# A THEORETICAL DIFFICULTY IN DETERMING THE UNIVERSALITY OF GRAVITATIONAL CONSTANT

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ABSTRACT

The paper intends to prove that due to the finite value of quantum of action there exist a limitation to the transfer of energy and this requirement is general and universal the if we do not incorporate this idea into our considerations we will be unable to solve some of the major challenges in Newtonian physics such as the existence of infinite distance when the body is projected with escape velocity and secondly, in spite of about 300 experiments why do we observe scatter in the value of G and is the gravitational constant really universal or specific?

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## INTRODUCTION

### Understanding action

There are various explanations to the term “action” in physics but the best and simple definition of action is that it is the change/transfer of energy multiplied by time. It is important to note that transfer/ change in energy are analogues due to the conservation of energy as energy is a conserved quantity when you change energy of a body or a system you simply make a transfer. Action is transfer of energy into time mathematically this is given as ΔEt = action. Many writers say that action is the change in energy with time which is just a matter of interpretation.

Max Planck in his observations on the energy interchanges on black body come up with a conclusion that the radiant energy is transferred in discreet packets of energies which are integral multiple of a constant called the Planck constant given by h and which has the unit of action given as Js.

While studying the black body curve Planck come up with a conclusion which is quoted in his own words “To interpret $U_N$ (the vibrational energy of N oscillators) not as a continuous, infinitely divisible quantity, but as a discrete quantity composed of a integral number of finite equal parts.”

The Einstein Plank relation tells us about the relation between action and energy and is given as E = h × f. Some writers use this form but the better form of this equation is because the equation relates with the change/ transfer of energy should be ΔE = h × f. It is extremely important to note that the quantity h is a constant in the above equation and Δ represents change/transfer of energy. The value of Planck constant h = $6.623\times10^{-34}$Js is the smallest action. We know that the the vacuum velocity of light is constant and is about $3 \times 10^{8}$m/s. and this velocity is related to frequency and wavelength by the relation c = f×ƛ. Where f is the frequency and ƛ is the wavelength. This implies that f = $\frac{c}{ƛ}$

Therefore we can write, ΔE = h × f

This can be written as $\frac{\Delta E}{f} = \mathrm{h}$

According to Planck hypothesis action is quantized. That is to say that the right hand side of the equation is quantized but there is no say about the left hand side. Planck did not said anything as minimum energy but his observations along with Einstein proves that light is emitted in **discreet** bundles of energy given by ΔE= hf and this equation is called the Planck Einstein relation and is used to demonstrate the photo-electric effect and is the experimental evidence that light is carried in discreet bundles of energy. Though few writers write it as E = hf which is not proper as it is the transfer/change of energy and we should always keep this in mind and therfore Δ in front of E is important.

Frequency is defined as the number of waves at a point in a unit time interval. A transverse wave consists of a crust and a trough. In physics, the wavelength is the spatial period of a periodic wave- the distance over which the wave shape repeats. We know that the vacuum velocity of light is constant and is about $3 \times 10^{8}$m/s. and this velocity is related to frequency and wavelength by the relation c = f×ƛ. Where f is the frequency and ƛ is the wavelength. This implies that f = $\frac{c}{ƛ}$

We know, ΔE = h × f

**This can be written as** $\frac{\Delta E}{f} = \mathrm{h}$

It is extremely important to note that the quantity h is a constant in the above equation whose value is $6.623\times10^{-34}$Js and is known as Planck constant. It is important to note that the smallest value of a complete action is $6.623\times10^{-34}$Js. But what is a complete action, a complete action is an action in which there has been the required transfer of energy and unit frequency has lapsed. Frequency is defined as the number of waves at a point in a unit time interval. A transverse wave consists of a crust and a trough. This implies that in a unit time interval i.e. in 1 second for the action to be complete 1 crust and 1 has passed through that point which in other words implies that the minimum energy transferred/changed = $6.623\times10^{-34}$J

$$\frac{\Delta E}{f} = \mathrm{h}$$

$$\frac{\Delta E}{1Hz} = 6.623\times10^{-34}\,\mathrm{Js}$$

Therefore, ΔE = $6.623\times10^{-34}$Js × 1Hz = $6.623\times10^{-34}$J

This means that this is the minimum energy transferred by a complete action in unit time. if, the amount of energy transferred in a time interval of 1 second is less than this value than this will amount an incomplete action, and this requirement exist due to Planck constant being a fundamental constant of nature. The complete action means that the wavelength has completed its full cycle around the point in question. The essence of argument is that a complete minimum action demands minimum transfer of energy and this cannot be less than $6.623 \times 10^{-34}$ J for a unit action in unit time interval.

If f = 0.5 Hz for a particular situation, will this amount to a complete action? The obvious answer is ~~no~~. Because electromagnetic wave has a crust and a trough when I say that f = 0.5Hz I am talking about either a crust or a trough in unit time interval in other words I am talking about a incomplete transfer/change i.e. about an incomplete action the equation $\Delta E = h \times f$ puts a limitation on the amount of energy transferred per action as f cannot be less than 1for a unit time interval for the action minimum to make a physical and logical sense.

It could be argued that this consideration applies only to energy radiated but, it should be noted that in his mass-energy equivalence Einstein has proved that all form of energies are equivalent and we should not ignore this fact. This implies that there exists a minimum theoretical limit on the transfer of energy as a consequence of quantum of action and if we assume this hypothesis this will give rise to many theoretical explanation which could not be explained by classical mechanics.

Currently we do not believe in a minimum theoretical limit to the transfer of energy as a consequence we are unable to explain that when a body which is projected with a velocity greater than or equal to escape velocity, during its journey we cannot determine the point from where the motion becomes inertial from accelerated. The current understanding is that once projected with velocity greater than or equal to escape velocity the projected body will move away to infinite distance. Infinity could be a philosophical manifestation but it hardly makes any real physical measurement and physics is pertinent to measure. The existence of infinite in this specific calculation of distance/time calculation of escape velocity establishes the particular short-coming of Newtonian dynamics.

A "measure "is something which has two defined boundaries or interval or a division making logical sense, can we really use infinity as a measure? No matter what provision of error budget we are ready to allocate we can't have a measure of infinity. Infinity is not a number and hence the idea of measurement lapse at infinity. There can be no calculation without the determination of a measure and it is so fundamental that even nature is bonded to use some kind of a measure for its calculations. And in order to complete this obligation nature uses Plank constant as a fundamental measure to get over the problematic situation laid down by this infinite calculation.

We need to understand that Mother Nature uses some kind of "measure". It is important to note that in a chemical reaction the atoms or molecules of the substances involved reacts chemically to form a new substance, the reaction can be exothermic or endothermic, and the amount of energy released or absorbed is depended on the quantity of substances involved, which in turn is dependent on the number of atoms/molecules present in the quantity involved. The number of atoms/molecules is calculated with the help of Avogadro's number and hence Avogadro's number is a measure But, if we extrapolate the chemical process we will realize that the chemical process is nothing but change in energy in some finite time interval and hence action .

It is interesting to note that temperature is an extensive property from this we conclude that it is the total number of atoms/molecules which determine the requirement of minimum energy from this example we can say that in general nature uses Planck constant and the number of atoms/molecules as a "measure" and this requirement is general. Now if a body compromises of n particles then for any change/ transfer of energy in such a body will demand that the requirement of a certain minimum action is accomplished this minimum action is the sum total of all the independent actions on the independent elements compromising that body? That is to say that if a body compromise of n particles then the minimum action is "nh" for that very specific body in question. Where n stands for number of atoms/molecules of the body in question and "h" is the unit quantum of action.

As stated above, $\dfrac{\Delta E}{f} = \mathrm{h}$

For a action minimum to be complete and logical the maximum value of f = 1 Hz and as "h" is a constant

Therefore, $\dfrac{\Delta E}{1Hz} = 6.623{\times}10^{-34}\mathrm{Js}$

This implies, $\Delta E = 6.623{\times}10^{-34}\mathrm{Js} \times 1\mathrm{Hz} = 6.623{\times}10^{-34}\mathrm{J}$.

This is the minimum energy per atom/molecule and is given as $\Delta E_{min}$.Technically, we want to say that nature not only uses the number of atoms/molecules in a body in question as a measure but also uses Planck constant as a measure and the minimum energy requirement is the product of two. This means that if a body compromises of n particles then the total requirement of energy $\Delta E_{min}$= n × ΔE. This $\Delta E_{min}$ is dependent on the mass and the material of body in question which means that a mass of 1kg iron will have $\Delta E_{min}$ = 1.083405 × $10^{25}$ × 6.623×$10^{-34}$J = 0.7175391315 × $10^{-9}$ J. for different material of same mass this value of $\Delta E_{min}$ will be different as Avogadro's number will be different.

Consider an example of a low mass asteroid and a test mass of 1 kg this example will help us to understand this argument mathematically and its consequence. Now consider an asteroid of mass of $10^4$kg and a test sphere of iron having mass = 1 kg let the number of atoms in this spherical test mass equal to 1.083405 × $10^{25}$ as stated earlier each atom/molecule will require a minimum amount of energy because there is a minimum quantum of action. As the test sphere has a mass of 1kg and is of iron the $\Delta E_{min}$ = 1.083405 × $10^{25}$ × 6.623×$10^{-34}$J = 0.7175391315 × $10^{-9}$ J. Any transfer of order less than 0.7175391315 × $10^{-9}$ J will amount to null action and hence zero work as this is the minimum required energy.

If this test mass is projected from the low mass asteroid of mass $10^4$kg and let the radius of this asteroid equal to 5.8097876714 m and let us assume the test mass as a point mass on its surface. The ball once projected will lose energy in increments of $\Delta E_{min}$ and between two consecutive points on the potential field separated by a energy gap of $\Delta E_{min}$ the motion will be inertial. The table below will help to understand the velocity changes as a function of distance and this also shows that there exists certain energy barrier equal to ΔE till which no velocity change occurs

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| Escape energy | Escape velocity | Distance between the center of masses of the two spheres | Distance between the center of masses of the two spheres |
|---|---|---|---|
| 11.480626104 × $10^{-8}$ J | 4.7917900388 × $10^{-4}$m/s | 5.8097876714 m | Onset of motion |
| 10.7630869725× $10^{-8}$ J | 4.63963079835 × $10^{-4}$m/s | 6.1971068495m | 0.3873191781m |
| 10.045547841× $10^{-8}$ J | 4.4823091908 × $10^{-4}$m/s | 6.6397573388m | 0.4426504893m |
| 9.3280087095× $10^{-8}$ J | 4.31926121217 × $10^{-4}$m/s | 7.1505079033 m | 0.5107505645 m |
| 8.610469578× $10^{-8}$ J | 4.1498114224 × $10^{-4}$m/s | 7.7463835619m | 0.5958756586m |
| 7.89229304465× $10^{-8}$ J | 3.97314244559 × $10^{-4}$m/s | 8.4506002494 m | 0.7042166875 m |
| 7.175391315× $10^{-8}$ J | 3.78824268361 × $10^{-4}$m/s | 9.29566027438m | 0.84506002498m |
| 6.4578521835× $10^{-8}$ J | 3.59384256291 × $10^{-4}$m/s | 10.328511459m | 1.0328511847m |
| 5.740313052× $10^{-8}$ J | 3.3883072633 × $10^{-4}$m/s | 11.6195753429 m | 1.2910638839m |
| 5.0227739205× $10^{-8}$ J | 3.16947122419 × $10^{-4}$m/s | 13.2795146779m | 1.6599393350m |
| 4.305234789× $10^{-8}$ J | 2.93436016501 × $10^{-4}$m/s | 15.4927671239m | 2.2132524460m |
| 3.587696575× $10^{-8}$ J | 2.67869209036 × $10^{-4}$m/s | 18.5913205487m | 3.09855342480m |
| 2.870156526× $10^{-8}$ J | 2.39589504194 × $10^{-4}$m/s | 23.2277500111m | 4.63642946240m |
| 2.1526173945× $10^{-8}$ J | 2.07490597112 × $10^{-4}$m/s | 30.9855342479m | 7.7577842368m |
| 1.435078263× $10^{-8}$ J | 1.69415363116 × $10^{-4}$m/s | 46.4783013719m | 15.492767124m |

| | | | |
|---|---|---|---|
| $0.7175391315\times 10^{-8}$ J | $1.19794752097 \times 10^{-4}$m/s | 92.9566027438m | 46.4783013719m |
| $0.7175391315\times 10^{-8}$ J | $1.19794752097 \times 10^{-4}$m/s | immaterial | No upper limit |

According to this hypothesis is it possible that I give a kick to a body and it will move without dissipating energy? The obvious answer is yes, provided that the escaping body is at a point above the center of mass of the system that the potential energy of the system is lesser than $0.7175391315 \times 10^{-9}$ J. no energy will be dissipated and the motion will be all inertial. In the case discussed above as the 1kg mass is on the asteroid whose mass is $10^{4}$kg and radius is 92.9566027438 m and this distance R will be the distances between the respective center of masses of the two bodies, and if the ball is applied with any action the motion will be inertial all the time

It is important to note that the incremental velocity changes are so small that they are hardly observable in daily routine thereby posing challenge to the above hypothesis though it is admitted that to set up an experiment to observe such fine changes will be a technical challenge so it can be said that we do not have a direct proof to the argument but we do have many indirect proofs in the form of experiments which deal with the determination of gravitational constant “G”.  It is well known that since Cavendish many experiments has been performed to determine the absolute universal value of “G” some around 300 precise experiments are talked about. But, there are no consensuses on the absolute value of “G”. the experimenters and organizations such as NIST and HUST along with others are conducting elaborate and extensive experiments to determine the value of “G” [1]

But there is scatter in the value of “G” and this scatter is theoretical it is important to note that in any experiment intended to determine the gravitational constant we will try to measure the force between the masses using the torsion balance and these forces are extremely small in comparison to our daily routine. But when the forces involved is extremely small the concept of action as a ultimate natural measure comes into existence and the ignorance to this fact is the very cause of scatter.

It is well established that in some measurement of weak forces as in the case of torsion balance we take the geometries of the bodies rather than the idea of point mass this proves that nature does not use the concept of center of mass as a general rule but it is a human endeavor to facilitate calculations. Now comes a question that mother nature in principle does not use the idea of center of mass as it elementary measure then how does mother nature decide the trajectories of falling bodies to an outmost precession and how does it goes with the enormous variations in shapes, sizes forces and other interactions. The obvious answer is that nature uses the quantum of action and the number of atoms/molecules as a measure

The main point of the argument that if we use unit masses of different materials then though the masses are same but as the number of atoms in each unit mass is different so if we go for an observation of gravitational interactions between the masses, we are observing nothing, but some kind of mutual energy transfer among the masses and in observing so if we ignore the constrains of action and energy transfer we will never be able to get a universal value of “G”.

We can determine a specific value of “G” but not a universal value and for that we need to come on consensus about that very specific material of the attracting and attracted masses because in doing so we will have a complete knowledge on the number of atoms in the two bodies and even if a cross experiment is carried out to verify the validity of the initial experiment, then also we will have the knowledge of number of atoms in the new set up and we will be able to project the scatter in the new set up on a pre hand basis thereby validating the **specific value of “G”.**

The current situation is such that we are using the time of swing method, static deflection method, beam balance method, pendulum method to determine the universal gravitational constant. Though over the period of time our knowledge about the difficulties associated in conducting such precise experiments has improved. There are issues such as thermal variation, inelasticity of the fiber etc. which are being worked out extensively to come up with the possible solution. But, if the problem is fundamental then we will never be able to come up with a clear solution.

A very simple experiment can be conducted using a differential beam balance to prove that if the mass remains constant but the material of the test body under gravitational influence is varied then the required action on the bodies will vary and as a consequence to it we will observe a scatter in the value of "G" a quantity we intend to measure.

Consider the time of swing experiment in which we are using the same source mass but test mass of different materials say iron and copper each of mass = 1 kg now as stipulated the changes in energy are quantized so is in velocity. There is is no question of quantization in potential field but kinetic energy is quantized so among the two spheres one will more number of atoms in comparison to other therefore one will have more minimum energy than other and the $\Delta E_{min}$ of the two test masses will be different.

We will try to understand the idea with the Cavendish torsion balance type experiment the force of gravitational attraction between the large and test mass under equilibrium condition is given as

$$L \times F = ƙ \times \theta$$

Where, L is the torsion balance arm length

F = The gravitational force of attraction between the masses

Ƙ = kappa is the torsion constant

θ = The angle of maximum deflection

Now θ will depend on the force of gravitational attraction between the two masses and will be independent to the material of test masses as per classical physics. That is to say as per our classical regime whether the ball is of iron or copper so long as there mass remains the same and the distance between them remain constant the force of gravitational attraction will remain constant. But, according to our argument it is the action which determines the energy transfer in a dynamic system and as the action on the two masses will differ due to the relation between action and minimum energy transfer and the above equation can be written as,

$$L \times \frac{GMm}{R^2} = ƙ \times \theta$$

The period of oscillation of the torsion balance is

$$T = 2\Pi\sqrt{\frac{I}{ƙ}}$$

Where, T = time period

I = moment of inertia

The moment of inertia of the torsion balance is $\frac{mL^2}{2}$

Finally on solving for ƙ and rearranging for G we get

$$G = \frac{2\Pi^2 Lr^2\,\theta}{MT^2}$$

It is important to note that the equation for G does not contain m (test mass) in it. and others are constant and if θ is not a function of action then there will be no scatter in the value of G weather we change the material of test mass or not but we know that it is the action which determines the minimum energy transfer in a dynamical system and so the scatter in the value of G becomes fundamental.

It is future important to note that quantized energy change are not applicable to potential energy as it is a static system and the energy is by virtue of position but a dynamical system is a system in which the constituents compromising the body needs to obey equi partition as all can move with a unique velocity so quantization is the natural requirement.

It is admitted that for potential energy changes there is is no such binding by the action minimum, if we are observing a static deflection b y using a beam balance method and are trying to measure "G" again by keeping mass constant but the material of the body different. But the densities of different materials are different and if we try to make the two spheres geometrically identical we can do so by placing some intermediate vacuum in the sphere with low density as a compensation now if we place this two test sphere one by one at a fixed constant distance say R from the source mass and try to determine "G" this method will be a static method, but in this method also we will observe scatter in the value of "G".

We will try to understand the static deflection method with a simple technique, consider a test mass on a spring balance [2]and a large source mass at a distance R from it the spring balance will read the force and the force will be

$$F = G \frac{M_S m_t}{R^2}$$

This is the famous inverse square law, where, $M_S$ = source mass and $m_T$ = test mass and R is constant distance between the two masses then the material of the test mass will have no effect on the mutual force of attraction as per classical physics,

But, if the test mass is changed from iron to copper keeping R constant then, the force should change as the $\Delta E_{min}$ of the two sphere will be different as the atomic density of the two elements is different . But, as we believe in the validity of inverse square law so we will blame the variation in force to the scatter in the value of G so as to compensate for the variation in gravitational force.

From this discussion on dynamic and static gravitational system it is clear that the scatter in the value of G is a theoretical requirement and is independent of the technique used,we can have only have a specific value of G but not a universal value.

CONCLUSION

Discrete in science is the opposite of continuous: something that is separate; distinct; individual. **Discrete** may refer to: **Discrete** particle or quantum in **physics**, for example in quantum theory. If Planck constant is discreet than it means that there exist a limit to it sub-division and mathematically a structure without continuity

Hatwig W Thim conducted an experiment to determine the relativistic transverse Doppler shift at microwave frequency[3] in which the the Doppler frequency shift was of the order of $10^{-3}$ Hz **but** the equivalent changes were unobserved **Dr** Thim concluded **that time dilation does not** exist but we can also say that the experiment proves that for an action frequencies below 1 Hz are not observable in any experiment as there are other experiments with atomic clocks that had validated relativity. Now the question is how there can be such a mutual contradictory situation. And the answer is that we cannot have an observation of an action that is smaller than the $6.623\times10^{-34}$Js ( Planck constant)

The limiting condition by Planck constant is , $\frac{\Delta E}{1Hz} = 6.623\times10^{-34}\text{Js}$

$$\Delta E_{min} = 6.623\times10^{-34}\text{Js} \times 1\text{Hz} = 6.623\times10^{-34}\text{J}.$$

The minimum transfer of energy to be observable should be equal $6.623{\times}10^{-34}$J but in Dr Thim's experiment it was ≈ $6.623{\times}10^{-37}$J and was thus unobservable. The reason for citing Dr Thim's experiment is that it gives a clear understanding of the term action is viable and observable only when the transfer/change of energy is $6.623{\times}10^{-34}$J in unit time (1 second) and it is the "quantum of action" which governs the universal measure for transfer of energy and the non acceptance is the cause of multiple misunderstandings.

Finally, I will conclude that any transfer of energy less than $6.623{\times}10^{-34}$J in a single event in 1 second is formidable as a law of nature and any experiment demonstrating it will stood as a challenge to this hypothesis and will be highly welcomed.

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