Basic Hydraulics

Introduction to Hydraulics

Introduction to Hydraulics

Objectives

After the completion of this module, the student will be able to:

- **Identify the common uses of hydraulic systems.**
- **Identify the fundamental parts of a hydraulic system.**
- **Observe how hydraulic components can be connected together to construct a hydraulic circuit.**
- **Identify the main components of the hydraulic work station**
- **Explain the importance of using standard hydraulic symbols.**
- **Identify the basic hydraulic laws.**
- **Calculate the piston area, force, and pressure.**
- **Explain Pascal's law and apply it on different examples.**
- **Differentiate between the flow rate and flow velocity.**
- **Demonstrate the continuity equation.**
- **Calculate the area, velocity, and flow rate at different sections of a pipe.**
- **Describe how to read a pressure gauge in the US and SI units.**

Introduction to Hydraulics

All machines require some type of power source and a way of transmitting this power to the point of operation.

The three methods of transmitting power are:

- **Mechanical**
- **Electrical**
- **Fluid**

- **Hydraulics belong to the third type of power transmission which is the Fluid Power**

Introduction to Hydraulics

- **Fluid power** is the method of using pressurized fluid to transmit energy.

- **Liquid** or **Gas** is referred to as a **fluid.** Accordingly, there are two branches of fluid power; **Pneumatics,** and **Hydraulics**.

We have discussed Pneumatic systems which uses **air** to transfer force from one point to another.

- **Hydraulic systems** use **liquid** to transfer force from one point to another.

Introduction to Hydraulics

- **Air** is **Compressible:**

(*This describes whether it is possible to force an object into a smaller space than it normally occupies. For example, a sponge is compressible because it can be squeezed into a smaller size*).

- **Liquid** is **Incompressible:**

(*The opposite to compressible. When a "squeezing" force is applied to an object, it does not change to a smaller size. Liquid, for example hydraulic fluid, possesses this physical property*).

Introduction to Hydraulics

- **Hydraulic systems are commonly used where mechanisms require large forces and precise control.**

- **Examples include vehicle power steering and brakes, hydraulic jacks and heavy earth moving machines.**

Uses of hydraulics

- **Hydraulics plays an important role in many industries; there are a lot of hydraulic applications in manufacturing, transportation, and construction sectors.**

- **Hydraulics systems are used where large, precise forces are required.**

Common examples of hydraulic systems include:

Vehicle brake hydraulic systems

The function of a vehicle braking system is to stop or slow down a moving vehicle. When the brake pedal is pressed as illustrated in Fig. 1.1, the hydraulic pressure is transmitted to the piston in the brake caliper of the brakes. The pressure forces the brake pads against the brake rotor, which is rotating with the wheel. The friction between the brake pad and the rotor causes the wheel to slow down and then stop.

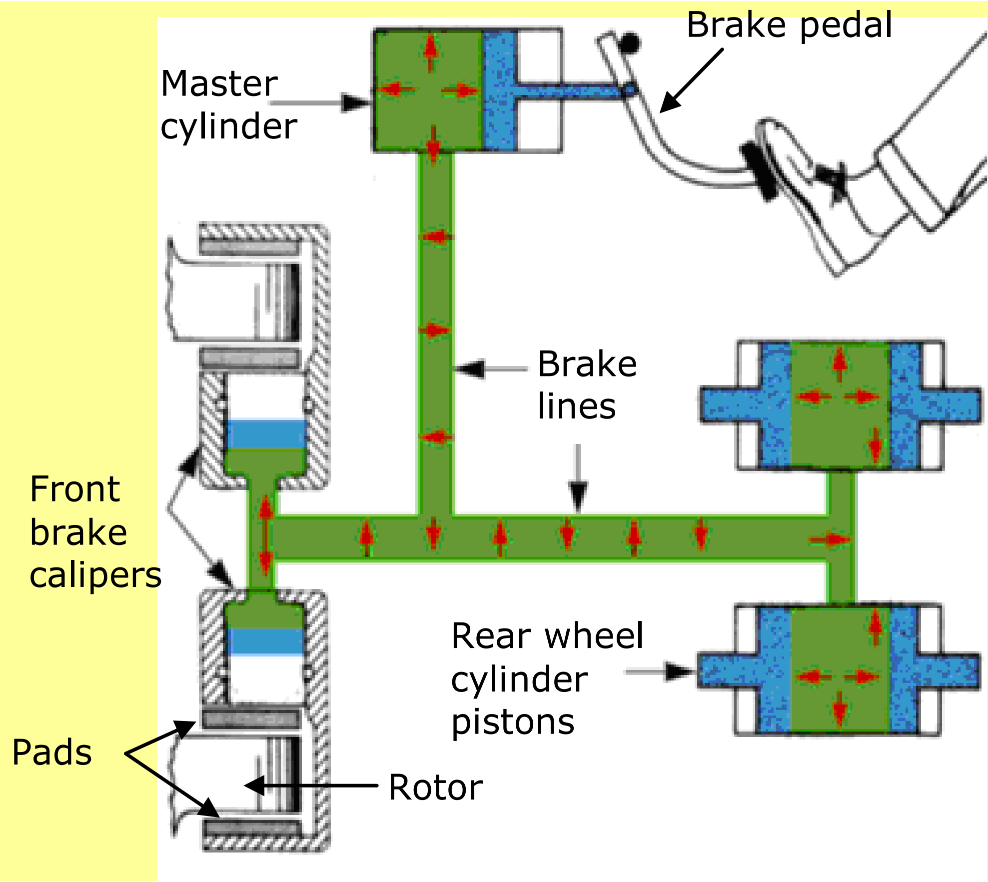


Fig.1.1: A schematic diagram of the vehicle's hydraulic brake system.

Common examples of hydraulic systems include:

Vehicle power steering

The vehicle power steering system uses hydraulic oil, the hydraulic pump supplies the oil through the control valves to the power cylinder as shown in Fig. 1.2. The major advantage of using this system is to turn the vehicle's wheels with less effort.

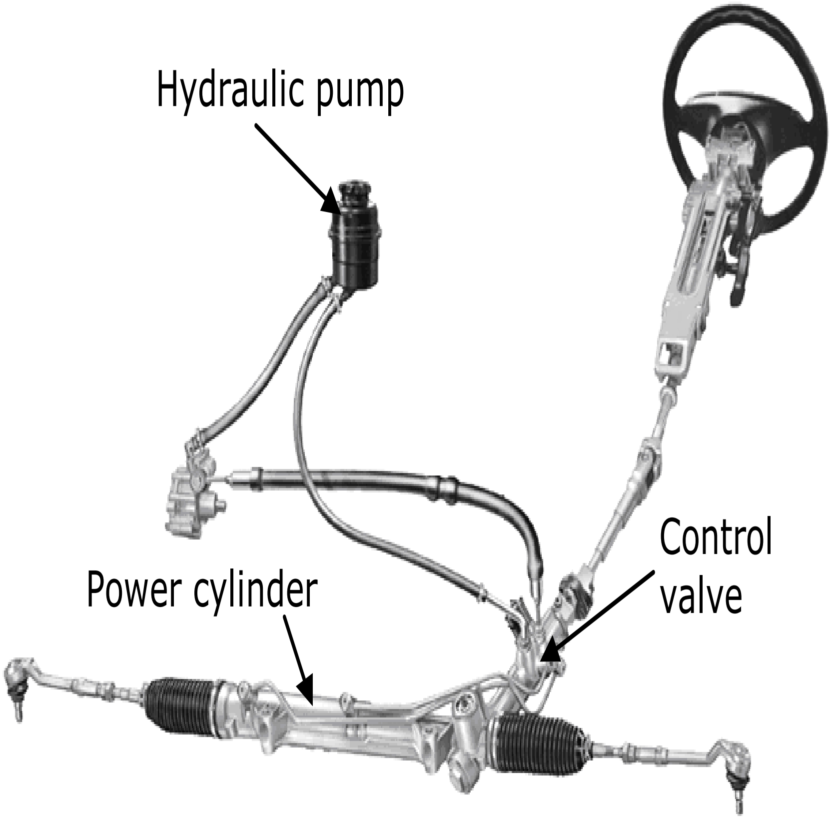


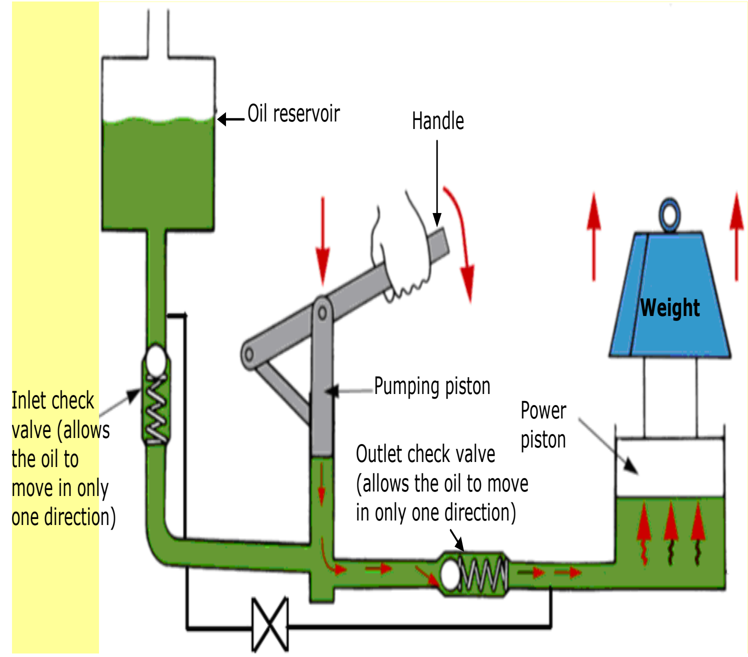
Fig.1.2:Vehicle hydraulic power steering system

Common examples of hydraulic systems include:

Hydraulic jack

- In a hydraulic jack, a small piston (pumping piston) transmits pressure through the oil to a large piston (power piston) through a check valve, resulting in the weight being lifted as shown in Fig.1.3.

(a) Hydraulic jack

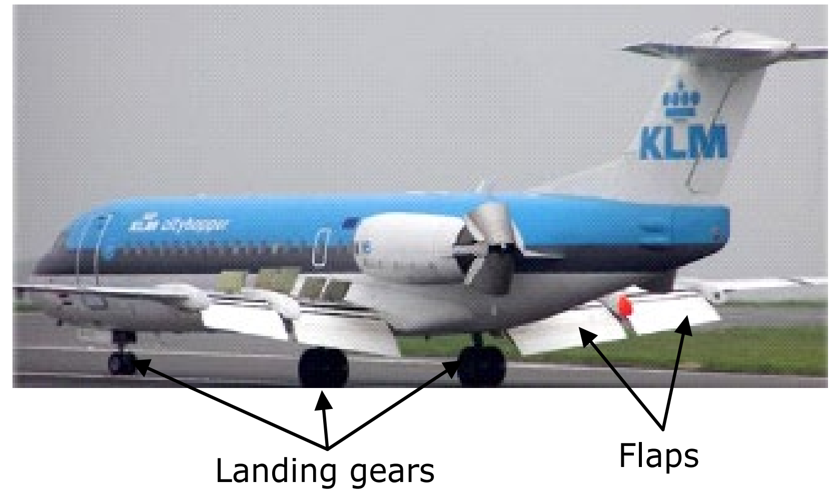


(b) Hydraulic jack schematic diagram

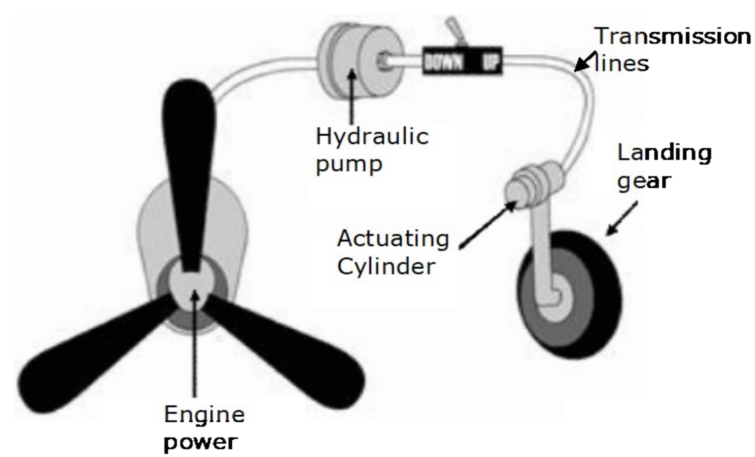
Common examples of hydraulic systems include:

Aircraft hydraulic systems

- All modern aircraft contain hydraulic systems to operate mechanisms, such as:
- Flaps (Fig. 1.4a)
- Landing gear (Fig. 1.4a)
- The hydraulic pump that is coupled to the engine provides hydraulic power as illustrated by Fig. 1.4b.
- Power is also distributed to systems through the aircraft by transmission lines.
- Hydraulic power is converted to mechanical power by means of an actuating cylinder or hydraulic motor.



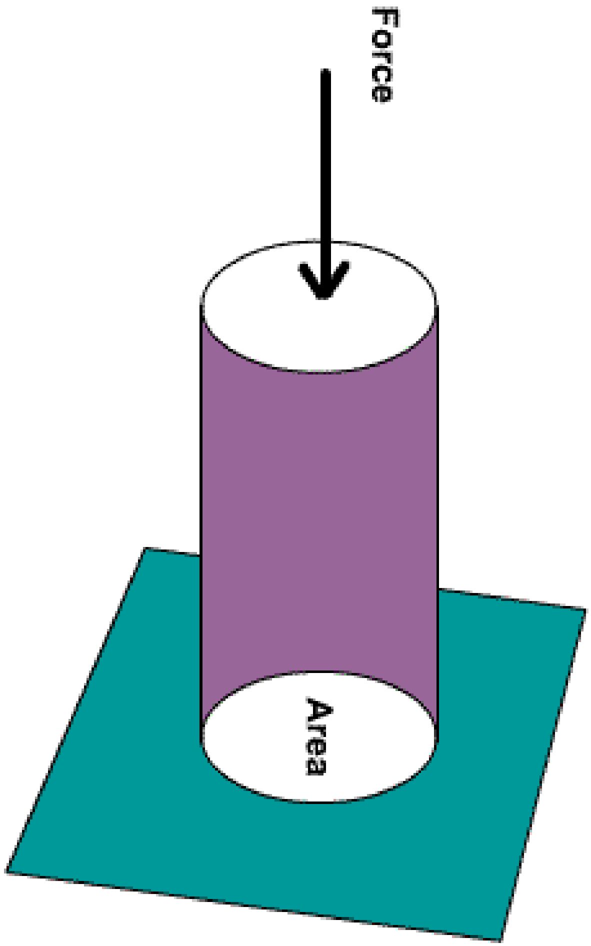
(a) Landing gears and flaps



(b) Landing gear schematic diagram

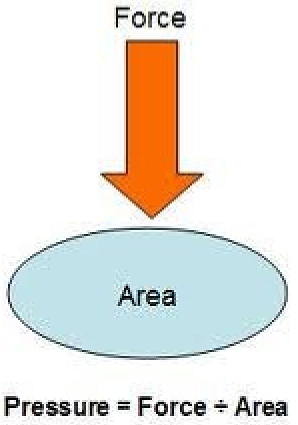
Fundamental laws of Hydraulics

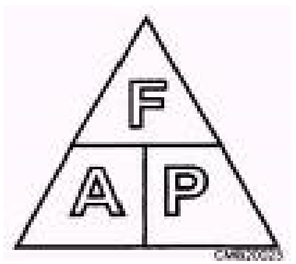
- All hydraulic systems operate following a defined relationship between area, force and pressure.
- Laws have been established to explain the behavior of hydraulic systems.
- Hydraulic systems use the ability of a fluid to distribute an applied force to a desired location.



Fundamental laws of Hydraulics Pressure

- **When a force (F) is applied on an area (A) of an enclosed liquid, a pressure (P) is produced as shown in Fig.**
- **Pressure is the distribution of a given force over a certain area.**
- **Pressure can be quoted in bar, pounds per square inch (PSI) or Pascal (Pa) .**





$$P = \frac{\mathbf{F}}{\mathbf{A}}$$

Pressure

$$P = \frac{\mathbf{F}}{\mathbf{A}}$$

Where
Force is in Newtons (N) and
Area is in square meters (m^2).

1 Pascal (Pa) =1 N/m^2.
1 bar= 100,000 Pa= 10^5 Pa.
10 bar= 1 MPa (mega Pascals)

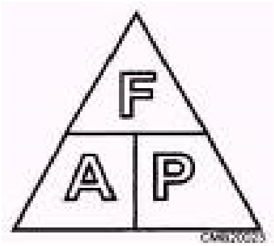
Pressure

- If the pressure is calculated using a force in Newton, and area in square millimeters, the pressure in bar can be calculated.

Example 1-1.

A cylinder is supplied with 100 bar pressure; its effective piston surface is equal to 700 mm2. Find the maximum force which can be attained.

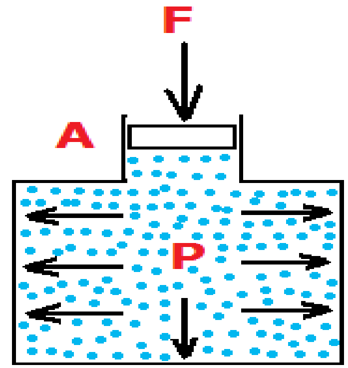
- P= 100 bar = 100X100000 N/m2.
- A= 700/1000000=0.0007 m2.
- F= P.A= 100X100000X0.0007= 7,000 N



Pascal's Law

- **Pascal's law** states that: "*The pressure in a confined fluid is transmitted equally to the whole surface of its container*"

- **When force F is exerted on area A on an enclosed liquid, pressure P is produced. The same pressure applies at every point of the closed system as shown in Fig. 1.10a.**



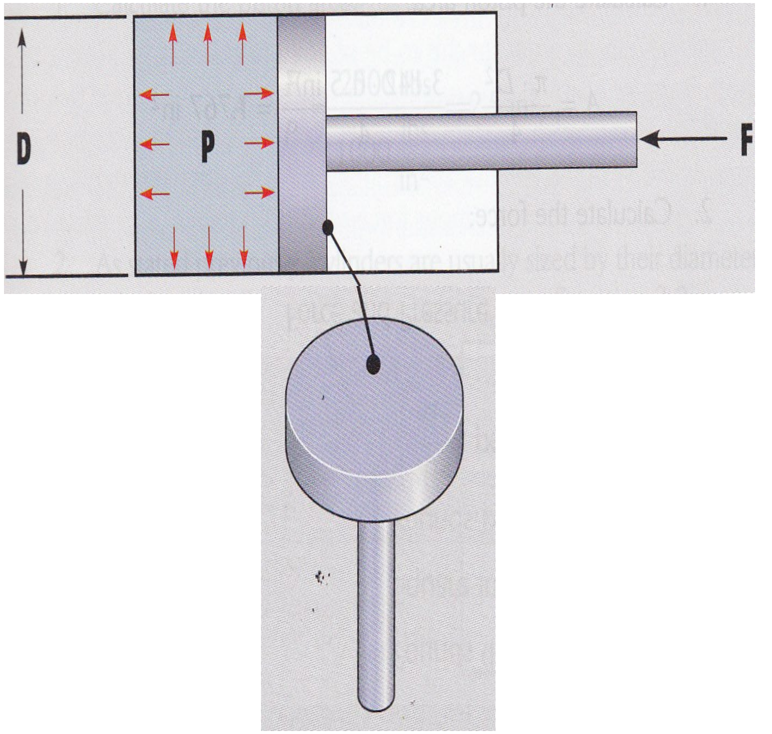


Fig.1.10: (a) Pascal's law.

Pascal's Law

- Fig.1.10b shows that, if a downward force is applied to piston A, it will be transmitted through the system to piston B.
- According to Pascal's law, the pressure at piston A (P1) equals the pressure at piston B (P2)

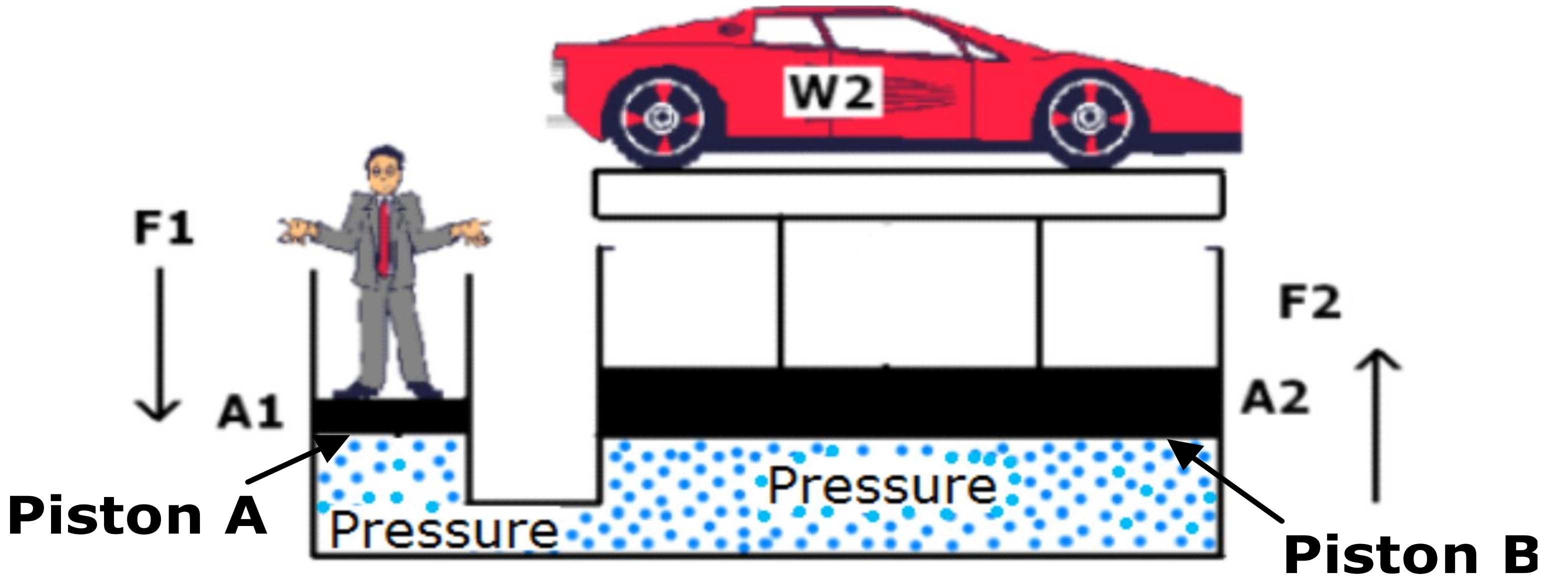


Fig.1.10: (b)Power transmission

Pascal's Law

Fluid pressure is measured in terms of the force exerted per unit area.

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

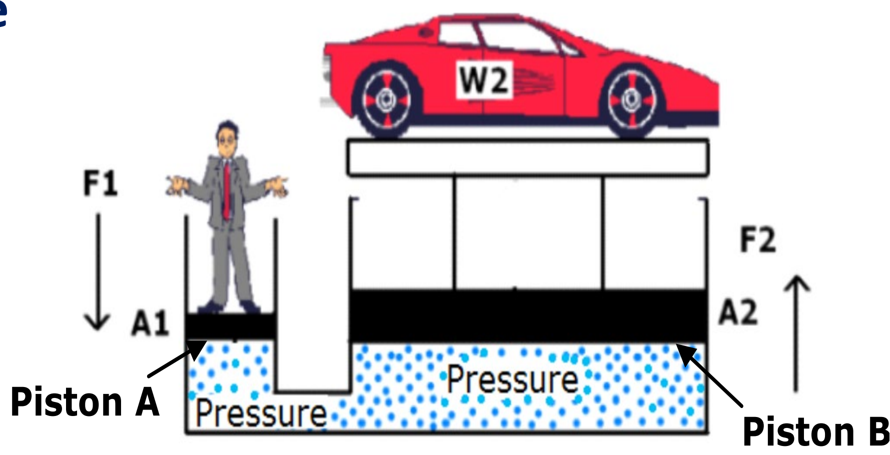
The values F1, A2 can be calculated using the following formula:

$$F_1 = \frac{A_1 \times F_2}{A_2}$$

$$A_2 = \frac{A_1 \times F_2}{F_1}$$

Pascal's Law

- **Example 1-2.**
- **In Fig.11, find the weight of the car in N, if the area of piston A is 0.0006m^2, the area of piston B is 0.0105 m^2, and the force applied on piston A is 500 N.**
- **Solution:**

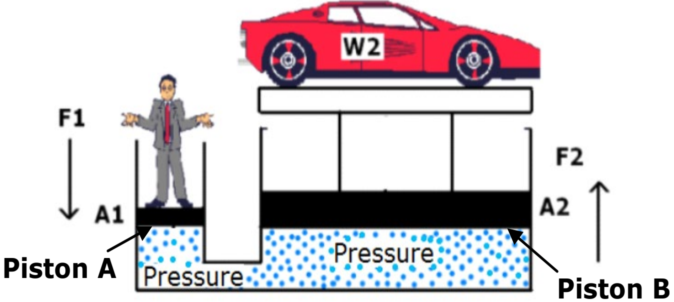


$$P_1 = P_2$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \Rightarrow F_2 = \frac{F_1 * A_2}{A_1} \Rightarrow F_2 = \frac{500 \times 0.0105}{0.0006}$$

$$\Rightarrow F_2 = 8750\ N = 8.75\ kN$$

Pascal's Law



- **Example 1-3.**

  In Fig 1.11, if the weight of the car is 10,000 N, the diameter of piston A is 0.01 m, and the force applied on piston A is 250 N. Calculate the area of piston B.

- **Solution:**

  1. Calculate the area of piston A, the piston shape is circular as shown in Fig. 1.10a, accordingly the area will be calculated using the following formula.

$$A_1 = \pi \frac{D^2}{4} = 3.14 \times \frac{(0.01)^2}{4} = 0.0000785\,\mathrm{m}^2$$

$$F_1 = 250\ N \qquad F_2 = 10{,}000\ N$$

Pascal's Law

- 2. Apply Pascal's law

$$P_1 = P_2 \qquad \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

- 3. Use Pascal's law to calculate the area of piston B

$$A_2 = \frac{A_1 \times F_2}{F_1}$$

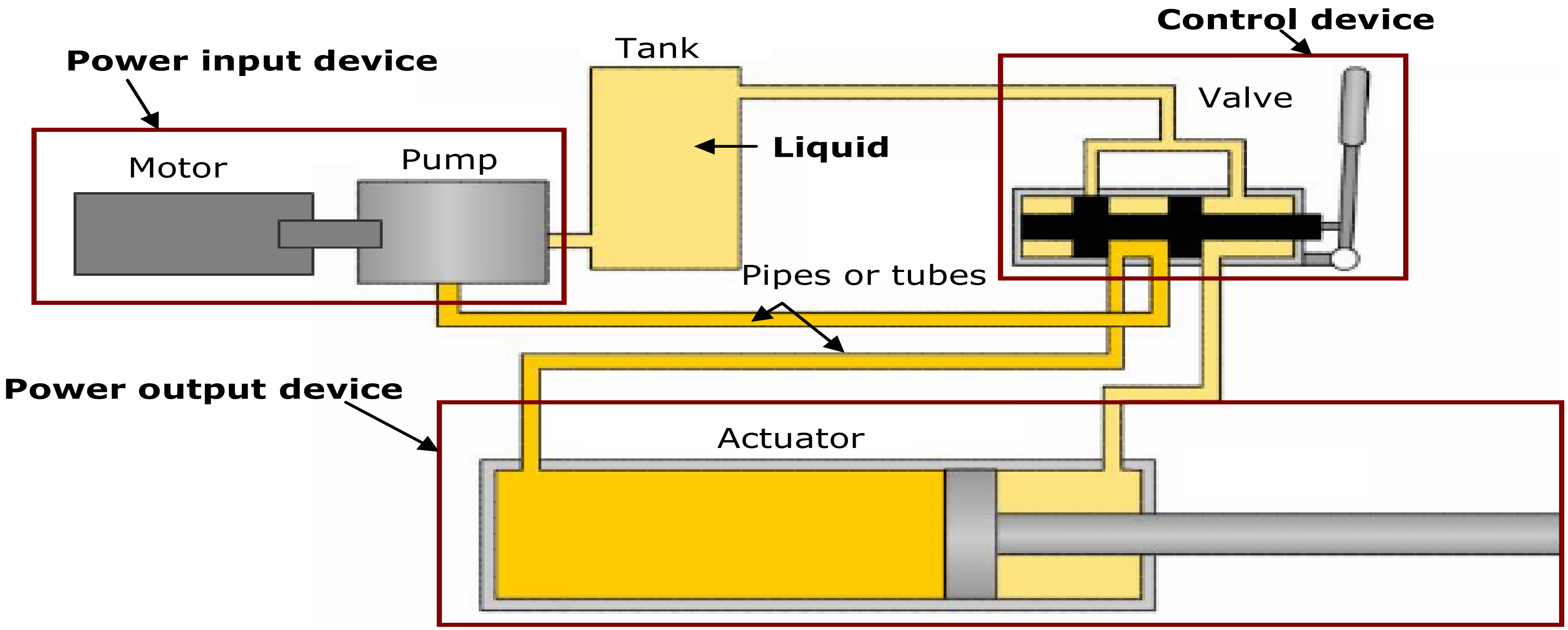
$$A_2 = \pi \times \frac{(D_2)^2}{4} = 0.003140\mathrm{m}^2$$

$$A_2 = \frac{0.0000785 \times 10{,}000}{250} = 0.00314\mathrm{m}^2$$

Hydraulic system components

- **All industrial hydraulic systems consist of the following basic components**
- **Power input device:**

  The pump and motor together are called the power input device; the pump provides power to the hydraulic system by pumping oil from the reservoir/tank. The pump's shaft is rotated by an external force which is most often an electric motor as illustrated in Fig 1.5.



Hydraulic system components

- **Control device**: Valves control the direction, pressure, and flow of the hydraulic fluid from the pump to the actuator/cylinder.
- **Power output device**: The hydraulic power is converted to mechanical power inside the power output device. The output device can be either a cylinder which produces linear motion or a motor which produces rotary motion.
- **Liquid**: The liquid is the medium used in hydraulic systems to transmit power. The liquid is typically oil, and it is stored in a tank or reservoir.
- **Conductors**: The conductors are the pipes or hoses needed to transmit the oil between the hydraulic components.

Hydraulic power pack

- **The hydraulic power pack combines the pump, the motor, and the tank. The hydraulic power pack unit provides the energy required for the hydraulic system. The parts of the hydraulic power pack unit are shown in Fig. 1.6.**

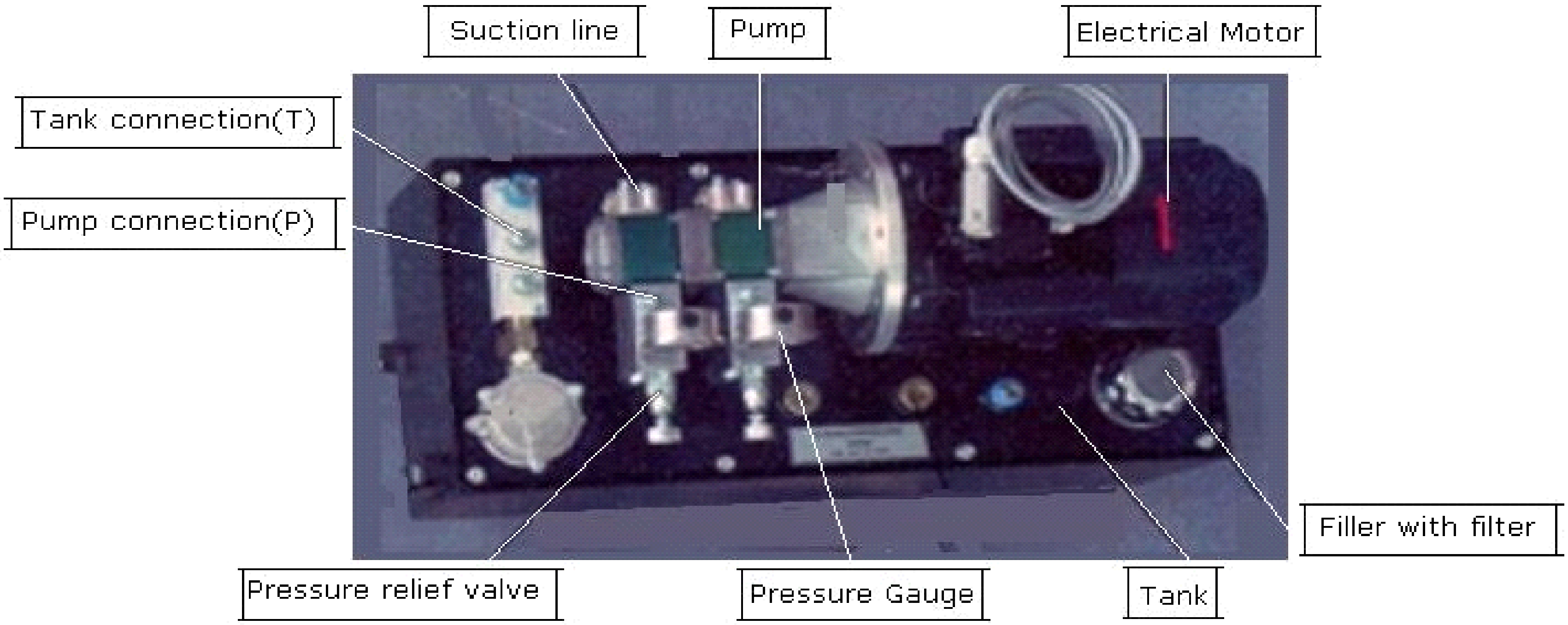
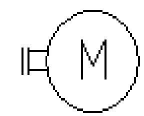


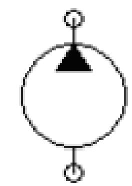
Fig.1.6: The main parts of the hydraulic power pack

Hydraulic symbols

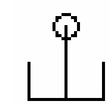
- **The way hydraulic components direct and control liquid around a circuit can be complex.**
- **This would cause difficulty for one engineer explaining to another engineer how the circuit works.**
- **A common form of representing components and circuits is used to more easily explain what is happening.**
- **This form of representation uses common symbols to represent components and the ways in which they are connected to form circuits. Fig. 1.7 shows some of the components' symbols used in hydraulics.**
- **The symbols don't show the component construction, or size, however, it is a standard form that is used by all engineers to represent that specific component.**



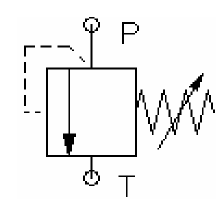
(a) Electric motor



(b) Hydraulic pump



(c) Tank or reservoir

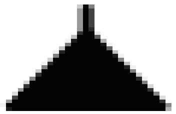


(d)Pressure relief valve

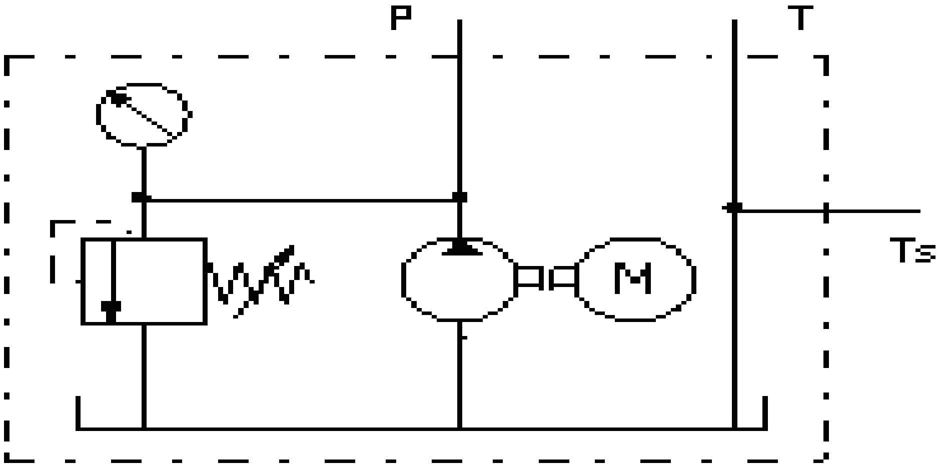
Fig.1.7: (a) Electric motor. (b) Hydraulic pump. (c) Tank or reservoir. (d) Pressure relief valve.

Power Pack Symbols

- **The simplified and detailed symbols of the hydraulic power pack are shown in Fig. 1.8.**



(a) Simplified



(b) Detailed

Fig.1.8: (a) Simplified symbol of the hydraulic power pack.
(b) Detailed symbol of the hydraulic power pack.

Liquid flow

Flow rate versus flow velocity

The flow rate is the volume of fluid that moves through the system in a given period of time.

Flow rates determine the speed at which the output device (e.g., a cylinder) will operate.

The flow velocity of a fluid is the distance the fluid travels in a given period of time.

These two quantities are often confused, so care should be taken to note the distinction. The following equation relates the flow rate and flow velocity of a liquid to the size (area) of the conductors (pipe, tube or hose) through which it flows.

$$Q = V \times A$$

Where: Q= flow rate (m^3/s); V= flow velocity (m/s)

A= area (m^2)

Liquid flow

This is shown graphically in Fig. 1.11. Arrows are used to represent the fluid flow. It is important to note that the area of the pipe or tube being used.

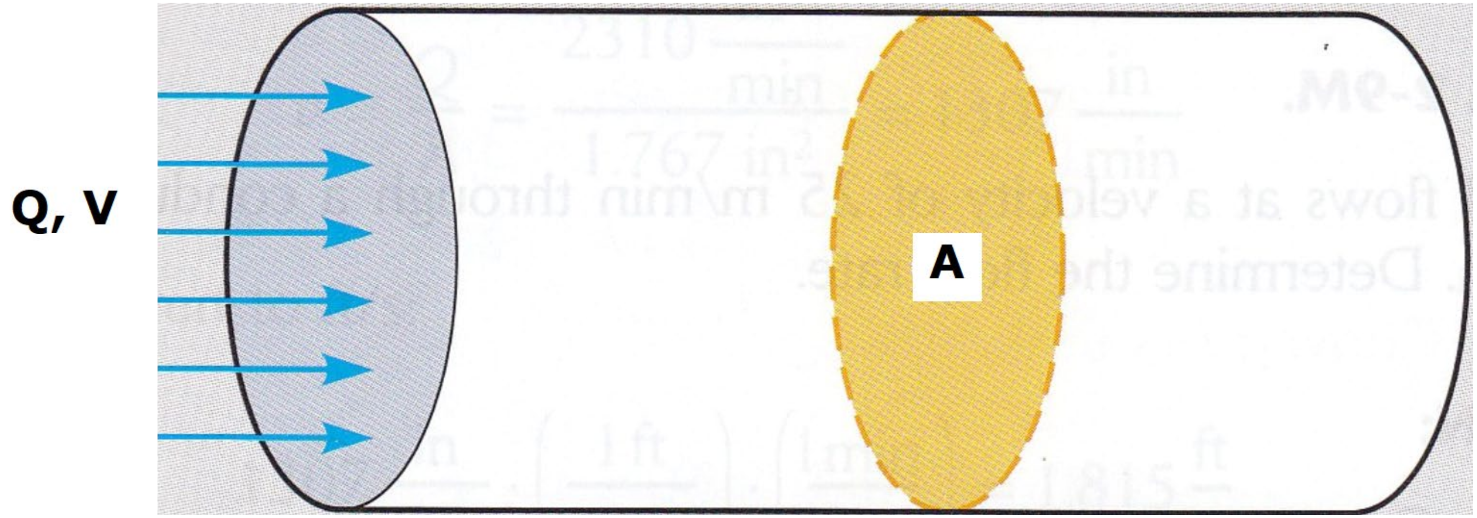


Fig.1.11: Flow velocity and flow rate

Liquid flow

- **Example 1-4.**

A fluid flows at a velocity of 2 m/s through a pipe with a diameter of 0.2 m. Determine the flow rate.

Solution:

1. Calculate the pipe area

$$A = \pi \frac{D^2}{4} = 3.14 \times \frac{(0.2)^2}{4} = 0.0314\,\mathrm{m}^2$$

2. Calculate the flow rate

$$Q = V \times A \qquad Q = 2 \times 0.0314 = 0.0628 \quad \frac{\mathrm{m}^3}{\mathrm{Sec}}$$

The continuity equation

Hydraulic systems commonly have a pump that produces a constant flow rate. If we assume that the fluid is incompressible (oil), this situation is referred to as steady flow. This simply means that whatever volume of fluid flows through one section of the system must also flow through any other section. Fig. 1.12 shows a system where flow is constant and the diameter varies

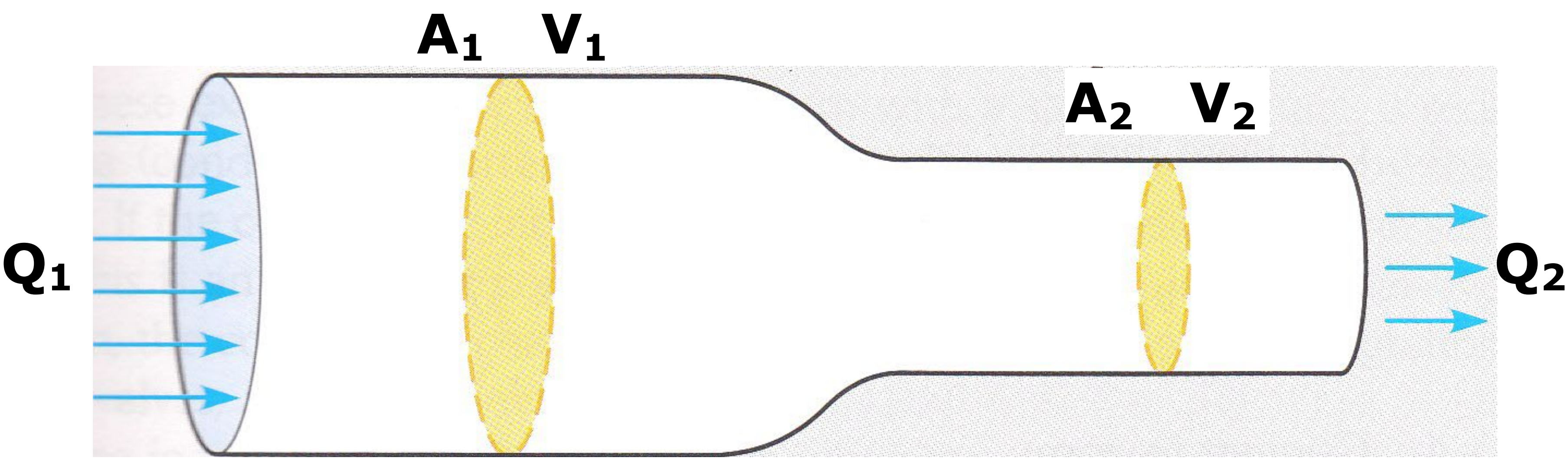


Fig.1.12: Continuity of flow.

The continuity equation

The following equation applies in this system:

$$Q_1 = Q_2$$

Therefore,

$$V_1 \times A_1 = V_2 \times A_2$$

The following example illustrates the significance of the continuity equation shown above.

The continuity equation

- **Example 1-5.**
- A fluid flows at a velocity of 0.2 m/s at point 1 in the system shown in Fig. 1.12. The diameter at point 1 is 50mm and the diameter at point 2 is 30 mm. Determine the flow velocity at point 2. Also determine the flow rate in m/s.
- 1. Calculate the areas

$$A_1 = \pi \times \frac{D_1}{4}^2 = 3.14 * \frac{(50 \times 10^{-3})^2}{4} = 1.963 \times 10^{-3} m^2$$

$$A_2 = \pi \times \frac{D_2}{4}^2 = 3.14 * \frac{(30 \times 10^{-3})^2}{4} = 7.068 \times 10^{-4} m^2$$

The continuity equation

2. Calculate the velocity at point 2

$$Q_1 = Q_2$$

Therefore,

$$V_1 \times A_1 = V_2 \times A_2$$

$$V_2 = V_1 \times \frac{A_1}{A_2} = 0.2 \times \frac{1.963 \times 10^{-3}}{7.068 \times 10^{-4}} = 0.55 m/s$$

3. Calculate the flow rate in m/s

$$Q_1 = V_1 \times A_1 = 0.2 \times 1.963 \times 10^{-3} = 3.926 \times 10^{-4}\ m^3/s$$

The continuity equation

From the Continuity equation is shows that in a system with a steady flow rate, a reduction in area (pipe size) corresponds to an increase in flow velocity by the same factor. If the pipe diameter increases, the flow velocity is reduced by the same factor. This is an important concept to understand because in an actual hydraulic system, the pipe size changes repeatedly as the fluid flows through hoses, fittings, valves, and other devices.

Reading the pressure gauge

- **The pressure gauge indicates the amount of pressure in a system. Technicians read these gauges to determine if a machine is operating properly.**
- **Most pressure gauges have a face plate that is graduated either in US units (psi) or SI units (Pascal or bar) note that;**

  1 bar=0.1 mega pascals as explained

Reading the pressure gauge

- A pointer rotates on the graduated scale as the pressure changes to indicate the pressure in the system. The pressure gauge used in the hydraulic power pack is shown in Fig. 1.13. The outer black scale indicates pressure units of bar, and the inner red scale indicates pressure units in psi

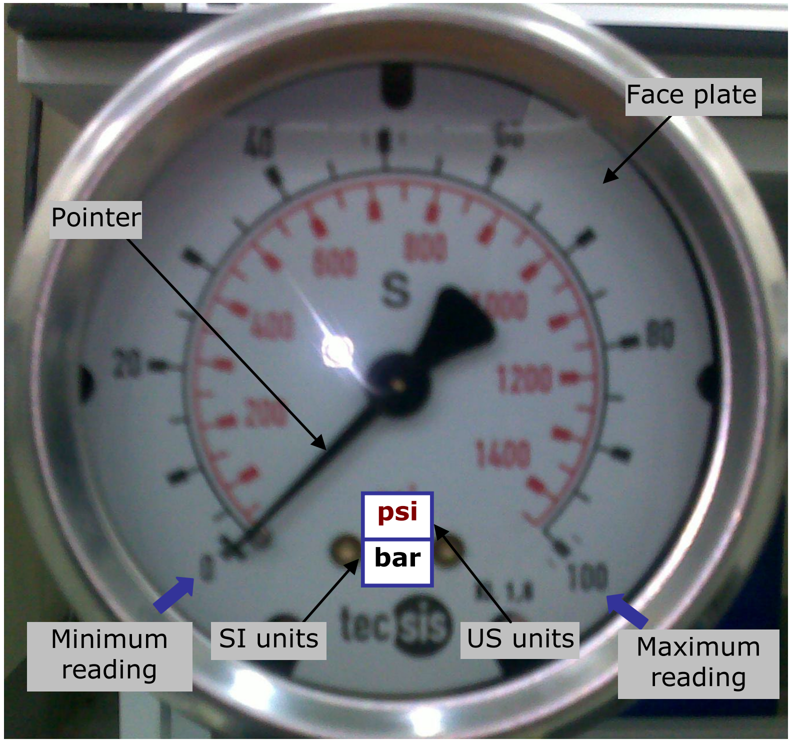


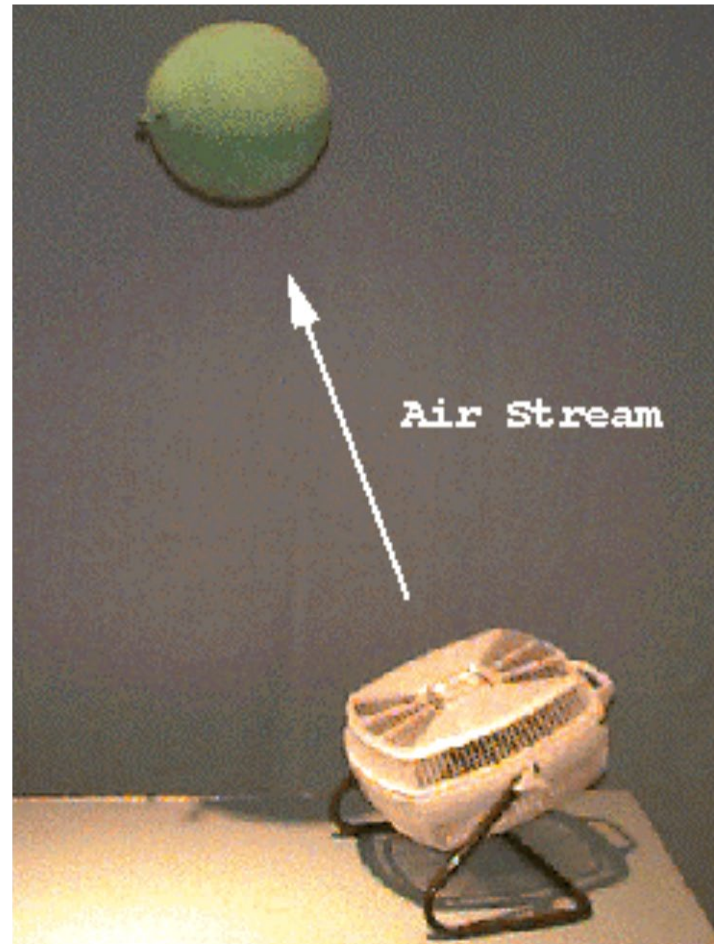
Fig. 1.13: A pressure gauge.

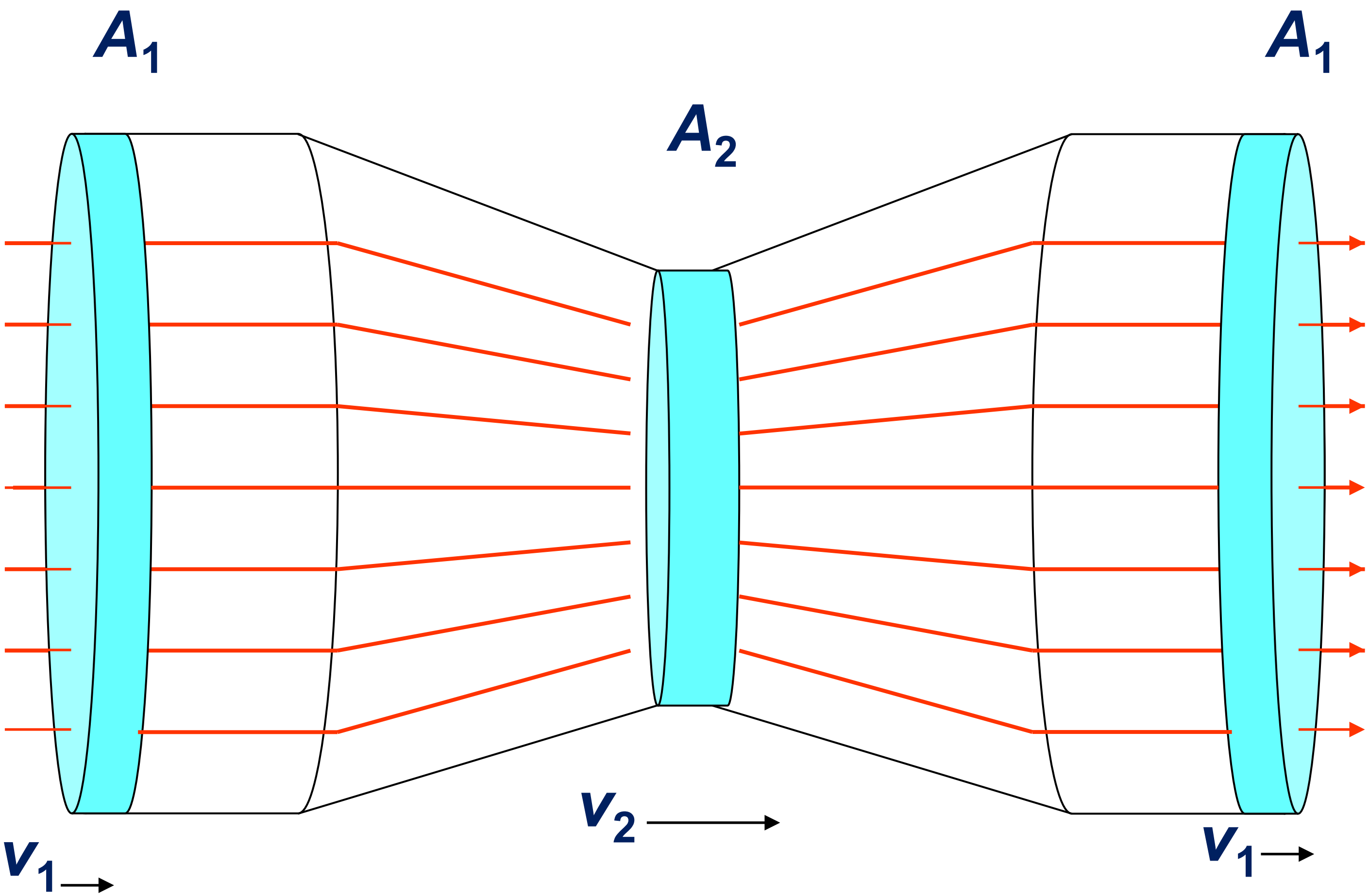
FLUID FLOW
IDEAL FLUID
BERNOULLI'S PRINCIPLE

How can a plane fly?
How does a perfume spray work?
What is the venturi effect?
Why does a cricket ball swing or a baseball curve?

Daniel Bernoulli (1700 – 1782)

Floating ball

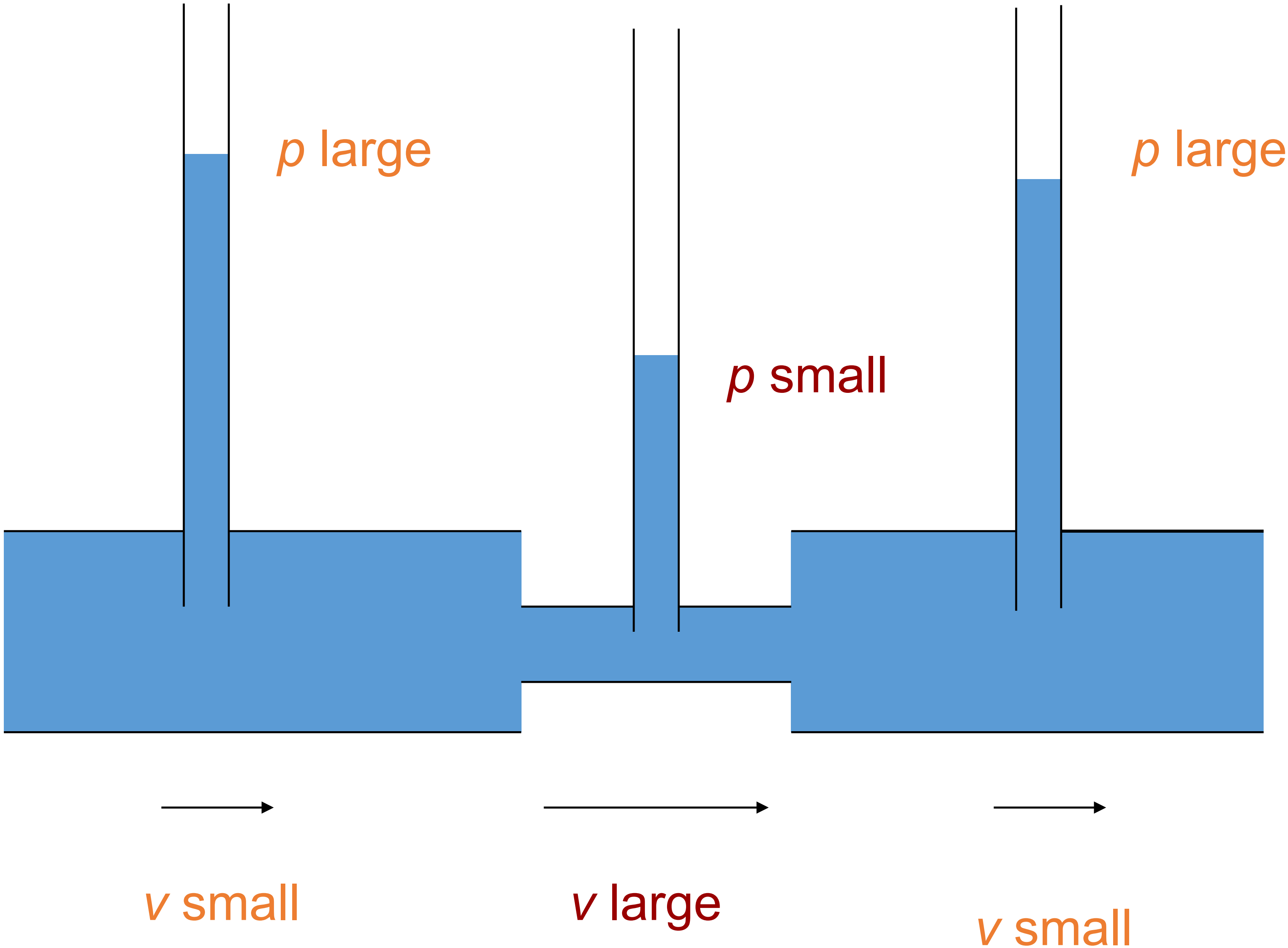




Low speed
Low KE
High pressure

high speed
high KE
low pressure

Low speed
Low KE
High pressure


p large
p small
p large
v small
v large
v small

In a severe storm how does a house loose its roof?

Air flow is disturbed by the house. The "streamlines" crowd around the top of the roof $\Rightarrow$ faster flow above house $\Rightarrow$ reduced pressure above roof than inside the house $\Rightarrow$ room lifted off because of pressure difference.

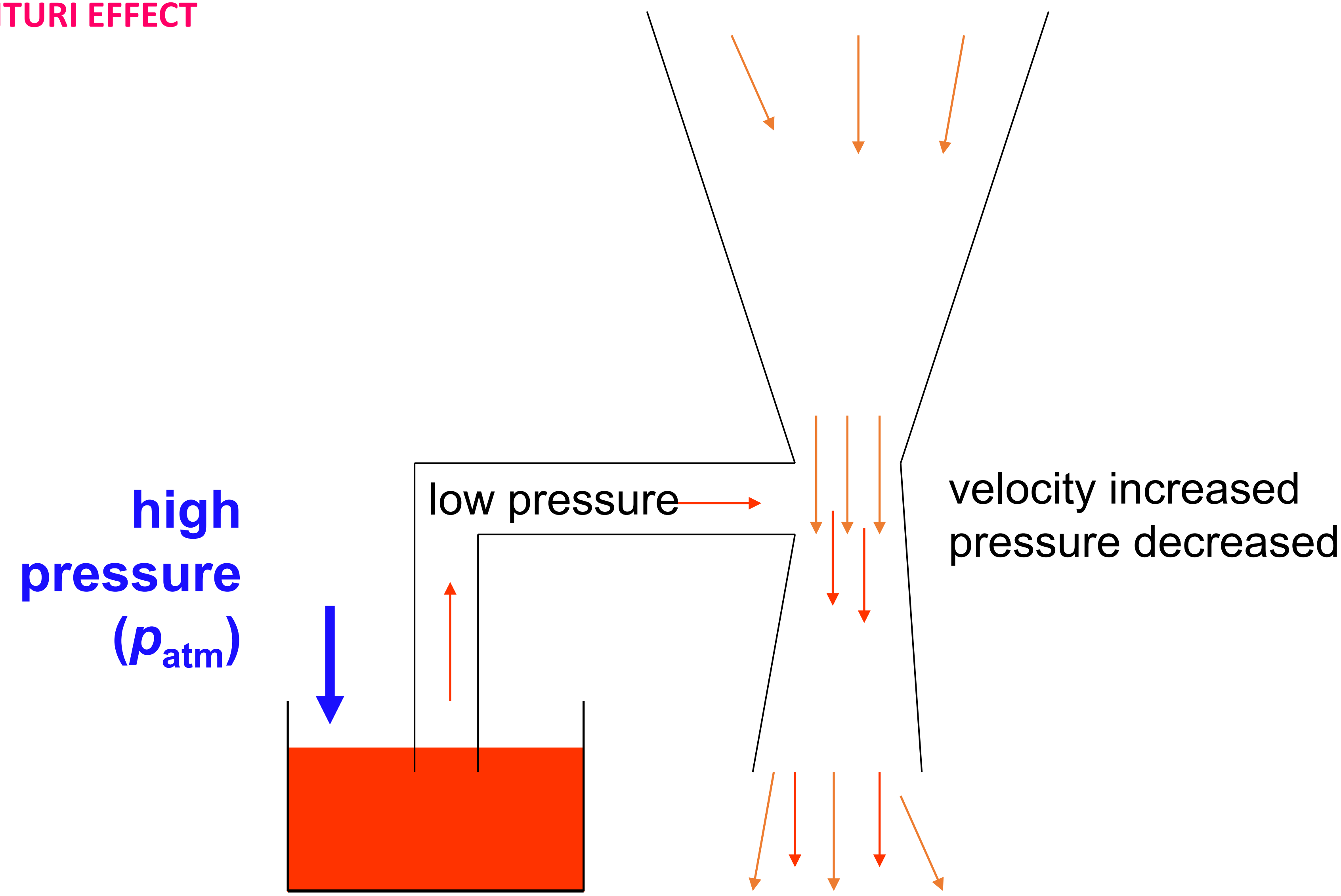
Why do rabbits not suffocate in the burrows?

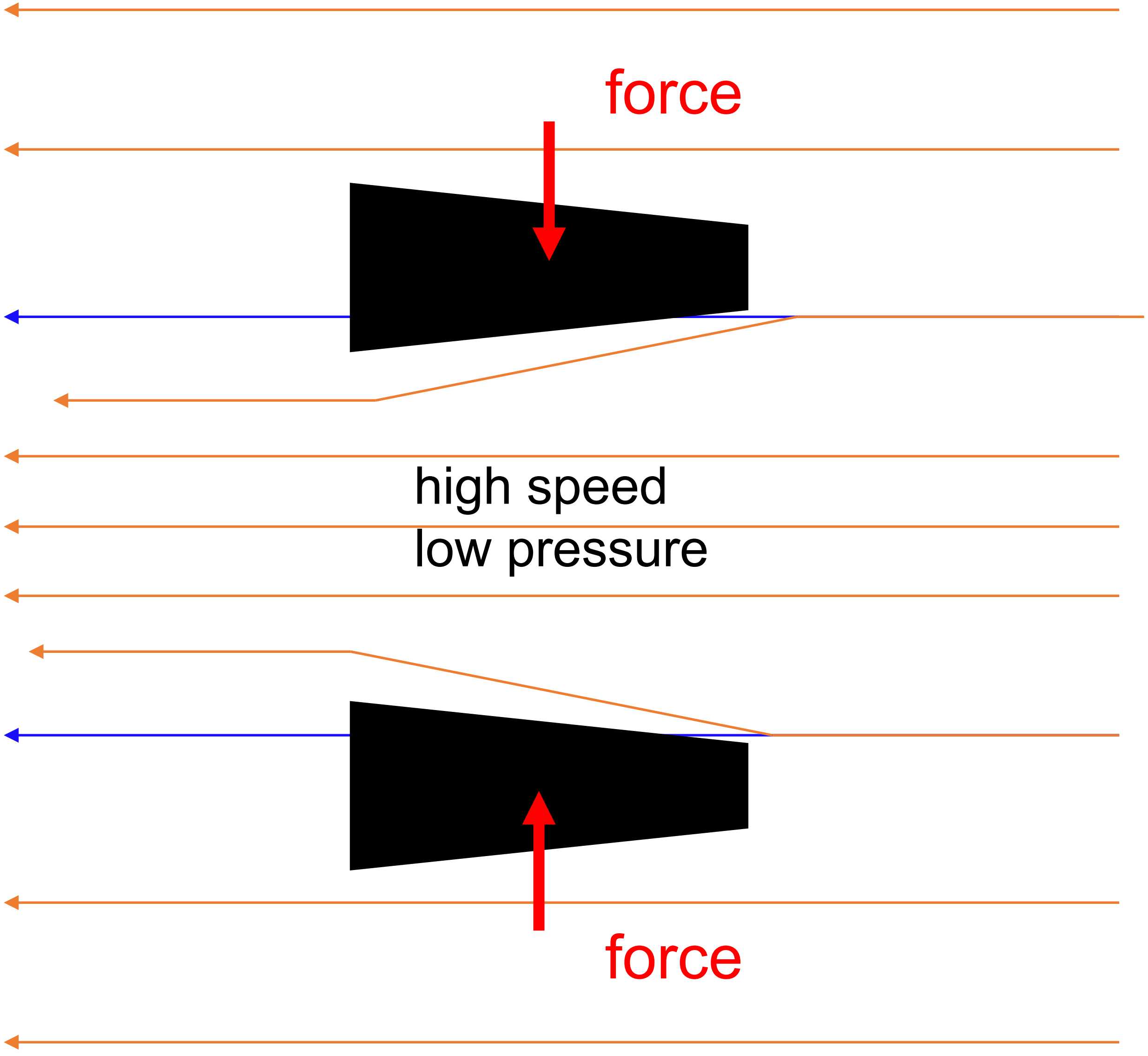
Air must circulate. The burrows must have two entrances. Air flows across the two holes is usually slightly different $\Rightarrow$ slight pressure difference $\Rightarrow$ forces flow of air through burrow.

One hole is usually higher than the other and the a small mound is built around the holes to increase the pressure difference.

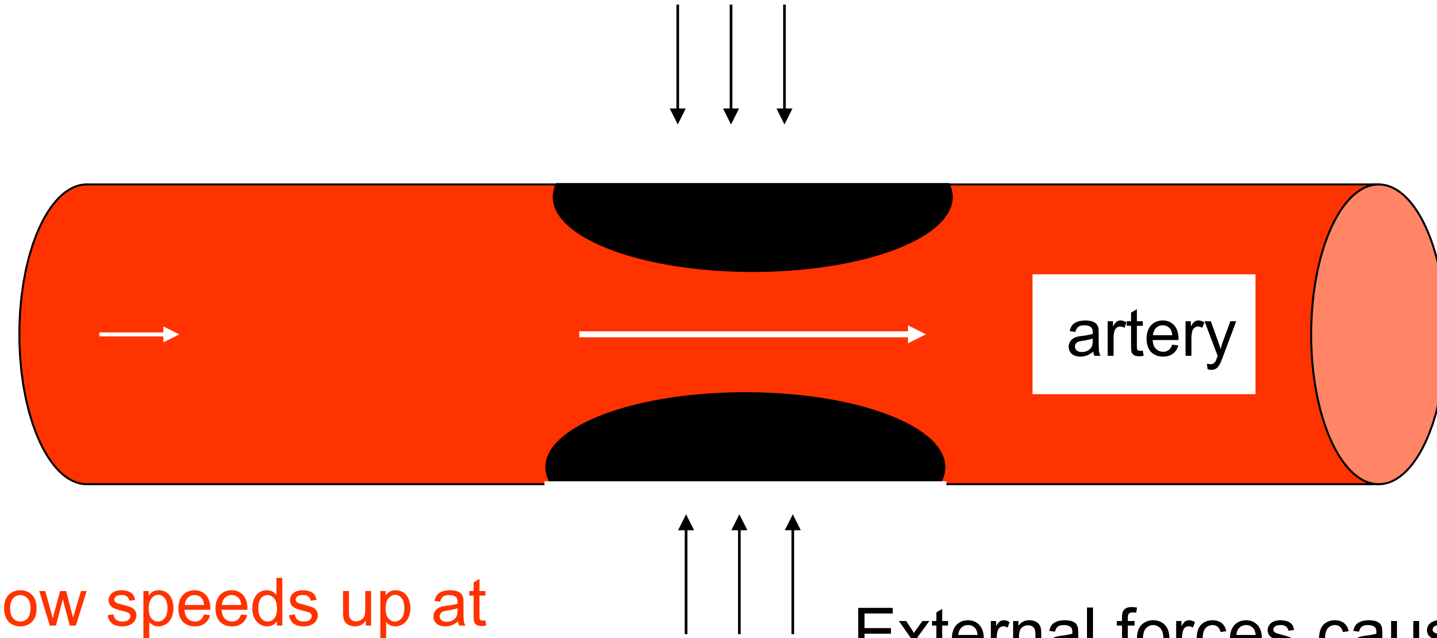
Why do racing cars wear skirts?

VENTURI EFFECT





What happens when two ships or trucks pass alongside each other?
Have you noticed this effect in driving across the Sydney Harbour Bridge?



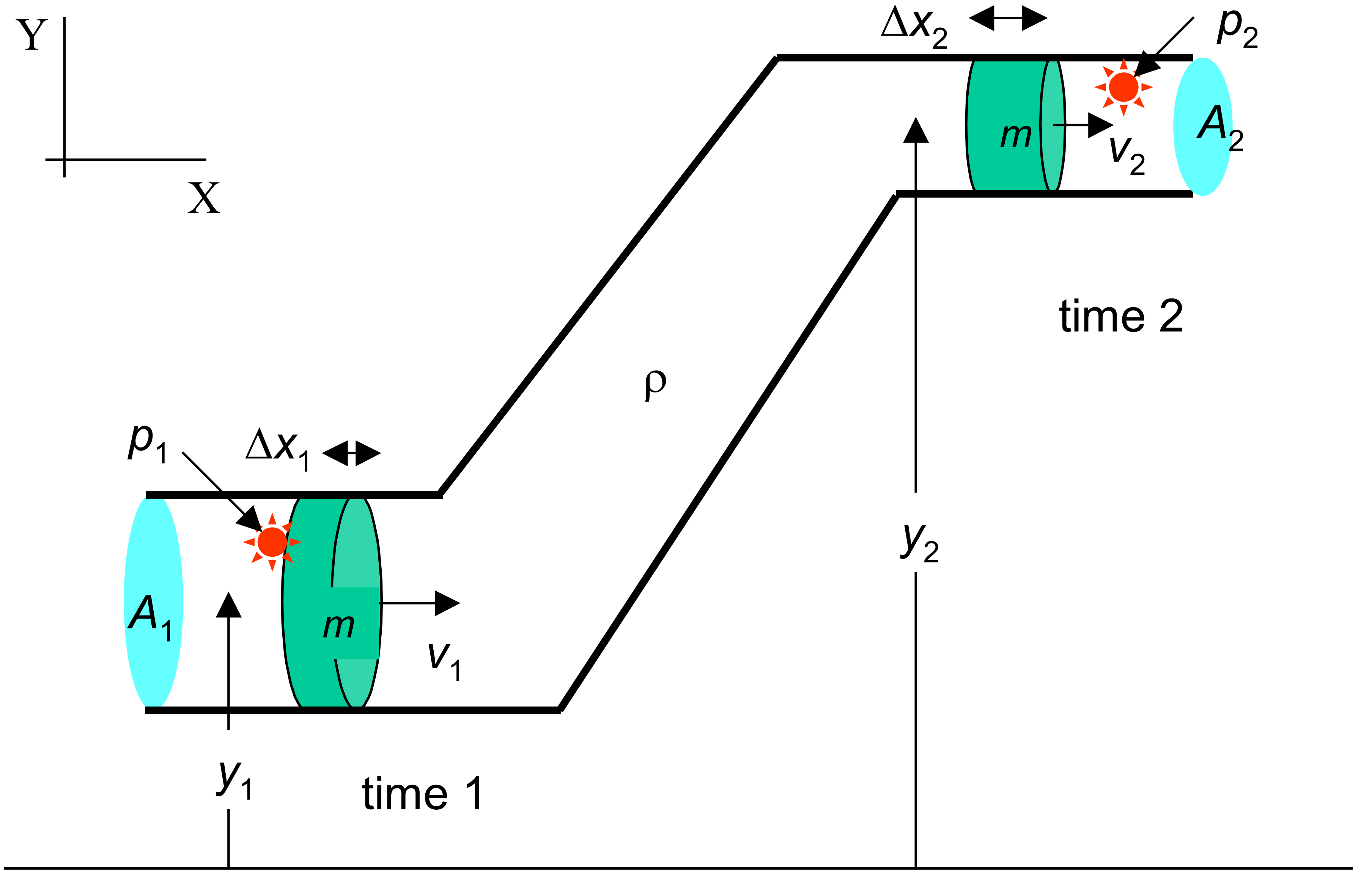
Flow speeds up at constriction

Pressure is lower

Internal force acting on artery wall is reduced

External forces causes artery to collapse

Arteriosclerosis and vascular flutter


Y
X
Δx2
p2
m
v2
A2
time 2
ρ
p1
Δx1
A1
m
v1
y2
y1
time 1

Bernoulli's Equation

for any point along a flow tube or streamline

$$\boldsymbol{p + \tfrac{1}{2}\rho v^2 + \rho g y = \text{constant}}$$

Dimensions

p [Pa] = [N.m^{-2}] = [N.m.m^{-3}] = [J.m^{-3}]

$\frac{1}{2}\rho v^2$ [kg.m^{-3}.m^2.s^{-2}] = [kg.m^{-1}.s^{-2}] = [N.m.m^{-3}] = [J.m^{-3}]

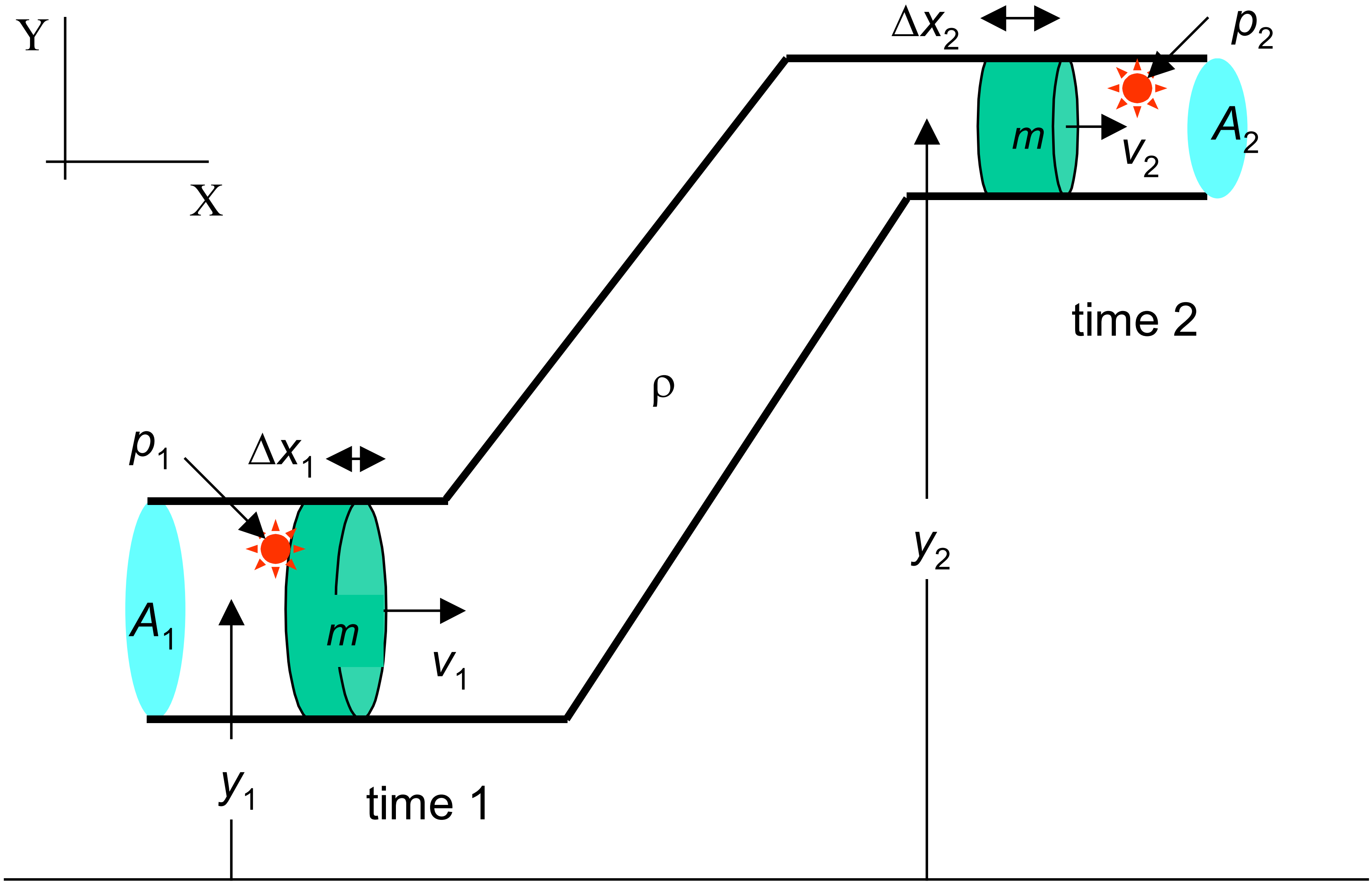
ρ g h [kg.m^{-3} m.s^{-2}. m] = [kg.m.s^{-2}.m.m^{-3}] = [N.m.m^{-3}] = [J.m^{-3}]

Each term has the dimensions of energy / volume or energy density.

$\frac{1}{2}\rho v\ 2$ KE of bulk motion of fluid

$\rho g h$ GPE for location of fluid

p pressure energy density arising from internal forces within moving fluid (similar to energy stored in a spring)



Y
X
Δx2
p2
m
A2
v2
time 2
ρ
p1
Δx1
A1
m
v1
y2
y1
time 1

Mass element m moves from (1) to (2)

$$m = \rho A_1 \Delta x_1 = \rho A_2 \Delta x_2 = \rho \Delta V \quad \text{where } \Delta V = A_1 \Delta x_1 = A_2 \Delta x_2$$

Equation of continuity $A V$ = constant

$$A_1 v_1 = A_2 v_2 \qquad A_1 > A_2 \Rightarrow v_1 < v_2$$

Since $v_1 < v_2$ the mass element has been accelerated by the net force

$$F_1 - F_2 = p_1 A_1 - p_2 A_2$$

Conservation of energy

A pressurized fluid must contain energy by the virtue that work must be done to establish the pressure.

A fluid that undergoes a pressure change undergoes an energy change.

$$\Delta K = \frac{1}{2}\, m\, v_2^{\,2} - \frac{1}{2}\, m\, v_1^{\,2} = \frac{1}{2}\, \rho\, \Delta V\, v_2^{\,2} - \frac{1}{2}\, \rho\, \Delta V\, v_1^{\,2}$$

$$\Delta U = m\, g\, y_2 - m\, g\, y_1 = \rho\, \Delta V\, g\, y_2 = \rho\, \Delta V\, g\, y_1$$

$$W_{\mathrm{net}} = F_1\, \Delta x_1 - F_2\, \Delta x_2 = p_1\, A_1\, \Delta x_1 - p_2\, A_2\, \Delta x_2$$

$$W_{\mathrm{net}} = p_1\, \Delta V - p_2\, \Delta V = \Delta K + \Delta U$$

$$p_1\, \Delta V - p_2\, \Delta V = \frac{1}{2}\, \rho\, \Delta V\, v_2^{\,2} - \frac{1}{2}\, \rho\, \Delta V\, v_1^{\,2} + \rho\, \Delta V\, g\, y_2 - \rho\, \Delta V\, g\, y_1$$

Rearranging

$$p_1 + \frac{1}{2}\, \rho\, v_1^{\,2} + \rho\, g\, y_1 = p_2 + \frac{1}{2}\, \rho\, v_2^{\,2} + \rho\, g\, y_2$$

Applies only to an ideal fluid (zero viscosity)

Assume liquid behaves as an ideal fluid and that Bernoulli's equation can be applied

$$p_1 + \tfrac{1}{2}\rho\, v_1^2 + \rho\, g\, y_1 = p_2 + \tfrac{1}{2}\rho\, v_2^2 + \rho\, g\, y_2$$

A small hole is at level (2) and the water level at (1) drops slowly $\Rightarrow v_1 = 0$

$$p_1 = p_{atm} \qquad p_2 = p_{atm}$$

$$\rho\, g\, y_1 = \tfrac{1}{2}\rho v_2^2 + \rho\, g\, y_2$$

$$v_2^2 = 2\, g\, (y_1 - y_2) = 2\, g\, h \qquad h = (y_1 - y_2)$$

$v_2 = \sqrt{(2\, g\, h)}$ Torricelli formula (1608 – 1647)

This is the same velocity as a particle falling freely through a height h

Assume liquid behaves as an ideal fluid and that Bernoulli's equation can be applied for the flow along a streamline

$$p_1 + \tfrac{1}{2}\,\rho\, v_1^2 + \rho\, g\, y_1 \;=\; p_2 + \tfrac{1}{2}\,\rho\, v_2^2 + \rho\, g\, y_2$$

$$y_1 \;=\; y_2$$

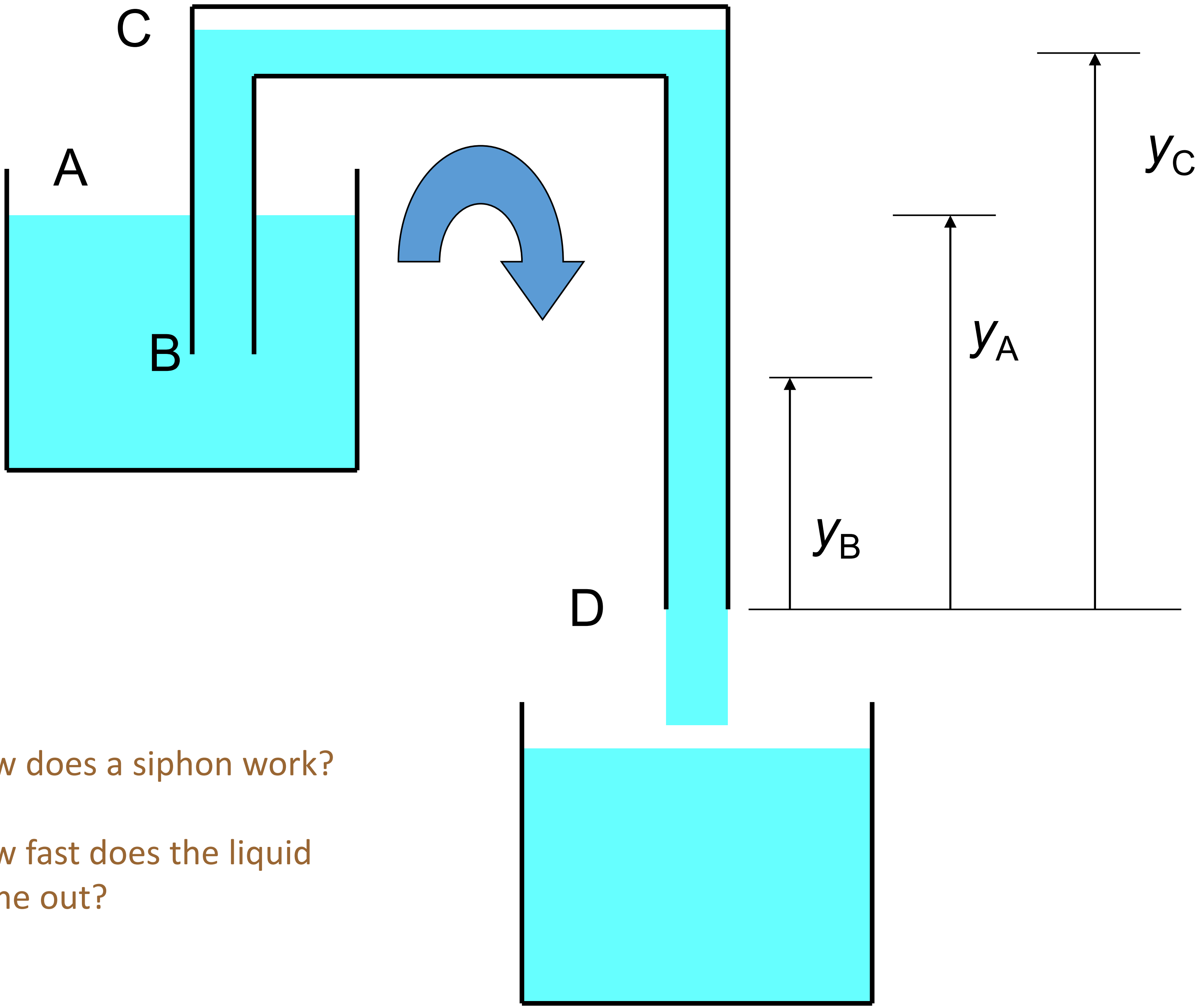
$$p_1 - p_2 \;=\; \tfrac{1}{2}\,\rho_F\,(v_2^2 \,-\, v_1^2)$$

$$p_1 \,-\, p_2 \;=\; \rho_m\, g\, h$$

$$A_1\, v_1 \;=\; A_2\, v_2 \quad \Rightarrow \quad v_2 \;=\; v_1\,(A_1 / A_2)$$

$$\rho_m\, g\, h \;=\; \tfrac{1}{2}\,\rho_F\,\{\, v_1^2\,(A_1 / A_2)^2 - v_1^2 \,\} \;=\; \tfrac{1}{2}\,\rho_F\, v_1^2\,\{(A_1 / A_2)^2 \,-\, 1\}$$

$$v_1 = \sqrt{\frac{2 g\, h\, \rho_{\mathrm{m}}}{\rho_{\mathrm{F}}\left\{\left(\dfrac{A_1}{A_2}\right)^2 - \;1\right\}}}$$



How does a siphon work?

How fast does the liquid come out?

Assume that the liquid behaves as an ideal fluid and that both the equation of continuity and Bernoulli's equation can be used.

Heights: $y_D = 0$ $\quad y_B \quad y_A \quad y_C$

Pressures: $p_A = p_{atm} = p_D$

Consider a point A on the surface of the liquid in the container and the outlet point D. Apply Bernoulli's principle to these points

Now consider the points C and D and apply Bernoulli's principle to these points

From equation of continuity $v_C = v_D$

The pressure at point C can not be negative

$$p_A + \tfrac{1}{2}\rho v_A^2 + \rho g y_A = p_D + \tfrac{1}{2}\rho v_D^2 + \rho g y_D$$

$$v_D^2 = 2(p_A - p_D)/\rho + v_A^2 + 2g(y_A - y_D)$$

$p_A - p_D = 0$ $\quad$ $y_D = 0$ $\quad$ assume $v_A^2 << v_D^2$

$$v_D = \sqrt{(2 g y_A)}$$

$$p_C + \tfrac{1}{2}\,\rho\, v_C^{\,2} + \rho\, g\, y_C \;=\; p_D + \tfrac{1}{2}\,\rho\, v_D^{\,2} + \rho\, g\, y_D$$

$v_C = v_D$

$$p_C \;=\; p_D \;+\; \rho\, g\,(y_D - y_C) \;=\; p_{atm} \;+\; \rho\, g\,(y_D - y_C)$$

The pressure at point C can not be negative

$p_C \geq 0$ and $y_D = 0$

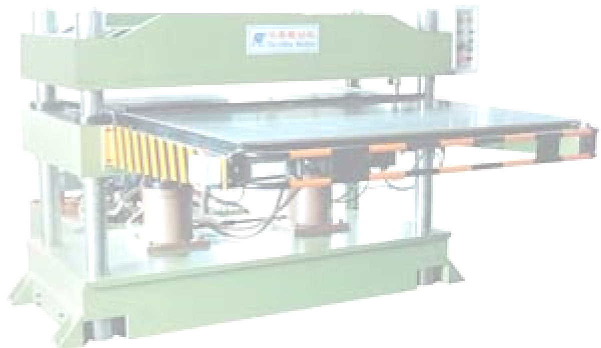
$p_C = p_{atm} - \rho\, g\, y_C \geq 0 \qquad y_C \leq p_{atm} / (\rho\, g)$

For a water siphon

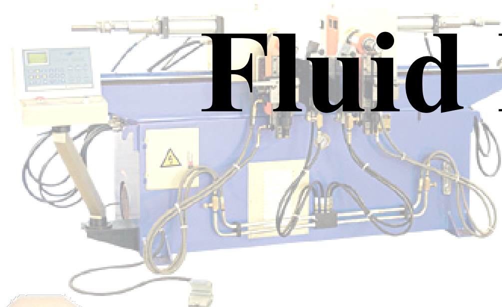
$p_{atm} \sim 10^5$ Pa $\qquad g \sim 10$ m.s^{-1} $\qquad \rho \sim 10^3$ kg.m^{-3}

$y_C \leq 10^5 / \{(10)(10^3)\}$ m

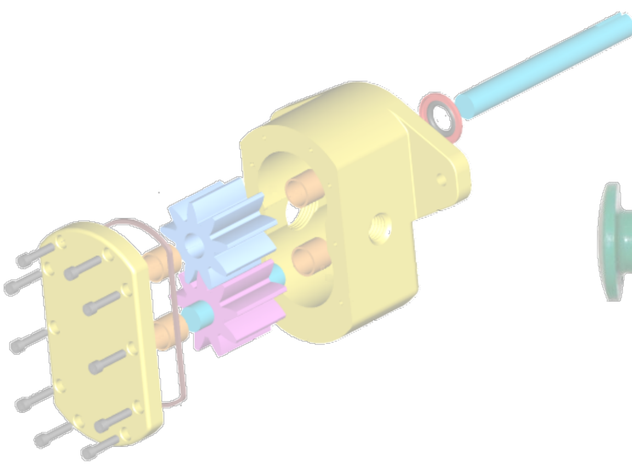
$y_C \leq 10$ m

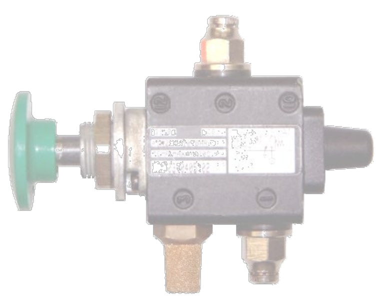


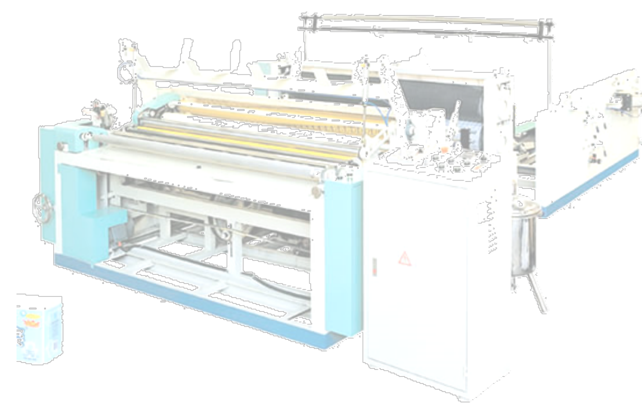
Fluid Power



Hydraulics Versus Pneumatics







Pneumatic and Hydraulic Control Comparison

Pneumatic Control Is:

- **Clean**
- **Fast**
- **Intrinsically Safe**
- **Overload Safe**
- **Inexpensive for Individual Components**

Hydraulic Control:

- **Is Infinitely Controllable**
- **Produces Extremely Large Forces**
- **Requires High Pressures**
- **Requires Heavy Duty Components**

Pneumatic and Hydraulic Dangers

The dangers of the use of compressed air include:

- Air Embolism
- Hose/Pipe Whipping
- Noise
- Crushing/Cutting

The dangers of working with high pressure oil can be infinitely more drastic:

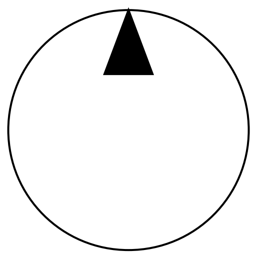
This injury is a result of placing the hand in front of a jet of leaking hydraulic fluid at around 180 Bar

- **High Pressure Oil Injection**
- **Oil Burns**
- **Crushing/Cutting**
- **Carcinogens**

Differences in Symbols

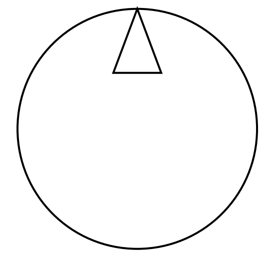
Symbols Reminder

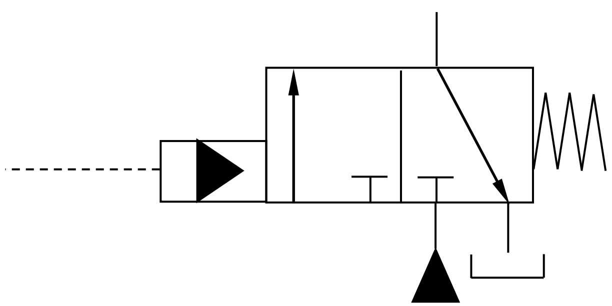
Hydraulic Pump



Pumps and Motors differ only by filling in the direction arrow or leaving it white.

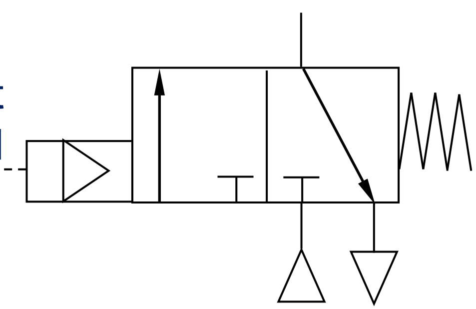
Compressor





Hydraulically Actuated and supplied 3/2 Pilot Spring

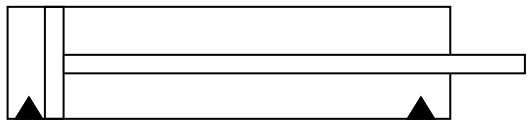
Supply and Pilot arrows are also filled in or left white.



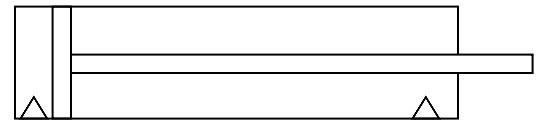
Pneumatically Actuated and supplied 3/2 Pilot Spring

Differences in Symbols

Cylinders and other actuators also differ with respect to supply and direction arrows.

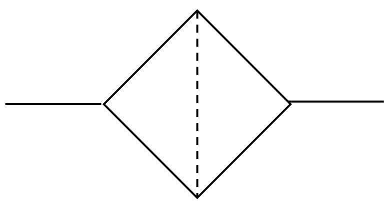


Hydraulic Double Acting Cylinder

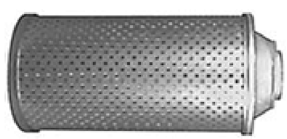


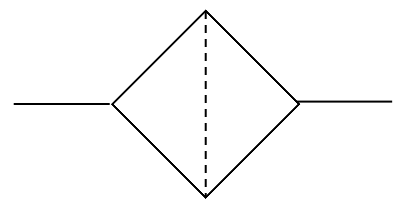
Pneumatic Double Acting Cylinder

Many symbols do not change, for example the **Filter** symbol.

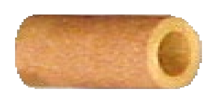


Hydraulic Filter





Pneumatic Filter

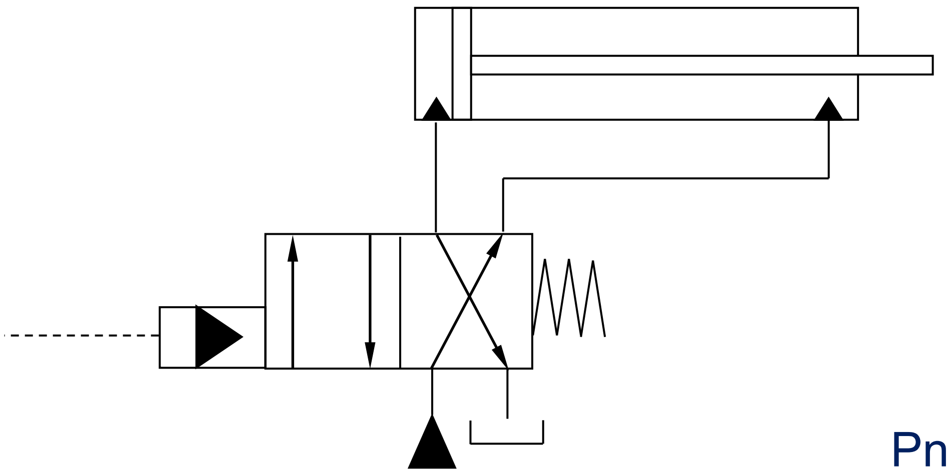


Remember however that the physical construction is completely different.

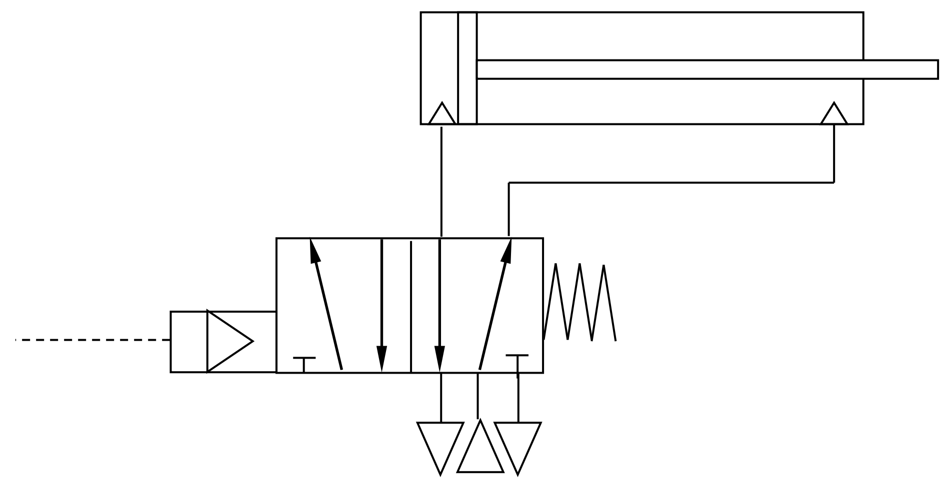
For example, hydraulic filters can be either **Suction Strainers** (suction side of the pump), **Pressure Filter** (pressure side of the pump) or **Return Filter** (in the return to tank line). Each filter requires different properties.

Differences in Symbols

Hydraulic valves have a crossover to **Tank.**



Pneumatic valves tend to have two **Exhaust** outlets to **Atmosphere**.



Differences in Medium

Hydraulic Oil is **Hygroscopic** and can be easily **Oxidised** at high temperatures**.**

Hydraulic Fluid is **viscous** and can be various types with varying **Viscosities** including:

- Flame Retardant
- Mineral Oil
- Synthetic Oil
- Water Glycol

Hydraulic fluid can have many additives including:

- Anti Oxidants
- Lubricity Improvement
- Anti Foaming Additive
- Anti Wear Additives

Air can hold **Moisture** which can turn into **Condensation** at the **Dew Point.**

The pneumatic components must remove the **Condensation** from the air and provide **Lubrication**.

Air is safe under a wide range of operating temperatures.

Differences in Principles and Properties

Pneumatic systems rely on a supply of **Compressed** air flowing through **Pipes** to **Actuators.** The **Force** for work is produced due to the **Pressure** of the **Air** acting on the **Area** of the actuator.

Air is **Compressible.**

Gas laws such as **Boyle's and Charles's** Laws govern **medium** behaviour

Actuator demand is measured in **m^3 per hour** or operation
Compressor output is measured in m^3 per hour **Free Air Delivery** (FAD)

Hydraulic systems rely on a supply of **incompressible** fluid flowing through **Hoses** to **Actuators.** The **Force** for work is produced due to the **Pressure** of the **Oil** acting on the **Area** of the actuator.

Oil is considered **Incompressible.**

Bernoulli's and other **Fluid Flow** Laws govern **medium** behaviour

Actuator demand is measured **litres per minute** for a specific speed

Pump output is measured **litres per minute**

Both Hydraulics and Pneumatics are described with **Pascal's Law** and **F=PA**

Differences in Pressure and Force

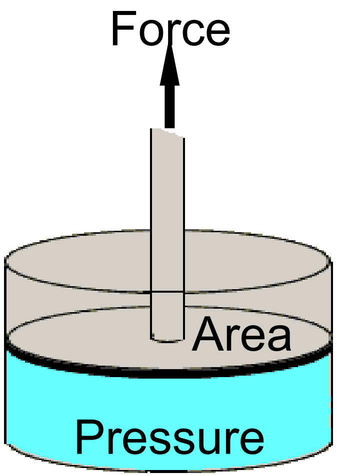
Pneumatic Pressures and Forces

- **Produced at 10Bar**
- **Used at 0~6 Bar**
- **Forces up to 5000Kg**

Hydraulic Pressures and Forces

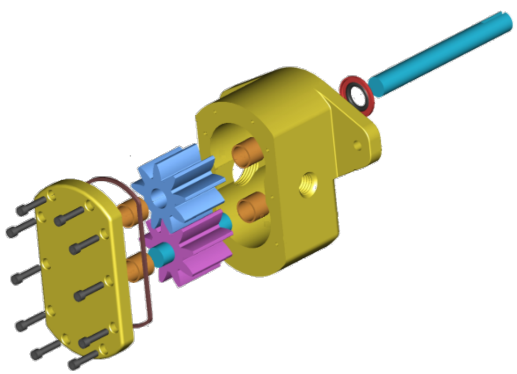
- **Produced and used at 200~400Bar**
- **Forces up to Thousands of tonnes**

Force Calculator

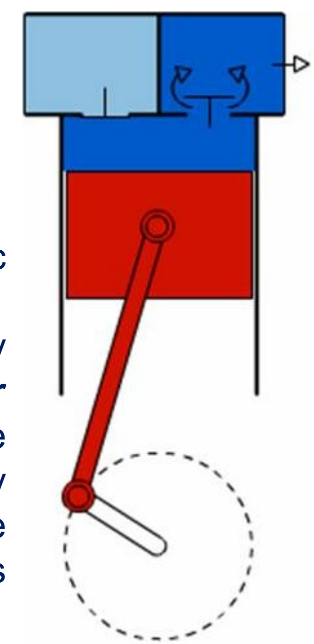


Differences in Construction

Production



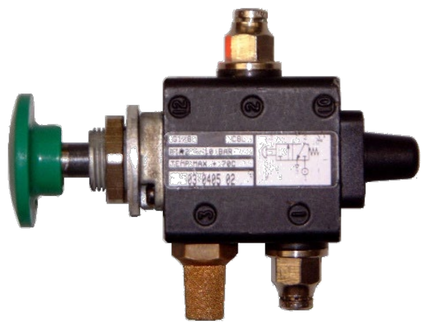
The hydraulic **Power Pack** contains the Pump, **Tank** (**Reservoir**), Filters and commonly a **Relief Valve** for protection of the system. The unit is usually local to the machine that is using it. Hydraulic pumps are usually **Positive Displacement** devices which means they displace all the oils they pump.

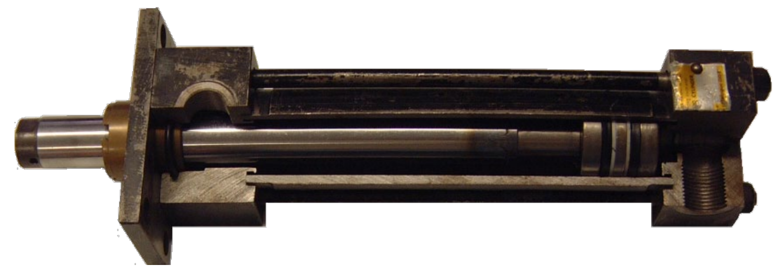


The Pneumatic **Compressor** installation usually includes a **Dryer** and **Receiver**. The unit is usually remote from the machine that is using it.

Differences in Construction

Valves and Actuators





Pneumatic valves and actuators are generally of light construction as they need to deal with pressure up to a maximum of 10 Bar.

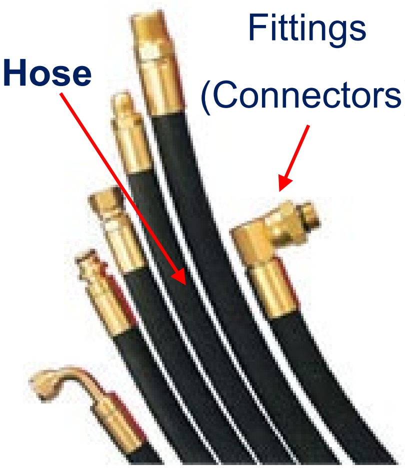
The cost of these components is cheap when compared to the much more heavily constructed hydraulic components.

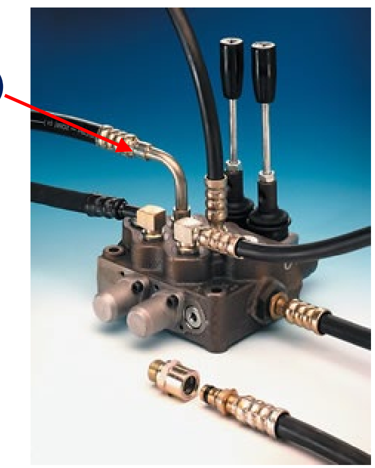
Hydraulic valves and actuators are much more heavily constructed than pneumatic components. This is because the components must deal with pressures up to 400 Bar+. Hydraulic actuators can be very large when compared with common pneumatic actuators. Hydraulic components are much more expensive than standard pneumatic components. A standard hydraulic DCV is in the region of hundreds of Euro, a standard application pneumatic valve would typically cost tens of Euro.

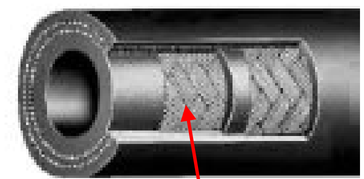
Differences in Construction

Hoses, Pipes and Connectors

Hydraulic hoses and connectors are heavily constructed to hold the higher pressures. Rubber hoses are steel **Reinforced** (**Braided**) to **Strengthen** them.



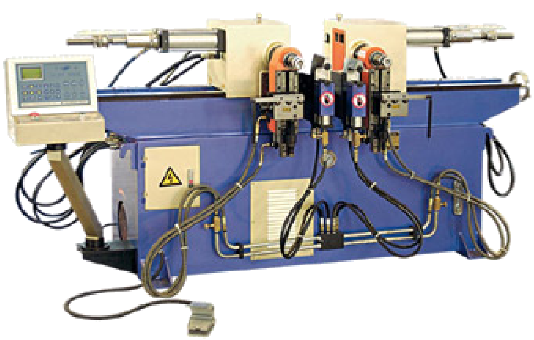




Pneumatic **Pipes** and **Fittings** are of light construction.
Pneumatic **Pipe** is made from nylon and generally connects to the fittings using '**Push Fit**' connectors.

Differences in Application

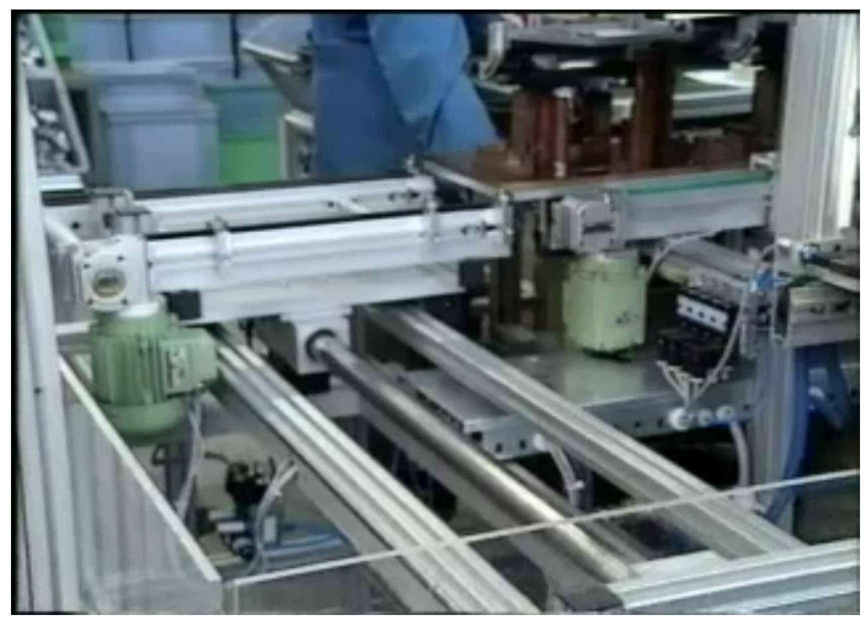
Hydraulic systems are used where large forces are required such as in earth moving equipment, heavy cutting, Pressing and Clamping



Pneumatic systems are used for relatively light moving, Clamping and Process operations

Application Example

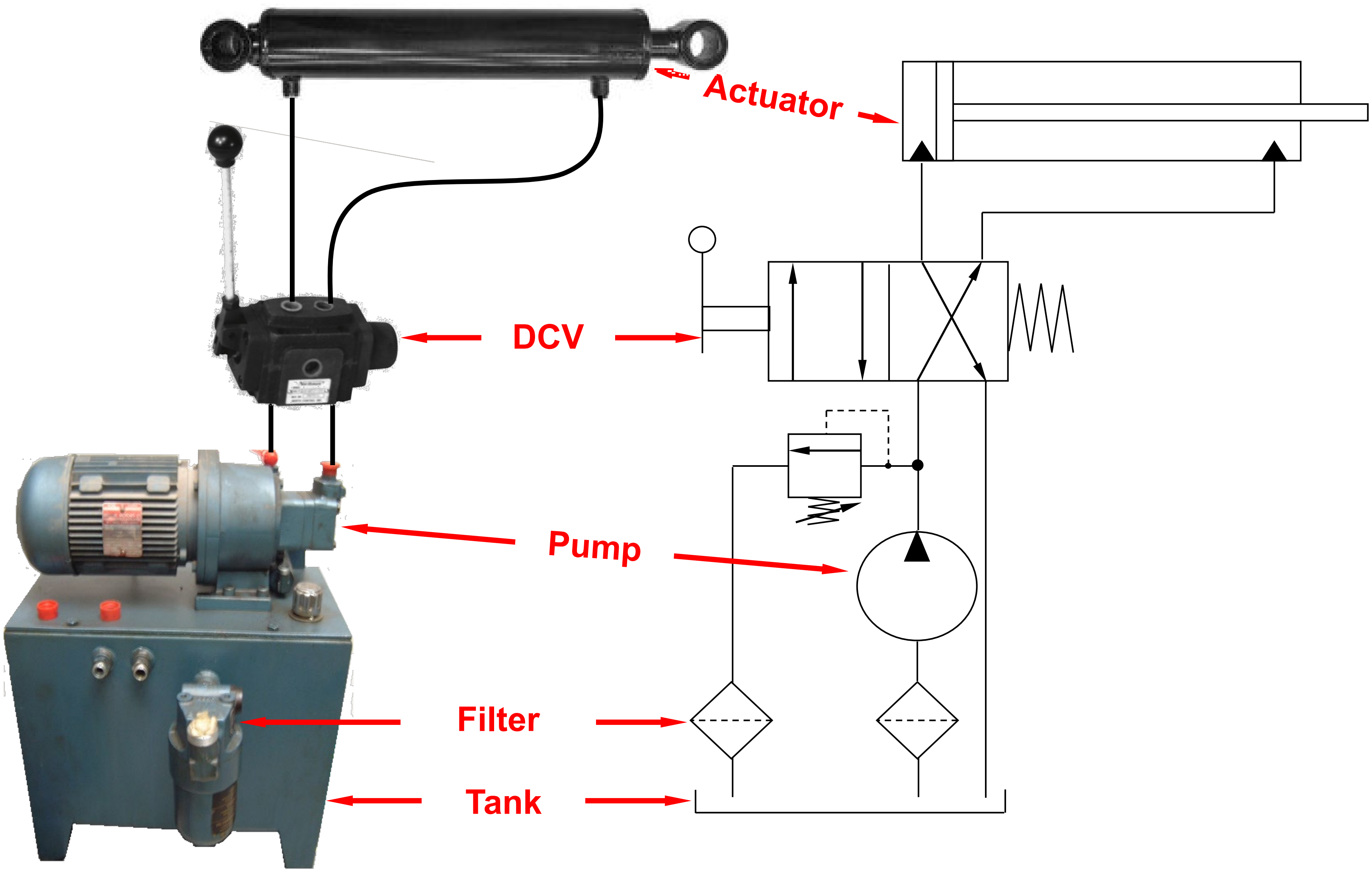
Lifting a car on a Car Ramp does not require high speed or clean control systems. Large forces are required to lift the heavy car. This application is particularly suited to the use of hydraulics.



Moving and light clamping of components is easily, cleanly and quickly achieved using a pneumatic control system.

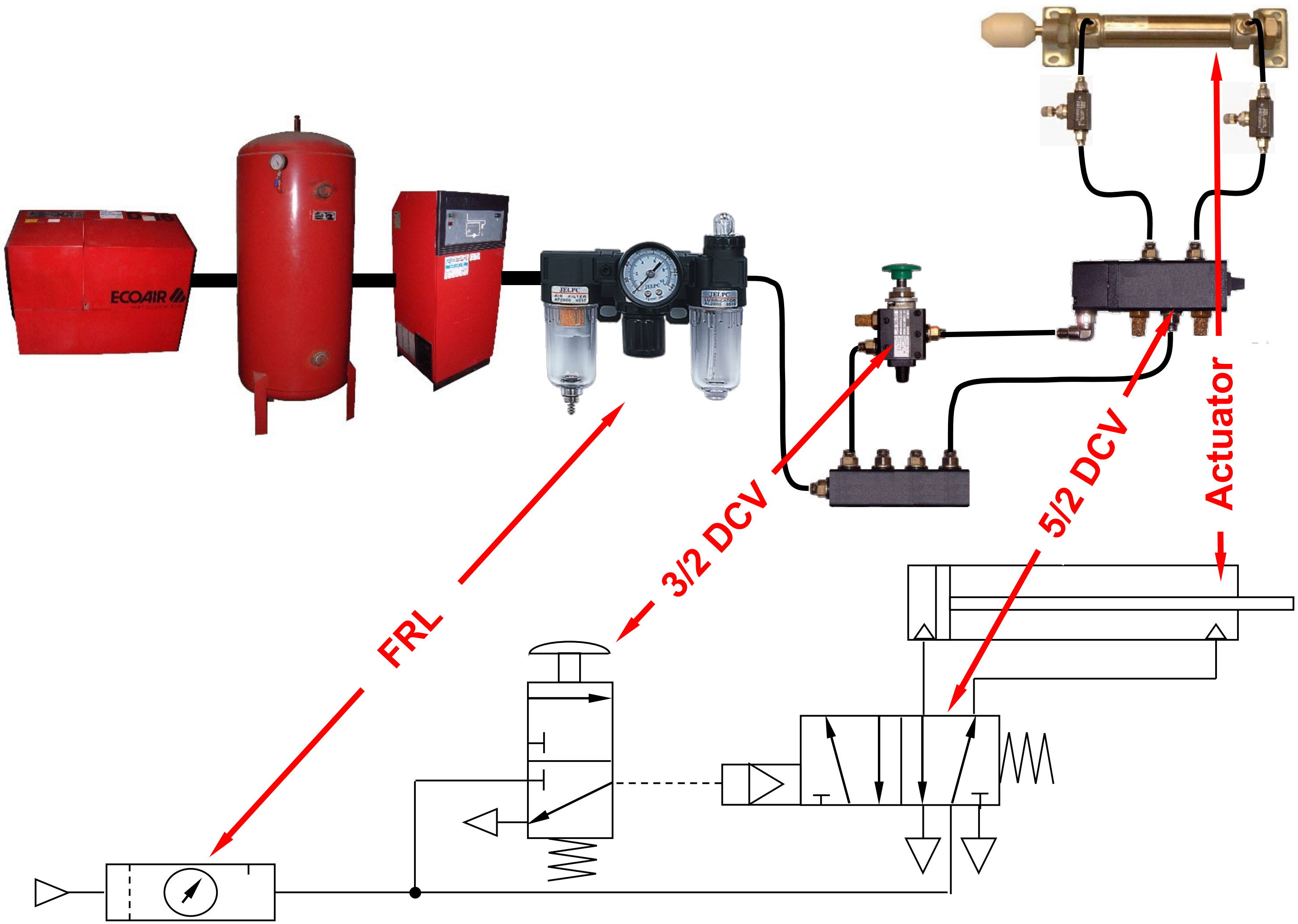
Simple Application Example

Hydraulic



Simple Application Example

Pneumatic



Electro-Pneumatic and Hydraulic Systems

Control of Electro-Pneumatic and Hydraulic systems using Electrical control systems is similar for both media types.

Both systems would use Solenoid actuated valves, either Directly Actuated or Indirectly Actuated.

An Electronic system would commonly incorporate Push Button Switches (for human input), Reed Switches (to detect cylinder position), Proximity Sensors and Photocells (to detect machine/component position).

An Electronic system would also commonly incorporate Relays and computer controlled systems such as Programmable Logic Controllers.

Electro-Pneumatic and Hydraulic Systems