DEFINITION OF WORK: UNSOLVED PROBLEM IN CLASSICAL MECHANICS

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Abstract

The critical analysis of the foundations of classical mechanics is proposed. Methodological basis of the analysis is the unity of formal logic and rational dialectics. The main results of the analysis of concepts “force”, “work” and “work of force” are the following statements: (1) the standard concept “work of force” contradicts to dialectics (practice) and formal logic because the concept “force” is a general abstract concept. The concept “force of interaction of material objects” is a general concrete concept because this concept expresses the property (feature, sign, quality) of the interaction of material objects. But the property does not perform the work because the property is not a material object. Work is performed by a controllable (operated) material object. Consequently, the standard mathematical definition of work is an incorrect relationship; (2) the concept “force of interaction of material objects” can only be defined in a genetic way: one should measure the force of interaction with the help of a dynamometer. The dynamometer reading represents the value of the measured quantity (force). If the measured quantity (force) is a variable quantity, then a change of this quantity (force) is called the movement of this quantity (force). But if the force is a constant quantity, then the movement of the force does not exist. Consequently, the standard mathematical definition of work is an incorrect relationship; (3) the position of the force in the coordinate system cannot be determined because a force is not a material object, and the quantity of the force does not have the dimension (measure) “meter”. This signifies that: (a) a force does not exist in the material coordinate system; (b) a force does not exist on the material path; the path length (distance) for force does not exist. Consequently, force cannot move over a distance that has the dimension “meter”. This signifies that the standard mathematical definition of work is an incorrect relationship; (4) in point of view of dialectics, work and energy are nonidentity concepts. Work is the activity of man, a robot, a controllable machine created by man. Work represents a rational, reasonable, well-directed, purposeful, purposive activity which manifested in the informational and material change of reality. This activity is the impossible if intellectual, informational, energy, and material resources do not exist.

Thus, the standard mathematical definition of the work of force is a formal-logical, dialectical (practical), and physical errors.

Keywords: general physics, classical mechanics, Newtonian mechanics, mathematical methods in physics, formalisms in classical mechanics, education, philosophy of science, history of science.

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Introduction

Science as a human means of cognition of the world is a system of concepts. Concepts are the starting point and foundations of theories. Correct definitions of concepts are possible only within the framework of the correct methodological basis: the unity of formal logic and rational dialectics. The unity of formal logic and rational dialectics represents the correct criterion of truth.

Recently, it has become obvious that the standard foundations of theoretical physics and mathematics do not satisfy the correct criterion of truth [1-133]. The existence of methodological errors in the works of the classics of sciences is explained by the fact that sciences are developed by the inductive way: by "negation of negation". Negation of the "old" theories is possible if and only if one questions the "old" theories within the framework of the correct methodological basis. But the analysis of theories is idle talk (empty words) if the analysis is not performed within the framework of the correct methodological basis.

As is known [134-144], classical mechanics as a branch of physics arose from the needs of sciences and practice and has a long history of development. The important significance of classical mechanics is determined by the contribution of the prominent scientists of past time: J. Kepler, Galileo Galilei, I. Newton, J. L. Lagrange, W. R. Hamilton, et al. Classical mechanics created by the prominent scientists operates with the concepts "vector", "force", "work", "work of force", etc. Currently, these concepts are widely used in physics because they seem customary, understandable, and clear to physicists. But, in my opinion, the concepts "vector", "force", "work", and "work of force" do not satisfy the correct criterion of truth: they are shaky, unstable, pseudo-scientific concepts. The purpose of this work is to propose the critical analysis of the concepts "work" and "work of force" within the framework of the correct methodological basis: the unity of formal logic and rational dialectics. The dialectical analysis is based on the dialectical concept of measure: the measure of material object is the unity of qualitative and quantitative determinacy of the material object; the measure of physical quantity is the unity of qualitative and quantitative determinacy of the physical quantity. The formal-logical analysis is based on the law of identity and the law of lack of contradiction: the correct mathematical equation represents the relationship between the identical measures of the identical physical quantities. This signifies that the sides of the mathematical equation must have identical measures, i.e. both sides of the mathematical equation must belong to identical qualitative determinacy.

1. The correct definition of the concept of force

Force is not a material object. Force is not a property of a material object. "Force is a property of the material structure of the system of the material elements (material objects). Force as a property of the material interaction of the elements of the system of the objects can be depicted as follows:

Figure 1. Illustration of the material structure of the system of the interacting material objects N and M. The force of the interaction is a property of the structure (i.e., the property of the interconnection of the objects N and M). The arrows depict the directions of the force.

(The material objects N and M can be connected by material straight-line segment. But the material straight-line segment is not a force). The force of the interaction between two objects N and M is depicted as imaginary straight-line segment with two arrows (arrowhead) at the endpoints. The two arrows show (indicate) the directions of the force. The endpoints of the segment represent the two points of application (apposition) of the force of the interaction: one end shows (indicates) the point of application (apposition) of the force to the object N, the other end shows (indicates) the point of application (apposition) of the force to the object M. The segment with only one point of application (apposition) of force and with only one arrow does not represent force in general and the force of the interaction because such segment has no physical meaning: force is always the force of the interaction. In other words, the interaction force is a single force,

$$F^{NM} \equiv F^{MN} \equiv F^{(\text{interaction})},$$

which cannot be decomposed into two independent components: the action force $F^{(action)}$ and the counteraction force $F^{(counteraction)}$. The action force does not exist without the counteraction force; the counteraction force does not exist without the action force.

Mathematical expression

$$F^{NM} - F^{MN} \equiv 0$$

signifies the complete extermination of the interaction force, i.e.,

$$F^{(\text{interaction})} \equiv 0.$$

Therefore, the standard relationship

$$\vec{F}^{(action)} = -\vec{F}^{(counteraction)}$$

represents an error.

9. In the dialectical point of view, the force of the interaction of the material objects N and M represents the unity of opposite aspects: action and counteraction. In formal-logical point of view, the unity of opposites does not signify the identity of the opposites because the opposite concepts are in the relation of the collateral subordination. (In other words, this concepts are collaterally subordinated concepts). The force of interaction of the material objects N and M is a concrete concept and is measured in the units "$kg\,f$" by a dynamometer. The general concept "force" is an abstract concept.

10. In formal-logical point of view, the concepts "action" and "counteraction" are dissenting concepts. There are no relation of identity, relation of subordination, and relation of partial coincidence between these concepts. The logical relation between the concepts "action" and "counteraction" is the relation of disagreement: one concept eliminates another concept; both the concepts cannot be applied to the same object. (For example, the concept "action" characterizes the active object N, the concept "counteraction" characterizes counteracting object M). These concepts are collaterally subordinated and opposite concepts: the scopes (volumes) of these two concepts enter into the scope (volume) of another – more general – concept "interaction" as a "unity of opposites". Therefore, the concepts "action" and "counteraction" are connected by the following formal-logical law of lack (absence) of contradiction:

$$(action) \neq (counteraction).$$

The relationship

$$F^{NM} \equiv F^{MN} \equiv F^{(\text{interaction})}$$

satisfies the following formal-logical law of identity:

(interaction force) = (interaction force).

Consequently, the standard assertion that

(action force) = (counteraction force)

represents violation of the formal-logical law of lack (absence) of contradiction.

Thus, Newton's doctrine of force is incorrect" [114-117, 120].

2. System approach to the analysis of the concept of work

In the point of view of formal logic, force is a general abstract concept. Therefore, force does not do a work. Work is done by one material object on another material object.

1. The concept of work can be analyzed within the framework of the system approach as follows. If the material system represents the unity of the following elements (Figure 2): the hoisting crane (with the steel cable c), the cargo (concrete slab), the dynamometer D, the building yard, - then the hoisting crane performs the work of lifting the cargo (concrete slab) over the building yard.

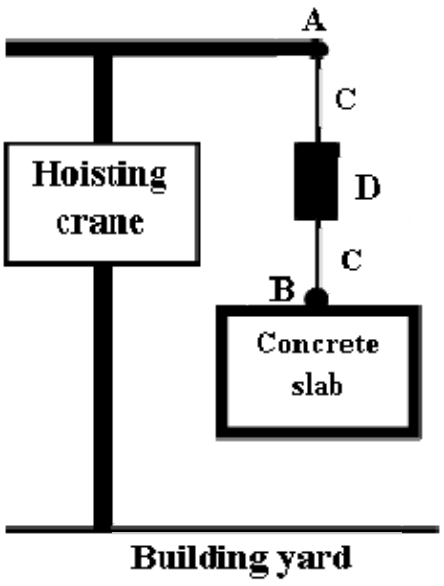

Figure 2. Lifting of the cargo (concrete slab) is the work which is performed by the hoisting crane. c is a steel cable; D is a dynamometer which measures the confining force of the steel cable c.

In this case, the hoisting crane is the active subsystem (object, element A) that does the work; the cargo (concrete slab) is a passive subsystem (object, element B) that is exposed to influence (i.e., B is the subsystem on which work is performed). The steel cable c that connects the crane point A and the point B of the cargo (concrete slab) represents the material means of connection of the points (elements) A and B. The steel cable c holds the cargo (concrete slab) over the building yard.

2. In a practical point of view, the operation of the crane is manifested in the fact that the steel cable c lifts the cargo (concrete slab) with the speed $v^{(cargo)} = const$ to a height $h^{(cargo)}$ relative to the building yard. (In other words, change in the length $l^{(c)}$ of the steel cable c leads to a change in the position of cargo (concrete slab) relative to the building yard). The dynamometer D measures the weight $F^{(cargo)}$ of the cargo (concrete slab). The dimension of the weight is "kilogram-force (kgf)". The dynamometer reading is independent of the length $l^{(c)}$ of the steel cable c and the speed $v^{(cargo)} = const$.

3. In a physical point of view, the force $F^{(terrestrial\ attraction\ of\ cargo)}$ of attraction of the cargo (concrete slab) to the Earth — i.e. the weight $F^{(cargo)}$ of the cargo (concrete slab) — is a constant and determines the confining (holding) force $F^{(confining)}$ of the steel cable. The confining (holding) force $F^{(confining)}$ of the steel cable is equal $F^{(terrestrial\ attraction\ of\ cargo)}$ if the cargo moves at a constant speed. In other words, the force $F^{(terrestrial\ attraction\ of\ cargo)}$ is balanced (counterpoised) by the confining (holding) force of the steel cable c:

$$F^{(terrestrial\ attraction\ of\ cargo)} \equiv F^{(cargo)} = F^{(confining)} = const$$
$$\text{under } v^{(cargo)} = 0 \text{ or } v^{(cargo)} \neq 0.$$

As the dynamometer shows, the relationship

$$F^{(terrestrial\ attraction\ of\ cargo)} \equiv F^{(cargo)} = F^{(confining)} = const$$

does not change under lifting the cargo (concrete slab) over (above) the building yard. Change in the steel cable length $l^{(c)}$ and change in the quantity $h^{(cargo)}$ do not signify the movements of the quantities $F^{(cargo)}$ and $F^{(confining)}$. The quantities $F^{(cargo)}$ and $F^{(confining)}$ do not move over the distance because the force does not represent the cargo (concrete slab). The movement of the cargo (concrete slab) in a certain reference frame is a change in the position of the cargo (concrete slab) in this reference frame.

4. A change in the length $l^{(c)}$ of the steel cable c and a change in the quantity $h^{(cargo)}$ characterize the operation (work) of the crane. The cargo (concrete slab) moves because the moving steel cable c imparts momentum $p^{(cargo)} = m^{(cargo)} v^{(cargo)}$ (where $m^{(cargo)}$ is cargo's mass, $v^{(cargo)} \neq 0$) to the cargo (concrete slab). The dynamometer reading does not change under $0 < v^{(cargo)} = const$. The moving cargo (concrete slab) has the kinetic energy $E^{(cargo)} = m^{(cargo)} \left(v^{(cargo)}\right)^2$. Consequently, the work of the crane on the cargo is characterized by three quantities: the momentum $p^{(cargo)} \neq 0$, the energy $E^{(cargo)} \neq 0$, and the time $t \neq 0$. Work does not exist under $v^{(cargo)} = 0$.

5. As is known, the system principle reads as follows: the properties of the system determine the properties and the interconnections of the elements of the system; the properties and the interconnections of the elements of the system characterize the properties of the system. The operation (work $W^{(crane)}$) of the crane is a property of the subsystem. The quantity $W^{(crane)}$

depends on the following quantities: $F^{(cargo)}$, $0 < v^{(cargo)} = const$, $h^{(cargo)} = v^{(cargo)} t$, $t > 0$. In accordance with practice and methodological basis, the quantity of work $W^{(crane)}$ of the crane is expressed in the following proportions:

$$\left(\frac{W^{(crane)} - W_0^{(crane)}}{W_0^{(crane)}} \right) = \left(\frac{\mathrm{E}^{(cargo)} - E_0^{(cargo)}}{E_0^{(cargo)}} \right),$$

$$W^{(crane)} = \left(\frac{W_0^{(crane)}}{E_0^{(cargo)}} \right) E^{(cargo)};$$

$$\left(\frac{W^{(crane)} - W_0^{(crane)}}{W_0^{(crane)}} \right) = \left(\frac{\mathrm{h}^{(cargo)} - h_0^{(cargo)}}{h_0^{(cargo)}} \right), \quad F^{(cargo)} = const;$$

$$\left(\frac{W^{(crane)} - W_0^{(crane)}}{W_0^{(crane)}} \right) = \left(\frac{\mathrm{F}^{(cargo)} - F_0^{(cargo)}}{F_0^{(cargo)}} \right), \quad h^{(cargo)} = const$$

where $W_0^{(crane)}$ is a certain value of unknown quantity $W^{(crane)}$ which should be determined on base of dialectics (practice); $F_0^{(cargo)}$ and $h_0^{(cargo)}$ are certain values of known quantities.

6. The relationships

$$W^{(crane)} = E^{(cargo)}, \quad W^{(crane)} = F^{(cargo)} h^{(cargo)}, \quad W^{(cargo)} = F^{(cargo)} h^{(cargo)}$$

contradict to the formal-logical law of identity and the law of lack of contradiction, respectively:

$$W^{(crane)} = W^{(crane)}, \quad E^{(cargo)} = E^{(cargo)} \qquad \text{(the law of identity);}$$

$$W^{(crane)} \neq E^{(cargo)}, \quad W^{(crane)} \neq W^{(cargo)} \qquad \text{(the law of lack of contradiction).}$$

7. In accordance with practice, confining (holding) force of the steel cable c is not the lifting force of the cable c. Confining (holding) force of the steel cable c is the force that holds the cargo (concrete slab) over the building yard. Confining (holding) force of the cable c is a physical property of the steel cable c. In the point of view of dialectics (practice), the moving steel cable c and confining (holding) force (as a physical property) of the steel cable c do not perform the work.

8. Work is performed by the hoisting crane due to the expended internal energy $E^{(crane)}$ of the crane. But $W^{(crane)} \neq E^{(crane)}$ because the qualitative determinacy (essence) of work is not identical with the qualitative determinacy (essence) of energy. The expended internal energy of the crane is the energy expended by the internal combustion engine. The cable c is only a material means of transmission of movement from an internal combustion engine of the hoisting crane to the cargo. The energy expended by the internal combustion engine cannot be expressed (i.e. calculated theoretically) with the help of the quantities $F^{(cargo)}$, $0 < v^{(cargo)} = const$, $h^{(cargo)} = v^{(cargo)} t$. The power of the internal combustion engine is independent of the quantities $F^{(cargo)}$, $0 < v^{(cargo)} = const$, $h^{(cargo)} = v^{(cargo)} t$. The expended energy and power of the engine can only be determined experimentally if someone knows reliably, authentically, substantively what are energy and power.

3. Incorrect definition of work

1. The standard mathematical definition $W = Fl$ of work can be concretized as follows:

$$W^{(\,extraneous\ \ force\,)} = F^{(\,extraneous\,)}\, l^{(\,extraneous\ \ force\,)}$$

(where W is the work performed by the moving force F; F is the force acting (moving) over the distance l. The dimension of work is ML^2T^{-2}). The definition of work in the concrete form satisfies the formal-logical law of identity because the left and right sides of the relationship have identical qualitative determinacy. This qualitative determinacy expresses the standard concept "work of force".

2. But does the right side of the standard definition have sense? The answer is the followings. The standard concept "work of force" contradicts to dialectics (practice) and formal logic because the concept "force" is a general abstract concept. (An abstract concept is a concept of a property of a material object if a property is considered as an independent object of thought). The concept "force of interaction of material objects" is a general concrete concept because this concept expresses the property (feature, quality) of the interaction of material objects. But the property does not perform the work because the property is not a material object. Work is performed by a material object. Consequently, the standard definition $W = Fl$ of work is an incorrect relationship.

3. The concept "force of interaction of material objects" can only be defined in a genetic way: one should measure the force of interaction by the use of dynamometer. The dynamometer reading represents value of the measured quantity (force). If the measured quantity (force) is a variable quantity, then a change of this quantity (force) is called the movement of this quantity (force). But if the force represents a constant quantity, then the movement of the force does not exist. Consequently, the standard definition of work is an incorrect relationship.

4. The position of the force in the coordinate system cannot be determined because a force is not a material object, and the quantity of the force does not have the dimension "meter". This signifies that: (a) force does not exist in the material coordinate system; (b) force does not exist on the material path; the path length (distance) for force does not exist. Consequently, a force cannot move over a distance that has the dimension "meter". This signifies that the standard definition of work is an incorrect relationship.

Thus, the standard mathematical definition of work represents formal-logical, dialectical (practical), and physical errors.

4. Discussion

1. Classical mechanics created by G. Galilei, Ch. Huygens, I. Newton et al. operates with the concepts "vector", "force", "work", "work of force", etc. Generations of physicists believed in the statement that "work is energy dissipated by a force moving over a distance; work is scalar product of the force and the movement vector. Dimension of work is "joule". Energy is the capacity of a body or system to do work; energy is extensive, scalar quantity. Dimension of energy is "joule"" (Wikipedia).

Because of lack of wisdom, physicists fall into the trap called pseudo-science. Pseudo-science ignores the correct methodological basis: the unity of formal logic and rational dialectics. Therefore, pseudo-science does not have a logical and dialectical certainty. If pseudo-science identifies the concept "work" with the concept "energy", then thoughtlessness is manifested in the following formal-logical errors: (a) tautology in the definition (in Latin: "idem per idem"), i.e. the definable object (quantity) is defined through itself; (b) the definition of an unknown object (quantity) through an unknown object (quantity) (in Latin: "ignotum per ignotus").

2. In terms of dialectics, work and energy are nonidentity concepts. Work is the activity of man, a robot, a machine created by man. Work is the rational, reasonable, well-directed, purposeful, purposive activity which represents the informational and material change of reality.

3. The development of “rational thinking” (Werner Heisenberg) in rising generation of scientists is urgent problem of our time. Only rational thinking can exterminate (eliminate, remove) errors in sciences.

Conclusion

Thus, the correct scientific analysis of the generally accepted foundations of classical mechanics is possible only within the framework of the correct methodological basis: the unity of formal logic and rational dialectics. The results of the correct analysis of concepts “force”, “work”, and “work of force” are the following statements:

1) the standard concept “work of force” contradicts to dialectics (practice) and formal logic because the concept “force” is a general abstract concept. The concept “force of interaction of material objects” is a general concrete concept because this concept expresses the property (feature, quality) of the interaction of material objects. But the property does not perform the work because the property is not a material object. Work is performed by a material object. Consequently, the standard definition $W = Fl$ of work is an incorrect relationship;

2) the concept “force of interaction of material objects” can only be defined in a genetic way: one should measure the force of interaction with the help of a dynamometer. The dynamometer reading represents the measured quantity (force). If the measured quantity (force) is a variable quantity, then a change of this quantity (force) is called the movement of this quantity (force). But if the force is a constant, then the movement of the force does not exist. Consequently, the standard definition $W = Fl$ of work is an incorrect relationship;

3) the position of the force in the coordinate system cannot be determined because the force is not a material object, and the quantity of the force does not have the dimension “meter”. This signifies that: (a) force does not exist in the material coordinate system; (b) force does not exist on the material path. Consequently, the force cannot move over the distance l that has the dimension “meter”. This signifies that the standard definition $W = Fl$ of work is an incorrect relationship.

4) In terms of dialectics, work and energy are nonidentity concepts. Work is the activity of man, a robot, a machine created by man. Work is the rational, reasonable, well-directed, purposeful, purposive activity which manifested in the informational and material change of reality.

Thus, the standard mathematical definition of the work of force is a formal-logical, dialectical (practical), and physical errors.

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