FIZ101E – Lecture 11
Gravitation

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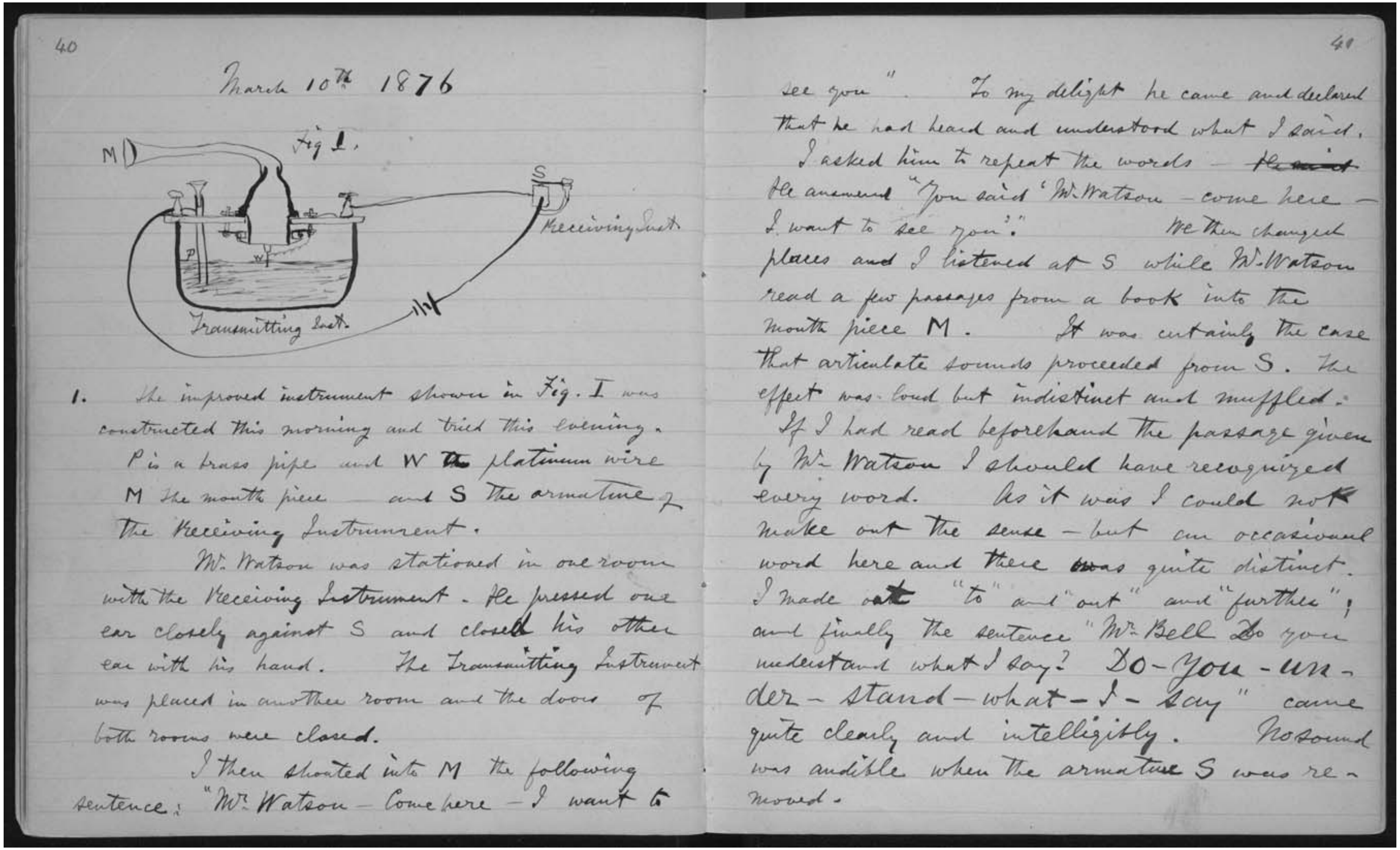
What did we cover last week?



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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

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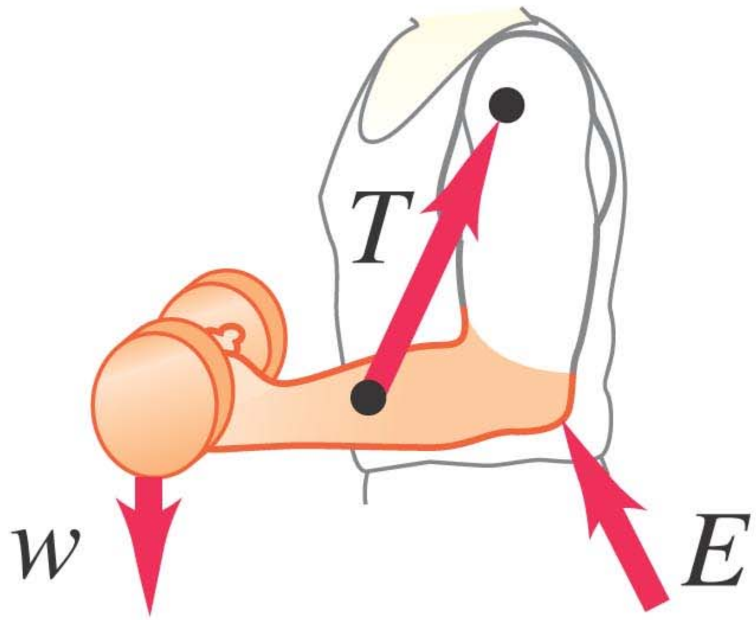
see you". To my delight he came and declared that he had heard and understood what I said.

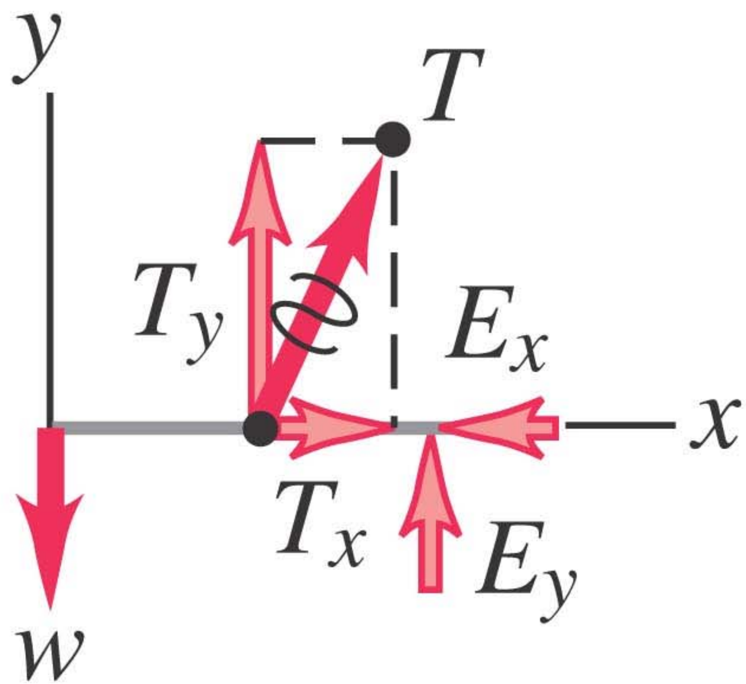
I asked him to repeat the words — ~~He said~~ He answered "You said 'Mr. Watson — come here — I want to see you'." We then changed places and I listened at S while Mr. Watson read a few passages from a book into the mouth piece M. It was certainly the case that articulate sounds proceeded from S. The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

Conditions for equilibrium of a rigid body





<u>Rigid body in equilibrium</u>

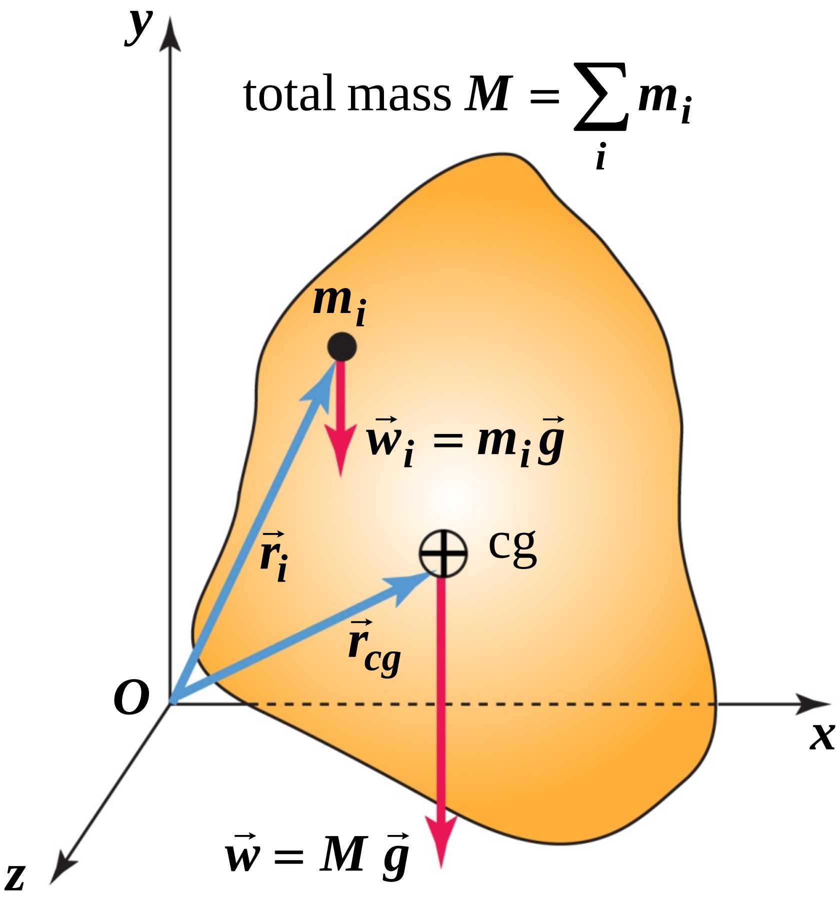
1) Vector sum of all forces must be zero: $\sum F_x = 0 \quad \sum F_y = 0 \quad \sum F_z = 0$

<u>AND</u>

2) Sum of torques about any point must be zero: $\sum \vec{\tau} = 0$

Conditions for equilibrium of a rigid body

The torque due to the weight of a body can be found by assuming the entire weight $\vec{w} = M\,\vec{g}$ is concentrated at the <u>center of gravity</u> (cg).



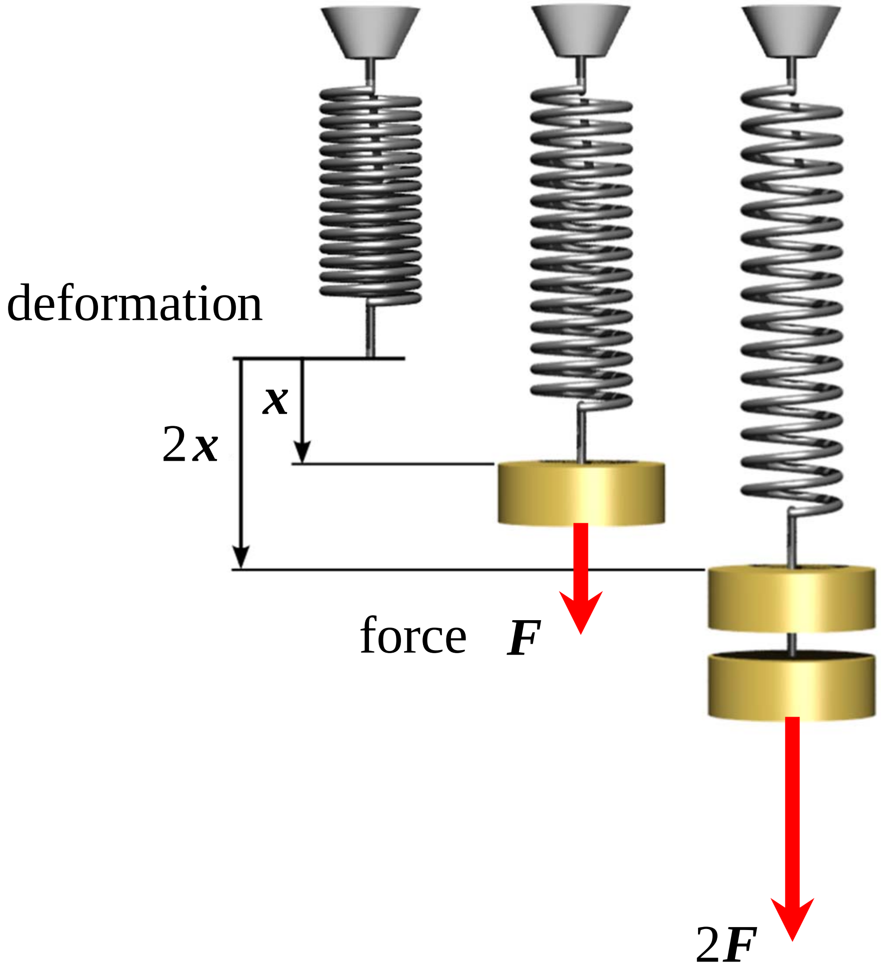
For a constant value of the acceleration of gravity $\vec{g}$, the center of gravity is <u>identical to the center of mass</u> (cm)

$$\vec{r}_{\rm cg} = \vec{r}_{\rm cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \cdots}{m_1 + m_2 + \cdots} = \frac{\sum_i m_i\vec{r}_i}{\sum_i m_i}$$

Stress, strain, and Hooke's law

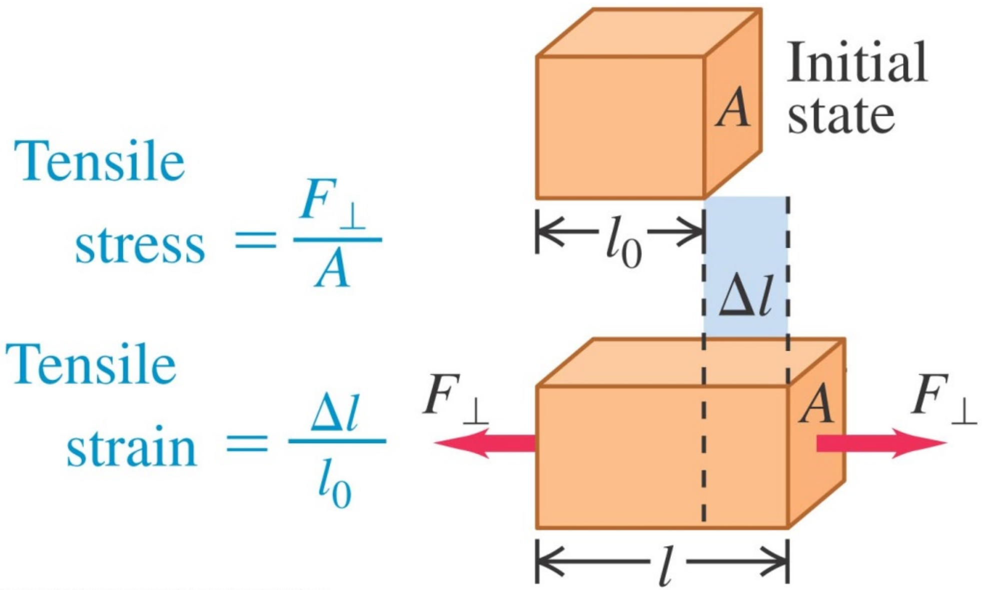
Hooke's law

In elastic deformations, stress (force per unit area) is proportional to strain (fractional deformation). The proportionality constant is called the elastic modulus.



$$\frac{\text{stress}}{\text{strain}} = \text{elastic modulus}$$

Tensile and compressive stress



<u>Tensile stress</u>

→ tensile force per unit area

<u>Tensile strain</u>

→ fractional change in length

$\boldsymbol{F_\perp}$ ... tensile force

$\boldsymbol{A}$ ... area

$\boldsymbol{\Delta l}$ ... change in length

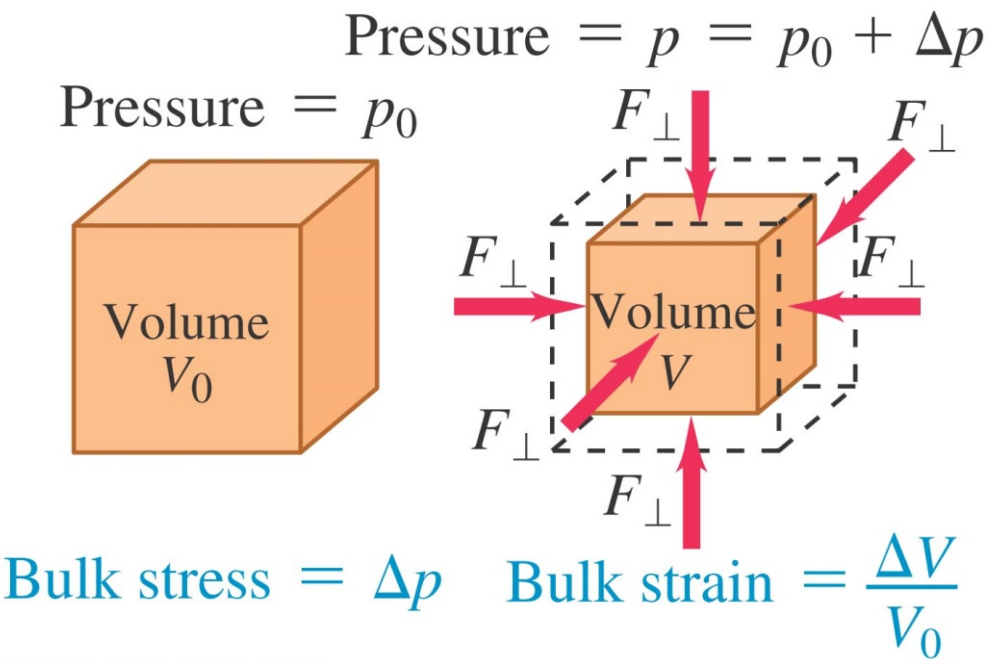
$\boldsymbol{l_0}$ ... original length

<u>Young's elastic modulus</u>

$$Y = \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{F_\perp / A}{\Delta l / l_0} = \frac{F_\perp}{A}\frac{l_0}{\Delta l}$$

Compressive stress and strain are defined in the same way

Bulk stress



Bulk stress

→ pressure change

Bulk strain

→ fractional change in volume

$\Delta p \ldots$ pressure change

$\Delta V \ldots$ volume change

$V_0 \ldots$ original volume

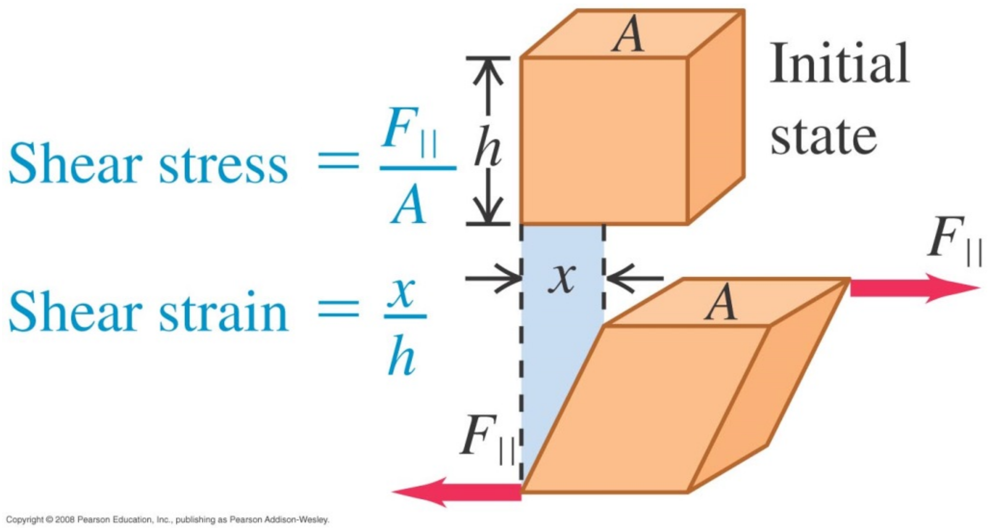
Bulk elastic modulus

$$B = \frac{\text{bulk stress}}{\text{bulk strain}} = -\frac{\Delta p}{\Delta V / V_0} = -V_0 \frac{\Delta p}{\Delta V}$$

Compressibility:

$$k = \frac{1}{B} = -\frac{1}{V_0} \frac{\Delta V}{\Delta p}$$

Shear stress



Shear stress

→ tangential force per unit area

Shear strain

→ displacement of one side normalized by the transverse dimension

$F_{||}$… tangential force

A… area

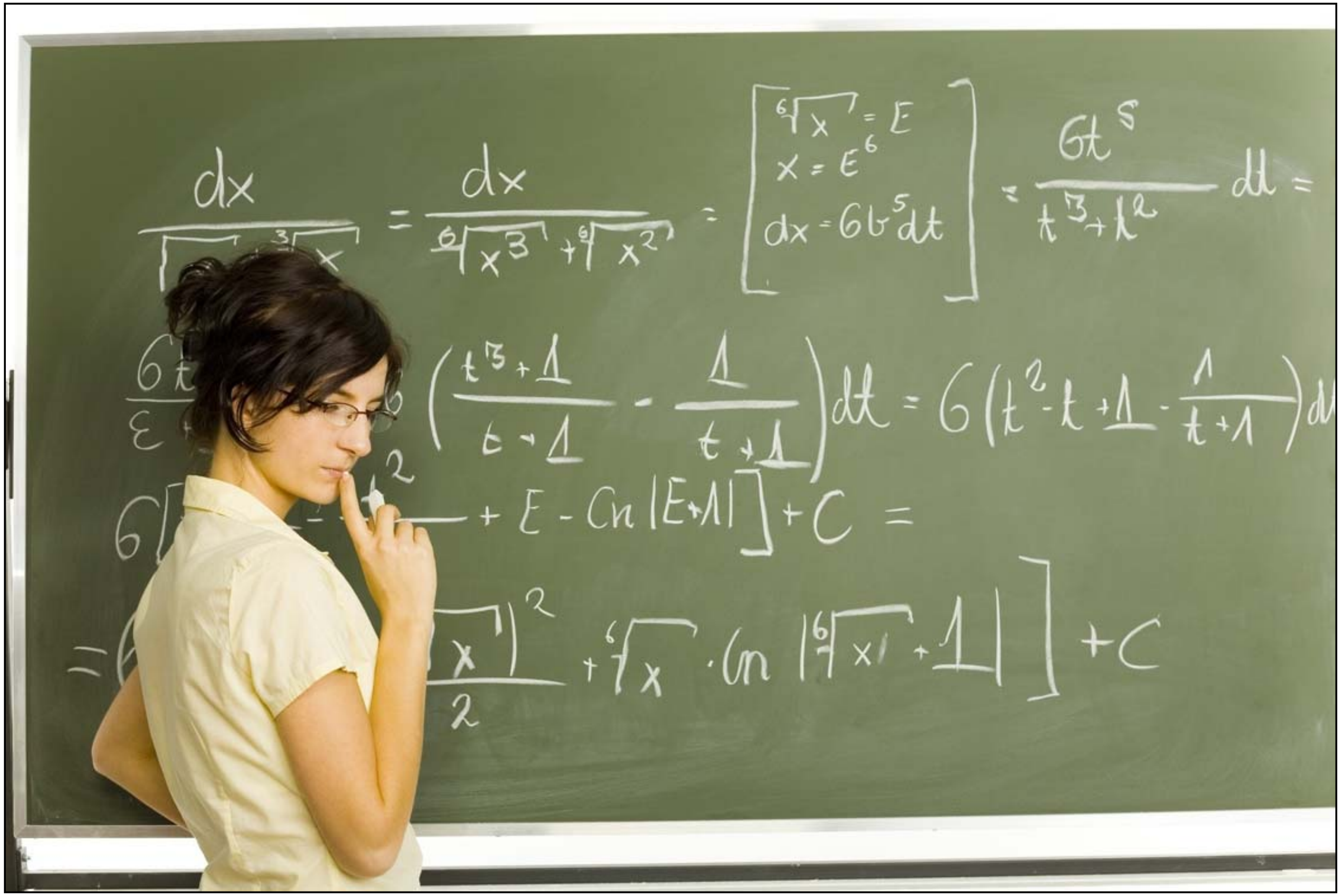
x… displacement

h… transverse dimension

Shear elastic modulus

$$S = \frac{\text{shear stress}}{\text{shear strain}} = \frac{F_{||}/A}{x/h} = \frac{F_{||}}{A}\frac{h}{x}$$

What will we cover today?



Lesson plan

1. Newton's law of gravitation

2. Weight

3. Gravitational potential energy

4. The motion of satellites

5. Kepler's laws and the motion of planets

6. Black holes