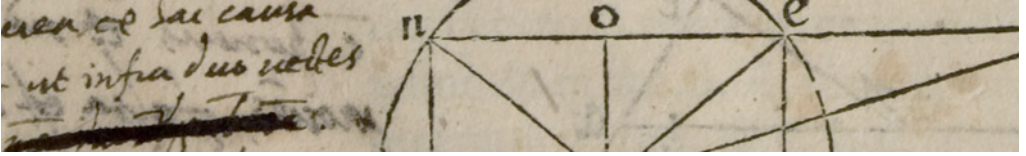


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## The Equilibrium Controversy

A case study of the long-term development of mechanical knowledge

By Jürgen Renn

The equilibrium controversy is concerned with the question of whether a balance in equilibrium, after being deflected, returns to its original position. This seemingly trivial question captured the imagination of philosophers and scientists for almost two millennia, from Greek antiquity to the sixteenth century when it became a central question among scholars such as Guidobaldo del Monte and Giovanni Battista Benedetti. In the course of the equilibrium controversy a key aspect of mechanical knowledge—the understanding of the positional effect of a weight or a force—was clarified as the result of a long-term historical development. Modern concepts such as ‘torque’ and ‘potential energy’ have their roots in this development, which goes back to antiquity and culminates in Renaissance science.

Since ancient times, scales have symbolized justice and equilibrium. Balance and equilibrium in this wider sense are fundamental to the human condition, but what about the real, physical balance and its equilibrium? Does a

balance in equilibrium, after being deflected from its normal horizontal position, remain in the deflected position, return to its original position, or tilt to the vertical? This question has no immediate practical relevance and

certainly no fundamental significance for the human condition. Nevertheless, it became a key issue of controversy among scholars in the sixteenth century. A conclusive answer to this question, however, was not found until the firm establishment of classical physics in the eighteenth and nineteenth centuries, and even then there were still aspects that provoked controversial discussion.



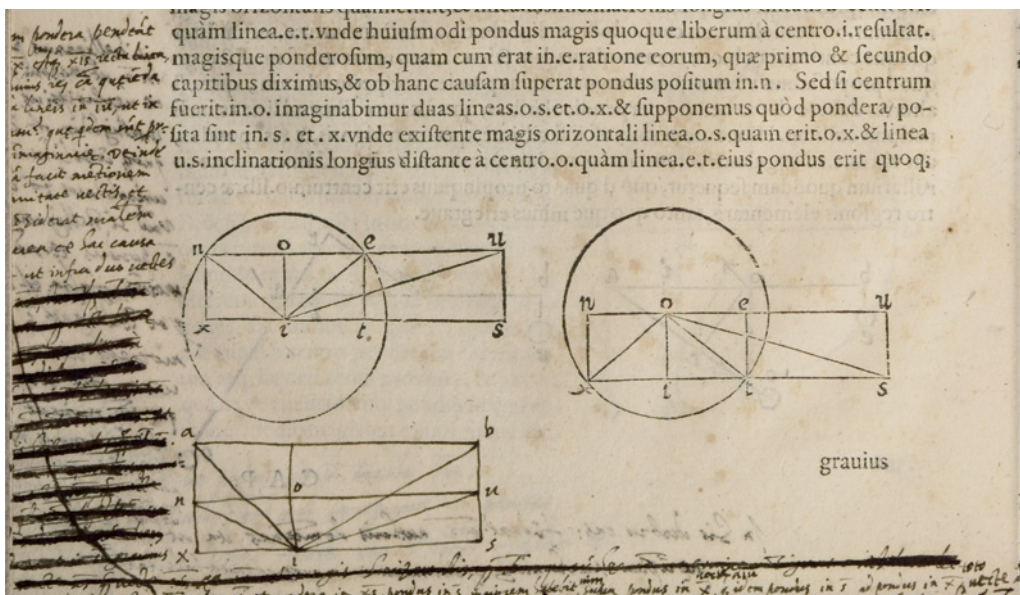
Title vignette of Apianus' edition of Jordanus' *Liber de ponderibus* (1533) showing a scholar and a practitioner. The scholar explains the functioning of a steelyard according to Aristotelian principles. Courtesy Linda Hall Library.

Why was it so difficult to resolve this question? Can a few simple experiments not settle the issue? The answer to such elementary questions about the progress of physics can only be found if we take into account the role that the historical development of fundamental concepts such as 'force,' 'weight,' 'center of gravity,' and 'torque' have played in understanding seemingly simple physical problems such as those that formed part of the equilibrium controversy. And the nature of the historical evolution of mechanical knowledge, as the subject of an historical epistemology, can only be understood if one real-

izes that this evolution was not a linear process, but rather involved an extensive restructuring of knowledge accompanied by concept developments in the sciences that dealt with this knowledge.

Classical mechanics is often considered to be the most pure, abstract and rational of the physical sciences. It is hence natural to assume that its historical development must also have been essentially a history of linear progress, or at least of the steady accumulation of knowledge. This may have suffered interruptions and aberrations, but it nevertheless tended to reach clear conceptual foundations based on the consideration of idealized objects such as the balance described above. One aspect that becomes particularly evident when following the equilibrium controversy is the role historical contingencies played for conceptual development at the heart of mechanics. There is, first of all, the contingency of those aspects of the material culture that become the object of scientific enquiry. These could include the balance, the pendulum, an elixir, or even the shadow of a gnomon. Then there is the contingency of the social and cultural conditions under which knowledge is recorded, transmitted, and appropriated, including the losses and transmutations occurring in such processes. Such losses and transmutations not only acted as disturbances in an otherwise linear progress toward clarity, but they also determined, to a large extent, the very nature of concept development in mechanics.

In 2006 the library of the Max Planck Institute for the History of Science acquired a copy of the first edition of Giovanni Battista Benedetti's *Diversarum speculationum mathematicarum et physicarum liber* (1585). While Benedetti's



Guidobaldo del Monte's annotations to the fourth chapter "Quemadmodum ex supra dictis causis omnes staterarum et vectium causae dependeant" of Giovanni Battista Benedetti's *Diversarum speculationum mathematicarum et physicarum liber* (1585). MPIWG, library.

book is itself an important source for understanding the struggles of early modern engineer-scientists with the ancient heritage of the mechanical knowledge of Aristotle, Archimedes and others, this specific copy is of particular value since it contains handwritten marginal notes by the leading expert on mechanics of the generation before Galileo: Guidobaldo del Monte, himself the author of the most influential Renaissance text on mechanics, the *Mechanicorum liber* (1577).

The contents of the notes indicate a strong criticism of Benedetti's theory. Guidobaldo's criticism concerns the central question of the equilibrium controversy: the behavior of a deflected balance. This controversy, however, only scratched the surface of a deeper-going conceptual crisis that is indicated by the introduction—based on medieval sources—of a new,

but ambiguous concept, the concept of 'positional heaviness.' This crisis of the conceptual foundations of early modern mechanics helped to establish fundamental insights on which Galileo eventually built his theory of mechanics, as well as his theory of motion. More precisely, they concern the various controversial attempts to replace the ancient concepts of 'force' and 'heaviness' in the context of the causal interpretation of motion by modified concepts that were used to address the more complex technical experiences of the early modern period.

The controversial opinions of Guidobaldo and Benedetti—as reflected in Guidobaldo's marginal notes on Benedetti's systematic treatment of the concepts of force and heaviness—concern core problems of reorganizing the conceptual framework of ancient mechanics.

In particular, Galileo's theory of motion along inclined planes, as well as many of his other characteristic themes, such as the motion of a pendulum, projectile motion, the motion of fall and even Copernicanism, were directly or indirectly related to the equilibrium controversy. In fact, Galileo's new science of motion would probably not have developed as it did without the insights he gained from Benedetti, or rather from the conflictual encounter between Benedetti's and Guidobaldo's perspectives on mechanics.

A new volume has been published which analyzes this controversy in detail: *The Equilibrium Controversy: Guidobaldo del Monte's Critical Notes on the Mechanics of Jordanus and Benedetti and their Historical and Conceptual Background* (Renn and Damerow, 2012). The volume mirrors research carried out within the project "Mental Models in the History of Knowledge: The Relation of Practical Experience and Conceptual Structures in the Emergence of Science." It is an assessment of two new sources related to the controversy on the deflected balance, equilibrium and heaviness. The first is del Monte's annotated copy of Benedetti's *Diversarum speculationum mathematicarum et physicarum liber*, and the second is his annotated copy of Jordanus de Nemore's *Liber de ponderibus* (Apianus' edition of 1533).

This volume has appeared as *Sources 2* of the series *Max Planck Research Library for the History and Development of Knowledge*. This

series presents historical documents in a new format that combines the advantages of traditional printed books with those of the digital medium. In each volume a source text relevant for the history of knowledge is reproduced, typically in facsimile, together with an introduction and commentaries reflecting original scholarly work. The volumes are available both as print-on-demand books and as open-access publications on the Internet. The material is freely accessible online at [www.edition-open-access.de](http://www.edition-open-access.de), supplemented by additional information and interactive features. The original works reproduced in this series are typically rare books or manuscripts that are not readily accessible in libraries.

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