EPH - International Journal of Science And Engineering
ISSN (Online): 2454-2016
Volume 07 Issue 01 March 2021

DOI: https://doi.org/10.53555/eijse.v7i1.105

A QUESTION OF GRAVITY: FORCES FROM THE PLANETS

William A. Mendoza, PhD[1*]
[*1]*Department of Natural Sciences, Florida State College, Jacksonville, FL 32246 USA*

Corresponding author:
Email: w.a.mendoza@fscj.edu

1. INTRODUCTION

Throughout history, people searched for additional meaning in their lives by following the stars in the night sky. In addition to the "fixed stars", the ancient and medieval worlds were aware of five "wandering stars", the planets Mercury, Venus, Mars, Jupiter, and Saturn. People of the ancient world frequently associated the moving lights in the night sky with signs from gods. Truly, we *are* physically connected to the cosmic world by gravitational forces and electromagnetic radiation [1]. Also, the positions of the Sun and Moon are related to ocean tides, and the celestial (heavenly) bodies served both as clock and calendar until just a few hundred years ago [2]. As a result of such connections, ancient students of the night sky would seek to learn how the celestial bodies could possibly affect human character and destiny.

In the modern world, students in college physics courses, whether requiring algebra/trigonometry or calculus, usually encounter Newton's law of gravity in the first course of a two course sequence. Equations related to the theory are used to derive other equations and solve problems related to the motion of rockets leaving the Earth and satellites in outer space [3, 4]. Students are also informed that gravity physically connects all the mass in the Universe. As a result of such considerations, gravity remains an interesting subject for modern students.

Discussion of the gravitational effect on a human infant from a celestial body is discussed in one physics textbook [4]. The particular problem in a calculus-based course asks a student to compare the effect from Jupiter, the largest planet, to that from a 70 kilogram (kg) obstetrician standing a distance of one meter from the infant. The mass of 70 kg corresponds to an Earth weight of 154 pounds (lb) or 686 newtons (N). The belief of some scientists that a nearby adult exerts a force greater than any planet is mentioned in the problem. In order to explore this issue fully, this report will consider many of the larger bodies in our solar system in terms of gravitational and tidal forces exerted on the mass of a new born infant. The tidal forces discussed here refer to differences in gravitational forces measured in two perpendicular directions. For a small object like a newborn these tidal forces will be relatively small, and the forces celestial bodies exert on an infant will also vary as the earth rotates changing relative distances between infant and celestial object.

Before the International Astronomical Union voted to classify Pluto as a "dwarf planet", it historically was considered one of nine major planets [5]. As this paper is written by a physicist rather than an astronomer, the author will include Pluto in the planetary calculations in addition to some additional bodies discovered by optical telescopes such as "minor planets" (larger asteroids in the "asteroid belt" between Mars and Jupiter) and some of the larger planetary satellites or "moons" [6].

2. Gravitational forces

In what ways could planets exert forces on us at birth and later? In Newtonian Mechanics, *contact forces* occur in pairs and are capable of producing resulting accelerations [7]. Gravitational *field forces* acting between two bodies at a distance also may produce accelerations. The magnitude of the gravitational field force in newtons (N) may be writtenas

$$F = GmM/D^2 \quad (1)$$

where G is the gravitational constant (6.673 x 10^{-11} Nm^2/kg^2 in SI units), M is the mass of the attracting body in kg, m is the mass of the attracted body in kg, and D is their separation distance in meters, essentially from the center of one body to the center of the other body, assuming they are spherical or round. The direction of the gravitational force is along an imaginary line connecting these centers, the centers of mass of the two bodies. This center of mass concept supposes that the straight line motion produced by a large, extended body is the same as that of a smaller but denser body (basically a "point particle") of the same mass at the same location. Mass itself is a manifestation of matter (a measure of inertia) and usually (except in the case of a "singularity") occupies some region (volume) of space. In the general theory of relativity (Einstein's theory of gravity), *forces from mass* are replaced by *curvature from mass*, a large mass producing curvature of the surrounding space which in turn can alter the straight line motion a second mass would otherwise have in the absence of the first mass. Regardless of these different concepts, the effects from gravitation are virtually the same even if the causes are different so Newton's theory is still useful for most situations and will be usedin this paper. Einstein's theory is useful in making small corrections to results derived from the force theory, and in making some new predictions such as the bending of a ray of light passing by a massive star, not predicted by the force theory as light has no mass [3].

4. Tidal Forces

Tidal forces may be thought of as the difference between gravitational forces acting at the center and at the surface of a world [8]. The force of attraction by an external body of mass M can essentially stretch another body of mass m along a line joining the body centers which effectively compresses the attracted body perpendicular to that line. The tidal force component T_x which lies along the connecting line for two bodies can be written as

$$T_x = 2GmM\, R_E \cos(\phi) \sin(\theta)/D^3 \quad (2)$$

while the tidal force component T_Y which acts at a right angle to the line connecting the centers can be written as

$$T_y = -GmM\, R_E \sin(\phi) \sin(\theta)/D^3 \quad (3)$$

In equations (2) and (3), R_E is the radius of the Earth, m is the mass of a body at the surface of the Earth, M is the mass of a celestial body other than Earth, D is the distance between the two masses, ϕ is a longitude angle about the equator, and θ is a latitude angle between the North and South poles. These angles are complicated by the facts of Earth's daily spin and inclined axis of rotation.

5. Plane of the Orbit

Since the celestial bodies discussed here do not all share the same plane of orbit, as shown below in Figure I for Mars, some consideration must be given to the angle of inclination α which other planets have with respect to Earth's orbital plane.

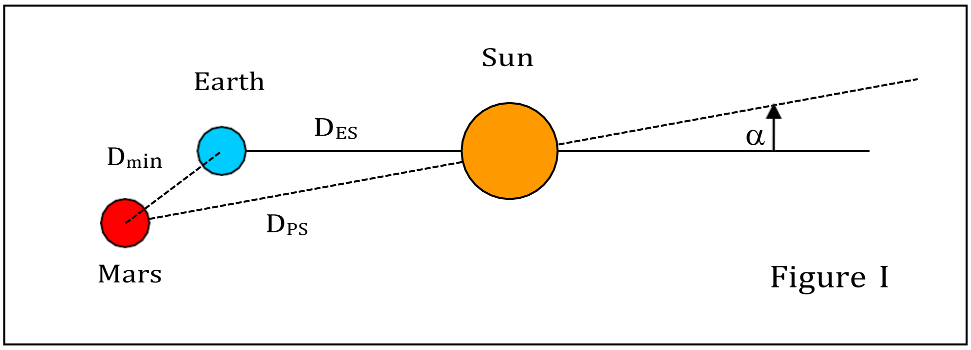

Figure I

The law of cosines, a generalization of the Pythagorean theorem for a triangle lacking a 90° angle, was used to calculate the theoretical minimum distance D_{min} which by equations (1), (2), and (3) will generate the maximum forces. The expression below is for *superior* planets (Mars and other outer planets):

$$D_{min}^2 = D_{ES}^2 + D_{PS}^2 - 2\, D_{ES} D_{PS} \cos(\alpha) \quad (4).$$

Here D_{ES} is the *maximum* distance from Earth to the Sun and D_{PS} is the *minimum* distance from the outer planet to the Sun. This would minimize the interplanetary distance D_{min}.

The geometry is similar for *inferior* planets (Venus and Mercury) and so is the expression for the theoretical minimum distance D_{min} except that D_{ES} is now the *minimum* distance between Earth and Sun and D_{PS} is the *maximum* distance between the inner planet and the Sun, as shown below in Figure II. Again, this should minimize the interplanetary distance D_{min}.

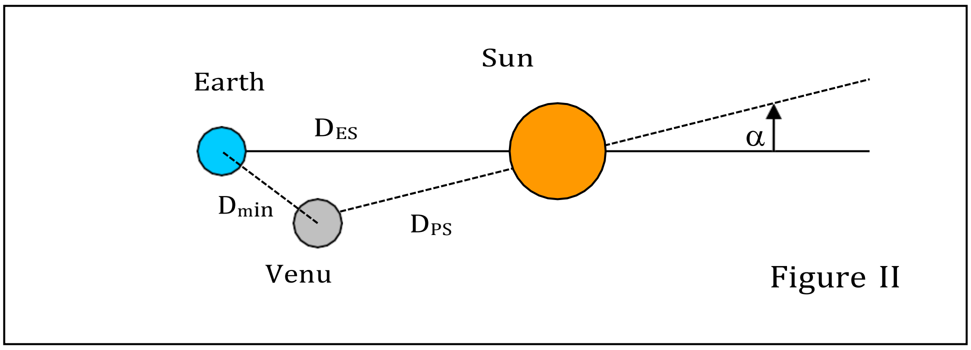

Figure II

The theoretical maximum distance D_{max} will produce the minimum planetary forces. These were also calculated to show the range of forces from the planets. The geometry for this situation is shown in Figure III for Venus.

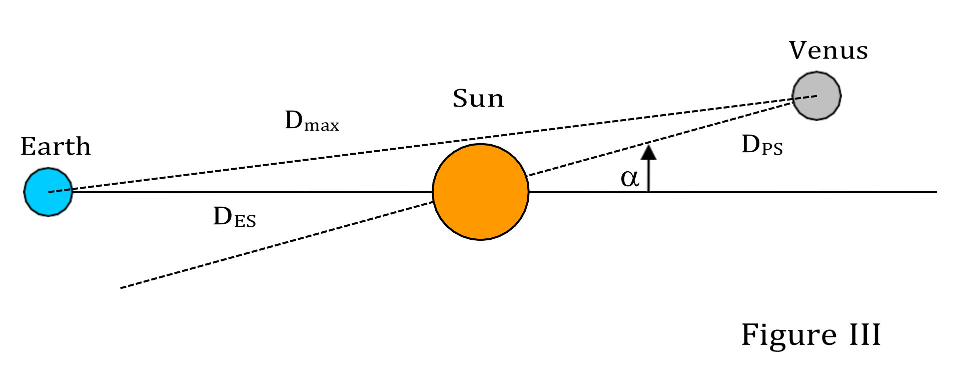

Figure III

Here D_{ES} is the *maximum* distance between Earth and Sun and D_{PS} is also the *maximum* distance between an inner or outer planet and the Sun. For D_{max}, the law of cosines gives a similar expression except the angle between the two distances D_{ES} and D_{PS} now is the difference between a straight angle
(180°) and the planet's angle of inclination (α):

$$D_{ES}{}^2 = D_{max}^2 + D_{PS}{}^2 - 2D_{ES}D_{PS}\cos(180° - \alpha) \quad (5).$$

The four Galilean moons of Jupiter and Saturn's large moon Titan were included in the tables which required for D_{min} a consideration of the minimum distance of the planet from the Sun minus the maximum distance of the moon from the planet, with the moon on the Earth side. For D_{max}, the planet was at the farthest from the Sun with the moon the farthest from the planet, on the side away from Earth. This approach neglects gravitational screening effects from the planet.

6. Data from Planets, Asteroids, and Moons

We know from Kepler's First Law that the orbits of the planets are elliptical [3]. The Sun is at one focus of the ellipse, not at the center of the orbital ellipse. In Table I (below on this page) column 2 gives the eccentricity e of the orbit, a measure of the elliptical shape. Elliptical orbits have eccentricity e < 1 while circular orbits have e = 0. The major axis $2a$ is the long axis of an ellipse, the length of the longest line through the center. Minimum D_{PS} is R_{min} (perihelion) in column 5 and maximum D_{PS} is R_{max} (aphelion) in column 6. (These are the nearest and farthest distances between each body and the Sun. For the Moon orbiting the Earth, R_{min} is perigee and R_{max} is apogee.) Note $R_{max} + R_{min} = 2a$.

Celestial body mass M in kg is in column 3, orbital angle of inclination α in degrees is in column 7, and the distances D_{min} and D_{max} are in columns 8 and 9. The astronomical unit (a.u.), the average distance between Earth and Sun, is used for all distances where 1 a.u. = 149 597 870 kilometers (km) [4]. The distances D_{min} and D_{max} are center to center distances. For a body on the surface of Earth affected by a distant planet, D_{min} can be corrected to $D_{min} - R_E$ and D_{max} can be corrected to $D_{max} + R_E$, assuming the body on the surface is in line with the distant planet on the near and far sides of Earth, respectively. However, this is a minor correction which will not significantly affect the force calculations reported in the next section. For the Earth R_{min} = 0.9833 a.u. and R_{max} = 1.0167 a.u. but D_{min} and D_{max} are the radius of the Earth (R_E = 6370 km = 0.000043 a.u.) for a mass *m* resting on the surface.

Table I

Body	eccentricity e	mass (kg)	major axis (a.u.)	R_{min} (a.u.)	R_{max} (a.u.)	inclination	D_{min} (a.u.)	D_{max} (a.u.)
Sun	0	1.989E+30	0.00	0.00	0.00	0.00	0.982	1.016
Mercury	0.2056	3.302E+23	0.780	0.310	0.470	7.004	0.520	1.484
Venus	0.0067	4.869E+24	1.440	0.715	0.725	3.394	0.263	1.741
Earth	0.0167	5.974E+24	2.000	0.983	1.017	0.00	0.000	0.000
Moon*	0.055	7.348E+22	0.005	0.002	0.003	5.145	0.002	0.003
Mars	0.0935	6.419E+23	3.040	1.378	1.662	1.85	0.363	2.678
Ceres	0.0789	8.652E+20	5.531	2.547	2.984	10.61	1.509	4.037
Pallas	0.230	3.182E+20	5.539	2.133	3.406	34.81	1.549	4.143
Vesta	0.0895	3.023E+20	4.722	2.150	2.572	7.14	1.130	3.601
Jupiter	0.0489	1.899E+27	10.400	4.946	5.454	1.308	3.932	6.468
Io‡	0.004	8.932E+22	0.006	0.003	0.003	0.04	3.929	6.471
Europa‡	0.0101	4.800E+22	0.009	0.004	0.005	0.47	3.928	6.472
Ganymede‡	0.0015	1.482E+23	0.014	0.007	0.007	0.19	3.925	6.475
Callisto‡	0.007	1.076E+23	0.025	0.012	0.013	0.288	3.919	6.481
Saturn	0.0565	5.685E+26	19.080	9.001	10.079	2.488	7.994	11.086
Titan†	0.0292	1.346E+23	0.016	0.008	0.008	0.33	7.984	11.096
Uranus	0.0457	8.683E+25	38.360	18.303	20.057	0.774	17.279	21.081
Neptune	0.0113	1.024E+26	60.120	29.720	30.400	1.774	28.752	31.368
Pluto/Charon	0.2488	1.250E+22	78.880	29.627	49.253	17.148	28.673	50.209

**Earth orbit, ‡Jupiter orbit, †Saturn orbit*

7. Results and Discussion

At birth, the average North American newborn infant weighs seven pounds, seven ounces [9]. In terms of the metric system, this weight corresponds to mass m = 3.373 kg which was used in equations (1), (2), and (3) along with the mass M of the attracting planetary or celestial body in question. These forces are then compared to the gravitational force between a 70 kg obstetrician (OB) and the 3.373 kg newborn using an average separation distance of 1.00 m, and the approximation of both bodies as point masses. Under these conditions, the medical doctor and the baby exert a gravitational force $F_{OB} = 1.575 \times 10^{-8}$ N on each other.

Table II (below on this page) reports the force calculations in newtons (N) where 1 N = 0.2248 pounds. The maximum gravitational force F_{max} (calculated from D_{min}) appears in column 2 and the minimum gravitational force F_{min} (calculated from D_{max}) appears in column 3. Column 4 gives the ratio of F_{max} to F_{OB}.

Table II

Body	F_{max} (N)	F_{min} (N)	F_{max} / F_{OB}	T_X (N)	T_Y (N)	T_X / F_{OB}	T_y / F_{OB}
Sun	0.021	0.019	1.316E+06	1.796E-06	-8.981E-07	114.111	-57.056
Mercury	1.229E-08	1.507E-09	7.809E-01	2.014E-12	-1.007E-12	1.28E-04	-6.40E-05
Venus	7.065E-07	1.615E-08	4.488E+01	2.286E-10	-1.143E-10	1.45E-02	-7.26E-03
Earth	33.123	33.123	2.104E+09	6.625E+01	-3.312E+01	4.21E+09	-2.10E+09
Moon*	1.255E-04	1.007E-04	7.976E+03	4.407E-06	-2.204E-06	280.009	-140.004
Mars	4.886E-08	8.991E-10	3.104E+00	1.145E-11	-5.725E-12	7.27E-04	-3.64E-04
Ceres	3.817E-12	5.336E-13	2.425E-04	2.154E-16	-1.077E-16	1.37E-08	-6.84E-09
Pallas	1.333E-12	1.864E-13	8.472E-05	7.332E-17	-3.666E-17	4.66E-09	-2.33E-09
Vesta	2.379E-12	2.344E-13	1.511E-04	1.793E-16	-8.963E-17	1.14E-08	-5.69E-09
Jupiter	1.235E-06	4.565E-07	7.844E+01	2.674E-11	-1.337E-11	1.70E-03	-8.49E-04
Io‡	5.817E-11	2.145E-11	3.695E-03	1.261E-15	-6.303E-16	8.01E-08	-4.00E-08
Europa‡	3.125E-11	1.151E-11	1.986E-03	6.777E-16	-3.388E-16	4.31E-08	-2.15E-08
Ganymede‡	9.636E-11	3.541E-11	6.121E-03	2.091E-15	-1.045E-15	1.33E-07	-6.64E-08
Callisto‡	7.031E-11	2.572E-11	4.467E-03	1.528E-15	-7.638E-16	9.70E-08	-4.85E-08
Saturn	8.945E-08	4.651E-08	5.683E+00	9.529E-13	-4.765E-13	6.05E-05	-3.03E-05
Titan†	2.120E-11	1.098E-11	1.347E-03	2.261E-16	-1.131E-16	1.44E-08	-7.18E-09
Uranus	2.923E-09	1.964E-09	1.857E-01	1.441E-14	-7.203E-15	9.15E-07	-4.58E-07
Neptune	1.245E-09	1.046E-09	7.908E-02	3.687E-15	-1.843E-15	2.34E-07	-1.17E-07
Pluto/Charon	1.785E-13	5.822E-14	1.134E-05	5.302E-19	-2.651E-19	3.37E-11	-1.68E-11

**Earth orbit, ‡Jupiter orbit, †Saturn orbit*

The column 4 force ratios show some interesting results. It may not be too surprising that the great mass of the Sun would produce a force 1.3 million times greater than that from the obstetrician. The proximity of the Earth also accounts for a force that is 2.1 billion times greater. However, the ratios for Moon, Venus, Mars, Jupiter, and Saturn are 7976, 44.9, 3.1, 78.4, and 5.68 times greater, respectively! Thus, all of these celestial bodies generate greater gravitational forces on a newborn than does a 70 kg person at a distance of 1 meter. The remaining bodies generate lesser but still considerable forces. The largest of these is Mercury (0.78) followed by Uranus (0.19) and Neptune (0.08). All of the other bodies produce lesser effects. Pluto and its satellite Charon were treated as a unit because of their proximity to each other and their great distance from the Earth. The three largest asteroids (Ceres, Pallas, Vesta), the four Galilean moons (Io, Callisto, Ganymede, Europa), and Saturn's largest moon (Titan) all exert greater relative forces than Pluto and its satellite Charon combined as those asteroids and other planetary satellites are much closer to a body on Earth than Pluto and Charon.

Columns 5 and 6 have the maximum tidal forces on axis (T_x) and off axis (T_y) (both calculated from D_{min}). The on-axis or in-line tidal forces (T_x) are generally stronger than the off-axis ones (T_y). The T_x values shown in column 5 calculated from equation (2) assume azimuth (equatiorial) angle $\phi = 0°$ (on-axis) while T_y values shown in column 6 calculated from equation (3) assume angle $\phi = 90°$ (off-axis). A further assumption is that polar angle $\theta = 90°$ which is appropriate for a birth at the equator. This angle gives accurate estimates for T_y over a range of dates but given the 23.5° tilt of the Earth's rotation axis this angle gives accurate values for T_x only during the Spring and Autumn Equinox. The tidal forces from the Moon and Sun are greatest with negligible ones from the other worlds, as can be seen in the comparative ratios in columns 7 and 8.

Classical astrology associates personality traits with the position of the Sun and planets in a band of constellations known as the Zodiac at the time of birth however astronomers will point out that the path of the Sun through those "star patterns" has shifted one full Zodiacal sign westward in the past 2000 years [1]. Interestingly though, there has been some significant statistical research demonstrating a surprising correlation between the planets Jupiter, Saturn, and Mars (rising above the Eastern horizon at the time of birth) and notable political, military, and athletic figures [10]. However, these findings are different from, and do not confirm, Western astrology. From the viewpoint of physics, planetary forces are present in the lives of individuals from conception, 9 months before birth, until death. The configuration of celestial forces is likely unique for each individual, based on their position on the Earth at the time of birth, but the force configuration varies and is continuous throughout the life of each individual. There may or may not be some unique biological effect of these forces on the individual at the time of birth or perhaps such an influence could actually occur atthe moment of conception.

While this report has concentrated on gravitation, it is noteworthy that among the major forces in physics gravitation is the weakest [3]. It is often claimed that the planets are electrically neutral but they do exist in a "spray" of charged particles (protons and electrons) and high energy photons from the Sun (the Solar "wind") and also from other stars in the galaxy (galactic cosmic rays, or the interstellar "wind'). It is well established that moving charged particles do create magnetic fields [3, 4, 7]. In addition to induced magnetic fields from the motion of these "exterior" charges, there are also magnetic fields present both in the Earth and in the Sun from interior processes. In fact the four "gas giant" planets (Jupiter, Saturn, Uranus, Neptune) have significant magnetic fields of their own with that of Jupiter being much greater than that of the Earth [11]. While magnetic forces have not been considered in this report, it is important to note that certain tissues of the body such as those in the brain, heart, and liver are more susceptible in varying degrees to magneticeffects [12]. As is the case with gravitational forces, variable magnetic forces would be present throughout the life of each individual from conception through birth and throughout the rest of his or her life.

REFERENCES

[1]. George O. Abell, David Morrison, and Sidney C. Wolf, *Exploration of theUniverse*, 5th Edition. Saunders College Publishing, New York, 1987.
[2]. Mark R. Chartrand, *National Audobon Society Field Guide to the NightSky*. Alfred A. Knopf, Inc., New York. 1995.
[3]. Raymond Serway and John Jewett, Jr., *Physics for Scientists andEngineers*, 8th Edition, Cengage Learning, 2010.
[4]. David Halliday, Robert Resnick, and Jearl Walker, *Fundamentals ofPhysics*, 6th Edition. John Wiley & Sons, Inc., New York, 2001.
[5]. David Baker, *Astronomy*. Henry Holt and Company, New York. 1978.
[6]. John D. Fix, *Astronomy: Journey to the Cosmic Frontier*, 2nd Edition
[7]. updated. McGraw-Hill, New York, 2001.
[8]. Paul A. Tipler, *Physics*, 2nd Edition. Worth Publishers, Inc., New York,
[9]. 1982.
[10]. Stephen T. Thornton and Jerry B. Marion, *Classical Dynamics of Particle*
[11]. *and Systems*, 5th Edition. Brooks/Cole-Thomson Learning, Belmont,
[12]. California, 2004.
[13]. *A Healthy Me!*, Blue Cross Blue Shield of Massachusetts, First publishedAugust 21, 1997,

http://www.ahealthyme.com/topic/1620#2.
[14]. Michel Gauquelin, *Cosmic Influences on Human Behavior*, 2nd Edition.
[15]. ASI Publishers, New York, 1978.
[16]. J. B. Zirker, *The Magnetic Universe: the elusive traces of an invisible force*,Johns Hopkins University Press, Baltimore, 2009.
[17]. N. Siauve, R. Scorretti, N. Burais, L. Nicolas, and A. Nicolas.
[18]. Electromagnetic fields and human body: a new challenge for the
[19]. electromagnetic field computation. *Compel*, Vol. 22, No. 3, 2003, pp. 457- 469.