilities/lifts etc., special tools e.g. coil spring compressors, taper joint breakers etc.
- Access to suspension/steering test equipment, NCT/DoT VTM test regulations and procedures

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