Mechanical Dissection Laboratory
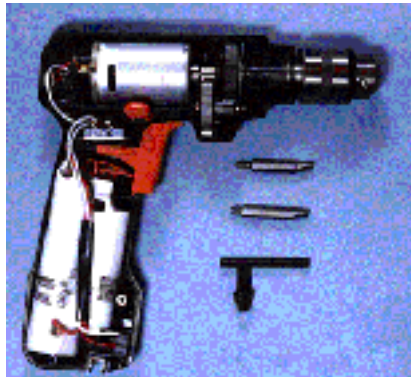
Power Hand Drill

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OBJECTIVES OF THIS DOCUMENT

It is the intent of this document to give the reader an understanding of the function of an electric hand drill. Overall function, as well as details of specific components are discussed. The Makita Model is used to illustrate many of the ideas.

This document can be used in a stand alone manner, or as a supplement to a hands-on dissection-based laboratory exercise. It was developed as part of a larger program to introduce freshman and sophomore level engineering students to the machines that form the foundation of much of engineering.

Comments and suggestions are welcomed by the authors, and can be directed to

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1 Introduction

The power hand drill is used with drill bits to create or enlarge holes in a variety of materials (e.g., steel, plastic, wood). With other accessories the power drill can be used for grinding, buffing, wire brushing, or as a power screw driver or a nut driver. An example of the power hand drill to be described in this document is shown in Figure 1.

Drills are available that can accommodate drill bits and accessories with shaft diameters of 1/4-, 3/8-, 1/2-, and 3/4-in. sizes; only 1/4- and 3/8-in. sizes are practical for home and small appliance repair shop use. Electric drills are named or grouped by the maximum size of the drill bit shaft that the drill chuck can hold. Drill speeds are fixed on some models and are variable on newer models. One-quarter inch (1/4-in.) drills run between 0 and 2250 revolutions per minute (rpm) and the three-eighth inch (3/8-in.) drills run between 0 and 2100 rpm. Both 1/4-in. and 3/8-in. drills use a small electric motor having a rating of 1/6 to 1/4 horsepower.

A power drill is comprised of two sub-systems; mechanical and electrical. The Mechanical subsystem is made up of components whose purpose is to transfer, translate or apply forces. The Electrical subsystem contains components that supply and control power flow. These two subsystems are discussed in greater detail below. The Makita Model 6404 3/8" drill is used extensively to illustrate concepts.

Figure 1. Assembly drawing of Makita Power Drill (see component list on next page).

1. Drill Bit
2. Drill Chuck
3. Gear
4. Bearing
5. Housing
8. Bearing
10. Fan
9. Armature Assembly
11. Bearing
7. Field Assembly
6. Terminal Base
18. Name Plate
17. Housing Set
16. Tapping Screw BT 4 x 25
15. Dust Cover
13. Carbon Brush
12. Switch
14. Cord
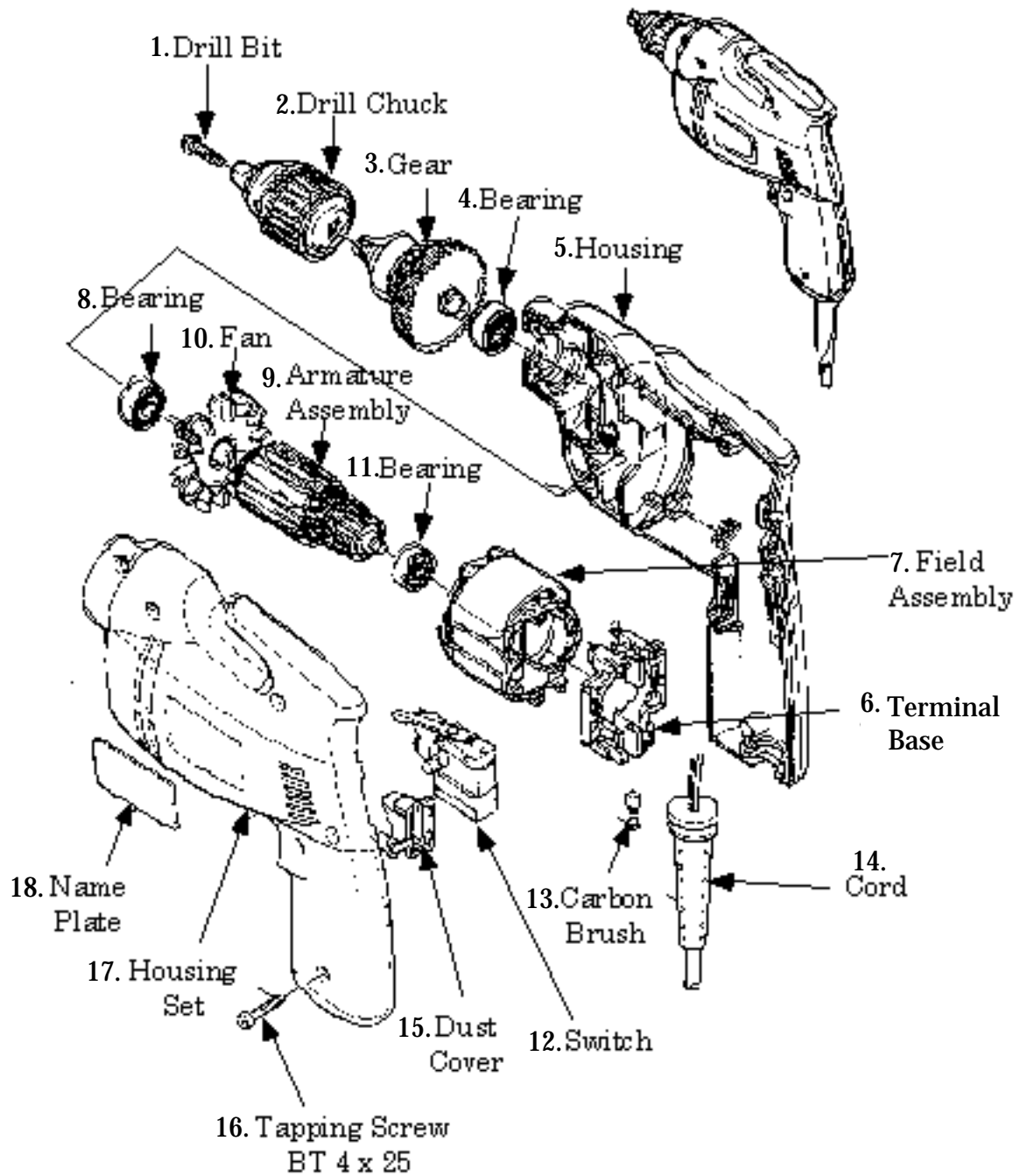
Diagrammatic Layout of a Makita Model 6404 Drill

Component List for Figure 1.

Name of the different parts of the Makita drill:

1.   Drill Bit
2.   Drill Chuck
3.   Gear
4.,8.,11.   Bearings (Ball type)
5.   Housing
6.   Motor Component: Terminal Base
7.   Motor Component: Stator or Field Assembly
9.   Motor Component: Rotor or Armature Assembly
10.   Motor Component: Fan
12.   Switch
13.   Motor Component: Carbon Brush
14.   Cord
15.   Dust Cover
16.   Tapping Screw BT 4 x 25
17.   Housing
18.   Name Plate

2 Description of the mechanical subsystem

The Mechanical subsystem is comprised of components whose purpose is to transfer, translate or apply forces. Components are discussed below, as defined in Figure 1.

2.1 Chuck (Part # 2)

The drill chuck is a three-jaw attachment that applies a radial "gripping" force to a semi-infinite number of drill bits and accessory shafts, as shown in Figure 2.1A. The maximum usable size of the drill bit or accessory for a particular drill is determined by the size of the chuck. Chucks are generally attached to the drill shaft with a left-handed threaded fastener. This means that the fastener is turned in a counter-clockwise direction during installation. The chuck turns in a clockwise direction when viewed from the user's perspective; resulting in the fastener continually being tightened during use.

Figure 2.1A photos of drill chuck with chuck key in place (Makita)

Chuck Operation - Insertion & Manipulation

Chuck Cap

Drill Bit

Tighten

Loosen

Chuck

Chuck Key

Close-Up of the Chuck Mechanism

Clamp Gear

Bit Slot

Chuck Cap
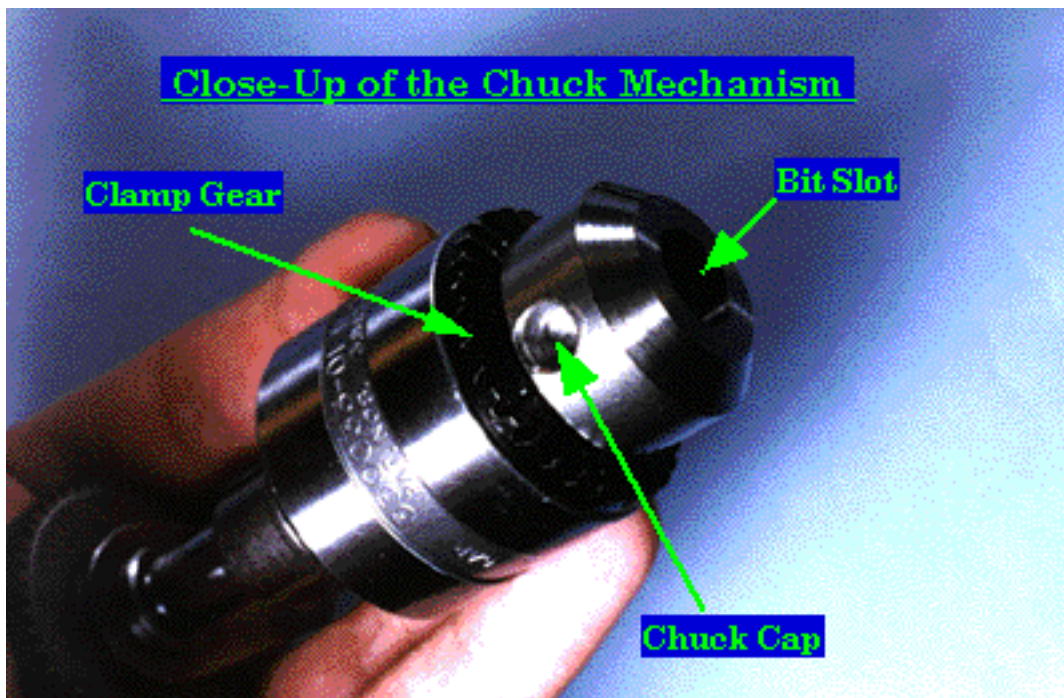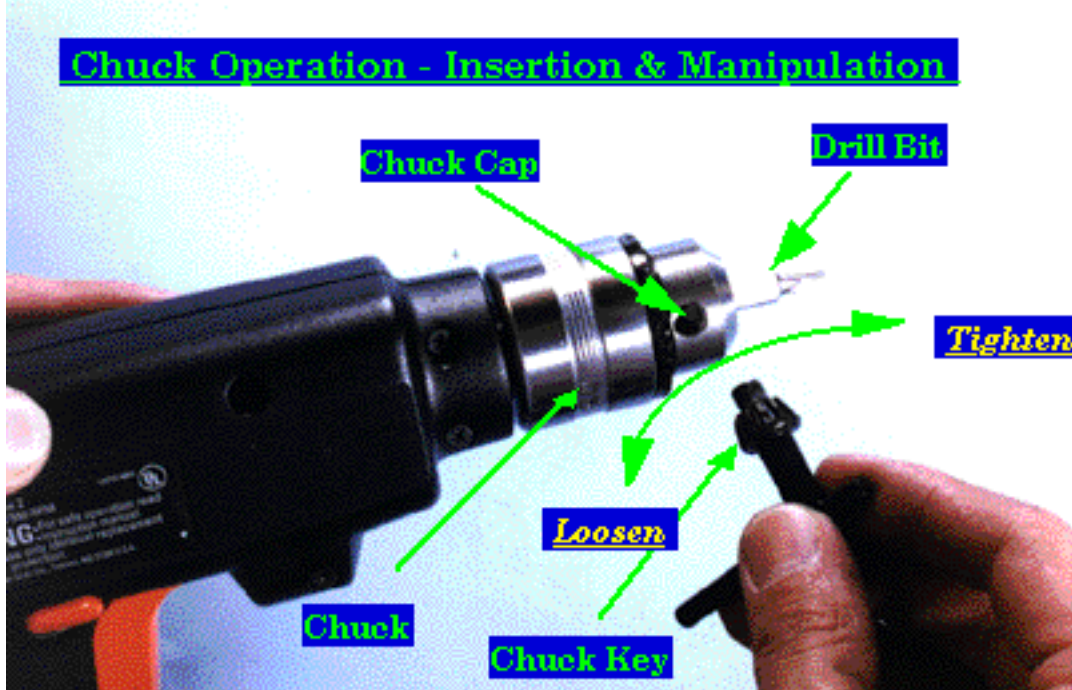
The three-jaw configuration is designed to always maintain axial alignment between the chuck rotational axis and center of the bit. The chuck is tightened by a tee-handled wrench, called a chuck key, as shown in Figure 2.1A. The bevel teeth of the key mate with teeth on the chuck. As the key is rotated, the chuck rotates about its axis (when viewed from the "drill-bit" perspective, clockwise to tighten, counter-clockwise to loosen). This results in the action shown in Figure 2.1B; the fingers of the chuck "grip" the shaft of the drill bit.

Figure 2.1B schematic showing chuck action
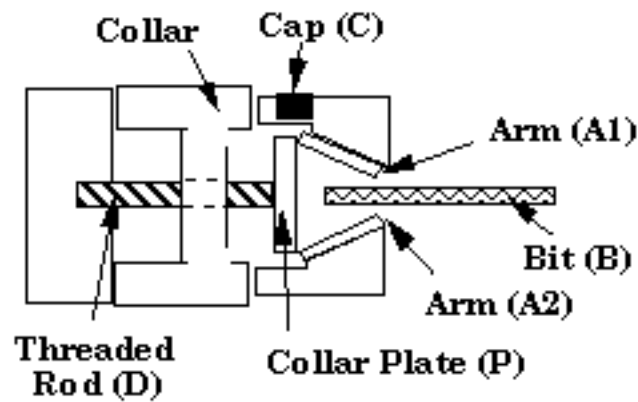
QUESTIONS ON CHUCK:

1. Why is having "continual tightening" of the attachment fastener and drill bits desirable "feature" in the chuck? Can you think of a component on a bicycle or car where this same feature is desirable?

2. As you drill, what direction is the necessary applied reaction torque to prevent the workpiece from rotating? Show in a sketch.

3. Come-up with one alternate design for the chuck.

2.2 Gears (Part # 3)

Between the chuck and the motor is the transmission, as shown in Figure 2.2A. The transmission (also called the gear train) consists of gear pairs. The transmission is a vital part used in many tools to transfer mechanical motion and energy. Note that both of the gears in the gear pair in the Makita drill shown in Figure 1 are not labeled; where is the other bear?

Gears are mounted on shafts and are grouped according to tooth forms, shaft arrangement, pitch, and quality. Tooth forms and shaft arrangement, illustrated in Figure 2.2B, are listed in Table 1. Shaft arrangement defines the relative directions of input and output motion.

Figure 2.2A Gear train in Makita Drill

The Gear Train

The Makita 6404 Drill
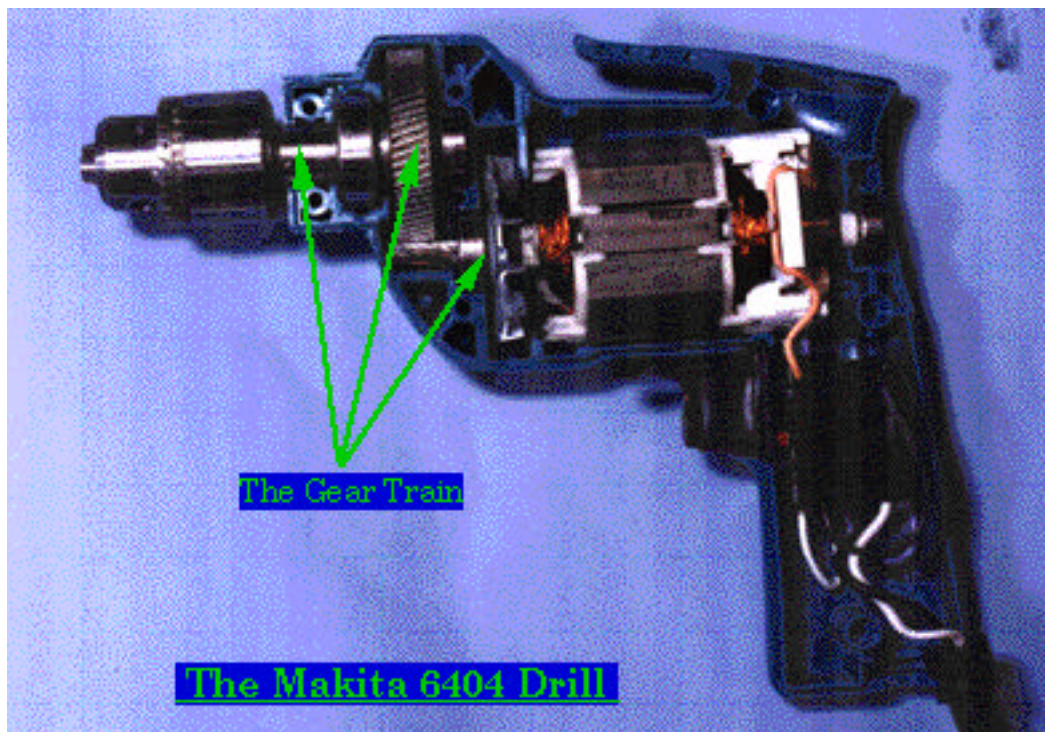
Figure 2.2B Various Gear Systems

Spur Gear   Ring Gear   Helical Gear

Hypoid Gear   Bevel Gear   Worm Gear
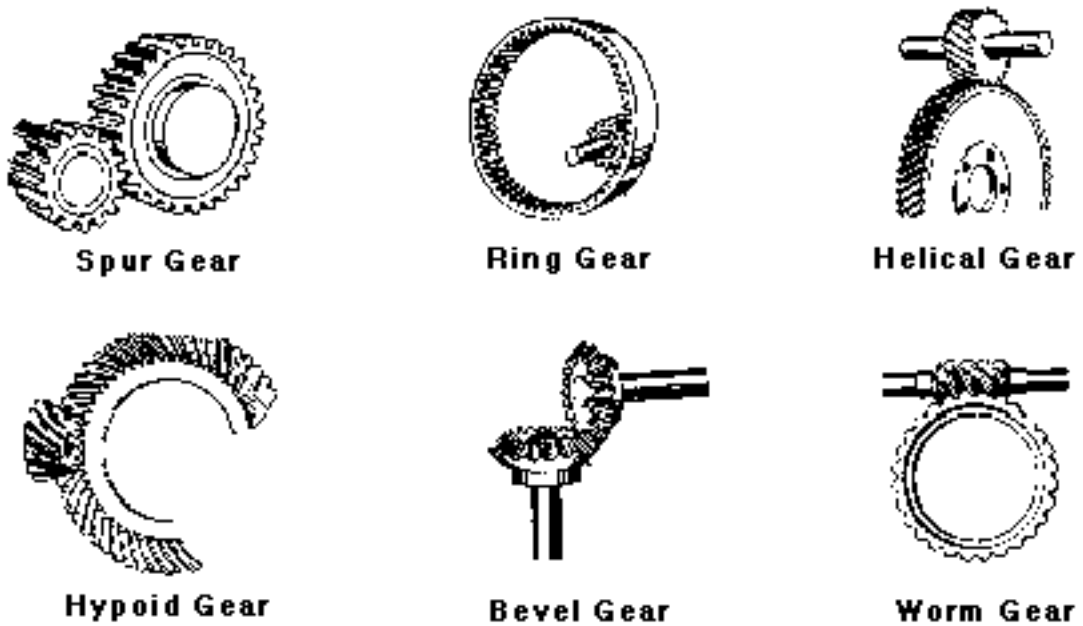
Table 1. Commonly used gear types

Tooth form (or gear type)	Shaft arrangement	Examples of Use
Spur	Parallel	clock, movie projector, car steering (rack & pinion, which is a special case of of a spur gear pair)
Helical	Parallel or skew	manual transmission
Worm	Skew	electric mixer, sprinkler, speedometer
Bevel[*]	Intersecting	hand drill
Hypoid	Skew	automobile differential

[*] The chuck key and chuck are a bevel gear pair

Gear trains are used in designs for a number of reasons:

> (1) Need to change type and direction of motion. For example, a differential train, a screwdriven material testing machine, or a hand-powered egg beater.
> (2) Need to increase (reduce) output rotational speeds relative to input speed.
> (3) Need to increase (reduce) output torque relative to input torque.

To understand reasons 2 and 3 consider the ideas of work (W) and power (P). Power is the rate at which work is being done (simple example here). The electric motor (to be discussed in detail in Section 3) drives the gear train with torque. Torque can be related to the input horsepower, as shown below.

$$P = \partial W / \partial t, \tag{1}$$

where P is power, W is work, and ∂ denotes the partial derivative with respect to time t. For linear motion, W=Fxl, where F is the applied Force and l is the distance traveled. For rotational motion, W=Txθ, where T is applied torque and θ is the angle of rotation in radians. Therefore Eqn. (1) can be rewritten as follows when the force F or torque T is constant:

$$P = \partial(Fxl) / \partial t = F v \tag{2a}$$

or

$$P = \partial(T\theta) / \partial t = T\omega \tag{2b}$$

where v and ω are linear and rotational speeds, respectively. Both Eqns. (2a) and (2b) say the same thing; the one you consider depends upon whether you are describing linear (Eqn. (2a)) or rotational (Eqn. (2b)) motion.

Table 2 summarizes the units in SI and English for the various quantities presented above.

Table 2. SI and English Units

quantity	SI system	English system
Power, P	Watts (W) =Nm/sec	Horsepower (hp)
Work, W	Newton-meters	ft-lbs
Torque	Newton-meters	ft-lbs
Velocity, v	meters/sec	ft/sec

ACTION BETWEEN MATING GEAR TEETH

Transmissions (which typically involve rotational motion) are described by the relationship between power, torque and rotational speed laid out in Eqn. (2b). Now consider the action between the two gears of a gear pair, as shown in Figure 2.2C. Pinion A (referred to as the pinion because it is the smaller of the gear pair) is the driving (or input) gear, Gear B is the driven (or output) gear. Because the system is in static equilibrium, Gear B must push back on Pinion A with a force equal to the "push" of A on B.   Two things should become apparent by looking at Figure 2.2C: Gear B rotates at a slower rotational speed than Pinion A, and that the torque applied about Shaft B ($T_B = Fxr_b$) is greater than the torque applied about Shaft A ($T_A = Fxr_a$). We can quantify these differences in rotational speed and torque by considering the transfer of power from Shaft A-Pinion A to Shaft B-Pinion B; if we assume that the power input to Shaft A is the same as the output horsepower, through the system is constant, the power relationship presented in Table 2 becomes

$$HP)_{input} = HP)_{output} \tag{3}$$

$$T_A \ _A = T_B \ _B \tag{4}$$

where   is equal to 2 N/60, and N is the revolutions per minute (RPM) of the gear. Rearranging Eqn. (4) gives,

$$T_A / T_B = \ _B / \ _A \tag{5}$$

Figure 2.2C Gear teeth meshing
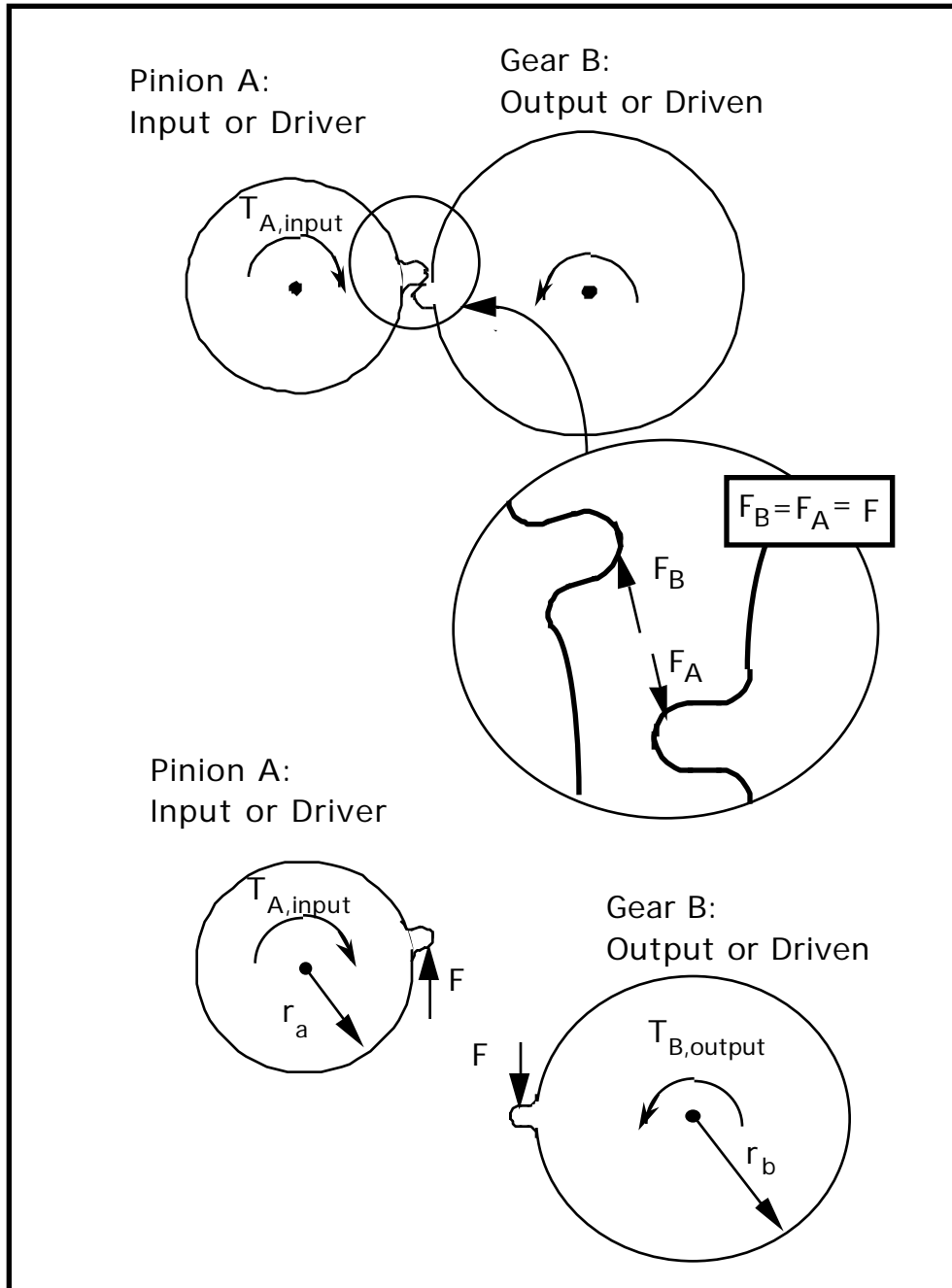
Recall that $T_A = F\, r_a$ and $T_B = F\, r_b$ (see Figure 2.2C), therefore Eqn. (5) can be rewritten as

$$T_A/T_B = \omega_B/\omega_A = r_a/r_b = N_a/N_b \tag{6}$$

The last term (N_a/N_b) comes from the fact that the number of teeth on a gear is directly proportional to the diameter of the gear.

Equation (6) shows that gear pairs can result in torque multiplication (reduction) and rotational speed decrease (increase), all proposal to the relative sizes of the gears in the pair.

Figure 2.2D Gear nomenclature
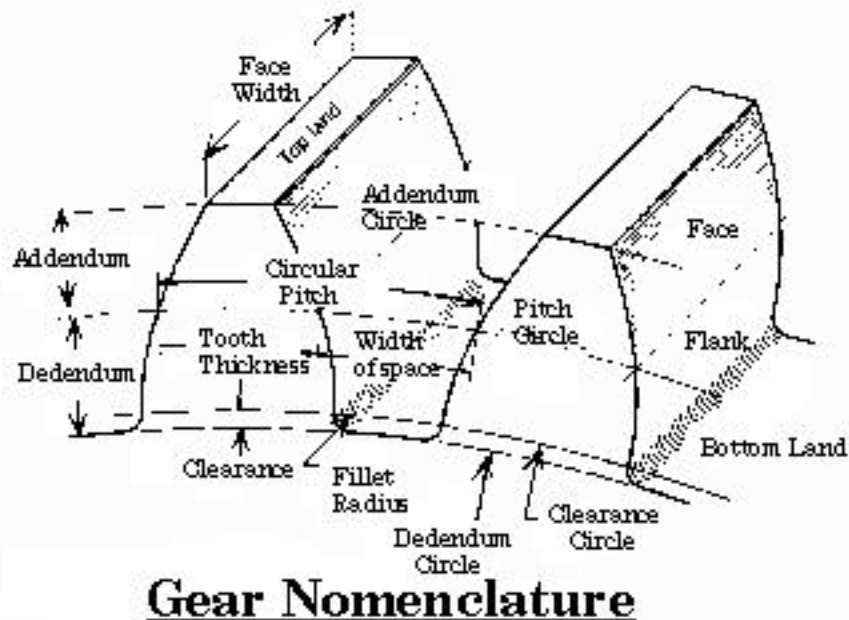
Gear Nomenclature

A BIT MORE ON GEAR NOMENCLATURE

There are a number of additional terms used in describing gears and gear teeth. Typical tooth nomenclature is shown in Figure 2.2D.

A few key terms are:

Circular pitch p as shown in Figure 2.2D, is the distance from a point on one tooth to a corresponding point on an adjacent tooth.

Diametrial pitch P (teeth per inch) is the ratio of the number of teeth on the gear to the pitch diameter.(teeth per inch) is defined as N/d, where N is the number of teeth and d is the pitch diameter in inches. Pitch is specified as fine (P>=20) or course (P<20). Gear quality types are : Precision, ultra precision, and commercial.

Pressure angle for all gear types is the acute angle between the common normal to the profiles at the contact point and the common pitch plane. For standard gears pressure angles of 14.5° and 20° have been adopted by the the gear industry.

The **base circle** is the circle from which the involute tooth profiles are generated.

There are gear standards in English units established by the American Gear Manufacturers Association (AGMA) and the American National Standards Institute (ANSI) for tooth proportions (e.g., addendum, dedendum, working depth, clearance, tooth circular thickness, and the pressure angle). Standards ensure interchangability and standard cutters which are economical to purchase. For limited or small-scale production, gear pairs are generally purchased parts.

There are a large number of ways of forming the teeth of gears, such as sand casting, shell molding, investment casing, permanent-mold casting, die casting, and centrifugal casting. Teeth can be formed by using the power-metallurgy process; or by using extrusion, a single bar of aluminum may be formed and then sliced into gear. Gears which carry large loads in comparison with their size are usually made of steel and are cut with either form cutters or generating cutters.

QUESTIONS ON GEARS:

1. What is the number of gear pairs on the drill that you are working with? Would you define them as course or finer. Do you think that the quality is precision, ultra precision, or commercial?

2. What are the gear ratios involved in the transmission of your drill? Is there torque multiplication or reduction? Why was the transmission designed like this?

3. How are the gears mounted to their shafts? keyed, press fit, cast?

4. In describing the motion of a bicycle, when would you use Eqn. (2a) and when would you use Eqn. (2b)?

5. Prove Eqn. (6).

2.3 Ball Bearing (Parts # 4, 8, 11):

It is the intent of most machines to do useful work with a minimum expenditure of energy, either of manual or of natural origin. Translational or rotational motion of one component relative to another always involves a resistance varying in degree according to the nature of material in contact, the mating surfaces, and the character of the movements taking place.

Whenever you try to move any object that is touching another object, you'll encounter some resistance to that movement. That resistance is called friction. Energy is required to overcome friction, but friction is not necessarily a disadvantage. The friction between the wheels of a car and roadway not only keep the car from skidding, but enable the car to move in the first place. The friction between a disk and a brake pad allow a car to be stopped.

Any movement involves some friction. Friction is present not only when one surface is sliding against another, but also when one of the surface is rolling against the other, and when an object is moving through a liquid or gas (e.g., consider re-entry of the space shuttle).

Some of the energy you put into moving an object against frictional resistance is converted to heat. The faster an object moves, and the greater the

friction, the more heat will be produced. This is clearly shown by the old Scouting feat of starting a fire by rubbing two sticks together.

For thousands of years, people moved things by lifting or dragging them. Even as recently as the 17th century, native Americans could move only what they could carry themselves or put on horseback or have a house drag on a stretcher; they learned of the very useful invention, the wheel, from the European settlers.

Wheeled vehicles are effective because *rolling friction* is much lower than *sliding friction.* Round sticks used as rollers under heavy objects were the forerunners of the wheel; the rollers, of course, had to be moved from behind the load to the front. The Egyptian pyramids were built out of immensely heavy stone blocks that were moved in this manner.

Eventually a way was found to eliminate the perpetual recirculation of the round sticks. Each end of the stick was whittled down and inserted into a drilled hole in a block, which was then attached to a platform. This drilled block was a bearing. It was a short step from this device to disk-shaped wheels and spooked wheels. Finally, ball bearings or roller bearing reduced the friction to almost negligible levels. Commonly known, modern bearing types are described in Table 3.

Rolling bearings can be classified as ball or roller bearings and consist of two rings with a set of rolling elements running in their tracks. Standard shapes of rolling elements include the ball, cylindrical roller, needle roller, tapered roller, symmetrical and unsymmetrical barrel roller, as shown in Figure 2.3B.

Figure 2.3A Ball bearings

Deep Groove Ball Beairng with Shields

Deep Groove Ball Bearing with Seals

End View of Ball Bearing showing inner and outer race

Ball

Cylindrical roller

Needle roller

Tapered roller

Symmetrical barrel roller

Unsymmetrical barrel roller

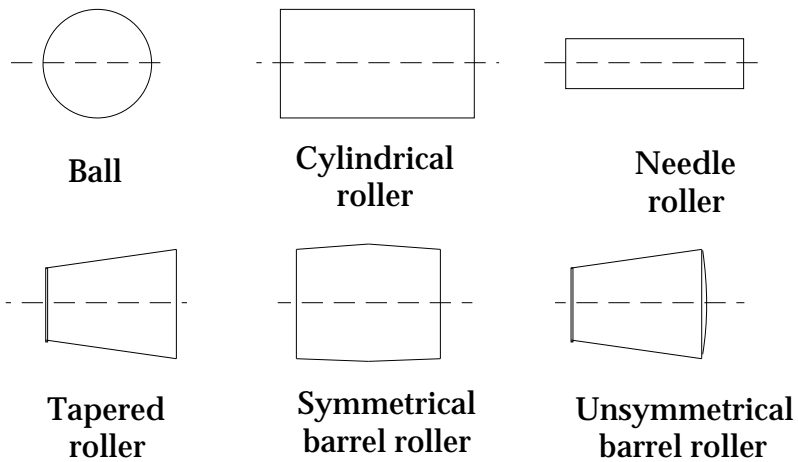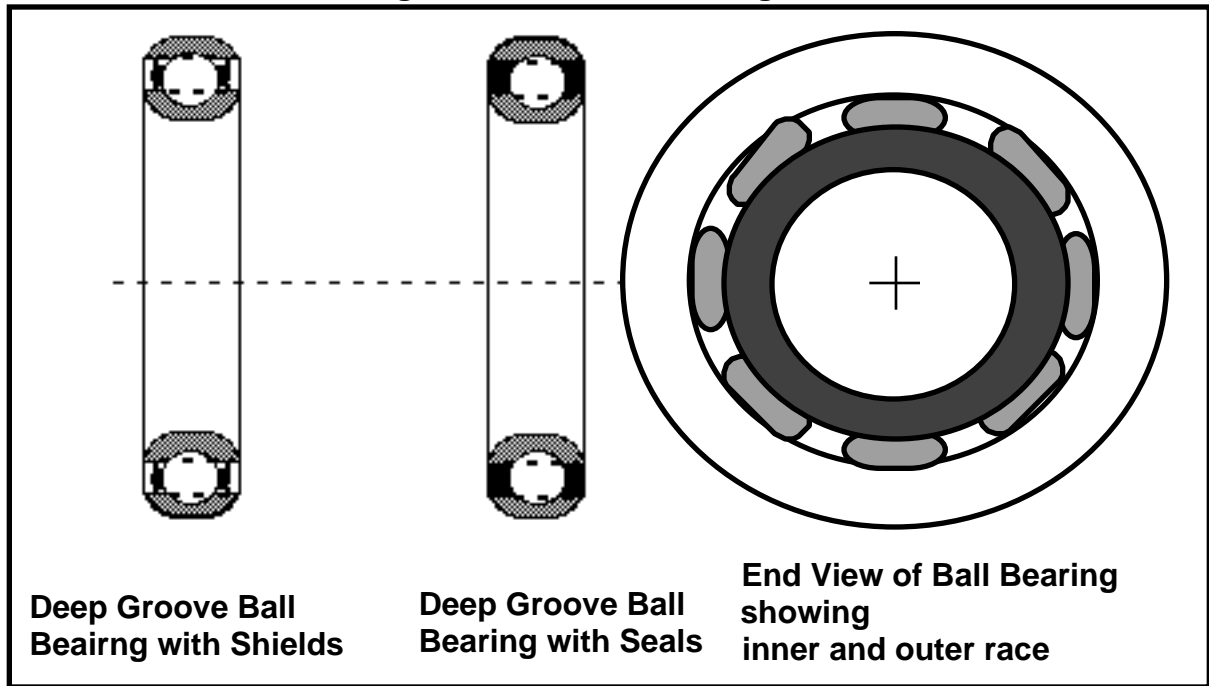**Figure 2.3B Types of Balls and Rollers**

Table 3. Bearing types

Type	description	typical values of coefficient of friction
Sliding, plain or journal bearing with boundary lubrication	direct sliding of load-carrying member on its support. Contact is continuous and extensive.	0.05 to 0.20
Sliding, plain or journal bearing with mixed boundary lubrication	surface peaks between sliding members are intermittently in contact and there is partial hydrodynamic support	0.004 to 0.10
Sliding, plain or journal bearing with hydrodynamic lubrication	surfaces are completely separated by the lubricant film. The load tending to bring the surfaces together is supported entirely by fluid pressure generated by relative motion of the surfaces. Good for applications that involve high rotational speeds.	0.002 to 0.010
Ball Bearings	Balls between moving members introduce rolling action (and rolling friction). Used at higher speeds than Roller bearings. Classified as (1) Radial (2) Thrust (3) Annular-contact See Figure 2.3A, 2.3B	much lower friction than plain bearings. Likely to be more costly. Often ordered from catalogues
Roller Bearings	Used at higher loads than ball bearings. Classified as (1) Radial (2) Thrust (3) Annular-contact See Figure 2.3B	Needle bearings are a special case of Roller bearings and are capable of very high loads.

Today, the bearing rings and rolling elements are produced worldwide predominantly from the through-hardenable chromium steel, but casehardening steel is also used. Special bearings designed for extreme operating conditions - load, speed, temperature, corrosion - are produced from tool steel, stainless steel, plastics, and from other materials.

QUESTIONS ON BEARINGS:

1. Sketch the bearings described above that involved the use of sticks with whittled down ends.

2. What sort of bearing is used in the drill that you are taking apart?

3. Not all of the bearings are labeled in Figure 1; where is the missing bearing?

3 Description of the electrical subsystem

In this section, we are going to discuss the power drill's electrical components. The electrical system consists of the motor, a switch(s), a cord or a set of batteries, and the necessary internal wiring.

It has been estimated that the average household contains more than 40 electric motors. They power the refrigerator, the washer and dryer, the vacuum cleaner, the record player; the pump that brings in water; hair dryers.

A motor is nothing more than a device that converts electrical current into rotary motion. As will be described in greater detail below, the basis of the motor is that opposite magnetic poles attract each other and like poles repel each other. A motor sets up a stationary magnetic field and another magnetic field that is free to rotate within it. The rotating magnetic field rotates in an attempt to line up its poles with the opposite pole of the stationary field.

Series wound universal motors are used for most power drills because of high torque ratings. These motors provide the required starting torque (i.e., they have the ability to start even when under considerable load). The rotational speed (in RPM) for a motor is determined by the load; the greater the required torque, the slower the rotational speed of the drill (recall Eqn (3) in the description of gear trains). Universal motors have enough torque to work under heavy loads at a slow operating speeds. The motor speed may also be varied with voltage. Incidentally, these motors operate using DC (direct current) or AC (alternating current) power sources.

3.1 BACKGROUND ON MAGNETISM

At this point, it is necessary to discuss the fundamental laws of magnetism and electro-magnetic induction; they provide the "action" of a motor.

Reference to a compass and the poles that are on a magnet will be made. The compass is thus an instrument that can give an indication of a magnetic field; for example, as created by the earth. The location on the magnet that points to the north and the other to the south are called the poles. If you have two magnets and place the south pole of each against each other, the magnets will repel each other. If the two north poles of the magnets are place together, they will try to repel each other also. But if a north pole is brought near a south pole of another magnet, or a south pole is brought near a north pole, the two unlike poles will attract each other. In other words, like poles repel each other, and unlike poles attract each other. This is shown schematically in Figure 3.1A.

In the early 18th century, Oersted observed that when a current carrying wire was held over a compass needle, the north end of the needle which represents the north pole was deflected. A wire placed under the compass caused the north end of the needle to be deflected in the opposite direction. What Oersted found was that an electric current produces a magnetic field. He had found a connection between electricity and magnetism; a compass needle which is placed near a straight section of wire aligns itself so it is tangent to a imaginary circle drawn around the wire.

The magnetic field lines B of the wire are in the form of circles drawn around the wire at the center. There is a simple rule to remember the direction of the magnetic field lines. It is called the right-hand rule; you grasp the wire with your right hand so that the thumb of your hand points in the direction of the conventional (positive) current; then your fingers will naturally encircle the wire in the direction of the magnetic field lines; if your hand does not follow this rule, you should orient your hand and wrist until the law is obeyed, remembering that your straightened thumb must point along the direction of the current. Check the rule out in Figure 3.1B.
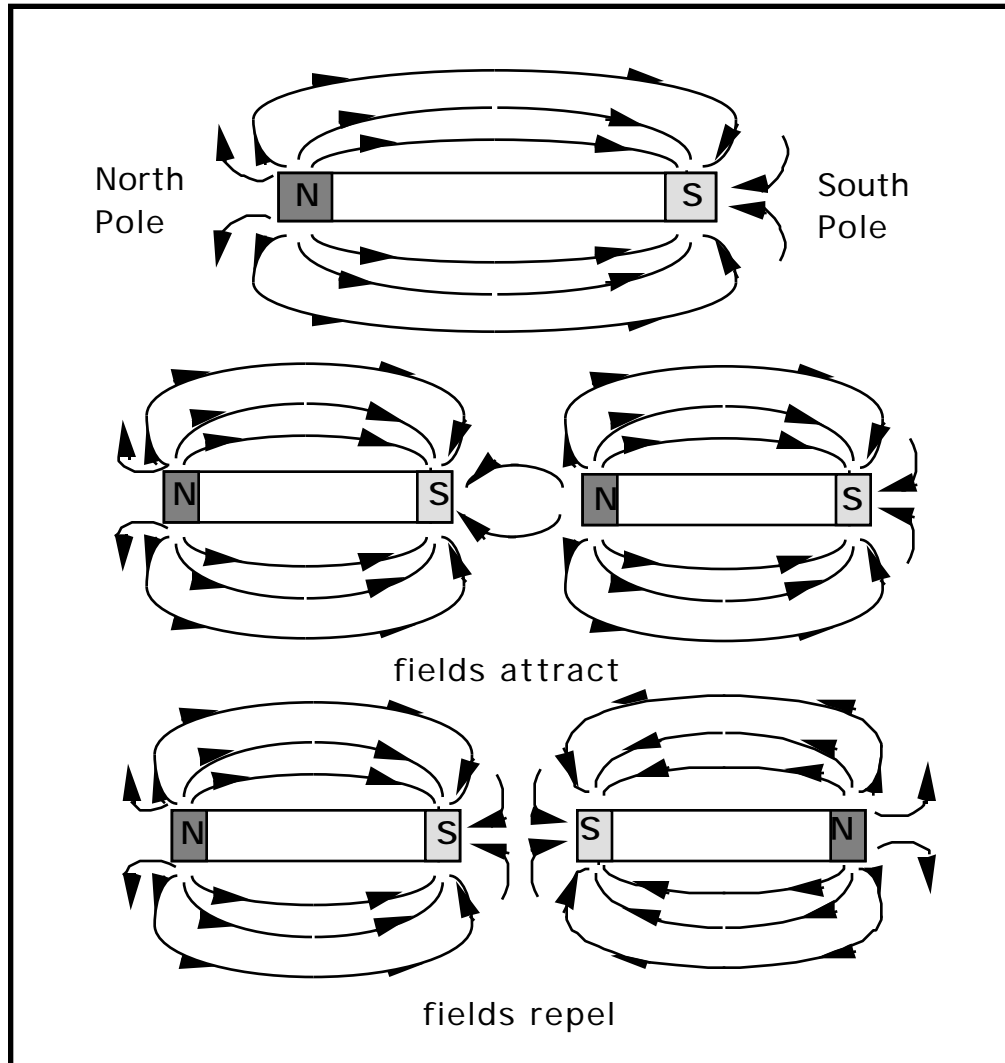
Figure 3.1A Principals behind magnets

North
Pole

N   S

South
Pole

fields attract

fields repel

**Figure 3.1B: current flow through a straight wire
(right hand rule)**
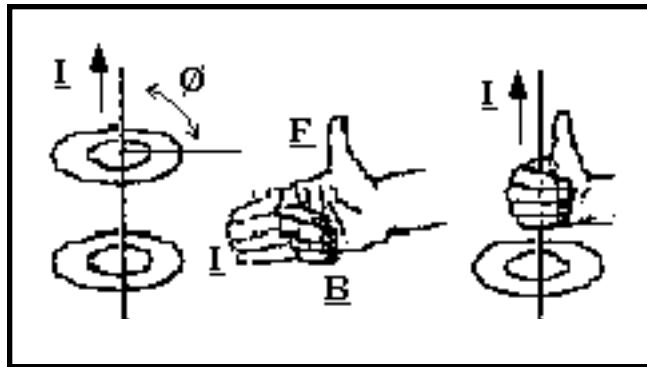
Figure 3.2A Magnetic Field created by current flowing through a straight wire.

Figure 3.2B Magnetic Field created by current flowing through a curved wire.
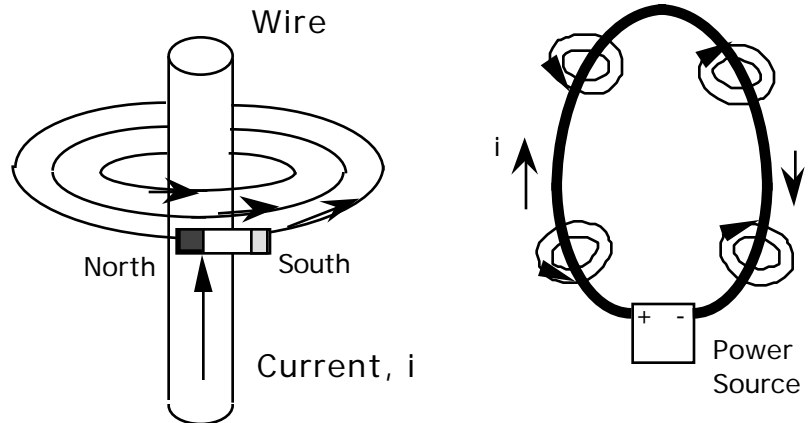
3.2 EXTENSION TO THE IDEA OF A MOTOR

Figures 3.2A and 3.2B show a magnet aligned with the magnetic field produced by straight and coiled current-carrying wires. Now imagine that the coil shown in Figure 3.2B is placed between the ends of two permanent magnets (see Figure 3.2C). With current flowing through the coil C1 as shown, there is a net torque (turning force) on the coil that is produced by the magnetic field B_{r1} (from the current carrying coil C1) attempting to align itself with the magnetic field B_s on the permanent magnet pair, as shown in Figure 3.2D. The

current travels from the power source (e.g., battery) through the brushers and through the commutator section associated with Coil C1.

Figure 3.2C **Direct Current (DC) Motor**

North Pole of Stator

Coil C1 of Rotor

Commutator

Carbon Brushes

Power Source

South Pole of Stator

B_{r1} B_{r1} C1

B_s

Direction of rotation

Axis of rotation

Figure 3.2D **Section through x-axis of DC Motor. Current flow through C1**

Figure 3.2E **Section through x-axis of DC Motor. Current flow through Coil C2, no current through C1.**

B_{r2} B_{r2} C2

B_s

Direction of rotation

Axis of rotation

Now imagine that there is not a single coil but a series of them (see Figure 3.2E) and that when B_{r1} aligns itself with B_s the current is redirected from C1 to C2 (the next coil in the coil series). The magnetic field B_{r2} created by current passing through C2 will cause it to move into alignment with field B_s.

Note that bruches are now aligned with C2 and not with C1 (i.e., there is current flow through C2, but not through C1). This sequential current re-distribution through coils C1, C2, etc. results in rotational motion of the coil configuration about the x-axis shown in Figure 3.2C. What we have just described is the basis of a **Direct Current Motor**. The coil configuration is referred to as the rotor or armature, and the stationary permanent magnet pair as the stator.

In a **Universal Motor** both the rotor and stator are created by electromagnetic effects. When current is allowed to flow through the stator pair (see Figure 3.2F), two electromagnetic fields with a south and north pole are set up. Also note that the current flows from the first stator to one of the carbon brushes, and then into one of the copper bars in the commutator that it rests against. The current flows from the copper bar through the coil around the rotor to the opposite copper bar, which rests against the other carbon brush. The current then goes through the second stator and back to the power source.

The stator coils are generating a magnetic field. As with the Direct Current Motor, the current traveling through the commutator bars and the rotor and generating an opposing magnetic field, which repels the field generated by the stator. The rotor tries to align itself with the stator's magnetic field by rotating slightly. But be doing so, the carbon brushes in the commutator are now in contact with two different copper bars. The current is removed from the original coils and is applied to a different set of coils. Once again, the two magnetic fields are in opposition. The result is that the rotor continues to rotate in a futile attempt to line itself up with the magnetic current of the stator.

Figure 3.2F: Universal Motor

Diagrammatic Layout of a Typical Motor

Stator Coil
Commutator
Stator Coil
Armature
Carbon Brush
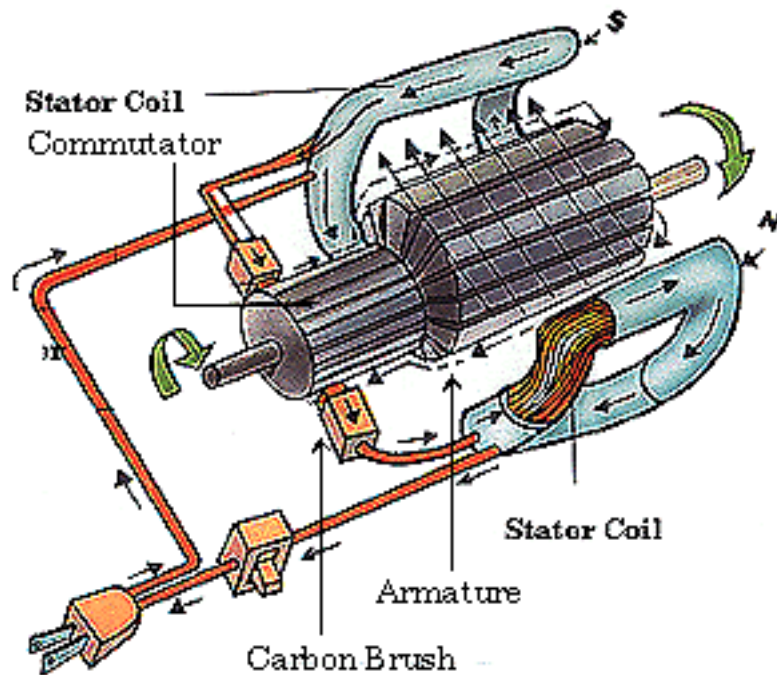
A few more notes on the commutator: the commutator, which consists of the copper conducting bars, is keyed to the shaft that spinns with the rotor. On each end of the shaft are bearings (see Section 2.3) to minimize friction.

BRUSHES (Part # 13):

At this point we must take a look at the brushes. The brushes carry the current from the external circuit through the commutator to the rotor. Brushes are usually a mixture of graphite and metallic powder. The brushes are designed to slide freely in their holders because the commutator is not even. The freedom of the brushes to move is required, to promote good contact. The proper pressure of the brushes against the commutator is maintained constant by the use of springs (see Figure 3.3A). The pressure on the brushes is usually about 1.5 to 2 pounds per square inch of contact area.

Figure 3.3A: brushes in motor
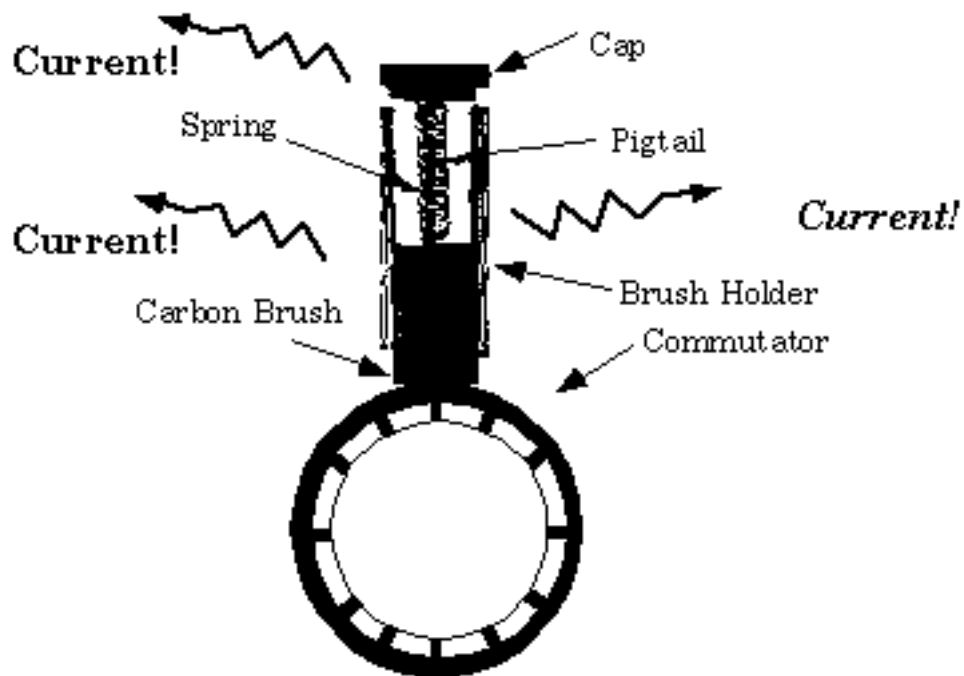
SWITCH (Part #12):

The Makita drill switch (see Figure 3.3B) has several important functions. The main function of this switch is to complete the circuit of the drill motor and allow current flow through the stators and rotor. The second feature of the switch is the ability to adjust the speed. The switch also has the capability to reverse the motion of the bit.

Note that not all drills use a single switch to accomplish all of these tasks.

Figure 3.3B Switch in the Makita Drill
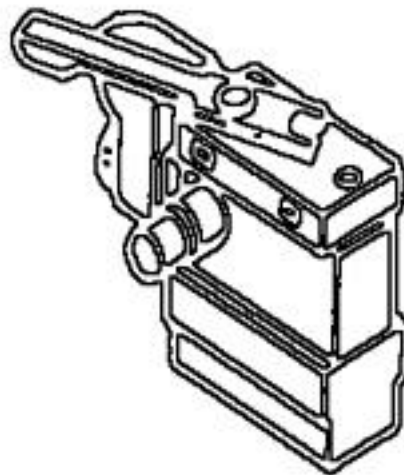
FAN (Part #10).

Though not strictly speaking an electrical component, many motors in appliances/hand tools are equipped with a fan. This fan cools the motor by dissipating heat. The heat is produced by current flowing through the wires of the rotor and stator and the fact that they have some electrical resistance. Resistive heating (in units of watts) is equal to the (I^2R), where I is the current in amperes, and R is the electrical resistance of the conducting wire in ohms.

Electrical components questions:

1. How is a Safety switch implemented?

2. Why would one want the capacity to run the drill in reverse?

4   DRILLING

Bits (Part #1):

Drilling involves using a drill bit to make a hole of accurate size. A power hand drill is one of the various tools to power the bit.

Types:

Drill bits are of various types, some of which are used to drill a hole in metal, some in wood, some in cement, etc. A few types of metal drill bits, countersinks, spot facers etc. are shown in Figure 4.1A.

Figure 4.1A Examples of types of drill bits

Drill Bit, Round Shank

Drill Bit, Square Shank

Countersink

Counterbore or Spot Facer
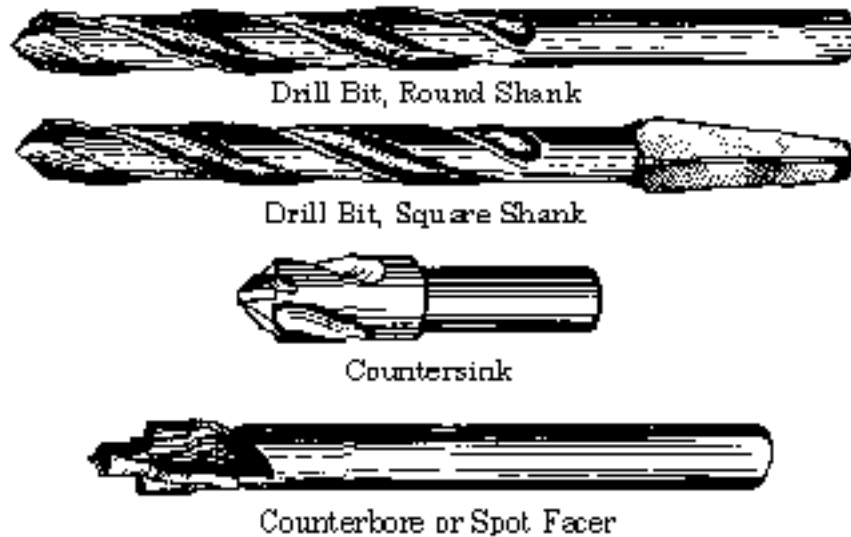
Examples Of Different Types Of Drill Bits
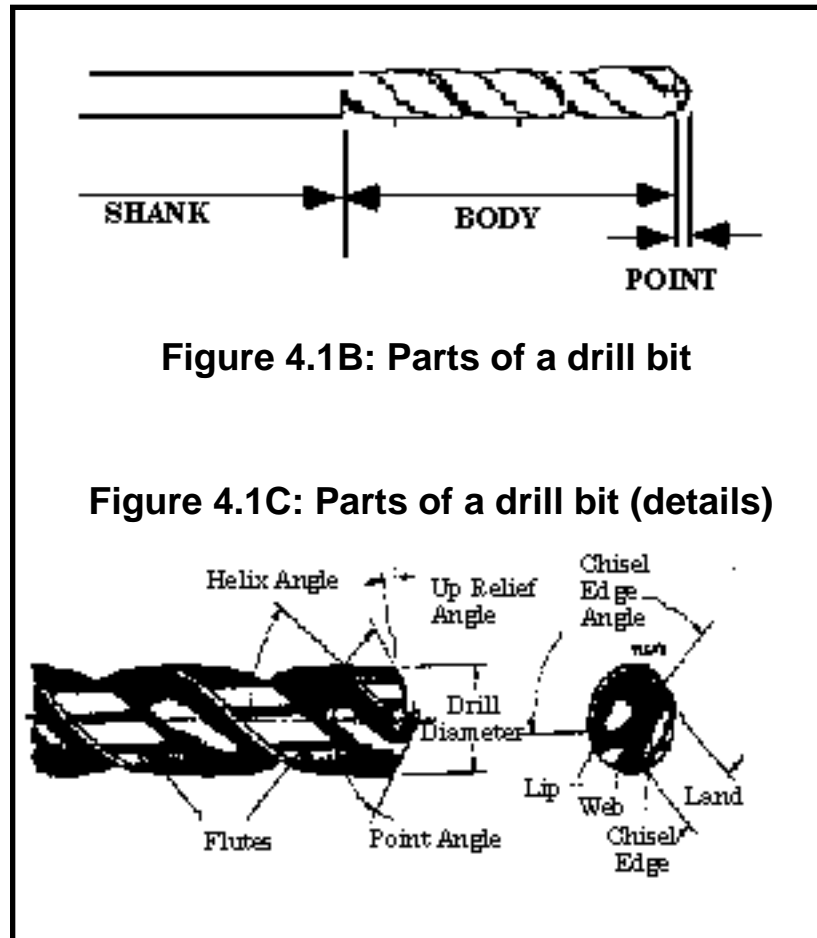
Figure 4.1B: Parts of a drill bit

Figure 4.1C: Parts of a drill bit (details)

<u>**Sizes:**</u>

The size of a drill bit is stamped on the shank of the bit (see Figure 4.1B). Drill bits come in sizes of fractions of an inch as well as sizes designated by letters designating specific sizes. This method of sizing a drill bit is used so that "in between" sizes of fractional drill bits can be made and used without confusing the user. For example, a 0.375 is a 3/8 in. drill bit, but a 0.377 drill bit would be designated by a letter, V. Various handbooks and tables are available to give the user the letter drill bit size to use for a specific size of hole.

Number drill bits are designed and made in sizes which coincide with the sizes of wire gage. For example, a No. 21 drill bit is exactly the size of a piece of

No. 21 wire. Table 5 shows the correct number of the wire drill bit to use to tap a hole to any certain size.

Care of Drill Bits:

Since the sharpness of a drill bit determines how well the bit will cut, as well as how close to the desired hole size the bit will produce, it is obvious that good care must be taken of the bit. After a drilling operation has been performed, it is good practice to dip the bit in oil and then wipe it dry. This cools the bit and cleans the flutes (see Figure 4.1C) and cutting edges. Particular care must be taken of the shank of the bit; as this is the end which is chucked in the chuck of the powering tools. If the shank is "roughed up" or scarred, the jaws in the chuck will not grasp it firmly; as a result the bit will not run true or straight. Therefore, the user should keep the bit end and shank end in good condition at all times.

Naturally, a drill bit will become dull in time and must be sharpened.

Use of drill bit:

While there is no uniform method of drilling, a few principles govern the "art" of drilling. These are as follows:

1. The drill bit will always cut a hole slightly larger than the size of the bit. The user must remember this at all times when selecting the correct size of bit to use.

2. The drill bit must be sharp and chucked straight in the drill holder or chuck.

3. The drill bit must contact the material at right angles to produce a good hole. There is one exception to this rule, that is when the job calls for a diagonal hole. Special setups are required for this type of work.

4. The pressure applied to the bit to make it cut must be uniform, but not enough to bend the drill bit and cause an "egged" hole.

5. The feed and speed must be correct for the material to be drilled.

6. The bit must be lubricated from time to time to cool it and to carry away the chips.

Table 4: Drill bit designations

Letter Sizes	Drill diameter (inch)	Letter Sizes	Drill diameter (inch)	Letter Sizes	Drill diameter (inch)
A	0.234	J	0.277	S	0.348
B	0.238	K	0.281	T	0.358
C	0.242	L	0.290	U	0.368
D	0.246	M	0.295	V	0.377
E	0.250	N	0.302	W	0.386
F	0.257	O	0.316	X	0.397
G	0.261	P	0.323	Y	0.404
H	0.266	Q	0.332	Z	0.413
I	0.272	R	0.339		

Table 5: Wire Gage Size and Corresponding Drill Diameters

Wire Gage Sizes	Drill diameter (inch)	Wire Gage Sizes	Drill diameter (inch)	Wire Gage Sizes	Drill diameter (inch)
1	0.2280	28	0.1405	55	0.0520
2	0.2210	29	0.1360	56	0.0465
3	0.2130	30	0.1285	57	0.0430
4	0.2090	31	0.1200	58	0.0420
5	0.2055	32	0.1160	59	0.0410
6	0.2040	33	0.1130	60	0.0400
7	0.2010	34	0.1110	61	0.0390
8	0.1990	35	0.1100	62	0.0380
9	0.1960	36	0.1065	63	0.0370
10	0.1935	37	0.1040	64	0.0360
11	0.1910	38	0.1015	65	0.0350
12	0.1890	39	0.0995	66	0.0330
13	0.1850	40	0.0980	67	0.0320
14	0.1820	41	0.0960	68	0.0310
15	0.1800	42	0.0935	69	0.0292
16	0.1770	43	0.0890	70	0.0280
17	0.1730	44	0.0860	71	0.0260
18	0.1695	45	0.0820	72	0.0250
19	0.1660	46	0.0810	73	0.0240
20	0.1610	47	0.0785	74	0.0225
21	0.1590	48	0.0760	75	0.0210
22	0.1570	49	0.0730	76	0.0200
23	0.1540	50	0.0700	77	0.0180
24	0.1520	51	0.0670	78	0.0160
25	0.1495	52	0.0635	79	0.0145
26	0.1470	53	0.0595	80	0.0135
27	0.1440	54	0.0550		

References:

1. 'The Repaired Service for Small Appliances' by George R. Drake Reston Publishing Company, Inc (c) 1977.

2. 'Small Appliances Servicing Guide' by Robert Scharff McGraw - Hill, Inc (c) 1976.

3. 'Electric Motors' by Edwin P. Anderson & Rex Miller Macmillon Publishing Company, 4th Edition.

4. 'Ball and Roller Bearings Theory, Design & Applications' by Eschmann Hasbargen Weigaud & R. Oldenbourg Verlag Miinchen Wien, John Wiley & Sons (c) 1985.

5. 'Rolling Bearings' by R. K. Allen, 3rd Edition, Sir Issac Pitman & Sons LTD (c) 1964.

6. 'Rolling Bearing Analysis' by Tedric A. Harris, J. Wiley, (c) 1991.

7. 'Fundamentals of Machine Component Design' by Robert Juvinall and Kurt Marshek, J. Wiley, Second Edition, 1991.

8. 'The Way Things Work' by David Macaulay, ` Houghton Mifflin Company, 1988.

9. 'How Things Work' by the Editors of Consumers Guide, Publishers International, 1990.

Sample Quiz Questions:

Answer the following questions:

1)   What is a chuck and what is its use in the drill?

2)   Write down the function of gear (part # 3) and what is its use in hand drill?

3)   What tools would you use in drill dissection?

4)   What are the different types of ball bearings used in the hand drill?   What type of motion is involved and write down its advantages and disadvantages?

5)   Explain the working of an electric motor? What are the factors governing the speed of a motor?

6)   What are the use of brushes in an electric hand drill?

7)   What precautions would you take in buying a drill bit?

8)   Write down five artifacts (according to your priority) that can be used in this lab.

9)

(i) Tooth proportion in a gear is established by

(a) addendum (b) dedendum

(c) working depth (d) all (a, b & c)

(ii) The speed of the motor is determined by

(a) revolutions per minute (b) Torque

(c) load (d) moment

(iii) Who found the connection between electricity and magnetism

(a) Newton (b) Fleming's

(c) Oerested (d) Einstein

(iv) The part that rectifies the generated alternating current to direct current is

(a) field winding (b) brushes

(c) commutator (d) armature

(v) The main function of the switch is to

(a) adjust the speed (b) reverse the direction of rotation of the bit

(c) complete the circuit of the drill motor

(vi) Which part of the drill bit goes inside the chuck

(a) shank (b) body

(c) point (d) all (a, b &c)

(vii) Write two principles that govern the art of drilling?

(viii) How do you rate the offering of a class in mechanical dissection at the freshmen or sophomore level

(a) Low (b) Average (c) High

(ix) How do you rate what you learned about the drill which you were not aware of it before (especially the function)

(a) Good (b) Average (c) Not enough

(x) How many people should be in each group

(a) 10-12 (b) 6-8 (c) 4-6