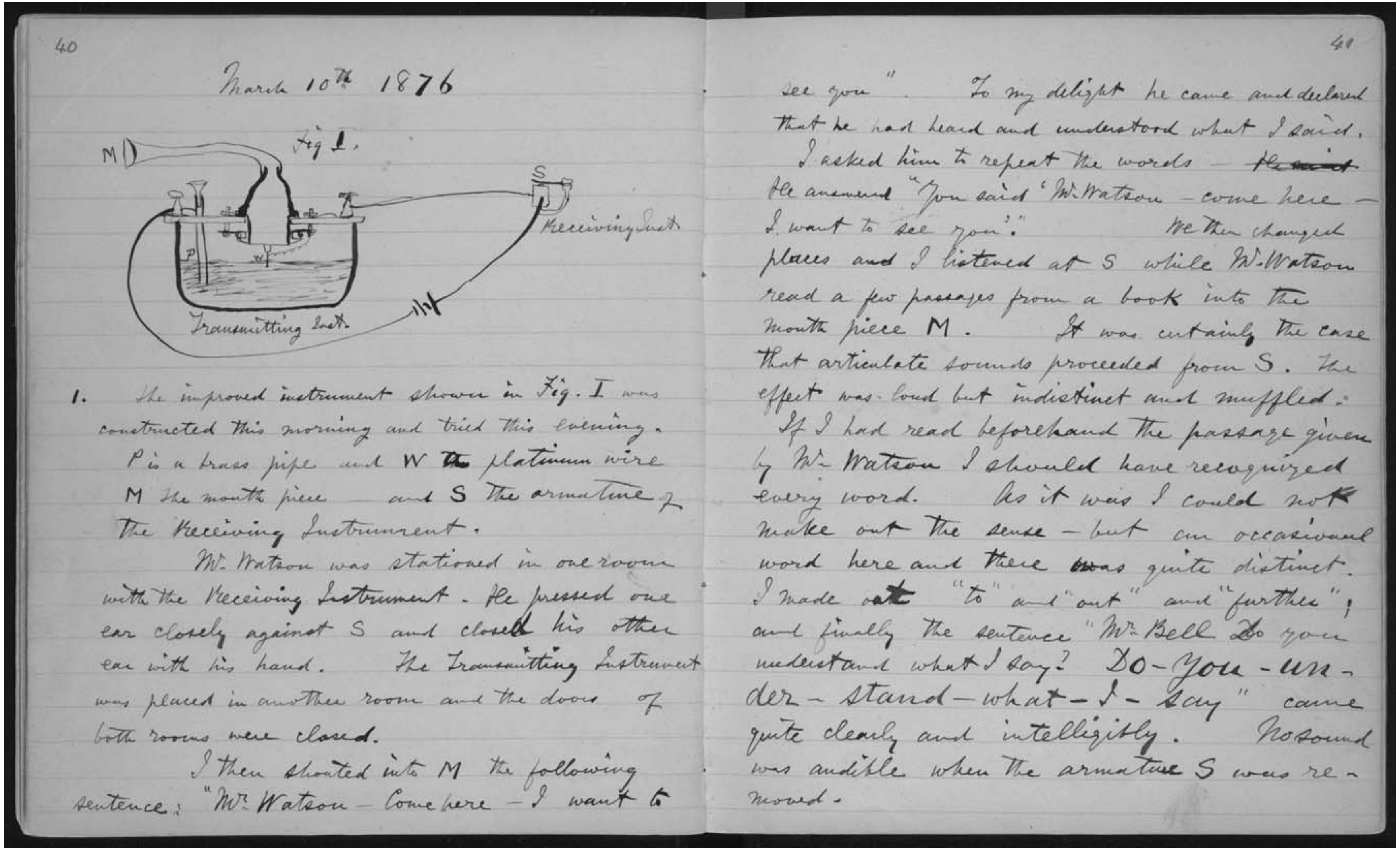
FIZ101E – Lecture 2
Motion of an object in space

Alexandr Jonas

Department of Physics Engineering

Istanbul Technical University

What did we cover last week?



March 10th 1876

1. The improved instrument shown in Fig. I was constructed this morning and tried this evening. P is a brass pipe and W ~~the~~ platinum wire M the mouth piece and S the armature of the Receiving Instrument.

Mr. Watson was stationed in one room with the Receiving Instrument. He pressed one ear closely against S and closed his other ear with his hand. The Transmitting Instrument was placed in another room and the doors of both rooms were closed.

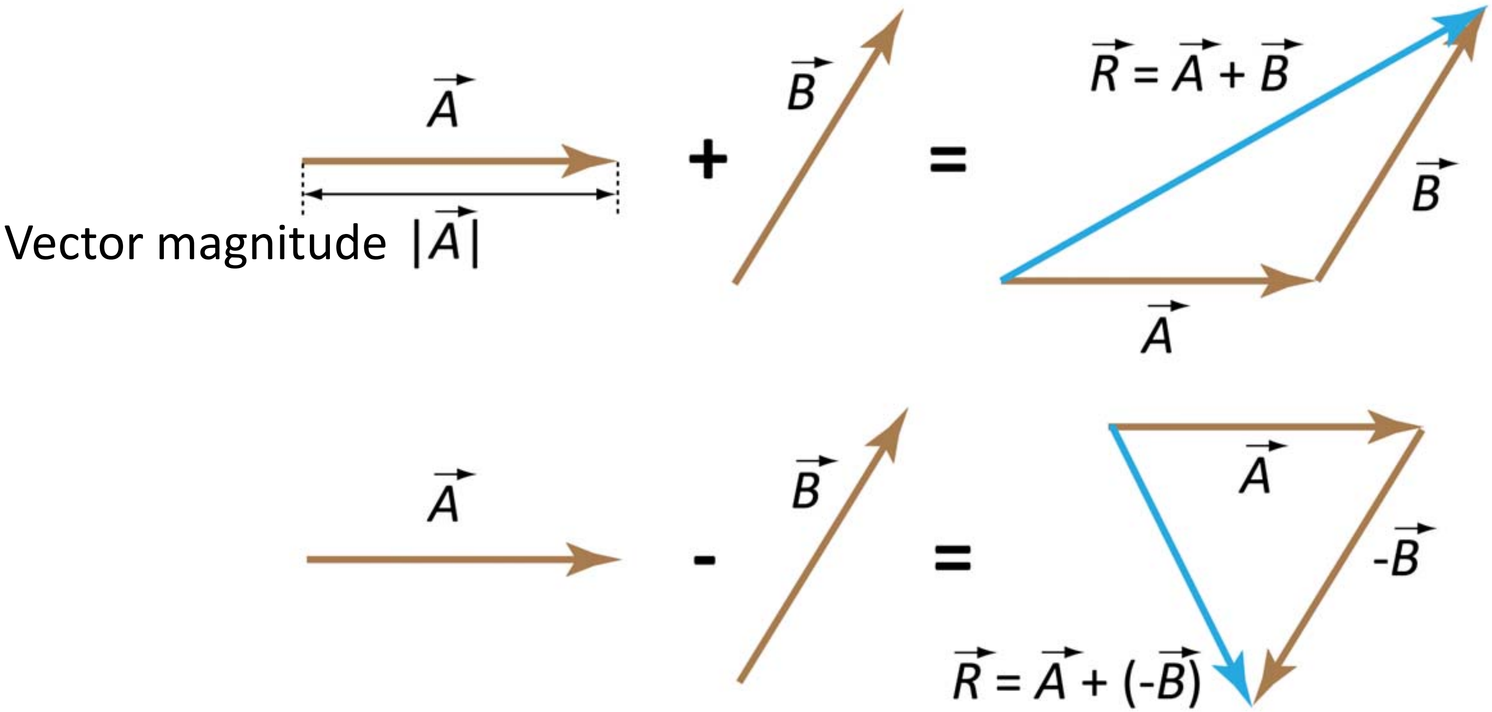
I then shouted into M the following sentence: "Mr. Watson — Come here — I want to

see you". To my delight he came and declared that he had heard and understood what I said.

I asked him to repeat the words — ~~He said~~ He answered "You said 'Mr. Watson — come here — I want to see you'." We then changed places and I listened at S while Mr. Watson read a few passages from a book into the mouth piece M. It was certainly the case that articulate sounds proceeded from S. The effect was loud but indistinct and muffled.

If I had read beforehand the passage given by Mr. Watson I should have recognized every word. As it was I could not make out the sense — but an occasional word here and there was quite distinct. I made out "to" and "out" and "further"; and finally the sentence "Mr. Bell Do you understand what I say? Do-you-un-der-stand-what-I-say" came quite clearly and intelligibly. No sound was audible when the armature S was removed.

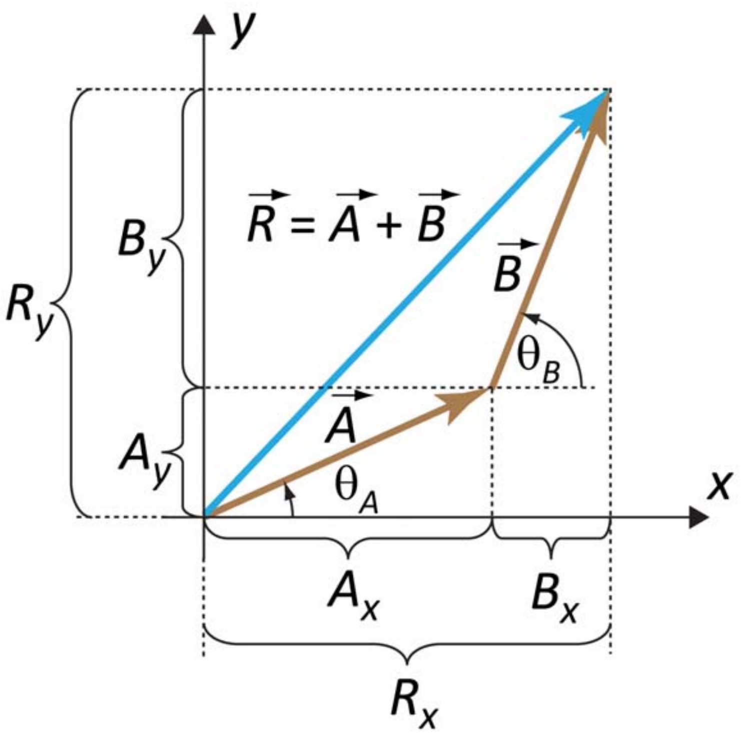
Vector addition and subtraction



- Vectors have direction as well as magnitude
- Rules of vector addition and subtraction can be represented graphically
- Vector subtraction corresponds to addition of the negative of a vector

Vector components and vector addition

Vectors are characterized by the magnitude and the angle between the vector and the +*x*-axis of a rectangular (Cartesian) coordinate system (measured counter-clockwise)



$$A_x = \left|\vec{A}\right| \cos(\theta_A), \quad B_x = \left|\vec{B}\right| \cos(\theta_B)$$

$$A_y = \left|\vec{A}\right| \sin(\theta_A), \quad B_y = \left|\vec{B}\right| \sin(\theta_B)$$

Vector $\vec{A}$: components A_x, A_y (A_z)

Vector $\vec{B}$: components B_x, B_y (B_z)

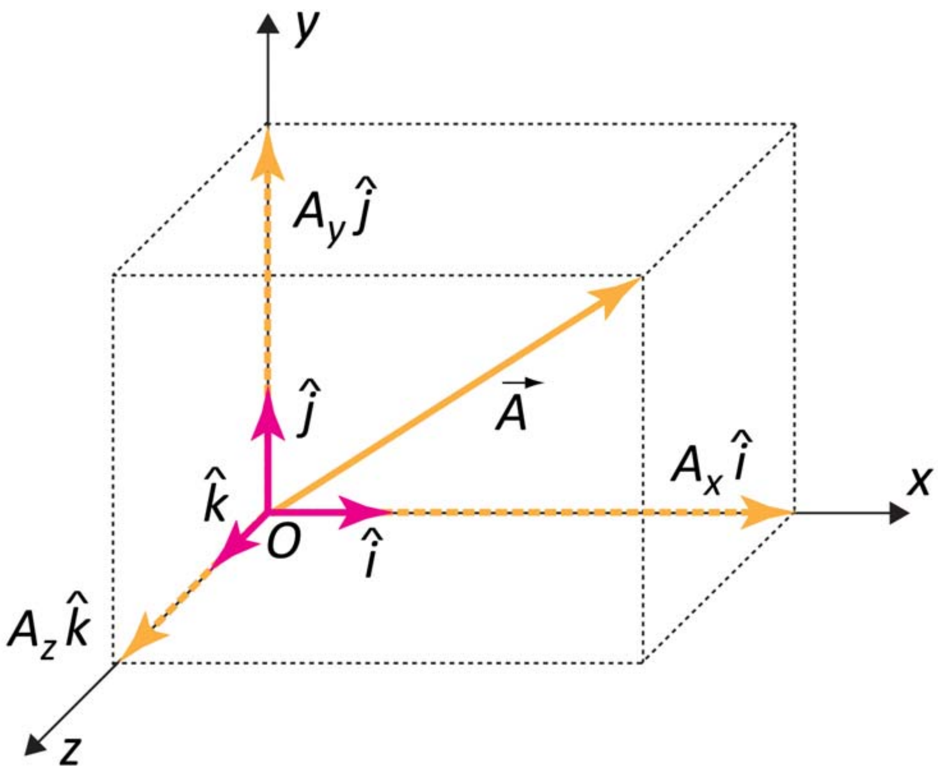
Vector $\vec{R}$: components R_x, R_y (R_z)

$$\boxed{\begin{aligned} R_x &= A_x + B_x + \cdots \\ R_y &= A_y + B_y + \cdots \\ R_z &= A_z + B_z + \cdots \end{aligned}}$$

$$\boxed{\left|\vec{R}\right| = \sqrt{R_x^2 + R_y^2 + R_z^2}}$$

Unit vectors

Unit vectors describe directions in space, they have a magnitude of one with no physical units



$\hat{\boldsymbol{i}}$ … unit vector along the +*x*-axis

$\hat{\boldsymbol{j}}$ … unit vector along the +*y*-axis

$\hat{\boldsymbol{k}}$ … unit vector along the +*z*-axis

Vector $\vec{A}$ can be expressed in terms of its components and unit vectors along the coordinate axes as

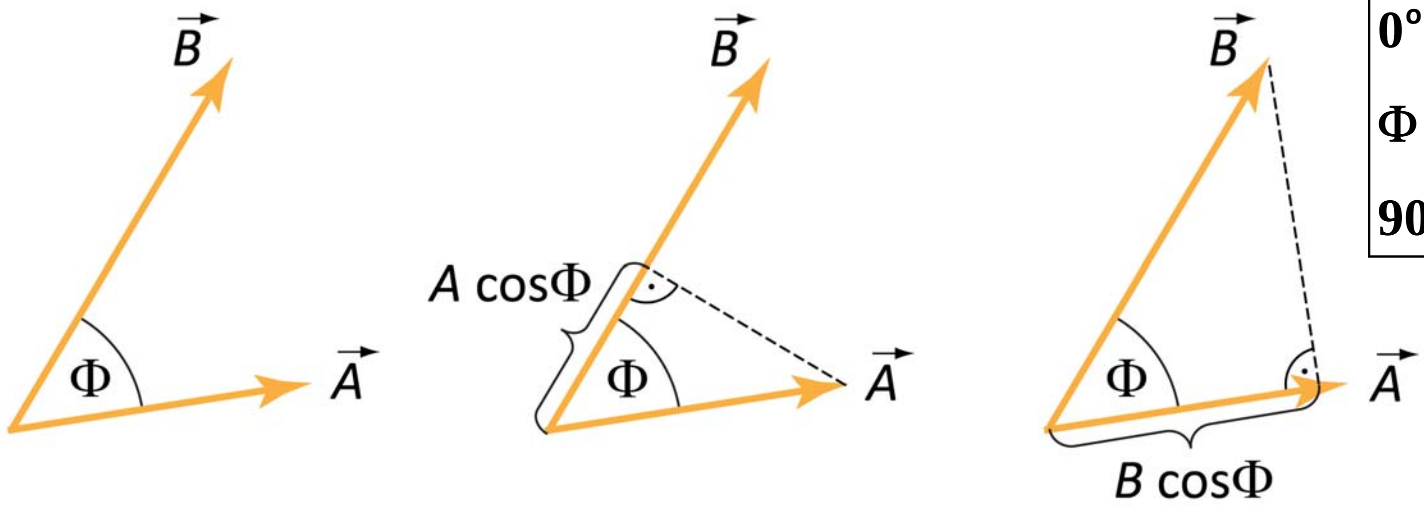
$$\boxed{\vec{\boldsymbol{A}} = \boldsymbol{A}_x\,\hat{\boldsymbol{i}} + \boldsymbol{A}_y\,\hat{\boldsymbol{j}} + \boldsymbol{A}_z\,\hat{\boldsymbol{k}}}$$

Scalar product

The scalar (dot) product of two vectors is a scalar quantity defined as

$$\boxed{C = \vec{A} \cdot \vec{B} = A\,B\cos\Phi = |\vec{A}||\vec{B}|\cos\Phi}$$

where Φ is the smaller of the two angles between the two vectors



$$\boxed{\begin{aligned} &0^\circ \le \Phi < 90^\circ \Rightarrow \vec{A} \cdot \vec{B} > 0 \\ &\Phi = 90^\circ \Rightarrow \vec{A} \cdot \vec{B} = 0 \\ &90^\circ < \Phi \le 180^\circ \Rightarrow \vec{A} \cdot \vec{B} < 0 \end{aligned}}$$

The scalar product can be expressed in terms of the vector components as

$$\boxed{C = \vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z}$$

The scalar product is commutative: $\boxed{\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}}$

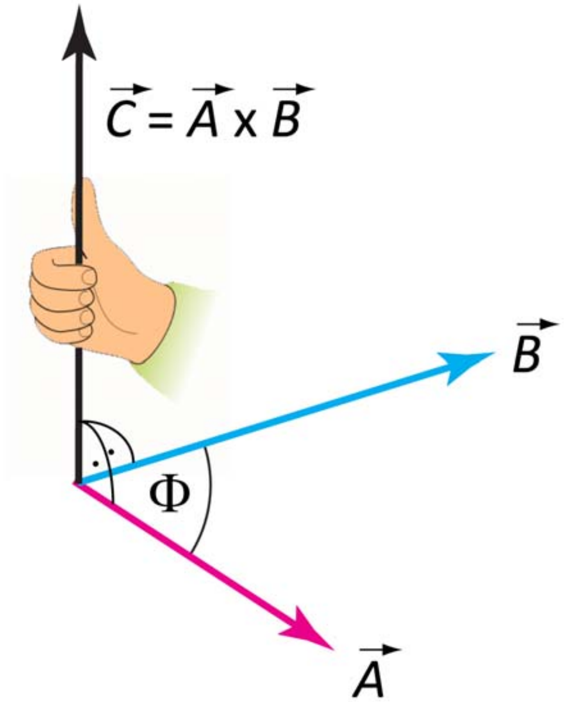
Vector product

The vector (cross) product of two vectors is a vector quantity perpendicular to both vectors, with the magnitude defined as

$$\boxed{\left|\vec{C}\right| = \left|\vec{A}\times\vec{B}\right| = A\,B\sin\Phi = \left|\vec{A}\right|\left|\vec{B}\right|\sin\Phi}$$

$$\boxed{0^\circ \le \Phi \le 180^\circ \Rightarrow \left|\vec{A}\times\vec{B}\right| \ge 0}$$

where Φ is the smaller of the two angles between the two vectors



Correct direction of $\vec{C}$ is determined from the right-hand rule

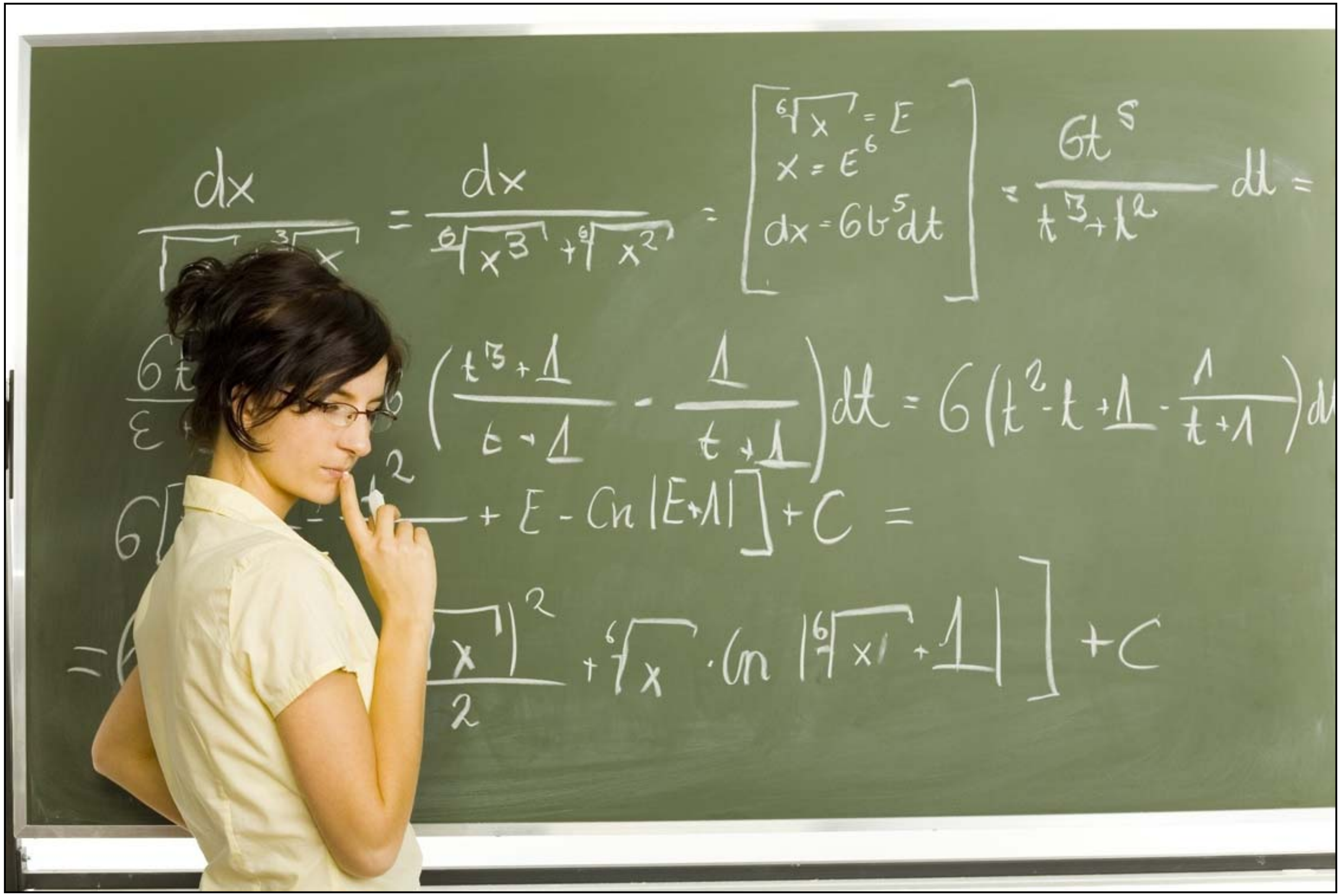
The vector product is not commutative:

$$\boxed{\vec{A}\times\vec{B} = -\,\vec{B}\times\vec{A}}$$

The vector product can be expressed in terms of the vector components as

$$\boxed{\begin{aligned} C_x &= A_yB_z - A_zB_y \\ C_y &= A_zB_x - A_xB_z \\ C_z &= A_xB_y - A_yB_x \end{aligned}}$$

What will we cover today?



Lesson plan

1. Displacement, time and velocity
2. Acceleration
3. Motion with constant acceleration, free falling
4. Position, velocity, and acceleration vectors
5. Projectile motion
6. Motion in a circle
7. Relative velocity