

The Quintuple Identity

Photon = graviton = gluon = phonon = magnon:
one stroke of the one medium, the same in every regime

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Fundamental Density Theory

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Abstract

In Fundamental Density Theory photon, graviton, gluon, phonon and magnon are one carrier: the stroke of the omnium, read in five regimes (core I-2). This paper proves that the stroke's type is the same in every regime, and with I-2's placement of the five names that is the identity. A carrier's type is fixed by six readings taken on the stroke's own terms: the medium it disturbs, the null form of its two grades, its rate measured on the spot, its action per cycle, its angular momentum per quantum and the share of its rate that circulates. The omnium's two response coefficients give the stroke one equation with one rate, $c^2 = 1/(\varepsilon_0\mu_0)$, and a null pair of grades, $F = \mathbf{E} + cI_3\mathbf{B}$ with $F^2 = 0$. Clocks and rulers are closed strokes, so every stroke measured on the spot runs at c , and the central invariant $E/m = c^2 = 1/(\varepsilon_0\mu_0) = (d/t)^2$ gives that one rate to the quantum, the electromagnetic and the gravitational readings; the field equations carry it too, so the geometry's own ripple runs at c . Planck's bridge gives h per cycle. The grades of a stroke of definite hand turn about its run, and their spin density gives $1/\omega$ per unit energy about the run: $\hbar$ per quantum, the momentum E/c times the radius $\bar{\lambda} = c/\omega$ of a helix standing at $\pi/4$ at every frequency. The stroke runs its whole rate and keeps no time. None of the six readings depends on frequency, amplitude, direction, hand, support, boundary data or the density crossed. A regime is geometry: a density gradient read through the clock factor and the optical metric, the boundary data of a closed pattern's support, the clamps of a vibrating volume, a helical density gradient. A change of regime changes the mode's geometry and the bookkeeper's readings of it and leaves the type of every component unchanged, among clamps for the components transverse to the line (Theorem 1), and photon = graviton = gluon = phonon = magnon follows (Theorem 2): Einstein's identification of gravity with geometry, carried to every carrier. Closure flips the stroke's run into circulation, a change of type, so the braided closures of matter keep time and stand outside the identity, made of the stroke; read as carriers, the chain is QM = EM = GR. Gravity's ripple carries $2/\omega$ per unit energy about its run on a binary's axis, which no linear composition of the stroke carries; its composition from the stroke is bilinear, and two quanta of one hand at the binary's orbital rate carry $2\hbar$ in $2\hbar\Omega_{\text{orb}} = \hbar\omega$, Planck's bridge kept. How the stroke's quanta compose the ripple, the graviton's place as its carrier, is to be derived, as are the longitudinal branch among clamps and the turning of the stroke's twist in a helical gradient. The record agrees: the gravitational and electromagnetic strokes of GW170817 ran at one rate to within -3×10^{-15} and $+7 \times 10^{-16}$; circularly polarized light carries $\hbar$ per quantum; the gluon of three-jet events has spin one; creating a magnon flips a neutron's spin; polarized phonons carry angular momentum; and magnons, phonons and photons share hybrid modes wherever their regimes meet. A receipt script checks the displayed identities and numbers: 57/57 pass.

1 One medium, one carrier

Einstein's equivalence principle identified gravity with geometry. A freely falling laboratory carries no reading of the field it falls through; what remains, the tide between neighbouring falls, is curvature, and the field equations make that curvature the geometry of the source [4, 5]. Fundamental Density Theory carries the identification further. There is one substance, the omnium, and the central invariant

$$\frac{E}{m} = c^2 = \frac{1}{\varepsilon_0 \mu_0} = \left(\frac{d}{t}\right)^2 \quad (1)$$

is one identity, read by quantum mechanics, electromagnetism and general relativity (core 0.1). A carrier is a disturbance of a medium at that medium's speed. The chain gives one speed to every reading, and there is one medium for the readings to be disturbances of; hence there is one carrier, the stroke, and the five names photon, graviton, gluon, phonon and magnon are the stroke read in different density and geometry regimes (I-2):

$$\text{photon} = \text{graviton} = \text{gluon} = \text{phonon} = \text{magnon}. \quad (2)$$

This paper proves that the stroke's type is the same in every regime, on the locked core v6.2 [1] and its companion derivation of c [2]; with I-2's placement of the five names in their regimes, that is (2). A carrier's type is fixed by six readings taken on the stroke's own terms: the medium it disturbs, the null form of its two grades, its rate measured on the spot, its action per cycle, its angular momentum per quantum and the share of its rate that circulates (§3). Each is the medium's, and none depends on the frequency, the amplitude, the direction or the hand of the stroke (§4). A regime is geometry: the clock factor and the optical metric of a density gradient, the boundary data of a closed pattern's support, the clamps of a vibrating volume, a helical density gradient. A change of regime changes the geometry of the mode and the bookkeeper's readings of it, and leaves the type unchanged (Theorem 1, §5). The five names are the stroke in five regimes, and (2) follows (Theorem 2, §6). The theorem is Einstein's identification carried to every carrier: no reading on the stroke's own terms tells the regime it runs in, and the regime is the geometry it runs through. A regime's density therefore enters the identity as geometry, never as an address of the carrier.

Two further results follow. Closure flips the stroke's run into circulation, a change of type: a closed pattern keeps time, and the braided closures of matter stand outside (2) while being made of the stroke (Proposition 2). Read as carriers, the chain (1) is QM = EM = GR, with one force law and nothing mediated (§7). Gravity's ripple is read in §8, where its angular momentum shows that its composition from the stroke is bilinear and fixes the target of the graviton's place as its carrier, which is to be derived; the record and the tests are in §9, the declined readings and the convergence statement in §10. The receipt script of Appendix A checks the displayed identities and numbers; check labels appear in brackets, [Q05b].

2 Premises, charts and symbols

The derivation uses the locked core v6.2 [1]; each premise is quoted by section.

- (P1) *One substance, only patterns.* There is one substance, the omnium, and there are only its patterns; a room, box or cell is a pattern's own support with its own boundary data, never a vessel (0.1, 0.1b).

- (P2) *The chain is one state.* The four terms of (1) adjust together, and the bridges are constants of the medium: $E_q = m_q c^2 = \hbar \omega_q$, $T_q = 2\pi/\omega_q = \hbar/E_q$, $\ell_q = cT_q = \hbar/(m_q c)$, with $d/t = c = 299\,792\,458 \text{ m s}^{-1}$ exactly. The floor $F_{\max} d_{\min} t_{\min} = \hbar$, $d_{\min} = c t_{\min}$, gives $d_{\min} = 2\ell_P$ and $t_{\min} = 2t_P$, an infimum approached and never occupied (0.1a).
- (P3) *Two responses, one rate.* ε_0 and μ_0 are response coefficients of the omnium. In a region crossed by no closed pattern the two grades drive each other, $\nabla \times \mathbf{E} = -\partial_t \mathbf{B}$ and $\nabla \times \mathbf{B} = \varepsilon_0 \mu_0 \partial_t \mathbf{E}$, with $\nabla \cdot \mathbf{E} = 0 = \nabla \cdot \mathbf{B}$, and give $\nabla^2 f - c^{-2} \partial_t^2 f = 0$ with $c^2 = 1/(\varepsilon_0 \mu_0)$, isotropic. Inside a closed pattern's own support and in the interstitial omnium among clamps the medium is the same omnium with the same two responses, so the stroke obeys the same local law there (0.1b, 0.1d); the closures enter as boundary data, and mode geometry is set by the boundary conditions, not by the medium (P-2, P-3). Clocks and rulers are closed strokes, so a stroke measured on any pattern's own clocks and rulers returns one number, the ratio of two of their scales, and every outside rate and every common rescaling cancels. The stroke is the null multivector $F = \mathbf{E} + cI_3 \mathbf{B}$, $F^2 = 0$ (0.1, 0.1d).
- (P4) *The carrier and its helix.* A carrier is a disturbance of a medium at that medium's speed. An open stroke runs straight at c and keeps no time; its grades turn about the run on a helix of radius $\bar{\lambda} = \hbar c/E = c/\omega = \lambda/2\pi$, standing at $\pi/4$ at every frequency, and its momentum E/c carries its spin $\hbar$ at that radius (I-2). A closed pattern's strand runs at c on a helix, $v^2 + u^2 = c^2$, and keeps time by circulating, $c d\tau = u dt$ (0.1d).
- (P5) *Two readings.* A pattern's kept time and thread length rescale together by the clock factor $\mathbf{m}$ with the density it crosses; $g_{\mu\nu} \mapsto \mathbf{m}^2 g_{\mu\nu}$ keeps $d/t = c$ on the spot, every ratio of the chain and the null cone, and the pattern's clocks run slower toward smaller $\mathbf{m}$. A conformal clock factor never bends a stroke; strokes bend by the optical metric of I-3 (0.1c).
- (P6) *The geometry.* $G_{\mu\nu} = \kappa T_{\mu\nu}$ stands unchanged, $\kappa = 8\pi G/c^4$, $\kappa F_{\max} = 2\pi$; on the exterior branch the exact optical metric is $d\ell_{\text{opt}}^2 = dr_f^2/(1-\alpha_{\text{ext}})^2 + r_f^2 d\Omega^2/(1-\alpha_{\text{ext}})$, and generalized Snell's law is its Fermat law. For the same source and data FDT and GR return the same curvature (I-3, containment). Curvature is read between neighbours (I-3a).
- (P7) *The regimes' geometry.* A closed pattern has its own support Ω and boundary data B , and its modes obey $D(\Omega, B; n, \chi, t) u_q = \omega_q u_q$ with cost $m_q c^2 = \hbar \omega_q$ (I-5). Observed structure is nodal architecture: mode geometry is set by the boundary conditions, the clamps of saturated nuclear cores, not by the medium (P-2, P-3). A magnetic field is a helical density gradient of the omnium, the bivector grade of the density field coherently aligned along an axis (P-5).
- (P8) *Settlement.* Every step is a system-wide settlement of the state it starts from; responses are many-to-many, never particle by particle (0.1a).
- (P9) *The five names placed.* The photon is the stroke in a region crossed by no closed pattern; the graviton is the stroke in the gravitational regime, the carrier of the geometry's adjustment to a changing source; the gluon is the stroke standing inside a closed pattern's own region; the phonon is the medium's stroke among the clamps of a vibrating volume; the magnon is the stroke through a helical density gradient (I-2, P-2, P-3, P-5).

Charts. The five regimes of I-2 are named; they are not ranked, spaced or given density addresses (A-5). Two readings on the A-1 compactness chart, exterior branch $\sigma = +1$, appear. In the gravitational regime of a source, $\alpha_{\text{ext}} = R_s/r_f$, with $R_s = 2G\mathcal{M}/c^2 = \mathcal{M}c^2/(2F_{\max})$ and $x \equiv r_f/R_s$;

it enters through the lapse $N = \sqrt{1 - \alpha_{\text{ext}}}$ and the optical metric. In the force law of §7 the I-1 inputs are each body's exterior reading at the separation, $\alpha_i(d) = R_{s,i}/d$, on two nonoverlapping spherical supports. The clock factor $\mathbf{m}$ and the lapse N are not an α and occupy no force, optical or density slot. On the A-1 chart the seam is $r_f = 2R_s$; the fold $r_f = R_s$ is a limit, never reached (0.3a, I-6).

symbol	meaning
$\mathbf{E}, \mathbf{B}, F, \mathbf{A}$	the stroke's vector grade and twist grade; $F = \mathbf{E} + cI_3\mathbf{B}$, with I_3 the unit pseudoscalar of space; a component's potential, $\mathbf{E} = -\partial_t\mathbf{A}$, $\mathbf{B} = \nabla \times \mathbf{A}$
$\omega, k, \lambda, \bar{\lambda}, \pm$	angular frequency, wavenumber, wavelength, helix radius $\bar{\lambda} = \lambda/2\pi = c/\omega$ and hand of a component
E, T, m_E	energy of one quantum, its period, its mass reading E/c^2
$ \mathcal{S} , c_{\text{spot}}$	angular momentum per quantum about the run; rate measured on the spot
v, u	translation and circulation of a strand, $v^2 + u^2 = c^2$; u/c the share of the rate that circulates (0.1d)
$\mathfrak{M}$	the medium a disturbance belongs to
$\tau(p)$	the type of a presentation p (Definition 2)
$\mathbf{m}, N$	clock factor of 0.1c; lapse $\sqrt{1 - \alpha_{\text{ext}}}$ of a source's exterior
Ω, B, D, q	support and boundary data of a mode; confinement operator; mode label (I-5)
a, μ, c_s	clamp spacing and loading on a line; transport speed of a long-wave mode
$\mathbf{w}, \Sigma, \mathbf{f}$	strand spinor $v + u\Sigma$; unit bivector of the strand plane; spinor flip $\mathbf{f}(\mathbf{w}) = \Sigma\tilde{\mathbf{w}}$ (0.1d)
Ω_{orb}, J	orbital rate and angular momentum of a radiating source

3 The type of a carrier

Definition 1 (Components and presentations). The stroke equation of (P3) is linear. A disturbance of the omnium is a solution of it, and its *components* are the open strokes of definite frequency ω , direction and hand $\pm$ into which it decomposes; inside a support or among clamps the components are those of the local law between the closures, with the closures as boundary data (P3). A closed pattern is not a solution of the stroke equation, and it has no components. A *presentation* p is a disturbance together with its regime: the geometry it runs in, namely its frequencies, the support Ω and boundary data B of its mode, and the density it crosses, read through the clock factor and the optical metric.

Definition 2 (Type). The *type* of a presentation is

$$\tau(p) = (\mathfrak{M}, F^2, c_{\text{spot}}, ET, |\mathcal{S}|, u/c), \quad (3)$$

read on each component: $\mathfrak{M}$ the medium of which the component is a disturbance; F^2 the square of its grades, $F = \mathbf{E} + cI_3\mathbf{B}$; c_{spot} its rate measured on the spot by closed patterns' clocks and rulers; ET the energy of one quantum times its period; $|\mathcal{S}|$ the magnitude of the angular momentum one quantum carries about its run; and u/c the share of the rate that circulates on the strand the reading is taken on, its kept time per unit of the rate: on a component, its run; on a closed pattern, its own strand (0.1d). $\tau(p)$ is defined when every component of p gives the same six entries.

Definition 3 (Carrier identity). Two presentations are one carrier, $p \equiv p'$, when $\tau(p) = \tau(p')$.

The relation is reflexive, symmetric and transitive, because equality of types is: it is the kernel of τ . Its content lies in τ , which is computed from the stroke's local law and read on the stroke's own terms; nothing in Definition 3 is identified by naming. Every entry of (3) is a reading a pattern can

make where the stroke passes. The frequency, the direction, the hand, the support, the boundary data and the density crossed are deliberately absent: the hand labels a component as its direction does, and the rest are the regime, and the regime is what the identity is about.

4 The type is the medium's

Lemma 1 (One medium). *Every component of every presentation is a disturbance of the omnium.*

Proof. There is only omnium and its patterns (0.1b); a disturbance is a configuration of the one medium, whatever the regime. $\square$

Lemma 2 (One equation, null grades). *In a region crossed by no closed pattern the two responses give every Cartesian component of the grades the stroke equation*

$$\nabla^2 f - \frac{1}{c^2} \partial_t^2 f = 0, \quad c^2 = \frac{1}{\varepsilon_0 \mu_0}. \quad (4)$$

A component of hand $\pm$ running along $\hat{\mathbf{x}}$, with $\varphi = kx - \omega t$,

$$\mathbf{E} = E_0 (\hat{\mathbf{y}} \cos \varphi \mp \hat{\mathbf{z}} \sin \varphi), \quad \mathbf{B} = \frac{E_0 k}{\omega} (\hat{\mathbf{z}} \cos \varphi \pm \hat{\mathbf{y}} \sin \varphi), \quad (5)$$

has $|\mathbf{E}|^2 - c^2 |\mathbf{B}|^2 = 0$ and $\mathbf{E} \cdot \mathbf{B} = 0$, so

$$F^2 = (|\mathbf{E}|^2 - c^2 |\mathbf{B}|^2) + 2cI_3 \mathbf{E} \cdot \mathbf{B} = 0. \quad (6)$$

A linearly polarized stroke is the sum of the two hands.

Proof. Faraday's circulation law holds for the pair (5) identically; Ampère's fixes $\omega^2 = k^2/(\varepsilon_0 \mu_0)$, so every component runs at the one rate c and obeys (4). [Q02a–c] With $\omega = ck$, $|\mathbf{B}| = E_0/c$, and the two grades are orthogonal to each other and to the run. [Q03a, Q03b] The CODATA 2022 values take μ_0 from the measured fine-structure constant and set $\varepsilon_0 = 1/(\mu_0 c^2)$, so with them $1/(\varepsilon_0 \mu_0) = c^2$ holds to the last digit [6]. [Q01c] $\square$

Lemma 3 (One rate in every reading). *The rate c of (4) is the rate of the quantum, the electromagnetic and the gravitational readings, and of the geometry's own adjustment; measured on the spot, every stroke runs at it.*

Proof. (a) The electromagnetic reading is (4). (b) The quantum reading $E/m = c^2$ and the gravitational reading $(d/t)^2 = c^2$ are the other entries of the one identity (1), held together by the bridges of (P2): $E_q/m_q = c^2$ and $\ell_q/T_q = c$ for every mode. [Q01a, Q01b, Q04b, Q04c] (c) The field equations carry the same rate. $\kappa = 8\pi G/c^4 = 2\pi/F_{\max}$ is built from it, [Q17a] and wherever the field is weak, I-3 linearized in harmonic gauge reads

$$\left(\nabla^2 - \frac{1}{c^2} \partial_t^2 \right) \bar{h}_{\mu\nu} = -2\kappa T_{\mu\nu}, \quad (7)$$

whose characteristic rate is the c of (4): the adjustment of the geometry to a changing source, gravity's ripple, runs at the stroke's rate. (d) Clocks and rulers are closed strokes. A stroke that passes a clock whose tick is a strand length Λ_C and a ruler of length Λ_R reads Λ_C/Λ_R rulers per tick whatever rate strokes run at in any outside bookkeeping and whatever common rescaling the region has undergone, because the clock is made of the thing it times (0.1d). The rate on the spot is c in every reading and every region. $\square$

Lemma 4 (One action per cycle). *Every quantum of every stroke carries $ET = h$.*

Proof. $E_q = \hbar\omega_q$ and $T_q = 2\pi/\omega_q$ give $E_q T_q = 2\pi\hbar = h$ for every ω_q (0.1a). [Q04a] The 21 cm line of hydrogen shows one state read four ways: $E = h\nu = 9.41 \times 10^{-25} \text{ J} = 5.874 \text{ } \mu\text{eV}$, $m_E = E/c^2 = 1.047 \times 10^{-41} \text{ kg}$, $T = 0.704 \text{ ns}$ and $\ell = cT = 21.106 \text{ cm}$. [Q04d, Q04e] $\square$

Lemma 5 (One quantum of angular momentum; the helix at $\pi/4$). *A component of hand $\pm$ carries angular momentum $\pm\hbar$ per quantum about its run, at every energy: $1/\omega$ per unit energy. Its grades turn about the run on a helix of radius $\bar{\lambda} = c/\omega$, standing at $\pi/4$ at every frequency.*

Proof. The component (5) has the potential $\mathbf{A} = (E_0/\omega)(\hat{\mathbf{y}} \sin \varphi \pm \hat{\mathbf{z}} \cos \varphi)$, with $\mathbf{E} = -\partial_t \mathbf{A}$ and $\mathbf{B} = \nabla \times \mathbf{A}$. [Q05a] Its spin density and its energy density are

$$\varepsilon_0 \mathbf{E} \times \mathbf{A} = \pm \frac{\varepsilon_0 E_0^2}{\omega} \hat{\mathbf{x}}, \quad \frac{\varepsilon_0}{2} (|\mathbf{E}|^2 + c^2 |\mathbf{B}|^2) = \varepsilon_0 E_0^2, \quad (8)$$

so the angular momentum per unit energy about the run is $\pm 1/\omega$; [Q05b] a linearly polarized stroke, the sum of the two hands, carries none. [Q05c] Per quantum, $E = \hbar\omega$, the angular momentum is $\pm\hbar$: the momentum E/c of one quantum times the radius $\bar{\lambda} = c/\omega$ of the cylinder on which its grades turn,

$$|\mathcal{S}| = \frac{E}{\omega} = \frac{E}{c} \bar{\lambda} = \frac{E}{c} \cdot \frac{\hbar c}{E} = \hbar, \quad (9)$$

and the energy cancels (I-2). [Q05d] The helix advances one wavelength $\lambda = 2\pi\bar{\lambda}$ per turn around a circumference $2\pi\bar{\lambda}$, so it stands at $\pi/4$ at every frequency, and its turning rate $\omega\bar{\lambda} = c$ equals its run, the non-dispersive stroke $\omega = ck$ (I-2). [Q05e, Q05f] A rotation by θ about the run turns the grades by θ : [Q14b] one quantum $\hbar$ about the run is spin one. $\square$

Lemma 6 (Open: the whole rate translates). *An open stroke runs its whole rate as translation, $v = c$ and $u = 0$, and keeps no time.*

Proof. The boost with parameter c carries the run $x = ct$ onto $x' = ct'$, so the stroke runs at c in every frame. [Q06a] The strand relation $v^2 + u^2 = c^2$ of (P4) with $v = c$ gives $u = 0$, [Q06b] and a pattern keeps time by circulating, $c d\tau = u dt$, so the stroke keeps none. The turning of its grades is not a clock it keeps (I-2). $\square$

Proposition 1 (The type of the stroke). *Every open stroke has the type*

$$\tau_{\text{stroke}} = (\text{omnium}, 0, c, h, \hbar, 0), \quad (10)$$

whatever its frequency, amplitude, direction and hand.

Proof. Lemmas 1–6; no entry contains ω , the amplitude E_0 , the direction of the run or the hand. $\square$

5 The type in every regime

Theorem 1 (Regime invariance). *Let p be the stroke in any of the regimes*

- (R1) *a density gradient, read through the clock factor $\mathbf{m}$ (0.1c);*
- (R2) *the static exterior of a source, read through its lapse and its optical metric (I-3);*
- (R3) *the support and boundary data of a closed pattern's own region (I-5, P-2);*

(R4) the clamps of a vibrating volume, for the components transverse to the clamps' line (P-2, P-3);

(R5) a helical density gradient (P-5).

Then every component of p has the type τ_{stroke} . The regime sets the geometry of the mode and the bookkeeper's readings of it; it leaves the type unchanged.

Proof. (R1) The clock factor. The rescaling $g_{\mu\nu} \mapsto \mathbf{m}^2 g_{\mu\nu}$ keeps $d/t = c$ on the spot and keeps every null direction null (0.1c). [Q08a] The source-free stroke equations are the equations of the two-form F and of its dual, and in four dimensions the dual of a two-form is unchanged by the rescaling, since $\sqrt{|g|} g^{\mu\alpha} g^{\nu\beta}$ scales as $\mathbf{m}^4 \mathbf{m}^{-4}$; a solution stays a solution and (6) is kept. [Q07] A pattern's clocks keep $\mathbf{m}$ of the bookkeeper's time and its rulers measure $\mathbf{m}$ of the bookkeeper's lengths, so the bookkeeper reads the frequency as $\mathbf{m}\omega$, the period as $T/\mathbf{m}$, and the radius and the wavelength as $\bar{\lambda}/\mathbf{m}$ and $\lambda/\mathbf{m}$; [Q08b] $ET = h$, $(E/c)\bar{\lambda} = \hbar$ and the angle $\pi/4$ are unchanged, [Q08c-e] and the rescaling moves no strand, so $u = 0$ stays 0.

(R2) *The static exterior.* With $N^2 = 1 - \alpha_{\text{ext}}$ the exterior metric is the clock factor N^2 times the optical spacetime,

$$\begin{aligned} ds^2 &= -N^2 c^2 dt^2 + \frac{dr_f^2}{1 - \alpha_{\text{ext}}} + r_f^2 d\Omega^2 = N^2 \left[-c^2 dt^2 + d\ell_{\text{opt}}^2 \right], \\ d\ell_{\text{opt}}^2 &= \frac{dr_f^2}{(1 - \alpha_{\text{ext}})^2} + \frac{r_f^2 d\Omega^2}{1 - \alpha_{\text{ext}}}, \end{aligned} \quad (11)$$

and the bracket's spatial part is the optical metric of I-3. [Q09] By (R1) with $\mathbf{m} = N$ the stroke's type is kept, and its run is a null geodesic of the bracket: it runs on the geodesics of $d\ell_{\text{opt}}^2$, which is Fermat's principle on the optical metric, generalized Snell's law. The regime bends the run, by $4GM/(bc^2)$ at leading order, $1.75''$ for a stroke grazing the photosphere, twice the $0.88''$ a slow pattern taken to c would read. [Q10a, Q10b] A held reader at x_o reads a stroke emitted by a held pattern at x_e at $\omega_o/\omega_e = N(x_e)/N(x_o)$, the reading $\mathbf{m}\omega$ of (R1) taken at both ends; from the seam, $x_e = 2$, the far field reads $z = \sqrt{2} - 1 = 0.414$, and from $x_e = 1.05$, $z = 3.583$. [Q11a, Q11b] At every height the reader finds $ET = h$ and $(E/c)\bar{\lambda} = \hbar$. [Q11c]

(R3) *A closed pattern's support.* By (P3) the stroke obeys (4) inside a closed pattern's support, with the support's boundary data. The solutions are standing modes, and a standing mode is a sum of counter-running open strokes,

$$\cos kx \cos \omega t = \frac{1}{2} [\cos(kx - \omega t) + \cos(kx + \omega t)], \quad (12)$$

each of type τ_{stroke} . [Q12a] The support sets the frequencies that stand: between two reflecting walls a distance L apart, $\omega_n = n\pi c/L$, and the mode energies stand in the ratio $E_n/E_1 = n$. [Q12b, Q12c] In a closed pattern the confinement operator $D(\Omega, B; n, \chi, t)$ sets ω_q , with cost $m_q c^2 = \hbar \omega_q$ (I-5), and its spectrum is to be derived (D-02). The regime fixes which frequencies stand; it does not touch the components.

(R4) *Clamps.* Saturated nuclear cores are the clamps of a vibrating volume, and the load is taken by the interstitial omnium between them (P-3). On a line of clamps with spacing a , each component transverse to the line runs by (4) between clamps, and each core loads the line at its site: a clamp of loading μ enters as boundary data, $u'(na^+) - u'(na^-) = -\mu k^2 u(na)$ with $k = \omega/c$, for $u = u_y$ and $u = u_z$ alike. The modes of the line obey

$$\cos qa = \cos ka - \frac{\mu k}{2} \sin ka, \quad (13)$$

and at long wavelength they travel at $c_s = c/\sqrt{1 + \mu/a}$, $c/3$ at $\mu/a = 8$. [Q13a–c] The two transverse components obey one law, so a mode of definite hand, $u_y \pm iu_z$, is a mode too; in it every element of the line circles at ω , and the mode carries $1/\omega$ per unit energy about the line, $\hbar$ per quantum, whatever the loading. [Q13d] The clamps set the transport; between them every component runs at c and keeps τ_{stroke} . Mode geometry is set by the boundary conditions, not by the medium (P-2). The longitudinal branch, a compression of the packing along the line, carries no angular momentum about the line; its place in the identity and its reading on the stroke are to be derived (D-05).

(R5) *A helical gradient.* A magnetic field is a helical density gradient (P-5), held by a magnetically ordered support whose closures enter as boundary data (P3). A stroke running through it runs at c on the spot by (R1), and its components keep τ_{stroke} . The gradient sets the geometry of the mode, the turning of its twist grade about the gradient's axis, which is the magnon's precession; that turning and its dispersion are to be derived (D-06). The record reads the magnon's quantum as one unit along the magnetization, the gradient's axis [10]. $\square$

Corollary 1 (The carrier equivalence principle). *No reading of a component on its own terms, neither its medium, the null form of its grades, its rate on the spot, its action per cycle, its angular momentum per quantum, its kept time nor the angle of its helix, tells the regime it runs in. The regime is read in the geometry: in the bookkeeper's frequencies and radii, in the bending of the run, in the frequencies a support admits, in the transport across clamps and in the turning in a gradient.*

Remark. Einstein's principle says that no reading in a freely falling laboratory separates its fall from free motion, and that the field is the geometry. Corollary 1 is the same statement for the carrier. The extended equivalence principle of 0.1c, moving at constant speed on a pattern's own clocks and rulers through a density gradient is gravity, is its counterpart for patterns [3]: a pattern carries no reading of the gradient it crosses, and a stroke carries no reading of its regime.

6 The five presentations

Theorem 2 (The quintuple identity). *By (P9) the five names are the stroke in five regimes:*

- photon: *the stroke in a region crossed by no closed pattern, running straight at c and keeping no time (Lemmas 2 and 6);*
- graviton: *the stroke in the gravitational regime, read through (R1)–(R2); its place as the carrier of gravity's ripple, whose rate is the stroke's by (7), is to be derived (D-04);*
- gluon: *the stroke standing inside a closed pattern's own region (R3);*
- phonon: *the medium's stroke among the clamps of a vibrating volume, transverse to the line (R4);*
- magnon: *the stroke through a helical density gradient (R5).*

Hence

$$\tau(p_\gamma) = \tau(p_{\text{grav}}) = \tau(p_{\text{glu}}) = \tau(p_{\text{ph}}) = \tau(p_{\text{mag}}) = (\text{omnium}, 0, c, h, \hbar, 0), \quad (14)$$

and *photon* $\equiv$ *graviton* $\equiv$ *gluon* $\equiv$ *phonon* $\equiv$ *magnon*: *one carrier, of spin one.*

Proof. (P9) places each name in its regime of Theorem 1. Proposition 1 and Theorem 1 give (14), and Definition 3 gives the identity, with transitivity carrying it through all five. $\square$

Three readings of the regimes are to be derived: the graviton's place as the carrier of gravity's ripple (D-04, §8), the longitudinal branch among clamps (D-05), and the turning of the twist in a helical gradient (D-06). Theorem 2 rests on none of them.

name	regime: the geometry it runs in	what the regime sets	type
photon	a region crossed by no closed pattern	the direction of the run, the hand and the frequency	τ_{stroke}
graviton	the clock factor and optical metric of the density crossed	the bending of the run; the redshift read by held patterns; the ripple, bilinear in the stroke (D-04)	τ_{stroke}
gluon	a closed pattern's own support with its boundary data	the frequencies that stand, ω_q , and the mode cost $m_q c^2 = \hbar \omega_q$ (spectrum D-02)	τ_{stroke}
phonon	the clamps of saturated nuclear cores and the interstitial omnium	the dispersion and the transport c_s of the transverse modes; the longitudinal branch (D-05)	τ_{stroke}
magnon	a helical density gradient held by an ordered support	the rate and sense of the twist grade's turning (D-06)	τ_{stroke}

A regime's density enters through its geometry. In a source's exterior it is read on the A-1 chart, $\alpha_{\text{ext}} = R_s/r_f$, which sets the lapse N and the optical metric, and the stroke's readings do not move with it (R2). The regimes are named and never ranked (A-5): since the type is independent of the regime, the identity needs no density address for any presentation.

Proposition 2 (Carrier only: closure is a change of type). *A closed pattern's strand circulates, $u/c > 0$, and the pattern keeps time, so a closure is never of type τ_{stroke} ; no regime of Theorem 1 gives a component that property. The braided closures of I-5 are made of the stroke and stand outside (2).*

Proof. In the bivector reading of 0.1d a strand's state is the spinor $\mathbf{w} = v + u\mathbf{\Sigma}$ of its translation v and circulation u , and the spinor flip $\mathbf{f}(\mathbf{w}) = \mathbf{\Sigma}\tilde{\mathbf{w}} = u + v\mathbf{\Sigma}$ exchanges the two and keeps c^2 . [Q18a, Q18c] An open stroke's run is $\mathbf{w} = c$, all translation, $u/c = 0$ (Lemma 6). Closure is the flip of the run, $\mathbf{f}(c) = c\mathbf{\Sigma}$: a closed pattern at rest is all circulation, $u/c = 1$, and in motion it circulates with $u > 0$, keeps time by circulating, $c d\tau = u dt$, carries its rest energy as the bivector grade of $\mathbf{P} = pc + mc^2\mathbf{\Sigma}$, and has inertia E/c^2 , closure included (0.1d, I-5). [Q18b] Read on its strand, the sixth entry is $u/c > 0$, so closure is a change of type. In every regime of Theorem 1 the components remain open strokes with $u = 0$. A standing mode of (R3) has no strand of its own: it is two counter-running components, each with $u = 0$, and its zero momentum, its inertia E/c^2 and its cost $\hbar\omega_q$ belong to the pair together, read as the I-5 mode of the support it stands in. No strand of the pair circulates; the closed pattern whose support it stands in keeps time. The stroke's helix $c + c\mathbf{\Sigma}$, run c and turning c , is the flip's fixed point. [Q18b] $\square$

7 QM = EM = GR, one force

Read as carriers, the three readings of (1) are readings of the one stroke.

reading	entry of (1)	where it is read on the stroke
QM	$E_q/m_q = c^2$, $E_q = \hbar\omega_q$	the quantum $\hbar\omega$ of every presentation and its mass reading E/c^2 ; the cost of a standing mode, $m_q c^2 = \hbar\omega_q$ (gluon)
EM	$1/(\varepsilon_0\mu_0) = c^2$	the two responses that make the stroke (photon) and its twist grade in a helical gradient (magnon)
GR	$(\ell_q/T_q)^2 = c^2$	clocks and rulers adjusting with the density they cross (0.1a, 0.1c); the geometry's ripple (7) (graviton); the bending of the run (R2)

The phonon reads all three at once: the medium's two responses carry it, its quanta are $\hbar\omega$, and its transport is the geometry of the clamps. One carrier has one force law. I-1 reads the force between two configurations with each body's exterior input at the separation, $\alpha_i(d) = R_{s,i}/d$, on two nonoverlapping spherical supports at monopole order, $R_{b,i} \geq R_{s,i}$ and $d \geq R_{b,1} + R_{b,2}$. There, with $\lambda_i = \mathcal{M}_i/d$,

$$F = F_{\max} \alpha_1 \alpha_2 = \frac{2\pi}{\kappa} \alpha_1 \alpha_2 = G \lambda_1 \lambda_2 = \frac{G \mathcal{M}_1 \mathcal{M}_2}{d^2}, \quad F_{\max} = \frac{c^4}{4G} = 3.0256 \times 10^{43} \text{ N}, \quad (15)$$

exactly, [Q17b-d] and

$$\frac{F}{F_{\max}} = \frac{R_{s,1} R_{s,2}}{d^2} \leq \frac{R_{s,1} R_{s,2}}{(R_{s,1} + R_{s,2})^2} \leq \frac{1}{4}, \quad (16)$$

with equality only for equal, saturated supports in contact. [Q17e] The same law at different input pairs is what consensus physics names gravity, electromagnetism and the weak and strong interactions (I-1). The maps from a charge or a colour seat to an I-1 input are to be derived (D-01; core O-6). Nothing is mediated: interactions are curvature plus geodesic motion (I-2), and Newton = GR = QM = FDT is one statement read in different limits (I-4).

8 Gravity's ripple

The ripple of a changing source runs at the stroke's rate, (7). Its waveform, its two transverse polarizations and the energy and angular momentum it carries are those the field equations return for the same source and data (I-3, containment), and FDT accepts them as measured. Four facts place them.

- Proposition 3** (The ripple's rank and its angular momentum). *(a) A symmetric trace-free tensor transverse to a run has two independent components, h_+ and $h_\times$, and a rotation by θ about the run turns them by 2θ ; a transverse vector turns by θ . [Q14a, Q14b]*
- (b) A circularly polarized wave whose pattern turns by $s\theta$ under a rotation θ about its run is, in time, a rigid rotation of that pattern at ω/s , and so carries s/ω per unit energy about its run: $1/\omega$ for the stroke, as (8) gives, and $2/\omega$ for the transverse trace-free ripple. [Q15a, Q15b]*
- (c) Radiation from a source turning rigidly at Ω_{orb} , in a mode of azimuthal order m at $\omega = m\Omega_{\text{orb}}$, carries $dJ/dE = m/\omega = 1/\Omega_{\text{orb}}$ in total, whatever the field; for a circular binary $dE = \Omega_{\text{orb}} dJ$ along the circular sequence, and its quadrupole ripple at $\omega = 2\Omega_{\text{orb}}$ carries $2/\omega$. On the binary's axis the ripple is circularly polarized and carries its $2/\omega$ about its run, while a source of order $m = 2$ radiates no light along its axis. [Q15c, Q15d]*
- (d) A superposition of components at the ripple's frequency ω carries at most $1/\omega$ per unit energy about the run, and one at $\omega/2$ runs at $\omega/2$: no linear composition of the stroke carries (c). The symmetric trace-free square of a component of one hand at $\Omega_{\text{orb}} = \omega/2$ is a pattern of rank two turning at $2\Omega_{\text{orb}} = \omega$, and two quanta of one hand at Ω_{orb} carry $2\hbar$ in $2\hbar\Omega_{\text{orb}} = \hbar\omega$. [Q15e]*

The ripple is read as a tide, the symmetric trace-free part of the deviation between neighbours (I-3a), and its two-fold turning (a) is the rank of that tide. Its angular momentum about its run on the axis (c), $2/\omega$ per unit energy, is what the field equations return, and FDT accepts it (I-3). The standard account quantizes it as a second carrier of helicity two, $2\hbar$ per quantum $\hbar\omega$. FDT reads one carrier, the stroke, whose quanta carry $\hbar$ about their run (Lemma 5). By (d) no linear composition of the stroke carries the ripple and a bilinear one does: a pair of quanta of one hand at the source's orbital rate carries the ripple's $2\hbar$ per $\hbar\omega$, Planck's bridge kept. How the stroke's quanta compose the ripple's transverse trace-free adjustment, the graviton's place as its carrier, is to be derived (D-04).

9 The record and the tests

what the record shows	the measurement	where it is returned
one rate for the gravitational and the electromagnetic stroke	the gamma rays of GRB 170817A arrived 1.74 ± 0.05 s after the merger in GW170817; the two rates are equal within -3×10^{-15} and $+7 \times 10^{-16}$ [7] [Q16]	Lemma 3; Theorem 2
$\hbar$ per circularly polarized stroke	the torque circularly polarized light exerts on a wave plate that reverses its hand agrees with $\hbar$ per quantum [8]	Lemma 5
spin one in a closed pattern's region	the angular correlations of three-jet events at PETRA favour a spin-one gluon over a scalar one [9]	Theorem 1 (R3); the map to the correlations, D-01
one unit in a helical gradient	creating or destroying a magnon flips the spin of a polarized neutron, one unit along the magnetization [10]	Theorem 1 (R5); D-06
angular momentum among clamps	chiral phonons [11]; polarized phonons carry the angular momentum lost in ultrafast demagnetization [12]	Theorem 1 (R4)
shared modes where regimes meet	magnons and microwave photons hybridize in strong coupling [13, 14]; light and sound share hybrid modes in one fibre with no cavity [15]; propagating spin waves and resonator photons couple strongly in one circuit [16]	Theorem 2; (P8)
the stroke reads the optical metric	deflection $1.75''$ at the photosphere; $\gamma = 0.99992 \pm 0.00012$ by VLBI [17]	Theorem 1 (R2)

Each test below is the converse of a derived result: the measurement that would end it.

T-1 *One rate.* A measured difference between the rates of the gravitational and the electromagnetic stroke of one source, away from closed patterns, ends Lemma 3's one rate for the ripple.

T-2 *One quantum.* A circularly polarized stroke whose angular momentum per unit energy about its run differs from $1/\omega$, or per quantum from $\hbar$, ends Lemma 5.

T-3 *Spin one in every regime.* A component of definite hand, in any regime of Theorem 1, whose quanta carry other than $\hbar$ about its run ends Theorem 1; a scalar gluon would.

T-4 *The factor of two.* A stroke bending by other than twice the slow reading at leading order, $\gamma \neq 1$, ends (R2).

Six pieces sit outside the derivation and leave every result in it unchanged:

- D-01 *Colour*. The gluon octet's dynamics, the A_2 seat table derived from cone geometry, and the maps from a charge or a colour seat to an I-1 input, are to be derived (core O-6).
- D-02 *Spectra*. The confinement operator D , its domains and its spectrum, which fix the frequencies a closed pattern's support admits, are to be derived (core O-9).
- D-03 *The aperture*. The stroke read across closed patterns themselves, through the medium's aperture, which sets the transport of strokes through matter, is to be derived (core O-8).
- D-04 *The ripple's strokes*. The graviton's place as the carrier of gravity's ripple: how the stroke's quanta compose the transverse trace-free adjustment of the geometry, bilinearly by Proposition 3(d), is to be derived. Its target is the ripple's $2/\omega$ per unit energy about its run on a source's axis.
- D-05 *The longitudinal branch*. The compression of the packing along a line of clamps carries no angular momentum about the line; its place in the identity and its reading on the stroke, the trace of the deviation among clamps (I-3a), are to be derived.
- D-06 *The turning in a helical gradient*. The turning of the stroke's twist grade about a helical gradient's axis, the magnon's precession and its dispersion in an ordered support, and the one unit along the magnetization the record reads, are to be derived (P-5).

10 Declined readings and convergence

The standard account mediates each force by the exchange of its own carrier, virtual where the exchange is not observed. FDT reads one carrier and no mediation: interactions are curvature plus geodesic motion (I-2, Theorem 2).

The standard account assigns the four interactions four kinds of carrier, unified at a high energy. FDT reads one carrier from the outset: the type (10) contains no frequency, so there is nothing to unify at any energy (I-2, Proposition 1).

The standard account quantizes the metric perturbation into a spin-two graviton, a second carrier. FDT reads one carrier: the ripple is the geometry's adjustment, its two-fold turning is the rank of the tide that reads it (I-3a), and the geometry is carried by the stroke, with the ripple's bilinear composition from the stroke's quanta to be derived (D-04; Proposition 3).

The standard account makes the photon the quantum of an independent electromagnetic field in an empty vacuum, with ε_0 and μ_0 constants of that vacuum. FDT reads the stroke in a region crossed by no closed pattern, with ε_0 and μ_0 the omnium's response coefficients (0.1, 0.1d).

The standard account makes the phonon a quasiparticle of the ions' vibration, a different kind of excitation from light. FDT reads the medium's stroke among clamps: the saturated cores clamp and load the line, the interstitial omnium carries the stroke, and the clamps set the mode's geometry and transport (P-2, P-3, Theorem 1 (R4)).

The standard account makes the magnon a quantum of the precession of the electrons' intrinsic spins. FDT reads the stroke through a helical density gradient, which is what a magnetic field is; there are no intrinsic properties (P-5, I-5), and the turning is to be derived (D-06).

The standard account has gluons carry colour charge between quarks. FDT reads the stroke standing inside a closed pattern's own region, with colour the $SU(3)$ of the internal nodal surface of an $n = 3$ braid (I-5); the octet's dynamics are to be derived (D-01).

Convergence. For the same sources and data FDT returns: the equal rates of the gravitational and electromagnetic strokes of GW170817, within the published bounds; the angular momentum

$\hbar$ per quantum of circularly polarized light; the deflection of light with $\gamma = 1$; and the waveforms, polarizations, fluxes and angular momentum of gravitational radiation, by containment (I-3). It reads the spin-one correlations of three-jet events, the spin flip of magnon scattering, the angular momentum of chiral and polarized phonons and the hybrid splittings of magnons, phonons and photons as the one carrier's; the maps from the stroke to those numbers run through D-01, D-02, D-05 and D-06. No divergence is claimed: the paper supplies what a carrier is, not a changed observable.

11 The quintuple identity

There is one medium, and it has one disturbance. The omnium's two responses give it one equation and one rate, and its two grades are a null pair. Clocks and rulers are made of the same stroke, so every stroke measured on the spot runs at c , and the chain gives that rate to the quantum, the electromagnetic and the gravitational readings, as the field equations give it to the geometry's ripple. Each quantum carries h per cycle and $\hbar$ about its run, on a helix standing at $\pi/4$ at every frequency, and runs its whole rate, keeping no time. These six readings are the stroke's type, and none of them depends on where the stroke runs. A regime is geometry: the density crossed, read through the clock factor and the optical metric; a closed pattern's support; the clamps of a vibrating volume; a helical gradient. Free, crossing a source's exterior, standing, transverse among clamps or through a twist, the stroke is the same stroke, and photon = graviton = gluon = phonon = magnon is Einstein's gravity = geometry carried to every carrier; the ripple it carries is bilinear in it. Closed, the stroke keeps time and is matter.

12 Status register

result	rests on	status
One medium (Lemma 1)	0.1b	derived
One equation, null grades, for components of either hand (Lemma 2)	0.1, 0.1d	derived
One rate in every reading, the ripple included (Lemma 3)	0.1, 0.1a, 0.1d, I-3	derived
One action per cycle (Lemma 4)	0.1a	derived
$1/\omega$ per unit energy and $\hbar$ per quantum about the run; the helix at $\pi/4$ (Lemma 5)	0.1, I-2	derived
The whole rate translates; no kept time (Lemma 6)	0.1d, I-2	derived
The type of the stroke (Proposition 1)	Lemmas 1–6	derived
Regime invariance (R1)–(R5) (Theorem 1)	0.1c, I-3, I-5, P-2, P-3, P-5	derived
The bookkeeper's readings $m\omega$, T/m , $\bar{\lambda}/m$	0.1c	derived
The exterior as clock factor times optical spacetime (11)	I-3, 0.1c	derived, exact
The loaded line (13), its transport, and $1/\omega$ per unit energy for its modes of definite hand	P-2, P-3	derived, exact for the line
The carrier equivalence principle (Corollary 1)	Theorem 1	derived
The quintuple identity (Theorem 2), the graviton read through (R1)–(R2) and the phonon transverse to the line	(P9), Theorem 1	derived
Closure as a change of type (Proposition 2)	0.1d, I-5	derived

result	rests on	status
QM = EM = GR as readings of the stroke; one force law and its pair bound	0.1, I-1, I-4	derived on the pair domain
The ripple's rank and angular momentum (Proposition 3)	I-3, I-3a	derived
The gluon octet's dynamics; the seat table; the maps from charge and colour seat to an I-1 input	I-1, I-5a	to be derived (D-01; core O-6)
The confinement operator and the spectrum of a support	I-5	to be derived (D-02; core O-9)
The medium's aperture for strokes across closed patterns	P-4	to be derived (D-03; core O-8)
The graviton's place as the ripple's carrier: the ripple composed bilinearly of the stroke's quanta	I-2, I-3	to be derived (D-04)
The longitudinal branch among clamps and its place in the identity	P-3, I-3a	to be derived (D-05)
The turning of the twist in a helical gradient; the magnon's unit along the magnetization	P-5	to be derived (D-06)

invariant	where it enters
I-1	one force law for one carrier, (15), exact on the pair domain with the exterior inputs $\alpha_i(d) = R_{s,i}/d$, and $F \leq F_{\max}/4$ there (16); one equation with four names
I-2	the carrier as a disturbance of the medium at the medium's speed; the helix at $\pi/4$ and $\hbar$ per quantum (Lemma 5); the placement of the five names (P9) and the identity itself (Theorem 2)
I-3	the field equations carry the stroke's rate (7); the exterior as clock factor times optical spacetime (11); the stroke's bending by generalized Snell's law; containment for the ripple's waveforms, fluxes and angular momentum
I-4	QM = EM = GR read on the stroke; one statement in different limits
I-5	the gluon's regime: a closed pattern's support and its modes, $m_q c^2 = \hbar \omega_q$; the braided closures kept outside the identity (Proposition 2)
I-6	the fold $r_f = R_s$ a limit, never a state: $N > 0$ in (R2), so every redshift is finite
I-7	every channel of a source's energy enters $\mathcal{M}$ once and sets R_s , hence the lapse and optical metric through which the graviton and the bent stroke are read

A Receipt

The script `receipt Quintuple.py`, in the folder of this paper, checks the displayed identities symbolically with SymPy and the displayed numbers numerically, with an independent transfer-matrix computation for the loaded line, the normal modes of loaded bead chains for the angular momentum of modes of definite hand, and the Ricci tensor of a transverse trace-free ripple for the rate of (7) in vacuum. Its output is `receipt_output.txt`; run it with `python3 receipt_Quintuple.py`. Result: **57/57 PASS**.

check	content
Q01a-c	$E/m = c^2$; $(d/t)^2 = c^2$; $1/(\varepsilon_0 \mu_0) = c^2$ with the CODATA 2022 values
Q02a-c	Faraday's law for the components (5) of both hands; Ampère's law fixes $\omega^2 = k^2/(\varepsilon_0 \mu_0)$; the stroke equation (4)
Q03a-b	$ \mathbf{E} ^2 - c^2 \mathbf{B} ^2 = 0$ and $\mathbf{E} \cdot \mathbf{B} = 0$ for both hands: $F^2 = 0$

check	content
Q04a-e	$ET = h$; $\ell = cT = h/(m_E c)$, $\ell/T = c$; $E/m_E = c^2$; the 21 cm line: 9.41×10^{-25} J, $5.874 \mu\text{eV}$, 1.047×10^{-41} kg, 0.704 ns, 21.106 cm
Q05a-f	$\mathbf{E} = -\partial_t \mathbf{A}$, $\mathbf{B} = \nabla \times \mathbf{A}$; spin density over energy density $\pm 1/\omega$ about the run (8); none for the sum of the two hands; $ \mathbf{S} = E/\omega = (E/c)\bar{\lambda} = \hbar$; the angle $\pi/4$; $\omega\bar{\lambda} = c$
Q06a-b	the boost carries $x = ct$ onto $x' = ct'$; $v = c$ gives $u = 0$
Q07	the dual of a two-form is unchanged by $g \mapsto \mathbf{m}^2 g$ in four dimensions
Q08a-e	null directions kept; a pattern at rest in $\mathbf{m}^2 g$ keeps $\mathbf{m}$ of the bookkeeper's time and length, so the bookkeeper reads $\mathbf{m}\omega$ and $\lambda/\mathbf{m}$; $ET = h$, $(E/c)\bar{\lambda} = \hbar$ and the angle $\pi/4$ kept
Q09	the exterior is N^2 times the optical spacetime (11)
Q10a-b	$4GM_\odot/(bc^2) = 1.75''$ at the photosphere, $b = 695.5$ Mm [18]; half of it, $0.88''$
Q11a-c	$z = \sqrt{2} - 1 = 0.414$ from the seam; $z = 3.583$ from $1.05 R_s$; $\omega_o/\omega_e = N_e/N_o$ from $\mathbf{m}\omega$ at both ends, with $ET = h$ and $(E/c)\bar{\lambda} = \hbar$ at every height
Q12a-c	the standing stroke as two counter-running strokes; $\omega_n = n\pi c/L$; $E_n/E_1 = n$
Q13a-d	the loaded line: transfer matrix against (13) in 200 random cases; $c_s = c/\sqrt{1 + \mu/a}$; $c/3$ at $\mu/a = 8$; modes of definite hand on 50 random loaded bead chains carry $1/\omega$ per unit energy
Q14a-b	a transverse symmetric trace-free tensor turns by 2θ ; a transverse vector by θ
Q15a-e	the circular ripple is a rigid rotation at $\omega/2$, $2/\omega$ per unit energy; the circular stroke at ω , $1/\omega$; $dE = \Omega_{\text{orb}} dJ$ on the circular sequence; an $m = 2$ source radiates no light on its axis, $ \mathbf{X}_{22} ^2 \propto 1 - \cos^4 \theta$; components at ω carry at most $1/\omega$, the trace-free square of a component at Ω_{orb} turns at $2\Omega_{\text{orb}}$ with rank two, and two quanta at Ω_{orb} carry $2\hbar$ in $\hbar\omega$
Q16	GW170817: 1.74 s over 26 Mpc, $+6.5 \times 10^{-16}$; with a 10 s emission window, -3.1×10^{-15}
Q17a-e	$\kappa F_{\text{max}} = 2\pi$; $F_{\text{max}}\alpha_1\alpha_2 = GM_1M_2/d^2$ with $\alpha_i = R_{s,i}/d$; $(2\pi/\kappa)\alpha_1\alpha_2 = G\lambda_1\lambda_2$; $F_{\text{max}} = 3.0256 \times 10^{43}$ N, $d_{\text{min}} = 2\ell_P = 3.2325 \times 10^{-35}$ m, $t_{\text{min}} = 1.0782 \times 10^{-43}$ s; the pair bound (16)
Q18a-c	the spinor flip exchanges translation and circulation; $\mathbf{f}(c) = c\mathbf{\Sigma}$, $u/c = 1$, and the fixed helix $c + c\mathbf{\Sigma}$; c^2 kept
Q19	a transverse trace-free ripple $h_+ \cos(kz - \omega t)$ solves the vacuum field equations at first order exactly when $\omega = ck$: the rate of (7)

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