## PREFACE

### *I*

I have always thought that the most sacred duty of men was to give their children an education that prevented them at a more advanced age from regretting their youth, the only time when one can truly gain instruction. You are, my dear son, in this happy age when the mind begins to think, and when the heart has passions not yet lively enough to disturb it.

Now is perhaps the only time of your life that you will devote to the study of nature. Soon the passions and pleasures of your age will occupy all your moments; and when this youthful enthusiasm has passed, and you have paid to the intoxication of the world the tribute of your age and rank, ambition will take possession of your soul; and even if in this more advanced age, which often is not any more mature, you wanted to apply yourself to the study of the true Sciences, your mind then no longer having the flexibility characteristic of its best years, it would be necessary for you to purchase with painful study what you can learn today with extreme facility. So, I want you to make the most of the dawn of your reason; I want to try to protect you from the ignorance that is still only too common among those of your rank, and which is one more fault, and one less merit.

You must early on accustom your mind to think, and to be self-sufficient. You will perceive at all the times in your life what resources and what consolations one finds in study, and you will see that it can even furnish pleasure and delight.

### *II*

The study of physics seems made for man, it turns upon the things that constantly surround us, and on which our pleasures and our needs depend. In this work, I will try to place this science within your reach, and to disengage it from this admirable art, called algebra, which separating things from images, eludes the senses, and speaks only to the understanding. You are not yet able to understand this language, which seems rather that of the mind than of the whole of man. It is reserved to be the study of the years of your life that will follow those of today; but the truth can take different forms, and I will try to give to it here that which suits your age, and only to speak to you of things that can be understood by resorting only to the standard geometry which you have studied.[31]

31. Du Châtelet is referring to Euclid's geometry (from the fourth century BCE), which she probably studied with her brother when he was just a bit younger than her son. She also stud-

UTILITY OF GEOMETRY.

Never cease, my son, to cultivate this science that you have learned from your very tender years. With no resort to it, one would hope in vain to make great progress in the study of nature. It is the key to all discoveries; and if there are still several inexplicable things in physics, that is because geometry has been insufficiently used to explain them, and one has perhaps not yet gone far enough in this science.

*III*

I am often surprised that so many clever people as France possesses have not preceded me in this work that I embark upon for you today. For, it must be admitted that, although we have several excellent books of physics in French, we have no complete book of physics, except the short treatise of Rohault, written eighty years ago.[32] But this treatise, although very good for the time when it was composed, has become very insufficient because of the quantity of discoveries that have been made since it was written; and a man who had studied physics only in this book, would still have many things to learn.

As for me, who in deploring this scarcity, am very far from believing myself capable of supplying it, I only propose in this work to gather together before your eyes the discoveries scattered in so many good Latin, Italian, and English books. Most of the truths they contain are known in France by only a few readers, and I want to spare you the trouble of drawing them from sources, the depth of which would frighten and might discourage you.

*IV*

Although the work I undertake requires much time and effort, I will not regret the trouble it will cost me, and I will believe it well spent if it can instill in you love of the sciences, and the desire to cultivate your reason. What trouble and what cares does one not give oneself every day in the uncertain hope of procuring honors and augmenting the fortune of one's children! Are the knowledge of the truth and the habit of looking for it and following it objects less worthy of my pains—especially in a century when a taste for

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ied with Alexis-Claude Clairaut (1713–1765), a gifted young mathematician, whose *Elémens de géométrie* (1749) was probably based on their lessons. According to the publisher of Du Châtelet's translation of and commentary on Newton's *Principia*, she also used them in lessons for her son.

32. Du Châtelet is referring to the standard French physics text of her day, the *Traité de physique* [Treatise of Physics] by Jacques Rohault (1618–1672), published in 1671. His was the leading explanation of the universe according to Descartes.

physics has reached all ranks, and is beginning to become a part of the science of the world?

*V*

I will not write for you here the history of the revolutions experienced by physics, a thick book would be needed to report them all. I propose to make you acquainted *less with what has been thought than with what must be known.*

Up to the last century, the sciences were an impenetrable secret, to which only the so-called learned were initiated; it was a kind of cabal,[33] the cipher of which consisted of barbarous words that seemed to have been invented to confuse the mind and to discourage it.

HOW MUCH WE OWE TO DESCARTES.[34]

Descartes appeared in that profound night like a star come to illuminate the universe. The revolution that this great man caused in the sciences is surely more useful, and perhaps even more memorable, than that of the greatest empires, one, it can be said, that human reason owes most to Descartes. For it is very much easier to find the truth, when once one is on the track of it, than to leave those of error. The geometry of this great man, his dioptrics, his method, are masterpieces of sagacity that will make his name immortal, and if he was wrong on some points of physics, that was because he was a man, and it is not given to a single man, nor to a single century, to know all.

We rise to the knowledge of the truth, like those giants who climbed up to the skies by standing on the shoulders of one another.[35] The Huygenses,

33. The word *Cabal* in both French and English suggests *cabbala*, secret arts known only to the learned.

34. Du Châtelet is referring to many aspects of René Descartes' (1596–1650) thinking and writings: his assertions about the authority of one's own reasoning from his *Discours de la methode* [Discourse on Method] (1637); and two of the three essays published with it: the *Géométrie* [Geometry], his development of analytic geometry; the *Dioptrique* [Dioptrics], his study of refraction in optics. Du Châtelet also read his *Principes de la philosophie* [Principles of Philosophy] (1723 ed.). His greatest error in physics from Du Châtelet's perspective would be his system of the universe, a universe of constantly moving particles that formed vortices that carried the planets in their orbits through impulsion, the impact of the particles on one another. By the end of the seventeenth century, Descartes' description of the universe had been accepted by Continental physicists and astronomers. Sir Isaac Newton wrote opposing his ideas in his *Philosophiae naturalis principia mathematica* [Mathematical Principles of Natural Philosophy]. Du Châtelet studied two of the three editions of the *Principia*, those from 1713 and 1726. She favored Newton's planetary system of universal attraction, and wrote the *Foundations* in part to give his ideas a metaphysical basis.

35. An often-quoted statement by Newton, originally from his 1676 letter to Robert Hooke (1635–1703), an English experimental philosopher.

and the Leibnizes learned from Descartes and Galileo, these great men who, so far, are known to you only by name, and with whose works I hope soon to make you acquainted.[36] It is by making the most of the works of Kepler, and using the theorems of Huygens, that M. Newton discovered this universal force spread throughout nature, which makes the planets circle around the Sun, and that operates as gravity on Earth.

*VI*

Today the systems of Descartes and Newton divide the thinking world, so you should know the one and the other; but so many learned men have taken care to expound and to correct Descartes' system that it will be easy for you to learn from their works. One of my aims in the first part of this work is to put before your eyes the other part of this great process, to make you acquainted with the system of M. Newton, to show you how far making connections and determining probability are pushed, and how the phenomena are explained by the hypothesis of attraction.

You can draw much instruction on this subject from the *Elémens de la philosophie de Newton* [Elements of the Philosophy of Newton], which appeared last year.[37] And I would omit what I have to tell you about that—Newton's system—if the illustrious author had embraced a vaster terrain; but he confined himself within such narrow boundaries that he made it impossible for me to dispense with my own exposition of this matter.

*VII*

Guard yourself, my son, whichever side you take in this dispute among the philosophers, against the inevitable obstinacy to which the spirit of partisanship carries one: this frame of mind is dangerous on all occasions of life; but it is ridiculous in physics. The search for truth is the only thing in which the

36. Christiaan Huygens (1625–1695), Dutch physicist, was most famous for his discoveries about the rings of Saturn, and his experiments with the pendulum to establish general principles of motion. Gottfried Wilhelm Leibniz (1646–1716) wrote numerous works on a wide range of philosophical and scientific subjects. Du Châtelet made his ideas about knowledge, the role of God in the universe, and the laws of motion the basis for chapters of her *Foundations*. Galileo Galilei (1564–1642), the Italian astronomer, physicist, and mathematician, was known in Du Châtelet's time for his experiments with falling bodies and his affirmation of the Copernican system of the universe. Johannes Kepler (1571–1630), the German mathematician and astronomer, is most famous as the discoverer of the elliptical path of the planets.

37. This was Voltaire's *Elements of the Philosophy of Newton*, a product of collaboration with Du Châtelet while at Cirey, published first in 1738 in an unauthorized Dutch edition. In the revised editions, Voltaire added sections that explicitly argued against Leibnizian philosophy and physics, the metaphysical ideas and the laws of motion that Du Châtelet presented in her *Foundations*.

love of your country must not prevail, and it is surely very unfortunate that the opinions of Newton and of Descartes have become a sort of national affair. About a book of physics one must ask if it is good, not if the author is English, German, or French.

DISCUSSIONS OF ATTRACTION.

It seems to me, moreover, that it would be just as unfair on the part of the Cartesians to refuse to admit attraction as a hypothesis as it is unreasonable of a few Newtonians to want to make it an inherent property of matter.[38] It must be admitted that a few among them have gone too far in this, and it is with some reason that they are reproached for resembling a man at the opera whose bad eyesight prevents him from seeing the ropes that make flights possible, and who, for example, on seeing Bellerophon suspended in the air, said: *Bellerophon is suspended in the air because he is pulled equally on all sides from the wings*. For, in order to decide that the effects the Newtonians attribute to attraction are not produced by impulsion, it would be necessary to know all the ways in which impulsion can be used, but we are still very far from knowing that.[39]

We are still in physics, like this man blind from birth whose sight Chiselden restored.[40] At first this man saw nothing but a blur; it was only by feeling his way and at the end of a considerable time that he began to see well. This time has not quite come for us, and perhaps will never come entirely; there are probably some truths not made to be perceived by the eyes of our mind, just as there are objects, that those of our body will never perceive. But he who refused to learn because of this limitation would resemble a lame person who, having a fever, would not take the remedies which can cure it, because these remedies would not stop him from limping.

*VIII*

38. Two of Newton's followers, Henry Pemberton (1694–1771) in his commentary on the *Principia*, *A View of Sir Isaac Newton's Philosophy*, and Roger Cotes (1682–1716) in his preface to the second edition of Newton's work (1713), took this position. Du Châtelet certainly had access to both of these books.

39. *Impulsion* was the term used to describe the collision of particles in Descartes' universe. It was possible to believe in attraction and to think that impulsion was somehow its cause. Du Châtelet's contemporaries, the mathematicians, Johann Bernoulli (1667–1748) and Leonhard Euler (1707–1783) took this position and rejected gravity as a property of matter. See chapter XI of the *Foundations* where Du Châtelet discusses their work, if indirectly. She corresponded with both of them.

40. William Chiselden (1688–1752) was an anatomist and the surgeon for Chelsea College in England.

HYPOTHESES ARE NECESSARY IN PHYSICS.

One of the mistakes of some philosophers of our time is to want to banish hypotheses from physics;[41] they are as necessary as the scaffolding in a house being built; it is true that, when the building is completed, the scaffolding becomes useless, but it could not have been erected without it. All of astronomy, for example, is founded only on hypotheses, and if they had always been avoided in physics, it seems that fewer discoveries would have been made. So nothing is more likely to delay the progress of the sciences than to want to banish them, and to persuade oneself that one has found the great mainspring that moves all of nature, for one does not search for a cause that one believes one knows. This is why the application of the geometric principles of mechanics to physical effects, which is very difficult and very necessary, remains imperfect, and why we find ourselves deprived of the work and the research of several fine geniuses who would perhaps have been able to discover the true cause of phenomena.

WHEN THEY CAN BECOME DANGEROUS.

It is true that hypotheses become the poison of philosophy when they are made to pass for the truth, and perhaps they are then even more dangerous than was the unintelligible jargon of the Schoolmen;[42] for this jargon being absolutely meaningless, it only required a little attention from a clear-thinking mind to perceive how ridiculous it was, and to seek the truth elsewhere. But an ingenious and bold hypothesis, which has some initial probability, leads human pride to believe it, the mind applauds itself for having found these subtle principles, and next uses all its sagacity to defend them. Most great men who have made systems provide us with examples of this failing. These are great ships carried by the currents; they make the most beautiful maneuvers in the world, but the current carries them away.

## *IX*

USEFULNESS OF EXPERIMENTS.

In all your studies, remember, my son, that experiment is the cane that nature gave to us blind ones, to guide us in our research; with its help we will make good progress, but, if we cease to use it, we cannot help falling. It is

41. Du Châtelet discusses this controversy at great length in chapter 4 of the *Foundations*.

42. By *Schoolmen* Du Châtelet means the learned of the universities such as the Sorbonne in Paris, who, through the works of St. Thomas Aquinas, used his system of reasoning and taught the ideas of Aristotle about philosophy in its broadest sense. It was their authority that Descartes so successfully challenged.

experiment that teaches us about the physical characteristics of things and it is for our reason to use it and to deduce from it new knowledge and new enlightenment.

## *X*

TO WHAT EXTENT RESPECT IS OWED TO GREAT MEN.

If I thought it incumbent upon me to caution you against the spirit of partisanship, I believe it even more necessary to advise you not to carry respect for the greatest men to the point of idolatry, as the majority of their disciples do. Each philosopher has seen something, and none has seen all; no book is so bad that nothing can be learned from it, and no book is so good that one might not improve it. When I read Aristotle, this philosopher who has suffered fortunes so diverse and so unjust, I am astonished sometimes to find ideas so sound on several points of general physics, beside the greatest absurdities; but when I read some of the questions that M. Newton put at the end of his *Opticks*, I am struck with a very different astonishment.[43] This example of the two greatest men of their century can but make you see that he who is endowed with reason must take nobody at his word alone, but must always make his own examination, setting aside the consideration always allotted to a famous name.

## *XI*

This is one of the reasons why I have not filled this book with citations, I did not want to seduce you with authorities; and more, there would have been too many. I am very far from believing myself capable of writing a book of physics without consulting any book, and I even doubt that without this help one might be able to write a good one. The greatest philosopher may well add new discoveries to those of others, but once a truth has been found, he has to follow it; for example, M. Newton had to begin by establishing Kepler's two analogies when he wanted to explain the course of the planets, without which he would never have arrived at the beautiful discovery of the gravitation of the celestial bodies.[44]

Physics is an immense building that surpasses the powers of a single

43. Du Châtelet probably knew of Aristotle, the fourth century BCE Greek philosopher, through his critics. Newton's *Opticks*, in contrast, she once wrote to her mentor, the mathematician and philosopher, Pierre-Louis Moreau de Maupertuis (1698–1759), she had studied so thoroughly that she knew it almost by heart.

44. Du Châtelet uses the term *analogy* instead of *law* in a Newtonian sense, a mathematical model from which, by analogy, laws of nature could be hypothesized and then verified by observation and experiment.

man. Some lay a stone there, while others build whole wings, but all must work on the solid foundations that have been laid for this edifice in the last century, by means of geometry and observations; still others survey the plan of the building, and I, among them.

In this work, I have not aimed at flaunting my intelligence, but at being right; and I have nurtured your reason enough to believe that you are capable of seeking the truth independently of all the alien adornments with which it is being overwhelmed in our day. I merely removed the thorns that might have wounded your delicate hands, but I did not think that I must replace them with alien flowers, and I am certain that a good mind, however weak it might still be, finds more pleasure, and a more satisfying pleasure, in clear, precise reasoning that it grasps easily, than in an ill-timed joke.

*XII*

In the first chapters I explain to you the principal opinions of M. Leibniz on metaphysics; I have drawn them from the works of the celebrated Wolff, of whom you have heard me speak so much with one of his disciples, who was for some time in my household, and who sometimes made abstracts for me.*[45]

M. Leibniz's ideas on metaphysics are still little known in France, but they certainly deserve to be. Despite the discoveries of this great man, there are no doubt still many obscure things in metaphysics; but it seems to me that with the principle of sufficient reason, he has provided a compass capable of leading us in the moving sands of this science.

The obscurities in which some parts of metaphysics are still shrouded serve as pretext for the laziness of the majority of men not to study it. They persuade themselves that because not everything is known, nothing can be. Yet, there certainly are points of metaphysics susceptible to demonstrations as rigorous as geometric demonstrations, although they are of another type. We lack a system of calculation for metaphysics similar to that which has been found for mathematics, by means of which, with the aid of certain *givens*, one arrives at knowledge of *unknowns*. Perhaps some genius will one day

45. Du Châtelet offered her own note here: "*See the *Ontology of Wolff*, and principally the following chapters: *De Principio Contradictionis, de Principio Rationis Sufficientis, de Possibili, and Impossibili, de Necessario and Contingente, de Extensione, Continuitate, Spatio, Tempore* [Of the Principle of Contradiction, of the Principle of Sufficient Reason, of Possibility, and Impossibility, of Necessity and Contingency, of Extension, Continuity, Space, Time]. Christian Wolff (1679–1754) was a German philosopher, student and explicator of Leibniz. Frederick of Prussia (1712–1786) first sent French translations of Wolff to Voltaire and Du Châtelet in 1736. She is here referring to Samuel König (1712–1757), the Swiss mathematician, who studied under Wolff and later became her tutor in advanced algebra and in Wolff's version of Leibnizian ideas.

find this system. M. Leibniz gave this much thought; he had ideas on this, which he unfortunately never communicated to anyone, but even if it could be invented, it seems that there are some unknowns for which no *equation* could ever be found. Metaphysics contains two types of things: the first, that which all people who make good use of their mind, can know; and the second, which is the most extensive, that which they will never know.[46]

Several truths of physics, metaphysics, and geometry are obviously interconnected. Metaphysics is the summit of the edifice; this summit is so elevated that our image of it often is a little blurred. This is why I thought I should begin by bringing it closer to you, so that, no cloud obscuring your mind, you might be able to have a clear and unassailable view of the truths in which I want to instruct you.[47]

## CHAPTER ONE: *OF THE PRINCIPLES OF OUR KNOWLEDGE*

### *I*

ON WHAT OUR KNOWLEDGE IS FOUNDED.

All aspects of our knowledge are born from each other and are founded on certain principles whose truth is known without even reflecting on it, because they are self-evident.

Some truths immediately depend on these first principles, and are derived from them as a result of a small number of conclusions only. In that case the mind easily perceives the sequence that has led to them; but it is easy to lose sight of this sequence in the search for truths that can only be reached by a great number of conclusions drawn one from another. There are a thousand examples of this in geometry; it is very easy, for example, to see that the diameter of a circle divides it into two equal parts, because only one conclusion is needed to pass from the nature of the circle to this property. But it is not so easily seen that the square of the ordinate BM is equal to the rectangle of line AB by line BC, although this property results from the

46. This sentence reflects an interchange late in the 1730s between Voltaire and Frederick of Prussia, in which Voltaire made this distinction. See D1376, Voltaire to Frederick of Prussia (15 October 1737) *Oeuvres complètes*, v. 88, 381.

47. Natural philosophers commonly offered a visual representation of the constituent parts of "Knowledge." Du Châtelet certainly knew of Descartes' Tree of Knowledge from his *Principles*, in which metaphysics forms the roots, physics the trunk, and the other sciences (mechanics, medicine, morals), the branches.