Chapter 6

Analysis of the Particle Model and Derivation of Gravity

In chapter 5 the spacetime-based model of a fundamental particle was presented without any analysis to see if it can satisfy the known characteristics of fundamental particles. This chapter will be devoted to testing the rotar model of fundamental particles for plausibility. We will first analyze whether this model will appear to be a point particle in collision experiments. Then we will see if the particle model produces the required energy, angular momentum, and forces including the correct gravity. Finally the implied inertia of the particle model will be discussed.

Particle Size Problem: Perhaps the biggest objection to the hypothesis proposed in chapter 5 is that experiments seem to indicate that fundamental particles are points with no physical size. Now we will examine whether the rotar model is compatible with the experiments that seem to indicate a point particle.

Recall that the spacetime field is a sea of waves predominantly at Planck frequency but all other frequencies are also present at lower density. The waves are undetectable as individual waves because their amplitude is a spatial displacement of Planck length and a temporal displacement (difference between clocks) of Planck time. These waves are the zero point energy and vacuum fluctuations required by quantum electrodynamics and quantum chromodynamics. They introduce uncertainty into any measurement. They also have no angular momentum and exhibit superfluid properties. One of these properties is that any angular momentum is isolated into quantized units. As discussed in the last chapter, a superfluid Bose-Einstein condensate isolates angular momentum into small rotating vortices, each one with $\hbar$ angular momentum. It is proposed that the superfluid spacetime field also isolates angular momentum that has existed in the spacetime field since the Big Bang (discussed in chapters 13 and 14).

A fermion such as an electron or quark is nothing more than a unit of quantized angular momentum quarantined by the superfluid spacetime field into quantized units with angular momentum of ½ ħ or ħ (fermions or bosons). An electron is a dipole wave rotating at its Compton angular frequency (7.7634×10^{20} s^{-1}). The point is that an electron, and all other fundamental particles, are nothing but an organized rotation of the spacetime field. There is nothing there if the expectation is a physical object other than spacetime. There is no vibrating string; there is no elastic sphere that can be characterized by a collision experiment. Even though the radius of the rotating dipole wave is a relatively large $4.18\text{x}10^{-13}$ m, this is just a slight rotating distortion of spacetime that is that size.

For an electron, the very small strain produced in the spacetime field is only about 4 x 10^{-23} (dimensionless strain slope). Spatially, this is a strain of spacetime comparable to stretching Jupiter's orbit by the radius of a hydrogen atom. Temporally this is comparable to retarding the rate of time by one second over 50,000 times the age of the universe. It is only the incredibly large impedance of spacetime ($c^3/G \approx 4\text{x}10^{35}$ kg/s) and the high rotational frequency ($\sim 10^{21}$ s^{-1}) that gives this small strain of spacetime a detectable physical presence. Even then, the oscillations are not detectable as waves because the maximum displacement of spacetime is only Planck length and Planck time.

When we do detect the presence of an electron, it exhibits properties that are not explainable from classical physics. For example, "finding" an electron (interacting with a wave with quantized angular momentum) is a probabilistic event. An electron can seem to jump from one location to another without traversing the space between these two points. This is because the rotating dipole in spacetime that is an isolated electron is distributed over a relatively large volume with a radius in the range of 4 x 10^{-13} m. Interacting with the quantized angular momentum happens at a point anywhere within this volume but even sometimes outside this volume. This gives the appearance of a point particle discontinuously jumping from point to point. Also the quantized angular momentum causes the electron's energy to be quantized. The list of counter-intuitive properties of an electron is long, but the non-classical property of interest here is the fact that an electron seems to have no physical size in a collision experiment.

Even though the rotar model gives a physical size to fundamental particles, it is not the classical "billiard ball" type of physical size. For example, a "collision" between an electron and a positron (rotar model) often results in these two rotating dipole waves merely passing through each other with the only interaction being a slight scattering from the original trajectories. When an electron and positron annihilate each other in an interaction that forms positronium (not a high speed collision), about 10^{-10} seconds is required for this annihilation (photon emission) to take place. In a collision at near light speed the overlap time is less than 10^{-20} seconds in the frame of reference where the total momentum is zero. When the collision energy is less than the about 1 GeV, then the scattering cross-section of an electron-positron collision decreases as the collision energy increases. At higher collision energy where new fundamental particles can be formed the interaction cross-section becomes complex with the formation of new particles.

In a collision between two electrons, the electrostatic repulsion can be visualized as momentarily bringing the two colliding electrons to a halt. What happens to the kinetic energy at the moment of closest approach? With the rotar model the kinetic energy of each electron is momentarily converted into internal energy of the two electrons. This increase in energy means that the frequency increases, the wavelength decreases, the circumference decreases, and the rotar radius decreases. These changes keep the angular momentum constant because the decrease in radius offsets the increase in mass/energy. The rotar radius λ_c scales with the rotar's internal energy E_i as: $\lambda_c = \hbar c/E_i$. At the moment of "closest approach" the two rotars are actually partially overlapping. They also have the smaller radius and higher frequency appropriate for their higher energy condition.

How does this radius compare with the particle size resolution limit in a collision experiment? This resolution limit is set by the uncertainty principle $\Delta x\, \Delta p = \hbar/2$. We have been ignoring dimensionless constants like ½, so we will use $\Delta x\, \Delta p = \hbar$ and then include a single all-inclusive constant k. In a collision between two electrons, we have an uncertainty about the momentum transferred at the moment of closest approach. Is the collision head on or a glancing collision? All we really know is the maximum momentum available, so the uncertainty becomes $\Delta p = mv$. For a collision between electrons with ultra-relativistic velocity ($v \approx c$), the special relativity gamma is $\gamma \approx E_k/mc^2$ where E_k is the relativistic kinetic energy. Also, when γ is large, the momentum is: $p \approx \gamma mc$. With this information we can solve for Δx.

$$\Delta x = \frac{\hbar}{\Delta p} = \frac{\hbar}{\gamma mc} = k\left(\frac{\hbar}{mc}\right)\left(\frac{mc^2}{E_k}\right) \qquad \text{dimensionless constant k included}$$

$$\Delta x = k\,\frac{\hbar c}{E_k}$$

Therefore, in a collision between ultra-relativistic rotars, the kinetic energy is momentarily added to the rotar's internal energy ($E = mc^2$ energy) for a total energy of $E + E_k \approx E_k$. This means that the rotar radius momentarily shrinks to $\lambda\!\!\!^{-}_c \approx \hbar c/E_k$ which matches the uncertainty resolution limit of the experiment $\Delta x = \hbar c/E_k$. It is no coincidence or lucky result that the resolution of the experiment matches the momentary size of a rotar. If fundamental particles really are rotars with a probabilistic interaction radius, then this size <u>must</u> match the uncertainty in the interaction.

The combination of the overlap and the reduction in $\lambda\!\!\!^{-}_c$ results in an expectation separation distance that is less than the Δx uncertainty resolution of the experiment that attempts to measure the size of the rotar (particle). This is analogous to the uncertainty principle saying that an experiment cannot simultaneously measure the position and momentum of a particle to better than ½ħ. Similarly, an experiment cannot measure the size of a fundamental particle because the measurement process introduces energy that momentarily decreases the size of the particle to below the measurement resolution ($\lambda\!\!\!^{-}_c = \hbar c/E_i < \Delta x$). This is a classic case of the experiment distorting the property being measured and invalidating the measurement. Therefore, the rotar model gives a plausible explanation of why fundamental particles always appear to be point particles in experiments that attempt to measure their size.

The current upper limit for the size of an electron is set by an experiment using two electrons accelerated to a kinetic energy of about 50 GeV. When the rotar model of an electron undergoes a collision, the 50 GeV kinetic energy is temporarily converted to the electron's internal energy. This momentarily increases the electron's internal energy (dipole wave energy) by a factor of 100,000 and reduces the rotar radius by a factor of 100,000. An isolated electron has a rotar radius of about 4 x 10^{-13} m. However when 50 GeV of kinetic energy is converted to an electron's internal energy at the moment of closest approach, this reduces λ_c by a factor of 100,000 to about 4 x 10^{-18} m. Combined with the ability to partially overlap rotar volumes, the electron always has an instantaneous size smaller than the Δx resolution limit of the experiment. A 50 GeV electron undergoing a collision temporarily becomes much smaller than a proton (~10^{-15} m) and can be used as a probe of the internal structure of a proton.

The rotar model of an electron also has an advantage over the point particle model of an electron when it comes to explaining the behavior of an electron in an atom. An electron bound in an atom appears to be bigger than the isolated rotar size. For example, an electron bound in a hydrogen atom has a different boundary condition than an isolated electron. This creates a different stability condition that results in the dipole wave energy of the electron distributed around the nucleolus of an atom in a way that enlarges the apparent size and explains the cloud-like quality of an electron bound in an atom.

Equations Demand Size: One of the strengths of the spacetime model of fundamental particles is that it gives a plausible explanation of how the fundamental particle (rotar) can have a physical size equal to the reduced Compton wavelength (equal to λ_c) and yet also always appear to be a point particle in collision experiments. One of the "mysteries" of quantum mechanics has been that the equations of quantum mechanics yield an unreasonable answer of infinity when they incorporate the assumption that fundamental particles are point particles. These equations are screaming that this is a wrong starting assumption. Yet the equations are ignored because the physical interpretation of experiments is that the fundamental particles must be point particles.

However, this is a failure of the physical interpretation of the experiments, not a failure of the equations. The process of renormalization used to eliminate the infinity is actually adjusting the starting assumption to give a physical volume to fundamental particles. Physicists believe that experiments are the ultimate referee of a theory. Usually experiments are easy to interpret correctly. However, the physical interpretation of collision experiments always makes the erroneous assumption that the colliding particles do not change any of their characteristics compared to the same particles not undergoing a collision. In particular, the assumption is that the physical size of a fundamental particle remains constant, even if the collision is ultra-relativistic. However, where is the kinetic energy stored at the instant when both particles are stopped? It is proposed that the collision experiments are giving the correct answer for this instant but this collision moment cannot be extrapolated to deduce the size of isolated particles. This is like a self-fulfilling prophecy. If you assume point particles, then you can interpret the experimental results to support this model.

Stability Mechanism: How exactly does the spacetime dipole achieve stability? What prevents the waves from simply propagating in a straight line rather than forming a rotating dipole? This question will be addressed later, but an introductory explanation will be given here. Chapter 5 started by recounting Erwin Schrodinger's attempted to give a wave based explanation to fundamental particles. Schrodinger eventually abandoned this explanation because he was unable to explain what prevented his "wave packet" from dissipating.

The proposed rotar model has a single frequency dipole wave in spacetime that forms a rotating closed loop. This dipole wave is still propagating at the speed of light. This model achieves a large energy density that will be calculated later. However, it also implies a large pressure required to confine this energy. In fact, any concentration of energy density fundamentally implies pressure. Therefore, this proposed rotar model requires some means to counteract the pressure associated with the energy density. This is accomplished by an interaction with the vacuum energy dipole waves in the spacetime field. This vacuum energy possesses a vastly larger energy density than any rotar. Therefore the vacuum energy exists at a vastly larger pressure than is required to stabilize the rotar. There are only a few quarks and leptons in the standard model. These represent only a few Compton frequencies that have achieved at least partial stability interacting with the surrounding vacuum energy dipole waves in spacetime. This explanation will be expanded later.

Rotar Energy Test: Now we are going to subject the rotar model and the concept of dipole waves in spacetime to a critical test. We will use one of the 5 wave-amplitude equations and attempt to calculate the energy of any rotar. We are not attempting to calculate the energy of specific particles. Instead, we are checking to see if the concept of dipole waves in spacetime that are confined to a specific volume can produce the equivalent mass/energy for a rotar. For this plausibility test to be successful, inserting a rotar's amplitude, frequency and volume into the wave-amplitude equation must produce the correct energy for a rotar (ignoring dimensionless constants near 1). The equation to be used is:

$E = k A^2 \omega^2 Z V/c$ wave-amplitude equation expressing energy E in a volume V

We know that the angular frequency ω equals the Compton frequency: $\omega = \omega_c = c/\lambda\!\!\!^{-}_c = mc^2/\hbar$. We will also set the amplitude as: $A_\beta = L_p/\lambda\!\!\!^{-}_c = T_p\omega_c$. Where A_β = strain amplitude in the rotar volume of a rotar. This amplitude was obtained in the last chapter using the starting assumption about the maximum displacement of spacetime allowed by quantum mechanics for dipole waves in the spacetime field.

The volume term V should be equal to the volume of the rotar volume: $V = k\lambda\!\!\!^{-}_c{}^3$. It is true that we are not addressing the question about how uniformly this volume is filled, but this is just a plausibility test and we are using the constant k which permits us to be vague about this point. Finally, the impedance term Z is set equal to the previously obtained impedance of spacetime: $Z_s = c^3/G$. We will lump all dimensionless constants into a single constant k.

$E = k A^2 \omega^2 Z V/c$ set $A = A_\beta = L_p/\lambda\!\!\!^{-}_c$ $\omega = \omega_c = c/\lambda\!\!\!^{-}_c$ and $Z = Z_s = c^3/G$

$$E = k\left(\frac{L_p}{\lambda_c}\right)^2\left(\frac{c}{\lambda_c}\right)^2\left(\frac{c^3}{G}\right)\left(\frac{\lambda_c^3}{c}\right) = k\frac{L_p^2 c^4}{G\lambda_c} = k\left(\frac{\hbar G}{c^3}\right)\left(\frac{c^4}{G}\right)\left(\frac{mc}{\hbar}\right)$$

$$E = k\,mc^2$$

This important plausibility test is successful. The rotar model establishes the famous relationship between energy and mass (inertia). We have shown that an amplitude of $A_\beta = L_p/\lambda_c$, a frequency of ω_c and a volume of $k\lambda_c{}^3$, together produce the correct energy of $E = mc^2$ (times a possible constant). The mass in this equation should be thought of as the inertia exhibited by confined energy circulating at the speed of light. The calculation that was just made represents a bridge between the familiar concept of particles exhibiting mass and the unfamiliar concept of confined waves in the spacetime field that exhibit energy and inertia.

We are presuming that $k = 1$. We actually have a little bit of flexibility in this regard. Previously we gave an example where the displacement amplitude was defined as the normal ± amplitude of a sine wave. It would also be possible to define the amplitude as the RMS amplitude or the peak to peak amplitude. These three ways of defining amplitude all apply to the same wave. Furthermore, there may be another way of defining amplitude. I am going to presume that some definition of amplitude will permit $k = 1$.

It should be emphasized that the rotar radius λ_c is a convenient mathematical representation of a rotar model, but the rotar does not abruptly stop at a distance of λ_c. The rotar model is more complex than this and part of the quantum wave that forms the rotar extends beyond the rotar radius. For example, it will be shown later that the rotar's electric field and gravity are the result of the rotar's wave structure that extends far beyond the rotar radius. However, the energy in the electric and gravitational fields beyond λ_c contains less than 1% of the rotar's total energy. The use of λ_c can be thought of as a convenient mathematical tool to easily represent the entire rotar in simple calculations.

Angular Momentum Test: The next test of the model is to see if the model has approximately the correct angular momentum. We will build on the energy calculation and test to see if the angular momentum $\mathcal{L}$ of this rotar model has the same angular momentum for all fundamental particles regardless of mass/energy and furthermore whether this angular momentum is equal to $\hbar$ when numerical factors near 1 are ignored.

$\mathcal{L} = pr$ set: p = momentum = $E/c = mc$ and $r = \lambda_c = \hbar/mc$;
$\mathcal{L} = mc(\hbar/mc) = \hbar$

Mass cancels and all mass/energy has the same angular momentum. This solves one of the problems associated with fundamental particles. How is it possible that particles with vastly different energy possess the same angular momentum? The standard approach has been to merely label it as "spin" and declare that this is merely one of the many mysteries of quantum mechanics beyond human understanding. When we adopt a different model of a fundamental particle, we discover that the answer is actually quite simple.

We still have the pesky problem that the angular momentum should be ½ $\hbar$ rather than $\hbar$. It turns out that there are actually two considerations we haven't accounted for and both have the effect of lowering the angular momentum towards ½$\hbar$. First, this angular momentum is at the limit of causality and it does not have a single well defined axis of rotation. You can visualize the rotating dipole wave as existing in the spacetime field which is a sea of Planck amplitude waves at all frequencies up to Planck frequencies. This turbulence causes the spin axis to have an expectation direction, but all other rotational directions are permitted with lower probability except for the opposite of the expectation direction which has a probability of zero. A graph of the probabilities of spin direction is shown in figure 10-8. The point is that this distribution of spin directions lowers the angular momentum around the Z axis. In fact, it appears to lower the Z axis angular momentum towards half of the angular momentum it would have if there was a fixed axis and rotational direction. However, this is a simplified analysis, and there is still another consideration. Therefore I will leave the analysis to others.

The second consideration is that a rotating wave is distributed over a volume. If we only had energy traveling at the speed of light around a circle (a hoop) of radius λ_c, (for example, light in a waveguide) then we should use the moment of inertia of a hoop ($\mathcal{I} = mr^2$). However, the dipole wave is diffuse and as shown in figure 5-2, there is also a "rotating grav field" filling the center of the rotar volume. In chapter 8 it will be shown that the energy density contained in the strongest part of the rotating grav field (the center) is exactly the same as the energy density contained in the strongest part of the rotating dipole wave (the circumference). In fact, the rotating grav field is a fundamental part of the dipole wave and energy is just being transferred between these two states. This means that the energy density is relatively evenly distributed across the rotar volume. The moment of inertia of a rotar is most closely approximately by the moment of inertia for a disk: ($\mathcal{I} = \frac{1}{2} mr^2$). We will calculate the angular momentum of the disk analogy spinning in a plane.

$\mathcal{L} = \mathcal{I}\,\omega$ set: $\mathcal{I} = \frac{1}{2} mr^2 = \frac{1}{2} m\lambda_c^2$ $\omega = c/\lambda_c$ $\lambda_c = \hbar/mc$

$\mathcal{L} = (\frac{1}{2} m\lambda_c^2)\left(\frac{c}{\lambda_c}\right) = (\frac{1}{2} mc)\left(\frac{\hbar}{mc}\right)$ note that mass cancels

$\mathcal{L} = \frac{1}{2}\hbar$

Therefore, this is another consideration which also lowers the angular momentum towards ½$\hbar$. In fact, if we combine both considerations we would have angular momentum lower than ½$\hbar$. A third consideration is that a rotar is also not a spinning disk. Its energy does not end abruptly at the radial distance λ_c. In fact, the energy distribution is not known beyond the generalizations presented here. Calculating the energy distribution and angular momentum is a complicated problem that requires a more advanced model and a rigorous analysis. The point is that there are a large number of ways that the energy can be distributed within the model that result in angular momentum of *½ ħ.* In fact, achieving this angular momentum would become one of the requirements for choosing the "correct" energy distribution. However, this is a successful plausibility test. The proposed model inherently incorporates angular momentum into the structure of a rotar and it is plausible that further analysis will confirm ½ħ.

Molecules also possess quantized angular momentum, but in the case of molecules it is easy to prove that this quantized angular momentum results from the physical rotation of the molecule. There are other examples of quantized angular momentum involving the rotation of physical objects such as the quantized vortices that form in superfluid liquid helium. The point is that the angular momentum is physical. There is no need to invoke the abstract concept of an object possessing "intrinsic angular momentum" in these cases. Something external is enforcing this quantization of angular momentum. The spacetime based model proposed here attributes this enforcement to all matter (fundamental particles, molecules, etc.) being immersed in a sea of superfluid vacuum energy. This spacetime based model also gives a conceptually understandable explanation of how a fundamental particle such as an electron can possess angular momentum. The electron is a rotating disturbance in the spacetime field with a physical size that gives conceptually understandable angular momentum. The concept that a point particle can possess angular momentum is an admission that the model being used is inadequate.

Planck's Constant *Always* Implies Angular Momentum: The spacetime based model of the universe elevates angular momentum to the single characteristic which creates all quantized effects including particles. There is a good article[1] that also makes the point that "spin" of fundamental particles implies physical rotation of a wave. In the conclusion of this article, the statement is made, "*The preceding has great intuitive appeal because it confirms our deep prejudice that angular momentum ought to be due to some kind of rotational motion. But the rotational motion consists of a circulation of energy in the wave fields rather than the rotation of some kind of rigid body.*" Another statement from this article is, "*A comparison between calculations of angular momentum in the Dirac and electromagnetic fields shows that the spin of an electron is entirely analogous to the angular momentum carried by a classical circularly polarized wave.*"

All the energy of an electron can be traced to the fact that the electron possesses angular momentum. The previous calculation in this chapter that resulted in $E = k\, mc^2$ made some simplifying assumptions, but even with a more advanced model, all the observable energy is either directly attributable to angular momentum or associated with effects such as the grav field or the electric field which are both the result of quantized angular momentum. The dimensional analysis units of angular momentum are: ML^2/T. Merely multiplying angular momentum by frequency (rotation rate) with units 1/T yields energy with units of ML^2/T^2. This is stated because the current attitude is to treat *h* or *ħ* as a constant that happens to have units which are

[1] Ohanian, H. "What is spin?" Am. J. Phys. 54, 500 (1986);

the same as angular momentum but angular momentum is not a key part of the explanation. For the energy of a photon we say $E = \hbar\omega$. However, this is not an abstract equation. As will be shown in chapters 9 and 10, there is real angular momentum associated with a photon. Multiplying this angular momentum by rotation frequency gives the photon's energy.

When an electron is placed in an external magnetic field that is not aligned with the electron's magnetic moment, the electron undergoes Larmor precession. This is analogous to the precession exhibited by a gyroscope when a torque is applied with a component perpendicular to the axis of rotation.

There is no such thing as "intrinsic angular momentum". This term implies an abstract property which does not include anything that is physically rotating. If dipole waves in spacetime and quantized angular momentum are elevated to the status of physical entities, then all of physics would be transformed into "classical physics". All of physics would potentially be conceptually understandable and a new golden age of physics would be born.

720° Rotation Test: One of the biggest mysteries of quantum mechanics is that fundamental particles with spin ½ needs two full rotations (2x360° = 720°) until they return to the same state. Since there is nothing in our macroscopic world with symmetry like that, the structure of spin ½ particles such as an electron is often considered to be beyond our conceptual understanding. The calculation that demonstrates this 720° effect involves referencing the phase of an electron that is going to undergo a rotation against a hypothetical standard electron that is not going to undergo a rotation. The spin of an electron gives the electron a magnetic field with North and South poles. It is possible to impose an external magnetic field which can be used to rotate the electron since the electron's North – South magnetic poles attempt to remain aligned with the external magnetic field. Any rotation of the external magnetic field also causes the electron to undergo precession, but that is another subject. The point is that when the electron has undergone one complete 360° flip, it is out of phase with the reference electron. It takes another 360° flip to bring the test electron back into phase with the reference electron.

The first point is that this experiment is not exactly the same as rotating a classical object such as a ball through 360°. We are referencing the phase of an electron not some feature on the surface of a ball. The electron has no physical surface. Next, we will attempt to visualize what will happen if we subjected the rotar model of an electron to a force which caused the axis of rotation to be flipped 360°. The first consideration is that the rotating dipole wave that forms the electron is already propagating at the speed of light. It is not possible to maintain its physical size and frequency when we also flip the axis of rotation because maintaining phase would require parts of the dipole wave to exceed the speed of light. The external magnetic field must exert a force on the electron to cause the axis of the electron to rotate. This force applied through a distance is adding energy to the electron which causes the rotational frequency to increase and the radius (λ_c) to decrease. This would produce a phase change relative to a standard which is not undergoing such an axis flip. I cannot prove that it would take a 720° axis flip to return to the original phase, but a 360° rotation definitely will not return to the original phase.

Dipole Moment: Not only does the proposed rotar model give the same angular momentum to all rotars, the rotar model also specifies that all rotars have the same dipole moment d_m. The dipole moment of a rotar is the dipole amplitude times the rotar radius. We will calculate the value of the dipole moment shared by all rotars.

$$d_m = A_\beta ƛ_c = \sqrt{\frac{Gm^2}{\hbar c}}\left(\frac{\hbar}{mc}\right) = \sqrt{\frac{\hbar G}{c^3}}$$ d_m = dipole moment A_β - see explanation below

$$d_m = L_p$$ L_p = dynamic Planck length

A dipole made of two electrically charged particles has a dipole moment with units of Coulomb meters. However, a spacetime dipole has a dipole moment with units of just meters because A_β is a dimensionless number. Rotars with a large mass have a large value of A_β, but this is offset by a small rotar radius $ƛ_c$. Therefore, all rotars have the same dipole moment of dynamic Planck length L_p.

Planck Units: Before proceeding further, I would like to pause and discuss "Planck units" which are physical units of measurement derived from 5 physical constants which are: ħ, c, G, the Coulomb force constant $1/4\pi\varepsilon_o$ and the Boltzmann constant k_B. These 5 constants are combined to give 5 Planck "base units": Planck length L_p. Planck time T_p, Planck mass m_p, Planck charge q_p and Planck temperature $\mathbb{T}_p$ as well as numerous "derived Planck units". Some of the more important derived Planck units are: Planck energy E_p, Planck force F_p, Planck energy density U_p, Planck pressure $\mathbb{P}_p$, Planck density ρ_p, Planck voltage $\mathbb{V}_p$, and Planck impedance Z_p.

We have already frequently mentioned Planck length, Planck time and Planck mass. However, it will be shown that the properties of spacetime are most naturally expressed in Planck units. Going further with this thought, Planck units are based on the properties of spacetime. We can actually learn about the properties of spacetime by examining a particular unit when it is expressed in Planck units.

The table below gives the conversions for these Planck units. Also, this table is repeated at the end of the book in chapter 15 for easy reference. Any serious analysis of the spacetime model of the universe will make frequent reference to this table.

Planck Units

L_p = Planck length	$L_p = cT_p = \sqrt{\hbar G/c^3}$	1.616×10^{-35} m
m_p = Planck mass	$m_p = \sqrt{\hbar c/G}$	2.176×10^{-8} kg
T_p = Planck time	$T_p = L_p/c = \sqrt{\hbar G/c^5}$	5.391×10^{-44} s
q_p = Planck charge	$q_p = \sqrt{4\pi\varepsilon_o \hbar c}$	1.876×10^{-18} Coulomb
$\mathbb{T}_p$ = Planck temperature	$\mathbb{T}_p = E_p/k_B = \sqrt{\hbar c^5/G k_B^2}$	1.417×10^{32} °K
E_p = Planck energy	$E_p = m_p c^2 = \sqrt{\hbar c^5/G}$	1.956×10^{9} J
ω_p = Planck angular frequency	$\omega_p = 1/T_p = \sqrt{c^5/\hbar G}$	1.855×10^{43} s^{-1}
F_p = Planck force	$F_p = E_p/L_p = c^4/G$	1.210×10^{44} N
P_p = Planck power	$P_p = E_p/T_p = c^5/G$	3.628×10^{52} w
U_p = Planck energy density	$U_p = E_p/L_p^3 = c^7/\hbar G^2$	4.636×10^{113} J/m^3
$\mathbb{P}_p$ = Planck pressure	$\mathbb{P}_p = F_p/L_p^2 = c^7/\hbar G^2$	4.636×10^{113} N/m^2 (= U_p)
ρ_p = Planck density	$\rho_p = m_p/L_p^3 = c^5/\hbar G^2$	5.155×10^{96} kg/m^3
A_p = Planck acceleration	$A_p = c/T_p = \sqrt{c^7/\hbar G}$	5.575×10^{51} m/s^2
$\mathbb{V}_p$ = Planck voltage	$\mathbb{V}_p = E_p/q_p = \sqrt{c^4/4\pi\varepsilon_o G}$	1.043×10^{27} V
$\mathbb{E}_p$ = Planck electric field	$\mathbb{E}_p = F_p/q_p = \sqrt{c^7/4\pi\varepsilon_o \hbar G^2}$	6.450×10^{61} V/m
$\mathbb{B}_p$ = Planck magnetic field	$\mathbb{B}_p = Z_s/q_p = \sqrt{\mu_o c^7/4\pi\hbar G^2}$	2.152×10^{53} Tesla
$\mathbb{I}_p$ = Planck current	$\mathbb{I}_p = q_p/T_p = \sqrt{4\pi\varepsilon_o c^6/G}$	3.480×10^{18} amp
Z_p = Planck impedance	$Z_p = \hbar/q_p^2 = 1/4\pi\varepsilon_o c$	29.98 Ω

It is often said that Planck units are the "natural units" because they are based on 5 constants of nature. However, this explanation does not do justice to the importance of Planck units. The properties of spacetime are finite. These Planck units represent the limiting values (maximum of minimum) that spacetime can support. For example, it is impossible to make a length measurement between two points more accurate than Planck length (device independent). It is also impossible to make a time measurement more accurate than Planck time. As previously explained, the spacetime field has dipole waves which are modulating the distance between two points by Planck length and modulating the rate of time (the difference between two clocks) by Planck time. Therefore, the inability to make measurements smaller than Planck length and Planck time can be considered to be due to the "noise" created by vacuum fluctuations.

One of the many insights obtained from Einstein's field equation is that the universe has a limit to the maximum possible force that can be exerted and this limiting force is equal to

Planck force[2,3]. (This ignores a numerical factor near 1.) The equations of general relativity deviate from Newtonian gravitational physics in strong gravity partly because of the existence of a maximum possible force which introduces nonlinearity. Therefore, general relativity and quantum mechanics agree on the significance of Planck force. If two of the same size black holes are about to merge, the force between them is Planck force. It does not matter the size of the black holes, the maximum is always Planck force.

Planck energy and Planck mass are a little harder to explain. It is easy to exceed Planck mass (~2x10^{-8} kg) or Planck energy (~2×10^{9} J), but this assumes a large number of fundamental particles. Planck energy is the maximum energy that a single quantized unit can support. A photon with $\hbar$ of quantized angular momentum cannot have more than Planck energy. A fermion with ½ $\hbar$ of quantized angular momentum cannot have more mass than Planck mass. The rotar model of a fundamental particle with Planck energy would have a radius equal to Planck length and a Compton frequency equal to Planck frequency. This would form a black hole with a Schwarzschild radius $R_s \equiv Gm/c^2$ equal to Planck length. As previously explained, a photon black hole (rotating at the speed of light) has a smaller Schwarzschild radius than a non-rotating black hole. Also, the rotar model of a fundamental particle has energy propagating at the speed of light around a circle with radius $\lambda\!\!\!^{-}_c$. When scaling gravitational effects produced by a rotar, the appropriate Schwarzschild radius is $R_s \equiv Gm/c^2$ rather than $r_s = 2Gm/c^2$.

Dimensionless Planck Units: The previous Planck units quoted had dimensions. For example, Planck force is $F_p \approx 1.2 \text{x} 10^{44}$ Newton and Planck energy is $E_p \approx 2 \text{x} 10^{9}$ Joule. There is another form of Planck units that is a dimensionless ratio. For example, there are times when it is very revealing to express force or energy as a ratio relative to the largest possible force or energy. In this case we would divide the particular force or energy by Planck force or Planck energy respectively. When we are expressing force as this dimensionless ratio we will use the symbol $\underline{\boldsymbol{F}} = F/F_p$. Note the underline signifying that this is dimensionless Planck units. Similarly dimensionless Planck energy $\underline{\boldsymbol{E}}$ would be the actual energy E in SI units divided by Planck energy therefore: $\underline{\boldsymbol{E}} = E/E_p$. While force and energy were used as examples, the concept applies to all other units. Therefore we would have $\underline{\boldsymbol{m}}$, $\underline{\boldsymbol{\omega}}$, etc.

It is counter intuitive to mix different units in an equation. Even though we know that we are dealing with dimensionless ratios, it does not seem correct to write an equation which equates dimensionless energy to dimensionless force. However, on the level where we are reducing everything to a distortion of spacetime, there is actually a way of looking at force and energy where they are equivalent. A specific amount of energy in the form of fermions requires a specific amount of force to stabilize them. This statement might not be understandable now, but

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[2] T. Jacobson, "Thermodynamics of Spacetime: The Einstein Equation of State." Phys.Rev. Lett. ***75***, 1260 (1995)
[3] G. W. Gibbons, "The Maximum Tension Principle in General Relativity." Found. Phys. ***32***, 1891 (2002) http://arxiv.org/pdf/hep-th/0210109.pdf

in later chapters this will become clearer. The point is that if a particular term is expressed as a dimensionless number such as 10^{-20}, then it is using 10^{-20} of the available properties of spacetime and there is a connection to another term which also is using 10^{-20} of the available properties of spacetime. We will next return to the particle properties previously being explained.

Quantum Amplitude Equalities: The strain amplitude A_β of the spacetime wave inside the rotar volume of a rotar is an important dimensionless number for a rotar that has been designated with the symbol A_β. This symbol was chosen because it is amplitude that affects the rate of time and proper volume with similarities to gravitational magnitude β. The above calculation used the substitution that $A_\beta = L_p/\lambda\!\!\!^-_c$, but there are several other ways of expressing this strain amplitude.

$$A_\beta = L_p/\lambda\!\!\!^-_c = T_p\omega_c = \sqrt{Gm^2/\hbar c} = m/m_p = E_i/E_p = \omega_c/\omega_p = \sqrt{R_s/\lambda\!\!\!^-_c} = \sqrt{P_c/P_p}$$

E_i = internal energy of a rotar (mc^2 energy)
R_s = Schwarzschild radius $\quad R_s \equiv Gm/c^2$
P_c = circulating power $\quad P_c = E_i\,\omega_c = \omega_c^2\hbar$ (explained later)
The symbols m_p, ω_p, E_p, and P_p are Planck mass, Planck energy and Planck power. They are defined further in the table below.

To help convey the significance of this string of equalities, I will use an electron for a numerical example. The mass of an electron is: $m_e = 9.1094 \times 10^{-31}$ kg

Electron's Characteristics

$\lambda\!\!\!^-_c = \hbar/mc = c/\omega_c = 3.8616 \times 10^{-13}$ m	Compton radius (rotar radius)
$\omega_c = mc^2/\hbar = c/\lambda\!\!\!^-_c = 7.7634 \times 10^{20}$ s^{-1}	Compton angular frequency
$E_i = mc^2 = \hbar\omega_c = 8.1871 \times 10^{-14}$ J	internal energy
$P_c = E_i\,\omega_c = \omega_c^2\hbar = 6.356 \times 10^7$ w	circulating power (explained below)

Electron's Characteristics in Dimensionless Planck Units

$A_\beta = \sqrt{Gm^2/\hbar c}$	$= 4.185 \times 10^{-23}$	strain amplitude
$L_p/\lambda\!\!\!^-_c = 1.616 \times 10^{-35}/3.8616 \times 10^{-13}$	$= 4.185 \times 10^{-23}$	Compton radius (rotar radius)
$\omega_c T_p = \omega_c/\omega_p = 7.76 \times 10^{20}/1.855 \times 10^{43}$	$= 4.185 \times 10^{-23}$	Compton frequency
$m/m_p = 9.109 \times 10^{-31}/2.176 \times 10^{-8}$	$= 4.185 \times 10^{-23}$	mass
$E_i/E_p = 8.187 \times 10^{-14}/1.956 \times 10^{9}$	$= 4.185 \times 10^{-23}$	energy
$\sqrt{R_s/\lambda\!\!\!^-_c} = (6.76 \times 10^{-58}/3.86 \times 10^{-13})^{1/2}$	$= 4.185 \times 10^{-23}$	Schwarzschild radius
$\sqrt{P_c/P_p} = (6.36 \times 10^{7}/3.63 \times 10^{52})^{1/2}$	$= 4.185 \times 10^{-23}$	circulating power
$(U_q/U_p)^{1/4} = (1.42 \times 10^{24}/4.64 \times 10^{113})^{1/4}$	$= 4.185 \times 10^{-23}$	energy density
$(A_q/A_p)^{1/2} = (9.74 \times 10^{6}/5.58 \times 10^{51})^{1/2}$	$= 4.185 \times 10^{-23}$	grav acceleration
$(g_q/A_p)^{1/3} = (4.08 \times 10^{-16}/5.58 \times 10^{51})^{1/3}$	$= 4.185 \times 10^{-23}$	gravitational acceleration at $\lambda\!\!\!^-_c$

It is amazing that the dimensionless number A_β that represents the strain amplitude of a rotar is related to so many rotar properties. These include the rotar's mass, energy, Compton frequency, Schwarzschild radius, rotar radius and circulating power (defined below). These properties can also be expressed in dimensionless Planck units. As previously explained, symbols written in bold and underlined such as $\underline{\boldsymbol{m}}$ and $\underline{\boldsymbol{\lambda}}_c$ will represent values expressed in dimensionless Planck units. Using this designation, A_β has the following equalities:

$A_\beta = \underline{\boldsymbol{m}} = \underline{\boldsymbol{\omega}}_c = \underline{\boldsymbol{E}}_i = 1/\underline{\boldsymbol{\lambda}}_c = \underline{\boldsymbol{P}}_c^{1/2} = \underline{\boldsymbol{A}}_q^{1/2} = \underline{\boldsymbol{U}}_q^{1/4} = \underline{\boldsymbol{R}}_s^{1/2}$ dimensionless Planck units

Each fundamental rotar has a single dimensionless number that expresses all of a rotar's unique properties. Angular momentum and charge are not unique to a specific fundamental particle. For example, an electron, muon and tauon each have their own unique values of quantum strain amplitude A_β (shown below). The values of angular momentum and charge are not unique.

$A_\beta = 4.18 \times 10^{-23}$ electron's amplitude, Planck frequency, mass, energy and inverse size
$A_\beta = 8.66 \times 10^{-21}$ muon's amplitude, Planck frequency, mass, energy and inverse size
$A_\beta = 1.46 \times 10^{-19}$ tauon's amplitude, Planck frequency, mass, energy and inverse size

Maximum Amplitude Rotar: Out of curiosity, let's calculate the mass of the rotar that has the maximum possible amplitude which is a quantum amplitude of $A_\beta = 1$.

$A_\beta = \sqrt{Gm^2/\hbar c}$ substitute $A_\beta = 1$ and square both sides
$1 = Gm^2/\hbar c$
$m = \sqrt{\hbar c/G} = m_p$ $A_\beta = 1$ when the mass equals the Planck mass (m_p).

Therefore, the proposed rotar model has Planck mass as the natural basis. However, $A_\beta = 1$ not only represents a rotar with Planck mass, but because of the above equalities, $A_\beta = 1$ also represents a rotar with Planck angular frequency ω_p, and a rotar with a rotar radius equal to Planck length l_p. Going even further, a rotar with $A_\beta = 1$ also has a circulating power equaling Planck power P_p, an internal energy equal to Planck energy E_p, and an energy density equal to Planck energy density U_p. If there were such a thing as a "Planck rotar", this proposed rotar model would have the Planck rotar as the natural basis.

Circulating Power: A rotar's internal energy is confined energy made of dipole waves in spacetime that are moving at the speed of light. Therefore, there is a specific amount of circulating power in any rotar. The circulating power (P_c) in an isolated rotar is the rotar's internal energy E_i times the rotar's Compton angular frequency ω_c. This is the momentary power that would leave the rotar volume if the circulating wave (rotating dipole) dissipated by all points in the wave traveling in straight lines. The wave would expand beyond the rotar radius in a time equal to $1/\omega_c$.

$P_c = E_i\,\omega_c = \omega_c^2\hbar = m^2c^4/\hbar = E_i^2/\hbar$ $\quad P_c$ = circulating power

An isolated electron's circulating power is about 63.56 million watts. $(8.2 \times 10^{-14}\ \text{J})^2/\hbar$ This high circulating power can be understood when it is realized that the electron's internal energy (8.2×10^{-14} J) is multiplied by the electron's Compton angular frequency ($7.8 \times 10^{20}\ \text{s}^{-1}$). The concept of circulating power will be important when we consider forces. For future reference, we will calculate the value of circulating power in Dimensionless Planck units by dividing conventional power by Planck power ($P_p = c^5/G$).

$\underline{\boldsymbol{P}}_c = P_c/P_p = (m^2c^4/\hbar)(G/c^5) = Gm^2/\hbar c$ $\quad \underline{\boldsymbol{P}}_c$ = circulating power in Planck units

Characteristics of an Electron: It is very useful to have a single table of the rotar characteristics and standard characteristics of an electron to test concepts. Therefore, the following table is provided here and in chapter 15 which is a compilation of equations and definitions.

Constants of an Electron	
$A_\beta = 4.1854 \times 10^{-23}$	= electron's strain amplitude
$ƛ_c = 3.8616 \times 10^{-13}$ m	= electron's Compton radius (rotar radius)
$\omega_c = 7.7634 \times 10^{20}\ \text{s}^{-1}$	= electron's Compton angular frequency
$\upsilon_c = 1.2356 \times 10^{20}$ Hz	= electron's Compton frequency
$P_c = 6.356 \times 10^7$ w	= electron's circulating power
$F_m = 0.21201$ N	= electron's maximum force at distance of $ƛ_c$
$R_s = 6.7635 \times 10^{-58}$ m	= electron's Schwarzschild radius $R_s \equiv Gm/c^2$
$U = E_i/ƛ_c^3 = 1.42 \times 10^{24}\ \text{J/m}^3$	= electron's energy density (cubic)
$U = (3/4\pi)E_i/ƛ_c^3 = 3.397\text{x}10^{23}\ \text{J/m}^3$	= electron's energy density (spherical)
$V = ƛ_c^3 = 5.7584 \times 10^{-38}\ \text{m}^3$	= electron's rotar volume (cubic)
$A_g = 9.7413 \times 10^6\ \text{m/s}^2$	= electron's grav acceleration at center of rotar volume
$m_e = 9.1094 \times 10^{-31}$ kg	= electron's mass
$E_i = 8.1871 \times 10^{-14}$ J	= electron's energy
$e = 1.6022 \times 10^{-19}$ Coulomb	= electron's charge

Forces

We are next going to examine the strong force, the electromagnetic force and the gravitational force between two of the same rotars. The only force exerted by dipole waves in spacetime is the relativistic force ($F_r = P_r/c$). Therefore, we would expect that the force between particles should be a simple function of the rotar's circulating power. Initially, we will examine the forces exerted under the simplest condition for the rotar model of fundamental particles. The forces will be calculated between two of the same rotars separated by the rotar's natural unit of length – separated by λ_c. This is an unrealistic assumption for an actual experiment because a separation distance of λ_c corresponds to the point where quantum mechanics becomes dominant. It is impossible to precisely hold this separation distance. However, this important separation distance can be rationalized as merely an extrapolation from longer distance to a separation distance of λ_c.

In later chapters we will examine other distances, but the spacetime based rotar model presented thus far only is able to define the characteristics at a distance equal to the rotar radius λ_c. It is reasonable that if the spacetime based model is correct, then the simplest separation distance would be λ_c, the rotar's natural unit of length. Calculations at arbitrary distance involve an additional consideration of how waves in the external volume of a rotar fall off with distance. Initially limiting the separation distance just to λ_c (the rotar radius) involves the fewest assumptions. We know the strain amplitude of a rotar at this distance is: $A = A_\beta = T_p\omega_c = L_p/\lambda_c$. Therefore, this fundamental test condition will be used exclusively for the remainder of this chapter.

Theoretical Maximum Force: We will begin this examination of forces by asking a simple question. Is there a theoretical maximum force that a fundamental rotar with a known energy can generate at a particular distance? This question considers only the energy of a rotar and the distance. Other characteristics of the rotar will determine whether the rotar can actually interact and achieve anything close to the theoretical maximum force. At this early stage of development of forces we are dealing with the relativistic force in its simplest form. Since the relativistic force is only repulsive, it follows that a simplified model of the theoretical maximum force will describe a repulsive force. Later the model will be expanded and eventually yield the strong force which is an attracting force with asymptotic freedom characteristics. For now we are merely logically following the narrow path associated with the starting assumption.

The standard model describes the strong force (the strong interaction) as the exchange of gluons between quarks. There are subtleties in this exchange that are explained by invoking color charge and quantum chromodynamics (QCD). We are starting from first principles and so far know nothing about gluons, etc. We only know the simplified rotar model presented so far. We have a dipole wave in spacetime that possesses quantized angular momentum and a specific amount of energy. The dipole wave is propagating at the speed of light in a closed loop one wavelength in circumference. This concept defines a specific rotational frequency and a specific amount of circulating power.

Maximum Force from Circulating Power: We will first use the concept of circulating power P_c of a fundamental rotar. Previously; it was found that the rotar model implies that every rotar can be considered to have a circulating power equal to:

$P_c = E_i\omega_c = \omega_c^2\hbar = \hbar c^2/\lambda_c^2$ P_c = circulating power of a rotar inside λ_c

Previously we concluded that the starting assumption (the universe is only spacetime) implied that there is only one truly fundamental force – the relativistic force $F_r = P_r/c$. The strongest force that a fundamental rotar can exert at distance λ_c will occur if all of a rotar's circulating power is deflected (set $P_r = P_c$). This presumes two of the same rotars, each with internal energy of E_i. Only quarks are actually capable of exerting something close to this maximum force, but it is still possible to calculate the theoretical maximum force that any rotar can generate if all the rotar's circulating power is deflected. This is equivalent to saying that some rotars cannot deflect all the circulating power at a separation distance of λ_c, but it is possible to calculate the maximum force that would be generated if all the circulating power was deflected. We take the relativistic force equation $F_r = P_r/c$ and set $F_r = F_m$ and $P_r = P_c = \hbar c^2/\lambda_c^2$.

$F_m = P_c/c = E_i/\lambda_c = m^2c^3/\hbar = \omega_c^2\hbar/c = A_\beta^2 F_p$ F_m = rotar's maximum force at distance λ_c

Later we will compare this value of the maximum possible force at λ_c to the electrostatic force at this distance to see if it is reasonable. However, first I want to explain a qualification on the physical interpretation of this maximum force $F_m = E_i^2/\hbar c$. This equation represents the maximum force that can be exerted if two of the same rotars are held stationary at a distance equal to their rotar radius λ_c. If two rotars are colliding at relativistic velocity, then a greater force can be generated because kinetic energy is converted to increase the rotar's internal energy E_i at the instant of collision. This momentarily increases the internal energy E_i of the colliding rotars which also momentarily increases F_m, ω_c and P_c and decreases the rotar radius λ_c.

For example, an electron with relativistic velocity equal to 50 GeV can temporarily convert this kinetic energy into internal energy in a collision raising the electron's internal energy from ~ 0.5 MeV to 50 GeV, a factor of about 100,000. This would momentarily decrease the electron's rotar radius by a factor of 10^5 from 3.86×10^{-13} m to 3.86×10^{-18} m. This would also increase both the circulating power and the maximum force by a factor of 10^{10}. Therefore, an electron undergoing a collision can exhibit a force greater than the theoretical maximum force calculated for an isolated electron (no collision). Trying to remove a quark from a hadron also changes the internal energy of the quark and can affect the binding force. This will be discussed later.

Maximum Force from the Wave-Amplitude Equation: We will also calculate the maximum force using the wave-amplitude equation: $F = A^2\omega^2 Z\mathcal{A}/c$. We have previously used a similar equation to calculate the energy in a rotar. For that calculation we made the following substitutions: $A = A_\beta = L_p/ƛ_c$; $\omega = \omega_c = c/ƛ_c$; and $V = kƛ_c^3$. This time we have an area term $\mathcal{A}$. Since the presumption is that we have two of the same rotars separated by $ƛ_c$, this means that the interaction area would be a constant times $ƛ_c^2$. ($\mathcal{A} = kƛ_c^2$). There are many other numerical factors close to 1 that have been previously ignored, so we will also ignore this constant.

$F = A^2\omega^2 Z\mathcal{A}/c$ set: $A = A_\beta = L_p/ƛ_c$; $\omega = \omega_c = c/ƛ_c$; $Z = Z_s = c^3/G$; $\mathcal{A} = ƛ_c^2$

$$F_m = \left(\frac{L_p}{ƛ_c}\right)^2 \left(\frac{c}{ƛ_c}\right)^2 \left(\frac{c^3}{G}\right)\left(\frac{ƛ_c^2}{c}\right) \qquad \text{set: } L_p^2 = \hbar G/c^3;$$

$$F_m = \frac{\hbar c}{ƛ_c^2} = \frac{E_i^2}{\hbar c} = \frac{\hbar\omega_c^2}{c} = \frac{m^2c^3}{\hbar} = A_\beta^2 F_p$$

Once more, I want to emphasize that this calculation assumed amplitude $A = A_\beta$ and distance $r = ƛ_c$ which was implied when we set area $\mathcal{A} = ƛ_c^2$ with the constant ignored. This is mentioned because in chapter 8 we will extend both the electrostatic force and the gravitational force to arbitrary distance. Also in a later chapter, two competing versions of the maximum force will be shown to make up the more complex strong force between quarks. The condition known as asymptotic freedom will be analyzed and shown to result from competing maximum forces which reach equilibrium. However, a slight displacement from this equilibrium separation distance results in a net restoring force which increases with displacement and can almost reach the maximum force.

Coulomb Force: To evaluate the maximum force it is necessary to compare it to the Coulomb force (electromagnetic force) that would exist between two electrically charged rotars at the separation distance of $r = ƛ_c$. There are actually two possible values of charge q that are interesting and we will evaluate both of them. One obvious choice is to use elementary charge e. However, the other interesting value is Planck charge $q_p = \sqrt{4\pi\varepsilon_0\hbar c} = e/\sqrt{\alpha} \approx 1.88 \times 10^{-18}$ Coulomb which is about 11.7 times larger than elementary charge e. Planck charge is derived from ε_0, the permittivity of free space and is the best choice of a unit of charge when we are comparing forces because Planck charge avoids dealing with the fine structure constant $\alpha = e^2/4\pi\varepsilon_0\hbar c \approx 1/137$. The fine structure constant α is known to be the coupling constant relating to the strength of the electromagnetic interaction between a particle with charge e and a photon. By choosing Planck charge we are setting this coupling constant equal to 1. By eliminating the coupling constant α, we would expect that at separation distance of $r = ƛ_c$ the electromagnetic force should be equal to the maximum force if the particle and force models described thus far are correct. The Coulomb force equation $F = q^2/4\pi\varepsilon_0\hbar c$ will be used for this critical test. We will use the force symbol F_E to specify that we are representing the electrostatic force between two Planck charges. Therefore we will make the following substitutions into the Coulomb force equation:

$$F = \frac{q^2}{4\pi\varepsilon_o r^2} \qquad \text{set: } F = F_E, \quad r = ƛ_c \quad q = q_p = \sqrt{4\pi\varepsilon_o \hbar c} \quad \text{and} \quad F_m = \hbar c/ƛ_c^2$$

$$F_E = \frac{q_p^2}{4\pi\varepsilon_o ƛ_c^2} = \frac{\hbar c}{ƛ_c^2} = F_m$$

Therefore, this is a spectacular success. When we use Planck charge to set the coupling constant equal to 1 and $r = ƛ_c$, then we obtain the equation that the electrostatic force equals the maximum force $F_E = F_m$. The fact that we obtain answers which imply Planck charge should not be interpreted that somehow Planck charge is a realistic possibility of the charge of a rotar. In the next chapter it will be shown that the wave characteristics which would be required to achieve Planck charge would also make an unstable rotar which would radiate away all its energy in a time period of $1/\omega_c$ which for an electron is only about 10^{-20} s. Planck charge is a theoretical idea that implies all of a particle's energy is transferred to its external field.

Any time in the rest of the book that we are representing the electrostatic force generated by particles with elementary charge e, we will use the symbol F_e. The following is the first of these calculations.

$$F = \frac{q^2}{4\pi\varepsilon_o r^2} \qquad \text{set: } F = F_e \quad r = ƛ_c; \quad q = e \quad \alpha = e^2/4\pi\varepsilon_o\hbar c \quad \text{and} \quad F_m = \hbar c/ƛ_c^2$$

$$F_e = \frac{e^2}{4\pi\varepsilon_o ƛ_c^2} = \frac{\alpha\hbar c}{ƛ_c^2} = \alpha F_m$$

Therefore, even using elementary charge e we obtain a connection between the electrostatic force and the maximum force, but this electrostatic force is diminished by the fine structure constant $\alpha \approx {}^1/_{137}$. The fine structure constant has never been able to be mathematically derived from first principles. It has been the source of mystery for generations of theoretical physicists. Therefore, we also will merely accept this mysterious number as a coupling constant of unknown origin.

Gravity

Now for the big question: Can we develop the force of gravity from first principles using the rotar model? Thus far we have discussed the fundamental dipole wave that can exist in the spacetime field. If we are going to be able to explain all the forces of nature with only dipole waves in spacetime, we have to examine the possibility that under some circumstances a dipole wave in spacetime may not be perfectly sinusoidal. Once again the starting assumption that the universe is only spacetime serves as a wonderful restriction. It keeps us focused on examining only the most basic properties of spacetime. The properties of the spacetime field are finite. There is a maximum force, a maximum frequency and a maximum strain amplitude for dipole waves in spacetime. These maximums can be considered as boundary conditions imposed on dipole waves in spacetime. Such boundary conditions should produce nonlinear effects.

If the universe is only spacetime, we do not have many possible explanations for gravity. In fact, the only plausible possibility is that the spacetime field is a nonlinear medium for dipole waves in spacetime.

Optical Kerr Effect: I see a similarity between gravity and a nonlinear optical effect called the optical Kerr effect. All transparent materials have a maximum intensity limit which is a boundary condition. Therefore, when light passes through any transparent material, a nonlinear effect occurs. Even for wavelengths for which the material is transparent, there is a limit to the maximum intensity (maximum electric field strength) that can propagate through the material. This limit results in nonlinearity (distortion) even for intensities that are far below this limit. The oscillating electric field of the light produces a non-oscillating nonlinear effect which changes the index of refraction of the transparent material. This nonlinear effect reduces the speed of light in the transparent material in addition to the normal reduction due to the material's index of refraction at zero intensity. An expression of the optical Kerr effect is given by the following simplified equation that ignores higher order terms.

$n_k \approx n_o + k_1\mathbb{E}_\omega^2$ simplified optical Kerr effect equation

n_k = the index of refraction which includes the optical Kerr effect contribution
n_o = the normal index of refraction at zero intensity
k_1 = a nonlinear constant that depends on the transparent material
$\mathbb{E}_\omega$ = electric field strength at frequency ω

This means that the speed of light in any transparent material has a fundamental term (n_o) and a second order term ($k_1\mathbb{E}_\omega^2$). The second order term depends on the square of the alternating electric field produced by the light.

Even sunlight passing through a window produces a slight nonlinear effect in the glass. When a high peak power pulse of laser light is focused in a transparent material, the light can reach oscillating electric field strength where the optical Kerr effect increases the index of refraction to the extent that the laser beam is further concentrated and confined to a small filament. This confinement can be so great that the beam is not allowed to diverge. This effect is easily seen in glass and other solids, but it has even been demonstrated in air.

While the analogy between the optical Kerr effect and gravity is far from perfect, the point is that homogeneous materials like glass or air exhibit a nonlinearity that scales proportional to the square of the electric field strength $\mathbb{E}^2$ where $\mathbb{E}$ can be considered a wave amplitude. This squaring produces an effect that is always positive. In the optical Kerr effect, the index of refraction always increases.

This nonlinearity in transparent materials is associated with the fact that any transparent material has a maximum electric field strength limitation. Exceeding this maximum electric field strength will physically damage the transparent material. The most extreme form of damage is ionization of the atoms, but molecules can be decomposed at electric field strength less than the ionization threshold. This maximum field strength introduces a nonlinearity that scales with $\mathbb{E}^2$ and higher powers of $\mathbb{E}$. However, the higher powers only become significant as the limiting intensity is approached. The spacetime field is also a medium that transmits waves. Is there any evidence that the spacetime field is a nonlinear medium?

Gravity – A Nonlinear Effect: We need to consider the force of gravity between two of the same rotars at distance $\lambda\!\!\!^{-}_c$. If the universe is only spacetime and if there is only one truly fundamental force (the relativistic force) then dipole waves in spacetime must also cause gravity. We are therefore looking for a mechanism whereby a rotar's circulating power can be converted into a force that has only one polarity and is vastly weaker than the other forces. There is really only one reasonable choice. Gravity must be the result of the spacetime field being a nonlinear medium for dipole waves in spacetime.

Fifth Starting Assumption: **The spacetime field is a nonlinear medium for dipole waves in spacetime. This nonlinearity ultimately produces gravity.**

The gravitational force must be the result of this nonlinearity while the other forces are a direct (linear) function of circulating power. Dipole waves in spacetime have a theoretical maximum amplitude of $A_\beta = 1$. This means that dipole waves in spacetime should also exhibit a nonlinearity that scales with A_β^2 even when $A_\beta \ll 1$. The strain produced by dipole waves in spacetime must have a linear term and a nonlinear term.

Strain = $A_\beta \sin\omega t + (A_\beta \sin\omega t)^2 = A_\beta \sin\omega t - \frac{1}{2} A_\beta^2 \cos 2\omega t + \boldsymbol{\frac{1}{2} A_\beta^2}$ (bold for emphasis)

The linear term is ($A_\beta\, sin\omega t$) and the nonlinear term is ($A_\beta\, sin\omega t$)^2. There are also higher order nonlinear terms (greater than square) but these can be ignored because A_β is a number very close to zero and any higher powers (cube or above) of this are insignificant. The nonlinear term has been further expanded into a weak oscillating term ($A_\beta{}^2 cos2\omega t$) and a non-oscillating term that is always positive (½ $A_\beta{}^2$). It is proposed that the strain in spacetime produced by the non-oscillating term ($A_\beta{}^2$ at distance $\lambda\!\!\!^{-}_c$) is responsible for the general relativistic curvature of spacetime which results in gravity.

An analysis in chapter 8 will show how the nonlinear term $(A_\beta\, sin\omega t)^2$ leads to both gravitational attraction as well as the gravitational effect on time and distance. In this chapter we are going to start with a simplified analysis that concentrates only on the magnitude of the force exerted by the gravity of a rotar. With this limitation we again are developing an over-simplified repulsive force with the correct magnitude of gravity. This will later be improved into an attracting force that also exhibits the spatial and temporal properties of gravity. The actual force of gravity will be shown in chapter 8 to result from a strain in spacetime that produces an unbalanced force on opposite sides of a rotar.

It is easy to demonstrate that the nonlinearity of the spacetime field gives the correct magnitude of the gravitational force at distance $\lambda\!\!\!^{-}_c$ using a calculation that is somewhat oversimplified. Previously we were using $A = A_\beta$ as the substitution of the wave amplitude for the maximum force and other rotar properties. To prove that gravity is caused by the nonlinearity of spacetime, we will now square the strain amplitude term and make the nonlinear amplitude substitution $A = A_\beta{}^2$ into the force equation: $F = kA^2\omega^2 Z\mathcal{A}/c$.

$F = kA^2\omega^2 Z\mathcal{A}/c$ for gravity set: $A = A_\beta{}^2 = L_p{}^2/\lambda\!\!\!^{-}_c{}^2$, $\omega = \omega_c$, $Z = Z_s = c^3/G$, $\mathcal{A} = k\lambda\!\!\!^{-}_c{}^2$

$$F_g = A_\beta{}^4\omega_c{}^2 Z_s\mathcal{A}/c = \left(\frac{L_p^4}{\lambda\!\!\!^{-}_c{}^4}\right)\left(\frac{c^2}{\lambda\!\!\!^{-}_c{}^2}\right)\left(\frac{c^3}{G}\right)\left(\frac{\lambda\!\!\!^{-}_c{}^2}{c}\right) = \left(\frac{\hbar^2 G^2}{c^6}\right)\left(\frac{m^2c^2}{\hbar^2}\right)\left(\frac{1}{\lambda\!\!\!^{-}_c{}^2}\right)\left(\frac{c^4}{G}\right)$$

$F_g = \dfrac{Gm^2}{\lambda\!\!\!^{-}_c{}^2}$ magnitude of the gravitational force between 2 particles of mass m at distance $\lambda\!\!\!^{-}_c$

Even though this is oversimplified, I find this calculation very exciting! We obtain the Newtonian gravitational force equation starting with rotating dipole waves in spacetime. It was not necessary to make an analogy to acceleration. This particular calculation was for two of the same rotars at a separation distance of $\lambda\!\!\!^{-}_c$, but in chapter 8 we will be able to broaden this to the more general case of any mass/energy at any distance. Furthermore, the model will be improved and result in this being an attracting force. To my knowledge, this is the first time that the gravitational force has ever been calculated from conceptually understandable first principles. There were no vague analogies to restraining a mass from following a geodesic.

This implies that gravity is really a force and not the result of the geometry of spacetime. Static curved spacetime is the result of dynamic (oscillating) curved spacetime exhibiting a nonlinear effect. In chapter 4 we described how the quantum mechanical model of the spacetime field possesses elasticity, impedance, energy density, etc. Introducing matter (dipole waves with quantized angular momentum) into this homogeneous medium produces distortion which has both a linear and a nonlinear component. Gravity is the nonlinear component. From the above calculation it is not hard to see that eventually we will obtain the Newtonian equation: $F = Gm_1m_2/r^2$. Even though this is a successful plausibility calculation, in chapter 8 it will be shown to be an oversimplification that gets the magnitude correct but the vector wrong. Additional steps will be introduced to obtain the complete picture. It should be recognized that for single particles the Newtonian gravitational equation can be considered almost exact. However, there are also small nonlinearities which are being ignored in these simple calculations. General relativity differs from Newtonian gravity because general relativity incorporates nonlinearities including a maximum possible force (Planck force). While this book does not carry this model to the strong gravity limit, it appears that a mature model incorporating nonlinear terms would be compatible with general relativity. In fact, chapters 8 and 10 discuss subtleties that go further than general relativity.

Review: We have just calculated a simplified version of Newton's gravitational equation from a set of starting assumptions. The steps that brought us to this point will be briefly reviewed.

The key assumptions are:

1) The universe is only spacetime.
2) Dipole waves in spacetime are permitted by quantum mechanics provided that the displacement of spacetime does not exceed the Planck length/time limitation.
3) Energy in any form is fundamentally made of dipole waves in spacetime propagating at the speed of light.
4) There is only one fundamental force: the relativistic force. This force occurs when waves in spacetime, propagating at the speed of light, are deflected.
5) Fundamental particles are dipole waves in spacetime that form a rotating dipole, one wavelength in circumference that possesses circulating power.
6) The spacetime field is a nonlinear medium for dipole waves in spacetime. This nonlinearity ultimately produces gravity.

Waves in the spacetime field are like sound waves propagating in the medium of the spacetime field. Spacetime has an impedance ($Z_s = c^3/G$) and the force generated by deflecting waves in spacetime is: $F = A^2\omega^2 Z_s \mathcal{A}/c$ where A is amplitude and $\mathcal{A}$ is area. Assumption #6 says that the spacetime field is a nonlinear medium. This nonlinear effect can be considered the source of a new nonlinear wave that has strain amplitude that is the square of the amplitude of the fundamental wave amplitude: $A_\beta{}^2 = A_{\beta g} = L_p{}^2/\lambda_c^2$. Inserting this amplitude into the force equation above yields $F_g = Gm^2/\lambda_c^2$ which is a simplified version of Newton's gravitational equation that assumes two of the same mass particles at distance λ_c (dimensionless constants near 1 ignored).

Connection Between the Forces and Circulating Power: If the forces of nature are caused by the interaction of waves in spacetime, then there should be a simple relationship between the force and the circulating power (P_c). I previously proposed that there is only one truly fundamental force in nature – the relativistic force ($F_r = P_r/c$). This is the repulsive force exerted when relativistic power (power propagating at the speed of light) is "deflected" which includes absorbed and reflected. For this to appear to be an attracting force this interaction must include pressure (repulsive force) exerted by vacuum energy. This is discussed in chapter 8. However, in all cases a force generated by a rotar must be related to both the circulating power and the rotar radius of the rotar. Furthermore, since gravity is the result of nonlinearity, we would expect that the gravitational force would be a function of P_c^2 while the other forces would be a linear function of P_c.

We are therefore going to perform a critical test of the rotar model and the concept of a single fundamental force. There is no single rotar that exhibits all three of the following properties: elementary charge, the strong force and gravity. Quarks and the charged leptons only exhibit 2 of the 3 properties. However, it is possible to calculate the magnitude of these three forces as if they were possessed by a single pair of the same rotars separated by a distance equal to their rotar radius. We will also be assuming the hypothetical case of two particles with Planck charge in some of the following calculations.

This critical test will examine whether there is an easy to understand relationship between the magnitudes of the forces (F_m, F_E, F_e, F_g) and the circulating power P_c of the rotar causing the force. This comparison will be done using the natural Planck units of force and power (bold and underlined indicates Dimensionless Planck units – $\underline{\boldsymbol{F}}_m$, $\underline{\boldsymbol{F}}_E$, $\underline{\boldsymbol{F}}_e$, $\underline{\boldsymbol{F}}_g$, and $\underline{\boldsymbol{P}}_c$). Initially, all comparisons will be made at the rotar's natural unit of length, its rotar radius $\lambda\!\!\!^-_c = c/\omega_c = \hbar/mc$. This is the only distance that we know the circulating power. Substitutions that will be used:

$$r = \lambda\!\!\!^-_c = \frac{\hbar}{mc}; \quad F_m = \left(\frac{m^2c^3}{\hbar}\right); \quad F_p = \frac{c^4}{G}; \quad P_c = \left(\frac{m^2c^4}{\hbar}\right); \quad P_p = \frac{c^5}{G}; \quad \frac{q_p^2}{4\pi\varepsilon_o} = \hbar c, \quad \frac{e^2}{4\pi\varepsilon_o} = \alpha\hbar c;$$

$$\underline{\boldsymbol{F}}_g = \frac{F_g}{F_p} = \left(\frac{Gm^2}{\lambda\!\!\!^-_c{}^2}\right)\left(\frac{G}{c^4}\right) = Gm^2\left(\frac{m^2c^2}{\hbar^2}\right)\left(\frac{G}{c^4}\right) = \left(\frac{G\,m^2}{\hbar c}\right)^2$$

$$\underline{\boldsymbol{F}}_m = \frac{F_m}{F_p} = \left(\frac{m^2c^3}{\hbar}\right)\left(\frac{G}{c^4}\right) = \frac{Gm^2}{\hbar c}$$

$$\underline{\boldsymbol{F}}_E = \frac{F_E}{F_p} = \left(\frac{q_p^2}{4\pi\varepsilon_o\lambda\!\!\!^-_c{}^2}\right)\left(\frac{G}{c^4}\right) = (\hbar c)\left(\frac{mc}{\hbar}\right)^2\left(\frac{G}{c^4}\right) = \frac{Gm^2}{\hbar c}$$

$$\underline{\boldsymbol{F}}_e = \frac{F_e}{F_p} = \left(\frac{e^2}{4\pi\varepsilon_o\lambda\!\!\!^-_c{}^2}\right)\left(\frac{G}{c^4}\right) = (\alpha\hbar c)\left(\frac{mc}{\hbar}\right)^2\left(\frac{G}{c^4}\right) = \alpha\left(\frac{Gm^2}{\hbar c}\right)$$

$$\underline{\boldsymbol{P}}_c = \frac{P_c}{P_p} = \left(\frac{m^2c^4}{\hbar}\right)\left(\frac{G}{c^5}\right) = \frac{Gm^2}{\hbar c}$$

Since all of these are related to $Gm^2/\hbar c$, we obtain simple relationships between forces and circulating power when we are dealing with two of the same rotars with charge e or q_p and separated by a distance λ_c. Recall that the concept of a single relativistic force says that there should be an easy to understand relationship between force and circulating power.

$\underline{\boldsymbol{F}}_m = \underline{\boldsymbol{P}}_c$ $\underline{\boldsymbol{F}}_m$ = maximum force in dimensionless Planck units (closely related to the strong force)
$\underline{\boldsymbol{F}}_E = \underline{\boldsymbol{P}}_c$ $\underline{\boldsymbol{F}}_E$ = electromagnetic force in dimensionless Planck units where $q = q_p$ (Planck charge)
$\underline{\boldsymbol{F}}_e = \alpha\underline{\boldsymbol{P}}_c$ $\underline{\boldsymbol{F}}_e$ = electromagnetic force in dimensionless Planck units where $q = e$ (elementary charge)
$\underline{\boldsymbol{F}}_g = \underline{\boldsymbol{P}}_c^2$ $\underline{\boldsymbol{F}}_g$ = gravitational force in dimensionless Planck units

This is a spectacular success that strongly supports the spacetime based model of forces. This simplification of relationships occurs at the spacetime based model's fundamental unit of length (the reduced Compton wavelength). The maximum force deflects all of the circulating power ($\underline{\boldsymbol{F}}_m = \underline{\boldsymbol{P}}_c$). The electromagnetic force also deflects all the circulating power if we assume Planck charge $\underline{\boldsymbol{F}}_E = \underline{\boldsymbol{P}}_c$ but elementary charge e only deflects about $^1/_{137}$ of the circulating power and is therefore about 137 times weaker ($\underline{\boldsymbol{F}}_e = \alpha\underline{\boldsymbol{P}}_c$). However, forces $\underline{\boldsymbol{F}}_m$ $\underline{\boldsymbol{F}}_E$ and $\underline{\boldsymbol{F}}_e$ are similar because they all scale linearly with circulating power (scale with $\underline{\boldsymbol{P}}_c^1$). Gravity is different because it is the result of a nonlinear effect and scales proportional to $\underline{\boldsymbol{P}}_c^2$. When circulating power is expressed in dimensionless Planck units it is always a dimensionless number close to zero. Therefore squaring this number produces a number even closer to zero. The weakness of gravity compared to the other forces is due to the difference between $\underline{\boldsymbol{P}}_c$ and $\underline{\boldsymbol{P}}_c^2$. The analysis of gravity will continue in chapter 8, but gravity is the result of the spacetime field being a nonlinear medium that scales with amplitude squared which in turn results in a $\underline{\boldsymbol{P}}_c^2$ scaling of the gravitational force.

We can also relate the rotar's internal energy $\underline{\boldsymbol{E}}_i$, energy density $\underline{\boldsymbol{U}}_q$, Schwarzschild radius $\underline{\boldsymbol{R}}_s$, reduced Compton wavelength $\underline{\lambda}_c$ and strain amplitude A_β to the forces between two of the same rotars separated by distance λ_c when terms are expressed in dimensionless Planck units. Again we show the relationship to $Gm^2/\hbar c$.

$$\underline{\boldsymbol{E}}_i = E_i/E_p = (mc^2)\sqrt{\frac{G}{\hbar c^5}} = \sqrt{\frac{Gm^2}{\hbar c}}$$

$$\underline{\boldsymbol{U}}_q = U_q/U_p = \left(\frac{m^4c^5}{\hbar^3}\right)\left(\frac{\hbar G^2}{c^7}\right) = \left(\frac{Gm^2}{\hbar c}\right)^2$$

$$\underline{\boldsymbol{R}}_s = R_s/L_p = \left(\frac{Gm}{c^2}\right)\sqrt{\frac{c^3}{\hbar G}} = \sqrt{\frac{Gm^2}{\hbar c}}$$

$$\underline{\lambda}_c = \lambda_c/L_p = \left(\frac{\hbar}{mc}\right)\sqrt{\frac{c^3}{\hbar G}} = \sqrt{\frac{\hbar c}{Gm^2}}$$

$$A_\beta = L_p/\lambda_c = \sqrt{\frac{\hbar G}{c^3}}\left(\frac{mc}{\hbar}\right) = \sqrt{\frac{Gm^2}{\hbar c}}$$

Combining all of these we obtain:

$$\underline{\boldsymbol{F}}_g = \underline{\boldsymbol{F}}_m{}^2 = \underline{\boldsymbol{F}}_E{}^2 = (\underline{\boldsymbol{F}}_e/\alpha)^2 = \underline{\boldsymbol{P}}_c{}^2 = \underline{\boldsymbol{E}}_i{}^4 = \underline{\boldsymbol{U}}_q = \underline{\boldsymbol{R}}_s{}^4 = 1/\underline{\boldsymbol{\lambda}}_c{}^4 = A_\beta{}^4$$

This is one of the most important findings in this book. It is a series of equalities that can be rewritten as 54 individual equations. The simplicity of this series of equations is jaw dropping. It shows how the gravitational force is closely related to not only the maximum force and the electromagnetic force but also to a rotar's energy, circulating power, energy density, Schwarzschild radius, Compton wavelength and strain amplitude. It will be shown later that the strong force is also related to these forces.

Just to help internalize these relationships, we will use two electrons separated by $\lambda_c = 3.86 \times 10^{-13}$ meters as illustration. All the other values are for electrons expressed in dimensionless Planck units. Readers are invited to substitute the following values of $\underline{\boldsymbol{F}}_m$, $\underline{\boldsymbol{F}}_e$, $\underline{\boldsymbol{F}}_g$, $\underline{\boldsymbol{P}}_c$, $\underline{\boldsymbol{E}}_i$ and A_β into the above equations.

$\underline{\boldsymbol{F}}_g = F_g/F_p \quad = (Gm^2/\lambda_c^2)/(c^4/G) \quad = 3.07 \times 10^{-90}$
$\underline{\boldsymbol{F}}_m = F_s/F_p \quad = (\hbar c/\lambda_c^2)/(c^4/G) \quad = 1.75 \times 10^{-45}$
$\underline{\boldsymbol{F}}_e = F_e/F_p \quad = (e^2/4\pi\varepsilon_o\lambda_c^2)/(c^4/G) \quad = 1.28 \times 10^{-47}$
$\underline{\boldsymbol{P}}_c = P_c/P_p \quad = (\hbar c^2/\lambda_c^2)/(c^5/G) \quad = 1.75 \times 10^{-45}$
$\underline{\boldsymbol{E}}_i = E_i/E_p \quad = (mc^2)(G/\hbar c^5)^{1/2} \quad = 4.19 \times 10^{-23}$
$\underline{\boldsymbol{U}}_q = U_q/U_p \quad = (m^4c^5/\hbar^3)(\hbar G^2/c^7) \quad = 3.07 \times 10^{-90}$
$\underline{\boldsymbol{R}}_s = R_s/L_p \quad = (Gm/c^2)(c^3/\hbar G)^{1/2} \quad = 4.19 \times 10^{-23}$
$\underline{\boldsymbol{\lambda}}_c = \lambda_c/L_p \quad = (\hbar/mc)(c^3/\hbar G)^{1/2} \quad = 2.39 \times 10^{22}$
$A_\beta = L_p/\lambda_c \quad = (Gm^2/\hbar c)^{1/2} \quad = 4.19 \times 10^{-23}$

Alternative Derivation: While the above calculations that relate the forces to circulating power is one way of deriving these equations, there is another derivation that is similar but makes some different points. It is based on the idea that we should be able to calculate the magnitude of the force exerted by waves in spacetime with amplitude A_β at frequency ω_c and separation distance λ_c using the following wave amplitude equation: $F = A^2\omega^2 Z\mathcal{A}/c$. We will start by making the substitution of $A = A_\beta$ for the maximum force F_m at the separation distance equal to the rotar radius R_q of a rotar.

$F = A^2\omega^2 Z\mathcal{A}/c \qquad$ set: $F = F_m$, $A = A_\beta = L_p/\lambda_c = E_i/E_p = \underline{\boldsymbol{E}}_i$, $\omega = \omega_c = c/\lambda_c$, $Z = Z_s$, $\mathcal{A} = k\lambda_c^2$
$F_m = A_\beta^2\omega^2{}_c Z_s\mathcal{A}/c = \underline{\boldsymbol{E}}_i{}^2(c/\lambda_c)^2(c^3/G)(\lambda_c^2/c)$
$F_m = \underline{\boldsymbol{E}}_i{}^2(c^4/G) \qquad$ set: $F_m = \underline{\boldsymbol{F}}_m F_p = \underline{\boldsymbol{F}}_m(c^4/G)$
$\underline{\boldsymbol{F}}_m = \underline{\boldsymbol{E}}_i{}^2$
Note: $\underline{\boldsymbol{E}}_i$ is both particle energy in dimensionless Planck units and wave amplitude: $\underline{\boldsymbol{E}}_i = L_p/\lambda_c$

When two particles with elementary charge e are separated by a distance λ_c, then the equation becomes $\underline{\boldsymbol{F}}_e = \alpha\underline{\boldsymbol{E}}_i^2$. However, the fine structure constant is known to be a coupling constant. If we set charge equal to Planck charge $q = q_p$, we are setting this coupling constant equal to 1. Planck charge is based on $1/4\pi\varepsilon_o$ and Planck charge is one of the "basic Planck units". considered to be more fundamental than charge e. Designating the electrostatic force between two Planck charges (q_p) as F_E the equation becomes:

$\underline{\boldsymbol{F}}_E = \underline{\boldsymbol{E}}_i^2$

Gravity is proposed to be the result of the spacetime field being a nonlinear medium for dipole waves in spacetime. This nonlinear effect scales with wave amplitude squared and higher order terms can be ignored because they are too small. Therefore, to calculate the gravitational force F_g at this separation distance ($r = \lambda_c$) we substitute $A = A_\beta^2$ into the same force equation.

$F = A^2\omega^2 Z\mathcal{A}/c$ *set:* $F = F_g$, and $A = A_\beta^2$

$F_g = (A_\beta^2)^2\omega_c^2 Z_s\mathcal{A}/c = \underline{\boldsymbol{E}}_i^4(c/\lambda_c)^2(c^3/G)(\lambda_c^2/c)$

$F_g = \underline{\boldsymbol{E}}_i^4(c^4/G) = \underline{\boldsymbol{E}}_i^4/F_p$

$\underline{\boldsymbol{F}}_g = \underline{\boldsymbol{E}}_i^4$

Therefore, we can combine $\underline{\boldsymbol{F}}_E = \underline{\boldsymbol{E}}_i^2$ and $\underline{\boldsymbol{F}}_g = \underline{\boldsymbol{E}}_i^4$ into the following:

$$\underline{\boldsymbol{F}}_g = \underline{\boldsymbol{F}}_E^2$$

This equation needs to be stated in words for full effect. Assuming a separation distance of $r = \lambda_c$ and $q = q_p$, the gravitational force equals the square of the electrostatic force when terms are stated in dimensionless Planck units. A numerical example helps to internalize this concept. Suppose we assume two particles, each with the mass of an electron $m_e \approx 9.1\text{x}10^{-31}$ kg therefore $r = \lambda_c = 4.185\text{x}10^{-13}$ m but with Planck charge $q_p = 1.88\text{x}10^{-19}$ C Here are the values:

$F_g = 3.7 \times 10^{-46}$ N	and	$\underline{\boldsymbol{F}}_g = 3.07 \times 10^{-90}$ dimensionless Planck units
$F_E = 0.212$ N	and	$\underline{\boldsymbol{F}}_E = 1.75 \times 10^{-45}$ dimensionless Planck units
$E_i = 8.19 \times 10^{-14}$ J	and	$\underline{\boldsymbol{E}}_i = 4.18 \text{x}10^{-23}$ dimensionless Planck units

The following equation makes the same assumptions of separation distance and charge, but it does not use dimensionless Planck units.

$$\frac{F_g}{F_E} = \frac{F_E}{F_p}$$

In words, $F_g/F_E = F_E/F_p$ says that at the previously stated conditions, the ratio of the gravitational force to the electrostatic force equals the ratio of the electrostatic force to Planck force. Therefore at $r = \lambda_c$. there is a symmetry between the gravitational force, the electrostatic force and Planck force Continuing with the numerical example previously given, Planck force is:

$F_p = c^4/G = 1.2\text{x}10^{44}$ N. Therefore both F_g/F_E and F_E/F_p equal the above dimensionless ratio: $1.75\text{x}10^{-45}$.

The above equations used Planck charge because Planck charge has a coupling constant of 1 and this simplifies the equations. However, it is easy to convert the above equations to elementary charge e by substituting $F_E = F_e\,\alpha^{-1}$ where F_e designates charge e and F_E designates Planck charge. The fine structure constant is α, therefore $\alpha^{-1} \approx 137$. In chapter 8 we will extend the force analysis to arbitrary separation distance.

Gravitational Wave Calculation: We will now move on to another plausibility test that can be performed on the proposed rotar model. Recall that dipole waves in spacetime have enough similarities to gravitational waves that we can use gravitational wave equations for analysis. However, we have to ignore dimensionless constants and interpret the results appropriately for dipole waves in spacetime. There is an equation used to estimate gravitational wave amplitude (A_{gw}) at the low intensity limit where nonlinearities can be ignored. This equation can be applied to the proposed rotar model.

$A_{gw} \approx k\,G\,\omega^2 I\varepsilon/c^4\,r$ $\quad I$ = moment of inertia, $\quad \varepsilon$ = asymmetry of a rotating object

This simplified equation, would normally be used to estimate the gravitational wave amplitude of a rotating rod or a rotating binary star system. It contains an angular frequency term ω, the moment of inertia (I) of the rotating object, the radius r of the rotating object, and a mass asymmetry term ε. For example, a spherically symmetric object would have no asymmetry $(\varepsilon = 0)$ and two equal point masses separated by $2r$ would have an asymmetry of $\varepsilon = 1$. We are going to assume that $\varepsilon \neq 0$ and the dimensionless asymmetry term ε will be included in the all-inclusive constant k. We will next convert the moment of inertia term to angular momentum.

$A_{gw} \approx k\,G\,\omega^2\,I\,\varepsilon\,/c^4\,r$ $\quad$ set: $I = \mathcal{L}/\omega$, $\quad \mathcal{L}$ = angular momentum, $\quad \varepsilon$ included in k
$A_{gw} = k\,G\,\omega\mathcal{L}/c^4\,r$

The reason for converting to angular momentum is because we want to apply this equation to rotars. We know the angular momentum of particles as $\mathcal{L} = ½\,\hbar$. However, the ½ in this angular momentum is subject to interpretation as previously discussed. The constant, whatever its value, will be included in the general constant k. The rotar model implies that $\varepsilon \neq 0$ because the dipole core of a rotar is two lobes rotating at the speed of light. We will also lump the eccentricity term ε, into the general constant k. We will now calculate the hypothetical gravitational wave amplitude for a fundamental rotar.

$A_{gw} = k\, G\, \omega\, \mathcal{L}/c^4\, r$ substitute: $\omega = \omega_c = c/\lambda\!\!\!^{-}_c$; $\mathcal{L} = k\hbar$ and $r = \lambda\!\!\!^{-}_c$

$$A_{gw} = k\, G \left(\frac{c}{\lambda\!\!\!^{-}_c}\right)\left(\frac{\hbar}{c^4 \lambda\!\!\!^{-}_c}\right)$$

$A_{gw} = k\, (\hbar G/c^3)\, /\lambda\!\!\!^{-}_c{}^2$

$A_{gw} = k\, L_p{}^2/\lambda\!\!\!^{-}_c{}^2 = kA_\beta{}^2$ we will ignore the constant k

This is another surprising connection. We take a gravitational wave equation used in cosmology and insert a rotar's angular momentum $\frac{1}{2}\hbar$ and Compton frequency ω_c. We then determine the gravitational wave amplitude (excluding constant) that would exist at a distance of $\lambda\!\!\!^{-}_c$. We obtain the amplitude $A_{gw} = L_p{}^2/\lambda\!\!\!^{-}_c{}^2 = A_\beta{}^2$. We previously determined that the nonlinearity of the spacetime field creates a non-oscillating strain amplitude equal to $A_\beta{}^2 = L_p{}^2/\lambda\!\!\!^{-}_c{}^2$ in the rotar volume of a rotar. The same amplitude expression is obtained using an entirely different approach. Previously we employed reasoning based on the quantum mechanical properties of spacetime and also on the spacetime field being nonlinear. Now we obtain the same answer by inserting rotars properties (angular momentum and Compton frequency) into a gravitational wave equation from general relativity.

The above calculation is a success, but it also seems to imply a problem. Are all fundamental rotars continuously radiating away their energy as gravitational waves? It is true that if any arbitrary value of Compton frequency or rotar radius ($\lambda\!\!\!^{-}_c = c/\omega_c$) is assumed, then there would probably be radiated power both for the fundamental wave and for the nonlinear wave with amplitude $L_p{}^2/\lambda\!\!\!^{-}_c{}^2$. However, it is proposed that the fundamental rotars that do exist correspond to special frequency-amplitude combinations where a wave interaction occurs that cancels this radiated power. Even short lived fundamental rotars, such as the tauon (lifetime ≈ 3 x 10^{-13} s), are long lived compared to the lifetime they would have if their circulating power was radiated. Since $P_c = E_i\omega_c$, the time required to radiate the rotar's internal energy E_i would be the inverse of the rotar's Compton frequency. For a tauon this would be: $1/\omega_c \approx 3 \times 10^{-25}$ second. The tauon's lifetime is about 10^{12} times longer than its $1/\omega_c$ time and is considered to be a "semi-stable particle".

There are an infinite number of possible frequencies, amplitudes and configurations that could hypothetically exist, but do not exist long enough to be considered fundamental rotars. The few frequencies that exist long enough to be considered fundamental rotars have some sort of wave interaction that constructively interferes to reinforce the rotating dipole rotar model and destructively interferes in a way that eliminates radiated energy. There is an analogy to the stability condition achieved by electrons in atoms. Normally an accelerated electron radiates EM radiation. However, the electrons in the ground state of atoms achieve stability by finding a combination of conditions which eliminates energy loss. The bottom line is that the few fundamental rotars that exist belong to the small group of frequency-amplitude-configuration combinations that do not radiate either the fundamental dipole wave in spacetime or the nonlinear wave associated with gravity. Even though there is not continuous loss of energy, some of the rotar's energy does extend beyond the rotar volume. It will be shown that a particle's gravity and electric field are both the result of standing waves generated by a rotar interacting with the vacuum energy that surrounds a rotar. More will be said about this in chapter 8.

Gravitational Wave Radiation: Out of curiosity, we will calculate how long it would take for an electron to radiate away its internal energy if gravitational waves were being continuously radiated. We will assume a gravitational wave amplitude of $A_{\text{gw}} = L_p^2/\lambda\!\!\!^{-}_c^2$ and a radiation area equal to the electron's rotar radius squared. We will use one of the 5 wave-amplitude equations that relate the power in a wave.

$$P = A^2\,\omega^2\,Z\,\mathcal{A} \quad \text{set } A = A_{gw} = L_p^2/\lambda\!\!\!^{-}_c^2 \quad \omega = \omega_c = c/\lambda\!\!\!^{-}_c; \quad Z = c^3/G; \quad \mathcal{A} = \lambda\!\!\!^{-}_c^2$$

$$P = \left(\frac{L_p^2}{\lambda\!\!\!^{-}_c^2}\right)^2 \left(\frac{c}{\lambda\!\!\!^{-}_c}\right)^2 \left(\frac{C^3}{G}\right) \lambda\!\!\!^{-}_c^2 = \left(\frac{L_p}{\lambda\!\!\!^{-}_c}\right)^4 \left(\frac{c^5}{G}\right) \quad \text{set } c^5/G = P_p \text{ (Planck Power)}$$

$$P = \left(\frac{L_p}{\lambda\!\!\!^{-}_c}\right)^4 P_p = A_\beta^4 P_p$$

To obtain a physical feel for the magnitude of this power, we will examine the gravitational wave power that would be radiated using the properties of an electron. We know that an electron must have a mechanism that cancels this radiated power.

$P = (4.18 \times 10^{-23})^4 \text{ x } 3.63 \text{ x } 10^{52}$ w $= 1.1 \text{ x } 10^{-37}$ w
$t = E_i/P = 8.18 \text{ x } 10^{-14}$ J/$1.1 \text{ x } 10^{-37}$ w set $E_i = 8.18 \text{ x } 10^{-14}$ J = electron's energy
$t \approx 7 \text{ x } 10^{23}$ s $\approx 2 \text{ x } 10^{16}$ years

Therefore, since the universe is $1.38 \text{ x } 10^{10}$ years old, it would take more than one million times the age of the universe ($2 \text{ x } 10^{16}$ years) for an electron to radiate away its energy in gravitational waves. While this is a long time, it would be detectable because electrons in the early universe would have more energy (measured locally) than today's electrons. If up and down quarks radiated away power as gravitational waves, they would have radiate away all their energy in a time shorter than the age of the universe because of their much larger Compton frequency ω_c. The power radiated as gravitational waves scales with ω_c^4.

If rotars radiated energy with amplitude equivalent to the fundamental wave amplitude ($A_f = L_p/r$) with no cancelation mechanism from vacuum energy, then the picture changes completely. If an electron radiated away its energy in a wave at its Compton frequency and its fundamental amplitude, an electron would radiate about 63 million watts and it would survive for a time of only $1/\omega_c$ ($\sim 10^{-20}$ second). This is mentioned because it is proposed that the few fundamental rotars that exist have a cancelation mechanism (discussed later) that prevents this type of energy loss. Standing waves remain in the rotar's external volume after this cancelation. Standing waves have equal power flowing in opposite directions and therefore do not transfer energy. Only traveling waves are continuously transferring energy.

Inertia: In chapter 1, we found that light circulating around a circular fiber optic loop satisfies the condition of $p = 0$ because all momentum vectors cancel. Therefore this circulating light exhibits inertia even though the light is not superimposed like the reflecting box example. For example, suppose that we accelerate a fiber optic loop in a direction parallel to the plane of the loop. Light in different parts of the loop receives different Doppler shifts. For example, light traveling with a vector component in the direction of the acceleration will increase in frequency and light traveling with a vector component in the opposite direction will decrease slightly in frequency. Also light propagating perpendicular to the acceleration vector would be deflected and exert pressure on the wall of the fiber optic loop to keep the light within the fiber. The resultant distribution of frequencies and deflections around the loop produce the same inertial forces on the fiber optic loop as the reflecting box received from accelerating confined light. Even if the loop is only one wavelength in circumference, there would still be the same inertial forces. If the loop is accelerated perpendicular to the rotational plane, the light would exhibit inertia by exerting a pressure difference on opposite sides of the fiber optic.

The rotar model has a dipole wave traveling at the speed of light in a closed loop. This is similar to the example of light in a fiber optic loop, except that there is no physical wall confining the energy circulating at the speed of light. The interaction with the dipole waves in the spacetime field accomplishes the confinement. This is also confined energy propagating at the speed of light. The translational momentum vectors in a stationary rotar add up to zero ($p = 0$). This satisfies the condition to generate inertia by the same mechanism previously explained for the inertia generated by confined light in chapter 1. The inertia of the rotar model exactly matches the inertia of an equal amount of energy in the form of confined photons.

Equivalence Principle: Einstein needed to postulate the "equivalence principle" which states that inertial mass is equivalent to gravitational mass. For example, the equivalence principle implies that the force required to accelerate an electron at a rate of 9.8 m/s^2 is exactly the same as the force required to hold an electron stationary in a gravitational field with acceleration of 9.8 m/s^2. If the Higgs mechanism is presumed to be the mechanism by which an electron gains inertial mass, then there is no obvious connection to an electron's gravitational mass. It is therefore necessary to postulate the equivalence principle.

However, the proposed model of the universe reduces inertial mass and gravitational mass to their underlying energy. Energy does not need to be categorized as inertial confined energy or gravitational confined energy. Energy can be mathematically defined at a specific location and in a specific gravitational potential without referencing acceleration. If particles can be reduced to confined energy propagating at the speed of light, then there is no need to postulate the equivalence principle or the Higgs mechanism.

Inertia from the Higgs Field: The Higgs mechanism was originally devised to impart inertia to W and Z bosons. A photon is a boson and it has no rest mass when it is freely propagating. W and Z bosons need to interact with something to give them inertia and prevent them from being massless particles like photons. The spacetime model of the universe has not been developed sufficiently to address this question. Therefore W and Z bosons might interact with the Higgs boson to acquire inertia. However W and Z bosons are extremely rare in nature. Virtually all the mass in the universe is associated with the quarks and leptons that form ordinary matter. Therefore, the most important question concerning inertia is how do leptons and quarks acquire inertia? Is the inertia imposed by an external Higgs field or is the inertia the result of an internal structure that has energy propagating at the speed of light in a confined volume. The rotar model matches the way that confined photons acquire inertia. A rotar is energy propagating at the speed of light in a confined volume resulting in zero momentum ($p = 0$) in a rest frame. Therefore the inertia of a rotar exactly achieves the correct amount of inertia for a given amount of internal energy. The rotar model achieves a connection to gravity. It will also be shown that this structure produces curved spacetime.

The picture of the universe proposed here is very simple. Many of the mysteries of quantum mechanics and general relativity become conceptually understandable in the proposed model. It is predicted that in the future, Occam's razor will prevail and the simplest explanation will turn out to be the correct explanation. At the moment, the spacetime model of the universe with one field and one building block of everything in the universe appears to be by far the simplest model.