Solenoids

- A **solenoid** is a simple electromagnetic device that converts electrical energy directly into linear mechanical motion, but it has a very short **stroke** (length of movement), which limits its applications.
- consists of a coil of wire with an iron plunger that is allowed to move through the center of the coil.
- at unenergized state, the plunger is being held about halfway out of the coil by a spring. When the coil is energized [Figure 3.21(b)], the resulting magnetic field pulls the plunger to the middle of the coil.
- The magnetic force is unidirectional—a spring is required to return the plunger to its unenergized position.
- The main limitation of the solenoid is its short stroke, which is usually under an inch.
- Examples:
  - Activating electric car-door locks,
  - opening and closing valves, and
  - triggering mechanical latches.

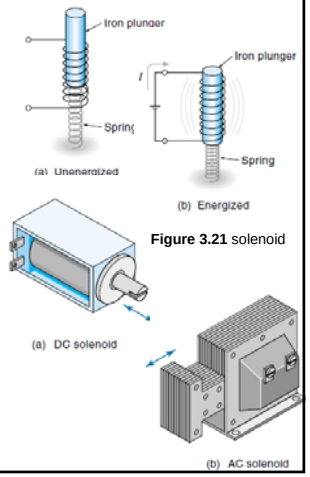

Figure 3.21 solenoid

Solenoids

- Most applications use the solenoid as a on or off device—that is, the coil is either completely energized or switched off.
- However, variable-position control is possible by varying the input voltage.
- Both AC and DC solenoids are used,
- the major difference being that AC solenoids use a plunger and frame made from laminations instead of solid iron.
- **Laminations** are thin sheets of lacquered iron that are riveted together to form the frame and plunger.
  - Laminations prevent power-consuming *eddy currents* (induced by the AC) from circulating in the metal parts of the solenoid.

Electric Linear Motors

- One of the newer types of linear actuators is the electric linear motor.
- Basically, a **linear motor** is a rotary brushless DC motor (BLDC) that has been rolled out flat.
- Linear motors convert electric power directly into linear motion.
- They are capable of high speed (up to 10 m/s), high force (over 1000 lb) and long travel (several meters), and, like a BLDC, they have no sliding contacts but do require an electronic dr
- A linear motor consists of two parts:
  - the base unit known as the *magnet way*, which consists of an iron plate with a row of alternate-pole permanent magnets, and
  - the moving part known as the *slider*, which contains the coils.
- The slider is supported on linear ball bearings so that it can slide along over the magnet way (there is a small air gap between them). A flexible cable connects the slider to the drive unit.

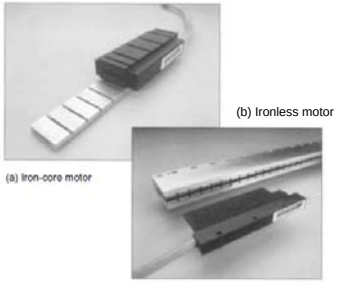

Figure 3.22 Electric linear motors.

Electric Linear Motors

- Figure 3.23 illustrates the operation of a simplified three-phase linear motor.
- Note that there are three coils spaced over four magnets.

(a), coil A is switched on, causing it to become a north pole (N).

  - The attractive force between this N pole and the nearest S pole on the magnet way causes the slider to move to the right.
- When the slider has moved to the position shown in (b), coil A is switched off and coil B is switched on, causing renewed attractive force to the right, and the slider moves further (to the right).
- When the slider gets to position (c), coil B is switched off and coil C is switched on, causing the slider to move to position (d).
- The coils have now advanced one full cycle. They are now back to the same orientation as in (a), and the whole sequence starts over.

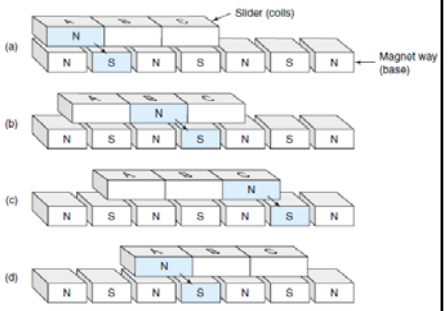

Figure 3.23 Operation of a simplified three phase linear motor.

Electric Linear Motors

- There are two basic designs for linear motors, the *iron-core linear motor* and the
- *ironless linear motor,* as shown in Figure 3.22.
- Iron-core motors (the subject of the preceding paragraphs) are more powerful because they have coils wound on steel laminations to maximize their magnetic force.
  - However, in addition to the linear force, they also generate a strong attractive force between the slider and the magnet way.
  - This attractive force is typically four times the linear force, so a motor pulling with 100 lb is pushing down on the magnet way with 400 lbs.
- Ironless linear motor has no iron at all in the slider, just copper wires embedded in an epoxy strip.
  - These motors are inherently weaker, even when two sets of magnets are used in the magnet way, but they have small mass (for quicker acceleration), no cogging, and no attractive forces.

- Linear motors are almost always used in a closed-loop system, which means they need some kind of linear position sensor.
- In some cases, the linear motor uses the position sensor data for electronic commutation, eliminating the need for Hall-effect sensors.