

## 2.007 Advanced Actuator Information

[The DC Motor](#) | [The Solenoid](#) | [The Pneumatic Piston](#) | [The Pneumatic Rotary Actuator](#)

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### The DC Motor

A DC motor is constructed by placing a loop of wire in a magnetic field as shown below. By then sending current through that wire a force normal to the magnetic field is produced. In a DC motor this wire is on a axle and thus the normal force causes the wire to rotate.

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The force created on the wire is proportional to the area of the loop projected on a plane perpendicular to the magnetic lines of force. Therefore, one can see that when the loop is parallel to the magnetic field, there is no force created on it, and when the wire loop is perpendicular with the field, the maximum force is created on it. Note that as the rotor turns the wire, it now enters the field from the opposite side and now the force created will rotate the wire back in the opposite direction. Also, note that the loop of wire is rotating while the power supply is not, so we must devise a system to send power to a rotating shaft. One common solution is to attach a brush to each end of the wire and the brush makes contact with a ring (or commutator) as it rotates. To alleviate the reversing force problem, we could either reverse the magnetic field or reverse the current direction. To reverse the current, we can make a split commutator. This is simply a ring cut in half and separated by an electrical insulator so that one side is the supply and the other ground. Do this to both commutators and now you have a mechanical switch that reverses the current in the wire. Now our motor will spin! But its torque output is sinusoidal (No torque at  $0^\circ$  and  $180^\circ$  and maximum torque at  $90^\circ$  and  $270^\circ$ ). To alleviate this problem we simply place another loop perpendicular to the first. Now the torque output is two overlapping sinusoids out of phase by  $90^\circ$ . Typically, most DC motors have at least 3 loops spaced equally about the shaft. To increase the torque the motor can produce, you can increase the number of loops, increase the voltage or increase the current. The engineers who design these motors must worry about a host of design issues and tradeoffs including: motor size, rotor inertia, number of loops, number of windings, wire size, wire insulation, heat buildup, brush switching, brush life, material selection and many other issues not to forget all the different types of motors: DC permanent magnet motors(explained above), brushless DC motors, or wound field motors(not very common anymore). For this, your first design exercise, your motors have already been designed, built and chosen for you.

If a voltage is applied across the leads of a DC motor it will produce torque. If the shaft is made to rotate by some external force, the same motor can be used as a generator.

When a motor is driven by electrical power it also acts a bit like a generator. This internally generated voltage reduces the ideal output of the motor according to the equation.

$$E = k \omega$$

$$V = E + IR$$

$$\omega = k \frac{V}{R}$$

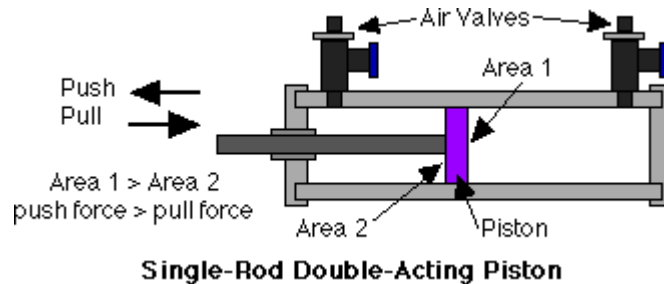
# The Solenoid

A solenoid is constructed by wrapping wire in a coil and energizing it. If a ferrous object is in this field it will be pulled towards the center of the coil. The force applied by a solenoid is approximately proportional to the square of the current and the square of the number of windings in the coil. For the contest, you cannot do anything to change the number of coils in the plunger and thus the only thing you can adjust is the current. You cannot do anything to increase the current in the solenoid, but you can decrease the current and thus the force of the solenoid. To do this, simply wire the solenoid in parallel with some other electrical resistance such as a motor.

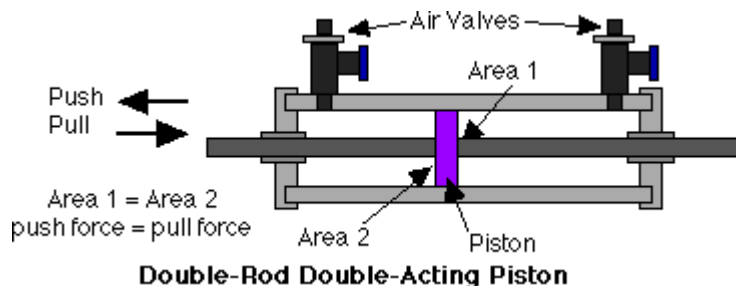
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# The Pneumatic Cylinder

The pneumatic cylinder in your kit is more properly called a single-rod double-acting compressed air actuator. For obvious reasons, the full name is often shortened. There are a great variety of pneumatic linear actuators of which the single-rod double-acting is the most commonly used in industry. Some other types are shown below.



The single-rod double-acting actuator has a more powerful push than the pull force.



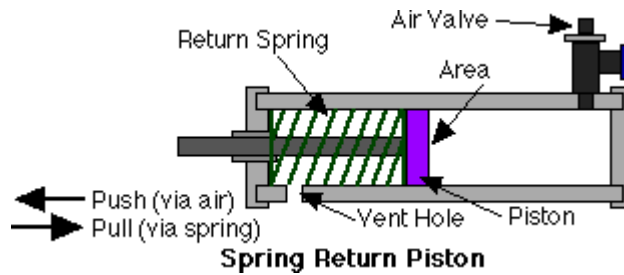
The double-rod double-acting actuator has equal push and pull forces and can be used to simultaneously pull and push.

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The rodless double-acting actuator has equal push and pull forces that for the same bore is higher than the double rod type. As the internal piston moves, it drives the external slide as it moves in a zip lock fashion. Other cylinders use magnetic coupling to eliminate the sealing problems but are limited in force transmission capacity.

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The double-acting cable air actuator has a cable tied to an external slide. The cable wraps around a pulley at each end of the piston.



The spring-return (or extend) single-acting actuator. This cylinder uses a spring force to move the piston in one direction. When pressurized, the air pressure overcomes the force of the spring and compresses it. One must be sure to allow air to escape from the end with the spring lest you compress the air inside and in effect make a much stiffer spring.

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The ram actuator is one of the simplest actuators and requires an external force to push it back.

To use the cylinders as dampers, you should connect one flow control to the other with a short section of tube. Use the flow controls to adjust the damping. (The smaller the opening, the more damping you will get.) A rotary damper can also be made in this way. An excellent use for a damper would be to smooth out the jerky motion created when driving a mechanism with the on/off controls.

Both actuator types can also be used to provide a spring force. You can close off one side of the actuator by simply turning the flow control all the way down. If this does not seal well enough for you, you can try finding a bolt with the same threading as the flow controls, and applying a very small amount of grease or Vaseline to the threads. Either way you will notice if you try to compress the air, a much higher force is needed than if you create a partial vacuum. You can easily calculate the force generated in either situation. With one side open the pressure is known: atmospheric. If you are compressing air, the other side starts at atmospheric and increases in pressure as the volume is decreased according to:

$$P_1V_1 = P_2V_2$$

If the piston is held at mid-stroke, the volume is half the stroke of the cylinder multiplied by the effective area of the piston. If the piston is compressed \_" the volume is decreased by CONTINUE ME>>>

To construct your own pneumatic cylinder, you need to create a smooth hollow cylinder and a tight-fitting piston. You could create a short stroke, large bore piston by using the following steps:

1. Measure the diameter of ~1" diameter Delrin stock using a caliper. It should be slightly oversize.
2. Bore a 1" diameter hole in the 2" diameter Delrin stock but do not go all the way through the part. Use an undersized drill 63/64" to get close, then use a 1" reamer to get the bore to 1" ± .001". Measure the hole size with a calipers.
3. Place the 1" Delrin rod in the lathe and using a sharp tool, turn the diameter to .001" less than the measured hole you just drilled.
4. Try to slide the two parts together. If they stick, try chamfering both edges slightly. If they still stick, try adding some lubricant. If this does not work, remove a little more material with the lathe.
5. Add some Vaseline or other viscous grease to the Delrin rod and add a hole to the base of the newly created ram actuator for the air inlet. Seal the tube into the hole.

This actuator could obviously be made using a different size bore and if it is to be used repetitively,

you need to have some external force push the ram back. This could also be used to fire a projectile, and would be especially powerful if pressure was allowed to build up. (See Chapter 8, Mechanisms.)

You may also find that the Vaseline (or other lubricant) is rubbing off and you are losing your seal. There are two solutions to this problem. You could make an O-ring with the Buna-N cord and cut a groove in the Delrin ram. (A double seal is even better, but each seal you add increases the friction the piston must overcome to move.) The other solution would be to create a small reservoir and have the pressure of the air force the lubricant out. Both solutions are shown below.

## The Pneumatic Rotary Actuator

The rotary vane actuator is one of the ways to make pneumatic elements apply torque. A single vane actuator (the type provided in the kit) is shown below with the top removed so you can see how it is constructed. As you can see, single vane actuators are limited in rotation and most do not exceed 315°. Vane actuators are made with different rotation angles, the most common are: 90°, 180°, 270° and 315°. There are other ways to convert pneumatic pressure into rotational motion and these are also shown below.

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The single-vane actuator is limited to rotation angles up to about 315°

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The double-vane actuator has twice the torque of a similar sized single vane actuator but is limited to angles less than 140°.

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A rack and pinion system directly coupled to a linear pneumatic can provide multiple revolutions determined by the stroke and gear sizing.

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Another unique solution uses a continuous toothed belt and a drive wheel. The pressure acts on the belt and the edges of the belt seal against the side of the chamber.

MORE STUFF HERE...