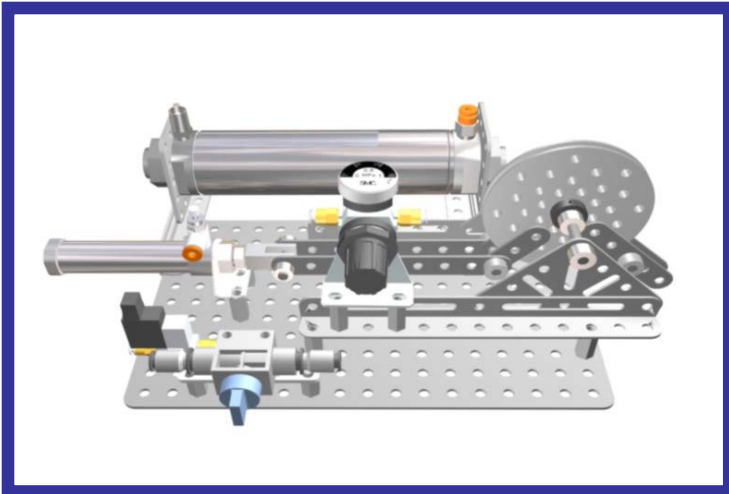




# Build a Pneumatic Test Module

**Build and use the Pneumatic Test Module to Explore These Engineering Principles:**



## DESIGN/BUILD/TEST/PLAY

Use The **GEARS-IDS™** Invention and Design System to create **Radio Controlled Game Playing Machines** (*designed and built by students*). Students and teachers can create exciting engineering challenges similar to those played at major engineering colleges and on TV!

Students and teachers who participate in these 4 activities learn the necessary math, science and principals of engineering they need to create competitive machines.

- **Learn to build a Drive Train and Chassis**
- **Learn to build a Pneumatics Test Stand**
- **Learn to configure a Control System**
- **Learn to design and build Electro-Mechanical game playing machines.**

Basic Physics, Mathematical reasoning and the iterative process of experimenting, building, modifying and playing with ideas are the skills needed to successfully complete the challenge.

### Pneumatic Principles

- **Pneumatic Safety**
- The Operation of Pneumatic Components
- Building a Pneumatic Circuit

### Science and Engineering Principles

- Force and Torque
- Work and Power
- Levers, Wheels and Axles
- Piston Force and Pressure
- Pressure and Boyle's Law
- Air Storage Capacity and Flow

### Design Principles

- Subassemblies and Components
- Linkages and Power Transfer
- Rigidity and Structures
- Threaded Fasteners

### Mathematics

- How to Create and Use Basic Mathematical Models to Evaluate and predict Component Performance
- Using Spread Sheets to Assess Performance
- Algebraic and Geometric Manipulations

### History of Science and Technology

- Physicists, Chemists and Philosophers that contributed to the science of Pneumatics.

### Personal and Interpersonal Skills

- Organization, Order and Teamwork
- Allocate Resources

NOTE: **Integrate the Pneumatic Test Stand with a mobile chassis and play a variety of mechanized Games.**

**Performance Tip.** Before beginning any project, it helps to have a sense of what the beginning, middle and end of the project looks like. For **Best Results Read the Entire Document Before Beginning**

**The test module can**

**be built in under 1 hour by a team of 2-3 people. Each team member can build 1 or more of the subassemblies from which the test stand is constructed. Each person in the group should participate in the activities listed below.**

**Performance Tip.** Engineering is a team sport. Be an engineering MVP. **Accept and commit to completing specific responsibilities.**

- 1. Obtain and organize the Tools and Materials** (*Listed below*)
- 2. Build one or more of the subassemblies** (*Illustrated in this document*)
- 3. Integrate the subassemblies into a working module**
- 4. Collect, organize and carefully store the Materials Tools and Equipment at the appropriate times.**

## Tools

Safety Glasses

2-3 Phillips Head Screwdrivers

5/16" Combination Wrench (*For the Stand Offs*)

3/8" Combination Wrench

6" Needle Nose Pliers

Tubing Shears or Sharp Shop Scissors

Hack Saw (*For Cutting Axles*)

Allen Wrench or Hex Key Set

Dial Calipers and Tape Measures

9/16" Combination Wrench (*For Pneumatic Cylinder*)

Bicycle Tire Pump with an integral gauge to pressurize the system.

Wire Strippers

Wire Nuts or Solderless Connectors

On/Off Electrical Switch and 12V Battery

## Pneumatics, Structural Components and Hardware

### Structural Components

- 1 6x9 Flat Plate GIDS-SC-10002
- 2 13 Hole Angles GIDS-SC-10006
- 2 7 Hole Angles GIDS-SC-10007
- 2 9 Hole Flat Bars GIDS-SC-10001-9
- 2 3 Hole Flat Bars GIDS-SC-10001-3
- 2 5 Hole Flat Bars GIDS-SC-10001-5
- 2 Sine Triangles GIDS-SC-10005
- 2 M15 Motor Mounts GIDS-SC-10009
- 1 3" Hex Wheel GIDS-SC-10014
- 2 1-3/8" x 3/16 Axles GIDS-SC-10018  
Note: Axles need to be cut; Use a hacksaw
- 1 3" x 3/16" axle GIDS-SC-100018
- 1 Servo Bracket GIDS-SC-10017

### Pneumatics

- 1 16mm Cylinder GIDS-PC-10001
- 1 Storage Reservoir GIDS-SC-10002
- 1 Regulator GIDS-SC-10003
- 1 On/Off Purge Valve GIDS-SC-10004
- 1 Solenoid Valve GIDS-SC-10006
- 3' 4mm Tubing

### Hardware

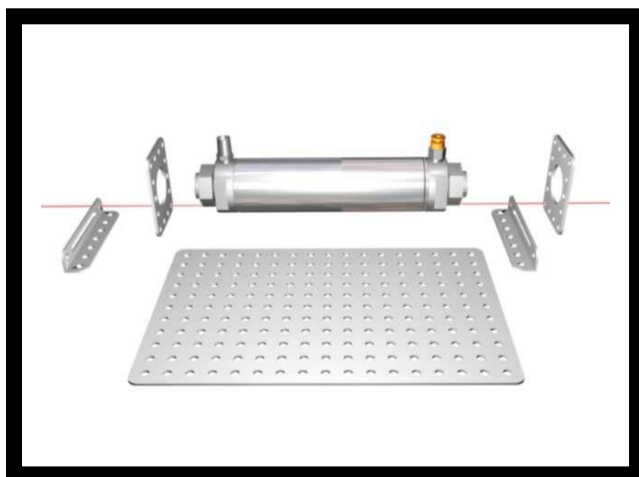
- 10 #10-24 x 3/4" Stand Offs GIDS-SC-10015
- 40+/- #10-24 x 3/8" PH Machine Screws
- 6 #10-24 x 3/4 PH Machine Screws
- 20+/- #10 Nuts and Lock washers

**Performance Tip.** Go to [www.gearseds.com](http://www.gearseds.com) to download a complete catalog and description of GEARS-IDS™ Invention and Design System components.

## Construct These Subassemblies

1. Base Plate, Support Structure and Storage Reservoir
2. Wheel and Axle Assembly
3. Pneumatic Cylinder and Linkage
4. Pneumatic On/Off/Purge Valve Assembly
5. Pneumatic Components
6. Electrical Switch and Circuit

### Subassembly 1: Base Plate, Support Structure and Storage Reservoir

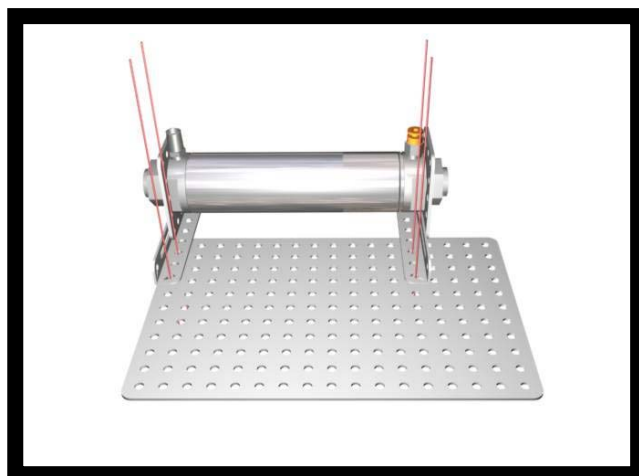


#### Step 1

Assemble 2 support brackets using two M15 motor mounts and two 7 hole angles.

Attach the M15 mounts to the Pneumatic Storage Reservoir as Shown.

Use two #10-24 x 3/8" Machine screws, nuts and star lock washers to attach the M15 mounts to the 7 hole angles.



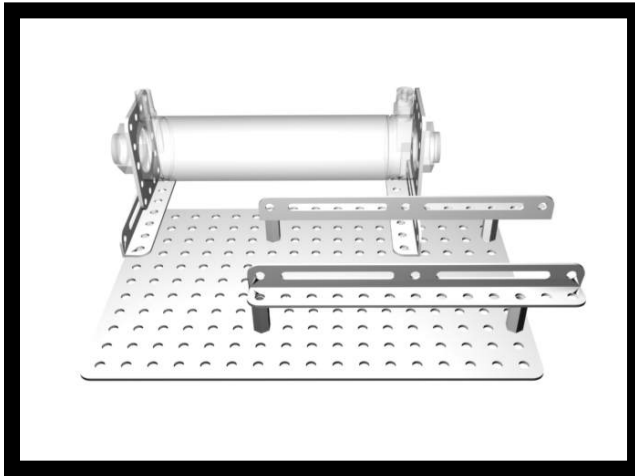
#### Step 2

Mount the storage reservoir to the 6x9" base plate as illustrated

Use four #10-24 x 3/8" Machine screws, nuts and star lock washers to attach the components.

# Subassembly 1: Base Plate, Support Structure and Storage Reservoir

Continued



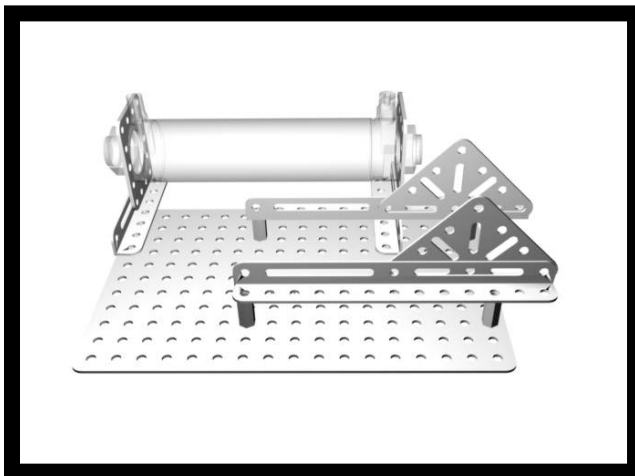
## Step 3

Mount 2, 13 hole angles and stand offs to the 6x9" Base Plate as shown.

Use #10-24 x 3/8" machine screws only.

Note: Machine screws longer than 3/8" will be too long and will not tighten in the standoffs.

Hint: Locate the components by counting the holes. Be certain to position and align the components exactly as shown



## Step 4

Mount 2 sine triangles to the inside face of the 13 hole angles as illustrated.

Use #10-24 x 3/8" Machine screws, nuts and star lock washers

## Think About This

The storage reservoir acts like a pneumatic battery. The pressurized air (Energy) contained in the storage reservoir is a finite resource. Young engineers, who accept the challenge of designing and building an Electro-Mechanical Athlete, are challenged to make optimal use of this finite resource.

### Knowledge and Information are Advantages in Engineering Competitions

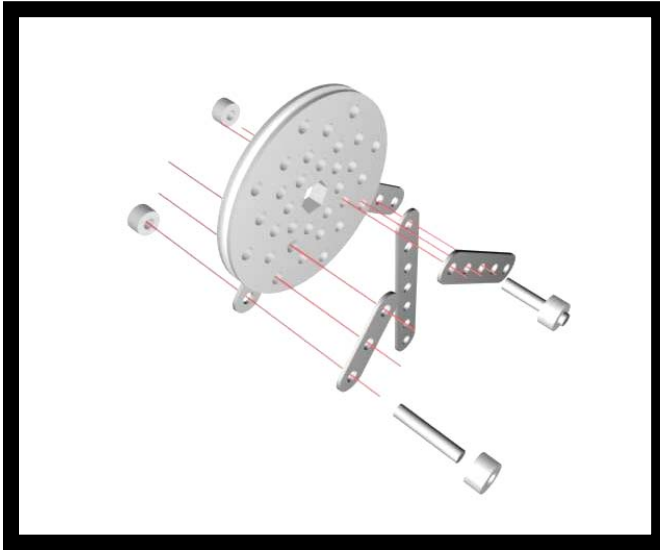
The amount of air contained in the reservoir is an engineering constraint placed on every competing group. The ability to use finite resources to advantage depends in part on how much can be known about the resource. Some important engineering question might be:

**What force can the pneumatic cylinder produce?**

**What effect does pressure have on the forces produced by the cylinder?**

**How many times can the pneumatic cylinder operate at a give pressure?**

## Subassembly 2: Wheel and Axle Assembly



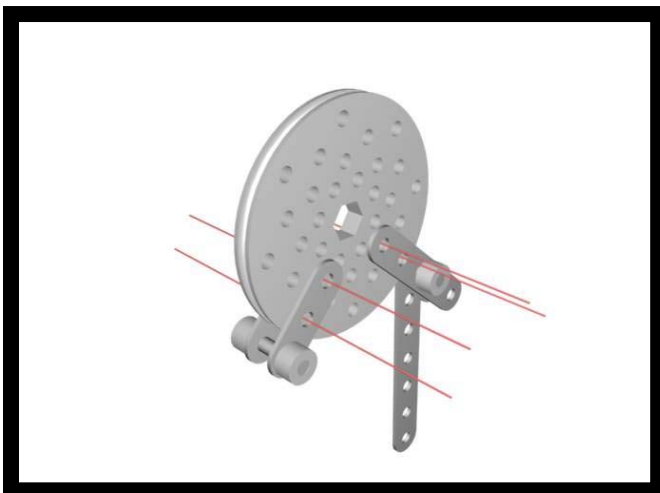
### Step 1

Attach two, 3 hole flat bar pieces to the 3" Aluminum Hex wheel as shown.

Attach two, 5 hole flat bar pieces as shown

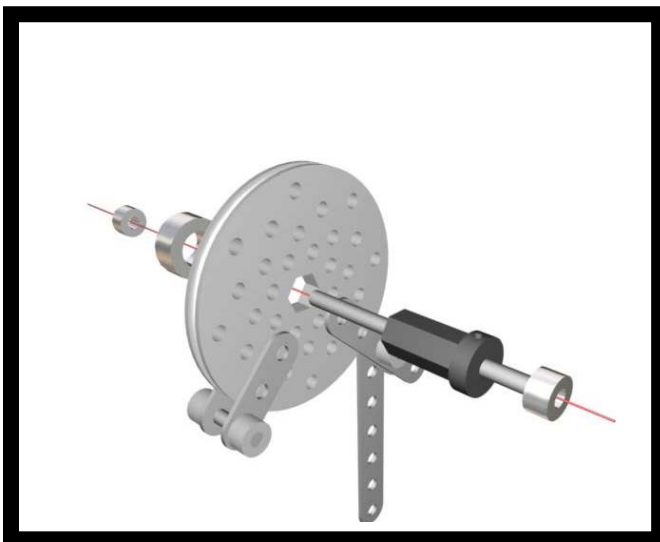
Attach a 1-3/8" long axle and shaft collars to the 3 hole flat bars.

**Additional Option:** Attach one, 7 hole flat bar piece between the 2, 5 hole flat bars. This makes an improved connector for attaching weights. This is not necessary. Use a #10-24 x 3/4" machine screw instead of the shaft and shaft collars shown.



**This picture shows the completed Assembly.**

Mount the flat bars using the hole spacing and locations shown.



### Step 2

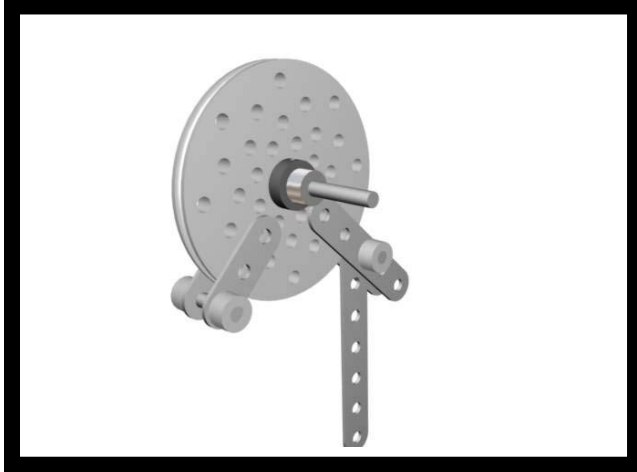
Attach a hex adapter to a 3" length of axle.

Pass the hex adapter through the 3" Wheel center and affix the wheel to the hex adapter using a 1/2" ID shaft collar.

**Hint:** DO NOT Tighten the hex adapter locking screws. Allow the hex adapter to spin freely. Center the wheel assembly on the axle and secure it in position with 3/16" shaft collars

# Subassembly 2: Wheel and Axle Assembly

Continued



## A Physics Moment

The two sets of flat bars act as levers. Each of these levers pivots on a fulcrum at the center of the wheel. The axle forms a rigid support for this fulcrum.

## Linear Motion to Rotary Motion

This wheel assembly will be used to transform the linear motion of the pneumatic cylinder into a rotational, or arcing, motion of the wheel. The rotational motion of the wheel will then be transformed to an approximation of linear motion used to lift a weight. **Note that the two linear motions will act at approximately 90**

**degrees to one another.** The piston force and motion will act horizontally and the weight will be lifted vertically.

## Input and Output Forces

One flat bar will be attached to the pneumatic cylinder. This will be the INPUT Force. The other flat bar will be attached to various weights or mechanisms. This will be OUTPUT force.

Imbalances between the INPUT and OUTPUT forces will create a torque on the wheel causing it to rotate in the direction of the greatest force. The net torque produced by these forces is a product of the difference of the forces times their distance (radius) from the center of the wheel. (*Torque is a measure of the force or forces that produce rotational motion about an axis or a pivot point.*)

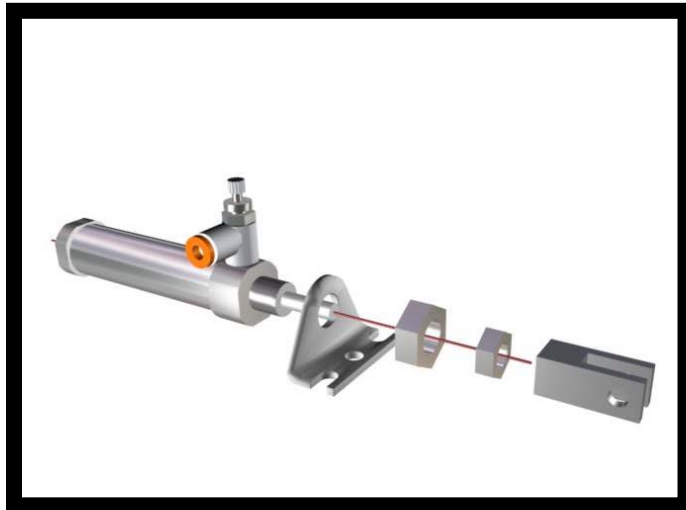
## Machines Defined

The wheel and axle assembly illustrated above, is by definition a machine. It is useful for engineers to think of machines as devices that produce useful work by either:

- **Converting energy from one form to another.** *Example: Electric motors convert electrical energy to mechanical energy.*
- **Changing the force or direction of the energy being applied.**

The **GEARS-IDS™** Invention and Design System components allow student designers to build machines capable of performing many different tasks in many different ways using a minimum of tools and material processes. In addition, the **GEARS-IDS™** Invention and Design System was intentionally constructed with components rugged enough to allow integration of “Off the Shelf”, real world components. This allows young engineers the opportunity to gain the skills and the vocabulary needed to effect nearly limitless electrical and mechanical design options.

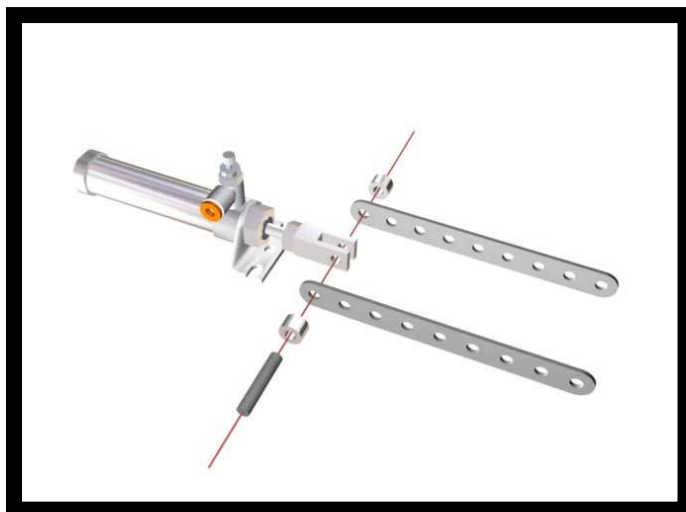
# Subassembly 3: Pneumatic Cylinder and Linkage



## Step 1

Assemble the pneumatic cylinder as shown. Be careful to position the foot of the mounting bracket facing out as shown

Carefully open the needle valve by turning the top thumbwheel counter clockwise. This will ensure flow when the cylinder is first pressurized



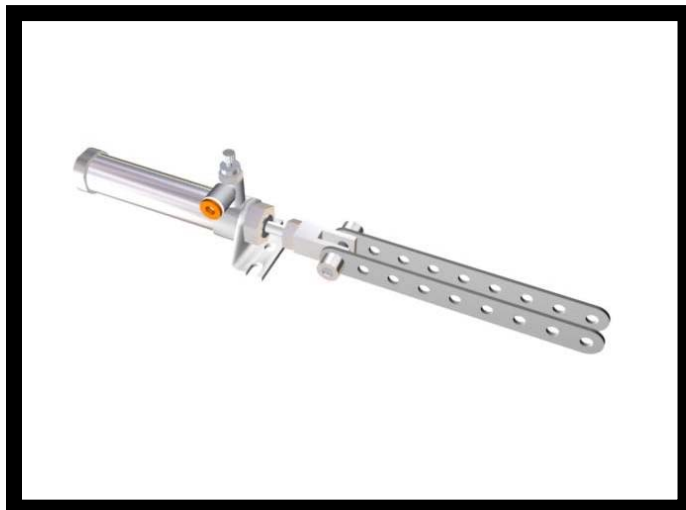
## Step 2

Attach 2, 9 hole flat bar pieces to the rod clevis on the end of the cylinder rod.

Use a 1-3/8" x 3/16" axle and 2 3/16" shaft collars.

**Note:** Clamp the axle in a bench vise and cut the axle with a hacksaw.

**Caution:** Carefully file or grind a small fillet or chamfer on both ends of the axle. This will remove the sharp burr caused by cutting.

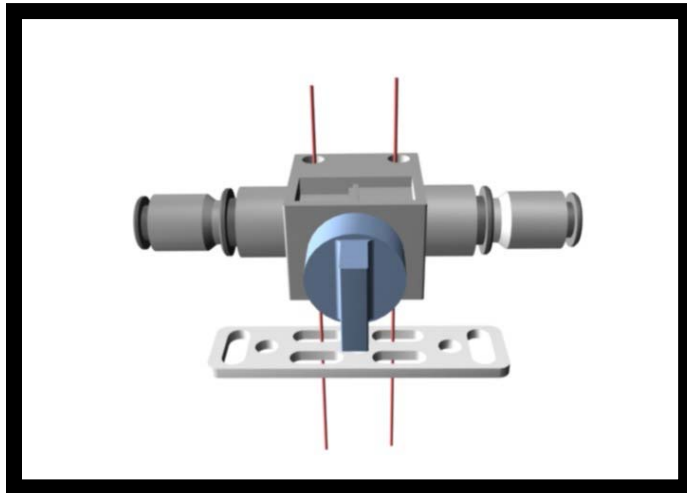


## Step 3

Set the initial adjustment of the clevis by screwing it all the way down on the piston rod.

Make certain that the shaft collars are set firmly on the axles but not so tight that they bind. The flat bars should swing easily on the pivots with a minimum of side play or looseness.

## Subassembly 4: Pneumatic On/Off/Purge Valve Assembly

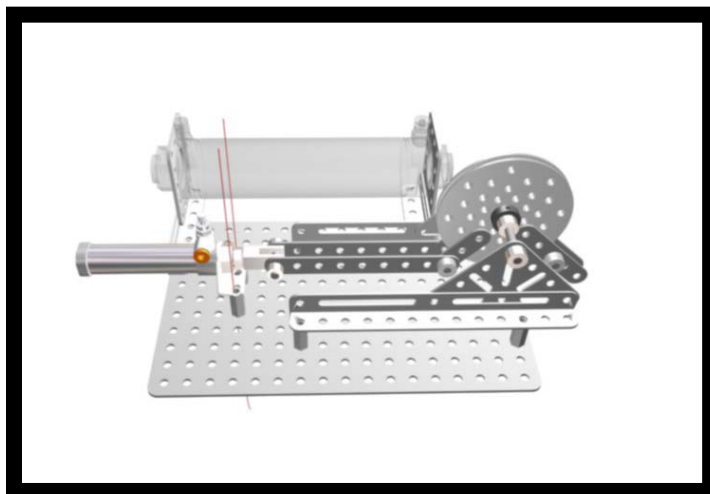


### Step 1

Attach the on off valve to a Servo Bracket using 2, #4-40 x 1" Machine Screws

Note: This valve has three functions or positions, ON, OFF and VENT. The valve is pictured in the OFF position. Turning the valve counter-clockwise, ON, aligns the blue rectangular indicator with the direction of flow. When the valve is turned off, the circuit pressure downstream of the valve is vented. This is a safe practice that de-energizes the circuit and renders it safe when not in use

## Subassembly 5: Pneumatic Components

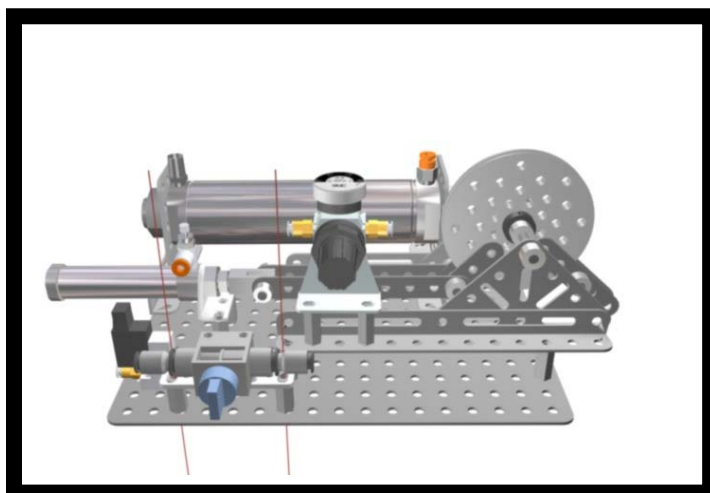


### Step 1

Attach the pneumatic cylinder, linkage and wheel assembly to the base plate.

Position the wheel in line with the piston rod.

Turn the wheel by hand and check to see that the mechanisms work smoothly without binding. Locate and relieve binding points. Check and tighten all connections.



### Step 2

Attach the on/off valve and regulator using stand offs and #10-24 x 3/8" machine screws.

Attach the solenoid with tye-wraps or Velcro.



# Subassembly 5: Pneumatic Components

continued



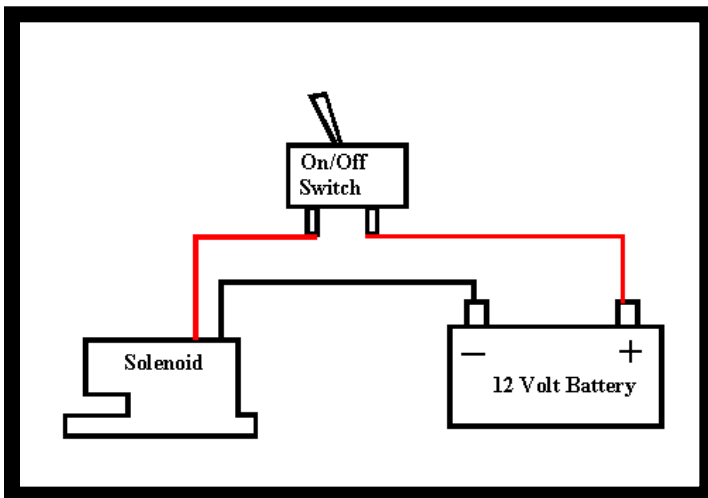
## Step 3

Connect the pneumatic circuit as shown. Use 4 mm plastic tubing.

Note: Download detailed information about the pneumatic components at the Support/Documentation section at [www.gearseds.com](http://www.gearseds.com)

Note: Flow direction is marked with arrows on the shut off valve and regulator. The solenoid input is marked with a “P” for pressure, and the number 1.

# Subassembly 6: Electric Switch and Circuit



## Step 1

Connect the black and red wires from the solenoid, to the battery and switch as shown in the schematic on the left.

Note: Always be certain the switch is off before you connect the circuit.

Caution: Never pressurize the pneumatic circuit until you are certain the electric switch circuit is functioning correctly.

Always wear safety glasses when operating pneumatic devices.

# Operating the Pneumatic Test Module Safely

Always wear safety glasses when operating or working with operable pneumatic systems. Be patient when working with pneumatic systems. Take the time to use and operate the pneumatic test module and become familiar with the operation of the flow valve, regulator settings and on/off/purge valve. It is also important to get familiar with the speed and forces produced by the cylinder and the capacities and performance of the system. The experience gained using this test module will enable students to create better designs for the mechanical game playing challenge.

## Initial Start Up and Operation

- 1. Remove all pressure from the system**
- 2. Disconnect the pneumatic cylinder linkages**
- 3. Turn off all valves and switches**
- 4. Back off the regulator adjustment knob to ensure a low initial pressure (30 lbs. or less)**
- 5. Perform a visual check of all fasteners, tubing connections and wiring connections.**
- 6. Operate the solenoid using the switch**
  - Note that the solenoid has two LED's
  - One of the LED's should light when the switch is thrown
  - If the LED does not light check the circuit continuity and the battery voltage with a Multimeter
- 7. Use a bicycle pump and pressure gauge to pressurize the storage reservoir. Do not exceed 100psi.**
  - Check for leaks using a paintbrush and soapy water
  - Common causes of leaks are loose connectors and fittings, or components that are connected with flow paths reversed.
- 8. Open the on/off valve and operate the system using the electrical switch**
- 9. Experiment with the flow valve on the pneumatic cylinder.**
- 10. Experiment with changing the regulator settings.**

These Lesson Plans for the Pneumatic Test Module will be available at the **GEARS-IDS™** Invention and Design System website. [www.gearseds.com](http://www.gearseds.com)

- Pneumatic Safety
- Basic Pneumatic Components and Circuits
- Levers, Wheels and Axles
- Force and Torque
- Work and Power
- Piston Force, Pressure and Flow
- Pressure and Boyle's Law
- Air Storage Capacity and Flow