Introduction to mathematical fluid dynamics pdf

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This is a basic, though hopefully fairly comprehensive, introduction to working with vectors. Vectors manifest in a wide variety of ways from displacement, velocity, and acceleration to forces and fields. This article is devoted to the mathematics of vectors; their application in specific situations will be addressed elsewhere. A vector quantity, or vector, provides information about not just the magnitude but also the direction of the quantity. When giving directions to a house, it isn't enough to say that it's 10 miles away, but the direction of those 10 miles must also be provided for the information to be useful. Variables that are vectors will be indicated with a boldface variable, although it is common to see vectors denoted with small arrows above the variable. Just as we don't say the other house is -10 miles away, the magnitude of a vector is always a positive number, or rather the absolute value of the "length" of the vector (although the quantity may not be a length, it may be a velocity, acceleration, force, etc.) A negative in front a vector doesn't indicate a change in the magnitude, but rather in the direction of the vector. In the examples above, distance is the scalar quantity (10 miles) but displacement is the vector quantity (10 miles to the northeast). Similarly, speed is a scalar quantity while velocity is a vector quantity. A unit vector is a vector that has a magnitude of one. A vector representing a unit vector is usually also boldface, although it will have a carat (^) above it to indicate the unit nature of the variable. The unit vector x, when written with a carat, is generally read as "x-hat" because the carat looks kind of like a hat on the variable. The zero vector, or null vector, is a vector with a magnitude of zero. It is written as 0 in this article. Vectors are generally oriented on a coordinate system, the most popular of which is the two-dimensional Cartesian plane. The Cartesian plane has a horizontal axis which is labeled x and a vertical axis labeled y. Some advanced applications of vectors in physics require using a three-dimensional space, in which the axes are x, y, and z. This article will deal mostly with the two-dimensional system, though the concepts can be expanded with some care to three dimensions without too much trouble. Vectors in multiple-dimension coordinate systems can be broken up into their component vectors. In the two-dimensional case, this results in a x-component and a y-component. When breaking a vector into its components, the vector is a sum of the components: F = Fx + Fy thetaFxFyF Fx / F = cos theta and Fy / F = sin thetawhich gives usFx = F cos theta and Fy = F sin theta Note that the numbers here are the magnitudes of the vectors. We know the direction of the components, but we're trying to find their magnitude, so we strip away the directional information and perform these scalar calculations to figure out the magnitude. Further application of trigonometry can be used to find other relationships (such as the tangent) relating between some of these quantities, but I think that's enough for now. For many years, the only mathematics that a student learns is scalar mathematics. If you travel 5 miles north and 5 miles east, you've traveled 10 miles. Adding scalar quantities ignores all information about the directions. Vectors are manipulated somewhat differently. The direction must always be taken into account when manipulating them. When you add two vectors, it is as if you took the vectors and placed them end to end and created a new vector running from the starting point to the end point. If the vectors have the same direction, then this just means adding the magnitudes, but if they have different directions, it can become more complex. You add vectors by breaking them into their components and then adding the components, as below: a + b = cax + ay + bx + by = (ax + bx) + (ay + by) = cx + cy The two x-components will result in the x-component of the new variable, while the two y-components result in the y-component of the new variable. The order in which you add the vectors does not matter. In fact, several properties from scalar addition hold for vector addition: Identity Property of Vector Additiona + 0 = aInverse Property of Vector Additiona + -a = a - a = 0Reflective Property of Vector Additiona = aCommutative Property of Vector Additiona + b = b + aAssociative Property of Vector Addition (a + b) + c = a + (b + c)Transitive Property of Vector Addition If a = b and c = b, then a = c The simplest operation that can be performed on a vector is to multiply it by a scalar. This scalar multiplication alters the magnitude of the vector. In other words, it makes the vector longer or shorter. When multiplying times a negative scalar, the resulting vector will point in the opposite direction. The scalar product of two vectors is a way to multiply them together to obtain a scalar quantity. This is written as a multiplication of the two vectors, with a dot in the middle representing the multiplication. As such, it is often called the dot product of two vectors. To calculate the dot product of two vectors, you consider the angle between them. In other words, if they shared the same starting point, what would be the angle measurement (theta) between them. The dot product is defined as: a * b = ab cos theta ababba In cases when the vectors are perpendicular (or theta = 90 degrees), cos theta will be zero. Therefore, the dot product of perpendicular vectors is always zero. When the vectors are parallel (or theta = 0 degrees), cos theta is 1, so the scalar product is just the product of the magnitudes. These neat little facts can be used to prove that, if you know the components, you can eliminate the need for theta entirely with the (two-dimensional) equation: a * b = ax bx + ay by The vector product is written in the form a x b, and is usually called the cross product of two vectors. In this case, we are multiplying the vectors and instead of getting a scalar quantity, we will get a vector quantity. This is the trickiest of the vector computations we'll be dealing with, as it is not commutative and involves the use of the dreaded right-hand rule, which I will get to shortly. Again, we consider two vectors drawn from the same point, with the angle theta between them. We always take the smallest angle, so theta will always be in a range from 0 to 180 and the result will, therefore, never be negative. The magnitude of the resulting vector is determined as follows: If c = a x b, then c = ab sin theta The vector product of parallel (or antiparallel) vectors is always zero The vector product will be perpendicular to the plane created from those two vectors. If you picture the plane as being flat on a table, the question becomes if the resulting vector go up (our "out" of the table, from our perspective) or down (or "into" the table, from our perspective). In order to figure this out, you must apply what is called the right-hand rule. When I studied physics in school, I detested the right-hand rule. Every time I used it, I had to pull out the book to look up how it worked. Hopefully my description will be a bit more intuitive than the one I was introduced to. If you have a x b you will place your right hand along the length of b so that your fingers (except the thumb) can curve to point along a. In other words, you are sort of trying to make the angle theta between the palm and four fingers of your right hand. The thumb, in this case, will be sticking straight up (or out of the screen, if you try to do it up to the computer). Your knuckles will be roughly lined up with the starting point of the two vectors. Precision isn't essential, but I want you to get the idea since I don't have a picture of this to provide. If, however, you are considering b x a, you will do the opposite. You will put your right hand along a and point your fingers along b. If trying to do this on the computer screen, you will find it impossible, so use your imagination. You will find that, in this case, your imaginative thumb is pointing into the computer screen. That is the direction of the resulting vector. The right-hand rule shows the following relationship: a x b = - b x a cabc cx = ay bz - az bycy = az bx - ax bzcz = ax by - ay bx abcxcyc At higher levels, vectors can get extremely complex to work with. Entire courses in college, such as linear algebra, devote a great deal of time to matrices (which I kindly avoided in this introduction), vectors, and vector spaces. That level of detail is beyond the scope of this article, but this should provide the foundations necessary for most of the vector manipulation that is performed in the physics classroom. If you are intending to study physics in greater depth, you will be introduced to the more complex vector concepts as you proceed through your education. Math is the study of numbers, shapes, and logic. It's using fractions to double a recipe. It's applying theoretical reasoning and patterns to understand the movements of atoms. It's the foundation of every system we have, from money to medicine.Math is an academic discipline and an everyday necessity. Whether you're calculating how long a trip will take or doing advanced data analysis to grow your business, understanding math helps you get ahead.Innovations in math have powered real-world advancements across society. Engineers, scientists, and medical researchers make the calculations that drive discoveries, from new lifesaving medicines to sustainable building materials.Math is also fascinating and rewarding in its own right. Professional and amateur mathematicians dive deeply into theoretical subfields such as number theory, learning about previously discovered quantitative concepts and developing new mathematical ideas along the way.Why learn math?Math shows you how the world works. Everything in the universe, from the movements of galaxies down to the motions of atoms, is governed by mathematical principles. A math education can help you to understand these principles that guide the world you live in.Studying math develops your mathematical thinking and problem solving abilities. You learn how to look at a problem, consider the relationships between various factors, and come to a logical conclusion. When you master this thought process, you can reason your way through many of life's toughest challenges.A math education can also give you a personal and professional edge. 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Dive deeply into topics like machine learning, algorithms, Python, and more.Build a career with mathMath-related career fields are growing fast.According to the U.S. Bureau of Labor Statistics, math-related fields will grow by 27% between 2019 and 2029—that's more than 56,000 new jobs. These rewarding and well-paying jobs include:ActuaryAccountantStatisticianOperations research analystData analystOf course, a math education isn't just for people who aspire to purely math-related fields. Math is the foundation of business, finance, and all the sciences. These fields are also growing fast.There's never been a better time to build your math education. Explore edX courses and get started today.

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