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Full Length Research Paper

The Unification of Coulomb's Electrostatic law with Newton's Gravitational law – A Generalised Model

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Abstract

The unification of electrostatic force and gravity is one of the most pressing research areas. Newton's universal gravitational constant G is and has been the key constant in the calculations of classical mechanics for the gravitational potential, the force of attraction between two masses, as well as the motion in the solar system. It is shown that Newton's Gravitational Law and Coulomb's Electrostatic Law are manifestations of the same fundamental interactions. G depends on the quantum physical composition of matter, being the atomic number/protons (Z) to atomic mass number (A) ratio. All planets orbiting the Sun yield, within statistical significance, the same G. However, the gravitational constants of atoms are distinctly different for each element and from that of the solar/planetary system. Kepler's third law ($\alpha = R^3 / T^2$) and Newton's gravitational law ($F = -GMm / R^2$) are fundamental references for orbital motion. It is shown that the unifying gravitational constant for all matter of nature is $G = \frac{Z}{A}\{1.5251892 \times 10^{29}\}$ N.m^2.kg^{-2}. It is further hypothesised that gravity is electrostatic in nature and that the two laws are reciprocally special cases of the general formula derived and presented in this paper.

Keywords: Relativity, Newton's gravitational law, Coulomb's electrostatic law, Schrödinger's equation, Astrophysics, gravitational constants of periodic table elements and planetary masses, atomic interactions, space-time, Kepler's laws, dimensionless numbers of nature, Gauss' theorem.

List of Symbols:

A: Relative Atomic Mass Number, r.a.m.;
amu: Atomic Mass Unit, 1.660 538 921 x 10^{-27} kg;
AU: Astronomical Unit, based on the mean distance between the Sun and Earth;
CoM: Centre of Mass;
E: Energy eigenvalue of the state of the quantum mechanical wave function, $\psi(\mathbf{r},t)$;
G: Newton's gravitational constant, 6.674 28 x 10^{-11} N.m^2.kg^{-2};
G_f: Relative gravitational constant, $\left(\frac{Z}{A}\right) * (1.5251892 \times 10^{+29})$ N.m^2.kg^{-2};
H: Hamiltonian in classical mechanics = T + V = *(Kinetic Energy)* + *(Potential Energy)*
$\hat{H}$: Hamiltonian operator in quantum mechanics;
M_i: Mass of the central body orbited by other bodies of mass m_i (e.g. Sun, Earth orNucleus);
M_n : Molar mass of substance;
m_i: Mass of Planet i;

m_e: Mass of electron, 9.109 382 91 x 10^{-31} kg;
m_n: Mass of neutron, 1.674 927 351 x 10^{-27} kg;
m_p: Mass of proton, 1.672 621 777 x 10^{-27} kg;
N_A: Avogadro's Constant, N_A = 6.022 141 x 10^{23} atoms.mol^{-1}
n: Principal quantum number;
n_m: number of moles of an element/substance = m/M_n;
p: Momentum;
q: Charge of proton (+q or +q_p), Charge of electron (-q or -q_e), 1.602 176 565 x 10^{-19} C;
R: Radial centre-to-centre distance from the central body M_i (CoM) to the orbiting body, m_i (CoM);
R: Radial vector (x, y, z, t);
r_i: Radius of Planet *i* (x, y, z);
r: radial vector of Planet *i*, ((x, y, z, t);
T_i: Orbital Period of Planet or orbiting mass,m_i around the central body, M_i;
Z: Atomic number;
ω_i: Angular speed of Planet m_i around the central body;
α : used to define Kepler's 3rd Law as$\alpha = R^3 / T^2$;
β : used to express the value of the relation between G = $\beta(4\pi\varepsilon_o)$;
δ : used to express the value of the relation between G = $\delta(q^2/4\pi\varepsilon_o)$;
∇^2: Del-squared or Laplacian Operator;
ε_o: permittivity of free space;
π: 3.14159265359;
θ angle in radians or degrees, as specified;
λ wavelength;
ρ: density of matter;
ψ; wave function, ψ(**r**,t);

1. INTRODUCTION

Johannes Kepler (1571 - 1630) empirically derived three laws from the data initially compiled by Tycho Brahe (1546 – 1601). Brahe made his observations without the use of a telescope (Walker, Halliday, & Resnick, 2014). Kepler's third law which states that:- The ratio of the cube of the orbital radius from the centre of the revolving object to the centre of the central body divided by the square of the corresponding orbital period is constant, herein denoted as $\alpha = R^3 / T^2$, is fundamental to gravitational postulations, derivations and calculations.

Based on Kepler's laws (Russell, 1964), Sir Newton (Herivel, 1974) followed with *Principia Mathematica*, including the derivation of F = ma (mass x acceleration) and developed the inverse square law of gravitational attraction, taking into account the centripetal force (mv^2 / R or $m\omega^2R$) and the central force of gravity ($F = - GMm / R^2$), which led to the empirical determination of the gravitational constant, G. Up to the writing of this paper, we used G as the universal constant for the determination of the gravitational potential and force of attraction between two objects of mass, M_i and m_i and a centre-to-centre distance R apart (Shapiro, 1980). On the other hand, recent research work on gravity focused on finding low-frequency gravitational waves (Vallisneri et al., 2020). For over 330 years, since Newton's derivation and naming the phenomenon "gravity", scientists have been searching for the origin of gravity and the unification of the four fundamental forces of nature, being: the strong and weak forces, and the electromagnetic forces and gravity (Wheeler, 1947). A study of Newtonian gravity measurements which imposed constraints on unification theories, found that such constraints were not viable (Gibbons & Whiting, 1981). Furthermore, using the Gauge Theory and "standard model", the unification of electromagnetic and weak forces has been treated (Greiner & Müller, 1996) (Quigg, 2013). However, the unification of gravity with electromagnetism/electrostatics remained unresolved up to the presentation of the hypotheses and derivations in this paper.

During the 20th century Einstein (1916) introduced General Relativity (GR), as a theory for us to describe gravity in terms of the curvature of space-time (Einstein, 1920). In addition to the famous $E^2 = m^2c^4 + p^2c^2$ equation, Einstein developed the well-known GR equation.

To date, that GR equation is applied to describe gravity as the curvature of space-time. However, Einstein himself asked the validity of reducing physical interactions to abstract geometrization (Lehmkuhl, 2014). The proposition in this paper is that G is not constant in all frames of reference. In this context, the frame of reference is the reference of the central mass. G depends on the central mass which is being

orbited. Thus, relative to the centricity of orbital motion. Furthermore, it will be shown in this paper that gravity is electrostatic in nature and related to electromagnetic fields as also supported in (Meis, 2022) and (Has, Miclaus, & Has, 2015). While Coulomb's law is an experimentally determined result, a fundamental theoretical model will be derived in this paper, which will also account for Newton's law of gravitation.
In this paper we take cognisance of the scientific principles necessary to present information and findings. We will avoid/minimize cluttering the derivations with vector notations, centre of mass and reduced mass provisions in the derivations. We will therefore present the derivations in scalar format and treat the mass of the heaviest body in the analysis as the CoM. It is also the purpose of this paper to present the hypotheses which are intended to lead us closer to a better understanding of how the universe works. We will show the relative (with respect to the central mass as reference) nature of the gravitational constant, gravitational field, potential and force of attraction. It is also shown that it correlates (Meis, 2022) with Coulomb force or interaction, not only in terms of similarity of principles or formulae but with regard to the actual natural phenomenon, the formulae and the calculated results. It will become evident that what we historically applied as the universal gravitational constant in all frames of reference, is in fact relative and applicable to a frame of reference (Jacobs, 2022) in which $\frac{4\pi^2 R^3}{MT^2}$ is constant and equivalent. The results will show that G is more specific in quantum mechanics and different for each periodic table element, based on the composition of respective atomic nuclei. It will also be shown that the proton is a key gravitational particle. The question as to whether G is universal or not was already raised in (Meis, 2022), but remained unresolved. Several efforts have been made to unify Coulomb's electrostatic law and Newton's gravitational law by equating the two forces (Has et al., 2015; Meis, 2022). The end result was the determination of a relational dimensionless number, without an explicit derivation of the origin of the number. In this paper the explicit mathematical derivation is provided. It also provides the explanation of the physical phenomenon and the link between gravity and electrostatics, so as to achieve unification. It will be shown that mass and charge are inextricably linked.

2. HYPOTHESES

The following hypotheses (Watkins, 2017) & (Watson, 1990) are formulated to test the validity of the competing claims. The H_0 (Null Hypothesis) being the status quo and which may be rejected when H_1,H_2 , H_3 (Alternative Hypotheses) are tested and provide supporting results to reject H_0:
H_0:Is the gravitational constant, G, **universal and applicable to all frames of reference**, where bodies, m_i, are in orbital motion and revolving a central body, *M*, and to determine the gravitation potential and force of attraction between the two bodies, *M* and *m*?
Is G= 6.674 x 10^{-11} [N.m^2.kg^{-2}] *universal, because the ratio* $\frac{R^3}{T^2}$*is* ***constant and equal*** *in* ***all frames*** *of reference?*

H_1: Is the gravitational constant, G, **specific to the respective frame of reference** of the central body, *M*, orbited by the other bodies, m_i, in the particular orbital system of the central body?
Is the ratio $\frac{R^3}{T^2}$***constant in a specific frame of reference****, but* ***not*** *equal* ***across*** *all frames of reference. Hence, is G* $\neq$6.674 x 10^{-11} [N.m^2.kg^{-2}] *in all reference frames?*

H_2:Is there a relation between Kepler's 3rd law $\frac{R^3}{T^2}$and the quantum composition of matter, such that the **central body,** *M***,** can be inferred by applying the gravitational constant formula for $M = \frac{4\pi^2 R^3}{GT^2}$ based on the bodies, m_i, revolving the central body, *M?*

H_3:Is the gravitational force of attraction an **electrostatic/electromagnetic** (Meis, 2022) **force,** based on the intrinsic nature (constituted of protons, neutrons and electrons) of all matter (Meis, 2022)? Is it expected that there is a relation between G and $\frac{q^2}{(4\pi\,\varepsilon_0)}$, such that G = $\delta\,\frac{q^2}{(4\pi\,\varepsilon_0)}$where:
δ is a value to be determined by way of derivation and computation, from fundamental principles of physics?
ε_0 is the permittivity of free space.

3. METHODOLOGY

In order to investigate and test the validity and application of the respective hypotheses, it is important for us to revert to the original Newtonian definition and derivation of the gravitational law, as well as the resulting gravitational constant (Cavendish, 1798) based on Kepler's 3rd law. The results should be congruent with existing laws and theories (Coulomb, 1785; Newton, 1687). It should also be able to produce testable predictions of the various interactions, from planetary bodies to quantum mechanics.
During February 2022, the media statement was released (Jacobs, 2022) which specified the result for the relative gravitational constant at atomic level, for Hydrogen (^{2}H - Deuterium), to be 7.55 x 10^{28} N.m^2.kg^{-2}. The result was obtained by applying the fundamental theory which was developed, from using the readily available empirical data for the ^{2}H atom. In order to advance the significance of that result, it is also essential to derive and show the general result which is applicable to all elements of the periodic table, and to the planetary system. Therefore, the derivations of the following key equations for planetary and atomic interactions were analysed: a) $\frac{R^3}{T^2}$;b)$\frac{4\pi^2 R^3}{MT^2}$; and c)G = $\delta\,\frac{q^2}{(4\pi\varepsilon_0)}$. EXCEL

Spreadsheets and readily available planetary and atomic data were used for the calculations. The source data for the planets was obtained from tables in (Walker et al., 2014) and (Spiegel, 1967). For atomic data, the information from the Particle Physics Booklet (Particle Data Group, 2020) and tables in (Wong, 2004) were used. The computed results were compared to the current Newtonian gravitational constant, G = 6.674 28 x 10^{-11}. The three frames of reference, namely: A) The Sun as the central body, *M*; B) The Hydrogen (Deuterium ^{2}H) nucleus as the central body, *M*; and C) The Earth as the central body, *M* for the moon orbiting the Earth, form the basis of the hypothesis tests.

It is worthwhile to note that, at the time of the development and presentation of the gravitational law of attraction in 1687, Sir Newton did not have access to some of the subsequent laws and theories. Examples of such theories are: those of *Coulomb's inverse square law* of electrostatic attraction and repulsion (1785) as well as other theoretical developments from Cavendish (1798) – *determination of the value of the gravitational constant*, G; Dalton (1803)– *constituents of an atom*; Avogadro (1811) – *number of atoms per mole of mass*; Thomson (1897) – *discovery of the electron*; Millikan (1909)– *the charge of an electron and its mass*; Rutherford (1911)– *the positive nucleus in an atom*; and Bohr (1913)– *atomic model and quantization of angular momentum*; Chadwick (1932)– *discovery of the neutron to complete the fundamental model of the atom*; and many other theories of atomic physics, nuclear physics, electromagnetism and quantum mechanics. Similarly, the model of the atom was not fully developed when Einstein published special relativity (1905) and the general theory of relativity (1916). Newton named the observed phenomenon "gravity".

4. ASSUMPTIONS AND DATA ANALYSES OF PLANETS, THE MOONAND THE HYDROGEN (^{2}H) ATOM

The following main assumptions are considered to ensure that the consistency of analyses, validity, rigour and vigour are not compromised:

4.1 That the data (Spiegel, 1967:Zyla, P. A., 2020) utilised are relevant to the extent of the analyses of planetary interactions, near-earth and atomic interactions. Secondly, that the data is significant enough to test the hypotheses and to draw material conclusions;

4.2 That the information and data obtained from long established and utilised Physics textbooks (Cassels, 1982; Giancoli, 2013; Walker et al., 2014) are accurate enough to test the hypotheses, without limitation to any other reliable source data that may be used by the reader;

4.3 That the variations in the data between the sources are not significant;

4.4 That significant numbers are not emphasised, but are only distinguished as far as indicating the principle which needs to be reconfirmed or fundamentally revised;

4.5 That based on the data sample sizes (where applicable and less than n = 50) the t-distribution will be utilised for calculations of descriptive statistics and indication of significance levels.

4.6 That for purposes of simplified algebra the respective central masses, M_i, being orbited are treated as the CoM, as each mass is more than 98% of the total mass of the respective system: the Sun (99.8%) of the system mass, the Earth (98.7%) of the system mass and the Deuterium - ^{2}H nucleus (99.9%) of the atomic Hydrogen mass.

Table 1 below contains the data (Jacobs, 2022) used to calculate, analyse and test the alternate hypotheses, H_1, H_2 and H_3.

A: Planetary Data, is for planets orbiting the Sun, including the dwarf planet Pluto (Spiegel, 1967).

B: Atomic (Hydrogen Atom) Data, as the Hydrogen atom forms the basis for many of our insights into atomic and nuclear mechanics (Giancoli, 2013).

C: Moon (orbiting the Earth) Data, as the closest permanent companion of the Earth, which also provides us with invaluable clues into the planetary system.

5. DERIVATIONS, CALCULATIONS, RESULTS AND OBSERVATIONS

The data of (A) the Solar System; (B) the Hydrogen Atom's System; and (C) the Earth-Moon System were analysed, by utilizing readily available data and the classical approach. The computed results in Table 1, p.10, reveal the following important information (Jacobs, 2022):

For H_1:Testing the universality of G

5.1 In congruence with Kepler's third law, the ratio $\frac{R^3}{T^2}$ for each planet in the Solar System, including the dwarf planet Pluto which also orbits the Sun is equal to 3.3888 x 10^{18} ± 0.024343 x 10^{18} ;

5.2 Although the quantum physics model of the atom has evolved over time, the semi-classical approach to analysing the Deuterium atom provides us some useful insights. For the ^{2}H-Deuterium Atom, the ratio $\frac{R^3}{T^2} = 6.39$, using empirical data;

5.3 For the Earth which is orbited by the Moon, the ratio $\frac{R^3}{T^2}$ = 1.023 x 10^{13};

Based on the available sample data utilized, the Keplerian ratios are specific to their frames of reference and significantly different. Thus, reject $\mathbf{H_0}$ and accept $\mathbf{H_1}$.

For H_2:Testing the universality of$\frac{R^3}{T^2}$

5.4 The ratio $\frac{R^3}{T^2}$ for the Sun (as central body, *M*) is not equal to the $\frac{R^3}{T^2}$ ratios of the Moon orbiting the Earth (as central body *M*), as well as the electron orbiting the Hydrogen nucleus (as central body *M*);

5.5 The ratio $\frac{R^3}{T^2}$ changes significantly from Helio-centric orbits to Geo-centric orbits to the nuclei-centric orbits. The values of the ratios between the three (3) categories of Table 1 being:

A (Planets) C (Moon) B (^{2}H Atom)
3.3888×10^{18}**:** 1.02371×10^{13}**:** 6.398562. Or
5.296×10^{17}**:** 1.5999×10^{12}**:** 1.

5.6 In further support of Sir Newton's law of gravitational attraction, the average G in the Solar system is calculated (utilizing available empirical data) to be $6.7262 \times 10^{-11} \pm 0.048318 \times 10^{-11}$ N.m^2.kg^{-2} This constant, as formulated by Sir Newton and determined by Cavendish (Cavendish, 1798), is within material range (± 0.77309 %) of the internationally accepted (SI) value of G = 6.6742×10^{-11} N.m^2.kg^{-2}

5.7 The gravitational constant of attraction of the Earth (as central body, *Macting on the Moon*) is calculated from the data to be $G_{earth} = 6.7583 \times 10^{-11}$ N.m^2.kg^{-2} This value of G is also within material range (± 1.2600 %) of the internationally accepted (SI) value of G = 6.6742×10^{-11} N.m^2.kg^{-2}

5.8 However, the gravitational constant of attraction, from the data in Table 1, for atomic nuclei, in this case ^{2}H-Deuterium – Hydrogen(Z = 1, M = m_p+ m_n), was found to be $G_{atomic} = 7.55 \times 10^{28}$ N.m^2.kg^{-2} which is materially different from the G for the Sun or the Earth.

Based on the available sample data utilised, the Gravitational constant is different in different frames of reference. Thus, reject $\mathbf{H_0}$ and accept $\mathbf{H_2}$.

For $\mathbf{H_3}$:Testing and deriving the relation between the Electrostatic Law and Gravitational Law

5.9 Lastly, to test H_3, the relation between G = $\delta \frac{q^2}{(4\pi\varepsilon_0)}$. Initially, $G = \beta(4\pi\ \varepsilon_0)$ was calculated and found to be $\beta = 0.599721$, such that $\frac{G}{(4\pi\varepsilon_0)} = 0.599721 \simeq \frac{3}{5}$. This result interestingly resembled the factor used in the Coulomb calculations in nuclear physics, except that in this case β is not dimensionless, but merely providing a very reduced relational number, which may be interpreted and understood in future work.

5.10 From 5.7 above and the Coulomb energy $V_C = \frac{3}{5}\left(\frac{1}{(4\pi\varepsilon_0)}\right)\frac{(Ze)^2}{R}$ for a spherical nucleus and assuming that the charge is distributed spherically. Nature gives us the clue of the likely relation between gravitational potential and electrostatic potential following the observation that the same factor appears in the Coulomb energy for the nucleus. The relation between the gravitational law and the electrostatic law was also investigated in (Meis, 2022) and the resulting "*…gravitational constant G is expressed exactly through the elementary charge e and the electromagnetic vacuum constants ξ, ε_0 and μ_0…*" . The resulting dimensionless constant in that derivation of Meis, η_{ij} (= 4.39×10^{-40}), is referred to as specific to the magnetic moment of interacting particles. Further generalisation of this calculation and its relation to gravity is required to account for the quantum physical composition of different matter, from subatomic particles to large masses and constellations.

5.11 In addition to the relation asserted in (Meis, 2022), we derive the following expanded relation to show certain variables were implicitly incorporated in the experimentally determined law of Coulomb (Coulomb, 1785). The formulation is as follows:

Original Coulomb's Law:

Two spherical objects of mass m_1 and m_2 are deployed in the Coulomb experiment. The principle of conservation of charge provides neutrality on each object. The Coulomb electrostatic force formula is:

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 R^2} \qquad (1)$$

The charges on the two objects are altered to perform the experimental analyses. We now follow the methodology below to analyse the above equation:

a) To alter the neutrality on the objects, m_1 and m_2, the quantity of charges Q_1 and Q_2 are either added or removed from objects of mass m_1 and m_2, respectively to attain the net charge on each object. It is important to note that the electron was only discovered in 1897 by Thomson and its charge and discrete nature were determined in 1909, by Millikan;

b) The masses m_1 and m_2 are constituted of their respective atoms (protons, neutrons and electrons) as:

m_1= {A_1*(a.m.u.) + $Z_1 m_e$}*(N_A*n_{m1});
m_2 = {A_2*(a.m.u.) + $Z_2 m_e$}*(N_A*n_{m2});
Z_i = The number of protons in the nuclei of the atoms of each mass;
Z*q_p = Z*q_e For neutral masses by virtue of charge conservation;
(A_i – Z_i) = Neutronsin respective mass;

c) Applying Gauss' Theorem (closed surface) on a neutral mass, then:

For mass $\mathbf{m_1}$:

$$\iint \mathbf{E_1}.d\mathbf{S} = \frac{(+Z_1 q_p - Z_1 q_e) * N_{A1} * n_{m1}}{\varepsilon_0} = 0$$

The **closed** Gaussian surface is such that it fully encloses $\mathbf{m_1}$. **The net charge is zero**

For mass $\mathbf{m_2}$:

$$\iint \mathbf{E_2}.d\mathbf{S} = \frac{(+Z_2 q_p - Z_2 q_e) * N_{A2} * n_{m2}}{\varepsilon_0} = 0$$

The **closed** Gaussian surface is such that it fully encloses $\mathbf{m_2}$. **The net charge is zero.**

d) Applying Gauss' Theorem (closed surface) when charge has been added or removed. Here we apply the following scenarios, but not limited here to:

For mass $\mathbf{m_1}$ to be +vely charged: (X number of –ve charges are removed from m_1)

For objectm$_1$ to be +vely charged, electrons are **removed**. Thus,

$$\iint \mathbf{E_1}.d\mathbf{S} = \frac{(+Z_1 q_p - Z_1 q_e) * N_{A1} * n_{m1} - (-\mathbf{X_1 q_e})}{\varepsilon_0} = \frac{+X_1 q_p}{\varepsilon_0}$$

The **new mass** $(m_1)' = \{A_1*(\text{a.m.u.}) + Z_1 m_e\}*(N_A*n_{m1}) - X_1 m_e$;

Although the change in charge on m_1 is noticed, the above change in mass would not be noticeable in the Coulomb experiment, due to its insignificance and the available theories and measurement tools, at the time.

For mass $\mathbf{m_2}$: example of **-ve charge**: (Y number of –ve charges)

For object $m_2$to be -vely charged, electrons are **added**. Thus,

$$\iint \mathbf{E_2}.d\mathbf{S} = \frac{(+Z_2 q_p - Z_2 q_e) * N_{A2} * n_{m2} + (-\mathbf{Y_2 q_e})}{\varepsilon_0} = \frac{-Y_2 q_e}{\varepsilon_0}$$

The **new mass** is $(m_2)' = \{A_2*(\text{a.m.u.}) + Z_2 m_e\}*(N_A*n_{m2}) + Y_2 m_e$;

Similarly, the change in charge is noticed. However, the above change in mass would not be noticeable in the Coulomb experiment.

5.12 The relations between charge and mass are presented now. Firstly, the charge on an electron and its mass are inextricable, and form its specific charge, $\frac{-q_e}{m_e}$. Secondly and similarly, the charge on a proton and its mass are inextricably linked and form its specific charge, $\frac{+q_p}{m_p} = \frac{+q_p}{A(\text{a.m.u.})}$.

For instance: If a Gaussian –ve charge of -2,000q_e = 2,000 x (-1.602 x 10^{-19} C) = **-**3.204 x 10^{-16} C is indicated, *then*, it is equivalent to **net mass** of 2,000$\mathbf{m_e}$= 2,000 x (9,109 x 10^{-31} kg) = 1.8219 x 10^{-27} kg **electrons added to an object of mass, m**. The change of the order of ~10^{-27} kg. This would be insignificant and missed in the observations, at the time, due to the limited available measurement tools and that the electron (-ve charge) and proton (+ve charge) were inferred as "like" and "opposite" charges at the time (Coulomb, 1785).

Similarly for the **positively charged object**. If a Gaussian **+ve charge** of +30,000$\mathbf{q_p}$= 30,000 x (**+**1.602 x 10^{-19} C) = +4.806 x 10^{-15} C is indicated, *then*, it is equivalent to **net mass** of 30,000$\mathbf{m_e}$= 30,000 x (9.109 x 10^{-31} kg) = 27.327 x 10^{-27} kg **electrons removed from an object of mass m**. Once again, the change is of the order of~10^{-27} kg. This would be insignificant and missed in the observations of the eighteenth century.

In short we note the ***specific*** mass-charge relations as:

For an electron: $\frac{-q_e}{m_e}$

For a proton: $\frac{+q_p}{m_p} = \frac{+q_p}{A(\text{a.m.u.})}$

The above relations are fundamental for us to realize the material change in the net Gaussian charge of the objects of masses, m_1 and m_2, from neutral to -vely charged or +vely charged.

5.13 Having introduced the above context of the relation of specific charge (the relations of charge and mass), we now revert to Coulomb's Law (in this example for m_1 +vely charged and m_2 –vely charged, but can be generalised) and apply lines 5.9 to 5.12 as follows:

Coulomb's Law $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 R^2} = \frac{(+X_1 q_p)(-Y_2 q_e)}{4\pi\varepsilon_0 R^2}$

The mass m_1 is +vely charged, Q1 = $+X_1 q_p$

The mass m_2 is –vely charged. Q2 = $-Y_2 q_e$

Now, we mathematically introduce the fundamental and important change of variable which relates to the physical and mathematical results of Gauss' Law. That is, relating the total +ve charge on m_1 to the specific charge, and the total –ve charge on m_2 to its respective specific charge as:

$$F = \frac{(+X_1 m_p(\frac{q_p}{m_p}))(-Y_2 m_e(\frac{q_e}{m_e}))}{4\pi\varepsilon_0 R^2}$$

$$F = \frac{(+X_1 m_p(\frac{q_p}{A(\text{a.m.u.})}))(-Y_2 m_e(\frac{q_e}{m_e}))}{4\pi\varepsilon_0 R^2}$$

Rearranging the above equation to separate the natural constants from other variables, as follows:

$$F = \frac{(\frac{q_p}{A(\text{a.m.u.})})(\frac{q_e}{m_e})}{4\pi\varepsilon_0 R^2}(+X_1 m_p)(-Y_2 m_e)$$

$$F = \frac{(1)}{A}\frac{(1)}{4\pi\varepsilon_0 R^2}\frac{(q_p)(q_e)}{(\text{a.m.u.})(m_e)}(+X_1 m_p)(-Y_2 m_e)$$

$$F = \frac{(1)}{A}\frac{(1)}{4\pi\varepsilon_0}\frac{(q_p)(q_e)}{(\text{a.m.u.})(m_e)}\frac{(+X_1 m_p)(-Y_2 m_e)}{R^2} \qquad (2)$$

The resulting equation includes the Coulomb variables of ***charge*** and ***radial distance***, as well as the Newtonian variables of ***mass*** and ***radial distance***. The Generalised Model retains the principle of a conservative field as well as the conservation laws of mass, energy, momentum and charge, as no new variables with dimensions are introduced, The result is that we may now gain more insight from what constitutes the gravitational constant, G.

Based on the above derivation and correlation of Coulomb's electrostatic law with Newton's gravitational law, there is a relation between the two fundamental laws of nature (Cavendish, 1798; Coulomb, 1785; Has et al., 2015; Jacobs, 2022; Lehmkuhl, 2014; Meis, 2022;Newton, 1687). Thus, reject $\mathbf{H_0}$ and accept $\mathbf{H_3}$.

5.14 Coulomb's law and Newton's law are fundamentally connected. For gravity: the *large masses are attracting each other*, (Cavendish, 1798) and (Has et al., 2015) as opposed to quantum particles which can *attract* or *repel* each other, depending on the *net Gaussian charge*. Based on this important connection, the derivation of the universal formula for the relative (based on the central body or mass) gravitation constant, G = $\frac{4\pi^2 R^3}{MT^2}$, which is applicable to all bodies from planetary, solar to atomic level (^{2}H – Deuterium) is provided as follows, before generalisation:

From Newton's 2nd law:

Force (F)= mass(m) x acceleration (a)=$\frac{mv^2}{R}$

The Generalised Model (equation 2) which relates the electrostatic law and the gravitational law contains:

$$F = \frac{(1)}{A}\frac{(1)}{4\pi\varepsilon_0}\frac{(q_p)(q_e)}{(\text{a.m.u.})(\text{m}_e)}\frac{(+\text{X}_1\text{m}_p)(-\text{Y}_2\text{m}_e)}{R^2}$$

For Coulomb's Law and ^{2}H-Deuterium ***special case***, we define the following:

We set A ≡1, a.m.u. ≡1, m_e≡1, m_p≡ 1, Y_2≡ 1 and X_1≡Z , similar to what was implied in the Coulomb experiment (Coulomb, 1785), when ***only charge added*** or ***removed*** and radial distance were considered. The result is:

$$F = \frac{Zq^2}{4\pi\varepsilon_0 R^2}$$

Applying the semi-classical atomic model, m_e = mass of the electron in orbital. And the Centripetal Force = Coulomb Force

$$\frac{\text{m}_e v^2}{R} = \frac{Zq^2}{4\pi\varepsilon_0 R^2}$$

$$\frac{\text{m}_e(2\pi R/T)^2}{R} = \frac{Zq^2}{4\pi\varepsilon_0 R^2}$$

$$\text{m}_e v \text{R}_n = \frac{nh}{2\pi} \ \ (\boldsymbol{Bohr\ Postulate})$$

$$and\ \ p = \text{m}_e v = \frac{h}{2\pi\text{R}_n/n} = \frac{h}{\lambda}\ (\boldsymbol{de\ Broglie\ Postulate})$$

After substitution and rearrangement, we have:

n = Principal quantum number;

$$\text{R}_n = \frac{n^2h^2\varepsilon_0}{Zq^2m\pi} = \frac{n^2}{Z}\text{R}_B$$

where R_B is the Bohr Radius.

Then:

From the Bohr quantum condition and de Broglie condition for angular momentum, L:

$$L = R_n \times p_n = mv_nR_n\sin(90^o) = \frac{nh}{2\pi}$$

We find v:

$$v_n = \frac{nh}{2\pi mR}$$

Using v_n and R_n, m = m_e, we find the orbital period, T, which is also applied in calculating the current ($I = -\frac{e}{T}$) to determine the Bohr Magneton, μ_B = IA:

$$T_n = \frac{2\pi R}{v}$$

Substituting v_n and R_n, we find the orbital period, T_n:

$$T_n = \frac{2\pi R_n}{v_n} = \frac{2\pi R_n}{\frac{nh}{2\pi m_e R_n}} = (\frac{2\pi R_n}{1})(\frac{2\pi m_e R_n}{nh}) = \frac{4\pi^2 m_e (R_n)2}{nh}$$

Then from the semi-classical approach using Kepler's 3rd Law we find $\frac{R^3}{T^2}$ by substituting T with T_n and R with R_n, the result is:

$$\frac{(\text{R}_n)^3}{T^2} = \frac{\left(\frac{n^2h^2\varepsilon_0}{Zq^2m_e\pi}\right)^3}{\left(\frac{4\pi^2m_e(\mathbf{R_n})^2}{\text{nh}}\right)^2} = \left(\frac{n^8h^8(\varepsilon_0)^3}{16Z^3q^6(\text{m}_\mathbf{e})^5(\pi)^7(\mathbf{R_n})^4}\right)$$

$$= \left(\frac{n^8h^8(\varepsilon_0)^3}{16Z^3q^6(\text{m}_\mathbf{e})^5(\pi)^7\left(\frac{\boldsymbol{n^2h^2\varepsilon_0}}{\boldsymbol{Zq^2}\text{m}_\mathbf{e}\boldsymbol{\pi}}\right)^4}\right) = \frac{Zq^2}{16\text{m}_e\pi^3\varepsilon_0}$$

$$= Z\ (6.414\ 095)$$

$$\frac{R^3}{T^2} = Z(\frac{q^2}{16m\pi^3\ \varepsilon_0})$$

Furthermore, it is fundamental for us to apply Sir Newton's derivation and definition to determine the gravitational constant, G:

$$G = \frac{4\pi^2R^3}{MT^2}$$

M is the mass of the atomic nucleus, based on the similar principal to the mass of the central body which is being orbited. The nuclear mass constitutes 99.9% of the mass of an atom. In the case of atomic nuclei, the mass, M is:

M = Relative atomic mass number (A) x atomic mass unit (a.m.u)

M = A(a.m.u.)

After substituting the results of $\frac{R^3}{T^2}$ and M in G = $\frac{4\pi^2R^3}{MT^2}$, we find [the "-" sign is added to indicate the attractive nature of (-q^2) = (+q) * (-q)]:

$$G = -\frac{Zq^2}{A(a.m.u.)m\ 4\pi\varepsilon_0}$$

After rearranging the above equation of G and will herein forward referred to as relative gravitational constant G_f, or G_{atomic} we find:

$$G_f = -\frac{Z}{A}\{\frac{1}{4\pi\varepsilon_0}\}\{\frac{q}{(a.m.u.)}\}\{\frac{q}{m}\}$$

$$= -\frac{Z}{A}\{1.5251892 \times 10^{29}\}\ \text{N.m}^2.\text{kg}^{-2}$$

The above general result for G_f contains *charges (+ve and –ve), masses (proton and electron), atomic number and relative atomic mass.* It shows that the attractive nature of gravity is:

a) electrostatic in nature based on the interactions of charges, *+q and -q.* Hence, the reference to gravitational **field**;

b) relates to the specific charges of the electron $\{\frac{-q}{(m)}\}$ and nucleon $\{\frac{+q}{(a.m.u)}\}$.

Table 1: Planetary, Moon and Hydrogen Atom Data						
A: Planetary						
#	**m_i**	**R_i**	**T_i**	**v_i**	**R^3/T^2**	**$4\pi^2R^3/MT^2$**
		km x 10^6	**[earth yr]**	**[km/s]**		
1	Mercury	58.20	0.241	47.90	3.4329E+18	6.8137E-11
2	Venus	108.00	0.615	35.10	3.3686E+18	6.6861E-11
3	Earth	150.00	1.00	29.80	3.4135E+18	6.7752E-11
4	Mars	227.00	1.88	24.10	3.3472E+18	6.6437E-11
5	Jupiter	778.00	11.86	13.10	3.3860E+18	6.7208E-11
6	Saturn	1 427.00	29.46	9.65	3.3863E+18	6.7213E-11
7	Uranus	2 871.00	84.00	6.80	3.3921E+18	6.7327E-11
8	Neptune	4 498.00	164.80	5.44	3.3890E+18	6.7266E-11
9	Pluto	5 910.00	248.40	4.75	3.3836E+18	6.7160E-11
				Average, μ	**3.3888E+18**	**6.7262E-11**
				STD, σ	2.4343E+16	4.8318E-13
B: Atomic (Hydrogen Atom)						
#	**m_i**	**R_i**	**T_i**	**v_i**	**R^3/T^2**	**$4\pi^2R^3/MT^2$**
		m x 10^{-12}	**[s]**	**[km/s]**		
10	Hydrogen	52.8	1.5167E-16	2187.2785	6.3986	7.5460E+28
C: Moon (orbiting the Earth)						
#	**m_i**	**R_i**	**T_i**	**v_i**	**R^3/T^2**	**$4\pi^2R^3/MT^2$**
		km x 10^6	**[earth yr]**	**[km/s]**		
11	Moon	0.384	0.07479	1.02	1.02371E+13	6.7583E-11

c) depends on the ratio of Atomic Number (Z) : Relative Atomic Mass Number (A).
d) each periodic table element has a gravitational constant based on its respective nucleon composition, as given in Appendix A. The ratio of Z: A gives a likely correlation to nuclear stability, since the relative gravitation constant reduces with decreasing Z/A factor, as depicted in Figure 1.
The above results indicate that G_f is not constant across all frames of reference (for each central body which is orbited). The aforementioned derivations, results and observations are significant, as they unify Coulomb's law and Newton's gravitational law as interactions of the same fundamental phenomenon. In support of unification, it was similarly asserted in Has et al., 2015, that *"… these two forces cannot exist simultaneously because superposition effect will give a(n) exaggerated value, and consequently they must be the same force…"*

Following the above derivation of G_f, the Newtonian gravitational potential and Coulomb electrostatic potential are unified into one fundamental equation as:

$$V(R) = -\frac{Zq^2}{A(a.m.u.)m\,4\pi\varepsilon_0}\frac{\mathrm{M\,m}}{\mathrm{R}}$$

As a result of the above generalised potential field, the Coulomb potential energy equation in the Schrödinger

Table 2: Calculation of Forces of Attraction on Planets, Moon and Hydrogen Atom electron									
A: Planetary				**M_S [kg]**	1.9890E+30				
#	**m_i**	**R_i**	**T_i**	**v_i**	**R^3/T^2**	**$4\pi^2R^3/MT^2$**	**m_i**	**Sun(acc.)**	**$Force_G$**
	[Name]	**km x 10^6**	**[earth-yr]**	**[km/s]**	**[m^3/s^2]**	**G_S**	**[kg]**	**$G_s.M_s/R_i^2$**	**[N]**
1	Mercury	58.2	0.241	47.9	3.4329E+18	6.8137E-11	3.20E+23	4.0010E-02	1.2803E+22
2	Venus	108	0.615	35.1	3.3686E+18	6.6861E-11	4.90E+24	1.1401E-02	5.5867E+22
3	Earth	150	1	29.8	3.4135E+18	6.7752E-11	5.98E+24	5.9893E-03	3.5816E+22
4	Mars	227	1.88	24.1	3.3472E+18	6.6437E-11	6.40E+23	2.5644E-03	1.6412E+21
5	Jupiter	778	11.86	13.1	3.3860E+18	6.7208E-11	1.90E+27	2.2085E-04	4.1961E+23
6	Saturn	1 427	29.46	9.65	3.3863E+18	6.7213E-11	5.70E+26	6.5651E-05	3.7421E+22
7	Uranus	2 871	84	6.8	3.3921E+18	6.7327E-11	8.70E+25	1.6246E-05	1.4134E+21
8	Neptune	4 498	164.8	5.44	3.3890E+18	6.7266E-11	1.03E+26	6.6129E-06	6.8113E+20
9	Pluto	5 910	248.4	4.75	3.3836E+18	6.7160E-11	5.40E+24	3.8245E-06	2.0652E+19
10				Average, μ	3.3888E+18	6.7262E-11			
B: Atomic (Hydrogen Atom)				**M_a [kg]**	3.348E-27			**Gravitational Law**	
#	**m_i**	**R_i**	**T_i**	**v_i**	**R^3/T^2**	**$4\pi^2R_a^3/M_aT_a^2$**	**m_{e-}**	**G_i(acc.)**	**$Force_G$**
	[Name]	**m x 10^{-12}**	**[s]**	**[km/s]**	**[m^3/s^2]**	**G_a**	**[kg]**	**$G_i.M_a/R_a^2$**	**[N]**
11a	Hydrogen	52.8	1.52E-16	2187.2785	6.3986	-	9.11E-31	8.0766E-17	7.3573E-47
11b	Hydrogen	52.8	1.52E-16	2187.2785	6.3986	7.55E+28	9.11E-31	-	8.2540E-08
B1: Atomic (Hydrogen Atom)				**Q_a [C]**	1.6022E-19			**Coulomb's Law**	
#	**Q_{e-}**	**R_i**	**T_i**	**v_i**	**R^3/T^2**	**$4\pi^2R_a^3/M_aT_a^2$**	**q_{e-}**	**Coul. Constant**	**$Force_C$**
	[Name]	**m x 10^{-12}**	**[s]**	**[km/s]**	**[m^3/s^2]**	**G_a**	**[C]**	**$1/4\pi\ \varepsilon_o$**	**[N]**
11c	Hydrogen	52.8	1.52E-16	2187.2785	6.3986	-	1.6022E-19	8.9877E+09	8.2757E-08
C: Moon (orbiting the Earth)				M_E [kg]	5.9800E+24				
#	**m_i**	**R_i**	**T_i**	**v_i**	**R^3/T^2**	**$4\pi^2R^3/MT^2$**	**m_i**	**Earth(acc.)**	**$Force_G$**
	[Name]	**km x 10^6**	**[earth-yr]**	**[km/s]**	**[m^3/s^2]**	**G_E**	**[kg]**	**$G_s.M_E/R_i^2$**	**[N]**
12a	Moon	0.384	0.07479	1.02	1.0237E+13	-	7.3800E+22	0.00272779	2.0131E+20
12b	Moon	0.384	0.07479	1.02	1.0237E+13	6.7583E-11	7.3800E+22	-	2.0227E+20

equation (Cassels, 1982) is unified with the Newtonian gravitational energy equation, such that the Hamiltonians in the **TDSE** (Time Dependent Schrödinger Equation) and TISE (Time Independent Schrödinger Equation) maybe substituted with the generalised potential equation for analyses of atomic and molecular interactions:

TDSE: $-\frac{\hbar^2}{2m}\nabla^2\,\psi\,(\mathbf{r},\mathrm{t}) + V(\boldsymbol{r},t)\,\psi\,(\mathbf{r},\mathrm{t}) = i\hbar\frac{\partial}{\partial t}\,\psi\,(\mathbf{r},\mathrm{t})$

TISE: $-\frac{\hbar^2}{2m}\boldsymbol{\nabla}^2\mathrm{u}(\mathbf{r}) + V(\boldsymbol{r})\mathrm{u}(\mathbf{r}) = E\ \mathrm{u}(\mathbf{r})$

Such that:

$\hat{H} \stackrel{\mathrm{def}}{=} -\frac{\hbar^2}{2m}\boldsymbol{\nabla}^2 + V(\boldsymbol{r})$

$E = E_S \stackrel{\mathrm{def}}{=} \hbar\omega_s$ and $\psi_s(\mathbf{r},t) \stackrel{\mathrm{def}}{=} u_s(\mathbf{r})e^{-i\omega t}$

and

$u(\mathbf{r}) = u_s(\mathbf{r})$; $\omega_s = \omega$

6. THEORETICAL AND EMPIRICAL ANALYSES

Utilising the results computed in Table 1, p. 10, and the observations in section 5 above, the following further calculations were made to draw conclusions and make propo-

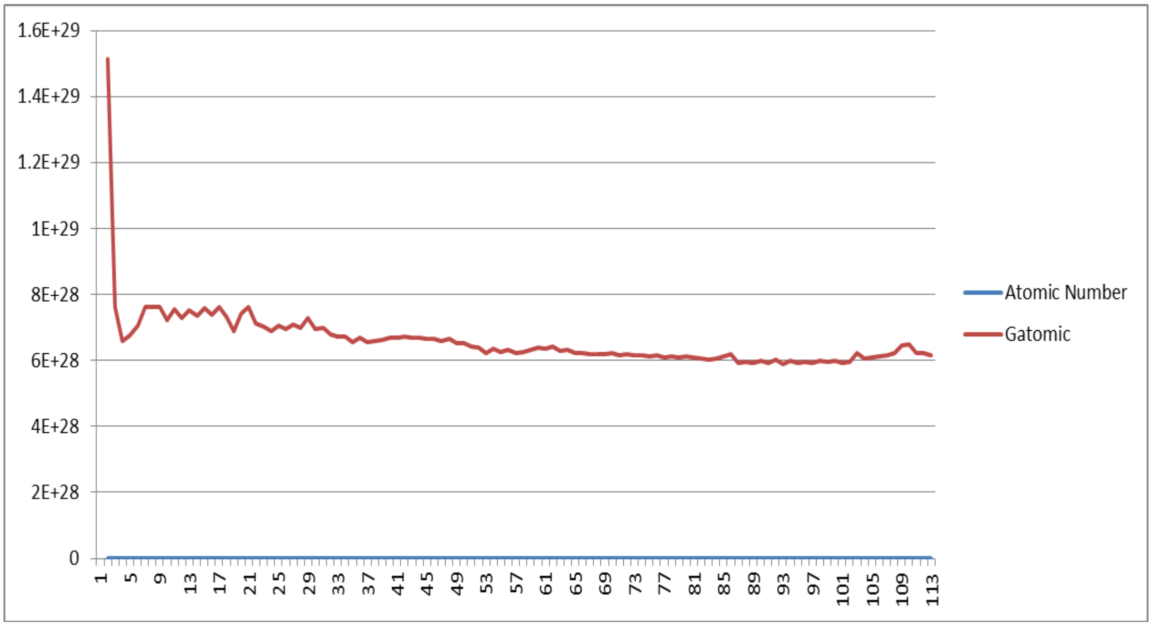

Figure 1: Trend of Relative Gravitational Constant vs Atomic Number.

sitions based on the results of the theoretical and empirical analyses:

6.1 Firstly, the gravitational constants, as calculated in section 4, are applied in the frames of reference of the Sun, Earth and nuclei as central bodies, respectively.

6.2 Secondly, the hypotheses, in section 2, are applied and tested.

The results are as presented in Table 2 (Jacobs, 2022):

The results computed and listed in Table 2, show several important outcomes. The observations are listed as follows:

a) Coulomb's Electrostatic Law and Sir Newton's Gravitational Law are fundamentally of the same natural phenomenon, a relation which was also studied in Meis, 2022, for the special case of G = 6.674 x 10^{-11}, but not generalised. Hence, their similarity in formulation and the determination of the same dimensionless constant;

It is therefore proposed that the model for Unifying Electrostatic/Gravitational Field Equation be:

Unifying Potential: $V(R) = -\frac{Z}{A}\{\frac{1}{4\pi\varepsilon_0}\}\{\frac{q}{(a.m.u.)}\}\{\frac{q}{m}\}\frac{Mm}{R}$

(i) For Coulomb's Law: $V(R) = -\frac{Z}{1}\{\frac{1}{4\pi\varepsilon_0}\}\{\frac{q}{(1)}\}\{\frac{q}{1}\}\frac{1}{R}$
(opposite charges)

Where we observe that : A $\equiv$ 1, a.m.u $\equiv$ 1, M $\equiv$ 1 and m $\equiv$ 1 is an implied special case of the general gravitational equation presented here.

(ii) For planetary gravitational analyses:

Gravitational Potential: $V = -\frac{Z}{A}\{\frac{1}{4\pi\varepsilon_0}\}\{\frac{q}{(a.m.u.)}\}\{\frac{q}{m}\}\frac{Mm}{R}$

Where G = 6.674 28 x 10^{-11}N.m^2.kg^{-2}

Is a special case of the general gravitational formula:

$$G = -\frac{Z}{A}\{\frac{1}{4\pi\varepsilon_0}\}\{\frac{q}{(a.m.u.)}\}\{\frac{q}{m}\}$$

Such that:solving for $\frac{Z}{A}$, we obtain:

$$6.674\,28 \times 10^{-11} = \frac{Z}{A}\{\frac{1}{4\pi\varepsilon_0}\}\{\frac{q}{(a.m.u.)}\}\{\frac{q}{m}\}$$

$$= \frac{Z}{A}\{1.5251892 \times 10^{29}\}\ N.m^2.kg^{-2}$$

Resulting in: $\frac{Z}{A} = 4.376\,03413 \times 10^{-40} = \frac{1}{2.285\,174 \times 10^{39}}$

This dimensionless number, 2.285 174 x 1039 has been a mystery for many decades. It may now be observed that it relates to the ratio of Z/A in matter, as opposed to the factor by which gravity is weaker than the electrostatic force.

7. OBSERVATIONS

7.1 From the above results, an important observation is made that the special dimensionless large number (2.285 174 x

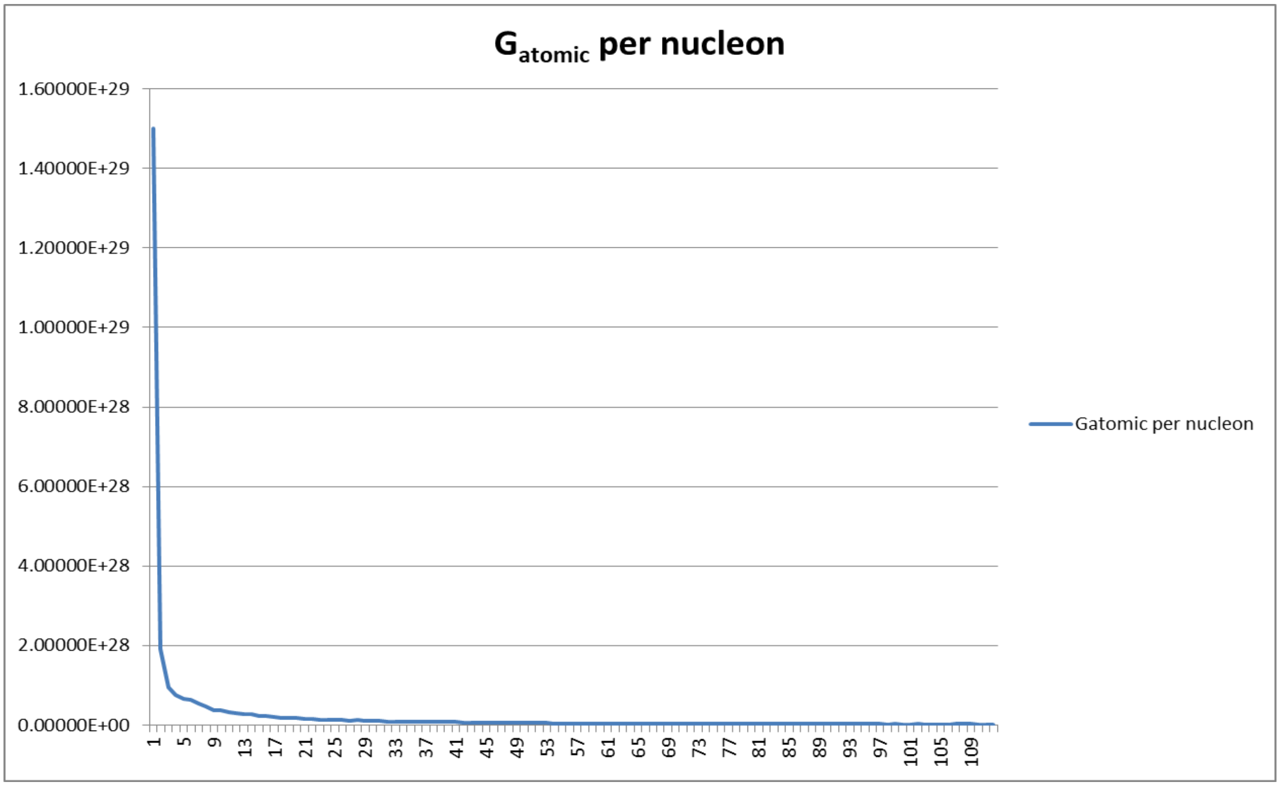

Figure 2: Trend of Relative Gravitational Constant per nucleon vs Atomic Number.

10^{39}) in the denominator of $\frac{Z}{A}$ indicates the ratio of the number of nucleons for each proton in the planetary masses. This ratio may not necessarily be the same for all large masses, leading to different gravitational interactions. The inverse of the same dimensionless number was also calculated in, Meis, 2022., as η_{ij} (= $4.39 \times 10^{-40} \simeq \frac{1}{2.285\ 174\ x\ 10^{39}}$)

7.2 The abovementioned large number ($2.285\ 174 \times 10^{39}$) used to be the unknown factor whenever the strength of the Coulomb Force was compared to the strength of the Gravitational Force. It follows from the above result that the large number is as a result of ***the ratio of protons (Z) to the number of nucleons (A)*** in the mass of the central body, M, in this case the Sun.

7.3 By applying Newton's Gravitational constant for the Sun at atomic for quantum mechanical interactions was an implicit assumption that the ratio of Z:A is the same for all reference frames, while the Z:A ratios at atomic level are distinctly different for each periodic table element.

7.4 The aforesaid application of the Newtonian gravitational constant in quantum mechanics also led to the disparities in observations between the predictions of interactions at planetary level and interactions at atomic level. This resulted in the historic conclusion that gravity can be ignored in quantum mechanical analyses. This paper shows to the contrary, that gravity and electrostatic fields, force and potential are of the same origin and should produce the same or similar predictions and results for the respective orbital systems.

7.5 It is evident from the result for G_f, in section 5 above, that the gravitational constant is relative to the centricity of orbital motion, based on the ratio of Z:A;

7.6 The interpretation that gravity is the curvature of space-time, is as a result of the influence and effect of the electrostatic field in space-time between masses.

7.7 The orbital characteristics of planets around the Sun and the Earth show significantly comparable results for a similar gravitational constant, as listed in Table 2, lines 1-10 and 12a and 12b. Hence, we may apply the Newtonian constant $G = 6.6742 \times 10^{-11}$ in calculations for interactions of bodies m_i, in these two frames of reference, with minimal deviation;

7.8 The gravitational constant for atomic nuclei, G_f (also referred to as G_{atomic}), based on the above findings, is distinctly different from that of the Sun and Earth, using empirical data:

$G = G_{Sun}$ (= 6.6742×10^{-11})$\simeq G_{Earth}$ (6.7583×10^{-11}) $\neq G_{Deuterium}$(7.55×10^{28})

The general gravitational constant is $G_f = \frac{Z}{A}\{1.5251892 \times 10^{29}\}$ $N.m^2.kg^{-2}$.

7.9 The respective gravitational constants were calculated (using empirical data) based on the central body, M_i and listed as per

Table 3: Calculations of Z and A for the Sun from empirical planetary data:

A: Planetary		6.414095	1.52519E+29		
#	m_i	Fixed	Fixed		
	[Name]	then $\mathbf{Z}_{sun}$	then $A_{empirical}$	**"Z/A"**	**Inverse of "Z/A"**
1	Mercury	5.3521E+17	1.198027E+57	4.4674E-40	2.2384E+39
2	Venus	5.2519E+17	1.198022E+57	4.3838E-40	2.2811E+39
3	Earth	5.3219E+17	1.198026E+57	4.4422E-40	2.2511E+39
4	Mars	5.2185E+17	1.198009E+57	4.3560E-40	2.2957E+39
5	Jupiter	5.2790E+17	1.197993E+57	4.4065E-40	2.2694E+39
6	Saturn	5.2795E+17	1.198010E+57	4.4069E-40	2.2692E+39
7	Uranus	5.2885E+17	1.198030E+57	4.4143E-40	2.2653E+39
8	Neptune	5.2837E+17	1.198021E+57	4.4103E-40	2.2674E+39
9	Pluto	5.2753E+17	1.198000E+57	4.4034E-40	2.2710E+39
Average, μ		**5.2834E+17**	**1.198015E+57**	**4.4101E-40**	**2.2676E+39**

Table 2, lines 1 to 10, 12a and 12b.

7.10 It is observed from the results in Table 2, lines 11a and 11b that imposing the Newtonian gravitational constant G, based on planetary motion in atomic level interactions, then the results for the calculation of the gravitational force of attraction on the orbiting electron are significantly different from the results of the Coulomb force of attraction.

7.11 When the relative gravitational constant, G_f, is applied and compared to the Coulomb force of attraction, then the results of the Newtonian and Coulomb forces correspond significantly. The results are shown in Table 2, lines 11b and 11c, to within margin of error of ±0.2622% (8.254 x 10^{-8} N ±0.2622%), using the readily available atomic data.

7.12 By applying the general gravitational formula to the naturally abundant isotopes of the periodic table, a list of relative gravitational constants is provided for each element, as per Appendix A, according to the distinct sequence of atomic numbers.

7.13 In Appendix B the elements are listed from the largest relative gravitational constant to the least, with the accompanying Periodic Table of constants. It is observed that this list shows a trend of atomic nuclei stability, from the *most stable nuclei* to the *least stable* nuclei. There are a set of 6 elements from Z = 78 to 83, namely: Pt (Z=78), Au (Z=79), Hg (Z=80), Tl (Z=81), Pb (Z=82) and Bi (Z=83) which are classified as naturally stable, but are among elements with unstable nuclei (Wong, 2004).

7.14 With the exception of Hydrogen (^1H) with the highest relative gravitational constant of 1.513 13 x 10^{+29} N.m^2.kg^{-2} as depicted in Figure 1, there is a similar range for the relative gravitational constants for the remaining elements from O (Z = 8) at 7.626 23 x 10^{+28}N.m^2.kg^{-2}to the lowest for U (Z = 92) at 5.894 97 10^{+28} N.m^2.kg^{-2}.

7.15 Figure 2 depicts the inverse reduction trend of the relative gravitational constant per nucleon plotted versus the atomic number of the periodic table elements.

7.16 A further important result of the general gravitational derivation is that:

a. All orbital motion obey Kepler's 3rd Law and the *universal relation* is:

$$\frac{\boldsymbol{R^3}}{\boldsymbol{T^2}} = \text{Z}\left(\frac{\boldsymbol{q^2}}{\boldsymbol{16 m_e \pi^3 \varepsilon_0}}\right) = \text{Z}\ (6.414\ 095)$$

The above result may be applied to new astrophysics observations of galaxies. The results for Z (for the Sun) from the data for the planets orbiting the Sun are listed in Table 3 below:

b. All gravitational interactions may be derived from the general gravitational potential energy equation:

$$\text{V} = -\frac{Z}{A}\left\{\frac{1}{4\pi\varepsilon_0}\right\}\left\{\frac{q}{(a.m.u.)}\right\}\left\{\frac{q}{m}\right\}\frac{Mm}{R}$$
$$= -\frac{Z}{A}\{1.525\ 189\ 2 \times 10^{29}\}\frac{Mm}{R}$$

c. From the above general gravitational potential energy equation, I observe that in the absence of a proton in any of the interactions between masses or particles, the gravitational interaction will be zero. The following set of equations are provided in support of this observation, depending on the radial distance R between the particles:

i. $\mathbf{F_{e\text{-}e}} = -\frac{0}{A}\{\mathbf{1.525\ 189\ 2 \times 10^{29}}\}\frac{m_e m_e}{R^2} = 0$
The gravitational force between electrons is zero.

ii. $\mathbf{F_{n\text{-}n}} = -\frac{0}{2.01733}\{\mathbf{1.525\ 189\ 2 \times 10^{29}}\}\frac{m_n m_n}{R^2} = 0$
The gravitational force between neutrons is zero.

iii. $\mathbf{F_{n\text{-}e}} = -\frac{0}{1.008665}\{\mathbf{1.525\ 189\ 2 \times 10^{29}}\}\frac{m_n m_e}{R^2} = 0$
The gravitational force between neutron and electron is zero.

iv. $\mathbf{F_{p\text{-}e}} = -\frac{1}{1.007825}\{\mathbf{1.525\ 189\ 2 \times 10^{29}}\}\frac{m_p m_e}{R^2} \neq 0$
The gravitational force between proton and electron is non-zero.

v. $\mathbf{F_{p\text{-}n}} = -\frac{1}{2.014102}\{\mathbf{1.525\ 189\ 2 \times 10^{29}}\}\frac{m_p m_n}{R^2} \neq 0$
The gravitational force between proton and neutron is non-zero.

vi. $\mathbf{F_{p\text{-}p}} = -\frac{2}{2.014552}\{\mathbf{1.525\ 189\ 2 \times 10^{29}}\}\frac{m_p m_p}{R^2} \neq 0$
The gravitational force between proton and proton is non-zero.

8 COMMENTS AND CONCLUSIONS

8.1 This study into the relative nature of the gravitational constant has provided material insight into the specific use of the computed gravitational constant, for a particular frame of reference.

8.2 The research was limited in the sense that only the readily available planetary data and that of the Hydrogen atom were utilised. More analyses may be carried out on other elements to evaluate and assess predictions as part of the work towards a grand unification theory (GUT) and to compare with empirical results.

8.3 However, based on the results computed and tabulated in Tables 1, 2 and 3, as well as the observations made, it is my proposition that the gravitational force of attraction is electrostatic in nature. By applying the relative gravitational constant principle we should be able to determine the effective/net/Gaussian charge as well as corresponding magnetic fields of planetary bodies and other large bodies, based on their orbital characteristics, similar to the interactions at atomic levels.

8.4 Lastly, with these findings and other research work, we should be able to strive towards our quest for the unification of the four fundamental forces of nature, being: the *strong* and *weak* nuclear forces, *electromagnetism* and *gravity* and a better understanding of the universe as well as for further technological advancement.

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APPENDIX A:
The Elements, sorted by Atomic Number

Atomic Number	Symbol	Name	Atomic Mass (amu, g/mol)	Atomic Number	Gatomic
1	H	Hydrogen	1.00797	1	1.51313E+29
2	He	Helium	4.0026	2	7.62099E+28
3	Li	Lithium	6.941	3	6.59209E+28
4	Be	Beryllium	9.01218	4	6.76946E+28
5	B	Boron	10.81	5	7.05453E+28
6	C	Carbon	12.011	6	7.61896E+28
7	N	Nitrogen	14.0067	7	7.62230E+28
8	O	Oxygen	15.9994	8	7.62623E+28
9	F	Fluorine	18.998403	9	7.22519E+28
10	Ne	Neon	20.179	10	7.55830E+28
11	Na	Sodium	22.98977	11	7.29763E+28
12	Mg	Magnesium	24.305	12	7.53025E+28
13	Al	Aluminium	26.98154	13	7.34853E+28
14	Si	Silicon	28.0855	14	7.60273E+28
15	P	Phosphorus	30.97376	15	7.38620E+28
16	S	Sulfur	32.06	16	7.61167E+28
17	Cl	Chlorine	35.453	17	7.31341E+28
18	Ar	Argon	39.948	18	6.87229E+28
19	K	Potassium	39.0983	19	7.41173E+28
20	Ca	Calcium	40.08	20	7.61072E+28
21	Sc	Scandium	44.9559	21	7.12453E+28
22	Ti	Titanium	47.9	22	7.00504E+28
23	V	Vanadium	50.9415	23	6.88620E+28
24	Cr	Chromium	51.996	24	7.03988E+28
25	Mn	Manganese	54.938	25	6.94050E+28
26	Fe	Iron	55.847	26	7.10064E+28
27	Co	Cobalt	58.9332	27	6.98759E+28
28	Ni	Nickel	58.7	28	7.27518E+28
29	Cu	Copper	63.546	29	6.96039E+28
30	Zn	Zinc	65.38	30	6.99842E+28
31	Ga	Gallium	69.72	31	6.78154E+28
32	Ge	Germanium	72.59	32	6.72352E+28
33	As	Arsenic	74.9216	33	6.71786E+28
34	Se	Selenium	78.96	34	6.56743E+28
35	Br	Bromine	79.904	35	6.68072E+28
36	Kr	Krypton	83.8	36	6.55213E+28
37	Rb	Rubidium	85.4678	37	6.60272E+28
38	Sr	Strontium	87.62	38	6.61461E+28
39	Y	Yttrium	88.9059	39	6.69049E+28
40	Zr	Zirconium	91.22	40	6.68796E+28

41	Nb	Niobium	92.9064	41	6.73073E+28
42	Mo	Molybdenum	95.94	42	6.67688E+28
43	Tc	Technetium	98	43	6.69216E+28
44	Ru	Ruthenium	101.07	44	6.63979E+28
45	Rh	Rhodium	102.9055	45	6.66957E+28
46	Pd	Palladium	106.4	46	6.59386E+28
47	Ag	Silver	107.868	47	6.64552E+28
48	Cd	Cadmium	112.41	48	6.51268E+28
49	In	Indium	114.82	49	6.50882E+28
50	Sn	Tin	118.69	50	6.42510E+28
51	Sb	Antimony	121.75	51	6.38888E+28
52	Te	Tellurium	127.6	52	6.21550E+28
53	I	Iodine	126.9045	53	6.36975E+28
54	Xe	Xenon	131.3	54	6.27267E+28
55	Cs	Caesium	132.9054	55	6.31166E+28
56	Ba	Barium	137.33	56	6.21937E+28
57	La	Lanthanum	138.9055	57	6.25863E+28
58	Ce	Cerium	140.12	58	6.31323E+28
59	Pr	Praseodymium	140.9077	59	6.38618E+28
60	Nd	Neodymium	144.24	60	6.34438E+28
61	Pm	Promethium	145	61	6.41631E+28
62	Sm	Samarium	150.4	62	6.28735E+28
63	Eu	Europium	151.96	63	6.32317E+28
64	Gd	Gadolinium	157.25	64	6.20745E+28
65	Tb	Terbium	158.9254	65	6.23798E+28
66	Dy	Dysprosium	162.5	66	6.19461E+28
67	Ho	Holmium	164.9304	67	6.19581E+28
68	Er	Erbium	167.26	68	6.20070E+28
69	Tm	Thulium	168.9342	69	6.22953E+28
70	Yb	Ytterbium	173.04	70	6.16986E+28
71	Lu	Lutetium	174.967	71	6.18908E+28
72	Hf	Hafnium	178.49	72	6.15237E+28
73	Ta	Tantalum	180.9479	73	6.15309E+28
74	W	Tungsten	183.85	74	6.13892E+28
75	Re	Rhenium	186.207	75	6.14312E+28
76	Os	Osmium	190.2	76	6.09434E+28
77	Ir	Iridium	192.22	77	6.10964E+28
78	Pt	Platinum	195.09	78	6.09794E+28
79	Au	Gold	196.9665	79	6.11728E+28
80	Hg	Mercury	200.59	80	6.08281E+28
81	Tl	Thallium	204.37	81	6.04493E+28
82	Pb	Lead	207.2	82	6.03598E+28
83	Bi	Bismuth	208.9804	83	6.05754E+28
84	Po	Polonium	209	84	6.12995E+28
85	At	Astatine	210	85	6.17339E+28

86	Rn	Radon	222	86	5.90839E+28
87	Fr	Francium	223	87	5.95029E+28
88	Ra	Radium	226.0254	88	5.93812E+28
89	Ac	Actinium	227.0278	89	5.97908E+28
90	Th	Thorium	232.0381	90	5.91571E+28
91	Pa	Protactinium	231.0359	91	6.00739E+28
92	U	Uranium	238.029	92	5.89497E+28
93	Np	Neptunium	237.0482	93	5.98370E+28
94	Pu	Plutonium	242	94	5.92429E+28
95	Am	Americium	243	95	5.96267E+28
96	Cm	Curium	247	96	5.92786E+28
97	Bk	Berkelium	247	97	5.98961E+28
98	Cf	Californium	251	98	5.95492E+28
99	Es	Einsteinium	252	99	5.99181E+28
100	Fm	Fermium	257	100	5.93459E+28
101	Md	Mendelevium	258	101	5.97070E+28
102	No	Nobelium	250	102	6.22277E+28
103	Lr	Lawrencium	260	103	6.04210E+28
104	Rf	Rutherfordium	261	104	6.07738E+28
105	Db	Dubnium	262	105	6.11240E+28
106	Sg	Seaborgium	263	106	6.14715E+28
107	Bh	Bohrium	262	107	6.22883E+28
108	Hs	Hassium	255	108	6.45963E+28
109	Mt	Meitnerium	256	109	6.49397E+28
110	Ds	Darmstadtium	269	110	6.23683E+28
111	Rg	Röntgenium	272	111	6.22412E+28
112	Uub	Ununbiium	277	112	6.16683E+28

APPENDIX B:
The Elements, sorted by G_f-Atomic (Relative Gravitational Constant)

Atomic Number	Symbol	Name	Atomic Mass (amu, g/mol)	Atomic Number	G_f (G_{atomic})
1	H	Hydrogen	1.00797	1	1.51313E+29
8	O	Oxygen	15.9994	8	7.62623E+28
7	N	Nitrogen	14.0067	7	7.62230E+28
2	He	Helium	4.0026	2	7.62099E+28
6	C	Carbon	12.011	6	7.61896E+28
16	S	Sulfur	32.06	16	7.61167E+28
20	Ca	Calcium	40.08	20	7.61072E+28
14	Si	Silicon	28.0855	14	7.60273E+28
10	Ne	Neon	20.179	10	7.55830E+28
12	Mg	Magnesium	24.305	12	7.53025E+28
19	K	Potassium	39.0983	19	7.41173E+28
15	P	Phosphorus	30.97376	15	7.38620E+28
13	Al	Aluminium	26.98154	13	7.34853E+28
17	Cl	Chlorine	35.453	17	7.31341E+28
11	Na	Sodium	22.98977	11	7.29763E+28
28	Ni	Nickel	58.7	28	7.27518E+28
9	F	Fluorine	18.998403	9	7.22519E+28
21	Sc	Scandium	44.9559	21	7.12453E+28
26	Fe	Iron	55.847	26	7.10064E+28
5	B	Boron	10.81	5	7.05453E+28
24	Cr	Chromium	51.996	24	7.03988E+28
22	Ti	Titanium	47.9	22	7.00504E+28
30	Zn	Zinc	65.38	30	6.99842E+28
27	Co	Cobalt	58.9332	27	6.98759E+28
29	Cu	Copper	63.546	29	6.96039E+28
25	Mn	Manganese	54.938	25	6.94050E+28
23	V	Vanadium	50.9415	23	6.88620E+28
18	Ar	Argon	39.948	18	6.87229E+28
31	Ga	Gallium	69.72	31	6.78154E+28
4	Be	Beryllium	9.01218	4	6.76946E+28
41	Nb	Niobium	92.9064	41	6.73073E+28
32	Ge	Germanium	72.59	32	6.72352E+28
33	As	Arsenic	74.9216	33	6.71786E+28
43	Tc	Technetium	98	43	6.69216E+28
39	Y	Yttrium	88.9059	39	6.69049E+28
40	Zr	Zirconium	91.22	40	6.68796E+28
35	Br	Bromine	79.904	35	6.68072E+28
42	Mo	Molybdenum	95.94	42	6.67688E+28
45	Rh	Rhodium	102.9055	45	6.66957E+28
47	Ag	Silver	107.868	47	6.64552E+28

44	Ru	Ruthenium	101.07	44	6.63979E+28
38	Sr	Strontium	87.62	38	6.61461E+28
37	Rb	Rubidium	85.4678	37	6.60272E+28
46	Pd	Palladium	106.4	46	6.59386E+28
3	Li	Lithium	6.941	3	6.59209E+28
34	Se	Selenium	78.96	34	6.56743E+28
36	Kr	Krypton	83.8	36	6.55213E+28
48	Cd	Cadmium	112.41	48	6.51268E+28
49	In	Indium	114.82	49	6.50882E+28
109	Mt	Meitnerium	256	109	6.49397E+28
108	Hs	Hassium	255	108	6.45963E+28
50	Sn	Tin	118.69	50	6.42510E+28
61	Pm	Promethium	145	61	6.41631E+28
51	Sb	Antimony	121.75	51	6.38888E+28
59	Pr	Praseodymium	140.9077	59	6.38618E+28
53	I	Iodine	126.9045	53	6.36975E+28
60	Nd	Neodymium	144.24	60	6.34438E+28
63	Eu	Europium	151.96	63	6.32317E+28
58	Ce	Cerium	140.12	58	6.31323E+28
55	Cs	Caesium	132.9054	55	6.31166E+28
62	Sm	Samarium	150.4	62	6.28735E+28
54	Xe	Xenon	131.3	54	6.27267E+28
57	La	Lanthanum	138.9055	57	6.25863E+28
65	Tb	Terbium	158.9254	65	6.23798E+28
110	Ds	Darmstadtium	269	110	6.23683E+28
69	Tm	Thulium	168.9342	69	6.22953E+28
107	Bh	Bohrium	262	107	6.22883E+28
111	Rg	Röntgenium	272	111	6.22412E+28
102	No	Nobelium	250	102	6.22277E+28
56	Ba	Barium	137.33	56	6.21937E+28
52	Te	Tellurium	127.6	52	6.21550E+28
64	Gd	Gadolinium	157.25	64	6.20745E+28
68	Er	Erbium	167.26	68	6.20070E+28
67	Ho	Holmium	164.9304	67	6.19581E+28
66	Dy	Dysprosium	162.5	66	6.19461E+28
71	Lu	Lutetium	174.967	71	6.18908E+28
85	At	Astatine	210	85	6.17339E+28
70	Yb	Ytterbium	173.04	70	6.16986E+28
112	Uub	Ununbiium	277	112	6.16683E+28
73	Ta	Tantalum	180.9479	73	6.15309E+28
72	Hf	Hafnium	178.49	72	6.15237E+28
106	Sg	Seaborgium	263	106	6.14715E+28
75	Re	Rhenium	186.207	75	6.14312E+28
74	W	Tungsten	183.85	74	6.13892E+28
84	Po	Polonium	209	84	6.12995E+28

79	Au	Gold	196.9665	79	6.11728E+28
105	Db	Dubnium	262	105	6.11240E+28
77	Ir	Iridium	192.22	77	6.10964E+28
78	Pt	Platinum	195.09	78	6.09794E+28
76	Os	Osmium	190.2	76	6.09434E+28
80	Hg	Mercury	200.59	80	6.08281E+28
104	Rf	Rutherfordium	261	104	6.07738E+28
83	Bi	Bismuth	208.9804	83	6.05754E+28
81	Tl	Thallium	204.37	81	6.04493E+28
103	Lr	Lawrencium	260	103	6.04210E+28
82	Pb	Lead	207.2	82	6.03598E+28
91	Pa	Protactinium	231.0359	91	6.00739E+28
99	Es	Einsteinium	252	99	5.99181E+28
97	Bk	Berkelium	247	97	5.98961E+28
93	Np	Neptunium	237.0482	93	5.98370E+28
89	Ac	Actinium	227.0278	89	5.97908E+28
101	Md	Mendelevium	258	101	5.97070E+28
95	Am	Americium	243	95	5.96267E+28
98	Cf	Californium	251	98	5.95492E+28
87	Fr	Francium	223	87	5.95029E+28
88	Ra	Radium	226.0254	88	5.93812E+28
100	Fm	Fermium	257	100	5.93459E+28
96	Cm	Curium	247	96	5.92786E+28
94	Pu	Plutonium	242	94	5.92429E+28
90	Th	Thorium	232.0381	90	5.91571E+28
86	Rn	Radon	222	86	5.90839E+28
92	U	Uranium	238.029	92	5.89497E+28

PERIODIC TABLE OF THE ELEMENTS

RELATIVE GRAVITATIONAL CONSTANTS OF ELEMENTS G_{atomic}

KEY

Atomic Number	Z
Symbol	**Element Symbol**
r.a.m.	**Relative Atomic Mass (of the most abundant neutral isotope)**
G_{atomic}	**Relative Gravitational Constant**

Atomic Number	=	Z		electron mass (m_e)	=	9.109E-31
Atomic Mass	=	r.a.m x (a.m.u.)		free space permittivity =		8.854E-12
Atomic Mass Unit (1u)	=	1.6605E-27	G_{atomic} Formula =	Pi	=	3.142E+00
				Electron Charge	=	-1.602E-19
G_{atomic} Formula =		[Z / {(r.a.m. x (a.m.u.) x m_e] x [$q^2/4\pi\varepsilon_o$]		Proton Charge	=	1.602E-19

A-GROUP	**1A**	**2A**											**3A**	**4A**	**5A**	**6A**	**7A**	**8A**
B-GROUP			**3B**	**4B**	**5B**	**6B**	**7B**	**—**	**8B**	**—**	**1B**	**2B**						
	- 1	**- 2**	**- 3**	**- 4**	**- 5**	**- 6**	**- 7**	**- 8**	**- 9**	**- 10**	**- 11**	**- 12**	**- 13**	**- 14**	**- 15**	**- 16**	**- 17**	**- 18**
PERIOD																		
1	1 $^{1}H_{1}$ 1.007825 -1.51335E+29																	2 He 4.002603 -7.62099E+28
1	1 $^{2}H_{1}$ 2.014102 -7.57256E+28																	
1	1 $^{3}H_{1}$ 3.016049 -5.05692E+28																	
2	3 **Li** 6.941 -6.59209E+28	4 **Be** 9.01218 -6.76946E+28											5 **B** 10.811 -7.05388E+28	6 **C** 12 -7.62595E+28	7 **N** 14.003074 -7.62428E+28	8 **O** 15.9994 -7.62624E+28	9 **F** 18.998403 -7.22519E+28	10 **Ne** 19.99244 -7.62884E+28
3	11 **Na** 22.98977 -7.29764E+28	12 **Mg** 23.985042 -7.63071E+28											13 **Al** 26.98154 -7.34853E+28	14 **Si** 27.976927 -7.63224E+28	15 **P** 30.97376 -7.38621E+28	16 **S** 31.972071 -7.63261E+28	17 **Cl** 35.453 -7.31341E+28	18 **Ar** 39.962383 -6.86982E+28
4	19 **K** 38.963706 -7.43734E+28	20 **Ca** 39.962591 -7.63309E+28	21 **Sc** 44.9559 -7.12454E+28	22 **Ti** 47.947942 -6.99805E+28	23 **V** 50.943957 -6.88588E+28	24 **Cr** 51.940506 -7.04740E+28	25 **Mn** 54.938 -6.94051E+28	26 **Fe** 55.934936 -7.08948E+28	27 **Co** 58.9332 -6.98760E+28	28 **Ni** 57.935342 -7.37121E+28	29 **Cu** 62.929598 -7.02857E+28	30 **Zn** 63.929142 -7.15726E+28	31 **Ga** 68.925574 -6.85971E+28	32 **Ge** 73.921178 -6.60245E+28	33 **As** 74.9216 -6.71786E+28	34 **Se** 79.916522 -6.48883E+28	35 **Br** 78.918338 -6.76417E+28	36 **Kr** 83.911498 -6.54343E+28
5	37 **Rb** 84.91179 -6.64596E+28	38 **Sr** 87.905612 -6.59312E+28	39 **Y** 88.9059 -6.69049E+28	40 **Zr** 89.904698 -6.78581E+28	41 **Nb** 92.9064 -6.73073E+28	42 **Mo** 97.905405 -6.54285E+28	43 **Tc** 97.907212 -6.69851E+28	44 **Ru** 101.904344 -6.58543E+28	45 **Rh** 102.9055 -6.66957E+28	46 **Pd** 105.90348 -6.62478E+28	47 **Ag** 107.905092 -6.64324E+28	48 **Cd** 113.903365 -6.42730E+28	49 **In** 114.903879 -6.50407E+28	50 **Sn** 119.902202 -6.36014E+28	51 **Sb** 120.903812 -6.43360E+28	52 **Te** 129.906223 -6.10517E+28	53 **I** 126.9045 -6.36976E+28	54 **Xe** 131.904155 -6.24395E+28
6	55 **Cs** 132.9054 -6.31167E+28	56 **Ba** 137.905247 -6.19343E+28	57 **La** 138.906356 -6.25860E+28	72 **Hf** 179.946557 -6.10257E+28	73 **Ta** 180.9479 -6.15309E+28	74 **W** 183.950931 -6.13556E+28	75 **Re** 186.95575 -6.11852E+28	76 **Os** 191.961477 -6.03842E+28	77 **Ir** 192.962922 -6.08613E+28	78 **Pt** 194.964792 -6.10186E+28	79 **Au** 196.9665 -6.11729E+28	80 **Hg** 201.970643 -6.04124E+28	81 **Tl** 204.974428 -6.02711E+28	82 **Pb** 207.976652 -6.01345E+28	83 **Bi** 208.980399 -6.05755E+28	84 **Po** 209.982874 -6.10126E+28	85 **At** 218.008695 -5.94661E+28	86 **Rn** 222.017578 -5.90793E+28
7	87 **Fr** 223.019736 -5.94977E+28	88 **Ra** 226.0254 -5.93813E+28	89 **Ac** 227.0278 -5.97909E+28	104 **Rf** 263.1125 -6.02859E+28	105 **Db** 268.12567 -5.97276E+28	106 **Sg** 271.13393 -5.96274E+28	107 **Bh** 274.14355 -5.95292E+28	108 **Hs** 270.13429 -6.09773E+28	109 **Mt** 278.15631 -5.97670E+28	110 **Ds** 281.16451 -5.96700E+28	111 **Rg** 281.16636 -6.02121E+28	112 **Cn** 285.17712 -5.99001E+28	113 **Nh** 286.1821 -6.02227E+28	114 **Fl** 289.19042 -6.01236E+28	115 **Mc** 289.19363 -6.06503E+28	116 **Lv** 293.20449 -6.03409E+28	117 **Ts** 294.21046 -6.06529E+28	118 **Og** 294.21392 -6.11706E+28
6				58 **Ce** 139.905443 -6.32292E+28	59 **Pr** 140.9077 -6.38618E+28	60 **Nd** 141.907729 -6.44866E+28	61 **Pm** 144.912756 -6.42018E+28	62 **Sm** 151.91974 -6.22446E+28	63 **Eu** 152.921238 -6.28343E+28	64 **Gd** 157.924112 -6.18096E+28	65 **Tb** 158.9254 -6.23798E+28	66 **Dy** 163.929182 -6.14061E+28	67 **Ho** 164.9304 -6.19581E+28	68 **Er** 165.9303 -6.25039E+28	69 **Tm** 168.9342 -6.22954E+28	70 **Yb** 173.938866 -6.13798E+28	71 **Lu** 174.940775 -6.19001E+28	
7				90 **Th** 232.0381 -5.91572E+28	91 **Pa** 231.0359 -6.00739E+28	92 **U** 238.050788 -5.89444E+28	93 **Np** 237.0482 -5.98371E+28	94 **Pu** 239.052164 -5.99735E+28	95 **Am** 243.061381 -5.96117E+28	96 **Cm** 247.070354 -5.92618E+28	97 **Bk** 247.070307 -5.98791E+28	98 **Cf** 251.079589 -5.95304E+28	99 **Es** 252.08298 -5.98985E+28	100 **Fm** 257.095106 -5.93240E+28	101 **Md** 258.098431 -5.96843E+28	102 **No** 259.10103 -6.00420E+28	103 **Lr** 262.10961 -5.99347E+28	