Chapter 15

Equations and Definitions

Properties of a Single Rotar

$A_\beta = \dfrac{L_p}{ƛ_c} = T_p\omega_c = \sqrt{\dfrac{Gm^2}{\hbar c}} = \dfrac{m}{m_p} = \dfrac{E_i}{E_p} = \dfrac{\omega_c}{\omega_p} = \sqrt{\beta_q} = \sqrt{\dfrac{P_c}{P_p}}$ A_β = rotar strain amplitude

$ƛ_c = \dfrac{\hbar}{mc} = \dfrac{c}{\omega_c} = \dfrac{\hbar c}{E_i} = \dfrac{L_p^2}{R_s} = \dfrac{L_p}{A_\beta}$ $ƛ_c$ = rotar radius (Compton radius)

$\omega_c = \dfrac{mc^2}{\hbar} = \dfrac{c}{ƛ_c} = A_\beta\omega_p$ ω_c = Compton angular frequency

$E_i = mc^2 = \omega_c\hbar = \dfrac{\hbar c}{R_q} = \dfrac{P_c}{\omega_c} = F_m ƛ_c = A_\beta E_p$ E_i = internal energy

$m = \dfrac{E_i}{c^2} = \dfrac{\hbar}{ƛ_c c} = \dfrac{\omega_c\hbar}{c^2} = T_p^2\omega_c Z_s = A_\beta m_p$ m = rotar mass

$P_c = E_i\,\omega_c = \omega_c^2\hbar = \dfrac{E_i^2}{\hbar} = \dfrac{\hbar c^2}{ƛ_c^2} = \dfrac{m^2c^4}{\hbar} = A_\beta^2 P_p$ P_c = circulating power

$F_m = \dfrac{m^2c^3}{\hbar} = \dfrac{\hbar c}{ƛ_c^2} = \dfrac{\hbar\omega_c^2}{c} = A_\beta^2 F_p$ F_m = maximum force at distance $ƛ_c$

$U_q = \dfrac{E_i}{ƛ_c^3} = \dfrac{m^4c^5}{\hbar^3} = \dfrac{a_g^2}{G} = A_\beta^4 U_p$ U_q = rotar volume energy density

$\beta_q = \dfrac{Gm^2}{\hbar c} = A_\beta^2$ β_q = gravitational magnitude at rotar radius

$\mathcal{N} = \dfrac{r}{ƛ_c} = \dfrac{rmc}{\hbar}$ $\mathcal{N}$ = distance *(r)* from a rotar expressed as the number of $ƛ_c$ units

$A_e = \dfrac{\sqrt{\alpha}L_p ƛ_c}{r^2} = \sqrt{\alpha}\,\dfrac{H_\beta}{\mathcal{N}^2}$ A_e = electromagnetic standing wave strain amplitude (oscillating)

$A_{\mathbb{E}} = \sqrt{\alpha}\,\dfrac{L_p}{r} = \sqrt{\alpha}\,\dfrac{H_\beta}{\mathcal{N}}$ $A_{\mathbb{E}}$ = electromagnetic non-oscillating strain amplitude

$A_g = \dfrac{L_p^2}{r^2} = \dfrac{H_\beta^2}{\mathcal{N}^2}$ A_g = gravitational standing wave strain amplitude oscillating at $2\omega_c$

$A_G = \beta = \dfrac{Gm}{c^2 r} = \dfrac{H_\beta^2}{\mathcal{N}}$ A_G = gravitational non-oscillating strain amplitude

$A_f = \dfrac{L_p}{r}$ A_f = hypothetical fundamental amplitude before cancelation

5 Wave-Amplitude Equations

$\mathcal{I} = kA^2\omega^2 Z$	$\mathcal{I}$ = intensity (w/m^2)	
$U = kA^2\omega^2 Z/c = \mathbb{P}$	U = energy density (J/m^3)	($U = \mathcal{I}/c$) and $U = \mathbb{P}$
$E = kA^2\omega^2 Z\,V/c$	E = energy (J)	($E = \mathcal{I}\,V/c$)
$P = kA^2\omega^2 Z\mathcal{A}$	P = power (J/s)	($P = \mathcal{I}\mathcal{A}$)
$F = kA^2\omega^2 Z\mathcal{A}/c$	F = force (N)	($F = \mathcal{I}\mathcal{A}/c$)

Planck Units

L_p = Planck length	$L_p = T_p c = \sqrt{\hbar G/c^3}$	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	$q_p = e/\sqrt{\alpha} = \sqrt{4\pi\varepsilon_o \hbar c}$	1.876×10^{-18} Coulomb
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
p_p = Planck momentum	$p_p = E_p/c = \sqrt{\hbar c^3/G}$	6.525 kg m/s
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)
$\mathbb{T}_p$ = Planck temperature	$\mathbb{T}_p = E_p/k_B = \sqrt{\hbar c^5/G k_B^2}$	1.417×10^{32} °K
A_p = Planck acceleration	$A_p = c/T_p = \sqrt{c^7/\hbar G}$	5.575×10^{51} m/s^2
ρ_p = Planck density	$\rho_p = m_p/L_p^3 = c^5/\hbar G^2$	5.155×10^{96} kg/m^3
$\mathbb{V}_p$ = Planck electrical potential	$\mathbb{V}_p = E_p/q_p = \sqrt{c^4/4\pi\varepsilon_o G}$	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

Gravitational Γ and *β* (excludes cosmology equalities)

$\Gamma \equiv \frac{dt}{d\tau} = \frac{1}{\sqrt{1-\left(\frac{2Gm}{c^2 R}\right)}} = \frac{1}{1-\beta}$ — Γ = gravitational gamma

$\Gamma \approx 1 + \frac{Gm}{c^2 r} \approx 1 + \beta$ — (weak gravity approximations)

$\beta \equiv 1 - \frac{d\tau}{dt} = 1 - \sqrt{1 - \frac{2Gm}{c^2 R}} = 1 - 1/\Gamma$ — β = gravitational magnitude

$\beta \approx \frac{Gm}{c^2 r} \approx \frac{gr}{c^2} \approx \frac{R_s}{r}$ — (weak gravity approximation)

$\beta_q = H_\beta^2 = \frac{Gm^2}{\hbar c}$ — β_q = gravitational magnitude in a rotar at $ƛ_c$

Properties of Spacetime

$Z_s = \frac{c^3}{G} = 4.038 \times 10^{35}$ kg/s — Z_s = impedance of spacetime

$K_s = \frac{F_p}{ƛ^2}$ — K_s = bulk modulus of spacetime ($K \equiv \frac{\Delta\mathbb{P}}{\Delta V/V}$)

$U_i = \frac{c^2\omega^2}{G} = \frac{F_p}{ƛ^2} = \left(\frac{\omega}{\omega_p}\right)^2 U_p$ — U_i = interactive energy density of spacetime

$A_{max} = \frac{L_p}{ƛ} = T_p\omega$ — A_{max} = maximum displacement amplitude of a dipole wave in spacetime

Charge Conversion Constant

$\eta \equiv \frac{L_p}{q_p} = \frac{\sqrt{\alpha}L_p}{e} = \sqrt{\frac{1}{4\pi\varepsilon_o F_p}} = 8.617 \times 10^{-18}$ m/Coulomb $\quad \eta$ = charge conversion constant

Characteristics of an Electron

$A_\beta = 4.1851 \times 10^{-23}$ — A_β = strain amplitude
$\lambda\!\!\!^{-}_c = 3.8616 \times 10^{-13}$ m — $\lambda\!\!\!^{-}_c$ = rotar radius
$\omega_c = 7.7634 \times 10^{20}$ s^{-1} — ω_c = Compton angular frequency
$\upsilon_c = 1.2356 \times 10^{20}$ Hz — υ_c = Compton frequency
$E_i = 8.1871 \times 10^{-14}$ J — E_i = internal energy
$m_e = 9.1094 \times 10^{-31}$ kg — m_e = electron's mass
$e = 1.6022 \times 10^{-19}$ Coulomb — e = elementary charge
$P_c = 6.3560 \times 10^{7}$ w — P_c = circulating power
$F_m = 0.21201$ N — F_m = maximum force at distance of $\lambda\!\!\!^{-}_c$
$R_s = 6.7635 \times 10^{-58}$ — R_s = classical Schwarzschild radius
$U = E_i/\lambda\!\!\!^{-}_c{}^3 = 1.4218 \times 10^{24}$ J/m^3 — U = energy density (cubic – ignores constant)
$U = (3/4\pi)E_i/\lambda\!\!\!^{-}_c{}^3 = 3.3942 \times 10^{23}$ J/m^3 — U = energy density (spherical)
$a_q = 9.7404 \times 10^{6}$ m/s^2 — a_g = grav acceleration at center of rotar volume
$g_q = 4.0764 \times 10^{-16}$ m/s^2 — g_q = gravitational acceleration at $\lambda\!\!\!^{-}_c$
$\mathbb{I}_e = e\nu_c \approx 19.796$ amps — $\mathbb{I}_e$ = equivalent circulating current
$\mathbb{B}_e = 3.22 \times 10^{7}$ Tesla — $\mathbb{B}_e$ = internal magnetic field

Some Useful Dimensional Analysis Conversions

		Dimensional Analysis Symbols:
$U \to$ M/LT^2	U = energy density	M = mass
$G \to$ L^3/MT^2	G = gravitational constant	L = length
$\hbar \to$ ML^2/T	$\hbar$ = Planck constant	T = time
$Z_s \to$ M/T	Z_s = impedance of spacetime	Q = charge
$Z_o \to$ ML^2/TQ^2	Z_o = impedance of free space	
$E \to$ ML^2/T^2	E = energy	
$F \to$ ML/T^2	F = force	
$\varepsilon_o \to$ T^{2}Q^2/ML^3	ε_o = permittivity	
$\mu_o \to$ ML/Q^2	μ_o = permeability	
$\mathbb{E} \to$ ML/ T^{2}Q	$\mathbb{E}$ = electric field	
$\mathbb{H} \to$ Q/LT	$\mathbb{H}$ = "H" magnetic field (ampere/meter)	
$\mathbb{B} \to$ M/TQ	$\mathbb{B}$ = "B" magnetic field (Tesla)	
$\Omega \to$ ML^2/TQ^2	Ω = resistance	
$\mathbb{V} \to$ ML^2/ T^{2}Q	$\mathbb{V}$ = electrical potential (voltage relative to neutral)	

Normalized Transformations
(assumes coordinate rate of time and proper length is coordinate length)

$L_o = L_g$	unit of length	$M_o = M_g/\Gamma$	unit of mass
$T_o = T_g/\Gamma$	unit of time	$Q_o = Q_g$	charge (coulombs)

$\Theta_o = \Theta_g$	temperature	$\sigma_o = \Gamma^2\ \sigma_g$	Stefan-Boltzmann constant
$C_o = \Gamma\ C_g$	normalized speed of light	$\mathbb{I}_o = \Gamma \mathbb{I}_g$	electrical current
$dR = dL/\Gamma$	circumferential radius	$\mathbb{V}_o = \Gamma\ \mathbb{V}_g$	electrical potential
$E_o = \Gamma\ E_g$	energy	$\varepsilon_{oo} = \varepsilon_{og}/\Gamma$	permittivity of vacuum
$v_o = \Gamma\ v_g$	velocity	$\mu_{oo} = \mu_{og}/\Gamma$	permeability of vacuum
$F_o = \Gamma\ F_g$	force	$p_o = p_g$	momentum
$P_o = \Gamma^2\ P_g$	power	$\alpha_o = \alpha_g$	fine structure constant
$G_o = \Gamma^3\ G_g$	gravitational constant	$\Omega_o = \Omega_g$	electrical resistance
$U_o = \Gamma\ U_g$	energy density	$\mathbb{B}_o = \mathbb{B}_g$	magnetic flux density
$\mathbb{P}_o = \Gamma\ \mathbb{P}_g$	pressure	$Z_{oo} = Z_{og}$	impedance of free space
$\rho_o = \rho_g/\Gamma$	density	$Z_{so} = Z_{sg}$	impedance of spacetime
$\omega_o = \Gamma\ \omega_g$	frequency		
$k_o = \Gamma\ k_g$	Boltzmann's constant		

Transformation of Planck Units into Spacetime Units

Planck Units	Standard Conversion	Spacetime Conversion
Planck length	$L_p = \sqrt{\hbar G/c^3}$	$L_p = cT_p$
Planck mass	$m_p = \sqrt{\hbar c/G}$	$m_p = Z_s T_p$
Planck frequency	$\omega_p = \sqrt{c^5/\hbar G}$	$\omega_p = 1/T_p$
Planck impedance	$Z_p = 1/4\pi\varepsilon_o c$	$Z_p = Z_s$
Planck charge	$q_p = \sqrt{4\pi\varepsilon_o \hbar c}$	$q_p = cT_p$
Planck energy	$E_p = \sqrt{\hbar c^5/G}$	$E_p = c^2 T_p Z_s$
Planck force	$F_p = c^4/G$	$F_p = cZ_s$
Planck power	$P_p = c^5/G$	$P_p = c^2 Z_s$
Planck energy density	$U_p = c^7/\hbar G^2$	$U_p = Z_s/cT_p^2$

Transformation of Standard Units into Spacetime Units

$\eta \equiv \frac{L_p}{q_p} = \frac{\sqrt{\alpha}L_p}{e} = \sqrt{\frac{1}{4\pi\varepsilon_o F_p}} = 8.617 \times 10^{-18}$ m/Coulomb η = charge conversion constant

Name	**Spacetime Conversion**
Elementary charge (e)	$e = \sqrt{\alpha}L_p/\eta = \sqrt{\alpha}\ cT_p/\eta$
Planck charge (q_p)	$q_p = L_p/\eta$
Coulomb force constant ($1/4\pi\varepsilon_o$)	$1/4\pi\varepsilon_o = cZ_s/\eta^2$
Permeability of free space (μ_o)	$\mu_o/4\pi = \eta^2 Z_s/c$
Electric field of EM radiation ($\mathbb{E}_\gamma$)	$\mathbb{E}_\gamma = H\omega\sqrt{Z_s Z_o} = H\omega Z_s \eta$
Magnetic field of EM radiation ($\mathbb{H}_\gamma$)	$\mathbb{H}_\gamma = H\omega\sqrt{Z_s/Z_o} = H\omega/\eta$
Impedance of free space (Z_o)	$Z_o = \eta^2 4\pi Z_s$
Planck impedance (Z_p)	$Z_p = \eta^2 Z_s$
Planck constant ($\hbar$)	$\hbar = c^2 T_p^2 Z_s = L_p^2 Z_s$
Gravitational constant (G)	$G = c^3/Z_s$

Useful Cosmic Information

$\mathcal{H} = 2.29 \times 10^{-18}$ m/s/m $= 70.8$ km/s/Mpc $\qquad$ $\mathcal{H} =$ Hubble parameter

1 parsec (pc) = 3.086×10^{16} m = 3.262 light years

1 light year (ly) = 9.4607×10^{15} m = 6.3241×10^{4} AU

Solar mass 1.989×10^{30} kg $\qquad$ Solar radius 6.96×10^{8} m

Earth mass 5.974×10^{24} kg

Earth radius 6.378×10^{6} m (equator) and 6.357×10^{6} m (polar)

Earth: average acceleration of gravity 9.807 m/s^2 at equator: 9.78 m/s^2

Earth – Sun (mean radial distance) 1.496×10^{11} m = 1 AU

Milky Way galaxy; mass: (1.2 to 3) $\times 10^{42}$ kg; radius: ~50,000 ly; rotation rate ~ 200,000 years

Sun distance to galactic center ~ 27,000 ly

CMB ~ 2.735 °K, ~ 4×10^{8} photons/m^3, CMB energy density 4.2×10^{-14} J/m^3

Sun's motion relative to the CMB ≈ 369 km/s

Planck spacetime: $U_{ps} = 5.53 \times 10^{112}$ J/m^3, quantized energy units: $\tfrac{1}{2}E_p = 9.78 \times 10^{8}$ J

Cosmology

$\Gamma_u(t) = a_u(t) = \dfrac{dt}{d\tau_u}$ $\qquad$ Γ_u = background gamma of the universe

$\Gamma_u(t) = \dfrac{a_u(t)}{a_p} = \dfrac{dL}{d\mathbb{R}}$

$\mathbb{C} = \dfrac{c}{\Gamma_u^2(t)} = \dfrac{d\mathbb{R}}{dt}$ $\qquad$ $\mathbb{C}$ = coordinate speed of light in the universe

$\boldsymbol{C} \equiv \dfrac{d\mathbb{R}}{d\tau_u} = c/\Gamma_u$ $\qquad$ $\boldsymbol{C}$ = hybrid speed of light

$\mathcal{H} = \dfrac{\frac{da_u}{d\tau_u}}{a_o} = \dfrac{\frac{d\Gamma_u}{d\tau_u}}{\Gamma_{uo}}$ or $\mathcal{H} = \dfrac{\dot{a}_u}{a_o} = \dfrac{\dot{\Gamma}_u}{\Gamma_{uo}}$ $\qquad$ $\mathcal{H} =$ Hubble parameter

$\dfrac{\lambda_2}{\lambda_1} = \dfrac{\Gamma_{u1}}{\Gamma_{u2}} = \dfrac{\nu_2}{\nu_1} = \dfrac{a_2}{a_1} = 1 + z$

$\dfrac{U_{ps}}{U_{obs}} = \Gamma_{uo}^3 \times \Gamma_{eq}$ $\qquad$ $\dfrac{U_{ps}}{U_{obs}}$ = energy density ratio - Planck spacetime /observable spacetime

$U_{ps} \equiv \left(\dfrac{3}{8\pi}\right)\left(\dfrac{c^7}{\hbar G^2}\right) \approx 5.53 \times 10^{112}$ J/m^3 $\qquad$ U_{ps} = Planck spacetime energy density

Symbol Definitions (Roman alphabet):

A = wave amplitude
$\mathcal{A}$ = area
a = acceleration
A_f = fundamental amplitude of a spacetime wave prior to any cancellation $A_f = L_p/r$
A_β = strain amplitude in the rotar volume of a rotar
$A_{\beta e}$ = wave amplitude required for a rotar's electromagnetic characteristics at $ƛ_c$
$A_{\beta g}$ = amplitude of the nonlinear wave at distance $ƛ_c$ ($A_{\beta g} = A_\beta{}^2$)
$A_{\beta w}$ = speculative amplitude of the weak force
A_e = amplitude of the wave responsible for electric field of charge e $A_e = \sqrt{\alpha}\, L_p ƛ_c/r^2$
$A_\mathbb{E}$ = electromagnetic non-oscillating strain amplitude $A_\mathbb{E} = \sqrt{\alpha}\frac{L_p}{r} = \sqrt{\alpha}\frac{A_\beta}{\mathcal{N}} = \underline{\mathbb{V}}$
A_{eq} = electric field standing wave amplitude at distance $ƛ_c$ $A_{eq} = \sqrt{\alpha}\, L_p/ƛ_c$
A_{gw} = amplitude of a gravitational wave ($A_{gw} = 2\,\Delta L/L \approx k\, G\, \omega^2 I\, \varepsilon/c^4\, r$)
A_{max} = maximum strain amplitude permitted for a dipole wave
$\mathcal{A}_o$ = cross sectional area in bulk modulus calculation
a_o = cosmological comoving scale factor at the present time
a_p = cosmological scale factor of Planck spacetime (when $\underline{t}_u = 1$)
a_u = cosmological scale factor of the universe relative to Planck spacetime
a_{em} = cosmological scale factor at emission
a_{obs} = cosmological scale factor at observation
a_g = rotar's grav acceleration at the center of the rotar volume
$\mathbb{B}$ = "B" magnetic field; magnetic flux density; magnetic induction
$\mathbb{B}_e$ = electron's internal magnetic field $\mathbb{B}_e \approx 3.22 \times 10^7$ Tesla
$\mathbb{B}_o$ and $\mathbb{B}_g$ = normalized magnetic flux density
c = speed of light (3×10^8 m/s)
C_o = normalized speed of light in zero gravity $C_o = c$
C_g = normalized speed of light in gravity $C_o = \Gamma\, C_g$
C_r = speed of light in the radial direction relative to C_o
C_t = speed of light in the tangential direction relative to C_o
$\boldsymbol{C}$ = hybrid coordinate speed of light $\boldsymbol{C} = d\mathbb{R}/d\tau_u$
$\mathbb{C}_u$ = cosmological coordinate speed of light $\mathbb{C}_u = d\mathbb{R}/dt = c/\Gamma_u{}^2$
$\mathbb{C}_1$ = cosmological coordinate speed of light for $\Gamma_u = 1$
$\boldsymbol{C}_T$ = coordinate speed of light in the tangential direction (Schwarzschild metric $dR = 0$)
$\boldsymbol{C}_R$ = coordinate speed of light in the radial direction (Schwarzschild metric $d\Omega = 0$)
d_m = dipole moment
e = elementary electrical charge ($e = 1.6 \times 10^{-19}$ coulomb)
E = energy
$\underline{E}$ = energy in Planck units: $\underline{E} = E/E_p$
$\mathbb{E}$ = electric field
$\mathbb{E}_\gamma$ = electric field strength in EM radiation
E_i = internal energy for a particle: $E_i = mc^2 = \omega_c \hbar$
E_p = Planck energy $E_p = \sqrt{\hbar c^5/G} = 1.956 \times 10^9$ J
E_ε = energy in the electric field external to "r" for charge e $E_\varepsilon = \alpha\hbar c/2r$

E_{el} = elastic potential energy in the context of bulk modulus
E_g = energy of the mass in gravity but measured using the zero gravity standard of energy
E_g = normalized energy of an object in gravity but measured using zero gravity standards
E_k = kinetic energy of mass falling from zero gravity to distance r from mass M
E_o = energy of a mass in zero gravity measured using the zero gravity standard of energy
E_y = Young's modulus E_y = stress/strain = $FL_o/A_o\Delta L$
E_u = Cosmological unit of energy for $\Gamma_u > 1$
E_1 = Cosmological unit of energy for $\Gamma_u = 1$
F = force
F_e = electromagnetic force - assumes charge e particles $F_e = e^2/4\pi\varepsilon_o r^2$
$\underline{\boldsymbol{F}}_e$ = electromagnetic force in dimensionless Planck units - assumes charge e particles
F_E = electromagnetic force - assumes Planck charge particles $F_e = q_p^2/4\pi\varepsilon_o r^2$
$\underline{\boldsymbol{F}}_E$ = electromagnetic force in dimensionless Planck units - assumes Planck charge particles
F_g = gravitational force $F_g = (G\,mM)/r^2$
$\underline{\boldsymbol{F}}_g$ = gravitational force in Planck units: $\underline{\boldsymbol{F}}_g = F_g/F_p$
F_g = normalized force in gravity but using zero gravity standards (note symbol duplication)
F_o = normalized force in zero gravity
F_m = maximum force possible at a distance of $\lambdabar_c = m^2c^3/\hbar$
F_s = the strong force at distance $\lambdabar_c$
F_p = Planck force $F_p = c^4/G$ $F_p = 1.210 \times 10^{44}$ N
F_r = relativistic force $F_r = P/c$
F_w = weak force at distance $\lambdabar_c$
g = acceleration of gravity
G = gravitational constant
G_o and G_g = normalized gravitational constant using zero gravity standards
$g_{oo}, g_{11}, g_{22}, g_{33}$ = general relativity matrix coefficients
$\mathbb{H}$ = "H" magnetic field; magnetic field strength; magnetic field intensity
$\mathbb{H}_\gamma$ = magnetic field strength in EM radiation
$\mathcal{H}$ = Hubble parameter currently $\mathcal{H} \approx 2.29 \times 10^{-18}$ m/s/m
h = Planck constant $h = 6.626 \times 10^{-34}$ J s
$\hbar$ = reduced Planck constant: $h\ bar = \hbar = h/2\pi = 1.055 \times 10^{-34}$ J s
$\mathbb{I}$ = electrical current
$\mathbb{I}_e$ = electron's equivalent circulating current $I_e = ev_c \approx 19.796$ amps
$\mathcal{I}$ = intensity
I = moment of inertia
k = dimensionless constants (k_1, k_2, etc.)
$k' = 3/8\pi$ (a constant used in cosmology)
K_b = bulk modulus
k_B = Boltzmann constant $\approx 1.38 \times 10^{-23}$ J/m^3
K_B = bulk modulus
K_p = Planck bulk modulus = $c^7/\hbar G^2$
K_s = bulk modulus of spacetime: $K_s = F_p/\lambdabar^2 = F_p(\omega/c)^2$
L = dimensional analysis symbol representing length
L_g = normalized length $dL_g = cd\tau$
L_o = normalized length $dL_o = cdt$

L_o = in the context of Young's modulus, L_o is the original length before stress
$\mathcal{L}$ = angular momentum
$\mathcal{L}_o$ and $\mathcal{L}_g$ = normalized angular momentum
L_r & L_t = proper length in the radial or tangential direction respectively
l_p = Planck length = $\sqrt{\hbar G/c^3}$ = 1.616 × 10^{-35} m (a static unit of length)
L_p = dynamic Planck length (wave amplitude of l_p)
L_u = cosmological unit of length for $\Gamma_u > 1$
m = mass
$\underline{\boldsymbol{m}}$ = mass in dimensionless Planck units: $\underline{\boldsymbol{m}} = m/m_p$
m_p = Planck mass $m_p = \sqrt{\hbar c/G}$ = 2.176 × 10^{-8} kg
m_e = mass of an electron = 9.1094 × 10^{-31} kg
m_r = pseudo rest mass when index of refraction $n > 1$
M = dimensional analysis symbol representing mass
M_0 and M_g = normalized unit of mass
M_u = cosmological unit of mass for $\Gamma_u > 1$
$\mathbb{M}_1$ = cosmological unit of mass for $\Gamma_u = 1$
N = an integer number
$\mathcal{N}$ = the distance between two rotars expressed as a multiple of $ƛ_c$ ($\mathcal{N} = r/ƛ_c$)
n_k = the index of refraction which includes the optical Kerr effect contribution
n_o = the index of refraction at zero intensity
p = momentum
p_p = Planck momentum $p_p = m_p c = \sqrt{\hbar c^3/G} \approx 6.525$ kg m/s
P = power
P_c = a Particle's circulating power: $P_c = E_i\,\omega_c$
$\underline{\boldsymbol{P}}_c$ = circulating power in Planck units: $\underline{\boldsymbol{P}}_c = P_c/P_p$
$\mathbb{P}$ = pressure
$\mathbb{P}_p$ = Planck pressure $\mathbb{P}_p = c^7/\hbar G^2$ = 4.636 × 10^{113} N/m^2 $(= U_p)$
P_p = Planck power $P_p = c^5/G$ = 3.63 × 10^{52} w
$\mathbb{P}_q$ = pressure generated by a rotar $\mathbb{P}_q = (\omega_c{}^4\hbar/c^3) = E_i/ƛ_c^3 = U_q$
q = electrical charge
Q_o, & Q_g = dimensional analysis units of charge used in various transformations
Q_1 = cosmological unit of charge for $\Gamma_u = 1$
Q_u = cosmological unit of charge for $\Gamma_u > 1$
q_p = Planck charge = $\sqrt{4\pi\varepsilon_0\hbar c}$ = $e/\sqrt{\alpha} \approx 11.7e \approx 1.876 \times 10^{-18}$ Coulomb
r = radial distance (proper length)
R = circumferential radius from general relativity (circumference/2π)
$\mathbb{R}$ = a unit of coordinate length pertaining to cosmology $d\mathbb{R} = dL_u/\Gamma_u$
$\mathbb{R}_1$ = cosmological unit of length for $\Gamma_u = 1$
r_h = radius of the Hubble sphere
r_{ph} = radius of the particle horizon
R_s = classical Schwarzschild radius: $R_s = Gm/c^2$
r_s = relativistic Schwarzschild radius $r_s = 2Gm/c^2$
$ƛ_c$ ≡ rotar radius of a rotar $ƛ_c \equiv \hbar/mc$ ($ƛ_c$ = reduced Compton radius)
$ƛ_c$ = rotar radius in Planck units: $\underline{\boldsymbol{ƛ}}_c = ƛ_c/L_p$
t = either time or coordinate time (depends on context)

t_c = time indicated on the coordinate clock
T = dimensional analysis symbol representing time
T_g = normalized unit of time in gravity
T_o = normalized unit of time in zero gravity
T_u = cosmological unit of time for $\Gamma_u > 1$
$\mathbb{T}_1$= cosmological unit of time for $\Gamma_u = 1$
t_p = Planck time $t_p = \sqrt{\hbar G/c^5} = 5.391 \times 10^{-44}$ s
T_p = dynamic Planck time (a wave amplitude with dimension of Plank time)
$\mathbb{T}$ = temperature
$\mathbb{T}_p$ = Planck temperature = $E_p/k_B \approx 1.4168 \times 10^{32}$ °K
u_d = de Broglie wave group velocity $u_d = v$
U = energy density
U_{el} = energy density of elastic potential energy (bulk modulus)
U_i = interactive energy density encountered by a wave in spacetime $U_i = c^2\omega^2/G$
U_o = energy density in coordinate units (assumes $\Gamma = 1$)
U_g = energy density in a location with gravity ($\Gamma > 1$)
U_u = energy density in the universe when $\Gamma_u > 1$
U_p = Planck energy density $U_p = c^7/\hbar G^2 = 4.636 \times 10^{113}$ J/m^3
U_{ps} = energy density of Planck spacetime $U_{ps} = (3/8\pi)(c^7/\hbar G^2) \approx 5.53 \times 10^{112}$ J/m^3
U_q = energy density of a rotar $U_q = E_i/ƛ_c^3 = (\omega_c{}^4\hbar/c^3) = \mathbb{P}_q$
U_u = cosmological unit of energy density for $\Gamma_u > 1$
U_1 = cosmological unit of energy density for $\Gamma_u = 1$
v = velocity
v_e = escape velocity $v_e = (2Gm/r)^{1/2}$
V = Volume
V_r = rotar volume $V_r = ƛ_c^3$ (cubic) $V_r = (4\pi/3)ƛ_c^3$ (spherical)
$\mathbb{V}$ = Electrical potential
$\underline{\mathbb{V}}$ = Voltage (electrical potential) in Planck units: $\underline{\mathbb{V}} = \mathbb{V}/\mathbb{V}_p$
$\mathbb{V}_p$ = Planck electrical potential (voltage) $\mathbb{V}_p = \sqrt{c/4\pi\varepsilon_o G}$
w_d = de Broglie wave phase velocity $w_d = c^2/v$
w_m = velocity of the modulation wave envelope (moving resonator) $w_m = c^2/v$
$\mathbb{X}$ = maximum displacement produced by dipole wave in spacetime
z = cosmological redshift
z_{eq} = cosmological redshift since the radiation/matter equality transition
$\Gamma_{eq} = \Gamma_u$ at the radiation/matter equality transition
Z = impedance
Z_s = impedance of spacetime $Z_s = c^3/G = 4.04 \times 10^{35}$ kg/s
Z_{s1} = cosmological impedance of spacetime for $\Gamma_u = 1$
Z_{su} = cosmological impedance of spacetime for $\Gamma_u > 1$
Z_e = electromagnetic impedance of free space $Z_e \approx 377\ \Omega$
Z_a = acoustic impedance $Z_a = \rho c_a$ (density × speed of sound)
Z_{oo} = normalized impedance of free space (zero gravity)
Z_{og} = normalized impedance of free space (in gravity)
Z_p = Planck impedance (electromagnetic) $Z_p = 1/4\pi\varepsilon_o c \approx 29.98\ \Omega$

Greek Symbols

α = fine structure constant $\alpha = e^2/4\pi\varepsilon_o\hbar c$ ≈ 1/137.036
β = gravitational magnitude $\beta \equiv 1 - (1 - 2Gm/c^2R)^{1/2} = 1 - 1/\Gamma = 1 - d\tau/dt \approx gm/c^2r$
β_q = gravitational magnitude at distance $ƛ_c$ $\beta_q = H_\beta^2 = Gm^2/\hbar c$
β_u = background gravitational magnitude of the universe $\beta_u = 1 - 1/\Gamma_u = 1 - d\tau_u/dt$
Γ = gravitational gamma $\Gamma = (1-2Gm/rc^2)^{-1/2}$
Γ_q = gravitational gamma at distance of $ƛ_c$ $(\Gamma_q - 1) \approx (Gm^2/\hbar c)$
Γ_u = background gravitational gamma of the universe $\Gamma_u = dt/d\tau_u = a_u/a_p$
Γ_{uo} = the current value of Γ_u where: $\Gamma_{uo} \approx 2.6 \times 10^{31}$
$\Gamma_{obs} = \Gamma_u$ at the time an observation of a photon is made
$\Gamma_{em} = \Gamma_u$ at the time of emission of a photon
$\Gamma_{eq} = \Gamma_u$ at the radiation/matter equality transition
γ = special relativity gamma $\gamma = (1 - v^2/c^2)^{-1/2}$
ε = asymmetry of an object - uniform sphere has $\varepsilon = 0$, two equal point masses have $\varepsilon = 1$
ε_o = permittivity of vacuum
ξ = spin axis probability
ξ_a = acoustic amplitude (particle displacement)
η = charge conversion constant $\eta \equiv L_p/Q_p = 8.617 \times 10^{-18}$ meters/Coulomb
Θ_o and Θ_g = normalized temperature
θ = angle symbol
λ = wavelength
$ƛ$ = reduced wavelength: lambda bar = $ƛ = \lambda/2\pi = c/\omega$
λ_d = De Broglie wavelength $\lambda_d = h/mv$
λ_{dd} = wavelength of confined photon in moving frame of reference (relativistic contraction)
λ_m = modulation envelope wavelength; $\lambda_m = \lambda_o c/v$
λ_c = Compton wavelength $\lambda_c = h/mc$
$ƛ_c$ = reduced Compton wavelength $ƛ_c = \hbar/mc = \lambda_c/2\pi$
λ_o = original wavelength or wavelength in zero gravity
λ_g = wavelength in gravity (blue shifted)
λ_{em} & λ_{obs} = wavelength at emission and observation respectively
λ_γ = wavelength of confined light (chapter 1)
$\boldsymbol{\lambda}$ = wavelength of light when measured in units of coordinate length.
Λ = cosmological constant
μ_B = Bohr magnetron = $e\hbar/2m_e = 9.274 \times 10^{-24}$ J/Tesla
μ_o = permeability of vacuum $\mu_o = 4\pi\times10^{-7}$ m kg/C^2 = 1.257×10^{-6} m kg/C^2
ν = frequency
ν_c = Compton frequency $\nu_c = mc^2/h$
υ_{obs} & υ_{em} = cosmological observed frequency & emitted frequency
ρ = matter density
ρ_p = Planck density $\rho_p = c^5/\hbar G^2$

σ = Stefan-Boltzmann constant: $\sigma = 5.670373 \times 10^{-8}$ W m^{-2} K^{-4}
τ = proper time – time interval on a local clock
τ_d = time indicated on the dipole clock
τ_{obs} = (cosmological) proper age of the universe at the time an observation is made
τ_{em} = (cosmological) proper age of the universe at the time of emission of a photon
τ_u = (cosmological) proper age of the universe at arbitrary time (cosmic time)
τ_{uo} = (cosmological) current proper age of the universe (cosmic time)
$\underline{\boldsymbol{\tau}}_u$ = (cosmological) age of the universe in nondimensional Planck units $\underline{\boldsymbol{\tau}}_u = \tau_u/t_p$
$\mathcal{T}$ = emission lifetime
χ = distance in comoving coordinates
Ψ = psi function
ω = angular frequency
ω_c = Compton angular frequency of a Particle $(\omega_c = mc^2/\hbar)$
$\underline{\boldsymbol{\omega}}_c$ = Compton angular frequency in Planck units: $\underline{\boldsymbol{\omega}}_c = \omega_c/\omega_p$
ω_p = Planck angular frequency $\omega_p = \sqrt{c^5/\hbar G} = 1.855 \times 10^{43}$ s^{-1}
Ω = a solid angle in a spherical coordinate system $(d\Omega^2 = d\theta^2 + \sin^2\theta\, d\Phi^2)$
Ω = symbol representing electrical resistance
Ω_M = matter density parameter
Ω_Λ = cosmological constant density parameter

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