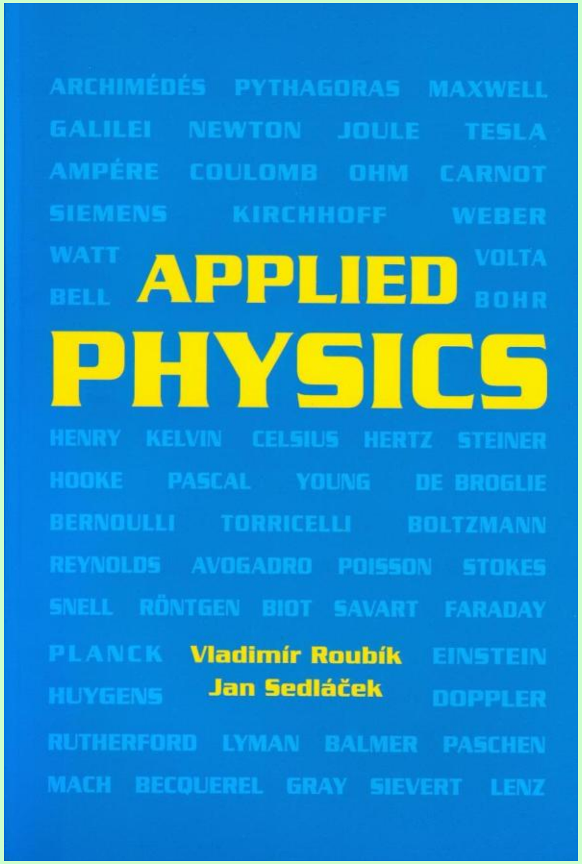
Topics of lectures

1. Introduction to Physics, Introduction to theory of measurement in physics. Introduction to vector calculus
2. Introduction kinematics of mass-point motion. Kinematics for special types of motion
3. Newton's dynamics of mass-point. Mechanical work and energy
4. Rotary motion, Static, center of gravity, forces balance
5. Structure of matter, friction, deformation, and Hooke's Law
6. Fluid models, hydrostatics, hydrodynamics, Surface phenomena in liquids, surface tension, ideal gas, state equation
7. Kinetic gas theory, temperature, heat, heat capacity, thermal conductivity, classical thermodynamics, entropy
8. Electrostatics, electric field and capacitors, Electric current in matter
9. Magnetism and magnetic field
10. Electrical induction, alternating electrical current and electromagnetic waves
11. Introduction to optics: wave, geometrical and photometry
12. Introduction to atomic and subatomic physics with short insight into the Quantum Mechanics, Nuclear Physics and Special Theory of Relativity

Literature:

ROUBÍK, Vladimír; SEDLÁČEK, Jan. Applied Physics. 1. vyd. Praha ČZU v Praze, 2011. 128 s. ISBN 978-80-213-2180-9.



Web:

https://home.czu.cz/sedlacek/uvod

Introduction

- **PHYSICS – Greek word – NATURE**
- **Physics deals with the relationship between matter and energy**
- **Physics as a science began in the 17th century with Galileo Galilei and his successor Isaac Newton**
- **The Classical Physics was developed for three centuries, culminating with the electromagnetic theory of light in the 19th century by J. C. Maxwell**
- **At the beginning of the 20th century new ideas and new experiments in physics indicated that some aspects of Classical Physics could not be applied to the tiny world of atoms or for objects travelling at very high speeds**
- **These new discoveries lead to the birth of Modern Physics**

Introduction

- **Physical branches:**
- **Mechanics, Thermodynamics, Electricity and Magnetism, Oscillations and Waves, Modern Physics (Quantum Physics, Nuclear Physics, Theory of Relativity)**
- **Physics – an exact science – it is possible to make and to describe precise measurements of things and events**
- **For this description <u>physical quantities</u> (time, mass, force, velocity, temperature, energy,…) are used**
- **The magnitude of physical quantities is expressed with <u>physical units</u>**
- **The International System of Units (SI) was adopted as a coherent system based on seven basic units**
- **The other units – derived units – are obtained as combinations from these seven basic (fundamental) units**

Introduction

- **SI units are being used in scientific work in all countries**

THE BASIC QUANTITIES AND THEIR UNITS

Quantity	**Unit**	**Symbol**
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamics temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol

Introduction

Physical Quantities

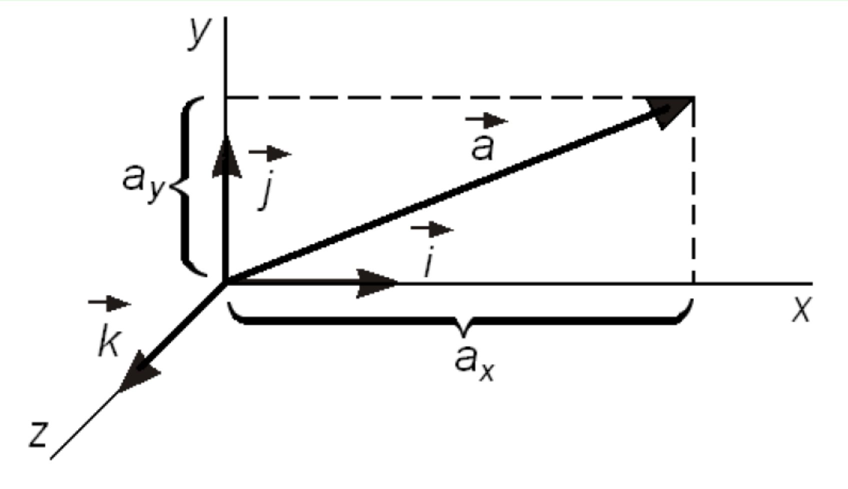
- A physical quantity which is completely specified by magnitude – scalar quantity
- It is a certain number of appropriate units
- The symbol for scalar quantity – mostly a simple letter:
- mass *m* = 5 kg, time *t* = 3 s, temperature *T* = 273 K
- A physical quantity such a force which requires a statement of direction as well as magnitude – vector quantity
- Vector quantity has magnitude and direction
- Vector quantities are indicated by using bold letters or arrow over symbol ($\vec{F}$)

Introduction

- ***Example:***
- **Speed *v* – a scalar quantity with only magnitude, it only tells us how fast an object is moving**
- **Velocity $\vec{v}$ – a vector quantity which provides the direction of travel and the speed**

<u>Vectors analytically</u>

- **For mathematical procedures, the vectors are described in a three-dimensional rectangular coordinate system with the *x, y, z* axes**



Introduction

- $\vec{i}, \vec{j}, \vec{k}$ – unit vectors along positive *x,y,z* axes
- the magnitude of the unit vectors = 1
- We can write vector $\vec{a}$: $\vec{a} = \overrightarrow{a_x} + \overrightarrow{a_y} + \overrightarrow{a_z} = a_x\vec{i} + a_y\vec{j} + a_z\vec{k}$

Magnitude of vector

For two dimensions (in plane *xy*) – Pythagorean theorem for right triangle:

$$a^2 = a_x^2 + a_y^2$$

The magnitude of a two dimensional vector: $a = |\vec{a}| = \sqrt{a_x^2 + a_y^2}$

Generally, the magnitude of a three dimensional vector:

$$a = |\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

Introduction

Unit vector

Unit vector $\overrightarrow{a_0}$ along a $\vec{a}$ vector – the vector that has a magnitude of 1 and direction of vector $\vec{a}$

- $|\vec{a}_0| = 1$ $\quad\quad$ $|\vec{a}_0| = \frac{\vec{a}}{a}$
- **Any nonzero vector $\vec{a}$ can be expressed as a product of its magnitude a and its unit vector $\overrightarrow{a_0}$:** $\vec{a} = a\,\overrightarrow{a_0}$

Negative (opposite) vector

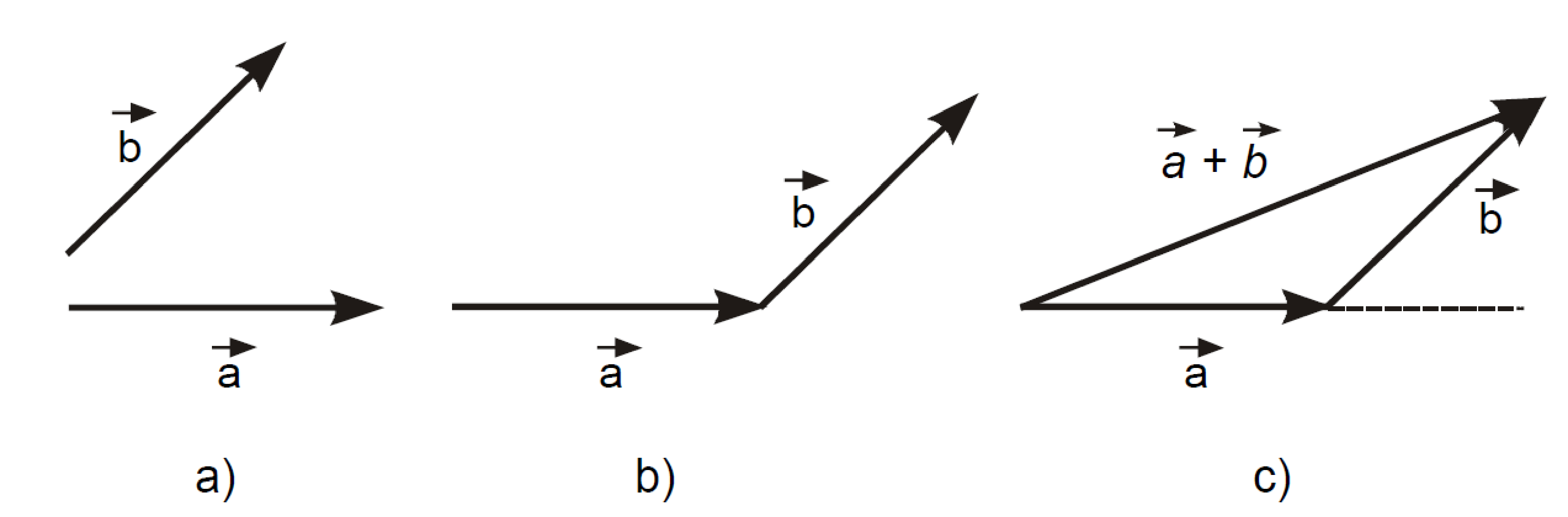
The opposite vector $-\vec{a}$ of vector $\vec{a}$ is a vector with the same magnitude as vector $\vec{a}$ but the opposite direction:

$\vec{a} = a_x\vec{i} + a_y\vec{j} + a_z\vec{k}$ **and** $-\vec{a} = -a_x\vec{i} - a_y\,\vec{j} - a_z\,\vec{k}$

Introduction

<u>Vector addition</u>

1 Graphical method



Introduction

2 Analytic method

Component method for vector addition: $\vec{c} = \vec{a} + \vec{b}$

$$c_x = a_x + b_x \quad , \quad c_y = a_y + b_y \quad , \quad c_z = a_z + b_z$$

$$\vec{c} = \vec{a} + \vec{b} = (a_x + b_x)\vec{i} + (a_y + b_y)\vec{j} + (a_z + b_z)\vec{k}$$

<u>Subtraction of vectors</u>

The subtraction of two vectors $\vec{a} - \vec{b}$ is equal to the resultant (addition) of the first vector $\vec{a}$ plus the opposite vector of the second one $(-\vec{b})$:

$$\vec{a} - \vec{b} = \vec{a} + (-\vec{b}) = (a_x - b_x)\vec{i} + (a_y - b_y)\vec{j} + (a_z - b_z)\vec{k}$$

Introduction

Multiplication of vectors

Vector multiplied by a scalar

- **vector $\vec{a}$ multiplied by scalar *k* forms the new vector $k\vec{a}$, which has the magnitude *ka***
- **its direction is the direction of vector $\vec{a}$ if $k > 0$ and opposite direction if $k < 0$**
- **the coordinates (scalar components) of vector $\vec{a}$ are , , . ka_x, ka_y, ka_z**

Introduction

Scalar product

- **the scalar product of two vectors $\vec{a}, \vec{b}$ is defined by**

$$\vec{a} \cdot \vec{b} = a\, b \cos\varphi \ ,$$

a, b **– the magnitudes of both vectors,**

φ **– the angle between vectors $\vec{a}$ and $\vec{b}$**

- **the result of the scalar product is scalar**
- **it is the product of the magnitude of one vector and the component of the second vector along the direction of the first vector**

Introduction

Example

- **scalar quantity work *W* is the scalar product of the vector of force $\vec{F}$ and the vector of displacement $\vec{s}$:**

  $W = \vec{F} \cdot \vec{s} = F\, s \cos \varphi$

- ***F* cosφ is the component of force $\vec{F}$ along vector $\vec{s}$**
- **work is done only with component of force $\vec{F}$ in direction of motion**
- **scalar product of two vectors in unit-vector notation:**

$$\vec{a} \cdot \vec{b} = \left(a_x\vec{i} + a_y\vec{j} + a_z\vec{k}\right) \cdot \left(b_x\vec{i} + b_y\vec{j} + b_z\vec{k}\right) = a_x b_x + a_y b_y + a_z b_z$$

Introduction

Vector product

- **vector product $\vec{a} \times \vec{b}$ of vectors $\vec{a}$ and $\vec{b}$ is the vector whose**

a) magnitude $\left|\vec{a} \times \vec{b}\right| =$ *a b* sinφ ,

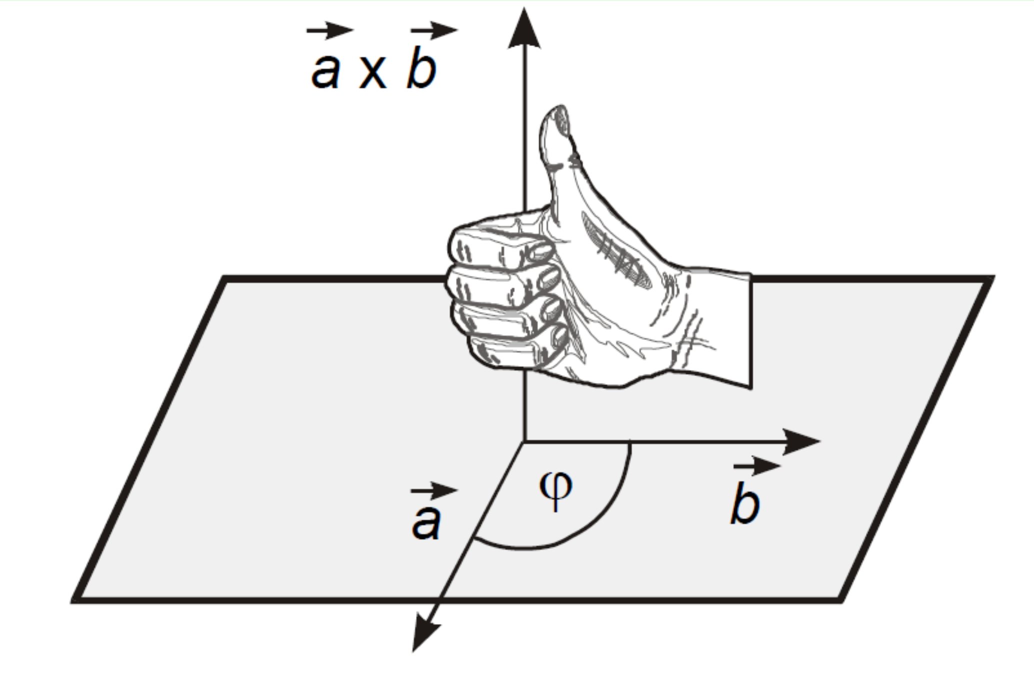
***a, b* – magnitudes of vectors $\vec{a}$ and $\vec{b}$,**

φ – the angle (<180°) between vectors $\vec{a}$ and $\vec{b}$

b) direction is perpendicular to the plane that contains vectors $\vec{a}$ and $\vec{b}$ and is given by the right-hand rule:

If the curled fingers of the right hand point from vector $\vec{a}$ to $\vec{b}$ (φ < 180°), the extended thumb points in the direction of vector product $\left|\vec{a} \times \vec{b}\right|$ – see Fig.

Introduction



- the vector product is anticommutative:

If we change the position of the vectors, the vector product has the opposite direction: $(\vec{b} \times \vec{a}) = -(\vec{a} \times \vec{b})$

Introduction

The vector product of vectors in unit-vector notation can be expressed as a determinant:

$$\vec{a}\times\vec{b}=\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ a_x & a_y & a_z\\ b_x & b_y & b_z\end{vmatrix}=(a_y b_z - a_z b_y)\,\vec{i}+(a_z b_x - a_x b_z)\,\vec{j}+(a_x b_y - a_y b_x)\,\vec{k}$$

Example

Given two vectors $\vec{a}=4\vec{i}+3\vec{j}$, $\vec{b}=6\vec{i}+8\vec{j}$.

Find:

a) unit vector $\vec{b}_0$ of vector $\vec{b}$,

b) angle φ between vectors,

c) vector sum $\vec{a}+\vec{b}$,

d) vector product $\vec{b}\times\vec{a}$

Introduction

Solution:

a) unit vector

$$\vec{b}_0 = \frac{\vec{b}}{b} = \frac{b_x\vec{i} + b_y\vec{j} + b_z\vec{k}}{\sqrt{b_x^2 + b_y^2 + b_z^2}} = \frac{6\vec{i} + 8\vec{j}}{\sqrt{6^2 + 8^2}} = \frac{6\vec{i} + 8\vec{j}}{10} = 0{,}6\vec{i} + 0{,}8\vec{j}$$

b) angle between vectors can be expressed from scalar product

$$\vec{a} \cdot \vec{b} = a\,b\cos\varphi$$

$$\cos\varphi = \frac{\vec{a} \cdot \vec{b}}{a \cdot b} = \frac{a_x b_x + a_y b_y + a_z b_z}{\sqrt{a_x^2 + a_y^2 + a_z^2} \cdot \sqrt{b_x^2 + b_y^2 + b_z^2}} = \frac{4 \cdot 6 + 3 \cdot 8}{5 \cdot 10} = \frac{48}{50} = \frac{24}{25}$$

$$\varphi = \arccos\frac{24}{25} = 16{,}3°$$

Introduction

c) vector sum (resultant vector)

$$\vec{a}+\vec{b}=\left(a_x+b_x\right)\vec{i}+\left(a_y+b_y\right)\vec{j}+\left(a_z+b_z\right)\vec{k}=(4+6)\vec{i}+(3+8)\vec{j}=10\vec{i}+11\vec{j}$$

d) vector product is expressed applying determinant formula

$$\vec{b}\times\vec{a}=\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ b_x & b_y & b_z\\ a_x & a_y & a_z\end{vmatrix}=\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ 6 & 8 & 0\\ 4 & 3 & 0\end{vmatrix}=18\vec{k}-32\vec{k}=-14\vec{k}$$