

Astro2020 Science White Paper

Theory of motion with historical perspective.

Thematic Areas:

[Cosmology and Fundamental Physics](#)

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Abstract: Discussion of the theory of motion from Aristotle to Newton

“And Newton's law itself? Its simplicity, so long undetected, is perhaps only apparent. Who knows if it be not due to some complicated mechanism, to the impact of some subtle matter animated by irregular movements, and if it has not become simple merely through the play of averages and large numbers? In any case, it is difficult not to suppose that the true law contains complementary terms which may become sensible at small distances. If in astronomy they are negligible, and if the law thus regains its simplicity, it is solely on account of the enormous distances of the celestial bodies. No doubt, if our means of investigation became more and more penetrating, we should discover the simple beneath the complex, and then the complex from the simple, and then again the simple beneath the complex, and so on, without ever being able to predict what the last term will be. We must stop somewhere, and for science to be possible we must stop where we have found simplicity. That is the only ground on which we can erect the edifice of our generalisations. But, this simplicity being only apparent, will the ground be solid enough? That is what we have now to discover....

For this purpose let us see what part is played in our generalisations by the belief in simplicity. We have verified a simple law in a considerable number of particular cases. We refuse to admit that this coincidence, so often repeated, is a result of mere chance, and we conclude that the law must be true in the general case....

Role of Hypothesis. — Every generalisation is a hypothesis. Hypothesis therefore plays a necessary role, which no one has ever contested. Only, it should always be as soon as possible submitted to verification.... It took into account all the known factors which seem capable of intervention in the phenomenon. If it is not verified, it is because there is something unexpected and extraordinary about it...It may be even said that it has rendered more service than a true hypothesis.

Conversely, if the experiment succeeds, must we suppose that it has verified all these hypotheses at once? Can several unknowns be determined from a single equation?...

We must also take care to distinguish between the different kinds of hypotheses. First of all, there are those which are quite natural and necessary.

It is difficult not to suppose that the influence of very distant bodies is quite negligible, that small movements obey a linear law, and that effect is a continuous function of its cause.

I will say as much for the conditions imposed by symmetry.

All these hypotheses affirm, so to speak, the common basis of all the theories of mathematical physics. They are the last that should be abandoned. There is a second category of hypotheses which I shall qualify as indifferent. In optical theories two vectors are introduced, one of which we consider as a velocity and the other as a vortex. This again is an indifferent hypothesis, since we should have arrived at the same conclusions by assuming the former to be a vortex and the latter to be a velocity. The success of the experiment cannot prove, therefore, that the first vector is really a velocity. It only proves one thing—namely, that it is a vector; and that is the only hypothesis that has really been introduced into the premisses. To give it the concrete appearance that the fallibility of our minds demands, it was necessary to consider it either as a velocity or as

a vortex. In the same way, it was necessary to represent it by an x or a y , but the result will not prove that we were right or wrong in regarding it as a velocity; nor will it prove we are right or wrong in calling it x and not y .

“The Role of Experiment and Generalisation. — Experiment is the sole source of truth...

However, mathematical physics exists. It has rendered undeniable service, and that is a fact which has to be explained....

Experiment only gives us a certain number of isolated points. They must be connected by a continuous line, and this is a true generalisation. But more is done. The curve thus traced will pass between and near the points observed; it will not pass through the points themselves.

This simplicity, real or apparent, has always a cause... The simplicity of Kepler's laws, for instance, is only apparent; but that does not prevent them from being applied to almost all systems analogous to the solar system, though that prevents them from being rigorously exact. ...

However solidly founded a prediction may appear to us, we are never *absolutely sure* that experiment will not prove it to be baseless if we set to work to verify it. But the probability of its accuracy is often so great that practically we may be content with it...

We draw a continuous line as regularly as possible between the points given by observation. Why do we avoid angular points and inflexions that are too sharp? Why do we not make our curve describe the most capricious zigzags? It is because we know beforehand, or think we know, that the law we have to express cannot be so complicated as all that. The mass of Jupiter may be deduced either from the movements of his satellites, or from the perturbations of the major planets, or from those of the minor planets. If we take the mean of the determinations obtained by these three methods, we find three numbers very close together, but not quite identical. This result might be interpreted by supposing that the gravitation constant is not the same in the three cases; the observations would be certainly much better represented. ***Why do we reject this interpretation? Not because it is absurd, but because it is uselessly complicated.*** (Henri Poincare Science and Hypothesis Chapter 9: Hypotheses in Physics pp 140, 143-145 149-150)

Cor. III. And universally, if equally swift bodies are resisted in the ratio of any power of the diameters, the spaces, in which the homogeneous globes, moving with any velocity whatsoever, will lose parts of their motions proportional to the wholes, will be as the cubes of the diameters applied to that power. Let those diameters be D and E ; and if the resistances, where the velocities are supposed to be equal, are as D^n and E^n ; the spaces in which the globes, moving with any velocities whatsoever, will lose parts of their motions proportional to the wholes, will be as D^{3-n} and E^{3-n} . And therefore homogeneous globes in describing spaces proportional to D^{3-n} and E^{3-n} , will retain their velocities in the same ratio to one another as at the beginning.” (Isaac Newton Mathematical Principals Book II The Motion of Bodies Page 107).

After Galileo and Newton the emphasis in studying dynamics and kinematics has been shifted from philosophy of motion transformation in kinematics with growing number of new problems solved. However, the existed controversy for around 2,000 years before them indicates different opinions on motion.

The year Fermat began work on analytic geometry, even before Galileo's publication of his research on the motion, Cornier, Descartes, and Beeckman tried in letters to persuade Mersenne, who later convinced himself that in the motion of free fall "the spaces grow in the duplicate ratio of the times." However, from the correspondence of Descartes and Mersenne and from requested by Mersenne answers to Descartes, written by Pierre Gassendi in "Impressed by the Mover of the Motion" along with his experiment on Theory of Galileo's transformation described in Galileo's "Dialogue Concerning the Two Chief World Systems" that performed it in the presence of Louis de Valois, Governor of the Provence in Marseilles with dropped ball on resting or fast moving ship, it is possible to learn about Descartes consequent disbelief in this dependence.

Galileo in his works advanced experiment and observation as scientific method to prove mathematical description of a phenomenon, and is credited with invention of the dynamics as a mathematical science for his doctrines in kinematics of distance proportional to the square of time interval for motion with constant acceleration starting from rest and with the doctrine of independence of mass and time in dynamics with his famous Tower of Pisa experiment with falling balls of different masses versus the doctrine of Aristotle "If one weight is twice another, it will take half as long over a given movement." (Book 1, On the Heavens).

The usual interpretation of the above statement, as it is presented by physics teachers is that $\text{Force}(F) = \text{mass}(m) * \text{velocity}(v)$, though there are possible other explanations, the most common is that it is related to arrows or the like, following Aristotle's suggestion that in case of such objects would continue to stay above the ground even when nothing is touching them, displaced air provides the force. Another possible explanation was given by Khuram Rafique, the author of "A Philosophical Rejection of The Big Bang Theory" by his interpretation of "Newton's second Law is $F = mv$ which can also be written as $F/t = ma \dots$ (i.e. only CONSTANTLY applied force can produce acceleration. Mere force does not produce acceleration.)" with the possible mention of idea that can be found in the huge Mersenne's correspondence on the subject, partially mentioned above, and possibly corresponds to the Britannica's description of Newton's Second Law that "states that the time rate of change of the momentum of a body is equal in both magnitude and direction to the force imposed on it. The momentum of a body is equal to the product of its mass and its velocity." In this context it is possibly was first developed by Alexandrian philosopher John Philoponus, who criticised and modified Aristotle's theory of motion 15 centuries ago to account for the motion of arrows to acquire temporary motive power, and contradicted Aristotle with the statement: "If you drop two weights, one much heavier than the other, from the same height, you will observe that the difference in time to fall is much less than the difference in their weights. If one is double the weight of the other, there will be no difference, or an undetectable difference in time." Some 750 years later French philosopher Jean

Buridan developed theory of impetus(momentum) to state that it is equal to weight multiplied by velocity.

The author some 35 years ago, studied some Hebrew Text dated the time of Philoponus and written somewhere northeast from present Italy that stated Newton's Second Law.

The author's explanation that was presented to professor Cvitanic of Columbia University some 20 years earlier and was based on the analysis of Aristotle's works on the whole that tend to integrate most of the objects in different subjects of investigation, and considering that all the prominent contemporary philosophers, physicists, and mathematicians in time of Galileo and Newton turned to analytical geometry with tendency to the philosophy of quadratic forms, was that Aristotle's scientific approach was to find solution in the form so called "in quadratures":

$F = ma$, where a is acceleration, but the solution is sought in form of integral over time

$\int ma dt = -mv + C$ that suggests Second and Third Newton's Laws with some constant C that can be determined from given conditions in different problems. It is possible that it is implied Newton's First Law, the law of inertia. The history of Greek mathematics suggests that they worked with continuous curves

Newton's First Law states that a body at rest or moving at a constant speed in a straight line would remain at rest or moving at the same speed in a straight line unless the force is applied and is called the law of inertia.

Newton's Second Law states that $F = ma$.

Newton's Third Law of action and counteraction states that the forces applied to two interacting bodies are equal in magnitude and opposite in direction.

Almost 5 centuries after Philoponus Iranian philosopher Abu Rayhan al-Biruni related acceleration to non-uniform motion in about 1021. And a century later, some 550 years before Newton's Second Law Iraqi philosopher Abu'l-Barakāt al-Baghdaī applied the result to state that force is proportional to acceleration. Around the same time Ibn Bājjah suggested Newton's Third Law that for every force there is a reaction force. And around the same time Al Khazini in the "Book of the Balance of Wisdom" wrote: "The weight of any heavy body of known weight at a particular distance from the center of the world varies according to the variation of its distance therefrom; so that as often as it is removed from the center, it becomes heavier, and when brought near to it, is lighter. On this account, the relation of gravity to gravity is as the relation of distance to distance from the center."

Dependence of the time it took the balls to fall was proportional to the square root of the distance they travelled described by Galileo, had been already discovered by French mathematician Nicole Oresme 3 centuries before.

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