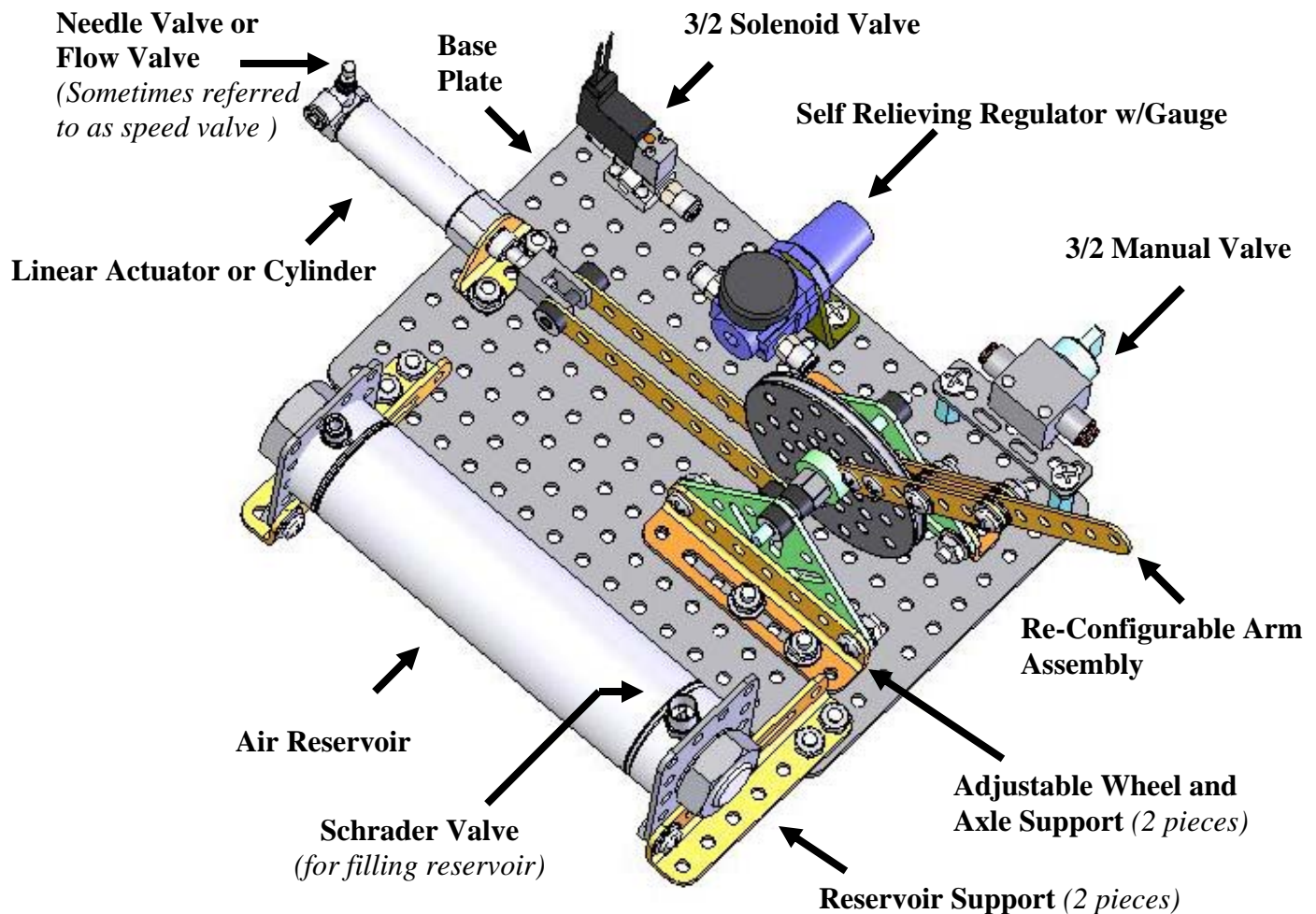


# The Pneumatic Module Construction Guide

The pneumatic module uses a system of components that store, control and regulate air pressure. The air pressure acts on a piston in the pneumatic actuator to produce a linear or straight line motion. Additional components are designed to transform the linear motion of the actuator into the rotary motion of the wheel and arm assembly. The pneumatic module is easily integrated onto an HMC chassis or other mobile platforms. It can be user-customized in order to accomplish a variety of tasks.



**Total pneumatic module construction time for two students: 70 – 90 minutes.**

It is recommended that students and teachers read through this manual and take the time to become familiar with the operation and connection requirements of each of the 5 pneumatic components before they begin assembly. Please refer to the Introduction to Pneumatic Components illustrated manual that accompanies this construction guide.

## Necessary Tools

Safety Glasses  
2 Phillips Head Screwdrivers (1pt and 2pt)  
5/16" Combination Wrench (*For the Stand Offs*)  
3/8" Combination Wrench  
6" Needle Nose Pliers  
Tubing Shears or Sharp Shop Scissors  
Allen Wrench or Hex Key (sizes .050, 1/16, 5/64, 3/32, and 1/8)  
7/64" Drill Bit and Drill

Dial Calipers and Tape Measure  
9/16" Combination Wrench (*For Pneumatic Actuator Mount*)  
Small Flat Head Screw Driver (*For C-Clip Removal*)  
Bicycle Tire Pump with an integral gauge to pressurize the system.  
Wire Strippers and crimpers

## Pneumatics, Structural Components and Hardware

### Structural Components

1 6x9 Flat Plate  
4 7 Hole Angles  
3 9 Hole Flat Bars  
(*Note: Only 2 required the third one can be a flat bar with any convenient number of holes*)  
1 5 Hole Flat Bars (optional)  
2 7 Hole Flat Bar  
1 Switch Plate  
2 Sine Triangles  
2 M15 Motor Mounts  
1 3" Hex Wheel  
2 1-1/2" x 3/16 Axles  
1 4" x 3/16" axle  
1 Servo Bracket  
1 Pneumatic Bracket (cylinder mount)  
1 3/16" Bore, Hex Adapter  
1 1/2" Shaft Collar  
8 3/16" Shaft Collars

### Pneumatics

1 16mm (5/8" ) Diameter Cylinder w/valve  
1 Clevis, Clevis Rod and E-clips  
1 Storage Reservoir  
1 Regulator  
1 On/Off Purge Valve  
1 Solenoid Valve  
3' 4mm Tubing

### Hardware

*The hardware count may be greater than indicated*

33 #10-32 x 1/2" PH Machine Screws (black)  
4 #10-32 x 3/4" PH Machine Screws (black)  
6 #10-32 Nylon Lock Nuts  
25 #10-32 Nuts (black)  
8 #10-24 x 1/2" Phillip Screws  
40 #10 Flat Washers  
25 #10 Lock Washers  
6 #10-24 x 3/4" Stand-off Coupling Nuts  
4 #10-24 x 3/8" Phillip Head Machine Screws  
2 #4 - 40 x 1" Round Head Machine Screws  
2 #4 - 40 Flat Washers  
2 2.5 x 16mm PH machine screws  
2 2.5mm hex nuts  
2 2.5mm Flat washers  
2 #4 - 40 Nuts  
2 #6 - 32 x 1/2" PH Machine Screws  
2 #6 Flat Washers  
2 #6 Nuts

### Electrical

1 Solenoid Cable Assembly  
4 Wire Nuts (grey)  
3' Black Wire  
3' Red Wire  
1 Single Pole Single Throw Toggle Switch  
4 0.187" Female Quick Connectors  
4 1/4" Female Quick Connectors  
1 12V Battery

# Sub -Assembly 1

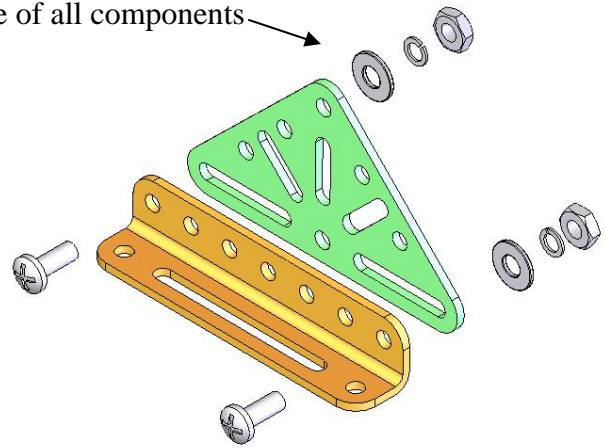
## Rotary Linkage and Wheel Supports (2 sets required)

( Average assembly time: 1 student about 10 - 15 minutes)

### Necessary Components and Tools

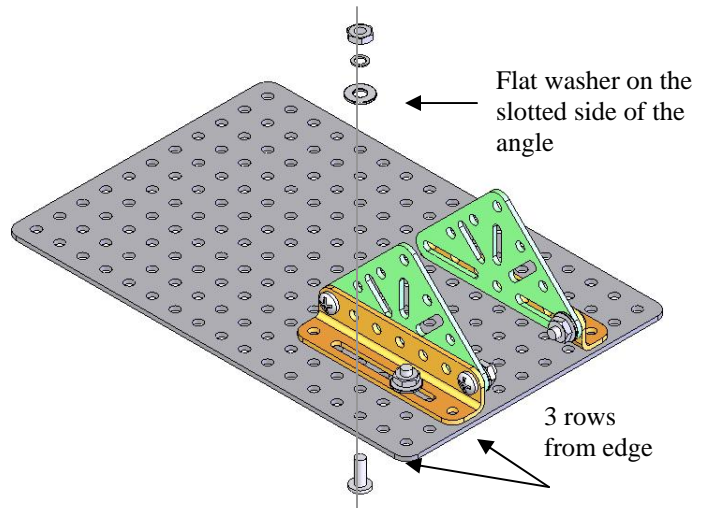
Qty.	Description
8	#10-32 Nuts
8	#10-32 x 1/2" Machine Screws
8	#10 Flat Washers
8	#10 Lock Washers
2	Sine Triangles
2	7 Hole Angles
1	6 x 9 Plate
1	3/8" Combination Wrench (not shown)
1	#2 Phillip Head Screwdriver (not shown)

Use flat washers on the slotted side of all components



### **Procedure**

1. Place the slotted side of the 7 hole angle as shown in the illustration above. Fasten the assembly together using 2, #10-32 x 1/2" machine screws, 2 #10 lock washers, 2 flat washers and 2 nuts exactly as illustrated above. Secure the nuts onto the machine screws by hand tightening them only. They will be firmly fastened after the assemblies have been fixed to the base plate. Remember to use flat washers on the slotted side of the sine triangle as noted above.
2. Make two identical copies of the assembly shown above.
3. Attach the rotary linkage and wheel supports to the base plate. Place the sine triangle and angle assembly onto the base plate as shown in the illustration below. The holes of the angle piece should be aligned along the third row of holes on each side of the base plate. Fasten each of the two assemblies to the base plate using 2, #10-32 x 1/2" machine screws, 2 #10 lock washers and 2 nuts exactly as illustrated above. Secure the nuts onto the machine screws using a 3/8" wrench and a #2 Phillip head screwdriver. The approximate torque (Tightening) specification is about 22 -26 inch pounds. If this specification is not familiar to you then take a moment to research torque specifications online or ask someone who knows.
4. Attach both assemblies to the base plate as shown. Do not tighten the fasteners at this time. Allow the wheel supports to slide in the slots for later adjustment.



### **Tightening Torque on the Machine Screws**

Torque is a force that acts in a rotary or circular direction. Torque is the product of force x distance. To compute the approximate tightening torque multiply the length of the wrench by the turning force on the wrench.

Example using a 6" long wrench: With what force should I push on the wrench to achieve 24 inch-lbs of force?

**Torque = Force x Distance = 6 inch wrench (distance) x 4 lbs (force) = 24 inch-lbs of torque. Push on the end of the wrench with only 4 lbs of force.**

## Sub -Assembly 2

### Wheel, Arm and Axle (1 required)

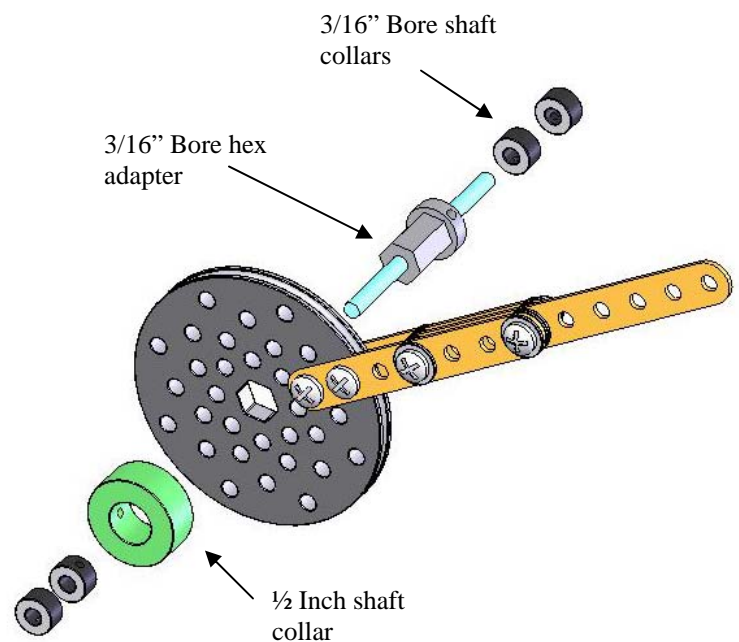
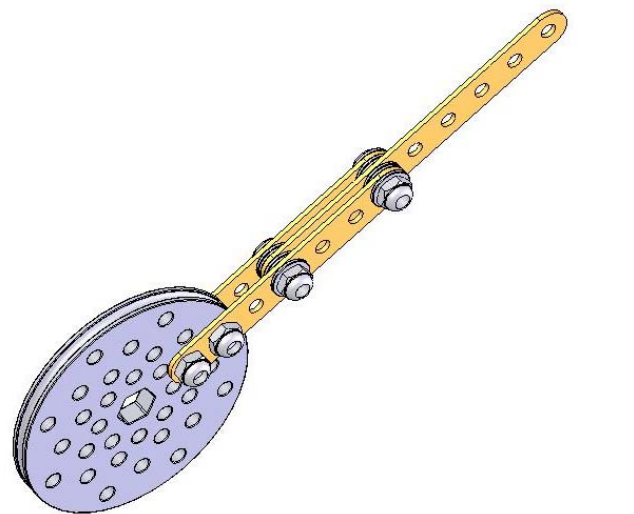
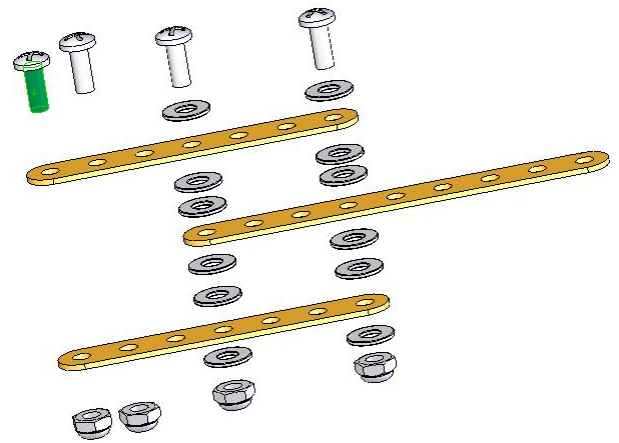
( Average assembly time: 1 student about 10 -15 minutes)

#### Necessary Components and Tools

Qty.	Description
4	#10-32 x 3/4" Phillip Machine Screws
4	#10-32 Nylon Lock Nuts
12	Flat Washers
1	1/2" Shaft Collar
4	3/16" Shaft Collars
1	3" Hex Wheel
1	3/16" Bore, Hex Adapter
1	3/16" Dia. x 4" Long Axle
2	7 Hole Flat Bar
1	9 Hole Flat Bar or any flat bar with a convenient number of holes.
1	3/8" Combination Wrench
1	2pt. Phillip Head Screwdriver

#### Procedure

1. Attach the (2) 7 hole flat bars to the 9 hole flat bar as shown in the illustration (top right). Use 2 spacer washers on each side of the 9 hole flat bar to center it. Hand tighten all threaded assemblies at this point.
2. Attach the arm assembly to the 3" wheel as shown in the center right illustration. Begin the assembly by positioning end hole of the 7 hole flat bar adjacent to the second ring of holes in the 3" wheel
3. Insert the 3/16" bore hex adapter and fasten it in place using the 1/2" shaft collar.
4. Tighten all fasteners to the required torque. (22 inch-lbs.)
5. Locate the 4" long x 3/16" diameter axle and the (4) four 3/16" bore shaft collars. Do not fit the axle to the hex bore or tighten the 3/16" shaft collars onto the axle at this point. This assembly can now be fitted to the supports on the base plate.



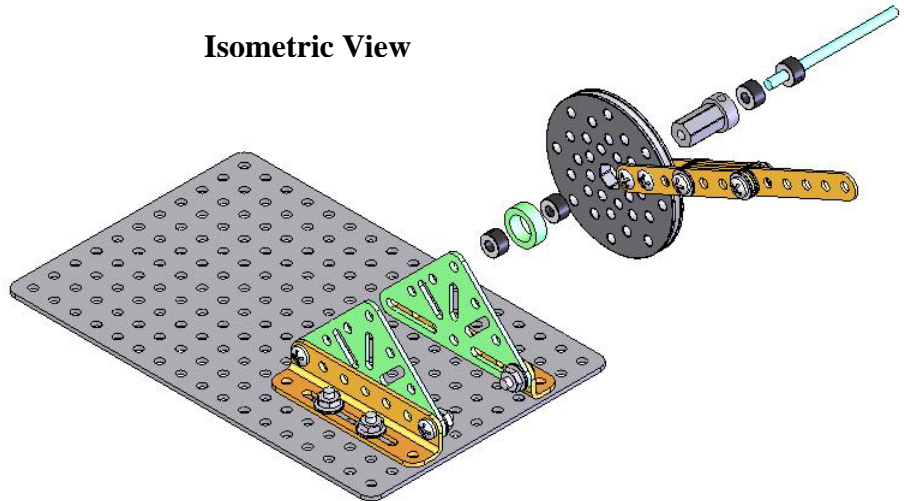
## Sub -Assembly 3

### Fitting the Wheel, Arm and Axle to the Base Plate Assembly (1 required)

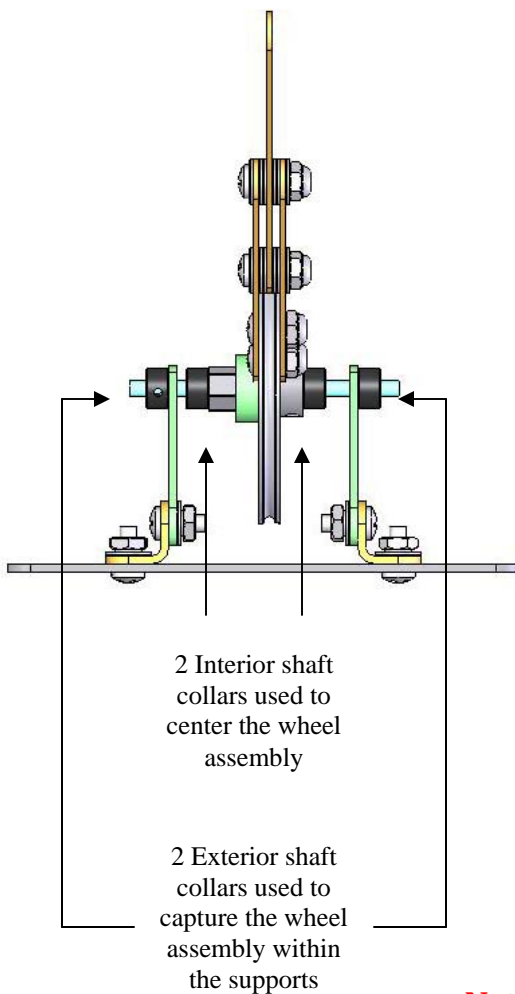
( Average assembly time: 1 students about 10 minutes)

1. Capture the wheel and axle assembly in the supports by threading the axle and shaft collars through the top hole in the sine triangles. One pair of shaft collars are fitted between the two support structures and used to retain and center the wheel assembly. The other pair of shaft collars are fitted to the outsides of the supports and used to hold the axle in place. Refer to the three images below for proper placement of the axle, wheel assembly, hex adapter and shaft collars with respect to the supports.

Isometric View

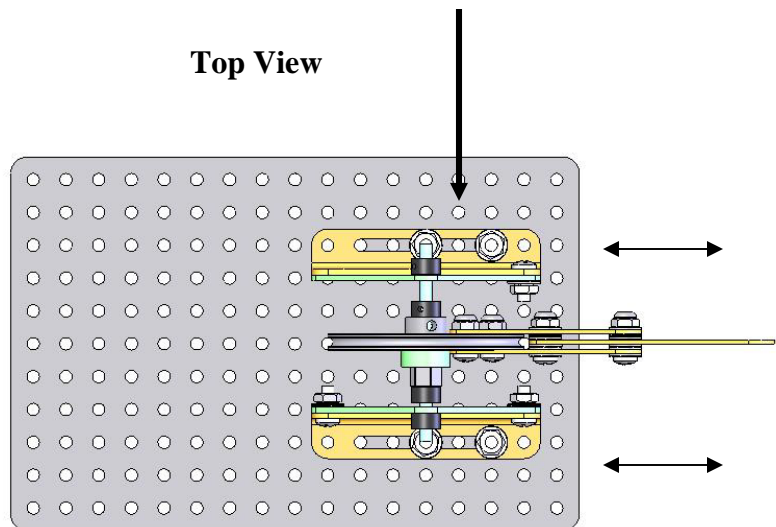


Right Side View



Slots in the 7 hole angle are used to make fine adjustments that control the throw or range of arm motion. This is accomplished by loosening the mounting screws and sliding the support assemblies for and aft on the base plate.

Top View



**Note: The wheel supports are slid back (1) hole in this view. Sliding the wheel supports is one of several available adjustments.**

## Sub -Assembly 4

### The Pneumatic Actuator (1 required)

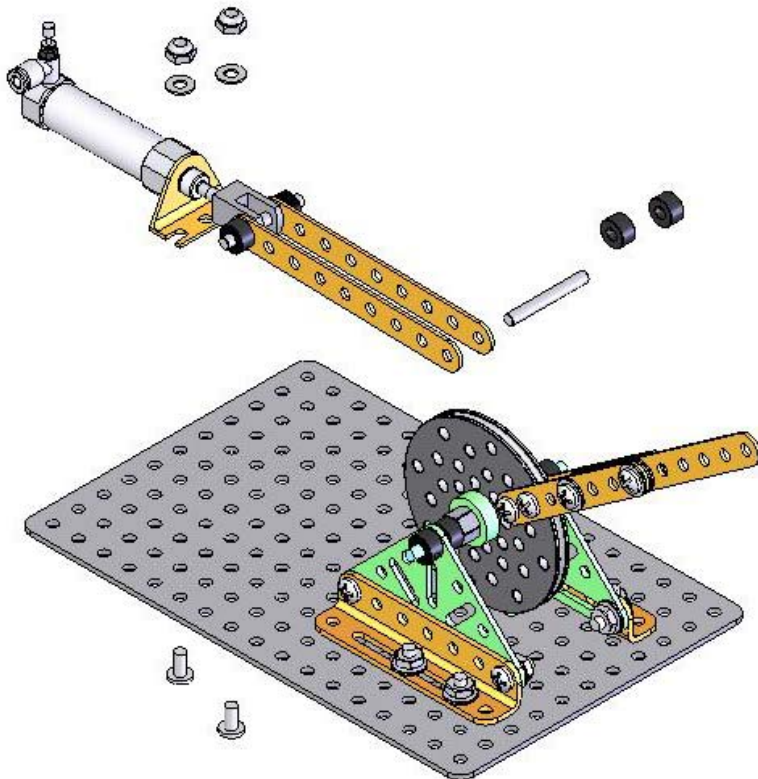
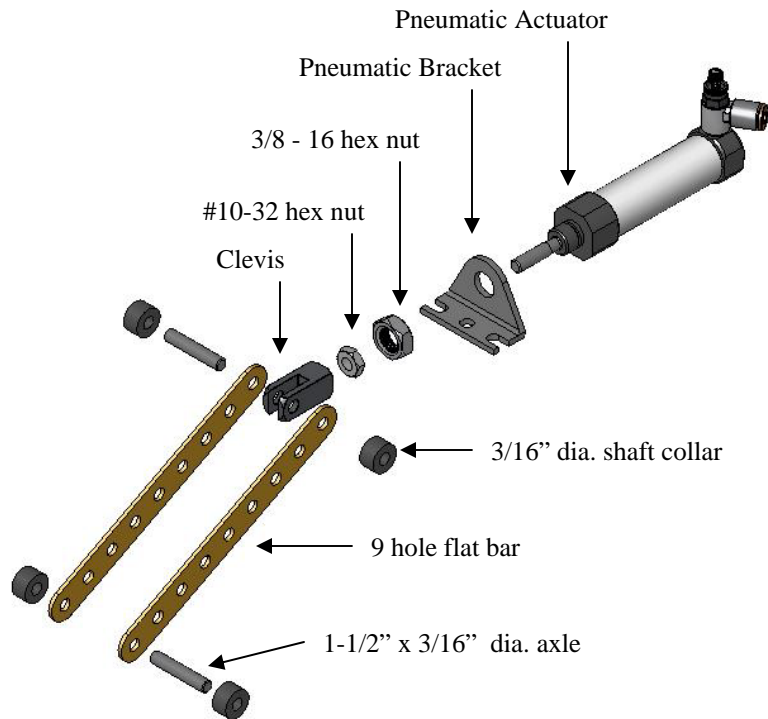
( Average assembly time: 1 students about 15 minutes)

#### Necessary Components and Tools

Qty.	Description
1	Pneumatic Actuator (Cylinder) Assembly
1	Pneumatic Bracket
1	3/8 - 16 Hex Nut
1	#10-32 Hex Nut
1	Clevis
2	1-1/2" x 3/16" dia. Axle
4	3/16" Shaft Collars
2	9 Hole Flat Bar
2	#10-32 x 1/2" Machine Screws
2	#10-32 Nylon Lock Nuts
2	#10 Flat Washers

#### **Procedure**

1. Fit up the pneumatic actuator, pneumatic bracket, 3/8"-16 hex nut, #10-32 hex nut and clevis into one assembly

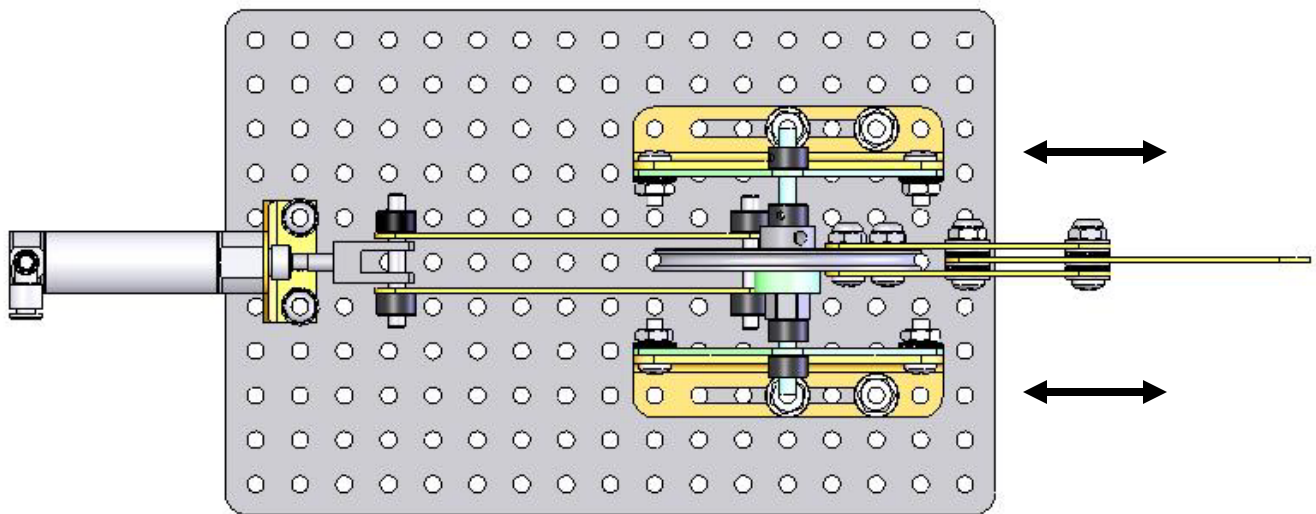
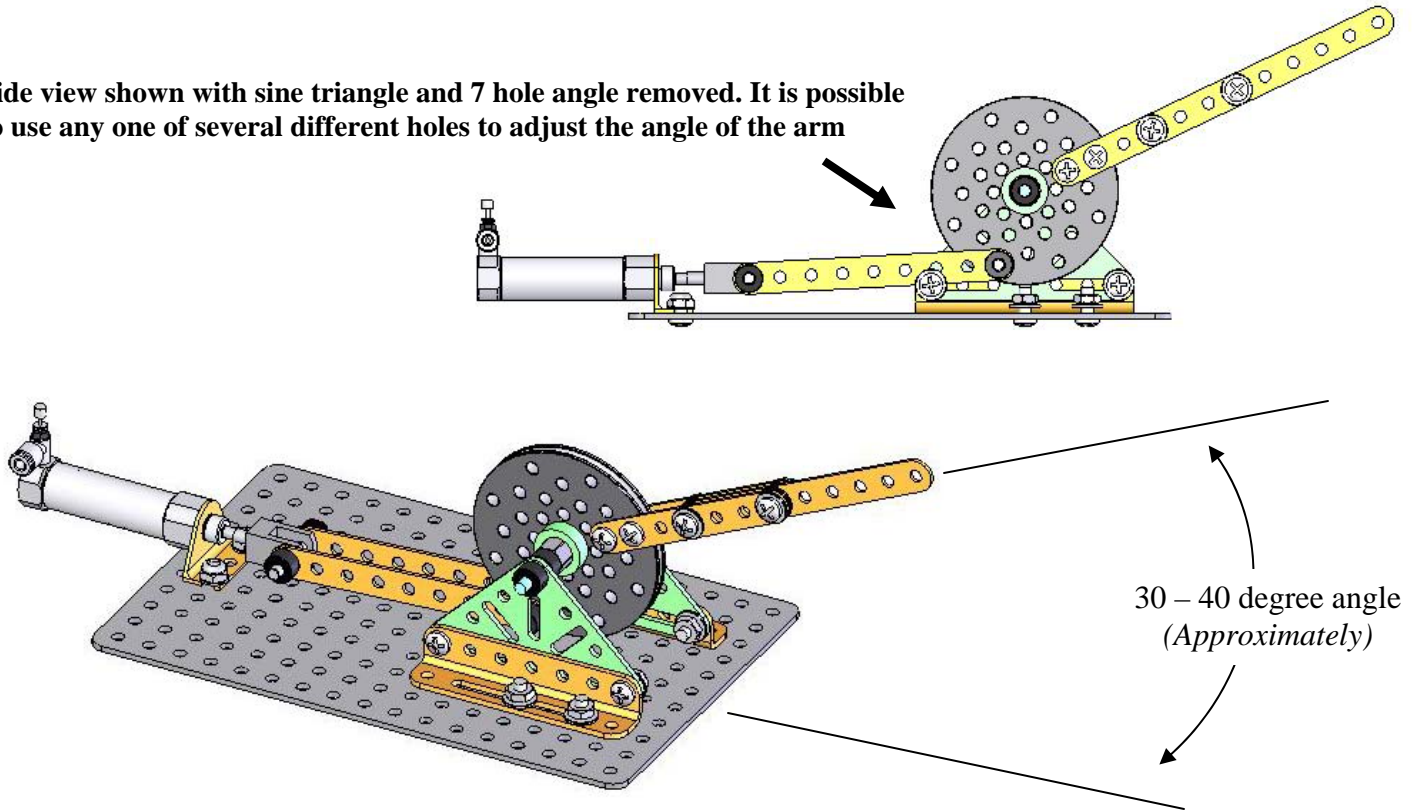


2. Attach the 9 hole flat bar to the clevis using a 1-1/2" x 3/16" dia. axle and two 3/16" bore shaft collars
3. Locate an additional set of 2 shaft collars and one axle. These components will be used to attach the 9 hole flat bars to the wheel and axle assembly.
4. Connect the pneumatic actuator assembly to the 3" wheel using the 1-1/2" axle and shaft collars. The decision about which hole to connect to on the wheel is determined by the intended function of the pneumatic module. For the purposes of this exercise we will attach the pneumatic assembly to the wheel, so the arm of the wheel is oriented at an (approximately) 30-40 degree angle to the base plate.

## Sub -Assembly 4 The Pneumatic Actuator (Continued)

5. Attach the pneumatic bracket to the base plate as shown in the illustrations below. Once completed the assembly should operate smoothly without binding. The total stroke or extension of the piston rod is only 1 inch. Do not attempt increase the stroke or travel of the piston rod beyond it's design limits by forcibly pulling or pushing on it in any way.

Side view shown with sine triangle and 7 hole angle removed. It is possible to use any one of several different holes to adjust the angle of the arm



**Wheel and axle supports are adjustable. Note the double headed arrows above. This is another method by which the angle of the arm can be adjusted to meet the needs of the builder.**

## Sub -Assembly 5

### The Air Reservoir and Mounting Brackets (2 required)

(Average assembly time: 2 students about 10 - 15 minutes)

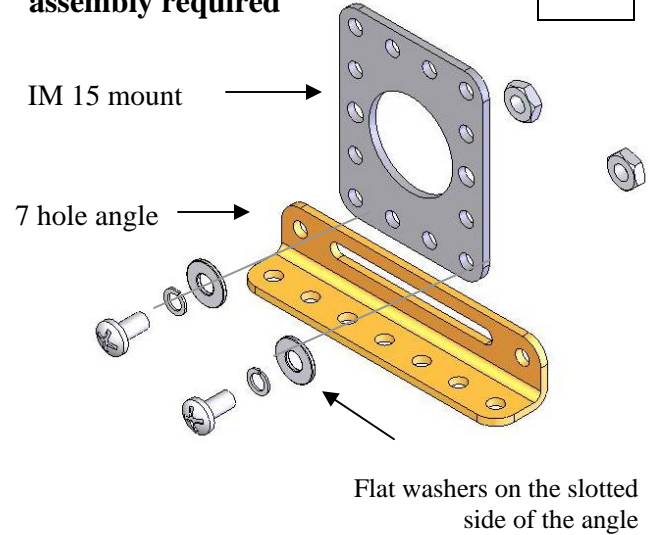
*Note: Two mounting brackets are required.*

#### Necessary Components and Tools

Qty.	Description
12	#10-32 Nuts
12	#10-32 x 1/2" Machine Screws
8	#10 Flat Washers
12	#10 Lock Washers
2	IM 15 Mounts
2	7 Hole Angles
1	Air Reservoir Assembly
1	3/8" Combination Wrench
1	#2pt. Phillip Head Screwdriver

2 versions of this assembly required

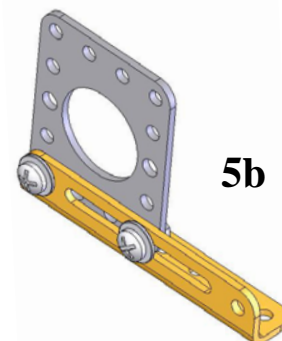
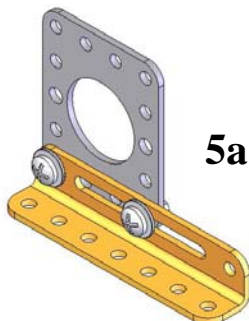
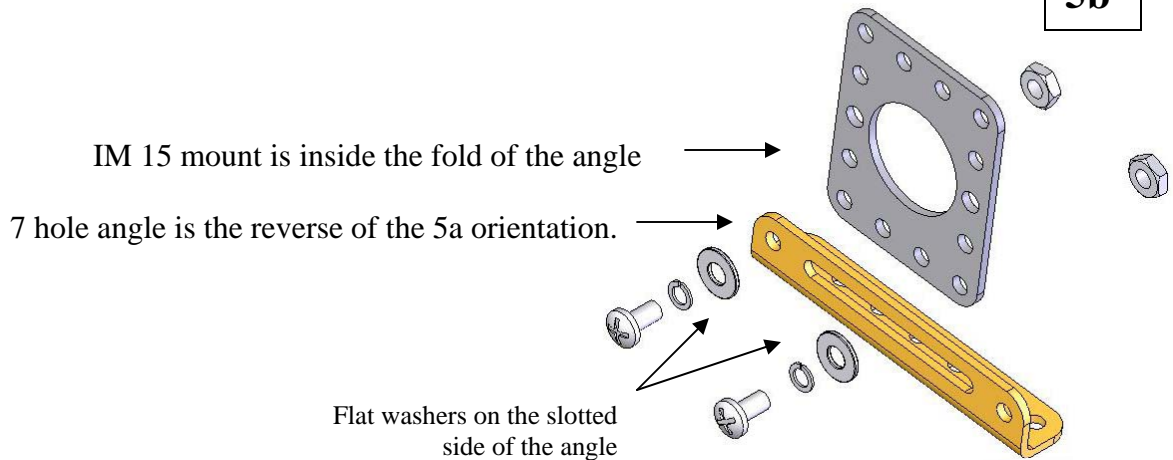
5a



#### Procedure

- Two versions of this assembly are required.. The differences are in the orientation of the 7 hole angle and the placement of the IM 15 mount inside and outside the fold of the angle.

5b





## Sub -Assembly 5 continued

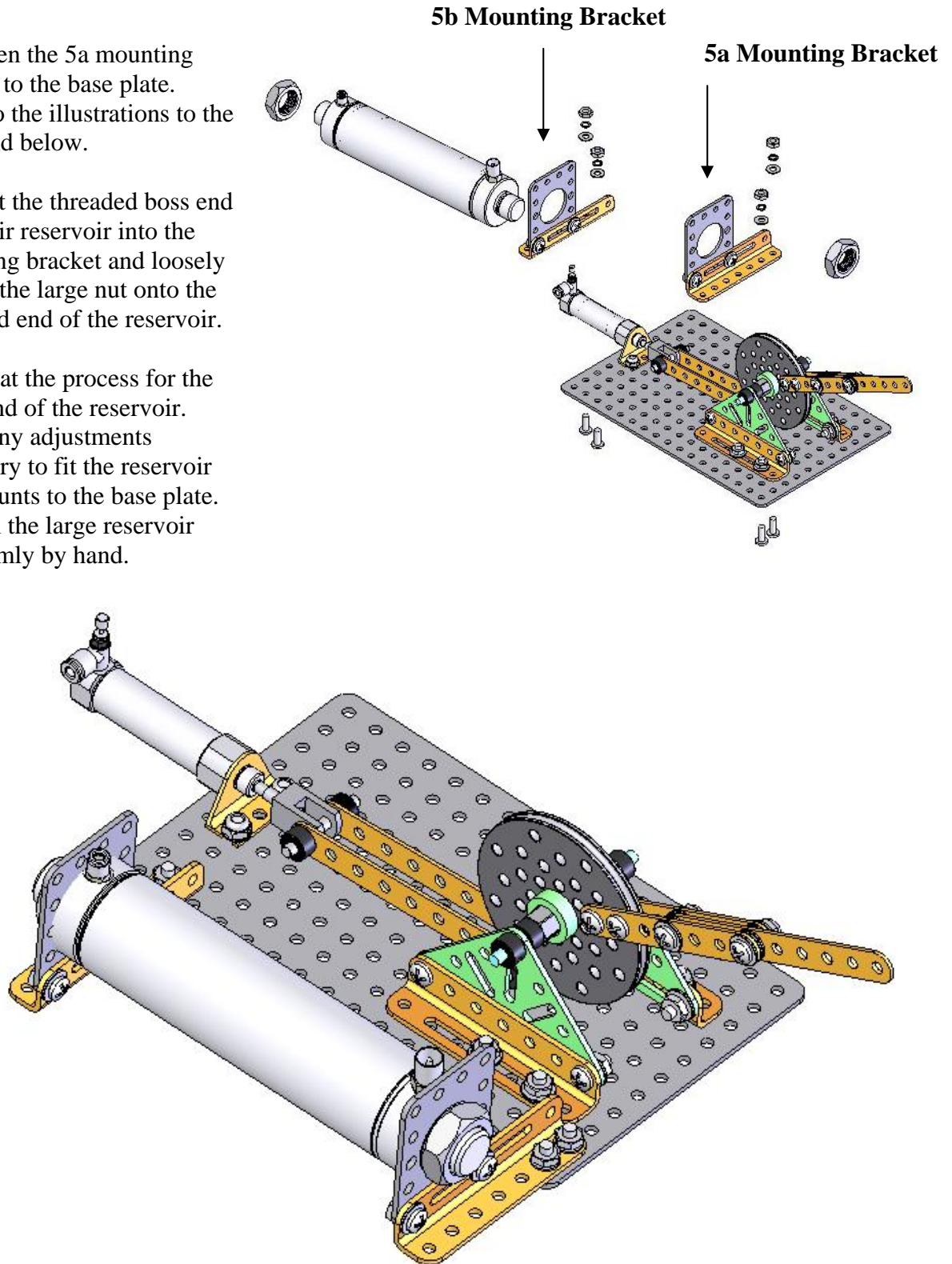
### The Air Reservoir and Mounting Brackets

2. Mount the air reservoir onto the base plate. Begin by removing the large hex nuts from the ends of the air reservoir.

3. Fasten the 5a mounting bracket to the base plate. Refer to the illustrations to the right and below.

4. Insert the threaded boss end of the air reservoir into the mounting bracket and loosely tighten the large nut onto the threaded end of the reservoir.

5. Repeat the process for the other end of the reservoir. Make any adjustments necessary to fit the reservoir and mounts to the base plate. Tighten the large reservoir nuts firmly by hand.



## Sub -Assembly 6

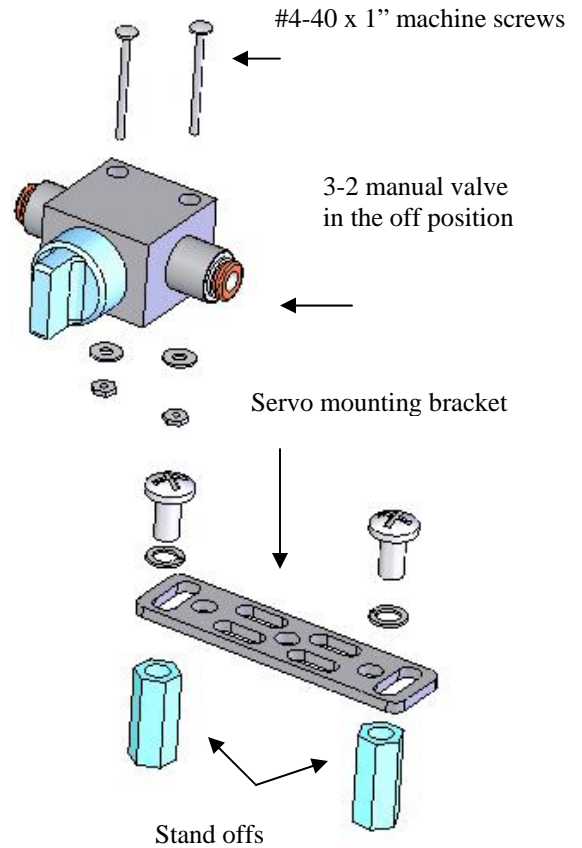
### Mounting and Connecting the Pneumatic Components

( Average assembly time: 2 students about 10 - 15 minutes)

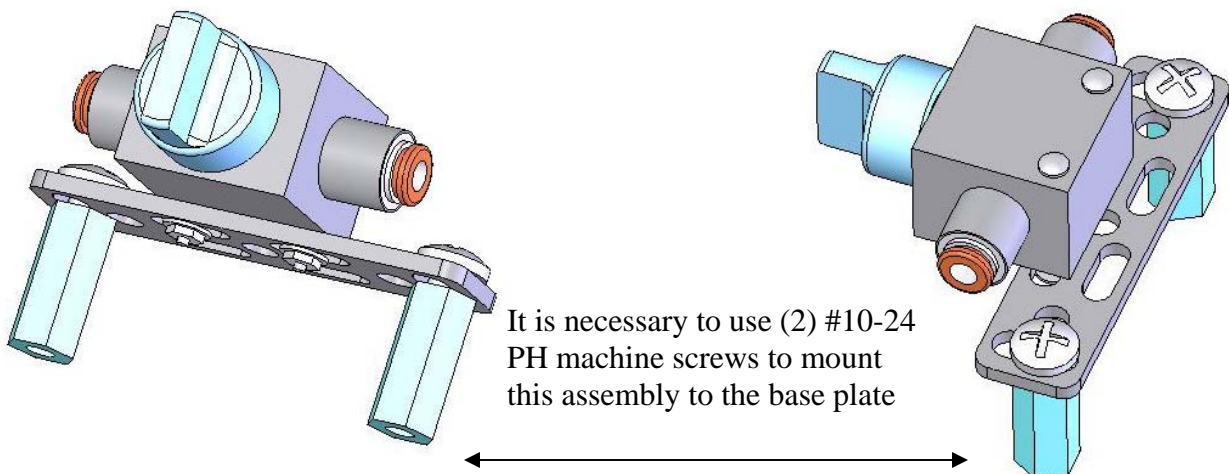
#### Necessary Components and Tools

Qty.	Description
4	#10 Lock Washers
2	#6 - 32 x 1/2" Machine Screws
2	#6 - 32 Hex Nuts
2	#6 Lock Washers
4	#4 - 40 x 1" Machine Screws
4	#4 - 40 Hex Nuts
4	#4 - 40 Flat Washers
2	#10-24 Hex Standoffs
4	#10-24 x 3/8" Phillip Head Machine Screws
1	3-2 Manual Valve
1	3-2 solenoid Valve
1	Self Relieving Regulator and Gauge
1	Servo Mounting Bracket
1	5/16" Combination Wrench
1	#2pt. Phillip Head Screwdriver
1	#1pt. Phillip Head Screwdriver
1	7/64" drill bit
1	Length of 4mm tubing

1. Fasten the 3-2 manual valve to the servo mounting bracket as shown on the right and below.
2. Fasten the stand offs to the servo mounting bracket as shown below.



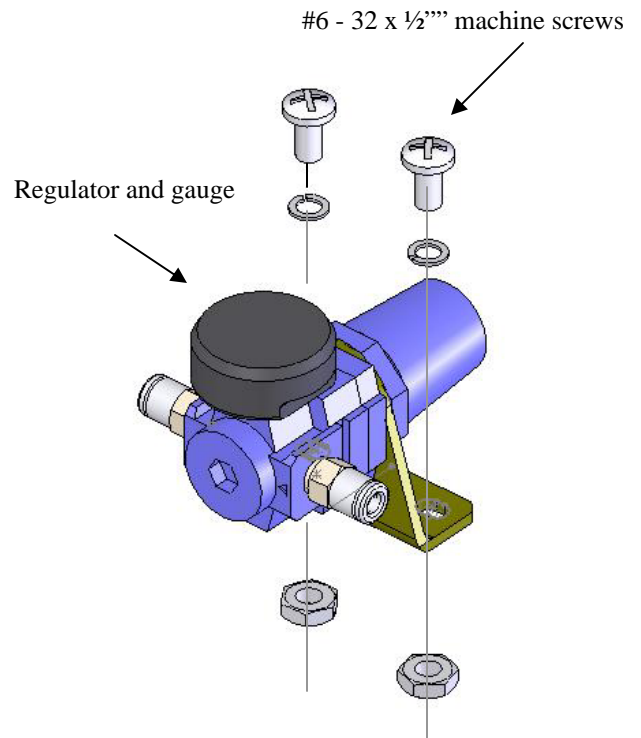
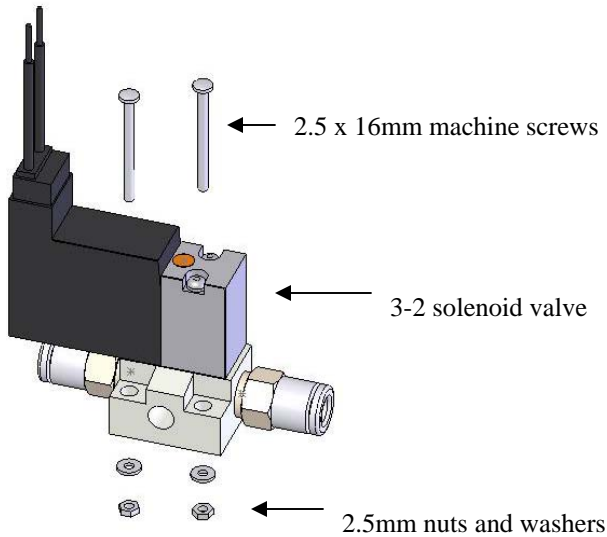
*Note: The stand offs might be either round or hexagonal. The shape does not affect the function, which is to lift the valve off the base plate enough to make it easier to operate.*



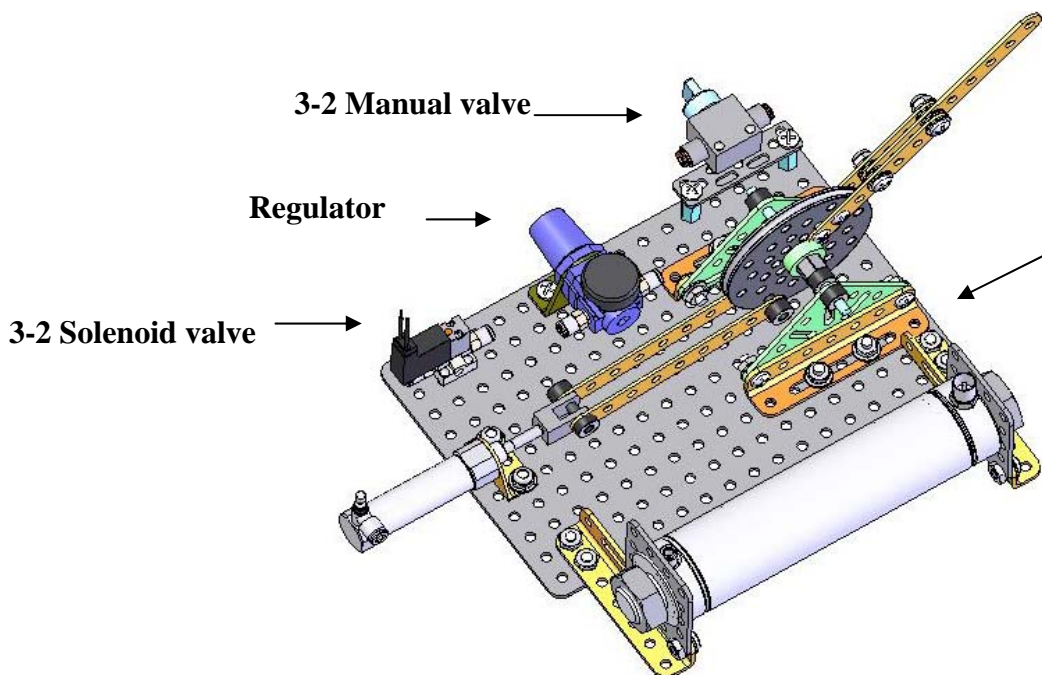
## Sub -Assembly 6 continued

### Mounting and Connecting the Pneumatic Components

3. Collect the following parts and prepare them for mounting to the base plate.
  - 2 #6 - 32 x 1/2" Machine Screws
  - 2 #6 - 32 Hex Nuts
  - 2 #6 Flat Washers
  - 1 Self Relieving Regulator and Gauge
  - 2 2.5 x 16mm Machine Screws
  - 2 2.5mm Hex Nuts
  - 2 2.5mm Flat Washers
  - 1 3-2 Solenoid Valve



4. Mount the 3-2 manual valve, regulator and solenoid as shown in the illustration (bottom)



Note: In this view the wheel supports are positioned nearly adjacent to the edge of the base plate. This was done to demonstrate how moving the wheel supports can vary the angle of the arm.

## Sub -Assembly 6 continued

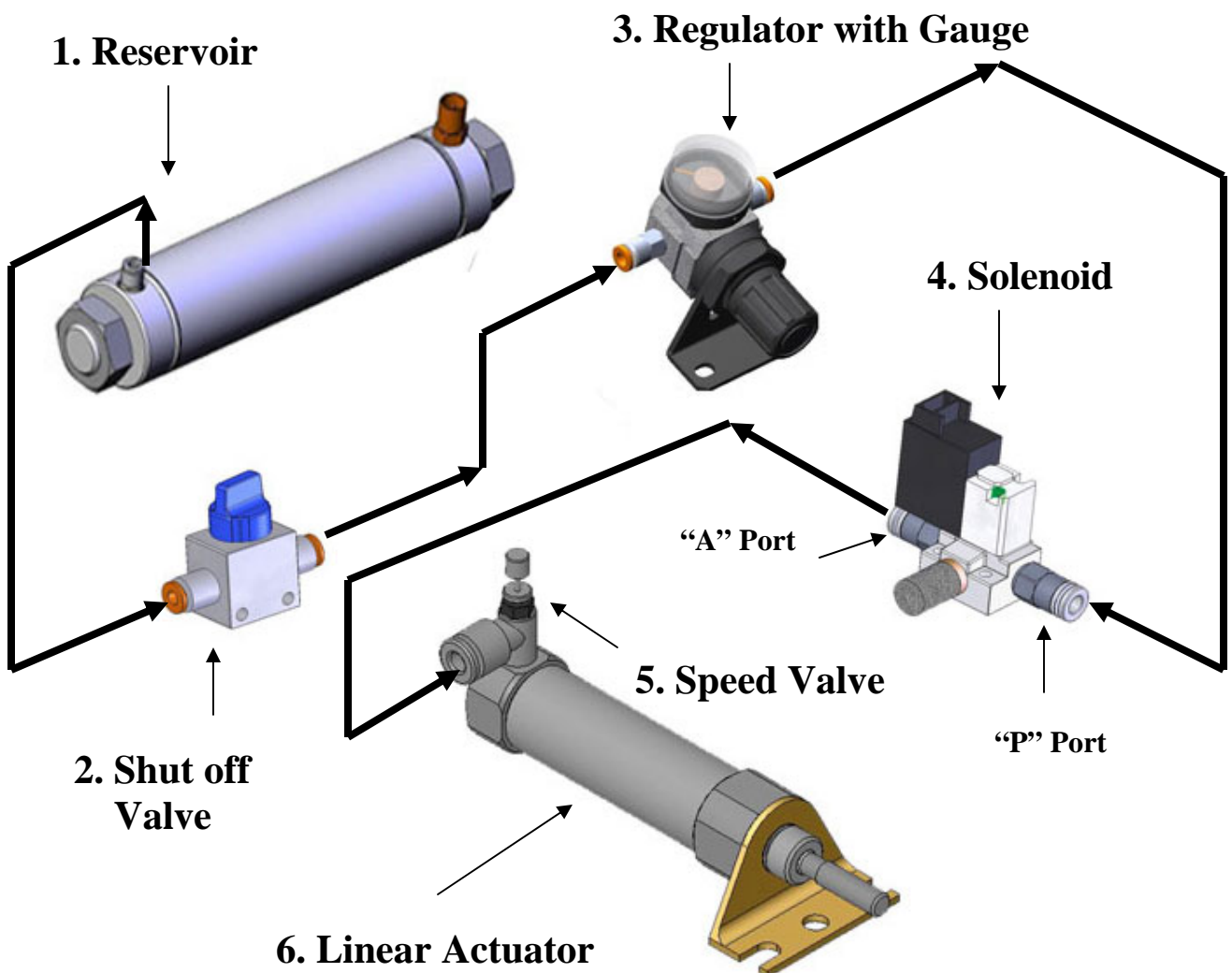
### Mounting and Connecting the Pneumatic Components

5. Connect the pneumatic components using the black 4mm tubing supplied with the kits.

Each of the pneumatic components has an input and output connection. The input and output connections are marked in several ways, these include:

- Directional arrows embossed on the body of the component
- Ports marked in and out
- Symbols such as “P” for pressure, “A” for outlet and “E” for exhaust

Refer to the Introduction to Pneumatics Lesson for detailed explanations of how to properly connect each component. Do not attempt to connect or disconnect pneumatic components unless direct to by an instructor.



## Sub -Assembly 7

### Create the Electric Circuit

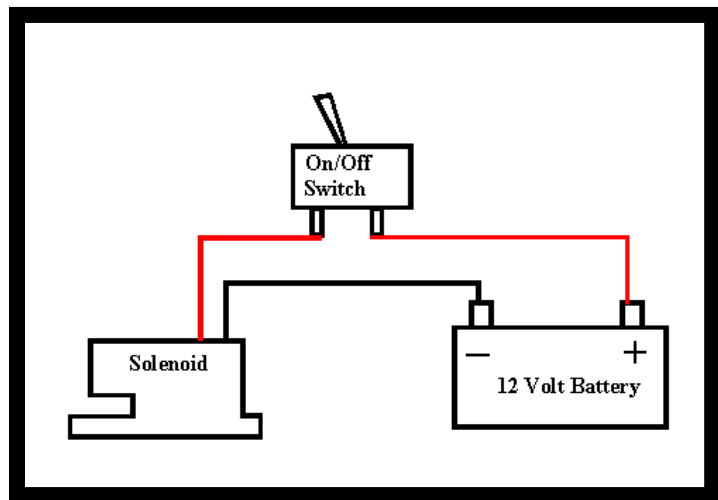
( Average assembly time: 2 students about 10 - 15 minutes)

#### Necessary Components and Tools

Qty.	Description		
1	Completed and connected Pneumatic Module	4	Wire Nuts (Grey)
1	Switch Plate	1	Pair Wire Strippers
4	#10-24 coupling nuts	1	Pair wire Crimps
8	#10-24 x 1/2" Phillip Screws	2	0.187" Female Quick Disconnects (For battery terminals)
10	#10 flat washers	1	Length #16 Gauge Black Wire
1	#10-32 Hex Nut	1	Length #16 Gauge Red Wire
1	#10-32 x 1/2" Phillip Screws	1	SPST Toggle Switch
		1	12V Battery
		2	1/4" Female Quick Disconnects

#### Procedure

1. Cut a 12" (*Approximately*) length of red wire and strip 1/4" of insulation off each end. Crimp a 1/4" female quick disconnect (Switch end) onto one end. Crimp a 0.187" female quick disconnect to the positive battery terminal end.
2. Cut another 12" (*Approximately*) length of red wire and strip 1/4" of insulation off each end. Crimp a 1/4" female quick disconnect onto one end. Connect that end to the remaining switch terminal. Connect the remaining end of the red wire to any one of the terminal wires on the 3-2 solenoid. Use a wire nut to make the solenoid to red wire connection.
3. Cut a 24" (*Approximately*) length of black wire and strip 1/4" of insulation off each end. Crimp a 1/4" female quick disconnect onto one end and connect the other end to the remaining terminal wire on the 3-2 solenoid. **DO NOT CONNECT THE BLACK WIRE TO THE BATTERY AT THIS TIME**

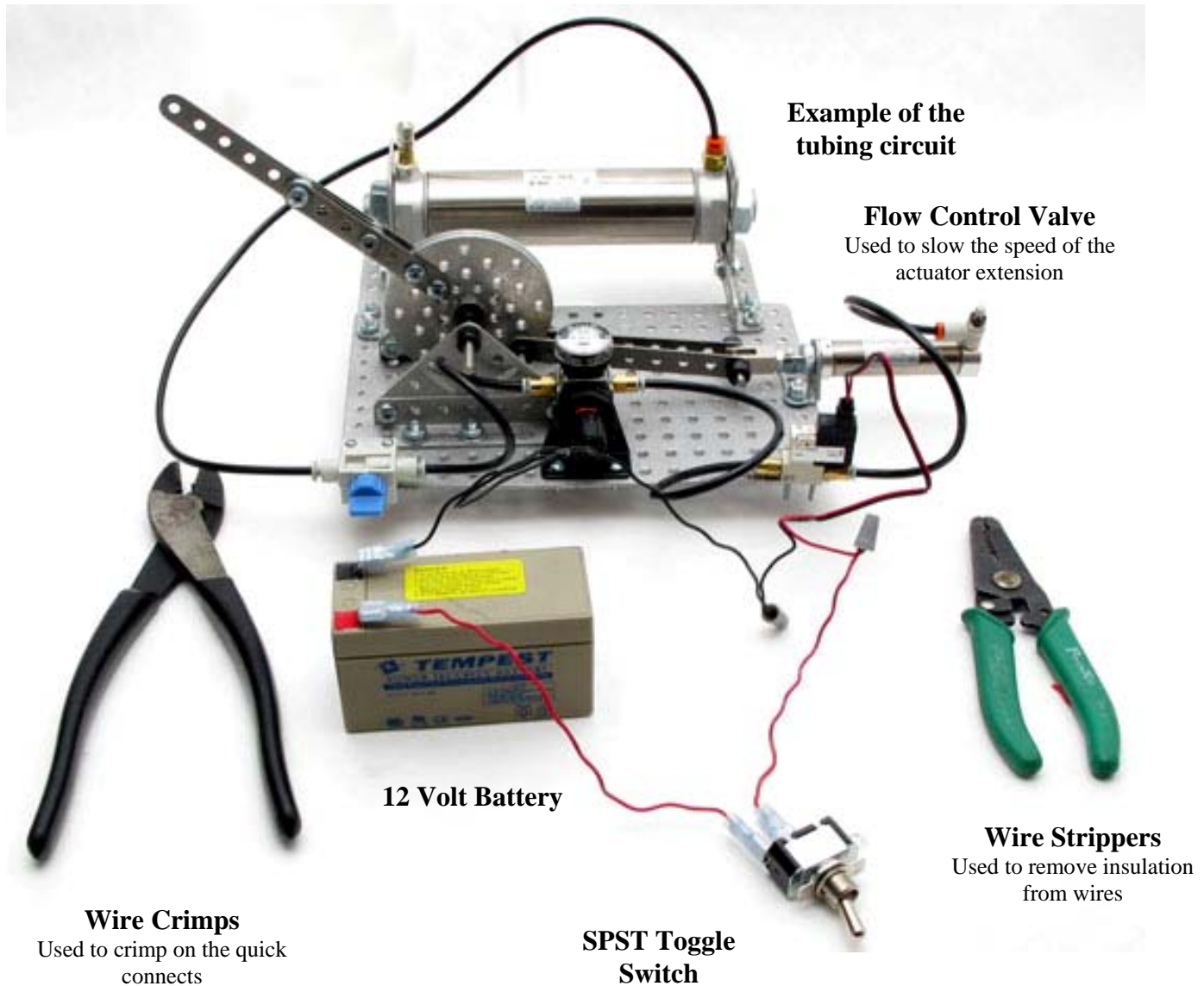


Note: Always be certain the switch is off before you connect the circuit.

**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.**

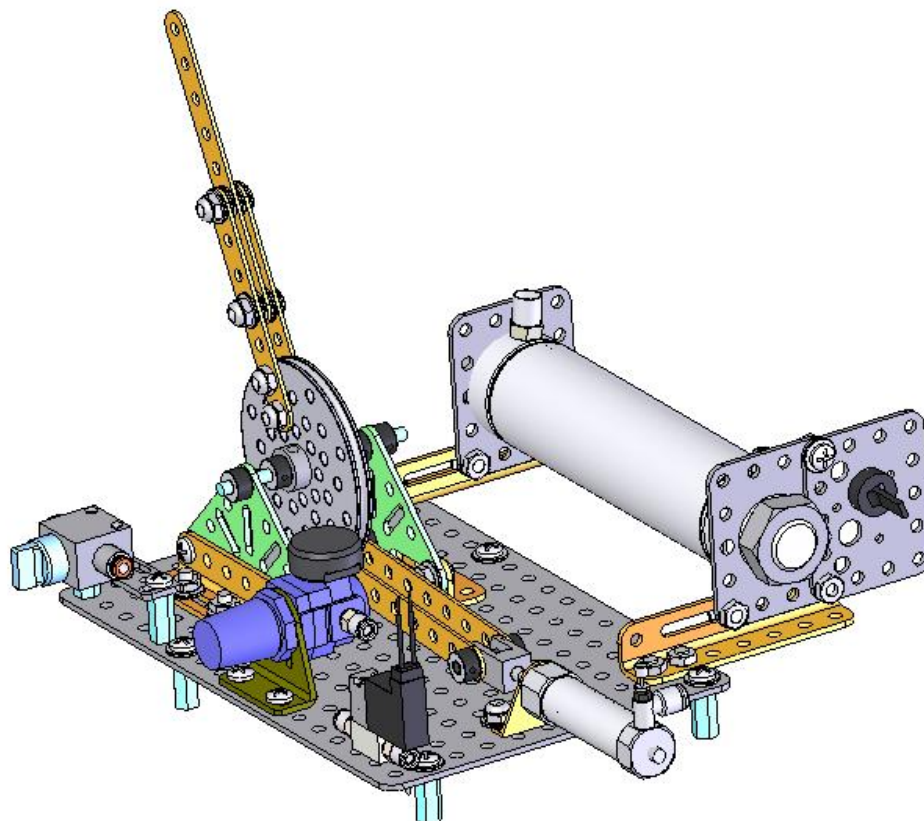
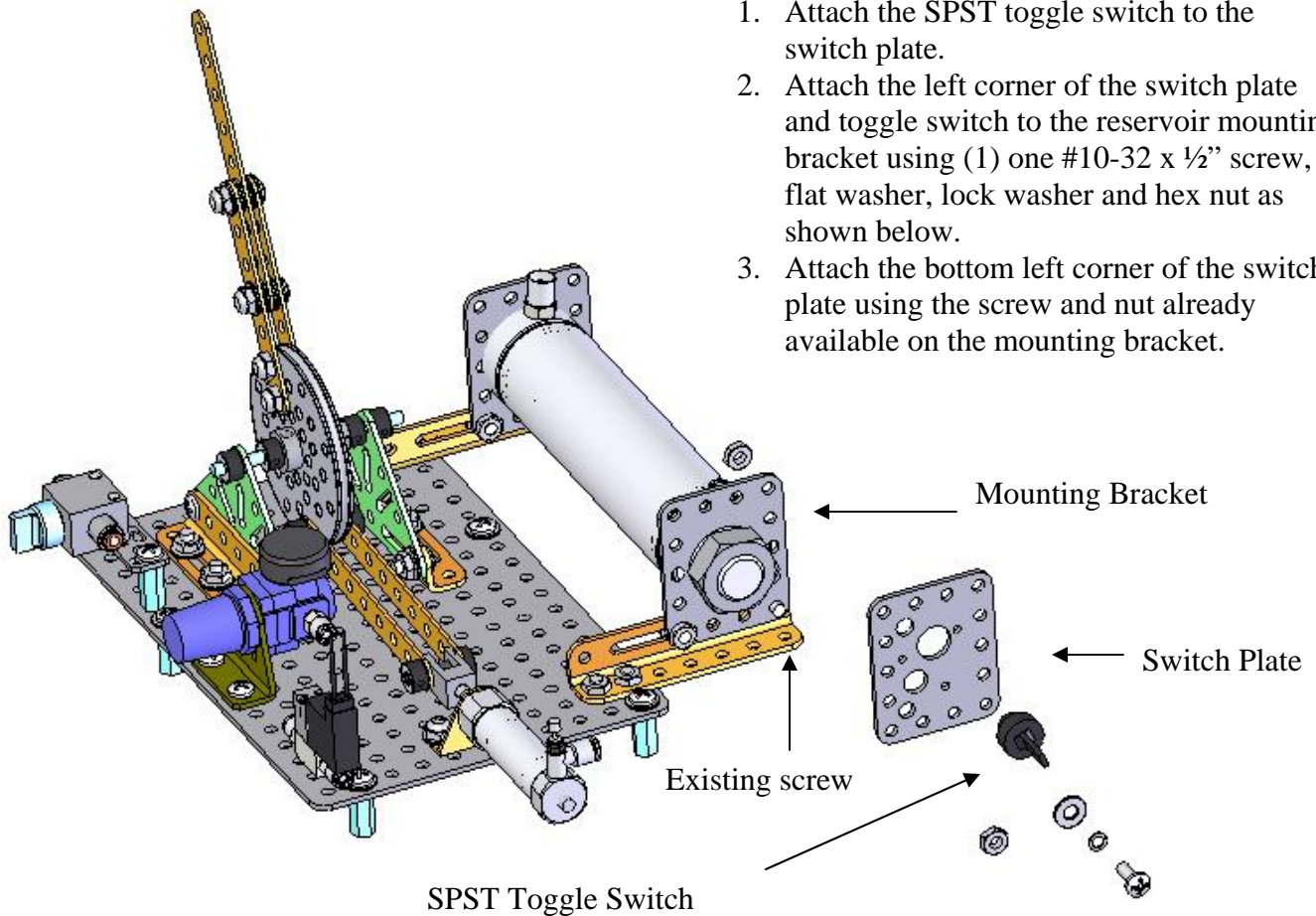
# The Completed Pneumatic Test Circuit

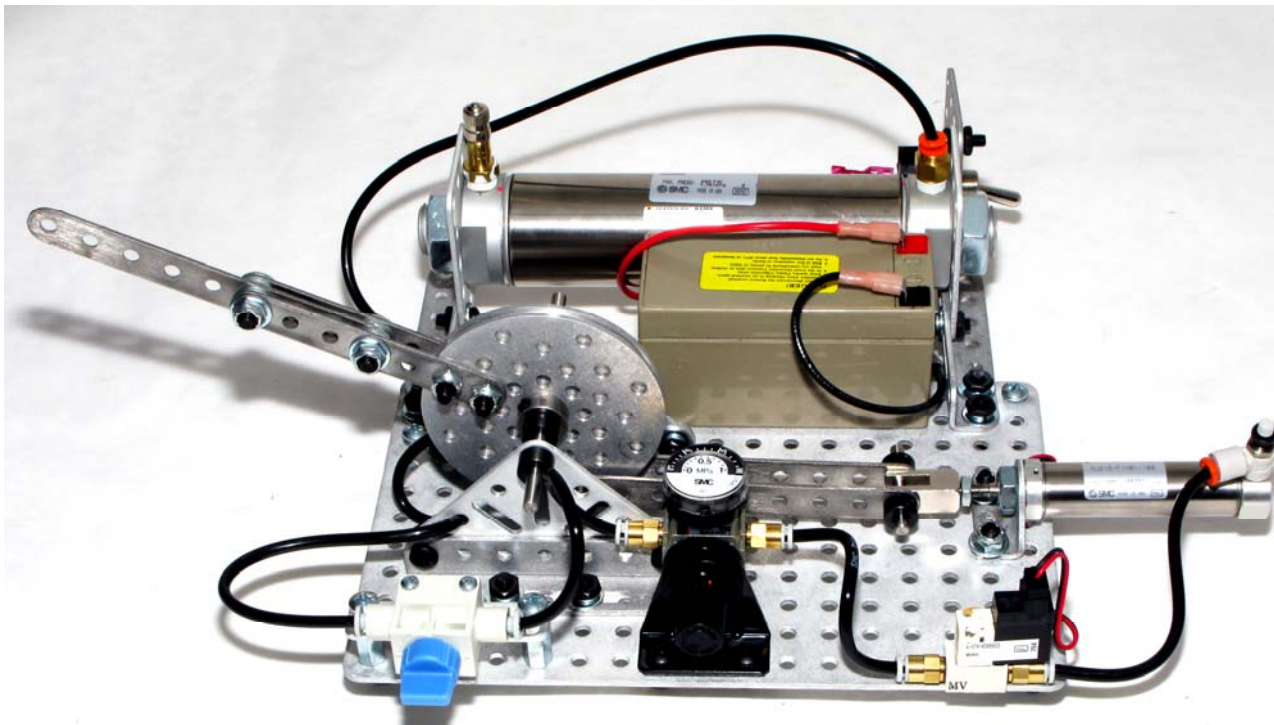


This image illustrates how to wire the on-off switch, battery and 3/2 solenoid valve to test the operation of the pneumatic module. The battery and switch are only necessary if the unit is to be used as a “Stand alone” mechanism. This is a simple, robust mechanism that can provide many opportunities for a wide variety of STEM based lessons and exercises. Students and teachers are encouraged to add other components including string, oak tag, rubber bands, popsicle sticks, plastic utensils, wire, straws and any other found items that can be used to “Invent” different games and uses for the completed module.

## Mounting the Switch Plate

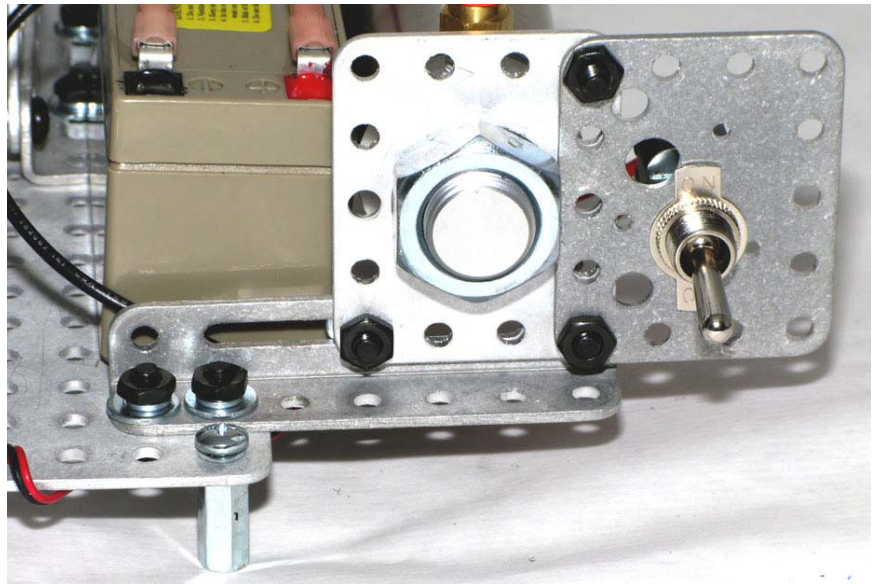
1. Attach the SPST toggle switch to the switch plate.
2. Attach the left corner of the switch plate and toggle switch to the reservoir mounting bracket using (1) one #10-32 x 1/2" screw, flat washer, lock washer and hex nut as shown below.
3. Attach the bottom left corner of the switch plate using the screw and nut already available on the mounting bracket.





The image above shows the pneumatic module configured as a stand alone system. The module is fitted with 4 stand-offs, SPST toggle switch, battery and solenoid cable.

The view to the right shows the switch and one of the four stand offs used for stability and/or as mounts to a base plate on the GEARS HMC chassis.



**Can this mechanism be creatively modified to perform some useful task?**

**Here is a partial list of imaginative uses for (similar) pneumatic powered devices: Are there more?**

Catapult	Tooth Puller	Bread Cutter
Window Wiper	Back Scratcher	Hammer
Light Switch Operator	Lever or Trigger Actuator	Door Opener
Mouse Trapper	Egg or Pancake Flipper	Drink Mixer
Miniature Golf Player	Painter	Pump Operator
Fishing Lure Caster	Sander	Draw opener
Dice Roller	Ice Fishing Trap	Ping Pong Ball Thrower
Elastic Band Shooter		Kicker



# Making Adjustments to the Pneumatic Module

There are many adjustments that can be made to the pneumatic module in order to fine tune the performance of the mechanism. Also, once the operation of the mechanism becomes familiar, it will be possible to reconfigure the assembly in a myriad of different ways. Some of the possible adjustments are detailed below.

**Reconfigure the arm or add materials to it. Mount it to the wheel in a different orientation**

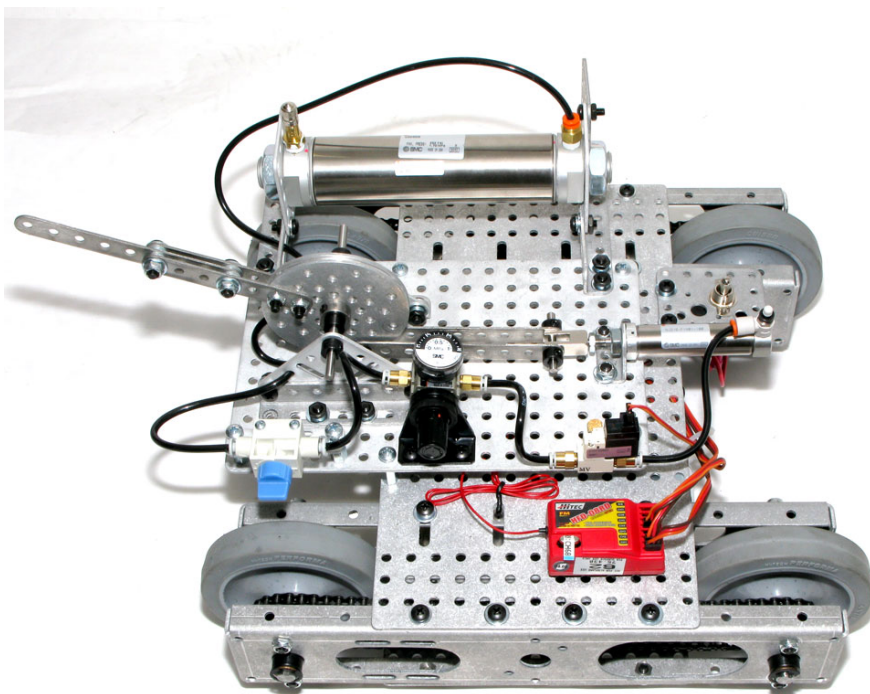


**Reposition where the pneumatic bracket is mounted**

**Reposition the wheel mounting assemblies. It is even possible to hang them over the edge in order to make a "Paddle" assembly.**



**Make fine adjustments to the piston arm length by using the clevis**



**This is what the pneumatic module looks like when it is integrated with the GEARS Heavy Metal Chassis.**

**This machine could be modified to perform many different tasks including launching objects, picking up objects or striking objects like in soccer or hockey. All that is needed to transform this into a robot competitor is just some simple materials and some imagination**

# Testing and Operating the Pneumatic Test Module

## Procedure

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 the 3-2 manual 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 challenges.

## 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**
- 5. Perform a visual check of all fasteners, tubing connections and wiring connections.**
- 6. Prepare to operate the solenoid using the switch**
  - Check to see that the SPST toggle switch is in the off position.
  - Connect the black lead to the negative terminal of the battery
  - Turn on the SPST toggle switch.
  - The solenoid has two LED's, one of the LED's should light when the switch is thrown and the operator should hear an audible "Click". The click is caused by the action of the valve opening under the force of the magnetic field induced in the energized solenoid coil.
  - If the LED does not light or a click is not heard, check the circuit continuity and the battery voltage with a Multimeter. Possible problems might include a dead battery, a faulty connection or a damaged solenoid valve.
  - If the solenoid functions properly move on to the next step.
- 7. The pneumatic circuit consists of 3 sub-circuits that can be pressurized at different times during the operation of the system. When the reservoir is pressurized, the reservoir and the tubing connecting the reservoir to the 3-2 manual valve are both pressurized. Leaks can happen anywhere within this part of the system. Be certain the 3-2 manual valve is closed. 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. Wipe every connection in the pneumatic circuit with the soap and water mixture. Leaks will be evidenced by the creation of bubbles.
  - Common causes of leaks at this point are; loose connectors, partially inserted tubing, threads on fittings, or a 3-2 manual valve that is reverse connected. If the air hisses out while the reservoir is being pressurized it usually means the 3-2 valve is connected in reverse. Stop pressurizing the reservoir and reverse the connection on the 3-2 manual valve. Repair leaks between the reservoir and the 3-2 manual valve.
- 8. Open the 3-2 manual valve on/off valve. This will pressurize the system up to the 3-2 solenoid valve.**
  - Check for leaks using a paintbrush and soapy water. Wipe every connection in the pneumatic circuit with the soap and water mixture. Leaks will be evident by the creation of bubbles.

- Common causes of leaks are loose connectors, partially inserted tubing, threads on fittings, components that are improperly connected or the flow paths are reversed. In this case it could be the regulator or the 3-2 solenoid that are connected in reverse. Check each component and ensure there are no leaks in the system to this point. Repair any leaks before continuing.

**9. Operate the 3-2 solenoid valve using the SPST toggle switch.**

- This should cause the pneumatic actuator (cylinder) to operate. If the actuator does not operate, check that there is pressure to the actuator. Do this by first shutting off the 3-2 manual valve and depressurizing the system. Disconnect the tubing connection to the flow valve on the actuator. Turn on the 3-2 manual valve and operate the toggle switch. Air should rush out the tube end that had been connected to the actuator.
- If there is pressure at the tube end, then reconnect the actuator and open the needle adjustment screw on the flow valve.
- After the components have been checked for proper operation, check for leaks using a paintbrush and soapy water. Wipe every connection in the pneumatic circuit with the soap and water mixture. Leaks will be evidenced by the creation of bubbles. Repair any leaks.

**10. Experiment with the flow valve on the pneumatic cylinder.**

**11. Experiment with changing the regulator settings.**

**12. Experiment with the general operation of the pneumatic module**

**GEARS Educational systems** offers additional **Pneumatic** curriculum and illustrated lessons and activities that address the following topics:

- 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
- And a whole lot more!

Contact GEARs Educational Systems to obtain additional pneumatic curriculum resources.