ENERGY – HISTORICAL, INTERACTIVE AND PEDAGOGICAL PATHS

Grzegorz Karwasz, Andrzej Karbowski, Józefina Turło
Institute of Physics, Nicolaus Copernicus University, Toruń, Poland

Jolanta Kruk
Institute of Pedagogy, Gdańsk University, Poland

Historical path

1. Antiquity

- The term „energy” comes from Greek, is originated from the word „wergon” (meant English „work”).
- Later it changed to „en-erg-eia” and evolved to an abstract meaning.
- Aristotle used the term “energy” (ένέργεια) as the principle determining the motion, but he was confusing the meaning of the power (*potenza*, *dynamics*, *δύναμις*) force, momentum and energy. He was far from using the “energeia” as the reason for making the objects fall.
- For Aristotle, following the principle of teleology, the heavy objects fall as their natural place is in the center of Earth.

Historical path

- The bizantine philosopher Joannes Philoponos (500-560 AD) supposed that the reason for falling was the “kinetic force” acquired from the human hand.

2. Middle Ages

- First separations of concepts of energy, force and momentum (impetus) come St. Thomas and Buridian, who following Copernicus noticed, that the steady motion does not require a force, and introduced clearly the principle of inertia.

3. XVII-XIX centuries

- Modern formulations of the principle of inertia and the conservation of momentum come from Descartes and Newton; but still without the proper identification of “energy”.

Historical path

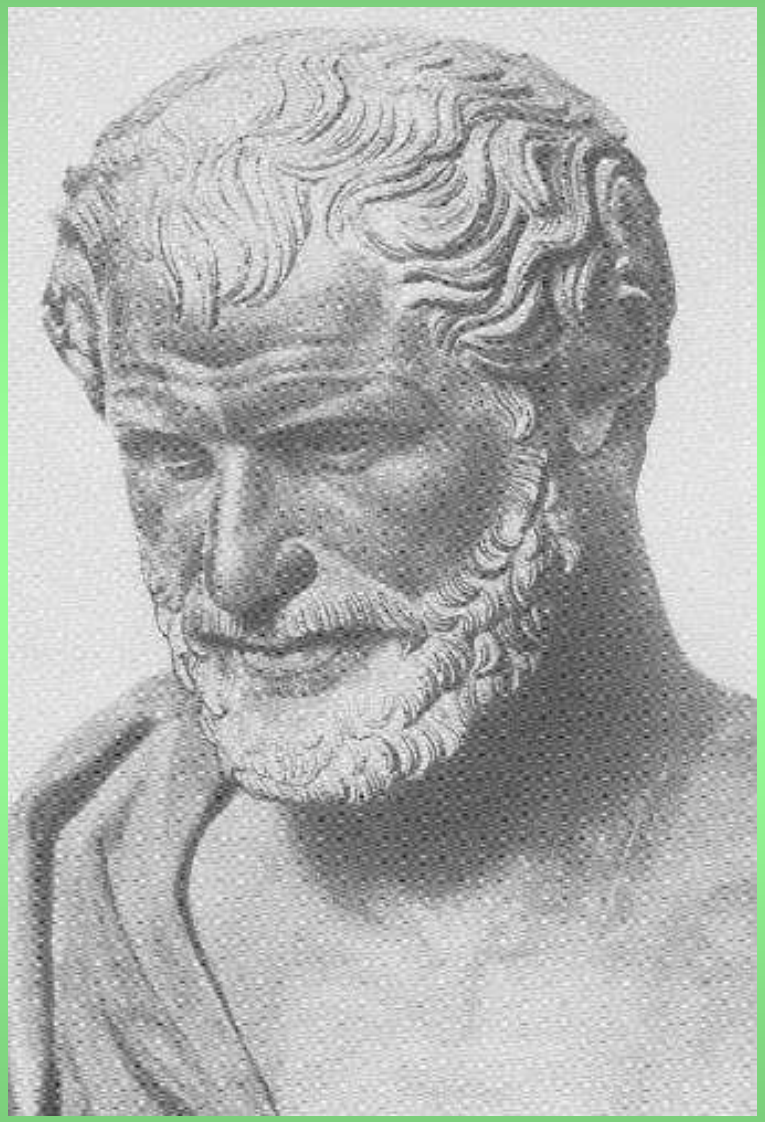
- The concept of mechanical energy includes the works of J. d'Alembert, Jean Bernoulli, Danish scientist Jeans Kraft and later Lagrange and Laplace.
- In 1860 thanks to works of Carnot, Joule and others the principle of energy conservation in the Universe was formulated by Clausius.
- At the same time, the distinction between the heat and useful energy was established in the second principle of thermodynamics.
- The Scotish **engineer Rankine** defined the energy as **"the capacity of the object to perform the work" in 1855.**

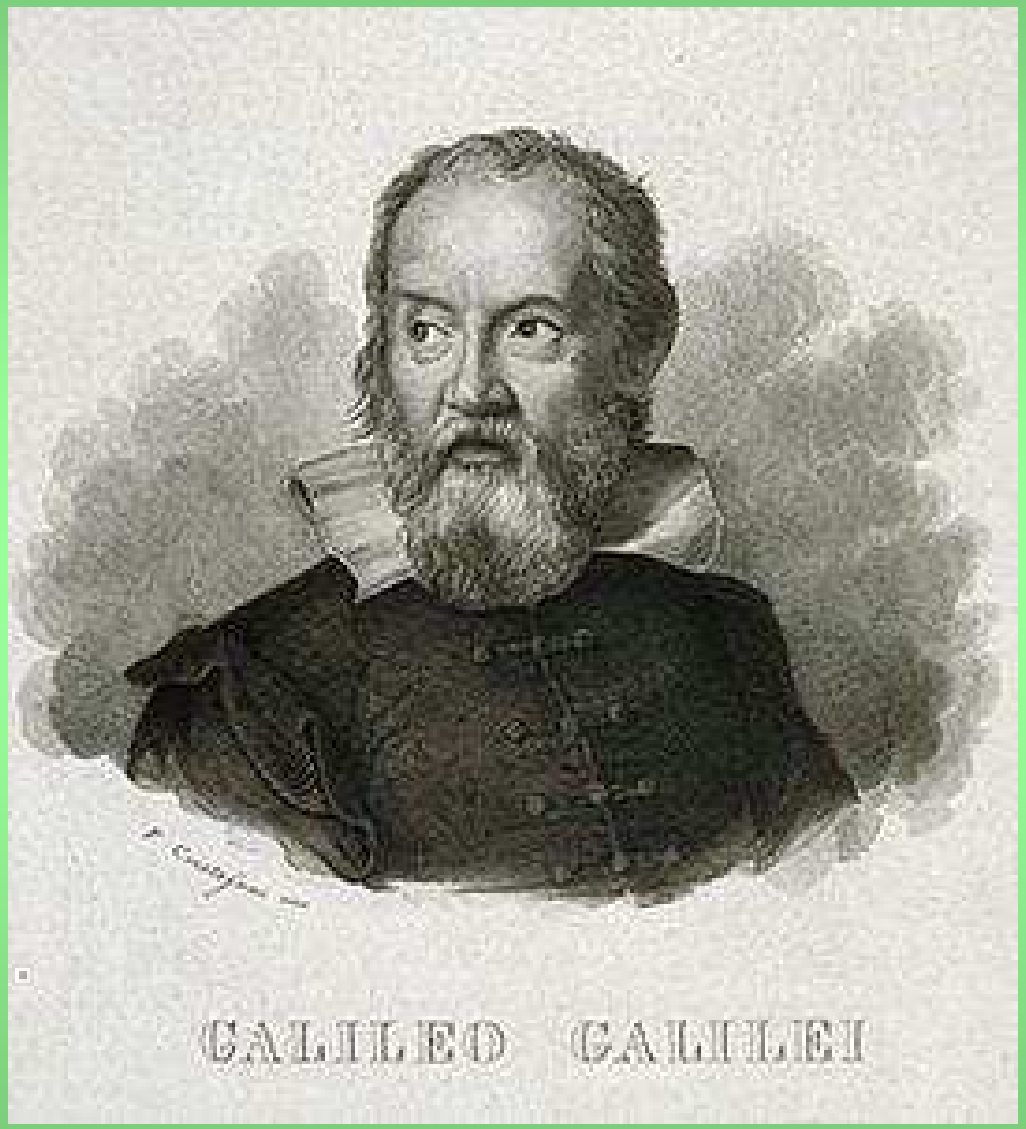
4. XIX and XX centuries

- Thanks to works of E. Mach the mechanical energy was divided into the kinetic and potential.
- Einstein generalized energy in the formula $E=mc^2$.

How to teach on energy?

- The recent Polish Curriculum proposal says “in intuitive way”. We agree, but how?
- Students use frequently pre-scientific meaning of energy, “which have strong roots in every day language and experience”.
- Van der Walk et al. accept different ways for teaching energy as fuel (casual agent), consumable (chemical energy), storage good.
- Papadouris, Kyratsi and Constantinou propose the concept of energy “as a model that accounts for changes in certain physical systems”.

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Questions:

- Why object fall?
- Why they are attracted by Earth?
- Usual answer - “Because of gravity”,
- What is gravity?

  “Gravity is a general force making masses attract?”.
- On these tree questions we close the loop of the tautology:

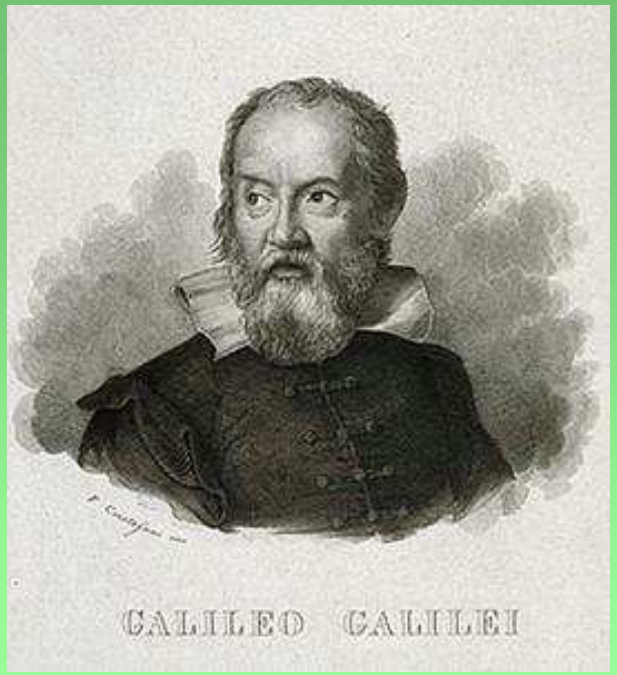
  “Objects fall because are attracted by gravity and gravity is the attracting force”.

Kinematics ↔ Dinamics

- How objects fall?
- Why objects fall?

•Aristotle used the term “energy” (ένέργεια) as the principle determining the motion, but he was confusing the meaning of the power (*potenza, dynamics, δύναμις*) force, momentum and energy. He was far from using the “energeia” as the reason for making the objects fall.

How objects fall?



- *Ma questa general cognizione è di niun profitto, quando non si sappia secondo quale proporzione sia fatto questo accrescimento di velocità, conclusione stata sino ai tempi nostri ignorata a tutti i filosofi, e primieramente ritrovata e dimostrata dall'Accademico, nostro comun amico: il quale, in alcuni suoi scritti non ancora pubblicati, ma in confidenza mostrati a me e ad alcuni altri amici suoi, dimostra come l'accelerazione del moto retto de i gravi si fa secondo i numeri impari ab unitate, cioè che segnati quali e quanti si voglino tempi eguali, se nel primo tempo, partendosi il mobile dalla quiete averà passato un tale spazio, come per esempio, un canna, nel secondo tempo passerà tre canne, nel terzo cinque, nel quarto sette, e così conseguentemente secondo i succedenti numeri caffi, che in somma è l'istesso che il dire che gli spazii passati dal mobile, partendosi dalla quiete, hanno tra di loro proporzione duplicata di quella che hanno i tempi ne' quali i tali spazii son misurati, o vogliam dire che gli spazii passati son tra di loro come i quadrati de' tempi.*

What do we teach now?

- $\Delta s = 1 : 3 : 5$

Simply because $(n+1)^2 - n^2 = 2n+1$ [=dispari]
i.e. this the property of Mathematics, not Physics!

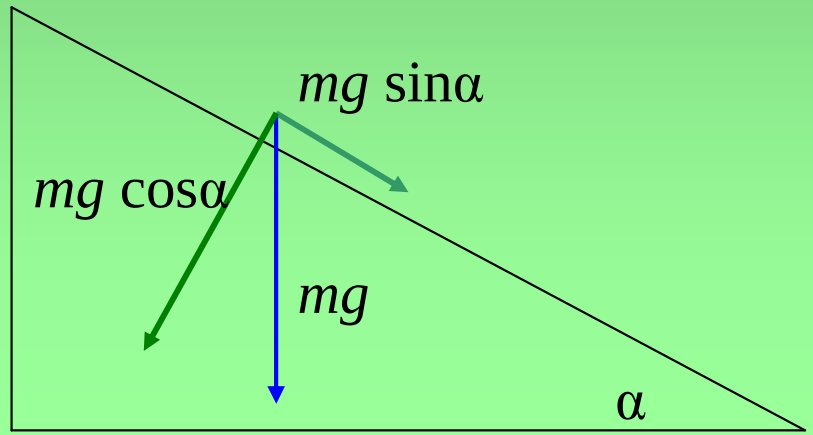
Intuitive and interactive path

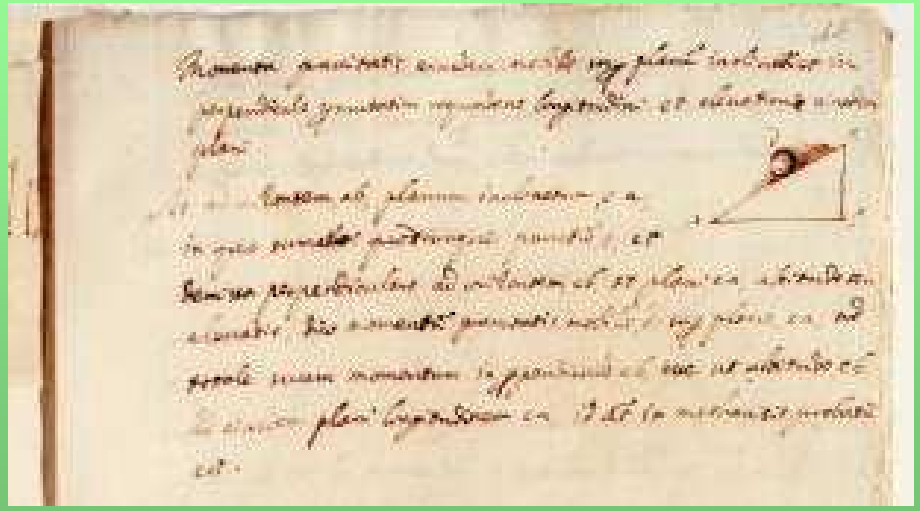
Photo 1. A didactical path on energy and Galileo inclined plane: about 50 experiments in the Institute of Physics.

1. The „velocity” rises !

- How can we measure the velocity (by eye)?

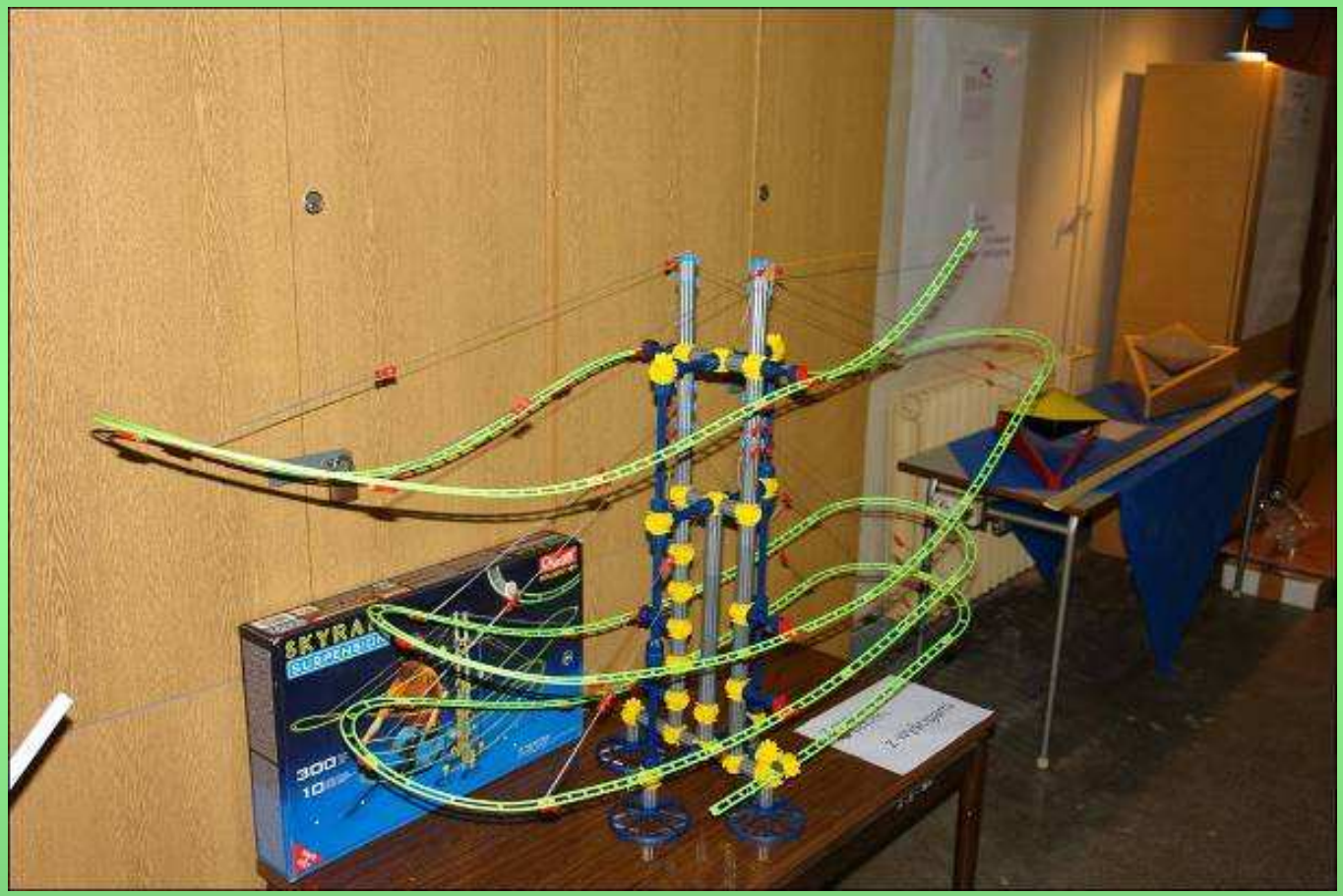
2. The velocity rises with angle!





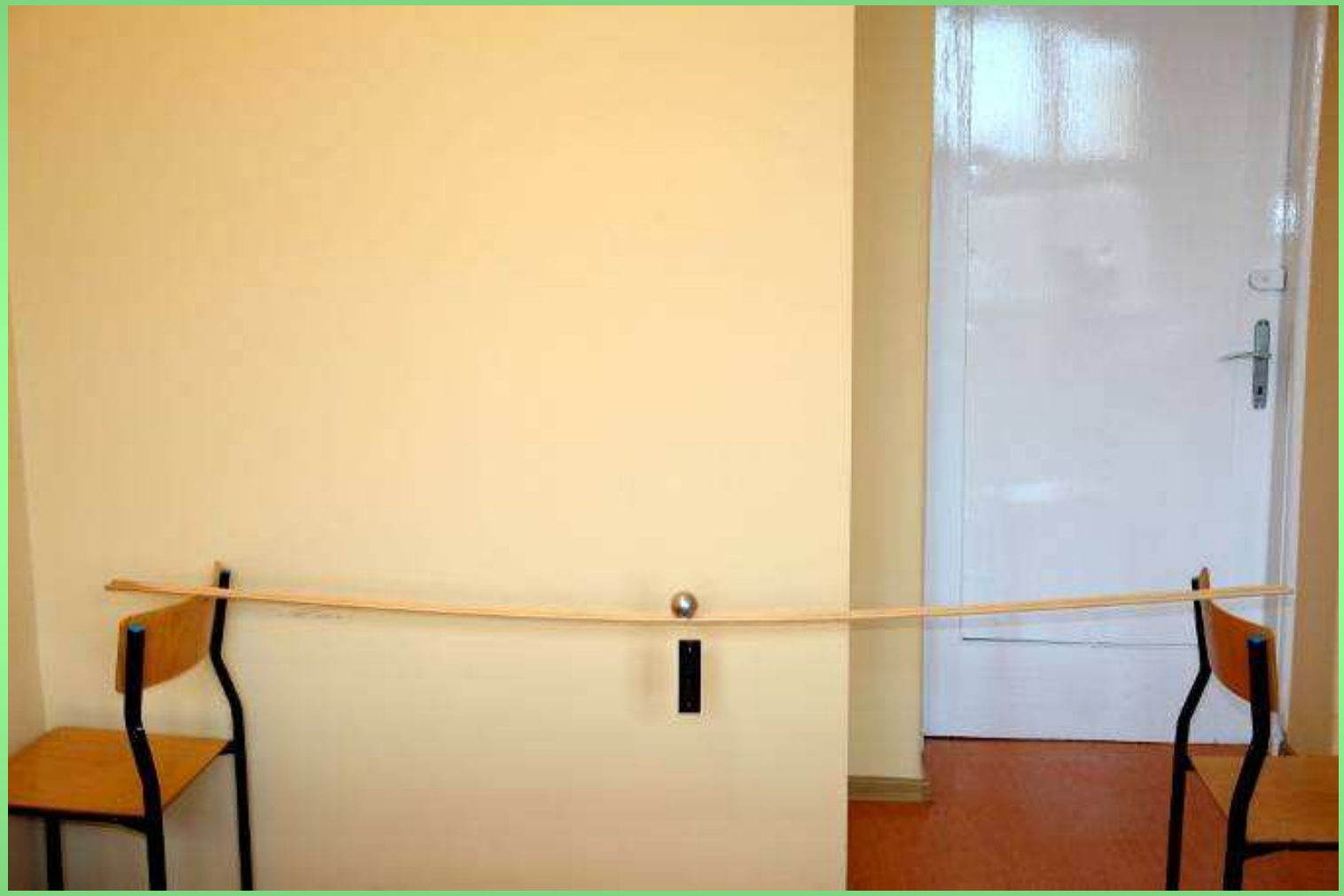
3. The „velocity” does not depend on the mass

4. Why do objects fall?



Because the natural place of heavy objects is „below”!

4b. Why do objects fall?



Because they posses „ENERGY”!

5. Object can gain energy

6. Object can *exchange* energy

7. and more and more aspects…

8. and more and more aspects…

Energy → heat

9. and more and more aspects…

Energy of rotation

10. and more and more aspects…

Superelastic collisions

Heurestic and pedagogical aspects

- Using an intuitive and interactive educational path stimulates the learning activity.
- Spontaneous manipulations leads to the formulation of hypothesis on the behaviour of objects and their physical features and then to fully intuitive formulation of the laws of Physics.
- The interactivity and the possibility of independent exploration create conditions for emotional involvement, which activates all learning abilities of the pupils, concentrating his attention and giving a deepen dimension for the acquired knowledge.
- Activities that verify learning at the interactive exhibitions are, resemble closely the scientific research.

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Conclusions

- The richness of the meaning of „energy” and the bibliographic record on it make difficult univalent conclusions.

- Energy as an abstract feature attributed to the physicsal body does not exceed the comprehension capabilities even of small children.

- Not all forms of energy „can perform work”, thus we should not base the definition of the energy concept on the work.

- In this way we agree with the proposal by Papadouris, Kyratsi and Costaninou, to stress the aspect of energy as “a flowing agent”. The energy appears, if objects exchange it. This makes objects fall, when they are free to change their potential energy to kinetic one, and hitting the floor to produce the heat. At the end, this is not far from Aristotle’s meaning of energy, i.e. the reason for bodies to move!

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