ValerieX (VXXX)

Volume I — Theory

Density-State Disequilibrium, the Bounded Contrast Variable, and Valerie's Law

Nicholas Parkyn

Independent Researcher · nikparkyn@googlemail.com

Supporting deep-dive to the main manuscript

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Abstract

Volume I is the theoretical deep-dive companion to the main ValerieX manuscript. It develops, from a minimal axiomatic base, the bounded contrast variable

$$\chi = \frac{\rho_{\mathrm{o}} - \rho_{\mathrm{m}}}{\rho_{\mathrm{o}} + \rho_{\mathrm{m}}},$$

proves it is the unique lowest-degree rational function satisfying four foundational conditions (equilibrium, antisymmetry, scale-neutrality, boundedness), characterises every higher-degree rational solution as $\chi \cdot R$ with R even and scale-neutral, and derives Valerie's Law $a = g\chi$ by minimal sufficiency. The bounded contrast variable is mathematically identical to the classical *Atwood number* of buoyancy-driven flow; the framework is consistent with the recognised buoyancy-plus-added-mass family of fluid mechanics (Lamb 1932; Brennen 1982; Kelvin 1871), and the law $a = g\chi$ is the $C = 1$ branch of the geometry-aware general law $a = g(\rho_{\mathrm{o}} - \rho_{\mathrm{m}})/(\rho_{\mathrm{o}} + C\rho_{\mathrm{m}})$, which coincides classically with the participating-medium-load coefficient for a circular cylinder moving perpendicular to its axis.

This volume is scope-restricted: it covers theory, derivation, axioms, and limiting behaviour. Regime classification is treated in Volume II, computational predictions and figures in Volume III, experimental protocols in Volume IV.

Keywords: ValerieX, Valerie's Law, density-state disequilibrium, bounded contrast variable, Atwood number, added-mass, participating medium load, classical reorganisation, falsifiability.

1 Purpose of this Volume

The main manuscript presents ValerieX as a symmetry-based reorganisation of classical buoyancy-and-added-mass behaviour into a unified framework. Volume I supplies the theoretical machinery on which the main manuscript depends: the axioms, the uniqueness proof for χ, the characterisation theorem for higher-degree solutions, the participating-medium-load derivation, the identification of Valerie's Law as the $C = 1$ branch of a recognised classical family, and the limiting-regime structure.

Nothing in this volume contests classical mechanics, Newtonian gravitation, or the precision-G programme. The contribution is structural: one bounded organising variable, one drive–coupling–

resistance separation, one regime-aware reading of how the same density-state drive is realised under different pathway conditions.

2 Ontological Starting Point

Three primitives: an object characterised by density-state ρ_{o}; an environment characterised by density-state ρ_{m}; an interaction domain in which both coexist. No primitive upward or downward force is introduced. Motion is treated as relational, in the spirit of Archimedes (c. 250 BCE) and Galileo (1638).

2.1 Substance, Volume, Density-State

The framework uses substance rather than matter, volume rather than mass as the primary descriptive basis, and density-state as the primary state variable. These choices are operational: substance is what physically occupies volume and carries density; volume and density are directly measurable. The standard formal definition $\rho = m/V$ is not denied; it is simply not the primary explanatory starting point.

2.2 Disequilibrium as Source of Motion

Foundational statement. Vertical motion arises from density-state disequilibrium between substance and its surrounding environment.

The raw difference $\Delta\rho = \rho_{\mathrm{o}} - \rho_{\mathrm{m}}$ is unbounded. The framework therefore requires a bounded relational measure of disequilibrium, constructed in Section 3.

2.3 Equilibrium and Direction

Equilibrium is defined by $\rho_{\mathrm{o}} = \rho_{\mathrm{m}}$. At this condition there is no vertical motion and no directional preference; rest is state equivalence, not the cancellation of opposing causes. “Up” and “down” are not primitive: they emerge from contrast. Vertical direction within ValerieX is locally defined by the gradient structure of the surrounding medium, not asserted as a universal absolute.

2.4 Electromagnetic Field as Structural Condition

Within ValerieX, the electromagnetic field is treated as the continuous environmental condition that allows particles and substance to exist in differentiated states, structures, and densities. The U.S. Department of Energy describes the electromagnetic force as what keeps atoms together and electrons bound to nuclei (DOE; NASA EFM). ValerieX takes this established structuring role as foundational: differentiated substance, distinct phase states, and meaningful density contrast all depend on a field-conditioned environment. The EM field is not a competing motion force; it is the condition under which motion-relevant contrast is possible at all. Vertical motion arises from density contrast within that field; horizontal behaviour arises from direct electromagnetic interactions within it.

2.5 Axioms

1. **Relational motion.** Motion is defined only relative to an environment.

2. **Density-state sufficiency.** Vertical behaviour is determined by the relation between ρ_{o} and ρ_{m}.
3. **Disequilibrium drives motion.** Motion occurs only when $\rho_{\mathrm{o}} \neq \rho_{\mathrm{m}}$.
4. **Bounded response.** Acceleration must remain finite.
5. **Symmetry of contrast.** Positive and negative disequilibrium are opposite branches of the same law.
6. **Minimal sufficiency.** No structure is introduced unless required by the axioms.
7. **Field-conditioned differentiation.** Stable density-states exist because substance exists within a field-conditioned environment.

3 Derivation of the Bounded Contrast Variable

We seek a function $\chi = f(\rho_{\mathrm{o}}, \rho_{\mathrm{m}})$ measuring density-state disequilibrium in a bounded, symmetric way, satisfying four conditions:

(i) **Equilibrium:** $f(\rho_{\mathrm{o}}, \rho_{\mathrm{m}}) = 0$ whenever $\rho_{\mathrm{o}} = \rho_{\mathrm{m}}$.
(ii) **Antisymmetry:** $f(\rho_{\mathrm{o}}, \rho_{\mathrm{m}}) = -f(\rho_{\mathrm{m}}, \rho_{\mathrm{o}})$.
(iii) **Scale-neutrality (homogeneous of degree zero):** $f(\lambda\rho_{\mathrm{o}}, \lambda\rho_{\mathrm{m}}) = f(\rho_{\mathrm{o}}, \rho_{\mathrm{m}})$ for any $\lambda > 0$.
(iv) **Bounded response:** $|f(\rho_{\mathrm{o}}, \rho_{\mathrm{m}})| < 1$ for all $\rho_{\mathrm{o}}, \rho_{\mathrm{m}} > 0$.

The unique minimal rational function satisfying all four is

$$\chi = \frac{\rho_{\mathrm{o}} - \rho_{\mathrm{m}}}{\rho_{\mathrm{o}} + \rho_{\mathrm{m}}}. \tag{1}$$

This is mathematically identical to the classical Atwood number of buoyancy-driven flow.

3.1 Algebraic Verification

Let $\rho_{\mathrm{o}}, \rho_{\mathrm{m}} > 0$.

- *Equilibrium:* if $\rho_{\mathrm{o}} = \rho_{\mathrm{m}}$, the numerator vanishes and $\chi = 0$.
- *Antisymmetry:* $\chi(\rho_{\mathrm{m}}, \rho_{\mathrm{o}}) = (\rho_{\mathrm{m}} - \rho_{\mathrm{o}})/(\rho_{\mathrm{m}} + \rho_{\mathrm{o}}) = -\chi(\rho_{\mathrm{o}}, \rho_{\mathrm{m}})$.
- *Scale-neutrality:* $\chi(\lambda\rho_{\mathrm{o}}, \lambda\rho_{\mathrm{m}}) = \lambda(\rho_{\mathrm{o}} - \rho_{\mathrm{m}})/[\lambda(\rho_{\mathrm{o}} + \rho_{\mathrm{m}})] = \chi(\rho_{\mathrm{o}}, \rho_{\mathrm{m}})$.
- *Boundedness:* the strict triangle inequality $|\rho_{\mathrm{o}} - \rho_{\mathrm{m}}| < \rho_{\mathrm{o}} + \rho_{\mathrm{m}}$ gives $|\chi| < 1$, with equality approached only in the singular vacuum limits $\rho_{\mathrm{m}} \to 0$ ($\chi \to +1$) and $\rho_{\mathrm{o}} \to 0$ ($\chi \to -1$).

All four conditions are satisfied exactly.

3.2 Minimality at Lowest Degree

Step 1. Scale-neutrality forces a homogeneous-of-degree-zero ratio. Any rational function representing χ can be written as $P(\rho_{\mathrm{o}}, \rho_{\mathrm{m}})/Q(\rho_{\mathrm{o}}, \rho_{\mathrm{m}})$, where P and Q are homogeneous polynomials of equal degree d.

Step 2. Antisymmetry forces parities: P must be odd under the swap, Q must be even.

Step 3. At lowest degree $d = 1$, the only odd linear form (up to scaling) is $a(\rho_{\mathrm{o}} - \rho_{\mathrm{m}})$; the only even linear form is $b(\rho_{\mathrm{o}} + \rho_{\mathrm{m}})$. So the most general lowest-degree solution is $f = k(\rho_{\mathrm{o}} - \rho_{\mathrm{m}})/(\rho_{\mathrm{o}} + \rho_{\mathrm{m}})$

with $k = a/b \neq 0$.

Step 4. Boundedness fixes $|k| \leq 1$; equality at the vacuum limits gives $k = \pm 1$. The conventional positive sign under positive disequilibrium fixes $k = +1$.

The unique lowest-degree rational function satisfying all four conditions is therefore $\chi = (\rho_{\mathrm{o}} - \rho_{\mathrm{m}})/(\rho_{\mathrm{o}} + \rho_{\mathrm{m}})$.

3.3 Higher-Degree Characterisation

It is natural to ask whether higher-degree rational functions can also satisfy the four conditions. They can — but every such solution factors through χ multiplied by an even, scale-neutral correction.

By Steps 1–2, any solution can be written as P/Q with P odd and Q even of equal degree d. Because P is odd and vanishes on the diagonal $\rho_{\mathrm{o}} = \rho_{\mathrm{m}}$, it admits the unique factorisation $P = (\rho_{\mathrm{o}} - \rho_{\mathrm{m}}) \cdot E_1$, where E_1 is homogeneous of degree $d-1$ and even under the swap. The denominator Q is already even and homogeneous of degree d. Substituting,

$$f \;=\; \chi \cdot \frac{(\rho_{\mathrm{o}} + \rho_{\mathrm{m}}) \cdot E_1}{Q} \;=\; \chi \cdot R,$$

where R is even and scale-neutral.

General theorem. Every rational solution of the four conditions has the form $f = \chi \cdot R$ for some even, scale-neutral rational R.

At $d = 1$, R reduces to a constant fixed by boundedness, recovering basic χ. At higher d, non-trivial R produces solutions such as $\chi^3 = \chi \cdot \chi^2$ (with $R = \chi^2$). These exist algebraically but introduce structure not required by the axioms. By Axiom 6 (minimal sufficiency), ValerieX selects the lowest-degree form: the unadorned χ.

4 Valerie's Law

By Axiom 3, motion follows disequilibrium. By Axiom 4, motion remains finite. By Axiom 5, opposite contrasts are opposite branches of the same law. The simplest governing relation is linear proportionality:

$$a \;=\; g \cdot \frac{\rho_{\mathrm{o}} - \rho_{\mathrm{m}}}{\rho_{\mathrm{o}} + \rho_{\mathrm{m}}} \;=\; g\chi. \tag{2}$$

This is the governing law of available vertical motion. It is parameter-free, bounded, antisymmetric, scale-neutral, and continuous.

4.1 The Force of Density

The physical drive expressed through Valerie's Law is named the *force of density* — the density-state drive by which less dense and more dense regions of substance resolve their disequilibrium within an electromagnetic-field-conditioned environment.

Term for term, the net density-driven force

$$F_{\mathrm{net}} \;=\; V \cdot g \cdot (\rho_{\mathrm{o}} - \rho_{\mathrm{m}})$$

is mathematically identical to the classical net of gravitational weight on the object minus Archimedes' buoyant force from the displaced medium:

$$V\rho_{\mathrm{o}}g - V\rho_{\mathrm{m}}g \;=\; Vg(\rho_{\mathrm{o}} - \rho_{\mathrm{m}}).$$

Within ValerieX this single expression is read as one density-state drive rather than as the sum of two primitive force constructs.

4.2 Interpretation of g

Within ValerieX, g is taken as a primitive observed environmental quantity rather than a derived one. NIST gives $g_n = 9.80665\,\mathrm{m\,s^{-2}}$ (CODATA). ValerieX treats this near-surface terrestrial value as the observed ceiling of realised vertical particle acceleration under full contrast. Classical mechanics derives the local value of g from Newtonian gravitation as $g = GM_E/r^2$; ValerieX makes no equivalent derivation. This is a real explanatory deficit relative to the classical picture, stated as such, not as an absence in scope.

5 Participating Medium Load and the C-Family

Valerie's Law also arises from a direct dynamics argument when the effective inertia of the object–environment system is written correctly. The net density-driven force on an object of volume V is $F_{\mathrm{net}} = Vg(\rho_{\mathrm{o}} - \rho_{\mathrm{m}})$. In classical terminology, the medium's inertial participation is described as added mass or virtual mass; ValerieX retains the observable effect but reframes its meaning as *participating medium load*, the measurable extent to which surrounding substance must be co-disturbed when disequilibrium resolves (Lamb 1932; Brennen 1982; McKee & Czarnecki 2019).

The effective motion-resistance term is $R_{\mathrm{eff}} = (\rho_{\mathrm{o}} + C\rho_{\mathrm{m}})V$, where C is the participation coefficient. The available acceleration is

$$a \;=\; \frac{F_{\mathrm{net}}}{R_{\mathrm{eff}}} \;=\; g \cdot \frac{\rho_{\mathrm{o}} - \rho_{\mathrm{m}}}{\rho_{\mathrm{o}} + C\rho_{\mathrm{m}}}. \tag{3}$$

Brennen (1982) tabulates classical potential-flow added-mass coefficients: $C = 0.5$ for a sphere, $C = 1.0$ for a circular cylinder moving perpendicular to its axis. Valerie's bounded form is recovered exactly at $C = 1$.

5.1 Drive–Coupling–Resistance Separation

Within the law a clean separation is maintained between drive, coupling, and resistance.

- **Drive:** density-state contrast $(\rho_{\mathrm{o}} - \rho_{\mathrm{m}})$ determines the direction and available magnitude of motion through χ.
- **Coupling:** the participation coefficient C describes how much of the surrounding medium is co-disturbed when motion is realised; set by geometry, orientation, surface interaction.
- **Resistance:** viscosity (drag) is the dissipative term that limits realised motion in real media.

C is therefore not a universal constant: it is a measurable coupling parameter that varies with shape and orientation. Real systems express the geometry-dependent C-family, including $C = 0$

(classical strict object-normalised), $C = 0.5$ (sphere in inviscid flow), $C = 1$ (cylinder $\perp$-axis), and intermediate values (capsules and other geometries). In the vacuum limit $\rho_{\mathrm{m}} \to 0$ the participating medium load $C\rho_{\mathrm{m}}$ vanishes for any value of C; viscous resistance also vanishes; geometry has no effect on realised acceleration; and all positive-density bodies share the same environmental ceiling g.

5.2 Label-Exchange Algebraic Property of $C = 1$

The four foundational conditions of χ apply to the contrast variable. It is natural to ask whether they are preserved when read as algebraic properties of the full acceleration law $a(\rho_{\mathrm{o}}, \rho_{\mathrm{m}}; C) = g(\rho_{\mathrm{o}} - \rho_{\mathrm{m}})/(\rho_{\mathrm{o}} + C\rho_{\mathrm{m}})$.

Equilibrium and scale-neutrality are satisfied throughout the family for every $C \geq 0$. Antisymmetry, however, places a non-trivial constraint on the denominator:

$$a(\rho_{\mathrm{o}}, \rho_{\mathrm{m}}) = -a(\rho_{\mathrm{m}}, \rho_{\mathrm{o}}) \quad \Leftrightarrow \quad \rho_{\mathrm{o}} + C\rho_{\mathrm{m}} = \rho_{\mathrm{m}} + C\rho_{\mathrm{o}},$$

which simplifies to $(1 - C)(\rho_{\mathrm{o}} - \rho_{\mathrm{m}}) = 0$, requiring $C = 1$ for all $\rho_{\mathrm{o}} \neq \rho_{\mathrm{m}}$. Boundedness then follows automatically.

$C = 1$ is therefore the unique value at which the C-family acquires the additional algebraic property of antisymmetry under exchange of density labels, together with the corresponding bounded form $a = g\chi$.

Status caveat. Exchange of density labels is an operation on the equation, not a physical symmetry of the configuration the equation describes. In a real fluid-dynamical setting, object and surrounding medium play physically distinct roles. The label-exchange operation therefore does not correspond to a physical invariance of the system, and $C = 1$ is not derived as a unique physical solution. What is established is more precise: of the C-family, $C = 1$ is the unique branch on which the equation acquires the algebraic property of antisymmetry under label exchange, and on which Valerie's Law is recovered. Its independent classical identity as the cylinder $\perp$-axis added-mass coefficient (Kelvin 1871; Lamb 1932; Brennen 1982) is a separate, physically grounded fact. The two together motivate the position of the $C = 1$ branch within the framework. Neither establishes $C = 1$ as a universal participation constant.

6 Limiting Regimes

Regime	Condition	Consequence
Equilibrium	$\rho_{\mathrm{o}} = \rho_{\mathrm{m}}$	$\chi = 0$, $a = 0$ (rest as state equivalence)
Positive disequilibrium	$\rho_{\mathrm{o}} > \rho_{\mathrm{m}}$	$\chi > 0$, $a > 0$ (denser falls)
Negative disequilibrium	$\rho_{\mathrm{o}} < \rho_{\mathrm{m}}$	$\chi < 0$, $a < 0$ (lighter rises)
Full positive saturation	$\rho_{\mathrm{o}} \gg \rho_{\mathrm{m}}$	$\chi \to +1$, $a \to +g$ (vacuum-limit fall)
Full negative saturation	$\rho_{\mathrm{o}} \ll \rho_{\mathrm{m}}$	$\chi \to -1$, $a \to -g$
Near-equilibrium (linear)	$\rho_{\mathrm{o}} = \rho_{\mathrm{m}} + \varepsilon$	$\chi \approx \varepsilon/(2\rho_{\mathrm{m}})$, $a \approx g\varepsilon/(2\rho_{\mathrm{m}})$
Antisymmetry swap	$\rho_{\mathrm{o}} \leftrightarrow \rho_{\mathrm{m}}$	$a(\rho_{\mathrm{o}}, \rho_{\mathrm{m}}) = -a(\rho_{\mathrm{m}}, \rho_{\mathrm{o}})$

6.1 Vacuum Limit

Substituting $\rho_{\mathrm{m}} \to 0$ into Valerie's Law:

$$a \;=\; g \cdot \frac{\rho_{\mathrm{o}} - 0}{\rho_{\mathrm{o}} + 0} \;=\; g \quad \text{for all positive } \rho_{\mathrm{o}}.$$

In this limit $\rho_{\mathrm{o}}/\rho_{\mathrm{m}} \to \infty$, so all positive-density objects occupy the same maximum-contrast state with $\chi \to 1$. This does not imply infinite object density; it reflects that all objects share the same limiting maximal density-contrast condition. Universal free-fall equality follows directly — the observable demonstrated on the lunar surface during Apollo 15 (Scott 1971), in line with Galileo (1638). More generally, in the vacuum limit the geometry-aware general law collapses to $a = g$ for every C-branch simultaneously: geometry, coupling, and drag have no effect on realised acceleration.

6.2 Comparison with the Classical Object-Normalised Form

The strict object-normalised acceleration form, in which the medium's inertial participation is neglected, is $a_{\mathrm{classical}} = g(\rho_{\mathrm{o}} - \rho_{\mathrm{m}})/\rho_{\mathrm{o}}$.

ValerieX (bounded $C = 1$ branch) gives

$$a_{\mathrm{VX}} \;=\; \frac{g(\rho_{\mathrm{o}} - \rho_{\mathrm{m}})}{\rho_{\mathrm{o}} + \rho_{\mathrm{m}}} \;=\; a_{\mathrm{classical}} \cdot \frac{1}{1 + \rho_{\mathrm{m}}/\rho_{\mathrm{o}}}.$$

When $\rho_{\mathrm{o}} \gg \rho_{\mathrm{m}}$, the two forms agree asymptotically. In the vacuum limit, recovery is exact. The observable difference between the $C = 1$ bounded branch and the $C = 0$ strict object-normalised limit is largest in intermediate-density regimes (Volume IV). Both forms are members of the recognised added-mass family; the $C = 0$ limit is appropriate when medium participation is genuinely negligible (dense bodies in air, vacuum). The intermediate-regime measurements proposed in Volume IV therefore validate the C-family structure rather than testing ValerieX against classical fluid mechanics.

7 Available vs Realised Motion

Valerie's Law gives the *available* acceleration $a_{\mathrm{available}} = g\chi$. Not all available motion is fully realised in a real environment. ValerieX therefore distinguishes available motion (set by χ) from realised motion (set by environmental constraint).

Pathway availability is the extent to which the environment provides accessible routes for disequilibrium to resolve. **Motion constraint** is the limiting effect of the environment on realised motion: viscous resistance, confinement, internal dissipation. Classical drag composes with Valerie's Law to give terminal behaviour (Stokes 1851; Reynolds 1883; Batchelor 1967).

Terminal velocity. For low-Reynolds Stokes flow:

$$v_t \;=\; \frac{F_{\mathrm{net}}}{6\pi\eta r}.$$

For general bluff-body regime:

$$v_t \;=\; \sqrt{\frac{2|\Delta\rho| g V}{C_d \rho_{\mathrm{m}} A}}.$$

Both are dissipative completions of the picture: density-state disequilibrium sets the drive; the medium sets the constraint; terminal velocity is the realised steady state.

7.1 Pathway Availability and Weight

Within ValerieX, weight is not a continuously expressed property but a realised condition arising from environmental constraint. A body expresses weight only when its downward motion is blocked from below by a rigid surface. Weight is the realised expression of constrained vertical motion under blocked pathway availability. When the downward pathway is available, the same underlying motion tendency is realised as motion (unconstrained regime) or transmitted through support (supported regime).

This unified reading is developed in detail in Volume II:

> Density contrast defines the available motion tendency. Pathway availability determines whether that tendency is realised as motion, tension, or weight.

8 Recovery of Classical Vertical-Motion Behaviour

The principal observables explained classically through gravity, buoyancy, and effective weight are rebuilt from Valerie's Law:

- *Neutral equilibrium*: $\rho_{\mathrm{o}} = \rho_{\mathrm{m}} \Rightarrow a = 0$.
- *Rise/fall*: $\rho_{\mathrm{o}} > \rho_{\mathrm{m}} \Rightarrow$ positive branch (fall); $\rho_{\mathrm{o}} < \rho_{\mathrm{m}} \Rightarrow$ negative branch (rise).
- *Vacuum equality*: $\rho_{\mathrm{m}} \to 0 \Rightarrow a = g$ for all positive ρ_{o}.
- *Weight-like behaviour*: positive branch of density-state resolution under blocked pathway.
- *Buoyancy-like behaviour*: negative branch of the same relation.
- *Terminal behaviour*: realised-motion constraint via drag.
- *Geometry-dependent realised acceleration*: through participating medium load $(\rho_{\mathrm{o}} + C\rho_{\mathrm{m}})V$.

The recovery is achieved from one law plus medium participation rather than from a stack of separate primitive force terms. Where ValerieX and classical mechanics describe the same observables, they agree at the level of behaviour.

9 Worked Examples

Scenario	ρ_{o}	ρ_{m}	χ	$a\ (\mathrm{m\,s^{-2}})$	Direction
Lead ball in air	11340	1.225	$+0.99978$	$+9.805$	falls
Volleyball in air	80	1.225	$+0.9699$	$+9.511$	falls
Iron anvil in mercury	7870	13534	-0.2647	-2.596	floats high
Ice in water	917	1000	-0.0433	-0.425	floats low
Volleyball in water	80	1000	-0.8519	-8.353	rises fast
Helium balloon in air	0.179	1.225	-0.7451	-7.305	rises
Hot-air balloon (100 °C)	0.95	1.225	-0.1264	-1.239	rises gently

Scenario	ρ_o	ρ_m	χ	a $(\mathrm{m\,s^{-2}})$	Direction
Air bubble in water	1.225	1000	-0.99756	-9.783	rises maximally
Rock in water	2700	1000	$+0.4595$	$+4.505$	sinks
Vacuum (ideal)	any > 0	0	$+1.0000$	$+9.807$	universal fall

Densities in $\mathrm{kg\,m^{-3}}$. One law, one χ, one direction rule. Every demonstration sits somewhere on the curve $a = g\chi$.

10 Scope and Limitations

ValerieX applies specifically to vertical motion in a surrounding environment, scope-restricted to phenomena that can be directly observed, measured, and repeated under everyday or accessible laboratory conditions. The framework does not yet provide:

- A first-principles derivation of g (treated as observed, not derived).
- Cosmological-scale extensions (out of scope; vertical direction is locally defined).
- Quantitative reproduction of precision-G measurements within the density-state framework (named explicitly as future work; see Volume II Appendix A).
- Full transient drag integration (treated computationally in Volume III §8).

These are stated as boundaries of the present formulation rather than as defects.

11 References (key)

Archimedes (c. 250 BCE). *On Floating Bodies*.

Brennen, C. E. (1982). *A Review of Added Mass and Fluid Inertial Forces*. Naval CEL Report CR 82.010.

Galilei, G. (1638). *Discorsi e dimostrazioni matematiche intorno a due nuove scienze*.

Gillies, G. T. (1997). The Newtonian gravitational constant. *Rep. Prog. Phys.* 60, 151–225.

Kelvin, Lord (W. Thomson) (1871). Hydrokinetic solutions and observations. *Phil. Mag.* 42, 362–377.

Lamb, H. (1932). *Hydrodynamics*, 6th ed. Cambridge University Press.

McKee, K. & Czarnecki, A. (2019). Acceleration due to buoyancy and mass renormalization. *Am. J. Phys.* 87(3), 165–170.

NIST (2019). CODATA recommended value: standard acceleration of gravity, $g_n = 9.80665\,\mathrm{m\,s^{-2}}$.

Reynolds, O. (1883). *Phil. Trans. Roy. Soc.* 174, 935–982.

Scott, D. (1971). *Apollo 15 Mission Report*. NASA MSC-05161.

Stokes, G. G. (1851). *Trans. Camb. Phil. Soc.* 9, 8–106.

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