PAST KNOWLEDGE PEOPLE

ISSN: 2997-6170

Review Article

Space Science Journal

Simple Formulas for Calculating Tidal Force, Tidal Amplitude and Perihelion Precession of Mercury

Xiaozhong Zhai*

City of Residence Odense in Denmark

***Corresponding Author**
Xiaozhong Zhai, City of Residence Odense Kommune in Denmark.

Submitted: 2026, Jun 24; **Accepted:** 2026, Jul 09; **Published:** 2026, Jul 30

Citation: Zhai, X. (2026). Simple Formulas for Calculating Tidal Force, Tidal Amplitude and Pherihelion Precession of Mercury. *Space Sci J, 3*(2), 01-10.

Abstract

This paper presents a series of straightforward equations for the calculation of tidal forces, tidal amplitude and the precession of Mercury's perihelion. The outcomes derived from these equations exhibit a high degree of consistency with the observations documented in the extant literature. Moreover, it offers a novel perspective for comprehending the tide phenomenon and the precession of Mercury's perihelion.

Keywords: Earth, fulcrum, Mercury, Moon, precession, Tide, Venus.

1. Introduction

Tides are the cyclic rise and fall of sea levels. The forces that cause tides mainly come from the Moon's gravitational pull on the Earth's surface, with the Sun contributing less. Uncertainty persists in the scientific community despite this view being accepted today. The Sun and Moon exert gravitational forces of approximately 0.0059 m/s² and 3.1148E−05 m/s² on Earth, respectively. These values are negligible compared to Earth's surface gravity of 9.78638037m/s². Small gravitational accelerations creating substantial tides perplex people.

The Sun's gravitational pull on Earth is much greater than the Moon's, so why is the tidal force mainly attributed to the Moon?

During a new moon, the Moon and Sun are on the same side of Earth. During a neap tide, the Moon is on one side of Earth. Why does seawater uplift still occur when Earth's opposite side is not subject to its gravitational influence?

Physicists and astrophysicists do not widely comprehend these concepts. Therefore, the enigmatic nature of tide formation persists, lacking definitive validation. There has never been a theory that can accurately calculate both tidal forces and tidal amplitudes now.

Mercury's perihelion precession captivates physicists and astronomers. In 1859, Le Verrier first asserted that Newtonian mechanics and known planetary gravitational influences could not entirely explain the gradual shift in Mercury's orbit around the Sun [1]. He suggested an undiscovered planet or a cluster of corpuscles closer to the Sun than Mercury to explain the anomalous perturbation [1]. His speculation never became a reality.

The new theory in this paper responds to these questions and proposes new equations to accurately calculate tidal force, tidal amplitude, and Mercury's perihelion precession.

2. Theory and Equations

Planets in our solar system are often considered particles in physical research. However, they are giant spherical objects. From a distant space station, to see them, Earth appears as a huge sphere gracefully rolling at orbital speed around the Sun in the vast universe. Thus, the planet and its moon exhibit a rotation-rolling motion with a recognizable fulcrum. This fulcrum, like the orbits of the planets, is a imaginary point.

Since the rotation-rolling velocity equals its orbital velocity, the radius of the planets' and moons' rotational or rolling motion can be determined using the following equation:

2πrX=tv (1)

Here, r is the celestial body's radius, t is its rotational period, v is its orbital velocity, and x is the radius magnification factor.

The rolling radius for most planets is smaller than their semi-major axis. The fulcrum of the rotation-rolling motion is between the Sun and the planet.

However, the moon's orbital period (T) and its spin period (t) are equal. it can be seen from Equation 1 $\left(rX = \frac{tv}{2\pi} = \frac{TV}{2\pi} = \frac{2\pi R}{2\pi} = R\right)$. So, its rotation- rolling radius is equal to its orbital radius, R.

The position of the fulcrum for the Moon's rotation-rolling motion is situated at the Earth's center of mass.
In this way, the moon can be seen as a huge rotation-rolling sphere with a radius equal to rX or R around its axis on its fulcrum, as shown in Figure 1.

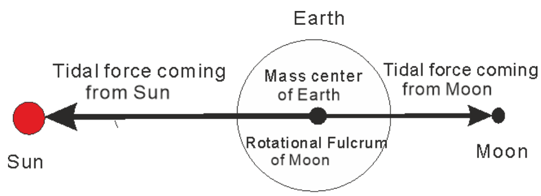

Figure 1

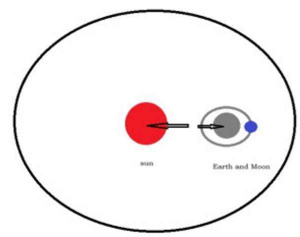

Figure 2: Sun's gravitational field and its three-body system: Sun Earth and Moon
The arrow indicates the direction of the gravitational field

The Moon's tidal force felt by the Earth center is calculated using the following equation:

$$g_{moon-tide} == \frac{GM_{Moon}}{R^2} \qquad (2)$$

Here, r is Moon's radius, M_{Moon} the mass of Moon and R the orbital radius of the Moon. G is gravitational constant. The symbol of $g_{moon-tide}$ is the tidal force coming from the field of Moon's mass and exerting on the Earth center, as shown in Figure 1.

The Sun's tidal force felt by the Earth center is calculated using this equation:

$$g_{sun-tide} = \frac{GM_{sun}}{R^2} \qquad (3)$$

Here, the symbol of $g_{sun-tide}$ represents the tidal forces that are exerting on the Earth center and R is the orbital radius of Earth. M_{sun} is the mass of Sun. G is gravitational constant.

At the center of the Earth, the tidal force acts in opposition to the surface gravity, resulting in a diminishing gravity on Earth's surface. The surface gravity equation $\left(g = \frac{Gm}{r^2}\right)$ shows that a diminishing gravity on Earth's surface means that the radius or diameter inevitably is increased if its mass remains unchanged.

Therefore, tidal force is a tensile force that elongates the radius and diameter of the Earth, leading to the flow and convergence of seawater in the direction of the increasing diameter, thereby forming tides.

By this definition, suppose that seawater covers the surface of the earth evenly. L represents the length elongated by tidal forces. The value of L can be calculated using the following formula:

$$L = r_{tide} - r \qquad (5)$$

Here, r is Earth's radius; r_{tide} represents its radius where the tide occurs.

Based on the equation: $\left(g = \frac{Gm}{r^2}\right)$, we have the following equation for calculating the the length of radius r_{tide} elongated by tidal forces:

$$r_{tide} = \sqrt{\frac{Gm_{earth}}{\frac{Gm_{earth}}{r^2} - \frac{g_{tidal\ force\ felt\ by\ earth}}{2}}} \quad (6)$$

The term of $\left(\frac{g_{tidal\ force\ felt\ by\ earth}}{2}\right)$ refers to the gravity experienced by Earth's radius where the tide occurs. The gravity (g) on Earth's surface is equal to $\frac{Gm_{earth}}{r^2}$ (Here,the rotational centrifugal force is ignored.) without tide force. So, the following equation is derived.

$$L = r_{tide} - r = \sqrt{\frac{Gm_{earth}}{g - \frac{g_{tidal\ foece\ felt\ by\ earth}}{2}}} - r$$

$$L = \sqrt{\frac{Gm_{earth}}{g - \frac{g_{tidal\ foece\ felt\ by\ earth}}{2}}} - \quad (7)$$

Here, r is the Earth's original radius.

Seawater volume is approximately $1.331368e{+}10^{18}$ cubic meters (ocean: surface area =3.61×e⁺ $10^{148} m^2$. Average depth =3688m). Earth's total volume is $1.08321 \times e{+}10^{21}\ m^3$ [2]. The ratio of the two volumes is equal to 0.0012291.

Because the volume of ocean water is 0.12291% of the total volume of the Earth, the amplitude (h) of tide may be calculated using the following equation:

$$h = 0.0012291 \left(\sqrt{\frac{Gm_{earth}}{g - \frac{g_{tidal\ foece\ felt\ by\ earth}}{2}}} - r \right) \quad (8)$$

If the amplitude of tide h is a known number, the tidal force felt by Earth may be calculated by equation 9:

$$g_{tidal\ foece\ felt\ by\ earth} = 2g - \frac{2Gm_{earth}}{\left(\frac{h}{0.0012291} + r\right)^2} \quad (9)$$

Here, m_{earth} is Earth's mass and h its tidal amplitude. g represents Earth's surface gravity and r the radius.

The tidal force felt by seawater may be also calculated by the following equation:

$$g_{tidal\ foece\ felt\ by\ seawater} = 0.0012291 \left(2g - \frac{2Gm_{earth}}{\left(\frac{h}{0.0012291} + r\right)^2} \right) \text{ or} \quad (10)$$

$$g_{\text{tidal force felt by seawater}} = 6.155e - 6\ s^{-2}\ h$$

Here, $6.155 s^{-2}$e - 6 can be regarded as a constant denoting the tidal force experienced by seawater at a tidal amplitude of 1 meter. Then, we have :

$$g_{tidal\ foece\ felt\ by\ earth} = \frac{6.155e{-}6\ s^{-2}\ h}{0.0012291}$$

$$\text{Or} \quad g_{tidal\ foece\ felt\ by\ earth} = 0{,}005 s^{-2} h \quad (11)$$

Water exhibits incompressibility and fluidity. Tidal forces cause the elevation of seawater, resulting in an increase in water depth at points A and B (Points A and B are regarded as the high tide points in the tide process) and a decrease at points C and D (Points C and D are regarded as the low tide points in the tide process.). Seawater flows from points C and D along the arcs CA and DA towards point A, and from points C and D along the arcs CB and DB towards point B, as depicted in Figures 3 and 4.

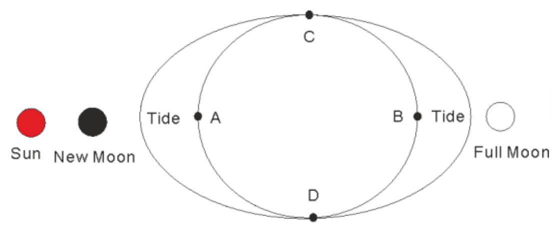

Figure 3 Spring Tide

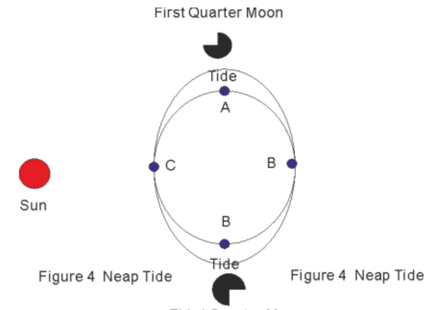

Figure 4 Neap Tide   Figure 4 Neap Tide

The formula $t^2 = \frac{2.83\,\pi^2 r^3}{Gm - r^2 g} \cong \frac{4\pi^2 r^3}{Gm - r^2 g}$ allows us to calculate gravity (g) on Earth's surface as g= $\frac{Gmt^2 - 4\pi^2 r^3}{t^2 r^2}$ [3,4]. Here, r denotes Earth's radius, m its mass, and t its rotational period.

During tide formation, the gravity (g_{AB}) at points A or B where seawater rises in the high tidal process (see Figure 3 and 4) can be calculated using this equation.

$$g_{AB} = \frac{\mathrm{Gmt^2 - 4\pi^2\,(r+h)^3}}{\mathrm{t^2 (r+h)^2}} \qquad (12)$$

The gravity (g_{CD}) at points C or D on Earth can be calculated using the following equation in the low tidal process (shown in Figure 3 and 4 :

$$g_{CD} = \frac{\mathrm{Gmt^2 - 4\pi^2\,(r-h)^3}}{\mathrm{t^2 (r-h)^2}} \qquad (13)$$

When high and low tides balance, the difference between g_{AB} and g_{CD} is the tidal force felt by seawater. So, we have the following equation:

$$g_{tidal\ forcefelt\ by\ seawater} = \frac{\mathrm{Gmt^2 - 4\pi^2\,(r-h)^3}}{\mathrm{t^2 (r-h)^2}} - \frac{\mathrm{Gmt^2 - 4\pi^2\,(r+h)^3}}{\mathrm{t^2 (r+h)^2}} \qquad (14)$$

Here, $g_{tidal\ forcefelt\ by\ seawater}$ represents the tidal force felt by seawater. m is Earth's mass, r its radius, t its rotational period and h the tide amplitude. G is the gravitational constant.

Similarly, Venus can be considered as a massive sphere with a radius equal to rX. It rotates or rolls around its axis at its fulcrum.in Figure 5,6.7.

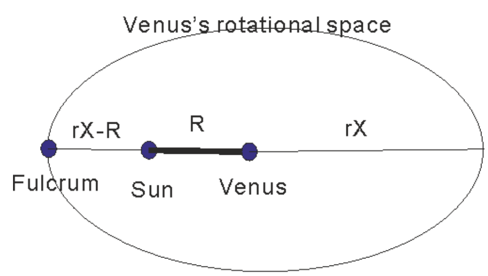

Figure 5

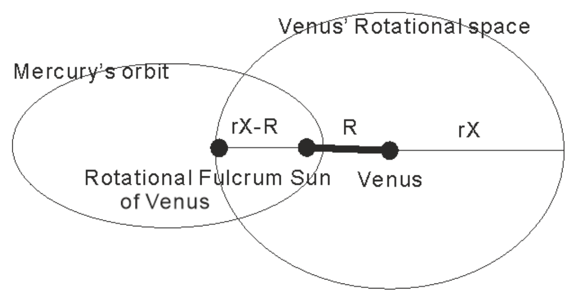

Figure 6

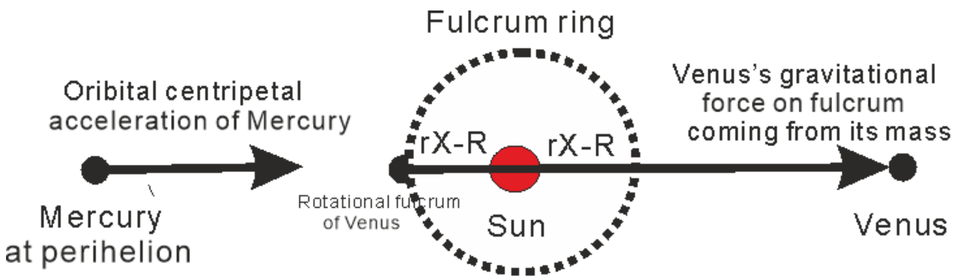

Figure 7

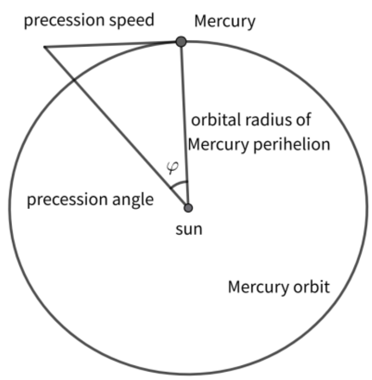

Figure 8： Precession of the perihelion of Mercury

The radius (rx = 1.17769232e+11m) of Venus's rotation-rolling is bigger than its semi-major axis R (R = 1.08205689e+11m). The fulcrum of Venus's motion is on the other side of the Sun and between the Sun and Mercury showed by Figure 5,6,7.

As Venus undergoes orbital and rotation-rolling motion, the trajectory of the fulcrum forms a ring around the Sun between Mercury and Venus as depicted in Figure 7. The radius of this ring is equivalent to rX - R (9.563543×10^9 m), as shown in Figures 5, 6, and 7. This phenomenon creates an illusion as if there were a celestial body moving along the ring. This imaginary ring can be referred **Le Verrier ring** , and the imaginary celestial body can be termed **Le Verrier body**.

When the perihelion of Mercury, the Sun, and the rotation-rolling fulcrum of Venus, the three points, are aligned in a straight line (as depicted in Figure 7), the direction of the gravitational force exerted by Venus's mass at the fulcrum, coincides with the orbital centripetal acceleration of Mercury. As a result, Mercury acquires an additional orbital centripetal acceleration. Simultaneously, Mercury at perihelion obtains an additional orbital velocity.

Given that the velocity of the fulcrum's movement is equivalent to Venus's orbital velocity, the centripetal acceleration (g_{extra}) at the fulcrum determined by Venus's mass and acquired by Mercury can be computed using the following equation:

$$g_{extra} = \left(\sqrt{\frac{(v_{venus})^2}{(rx)_{Venus}}} cos\theta\right) \quad (15)$$

Then, the additional orbital velocity, v_{extra}, gained by Mercury at perihelion, called perihelion precession speed of Mercury, is produced and can be calculated using the following equation.

$$v_{extra} = \sqrt{\frac{(v_{venus})^2}{(rx)_{Venus}} cos\theta R} \quad (16)$$

R is Mercury's orbital radius at perihelion; the term of $\frac{(v_{venus})^2}{(rx)_{Venus}} cos\theta$ represents the extra orbital centripetal acceleration gained by Mercury. v_{venus} is Venus's orbital velocity, r its radius, and x its magnification factor and θ spin axis tilt.

So, the value of tan φ may be calculated using the following equation shown in Figure 8:

$$\tan \varphi = \frac{\mathrm{v_{extra}}}{\mathrm{R}} = \frac{\sqrt{\frac{(v)venus^2}{(rx)Venus} cos\theta R}}{\mathrm{R}} \quad (17)$$

3. Result

The value of $g_{moon-tide}$ calculated by equation 2 is equal to 3.1148e-5 $\mathrm{m}\, s^{-2}$ $[\mathrm{G}7.346\mathrm{e} + 22\mathrm{kg}/\ (3.84784e + 8m)^2]$ and that of $g_{sun-tide}$ calculated by equation 3 is equal to $0.00592885\mathrm{m}s^{-2}[G1.988e + 30kg/(1.49598023e + 11m)^2]$.

'The tidal force felt by Earth in spring tide process calculated by equation 9 and 11 is equal to 0,00465ms^{-2} if the tidal amplitude of spring tide is equal to 0.93m.

According to the equation 10 and 14, the tidal force felt by seawater is equal to 6.155352E−06ms^{-2}, when the tidal amplitude is equal to one meter in the spring tide process. (r=6 378 137meter, $\mathrm{G}m_{Earth}$=$3.9861389091E + 14$, g=9.7986160814782).

The amplitude of spring tide is 0.93 meter. So, according to equation 10 and 14, the tidal force felt by seawater is equal to 5,72447736E−06 ms^{-2}.

Mercury and Venus's orbital planes are assumed to be in the same plane. The extra centripetal acceleration gained by Mercury at its perihelion is equal to 0,010467864 $\mathrm{m}s^{-2}$ $\left(\frac{v^2}{rX}\cos 2.64 = \frac{(3.502\mathrm{e}+4)^2}{6.0518\mathrm{e}+6\times 19\ 338.78} \times.\ 0.99894 = \frac{1\ 226\ 400400}{1.17\ 034\ 42088e+11} \times 0.99894\right)$ So, the extra orbital speed gained by Mercury at its perihelion, I.e., perihelion precession speed of Mercury is equal to 21 943,6332.1943633e+4 ms^{-1}

$$\left(\sqrt{\frac{\mathrm{v}^2}{\mathrm{rx}}\cos 2.64\ \mathrm{R}} = \sqrt{0{,}010478972 \times 0.99894 \times 4.6000124\mathrm{e}+10} = \sqrt{481\ 523\ 055{,}34045} = 21\ 943{,}6336\mathrm{m/s}\right).$$

The tangent linear of Mercury's velocity is perpendicular to its perihelion radius; thus, its tangent, tan φ, its tangent, tan φ, $\left(\tan \varphi = \frac{\mathrm{v_{extra}}}{\mathrm{R}} = \frac{\sqrt{\frac{(v)venus^2}{(rx)Venus} cos\theta R}}{\mathrm{R}}\right)$, is equal to 4.77034227E−07 (21 943,6636m/4.6000124e+10m =4.7702463E−07), as Figure 8 shows.

The shifting angle of Mercury's perihelion, φ, is equal to 2.7332e-5 degrees or 0,09839537 arc seconds per orbital period.

The orbital plane of Mercury and Venus is nearly co-planar (Venus: orbital inclination to Sun's equator:3.86 degree) (Mercury: orbital inclination to Sun's equator: 3.38 degree) [2].

The Sidereal rotation period of Venus and the Sidereal orbital period of Mercury are equal to 243.0226 days and the 87.9691 days respectfully. So, the precession value of Mercury's orbital perihelion per century is equal to 40.854 arcseconds (0,09839537 $\times \frac{365.25}{243.0226} \times \frac{243.0226}{87.9691} \times$ 100=0,09839537 × 1,50294664 ×2,7625905 × 100 =40.854)and (The term of $\frac{365.25}{243.0226}$ represents the spins number of Venus per year and the term of $\frac{243.0226}{87.9691}$ the probability that the orbital perigee of Mercury, Venus' fulcrum and Sun are in a straight line per year) [2].

4. Discussion

To comprehend the mechanism of tidal formation, it is imperative to initially emphasize the theories and phenomena acknowledged by both physics and astrophysics at present, and subsequently deliberate on the mechanisms of tidal formation.

Celestial bodies, irrespective of their shapes, possess a gravitational field, which is a spherical space featuring a spin axis [4]. The direction of the gravitational field of each celestial body is oriented towards its own center. Arbitrarily, due to the fact that the gravitational fields of these two celestial bodies are always in opposite directions, they exhibit mutual attraction. The mutual attraction between two objects represents the interaction of two field forces acting in opposite directions. Consequently, the gravitational attraction exerted by one celestial body on another represents the interaction between gravitational fields. This mutual interaction is manifested as the influence between the center of mass of one gravitational field and the center of mass of another gravitational field, rather than acting upon specific components of celestial bodies. Concerning the gravitational interaction between fields, it is the field rather than the mass substance itself, which plays a crucial role. Owing to this, when dealing with a field, the nearby substances cannot hold greater significance than the distant substances.

Second, when considering two celestial bodies, the curvature directions of one object relative to the other are opposite. Specifically, for two objects, the gravitational force (F) exerted by one object on the other is opposite to the gravity on its surface (g). Therefore, the gravitational pull exerted by one object on another object (F) weakens its gravity (g) on the surface. Therefore, if the mass of celestial body remains unchanged, its radius is forced to increase according to $\left(g = \frac{Gm}{r^2}\right)$. This change is also symmetrical because the field always remains symmetrical.

Tidal force refers to the gravitational pull exerted by one celestial body on another, which mutually reduces the gravitational acceleration on their surfaces. This leads to an elongation of its radius or diameter.

Considering that the Sun, Earth, and Moon constitute a three - body system, the gravitational field of the Sun exerts an influence not only on the Earth but also on the Moon (refer to Figure 2) and vice versa. Evidently, the tidal forces acting on the Earth are the outcome of the interaction among three celestial bodies. Regrettably, as of now, there exists no theory or formula capable of depicting the mathematical relationship of the three body system, particularly the Sun - Earth - Moon. the three body system. When combined with the rotation-rolling motion of the Earth and the Moon, the mathematical relationships among the three celestial bodies become even more intricate. Consequently, it is more challenging to describe tidal theory.

Physicists and astrophysicists have acknowledged another fact: The Earth rotates within a tidal space. This tidal space is a spherical region composed of a high - tide ring (AB ring) and a low - tide ring (CD ring) in figure 3 and 4. These two rings are mutually perpendicular, thereby giving rise to a spherical space within which the Earth rotates. This spherical space is the outcome of the interaction among the Sun, the Earth, and the Moon. Therefore, this spherical space can be referred to as the three - body tide-force space, shortly, tide-force space.

The force originating from the tide-force space represents the actual tidal force responsible for the occurrence of tidal phenomena.

The computational results demonstrate that the maximum tidal force (5,72447736E−06 ms^{-2}) experienced by seawater with the amplitude 0.93m of spring-tide is significantly smaller than the gravitational attraction of the Sun(0.00592885ms^{-2}) and the Moon (3.1148e-5 ms^{-2}). At the same time, the tidal force acting on the Earth (0,00465ms^{-2}), experienced by Earth, is considerably less than the Sun's gravitational force, yet substantially greater than the Moon's gravitational force. Evidently, tidal forces do not directly originate from the Sun or the Moon. Simultaneously, it also suggests that the tidal force is most probably the outcome of the three - body interactions.

The tide-force space rotates about its axis. This axis is the line of perpendicular intersection of the AB and CD rings. The rotational period of this space is exactly synchronized with the orbital period of the Moon. During rotation, the intensity of this space for tide varies periodically. Because of those, the tidal amplitude changes with the movement of the Moon, which has given rise to a long - standing academic issue: tides are regarded as the result of lunar gravitational force. In reality, this is merely an illusion.

As depicted in Figures 3 and 4, the seawater-depth increases at the points corresponding to A and B on the Earth's surface, which gives rise to a phenomenon referred to as high (rising) tide. Simultaneously, at the points corresponding to C and D, the seawater-depth decreases, which is termed low (ebb) tide.

More specifically, the tidal force stemming from the AB ring weakens the surface gravity at the corresponding locations on the Earth's surface. This weakening results in a disparity in surface gravity between the AB and CD rings. As a consequence, seawater migrates from the CD ring, where the surface gravity is relatively high, to the AB ring, where the surface gravity is relatively low. Seawater converges from regions with higher surface gravity to areas with lower, thus leading to the occurrence of tidal phenomena.

Therefore, during the tidal processes, the AB ring, the rising tidal ring, serves as the active ring, while the CD ring, the ebb tidal ring, functions as the passive ring.

It can be seen that only the AB ring, which is a spatial ring from the mutual influence of Sun-Earth-Moon three-body, is truly a tidal force ring.

Evidently, tides represent the Earth's reaction to tide-force space. The ultimate outcome is an elongation of its radius or diameter, which leads tidal bulges.

Precisely because of those, during the full - moon and new - moon phases, the AB ring (Figure 3,4), also known as the high - tide ring, aligns with the Earth's 90 - degree east - west longitude. The CD ring, which is the low - tide ring during the first - quarter and last - quarter moon phases, coincides with the Earth's zero and 180 degree longitude.

The same logic applies. From the full moon to the first quarter moon, the magnitude of tidal force Gradually transitions from a relatively strong state to a relatively weak state. From the first quarter moon to the new moon, the magnitude of tidal force Gradually shifts from a weak state to a strong state. Subsequently, from the new moon to the last quarter moon, the magnitude of tidal force Gradually changes from a strong state to a weak state. From the last quarter moon to the full moon, the magnitude of tidal force Gradually transforms from a weak state to a strong state. This cycle persists indefinitely.
The tide-force space of the three-body system exhibits symmetry, and the tidal manifestation is also symmetrical. This also explains why tidal waves of equal size appear on the non-lunar side.

The intensity of the tidal force varies with the movement of the three - body tidal space. When the high - tide ring is aligned with the new moon or the full moon, the tidal force and tidal amplitude reach their maximum values. This type of tide is referred to as a spring tide. When the high - tide ring is aligned with the first or last quarter moons, the tidal force and tidal amplitude reach their minimum values, and this tide is known as a neap tide.

The solid parts of Earth is surrounded by seawater. Seawater accounts for 8.136% of the Earth's total volume. Owing to the distinct properties of seawater and land, the tidal force experienced by Earth's seawater Does not the same with that felt by Earth.

Contemporary advancements in science and technology have enabled the precise measurement and observation of tidal amplitudes. In the open ocean, in the absence of the influence of wind and waves, the amplitude of the spring tide is measured to be 0.93 meters. Correspondingly, the magnitude of the tidal force felt by seawater is approximately $5,74\times10^{-6}$ m/s². At the same time, the tidal force felt by Earth is 0.00465ms^{-2}.

If the Moon is regarded as rotation-rolling body around its fulcrum and its rotational axis, its tidal force (centripetal acceleration at fulcrum) can be calculated using the following equation:

$$g_{moon-tide}=\frac{v^2}{r}cos\theta=\frac{(1022\text{m/s})^2}{3.84784e+8}cos6.687°=0{,}99319709572442=0{,}002696\text{m}s^{-2}$$

Here, v is Moon’s rotation-rolling speed of Moon, r its orbital radius and θ is the axis tilt.

This value (0,002696ms^{-2}) is smaller than the tidal force exerted on the Earth (0,00465ms^{-2}), yet significantly greater than the tidal force felt by seawater. This once again proves that Earth's tides are not a direct result of the Moon's influence.

The results computed by existing theories, for example, the Equilibrium Tidal Theory, exhibit significant discrepancies (Tidal force level:$10^{-7}ms^{-2}$) when compared with observational data (Tidal force level:$10^{-6}ms^{-2}$) Science 2023. Young [5,6].

Earth’s all points on the latitude responding to both AB and CD rings experience the same tidal force and tidal amplitude. As the latitude rises, the arc lengths of CA, CB, DA and DB gradually decrease, and the tides may become increasingly intense. This may potentially account for the occurrence of the world's well - known tides in high latitude regions.

Tidal amplitude exhibits a close correlation with water volume. Consequently, oceanic tidal phenomena are more pronounced compared to those in inland seas (such as the Caspian Sea) and lakes. The deeper the seawater, the higher the tidal amplitude. These facts further validate the correctness of the tidal theory hypothesis in this article.

Along the terrestrial coastline, the tidal amplitude is associated not only with the sea depth but also with the coastal topography. For instance, at the estuary where the river meets the sea, which is trumpet - shaped, a spectacular tidal phenomenon occurs.

A series of relatively straightforward equations are available for calculating tidal force and tidal amplitude. When the amplitude of the tide is a known quantity, the tidal force can be computed. Conversely, given a known tidal force, the amplitude of the tide can be determined.

The results computed by Equations 9 and 11 are the same. The results calculated by Equations 10 and 14 are also the same. Those validates the accuracy of the theoretical assumptions underlying these equations. This theory is solely applicable to the calculation of tidal forces and tidal amplitude, rather than reflecting the actual causes of tidal formation. Consequently, in the absence of theories and equations to depict the three - body system, it is impossible to explore the real scenario of tide theory.

The level of tidal force felt by seawater ($\times 10^{-6} ms^2$) is lower the gravitational force coming from Moon's mass ($3.1148 \times 10^{-5} ms^2$) The neap tide is governed by the three - body tidal space not only by the moon. The tidal force exerted on seawater accounts for merely 8.136% of. The remaining forces (91.864%) act on the Earth's solid land. Solid land is not prone to deformation. However, under the action of tidal forces, it causes the solid land to oscillate along the diameter within a tidal cycle. This provides a novel perspective for understanding the movement of the Earth's crustal plates as well as the causes of volcanoes and earthquakes [7,8].

The Moon rotates or rolls around its axis at a fulcrum, and its fulcrum is located at Earth's center. This is the reason why one side of the Moon always faces the Earth. Therefore, no special tidal locking force exists.
At present, the theory regarding the rotation-rolling motion of planets around its axis on a fulcrum can be summarized as the "rolling fulcrum theory".

This "rolling fulcrum theory" not only elucidates the phenomenon of why one side of the Moon perpetually faces the Earth but also accounts for the precession of the orbital perigee of Mercury.

During the rotation-rolling motion of Venus, the trajectory of its fulcrum is a ring encircling the Sun, as if there is a celestial body that moves along this ring. In honor of Le Verrier, the fulcrum ring and the virtual celestial body are respectively named Le Verrier's Ring and Le Verrier's Body. The radius of this ring is equivalent to rX - R (where r represents the radius of Venus, X denotes its amplification factor, and R represents its semi-major axis), as shown in Figures 5, 6, and 7.

The Rolling Fulcrum Theory states that Mercury gains an additional orbital centripetal acceleration from the gravity at the fulcrum of Venus. At the same time, it also gains an additional orbital velocity. Those explains Mercury's perihelion precession.

The magnitude of the angle φ, representing the additional shift of Mercury's perihelion per orbital period, is equal to 0.0983502 arc seconds, Meanwhile, the perihelion of Mercury's orbit undergoes a precession of 40.854 arc seconds per century, but, as calculated by general relativity, is equal to 42.9799 arc seconds per century.

Total observed precession is 574.10 arc seconds per century. The sum of gravitational tugs from other solar bodies (532.3035) and the Sun's oblateness (0.0286) equals 532.3321 arc seconds. The two values differ by 41.7679 arc seconds (574.10-532.3321=41.7679) [2].

The differ calculated by 'Rolling Fulcrum Theory' achieves 97.812% accuracy (40.854/41.7679), while Einstein's relativity yields 97.1801% accuracy (41.7679/42.9799) [9].

This once again verifies that Newton's and Einstein's theories for gravity are in consonance with each other [4,10,11].

5. Conclusion

The forces determined by the tidal force space signify actual tidal forces. Whereas tidal phenomena merely represent the Earth's reaction to the tidal force space. The tidal force space exhibits rotational characteristics and periodic fluctuations in the magnitude of tidal forces, with this cycle being precisely synchronized with the lunar orbital cycle. Owing to the distinct properties of seawater and land, the tidal forces acting on the Earth's seawater differ from those acting on the Earth itself.

The tidal forces felt by Earth and its seawater might result from the interaction among the Sun, the Earth and the Moon.

The equations employed for calculating tidal force and tidal amplitude are highly straightforward and simple, and the outcomes are entirely consistent with the reports in the literature.

When the perihelion of Mercury, the Sun, and the rotational fulcrum of Venus are aligned in a straight line, the centripetal gravitational force of Venus at the fulcrum is totally consistent with the orbital centripetal acceleration of Mercury. Mercury at its perihelion gains additional orbital centripetal acceleration and orbital velocity, ultimately leading to Mercury perihelion precession.

Data Availability Statements

The data and codes produced in this work will be made available upon reasonable request.

Ethical approval and consent to participate
I do not have funding or competing interests

Reference

1. Tisserand, F. (1880). Les travaux de le verrier. Annales de l'Observatoire de Paris, vol. 15, pp. 23-43, 15, 23-43.
2. Wikipedia. 2026, Tide and Precession of the Perihelion for Mercury.
3. Zhai, Z. (2021). A formula for calculating the rotational period of a planet or star. *preprints Research Square*.
4. Zhai, X. (2025). The Formulas for Calculating Surface Gravity and Rotational period of celestial Body and Black Hole in the A xial Spherical-Space. *ScienceOpen Preprints*.
5. Young, C. A. (1889). A Textbook of General Astronomy (PDF). p. 288. Archived (PDF) from the original on 2019-10-05. Retrieved 2018-08-13.[Google Scholar]
6. Haigh, I. D. (2017). Tides and Water Levels.
7. Ray, R. D., Eanes, R. J., & Chao, B. F. (1996). Detection of tidal dissipation in the solid Earth by satellite tracking and altimetry. *Nature, 381*(6583), 595-597.
8. Dumont, S., Custódio, S., Petrosino, S., Thomas, A. M., & Sottili, G. (2023). Tides, earthquakes, and volcanic eruptions. *A Journey through Tides*, 333-364.
9. Park, R. S., Folkner, W. M., Konopliv, A. S., Williams, J. G., Smith, D. E., & Zuber, M. T. (2017). Precession of Mercury's Perihelion from Ranging to the MESSENGER Spacecraft. *The Astronomical Journal, 153*(3), 121.
10. Ng, C. K. (2015). How tidal forces cause ocean tides in the equilibrium theory. *Physics Education, 50*(2), 159-164.
11. Feynman, R. P., Leighton, R. B., Sands, M., & Hafner, E. M. (1965). The feynman lectures on physics; vol. i. *American Journal of Physics, 33*(9), 750-752.