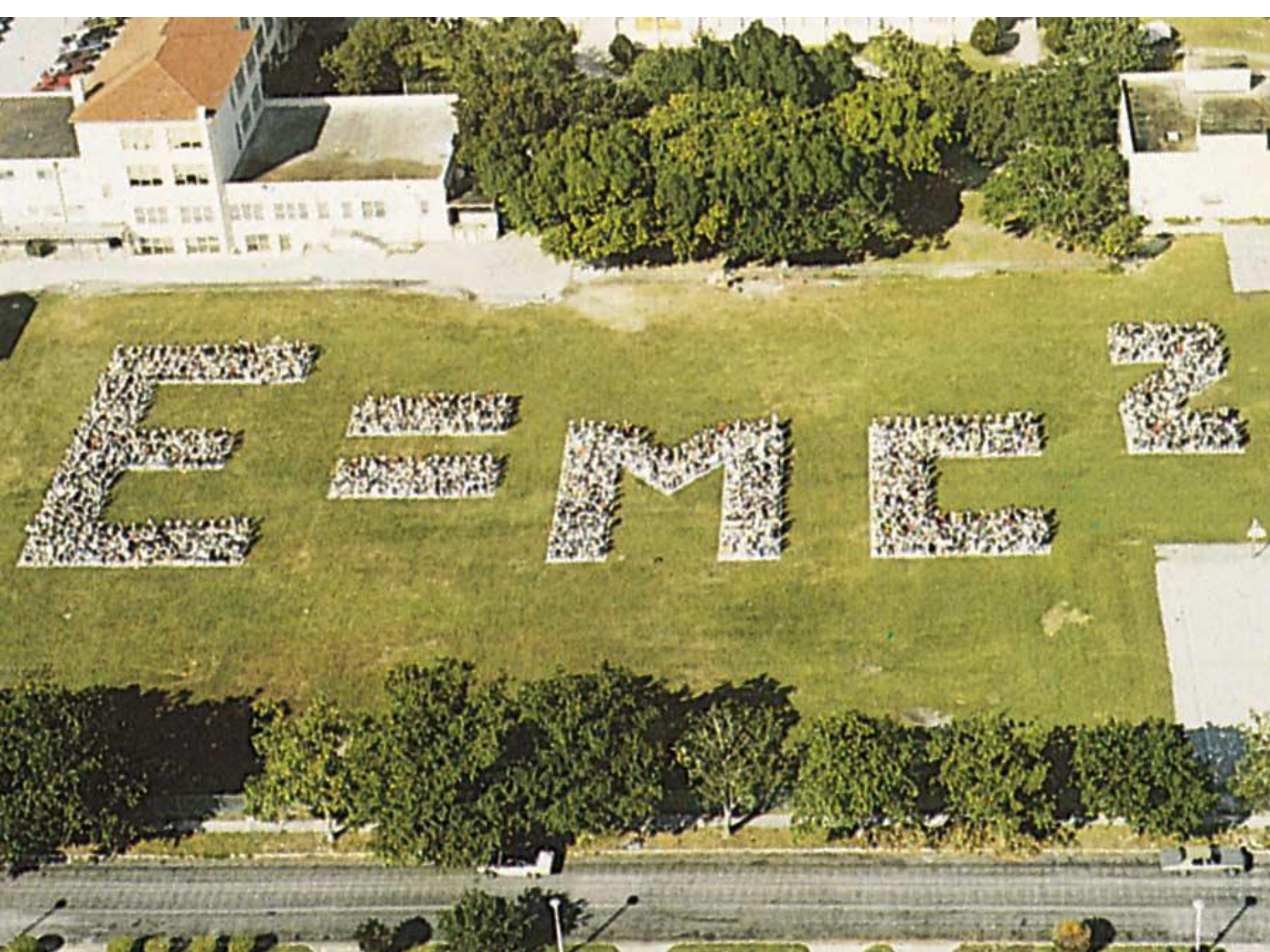
E=MC²

Physics education at FTS CTU

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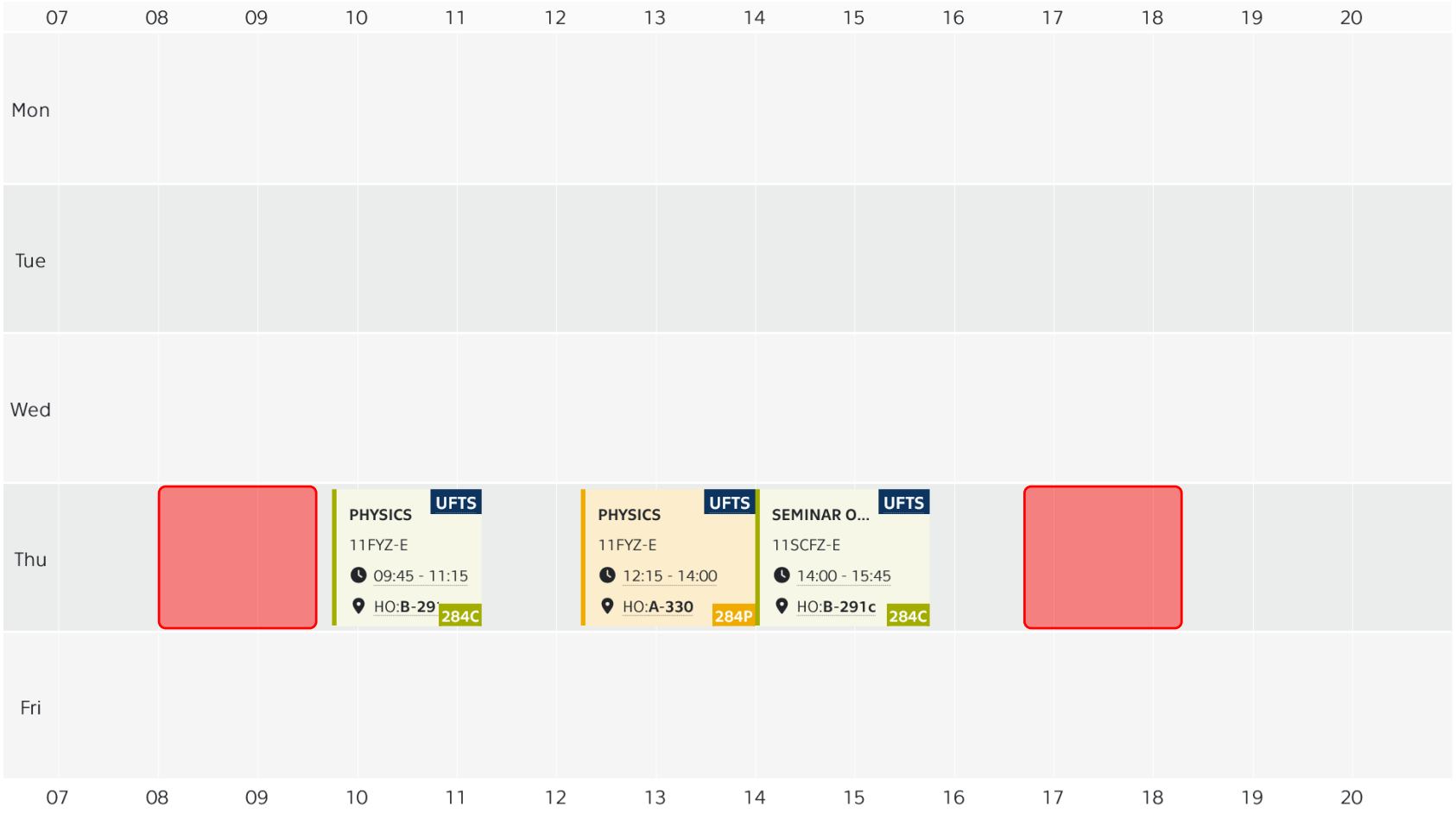
Dept. of Applied Mathematics K611 – Florenc

Subject website – **https://zolotarev.fd.cvut.cz/fyze**

Two terms (semester) of education (11FYZ-E and 11EMO-E)

- Lecture
- Practical exercises (labs) – compulsory
- Seminary exercise (11SCF-E) – voluntary but recommended

Official timetable



Assessment conditions (by 15th February 2026)

compulsory practical education (fully passed)

successful delivery of all measurement reports (A - E)

Exam conditions

final test of Seminary 11SCFZ-E at the end of the term

4 problems – classification 0 – 2 points = **0 – 8 points total**

topics of the problems – see the website

if 5/8 points are reached = oral exam only

Exams

written part (if the test exam was not successful)

4 problems – classification 0 – 2 points = **0 – 8 points total**

if 5/8 points are reached = oral exam

oral part – 2 topics from the list of topics (available on the website)

Supporting study literature

Lectures:

Halliday, D., Resnick, R., Walker, J.: Fundamentals of Physics (HRW)
pdf version at **http://libgen.rs/search.php**

Laboratory exercises:

subject website

Seminary exercises:

subject website

Pre-requisites of Physics

High school / grammar school physics level knowledge

physical quantities, units and basic laws
calculations without integration

Definition of vectors and scalars

direction of vector
components and magnitude of vector
addition and subtraction
dot product and cross product

Basic knowledge of differential and integral calculus

one variable

Multivariable differential and integral calculus

Stokes law, Green law, Gauss-Ostrogradsky law

Simplification and Abstraction

Abstraction of knowledge

- separation of numbers and real objects
- substitution of numbers by symbols
- separation of properties and math objects

= **linear vector field**

UNIVERSITY EDUCATION

Problem simplification – based on the error extent

- description of the problem using measurable variables
- mathematical description and solution
- matching rate to the practical observation
- next iteration (if needed)

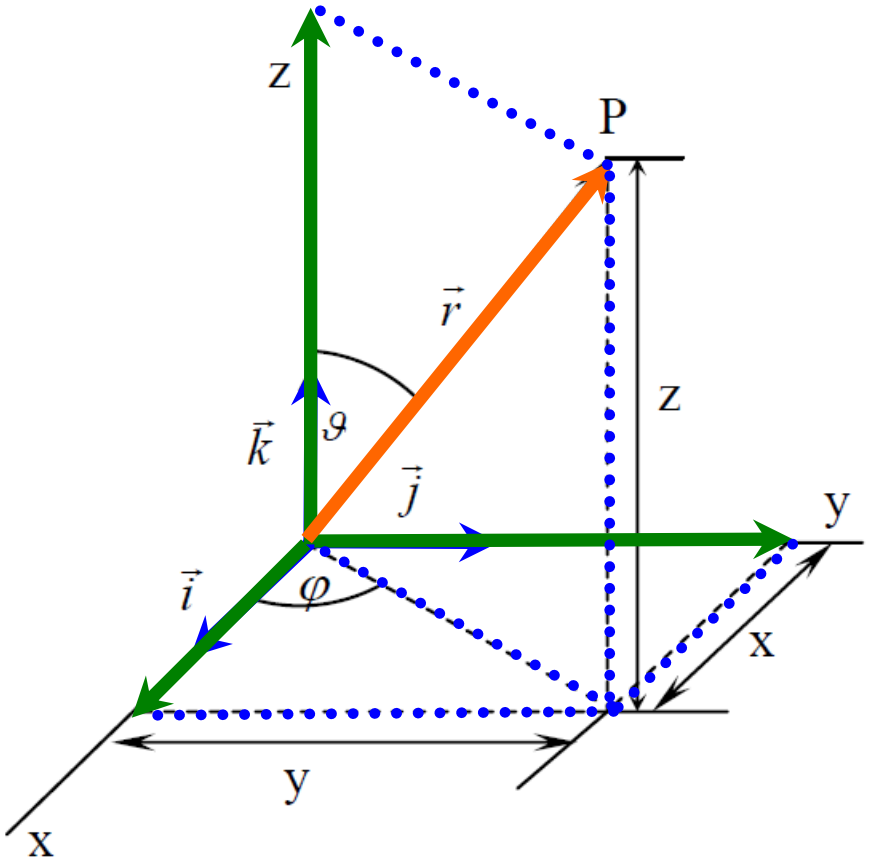
Kinematics

Mass point kinematics

Mass point position

Cartesian coordinates x, y, z

Spherical coordinates r, ϑ, φ *(polar angle, azimuth)*



$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$$

$$r = |\vec{r}| = \sqrt{x^2 + y^2 + z^2}$$

Displacement of the mass point

$$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$$

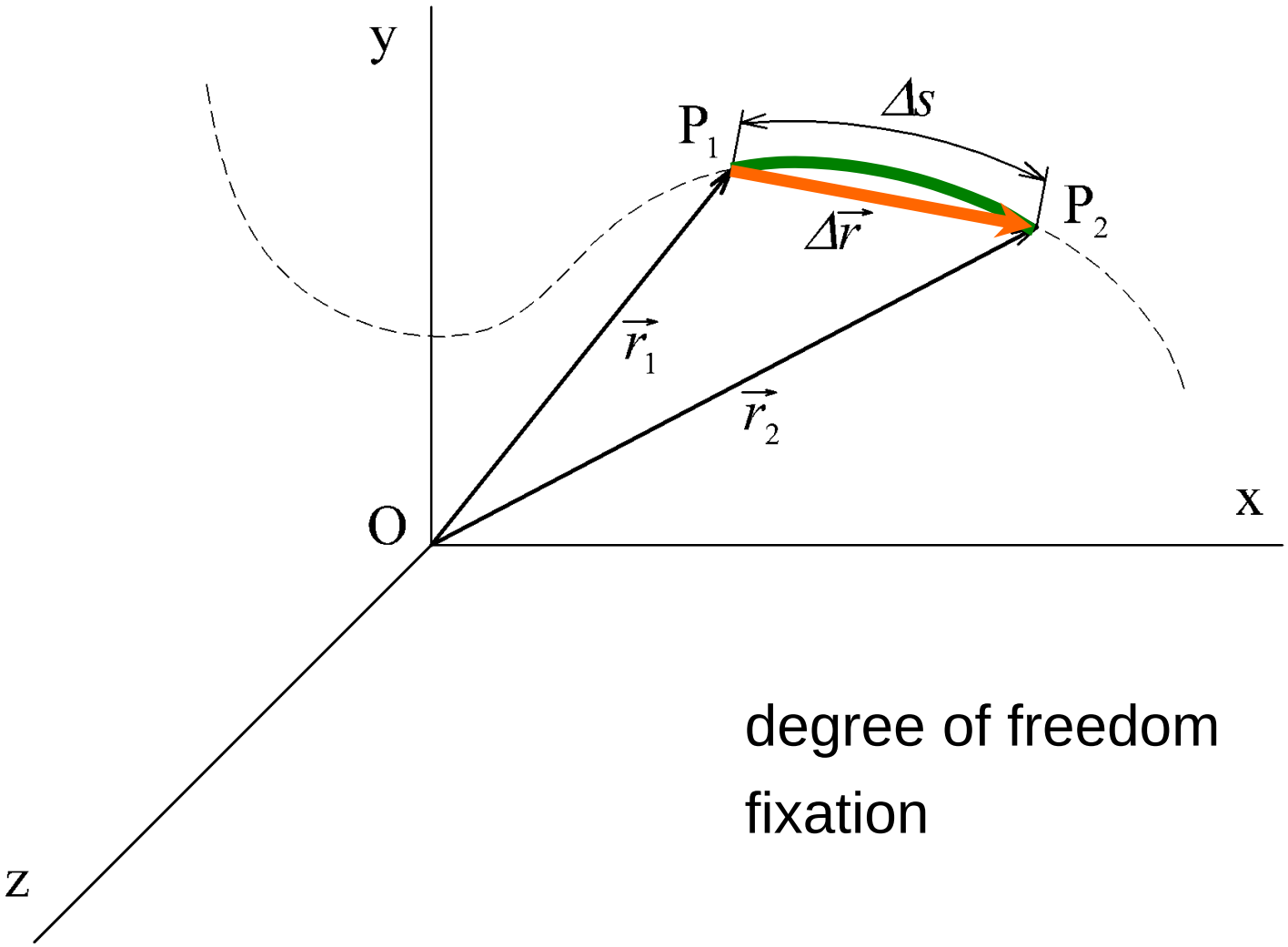
$$\vec{r} = \vec{r}(t)$$

$$x = x(t)$$

$$y = y(t)$$

$$z = z(t)$$

$$\Delta s \geq |\Delta \vec{r}|$$

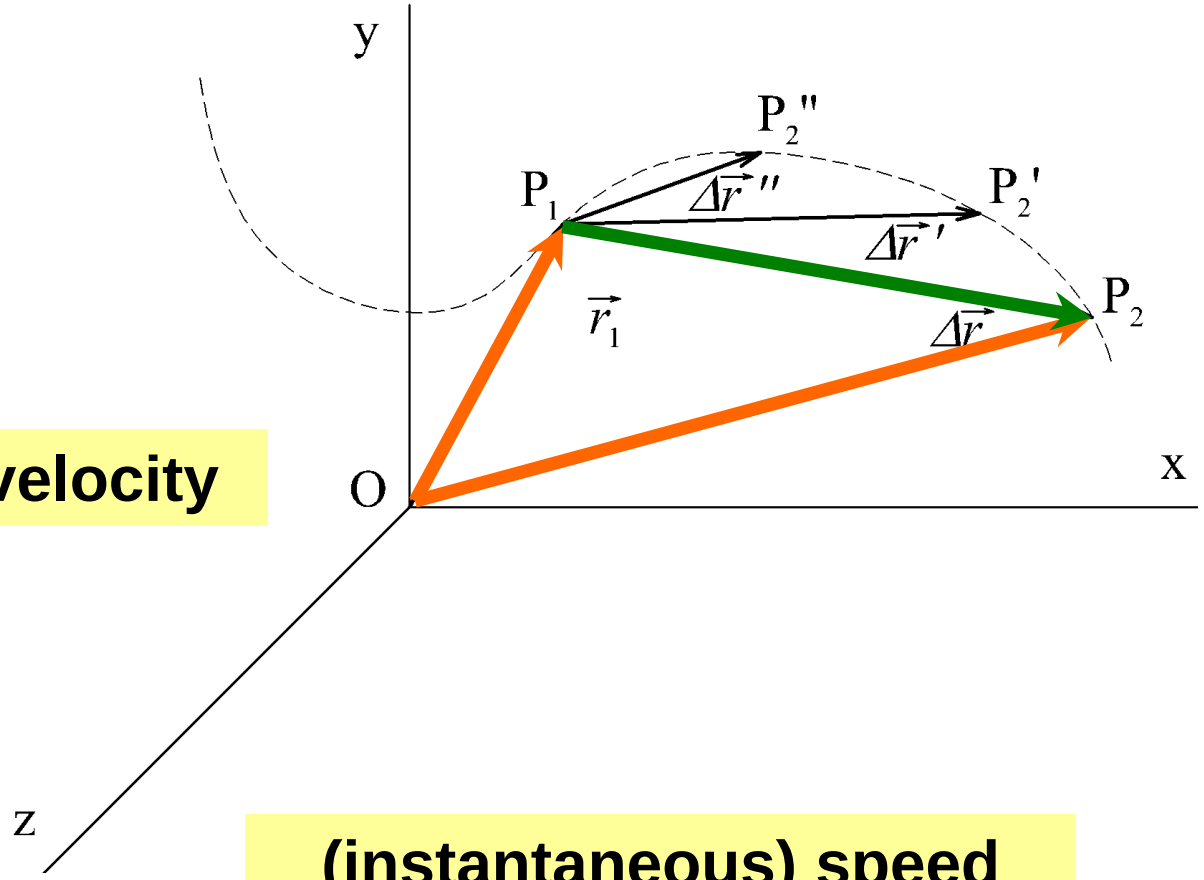


degree of freedom

fixation

average velocity

$$\bar{\vec{v}} = \frac{\Delta \vec{r}}{\Delta t}$$



(instantaneous) velocity

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

$$\vec{v} = v_x \vec{i} + v_y \vec{j} + v_z \vec{k}$$

(instantaneous) speed

$$v = |\vec{v}| = \sqrt{v_x^2 + v_y^2 + v_z^2}$$

$$v_x = \frac{dx}{dt} \qquad v_y = \frac{dy}{dt} \qquad v_z = \frac{dz}{dt}$$

mean acceleration

$$\bar{\vec{a}} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$$

(instantaneous) acceleration

$$\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

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

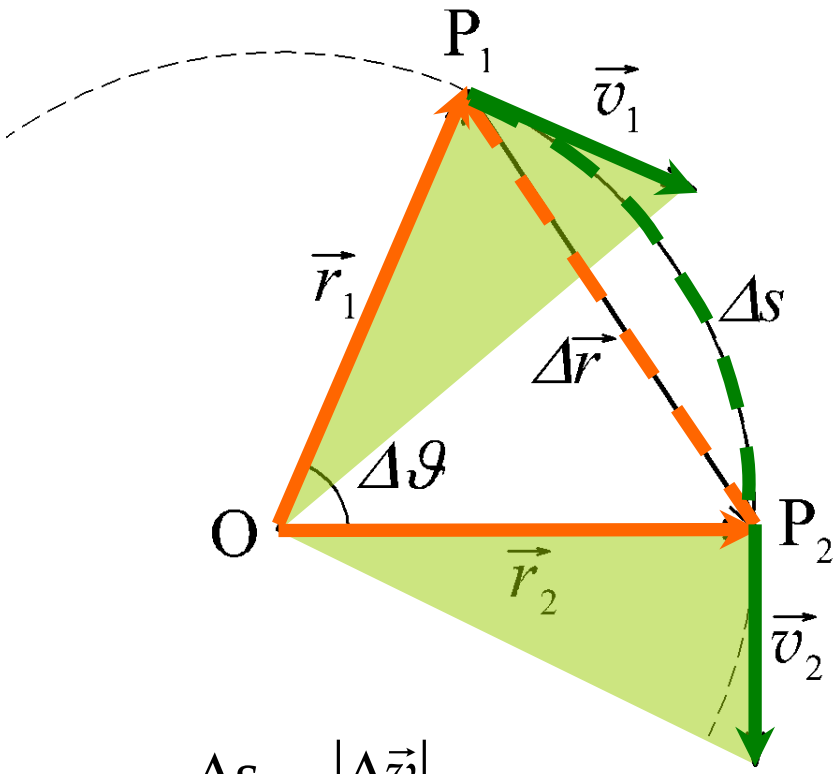
$$a_x = \frac{dv_x}{dt} = \frac{d^2x}{dt^2} \qquad a_y = \frac{dv_y}{dt} = \frac{d^2y}{dt^2} \qquad a_z = \frac{dv_z}{dt} = \frac{d^2z}{dt^2}$$

Types of Motion

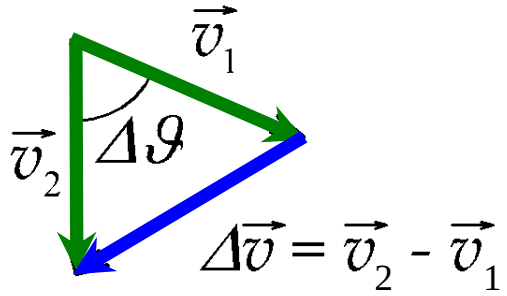
- straight-line, curved
- uniform, non-uniform

Uniform circular motion

constant speed + trajectory with constant curvature



$$|\vec{r_1}| = |\vec{r_2}| = r$$
$$|\vec{v_1}| = |\vec{v_2}| = v$$



$$\Delta\vartheta = \frac{\Delta s}{r} = \frac{|\Delta\vec{v}|}{v}$$
$$\Delta s = v\Delta t$$

$$\frac{v\Delta t}{r} = \frac{|\Delta\vec{v}|}{v}$$

$$\frac{|\Delta\vec{v}|}{\Delta t} = \frac{v^2}{r} = a_n$$

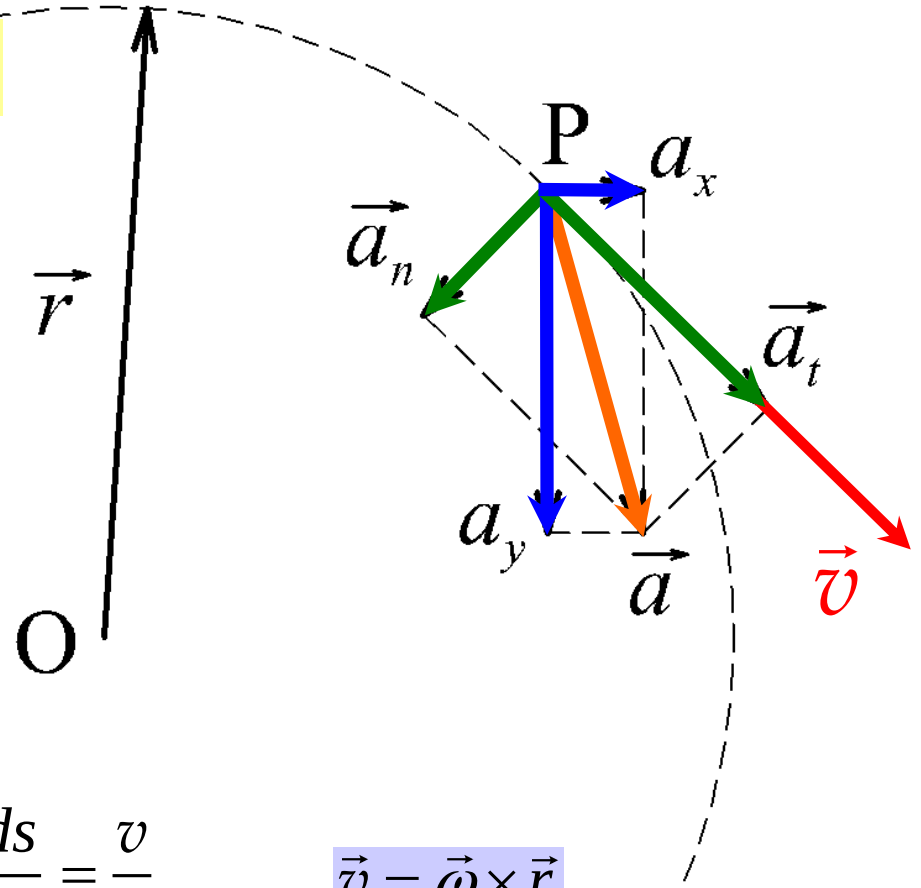
centripetal acceleration

Non-uniform circular motion

$$\vec{a} = \frac{d\vec{v}}{dt} = \vec{a}_t + \vec{a}_n$$

$$a_t = |\vec{a}_t| = \frac{dv}{dt} \qquad a = \sqrt{a_t^2 + a_n^2}$$

$$a_n = |\vec{a}_n| = \frac{v^2}{r} \qquad a = \sqrt{a_x^2 + a_y^2}$$



angular velocity $\vec{\omega}$

$$\omega = \frac{d\varphi}{dt} \qquad \omega = \frac{d}{dt}\left(\frac{s}{r}\right) = \frac{1}{r}\frac{ds}{dt} = \frac{v}{r}$$

$$\vec{v} = \vec{\omega} \times \vec{r}$$

angular acceleration $\vec{\varepsilon}$

$$\varepsilon = \frac{d\omega}{dt} = \frac{d^2\varphi}{dt^2}$$

$$\omega = 2\pi f$$

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

Galileo's theory of motion

$$\vec{r} = \vec{r}' + \vec{u}t$$

$$x = x' + |\vec{u}|t$$

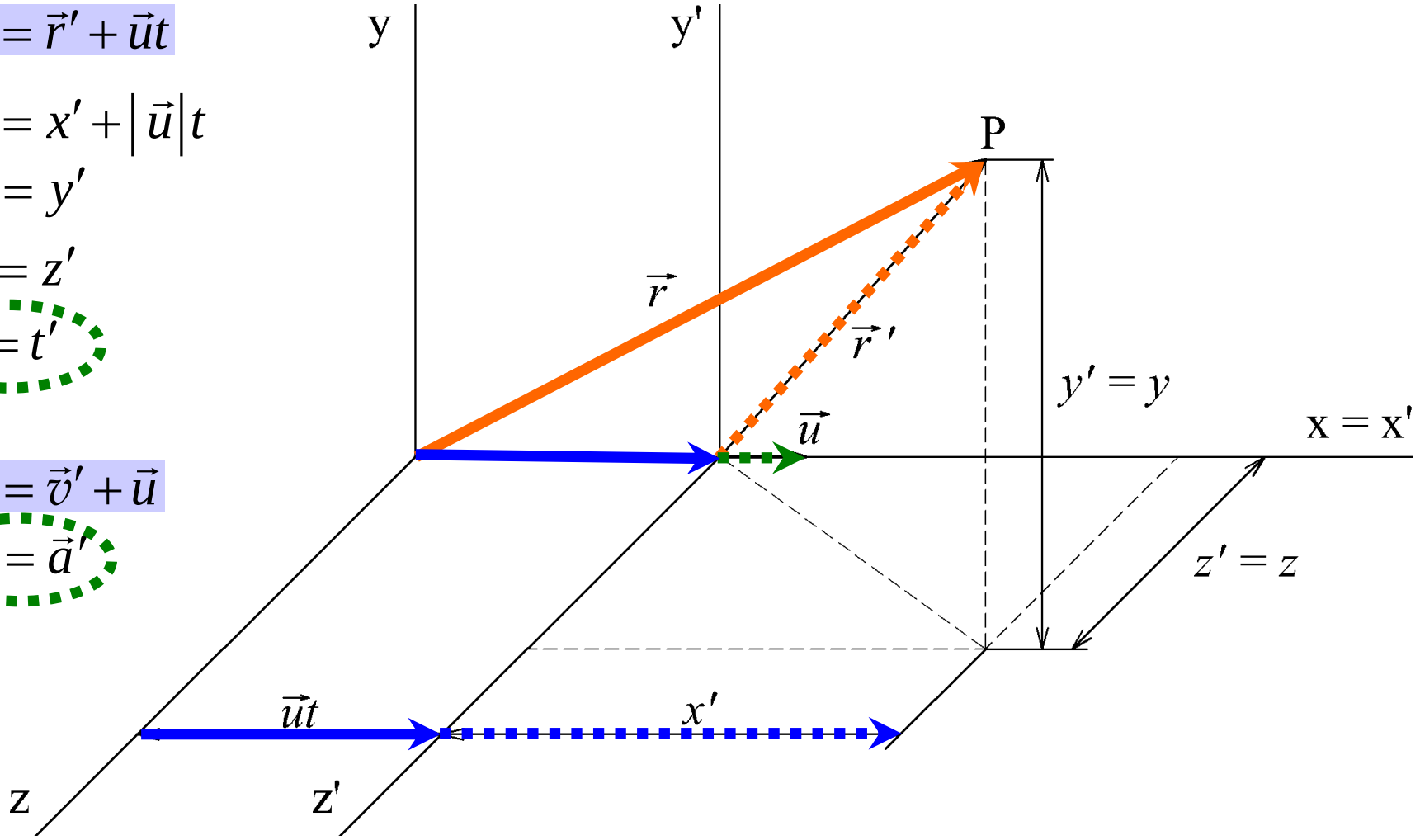
$$y = y'$$

$$z = z'$$

$$t = t'$$

$$\vec{v} = \vec{v}' + \vec{u}$$

$$\vec{a} = \vec{a}'$$



inertial reference frame – the acceleration is the same

Lorentz factor

STR postulate:
the speed of light is the same in all inertial reference frames

$$x = \gamma(x' + |\vec{u}|t)$$
$$y = y'$$
$$z = z'$$

$$\gamma = \frac{1}{\sqrt{1-\beta^2}}$$

Lorentz factor

$$\beta = \frac{u}{c}$$

speed ratio

$$m = m'\sqrt{1-\frac{u^2}{c^2}}$$

rest mass vs. relativistic mass

$$x = \frac{x' + u t'}{\sqrt{1-\frac{u^2}{c^2}}}$$
$$y = y'$$
$$z = z'$$

$$t = \frac{t' + \frac{ux'}{c^2}}{\sqrt{1-\frac{u^2}{c^2}}}$$

$$v = \frac{v' + u}{1 + \frac{v'u}{c^2}}$$

GPS – time correction for the GPS satellites (precision of position)