FIZ101E – Lecture 3
Newton's laws of motion

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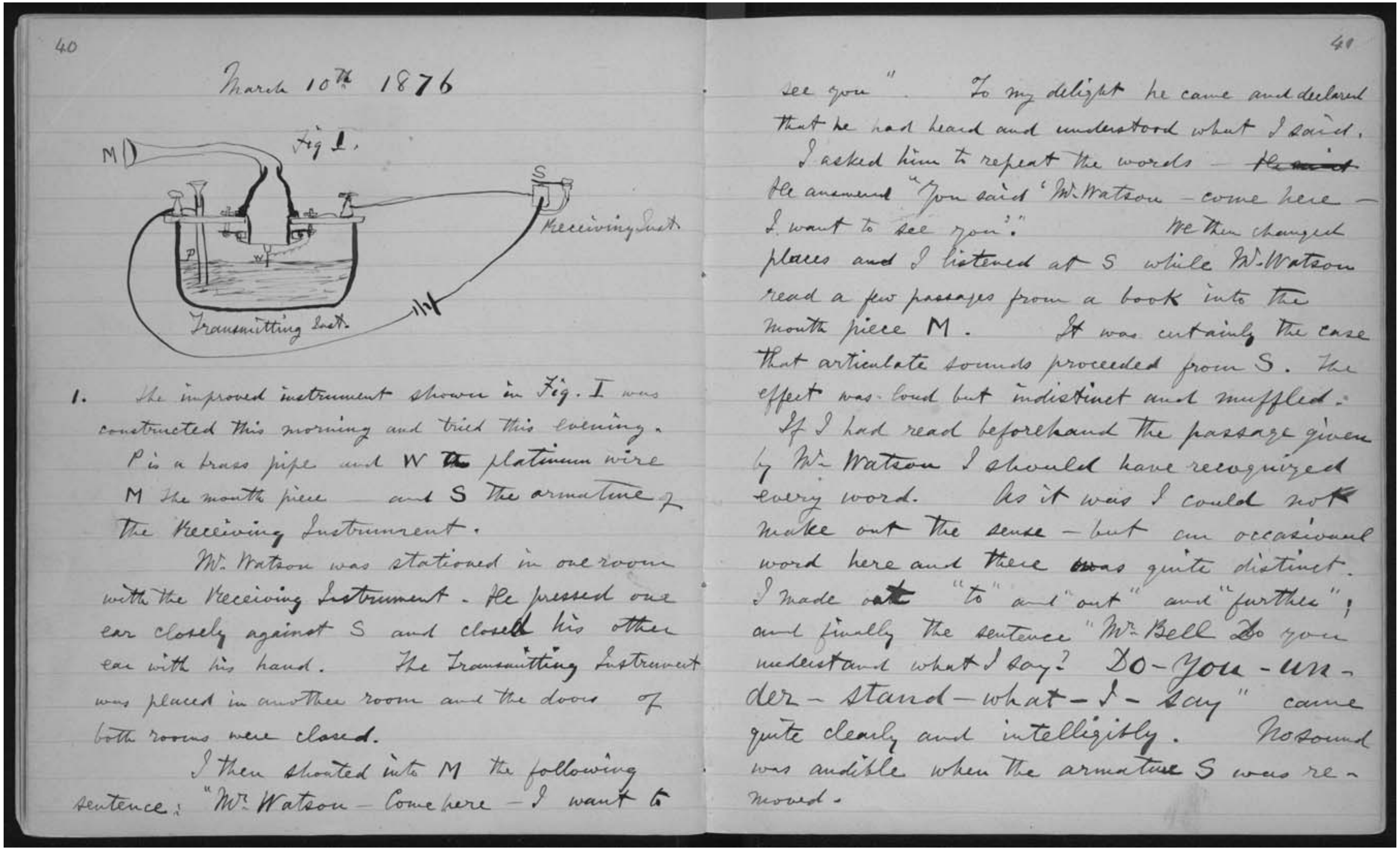
What did we cover last week?



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March 10th 1876

Fig. 1.

M

S

P

W

Receiving Inst.

Transmitting Inst.

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

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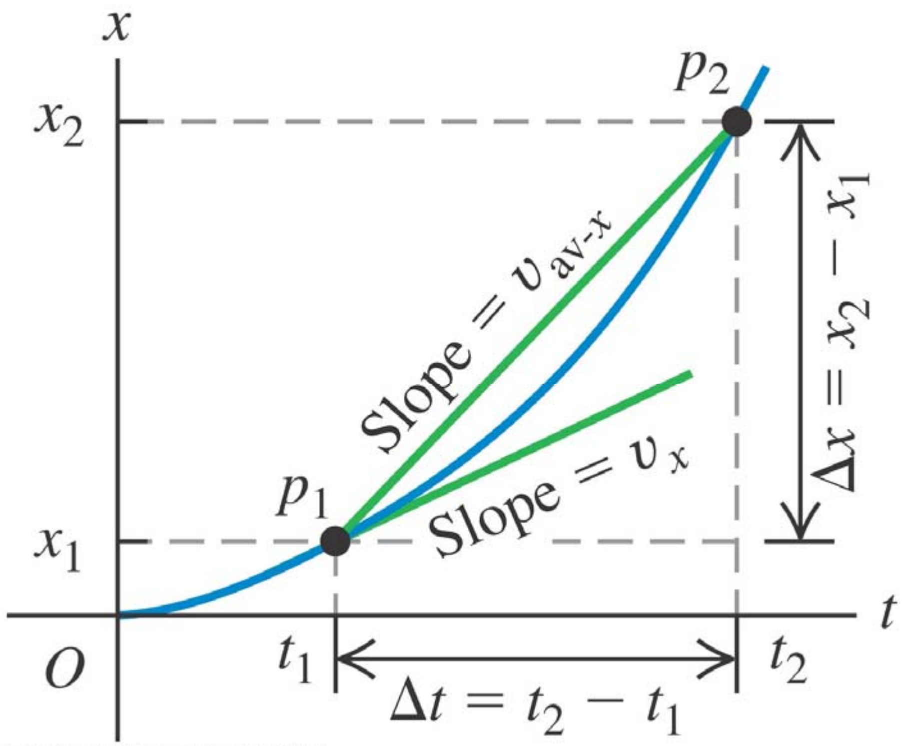
see you". To my delight he came and declared that he had heard and understood what I said.

I asked him to repeat the words — He 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.

Average and instantaneous velocity in one dimension



Average velocity of the particle in the time interval $\Delta t = t_2 - t_1$

$$v_{av-x} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

Instantaneous velocity of the particle at any time t

$$v_x = \lim_{\Delta t \to 0} v_{av-x} = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

⬇

Derivative of the particle position with respect to time

At time t_1, particle is located at x_1, at time t_2, it is located at x_2

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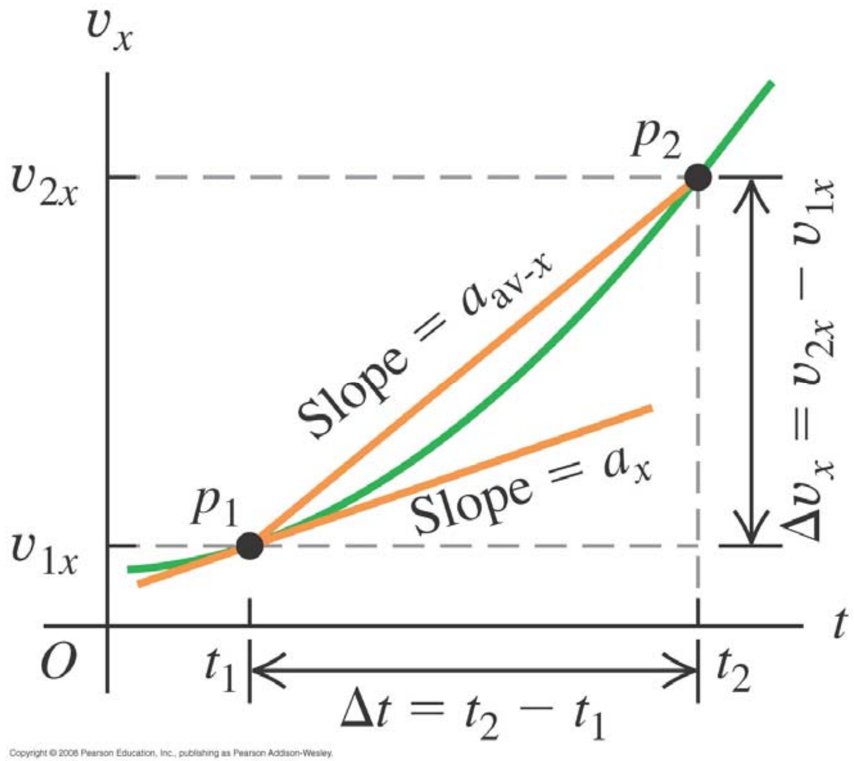
Particle displacement $\Delta x = x_2 - x_1$

Average and instantaneous acceleration in one dimension



At time t_1, particle has a velocity v_{1x}, at time t_2, it has a velocity v_{2x}

⬇

Change of particle velocity $\Delta v_x = v_{2x} - v_{1x}$

Average acceleration of the particle in the time interval $\Delta t = t_2 - t_1$

$$a_{av-x} = \frac{v_{2x} - v_{1x}}{t_2 - t_1} = \frac{\Delta v_x}{\Delta t}$$

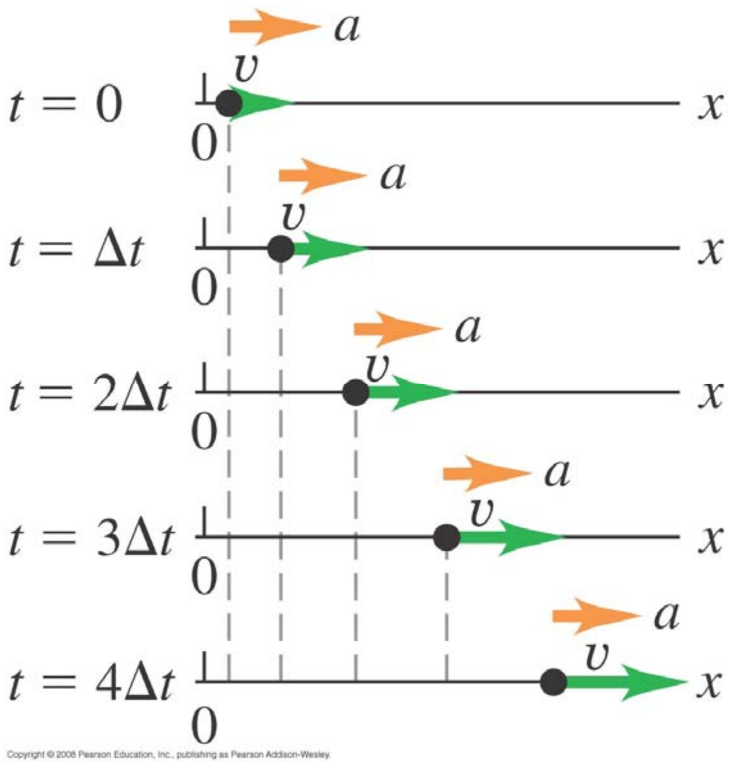
Instantaneous acceleration of the particle at any time t

$$a_x = \lim_{\Delta t \to 0} a_{av-x} = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt}$$

⬇

Derivative of the particle velocity with respect to time

Straight-line motion with constant acceleration



With constant acceleration a_x, particle velocity changes linearly with time:

$$v_x = v_{0x} + a_x t$$

With constant acceleration a_x, particle position changes quadratically with time:

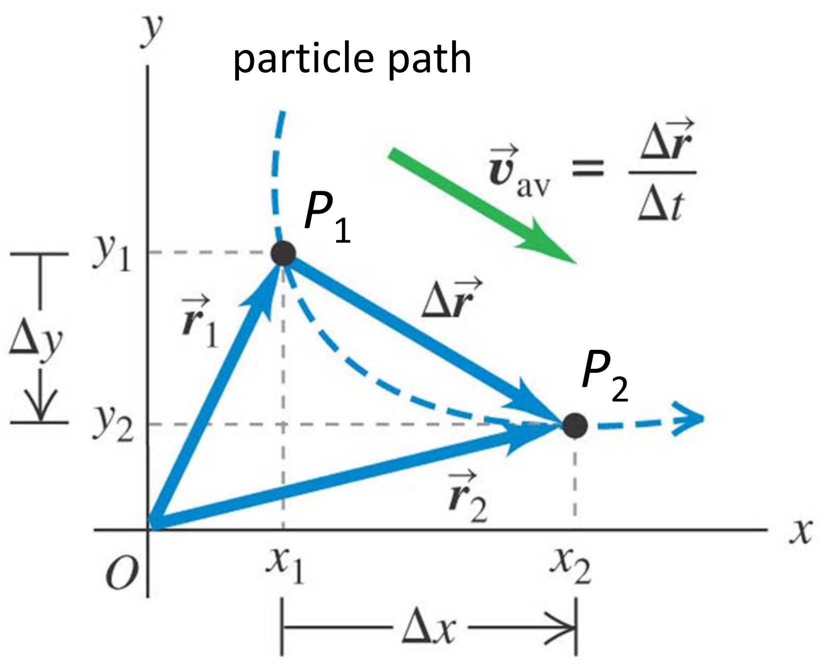
$$x = x_0 + v_{0x} t + \frac{1}{2} a_x t^2$$

Eliminating time from velocity and position equations, we can also write:

$$v_x^2 = v_{0x}^2 + 2a_x (x - x_0)$$

Only valid for constant acceleration motion!!!

Position and velocity vectors



Position vector $\vec{r} = x\,\hat{i} + y\,\hat{j} + z\,\hat{k}$

- Points from the origin *O* to point *P*
- Components are *x, y, z* coordinates

Displacement vector $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

Characterizes motion from P_1 to P_2

Average velocity of the particle in a time interval $\Delta t = t_2 - t_1$

$$\vec{v}_{av} = \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1} = \frac{\Delta\vec{r}}{\Delta t}$$

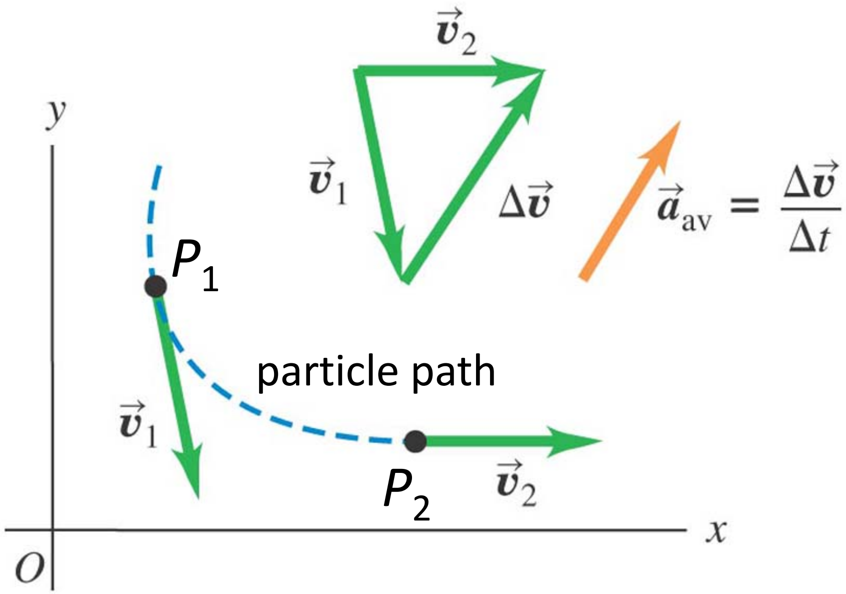
Instantaneous velocity of the particle at any time *t*

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

$$= \left(\frac{dx}{dt}\right)\hat{i} + \left(\frac{dy}{dt}\right)\hat{j} + \left(\frac{dz}{dt}\right)\hat{k}$$

Derivative of the particle position vector with respect to time

Acceleration vector



Velocity vector is always <u>tangent</u> to the particle path

During motion from P_1 to P_2, <u>both</u> magnitude <u>and</u> direction of velocity can change:

$$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$$

<u>Average acceleration</u> of the particle in a time interval $\Delta t = t_2 - t_1$

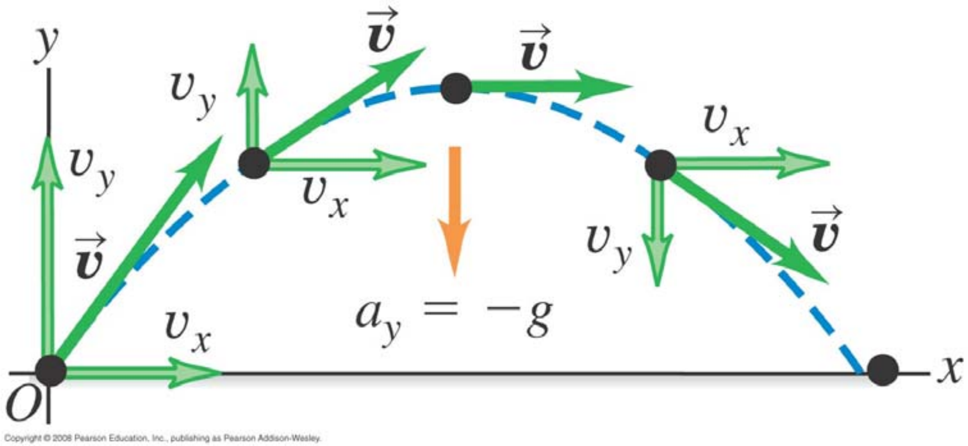
$$\vec{a}_{av} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1} = \frac{\Delta\vec{v}}{\Delta t}$$

<u>Instantaneous acceleration</u> of the particle at any time t

$$\vec{a} = \lim_{\Delta t \to 0} \vec{a}_{av} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$
$$= \left(\frac{dv_x}{dt}\right)\hat{i} + \left(\frac{dv_y}{dt}\right)\hat{j} + \left(\frac{dv_z}{dt}\right)\hat{k}$$

<u>Derivative</u> of the particle velocity vector with respect to time

Projectile motion



Idealized projectile

= particle given an initial velocity whose movement is then influenced only by the (constant) acceleration of gravity, with no air resistance

Position and velocity of the projectile are described by:

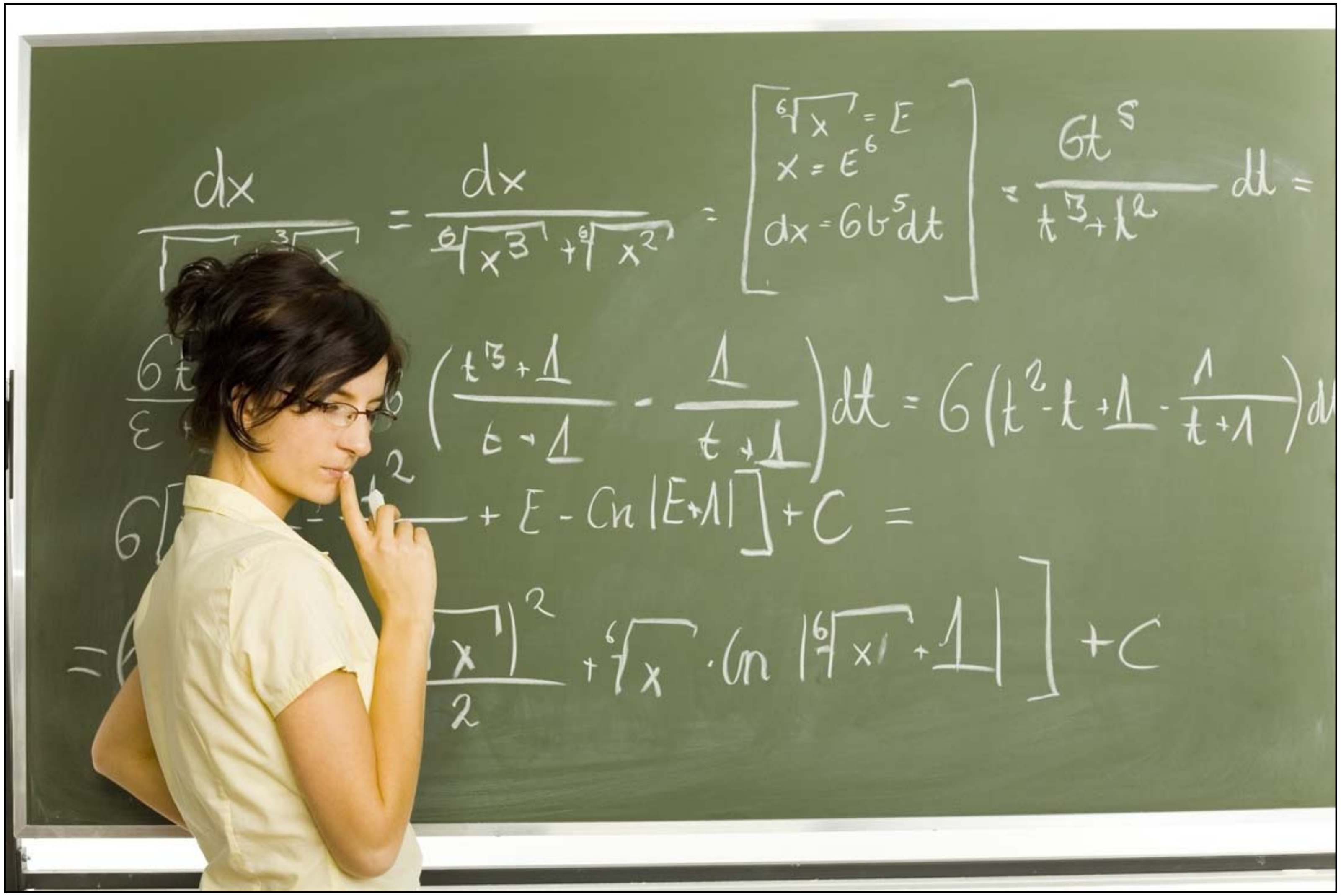
$$x = v_{0x} t$$
$$v_x = v_{0x}$$

Constant velocity motion in the horizontal *x*-direction

$$y = v_{0y} t - \frac{1}{2} g t^2$$
$$v_y = v_{0y} - g t$$

Constant acceleration motion in the vertical *y*-direction

What will we cover today?



Lesson plan

1. Force and interactions
2. Newton's First Law
3. Newton's Second Law
4. Mass and weight
5. Newton's Third Law
6. Free-body diagrams