Chapter 4

INERTIA, NEWTON'S THREE LAWS OF MOTION, & COVARIANCE

Galileo discovered the empirical relationships of gravitational acceleration and the phenomena of inertia. Later, Newton described his three laws of motion, and his law of gravitational attraction. When applied on any inertially moving body, Newton's second law of motion (F=ma) is invariant, and the values of its variable components (F, m, a) are algebraically 'covariant.'

A. Gravitational and Parabolic Motion, Inertia and Inertial Motion

Galileo Galilei (1561 – 1642) "was trained in the medieval Aristotelian tradition." (Goldberg, p. 22) Aristotle had conjectured that "heavy objects fall down faster than light ones." (Gamow, 1961, p. 35) In order to test Aristotle's conjecture, Galileo (in 1589) took a light cannonball and a heavy cannonball to the top of the Leaning Tower of Pisa and simultaneously dropped them. To everyone's amazement they appeared to hit the ground at the same instant. (Figure 4.1A)

Both of such objects appeared to go faster and faster as they fell. The inquisitive Galileo wanted to know what relationship governs this motion. So in order to dilute or slow down the fall of a ball he rolled it down an inclined plane. (Gamow, 1961, p. 35; Figure 4.1B) After several years of trial and error, in about 1604, Galileo finally discovered the mathematical relationship of gravitational acceleration near the surface of the Earth. The total distance covered by a free-falling terrestrial object "during a certain period of time" is proportional to the square of that time. (*Id*., p. 36; see Figure 4.2A)

As a by-product of these and similar experiments, Galileo also discovered (in about 1608) the law that governs the path of a projectile near the surface of the Earth. (Cohen, 1960, p. 212; Figure 4.1C) The trajectory of a projectile has two independent components (Gamow, 1961, p. 39), "a vertical component that follows the law of free fall (just as if there were no horizontal component) and a horizontal component of forward motion that is uniform (just as if there were no vertical component)." (Cohen, 1960, p. 212) The distance of the horizontal component is proportional to the time elapsed.[1] (*Id*., see Figure 4.2B) The combination of these components forms a parabola with yet a third distance traveled.[2] (see Figure 4.2C) These experimental conclusions also contradicted Aristotle who conjectured that an "object moves only as long as it is being pushed and will stop as soon as the force disappears." (Gamow, 1961, p. 42)

Thus, Galileo demonstrated and concluded that terrestrial objects (such as wagons) and projectiles (such as arrows and cannonballs) do tend to continue in motion through space or along the ground even after the force has been withdrawn.[3] He called this theoretical phenomenon of continuous uniform rectilinear motion of matter without applied force, 'inertia' or inertial motion.[4]

According to Aristotle's point of view, a stone released from the top of the mast of a sailing ship will fall vertically down and land close to the stern of the ship. By the end of the 16th century, several people had actually tested Aristotle's conjectures and found that the stone instead falls to the base of the mast. [5] (see Figure 5.1) However, no one could explain why this paradox occurs. No one, that is, except Galileo after 1608.

The reason for the paradox was the physical phenomenon of inertia and the

[1] Galileo demonstrated the path of an arrow, the path of a fired cannonball, and the path of any other spherical projectile on a wide slightly inclined plane, sometimes called a 'wedge.' (Cohen, 1960, p. 112; Figure 4.1C)
[2] By 1609, Galileo had mathematically confirmed such parabolic motions. (Cohen, 1960, p. 212) Galileo's mathematical language was geometry. "He compared speed to speed, position to position, time to time…" Algebra did not become popular until the 18th century. (Goldberg, p. 22)
[3] On Earth such motion gradually slows to a stop because of the resistance of the air and the friction of a surface. On the other hand, in empty space the object will *a priori* coast at the same velocity and in a straight line (although slightly curved due to the distant forces of gravity), possibly forever.
[4] But Galileo's concept of inertial motion did not continue in a straight line forever. Rather, it was limited to straight segments and segments that curved at great distances, because Galileo could not grasp the concept of spatial infinitely. (Cohen, 1960, pp. 117 – 119, 122)
[5] We must assume that the effects of the air and wind on the stone are negligible.

resulting inertial motions of moving objects.[6] Objects on the surface of the Earth which share a common lateral inertial motion, such as the ship, the man on the mast, and the stone, maintain this common lateral inertial motion relative to the Earth, even when the force is withdrawn and they become physically detached from one another, like the falling stone. The detached stone also tends to accelerate downward toward the Earth with a parabolic trajectory due to the forces of gravity.

Why does the falling stone share the common lateral inertial motion of the man on the mast and of the ship? One reason is that the lateral motion is perpendicular to the force of gravity; therefore, there is no opposing force in the lateral direction, so (ignoring the effects of air) inertial motion is sustained. Another reason is that they are all material bodies and have mass (m), similar velocity (v) and thus similar momentum. After the force on the stone is withdrawn (by the man dropping it), the stone continues to move inertially in common with the ship because of its material 'momentum:' its mass times its velocity (mv). (Goldberg, p. 52) On the other hand, a photon or a ray of light theoretically does not have any mass, and therefore it cannot exhibit inertia, inertial motion, or lateral material momentum like the stone. Such material concepts of mass, velocity, inertia, inertial motion, and momentum are all irrelevant to non-material light.[7]

Descartes was one of the first philosophers to fully understand the concept of inertia and to extend it to the motions of heavenly bodies. He theorized that a planet that continuously moves uniformly and rectilinearly (substantially in a straight line) does not require a force to maintain such motion. (Goldberg, p. 46; Cohen, 1960, p. 210) This is

[6] On or near the surface of the Earth, terrestrial inertial motion is usually lateral relative to the Earth's surface, because of the downward force of gravity. However, in the vacuum of space, far from gravitational influences, celestial inertial motion may occur in any direction.
[7] We shall refer to this subject again in various Chapters.

the classical law of celestial inertial motion (the persistence of motion without apparent applied force), which we observe as the perpetual motions of the planets, the stars, and the galaxies.[8]

B. Newton's Three Laws of Motion

Early in the *Principia*, Newton set forth three postulates that are commonly referred to as 'Newton's Laws of Motion.' They explain both the kinematics (the abstract description of motions) and the dynamics (the relationship of kinematic motions to the forces and masses which cause them) of terrestrial and celestial motions.

1. Newton's First Law of Motion (the law of 'inertia') states:

> "Every body continues in its state of rest, or of uniform motion in a right [straight] line, unless it is compelled to change that state by forces impressed upon it."[9] (Newton, *Principia* [Motte, Vol. 1, p. 13])

Newton described inertia as the theoretical 'state' of a body in equilibrium (where no net external force is acting upon it in any direction).[10] Newton also defined inertia as the "<u>innate force</u> of matter…[its] power of <u>resisting</u>…" (*Id*., p. 2) In this regard, it can be asserted that the inertia of a body (its power or <u>tendency to resist</u> change in its <u>state</u> of motion or of relative rest) is <u>proportional</u> to its mass.[11] (see Cohen, 1960, p. 156) This concept is often referred to as the 'inertial mass' of an object.

However, unlike Galileo, who merely described the orbital motions of the planets

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[8] However, the concept of celestial inertial motion without applied force is also an impossible idealization, because the gravitational forces of other celestial objects that produce orbital or curved motions are not taken into account.

[9] Newton did not invent the concept of inertia, but he did refine it into its current form. It had been thought about and discussed by Galileo, Kepler, Descartes, and other scholars for many years. (Goldberg, p. 53) Restated in modern terms: when the net external force on a body is zero its state of motion does not change, and it is described as being in equilibrium. (see Young, p. 97)

[10] The idea that inertial motion can be a 'state' of motion or a 'state' of rest was asserted by both Galileo and Descartes. (Cohen, 1960, p. 216)

[11] It also follows that bodies with the same quantity of matter (mass) have the same inertia. (Cohen, 1960, p. 157)

as inertial, Newton asserted that such inertial motion must have constant direction of motion in a straight line as well as a constant magnitude (speed).[12] In other words, Newton's inertial motion must maintain constant 'velocity,' because 'velocity' is defined as the speed (constant rate of motion) of an object in a particular direction.[13] (see Goldberg, p. 33; and Figure 4.3A) Although orbital motion is not rigidly inertial motion under Newton's definition, the continuous almost uniform straight-line motion of certain heavenly bodies (such as the Sun and our Milky Way (MW) galaxy) can be approximated to be inertial motion.[14]

Newton's first law also tells us whether or not a net external force is acting upon a body. Why? Because: a) by Newton's definition, 'inertial' means "uniform motion in a straight-line," and b) if a body (i.e. a planet) moves in a curved path, then according to Newton's first and second laws of motion, there must be net external "forces impressed upon it." (see Goldberg, pp. 52 – 53; Young, pp. 95 – 97)

German astronomer Johannes Kepler (1570 – 1631), who described the three laws of planetary motion in 1609 and 1618, also introduced the Latin word 'inertia' (meaning 'laziness') to physics. (Cohen, 1960, p. 210) Galileo described uniform inertial motion

[12] Although Galileo postulated that uniform motion on a "plane would be perpetual if the plane were of infinite extent" (Cohen, 1960, p. 117), he could not imagine this happening. At great distances Galileo imagined inertial motion to be curvilinear. (*Id*., pp. 119, 112, 124) In effect, Galileo was really describing uniform momentum.

[13] Newton had trouble describing his concept of celestial inertial motion relative to the nothing of empty space, so he merely postulated 'absolute space' as an immoveable reference frame from which he could describe motions. (Rohrlich, p. 52)

[14] Is the motion of celestial bodies ever rigorously uniform straight-line inertial motion? The answer is probably no. A galaxy's motion through space is about as close as one can get to idealized inertial motion, because its motion appears to be uniform and random and it doesn't seem to orbit anything. The Sun's combined galactic motion and slightly orbital motion is also close to straight-line inertial motion, and yet it is ever so slightly curved, because each 200 million years or so the Sun circumnavigates the Milky Way Galaxy. The Earth shares the Sun's almost uniform straight-line motion at about 225 km/s relative to the core of the galaxy, but because of the Earth's close proximity to the Sun, the Earth also orbits the Sun at 30 km/s every 365 Earth days. *A priori*, there can be no perfectly uniform and straight-line inertial motion, because the trajectories of all bodies are affected, more or less, by the gravitational attraction of other objects in the universe.

as where the increments of distance, time and speed "repeat itself always in the same manner." (*Id*., pp. 88 – 89; Figure 4.3A) French philosopher Rene Descartes (1596 – 1650) first clearly described the phenomenon of inertia as a 'state' in his unpublished book, 'Le Monde,' (Cohen, 1960, p. 210; Goldberg, p. 53), and French scientist Pierre Gassendi (1592 – 1655) first published a description of the law and he also tested it with experiments.[15] (Cohen, 1960, p. 211; Harrison, pp. 125 – 126) Thus, Newton's fully developed law of inertia was really a group effort.

2. Newton's Second Law of Motion (the law of 'force and acceleration') states:

> "The change of motion [acceleration] is proportional to the motive force impressed; and is made in the direction of the right [straight] line in which that force is impressed."[16] (Newton, *Principia* [Motte, Vol. 1, p. 13])

This law described the motion of a body that is not in equilibrium, vis., where a force is acting on the body and is not counterbalanced by another force. Newton defined 'impressed force' as "an action exerted upon a body, in order to change its state…" (*Id*, p. 2) Galileo mainly talked about accelerations, not forces. On the other hand, Newton stated and demonstrated that <u>forces cause</u> accelerations, and in which <u>direction</u>. Thus Newton explained why Galileo's gravitational accelerations and Kepler's planetary motions (accelerations) occur.

Newton intended the term "change of motion" to mean 'change in velocity' or, in modern terminology, 'acceleration.' (Goldberg, p. 54) Newton's second law, in effect, states that the acceleration (a) of a mass (m) is in the direction of the <u>continuous</u> net force

[15] Gassendi dropped rocks from the mast of a moving ship, and because of their inertia the rocks landed near the base of the mast, rather than toward the stern. (Harrison, pp. 125 – 126)
[16] It turns out that this second law was possibly first conceived and written down by Newton's contemporary and sometimes adversary, Robert Hooke. (McCall, p. 4)

(F) applied to it and is proportional to such force.[17] (see Figure 4.3B) Therefore, F = ma.[18] (Young, p. 100)

Newton also described another form of his second law that involved an impact or instantaneous (but not continuous) force, such as when a bat strikes a ball. Upon impact, the ball or other projectile is initially accelerated in proportion to the motive force applied, and it gains momentum. In space, far away from the Earth, the projectile will maintain a constant uniform rectilinear velocity, whereas near the surface of the Earth it soon succumbs to air resistance and the downward force of gravity and it decelerates. According to Newton, his law of continuous force law (F=ma) was derived from this impact law. [19] (Cohen, 1960, p. 184)

Newton defined the 'mass' (m) of an object to mean its "quantity of matter…its density and bulk [volume] conjointly." (Newton, *Principia* [Motte, Vol. 1, p. 1]) The greater a body's mass, the more a body 'resists' being accelerated, vis. having its state or direction of motion changed. Empirically, it is observed that: "If a force causes a large acceleration, the mass of the [accelerated] body is small; if the same force causes only a small acceleration, the mass of the [accelerated] body is large." (Young, p. 100) Thus, the mass of a body is the quantitative measure of its power or force of inertial resistance, and the magnitude of mass is inversely proportional to the force applied to cause its

[17] The standard unit of measure for any force is now called a 'Newton.' One Newton is the magnitude of net force necessary to accelerate 1 kilogram (kg) of mass 1 meter per second per second. (Young, pp. 100 – 101) The standard unit of measure for any mass is now the 'kilogram.' (Young., p. 100)

[18] This modern algebraic form of Newton's second law was created in 1750 by Swiss mathematician Leonhard Euler. (Gondhalekar, p. 94) But, as we will explain in later chapters, Euler's equation (F=ma) is not rigorously correct on Earth because of resistances such as air and surface friction.

[19] Newton asserted that a given force (F) results in a certain acceleration (a) of a body (m), but in order to determine the velocity v of mass m at any instant (during such acceleration), we must also know the duration of time (t) which such force has been applied. Therefore, v = at. (Cohen, 1960, p. 155)

acceleration: thus, m = F/a.[20] (*Id*.)

Newton's second law also empirically implies that the magnitude of acceleration of an object is *inversely proportional* to the mass of the accelerated object. (Zeilik, p. 68; Young, pp. 100 – 101) Feynman agreed: "a body reacts to a force by accelerating, or by changing its velocity every second to an extent inversely to its mass." (Feynman, 1965, pp. 4 – 5) Therefore, a = F/m. How do we know this to be true? Because (empirically) if you apply the same continuous force to two balls (m_1 and m_5) and one ball (m_5) accelerates only one-fifth as far and as fast as the other ball (m_1) during the same period of time (t), then *a priori* ball (m_5) must have 5 times as much mass as ball (m_1), and the magnitude of acceleration (a) of each ball is inversely proportional to the magnitude of its own mass. (*Id*.; see Figure 4.3B)

At the beginning of the *Principia*, Newton defined the "quantity of motion [as] the measure of the…velocity and quantity of matter conjointly." (Newton, *Principia* [Motte, Vol. 1, p. 1]) In other words, the term "quantity of motion," as defined by Newton, means the 'mass (m) times the velocity (v)' of a body, which since the time of Newton has been referred to as 'momentum,' or p. (Goldberg, p. 52) Thus p = mv. The more mass and/or velocity an object has, the more momentum it has, and therefore the more force which must be applied to accelerate it, slow it down, or change its direction of motion. (*Id*.)

It might be claimed that Galileo anticipated Newton's second law in his projectile experiments, because they combine two independent forces (one impact, i.e. the propulsion of a cannonball) and (one continuous, vis. gravity) in two different directions,

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[20] Again, since 'mass' is the quantitative measure of matter's inertial force of resistance, the magnitude of a body's mass is often referred to as its 'inertial mass.'

into the combined (uniform velocity and uniform acceleration) motion of a mass (a projectile), which results in a parabolic trajectory in a third direction. (Figure 4.2) But Galileo never took the next step and synthesized these motions, forces, masses and accelerations into a generalized law.

3. Newton's Third Law of Motion (the law of 'action and reaction') states:

> "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." (Newton, *Principia* [Motte, Vol. 1, p. 13])

Newton's third law asserts that action and reaction <u>motions</u> (caused by force) occur in equal (or equivalent) and simultaneous pairs, and in opposite directions. When an impressed (applied) force accelerates an object in one direction (the action motion), an equivalent <u>motion</u> and force of reaction is created in the opposite direction. This equivalent motion and force of reaction is exemplified by the backward 'g force' that a passenger experiences during the acceleration and take-off of an airplane, the recoil when a person fires a rifle, or when a person on the ground pulls on a rope attached to a heavy wagon, the person lurches (reacts) toward the wagon but the heavy wagon only moves (reacts) slightly towards the puller.

The impact force and acceleration motion of the relatively small mass of a bullet propelled out the barrel of a rifle is <u>equivalent</u> to the force and acceleration motion of the more massive rifle in the opposite direction. For example, when a bazooka is fired, the explosion (force in the barrel) causes the <u>action</u> motion of the projectile out the front of the barrel and the equivalent <u>reaction</u> motion and force of the exhaust out the rear of the barrel. (see Figure 4.3C) Because these opposite forces and motions are equivalent they offset each other, and the person who holds the bazooka does not feel any recoil; in effect, the bazooka remains in equilibrium.

In the third part of the Principia, entitled, "The System of the World," Newton described his law of the mutual gravitational attraction of all material objects: all masses attract each other with a force that is proportional to each mass, and which is inversely proportional to the square of the distance between their centers. Newton's law of gravitational attraction is basically an application of his three laws of motion working together with respect to the different masses of opposing bodies.[21]

C. Covariance and Invariance

Newton's second law of motion led to the classical mathematical concepts of 'covariance' and 'invariance.' (see Goldberg, pp. 80 – 81) By the classical term 'covariance' we refer to a comparison between two different accelerating events, where the magnitudes of mass, force and/or acceleration are different, but the interaction between such different magnitudes demonstrates that each acceleration event is the result of Newton's second law: a = F/m. (see Figure 4.4) In other words, in mathematical terms, the magnitudes of the variables (F, a, m) change in such a way ('covariantly') so that the <u>algebraic form</u> of Newton's second law of motion (F = ma) remains 'invariant' (it does not change) with respect to each different acceleration event. As Goldberg expressed it: "the quantities in the laws vary, each so that they leave the [algebraic] form of the law unvaried." (*Id*., p. 80) There is also a geometrical analogy to classical 'covariance' that might help to explain the concept. (see Figure 4.5)

The covariance of the interaction between the different variable quantities (F, m,

[21] In a treatise to follow this one, entitled the *Relativity of Gravity*, we shall fully discuss Galileo's, Kepler's and Newton's laws of gravity, and Einstein's attempt to supplant Newton's law with a radical new *ad hoc* mathematical theory of gravity (curved spacetime), which he called 'General Relativity.'

a) that invariantly results in the same fundamental law of motion (Newton's second law) is somewhat analogous to the various different visual perspectives of numerous observers with respect to the same motion of an object. (see Chapter 3) Algebraic transformation equations must be devised in order to relate such very different visual perspectives (or coordinate measurements) of the same motion or event, and likewise algebraic transformation equations have been devised to relate the interaction of such variable quantities which result in the same fundamental law of motion. The algebraic transformation equations for such variables are: F = ma, a = F/m and m = F/a. When any two of these variables or magnitudes are ascertained, the third variable can automatically be computed. (Figure 4.4)

There is also another form or set of transformation equations that relate the motions of the <u>same</u> mechanical experiment in two different <u>inertial</u> frames of reference, in order to demonstrate that Newton's second law of acceleration is independent of the velocity of the inertial frame in which it is applied. These transformation equations are called 'Galilean transformations' and they are discussed in detail in Chapter 14. Newton's second law of motion remains algebraically 'covariant' and the laws of <u>mechanics</u> remain mathematically 'invariant' with respect to Galilean mathematical transformations. (Goldberg, p. 80 – 81)

Newton's second law only appears to retain the form F = ma (and it is only obviously and intuitively covariant) in inertial reference systems. (Lindsay, p. 290) In accelerated reference systems, or reference systems with arbitrary motions (like a roller coaster), Newton's second law appears to take different algebraic forms and becomes very confusing. These functions of simplicity and intuitiveness are among the main reasons why inertial frames of reference became so important to classical mechanics during the 19th century. (see Chapters 13 and 14)

Toward the end of the 19th century, the mathematical concept of covariance was extended to the concept of ‘invariance’ for certain magnitudes and properties of matter. An ‘invariant magnitude or property’ is one that does not change for any observer regardless of his or the object’s velocity. [22] (Goldberg, p. 81) The magnitudes and properties of matter which were considered by late 19th century scientists to be invariant included: the mass of an object, its length, its other dimensions, its shape and its color. (see Resnick, 1968, pp. 11, 15)

Very importantly, it should be pointed out at this early juncture that Einstein drastically changed the above mechanical and empirical meaning of algebraic ‘covariance’ for his Special Theory to mean the algebraic ‘invariance’ of physical laws and physical magnitudes with respect to the Lorentz transformations. For Einstein, the term ‘covariance’ meant the transformation (or translation) of any algebraic law, equation, physical phenomenon or magnitude (including Maxwell’s constant transmission velocity of light at *c*) from one inertial reference frame to another inertial reference frame by means of his radical Lorentz transformation equations or the equivalent. (see Chapters 21 and 27)

When so transformed by Lorentz transformations, the classical laws of physics (including mechanics, electrodynamics and optics) would be distorted and would dramatically change from their classical meaning or magnitudes, but still they would remain invariant “with respect to Lorentz transformations.” (see Einstein, *Relativity*, p.

[22] The concepts of ‘property’ and magnitude ‘invariance’ were absolute concepts, not relative ones. (Goldberg, p. 80)

48) In other words, the distorted laws of physics and their magnitudes would be the same in each inertial reference frame.

All of these arbitrary and radical mathematical changes to physics were invented for one primary *ad hoc* purpose: to mathematically and artificially keep Maxwell's law for the constant transmission velocity of light at *c*, at the absolute magnitude of *c* relative to all inertial reference frames, regardless of their linear motions, so that the velocity of light relative to such reference frames could never mathematically be *c* – v or *c* + v. (see the Preamble) Rohrlich referred to this artificial mathematical result as "Einstein's fiat." (Rohrlich, pp. 55 – 62)

All of the fundamental concepts described in this chapter will be important to a full understanding of the phenomena and theories discussed in the chapters to follow.

D. Failures of Classical Mechanics

Newton's three laws of motion, along with his laws of gravitation and Galileo's theories of inertia, inertial motion, and projectiles (and related laws) are today referred to as 'classical mechanics.' (see Young, p. 92) Einstein stated that: "the purpose of mechanics is to describe how bodies change their <u>position</u> in space with time." (Einstein, '*Relativity*,' p. 10) "German mathematician Leonhard Euler, who was only 20 when Newton died, contributed much to making Newton's work accessible to a wider audience. He cast Newton's calculus and the mathematical formulation of his mechanics into the [algebraic] form which we use today"…F=ma. (Rohrlich, p. 42)

> "Many other important developments of Newtonian mechanics[23] and gravitation theory were made in the late eighteenth and early nineteenth century. Such men as Lagrange, Laplace, and Hamilton, who were both mathematicians, theoretical

[23] "Newton's mechanics…must be distinguished from 'Newtonian mechanics,' which refers to the later [mathematical] development of that subject." (Rohrlich, p. 35)

> physicists and astronomers, provided much more powerful mathematical techniques than were available to Newton. They made it possible to predict astronomical events with very great precision. But during this whole period of the elaboration and extension of Newton's work absolute space and time seemed to play no role at all. Everyone worked with *relative motion* and no difficulties were encountered." (*Id*.)

Since Newton's era, we have come to realize that classical mechanics had certain theoretical failings. We shall briefly describe three of the most important failings. As Einstein pointed out in 1905, classical mechanics failed to appreciate the importance of the distance/time interval delay of the light signal with respect to a local observer's perception of the 'time' (instant) of a distant event. Thus, classical mechanics also failed to fully appreciate the intertwined relationship between position and time for the algebraic description of motions.

During Newton's time, and throughout history until the dawn of the 20th century, the mass of an object was always considered to be an inherent and invariant property of the object. It never varied. Then during the period 1901 to 1904, Kaufmann and several other scientists discovered by experiments, calculations and theories that the 'electromagnetic' mass of an electron can vary depending upon how much energy is applied to it. (see Chapter 17) However, such variation can depend upon how one defines the word mass.[24] (see Chapters 17 and 31) Nevertheless, classical mechanics failed to realize these possibilities.

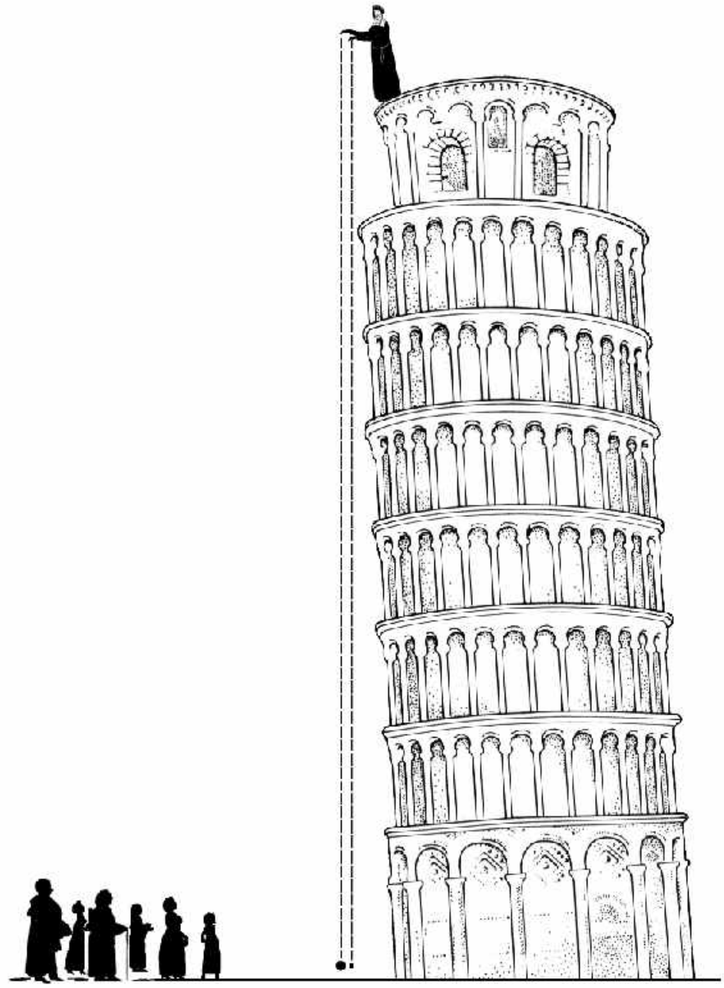
Classical mechanics also failed to recognize the correct relationship between matter, energy and mass. (Chapter 32) All of the above failings, in turn, may have affected the computation and mathematical description of positions, accelerations, momentum, resistance, time, and other values in classical mechanics and celestial

[24] For example, it turned out that the term 'electromagnetic mass' was actually a misnomer. In reality, electromagnetic mass was just an electromagnetic resistance.

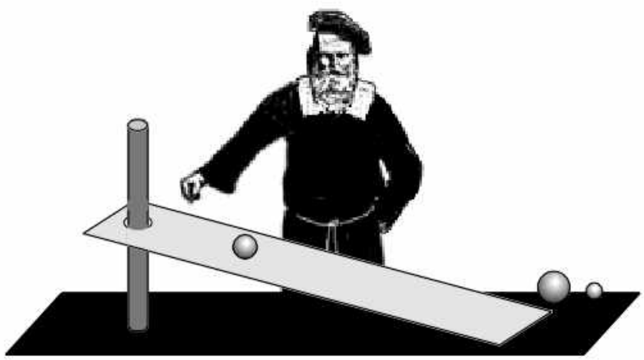
mechanics.[25]

Such theoretical failings must of course be adequately remedied by current physics. Nevertheless, Newton's three laws of motion along with his law of gravitational attraction have governed most areas of mechanics and astronomy for over 300 years. Einstein's Special Theory of Relativity claims *inter alia* to radically modify Newton's laws of motion well beyond that which is necessary for the correction of the previously described theoretical failings.[26] Einstein's General Theory of Relativity also claims *inter alia* to radically modify Newton's laws of gravity. We will demonstrate in this treatise that neither of Einstein's *ad hoc* theories of relativity was necessary or even relevant for the correction of such failings, nor for almost any other reason.

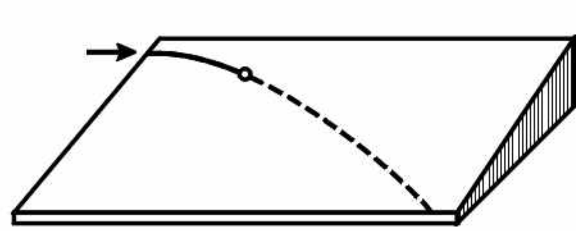
[25] The term 'celestial mechanics' refers to the application of Newton's laws of motion and gravitation to the Moon, the Earth and other heavenly bodies.
[26] The Latin phrase *inter alia* means "among other things."



A. Galileo's Leaning Tower of Pisa Experiment



B. Galileo's Inclined Plane Experiments



C. Galileo's Wedge Experiments

Figure 4.1 Galileo's Empirical Experiments Concerning Gravitational and Parabolic Motions

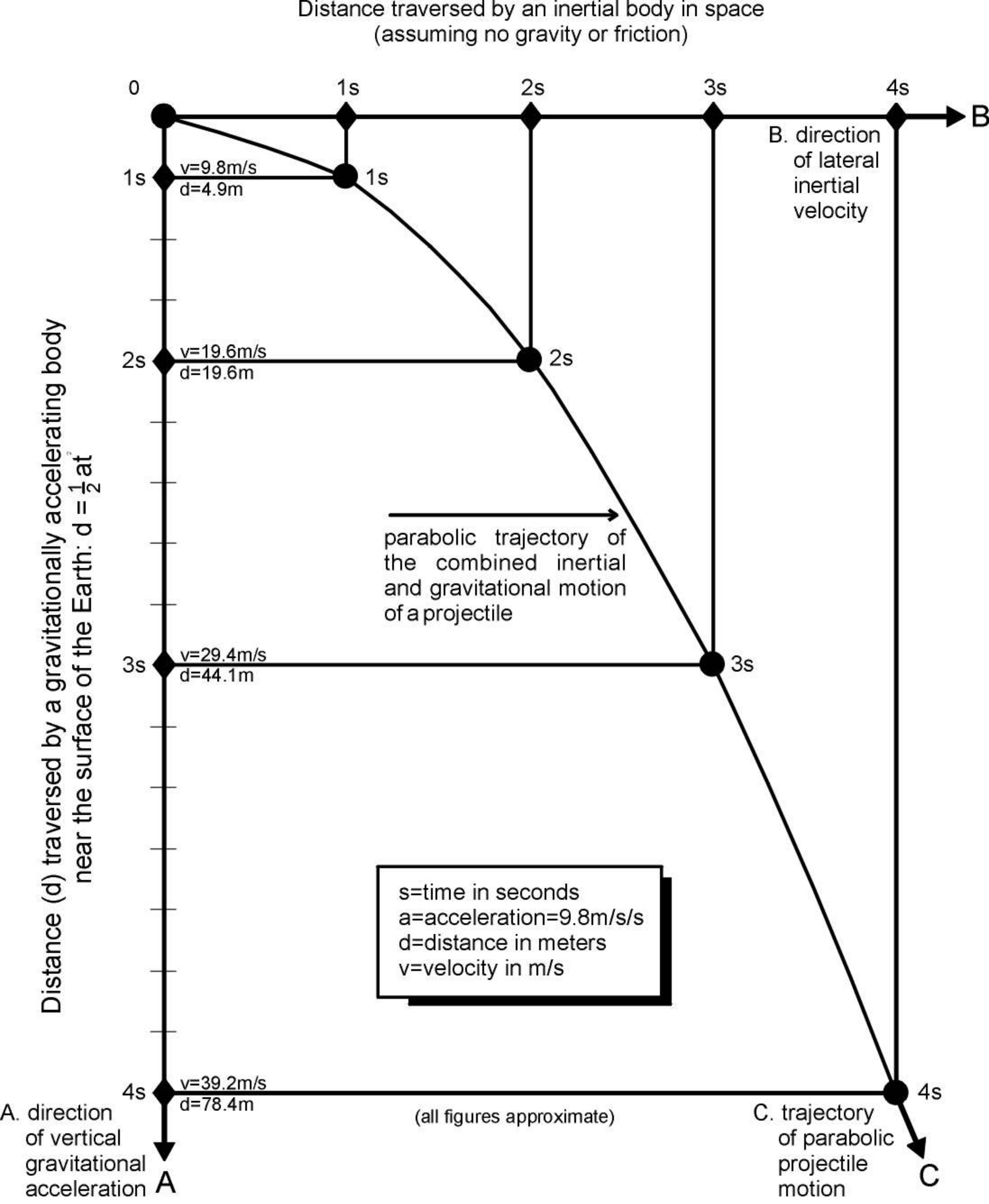
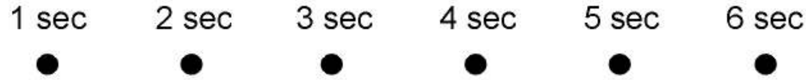


Figure 4.2 An Illustration Of The Combination Of Results Of Galileo's Inertial, Gravitational And Projectile Experiments Near The Surface Of The Earth

Partial Sources: Goldberg, pp. 26, 33, 34; Gamow, 1961, p. 42; Cohen, 1960, p. 110

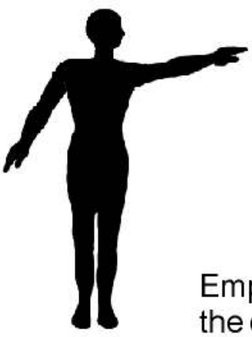
A. First Law: Inertia



Astronaut throws a ball in empty space. Empirical Result: The ball moves rectilinearly and travels equal distances during equal time intervals without application of continuous force.

B. Second Law: Force & Acceleration of Mass (F = ma; a = F/m; m = F/a)

Man pushes two balls of unequal mass with an equal magnitude of force.



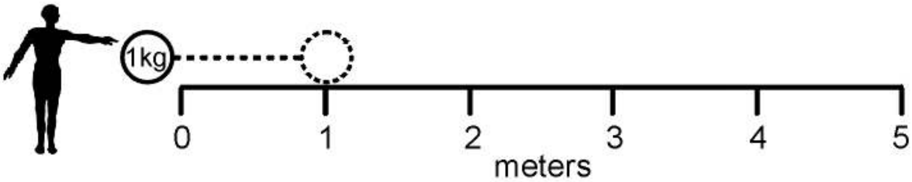
Empirical Result: The ball with 5 times the mass accelerates only 1/5th the distance during the same time interval (i.e. 1 second).

C. Third Law: Equal & Opposite Actions and Reactions

Empirical Result: The action of the projectile is equal to the reaction of the exhaust, and such motions are directed in contrary (opposite) directions.

Figure 4.3 Newton's Three Laws Of Motion Illustrated

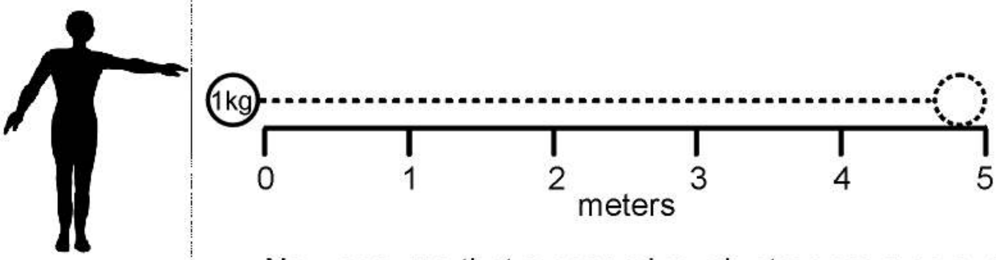
Acceleration Event A



$F = ma \ (1 = 1 \times 1)$
$a = F/m \ (1 = 1/1)$
$m = F/a \ (1 = 1/1)$

Assume that a man pushes a 1 kilogram ball with a force (F) of 1 Newton. Empirically, the mass (m) of the ball will accelerate (a) 1 meter during a 1 second time interval.

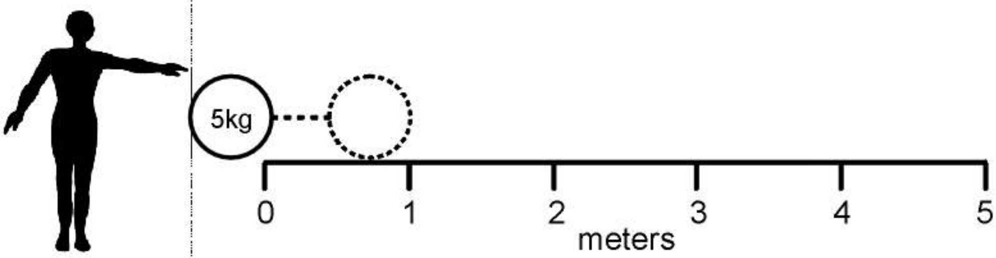
Acceleration Event B



$F = ma \ (5 = 1 \times 5)$
$a = F/m \ (5 = 5/1)$
$m = F/a \ (1 = 5/5)$

Now assume that a second much stronger man pushes the same 1 kg ball with a force (F) of 5 Newtons. Empirically, the mass (m) of the ball will accelerate (a) 5 meters during a 1 second time interval.

Acceleration Event C



$F = ma \ (5 = 5 \times 1)$
$a = F/m \ (1 = 5/5)$
$m = F/a \ (5 = 5/1)$

Finally, assume that the same stronger man pushes a different 5 kg ball with a force (F) of 5 Newtons. Empirically, the mass (m) of the ball will accelerate (a) 1 meter during 1 second.

Conclusion: Each acceleration event is algebraically 'covariant' as compared to the other two events. The values of F, m, and a, co-vary in such a way that the algebraic forms of Newton's second law (F = ma, a = F/m, m = F/a) remain 'invariant' (unchanged) for each event. The above equations may also be considered to be transformation equations. They transform and relate the magnitudes of F, m and a in each different event.

[Note: One 'Newton' is the force empirically required to accelerate 1 kg. of mass a distance of 1 meter during 1 second of time at sea level on the Earth's surface.]

Figure 4.4 A Demonstration Of Classical 'Covariance' And 'Invariance' With Respect To Newton's Second Law Of Motion

When a right-angled triangle is rotated relative to the eye of an observer, the observer's perspective of the triangle changes. The angles of the triangle appear to change, but they always total 180°. Likewise, the base and the hypotenuse of the triangle appear to change, but the geometric law, the Pythagorean Theorem ($a^2 + b^2 = c^2$), always remains the same. In other words, the sum of the angles are 'covariant,' and the squares of the sides are 'covariant,' but the Pythagorean law of geometry remains the same, 'invariant.'

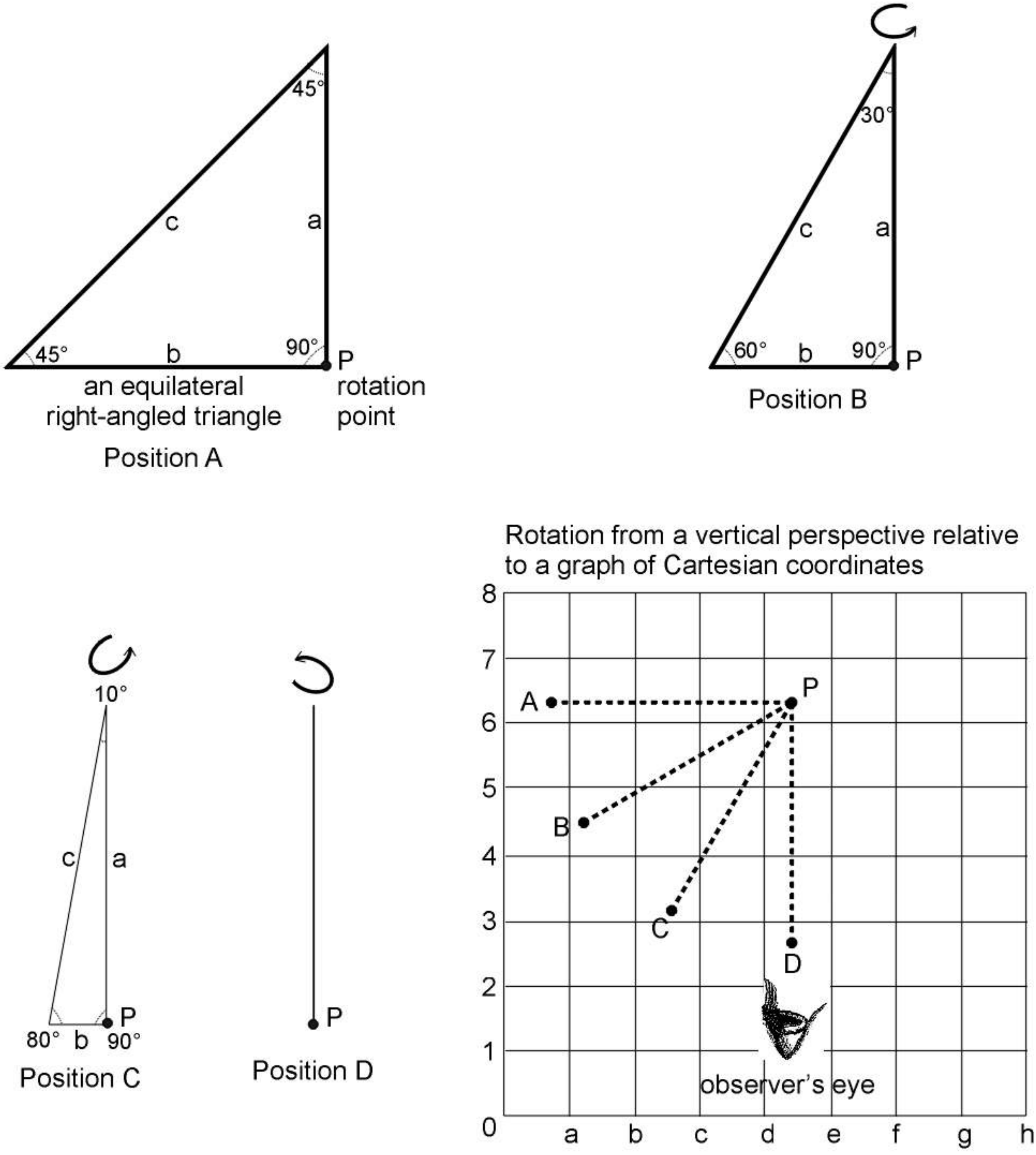


Figure 4.5 Geometrical Analogy To Classical Covariance

(not exactly to scale)

Source: McCall, p. 129