

# Principia Mathematica

- Date** ■ 1687
- Place** ■ London, England
- Type of Source** ■ Scientific/mathematical text (original in Latin)
- Author** ■ Sir Isaac Newton
- Historical Context** ■ Experiments in 1500s and 1600s proved that older ideas about the universe were wrong, but scientists were unsure about how this new information fit together. In 1684 Christopher Wren, Edmond Halley, and Robert Hooke discussed how to calculate orbits. Hooke said he had found the answer but never produced proof. Halley approached Isaac Newton who, unknown to Halley, had solved the problem almost 20 years earlier but hadn't published it. Halley pushed Newton to publish. The result, *Mathematical Principles of Natural Philosophy*, would become the basis of all modern physics.
- Internal Context** ■ Newton begins his work with his laws of motion, explaining every movement in the universe. He then explains how these laws explain the orbit of planets.

## Axioms, or Laws of Motion

**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.

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.

**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.

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.

**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.

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

### Axioms

*basic rules on which all conclusions are based.*

#### **perseveres**

*continues without interruption*

#### **impressed**

*pushed onto*

#### **rectilinear**

*straight lines*

#### **retarded**

*slowed*

#### **proportional**

*the same amount*

#### **subducted from**

*removed or subtracted from*

#### **obliquely**

*at an angle*

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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**...

**Scholium**

Hitherto I have laid down such principles as have been received by mathematicians, and are confirmed by abundance of experiments. By the first two Laws and the first two Corollaries, **Galileo** discovered that the descent of bodies observed the **duplicate ratio** of the time, and that the motion of projectiles was in the curve of a **parabola**; experience agreeing with both, unless so far as these motions are a little retarded by the resistance of the air. When a body is falling, the uniform force of its gravity acting equally, impresses, in equal particles of time, equal forces upon that body, and therefore generates equal velocities; and in the whole time impresses a whole force, and generates a whole velocity proportional to the time...

By the theory of **Wren** and **Huygens**, bodies absolutely hard return one from another with the same velocity with which they meet. But this may be affirmed with more certainty of bodies perfectly elastic. In bodies imperfectly elastic the velocity of the return is to be diminished together with the elastic force; because that force (except when the parts of bodies are bruised by their **congress**, or suffer some such extension as happens under the strokes of a hammer) is (as far as I can perceive) certain and determined, and makes the bodies to return one from the other with a relative velocity, which is in a given ratio to that relative velocity with which they met. This I tried in balls of wool, made up tightly, and strongly compressed. For, first, by letting go the pendulous bodies, and measuring their **reflexion**, I determined the quantity of their elastic force; and then, according to this force, estimated the reflexions that ought to happen in other cases of congress. And with this computation other experiments made afterwards did accordingly agree; the balls always receding one from the other with a relative velocity, which was to the relative velocity with which they met as about 5 to 9. Balls of steel returned with almost the same velocity: those of cork with a velocity something less; but in balls of glass the proportion was as about 15 to 16. And thus the third Law, so far as it regards **percussions** and reflexions, is proved by a theory exactly agreeing with experience....

**velocities**

*the distance and direction an object moves in a given time, similar to speed*

**reciprocally**

*oppositely. Essentially when two objects collide, they feel the same amount of force, but the force is moving in opposite directions.*

**scholium**

*explanation*

**Galileo**

*Italian scientist Galileo Galilei, see Atlas of World History, page 94, and Galileo's Dialogue Concerning Two World Systems on this website.*

**duplicate ratio**

*squared numbers (a number multiplied by itself). The acceleration of a falling object is 16 feet (or 9.8 meters) per second squared, so at 1 second the object falls 16 feet, at 2 seconds it falls 64 feet (16x2x2), and at 3 seconds it falls 144 feet (16x3x3).*

**parabola**

*a mathematical curve*

**Wren**

*Sir Christopher Wren, a major English scientist and architect. Wren was involved in the discussion with Halley and Hooke that led to the writing of the Principia.*

**Huygens**

*Christiaan Huygens, a major Dutch scientist.*

**congress**

*meeting*

**reflexion**

*reflection*

**percussions**

*hits*

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...in the pulley, or in a combination of pullies, the force of a hand drawing the rope directly, which is to the weight, whether ascending directly or obliquely, as the velocity of the perpendicular ascent of the weight to the velocity of the hand that draws the rope, will sustain the weight.

In clocks and such like instruments, made up from a combination of wheels, the contrary forces that promote and impede the motion of the wheels, if they are reciprocally as the velocities of the parts of the wheel on which they are impressed, will mutually sustain the one the other.

The force of the screw to press a body is to the force of the hand that turns the handles by which it is moved as the circular velocity of the handle in that part where it is impelled by the hand is to the progressive velocity of the screw towards the pressed body.

The forces by which the wedge presses or drives the two parts of the wood it cleaves are to the force of the mallet upon the wedge as the progress of the wedge in the direction of the force impressed upon it by the mallet is to the velocity with which the parts of the wood yield to the wedge, in the direction of lines perpendicular to the sides of the wedge. And the like account is to be given of all machines.

The power and use of machines consist only in this, that by diminishing the velocity we may augment the force, and the contrary: from whence in all sorts of proper machines, we have the solution of this problem; To move a given weight with a given power, or with a given force to overcome any other given resistance. For if machines are so contrived that the velocities of the agent and resistant are reciprocally as their forces, the agent will just sustain the resistant, but with a greater disparity of velocity will overcome it.

**Source:** "The Mathematical Principles of Natural Philosophy, Book I.," *Wikisource*, April 6, 2010, <[http://en.wikisource.org/wiki/The\\_Mathematical\\_Principles\\_of\\_Natural\\_Philosophy\\_\(1846\)](http://en.wikisource.org/wiki/The_Mathematical_Principles_of_Natural_Philosophy_(1846))> (June 7, 2011).