iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: II Month of publication: February 2022

DOI: https://doi.org/10.22214/ijraset.2022.40299

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

Gravitational Well

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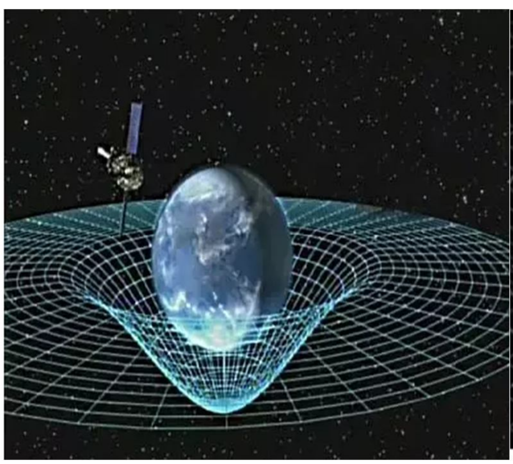
Abstract: A gravitational well is a potential well that describes an inhomogeneous gravitational field of an energy gradient, a quantum density gradient of a medium, and a gravitational action potential gradient. A Gravitational well is the distorted or warped Space-time. It is called a well, because it looks some kind of well.In the figure warped space-time is the Gravitational well. The mass of the object influences the depth of the well. It is not a visible thing, But its just the curvature of space-time and its real phenomenon The force of gravity is determined by the gradient of gravitational energy, the deformation vector of quantized space-time and the strength of the gravitational field. It should be noted that the force F of gravity is always directed to the bottom of the gravitational well in the direction of decreasing gravitational energy, quantum density of the medium and gravitational action potential [1-7].

Keywords: Quantum gravity, gravitational well, gradient, gravitational energy, quantum density, gravitational action potential, deformation vector.

I. INTRODUCTION

A **Gravitational well** is the distorted or warped **Space-time**. It is called a well, because it looks some kind of well (look at the figure). In the figure warped space-time is the Gravitational well. **The mass of the object influences the depth of the well.** It is not a visible thing, But its just the ***curvature*** of space-time and its real phenomenon.(*the lines in the picture which indicates the curvature of space-time is imaginary, no such lines are visible*)



Fig(1)

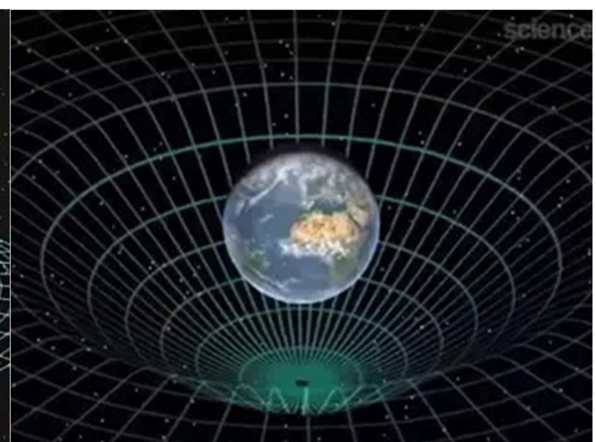


Fig (2)

A. Introduction to Gravity-Well

The well fascinated and intrigued me, and its very beautiful and sensible shape enabled me to anticipate many of the effects of gravity fields before my training covered these subjects in formal courses in orbital mechanics. For the benefit of those readers not familiar with the subject, the gravity-well is a surface of revolution formed by rotating a suitably shaped curve around a central vertical axis, sweeping out an axisymmetric surface resembling the bell mouth of a horn. As illustrated by the following figure the motions of a rolling ball on the well resemble those of a satellite of the Earth or planet of the Sun. It also provides the ability to play out orbits in a lab setting or planetarium which could otherwise only be experienced very slowly using a pencil, paper and calculator, more rapidly on a digital computer, or physically in orbit. In a real sense, the gravity-well provides a defacto analogue computer for orbital mechanics. In any case, a quick Google search on the World Wide Web will demonstrate the current use of this model in planetariums and other educational settings

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II. BASIC ORBITAL MOTION AND THE GRAVITY-WELL

The wonder of natural orbits is that they may be described using simple conic sections. A conic section is formed by the intersection of a cutting plane and right circular cone, thereby producing a circle, ellipse, parabola or hyperbola. As illustrated below and on the next page, any natural Keplerian orbit may have an eccentricity which is exactly equal to zero for a circle (e_c=0.0), between zero and one for an ellipse (0<e_e<1.0). exactly equal to one for a parabola (e_p=1.0), or greater than one for a hyperbola (e_h>1.0). Eccentricity is a measure of the shape of the conic and generally the larger the value of "e", the flatter the orbit. A conic section is defined as the locus of points in space whose ratio of distances from a fixed point and line is constant, called the eccentricity. Just why* the geometry of a conic section faithfully represents an orbit around a single gravitating body can not really be answered. In this instance we should think of the conic section as just another result of Newton's physics and a consequence of our beautiful mathematics. Any further thoughts we might have on the matter probably says more about us than any orbit. Among a handful of characterizing constants we will introduce to describe Keplerian orbits, there also exists the true anomaly angle "f" shown above, measured within the orbital plane between the lowest or minimum radius in orbit, called the " pericenter" (or rp), and our current location in orbit. The true anomaly angle "f" locates our instantaneous position in orbit at any time t past pericenter. * This is only a single example of this type of occurrence in physics. Other examples include: baseballs projected in constant gravity fields and electrons in uniform electric fields which travel along parabolas, structural cables having self weight hang in the shape of a perfect centenary, suspension bridge cables supporting a massive but uniform roadbed hang in parabolas, a single drop of water initially released from a dropper forms a sphere from its surface tension, and then becomes a tear shaped object as it falls and accumulates speed and streamlining air drag, etc.)

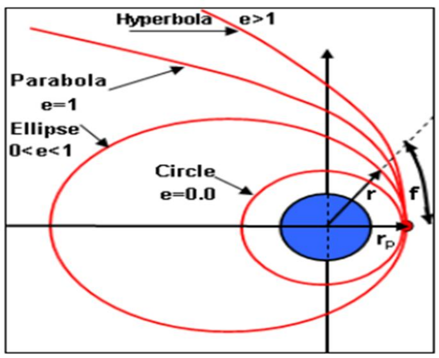
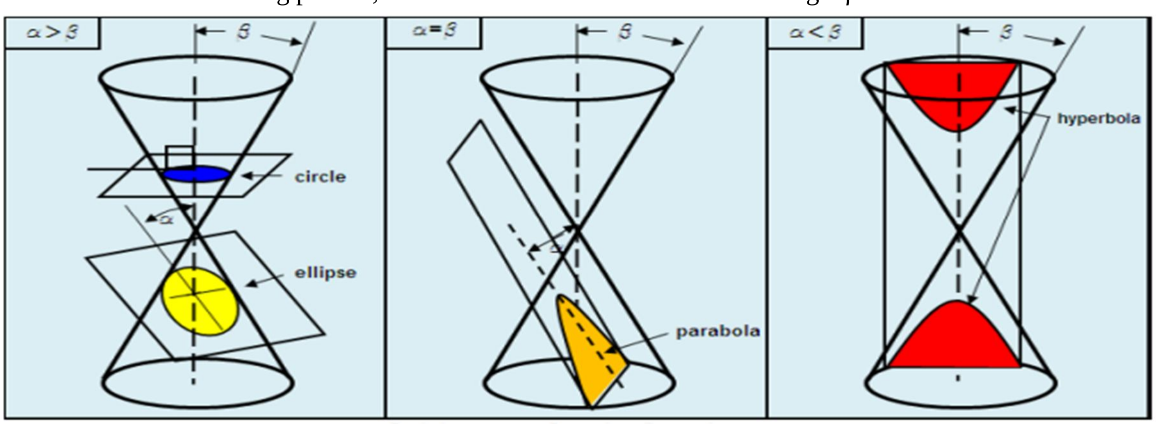


Fig (3) Orbits are Conic Sections

A conic section is formed by the four types of intersection produced by a cutting plane and a right circular cone, illustrated below. As noted previously, this intersection results in a circle, ellipse, parabola or hyperbola. The type of conic and shape of the orbit depend on the orientation of the cutting plane a, and the relative size of the semicone angle β.



Fig(4) Orbits are Conic Sections

Note that the conic section and resulting shape of the orbit reside in the common plane of intersection. The relative values of the semi-cone angle β and the cutting plane angle α, are also important (i.e., if α>β, α=β, & α<β).

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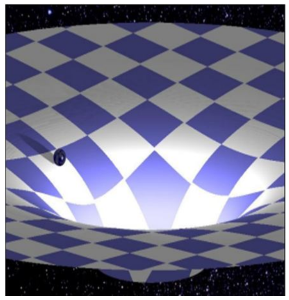
1) As shown in the left panel for $\alpha>\beta$, the required angle α, between the cutting plane and the center line of the cone must be precisely 90 degrees to generate the circle (shown in blue).
2) As also shown in the left panel for $\alpha>\beta$, the magnitude of the angle α, must be greater than the semi-cone angle β and less than 90 degrees to produce the ellipse (shown in yellow).
3) As shown in the middle panel for $\alpha=\beta$, the plane angle a required to produce the parabola (in orange) must be precisely equal to the semi-cone angle (β).
4) As shown in the right panel for a $\alpha < \beta$ in order to generate the (two legged) hyperbola (shown in red), α, the cutting plane angle measured to the cone centre line, must be equal to, or greater than 0.0 and less than the semi-cone angle (β).

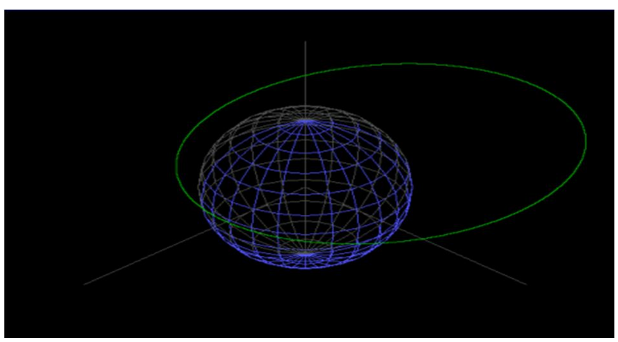


Fig(5)

A Body orbiting within a Gravity-Well contains computer generated illustrations of circular and elliptical orbits of the Earth

A. *Circular Orbits (eccentricity $e = 0$, a special case of ellipse)*

We see illustrated in the above figure a ball rolling in a circular orbit around the gravity-well. The circular orbit is illuminated and rendered using a point light source in the geometry model. When the ball is projected into a horizontal plane along the surface of the well with its initial velocity perpendicular to its instantaneous radius to the well centre and with precisely the correct value of speed, it is in a circular orbit. Any faster than this circular speed and the ball rises, any slower and it descends. A circular orbit on the well will maintain a constant speed and distance from the well center and a fixed elevation (ignoring friction and windage) on the gravity-well. The reader is invited to see "Gravity-Well Models of Celestial Objects" for additional details, and the governing equations.



Fig(6) An elliptical orbit-www.spaceanimations.

B. *Elliptical Orbits (eccentricity $0 < e$ 1) within their orbital plane*

Ellipses are a more general case of orbit in which the velocity of the orbiting body varies from a maximum speed at the point of closest approach to the Earth, called the perigee, to a minimum speed when most distant, called the apogee. When speaking in the context of a ball rolling on the gravity-well, it is suggested that the more general terms "pericenter" and "apocenter" be used, as these terms apply to all circumstances.

An ellipse type of shape is produced by a satellite in space (or a ball on the gravity-well) when it is projected at insert with a greater velocity than what is required for maintaining a purely circular orbit. The ball therefore rises above this point, and in gaining height and radius the ball gains potential energy at the expense of kinetic energy (and speed) until its subsequent velocity is insufficient to orbit in a pure circle. It therefore descends downward, only to oscillate up and down forming an ellipse like trajectory. The reader is invited to see "Gravity-Well Models of Celestial Objects" for additional details and working equations for elliptical orbits.

C. Parabolic Orbits (e=1)

The minimum energy escape trajectory from the Earth or any celestial body is parabolic in shape and has a numerical value of eccentricity exactly equal to one (e=1.0). As such, it is a special case of a just super elliptical orbit for which escape velocity is a minimum. Of course, the shapes of all escape trajectories are open as they do not close on themselves. The equation for the parabola is similar in form to that of an ellipse in which the eccentricity is assigned a value of exactly 1.0. Willy Ley, one of the original founding members of the German Rocket Society, has written that in his opinion, there are no precisely parabolic (or for that matter pure circular) trajectories since every orbital eccentricity when written out to a sufficient number of decimal places, will deviate, however slightly from exactly 1.0 (or 0.0 for the circular case).This is actually true, although when a circular orbit deviates slightly from a true circle, it is still in an approximately circular orbit, and can be more simply book kept as one. The same is true for an escape orbit which is only slightly super-parabolic, known as a hyperbolic escape trajectory. As such, a slightly hyperbolic trajectory may have an orbital eccentricity of just over 1.0 (e.g., 1.00000001), but be adequately represented by a parabola having an eccentricity of 1.0. It is a matter of application and convenience. In the context of the gravity-well, an escape parabola would permit a rolling ball so projected to be capable of ascending to the most distant and furthest modelled position along the gravity-well wall. If the gravity-well could actually be modeled out to an infinite radius, that most distant and theoretical point along the well would have a zero slope and be quite flat. All of the initial kinetic energy of motion of the ball near pericenter would be replaced by only potential energy of height at the distant apocenter. It is at this distant and theoretical flat point along the parabolic trajectory that the ball would very slowly come to rest. We say, therefore, that the ball has escaped from the well center, and for this reason the parabolic trajectory is said to be an “escape trajectory”. The reader is invited to see “Gravity-Well Models of Celestial Objects” for additional details and working equations describing parabolic trajectories.

D. Hyperbolic Orbits (e >1)

In the context of the gravity-well, an escape hyperbola would permit a rolling ball projected with greater than parabolic velocity to climb not just to, but infinitely beyond the most distant and furthest position along the well wall. At this great distance the slope of the well flattens out and remains level beyond. Instead of the ball slowly coming to rest, it would travel with some remaining linear velocity, called “residual velocity”. Here the well surface becomes an extended flat annulus shaped area, where the ball would continue infinitely on out maintaining its residual speed. All of the initial potential energy and kinetic energy of motion near pericenter would be replaced by both potential energy of height, and some remaining residual kinetic energy and its associated speed in deepest space. The hyperbolic trajectory can pass beyond that hypothetical point where a body with parabolic velocity would very slowly come to rest, and forever travel beyond that distant point maintaining constant residual velocity along this extended theoretical flat surface into deepest space. We therefore also say that the ball has escaped from the well, and for this reason the hyperbolic path is said to be another form of escape trajectory, which can carry us out to gravity-field free space, or until we might cross the threshold of the gravitational sphere of influence, and the gravity–well of a different celestial body. Note that corrections must be made for the relative velocities of these moving gravity wells. The reader is invited to see “Gravity-Well Models of Celestial Objects” for additional details and working equations for hyperbolic trajectories.

III. COMMENTS ON MOTIONS OBSERVED ON GRAVITY-WELL MODELS

I can’t recall how many times I have watched the gravity-well operate at the Hayden. At first, just to enjoy the show, and then more soberly while trying to make sense of its busy and continuous operation. The Hayden’s program for dispensing balls was an important part of their overall demonstration. This included the type of orbit, the number of balls, as well as the time of release of each ball. Close timing was needed for an entertaining and informative show.

A. Planets

Each new planetary ball was introduced to the gravity-well by slowly gathering speed by rolling down a calibrated and elevated acceleration ramp along the top left edge of the well shown below. This steel ramp had the required height to project the ball at the desired velocity along the well. In this fashion every planetary ball began its orbital life as a model planet, and as a member of a tiny solar system. The Hayden projected four such balls serially, spaced in time so that the earlier ball’s orbit had decayed a bit, and had a slightly smaller orbit. Viewers were treated to watching these planetary balls simultaneously as they orbited the well in near circular ellipses. The four balls could be thought to represent our first four inner planets, Mercury, Venus, Earth and Mars circling the model Sun at the well center. Naturally, while circling the well these orbits gradually decayed, and slowly spiraled inward and downward due to the influence of friction on the rolling balls.

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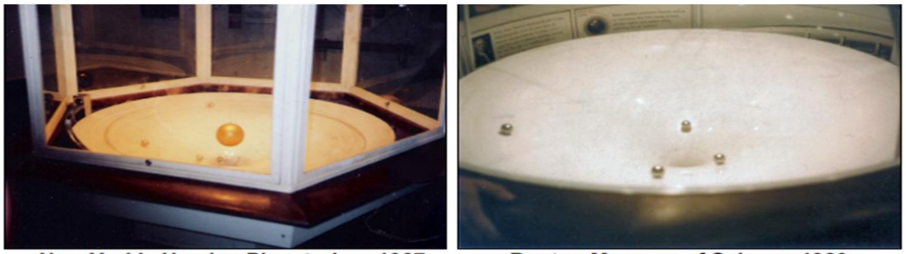
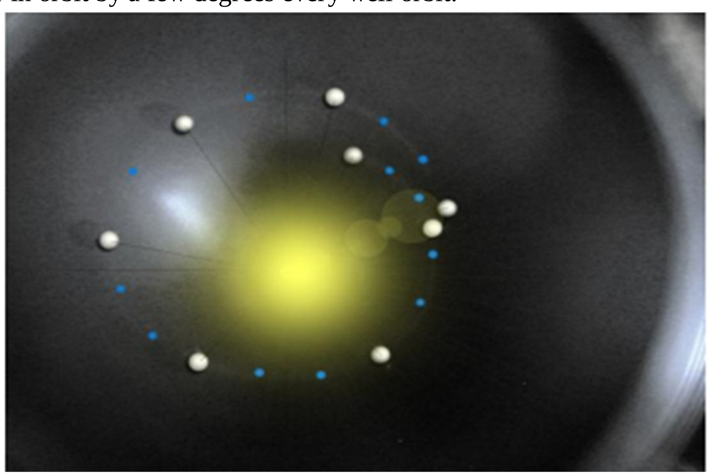


Fig (7)

Each ball steadily increased in speed due to reduced orbital radius, until the leading ball approached the central hole with amazing speed and noise. After the ball had spiraled in and descended from the top to the bottom of the well, it rapidly circled round the bottom central hole, orbiting madly like a crazed daredevil. Just when you thought the ball might continue indefinitely, it suddenly disappeared from sight and down the central hole with a muted but definite thump. Immediately on the heels of the first balls departure down the hole, a new planetary ball was automatically dispensed at the top of the well to repeat the entire process.

IV. PRECESSION

One comment regarding the motions of planetary balls is that their near circular and slightly elliptical motions were observed to precess. In the context of gravity-wells, precession produces a steady rotation of the ellipse and its axis of symmetry in the direction of rotation during each orbit. The axis of symmetry runs between the apocenter and pericenter of the rotating ellipse, and results in the angular advance of pericenter in orbit by a few degrees every well orbit.



Fig(8) Touched up time exposure taken by the author of the spiraling and precessing motions of a ball traveling in a roughly circular ellipse on a model gravity-well

This motion was only slightly like that of the actual planet Mercury. I say slightly, since Mercury experiences a very slight advance of pericenter by precession, and for different, but related reasons. Most of the small precession angle of the actual planet Mercury can be explained by Newton's laws as due to small disturbances or perturbations, produced by the other planets. Only, a very minute fraction of the total precession angle of Mercury was explained by Einstein as produced by the greater curvature of spacetime close to the more gravity warped space surrounding our Sun; the larger remainder being due to the planets. Since Mercury is the first and closest of all the planets to the Sun, it has demonstrated this slight orbital precession attributable to the relativistic effects of curved spacetime.

A. Comets

Next, without warning, the routine order of the above planetary series of balls would be broken by the loud crack of a single high speed projectile representing a solitary comet rapidly invading our solar system. Some comets are often near parabolic with eccentricities close to 1.0. However, others are elliptical as is Halley's Comet, which travels along an elongated ellipse with an eccentricity of about 0.97, and repeats its orbit about every 76 years.

This fast comet like ball had a significantly greater inward motion than the previous near circular planetary balls. The simulated well comet would quickly travel somewhat radially and more directly towards the central Sun, in its near parabolic orbit, then travel very rapidly round the Sun at perihelion. Last, almost as quickly as it appeared, return to deep space and roll off the top outer edge of the model, somewhere along the perimeter of the well. This speedy comet like motion was almost over before it began, and required one to keep a sharp watch to see it.

V. CONCLUSION

What is the ultimate fate of the gravity-well? Over the years, the gravitywell become an object of commerce. Gravity-well exhibits can now be purchased for between $1,000 and $10,000 dollars for sale on the web. The first commercial well was made and patented in 1985 by Mr. Steve Divnick, the inventor of the coin well who now operates www.spiralwishingwells.com. Improved commercial models, additional patents, sizes and colors have been added over the years.

REFERENCES

[1] Vladimir Fock, The Theory of Space, Time, and Gravitation, Translated from the Russian by N. Kemmer, Pergamon, New York, 1959. An advanced level mathematical discussion of the subject of gravity.
[2] Reginald J. Stephenson, Mechanics and Properties of Matter, John Wiley & Sons, Inc., 1960, Intermediate level mathematical introduction to Kepler's laws of celestial motions.
[3] Irving H. Shames, Engineering Mechanics, Prentice-Hall, Inc., Englewood Cliffs New Jersey, 1960, Intermediate engineering and college level mathematical introduction to motions in a Central Force Field.
[4] Arthur C. Clarke, The Exploration of Space, Printed by Kingsport Press, 1961. A simple descriptive introduction to the gravity-well concept.
[5] Willey Ley, Satellites, Rockets and Outer Space, Signet Science Library, 1961. Another simple and basic introduction to the gravity-well concept, and the vortex or solar whirlpool analogy by Willey Ley.
[6] Nelson and Loft, Space Mechanics, Statics and Dynamics, Prentice Hall International Series and Space Technology, Prentice Hall Englewood Cliffs, NJ. 1962, Engineering level discussion of the Role of the Moon in the Production of Tides and Tidal Friction.
[7] Battin, Astronautical Guidance, McGraw-Hill Electronic Science Series, 1964, A graduate engineering text book from MIT on Astronautical guidance in orbit.
[8] Peter van de Kamp, Elements of Astromechanics, W.H. Freeman and Company, 1964, An excellent and simple to follow mathematical introduction by a world class astronomer to celestial mechanics, the rotating binary and the LaGrange Restricted Three Body Problem.
[9] Archie E. Roy, The Foundations of Astrodynamics, The Macmillan Company, 1967, Graduate engineering details on the Rotating Binary and the LaGrange Restricted Three Body Problem.
[10] Albert Shadowitz, Department of Physics Fairleigh Dickinson University, Special Relativity, W. B. Saunders Company, 1968. Intermediate to graduate level physics introduction and a mathematical (and graphic) definition of the "Interval" in spacetime, world lines, length, mass, time, charge, momentum, etc.
[11] Dr. Wallace Arthur and Dr. Saul K. Fenster of Fairleigh Dickinson University, Mechanics, Holt, Rinehart, and Winston, Inc. 1969. Details on Motions in a Central Force Field (both gravitating and of charged particle)
[12] P. A. M. Dirac, General Theory of Relativity, John Wiley and Sons, 1975. Advanced level mathematical discussion of the subject.
[13] YH. L. Shipman, Black Holes, Quasars, & the Universe, Houghton Mifflin Company, Boston, 1976, A popular discussion of black hole theory
[14] Nigel Calder, Einstein's Universe, Viking Press, NY, 1979, A wonderful and easy to understand book on relativity that reads like poetry.
[15] Clifford Will, Was Einstein Right?: Putting General Relativity to the Test, New York: Basic Books, 1986, Discusses the many successful past tests as well as more current and further recent experiments performed to validate Einstein's theory made possible by advances in technology.
[16] Dr. A. Zee, Einstein's Universe Gravity at Work and Play, Oxford University Press, 1989, A fascinating and authoritative main stream popular book including very informed speculations on gravity
[17] Alyn & Allison Duxbury, Introduction to the World's Oceans, 1989. Very detailed Information on the formation of the tides
[18] John Gribbin, Unveiling the Edge of Time (Black Holes, White Holes, Wormholes), Three Rivers Press, NY, 1992, Wonderful popular book on Black Hole Theory and the strange structures of general relativity.
[19] J-P Luminet, Black Holes, Cambridge University Press, 1992, Also, one of the most authoritative popular books on the Black Hole by a French specialist and astronomer working with the Meudon Observatory
[20] NIST. "Fundamental Physical Constants - Complete Listing." Accessed Sep. 3, 2015. http://physics.nist.gov/cuu/Constants/Table/allascii.txt.
[21] Halliday, D. and Resnick, R. 1981. "Fundamentals of Physics." 2nd Edition, John Wiley& Sons, Inc. N.Y., Chichester, Brisbane, Toronto. ISBN 0-471-03363-4.
[22] Cook, A. H. "Gravity Physics." Encyklopaedia Britannica, Accessed Sep. 3, 2015. http://www.britannica.com/science/gravity-physics.
[23] Wikipedia. "Gravity." Accessed Sep. 3, 2015. https://en.wikipedia.org/wiki/Gravity.
[24] Einstein, A. 1915. "Die Feldgleichungen der Gravitation." In Sitzungsberichte der Preussischen Akademie der Wissenschaften zu Berlin.
[25] Einstein, A. 1916. "Die Grundlage der Allgemeinen Relativitätstheorie." Annalen der Physik 49: 769-822.
[26] Einstein, A. 1917. "Kosmologische Betrachtungen zur Allgemeinen Relativitätstheorie." In Sitzungsberichte der Preußischen Akademie der Wissenschaften. [28] Weinstein, S. "Quantum Gravity." Stanford Encyklopedia of Philosophy. Accessed Sep. 3,2015 (. http://plato.stanford.edu/entries/quantum-gravity/.
[27] Newton, I. 1687. Philosophiae Naturalis Principia Mathematica. ("Mathematical Principles of Natural Philosophy"), London.