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Re-discovering of Mechanical Equipments

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ABSTRACT

This paper presents the development and origins of mechanics and refers to old machinery, equipment, apparatus, which stand out from technical level of its time. Such analyses find out some similarities – parallels of mechanical principles between present and ancient age. On the base of the study of the origins of mechanics, it can be observed there are some equipments and also technologies that are currently undiscovered but utilized by previous (even extinct) civilizations. We do not expect it, because we have been influenced by the classical, traditional explanation of history from the simple (primitive) to the complex (sophisticated). The authors analyse the idea of "repeated discovery" – re-discovery.

Keywords: mechanics, mechanism, technological development, history, re-discovery

I. INTRODUCTION

The developments and emergence of mechanics goes back to ancient times when people started to use natural laws and create facilities for the conversion of energy humans, animals and natural elements for useful function. In generally, mechanics have started to develop as part of philosophy (antique age, so-called natural philosophy) and later physics (ancient age, Middle Ages) since the first civilizations that article presents. The first impulse of technological development was the discovery of the wheel, which dates back to the 4000 BC. We know already extinct civilisations, which although did not know wheel they was able to use technologies that are currently undiscovered. This paper presents the development and origins of mechanics and old refers to machinery, equipment, apparatus, which stand out from technical level of its time.

II. METHODS AND MATERIAL

The preferably used method is method of analysing, comparing, making synthesis, finding parallels, generalizing etc. Moreover, some presented mechanisms were made by authors ourselves. The sources are literature, personal observations, remarks, visits of museum and collection of facts.

III. RESULTS AND DISCUSSION

A. First mechanical Equipments

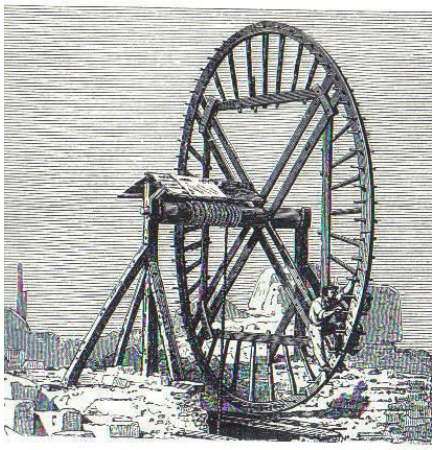

Figure 1. Reconstruction of old windlass pump wheel from Mesopotamia [1]

Around 1510 BC wheel entered mechanics. The use of a rope with a pulley was an important application. On the base of excavation, large-scale wheel can be considered the first machine driven by a human force,

which was actuated by walking along the outer rim (windlass pump). The force was transferred to the rope twined around the windlass with considerably smaller diameter than the wheel. Wheels of this type served mainly for pumping water from water wells (Fig. 1).
At the end of 4th century BC there occurs transformation from natural to artificial irrigation in Egypt. This fact is supported by the stone head of the clavia from 3100 BC on which ceremonial opening of a channel is illustrated. The equipment called "saqiya" brought simplification of water pumping. It is a chain with buckets and two wooden wheels driven by animals (Fig. 2).

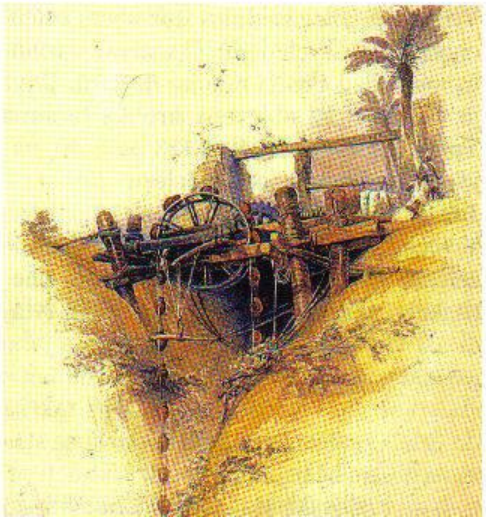

Figure 2. Water pump driven by animals

B. Close to our era

Around 700 BC Greek mechanics discovered technology of multiplication of power by hauling tackle (Fig. 3).

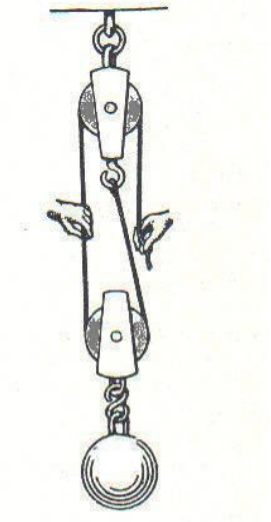

Figure 3. Hauling tackle from 700 BC

It is interesting that Archimedes constructed a hauling tackle based on different principle in 210 BC (Fig. 4). Leonardo da Vinci constructed a similar one (around 1500 AD).

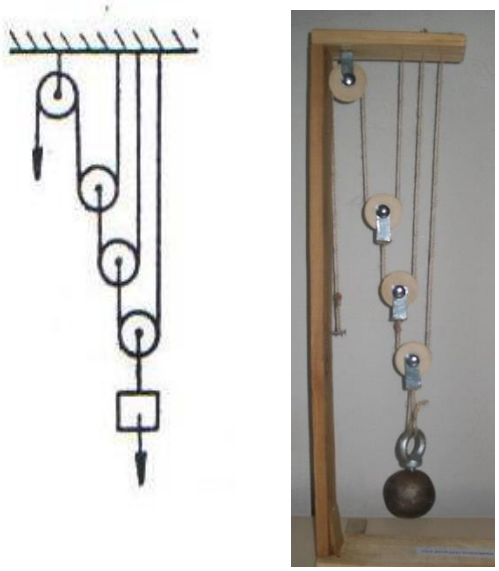

Figure 4. Archimedes´s hauling tackle from 210 BC and made by authors

Automatic machines were understood as moving toys in history. They were known to old Egyptians already. Archystas of Tarent (428-347 BC) can be considered their first designer. He was a personal friend of Plato (427-347 BC). Archystas made a wooden model of a dove with such a professional resourcefulness that it floated itself. It flew 200 metres. Its movement was secured by an air stream coming from a pressurised tank. One hundred years later, Demetrius of Phalerum (345-283 BC) constructed a crawling snail.

About 250 BC a Greek mechanic Ctesibios of Alexandria (285 -283 BC) started to work on technical use of the power of water and air. He used them in many mechanical applications. He invented inflation pump driven by pressurised air, firefighting pump, water organ, pneumatic bow and different mechanisms with gear rack. Besides that he improved water clock (klepsydru) from 422 BC, so they became reliable equipment for measuring time all year long.

He used wind for the construction of wind organ (Fig. 5). Wind drives propeller, which pumps air into organ by crank-handle in a cylinder. Obviously, the machinery only worked when the wind was blowing. He constructed water organ and pneumatic bow on similar principle.

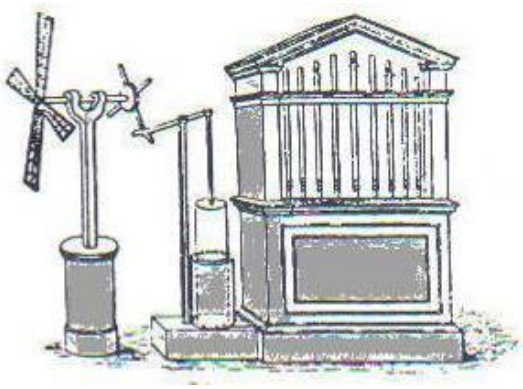

Figure 5. Wind organ

Water organ works as follows (Fig. 6). By the foot handle 1 air is pumped through the piston in the cylinder into the space 2 and 3, above the water surface in an enclosed tank. By the pressure of the air the surface of water rises and compresses the air above the surface by this the pressure of the air in space 3 is maintained. By pressing keys 5 the organ player allows the air into the pipes 6 and makes sounds.

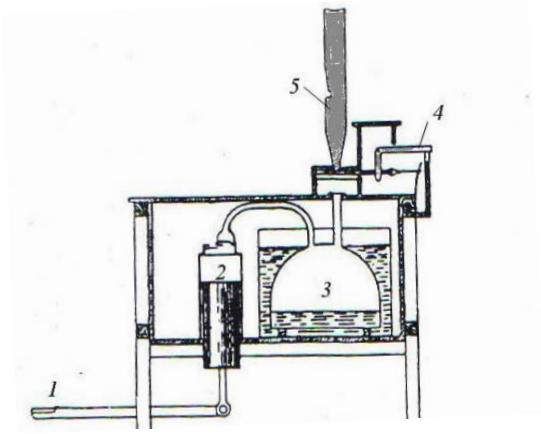

Figure 6. Water organ [1]

The principle of pneumatic bow (Fig. 7) is based on pressing the air in cylinders after stretching the bowstring. After it is released, the stone is thrown into the space.

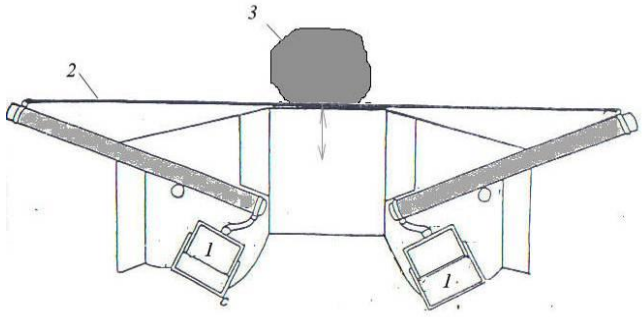

Figure 7. Pneumatic bow 1- pneumatic cylinders, 2- bowstring, 3- stone [1]

Physicist and writer Filon of Byzantium (he worked in Alexandria in 250 BC) dealt with water mechanics in detail. He wrote his conclusions on many inventions of his time, such as water siphon, principle of joined tanks, thermoscope (predecessor of thermometer), well with interrupted water outlet, pressure pump, water tap with multiple outlets and different mechanisms for water pumping. His report on siren says that it was driven by a water wheel with upper water inlet. At the same time it used kinetic energy of water stream. He described saws driven by water wheels. He dealt with hydraulics, where he used hydroscopic powers as well as mechanics. Then he discovered the principle of cross joint, which got a name of cardan (after its re-discoverer G. Cardano) after more than 1700 years. It is a connection of two rods, which could be inclined in all directions while the joint transferred torque as rigid connection (Fig. 8).

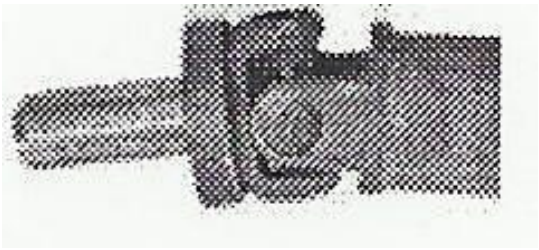

Figure 8. “Cardan“ joint

For the sake of interest, the Egyptians managed to use the stream of the Nile to drive the ship against the river flow. The ship had big wheels with float boards on both sides, which the stream of Nile turned. Wheel axes had considerably smaller diameters and during the turns rope was writhed on them, which was fixed in the front, far in front of the ship. It helped in pulling the ship automatically against the river flow (Fig. 9).

Figure 9. Egyptian ship floating against the river flow

On the level of Antikythera, Greek archaeologist Spiridon Stais (1859-1932) found and old wreck loaded

with marble and bronze statues in 1902. It was 40 metres under water. A shapeless clod was also found on the wreck, which after cleaning turned to be a bronze plate with circles, writing and teethed wheels.

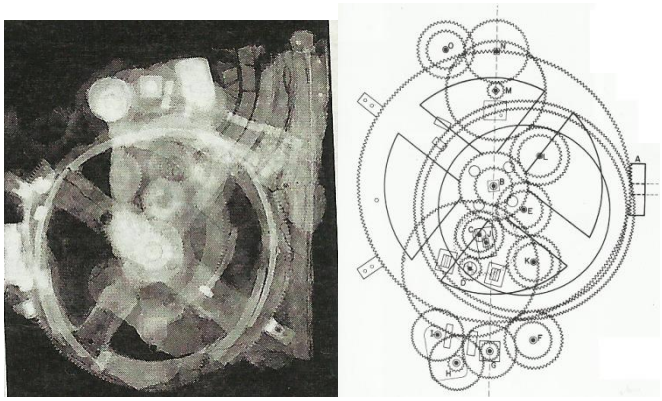

Figure 10. X-ray shot of the computer from Antikytherya, reconstruction of complex mechanism kinematics

Actual machine (*Fig. 10*) with moving hands, complex scales, metal plates and writings appeared after cleaning. It has 20 wheels, differential gear and plate wheel. On one side there is a crankshaft and if we start to turn it, all scales start moving, each of them in different speed. There are bronze flaps on the hands with writings. It is a certain kind of a computer, which determined the movement of planets, Moon and Sun. It probably served for naval navigation. The machine enabled the calculation of movements of the planets known at the time as well as the dates in the course of the year, for example equinox. Moon phases could be determined from the position of teethed wheels and also for several years in advance. It was all possible also thanks to the fact that the mechanism was equipped by balancing – differential gear, which was submitted for patent as late as 1828. It is basically a small planetarium produced by complex fine mechanics. The ship with the machine drowned in 82 BC, which is an approximate date of the production of the machine. Today it is considered to be the first analogue computer. It can be found in National archaeological museum in Athens.

C. New era

The most distinguished technician – inventor of the time was a Greek, Heron of Alexandria (10-70 AD), nicknamed Méchanikos (Fig. 11). He could be considered „the godfather“ of robotics. His artificial birds could move wings, open beaks and sing. At that time those inventions were considered to be toys. He also discovered the principle of air turbine (aerolipia), based on reactive drive.

Figure 11. Heron of Alexandria

He invented paid automatic machine for ritual cleansing, which was located in front of the temple. Religious person placed a bronze coin in the slot, which fell into the bowl at the end of rocker lever fixed to a pivot. The other end of the lever lead to a vent, which opened when the coin fell down and sprayed out water, with which the person washed his face and hands, so he could enter the temple „cleansed“.

He used to show a levitating metal ball as a toy. Steam, created in the kettle with water, was lead through a pipe into ring-shaped openings. The ball levitated above them, wafted by the pressure of the steam (Fig. 12).

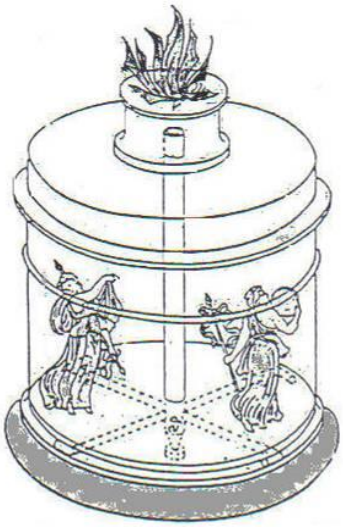

Figure 12. Heron´s reactive turbine cross – original diagram [1]

Heron´s steam ball (aeolipila (Fig. 13)) is based on the fact that the steam made by hot water is pressed out through bent pipes on the ball. So the ball turned by reactive force, it means it was the first reactive turbine.

However, the machinery was not powerful enough to perform useful work. It served as a toy.

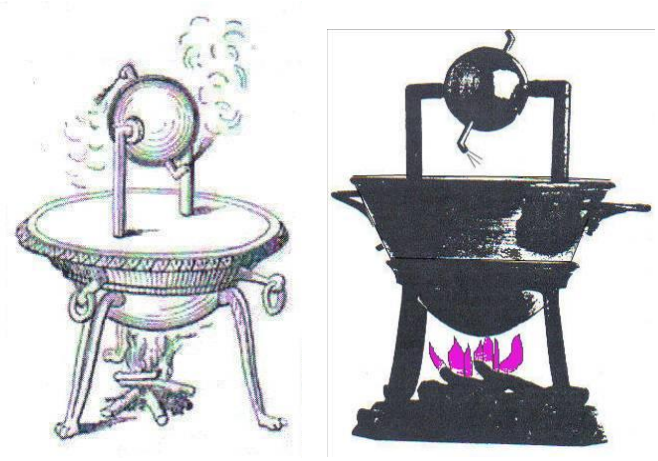

Figure 13. Original drawing and model of Heron´s steam ball (Science Museum London – photo of one of authors)

One of famous practical designs of Heron is his automatic temple gate opener (Fig. 14). After lighting up the sacrificial fire by the priest the air in the enclosed tank under the fireplace placed under the level of terrain heats up. A pipe leads from it into the space underground, a ball-shaped flask with water. The heated air pressed out the water through the pipe into the bucket, which dropped down by the influence of water weight and turned the gate beams with the help of rope gear. The gate slowly opens. When the fire burns out, opposite mechanism and weight return the gate into the original position.

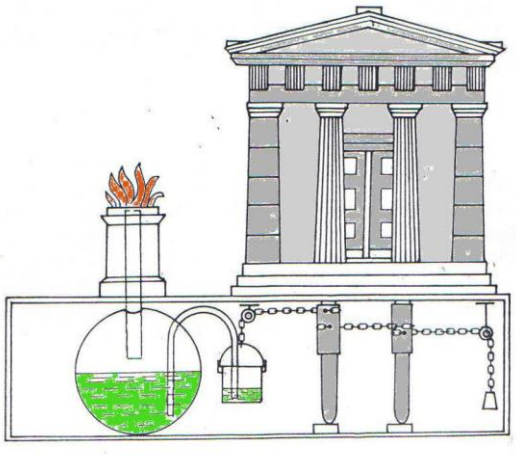

Figure 14. Heron´s automatic temple gate opener (110 AD) [1]

Codex Atlanticus and Leonardo´s museum in Vinci contain Leonardo´s robotic knight. It is controlled by a spring and ropes, which realise the movement of arms and legs. It might be the first robotic mechanism in the world (Fig. 15).

Figure 15. Leonardo´s android and its mechanism

Leonardo made a mechanical lion and presented it to the French king. The “robot” can walk, stand on its rear legs and hand in flowers (Fig.16). It is controlled by a spring.

Figure 16. Leonardo´s mechanic lion and its mechanism (reconstruction)

Homer describes Greek god of furnace men and smiths, Hefaistos (apparently, he was the first engineer), who made the metal soldiers. They had three legs and worked like people (Fig. 17).

Figure 17. Mechanism of Hefaistos´ three-legged android (there are wheels at the ends of its legs)

He also produced android soldiers. According to the myth, Zeus presented a robot to the island of Talos, which walked around the island three times a day, moved, fought and threw stones (Fig. 18). It presents the idea of robotic principle as it was understood in the ancient times.

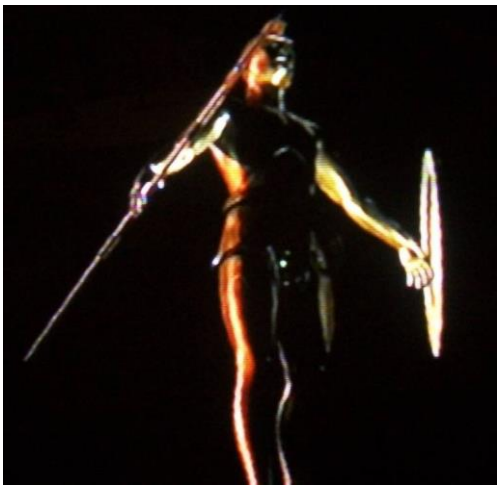

Figure 18. Design of an android soldier from the island of Talos

Water energy was frequently used to drive different technological machinery. One of the examples is drawing of a wire (Fig. 19). Water wheel is connected with a crank shaft, which draws the wire alternatively through a draw ring with the help of pliers, served by a man. After each lift he fixes the pliers forward. Water wheel evokes pulling force.

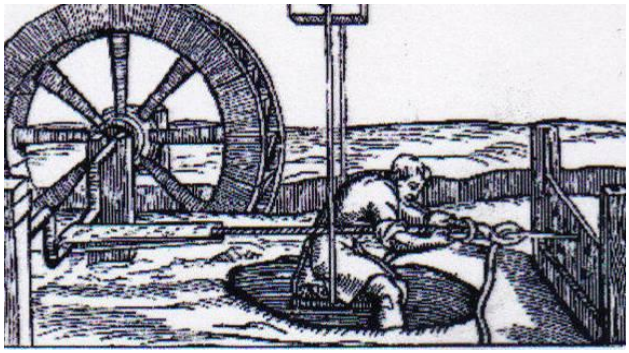

Figure 19. Machine for drawing wires, driven by a wheel turned by ground water

Figure 20. Space machine from China

Around 1000 AD, Su Song from China constructed a „space machine“ (Fig. 20). It was an exceptionally complex mechanism, which showed hours, days, months, seasons and years. It was 12 metres tall and consisted of 400 elements. It defined a year, which lasted 365 days, 5 hours, 49 minutes and 12 seconds. It was driven by a water wheel and comprised 400 parts. The machinery calculated the movement of the Earth and planets through space. It was considered to be an astronomic computer or cosmic globe. Su Song applied step mechanism in it. The machine was the most sophisticated mechanism of the middle ages.

In Song dynasty (2nd century AD), a Chinese Chang Cheng constructed the first seismograph in 132. However, modern seismographic machines did not start to be used earlier than the end of 19th century! The

machine signalled the occurrence and direction of an earthquake. There was a horizontal disc with cuttings, in the middle of which there was a reverse pendulum (Fig. 21) in a decorative brass body (Fig. 22). After moving the pendulum, the lever mechanism bows the head of the dragon; a ball falls out of its mouth and falls into the mouth of a brass toad. This is how it shows the direction of the earthquake and relevant measures can be undertaken. The machine was extremely sensitive. Within the period of 960-1272 AD, several inventions were created in China, such as paper, book printing, compass and gunpowder.

Figure 21. Chinese seismograph

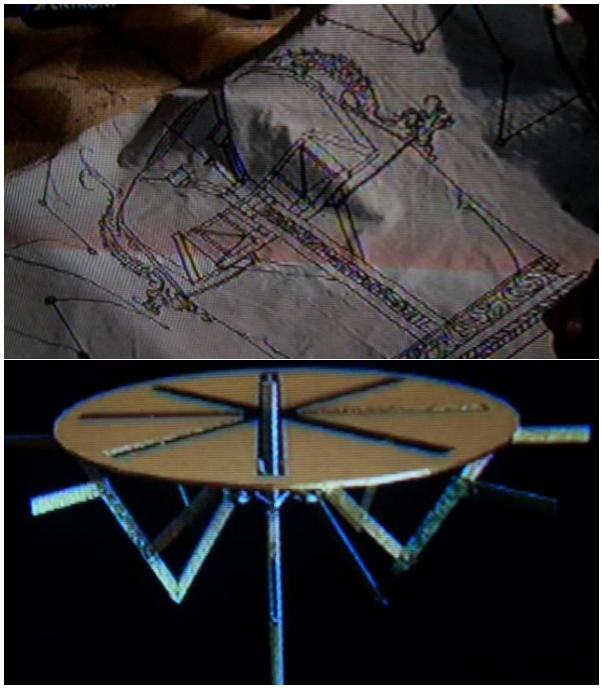

Figure 22. Seismograph mechanism; original drawing and model of mechanism (reverse pendulum)

Chinese technology brought outstanding inventions mainly in the 1st century AD. For instance, a signpost for directing army is interesting. At the beginning of the march, metal figure on the carriage was adjusted in the desired direction. It kept the direction however the carriage moved. The principle is shown in Fig. 23.

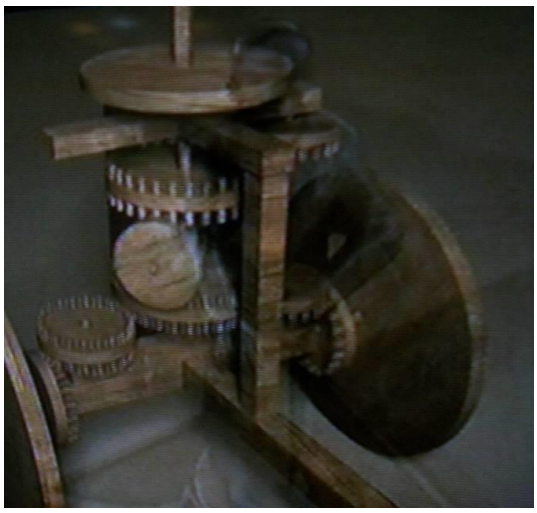

Figure 23. Chinese signpost of direction and its mechanism

There is the first use of a differential gear. Both wheels are independent and differential gear secures a steady position of the statue during movement forward and backward as well.

IV.CONCLUSION

Before mechanics was established as scientific field, people used natural forces, phenomena and relations without deeper explanation of their essence and

designed tools, equipment and machines since the dawn of human development. Mechanics started to develop as a part of philosophy (antique age, so-called natural philosophy) and later physics (ancient age, Middle Ages) since the start of the first civilisations as the paper presents them. Until today mechanics has overcome the way from classical mechanics (I. Newton) through relativistic one (A. Einstein) to quantum mechanics. On the way it has had to deal with the question of religion, which is the proof that it has always been a part of philosophy indirectly. In the previous century the humankind made an important step from understanding natural laws and trying to understand the space as a whole. [5]

Many times the history is presented on the principle from the simple to the more complex things – more developed things, which means the present. On the base of the study of the origins of mechanics, it can be observed that natural laws were sophisticatedly used long time ago too, although we might not have expected it, because we have been influenced by the classical, traditional explanation of history. However, very often the mankind only goes through repeated discovery. [4] Through detailed study of history, the people finds out that „it has all been here already". [2, 3]

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