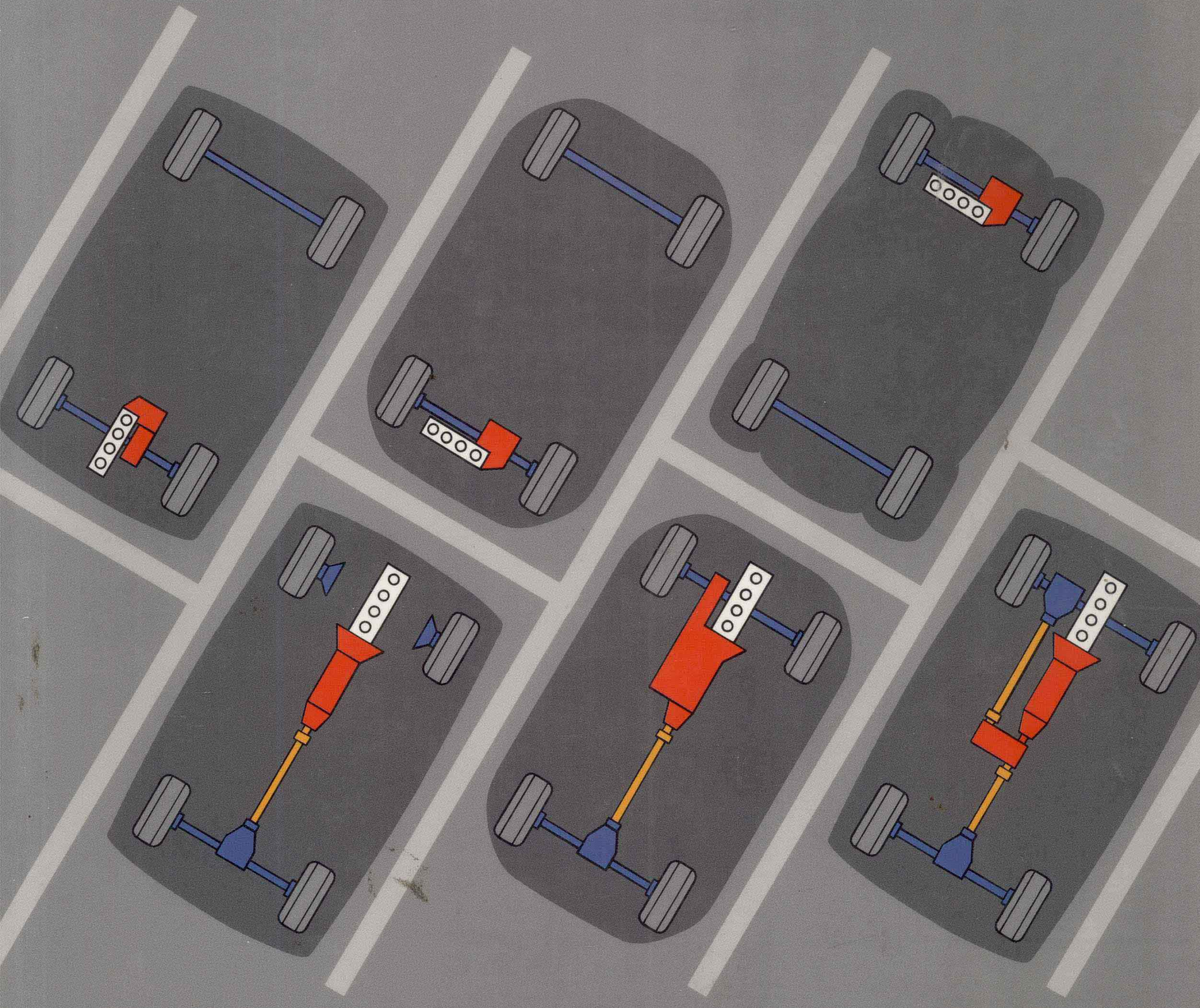
# Auto Drive Trains

## TECHNOLOGY

James E. Duffy & Chris Johanson



*Principles, Diagnosis, and Service for all major types of Drive Trains*

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# Auto Drive Trains

## TECHNOLOGY

by

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# Introduction

No vehicle can use the power in its engine without a drive train to deliver that power to the wheels and road. This is unlikely to change in the future. Whether the power plants in future vehicles are piston, rotary, or turbine designs that are powered by gasoline, diesel fuel, electricity, or steam, drive train components will always be needed to convert engine power to vehicle movement. Drive trains are used to move automobiles, trucks, farm equipment, construction machinery, and almost every other engine-powered device. Automotive and other transportation service businesses will always need trained and competent drive train technicians.

**Auto Drive Trains Technology** is designed to help you become that drive train technician. This textbook contains information on every type of drive train component used on modern cars and light trucks. Much of the information presented here will also apply to drive train components used on other vehicles, both on and off road. This book will be useful for those entering the automotive repair field, as well as for experienced technicians who want to upgrade their skills to include the latest drive train developments. Technicians studying for ASE tests and automotive hobbyists will also find **Auto Drive Trains Technology** a useful source of information.

Each chapter begins with learning objectives, which emphasize the important topics you will study. In the body of the text, new technical terms and manufacturer-specific component names are printed in *italics.* Defined terms are printed in ***boldface italics*** at their point of definition. Terms are defined in context. The words are stressed because of their importance and to help you to quickly learn the technical language of a drive train specialist.

The end-of-chapter material includes a summary, key terms, review questions, and supplemental certification-type questions. The summary will help you review the most important concepts covered in the chapter. "Know These Terms" provides a listing of the words and terms defined in the chapter. You should know the meanings of these and be able to use them. The review questions and certification-type questions will help you assess your knowledge of the information in the chapter. The certification-type questions are especially helpful in that they are written in the same format as questions prepared by the *National Institute for Automotive Service Excellence (ASE)* for ASE certification tests.

**Auto Drive Trains Technology** will help you pass three of the ASE certification tests: *Manual Drive Train and Axles; Automatic Transmission/Transaxle; Electrical Systems.* All of these subjects receive detailed coverage in this textbook. Chapter 28 summarizes the ASE voluntary testing program. If studied carefully, **Auto Drive Trains Technology** will give you valuable drive train information. This information, combined with the hands-on experience that can be received by completing the jobs in the accompanying workbook, will enable you to become a competent and successful drive train technician.

**James E. Duffy**
**Chris Johanson**

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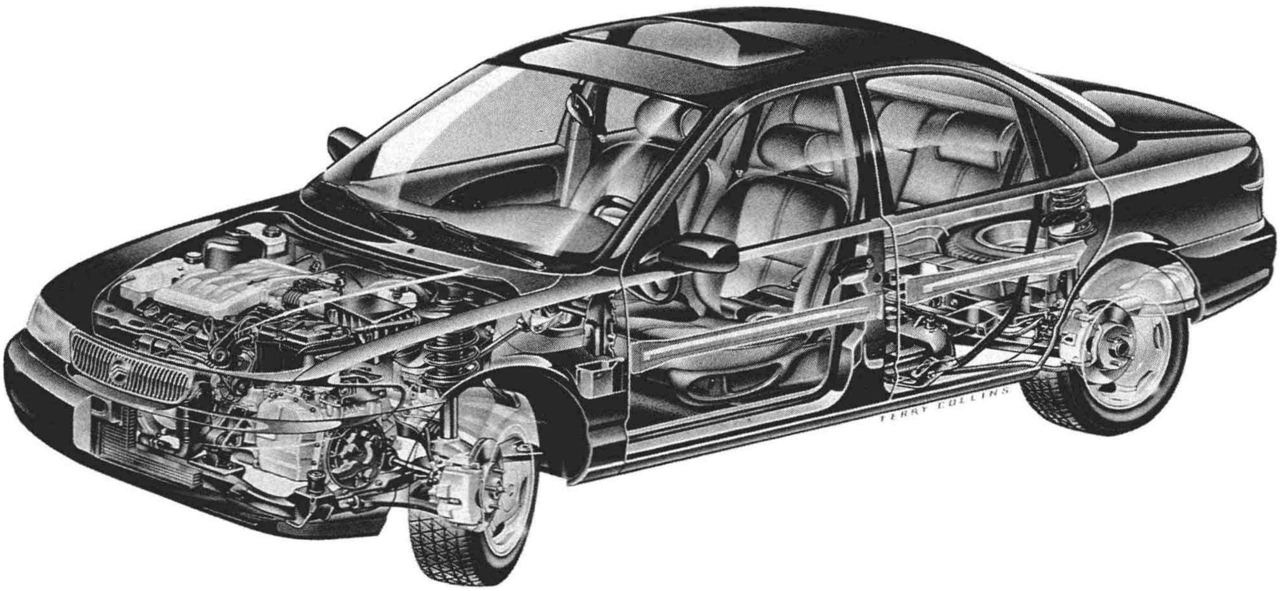
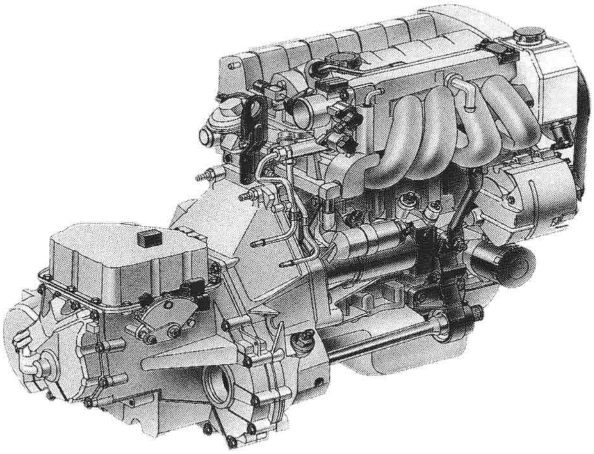
**IMPORTANT SAFETY NOTICE**

Proper service and repair methods are critical to the safe, reliable operation of automobiles. The procedures described in this book are designed to help you use a manufacturer's service manual. A service manual will give the "how-to" details and specifications needed to do competent work.

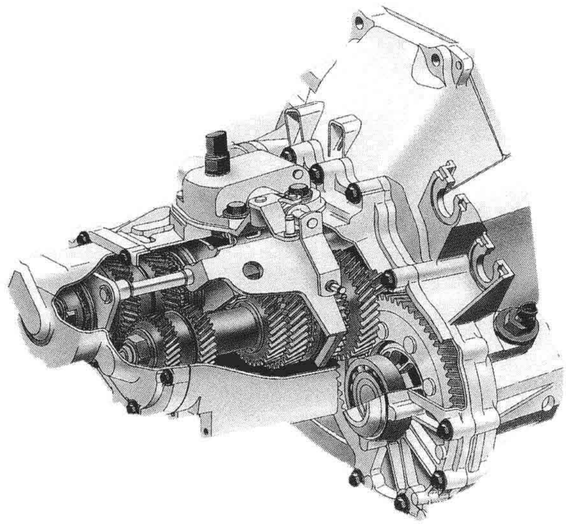
This book contains safety precautions that must be followed. Personal injury or part damage can result when basic safety rules are not followed. Also, remember that these cautions are general and do not cover some specialized hazards. Refer to a service manual when in doubt about any service operation!



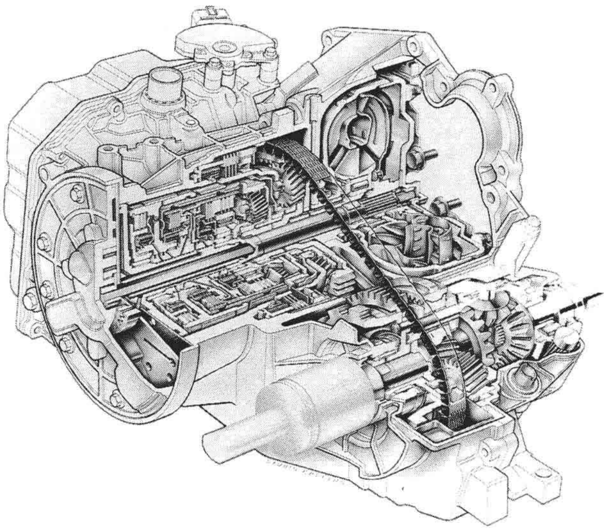
Cutaway shows the many systems of a modern automobile, one of which is a drive train system. (Ford)



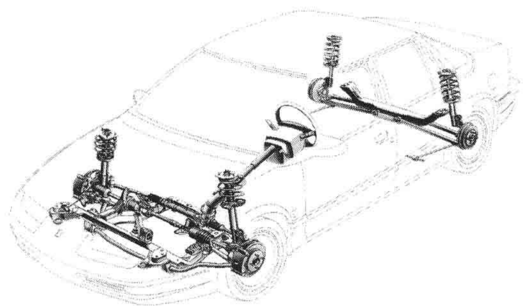
A transaxle, which is a combination transmission and differential assembly, is shown here mounted to a transverse engine.



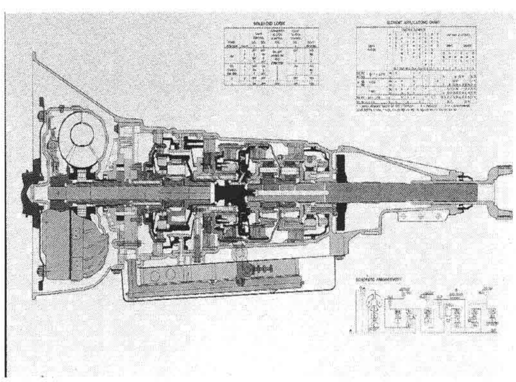
Transmission gearing and differential ring gear and side bearing are shown in this cutaway of a 5-speed manual transaxle. The clutch assembly (not shown) is housed within the bell-shaped housing (right).



Transmission and differential sections are shown on this Ford CD4E 4-speed automatic transaxle.



This phantom view shows CV axles on a front-wheel drive car, along with the vehicle suspension system.



Ford E4OD electronically controlled 4-speed automatic overdrive transmission.

Some of the major components used on vehicle drive trains are represented here. All of these types of components are discussed in detail in this text. (Saturn, Ford)

# Chapter 1

# Introduction to Drive Trains

After studying this chapter, you will be able to:

- List the basic functions of a drive train.
- Describe the different types of drive trains.
- List the basic parts of a rear-wheel drive system.
- List the basic parts of a front-wheel drive system.
- List the basic parts of a four-wheel drive system.
- Summarize the fundamental purposes for major drive train components.
- Explain the difference between a transmission and a transaxle.

The purpose of this chapter is to present the various vehicle *drive trains* and major drive train parts. The chapter will explain how the drive train relates to engine location and to body and chassis design.

Before you begin to learn the detailed principles and service of drive train components, you should know what components are part of the drive train. You have heard of *gears, clutches, bearings, couplings,* and *drive shafts.* All of these parts relate to a vehicle drive train. This chapter will help you more easily see the place of such parts in the operation of the drive train.

## The Drive Train

The vehicle engine, no matter how powerful, is useless if its power cannot be delivered to the wheels. The ***drive train*** is what transmits the engine power to the road. It is that part of the vehicle connecting the engine to the *drive wheels.* The drive train modifies engine power output to match vehicle needs. For example, the drive train provides a way to multiply *torque* (turning force) from the engine when starting off. It also provides a way to reduce engine rpm at higher speeds to improve gas mileage. In addition, the drive train provides a way to select the direction of vehicle travel, or select whether the vehicle moves forward or backs up.

The drive train consists of various mechanical and, sometimes, hydraulic and electronic components that form a path for engine power. This path is referred to as the ***power flow.*** Drive train components are usually arranged in a way that transmits power most efficiently. The arrangement may include, for example, *clutch, transmission, driveline, differential assembly,* and *drive axles.* Two basic ways the parts can be arranged are shown in Figure 1-1. Note that the parts of the drive train are shaded in the illustration.

Figure 1-1A shows a system where the engine is in front, and power is transmitted to the *rear drive axles.* This is a typical *front-engine, rear-wheel drive system.* For many years, this drive train design was almost the only kind used in domestic and imported vehicles.

Figure 1-1B shows a system where the engine is placed directly over the drive axles. This system features a ***transaxle***—a combination of a transmission and a differential assembly. The design can be used to drive either front or rear axles. Transaxles are common on front-engine vehicles. Mid- and rear-engine designs, which use transaxles to drive rear wheels, are less common. Examples of the rear-wheel drive version of this system are the Volkswagen Beetle and the Chevrolet Corvair. Porsche still uses this arrangement on 911 models.

### *Front-Engine, Rear-Wheel Drive*

Figure 1-2 is a further breakdown of a ***front-engine, rear-wheel drive system.*** The placement of the engine in the vehicle is called a ***conventional,*** or ***longitudinal, mounting.*** In this arrangement, the engine is positioned so that the water pump and drive belts are at the front of the vehicle. The crankshaft centerline runs in the lengthwise direction of the vehicle.

The engine feeds power into a ***clutch*** or a ***torque converter.*** The clutch is used on vehicles with *manual transmissions.* The torque converter is used on vehicles

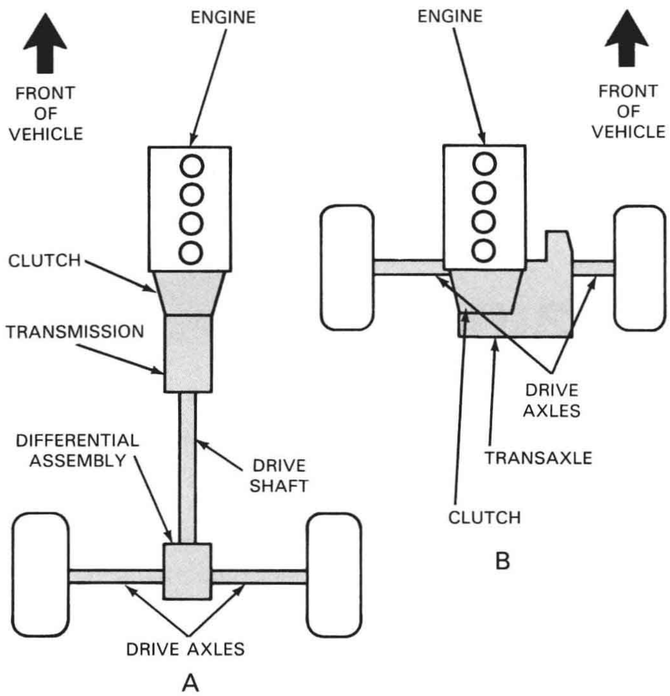



Figure 1-1. Two basic kinds of drive trains. A–This arrangement is found in front-engine, rear-wheel drive vehicles. B–This arrangement is found in some front-wheel drive and some rear-wheel drive vehicles.

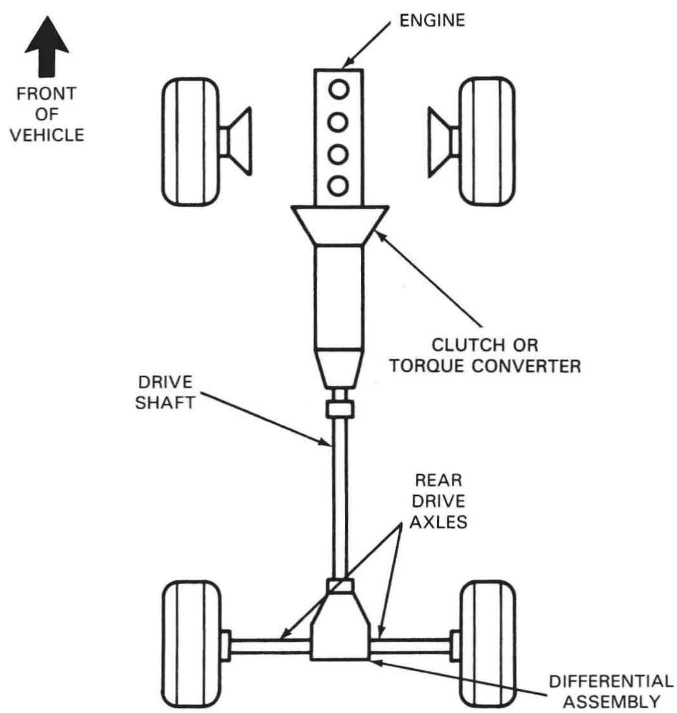



Figure 1-2. Power train layout of a typical rear-wheel drive vehicle. Notice that engine, clutch, transmission, drive shaft, and differential assembly are placed in a straight line. The ring and pinion cause the power flow to take a 90° turn inside the differential assembly to drive the rear wheels.

with *automatic transmissions.* (Though shown separately in Figure 1-2, the torque converter is considered an integral part of the automatic transmission, while the clutch on a manual transmission vehicle is a separate unit.) Both the clutch and torque converter serve as a way to connect or disconnect the flow of power from the engine to the drive wheels. The clutch transmits the power by means of a *friction* coupling, and the torque converter, by means of a *fluid* coupling.

From the clutch, engine power goes directly into the ***transmission***. Its purpose is to multiply engine torque or reduce engine rpm to match varying *forward* operating conditions. It also provides a way to move a vehicle in the reverse direction. The manual transmission uses gears of different sizes to obtain different gear ratios and achieve these results. The proper gear is selected by the driver on manual transmission vehicles.

Alternately, from the torque converter, engine power continues through the automatic transmission. The automatic transmission drives different combinations of *planetary gears* to obtain different gear ratios, as well as reverse. The proper gear is selected by a hydraulic control system on the automatic transmission.

From the transmission, the power flow goes to the ***drive shaft assembly,*** or ***driveline.*** This assembly consists of a drive shaft, front and rear *universal joints,* and a front *slip yoke.* The driveline is designed to provide a smooth delivery of power to the *rear axle assembly,* while allowing the rear axle to move up and down to compensate for road conditions.

The ***rear axle assembly,*** sometimes called the ***rear end,*** sends power from the driveline to the drive wheels. It is made up of a differential assembly and drive axles, which are encased in a housing that is considered part of the rear axle assembly.

Note that the rear axle assembly is sometimes referred to as the ***final drive.*** This term, which also applies to front-wheel drive vehicles, refers to final stage of a drive train. It includes the combination of the differential *and* drive axles.

The ***differential assembly*** houses a number of gears. They function, in part, to redirect the power flow 90° to drive the rear wheels. This function is served by a *drive pinion gear* and a *ring gear,* commonly referred to as a ***ring and pinion.***

The shaft of the drive pinion gear is connected to the driveline. The gear itself meshes with the ring gear. The rotational axes of the two gears are offset and form a 90° angle, making them *hypoid gears.* The number of teeth in the ring gear compared to the number in the drive pinion gear sets the ***rear axle ratio.*** Higher rear axle ratios provide better acceleration and pulling power. Lower ratios provide better fuel economy.

In addition to redirecting the power flow, the differential assembly allows the drive wheels to revolve at different speeds during vehicle turns. This function is served by two *differential spider gears* and two *differential side gears.* (This will be explained later on in greater detail.) The drive axles are attached to the differential side gears. As these gears rotate, power is transmitted from the rear axle assembly to the rear wheels.

## Front-Engine, Front-Wheel Drive

Most ***front-engine, front-wheel drive systems*** appear as in Figure 1-3. Note the engine is installed at a 90° angle to the vehicle. This sideways layout is usually referred to as ***transverse mounting.*** It eliminates the need to change the angle of power flow; therefore, a hypoid ring and pinion is not needed. This is a key difference between drive trains following longitudinally mounted, or *longitudinal,* engines and those following transversely mounted, or *transverse,* engines. A brief description of the latter follows:

Power flows from the engine to the transaxle, flowing first through a clutch in the case of a *manual transaxle.* The transmission, which is part of the transaxle, is located to one side of the engine. It performs the same function as on a rear-wheel drive system. The transaxle transmission sends the power flow directly into the differential assembly, also a part of the transaxle.

Power is split at the transaxle differential. It travels to each wheel through separate axles. These axles are not enclosed. The axles use flexible joints called ***constant-velocity universal joints,*** or ***CV joints.*** CV joints are used because they provide a constant flow of power through angles between drive and driven shafts. The transaxle differential allows each wheel to turn at different speeds during turns.

In some front-wheel drive vehicles, the engine is installed with a longitudinal mounting. See Figure 1-4. The transaxle is similar to that used with a transverse engine; however, it must include a ring and pinion that allows the engine power to make a 90° turn. The other drive train components operate in the same manner as those on a transverse engine.

## Mid-Engine, Rear-Wheel Drive

The ***mid-engine, rear-wheel drive system*** is illustrated in Figure 1-5. Power flows from the engine (through the clutch in manual transaxles) into the transaxle transmission. From here, power flows directly into the differential section of the transaxle, and then to the drive axles. This design resembles a conventional front-engine system in that the engine is mounted longitudinally. This rear-wheel drive system differs, however, in that it has a transaxle.

## Rear-Engine, Rear-Wheel Drive

Figure 1-6 shows a ***rear-engine, rear-wheel drive system.*** The engine is transverse mounted. The drive train

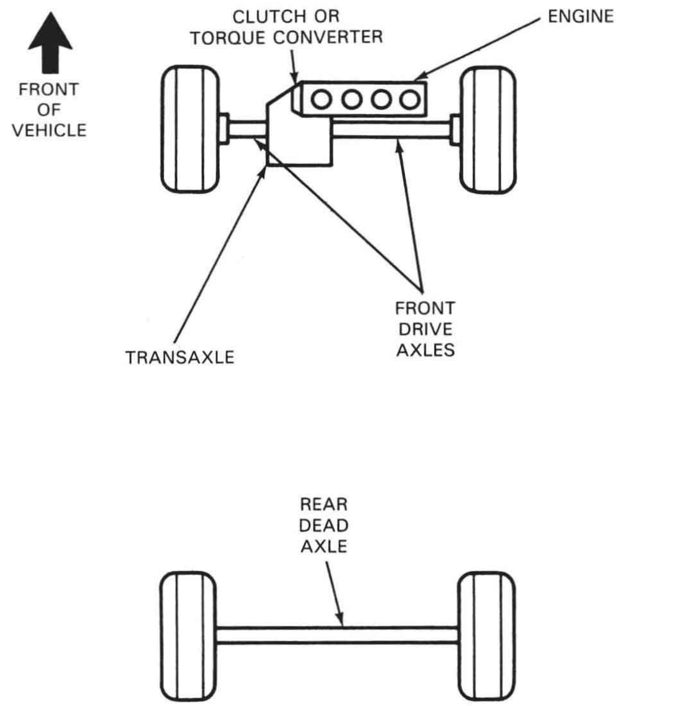



Figure 1-3. Front-wheel drive vehicle with transverse-mounted engine uses a transaxle to transmit power from engine to wheels. The axes of all rotating parts, from engine to wheels, have the same orientation. This makes it unnecessary for the power flow to make a turn at the differential assembly. The design makes a hypoid ring and pinion unnecessary in the differential assembly.

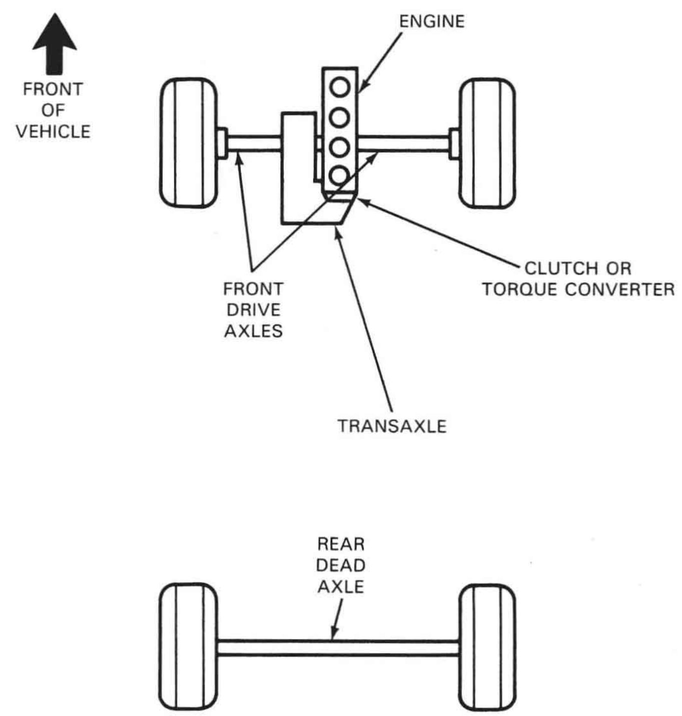



Figure 1-4. This is a front-wheel drive system, but the engine is longitudinally mounted, as it is on a rear-wheel drive vehicle. Although this system uses a transaxle, it has a hypoid ring and pinion.

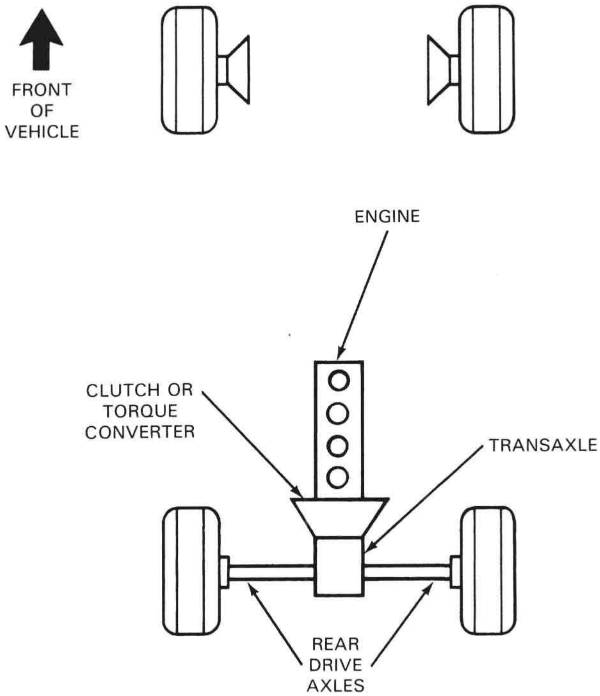



Figure 1-5. A mid-engine, rear-wheel drive system uses a transaxle. The power flow must be diverted 90°.

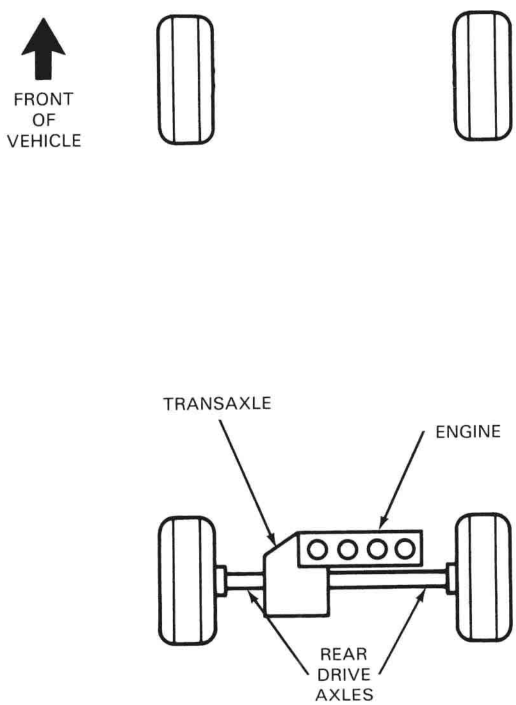



Figure 1-6. The power flow of the transverse-mounted rear-engine, rear-wheel drive system resembles that of a transverse-mounted front-engine, front-wheel drive system. Power flow is from engine to transaxle (through the clutch in manual transaxles) to rear drive axles to rear wheels.

operates in the same manner as that in a transverse front-engine, front-wheel drive vehicle.

On some rear-wheel drive vehicles, the engine is mounted behind the drive train components, Figure 1-7. The transaxle differential section and rear drive axles are mounted in front of the engine. The transmission section of the transaxle sits in front of them. Power flows from the transmission section to the differential section through a hollow shaft. Power flows to the transmission through a shaft that revolves inside of the *transmission output shaft.* Other drive train components operate as they do in the conventional rear-wheel drive system.

## *Four-Wheel Drive*

The ***four-wheel drive system,*** Figure 1-8, somewhat resembles a conventional rear-wheel drive system. In addition, the four-wheel drive system has a front axle assembly, similar to the rear axle assembly. It also has a separate gearbox, called a ***transfer case.*** Through the transfer case, power can be transmitted to front *and* rear axle assemblies through an arrangement of gears. The gear ratio from engine to rear wheels is always equal to the gear

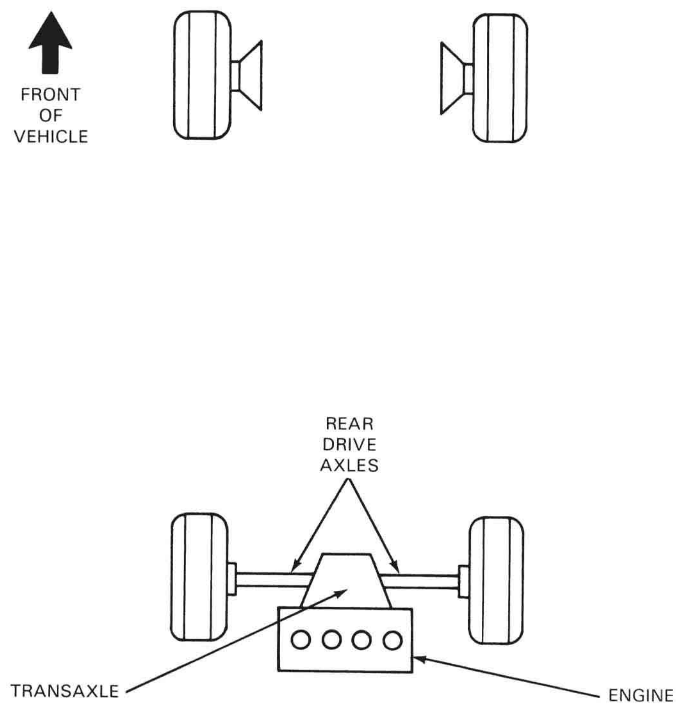



Figure 1-7. Rear-engine, rear-wheel drive system. The engine is mounted at the extreme rear of the vehicle. Power flow is forward to the transaxle. The transaxle differential is often mounted between the engine and transmission section of the transaxle. To transmit power, the input shaft to the transmission is placed inside of a hollow output shaft. Power flows through the input shaft into the transmission. The hollow output shaft transmits power into the transaxle differential.

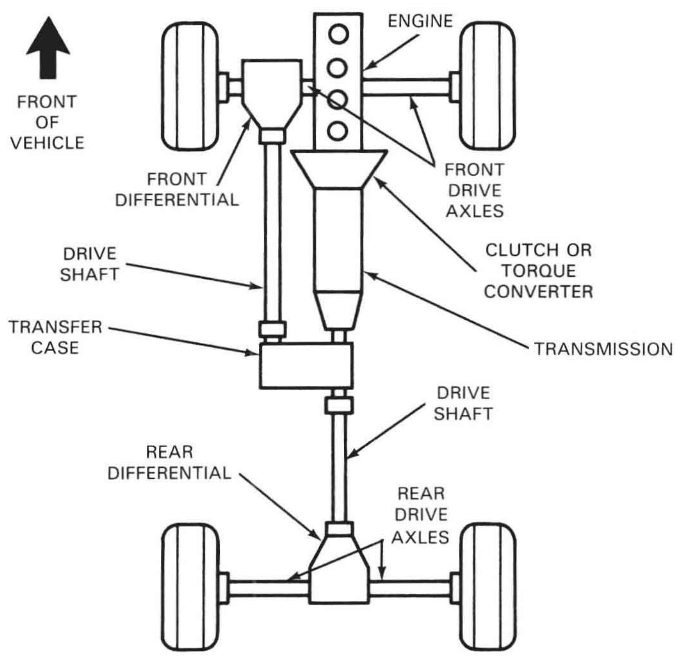



Figure 1-8. In the four-wheel drive system, power may be delivered to both front and rear wheels. The system contains a front drive shaft and final drive, which resemble the rear drive components. The heart of the four-wheel drive system is the transfer case. The driver selects two-wheel or four-wheel drive. In four-wheel drive, the transfer case divides power between front and rear drive shafts. In two-wheel drive, it sends power only to the rear.

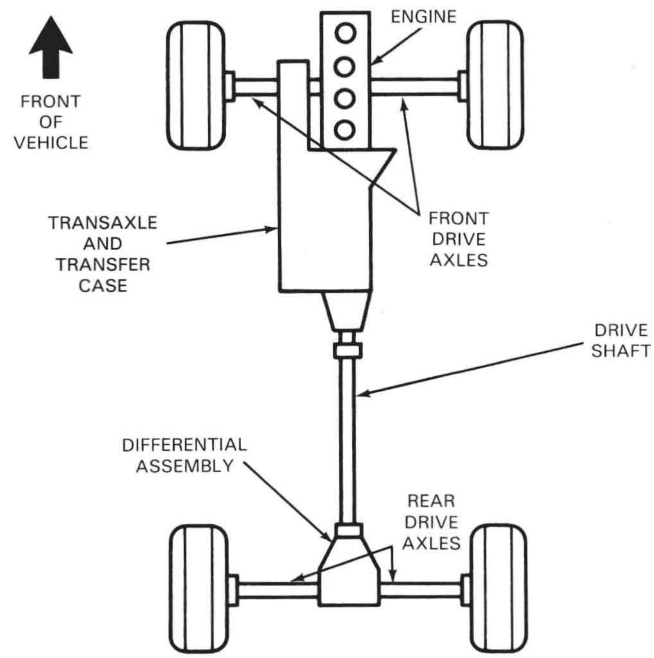



Figure 1-9. Transfer case of all-wheel drive vehicle automatically splits the power flow according to traction requirements. These transfer cases contain an internal *fluid coupling,* which is a device that transfers motion by using a fluid. It allows the front and rear wheels to turn at different speeds.

ratio from engine to front wheels; therefore, front and rear wheels revolve at the same rate.

In a four-wheel drive system, two- and four-wheel drive is selected manually; the vehicle driver decides which drive to use. The ***all-wheel drive system,*** Figure 1-9, a type of four-wheel drive system, is in four-wheel drive at all times. A special internal clutch in the transfer case can divert more or less power to the front wheels depending on road conditions.

## Drive Train Components

Certain drive train components are common to all types of drive train layouts. The difference often comes about only in the placement of the components on the various vehicles. Four-wheel drive systems have some additional components. Thus far, all of these parts have been mentioned. Following is a more detailed discussion.

### *Clutches and Torque Converters*

Clutches are always used on vehicles with manual transmissions and transaxles. The clutch is located directly behind the engine. It is almost always mounted on the engine *flywheel.* The clutch connects and disconnects the engine from the other parts of the drive train, Figure 1-10.

Clutches use friction to transmit rotary motion. This is called a *friction coupling.* The presence of friction between two parts in contact with each other will cause, to some degree, resistance of motion between them. At some point, relative motion between the two parts is altogether prevented.

A simple clutch is shown in Figure 1-11. In *normal* position, Figure 1-11A, the two surfaces are pressed together. The clutch is engaged. Rotary motion is transmitted through the disc surfaces. The clutch is disengaged, Figure 1-11B, by depressing a foot pedal connected to a clutch release mechanism. When the *clutch pedal* is released, the clutch reengages.

Torque converters are used with automatic transmissions and transaxles. They provide a hydraulic connection, or *fluid coupling,* between the engine and the other drive train components. The torque converter is installed directly behind the engine, in the front of the transmission.

A simple torque converter is shown in Figure 1-12. The basic construction includes an *impeller,* a *turbine,* and a *stator.* A *converter cover* is attached to the impeller, making the torque converter a sealed assembly. The cover is attached to the engine crankshaft. A brief description follows.

The ***impeller,*** also called a ***pump,*** consists of a set of curved blades, or vanes, attached to the inside of what forms the rear half of the torque converter assembly. As

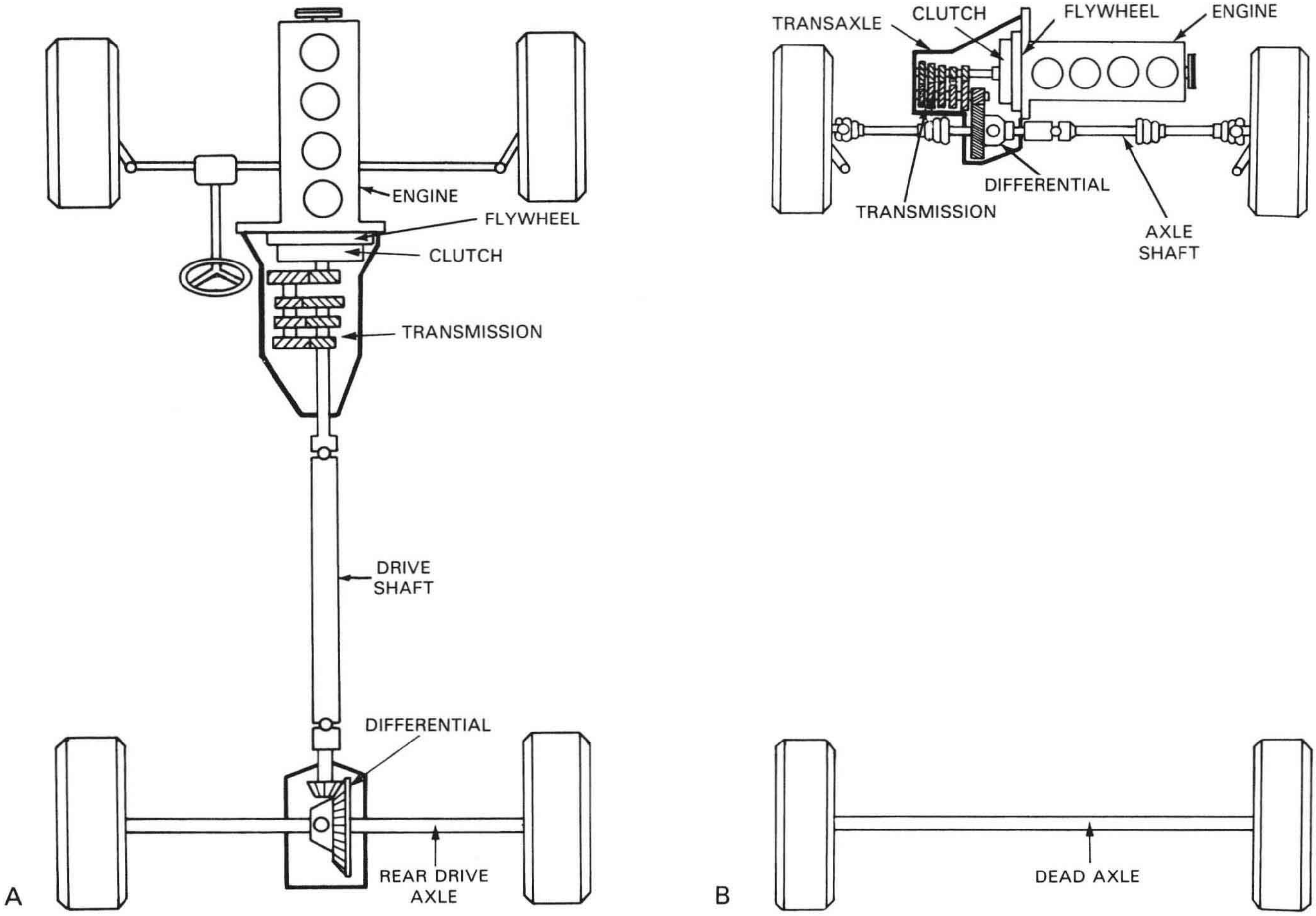



Figure 1-10. Compare the front- and rear-wheel drive systems shown here. The clutch is always mounted directly behind the engine, on the flywheel. Automatic transmissions and automatic transaxles will have a torque converter mounted directly behind the engine, instead of a clutch.

the engine turns, the converter cover and the attached impeller turn. The impeller, then, transfers power to fluid inside the assembly. The rotating fluid causes another set of blades, comprising the ***turbine,*** to revolve. This causes the *transmission input shaft,* which is connected to the turbine, to turn.

The ***stator,*** also called a ***guide wheel,*** consists of a smaller set of curved blades. The curve of the stator blades redirects the fluid, returning it to the impeller in the same direction that the impeller is turning. The stator helps the torque converter multiply power from the engine during takeoff and acceleration.

Torque converters operate whenever the engine is running. They allow the automatic transmission to be left in gear whenever the vehicle is stopped and the engine is running at low speed. In this case, the impeller will not have enough power to turn the turbine and, consequently, the transmission input and output shafts; as a result, the engine does not die. With a manual transmission, the clutch must be physically disengaged, under the same circumstances; otherwise, the engine will stall.

Torque converters are kept filled with fluid by the *automatic transmission oil pump.* Oil is pumped in through the converter rear shaft, which is open. Also, some torque converters have an internal *lockup clutch* that bypasses the fluid portion of the converter to provide direct mechanical drive during highway operation. Fluid leaving the converter passes through the *transmission oil cooler* and then returns to the transmission.

## Transmissions

The purpose of the transmission is to match engine power and speed to vehicle conditions. The transmission must provide a *high* gear ratio for takeoff and acceleration and a *low* gear ratio during highway operation. A transmission will have several gear ratios to allow for efficient operation under various conditions. Automatic transmissions can have fewer gears than manual because the torque converter provides some of the torque multiplication.

Transmissions are located behind the clutch in manual transmission vehicles. The automatic transmission mounts

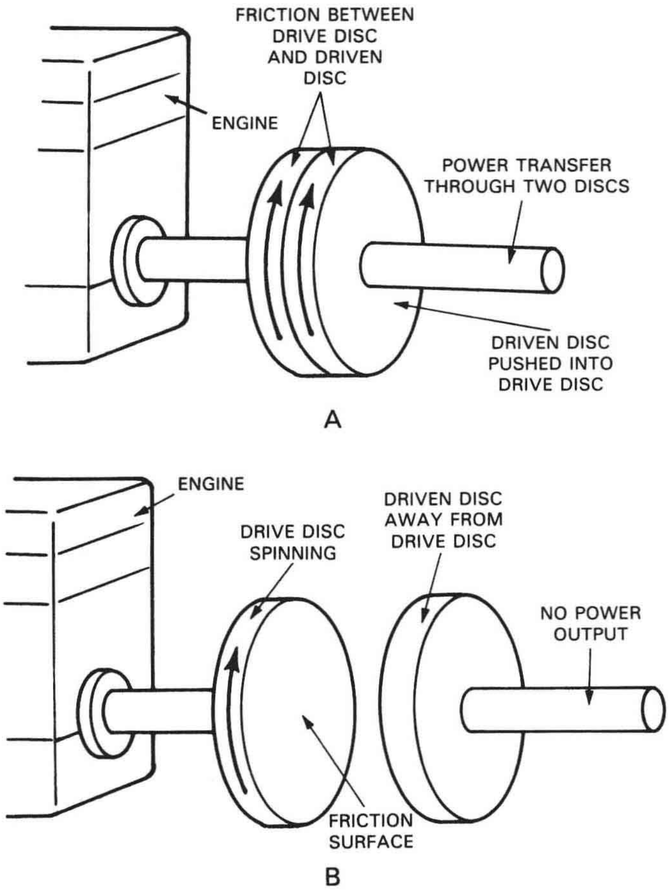



Figure 1-11. Operation of a simple clutch. A–When clutch discs are pressed together, a solid contact is formed. Rotation of the second disc is caused by the rotation of the first disc. B–One disc is spinning. There is no contact between the discs, and rotation is not transmitted.

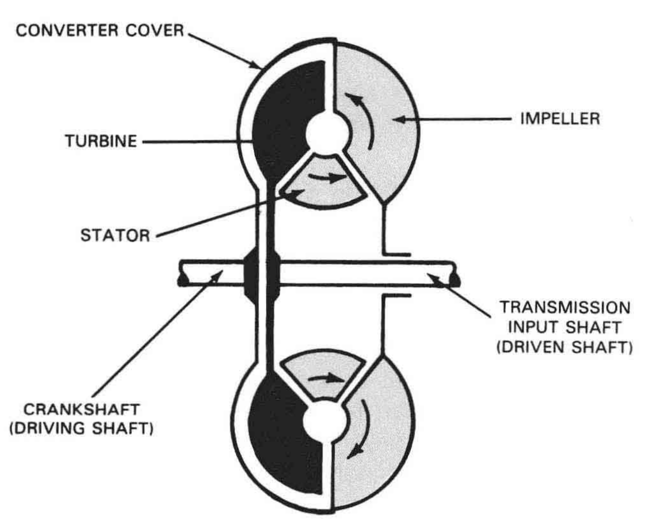



Figure 1-12. Sectional view of a torque converter. The torque converter operates whenever the engine is running. The relative position of the torque converter parts is the same for all converters.

directly behind the engine. Forwardmost in the automatic transmission is the torque converter, which takes the place of a clutch. The transmission output on a front-engine, rear-wheel drive vehicle goes to the drive shaft. See Figure 1-13. On front-engine, front-wheel drive vehicles, a drive shaft is not needed.

Transmissions are divided into two general classes–manual and automatic. In the ***manual,*** or ***standard, transmission,*** Figure 1-14, the gear selection decisions are made by the vehicle operator. Transmission gears and gear *synchronizers* are moved in and out of engagement by *shift forks.* The gears are meshed in different combinations. The driver selects different gear ratios by choosing the combinations needed. The driver must also operate the *clutch pedal* to disengage the clutch when changing gears. Manual transmissions require more skill to operate than automatic transmissions, but they allow more control over vehicle operation. They are usually easier and cheaper to repair.

In the ***automatic transmission,*** the gear selection decisions are made by the transmission automatic control system. Figure 1-15 shows a typical automatic transmission. Automatic transmissions usually use planetary gearsets. Planetary gearsets do not go in and out of engagement. In operation, one of the gears will be locked in place. The remaining, unlocked gears will be driven by engine power and will comprise the input and output. Different gear ratios are achieved, as needed, by alternate combinations of locked and unlocked gears. The gears are operated by holding members called *clutches* and *bands.* The clutches and bands are operated by a hydraulic control system. Late-model automatic transmissions have hydraulic systems that are controlled by *on-board computers.* Vehicles with automatic transmissions are easier to drive than manual. Also, they are more durable for heavy-duty operation, such as trailer towing.

## Drive Shaft Assemblies

All front-engine, rear-wheel drive vehicles have a drive shaft. The ***drive shaft,*** or ***propeller shaft,*** is the means of transmitting power from the transmission to the rear axle assembly. It usually consists of a steel tube with a welded or press-fit yoke at each end. See Figure 1-16. The yokes join ***universal joints,*** often called ***U-joints,*** at each end of the shaft. They allow for changes in driveline angles when the rear axle is moving up or down over road surface irregularities. Some drive shafts are two-piece units, with three universal joints.

The front of the drive shaft connects through the U-joint to the ***slip yoke,*** which slips back and forth within the transmission. It allows the drive shaft length to change with rear axle movement. A slip yoke may also be mounted at the rear of the front drive shaft in four-wheel drive vehicles.

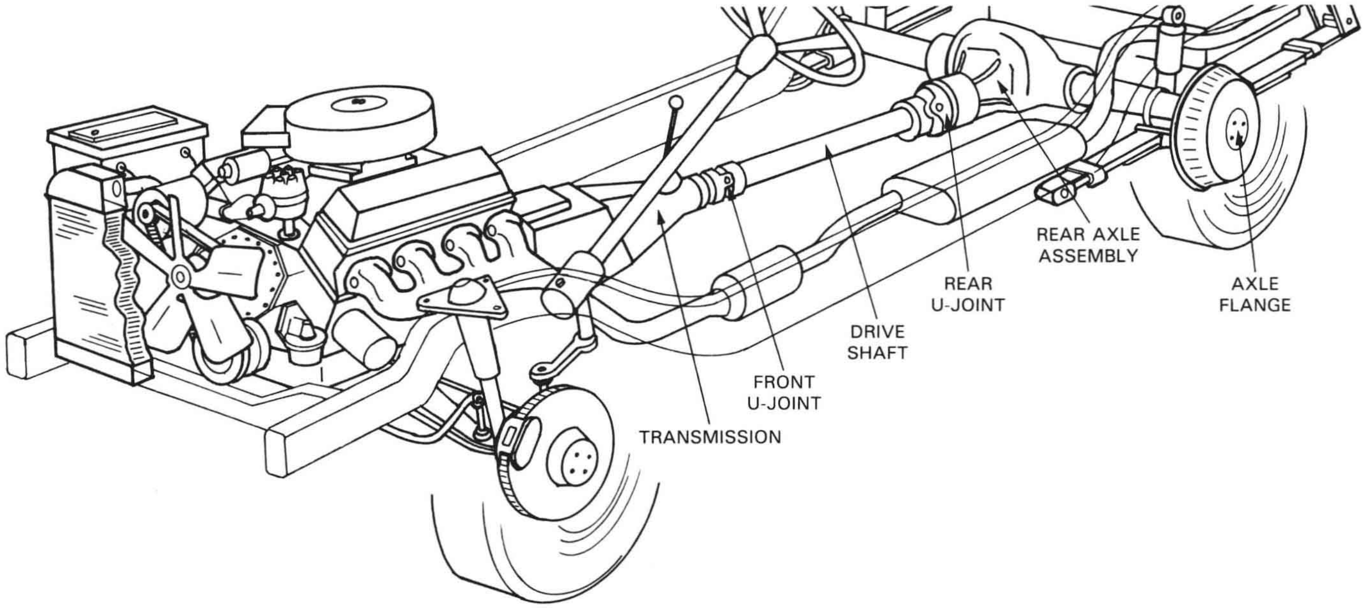



Figure 1-13. This shows how the drive train components of a rear-wheel drive vehicle relate to the other chassis components. The transmission is always directly behind the engine, and the drive shaft connects the transmission to the rear axle assembly.

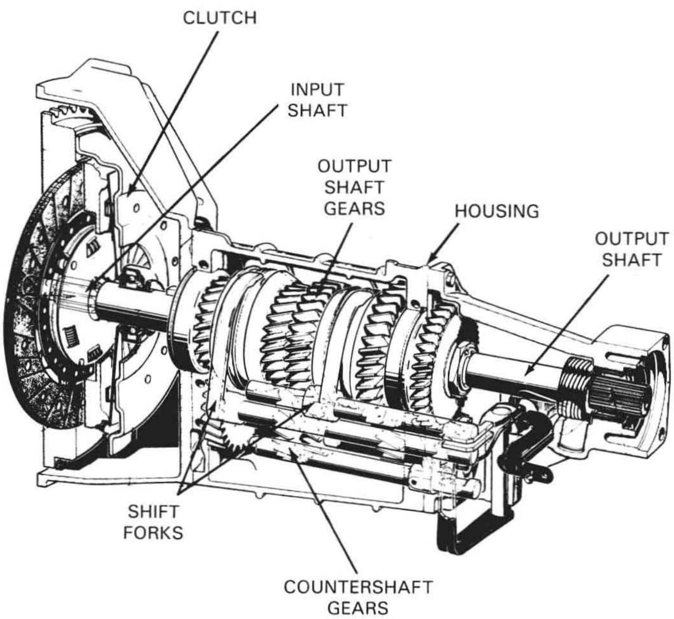



Figure 1-14. The rear-wheel drive system clutch and manual transmission shown here are typical. The components are found on all makes of manual transmissions. (Peugeot)

## Rear Axle Assemblies

The job of the rear axle assembly, Figure 1-17, is to transmit power from the drive shaft to the rear wheels. The ***rear axle housing*** contains the differential assembly, drive axles, and related parts. The housing forms a rigid support for the rear of the vehicle. Heavy *gear oil* contained in the housing lubricates the moving parts.

The drive pinion gear is attached to the rear universal joint by the *differential pinion yoke.* The pinion gear is in constant mesh with the ring gear. The pinion, turned by the drive shaft assembly, turns the ring gear. By design, the rpm at the ring and pinion output is reduced from driveline (input) rpm. In this way, the ring and pinion increases engine power. It also changes the power flow 90° so that it can drive the rear wheels. The ring gear has quite a few more teeth than the pinion. Therefore, the pinion must make more revolutions (usually between 2.5 and 4) to turn the ring gear one revolution. Note in Figure 1-18 that the ring and pinion gears are mounted on large bearings. These bearings must be strong to handle the thrust forces created during the transmission of power from ring to pinion.

The rear axle assembly also contains a *differential case.* The case is bolted to the ring gear. The power flow enters the case and passes through a set of small gears before going to the drive axles. The set of gears contains two differential spider gears and two differential side gears. All four gears are meshed together.

The four differential case gears are locked together and rotate as a unit when the vehicle is moving in a straight line. This causes the drive axles to revolve at the same speed. The gears are driven by a shaft that is connected to the differential case and that extends through the two spider gears. The shaft rotates end over end. The four gears do not rotate among themselves when the vehicle is moving straight ahead.