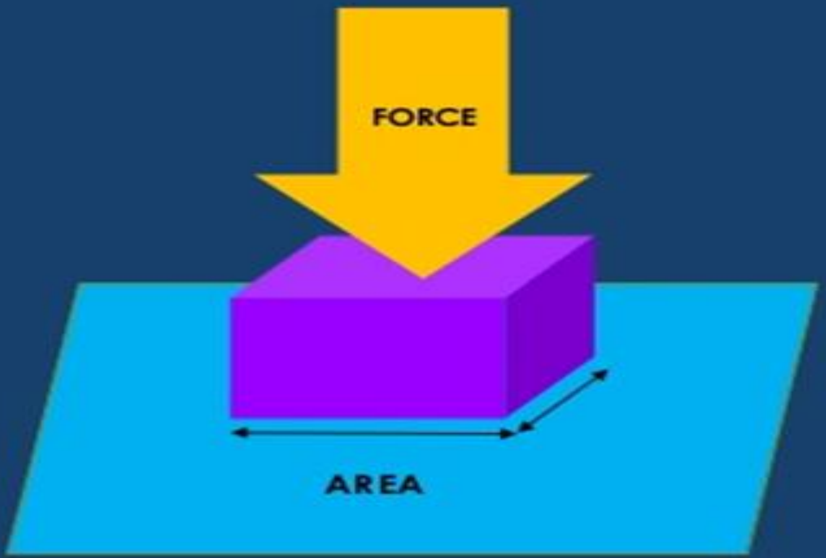
Fundamental laws of Hydraulics

Fundamental laws of Hydraulics

Pressure (P)

- Pressure is the force applied perpendicular to the surface of an object per unit area over which that force is distributed.
- Various units are used to express pressure. Some of these derive from a unit of force divided by a unit of area; the SI unit of pressure, the pascal (Pa).

WHAT IS PRESSURE?



Pressure is the force acting per unit area

In formula:

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

For a **constant force**, an **increase in the area** of contact will result in a **decrease in the pressure**

- P = Pressure = Force per unit of area.
- The unit of measurement of pressure is the Pascal (Pa).
- F = Force - which is the push or pull acting upon a body. Force is equal to the pressure times the area (F = P x A).
- Force is measured in Newtons (N).
- A = Area - which is the extent of a surface. Sometimes the surface area is referred to as effective area. The effective area is the total surface that is used to create a force in the desired direction.
- Area is measured in square metres (m2).

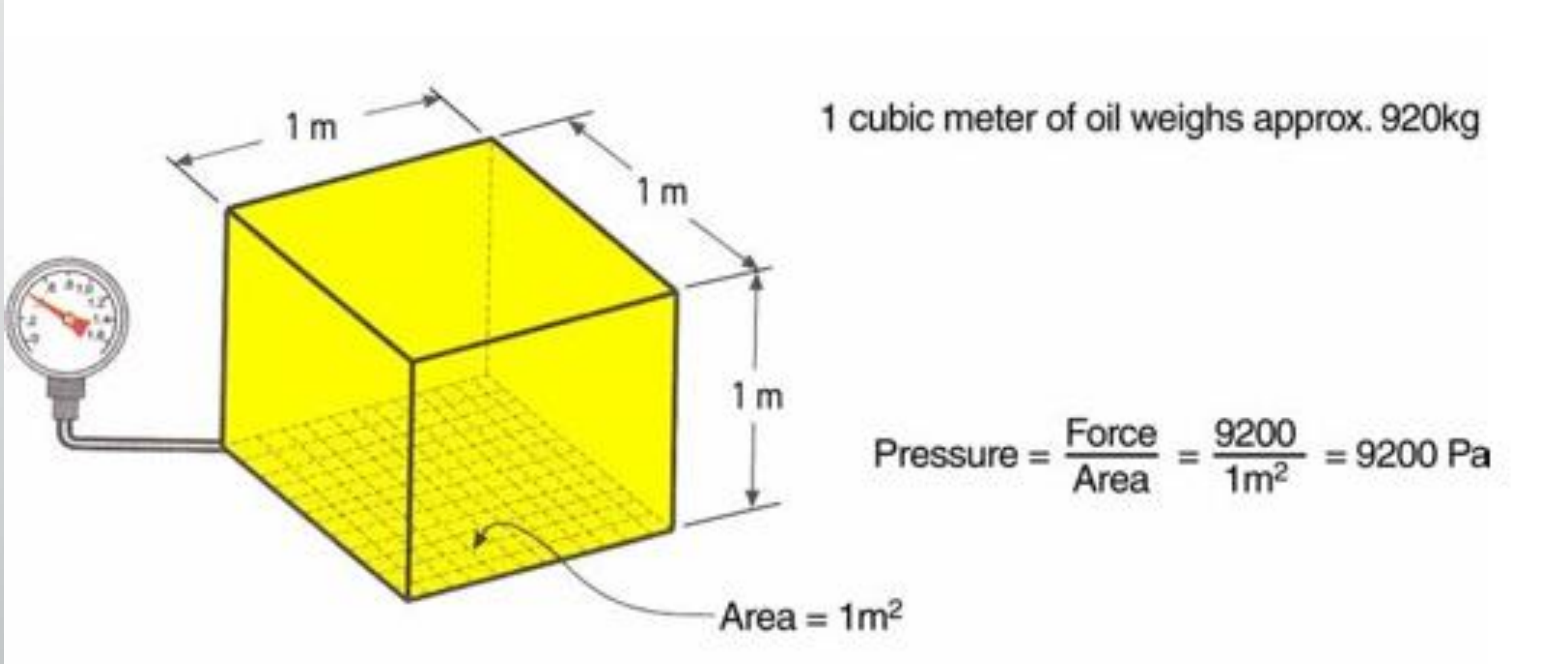
This formula is P=$\frac{F}{A}$

1 Pascal (Pa) =1 N/m2.

1 bar = $10^5 Pa$

1 MPa = 10 bar

EXAMPLE 1



Pressure caused by the weight of oil

Pascal's Law

The same relationship is used to determine the pressure in a fluid resulting from a force applied to it. Figure 1 shows a weight being supported by fluid over A=0.1m^2 area.

By rearranging the above formula, the fluid pressure of 100,000Pa can be determined by: P=$\frac{F}{A}$

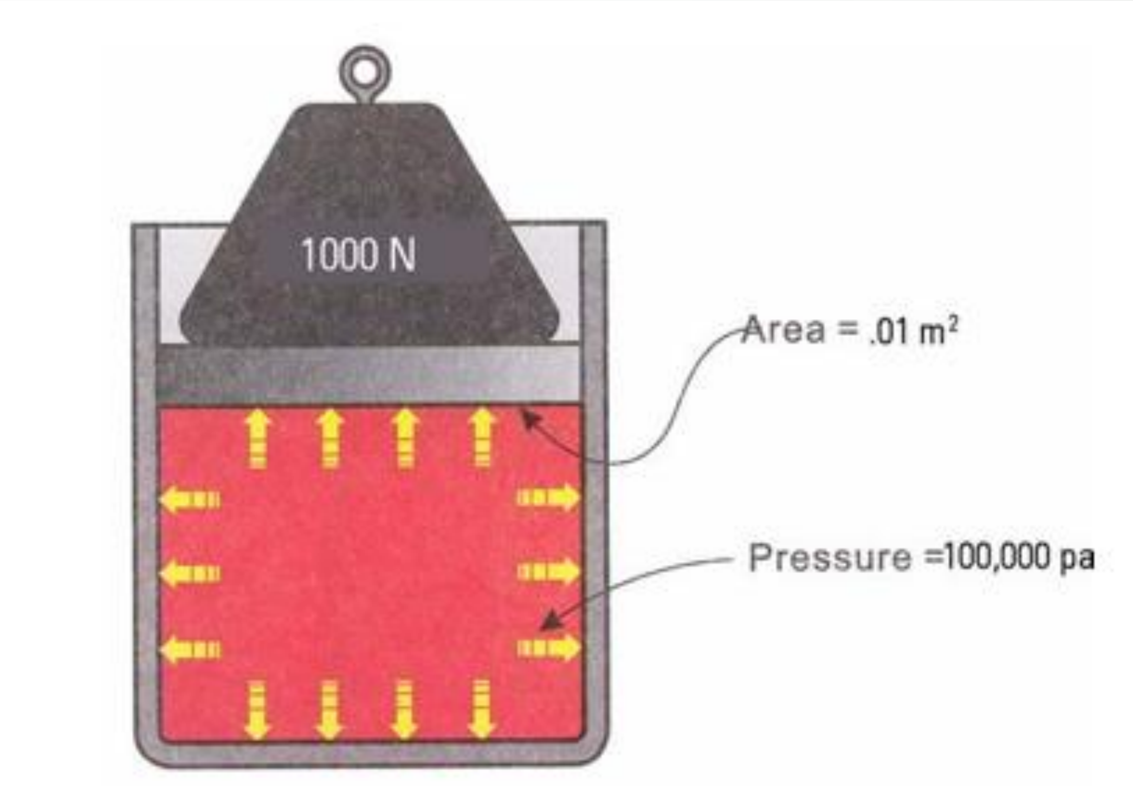


Figure 1 - Pressure created by weight

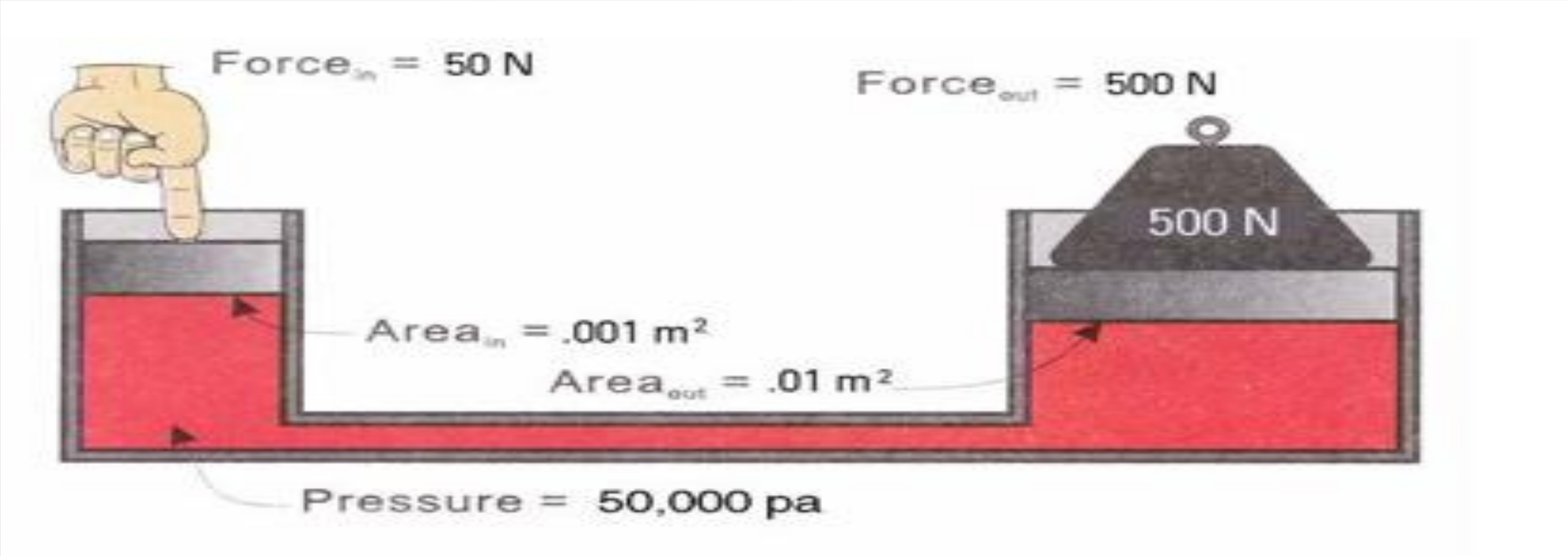
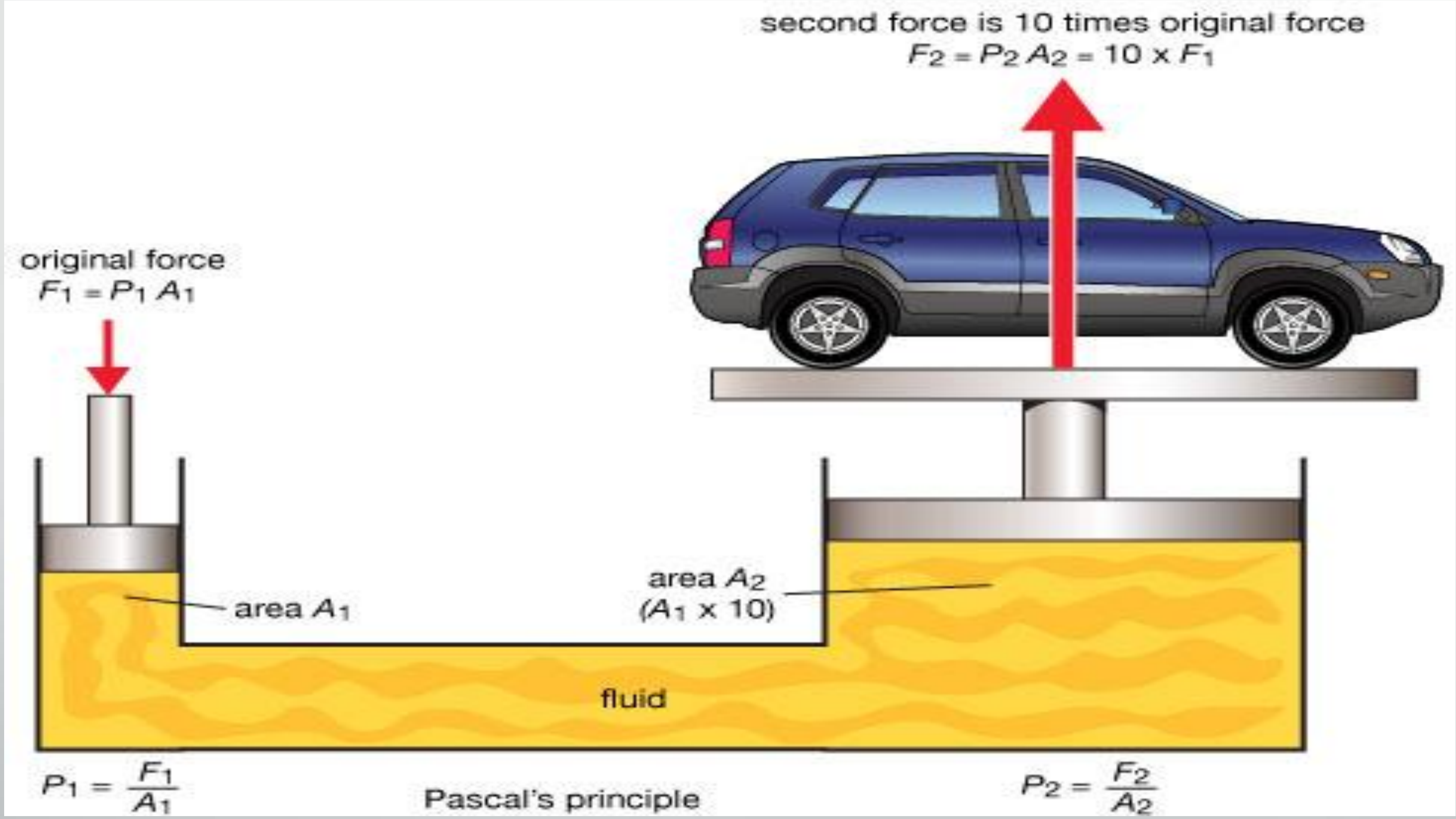


Figure 2 - Transmitting force by fluid

- Pascal demonstrated the practical use of his laws with illustrations such as that shown in Figure 2. This diagram shows how, by applying the same principle described above, a small input force applied against a small area can result in a large force by enlarging the output area.
- This pressure, applied to the larger output area, will produce a larger force as determined by the formula on the previous page. Thus, a method of multiplying force, much the same as with a pry-bar or lever, is accomplished using fluid as the medium.

Pascal's Law

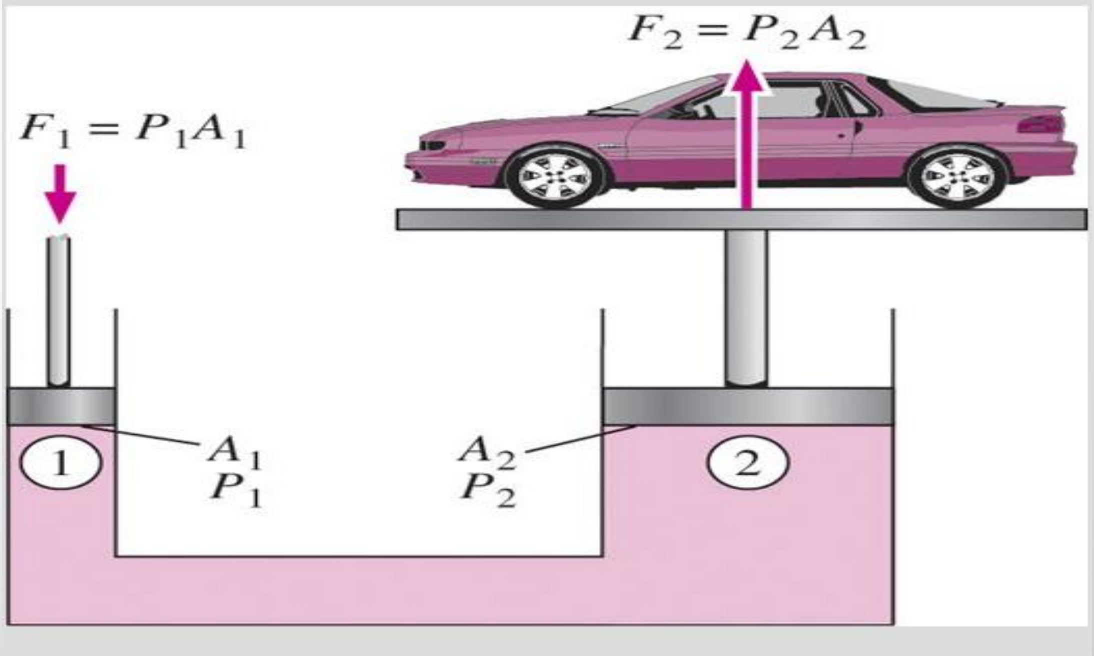


$P_1 = P_2$

EXAMPLE 2

F_1=100N
A_1=0.05m^2
F_2=850N
A_2=?

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



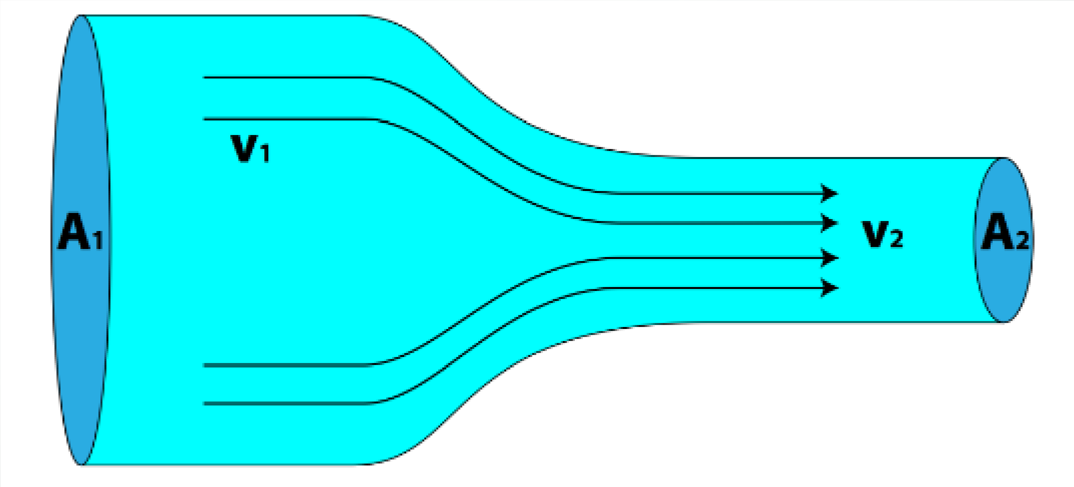
$$A_2 = \frac{F_2 X A_1}{F_1} = \frac{850N X 0.05m^2}{100N} = 0.425m^2$$

Liquid Flow

- Flow is simply the movement of a quantity of fluid during a period of time. Fluids are confined in hydraulics, such as in hoses, tubes, reservoirs and components, so flow is the movement of a fluid through these confining elements.
- Flow is normally designated by the letter "Q", and is usually expressed in litres-per- minute, or LPM, but may also be expressed in cubic-centimetres-per-minute (cm3/ min) or per-second (cm3/sec).
- Flow = Area x Velocity, or Q = A x V.
- Q= flow rate (m^3 /s)
- V= flow velocity (m / s)
- A= area (m^2)

The continuity equation

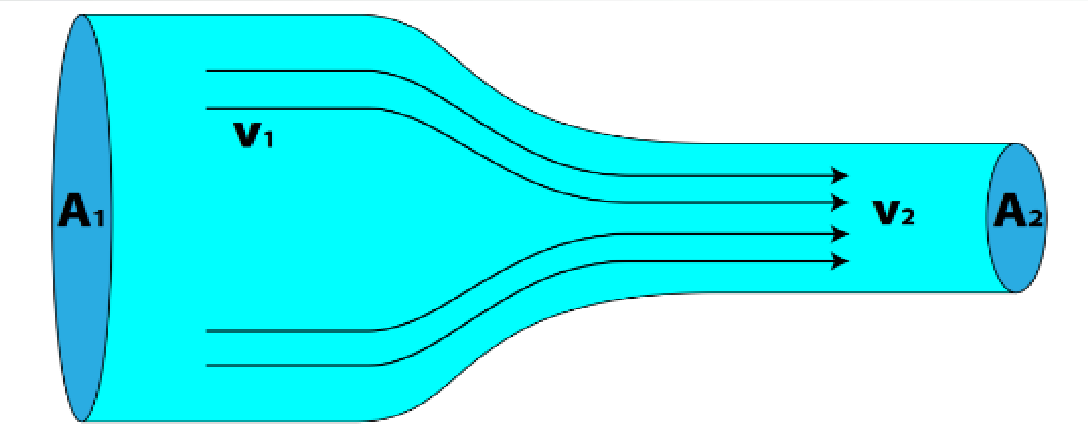
The volume of fluid moving through the pipe at any point can be quantified in terms of the volume flow rate, which is equal to the area of the pipe at that point multiplied by the velocity of the fluid. This volume flow rate must be constant throughout the pipe, therefore you can write the equation of continuity for fluids (also known as the fluid continuity equation) as



- When fluids move through a full pipe, the volume of fluid that enters the pipe must equal the volume of fluid that leaves the pipe, even if the diameter of the pipe changes. This is a restatement of the law of conservation of mass for fluids.

$$A_1 v_1 = A_2 v_2$$

EXAMPLE 3



- V_1=0.5m/s
- The diameter at point 1 is 70mm and the diameter at point 2 is 30 mm.
- V_2=?

$$A_1 = \pi \times \frac{{D_1}^2}{4} = 3.14 \times \frac{(70\times10^{-3})^2}{4} = 3.846 \times 10^{-3}\ m^2$$

$$A_2 = \pi \times \frac{{D_2}^2}{4} = 3.14 \times \frac{(30\times10^{-3})^2}{4} = 7.065 \times 10^{-4}\ m^2$$

$$Q_1 = Q_2$$

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

$$V_2 = V_1 \times \frac{A_1}{A_2} = 0.5 \times \frac{3.846 \times 10^{-3} m^2}{7.065 \times 10^{-4} m^2} = 2.72 \text{ m/s}$$