

1.2: Scalars and Vectors Part 1

To better understand the science of propulsion it is necessary to use some mathematical ideas from **vector analysis**. Most people are introduced to vectors in high school or college, but for those who were not introduced let's start with some videos

DON'T PANIC!



Spr10.3.1 - Understand and represent vectors from White Rose Education on Vimeo.

There are many complex parts to vector analysis and we aren't going there. We are going to limit ourselves to the very basics. Vectors allow us to look at complex, multi-dimensional problems as a simpler group of one-dimensional problems. We will be concerned mostly with definitions. The words are a bit strange, but the ideas are very powerful as you will see. If you want to find out a lot more about vectors you can download this report on [vector analysis](#).

Math and science were invented by humans to describe and understand the world around us. We live in a (at least) four-dimensional world governed by the passing of time and three space dimensions; up and down, left and right, and back and forth. We observe that there are some quantities and processes in our world that depend on the **direction** in which they occur, and there are some quantities that do not depend on direction. For example, the **volume** of an object, the three-dimensional space that an object occupies, does not depend on direction. If we have a 5 cubic foot block of iron and we move it up and down and then left and right, we still have a 5 cubic foot block of iron. On the other hand, the **location**, of an object does depend on direction. If we move the 5 cubic foot block 5 miles to the north, the resulting location is very different than if we moved it 5 miles to the east. Mathematicians and scientists call a quantity which depends on direction a **vector quantity**. A quantity which does not depend on direction is called a **scalar quantity**.

Vector quantities have two characteristics, a magnitude and a direction. Scalar quantities have only a magnitude. When **comparing** two vector quantities of the same type, you have to compare both the magnitude and the direction. For scalars, you only have to **compare** the magnitude. When doing any mathematical operation on a vector quantity (like adding, subtracting, multiplying ..) you have to **consider** both the magnitude and the direction. This makes dealing with vector quantities a little more complicated than scalars.

On the slide we list some of the physical quantities discussed in the [Beginner's Guide to Aeronautics](#) and group them into either vector or scalar quantities. Of particular interest, the **forces** which operate on a flying aircraft, the **weight**, **thrust**, and **aerodynamic forces**, are all vector quantities. The resulting **motion** of the aircraft in terms of displacement, velocity, and acceleration are also vector quantities. These quantities can be determined by application of [Newton's laws](#) for vectors. The scalar quantities include most of the

[thermodynamic state](#) variables involved with the propulsion system, such as the [density](#), [pressure](#), and [temperature](#) of the propellants. The [energy](#), [work](#), and [entropy](#) associated with the engines are also scalar quantities.

Vectors have magnitude and direction, scalars only have magnitude. The fact that **magnitude** occurs for both scalars and vectors can lead to some confusion. There are some quantities, like **speed**, which have very special definitions for scientists. By definition, speed is the scalar magnitude of a **velocity** vector. A car going down the road has a speed of 50 mph. Its velocity is 50 mph in the northeast direction. It can get very confusing when the terms are used interchangeably! Another example is **mass** and **weight**. Weight is a force which is a vector and has a magnitude and direction. Mass is a scalar. [Weight and mass](#) are related to one another, but they are not the same quantity.`

While Newton's laws describe the resulting motion of a solid, there are special equations which describe the motion of fluids, [gases and liquids](#). For any physical system, the [mass](#), [momentum](#), and [energy](#) of the system must be conserved. Mass and energy are scalar quantities, while momentum is a vector quantity. This results in a **coupled** set of equations, called the [Navier-Stokes equations](#), which describe how fluids behave when subjected to external forces. These equations are the fluid equivalent of Newton's laws of motion and are very difficult to solve and understand. A simplified version of the equations called the [Euler equations](#) can be solved for some fluids problems.

Here are some examples of scalar and vector quantities

Scalar Quantities	Vector Quantities
Length, area, volume	Displacement
Speed	Velocity
Mass, density	Acceleration
Pressure	Momentum
Temperature	Force
Energy	Lift, drag, thrust
Entropy	
Work, power	

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