Pearson BTEC Levels 4 Higher Nationals in Engineering (RQF)

Unit 29: Electro, Pneumatic and Hydraulic Systems

Unit Workbook 3

in a series of 4 for this unit

Learning Outcome 3

Applications of Pneumatic and Hydraulic Systems

INTRODUCTION

LO3 Examine the applications of pneumatic and hydraulic systems

System applications:

Calculation of appropriate capacities and specifications

Applied functions of control elements

Design and testing of hydraulic and pneumatic systems

Fluid power in real-life examples

Valued component choice

Contents

Background Theory

Defining Fluid

Before beginning the unit, it is important to know exactly what a fluid is. Fluids are commonly mistaken as a liquid, and while this is technically correct, fluids are defined as something that flows, which means that fluids actually encompass both liquids *and* gases. Fluids do not have a fixed shape and will yield easily to external pressure.

Pascal's Law

Pascal's law is an important consideration in fluid mechanics that was first coined by the French scientist Blaise Pascal. Pascal's Law states:

"A pressure change in one part of a fluid at rest in a closed container will transmit to every portion of the fluid and the walls of the container without any losses"

This is an important principle when considering hydraulic systems. Pressure P can be defined by Equation 1, where F is the force and A is the area.

$$\mathrm{P} = \frac{\mathrm{F}}{\mathrm{A}} \quad [1]$$

Therefore, being stood on by a high heel is more painful than being stood on by a flat shoe. The force applied will still be the same, but the pressure on the concentrated heel will be much greater than a flat shoe.

Hydraulics

Pascal's principle is applied to hydraulic systems. A force applied to a given area can be used to exert a force elsewhere through fluid transmission.

Hydraulics operate with two classes of piston, the "Master" and the "Slave" piston, the master piston is the dictator in the system and controlled by the operator, while the slave piston is the one that will move as a result. One of the most common hydraulic systems in day-to-day life are the brakes in cars. Fig.1 shows a basic schematic of a hydraulic system in place, the master piston is shown as the one receiving the operator's "effort force" $\mathrm{F_1}$, and the slave piston is applying the "load force" $\mathrm{F_2}$.

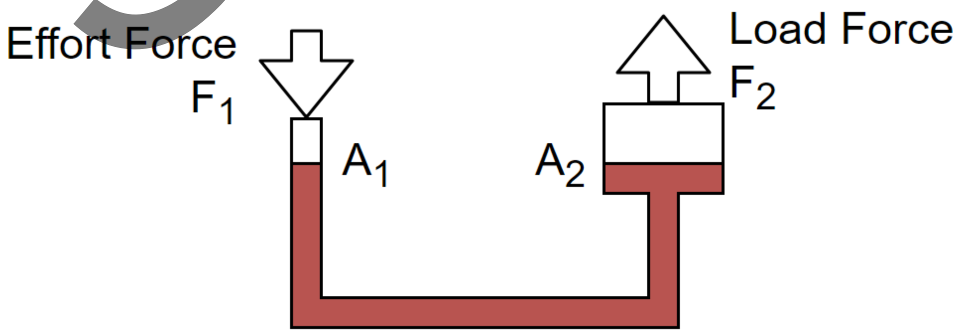


Figure 1 *Hydraulic diagram*

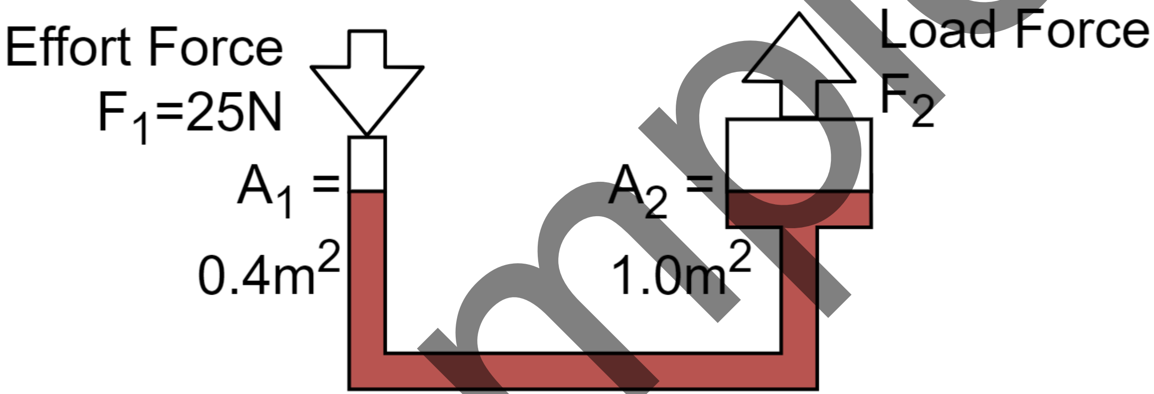
Since hydraulics are closed systems, energy and work transmitted out of the system is zero, which means that the pressures on each piston is the same, which means that the load force generated can be calculated using Equation 2.

$$equal\ pressures\ (says\ Pascal) \quad \therefore \quad \frac{F_1}{A_1} = \frac{F_2}{A_2} \quad \therefore \quad \mathrm{F_2 = F_1 \cdot \frac{A_2}{A_1}} \quad [2]$$

Example 1

A master piston, which has a cross sectional area of $0.4\ \mathrm{m}^2$ receives an effort force of $25\ \mathrm{N}$ to push a slave piston with a cross-sectional area of $1.0\ \mathrm{m}^2$. Calculate:

1. The pressure created on the fluid by the effort force.
2. The load force exerted.



1. The pressure is given as:

$$P = \frac{\mathrm{F_1}}{\mathrm{A_1}} = \frac{25}{0.4} = 62.5\ \mathrm{Nm^{-2}}$$

2. Since this is a closed system, the resultant load force can be calculated as:

$$\mathrm{F_2 = P \cdot A_2 = 62.5 \cdot 1.0 = 62.5\ N}$$

Hydraulics can be found in a lot of heavy equipment, such as cranes, diggers, etc. However, one of the most common uses is found in the brakes of a car. As the driver pushes the pedal, the small master cylinder pushes down on the hydraulic fluid, which will then push the slave pistons and clamp down on the brake discs, which will slow the turning speed of the wheels. A basic schematic of a car's brakes can be seen in Figure 2.

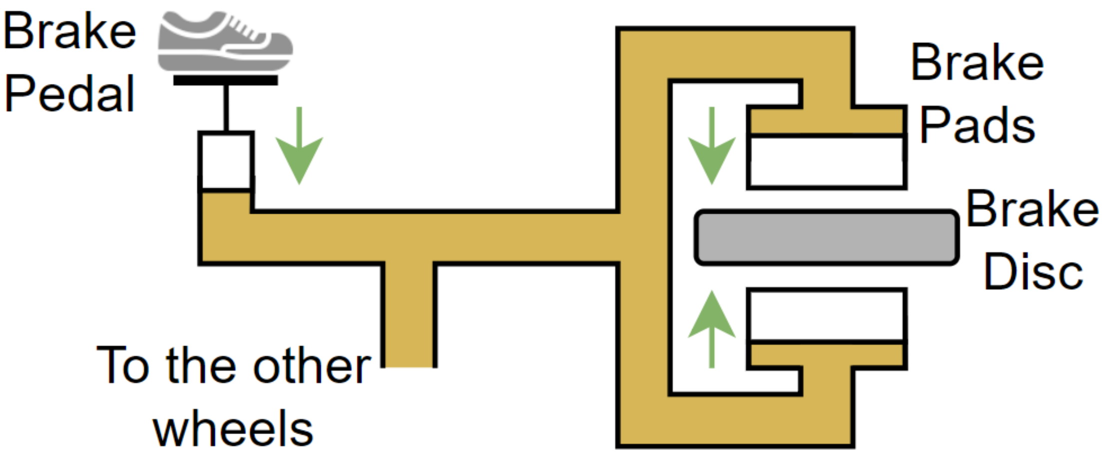


Figure 2 *A schematic of a vehicle's braking system*

This is a basic system and is very unlikely to be found in any modern vehicle. This configuration is prone to "locking", in which the brake disc does not rotate, and the wheel will slip. The solution for this is anti-lock brakes, which will incorporate a tachometer and several "bleed" valves in the hydraulics. Once the system detects that the brakes are locking (the tachometer will sense zero rotation in the wheel), the bleed valves will open and reduce the pressure on the brake pads, release the disc and allow it to rotate once again. With the disc rotating once again, the valves close and the brake pads are again pushed against the brake disc. Essentially creating a rapid clapping motion to optimise braking performance.

Measuring Pressure

Pressures will be defined as a measure of *absolute* or *gauge* pressure:

- *Absolute Pressure* is the pressure relative to a vacuum ($0\ \mathrm{Pa}$), absolute gauges are preferred when the measured pressure is below the atmospheric pressure.
- *Gauge Pressure* is the pressure measurement relative to atmospheric pressure ($1\ \mathrm{bar} = 101.3\ \mathrm{kPa}$).

Pressure can be measured by a manometer, which is a U-shaped system partially filled with liquid, typically this working liquid is mercury due to its high density relative to other liquids ($13{,}560\ \mathrm{kg/m^3}$). One side of the u-bend is sealed by the gas being measured, while the other side can be sealed off as a vacuum (absolute measurement) or left open to the atmosphere (gauge measurement).

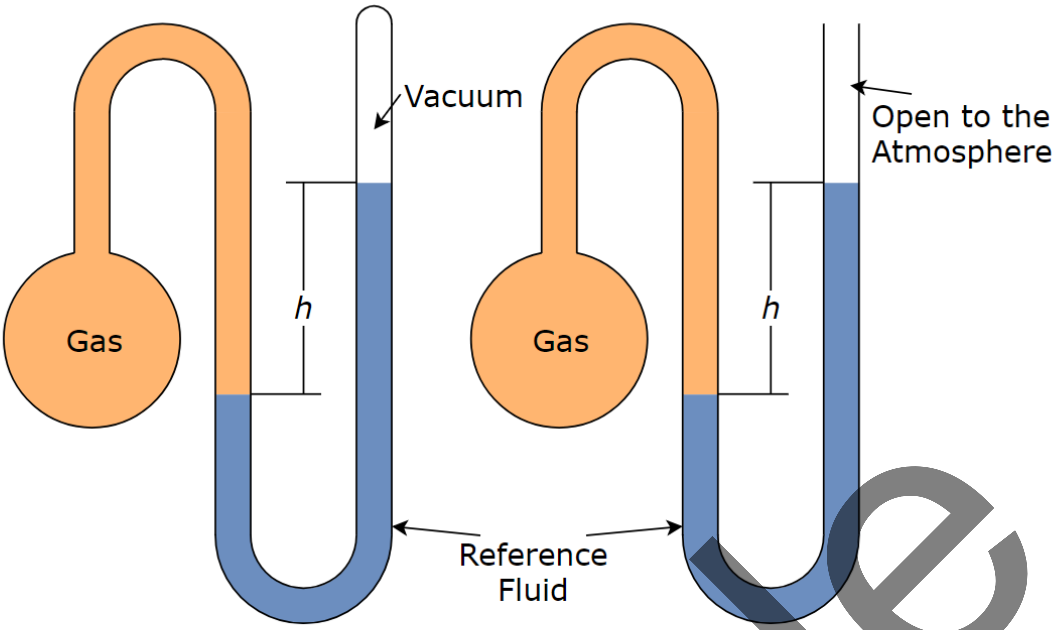


Figure 3 *An absolute pressure manometer (left) and a gauge pressure manometer (right)*

The pressure reading for the absolute pressure manometer is given as Equation 3, where ρ is the density of the reference fluid, g is acceleration due to gravity and h is the height difference in the reference fluid:

$$P = \rho g h \quad [3]$$

The pressure reading for the gauge will be the same as Equation 3, however, to find the absolute pressure of a gauge manometer, Equation 4 is required:

$$P_{abs} = P_{atm} + P = P_{atm} + \rho g h \quad [4]$$

Example 2

A manometer reading is showing a height difference of $+3$ cm, the working fluid is mercury ($13{,}560\ \mathrm{kg/m^3}$). Calculate the absolute pressure of the system if:

a) The manometer is sealed off to a vacuum.
b) The manometer is open to atmospheric pressure (101.3 kPa).

You are to assume that acceleration due to gravity is $9.81\ \mathrm{m/s^2}$

Answer:

a) If the manometer is sealed off to a vacuum, then the absolute pressure is given as: