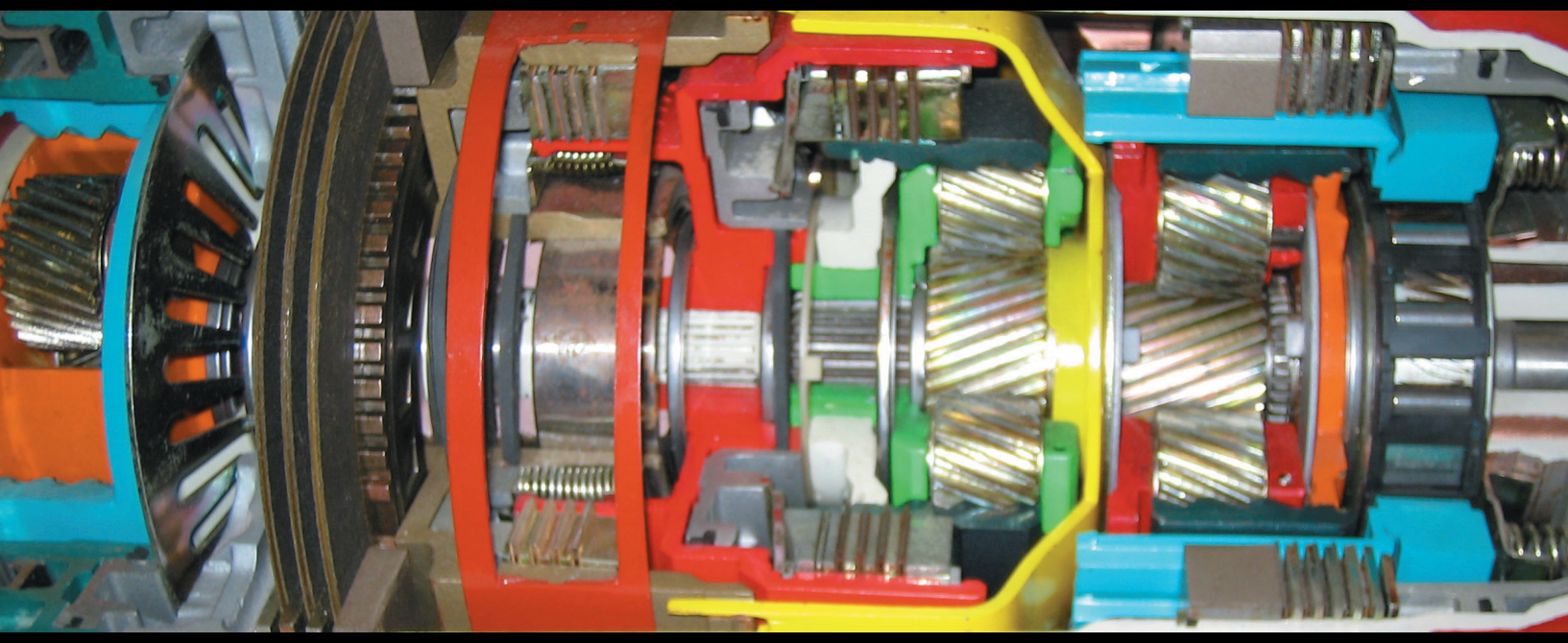
Automatic Transmissions and Transaxles

Seventh Edition

James D. Halderman



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SEVENTH EDITION

James D. Halderman

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PREFACE

PROFESSIONAL TECHNICIAN SERIES Part of the Pearson Automotive Professional Technician Series, the seventh edition of *Automatic Transmissions and Transaxles* represents the future of automotive textbooks. The series is a full-color, media-integrated solution for today's students and instructors. The series includes textbooks that cover all eight areas of ASE certification, plus additional titles covering common courses. The series is peer reviewed for technical accuracy.

UPDATES TO THE SEVENTH EDITION Based on conversations and recommendations from automotive instructors and reviewers, the following updates have been incorporated in the new seventh edition:

1. Automatic transmission/transaxle hydraulic systems has been greatly expanded and then split in to three chapters to make teaching and learning hydraulic systems easier:
   - **Automatic Transmission Fluid, Filters And Coolers**—Chapter 2
   - **Automatic Transmission/Transaxle Hydraulic System**—Chapter 3
   - **Hydraulic Control Valves And Solenoids**—Chapter 4
2. Updated throughout to match the latest ASE/NATEF tasks.
3. Over 50 new full color line drawings and photos make the subject come alive.
4. Case studies added to selected chapters that include the "three Cs" (Complaint, Cause and Correction).
5. Global electrical symbols added to Chapter 8.
6. All systems and components are described throughout with the following format to make learning complex systems easier:
   - Purpose and Function
   - Parts and Operation
   - Diagnosis and Service
7. All terms used adhere to the SAE J1930 standard.
8. Unlike other textbooks, this book is written so that the theory, construction, diagnosis, and service of a particular component or system is presented in one location. There is no need to search through the entire book for other references to the same topic.

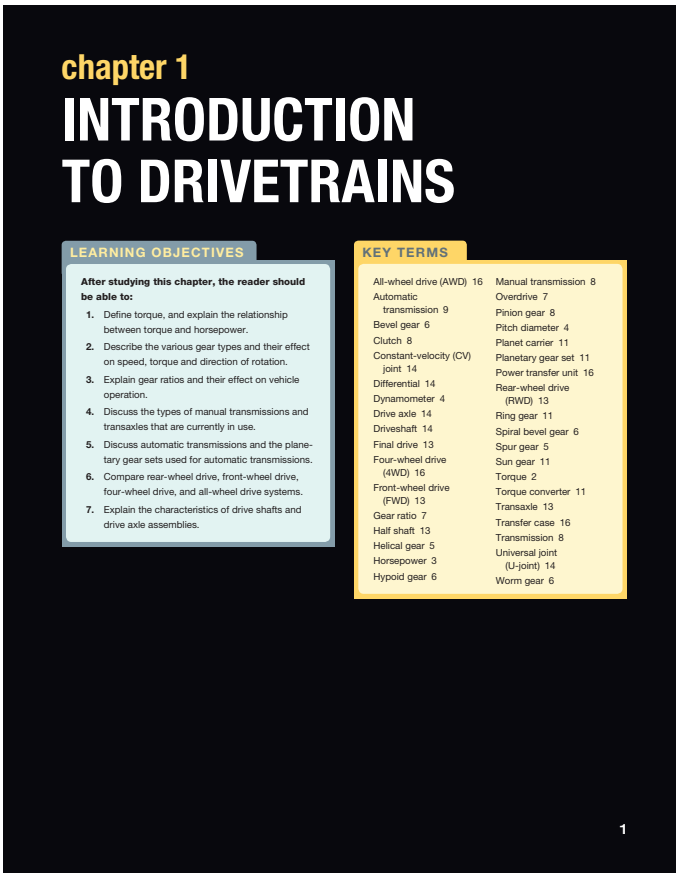
ASE AND NATEF CORRELATED NATEF-certified programs need to demonstrate that they use course material that covers NATEF and ASE tasks. All Professional Technician textbooks have been correlated to the appropriate ASE and NATEF task lists. These correlations can be found in the appendix.

A COMPLETE INSTRUCTOR AND STUDENT SUPPLEMENTS PACKAGE All Professional Technician textbooks are accompanied by a full set of instructor and student supplements. Please see page vi for a detailed list of supplements.

A FOCUS ON DIAGNOSIS AND PROBLEM SOLVING The Professional Technician Series has been developed to satisfy the need for a greater emphasis on problem diagnosis. Automotive instructors and service managers agree that students and beginning technicians need more training in diagnostic procedures and skill development. To meet this need and demonstrate how real-world problems are solved, "Real World Fix" features are included throughout and highlight how real-life problems are diagnosed and repaired.

The following pages highlight the unique core features that set the Professional Technician Series book apart from other automotive textbooks.

IN-TEXT FEATURES



chapter 1

INTRODUCTION TO DRIVETRAINS

LEARNING OBJECTIVES

After studying this chapter, the reader should be able to:

1. Define torque, and explain the relationship between torque and horsepower.
2. Describe the various gear types and their effect on speed, torque and direction of rotation.
3. Explain gear ratios and their effect on vehicle operation.
4. Discuss the types of manual transmissions and transaxles that are currently in use.
5. Discuss automatic transmissions and the planetary gear sets used for automatic transmissions.
6. Compare rear-wheel drive, front-wheel drive, four-wheel drive, and all-wheel drive systems.
7. Explain the characteristics of drive shafts and drive axle assemblies.

KEY TERMS

All-wheel drive (AWD) 16
Automatic transmission 9
Bevel gear 6
Clutch 8
Constant-velocity (CV) joint 14
Differential 14
Dynamometer 4
Drive axle 14
Driveshaft 14
Final drive 13
Four-wheel drive (4WD) 16
Front-wheel drive (FWD) 13
Gear ratio 7
Half shaft 13
Helical gear 5
Horsepower 3
Hypoid gear 6
Manual transmission 8
Overdrive 7
Pinion gear 8
Pitch diameter 4
Planet carrier 11
Planetary gear set 11
Power transfer unit 16
Rear-wheel drive (RWD) 13
Ring gear 11
Spiral bevel gear 6
Spur gear 5
Sun gear 11
Torque 2
Torque converter 11
Transaxle 13
Transfer case 16
Transmission 8
Universal joint (U-joint) 14
Worm gear 6

1

LEARNING OBJECTIVES AND KEY TERMS appear at the beginning of each chapter to help students and instructors focus on the most important material in each chapter. The chapter objectives are based on specific ASE and NATEF tasks.

TECH TIP

Solenoids Are Wear Items

Many technicians consider solenoids, especially PWM solenoids, to be "wear items" and automatically replace them if the transmission experiences problems after about 90,000 miles (150,000 km).

TECH TIPS feature real-world advice and "tricks of the trade" from ASE-certified master technicians.

Case Study

TSB to the Rescue

A Dodge Durango came in to the shop with a customer complaint of delayed engagement into reverse after sitting for a while. A check of a TSB (21-016-05) described filters with defective check valves. Replacement of the filter cured this problem.

SUMMARY:

Complaint—Customer complained of a delayed engagement into reverse after the vehicle sat for a while.

Cause—The original filter had a defective check valve.

Correction—A replacement filter fixed the concern.

CASE STUDY present students with actual automotive scenarios and show how these common (and sometimes uncommon) problems were diagnosed and repaired.

FREQUENTLY ASKED QUESTION

Is It Lb-Ft or Ft-Lb of Torque?

The unit for torque is expressed as a force times the distance (leverage) from the object. Therefore, the official unit for torque is lb-ft (pound-feet) or Newton-meters (a force times a distance). However, it is commonly expressed in ft-lb and most torque wrenches are labeled with this unit.

FREQUENTLY ASKED QUESTIONS are based on the author's own experience and provide answers to many of the most common questions asked by students and beginning service technicians.

NOTE: Most of these "locking nuts" are grouped together and are commonly referred to as *prevailing torque nuts*. This means that the nut will hold its tightness or torque and not loosen with movement or vibration.

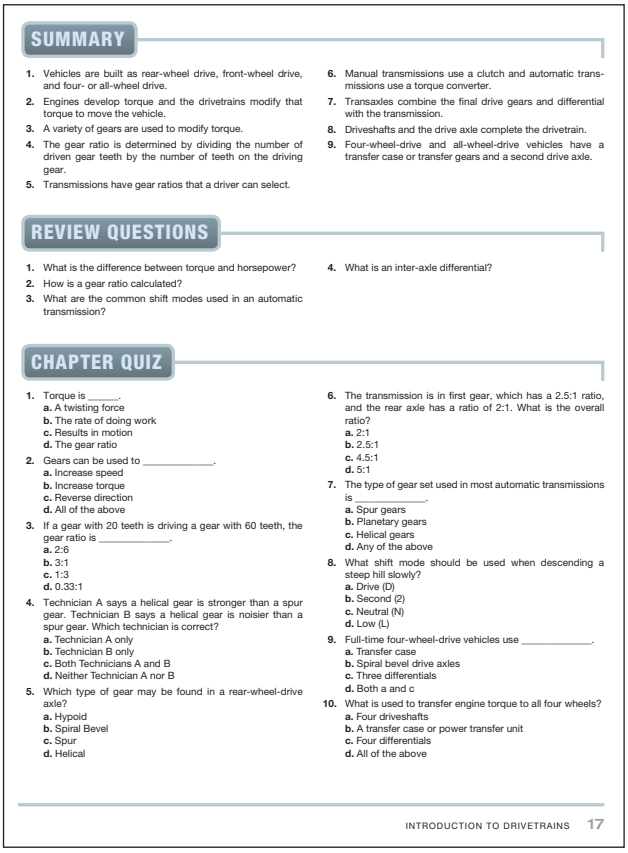
NOTES provide students with additional technical information to give them a greater understanding of a specific task or procedure.

CAUTION: Do not perform this quick check on a PWM solenoid because the lower coil resistance will allow excessive current flow that can damage the solenoid.

CAUTIONS alert students about potential damage to the vehicle that can occur during a specific task or service procedure.

WARNING

Use caution during servo cover removal because some servos use a strong piston spring. These require a special tool to hold the spring compressed during retainer ring removal and then allow the spring to be safely extended.



SUMMARY

1. Vehicles are built as rear-wheel drive, front-wheel drive, and four- or all-wheel drive.
2. Engines develop torque and the drivetrains modify that torque to move the vehicle.
3. A variety of gears are used to modify torque.
4. The gear ratio is determined by dividing the number of driven gear teeth by the number of teeth on the driving gear.
5. Transmissions have gear ratios that a driver can select.
6. Manual transmissions use a clutch and automatic transmissions use a torque converter.
7. Transaxles combine the final drive gears and differential with the transmission.
8. Driveshafts and the drive axle complete the drivetrain.
9. Four-wheel-drive and all-wheel-drive vehicles have a transfer case or transfer gears and a second drive axle.

REVIEW QUESTIONS

1. What is the difference between torque and horsepower?
2. How is a gear ratio calculated?
3. What are the common shift modes used in an automatic transmission?
4. What is an inter-axle differential?

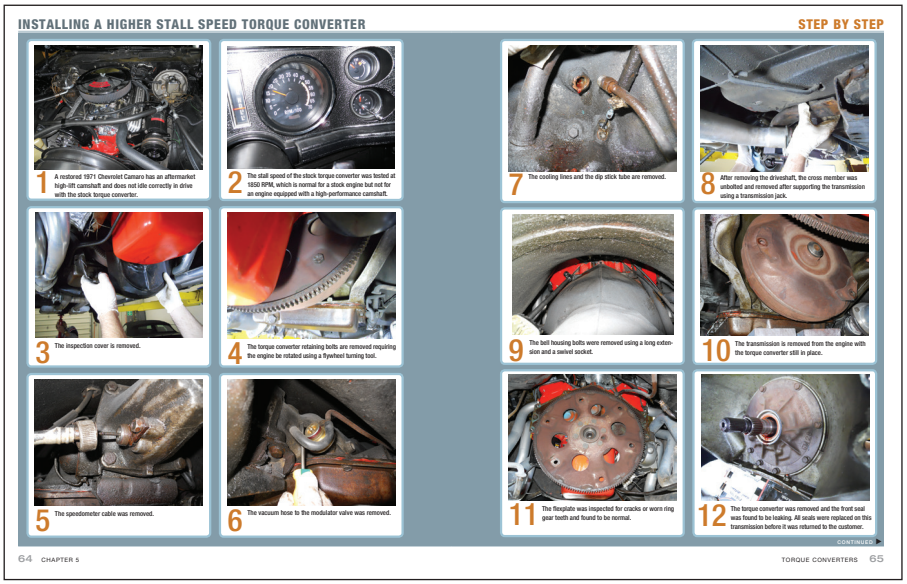
CHAPTER QUIZ

1. Torque is _____.
   a. A twisting force
   b. The rate of doing work
   c. Results in motion
   d. The gear ratio
2. Gears can be used to _____.
   a. Increase speed
   b. Increase torque
   c. Reverse direction
   d. All of the above
3. If a gear with 20 teeth is driving a gear with 60 teeth, the gear ratio is _____.
   a. 2:6
   b. 3:1
   c. 1:3
   d. 0.33:1
4. Technician A says a helical gear is stronger than a spur gear. Technician B says a helical gear is noisier than a spur gear. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B
5. Which type of gear may be found in a rear-wheel-drive axle?
   a. Hypoid
   b. Spiral Bevel
   c. Spur
   d. Helical
6. The transmission is in first gear, which has a 2.5:1 ratio, and the rear axle has a ratio of 2:1. What is the overall ratio?
   a. 2:1
   b. 2.5:1
   c. 4.5:1
   d. 5:1
7. The type of gear set used in most automatic transmissions is _____.
   a. Spur gears
   b. Planetary gears
   c. Helical gears
   d. Any of the above
8. What shift mode should be used when descending a steep hill slowly?
   a. Drive (D)
   b. Second (2)
   c. Neutral (N)
   d. Low (L)
9. Full-time four-wheel-drive vehicles use _____.
   a. Transfer case
   b. Spiral bevel drive axles
   c. Three differentials
   d. Both a and c
10. What is used to transfer engine torque to all four wheels?
    a. Four driveshafts
    b. A transfer case or power transfer unit
    c. Four differentials
    d. All of the above

INTRODUCTION TO DRIVETRAINS 17

WARNINGS alert students to potential dangers to themselves during a specific task or service procedure.

THE SUMMARY, REVIEW QUESTIONS, AND CHAPTER QUIZ at the end of each chapter help students review the material presented in the chapter and test themselves to see how much they've learned.



STEP-BY-STEP photo sequences show in detail the steps involved in performing a specific task or service procedure.

SUPPLEMENTS

RESOURCES IN PRINT AND ONLINE

Automatic Transmissions and Transaxles

Name of Supplement	Print	Online	Audience	Description
Instructor Resource Manual 0-13-460626-4		✔	Instructors	NEW! The ultimate teaching aid: Chapter summaries, key terms, chapter learning objectives, lecture resources, discuss/ demonstrate classroom activities, and answers to the in-text review and quiz questions.
TestGen 0-13-461684-7		✔	Instructors	Test generation software and test bank for the text.
PowerPoint Presentation 0-13-461687-1		✔	Instructors	Slides include chapter learning objectives, lecture outline of the test, and graphics from the book.
Image Bank 0-13-461688-X		✔	Instructors	All of the images and graphs from the text-book to create customized lecture slides.
NATEF Correlated Task Sheets— for Instructors 0-13-460625-6		✔	Instructors	Downloadable NATEF task sheets for easy customization and development of unique task sheets.
NATEF Task Sheets— for Students 0-13-461692-8	✔		Students	Study activity manual that correlates NATEF Automobile Standards to chapters and page numbers in the text. Available to students at a discounted price when packaged with the text.
VitalSource eBook 0-13-461685-5		✔	Students	An alternative to purchasing the print text-book, students can subscribe to the same content online and save up to 50% off the suggested list price of the print text. Visit **www.vitalsource.com**

All online resources can be downloaded from the Instructor's Resource Center: **www.pearsonighered.com/irc**

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A-1 Automatic Transmissions
Aceomatic Recon
AFM, Raytech Automotive Components Comp.
Alto Products Corp.
American Honda Motor Company
ATEC Trans-Tool and Cleaning Systems
Autotrans
AxiLine, Hicklin Engineering
BorgWarner, Morse TEC
Carl Borsani, Graphic Home
Tom Broxholm, Skyline College
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Chrysler Corporation
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KD Tools
Kent-Moore, SPX Corporation
Life Automotive Products
Dennis Madden, ATRA
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Pennzoil-Quaker State Company.
Raybestos Aftermarket Products Co.
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ZF Group North American Operations

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James D. Halderman

ABOUT THE AUTHOR

JAMES D. HALDERMAN Jim Halderman brings a world of experience, knowledge, and talent to his work. His automotive service experience includes working as a flat-rate technician, a business owner, and a professor of automotive technology at a leading U.S. community college for more than 20 years.

He has a Bachelor of Science degree from Ohio Northern University and a Master's degree in Education from Miami University in Oxford, Ohio. Jim also holds a U.S. patent for an electronic transmission control device. He is an ASE-certified Master Automotive Technician and is also Advanced Engine Performance (L1) ASE certified. Jim is the author of many automotive textbooks all published by Pearson. He has presented numerous technical seminars to national audiences, including the California Automotive Teachers (CAT) and the Illinois College Automotive Instructor Association (ICAIA). He is also a member and presenter at the North American Council of Automotive Teachers (NACAT). Jim was also named Regional Teacher of the Year by General Motors Corporation and a member of the advisory board for Technological Studies department at Ohio Northern University. Jim and his wife, Michelle, live in Dayton, Ohio. They have two children. You can reach Jim at:

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BRIEF CONTENTS

CONTENTS

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chapter 1

INTRODUCTION TO DRIVETRAINS

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KEY TERMS

DRIVETRAINS

PURPOSE AND FUNCTION The purpose of a vehicle drivetrain is to transfer power from the engine to the drive wheels. The drivetrain, also called a powertrain, serves the following functions:

- It allows the driver to control the power flow.
- It multiplies the engine torque.
- It controls the engine speed.

TORQUE

DEFINITION **Torque** is a rotating or twisting force that may or may not result in motion. A vehicle moves because of the torque the drive axle exerts on the wheels and tires to make them rotate. Being a form of mechanical energy, torque cannot be created or destroyed—it is converted from one form of energy to another form of energy.

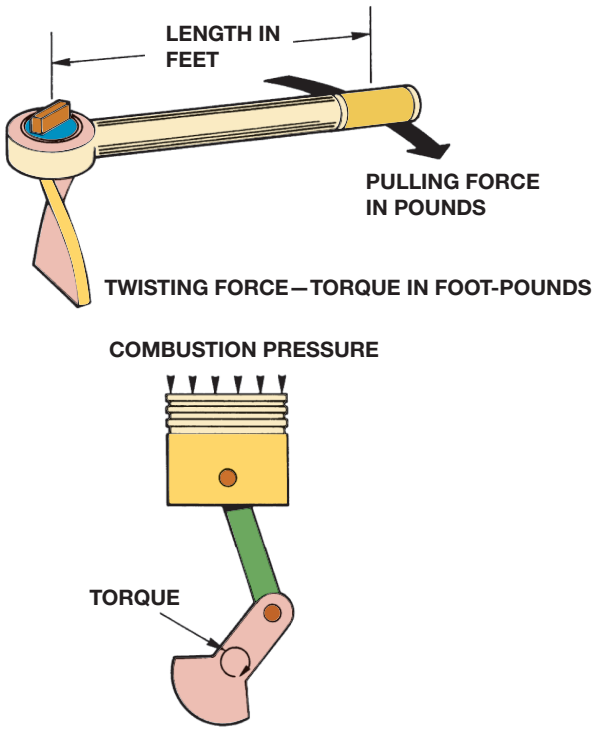


FIGURE 1–1 Torque, a twisting force, is produced when you pull on a wrench. An engine produces torque at the crankshaft as combustion pressure pushes the piston downward.

FREQUENTLY ASKED QUESTION

Is It Lb-Ft or Ft-Lb of Torque?

The unit for torque is expressed as a force times the distance (leverage) from the object. Therefore, the official unit for torque is lb-ft (pound-feet) or Newton-meters (a force times a distance). However, it is commonly expressed in ft-lb and most torque wrenches are labeled with this unit.

UNITS OF TORQUE Engine torque is developed when combustion pressure pushes a piston downward to rotate the crankshaft. ● **SEE FIGURE 1–1.**

The amount of torque produced will vary depending on the size and design of the engine and the throttle opening. Torque is measured in pounds-feet (lb-ft) or Newton-meters (N-m). One Newton-meter of torque is equal to 0.737 lb-ft. A factor that greatly affects drivetrain design is that very little or no torque is developed at engine speeds below 1000 RPM (revolutions per minute). An engine begins producing usable torque at about 1200 RPM and peak torque at about 2500 to 4000 RPM, with an upper usable speed limit of 5000 to 7000 RPM. The gear ratios in the transmission and drive axle are used to match the engine speed and torque output to the vehicle speed and torque requirements. ● **SEE FIGURE 1–2.**

DRIVE VS. DRIVEN GEARS The *drive* gear is the gear that is the source of the engine torque and rotation. The *driven* gear is the gear that is driven or rotated by the drive gear. Two gears meshed together are used to transmit torque and rotational motion. The driven gear can then rotate yet another gear. In this case, the second gear becomes the drive gear and the third gear is the driven gear.

TORQUE MULTIPLICATION The gear teeth are cut proportional to the diameter of the gear. If one of two mating gears was twice as large as the other, it would have twice as many teeth. For example, if the smaller gear has 10 teeth, a gear twice as large will have 20 teeth. If the teeth of these gears are intermeshed, 10 teeth of each gear will come into contact when the smaller gear rotates one revolution. This will require one revolution of the small gear and one-half revolution of the larger gear. It will take two revolutions of the small gear to produce one revolution of the larger gear. This is a gear ratio of 2:1, assuming that the small gear is the drive gear. To determine a gear ratio, divide the driven gear by the driving gear. ● **SEE FIGURE 1–3.**

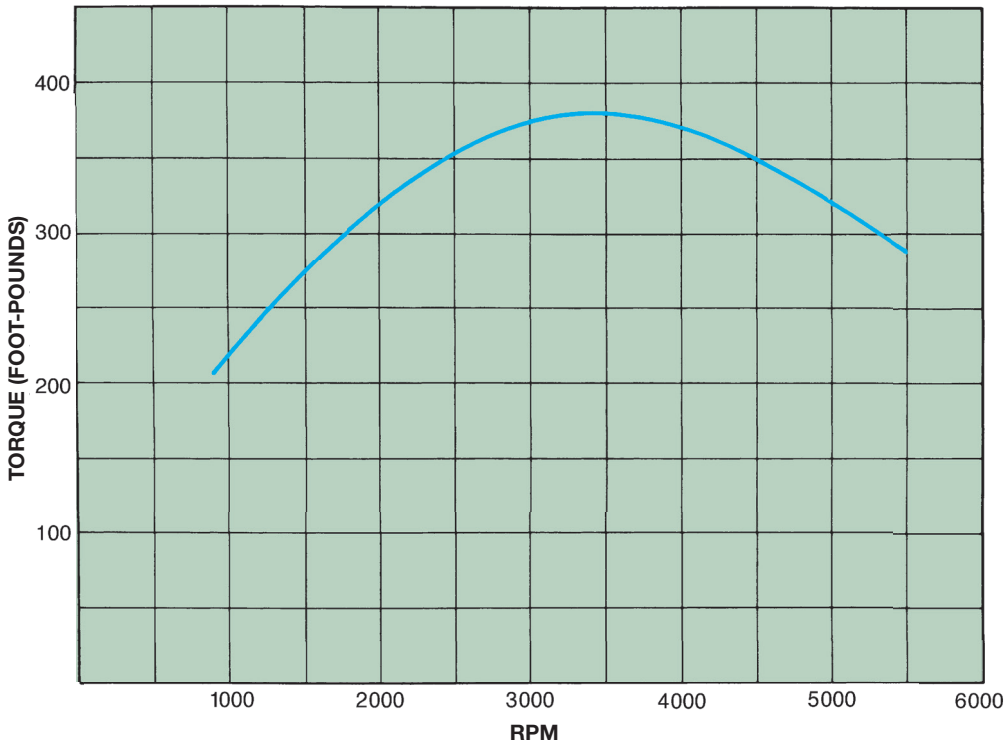


FIGURE 1–2 The torque produced by a 5.7 L engine as plotted on a graph. Note that the engine begins producing usable torque at 1000 to 1200 RPM and a maximum torque (381 ft-lb) at 3500 RPM. The torque produced by the engine decreases at higher RPM due to a decrease in volumetric efficiency.

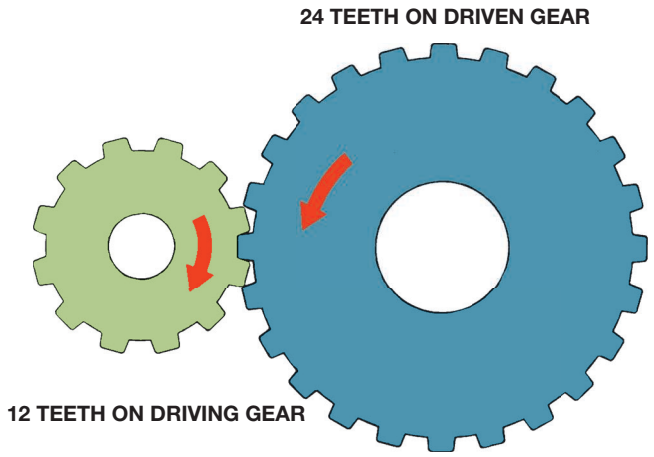


FIGURE 1–3 Gear ratio is determined by dividing the number of teeth of the driven (output) gear (24 teeth) by the number of teeth on the driving (input) gear (12 teeth). The ratio illustrated is 2:1.

GEARS ARE LEVERS Torque is increased because of the length of the gear lever, as measured from the center of the gear. Think of each tooth as a lever, with the fulcrum being the center of the gear. The lever lengths of the two gears can provide leverage much like that of a simple lever. Physics does not allow energy to become lost in a gear set, other than what is lost as heat in overcoming friction. Therefore, whatever power that comes in one shaft, goes out through another.

- If the speed is reduced, torque will increase by the same amount.
- If speed is increased, torque will decrease by the same amount.

For example, if the driving gear has 20 lb-ft (27 N-m) of torque at 500 RPM and the ratio is 2:1, the driven gear will have 40 lb-ft (54 N-m) of torque (twice as much) at 250 RPM (half the speed).

HORSEPOWER

DEFINITION The term power means the rate of doing work. Power equals work divided by time.

- Work is done when a certain amount of mass (weight) is moved a certain distance by a force. Whether the object is moved in 10 seconds or 10 minutes does not make a difference in the amount of work accomplished, but it does affect the amount of power needed. ● **SEE FIGURE 1–4.**
- Power is expressed in units of foot-pounds per minute. One **horsepower** is the power required to move 550 pounds one foot in one second, or 33,000 pounds one foot in one minute (550 lb × 60 sec = 33,000 lb). This

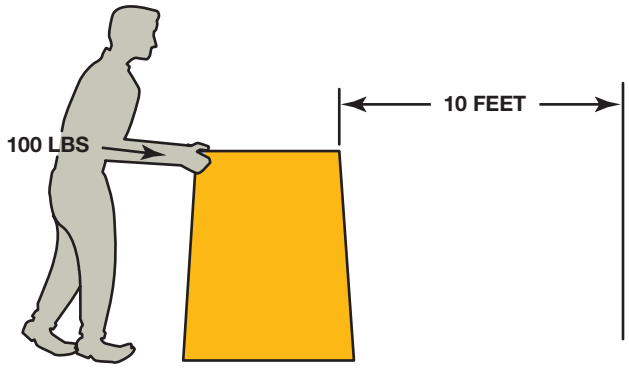


FIGURE 1–4 Work is calculated by multiplying force times distance. If you push 100 pounds 10 feet, you have done 1,000 foot-pounds of work.

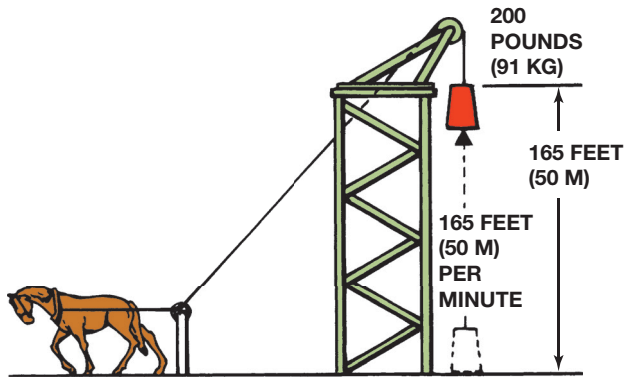


FIGURE 1–5 One horsepower is equal to 33,000 foot-pounds (200 lbs × 165 ft) of work per minute.

is expressed as 550 foot-pounds (ft-lb) per second or 33,000 foot-pounds per minute. ● **SEE FIGURE 1–5.**

HORSEPOWER AND TORQUE RELATIONSHIP To determine horsepower, a **dynamometer** is used to measure the amount of torque an engine can produce at various points through its operating range. The formula used to convert torque at a certain revolution per minute (RPM) into a horsepower reading is

Horsepower = Torque × RPM/5,252

NOTE: To determine how the constant "5,252" was derived, perform an Internet search to see an explanation.

The various readings are then plotted into a curve. A typical horsepower and torque curve shows us that an engine does not produce very much torque at low RPM. The most usable torque is produced in the mid-RPM range. Torque decreases with an increase in horsepower at a higher RPM.

The torque from an engine can be increased or decreased through the use of gears, belts, and chains. Gears, belts, or chains cannot increase horsepower; they can only modify its effect. A gear set can increase torque, but it will decrease speed by the same amount.

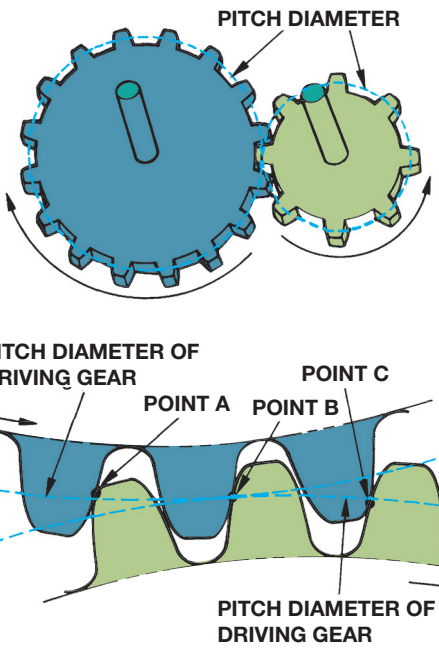


FIGURE 1–6 The pitch diameter is the effective diameter of the gear. Note how the contact points slide on the gear teeth as they move in and out of contact.

TECH TIP

How to Explain the Difference between Horsepower and Torque

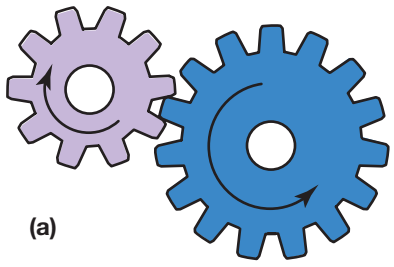
As Carroll Shelby, the well-known racer and business owner, said, "Horsepower sells cars, but torque wins races." Torque determines how fast the vehicle will accelerate, and horsepower determines how fast the vehicle will go.

GEARS

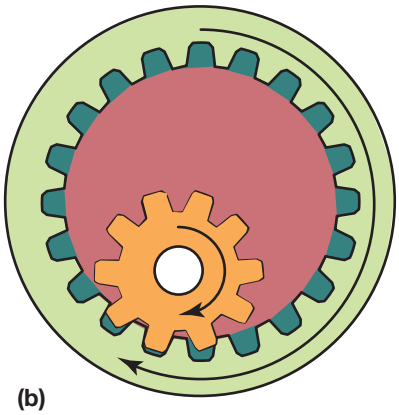
TERMINOLOGY The effective diameter of a gear is the **pitch diameter** (or *pitch line*). ● **SEE FIGURE 1–6.**

The pitch diameter is the diameter of the gear at the point where the teeth of the two gears meet and transfer power. The gear teeth are shaped to be able to slide in and out of mesh with a minimum amount of friction and wear. Major points include:

- Driven and driving gears will rotate in opposite directions.

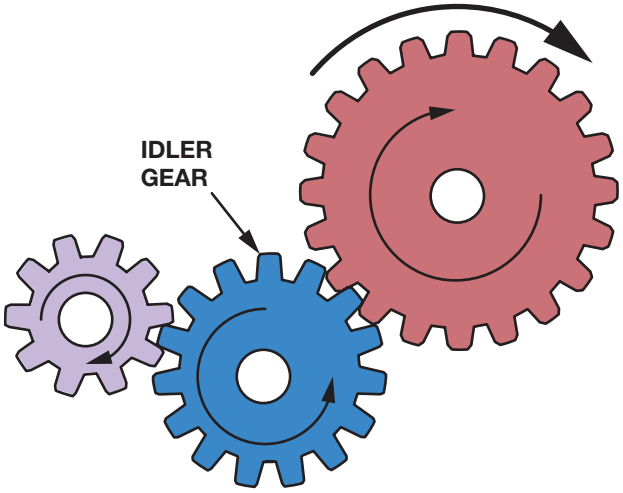


EXTERNAL GEARS



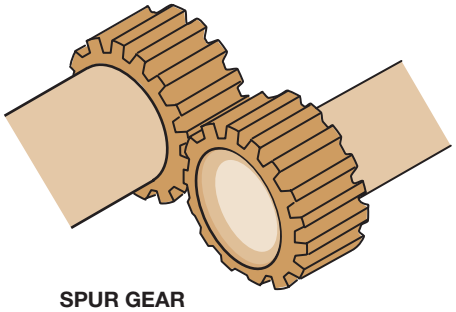
INTERNAL AND EXTERNAL GEARS

FIGURE 1–7 (a) When one external gear drives another, the direction of rotation is always reversed. (b) When an external gear drives an internal gear, the two gears will rotate in the same direction.



EXTERNAL GEARS

FIGURE 1–8 An idler gear reverses the direction of rotation so that the driving and driven gears rotate in the same direction.



SPUR GEAR

FIGURE 1–9 The teeth of a spur gear are cut parallel to the shaft, and this produces a straight pressure between the driving and the driven gear teeth.

- External gears will always reverse shaft motion.
- If same-direction motion is required, the power will be routed through two gear sets.
- When power goes through a series of gears, an even number of gears (2, 4, 6, and 8) will cause a reversal in direction and an odd number of gears (3, 5, 7, and 9) will produce same direction of rotation.

  ● **SEE FIGURE 1–7.**

REVERSING DIRECTION OF ROTATION

External gears reverse the direction of rotation when the drive gear transfers power to the driven gear. When it is necessary to change the ratio without changing the direction of power flow, an idler gear is added. An idler gear changes the rotational direction but does not affect the ratio. ● **SEE FIGURE 1–8.**

GEAR TYPES

Gears come in different types depending on the cut and relationship of the teeth to the shafts.

- **Spur gears**—Spur gears, the simplest gears, are on parallel shafts with teeth cut straight or parallel to the shaft. ● **SEE FIGURE 1–9.**
- **Helical gear**—Helical gears are the most used of all gears used in transmissions. These gears have teeth cut in a spiral or helix shape. ● **SEE FIGURE 1–10.**

Helical gears are quieter than spur gears, but generate axial or end thrust under a load. A helical gear is stronger than a comparable-sized spur gear and has an almost continuous power flow because of the angled teeth. ● **SEE FIGURE 1–10.**

NOTE: When discussing gears, a pinion gear is the smaller gear of a pair.

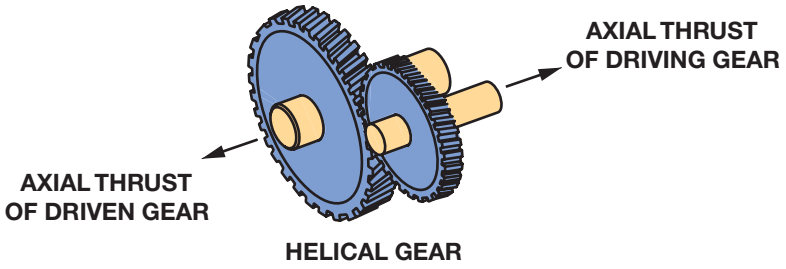


FIGURE 1–10 The teeth of a helical gear are cut on a slant, and this produces an axial or side thrust.

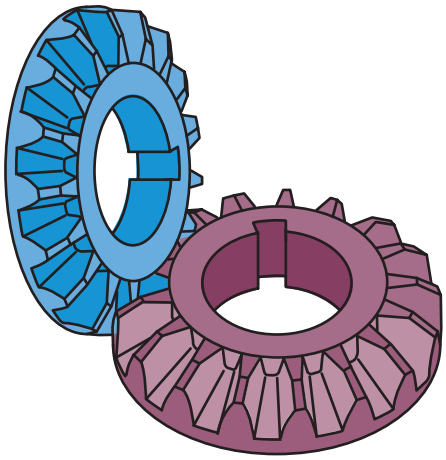


FIGURE 1–11 Bevel gears are commonly used in differentials.

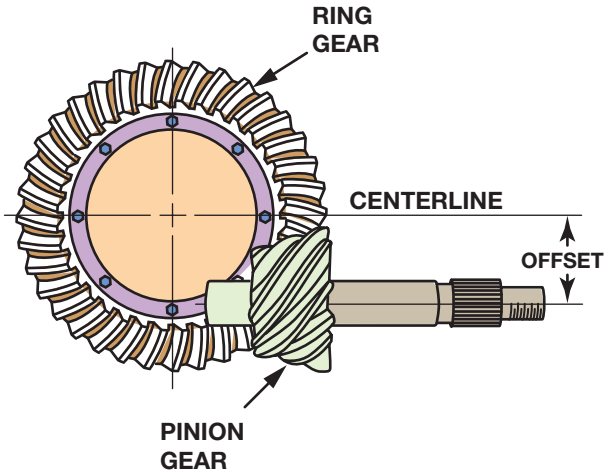


FIGURE 1–12 A hypoid gear set uses a pinion gear that is located below the centerline of the ring gear and is commonly used in drive axles.

- **Bevel gears**—Bevel gears are used on nonparallel shafts. The outer edge of the gear must be cut on the angle that bisects the angle of the two shafts. In other words, if the two shafts meet at an angle of 90° and the two gears are the same size, the outer edge of the gears will be cut at 45°. The simplest bevel gears have teeth cut straight and are called spur bevel gears. They are inexpensive but noisy. ● **SEE FIGURE 1–11.**
- **Spiral bevel gears**—Spiral bevel gears, like helical gears, have curved teeth for quieter operation.
- **Hypoid gear**—A variation of the spiral bevel gear is the hypoid gear, also called an *offset-bevel gear*. Hypoid gears are used in most drive axles and transaxles that have longitudinal mounted engines. The hypoid gear design places the drive pinion gear lower in the housing (below the centerline) of the ring gear and axle shafts. ● **SEE FIGURE 1–12.**
- **Worm gear**—A gear set used with shafts that cross each other but do not intersect is the worm gear. The worm gear or drive pinion is cut in a rather severe helix, much like a bolt thread, and the ring gear or wheel is cut almost like a spur gear. Worm gears are used in vehicle speed sensor drives. To determine the ratio of a worm gear, divide the number of teeth on the wheel by the pitch of the worm gear. For example, a single-pitch worm gear tooth driving a 20-tooth ring gear will have a ratio of 20:1, a very low ratio, and the wheel does not have to be 20 times larger than the worm gear. A 20:1 ratio in most gear sets requires the driven gear to be 20 times larger than the driving gear. ● **SEE FIGURE 1–13.**

? FREQUENTLY ASKED QUESTION

What Is a "Rock Crusher" Transmission?

A manual Muncie (M22) four-speed manual transmission in the muscle car era, was called the *rock crusher* because it used straight cut spur gears.

It was designed as a racing transmission because by using spur gears, the end thrust loads were reduced. However, spur gears are noisy and sounded like rocks being chewed up so therefore, the slang term "rock crusher" for this once popular transmission.

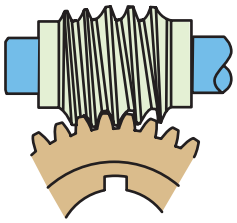


FIGURE 1–13 A worm gear set is also used to transmit power between angled shafts.

GEAR RATIOS

TERMINOLOGY **Gear ratios** are determined by the following methods:

- Dividing the number of teeth on the driven gear (output) by the number of teeth on the driving gear (input). Most of the time, this means dividing a larger number, such as 20, by a smaller number, such as 5. In this case, 20 ÷ 5 = 4, so the ratio will be 4:1.
- Gear ratio = driven gear/drive gear.
- The driving gear will turn four times for each revolution of the driven gear. This results in a speed reduction and a torque increase. The speed of the output will be 4 times slower than the input speed but, the output torque will be four times more than the input torque. The higher the ratio number, the lower the gear ratio. A 5:1 ratio is higher numerically, but, in terms of speed of the driven gear, it is a lower ratio than 4:1. **SEE FIGURE 1–14.**

Most of the time, the ratio will not end up as whole numbers. It will be something like an 11-tooth driving gear and a 19-tooth driven gear, which results in a ratio of 19 divided by 11, which equals 1.7272727 and can be rounded off to 1.73.

COMMONLY USED RATIOS The automotive industry commonly rounds off gear ratios to two decimal points. Drivetrain engineers usually do not use even ratios like 3:1 or 4:1 but instead use ratios that are at least 10 percent greater or less than even numbers. An even ratio, like 3:1, repeats the same gear tooth contacts every third revolution. If there is a damaged tooth, a noise will be repeated continuously, and most drivers will not like the noise. A gear set with a ratio such as 3.23:1 is called a hunting gear set, and a tooth of one gear contacts all of the other gear teeth, which produces quieter operation.

OVERDRIVE If the driving gear has more teeth (20) than the driven gear (5), there will be an increase in speed and a reduction in torque. This is called an **overdrive**. The ratio is computed by dividing 5 by 20, 5 ÷ 20 = 0.25, so the ratio would be expressed as 0.25:1. The driving gear will turn 0.25 or one-fourth of a revolution for each turn of the driven gear. Note that a gear ratio is always written with the number 1 to the right of the colon. This represents one turn of the output gear, while the number to the left represents the revolutions of the input gear.

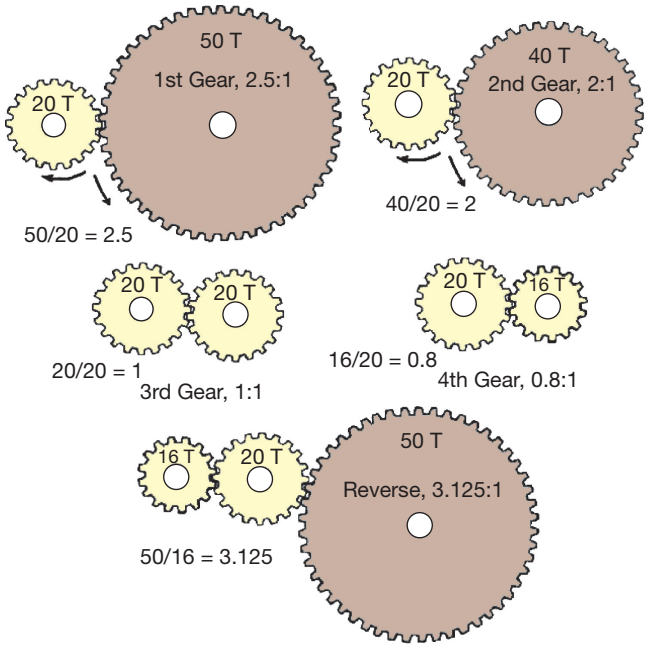


FIGURE 1–14 The gear ratio is determined by dividing the number of teeth on the driven (output) gear by the number of teeth on the driving (input) gear.

? **FREQUENTLY ASKED QUESTION**

What Is the Relationship between Speed and Gear Ratio?

The following formulas can be used to determine the vehicle speed based on the gear ratio and engine speed, or the engine speed based on the gear ratio and MPH:

- MPH = (RPM × tire diameter) ÷ (gear ratio × 336)
- Engine RPM = (MPH × gear ratio × 336) ÷ tire diameter

NOTE: The constant 336 is used to convert the units from inches (tire diameter) to feet and MPH to feet per hour.

CALCULATING OVERALL RATIOS When power goes through more than one gear set, two or more ratios are involved. In most cases, the simplest way to handle this is to figure the ratio of each set and then multiply the ratios. An

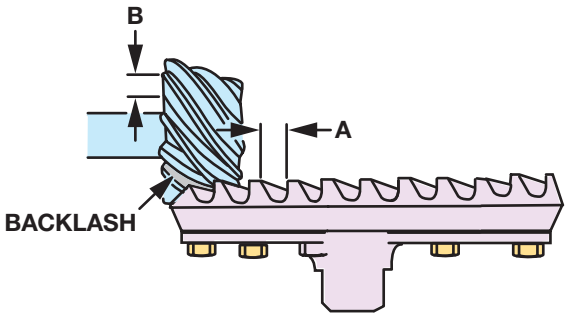


FIGURE 1–15 Backlash is the clearance between the teeth of two meshing gears. There has to be some clearance (backlash) to prevent the gears from getting into a bind condition when they are transmitting torque.

example of this is a vehicle with a first-gear ratio of 2.68:1 and a rear axle ratio of 3.45:1. The overall ratio in first gear is 2.68 × 3.45 or 9.246:1.

- At the same time there will be 9.246 times as much torque at the rear wheels than the engine produced.
- The engine will rotate at a speed that is 9.246 times faster than the rear axle shafts. The overall ratios for the other transmission gears would be figured in the same manner.

GEAR SET SUMMARY Typical rules about gear sets include the following:

- Two mated external gears will always rotate in opposite directions.
- Gear sets will multiply torque, but at a reduced speed.
- An idler gear allows the drive and driven gears to rotate in the same direction.
- To find the ratio, divide the driven gear by the drive gear.
- When power transfers through an even number (two or four) of gears, the input and output gears will rotate in opposite directions.
- When power transfers through an uneven number (one, three, or five) of gears, the input and output gears will rotate in the same direction.
- To find the overall ratio of multiple gear sets, multiply the ratios of the gear sets.
- Two gears transferring power push away from each other in an action called *gear separation*. The gear separation force (thrust) is proportional to the torque being transferred.
- The smaller gear(s) in a gear set may also be called a **pinion gear**.
- All gear sets *must* have backlash to prevent binding. **SEE FIGURE 1–15.**

TRANSMISSIONS

PURPOSE AND FUNCTION The purpose and function of gears in a **transmission** include the following:

- Low/first gear must provide enough torque to get the vehicle moving.
- High gear should provide an engine speed for fuel-efficient operation at highway speeds.
- The intermediate ratios should be spaced to provide adequate acceleration while minimizing the potential of overrevving the engine before the shift or lugging the engine after the shift.

TRENDS The majority of vehicles up to the 1970s used three-speed transmissions while some added an overdrive unit for a fourth gear ratio to lower engine RPM at cruise speeds. As the need to improve fuel economy and reduce exhaust emissions has improved, four-, five-, and six-speed transmissions have been introduced to provide lower first gears, overdrive, and/or smaller steps between gear ratios.

MANUAL TRANSMISSIONS

PURPOSE AND FUNCTION A **manual transmission**, also called a *standard transmission*, is constructed with a group of paths through which power can flow with each path used being a different gear ratio. **SEE FIGURE 1–16.**

Synchronizer assemblies or sliding gears and the shift linkage are used to control or engage the power paths.

CLUTCH Engine power must be stopped when making a shift in a manual transmission. The **clutch** is used to stop the power flow to allow the transmission to be shifted. It is also used to ease the engagement of the power flow when the vehicle starts from a standstill. The slight slippage as the clutch engages allows the engine speed to stay up where it produces usable torque as the vehicle begins moving.

Most vehicles use a foot-pedal-operated single-plate clutch assembly that is mounted on the engine flywheel. When the pedal is pushed down, the power flow is disengaged and

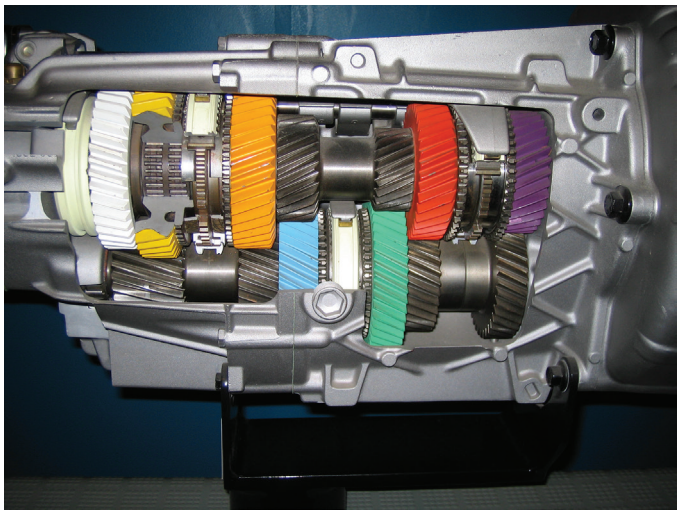


FIGURE 1–16 A manual transmission provides several gear ratios and a method to shift them.

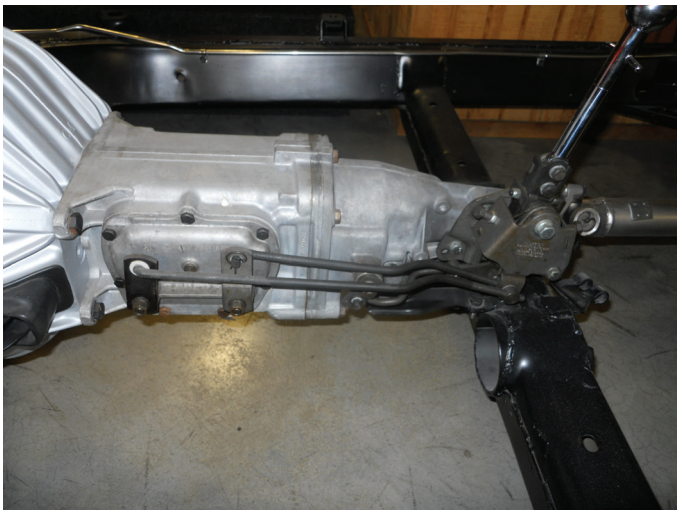


FIGURE 1–17 A Muncie four-speed manual transmission on a restored muscle car is an example of a close-ratio manual transmission.

FREQUENTLY ASKED QUESTION

What Is a "Close-Ratio" Transmission?

Gear ratio spread (GRS), is the difference between the lowest and highest ratios or, in other words, the overall range of the transmission gear ratios. In transmissions, it is fairly easy to visualize the difference between a 3.59:1 first gear and a 0.83:1 fifth gear. Gear ratio spread is determined by dividing the low gear ratio by the high gear ratio. The GRS for the gear transmission is 3.59 ÷ 0.83 = 4.33. RPM change/drop is fairly easy to determine:

- Subtract the higher ratio from the lower ratio and divide the product by the lower ratio.
- A close-ratio Muncie four-speed has ratios spaced fairly close together (25% or less), closer than the wide-ratio version. **SEE FIGURE 1–17.**

FREQUENTLY ASKED QUESTION

What Is an Automated Manual Transmission?

An automated manual transmission is a type of automatic transmission/transaxle that uses two clutches and a manual transmission-type gears and is shifted hydraulically by computer-controlled solenoids. This type of transmission is commonly called a *dual clutch* or an *electronically controlled manual transmission*.

when the pedal is released, power can flow from the engine to the transmission through the engaged clutch. **SEE FIGURE 1–18.**

AUTOMATIC TRANSMISSIONS

PURPOSE AND FUNCTION The purpose and function of an **automatic transmission** is to provide the forward and reverse gear ratios needed without requiring the driver to make the change in gearing as with a manual transmission. An automatic transmission has various gear ratios, but the paths of power flow are different from those of a manual transmission.

SHIFT MODES The transmission provides the various gear ratios for forward and reverse operations as well as two methods for the engine to run without moving the vehicle. Most automatic transmissions and transaxles include the following shift modes. **SEE FIGURE 1–19.**

- **Park.** In the park position, the output shaft is locked to the case of the transmission/transaxle which keeps the vehicle from moving. No power is transmitted through the unit so the engine can remain running while the vehicle is held stationary.

  In the park position

  1. The engine can be started by the driver.
  2. To move the shifter out of the park position on a late model vehicle, the brake pedal must be depressed to release the transmission shift interlock.