| Para[1] | Isaac Newton, *The Mathematical Principles of Natural Philosophy*, translated by Andrew Motte. (From https://en.wikisource.org/wiki/The_Mathematical_Principles_of_Natural_Philosophy_(1846)) | Remarks[2] |
|---|---|---|
| | **Book I** | |
| | **DEFINITIONS** | |
| 1 | DEFINITION I.<br><br>*The quantity of matter is the measure of the same, arising from its density and bulk conjunctly.* | 这里牛顿定义「质量」(mass)。The same 的意思是同一个概念，在这里就是 matter。这句说话前半可译为「物质的量就是物质这个概念的量度」。Bulk 是体积(volume)。Arising … conjunctly 有相乘之意。因此，质量是密度和体积的乘积。 |
| 2 | Thus air of a double density, in a double space, is quadruple in quantity; in a triple space, sextuple in quantity. The same thing is to be understood of snow, and fine dust or powders, that are condensed by compression or liquefaction; and of all bodies that are by any causes whatever differently condensed. I have no regard in this place to a medium, if any such there is, that freely pervades the interstices between the parts of bodies. It is this quantity that I mean hereafter everywhere under the name of body or mass. And the same is known by the weight of each body; for it is proportional to the weight, as I have found by experiments on pendulums, very accurately made, which shall be shewn hereafter. | 牛顿先提出一些例子，接着指出他不考虑介质会渗进物体空隙的情况。他说，此后他若用 body 或 mass，要表达的也是 the quantity of matter。他指出 mass 与 weight 成正比。 |

[1] Added by the course instructor.
[2] Added by the course instructor.

3

## DEFINITION II.

*The quantity of motion is the measure of the same, arising from the velocity and quantity of matter conjunctly.*

这是 motion 的量，亦即动量，是速度和质量的乘积。

4 The motion of the whole is the sum of the motions of all the parts; and therefore in a body double in quantity, with equal velocity, the motion is double; with twice the velocity, it is quadruple.

物体的动量是所有部分动量的总和。

5

## DEFINITION III.

*The* vis insita*, or innate force of matter, is a power of resisting, by which every body, as much as in it lies, endeavours to persevere in its present state, whether it be of rest, or of moving uniformly forward in a right line.*

这是惯性(inertia)，一种维持运动状态不变的倾向。牛顿形容为一种固有的力量。

6 This force is ever proportional to the body whose force it is; and differs nothing from the inactivity of the mass, but in our manner of conceiving it. A body, from the inactivity of matter, is not without difficulty put out of its state of rest or motion. Upon which account, this *vis insita*, may, by a most significant name, be called *vis inertiæ*, or force of inactivity. But a body exerts this force only, when another force, impressed upon it, endeavours to change its condition; and the exercise of this force may be considered both as resistance and impulse; it is resistance, in so far as the body, for maintaining its present state, withstands the force impressed; it is impulse, in so far as the body, by not easily giving way to the impressed force of another, endeavours to change the state of that other. Resistance is usually ascribed to bodies at rest, and impulse to those in motion; but motion and rest, as commonly conceived, are only relatively distinguished;

这种力量，可称为 inertia，与质量成正比，能维持物体在静止或运动的状态。最后，牛顿指出运动和静止的分别只有相对意义。

nor are those bodies always truly at rest, which commonly are taken to be so.

7 DEFINITION IV.

*An impressed force is an action exerted upon a body, in order to change its state, either of rest, or of moving uniformly forward in a right line.*

8 This force consists in the action only; and remains no longer in the body, when the action is over. For a body maintains every new state it acquires, by its *vis inertiæ* only. Impressed forces are of different origins as from percussion, from pressure, from centripetal force.

9 DEFINITION V.

*A centripetal force is that by which bodies are drawn or impelled, or any way tend, towards a point as to a centre.*

向心力是趋向一个中心的力。

10 Of this sort is gravity, by which bodies tend to the centre of the earth magnetism, by which iron tends to the loadstone; and that force, what ever it is, by which the planets are perpetually drawn aside from the rectilinear motions, which otherwise they would pursue, and made to revolve in curvilinear orbits. A stone, whirled about in a sling, endeavours to recede from the hand that turns it; and by that endeavour, distends the sling, and that with so much the greater force, as it is revolved with the greater velocity, and as soon as ever it is let go, flies away. That force which opposes itself to this endeavour, and by which the sling perpetually draws back the stone towards the hand, and retains it in its orbit, because it is directed to the hand as the centre of the orbit, I call the centripetal force. And the same thing is to be understood of all bodies, revolved in any orbits. They all endeavour to recede from the centres of their orbits; and were it not for the opposition of a contrary force which restrains them to, and detains them in their orbits,

牛顿先提出几个向心力的例子。他提出，在这些例子里，若向心力不存在，物体就会沿直线(rectilinear)飞走。

which I therefore call centripetal, would fly off in right lines, with an uniform motion. A projectile, if it was not for the force of gravity, would not deviate towards the earth, but would go off from it in a right line, and that with a uniform motion, if the resistance of the air was taken away. It is by its gravity that it is drawn aside perpetually from its rectilinear course, and made to deviate towards the earth, more or less, according to the force of its gravity, and the velocity of its motion. The less its gravity is, for the quantity of its matter, or the greater the velocity with which it is projected, the less will it deviate from a rectilinear course, and the farther it will go. If a leaden ball, projected from the top of a mountain by the force of gunpowder with a given velocity, and in a direction parallel to the horizon, is carried in a curve line to the distance of two miles before it falls to the ground; the same, if the resistance of the air were taken away, with a double or decuple velocity, would fly twice or ten times as far. And by increasing the velocity, we may at pleasure increase the distance to which it might be projected, and diminish the curvature of the line, which it might describe, till at last it should fall at the distance of 10, 30, or 90 degrees, or even might go quite round the whole earth before it falls; or lastly, so that it might never fall to the earth, but go forward into the celestial spaces, and proceed in its motion *in infinitum*. And after the same manner that a projectile, by the force of gravity, may be made to revolve in an orbit, and go round the whole earth, the moon also, either by the force of gravity, if it is endued with gravity, or by any other force, that impels it towards the earth, may be perpetually drawn aside towards the earth, out of the rectilinear way, which by its innate force it would pursue; and would be made to revolve in the orbit which it now describes; nor could the moon with out some such force, be retained in its orbit. If this force was too small, it would not sufficiently turn the moon out of a rectilinear course: if it was too great, it would turn it too much, and draw down the moon from its orbit towards the earth. It is necessary, that the force be of a just quantity, and it belongs to the mathematicians to find the

这是一个想象中的情况。发射铅球的速度愈高，它的射程就愈远，射程与地球中心形成 10、30，甚至 90 度的角。若速度够高，铅球可以绕地心一周。

月球受地球引力牵引而环绕地球，情况跟铅球受地球引力牵引而环绕地球一样。

| | | |
|---|---|---|
| | force, that may serve exactly to retain a body in a given orbit, with a given velocity; and vice versa, to determine the curvilinear way, into which a body projected from a given place, with a given velocity, may be made to deviate from its natural rectilinear way, by means of a given force. | 只要向心力和速度恰到好处，物体就会在特定的轨道上运行。 |
| 11 | The quantity of any centripetal force may be considered as of three kinds; absolute, accelerative, and motive. | |
| | […] | |
| 12 | I likewise call attractions and impulses, in the same sense, accelerative, and motive; and use the words attraction, impulse or propensity of any sort towards a centre, promiscuously, and indifferently, one for another; considering those forces not physically, but mathematically: wherefore, the reader is not to imagine, that by those words, I anywhere take upon me to define the kind, or the manner of any action, the causes or the physical reason thereof, or that I attribute forces, in a true and physical sense, to certain centres (which are only mathematical points); when at any time I happen to speak of centres as attracting, or as endued with attractive powers. | 牛顿说他不是要讨论各种力的物理性质(physically)，而是它们的数学性质(mathematically)。他并不在意怎样称呼这些力。 |
| | […] | |

## AXIOMS, OR LAWS OF MOTION.

13 LAW I.

*Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.*

14 Projectiles persevere in their motions, so far as they are not retarded by the resistance of the air, or impelled downwards by the force of gravity. A top, whose parts by their cohesion are perpetually drawn aside from rectilinear motions, does not cease its rotation, otherwise than as it is retarded by the air. The greater bodies of the planets and comets, meeting with less resistance in more free spaces, preserve their motions both progressive and circular for a much longer time.

15 LAW II.

*The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.*

The alteration of motion 指的是 quantity of motion 的改变，亦即动量的改变。

16 If any force generates a motion, a double force will generate double the motion, a triple force triple the motion, whether that force be impressed altogether and at once, or gradually and successively. And this motion (being always directed the same way with the generating force), if the body moved before, is added to or subducted from the former motion, according as they directly conspire with or are directly contrary to each other; or obliquely joined, when they are oblique, so as to produce a new motion compounded from the determination of both.

17

## LAW III.

*To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.*

Action 是力的意思。

18

Whatever draws or presses another is as much drawn or pressed by that other. If you press a stone with your finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse (if I may so say) will be equally drawn back towards the stone: for the distended rope, by the same endeavour to relax or unbend itself, will draw the horse as much towards the stone, as it does the stone towards the horse, and will obstruct the progress of the one as much as it advances that of the other. If a body impinge upon another, and by its force change the motion of the other, that body also (because of the equality of the mutual pressure) will undergo an equal change, in its own motion, towards the contrary part. The changes made by these actions are equal, not in the velocities but in the motions of bodies; that is to say, if the bodies are not hindered by any other impediments. For, because the motions are equally changed, the changes of the velocities made towards contrary parts are reciprocally proportional to the bodies. This law takes place also in attractions, as will be proved in the next scholium.

Reciprocally proportional to the bodies 是与质量成反比的意思。留意 Definition I 说 mass 也称为 body。

[…]

19

## COROLLARY VI.

*If bodies, any how moved among themselves, are urged in the direction of parallel lines by equal accelerative forces, they will all continue to move among themselves, after the same, manner as if they had been urged by no such forces.*

在提出三大定律后，牛顿就导出八个推论(corollary)。Corollary VI 说，两个物体被施以方向相同的力，并获得相同加速度后，两者的相对运动不会改变。

20 For these forces acting equally (with respect to the quantities of the bodies to be moved), and in the direction of parallel lines, will (by Law II) move all the bodies equally (as to velocity), and therefore will never produce any change in the positions or motions of the bodies among themselves.

[..]

**Book III.**

[…]

**RULES OF REASONING IN PHILOSOPHY.**

21 RULE I.

*We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.*

举个例，若 4 个原因已足够解释事物或现象的形成，就不用有第 5 个原因。

22 To this purpose the philosophers say that Nature does nothing in vain, and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes.

牛顿以拟人法来说大自然喜爱简单。

23 RULE II.

*Therefore to the same natural effects we must, as far as possible, assign the same causes.*

对相同的结果，应寻求相同的成因。

24 As to respiration in a man and in a beast; the descent of stones in *Europe* and in *America*; the light of our culinary fire and of the sun; the reflection of light in the earth, and in the planets.

每对现象的成因相同：人与兽的呼吸作用、欧洲和美国石头下跌、煮食的火发光和太阳发光、地球反光和行星反光。

25

## RULE III.

*The qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.*

物体的特性，若不能增加或减少，且在实验范围内属于所有物体，则该特性是所有物体的普遍特性。

26

For since the qualities of bodies are only known to us by experiments, we are to hold for universal all such as universally agree with experiments; and such as are not liable to diminution can never be quite taken away. We are certainly not to relinquish the evidence of experiments for the sake of dreams and vain fictions of our own devising; nor are we to recede from the analogy of Nature, which uses to be simple, and always consonant to itself. We no other way know the extension of bodies than by our senses, nor do these reach it in all bodies; but because we perceive extension in all that are sensible, therefore we ascribe it universally to all others also. That abundance of bodies are hard, we learn by experience; and because the hardness of the whole arises from the hardness of the parts, we therefore justly infer the hardness of the undivided particles not only of the bodies we feel but of all others. That all bodies are impenetrable, we gather not from reason, but from sensation. The bodies which we handle we find impenetrable, and thence conclude impenetrability to be an universal property of all bodies whatsoever. That all bodies are moveable, and endowed with certain powers (which we call the *vires inertiæ*) of persevering in their motion, or in their rest, we only infer from the like properties observed in the bodies which we have seen. The extension, hardness, impenetrability, mobility, and *vis inertiæ* of the whole, result from the extension, hardness, impenetrability, mobility, and *vires inertiæ* of the parts; and thence we conclude the least particles of all bodies to be also all extended, and hard and impenetrable, and moveable, and endowed with their proper vires inertia. And this is the foundation of all philosophy. Moreover, that the divided but

这一段相当长，大意是：

1. 物体特性的普遍性是从实验中的感知所推广出来的。
2. 这推广背后有个信念：大自然是简单、一致的。

这种推广出来的普遍特性（例如，广延性、硬度、不可穿透性、运动性、惯性）有两个推广的方向：

1. 向其他物体。
2. 向物体的内部（想象把物体拆开为更细小部分）。对于这一点，牛顿下了一个注脚。他说未必真的可以用大自然的力量来把物体拆开，但在思维上可以，就如在做数学计算时可以想象把物体拆开。

contiguous particles of bodies may be separated from one another, is matter of observation; and, in the particles that remain undivided, our minds are able to distinguish yet lesser parts, as is mathematically demonstrated. But whether the parts so distinguished, and not yet divided, may, by the powers of Nature, be actually divided and separated from one another, we cannot certainly determine. Yet, had we the proof of but one experiment that any undivided particle, in breaking a hard and solid body, suffered a division, we might by virtue of this rule conclude that the undivided as well as the divided particles may be divided and actually separated to infinity.

27 Lastly, if it universally appears, by experiments and astronomical observations, that all bodies about the earth gravitate towards the earth, and that in proportion to the quantity of matter which they severally contain; that the moon likewise, according to the quantity of its matter, gravitates towards the earth; that, on the other hand, our sea gravitates towards the moon; and all the planets mutually one towards another; and the comets in like manner towards the sun; we must, in consequence of this rule, universally allow that all bodies whatsoever are endowed with a principle of mutual gravitation. For the argument from the appearances concludes with more force for the universal gravitation of all bodies than for their impenetrability; of which, among those in the celestial regions, we have no experiments, nor any manner of observation. Not that I affirm gravity to be essential to bodies: by their *vis insita* I mean nothing but their *vis inertiæ*. This is immutable. Their gravity is diminished as they recede from the earth.

牛顿推出万有引力的普遍性。然而，他也下了注脚：

1. 在天体范围内，引力比天体的不可穿透性更可信，因为后者反而缺乏实验或观察的证据。
2. 万有引力不是物体的内在特性，但惯性(*vis inertiæ*)是。

28 RULE IV.

*In experimental philosophy we are to look upon propositions collected by general induction from phænomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phænomena occur, by which they may either be made more accurate, or liable to exceptions.*

命题(proposition)乃是从现象以归纳法得来。我们要把它视为真，直至有其他现象否定它或使它更准确。

29 This rule we must follow, that the argument of induction may not be evaded by hypotheses.

[…]

**GENERAL SCHOLIUM.**

30 The hypothesis of vortices is pressed with many difficulties. That every planet by a radius drawn to the sun may describe areas proportional to the times of description, the periodic times of the several parts of the vortices should observe the duplicate proportion of their distances from the sun; but that the periodic times of the planets may obtain the sesquiplicate proportion of their distances from the sun, the periodic times of the parts of the vortex ought to be in the sesquiplicate proportion of their distances. That the smaller vortices may maintain their lesser revolutions about *Saturn*, *Jupiter*, and other planets, and swim quietly and undisturbed in the greater vortex of the sun, the periodic times of the parts of the sun's vortex should be equal; but the rotation of the sun and planets about their axes, which ought to correspond with the motions of their vortices, recede far from all these proportions. The motions of the comets are exceedingly regular, are governed by the same laws with the motions of the planets, and can by no means be accounted for by the hypothesis of vortices; for comets are carried with very eccentric motions through all parts of the heavens indifferently, with a freedom that is

根据笛卡尔(René Descartes)的漩涡理论(Vortex Theory)，太阳处于一个以太(ether)漩涡的中心，其他行星在漩涡中随着以太流而环绕太阳公转。同样，地球也在一个小漩涡中心，月球因而环绕地球公转。牛顿指出漩涡理论有其困难。

*A* is in the sesquiplicate proportion of *B* 即 $A^{1/2}$ 和 $B^{1/3}$ 成正比。这段提到很多行星运行的现象，牛顿指出漩涡理论并不能解释某些现象（例如，彗星轨道）。

incompatible with the notion of a vortex.

31 Bodies projected in our air suffer no resistance but from the air. Withdraw the air, as is done in Mr. *Boyle's* vacuum, and the resistance ceases; for in this void a bit of line down and a piece of solid gold descend with equal velocity. And the parity of reason must take place in the celestial spaces above the earth's atmosphere; in which spaces, where there is no air to resist their motions, all bodies will move with the greatest freedom; and the planets and comets will constantly pursue their revolutions in orbits given in kind and position, according to the laws above explained; but though these bodies may, indeed, persevere in their orbits by the mere laws of gravity, yet they could by no means have at first derived the regular position of the orbits themselves from those laws.

Mr. Boyle 能制造真空，消除空气阻力。牛顿指出太空也没有空气阻力，星体的运行纯粹受重力所支配。

32 The six primary planets are revolved about the sun in circles concentric with the sun, and with motions directed towards the same parts, and almost in the same plane. Ten moons are revolved about the earth, Jupiter and Saturn, in circles concentric with them, with the same direction of motion, and nearly in the planes of the orbits of those planets; but it is not to be conceived that mere mechanical causes could give birth to so many regular motions, since the comets range over all parts of the heavens in very eccentric orbits; for by that kind of motion they pass easily through the orbs of the planets, and with great rapidity; and in their aphelions, where they move the slowest, and are detained the longest, they recede to the greatest distances from each other, and thence suffer the least disturbance from their mutual attractions. This most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent and powerful Being. And if the fixed stars are the centres of other like systems, these, being formed by the like wise counsel, must be all subject to the dominion of One; especially since the light of the fixed stars is of the same nature with the light of the sun, and from every

牛顿指出有两个现象十分奇特：

1. 六大行星（当时只知六颗）和十个月亮都几乎在同一个平面上以相同方向运行，但彗星的运行却很不规则。
2. 恒星之间距离很远，没有因引力彼此吸引而撞成一块。

牛顿认为原因是宇宙由一个有智慧和能力的存有（是 Being，不是 being）支配着。

system light passes into all the other systems: and lest the systems of the fixed stars should, by their gravity, fall on each other mutually, he hath placed those systems at immense distances one from another.

33 This Being governs all things, not as the soul of the world, but as Lord over all; and on account of his dominion he is wont to be called *Lord God παντοκράτωρ*, or *Universal Ruler*; for *God* is a relative word, and has a respect to servants; and *Deity* is the dominion of God not over his own body, as those imagine who fancy God to be the soul of the world, but over servants. The Supreme God is a Being eternal, infinite, absolutely perfect; but a being, however perfect, without dominion, cannot be said to be Lord God; for we say, my God, your God, the God of *Israel*, the God of Gods, and Lord of Lords; but we do not say, my Eternal, your Eternal, the Eternal of *Israel*, the Eternal of Gods; we do not say, my Infinite, or my Perfect: these are titles which have no respect to servants. The word *God*[3] usually signifies *Lord*; but every lord is not a God. It is the dominion of a spiritual being which constitutes a God: a true, supreme, or imaginary dominion makes a true, supreme, or imaginary God. And from his true dominion it follows that the true God is a living, intelligent, and powerful Being; and, from his other perfections, that he is supreme, or most perfect. He is eternal and infinite, omnipotent and omniscient; that is, his duration reaches from eternity to eternity; his presence from infinity to infinity; he governs all things, and knows all things that are or can be done. He is not eternity or infinity, but eternal and infinite; he is not duration or space, but he endures and is present. He endures for ever, and is every where present; and by existing always and every where, he constitutes duration and space. Since every particle of space is *always*, and every indivisible

这段讨论 Being 的属性。牛顿先指出 God 和 Lord God 的分别，接着从空间和时间的特性(every particle of space is always, and every indivisible moment of duration is every where)来推论空间和时间的创造者有甚么属性：

- 时常存在：因为空间的每一小部分都是时常存在(is always)。
- 无处不在：因为时间的每一刻是无处不在的(is every where)。

然后牛顿把上帝和人作比较。

[3] Dr. *Pocock* derives the Latin word *Deus* from the *Arabic du* (in the oblique case *di*), which signifies *Lord*. And in this sense princes are called *gods*, *Psal*. lxxxii. ver. 6; and *John* x. ver. 35. And *Moses* is called a *god* to his brother *Aaron*, and a god to *Pharaoh* (*Exod*. iv. ver. 16; and vii. ver. 1). And in the same sense the souls of dead princes were formerly, by the Heathens, called *gods*, but falsely, because of their want of dominion.

moment of duration is *every where*, certainly the Maker and Lord of all things cannot be *never* and *no where*. Every soul that has perception is, though in different times and in different organs of sense and motion, still the same indivisible person. There are given successive parts in duration, co-existent parts in space, but neither the one nor the other in the person of a man, or his thinking principle; and much less can they be found in the thinking substance of God. Every man, so far as he is a thing that has perception, is one and the same man during his whole life, in all and each of his organs of sense. God is the same God, always and every where. He is omnipresent not *virtually* only, but also *substantially*; for virtue cannot subsist without substance. In him[4] are all things contained and moved; yet neither affects the other: God suffers nothing from the motion of bodies; bodies find no resistance from the omnipresence of God. It is allowed by all that the Supreme God exists necessarily; and by the same necessity he exists *always* and *every where*. Whence also he is all similar, all eye, all ear, all brain, all arm, all power to perceive, to understand, and to act; but in a manner not at all human, in a manner not at all corporeal, in a manner utterly unknown to us. As a blind man has no idea of colours, so have we no idea of the manner by which the all-wise God perceives and understands all things. He is utterly void of all body and bodily figure, and can therefore neither be seen, nor heard, nor touched; nor ought he to be worshipped under the representation of any corporeal thing. We have ideas of his attributes, but what the real substance of any thing is we know not. In bodies, we see only their figures and colours, we hear only the sounds, we touch only their outward surfaces, we smell only the smells, and taste the savours; but their inward substances are not to be known either by our senses, or by any reflex act of our minds: much less, then, have we any

[4] This was the opinion of the Ancients. So *Pythagoras*, in *Cicer. de Nat. Deor.* lib. i *Thales*, *Anaxagoros*, *Virgil*, Georg. lib. iv. ver. 220; and Æneid, lib. vi. ver. 721. *Philo Allegor*, at the beginning of lib. i. *Aratus*, in his Phænom. at the beginning. So also the sacred writers; as St. *Paul*, *Acts*, xvii. ver 27, 28. St. *John's* Gosp. chap. xiv. ver. 2. *Moses*. in *Deut*. iv. ver. 39; and x ver. 14. *David*, *Psal*. cxxxix. ver. 7, 8, 9. *Solomon*, 1 *Kings*, viii. ver. 27. *Job*, xxii. ver. 12, 13, 14. *Jeremiah*, xxiii. ver. 23, 24. The Idolaters opposed the sun, moon, and stars, the souls of men, and other parts of the world, to be parts of the Supreme God, and therefore to be worshipped; but erroneously.

idea of the substance of God. We know him only by his most wise and excellent contrivances of things, and final causes: we admire him for his perfections; but we reverence and adore him on account of his dominion: for we adore him as his servants; and a god without dominion, providence, and final causes, is nothing else but Fate and Nature. Blind metaphysical necessity, which is certainly the same always and every where, could produce no variety of things. All that diversity of natural things which we find suited to different times and places could arise from nothing but the ideas and will of a Being necessarily existing. But, by way of allegory, God is said to see, to speak, to laugh, to love, to hate, to desire, to give, to receive, to rejoice, to be angry, to fight, to frame, to work, to build; for all our notions of God are taken from the ways of mankind by a certain similitude, which, though not perfect, has some likeness, however. And thus much concerning God; to discourse of whom from the appearances of things, does certainly belong to Natural Philosophy.

34 Hitherto we have explained the phenomena of the heavens and of our sea by the power of gravity, but have not yet assigned the cause of this power. This is certain, that it must proceed from a cause that penetrates to the very centres of the sun and planets, without suffering the least diminution of its force; that operates not according to the quantity of the surfaces of the particles upon which it acts (as mechanical causes use to do), but according to the quantity of the solid matter which they contain, and propagates its virtue on all sides to immense distances, decreasing always in the duplicate proportion of the distances. Gravitation towards the sun is made up out of the gravitations towards the several particles of which the body of the sun is composed; and in receding from the sun decreases accurately in the duplicate proportion of the distances as far as the orb of Saturn, as evidently appears from the quiescence of the aphelions of the planets; nay, and even to the remotest aphelions of the comets, if those aphelions are also quiescent. But hitherto I have not been able to discover the cause of those properties of gravity

这段牛顿为万有引力定律做一个总结，并说了一句名言：I frame no hypotheses。他承认不知道万有引力的成因。

from phænomena, and I frame no hypotheses; for whatever is not deduced from the phænomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phenomena, and afterwards rendered general by induction. Thus it was that the impenetrability, the mobility, and the impulsive force of bodies, and the laws of motion and of gravitation, were discovered. And to us it is enough that gravity does really exist, and act according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies, and of our sea.

And now we might add something concerning a certain most subtle Spirit which pervades and lies hid in all gross bodies; by the force and action of which Spirit the particles of bodies mutually attract one another at near distances, and cohere, if contiguous; and electric bodies operate to greater distances, as well repelling as attracting the neighbouring corpuscles; and light is emitted, reflected, refracted, inflected, and heats bodies; and all sensation is excited, and the members of animal bodies move at the command of the will, namely, by the vibrations of this Spirit, mutually propagated along the solid filaments of the nerves, from the outward organs of sense to the brain, and from the brain into the muscles. But these are things that cannot be explained in few words, nor are we furnished with that sufficiency of experiments which is required to an accurate determination and demonstration of the laws by which this electric and elastic Spirit operates.

Spirit 可译为精气。牛顿想象很多物理现象（电荷互相吸引、排斥，光的发射、反射、折射等）都要有精气来推动，但牛顿无法进一步解释这精气是甚么。

END OF THE MATHEMATICAL PRINCIPLES.