RoboJackets

FIRST - IGVC - BATTLEBOTS - ROBOCUP

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Manipulation and Fluid Power

October 07, 2008

Manipulation

Keys to Understanding Manipulators

- What is a manipulator?
- What kinds of manipulators are there?
- What are the different types of joints and linkages in a robotic arm?
- How can joints and linkages control an arm's motion (geometrically)?
- What kind of manipulation is a roller / conveyor system good for?
- How can a several manipulator concepts be combined?

What is a Manipulator?

- A mechanism that interacts directly with an object (or objects) of interest.
- Can take many forms
  - Dexterous arms
  - Roller/ conveyor systems
  - Combinations

Types of manipulators

- Dexterous arms
  - Serial
  - Parallel
- Roller / Conveyor systems
  - Single path
  - Mass flow
- Combinations

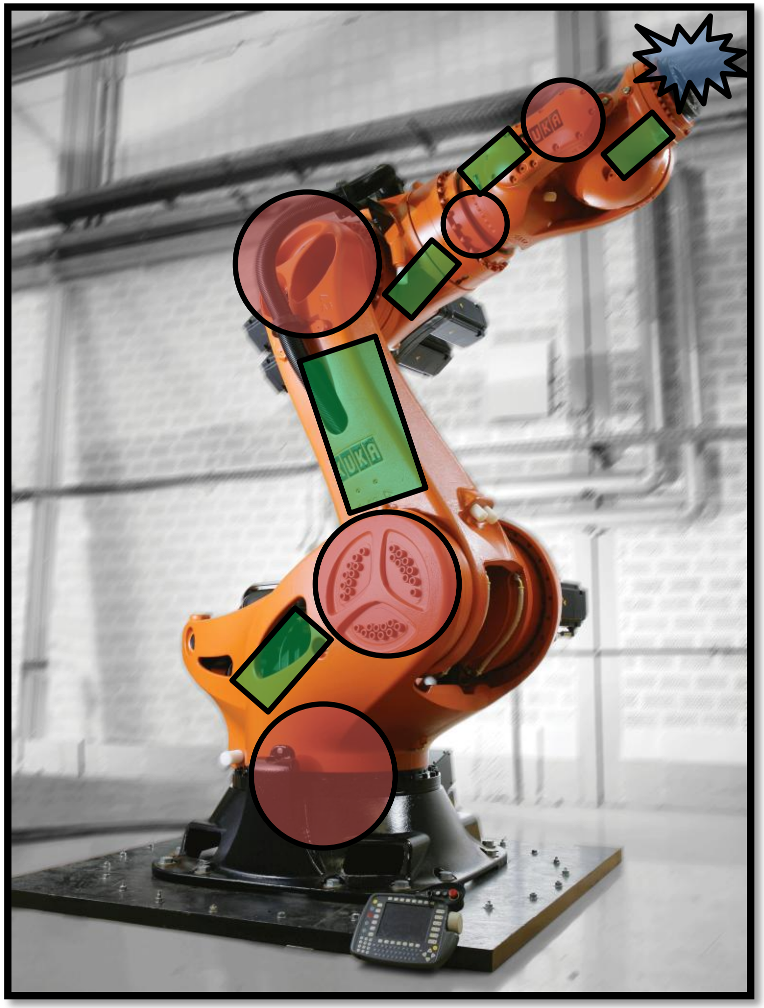
Manipulation – Arms

Dexterous Arms – Terms

- Dexterous
  - Able to move to several positions and orientations
- Serial Manipulator
  - Arm formed by a single chain of linkages
- Parallel Manipulator
  - Formed by multiple linkage chains
- Rotation
  - Change in an objects orientation (angle)
- Translation
  - Change in an objects position
- Degrees of Freedom
  - Number of ways in which the arm can move.

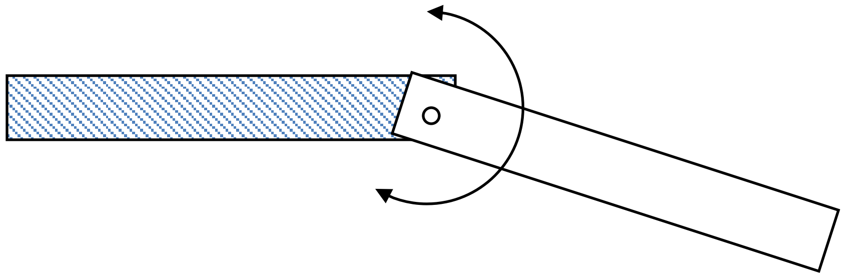
Dexterous Arms – Components

- Linkages
  - Rigid or flexible lengths of material
- Joints
  - Connection points between linkages can allow for rotation (rotary joints) or translation (sliding / prismatic joints)
- End Effector
  - Mechanism at the end of an arm that directly contacts the object of interest

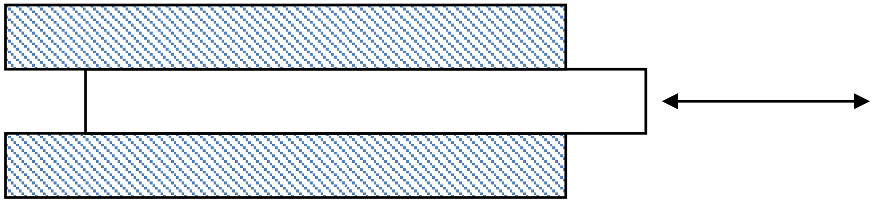


Joints

- Joints allow for controlled motion of one linkage relative to another
- Rotary or hinge joints allow rotation around a pivot

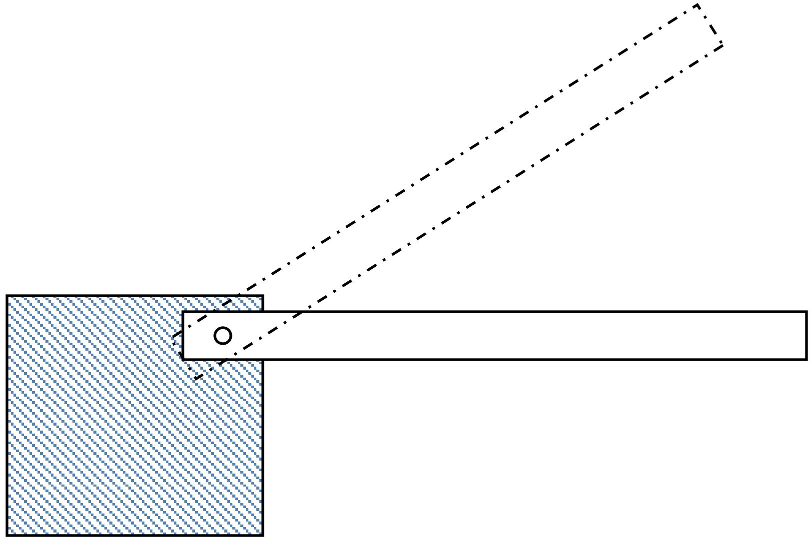


- Prismatic or sliding joints allow translation along one axis



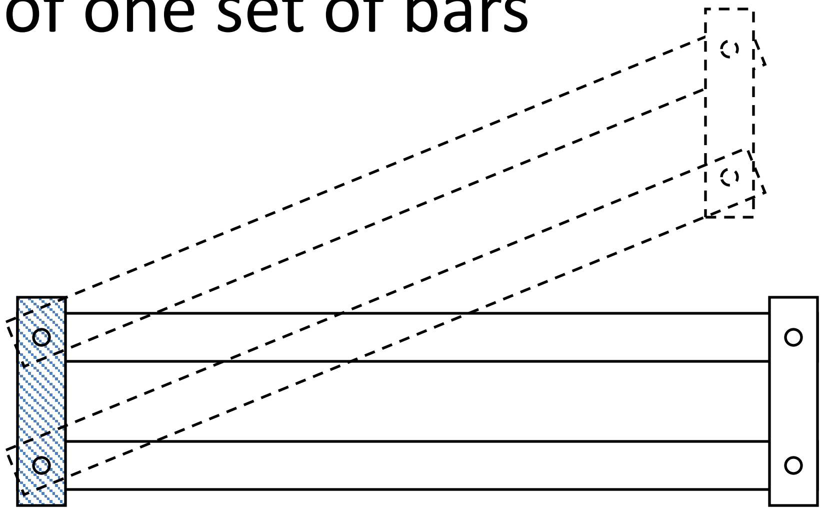
Linkages

- Single bar
  - Mostly rigid long piece of material
  - End of the bar changes orientation as the bar rotates



Linkages

- Parallel bar
  - A parallelogram created using single bars and hinge joints
  - Can move along an arc without changing orientation of one set of bars



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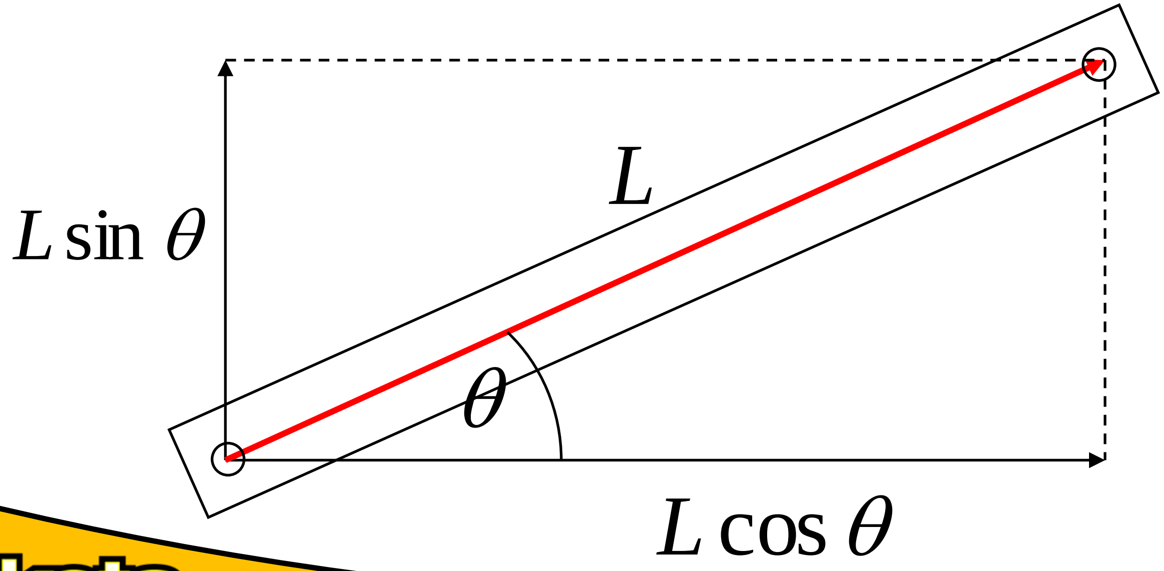
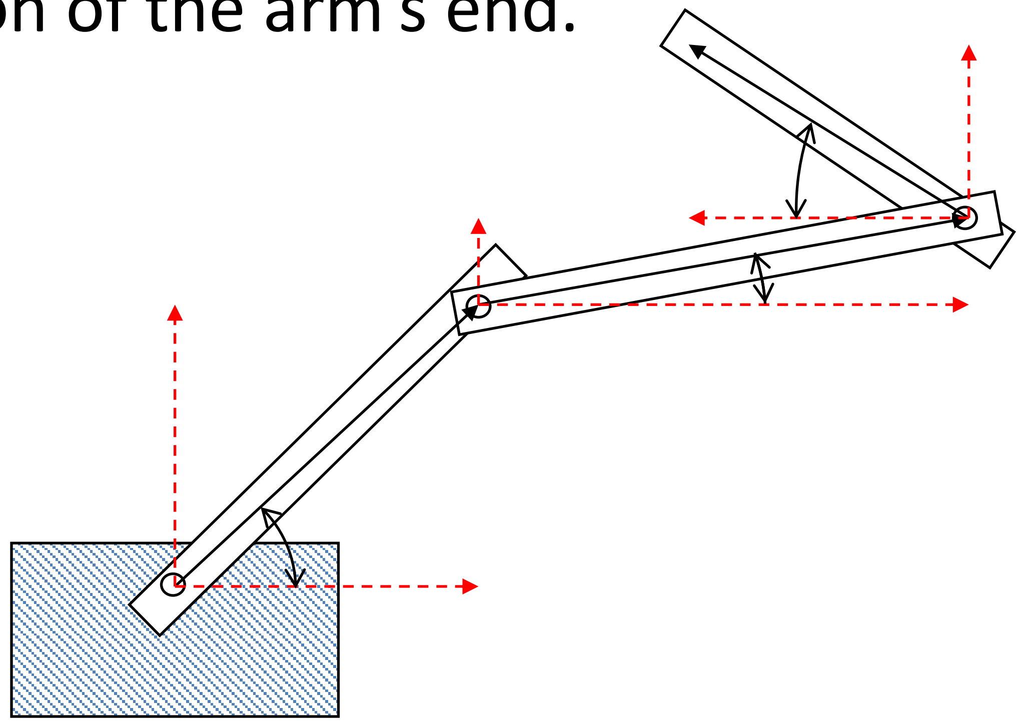
Arm Geometry

- Trigonometry
  - By using arm angles and linkage lengths, the position of the end can be found.
  - This can be simplified using projections of the linkages onto the x and y axes.



Arm Geometry

- With multiple linkages and joints the projections on the x and y axes just need to be added to find the final position of the arm's end.



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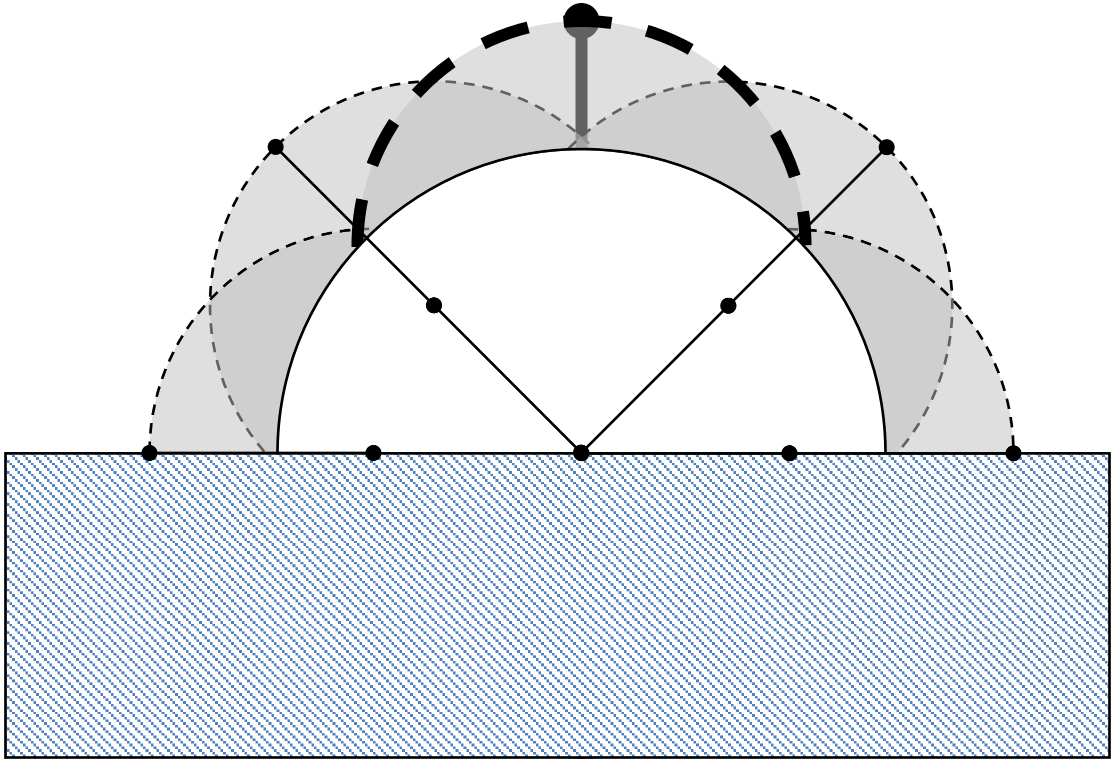
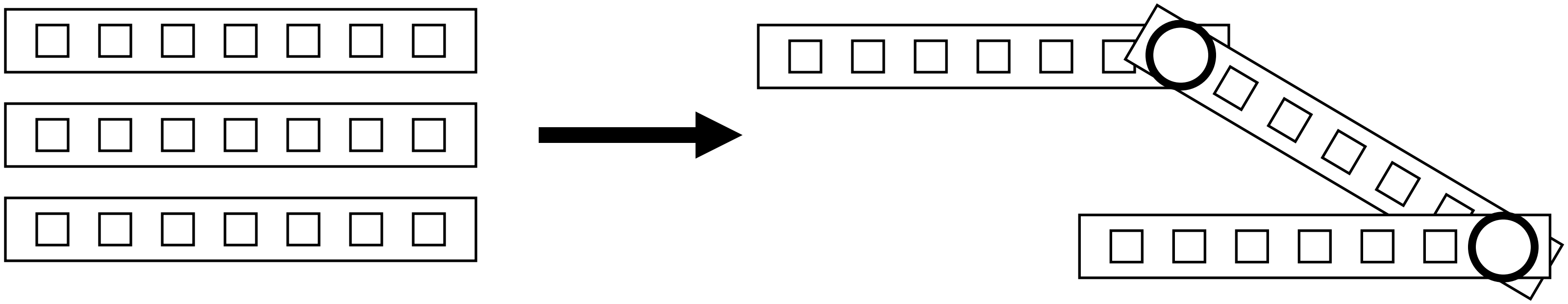
Workspaces

- Maximum reachable workspace
  - The largest possible reachable area around your arm



Activity

- Build a flat, unpowered arm with 2 rotary joints and 3 linkages.
  - 1 linkage – 3 holes long, 5 holes long, 15 holes long



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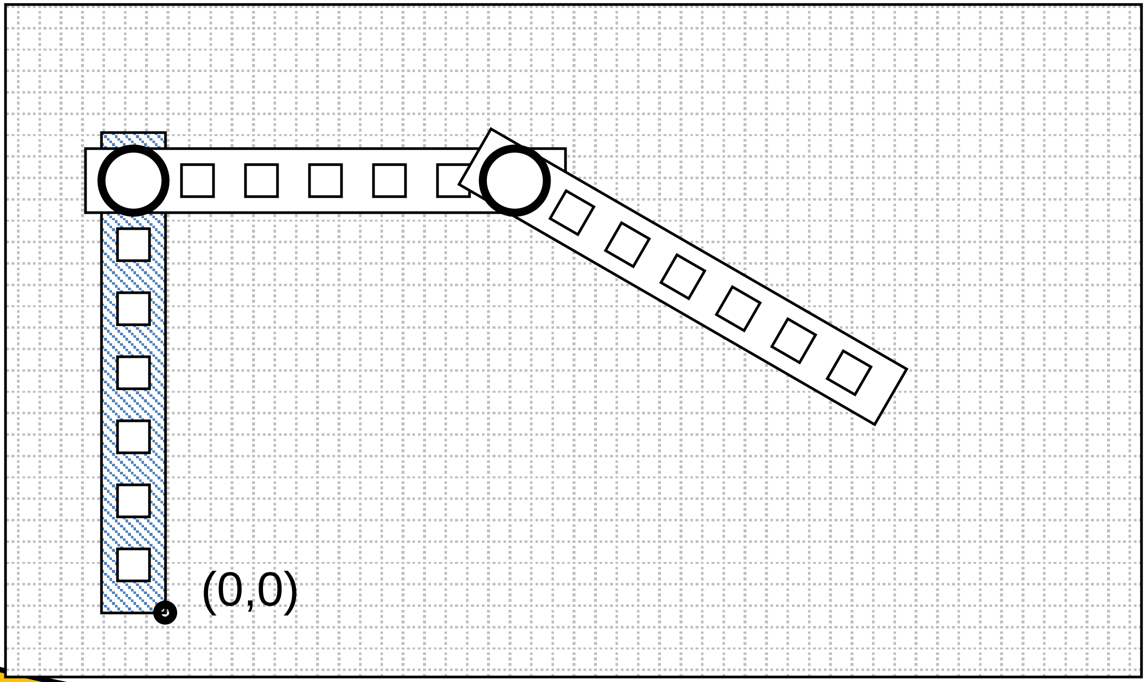
Activity (Cont'd)

- If the first linkage can not move and the joints can move 90 degrees each way from the parallel direction draw the maximum reachable workspace using your model.

Activity II

- Using a sheet of paper find and trace two ways to make your end effector reach the following coordinates. Your model should be oriented as follows.



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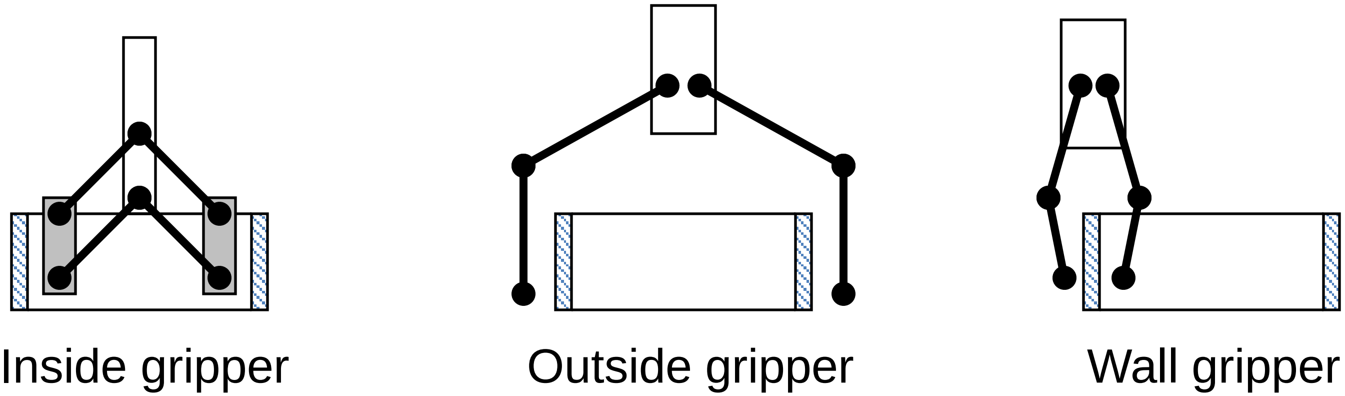
Manipulation – End Effectors

End Effectors

- End effectors are at the end of a robot arm and interact with the objects being manipulated.
  - Passive
    - Hooks and adhesive end effectors that do not have a powered grip
  - Active
    - Grippers, suction cups and other powered grasping deviced

End Effectors

- Active grippers
  - More complex, but end up being more reliable in cases where the robot is moving with an object.
  - Geometry must match the object(s) being grasped
    - Note : Consider objects deformation properties.



Rollers/Conveyors

- Good at moving large amounts of similar objects quickly.
- Past FIRST and FTC scoring objects that have been scored with conveyors or rollers.
  - Storage bins
  - Foam balls
  - Rubber balls
  - Softballs

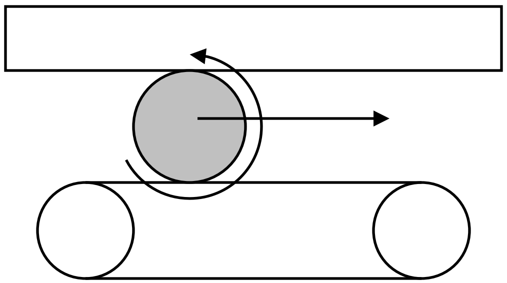
Types of Rollers

- Rigid rollers are generally good at picking up uniformly-sized, deformable objects
  - Foam balls
  - Inflatable balls

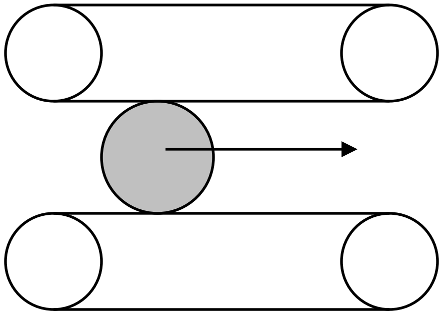
- Soft or deformable rollers are generally better at picking up harder or variable sized objects
  - Softballs

Enclosed Conveyor Systems

- Single belt
  - Rolls the object against a stationary surface

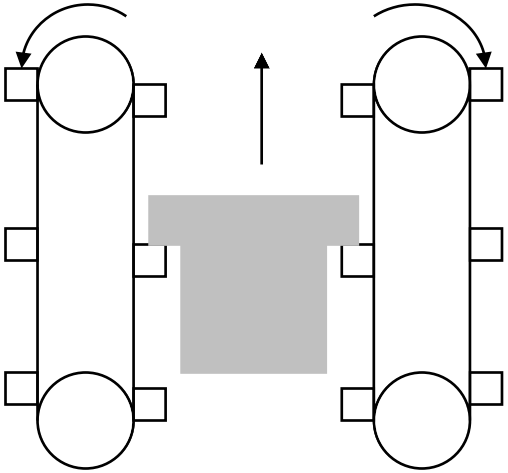


- Double belt
  - Translates the object between two conveyor belts
  - Object moves twice as fast as in a single belt system with the same belt speed



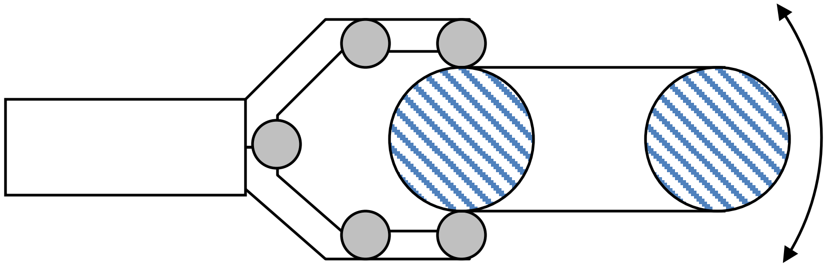
Enclosed Conveyor Systems

- Smooth belt
  - Belt provides more contact area with object
  - Has the ability to slide if there is a buildup of objects
- Profiled
  - Belt does not rely on friction but uses the geometry of the object to provide support
    - Used to stack boxes in 2003 FRC



Conveyor / Arm / Roller Combinations

- Grippers can use rollers to grasp objects and rotate them in their grasp



- Arms with limited dexterity can use rollers or conveyors to align objects for pickup
- Enclosed conveyors can be articulated like a simple arm to score several items quickly and semi-dexterously

Powering

- All previously mentioned methods from driving a robot apply
  - Gears
  - Chain
  - Belts
- Primarily seen with manipulators
  - Lead screws
  - Worm gears
  - Rack and Pinion
  - Pulley systems with cable
  - Pneumatics

Fluid Power

What is Fluid Power?

- Pressurized fluid does the work
- Hydraulics
  - Oil
  - Water
  - Other fluids
- Pneumatics
  - Air
  - Nitrogen
  - Hot gases
  - Other gases

When to use fluid power

- Electric
  - High speed but low torque (force) → requires gears
  - Control is often more precise and rapid and less expensive
- Hydraulic and pneumatic
  - Speed/torque combo is well suited to many motion applications
  - Well suited to high forces
  - Can be delivered “around the corner”
  - Control is usually by throttling, hence wastes energy
- Center for Compact Efficient Fluid Power
  - A brazen commercial

Hydraulics is Especially critical to the Mobile Equipment Industry

Mobile equipment (construction)

Pneumatics compared to hydraulics

- No problems of a spills
- Compressibility stores energy
  - Available for your use
  - Dangerous if excessive volumes or pressures
- Difficult to control precisely
- Fluid is readily available
  - Should be filtered, dry
- Usually lower forces

Safety Must Always Be Considered!

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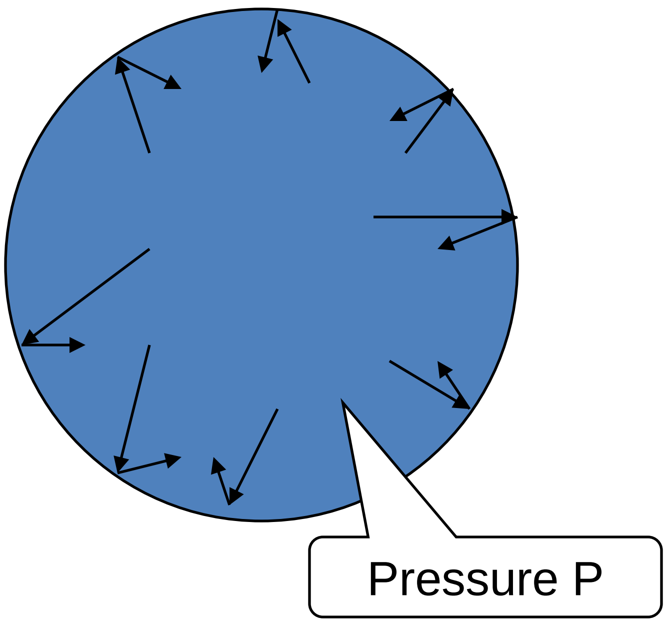
Pressure of an “ideal” Gas



$$P \times V = mR \times T$$

- Pressure of a gas is due to the force of gas molecules bouncing off the walls.
- Pressure increases when molecules are moving faster, heavier, or if there are more molecules.
- Molecules move faster when they are hot.
- mR depends on molecule.

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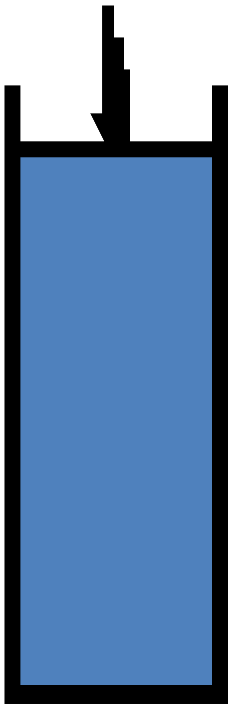
Getting Work out of Air



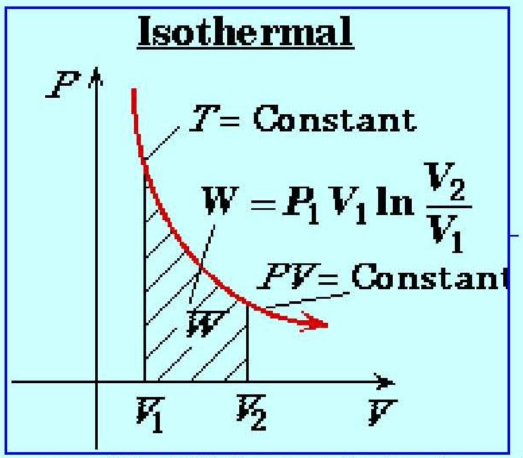
- Work is force acting over a distance of motion, e.g. Newton x meters
- Put air in a container under pressure
- Allow part of the container to expand
- The expanding part does work

How much energy is in your tank?

- Tank Volume = 150 ml or 9.154 in^3
- Pressure = 413,700 Pa or 60 psi
- Atmospheric pressure = 101,325 Pa or 14.7 psi
- Answer:
  - Assume constant temperature:
    PV = mRT = constant
  - Work = PV $\ln(P/P_{atm})$
    = 0.15 x 413,700 x ln(4.083) = 87.3 kJ

Alternative Work Possibilities

$$W = \int_{V_1}^{V_2} P(V)\,dV$$

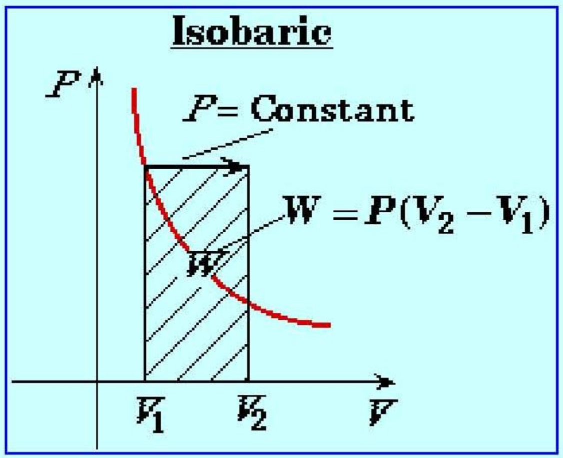


Blowup of the PV diagram for Isothermals

$$P = \frac{nRT}{V}$$

$$W = \int_{V_1}^{V_2} P\,dV = \int_{V_1}^{V_2} \frac{nRT}{V}\,dV$$

$$= nRT \int_{V_1}^{V_2} \frac{dV}{V} = nRT \ln \frac{V_2}{V_1}$$

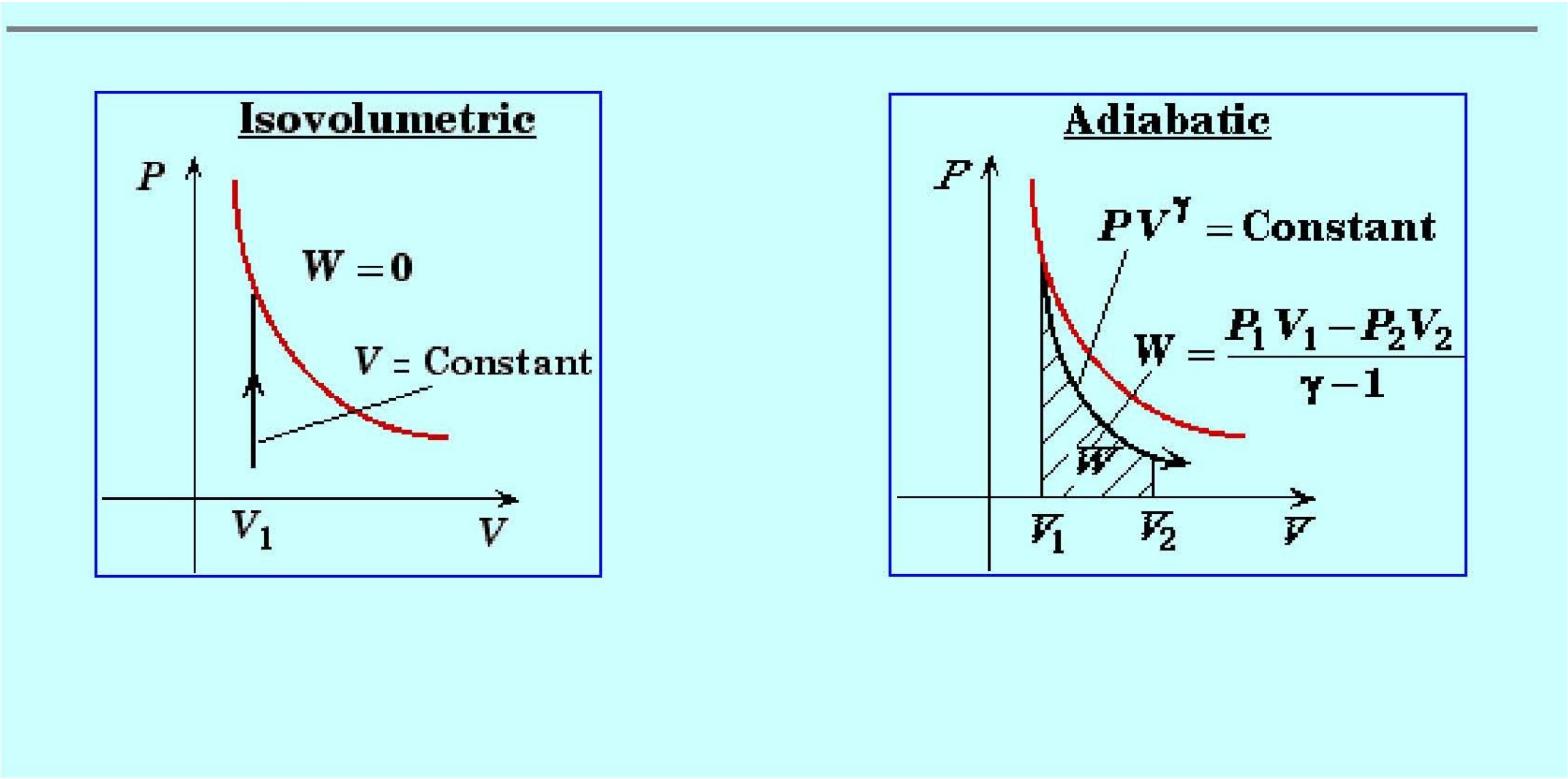


$$P = \text{Constant}$$

$$W = \int_{V_1}^{V_2} P\,dV = P \int_{V_1}^{V_2} dV$$

$$= P\,\Delta V$$

More work possibilities



http://www.ac.wwu.edu/~vawter/PhysicsNet/Topics/Thermal/PV_WorkDiag.html (1 of 2)10/23/2006 1:07:17 PM

How much energy in your tank can you use?

- Line losses:
  Pressure drop proportional to flow

- Throttling losses:
  Pressure drop proportional to flow squared

- Cylinder friction:
  Coulomb plus viscous friction, depends on seals

Force available

- Pressure x Area = Force
- Area = pi x Bore^2 / 4

- For Festo cylinder (at 80psi or 5.516 bar):
  - – Bore = 20 mm → Area = 314 mm^2
  - – Force = 551,600 x 314 x 10^{-6} = 173 N
  - – at 100 psi: F = 217 N

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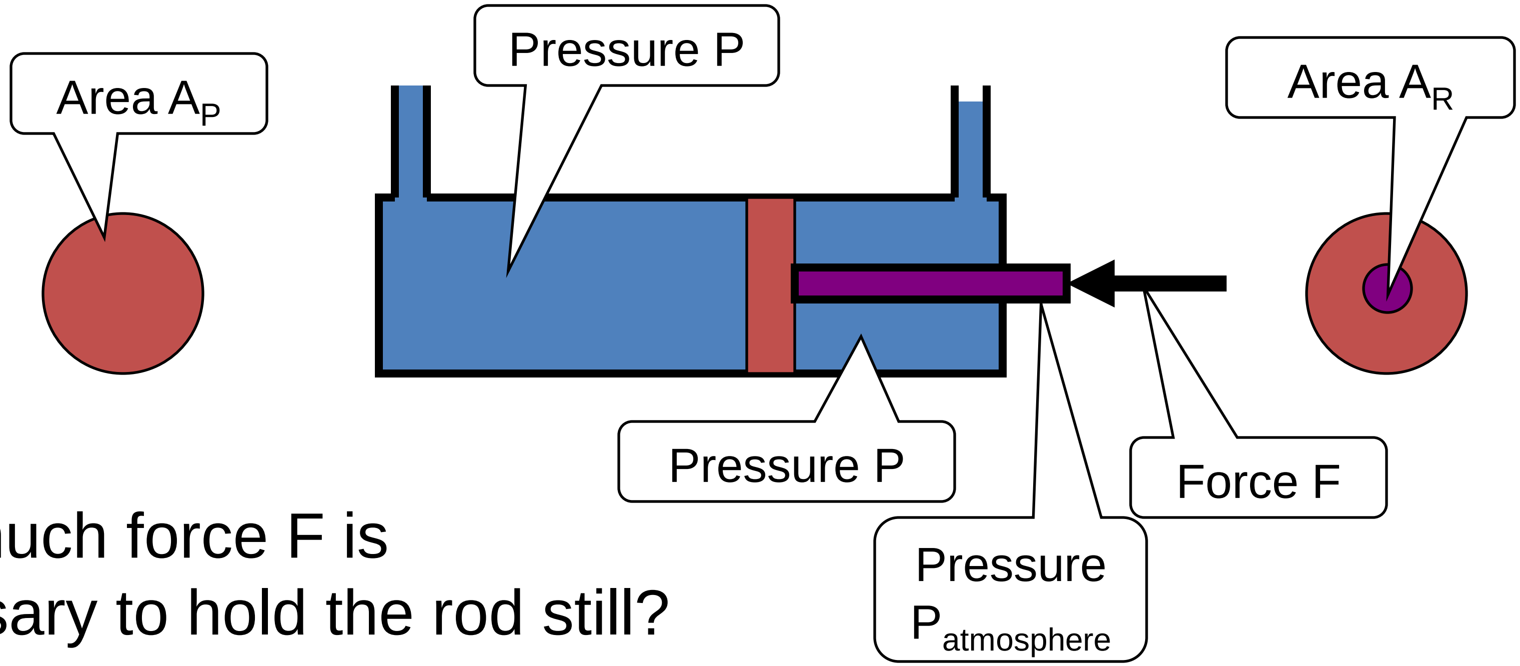
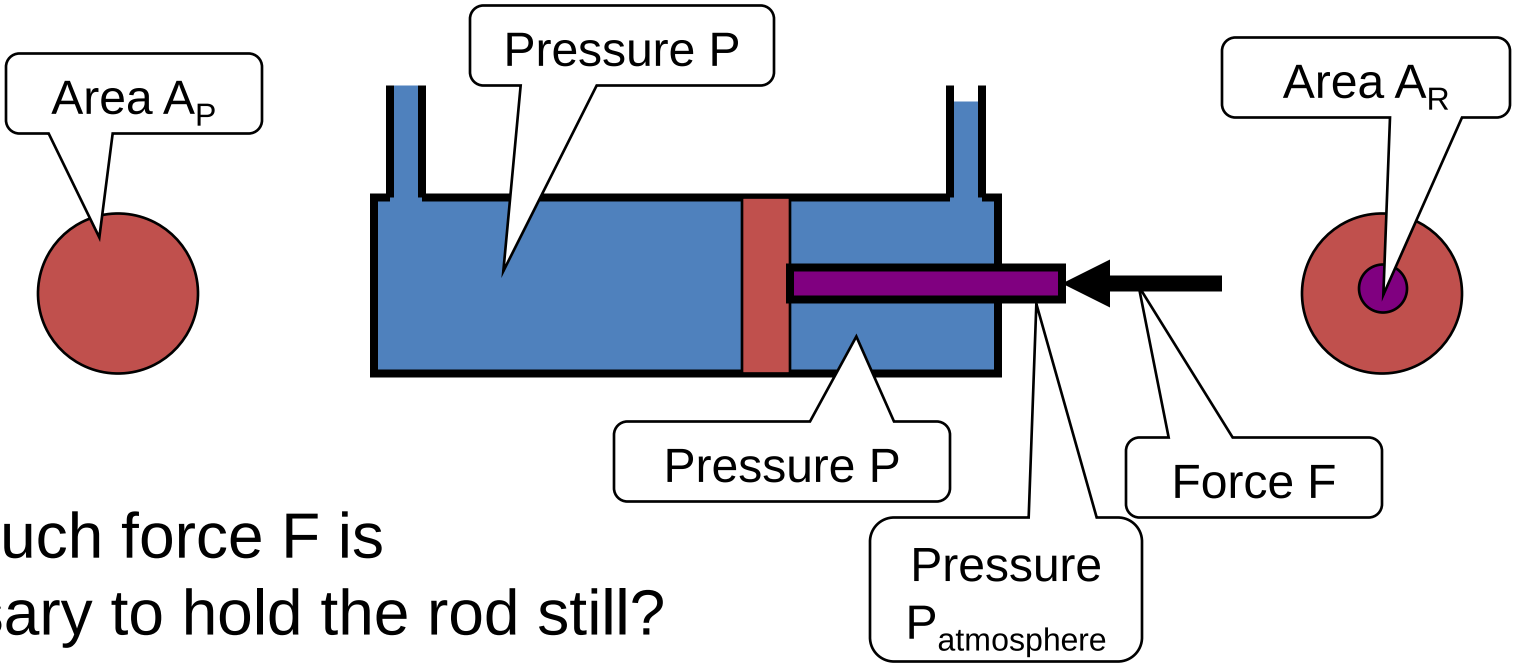
The Effect of Different Areas



How much force F is necessary to hold the rod still?

The Effect of Different Areas



How much force F is necessary to hold the rod still?

Answer: Force to the right = Force to the left

$$P \times A_P = P \times (A_P - A_R) + P_{atm} \times A_R + F$$

$$F = A_R \times (P - P_{atm})$$

Basic Operation of the Servo Valve
(single stage)

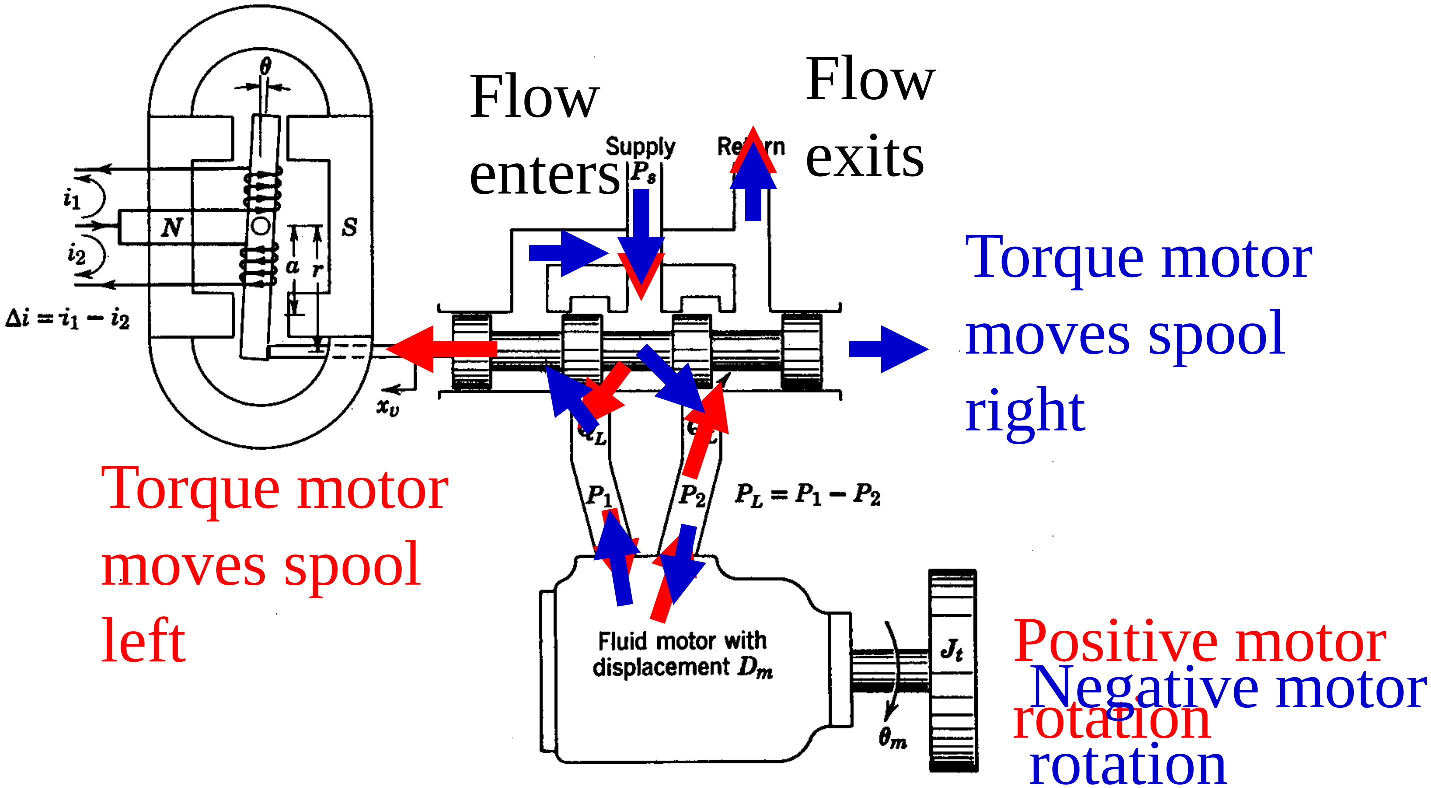
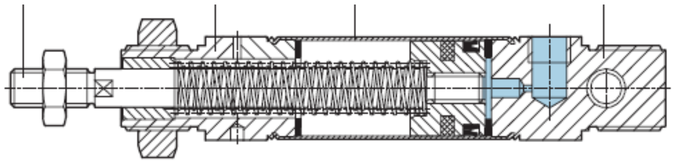


Figure 7-11 Schematic of a single stage electrohydraulic servovalve connected to a motor with inertia load.

Components for hands on task

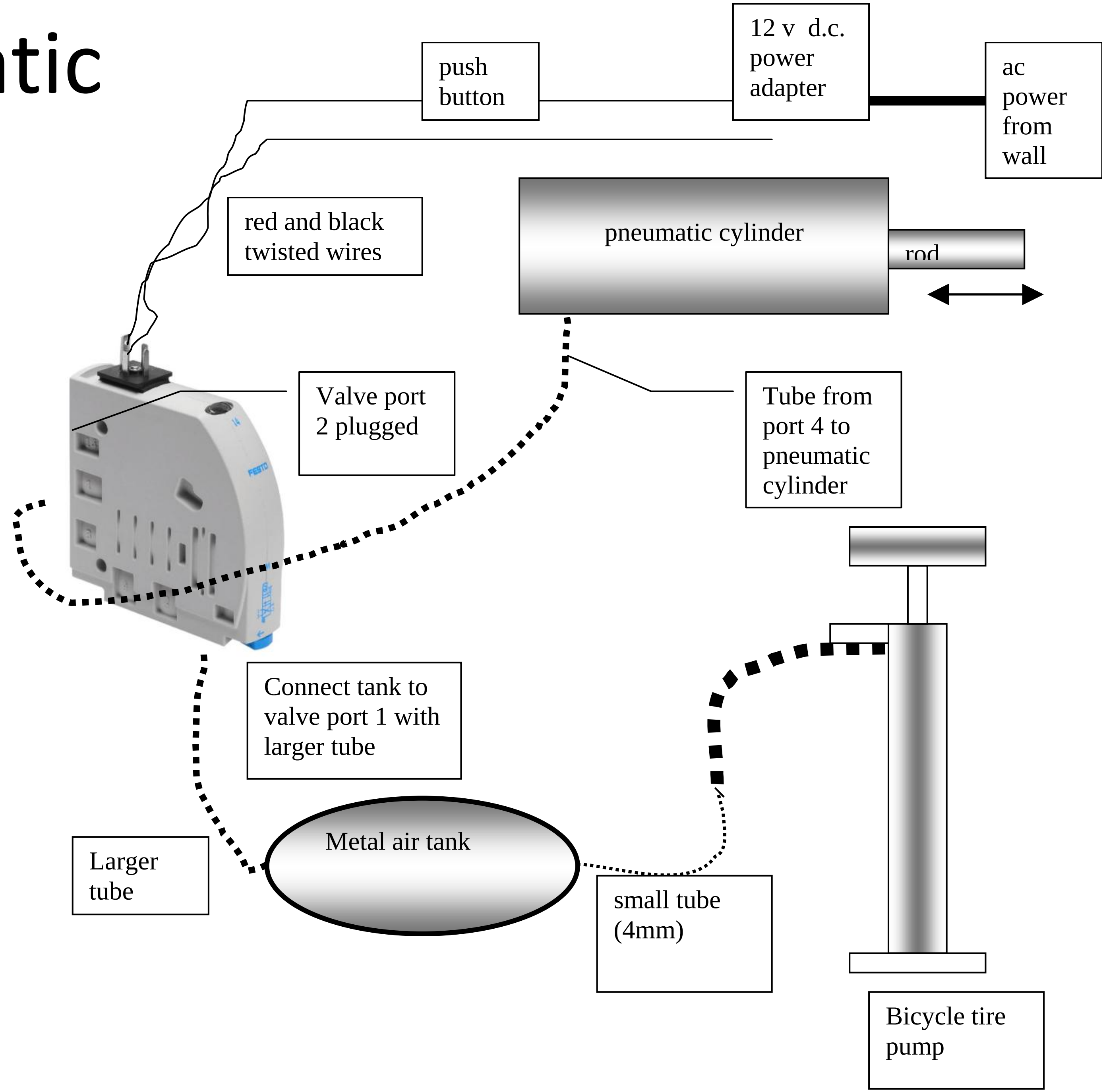
- Cylinder: single acting, spring return
  - Max force: 169 N or 38 lbf
  - Stroke: 50 mm or 1.987 in
  - Bore: 20 mm or 0.787 in



- Valve:
  - 4-way, 2-position
  - normally closed, vents to atmosphere

- Reservoir:
  - Size: 400 ml or 24.4 in^3
  - Max pressure: 16 bar (10^5 bar) or 232 psi

Pneumatic Kit



Today’s Challenge

Who can build the pneumatically powered bobsled with the longest travel?

- Rules
  - The reservoir shall be charged at 80 psi
  - "driver" weight can be chosen
  - Only fluid power actuators (pistons) shall be used
  - The best out of three rides shall be considered

GOOD LUCK!

Some YouTube Videos

- http://www.youtube.com/watch?v=jkft2qaKv_o
- http://www.youtube.com/watch?v=0gk-yQ1H3M8
- http://www.youtube.com/watch?v=7l0qIO7y6Cc
- http://www.youtube.com/watch?v=2cIuuplWRIQ

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