Study of Physics

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Abstract

This article was written for the purpose of documenting my process of studying physics.

1 Classical mechanics

1.1 Introduction

Just like every other "Physics documentation", this document starts with the field of mechanics. In this part we will focus on Classical mechanics. Classical mechanics is the area of physics concerned with the relationships between force, matter and motion among physical objects. This branch of physics has its origins in Ancient Greece, for instance, in the writings of Aristotle and Archimedes. Classical mechanics further breaks down to the sub topics of Dynamics, Kinematics, Continuum, Statistical and Celestial.

1.2 General properties and units

These properties and units are important for every branch of classical mechanics. First of all everything around us that we perceive in any kind of way, for instance, a cube out of stone is a physical object (*Ger. Körper*). Every physical object has a fix amount of properties. (The stone cube has a mass, takes up a certain amount of space, etc.)

1.2.1 Volume, mass and density

Volume, mass and density are three important physical quantities.
The Volume is a scalar quantity expressing the amount of three-dimensional spaced enclosed by a closed surface. For example, the space that the stone cube occupies. It can be usually measured using tools (like flow meters, etc.). For expressing the volume we use the symbol V and the units litre l, or cubic metre m^3.

$$1m^3 = 1000l$$

Mass is the quantity of matter in a physical body. Unlike the weight of an object, the mass of a specific object is the same everywhere (The stone cube has a mass of 1kg on the earth, on the mass, etc.). Mass has the symbol m and the unit kilogram kg. Mass can be measured using a scale. In an closed system, under the assumption of classical physics, the sum of all masses stays constant (Conservation of mass).

$$m = \sum_{i=1}^{n} m_i = constant$$

The density of a substance is its mass per unit volume. The symbol most often used for density is ρ (the lower case Greek letter rho). Mathematically, density is defined as mass divided by volume.

$$\rho = \frac{m}{V}$$

Thus the unit for density is kilogram per cubic metre $\frac{kg}{m^3}$. Every substance has a defined constant density.

1.2.2 Avogadro constant, mole and dalton

Every object consists of an one or more substances. Every substance consists of particles. These particles may be atoms, molecules or ions. A sample of a substance can be characterized using the number of particles. The number of particles N expresses the number of particles in the sample of a substance. The amount of substance n expresses the same thing *"the number of particles in the sample of a substance"* but using the unit mole $1mol$. The Avogadro constant N_A is the amount of particles in one mole of any substance.

$$N_A = 6.02214076 \times 10^{23} \frac{1}{mol}$$

One can calculate these values using the following equation.

$$n = \frac{N}{N_A} = \frac{m}{M} = \frac{V}{V_m}$$

m is the mass of the substance sample. M is the molar mass of the substance. This value is different for every substance. V_M is the molar volume i.e. the volume that one mole of given substance has and can be calculated with $V_M = \frac{M}{\rho}$.

Example: How many water molecules are in 10g of water.

$$m = 10g$$
$$M_{H_2O} = 18g \times mol^{-1}$$

$$\frac{N}{N_A} = \frac{m}{M}$$
$$N = N_A \times \frac{m}{M}$$
$$N = \frac{6.022 \times 10^{23} \times 10g \times mol}{mol \times 18} \approx 3.35 \times 10^{23}$$

10 grams of water consist of approximately 3.35×10^{23} molecules.
The unit dalton u is defined as $\frac{1}{12}$ of the mass of an unbound neutral atom of carbon-12.

$$1u = \frac{1g}{N_A} \approx 1,660540 \times 10^{-24} g$$

1.2.3 Cohesion and Adhesion

Cohesion is the action of two like molecules sticking together, being mutually attractive. Adhesion is the tendency of dissimilar particles to stick together.

1.3 Kinematics

Kinematics is all about movements and the laws of movements. Kinematics doesn't care about the cause of movement.

1.3.1 Frame of reference

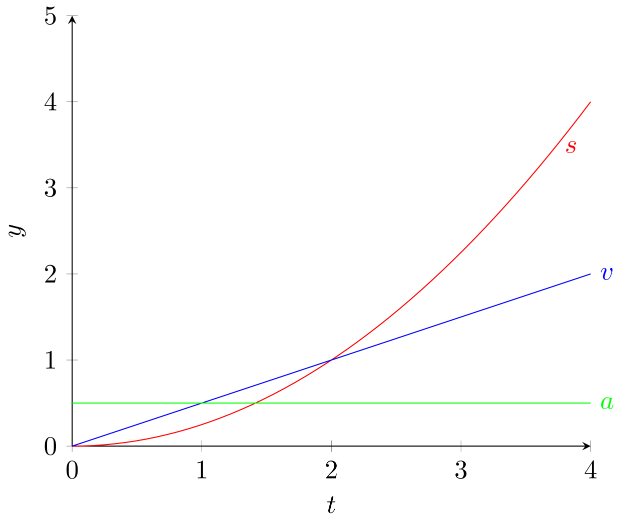
The movement of an object is defined as change of position. Change of position can only be measured in relation to an reference object or frame of reference *(Ger. Bezugssystem)*, e.g. a coordinate system.

1.3.2 Types of movements

There are two types of movements that are important for now. Linear and Nonlinear movements. Linear movements occur with a constant velocity. Nonlinear movements may change velocity over time.

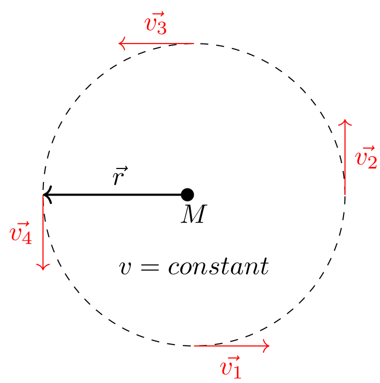
1.3.3 Physical quantities for describing movements

The important quantities for kinematics are location, distance, time, velocity and acceleration. The distance $\vec{s}$ expresses the distance travelled by an object, measured in metre m. Velocity expresses the rate at which the distance changes. The velocity has the symbol $\vec{v}$ and the unit metre per second $\frac{m}{s}$. Acceleration expresses the rate at which the velocity changes. The acceleration has the symbol $\vec{a}$ and the unit metre per square second $\frac{m}{s^2}$.



1.3.4 Uniform circular movements

Uniform circular movements occur when objects move along a circular path with a constant velocity v.



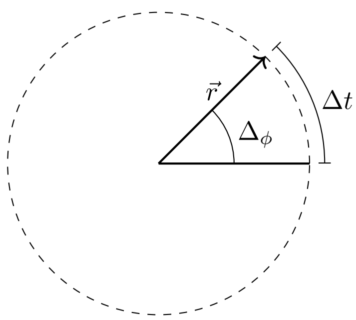
Uniform circular movements are usually described using the orbital period T, the rotational speed n and the frequency f.

$$T = \frac{1}{n}$$

$$f = n = \frac{1}{T}$$

$$v = \frac{s}{t} = \frac{2\pi r}{T}$$

Another way of describing circular movements is using angular velocity $\vec{\omega}$.



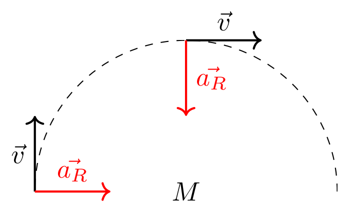
The angular velocity can be calculated using following euquations.

$$\vec{\omega} = \frac{\vec{\Delta_\phi}}{\Delta t} = constant$$

$$\omega = \frac{2\pi}{T} = 2\pi \times n = 2\pi \times f$$

1.3.5 Centripetal force

In order for an object to stay on a circular path a force is needed, wich holds the object on the path. This force is called centripetal force *(Ger. Radialbeschleunigung)*. The centripetal force $\vec{a_R}$ is always orthogonal to the velocity $\vec{v}$, thus the its always "pointed" towards the center of the curvature.



This centripetal force can be calculated with the following equations.

$$a_R = \frac{v^2}{r}$$
$$a_R = \omega^2 \times r$$

Example: A car is driving through an curve with the radius of 75m and an constant velocity of 16.6m/s. Calculate the centripetal force.

$$a_R = \frac{v^2}{r} = \frac{(16.6m/s)^2}{75m} \approx 3.674\frac{m}{s^2}$$

1.3.6 Constant acceleration

All of earlier explained movements had an acceleration of $a = 0$, thus the velocity was always $\int 0dt = 0 + C$. The velocity was some constant and didn't change, therefore they obeyed the law $v = \frac{s}{t} = constant$. Now lets assume that we have an constant acceleration this is a new type of movement. This type of movement obeys the following laws.

$$\frac{s}{t^2} = constant = \frac{a}{2}$$
$$a = \frac{v}{t} = constant$$

2 Einsteins field equations

I got bored and my whiteboard is full so I'm going to write this down here.

2.1 Metric Tensor

Consider a field, any type of field that has a defined height ϕ at any given point $P(X|Y)$. Now lets try to find out how ϕ changes. Lets move along the x axis of our plane. The change of ϕ called $d\phi$ will be derivative of the "function" $\phi(x)$ times the "change" along the x axis dx so we can write it as $\frac{d\phi}{\Delta x} \times dx$. But our field has more than just the x and ϕ coordinates, there is also the y coordinate, thus we shall consider our "function", which describes the field to be $\phi(x, y)$. Now we can get the partial derivatives of given function $\frac{\partial\phi}{\partial x}$ and $\frac{\partial\phi}{\partial y}$. Give those derivatives the change of ϕ will be $d\phi_x = \frac{\partial\phi}{\partial x} \times dx$ and $d\phi_y = \frac{\partial\phi}{\partial y} \times dy$. Now using vector math we know that the "vector" ds is related to the two orthogonal vectors dx and dy.

$$\vec{ds} = \vec{dx} + \vec{dy}$$

Now that we know that we can get the change of ϕ along given vector ds: $d\phi_s = d\phi_x + d\phi_y$ Expanding this to more than three dimensions using x^n for the nth dimension gives us the following rule:

$$d\phi = \sum_n \frac{\partial \phi}{\partial x^n} \times dx^n$$