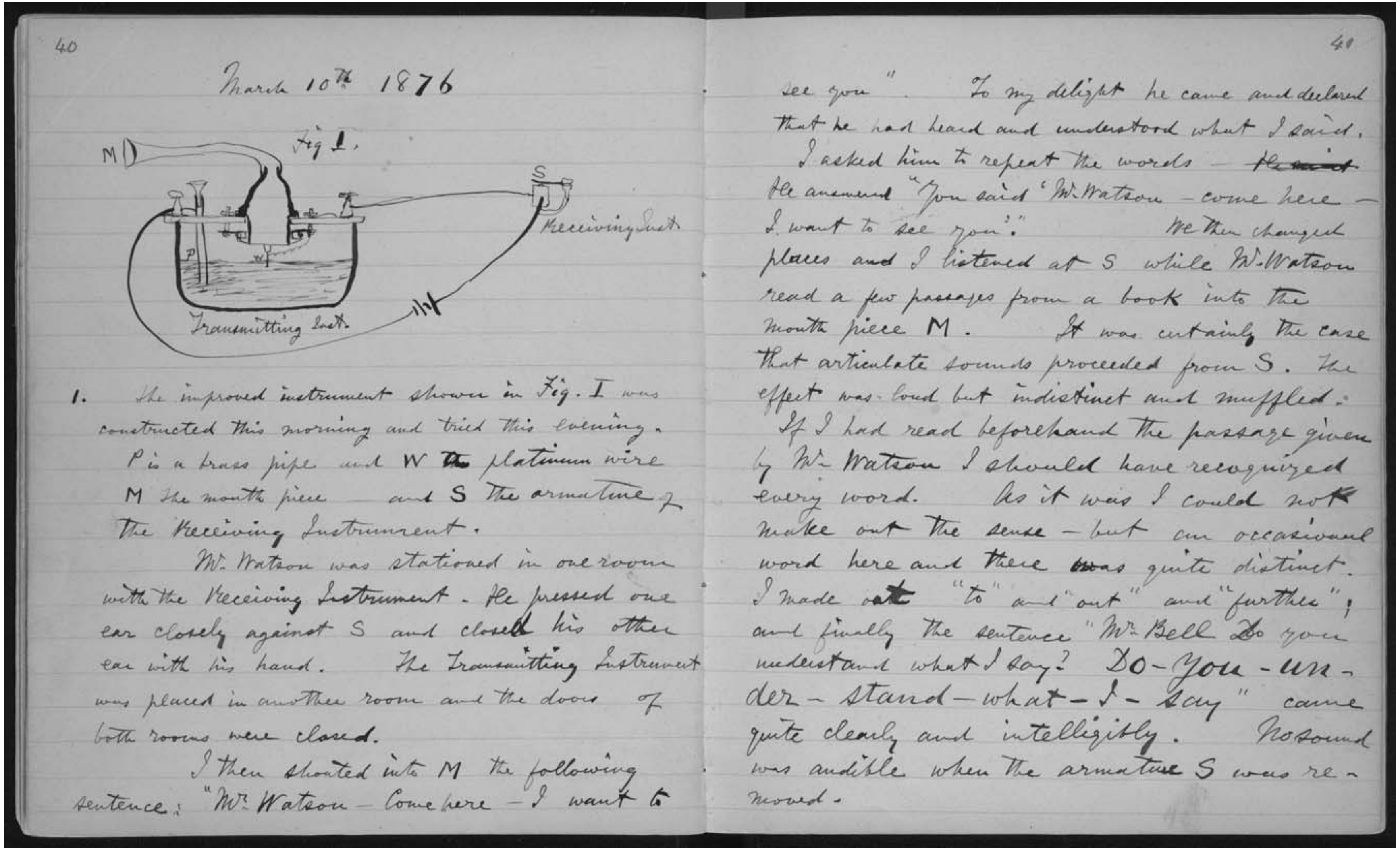
FIZ101E – Lecture 7
Momentum, impulse, and collisions

Alexandr Jonas

Department of Physics Engineering

Istanbul Technical University

What did we cover last week?



40

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.

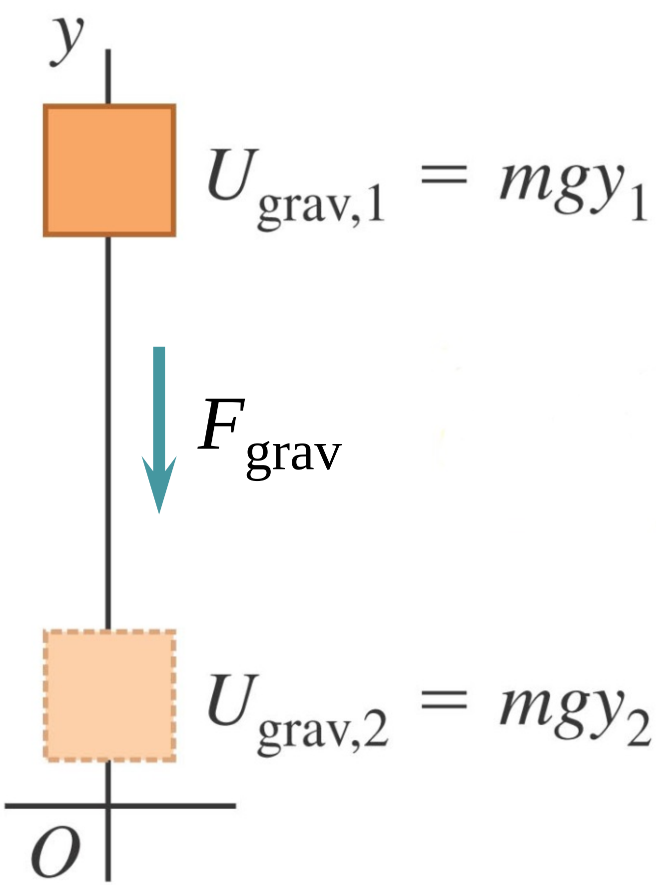
Mr. Watson was stationed in one room with the Receiving Instrument. He pressed one ear closely against S and closed his other ear with his hand. The Transmitting Instrument was placed in another room and the doors of both rooms were closed.

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

41

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.

Gravitational potential energy



The work W_{grav} done on a particle of mass m by a constant gravitational force F_{grav} = -mg while moving the particle from height y_1 to y_2 above the surface of the earth:

$$W_{grav} = mgy_1 - mgy_2 = U_{grav,1} - U_{grav,2} = -\Delta U_{grav}$$

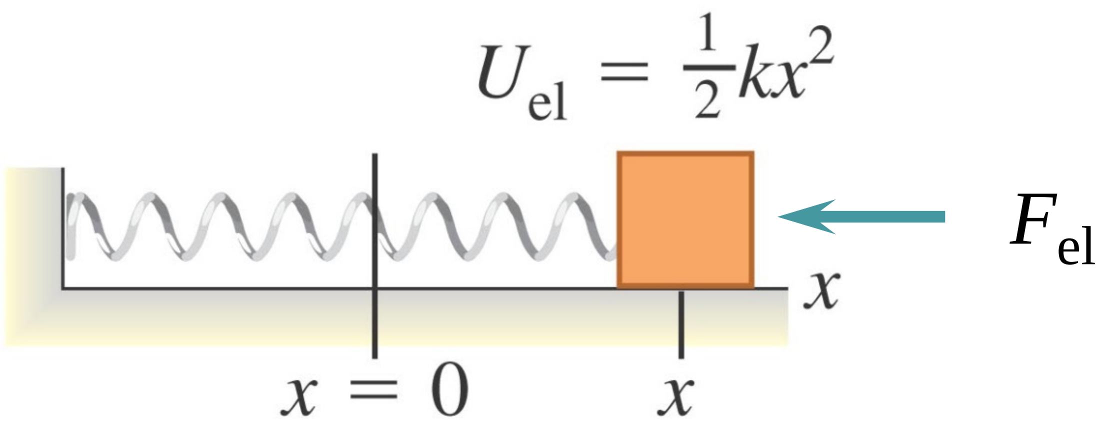
Change in the gravitational potential energy

$$U_{grav} = mgy$$

$$y_1 > y_2 \quad \Rightarrow \quad \Delta U_{grav} < 0 \quad \Rightarrow \quad W_{grav} > 0$$

Gravitational potential energy is a shared property of the particle and the earth.

Elastic potential energy



The work W_{el} done by an elastic force $F_{el} = -kx$ of a linear spring with force constant k while stretching or compressing the spring from initial deformation x_1 to final deformation x_2:

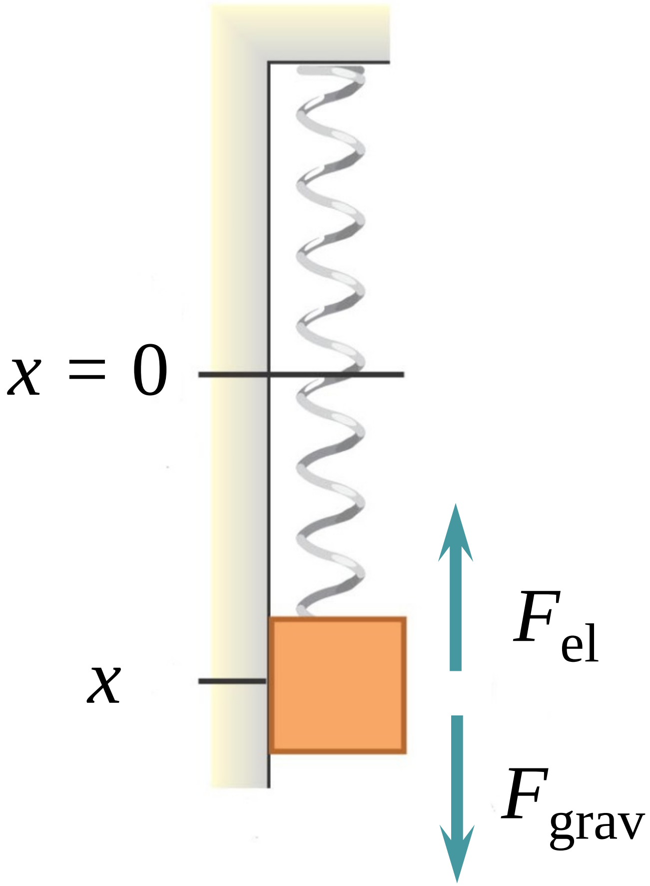
$$W_{el} = \frac{1}{2}kx_1^2 - \frac{1}{2}kx_2^2 = U_{el,1} - U_{el,2} = -\Delta U_{el}$$

Change in the elastic potential energy

$$U_{el} = \frac{1}{2}kx^2$$

$$x_1 > x_2 \quad \Rightarrow \quad \Delta U_{el} < 0 \quad \Rightarrow \quad W_{el} > 0$$

Conservation of total mechanical energy



The total <u>potential</u> energy *U* is the sum of the gravitational and elastic potential energy:

$$U = U_{\text{grav}} + U_{\text{el}}$$

The total <u>mechanical</u> energy *E* is the sum of the kinetic and total potential energy:

$$E = K + U$$

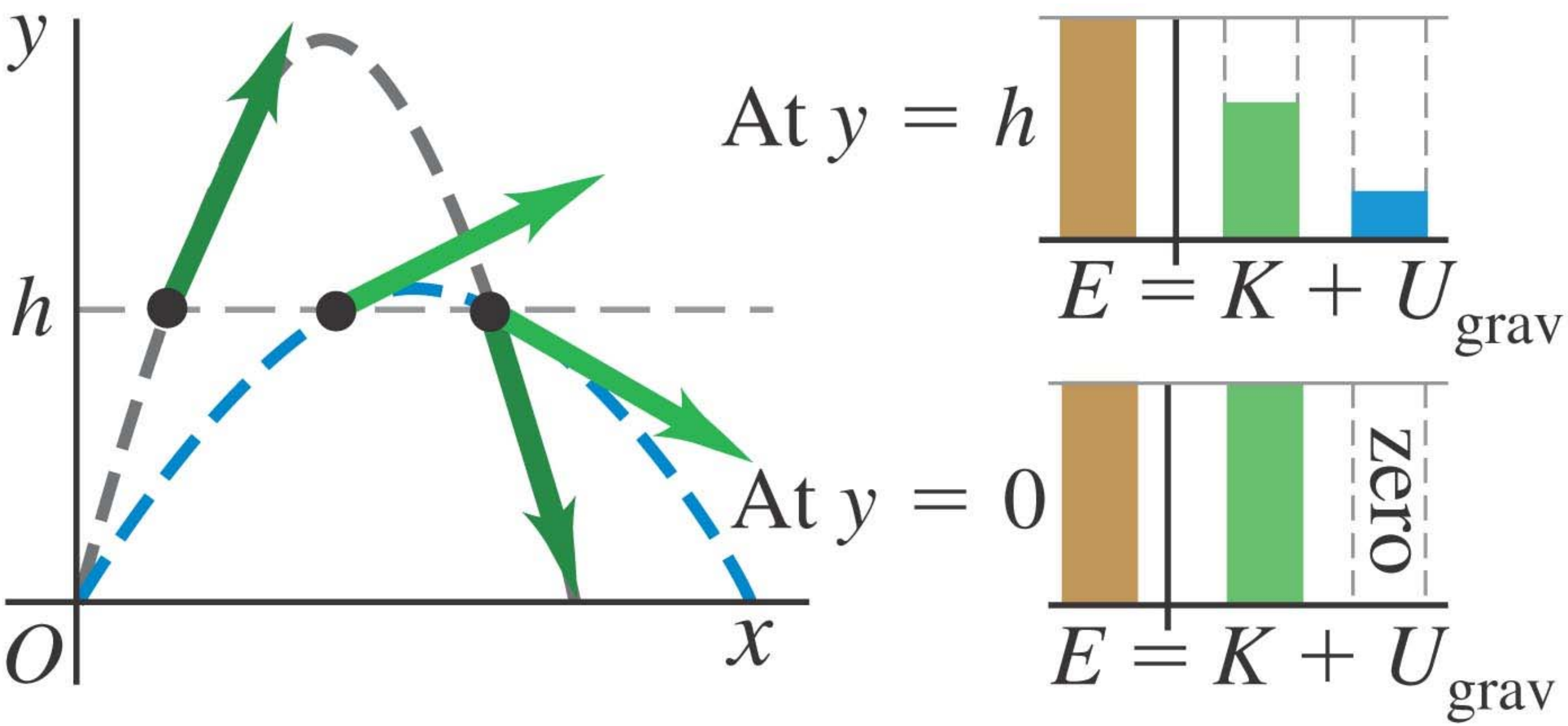
If no forces other than the gravitational and elastic forces do work on a particle, the sum of kinetic and total potential energy is conserved:

$$K_1 + U_1 = K_2 + U_2 \quad \Rightarrow \quad E_1 = E_2$$

Conservation of total mechanical energy

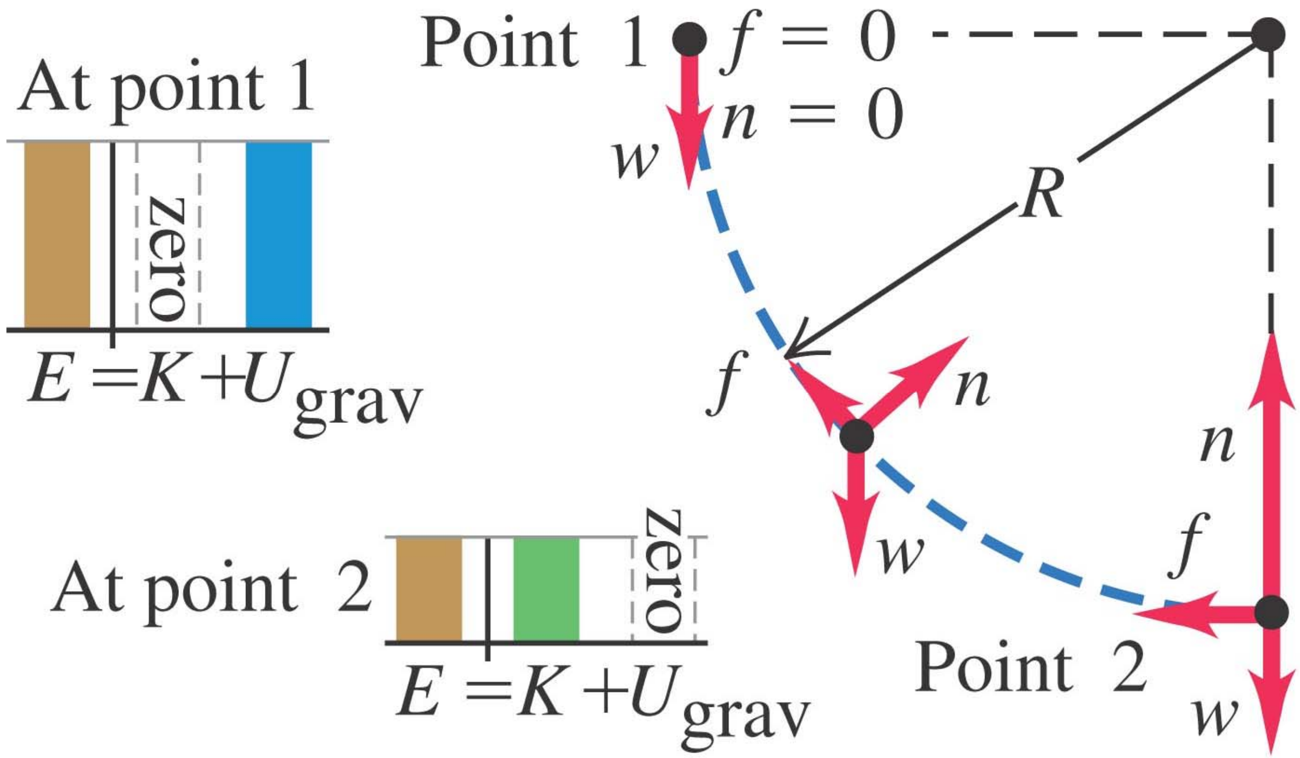
Example:

projectile motion with the same initial speed and different launching angles



At a given height *h* above the surface, the speed of the projectile *v* is independent of the launching angle

When total mechanical energy is not conserved



w … weight

n … normal force (no work)

f … friction force (negative work)

When forces other than the gravitational and elastic forces do work on a particle, the work W_{other} done by these forces equals the change in total mechanical energy:

$$K_1 + U_1 + W_{other} = K_2 + U_2 \quad \Rightarrow \quad W_{other} = E_2 - E_1$$

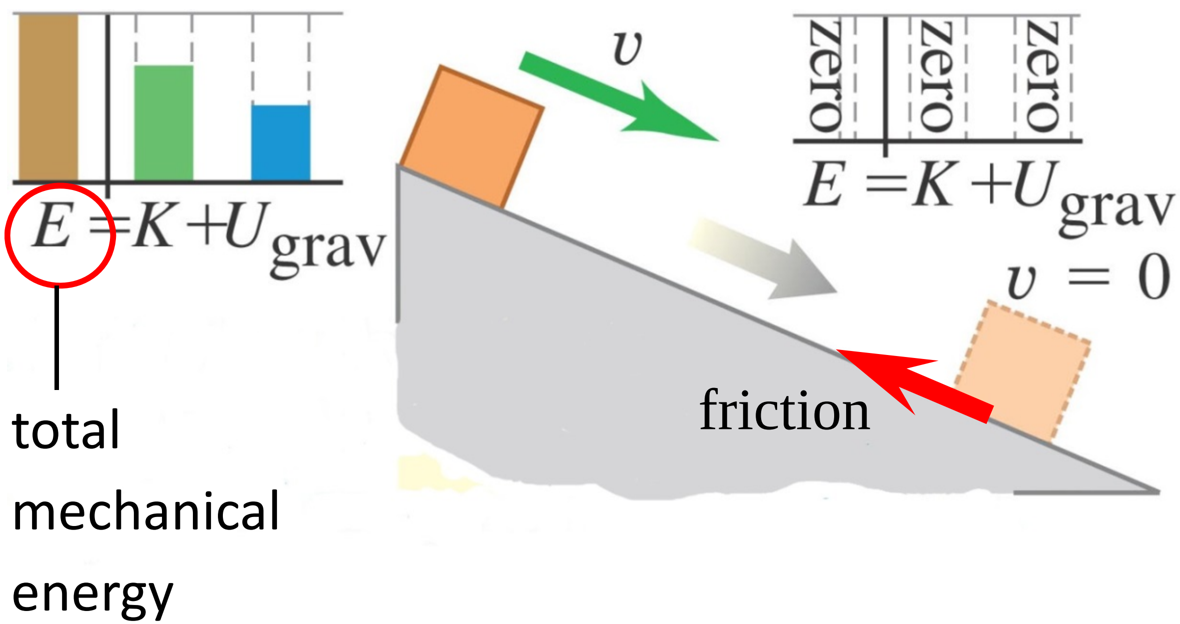
Conservative and non-conservative forces

Conservative forces (e.g. gravity, elastic force)

- total mechanical energy $E = K + U$ is conserved
- work can be expressed through a potential-energy function

Non-conservative forces (e.g. friction, push or pull)

- total mechanical energy $E = K + U$ changes
- no associated potential-energy function

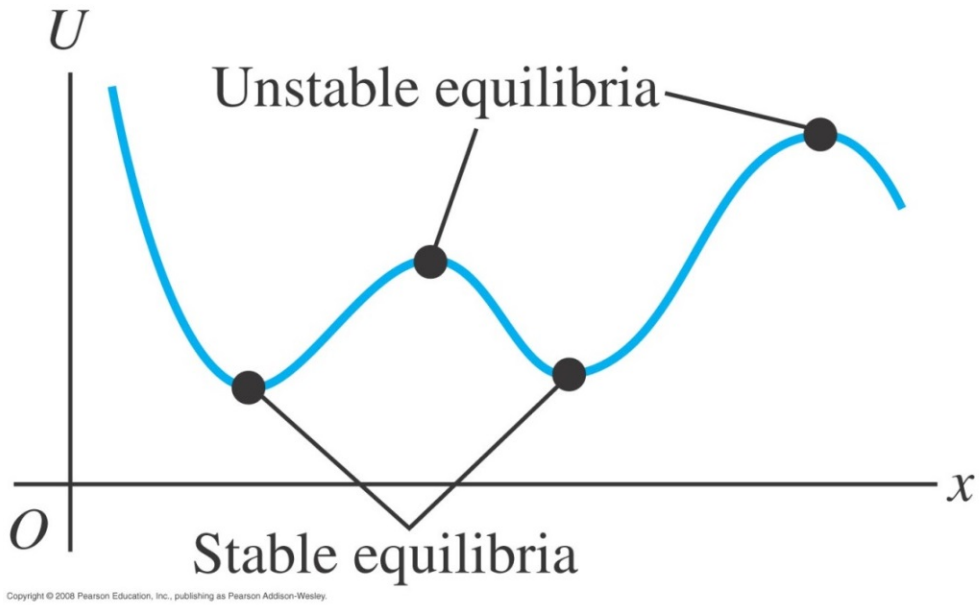


Friction increases internal energy U_{int} of the bodies

The total system energy $K + U + U_{int}$ is conserved:

$$\Delta K + \Delta U + \Delta U_{int} = 0$$

Determining force from potential energy



Conservative force

in one dimension:

$$F_x(x) = -\frac{\mathrm{d}U(x)}{\mathrm{d}x}$$

Conservative force in three dimensions:

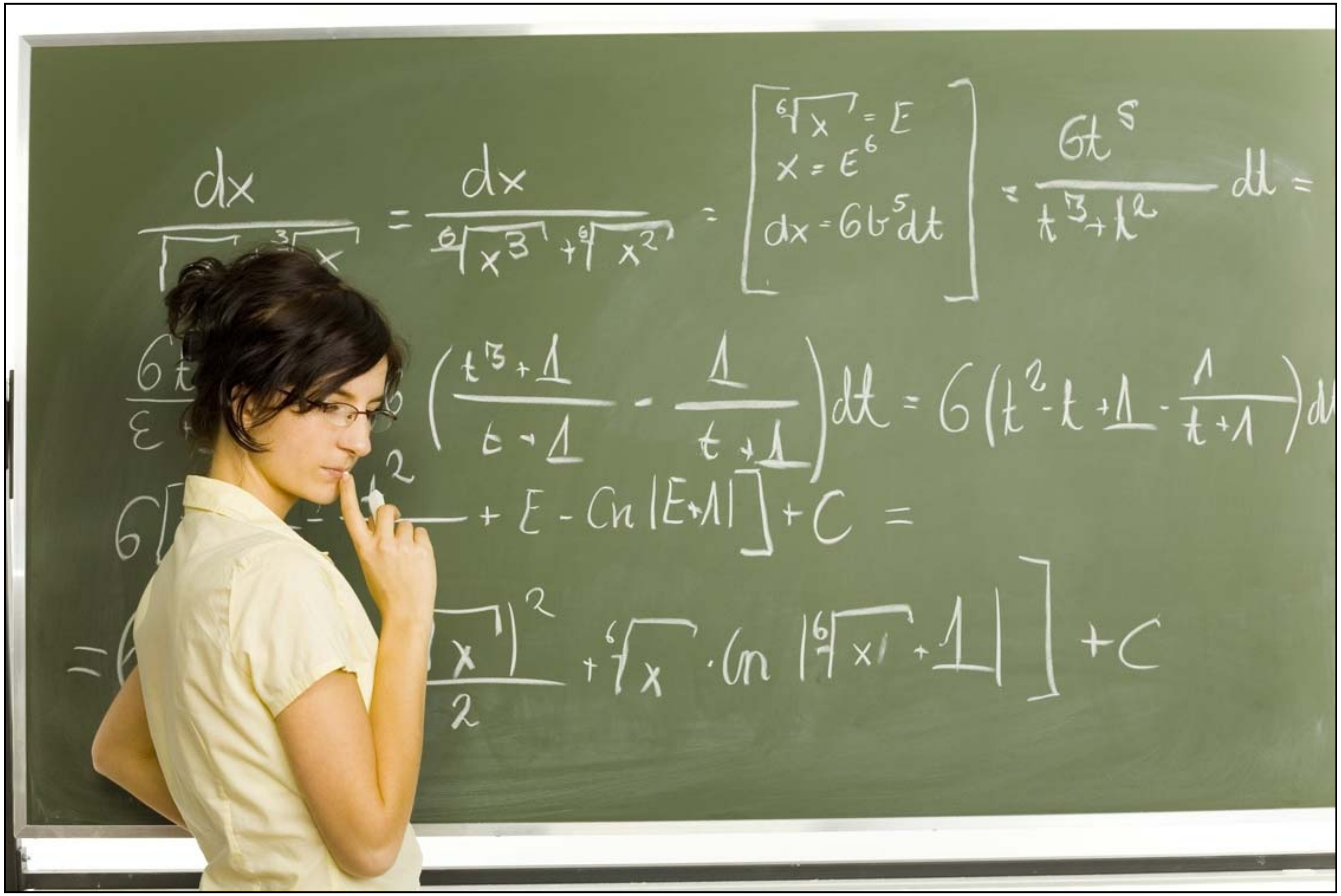
$$F_x = -\frac{\partial U(x,y,z)}{\partial x},\ F_y = -\frac{\partial U(x,y,z)}{\partial y},\ F_z = -\frac{\partial U(x,y,z)}{\partial z}$$

$$\vec{F} = -\,\mathbf{grad}\,U(x,y,z)$$

force = -(gradient of potential energy)

Conservative force always pushes the particle to the <u>minimum of potential energy</u>

What will we cover today?



Lesson plan

1. Momentum and impulse
2. Conservation of momentum
3. Collisions
4. Center of mass