How physics works, complete edition

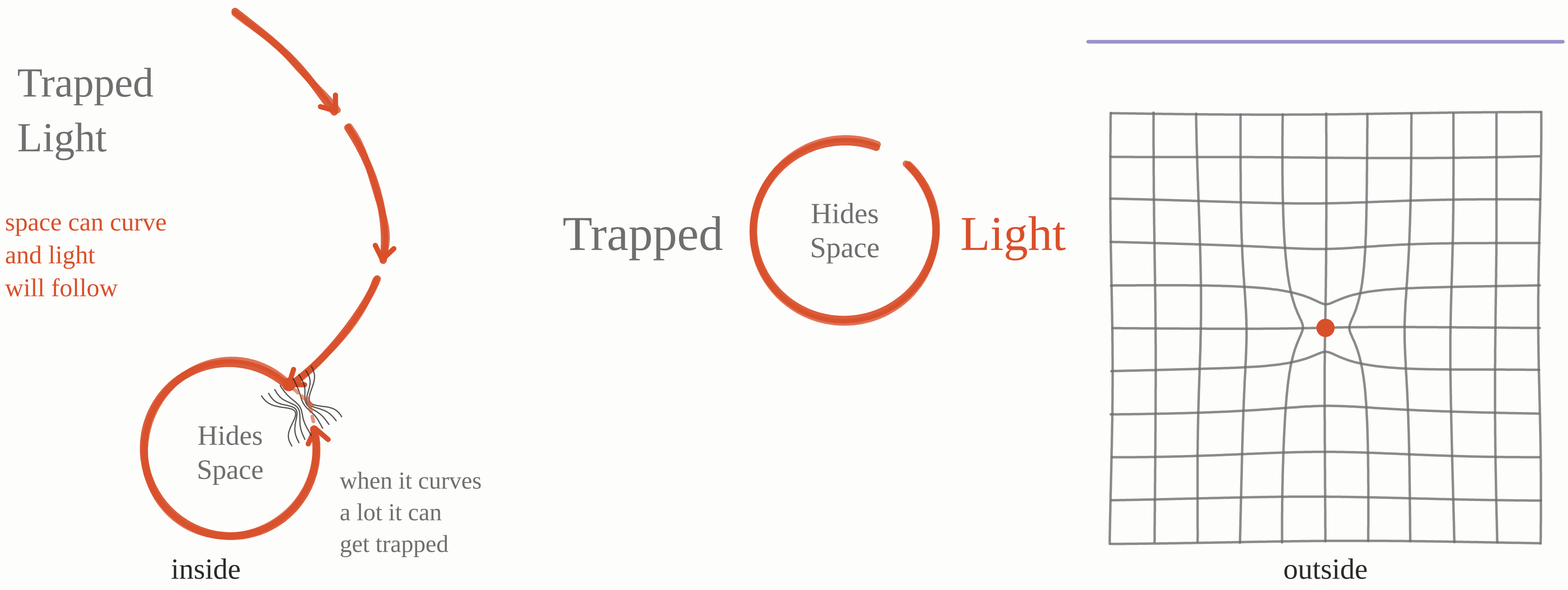
The eighteen pages of the front page, six topics at three reading levels, on one plain page with their drawings: for reading without JavaScript, for search, and for anyone who wants to quote or check a line. Every figure is computed from the published VMS documents; each page is exactly the one the front page shows, and each is also served on its own. Also as a PDF.

1 Mass · Elementary this page on its own

What is mass?

A photon is the smallest piece of light. Light always goes straight, as fast as anything can go, and it hides the space behind it.

If a photon gets curled into a loop it goes around and around, and it keeps hiding the space inside. That trapped light is what we call mass. Everything you can touch is made of trapped light.



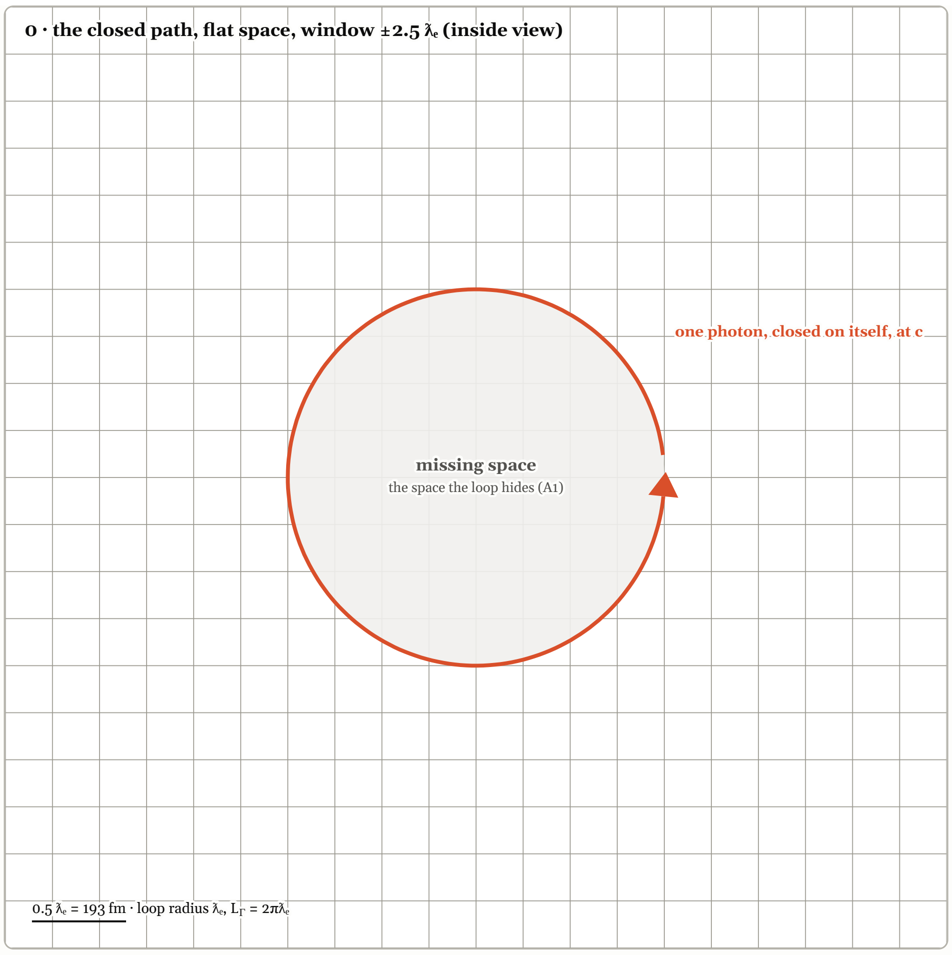
Inside (left): the photon runs around and around and hides the space in the middle.

Outside (right): you cannot see the hidden space at all, only a dot. But all the lines of space around it lean in toward it. That leaning is how you can tell something is there, and it is what makes things fall (next page).

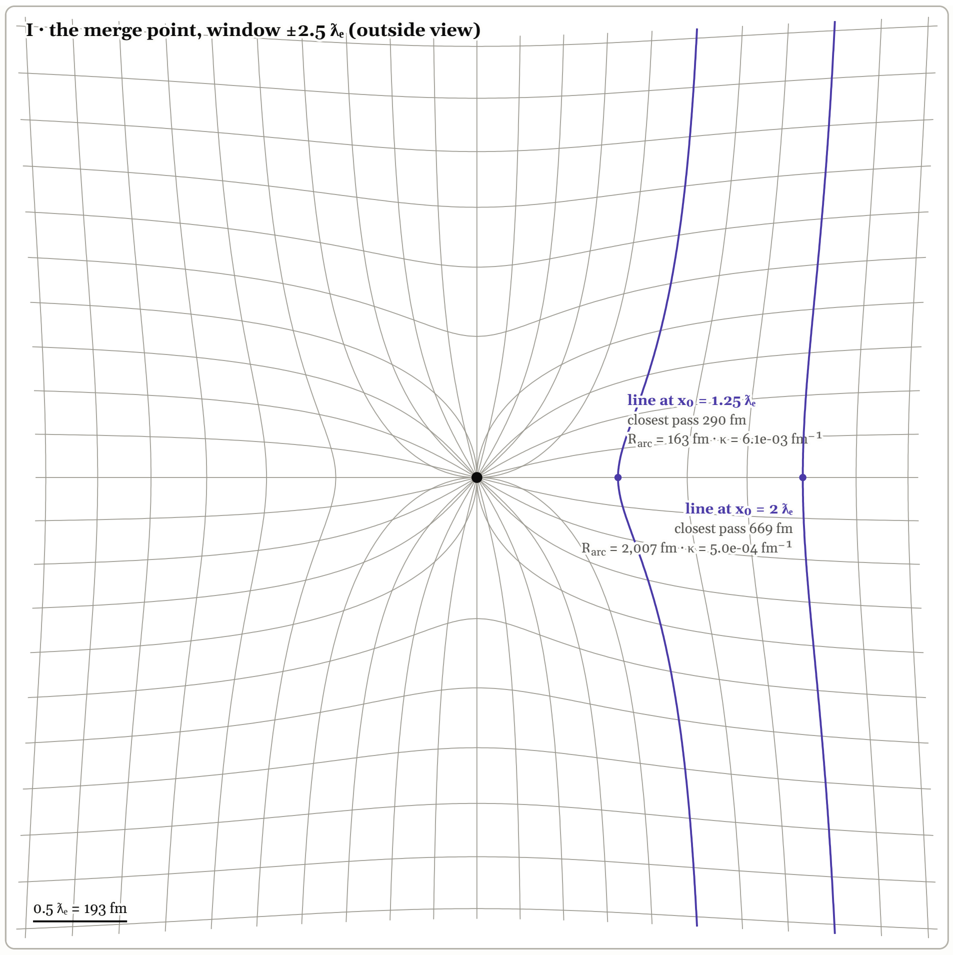
1 Mass · High school this page on its own

Mass: a closed path hiding space, and what speed does to it

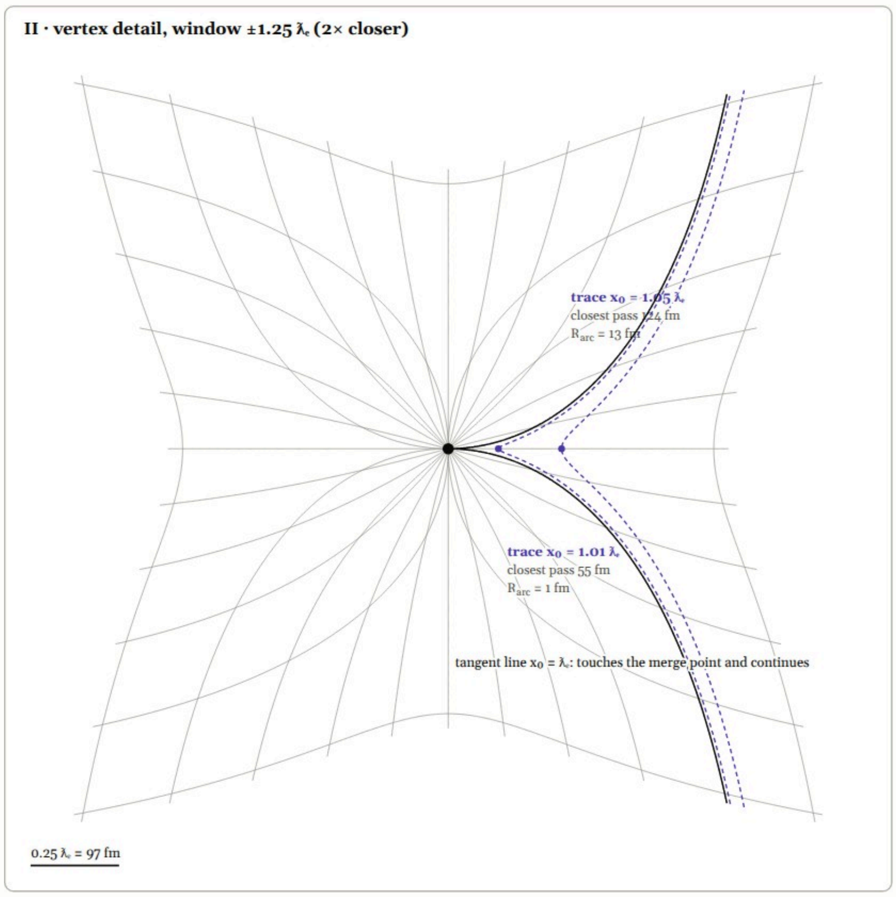
A photon is the smallest piece of light; this page follows one photon closed into a loop, the electron, and the space it hides. Light runs at c and hides the space behind it. Close its path into a loop and it hides a fixed amount of space every cycle; that hidden total is the inertial measure, mass. Seen from inside (panel 0) the loop is a path at c around a missing disk. Seen from outside (panels I to IV) the missing space cannot be seen at all: there is only a point, and every line of space that passes it leans in, the lines that would have crossed the missing disk meeting at the point and continuing. The electron sets the scale, $ƛ_e = \hbar/(m_e c) = 386.16$ fm, the framework's single calibration.



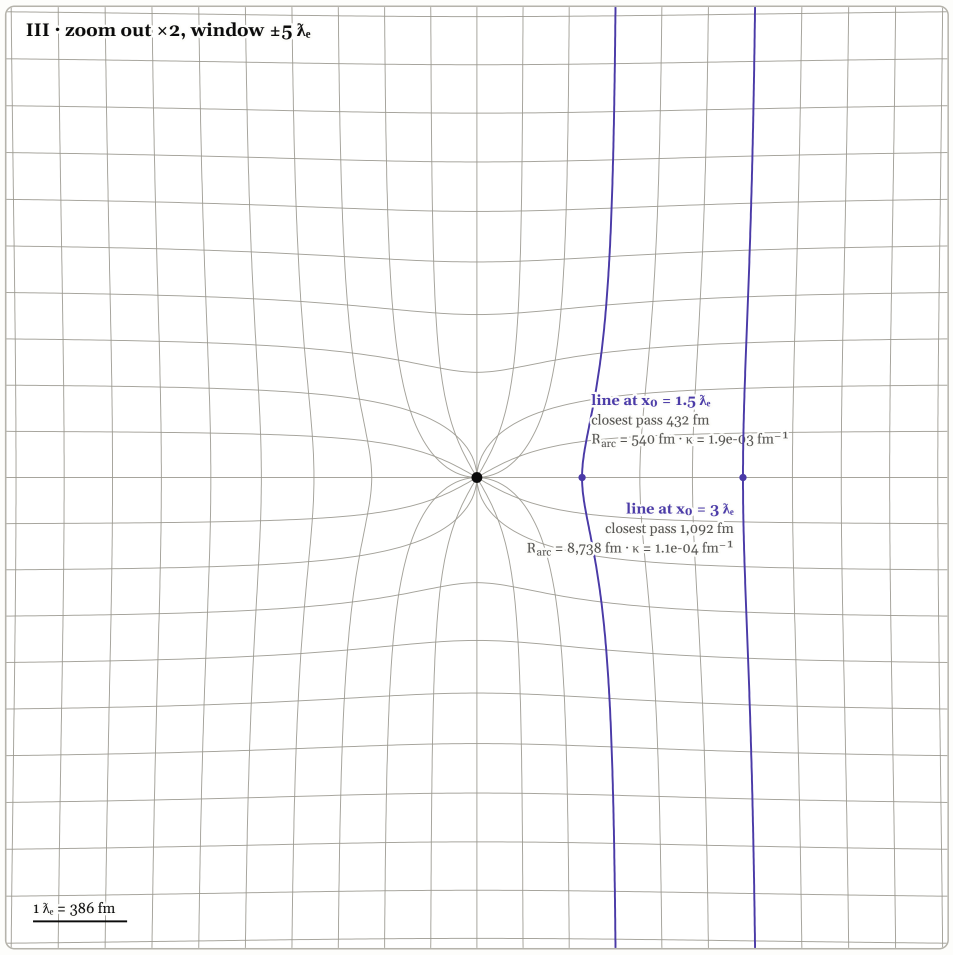
0 · the closed path, inside view. The electron: one photon on a closed path at c, hiding the space inside it. The grid is drawn straight; this view sets the object and the scale. $S_0 = \hbar$ on this loop is the single calibration; $m = (\sigma_S/c^2)\cdot L_\Gamma$, $L_\Gamma = 2\pi\lambda_e$.



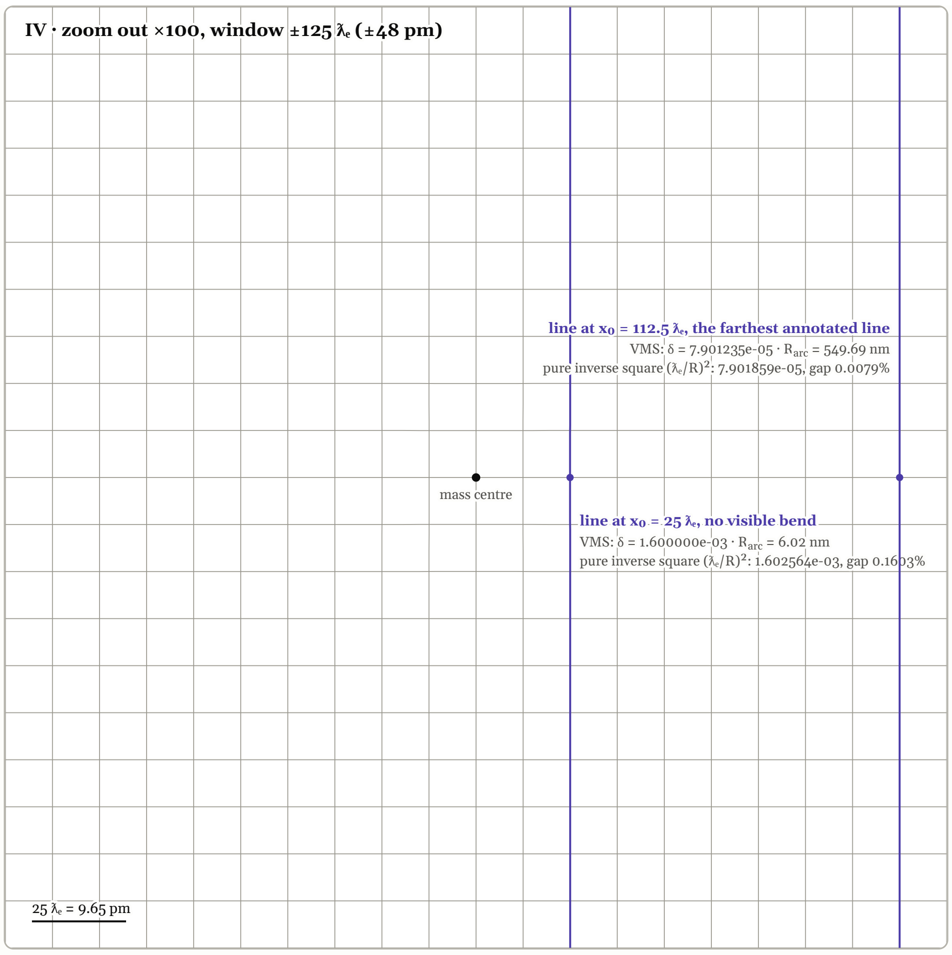
I · the merge point, outside view. The same electron seen from outside: the grid lines of space under the map. Lines that crossed the missing disk merge at the point and continue; passing lines bend inward. Two lines are annotated with their computed closest pass and their curvature there, where it is largest.



II · vertex detail, 2× closer. Every line that crossed the missing disk passes through this one vertex: formerly parallel lines meeting, the geometry of an interaction. The tangent line touches and continues. Two dashed traces (computed, not part of the grid) show how fast the closest pass collapses just outside tangency.



III · zoom out ×2. Same law, half the magnification. The arc radii grow fast with distance: one grid step farther out bends on a circle several times larger.



IV · zoom out ×100. At this distance no line shows a visible bend; the numbers carry the physics. For each annotated line, the share of space missing at its closest pass, δ, is printed next to the pure inverse square $(ƛ_e/R)^2$ at the same seen radius. On the farthest line they agree to five decimals: from here outward a single particle's missing space and the Newton form cannot be told apart, shown as arithmetic, not assertion.

Reading order. 0, the object itself in flat space, scale set. I, the object seen from outside, with measured bends. II, the vertex where every crossing line merges and continues. III, one zoom out, the bending dying as the square of the distance. IV, one hundred times out, nothing visibly bends and the printed arithmetic shows the missing-space profile and the pure inverse square agreeing to five decimals on the far line. No inverse-square law is used to draw any line; it appears in IV only as a printed number beside the computed value.

$$m \propto \oint_\Gamma A_d(s)\,ds, \quad m = (\sigma_s/c^2)\cdot L_\Gamma$$

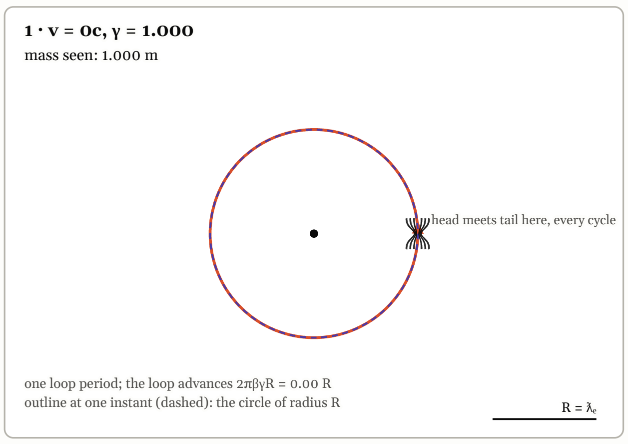
(the space a closed path hides per cycle is the inertial measure; for the electron $L_\Gamma = 2\pi ƛ_e$; Mathematical Bridge, section 3; Bridge Math Appendix, Inertial Mass)

$$\delta(R) = ƛ_e^2/(R^2 + ƛ_e^2) \;\rightarrow\; ƛ_e^2/R^2$$

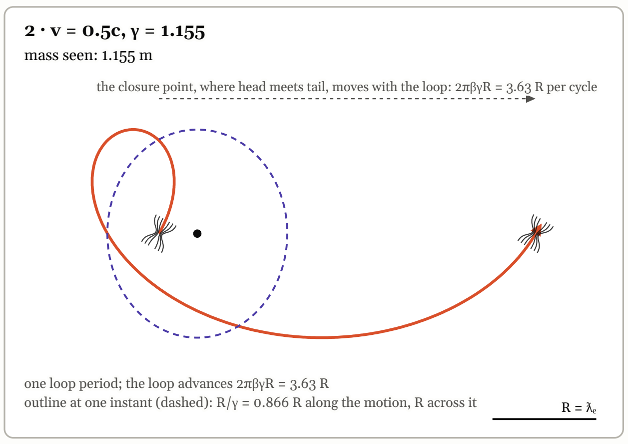
(the share of space missing at seen radius R: 1 at the point, the inverse square far away; the drawing's map of the Bridge's "fixing the missing volume" and "$\Delta g(r) \sim 1/r^2$")

What speed does: the same loop, seen moving

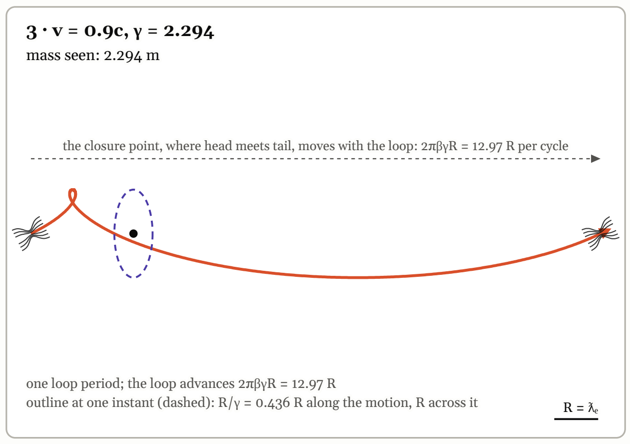
Nothing about the loop changes and the light still runs at c. Seen from a laboratory it is moving past, its cycle takes γ times longer, the photon's path opens into the curve drawn, and the loop's outline is squeezed to R/γ along the motion. In the loop's own frame the path is the closed circle and head meets tail at the same place every cycle; from the laboratory the point where head meets tail is itself moving, so the path never rejoins where it started (the small pinch marks). The mass seen is γ times the rest mass. In the textbook's letters this is $E = \gamma mc^2$, and the first two terms of that are the rest energy mc^2 and the kinetic energy $\frac{1}{2}mv^2$.



1 · at rest. The photon's path is the circle; the loop hides one disk of space per cycle. Mass seen: m.



2 · v = 0.5c, γ = 1.155. The path over one loop period, the loop advancing $2\pi\beta\gamma = 3.63$ loop radii per cycle; the outline at one instant is contracted to R/γ along the motion. Mass seen: 1.155 m.



3 · v = 0.9c, γ = 2.294. The loop advances 12.97 loop radii per cycle and its outline is squeezed to 0.436 R. Mass seen: 2.294 m. The loop can never reach c: a loop at v = c could not close.

$$E = \gamma mc^2 \approx mc^2 + \tfrac{1}{2}mv^2 + \tfrac{3}{8}mv^4/c^2 + \ldots, \quad \gamma = 1/\sqrt{(1 - v^2/c^2)}$$

(mass seen γm; the first term is the rest energy $E = mc^2$, the second the textbook's kinetic energy $\frac{1}{2}mv^2$; Mechanics Math Appendix, section 3, where these relativistic relations are stated and the Newtonian limit recovered)

$$p = \gamma mv, \quad E^2 = p^2c^2 + m^2c^4$$

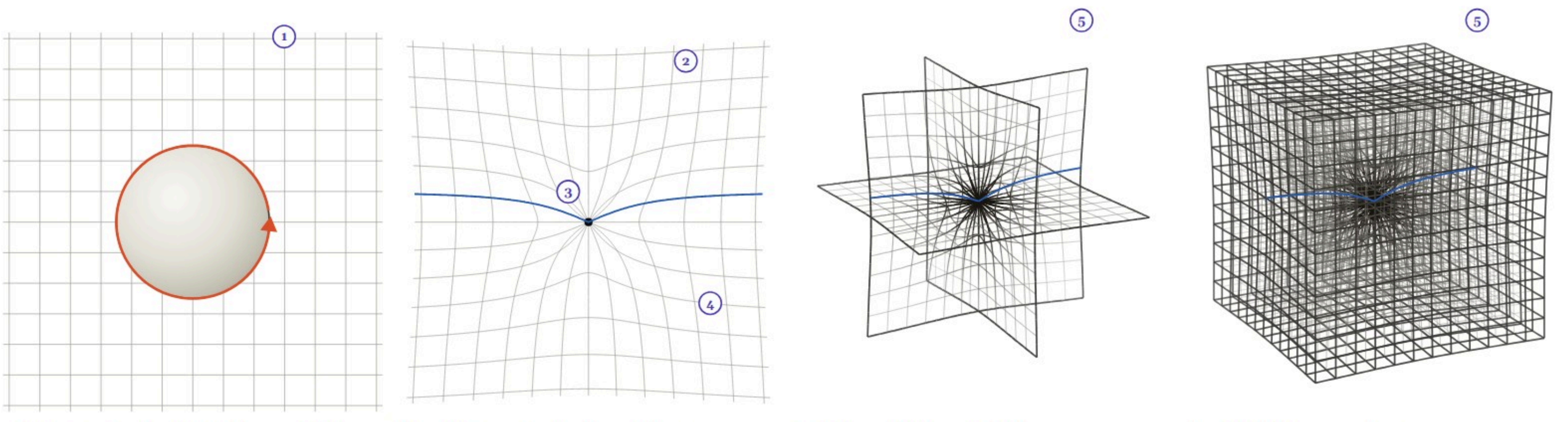
(the same section; a loop cannot exceed c because a loop at $v \geq c$ would fail to close, Bridge Math Appendix, Deflection, Elongation, and Observed Mass Increase)

<u>Mathematical Bridge, section 3 ($m \propto \oint A_d\,ds$; the missing volume; $\Delta g \sim 1/r^2$)</u>, <u>Bridge Narrative, step 3 (mass as missing space)</u>, <u>Bridge Math Appendix, Mass and Gravity, sections 1 to 4 and 6A</u>, <u>Mechanics Math Appendix, section 3 ($E = \gamma mc^2$)</u>, <u>Particle Mechanics Math Appendix ($S_0 = \hbar$, $ƛ_e$)</u>.

Every line computed. Panels 0 to IV: the disk of area $\pi ƛ_e^2$ is the space the loop hides (axiom A1); from outside it is not seen, and every point of space at true distance r from the loop centre is seen at $R(r) = \sqrt{(r^2 - ƛ_e^2)}$, points inside the disk all at the centre point. This map is the drawing's construction of two lines of the Mathematical Bridge, section 3: the loop "removes a volume of available transverse area from the surrounding space, fixing the missing volume", and "this deficit propagates outward with profile $\Delta g(r) \sim 1/r^2$"; it removes exactly $\pi ƛ_e^2$ from every circle around the point, and its missing share $\delta = ƛ_e^2/r^2$ is exactly the inverse square. Every grid line is the image of a straight line under that map; lines that crossed the disk are drawn through the point and out the other side. Annotated values: the closest pass of a line is its seen radius $\sqrt{(x_0^2 - ƛ_e^2)}$; the curvature κ is evaluated where the line crosses the centre line, its maximum; $R_{arc} = 1/\kappa$. Panel IV prints δ at each line's true offset x_0 beside $(ƛ_e/R)^2$ at its seen radius. Speed panels: the photon's path is the standard relativistic transformation of the rest-frame circle (Mechanics Math Appendix, section 3): $x = \gamma R \cos\theta + \beta\gamma R\theta$, $y = R \sin\theta$, its speed c at every point (axiom A2), the loop period γ times longer, the outline contracted to R/γ along the motion; γ values and the mass ratio computed, nothing else drawn.

Defining mass: a closed path and the space it hides, the full derivation

A photon is the smallest piece of light; this page follows one photon closed into a loop and derives what the high school page stated. A region of space is hidden; from outside the missing space is not observable, there is only the point and its effect on every line of space that remains. That is the definition of mass. A: the inside view, the closed path and the sphere it hides. B: the map acting on a flat plane through the centre. C: the identical map on the three mid-planes of a block, where every line stays traceable. D: the full block, every radius at once. In B, C and D the lines that met the hidden boundary merge at the point and continue; the crowding and darkening around it is the interaction zone, and the point is the only near-black. Each numbered circle is a panel below.



A · inside view: the closed path and the region it hides — B · outside view: a flat plane through the centre — C · the three mid-planes of the block — D · the full block, every radius at once

The case drawn.

$$m \propto \oint_\Gamma A_d(s)\,ds, \quad R^2 = r^2 - R_0^2, \quad \delta = R_0^2/(R^2 + R_0^2)$$

(the inertial measure, Mathematical Bridge section 3; the map, the drawing's construction of the Bridge's "fixing the missing volume" and "Δg(r) ~ 1/r²")

In the textbook's letters the same closed path gives the rest energy and, for the electron, its size:

$$E = mc^2, \quad m = (\sigma_s/c^2)\cdot L_\Gamma, \quad ƛ_e = \hbar/(m_e c) = 386.16 \text{ fm}$$

(Bridge Math Appendix, Inertial Mass from Energy; $S_0 = \hbar$ is the one calibration, Particle Mechanics Math Appendix)

Panels 1 to 4. The general solution, panels 5 and 6.

The general solution, and what it recovers, from the worldsheet action and nothing else:

the loop action $S_\Gamma = \oint A_d\,ds$, the inertial measure	**panel 1**
the map and the deficit δ, fixed missing area, $1/r^2$ far field	**panels 2 to 4**
$E = \sigma_s L_\Gamma$, $m = E/c^2$: rest energy and inertial mass	**panel 5**
the loop's stress–energy $T^{\mu\nu}$, the dent that curves space	**panel 6**

The coupling of that dent to the motion of a second loop, and Newton's law from it, is the gravity page.

Published documents used, and nothing else: the Mathematical Bridge (section 3, Closed Loop → Inertial Measure and Gravity, recipe steps 1 to 4) and its Math Appendix (Mass and Gravity from Closed Void Loops, sections 1 to 4); the Bridge Narrative, step 3 (mass as missing space); the Treatise on Caustics, Loop Closure (the closed path, head and tail merged, seen as one point); the Particle Mechanics Math Appendix ($S_0 = \hbar$, $ƛ_e$). Only ratios enter; $S_0 = \hbar$ is the one scale.

The case drawn (panels 1 to 4) and the general solution (panels 5 and 6)

1 In this case: one photon, closed on itself

A photon runs at c and hides the space behind it (axiom A1). Close its path so head and tail merge and it hides the same region every cycle: the closed path is the electron (Treatise on Caustics, Loop Closure). The path has the shape of the sphere $\|x\| = R_0$; it is a path, not the surface of an object. The region inside is obscured; from outside the whole path is seen as one point. The hidden total per cycle is the inertial measure:

$$m \propto \oint_\Gamma A_d(s)\,ds$$

Mathematical Bridge, section 3, step 1; Bridge Math Appendix, Mass and Gravity, section 1: "the integrated Display Area is S_Γ := ∮_Γ A_d(s) ds".

Scale: the electron loop, $ƛ_e = \hbar/(m_e c) = 386.16$ fm, the single calibration ($S_0 = \hbar$; Particle Mechanics Math Appendix). In these panels $R_0 = 2.5$ lattice steps.

2 The map: what is seen from outside

Distances measured from outside omit the hidden span. A point at true distance r from the centre is seen at R, with

$$R^2 = r^2 - R_0^2, \quad \text{equivalently} \quad \pi R^2 = \pi r^2 - \pi R_0^2$$

on every central plane, and every point with $r \le R_0$ is seen at the centre. The map rescales $\|x\|$ and keeps its direction, so it preserves every central plane; every curve in the block is a plane-figure curve (panels C, D). The missing share of the original disk at seen radius R is the deficit:

$$\delta = \pi R_0^2/\pi r^2 = R_0^2/(R^2 + R_0^2); \quad \delta(0) = 1; \quad \delta \to R_0^2/R^2 \text{ for } R \gg R_0$$

This map is the drawing's construction of two Bridge lines (section 3): the loop "removes a volume of available transverse area from the surrounding space, fixing the missing volume", and "this deficit propagates outward with profile Δg(r) ~ 1/r²". It is not itself a line of the Math Appendix.

3 The blue line, worked: y = 1 in the z = 0 sheet

The same line in panels B, C and D. Crossings from the chord equation with $A = (-6, 1, 0)$, $v = (1, 0, 0)$: $(A\cdot v)^2 - |v|^2(|A|^2 - R_0^2) = 36 - 30.75 = 5.25$, so the boundary sits at $x = \pm\sqrt{5.25} = \pm 2.291$. Both ends of the gap are seen at the same point, and the two outer pieces join there and continue.

x	$r = \|x\|$	$R = \sqrt{r^2 - R_0^2}$	$\delta = R_0^2/r^2$
-6.000	6.083	5.545	0.169
-4.000	4.123	3.279	0.368
-2.291 (boundary)	2.500	0, the point	1.000

−2.291 < x < 2.291: hidden, nothing that can be drawn

x = +2.291: the same point (δ = 1); x = +4, +6: mirror of the left

Treatise on Caustics (the crossing points seen at one point); the map as in panel 2.

4 The invariant: what the map removes, it removes everywhere equally

circle r	area πr^2	mapped R	area πR^2	missing
3	28.274	1.658	8.639	19.635
4	50.265	3.122	30.631	19.635
6	113.097	5.454	93.462	19.635

$R^2 = r^2 - R_0^2$, so every mapped circle encloses exactly $\pi R_0^2 = 19.635$ square steps less than before: the same missing area at every radius. The map does one thing, it removes a fixed amount of space, and nothing else: the Bridge's "fixing the missing volume" (section 3), drawn on the central plane.

The far field: the missing share δ against the pure inverse square R_0^2/R^2

- r = 4: δ = 0.3906, $R_0^2/R^2 = 0.6410$, ratio 0.609
- r = 10: δ = 0.0625, $R_0^2/R^2 = 0.0667$, ratio 0.938
- r = 20: δ = 0.0156, $R_0^2/R^2 = 0.0159$, ratio 0.984
- r = 40: δ = 0.0039, $R_0^2/R^2 = 0.0039$, ratio 0.996

The ratio tends to 1: far from the loop the deficit is inverse square, the Bridge's Δg(r) ~ 1/r².

⑤ The general solution: from the loop's action to its mass

As the closed loop Γ propagates in time it sweeps a worldsheet W, embedded as $X^\mu(\tau, \lambda)$ with induced metric $\gamma_{ab} = g_{\mu\nu}\, \partial_a X^\mu\, \partial_b X^\nu$. Its action is the minimal-area principle applied to the obscured area it transports ("analogous to the Nambu–Goto action"):

$$S_{\text{void}}[W; g] = \sigma_s \int_W \sqrt{(-\gamma)}\; d^2\xi$$

σ_s the surface-action density. In the static gauge $X^0 = c\tau$, $X^i = X^i(\lambda)$, the energy is σ_s times the loop's spatial length, and the inertial mass is

$$E = \sigma_s \oint_\Gamma |\partial_\lambda X|\, d\lambda = \sigma_s\, L_\Gamma, \quad m = E/c^2 = (\sigma_s/c^2)\, L_\Gamma$$

and when the display area varies along the loop, $m \propto \oint_\Gamma A_d(s)\, ds$. "Mass is not an independent assumption; it is the geometric consequence of how much space the Void loop obscures." For the electron, $L_\Gamma = 2\pi ƛ_e$.

Bridge Math Appendix, Mass and Gravity, sections 2 and 4; Bridge section 3, step 4.

⑥ What the loop does to the space around it

Varying the same action with respect to the metric gives the loop's stress–energy, localized on its worldsheet:

$$T^{\mu\nu}(x) = \sigma_s \int d^2\xi\, \sqrt{(-\gamma)}\, \gamma^{ab}\, \partial_a X^\mu\, \partial_b X^\nu\, \delta^{(4)}(x - X(\xi))$$

"In plain terms: a closed loop makes a local 'dent' in the fabric of space, proportional to the obscuration it carries." The stationary loop minimises its action, and that minimisation forces the deficit of transverse area drawn in panels B to D: the dent. Its outward profile is inverse square (panel 4), the seed of the Newtonian potential; how a second loop moves in it is the next page.

Bridge Math Appendix, Mass and Gravity, section 3; Mathematical Bridge, section 3, steps 2 and 3. The coupling of this $T^{\mu\nu}$ to geometry (sections 5 to 7) is the gravity page.

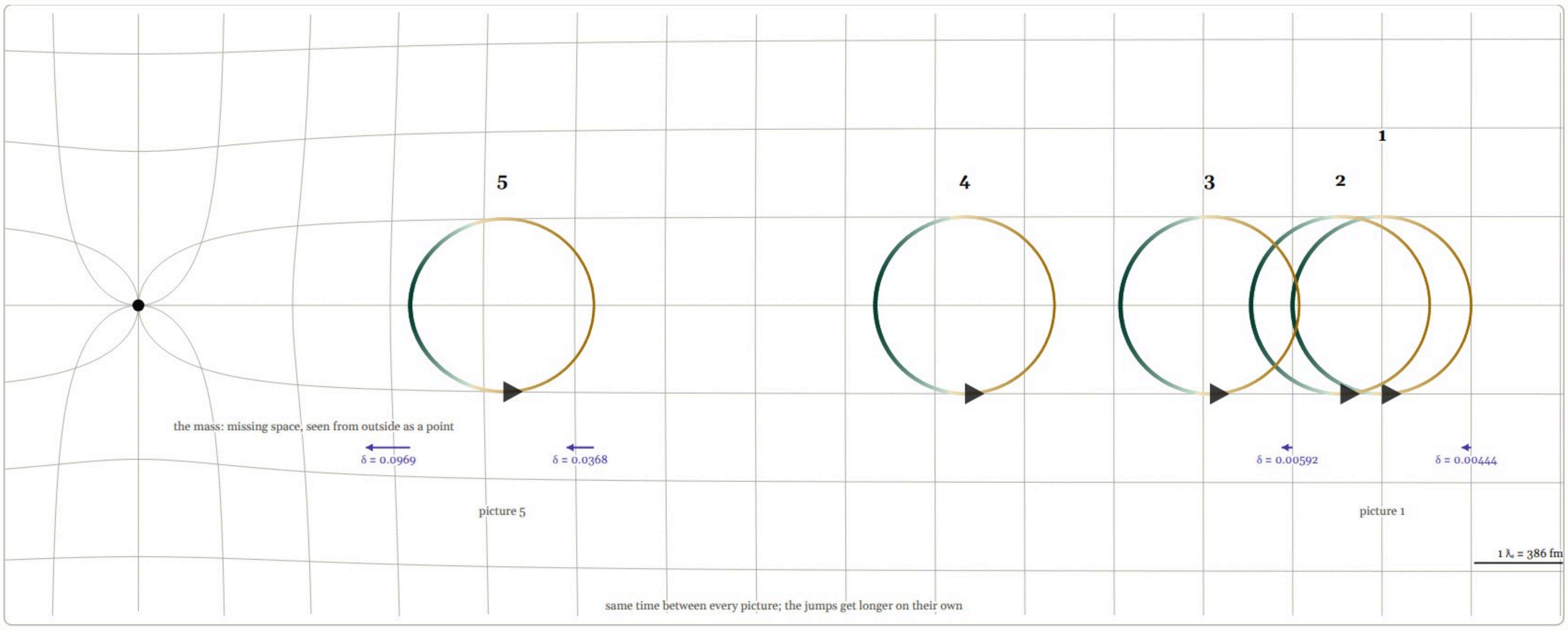
Symbol	Meaning	Where it is fixed
Γ, W	the closed path of the photon; the worldsheet it sweeps in time	Bridge Math Appendix, Mass and Gravity §1
A_d, S_Γ	display area, the space a front obscures; the loop action $\oint A_d\, ds$	Bridge §1 and §3; Appendix §1
σ_s	surface-action density (a derived constant)	Appendix §2
R_0, r, R	radius of the closed path; a point's true distance; its distance seen from outside, $R^2 = r^2 - R_0^2$	the map (the drawing's construction of Bridge §3)
δ	the deficit, the missing share of display area at seen radius R	the map; Bridge §3, $\Delta g \sim 1/r^2$
$ƛ_e$, $S_0 = \hbar$	the electron loop radius, 386.16 fm; the single calibration	Particle Mechanics Math Appendix

Every line computed. All four views use the same boundary $R_0 = 2.5$ lattice steps and the same extent (±6 steps). A draws the flat lattice with the closed path (orange, at c) and the sphere it hides; nothing is bent, because from inside the hidden region is simply there. B maps each grid line of the central plane point by point through $R(r) = \sqrt{(r^2 - R_0^2)}$; lines that cross the disk are drawn through the point and out the other side. C and D map their lines through the same map along each radius and then through a fixed perspective camera, nearer lines drawn darker; segment darkness and weight follow the local deficit δ (declared), so the interaction zone is where the ink itself accumulates; the near-black is reserved for $\delta = 1$, the point. The blue line $y = 1$ in the $z = 0$ sheet is the same line in B, C and D and is worked in panel 3. Tables in panels 3 and 4 are computed from the map. Sources: Mathematical Bridge, Bridge Math Appendix, Bridge Narrative, Treatise on Caustics, Loop Closure, Particle Mechanics Math Appendix. Generator: gen_mass_proofs3d.py.

Why things fall

A photon is the smallest piece of light. The ring is one photon trapped in a loop, like on the mass page. The black dot is a big trapped-light mass, seen from outside: you cannot see its hidden space, only the lines of space leaning in toward it.

Nothing pulls the little loop. The lines of space lean toward the missing space, and the loop just follows the lines it lives in. There is the same time between every picture, and the jumps get longer on their own. That is gravity.



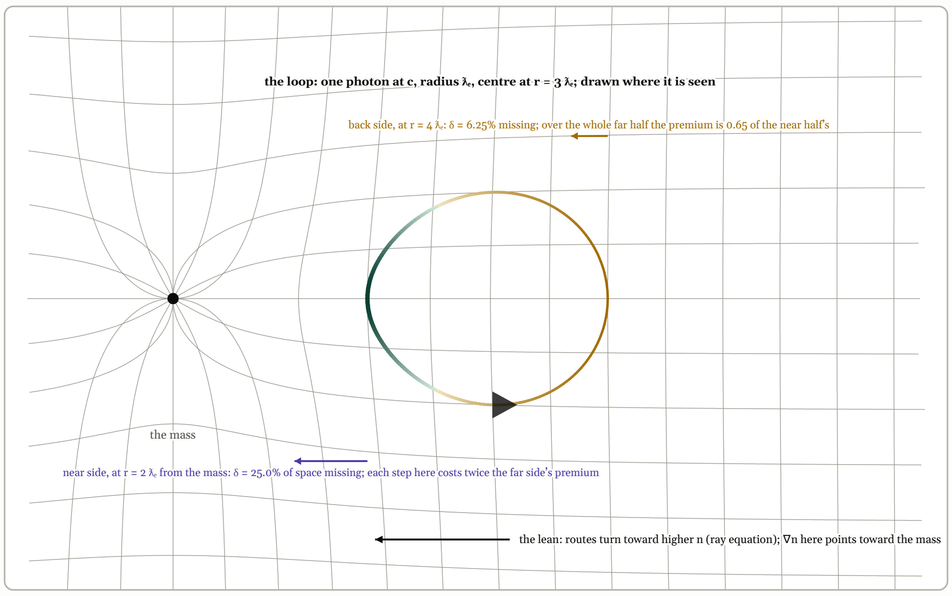
Each loop wears **dark green where space is squeezed shortest**, the side by the mass, and **yellow where space runs longest**, the side far away. The squeezed side always wins, so the loop swings toward its dark green.

Inside the little loop the photon keeps going around at the same speed the whole time. **Outside**, the mass is only a dot; the little arrows under pictures 1 and 5 show how much space is missing at the loop's near side and its far side. The near side is always deeper, and the pair grows as the loop falls.

Gravity: falling without a force, and who agrees where

A photon is the smallest piece of light; this page follows one photon closed into a loop, standing in the missing-space profile of another loop, a mass. Nothing pulls it. Around a mass the lines of space lean in, and the space itself is not the same on the loop's two sides: on the near side more of it is already missing. The loop's photon still runs at c, but its route "leans slightly toward the region with more space already hidden and pays a tiny time premium to get past" (Bridge Narrative, step 4). That lean, every cycle, is gravity: "no pushes or pulls; cleaner route wins". Far away and slow, it is Newton's law exactly; the four classical tests of general relativity come out of the same route picture with one factor set once.

1. Why a loop falls



One loop of light near a mass, drawn on the same mapped space as the Mass page, and drawn where it is seen: through the mass's map its circle appears elongated toward the mass (Bridge Math Appendix, 6A: "its apparent circle elongates toward the curvature source"). The photon runs at c the whole way round (axiom A2). The space under its two halves is not the same: at the near side, $r = 2$ $ƛ_e$ from the mass, 25% of the space is missing; at the back, $r = 4$ $ƛ_e$, only 6.25%. In the Walk-Through's cost map, $n(x) = 1 - 2\Phi/c^2$ with $\Phi = -GM/r$, a step near the mass costs more ("higher n means this step hides a bit more display-area than average"): the near edge's premium is twice the far edge's, and summed round the two halves the near half pays 1.53 times what the far half pays (computed, $\int(n - 1)\,ds$; G cancels in the ratio). The colour runs by that cost per step: green where each step hides the most space, yellow where it hides the least. Routes turn toward higher n, that is the ray equation $d/ds(n\,t) = \nabla n$, and ∇n at the loop points toward the mass; so every cycle the loop drifts that way. Only the size of the drift rests on G, an acceptance lock. As a seven-year-old put it: just like a Beyblade in a curved bowl, it wants to go toward the centre.

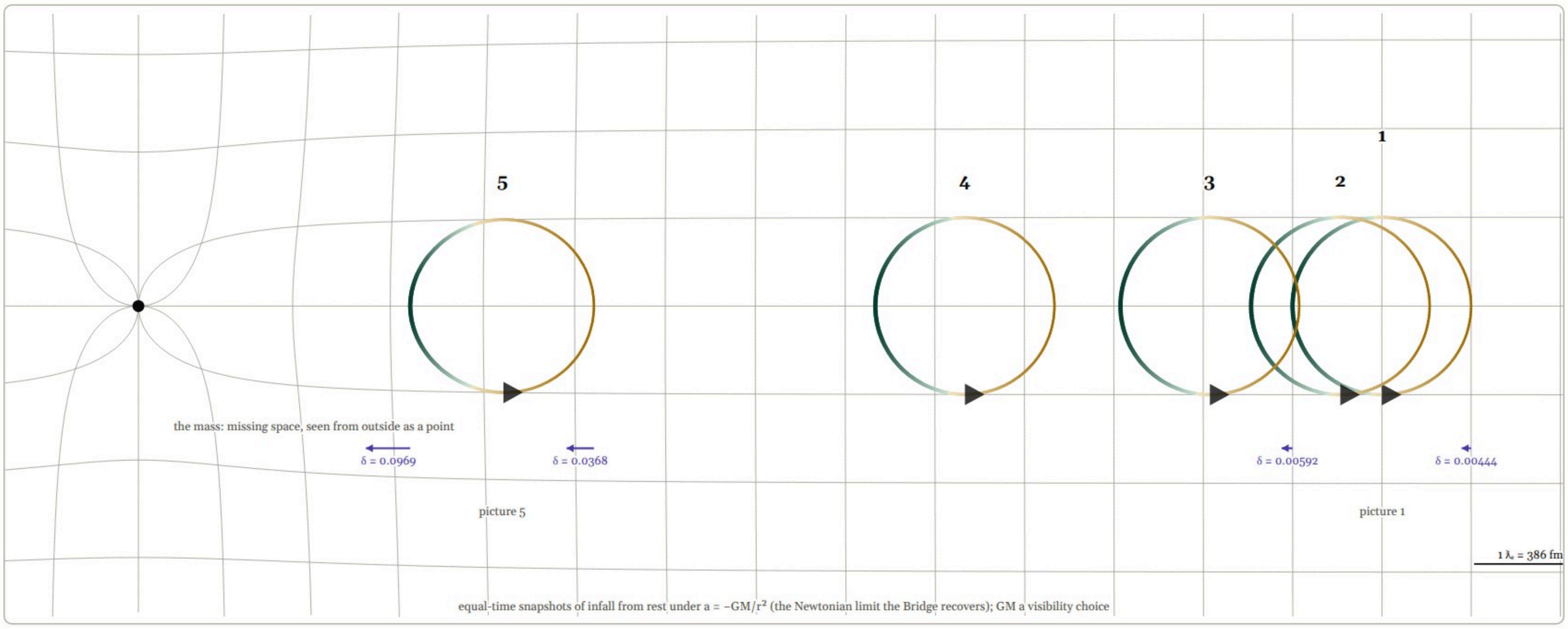
$$\delta(r) = ƛ_e^2/r^2, \quad n(x) = 1 - 2\Phi/c^2, \quad d\theta/ds \approx \nabla_\perp \ln n$$

(the share of space missing at true distance r, the map; the Walk-Through's cost map n, "higher n means this step hides a bit more display-area than average", and the lean per step, its sideways slope; Mechanics Math Walk-Through, conventions and section 1)

$$a = -\nabla\Phi = -GM/r^2 \quad (\Phi = -GM/r)$$

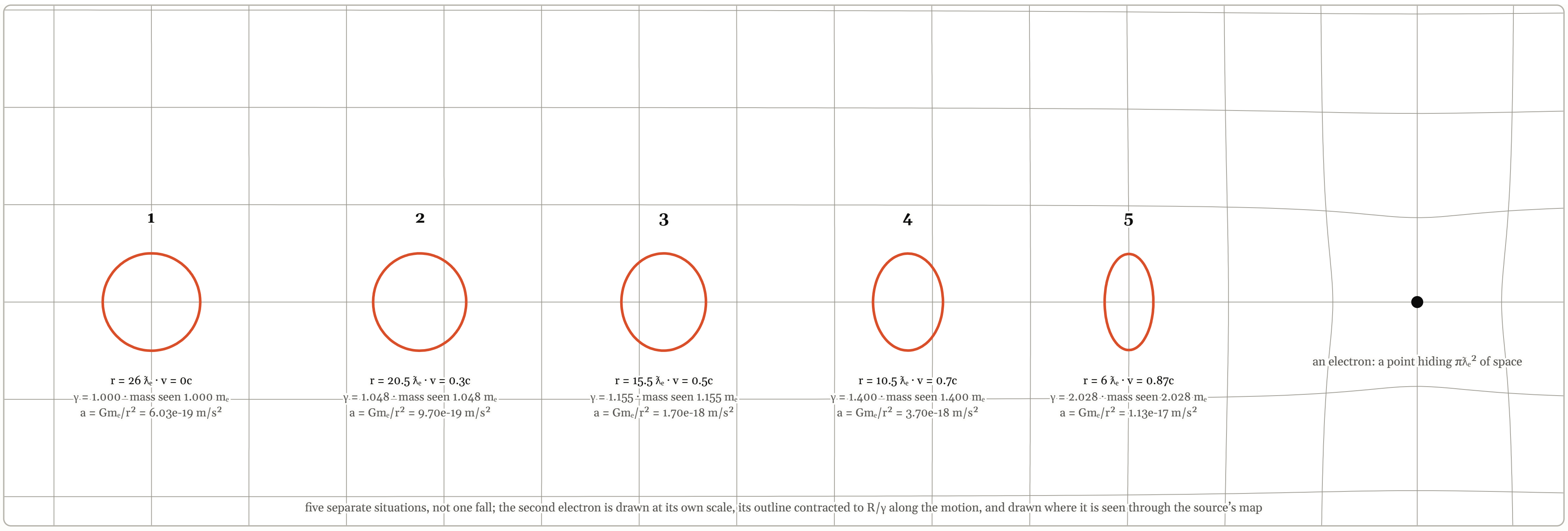
(the cycle-averaged drift of the loop's centre: the Newtonian limit, Bridge Math Appendix, Mass and Gravity 7)

2. Falling: same time between pictures



Five equal-time snapshots of one loop released from rest, drawn where each is seen. The small arrows under pictures 1 and 5 print the share of space missing at the loop's near and far edge: at picture 1, $\delta = 0.00592$ against 0.00444; by picture 5, 0.0969 against 0.0368. Both arrows of a pair point toward the mass, since gravity has no handedness to flip a side, only depth. The near side is always deeper, and the pair grows as the loop falls. Each loop is painted by the cost map along its rim, $n - 1 \propto 1/r$ at each rim point's distance from the mass: darkest green where each step hides the most space (the near side, drawn heavier), darkest yellow where it hides the least (the far side), pale between. The loop always swings toward its dark green.

3. How one electron sees another

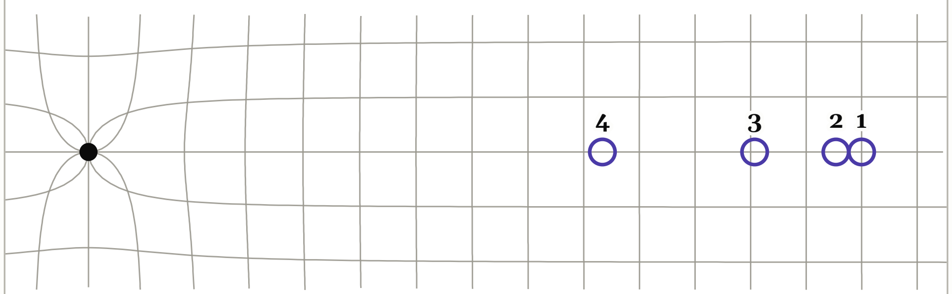


The point on the right is an electron; its missing space is what bends the grid. The five shapes are a second electron at five distances and five speeds, five separate situations. At rest (1) it hides exactly the same space as the first, $\pi ƛ_e^2$ each. Moving, its outline is contracted to R/γ along the motion and the mass seen is γm_e (the Mass page). Under each, the acceleration between them in the Newtonian limit, $a = Gm_e/r^2$: about 10^{-18} m/s², which is why gravity between two electrons is never felt, yet the geometry drawn here is the same machinery that runs planets.

4. Who agrees where

Three descriptions, one ladder. Far and slow, everyone tells the same story. Where light bends, is delayed, and clocks drift, Newton falls behind and VMS lands on the tested numbers with general relativity, from one route picture and one factor set once. At the core of a single particle GR runs to infinity where VMS stops, because you cannot hide more space than there is.

A · far and slow: everyone agrees



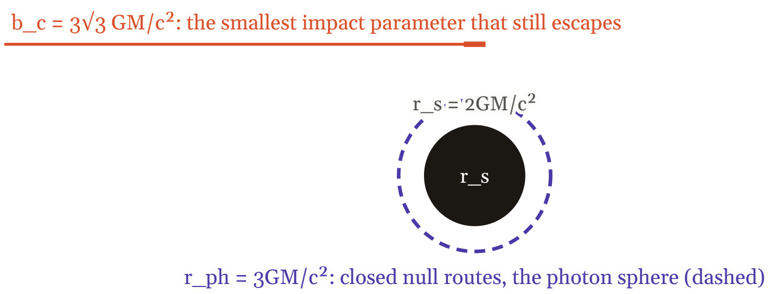
fall from rest, far from the mass; positions at equal ticks of a faraway clock:
Newton, $a = -GM/r^2$: $x_4 = 9.335880$ · GR, geodesic from rest: the same to O(r_s/r), 2.5×10^{-46} for
VMS: the loop deficit $\propto 1/r^2 \rightarrow \nabla^2\Phi = 4\pi G\rho \rightarrow a = -GM/r^2$, with $m = (\sigma_s/c^2)L\_\Gamma$ (Math Appendix 7)

B · the four tests: Newton falls behind, VMS and GR agree

effect	Newton	GR and VMS
light bending at the Sun's limb $4GM/(Rc^2)$; Mechanics Appendix 5	none *	**1.75 arcsec**
Shapiro delay, Earth to Mars at conjunction $(2GM/c^3)\ln(4r_1r_2/b^2)$; Appendix 6	none	**123.6 µs**
clock drift over a 22.5 m tower (Pound–Rebka) $\Delta\nu/\nu = g\Delta h/c^2$; Appendix 7	none	**2.455×10^{-15}**
Mercury's perihelion advance, per century $6\pi GM/(a(1-e^2)c^2)$; Appendix 8	0 from the Sun	**43.0 arcsec**

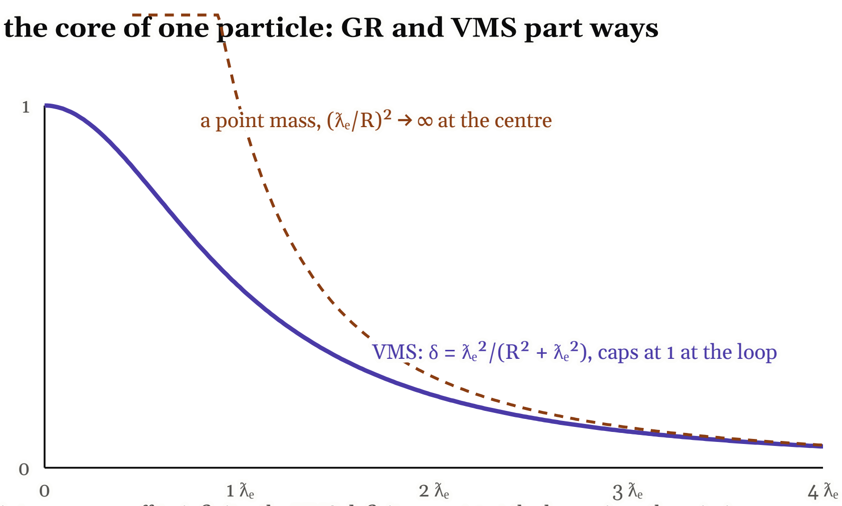
VMS: the same kernels for all four, one factor $\eta_0 = 2$ set once by the deflection (Mechanics Walk-Through 1 to 4). * a Newtonian corpuscle would bend half the GR value (textbook).

C · deep: light that circles, light that is captured



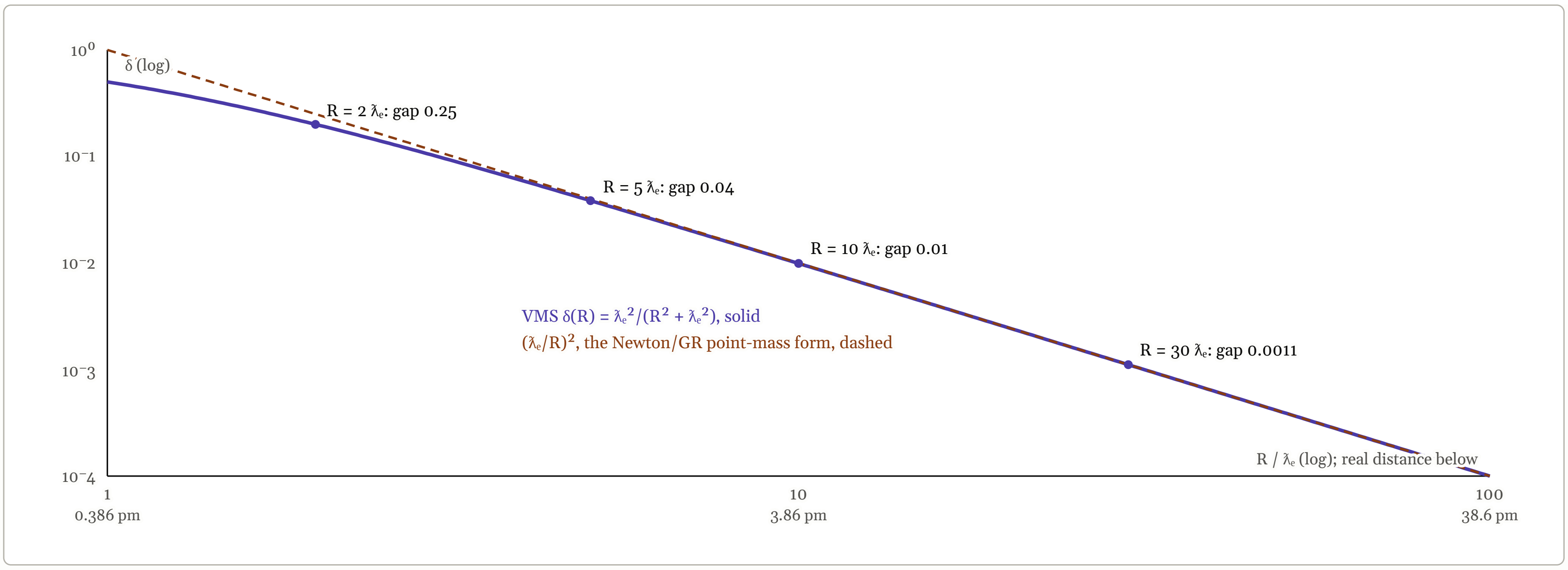
For a steep profile n(r) the same bending kernel $\alpha = \int \nabla_\perp \ln n \, ds$ diverges as $b \rightarrow b\_c^+$ and captures for $b < b\_c$; in the GR dictionary that is the photon sphere and the critical impact parameter above (Mechanics Walk-Through 1A). Newton's gravity has no such limit; a Newtonian mass captures nothing that moves at c.

D · the core of one particle: GR and VMS part ways



A point mass runs off to infinity; the VMS deficit caps at 1 at the loop, since the missing space is all the space there is to miss. For one electron GR's strong field would begin at $r\_s = 2Gm_e/c^2 = 1.4\text{e-}57$ m; the VMS core at $ƛ_e = 3.86\text{e-}13$ m comes 3e+44 times sooner.

5. The far field: the missing-space profile meets the Newton form



Solid: $\delta(R) = ƛ_e^2/(R^2 + ƛ_e^2)$, the quantity every line above is drawn from. Dashed: the pure inverse square $(ƛ_e/R)^2$, the point-mass form Newton's gravity and weak-field GR require, normalised in the far field. Near the core they disagree, VMS keeps the scale $ƛ_e$, a point mass has none. The gap closes as the square of the distance: by 10 $ƛ_e$ it is 1%; by the Bohr radius, 5×10^{-3} %. For a single particle the two are indistinguishable from there outward.

$$F = G\, m_\Gamma\, m_{\Gamma'} / r^2$$

(two loops, the probe's route computed in the geometry the source shapes; the weak-field, large-distance limit; Mathematical Bridge, section 3, step 6)

$$\alpha = 4GM/(bc^2), \quad \Delta t = (2GM/c^3)\ln(4r_1r_2/b^2), \quad \Delta\nu/\nu = g\Delta h/c^2, \quad \Delta\omega = 6\pi GM/(a(1 - e^2)c^2)$$

(bending, delay, clock drift, perihelion advance: the same kernels on the cost map n(x), $|\eta_0| = 2$ set once by the deflection; Mechanics Math Walk-Through 1 to 4, Math Appendix 5 to 8)

$$F = GMm/r^2, \quad g = GM/r^2, \quad U = -GMm/r$$

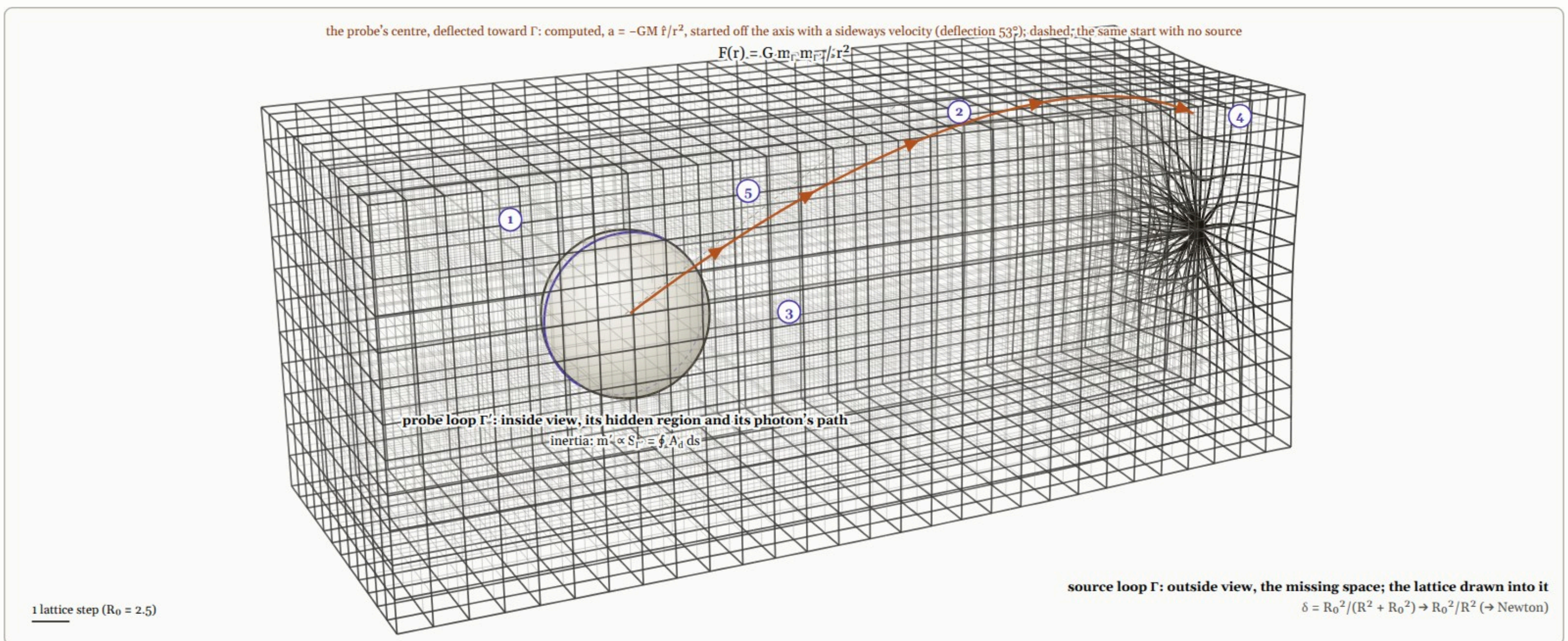
(the same line in the textbook's letters: Newton's law of gravitation, the field g, the potential energy; G is an acceptance lock, $\kappa = 8\pi G/c^4$ "fixed by comparison", not an input)

Mathematical Bridge, section 3, Bridge Narrative, step 4, Mechanics Narrative, Mechanics Math Walk-Through (the cost map, the ray equation, the three kernels, photon sphere), Mechanics Math Appendix (sections 4 to 8, the worked numbers), Bridge Math Appendix, Mass and Gravity (sections 5 to 7 and 6A).

Every line computed. Grids: the map $R(r) = \sqrt{r^2 - ƛ_e^2}$ about the mass, the Mass page's construction of the Bridge's fixed missing volume and $\Delta g \sim 1/r^2$. Loops: radius $ƛ_e$, their rims pushed through the same map, so each is drawn where it is seen, elongated toward the mass. Positions in sections 2 and 4A: equal-time snapshots of infall from rest under $a = -GM/r^2$ (GM a visibility choice; the spacing pattern is scale free). Gauges: $\delta = ƛ_e^2/r^2$ at each edge's true distance, arrow lengths $\sqrt{\delta}$ on one common scale (declared for visibility), values printed exact. Hue: the Walk-Through's cost per step along the rim, $n - 1 = 2GM/(rc^2) \propto 1/r$ at each rim point's true distance, normalised per loop; the near-to-far premium ratio printed in section 1 is $\int(n - 1)\,ds$ over the two halves, G cancelling. The lean arrow in section 1 is the direction of ∇n at the loop centre, computed; its length is drawn. Section 3: outlines contracted to R/γ along the motion (Mechanics Math Appendix, section 3), then mapped; accelerations Gm_e/r^2 with CODATA G, m_e, $ƛ_e$. Section 4B: the four numbers are the Mechanics Math Appendix's own worked examples (1.75 arcsec, 123.6 μs, 2.455×10^{-15}, 43.0 arcsec per century). 4C: $r_{ph} = 3GM/c^2$ and $b_c = 3\sqrt{3}\,GM/c^2$ from Walk-Through 1A, drawn to scale in units of GM/c^2. 4D: $\delta(R)$ from the map against $(ƛ_e/R)^2$; $r_s = 2Gm_e/c^2$ computed. The probe's own dent in space is omitted for clarity. "VMS lands with GR" means: through the Bridge's coupling $G_{\mu\nu} = \kappa T_{\mu\nu}$ and the Walk-Through's matched kernels, as published.

Gravity: two loops and the space between them, the full derivation

A photon is the smallest piece of light; this page follows one photon closed into a loop, the probe, standing in the space another loop has shaped, and derives what the high school page stated. A closed Void path removes a fixed transverse area, the deficit that is its inertial mass. That deficit does not stay local: it propagates outward as an inverse-square curvature of the surrounding space. A second loop, its action computed in that geometry, has its path deflected toward the first; in the weak-field, large-distance limit this is exactly Newton's law. Gravity is an emergent property of the geometric deficits carried by the loops, not an imposed field. Left, the probe from inside: its hidden region and the path its photon runs. Right, the source from outside: the missing space, with the lattice drawn into it. The orange curve is the probe's centre, computed, deflected toward the source. Each numbered circle is a panel below.



The case drawn.

$$F(r) = G\, m_\Gamma\, m_{\Gamma'} / r^2, \quad \delta = R_0^2/(R^2 + R_0^2) \;\to\; R_0^2/R^2$$

(two loops, the probe's geodesic deflected toward the source; Mathematical Bridge, section 3, step 6; the map, the drawing's construction of the Bridge's "fixing the missing volume" and "$\Delta g(r) \sim 1/r^2$")

In the textbook's letters, the same line and its field and potential:

$$F = GMm/r^2, \quad g = GM/r^2, \quad \Phi = -GM/r$$

(Newton's law of gravitation; G an acceptance lock, $\kappa = 8\pi G/c^4$ "fixed by comparison", Bridge Math Appendix, Mass and Gravity 7)

Panels 1 to 4. The route picture and what it recovers, panels 5 and 6.

The general solution, and what it recovers, from the worldsheet action, the Einstein–Hilbert coupling and nothing else:

the two-loop setup, inertia of each loop	**panel 1**
the dent $T^{\mu\nu}$ and $G_{\mu\nu} = \kappa T_{\mu\nu}$	**panel 2**
the geodesic, elongation toward the source, no loop faster than c	**panel 3**
$\nabla^2\Phi = 4\pi G\rho$, $\Phi = -Gm/r$, Newton's law	**panel 4**
the cost map n(x): bending, delay, clock drift, precession, photon sphere	**panel 5**
1.75″, 123.6 μs, 2.455×10^{-15}, 43″/century, $3GM/c^2$	**panel 6**

Named as the documents name them: the Einstein–Hilbert term is imported and coupled to the loop's $T_{\mu\nu}$; the four weak-field numbers follow from one factor set once.

Published documents used, and nothing else: the Mathematical Bridge (section 3, steps 1 to 6) and its Math Appendix (Mass and Gravity from Closed Void Loops, sections 3 to 7 and 6A, both framings of the Newtonian limit); the Bridge Narrative, step 4; the Mechanics Narrative and Math Walk-Through (the cost map n(x), the ray equation, the bending, delay and clock-drift kernels, periapsis, the photon sphere and capture); the Mechanics Math Appendix (sections 4 to 8, the worked numbers). Only ratios enter; $S_0 = \hbar$ is the one scale; c and G are acceptance locks.

The case drawn (panels 1 to 4), the route picture and what it recovers (panels 5 and 6)

1 In this case: two loops

The single-loop case (the Mass page) gives inertia. "To derive a force law, however, we must consider two loops: a source loop Γ that generates a curvature deficit, and a probe loop Γ′ whose action is computed within the distorted geometry created by Γ." Each carries its own loop action,

$$m_\Gamma \propto \oint_\Gamma A_d\, ds, \quad S_{\Gamma'} \propto \oint_{\Gamma'} A_d\, ds$$

and the probe's is evaluated in the curved geometry Γ generates: "The geodesic of Γ′ is deflected toward Γ, reflecting gravitational attraction. Evaluating the weak-field, large-R limit yields a mutual force law $F(r) = G\, m_\Gamma\, m_{\Gamma'}/r^2$."
In the drawing the probe is shown from inside (its hidden sphere, its photon's path) and the source from outside (the missing space the lattice leans into).

Mathematical Bridge, section 3 (Mass and Gravity), introduction and step 6.
$R_0 = 2.5$ lattice steps for both loops; the electron would set $R_0 = \lambda_e = 386.16$ fm.

2 The dent, and its coupling to geometry

The source loop's stress–energy is the variation of its worldsheet action with respect to the metric (the Mass page, panel 6); it is localized on the worldsheet and conserved. The total action is the Einstein–Hilbert action plus the Void action:

$$S_{\text{total}}[g, W] = (1/2\kappa) \int R \sqrt{(-g)}\, d^4x + S_{\text{void}}[W; g]$$

and varying with respect to $g^{\mu\nu}$ gives the Einstein field equations,

$$G_{\mu\nu} = \kappa\, T_{\mu\nu}$$

"the precise mathematical statement that a Void loop curves spacetime."
The Einstein–Hilbert term is imported here, with the loop's $T_{\mu\nu}$ as its source; $\kappa = 8\pi G/c^4$ is "fixed by comparison" in the Newtonian limit (panel 4): G is an acceptance lock, not an input and not a derivation.

Bridge Math Appendix, Mass and Gravity, sections 3 and 5.

3 The probe's motion: geodesic, elongation, no v > c

The second loop's action is $S_{\text{void}}[W'; g]$; its equations of motion are the minimal-surface equations in the curved g. In the small-loop limit its centre-of-energy worldline obeys the geodesic equation,

$$D^2x^\mu/D\tau^2 + \Gamma^\mu{}_{\alpha\beta}\, (dx^\alpha/d\tau)(dx^\beta/d\tau) = 0$$

"the geometry telling the second loop how to move." Each segment of the loop runs at c along its closed path (null: $g_{\mu\nu}u^\mu u^\nu = 0$); curvature tilts "straight ahead" inward, so to a distant observer the loop's circle is deflected and "elongates toward the curvature source", $L_{\text{eff}} = \oint \sqrt{(g_{ij}\, dx^i\, dx^j)} > L_{\text{flat}}$, and $m_{\text{obs}} = (\sigma_s/c^2)\, L_{\text{eff}}$ rises with it. A loop can never reach c: "if the loop attempted v > c, the path would fail to geometrically close"; in flat-space language $a_{\text{coord}} = a_{\text{proper}}/\gamma^3$. The drawing's probe path is that centre-of-energy motion in the Newtonian limit of panel 4, integrated from an off-axis start.

Bridge Math Appendix, Mass and Gravity, sections 6 and 6A.

4 The Newtonian limit: Newton's law recovered

Linearize $g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$, $|h| \ll 1$, in harmonic gauge:

$$\Box\, \bar{h}_{\mu\nu} = -2\kappa\, T_{\mu\nu}, \quad T_{00} \approx \rho c^2 \text{ (static source)}$$

Defining $h_{00} = -2\Phi/c^2$ reduces this to the Poisson equation, and for a pointlike loop of inertial mass m (panel 1) the solution and the force on m′ are

$$\nabla^2\Phi = 4\pi G\rho, \quad \Phi(r) = -Gm/r, \quad F = -\nabla\Phi = G\, m\, m'/r^2$$

"with $\kappa = 8\pi G/c^4$ fixed by comparison. Thus, the exact Newtonian law is recovered from the Void loop picture." Φ "is simply the mathematical shorthand for that elongation as seen by a distant observer." Kinematics split: segments of the front propagate at c (null); the centre of energy follows a timelike worldline; the static slice is a synchronous gauge valid for $|h| \ll 1$.

Bridge Math Appendix, Mass and Gravity, section 7 (both framings); Mathematical Bridge section 3, steps 3, 5 and 6; Mechanics Math Appendix 4 (imports these).

5 The route picture: the cost map and its three kernels

Seen from far away the stationary loop is a smooth cost map n(x): "higher n means this step hides a bit more display-area than average". Routes follow the eikonal $|\nabla S|^2 = n^2$, $d/ds(n\, t) = \nabla n$, with

$$n(x) = 1 + \eta_0\varphi, \quad \varphi = \Phi/c^2, \quad \Phi = -GM/r, \quad |\eta_0| = 2$$

bending $\alpha \approx \int \nabla_\perp \ln n\, ds \to 4GM/(bc^2)$ ($|\eta_0| = 2$ set once here, toward the mass);
delay $\Delta t = (1/c)\int(n - 1)\, ds \to (2GM/c^3) \ln((r_S + r_R + D)/(r_S + r_R - D))$;
clock drift $d\tau \approx dt\, \sqrt{(1 + 2\varphi)}$, $\Delta\nu/\nu \approx -\Delta\varphi$; periapsis $\Delta\varpi \approx 6\pi GM/(a(1 - e^2)c^2)$.
Steep profiles, same kernel: closed null routes at $r_{ph} = 3GM/c^2$, capture below $b_c = 3\sqrt{3}\, GM/c^2$. "One ontology, one scale ($S_0 = \hbar$), one cost map n(x). The once-set factor that matches solar deflection also fixes delay and clock-shift."

This is the same content as panels 2 to 4 in route language: the Bridge's "route choice in a shaped background set by another loop's missing-space circulation".

Mechanics Math Walk-Through, conventions, sections 1 to 5 and 1A; Bridge Narrative step 4.

6 What it recovers, and the far field of the drawing

result	value	where
Newton's law, $F = Gmm'/r^2$	**exact, weak field**	Appendix 7
solar limb deflection	**1.75 arcsec**	Mech. Appendix 5
Shapiro delay, Earth–Mars	**123.6 μs**	Mech. Appendix 6
Pound–Rebka, 22.5 m	**2.455×10^{-15}**	Mech. Appendix 7
Mercury's perihelion	**43.0″ per century**	Mech. Appendix 8
photon sphere, capture	**$3GM/c^2$, $3\sqrt{3}\, GM/c^2$**	W.-T. 1A

The drawing's far field: the source's missing share δ against the pure inverse square

r	$R = \sqrt{(r^2 - R_0^2)}$	$\delta = R_0^2/(R^2 + R_0^2)$	R_0^2/R^2	ratio
3	1.658	0.6944	2.2727	0.306
4	3.122	0.3906	0.6410	0.609
6	5.454	0.1736	0.2101	0.826
10	9.682	0.0625	0.0667	0.938
20	19.843	0.0156	0.0159	0.984

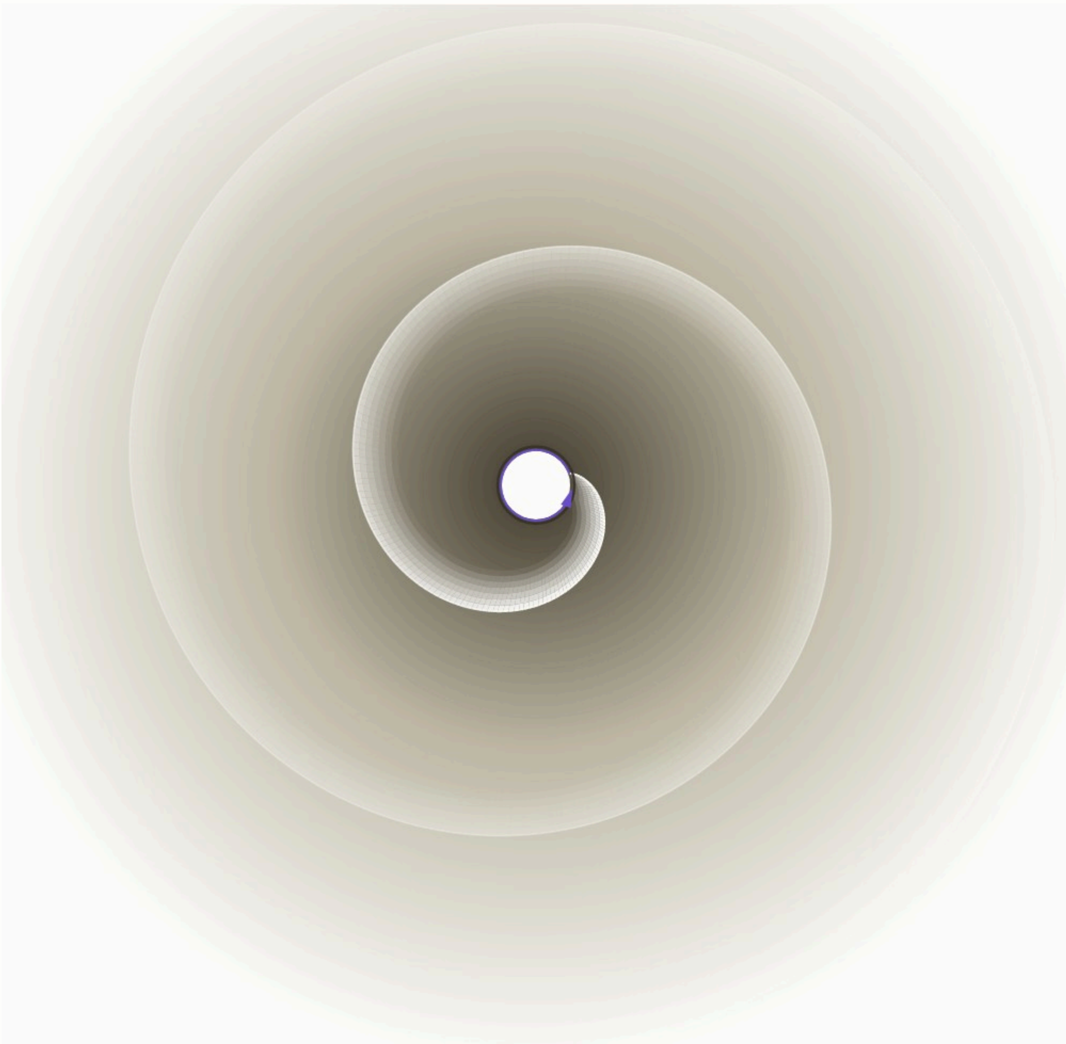
The ratio → 1: the deficit is inverse square far out, the seed of $\Phi = -Gm/r$ (Bridge §3, step 3).

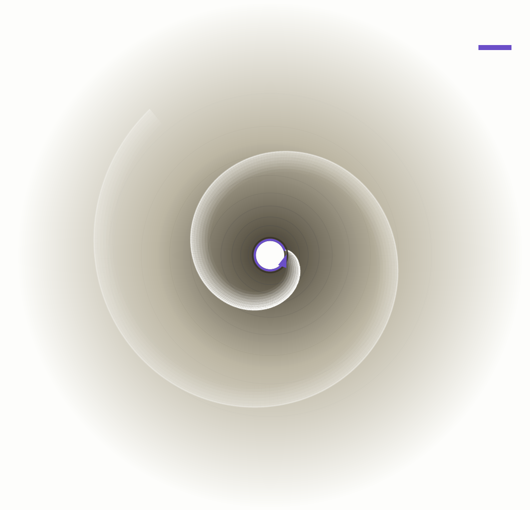
Symbol	Meaning	Where it is fixed
Γ, Γ′	the source loop; the probe loop (both closed Void paths)	Bridge §3
A_d, S_Γ, $S_{\Gamma'}$	display area; the loop actions $\oint A_d\, ds$ (source, probe)	Bridge §1, §3; Appendix §1
$T^{\mu\nu}$, $G_{\mu\nu}$, κ	the loop's stress–energy; the Einstein tensor; $\kappa = 8\pi G/c^4$, fixed by comparison	Appendix §3, §5, §7
Φ, $h_{\mu\nu}$	the Newtonian potential, −Gm/r; the metric perturbation, $h_{00} = -2\Phi/c^2$	Appendix §7
n(x), η_0	the cost map, $1 + \eta_0\Phi/c^2$; $|\eta_0| = 2$ set once by the deflection	Mechanics Walk-Through, conventions and §1
R_0, r, R, δ	loop radius; true distance; seen distance $R^2 = r^2 - R_0^2$; the missing share	the map (the drawing's construction of Bridge §3)
G, c, $S_0 = \hbar$	acceptance locks; the single scale	Mechanics Narrative, language and locks

Every line computed. The lattice is drawn through the map $R(r) = \sqrt{r^2 - R_0^2}$ about the source, $R_0 = 2.5$ lattice steps, the same map and scale as the Mass page; ink darkens with the local deficit δ (declared). The source loop removes a fixed transverse area πR_0^2 from every circle about it on the central plane (the Mass page, panel 4) and its deficit falls as $1/r^2$ (panel 6 table), the seed of the Newtonian potential. The probe loop is drawn from inside: its hidden sphere and its photon's path, the great circle in the loop's plane (front half solid, back half dashed), its lattice lines clipped at the sphere. The probe's centre (orange) is integrated under $a = -GM\,\hat{r}/r^2$ from a start off the axis with a transverse velocity, GM a visibility choice, then pushed through the map; the arrowheads sit at equal-time positions; the dashed line is the same start with no source. All relations are from the published Mathematical Bridge, section 3, its Math Appendix and the Mechanics documents; G is an acceptance lock and is not fit. Sources: Mathematical Bridge, Bridge Math Appendix, Bridge Narrative, Mechanics Math Walk-Through, Mechanics Math Appendix. Generator: gen_gravity_proofs3d.py.

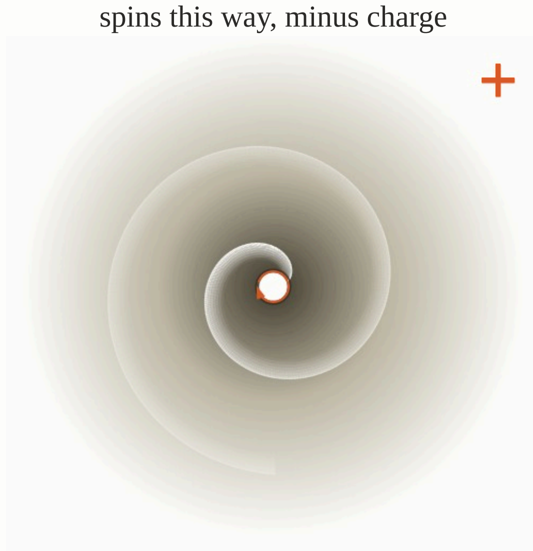
Why do things have charge?

A photon is the smallest piece of light. This is one photon trapped, one particle, seen from the inside like before. You saw before how it hides space and makes gravity. The direction it goes makes charge.





spins this way, minus charge



spins the other way, plus charge

Where the head meets the tail you can see how it hides the space around it, strongest up close, fading at the speed of light as it moves away. As it spins, it swooshes a bright ribbon through the grey, the swoosh always curls the same way it spins.

Charge: a curved null gravity wave

A photon is the smallest piece of light; this page follows one photon, closed into a loop. The base of this drawing is what was shown in the previous mass drawing: the inside view, where the electron establishes the space density from the space the mass hides.

Added is the effect from the head and the tail. Darkest along the outer edge of the loop where the most space is hidden, fading to white far away where it no longer leaves a visible mark.

The white line starts exactly at the photon's tail, the same white as the far page. The band is that white propagating back into the surrounding shade, the space density the mass has set at that distance, complete by the head's edge.

Thin and most intense at the start; wider as it winds out at c; gone where the page is white and there is no displayable difference from the space hidden that far out. Net change through and back: zero, a null gravity wave, curved. That winding is charge and the other direction is the opposite charge.

$$Q \propto \oint d\varphi = 2\pi n, \quad \text{so} \quad q = n\cdot q_0, \quad \sigma = \pm 1$$

(n the count of aligned turns per cycle; σ which way the loop turns; in the textbook's letters $q = ne$, with e the electron's charge, and the sign is σ)

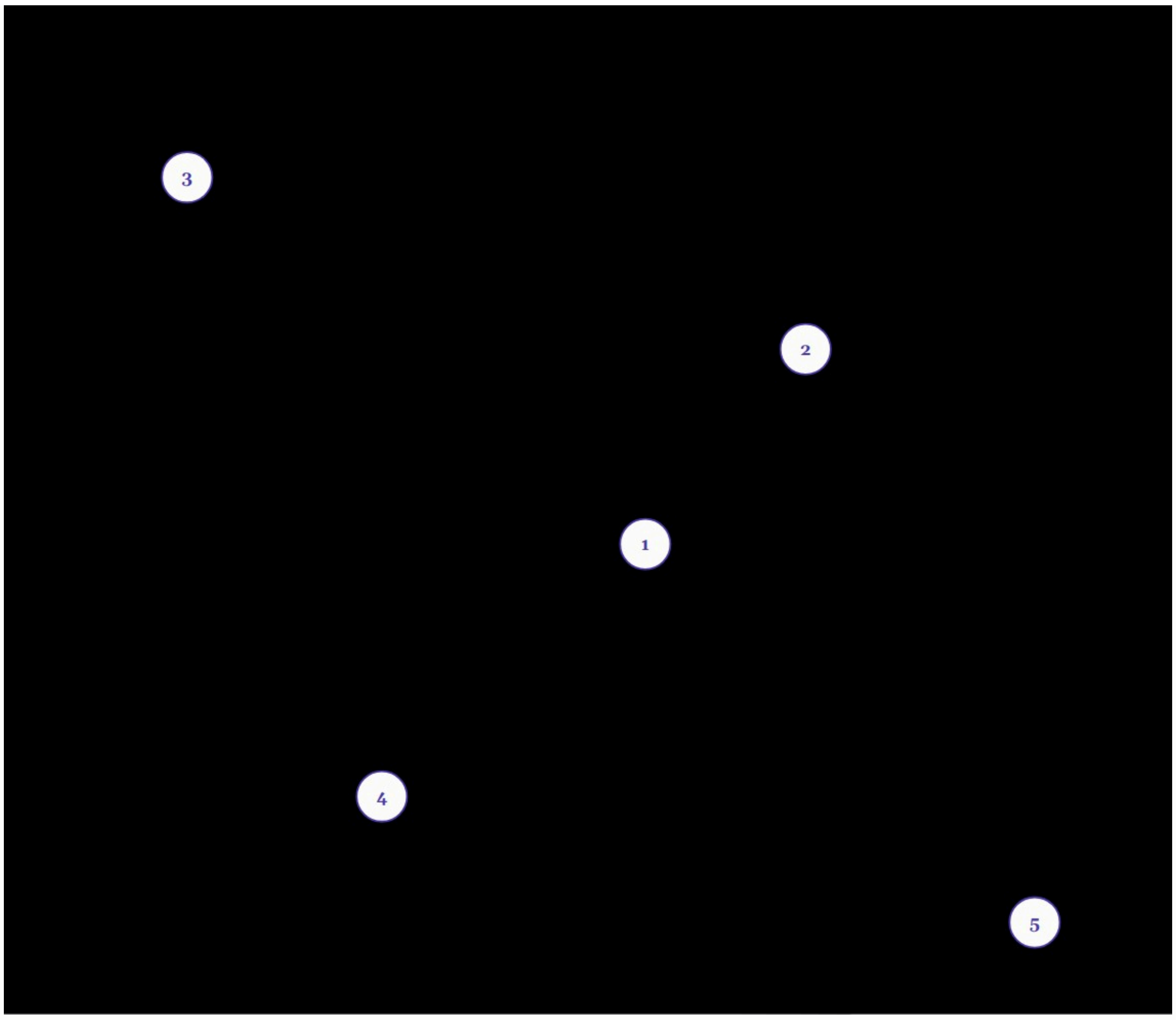
One turn per loop period here, $n = 1$. The winding drawn is that turn and its handedness is the sign. The count cannot drift: "no surprise jumps unless you actually cross a defect", which is why charge is conserved.

Particle Mechanics Math Appendix ($\Delta\varphi_{loop} = 2\pi n$), Particle Mechanics Narrative §7, Electromagnetism Narrative §3, §4, Mathematical Bridge §4.

Computed throughout. Base tint and every fade: $\delta(r) = \lambda_e^2/(r^2+\lambda_e^2)$. The sliver opens between tail and head at the loop surface (gap = the loop's drawn opening, Δ = 0.11 T, the head chases 0.7 rad behind the tail). Width: the white (release) edge advances through deficit space at drawn speed $c/(1-\delta)$ while the head (hide) edge chases through released space at c, so the gap grows fastest near the mass and saturates as δ dies (values printed at two crossings). Cross-band shading: sharp at the white line, fading gradually to the surrounding shade toward the head side (drawn brightness eased as $\sqrt{\delta}$ so the outer windings stay printable; the physical contrast is δ itself). The head side has no line of its own; equality with the background is its edge. Head propagates toward the tail; the pattern trails the rotation.

 this page on its own

What charge is, and why it has a sign: the full derivation



A photon is the smallest piece of light; this page follows one photon, closed into a loop, and derives what the high school page stated.
A closed loop turns one way or the other on the plane the expansion selects; that is its charge. Its size is the count of aligned turns per cycle, an integer; its sign is which way it turns:

$$Q \propto \oint d\varphi = 2\pi n, \quad \text{so} \quad q = n\cdot q_0, \quad \sigma = \pm 1$$

(n the count of aligned turns per cycle, one here; σ which way the loop turns; in the textbook's variables $q = \sigma e$)

The loop throws off a null gravity wave, a ripple with no net change of space density, and another loop feels it only through its own facing: right facing pushes, ninety degrees is a strict null, opposite facing pulls. Far away the interaction is inverse square with its sign from the two orientations:

$$F \propto \sigma_1\sigma_2 / r^2, \quad \sigma_i \in \{+1, -1\}$$

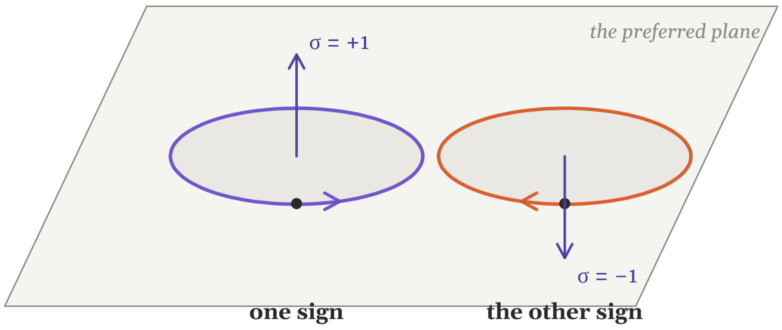
The general case, the transported display area as a 2-form, its conservation, the caustic axis, the $1/r^2$, sources and derivation of the Maxwell limit, is not drawn on the high school page; derived below (panels 6 to 11).

The small figure is the high school drawing. Each numbered circle is exploded below, and each number is a step of the derivation further down. Panels 1 to 5 are the case drawn: one electron loop, its orientation and count, the plane it faces, the base the mass has set, the null gravity wave as the drawing builds it, and the sign law. Panels 6 to 11 are the general solution: display area transported as a 2-form, the identities it obeys, the caustic axis and the two polarizations, flux conservation and the inverse square, sources and the charge as a closed-surface flux, the sign, and the Maxwell limit. The derivation uses these published documents and nothing else: the Mathematical Bridge (section 4, orientation; the waveform section, the preferred plane) and its Math Appendix (Electromagnetism from Void Transport, and its Source Extension), the Electromagnetism Narrative (what charge is; the plane; sign, size and steps; why it is not gravity), the Electromagnetism Math Walk-Through (the Maxwell set and Coulomb) and Math Appendix (section 9, the sign law), the Particle Mechanics Narrative (section 7, $q = n\cdot q_0$) and Math Appendix (the closure phase), and the Student Workbook (symbols). Only ratios enter; S_0 is the one scale; ε_0, μ_0 and k_e are limit locks, not inputs. Moving sources, magnetism and the Lorentz force are in the same documents (the Walk-Through's section 2; the Math Appendix's Transport Circulation from Moving Sources) and are not drawn on this page.

> **A note on the mathematics.** The general solution on this page is written in the language of differential forms on a Lorentzian manifold (a transport 1-form A, its exterior derivative K = dA, the Hodge dual ⋆, Stokes' theorem), with the preferred axis coming from the same fold-caustic asymptotics (the Airy function, the Maslov index) as the photon and matter pages. The forms language is standard graduate mathematics (Flanders, *Differential Forms with Applications to the Physical Sciences*, 1963; Frankel, *The Geometry of Physics*, 3rd ed., 2011) and it is the language in which vacuum electromagnetism is most compactly written; the caustic asymptotics are the province of the small community described on the matter page (Arnold, Gusein-Zade and Varchenko, 1985; Kravtsov and Orlov, 1998). Nothing here needs more than those two bodies of work.

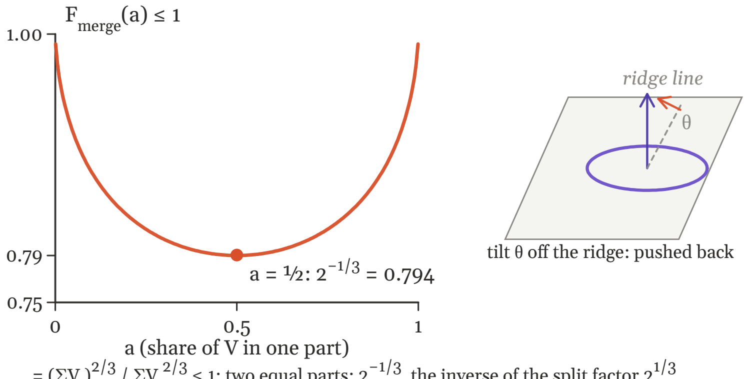
The case drawn (panels 1 to 5)

1. In this case: the loop, which way it turns, and how many turns



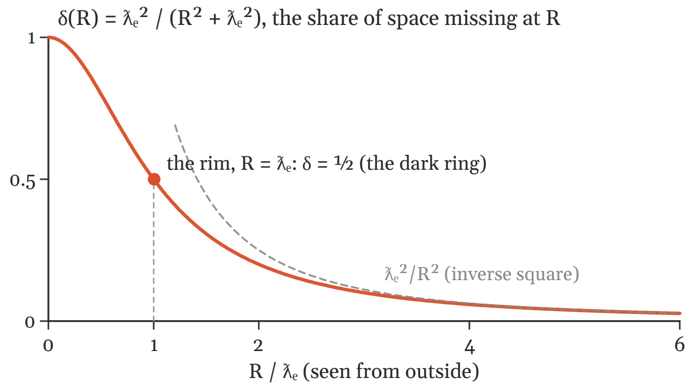
$\Delta\varphi_{loop} = 2\pi n$ (closure); $q = n\cdot q_0$, $n = 1$ here; $\sigma = \pm 1$, which way the loop turns
"the orientation of its rotation defines a polarity. This polarity is identified with electric charge" (Mathematical Bridge, section 4)

2. In this case: the preferred plane, why there is a facing



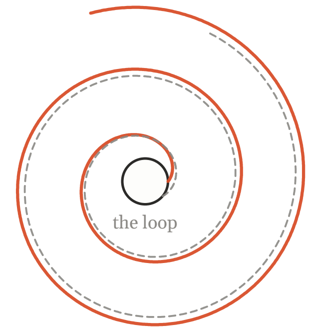
$F_{merge} = (\Sigma V_i)^{2/3} / \Sigma V_i^{2/3} \le 1$; two equal parts: $2^{-1/3}$, the inverse of the split factor $2^{1/3}$
splitting expands display area, merging contracts it; "that rule naturally picks out the preferred plane" (Electromagnetism Narrative, section 2)

3. In this case: the base, what the mass has already set



every shade of the base is this δ at that radius (the mass pages' map $R = \sqrt{r^2 - ƛ_e^2}$); the point itself is δ = 1. Nothing new is added by charge here: the base is the mass; the wave rides on it

4. In this case: the null gravity wave, as the drawing builds it



solid: the release edge, the white line, $dr/d\theta \propto 1/(1-\delta)$, faster where more space is missing

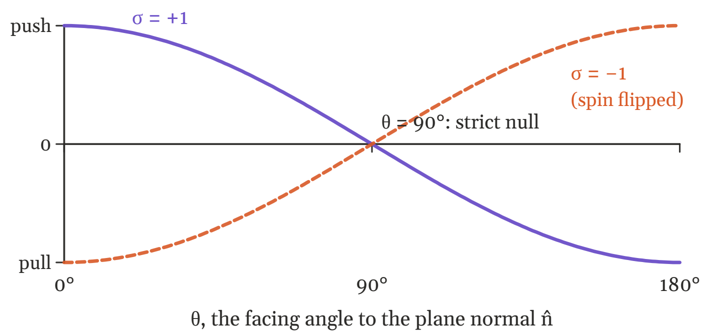
dashed: the head edge, $dr/d\theta \propto 1$, 0.7 rad behind

the band between them is released space easing back to the base shade: "no net space-density change", a null wave

the gap grows fastest at the rim (δ = ½) and saturates as δ → 0: the HS figure's 1.26 and 1.40 $ƛ_e$ at two crossings

"a rotating void-loop that's constantly throwing off null-gravity waves (NGWs) ripples. Those ripples don't pile anything up, no net space-density change" (EM Narrative). The $1/(1-\delta)$ width rule is the drawing's own, not a line in any document; everything moves at c.

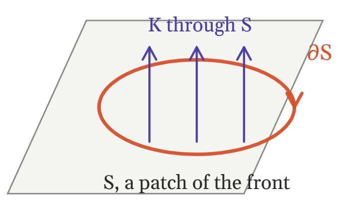
5. In this case: push, null, pull



$\langle\Delta p\rangle \propto \varepsilon \cdot \sigma \cdot \cos\theta$ (EM Math Appendix, Eq. 9.4, the neutral-rotor test): right facing → push, 90° → null, spin flip or opposite facing → pull. Two loops: opposite facing pulls, same facing pushes; "the outcome depends completely on how you're oriented" (EM Narrative, section 6)

The general solution (panels 6 to 11)

6. Display area transported: the 2-form K = dA



A: transport 1-form, the oriented accumulation of display area along the route

K := dA, its oriented flux

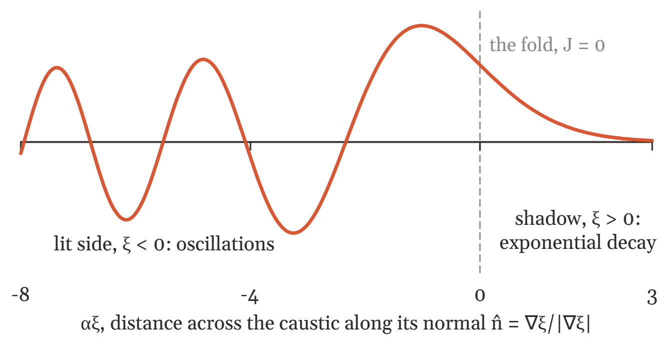
$\oint_{\partial S} A = \iint_S K$ (Stokes; no dynamics)

$dK = 0$ (geometric identity)

$d{\star}K = 0$ (conservation under expansion, A2 and A3)

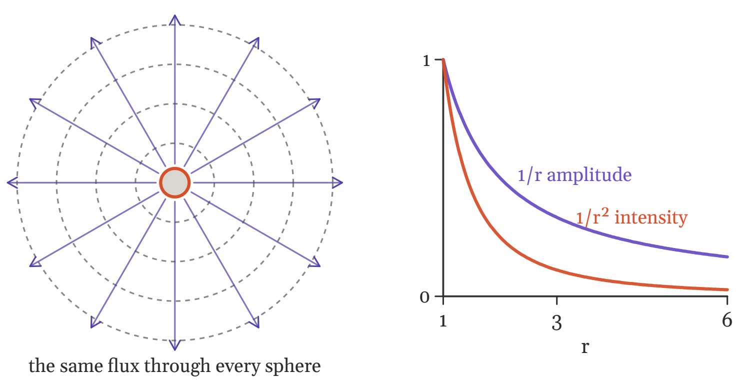
"No dynamics are assumed here: the identity follows from Stokes' theorem." Finite tension (A3) keeps the transported flux finite, "so conservation under expansion leads to an unavoidable $1/r^2$ falloff" (Math Appendix, Electromagnetism from Void Transport, section 3)

7. The caustic fixes the axis: Ai(αξ), one normal, two polarizations



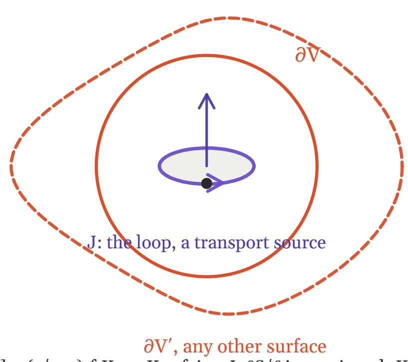
$u(\xi,\eta,t) \approx \mathscr{A}(\eta,t)\,\mathrm{Ai}(\alpha\xi)$, α > 0; a π/2 phase across the fold (Maslov ½); n̂ is the preferred axis, oscillations transverse to n̂; "Symmetry ensures only two polarizations (±) remain" (Math Appendix, Electromagnetism from Void Transport, section 2). Ai computed (scipy).

8. Flux conservation: amplitude 1/r, intensity $1/r^2$



$\mathscr{J} := (1/\sigma_s)\,{\star}(A \wedge K)$, $d\mathscr{J} = 0$ in vacuum (from $dK = 0 = d{\star}K$): the flux through spheres of radius r is constant, "hence amplitudes decay as 1/r and transported intensity as $1/r^2$. This derives entirely from expansion and finite tension (A2–A3)" (7). The wave's intensity; Coulomb's static $1/r^2$ is step 11.

9. A source: Q is the flux of ⋆K through any surface round it



$dJ = 0$ (continuity)

$\mathbf{dK = 0,\ d{\star}K = J}$

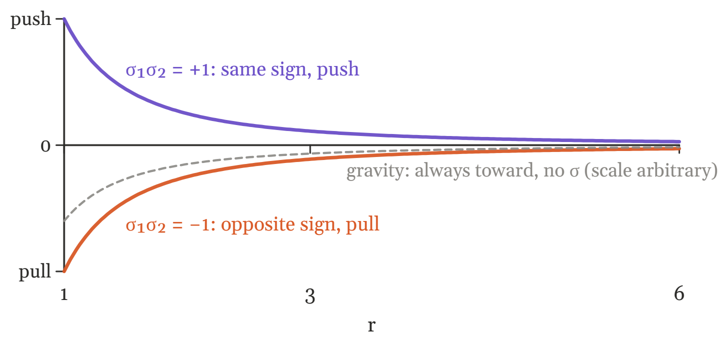
$\mathbf{Q[V] := \int_V J = \oint_{\partial V} {\star}K}$

the same through ∂V and ∂V′: surface independent, since dJ = 0

$\Box A = \mathscr{G}[J]$, retarded: causal at c

$S[A;J] = (1/2\sigma_s)\int K \wedge {\star}K + \int A \wedge J$; $\delta S/\delta A = 0$ gives $d{\star}K = J$; $A \to A + d\chi$ leaves S invariant iff $dJ = 0$. "Sources arise when Void transport fails to close perfectly (broken closures, defects, intersections)" (Math Appendix, Source Extension, sections 10 to 13)

10. The sign: the same $1/r^2$, its direction from $\sigma_1\sigma_2$



$F \propto \sigma_1\sigma_2 / r^2$, $\sigma_i \in \{+1, -1\}$ (Bridge, section 4): "The far-field again follows a $1/r^2$ dependence, but its direction depends only on σ." "Gravity behaves like a standing curvature gradient, a downhill … Electromagnetism here is different: there's no standing downhill" (EM Narrative, 6)

11. The limit engineers use: Maxwell, and Coulomb

F = dA, dF = 0, d⋆F = J

from panels 6 and 9, renamed at the end

$\nabla\cdot E = \rho/\varepsilon_0$, $\nabla\cdot B = 0$

Gauss

$\nabla\times E = -\partial B/\partial t$, $\nabla\times B = \mu_0 J + \mu_0\varepsilon_0\, \partial E/\partial t$

Faraday; Ampère–Maxwell

$\nabla^2 E - \mu_0\varepsilon_0\, \partial^2 E/\partial t^2 = 0$, $c = (\mu_0\varepsilon_0)^{-1/2}$

the wave equation

$\rho = q\,\delta^3(x) \Rightarrow \Phi = k_e q/r$, $F = k_e\, q_1 q_2 / r^2$

Coulomb, $k_e = 1/(4\pi\varepsilon_0)$ a limit lock

"When you average these orientation-gated path nudges over time and over many loops, in smooth, weak-curvature conditions, the effective path law you recover is the same set engineers already use: the standard Maxwell equations" (EM Narrative, 5). "This reinterpretation is optional and appears only here for comparison; the proof does not depend on it" (Math Appendix, section 8)

A. The case drawn, step by step (the numbers are the circles in the figure)

1. In this case: the loop, which way it turns, and how many turns

The loop is the electron loop of the matter pages, closed on the plane the expansion selects. The Mathematical Bridge (section 4): "Each loop carries an orientation $\sigma \in \{+1, -1\}$, preserved under expansion as specified in A3." And: "When a void loop closes on the preferred expansion plane, the orientation of its rotation defines a polarity. This polarity is identified with electric charge." How much charge is a count. The Electromagnetism Narrative (section 3): "Sign: which side of the preferred plane the loop's orientation locks to. Size: how many aligned turns per cycle the loop contributes (an integer count when you coarse-grain over time). Steps (quantization): you only change the count at discrete orientation-flip or merge/split events; it doesn't slide continuously when closure holds." The Particle Mechanics Narrative (section 7): "Stable loops carry integer winding numbers. Those give discrete charge steps and spin classes."

$\Delta\varphi_{\text{loop}} = (1/\hbar)\cdot\oint p\cdot dl = 2\pi n$, $n \in \mathbb{Z}$ (closure; Particle Mechanics Math Appendix)
$q = n\cdot q_0$ (Particle Mechanics Narrative, 7); $\sigma \in \{+1, -1\}$ (Bridge, 4); shadow: $q = \sigma e$ (Student Workbook, symbols)

The drawing's loop makes one turn per cycle, n = 1; the mirror loop is the same loop with σ flipped. Nothing else distinguishes them: same closed route, same obscured volume, same mass (matter page, step 7), opposite sign.

2. In this case: the preferred plane, why there is a facing

The Electromagnetism Narrative (section 2) gives the plane in the same bookkeeping as the matter pages' split. For fragments of volume V_i that merge into one body the display area contracts by

$F_{\text{merge}} = A_{\text{after}}/A_{\text{before}} = (\Sigma_i V_i)^{2/3} / \Sigma_i V_i^{2/3} \le 1$; two equal fragments: $F_{\text{merge}} = V^{2/3}/[2(V/2)^{2/3}] = 2^{-1/3} = 0.7937$ (inverse of the split factor $2^{1/3}$)

"When a loop splits and merges space along its route, splitting expands display-area and merging contracts it. That rule naturally picks out the preferred plane for the loop's motion from the caustic, on that plane the expansion/merging bookkeeping balances best. 'Facing' is judged against that plane. The sign we call 'positive' or 'negative' is just which direction, counterclockwise vs clockwise locked to that common plane." The Bridge (Waveform) says how the plane holds a loop: "Expansion-driven caustics select a preferred plane in the surrounding space; loops are steered toward that plane rather than 'choosing' it … tilt the loop off the ridge by a small angle θ and the transport pushes it back toward the plane, while reversing the loop's rotation flips the side toward which the transverse push acts, setting the handed response of the force." Panel 2 plots $F_{\text{merge}}(a)$ for two parts a and 1 − a; its minimum at a = ½ is the $2^{-1/3}$.

3. In this case: the base, what the mass has already set

The grey of the drawing is not charge; it is the mass. From the mass pages (Mathematical Bridge Math Appendix, Mass and Gravity from Closed Void Loops),

4. In this case: the null gravity wave, as the drawing builds it

The Electromagnetism Narrative (What Is Charge in VMS?): "A 'charged' thing here is a rotating void-loop that's constantly throwing off null-gravity waves (NGWs) ripples. Those ripples don't pile anything up, no net space-density change. Another loop only feels something if it's also spinning and its facing lines up with the ripple pattern. The effect is purely orientation-gated." The drawing shows one such ripple: a white line born at the tail (released space, the same white as no-mass space far away), a band easing back to the base shade, complete at the head's edge; net change through the band, zero. The drawing gives the band a width by one rule of its own, stated here as such and not as a line in any document: both edges run at c; where a share δ of space is missing, the release edge covers drawn distance faster, and the head edge, crossing space the release edge has already freed, does not:

release edge: $dr/du = c/(1 - \delta(r))$; head edge: $dr/du = c$, 0.7 rad behind; band contrast $\propto \delta$ (drawn eased as $\sqrt{\delta}$, declared)

Integrated from the rim, the gap grows fastest at the rim (δ = ½) and saturates as δ dies; the high school figure prints 1.26 λ_e and 1.40 λ_e at two crossings, and panel 4 recomputes the two edges from the rule. One turn of ribbon per loop period, its handedness the sign: that is the count of panel 1, made visible.

5. In this case: push, null, pull

The Electromagnetism Math Appendix (section 9) writes the facing law as an equation once, for its neutral-rotor test: a spinning body aligned to the caustic plane, with ε the closure/tear bias, σ the spin orientation (+1 right-handed, with +n̂; −1 opposite) and θ the facing angle to +n̂:

$\langle\Delta p\rangle \propto \varepsilon\cdot\sigma\cdot\cos\theta$ (Eq. 9.4); right spin + right facing (σ = +1, θ = 0°) → push; 90° tilt → strict null; spin-flip or opposite facing (σ = −1 or θ = 180°) → pull

That equation is the rotor prediction; for two loops the same push, null, pull is the Narrative's statement in words, and the two-charge sign law is the Bridge's $F \propto \sigma_1\sigma_2/r^2$ of step 10. The Narrative: "Right spin, right facing → you get a push; wrong facing → the pushes cancel over a cycle and you feel nothing net. opposite facing you get a pull." And why this is not gravity (section 6): "Gravity behaves like a standing curvature gradient, a downhill. Anything with inertia 'rolls' the same way no matter how it's turned. Electromagnetism here is different: there's no standing downhill, just a traveling pattern, so the outcome depends completely on how you're oriented." Two loops of opposite sign pull together, two of the same sign push apart: the push and pull page.

seen from outside a loop of radius $R_0 = \bar{\lambda}_e$ omits the span it hides, and the share of space missing at radius R is

$$R = \sqrt{r^2 - R_0^2},\quad \delta(R) = R_0^2/(R^2 + R_0^2) = R_0^2/r^2;\quad \delta(0) = 1,\quad \delta = \tfrac{1}{2} \text{ at the rim},\quad \delta \to R_0^2/R^2 \text{ far out (inverse square)}$$

Every shade of the base is this δ at that radius: the dark ring at the loop's edge is δ = ½, the point itself would be δ = 1, and the base fades to white where δ no longer leaves a visible mark. The wave of panel 4 rides on that base and returns to it.

B. The general solution: charge from transported display area

6. Display area transported: the 2-form K = dA

Now the general case, from the Mathematical Bridge Math Appendix, Electromagnetism from Void Transport (No Field Primitives). The objects: the display area density A_d, "transverse obscuration measured along transport"; a transport 1-form A that "encodes oriented accumulation of Display Area along worldlines/surfaces (no 'field' postulate)"; its exterior derivative K := dA, "oriented flux of Display Area (a curvature of transport; again, not a field primitive)"; and the Hodge dual ⋆ from the metric that A1 and A2 fix. For any oriented patch S carried by the front,

$$\oint_{\partial S} A = \iint_S K,\quad K := dA \ \ \text{(Stokes; "No dynamics are assumed here")}$$

$$dK = 0 \ \ \text{(geometric identity / absence of transport sources)},\quad d{\star}K = 0 \ \ \text{(conservation of transported obscuration density under expansion, from A2–A3)}$$

"Here A3 (finite tension) is crucial: it enforces that transported flux remains finite, so conservation under expansion leads to an unavoidable $1/r^2$ falloff. Without finite nonzero T_s, flux would dilute improperly or diverge." (section 3). This is the same finite tension that made a finite G exist on the matter page.

7. The caustic fixes the axis: one normal, two polarizations

Section 2 of the same derivation. Parameterise the Void front by rays x = X(q, t), q ∈ $\mathbb{R}^2$; the Jacobian J(q, t) = det(∂X/∂q) measures local area transport, and at J = 0 a fold caustic forms. With canonical coordinates ξ normal and η tangential to the caustic, the transported obscuration admits the uniform Airy form near the fold:

$$u(\xi, \eta, t) \approx \mathscr{A}(\eta, t)\, \mathrm{Ai}(\alpha\xi),\ \ \alpha > 0;\quad \text{oscillations for } \xi < 0, \text{ exponential decay for } \xi > 0, \text{ a } \pi/2 \text{ phase across the fold (Maslov index ½)}$$

$$\hat{n} = \nabla\xi/|\nabla\xi| \ \ \text{the preferred axis; oscillations transverse to } \hat{n}; \text{"Symmetry ensures only two polarizations (±) remain."}$$

This is the same fold that the photon page's x^3 normal form describes; here it does one more job: it fixes a direction in space, the axis against which "facing" in panels 1, 2 and 5 is measured. Panel 7 plots Ai(αξ), computed.

8. The wave operator, the action, and the inverse square

Sections 4, 5 and 7. Apply d⋆ to K = dA and use $d^2 = 0$: d⋆dA = 0. The relabelling freedom A → A + dχ allows ∇·A = 0, and the transport equation becomes the wave equation; the preferred axis enforces transversality. The two identities follow from stationarity of a geometric action, with the same σ_s as the matter page:

$$\Box A = 0,\quad \Box K = 0;\quad \hat{n}\cdot A = 0,\quad \hat{n} \lrcorner K = 0 \ \ \text{(exactly transverse; two independent polarizations)}$$

$$S[A] = (1/2\sigma_s) \int K \wedge {\star}K,\quad \delta S/\delta A = 0 \Rightarrow d{\star}K = 0 \ \ (dK = 0 \text{ is geometric})$$

$$\mathscr{J} := (1/\sigma_s)\, {\star}(A \wedge K),\quad d\mathscr{J} = 0 \ \ \text{in vacuum} \Rightarrow \text{flux through spheres constant: amplitude} \propto 1/r,\ \ \text{intensity} \propto 1/r^2$$

9. A source: the charge as a closed-surface flux

The Source Extension (sections 10 to 14). "Sources arise when Void transport fails to close perfectly (broken closures, defects, intersections), creating conserved transport currents." Introduce a transport current 3-form J, "oriented injection of transported Display Area"; consistency requires dJ = 0. The equations and the action that produces them:

$$dJ = 0 \ \ \text{(continuity)};\quad dK = 0,\quad d{\star}K = J$$

$$S[A; J] = (1/2\sigma_s) \int K \wedge {\star}K + \int A \wedge J \ \Rightarrow \delta S/\delta A = 0 \text{ gives } d{\star}K = J;\ A \to A + d\chi \text{ leaves S invariant iff } dJ = 0$$

$$Q[V] := \int_V J = \int_V d{\star}K = \oint_{\partial V} {\star}K \ \ \text{(surface independent, by dJ = 0)};\quad \Box A = \mathscr{J}[J]$$

$$\text{(retarded: causal at c; far zone } 1/r \text{ amplitude, } 1/r^2 \text{ intensity)}$$

"Thus Q is measured by the flux of ⋆K through any closed 2-surface surrounding the source." That is the general statement of what panel 1 counted: the closed loop, a transport that does not close perfectly, is the source, and its strength is the flux through any surface round it, the same for every surface. The integer of panel 1 is the count of that flux in units of the electron loop's; the Workbook's q = σe is the shadow of Q for one loop.

10. The sign: the same loop, the second far field

The Mathematical Bridge, section 4, closes the loop back to panel 1: "Relative orientation determines the sign of far-field interaction. The far-field again follows a $1/r^2$ dependence, but its direction depends only on σ. Binary polarity is therefore a direct geometric consequence of orientation."

$$F \propto (\sigma_1\sigma_2) / r^2,\quad \sigma_i \in \{+1, -1\} \quad \text{beside gravity, the matter page's } F = Gmm'/r^2 \ \ \text{(always toward, no σ)}$$

Same loop, two far fields, both inverse square: one from the volume the loop obscures, always attractive; one from which way it turns, with a sign. The high school drawing is the second one, seen at the loop; panel 10 is its far field. The Bridge Narrative says it in one line: "Mass is missing space; gravity is how another spinning Void responds to that missing space; electromagnetism is orientation on the same stage".

11. The limit engineers use: Maxwell, and Coulomb

The Electromagnetism Math Walk-Through carries the same two identities into the familiar variables. "Display-area flux is encoded as a 2-form F with dF = 0 (Bianchi). With action S[A] = ½∫F ∧ ⋆F and minimal coupling ∫J·A d^4x, Euler–Lagrange yields d⋆F = J." Splitting A = (Φ, A) gives E = −∇Φ − ∂A/∂t and B = ∇×A, and the components are the Maxwell set (Box 1); the static point source gives Coulomb (Box 4):

$$\nabla\cdot E = \rho/\varepsilon_0,\quad \nabla\cdot B = 0,\quad \nabla\times E = -\partial B/\partial t,\quad \nabla\times B = \mu_0 J + \mu_0\varepsilon_0\, \partial E/\partial t;\quad \nabla^2 E - \mu_0\varepsilon_0\, \partial^2 E/\partial t^2 = 0,\quad c = (\mu_0\varepsilon_0)^{-1/2}$$

$$\rho = q\, \delta^3(x) \Rightarrow \Phi = k_e q/r,\quad F = k_e\, q_1 q_2/r^2,\quad k_e = 1/(4\pi\varepsilon_0) \ \ \text{(a limit lock, not an input)}$$

This $1/r^2$ is the intensity of the transported wave, the far field of a radiating source; the static inverse-square force between two charges is a different statement, and comes from the source equation $d\star K = J$ through Poisson's equation in step 11. "This derives entirely from expansion and finite tension (A2–A3). Riding the wave outward, one perceives conservation: the further one goes, the wider the ripples spread, and the weaker each crest must be to conserve flux." And the remark that separates the two far fields: "Magnetism drops off faster than gravity because here the conserved flux is tied to transverse oscillations set by tension. Gravity, by contrast, is encoded in space curvature directly and dilutes differently." Panel 8 draws the equal flux through nested spheres and the two curves.

"Sources are geometric descriptors: (ρ, J) from orientation and topology of loops." The Narrative (section 5): "When you average these orientation-gated path nudges over time and over many loops, in smooth, weak-curvature conditions, the effective path law you recover is the same set engineers already use: the standard Maxwell equations." The Math Appendix names the dictionary in one line (section 8): "If one chooses to adopt conventional names at the end, components of K transverse to $\hat{n}$ coincide with the usual vacuum electromagnetism quantities, and the pair $dK=0$, $d\star K=0$ matches the standard homogeneous and inhomogeneous vacuum equations." And its caveat: "This reinterpretation is optional and appears only here for comparison; the proof does not depend on it." The only dimensional scale admitted is $S_0 = \hbar$; ε_0, μ_0 and k_e are acceptance locks.

What is published, what is derived here, what is chosen

Line	Status	Where it stands
orientation $\sigma \in \{+1, -1\}$ preserved under expansion (A3); polarity from the orientation of rotation on the preferred expansion plane, identified with electric charge; $F \propto \sigma_1\sigma_2/r^2$	published	Mathematical Bridge, section 4 (steps 1 and 10).
$\Delta\varphi_{loop} = 2\pi n$; $q = n\cdot q_0$; size = aligned turns per cycle, changed only at flip or merge/split events	published	Particle Mechanics Math Appendix; Particle Mechanics Narrative, 7; Electromagnetism Narrative, 3 (step 1).
$Q \propto \oint d\varphi$ as written on the high school page	reading	The two published lines above put together: the closure phase per cycle is $2\pi n$ and the charge is $n\cdot q_0$; the winding drawn is that n.
$q = \sigma e$	published (shadow)	Electromagnetism Student Workbook, symbols; the Workbook's word for the textbook name of Q.
$F_{merge} = (\Sigma V_i)^{2/3}/\Sigma V_i^{2/3} \le 1$, two equal parts $2^{-1/3}$; the rule picks the preferred plane; sign = counterclockwise vs clockwise on it	published	Electromagnetism Narrative, 2 (step 2); the same bookkeeping as the matter pages' $2^{1/3}$.
caustics select the plane; tilt θ is pushed back; reversing rotation flips the side	published	Mathematical Bridge, Waveform (step 2).
$\delta(R) = R_0^2/(R^2 + R_0^2)$, the map $R = \sqrt{r^2 - R_0^2}$	published (via the mass pages)	Math Appendix, Mass and Gravity from Closed Void Loops (step 3).
a charged loop throws off null-gravity waves; no net space-density change; felt only by a spinning loop whose facing lines up	published	Electromagnetism Narrative, What Is Charge in VMS? (step 4).
the ribbon's width: release edge at $c/(1 - \delta)$, head edge at c, 0.7 rad behind; brightness eased $\sqrt{\delta}$	the drawing's rule	Not a line in any of the site's documents; declared in panel 4 and in "Chosen". Everything moves at c; the rule converts c into drawn distance where space is missing. Measured on the stored figure: the release edge follows $1/(1 - \delta)$ to 2%.
$\langle\Delta p\rangle \propto \varepsilon\cdot\sigma\cdot\cos\theta$; push / strict null / pull	published	Electromagnetism Math Appendix, 9, Eq. 9.1 to 9.5, written for the neutral-rotor test; the two-loop push/pull is the Narrative's statement in words (What Is Charge; 6); the two-charge sign law is Bridge 4 (step 5).
A, $K = dA$, $\star$; $\oint A = \iint K$; $dK = 0$, $d\star K = 0$; finite tension ⇒ $1/r^2$	published	Math Appendix, EM from Void Transport, 1 and 3 (step 6).
the wave's $1/r^2$ intensity (step 8) and Coulomb's static $1/r^2$ force (step 11) are two statements	published, kept apart	Math Appendix, 7 (flux conservation of a radiating source); Walk-Through, 2 (Poisson, static point source).
$J = 0$ fold; $u \approx \mathscr{A}\,\mathrm{Ai}(\alpha\xi)$; $\hat{n} = \nabla\xi/\lvert\nabla\xi\rvert$; two polarizations	published + computed	Math Appendix, 2 (step 7); Ai evaluated here.
$\Box A = 0$; $\hat{n}\cdot A = 0$; $S[A] = (1/2\sigma_s)\int K\wedge\star K$; $\mathscr{J} = (1/\sigma_s)\star(A\wedge K)$, $d\mathscr{J} = 0$; amplitude $1/r$, intensity $1/r^2$	published	Math Appendix, 4, 5, 7 (step 8).
$dJ = 0$; $d\star K = J$; $S[A; J]$; $Q[V] = \oint_{\partial V}\star K$ surface independent; retarded $\Box A = \mathscr{J}[J]$	published	Math Appendix, Source Extension, 10 to 14 (step 9).
the integer of step 1 is the count of the flux of step 9 in units of the electron loop's	reading	The two published statements set side by side; the documents give Q as a flux and q as an integer count, and the electron anchor is the unit.
$F = dA$, $dF = 0$, $d\star F = J$ → the Maxwell set; Coulomb $F = k_e q_1 q_2/r^2$	published	Electromagnetism Math Walk-Through, Boxes 1 to 4 (step 11).
$S_0 = \hbar$ at the electron; ε_0, μ_0, k_e as limit locks	calibrations	One scale and the acceptance locks the Walk-Through names; never derived.
circle in the plane, inside view, which turn is minus, plotted ranges, the drawn surfaces	chosen	See "Chosen for the drawing".

Chosen for the drawing, not from the framework. The loop is drawn as a circle of radius λ_e in the preferred plane, seen from inside (the drawing's view); which way it turns, and which turn is called minus, is the drawing's choice, that the two are mirror images is the math. The ribbon's width rule (release edge at drawn speed $c/(1 - \delta)$, head edge at c, 0.7 rad behind) is the drawing's own, stated in panel 4; the band's brightness is eased as $\sqrt{\delta}$ so the outer windings print, with the physical contrast δ. In panels 6 to 11 the surface patch, the nested spheres, the two enclosing surfaces and the plotted ranges are drawing choices; the curves are the stated functions evaluated.

Computed from those choices. $F_{merge}(a) = 1/[a^{2/3} + (1 - a)^{2/3}]$ with its minimum $2^{-1/3}$ at $a = ½$; $\delta(R) = \lambda_e^2/(R^2 + \lambda_e^2)$ against λ_e^2/R^2; the two ribbon edges integrated from the rule; $\langle\Delta p\rangle \propto \sigma\cos\theta$ for both σ; Ai(αξ) from the standard library; $1/r$ and $1/r^2$; $\pm 1/r^2$ against gravity's $-1/r^2$.

Sources (vms-institute.org/theory). Proposed Mathematical Bridge: Loop Orientation to Electromagnetism ($\sigma \in \{+1, -1\}$ preserved under expansion, A3; $F \propto \sigma_1\sigma_2/r^2$; polarity identified with electric charge); Waveform (expansion-driven caustics select a preferred plane; tilt θ off the ridge; reversing the rotation flips the side). Mathematical Bridge Math Appendix: Electromagnetism from Void Transport (No Field Primitives), sections 1 to 9 (objects; the caustic axis and Airy form; $\oint A = \iint K$, $dK = 0$, $d\star K = 0$; $\Box A = 0$; $S[A] = (1/2\sigma_s)\int K\wedge\star K$; $\mathscr{J}$ and the $1/r^2$; naming only at the end); Source Extension, sections 10 to 17 (J, $dJ = 0$; $d\star K = J$; $S[A; J]$; $Q[V] = \oint\star K$; retarded $\Box A = \mathscr{J}[J]$); Mass and Gravity from Closed Void Loops (the map and δ, via the mass pages). Electromagnetism Narrative: What Is Charge in VMS?; sections 1 (the surfer), 2 (F_{merge}, the preferred plane, the sign as direction), 3 (sign, size, steps), 5 (the Maxwell limit), 6 (how this is not gravity). Electromagnetism Math Walk-Through: section 0 and 1 ($F = dA$; the Maxwell set, Boxes 1 and 2), section 2 (Lorentz force, Coulomb, Boxes 3 and 4).

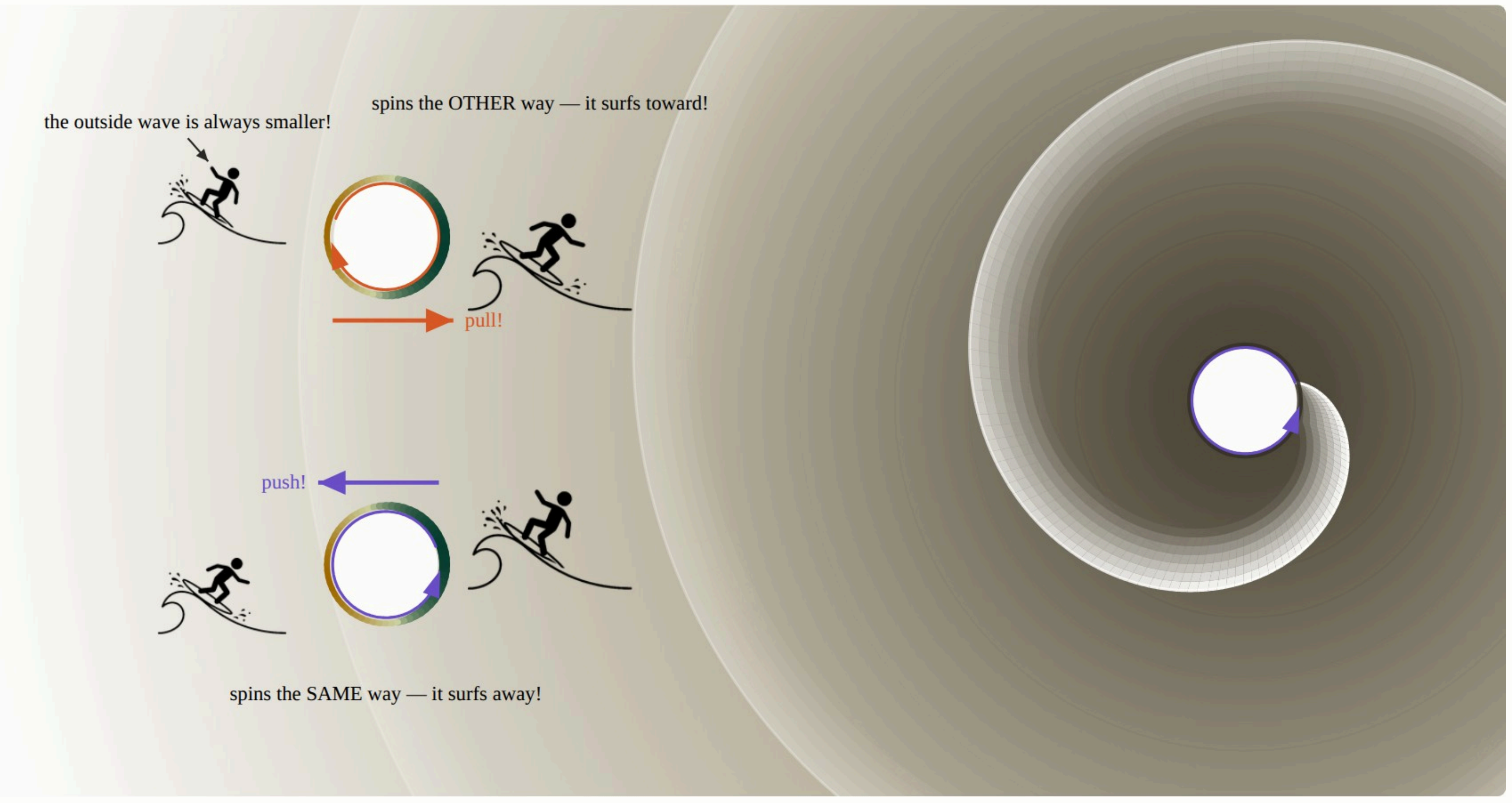
Electromagnetism Math Appendix: section 9, Eq. 9.1 to 9.5 (ε, σ, θ; $\langle\Delta p\rangle \propto \varepsilon\cdot\sigma\cdot\cos\theta$; push / null / pull). Particle Mechanics Narrative: section 7 (integer winding numbers; $q = n\cdot q_0$). Particle Mechanics Math Appendix: $\Delta\varphi_{loop} = (1/\hbar)\oint p\cdot dl = 2\pi n$. Electromagnetism Student Workbook: symbols (Q, closure measure from σ; shadow $q = \sigma e$). Generator: gen_charge_proofs3d.py.

Why charges pull, and push

A photon is the smallest piece of light. Each drawing here is one photon trapped, like before.

The drawing on the right swooshes its waves out across all the space. Big waves up close, smaller and smaller far away.

The masses to the left are surfing those waves. The side near the big drawing always rides a bigger wave than the side far away. So closest wins!

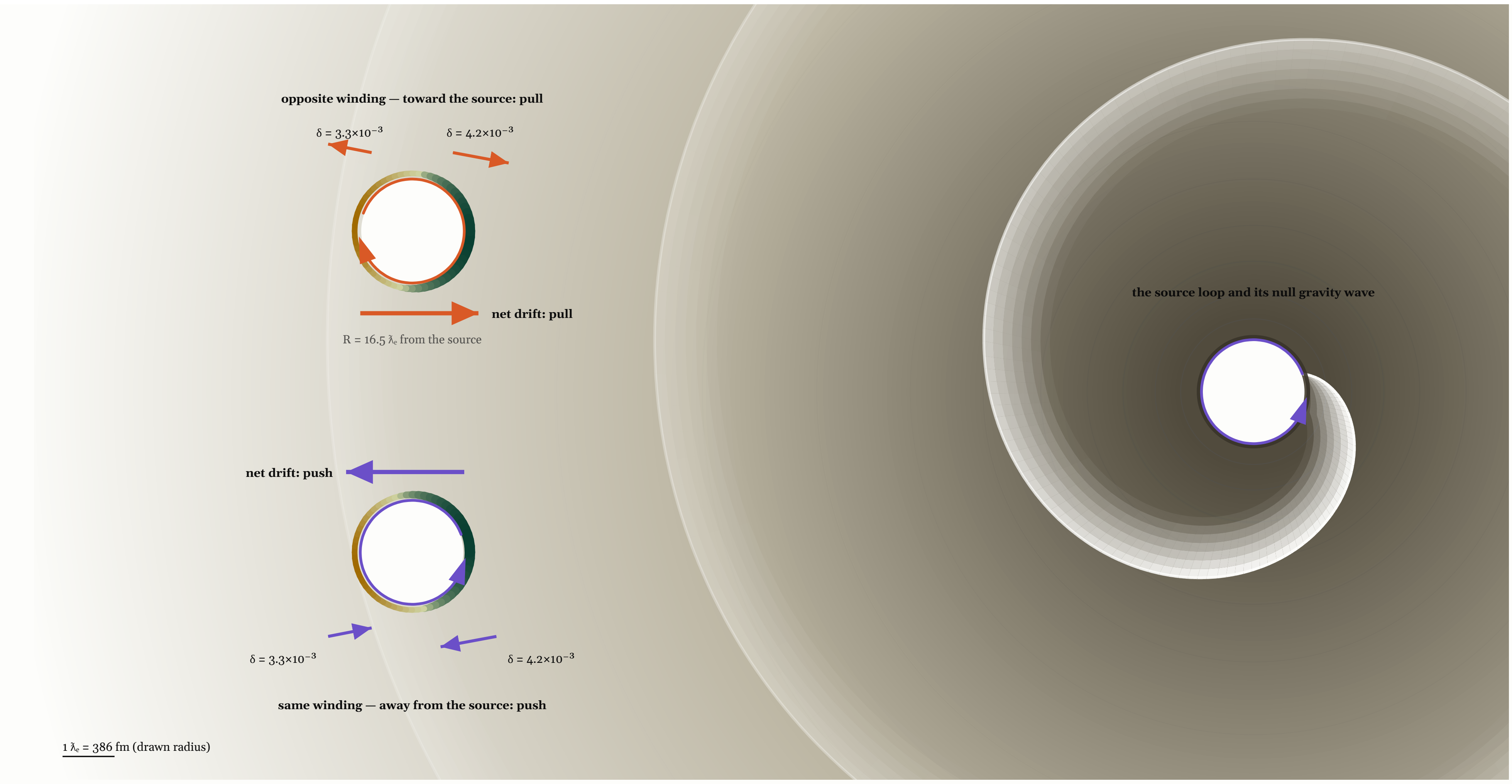


Each little mass drawing wears **dark green where space is squeezed shortest**, the side by the other mass, and **yellow where space runs longest** farther out.

Opposite spin direction or "charges" surf toward each other. Same spin directions they surf apart.

Why charges pull, and push

A photon is the smallest piece of light; this page follows one photon closed into a loop, and a second one standing in its wave. A charged loop fills the space around it with its null gravity wave, spreading at c and fading with the density deficit δ. A second loop stands in that wave with its two sides at different depths: the near side always rides a stronger wave than the far side, so the near side sets the size of the push or pull. Which way it goes is the facing: when the two loops turn opposite ways they pull together; when they turn the same way they push apart. Each particle's boundary is painted by route length: darkest green at the point nearest the source, darkest yellow at the farthest, pale at the perpendicular crossover where the two sides are equal.



$$\delta = ƛ_e^{2}/(R^2 + ƛ_e^{2}) \rightarrow ƛ_e^{2}/R^2$$

(far from the loop, the inverse square; the wave fades with it)

$$Q \propto \oint d\varphi = 2\pi n, \quad \text{so} \quad q = n \cdot q_0, \quad \sigma = \pm 1$$

(n the count of aligned turns per cycle; σ which way the loop turns)

$$F \propto \sigma_1 \sigma_2 / r^2, \quad \sigma_i \in \{+1, -1\}$$

(opposite facing pulls, same facing pushes; the size from the wave, the sign from the two orientations)

$$F = kq_1 q_2 / r^2, \quad E = kq / r^2, \quad F = qE$$

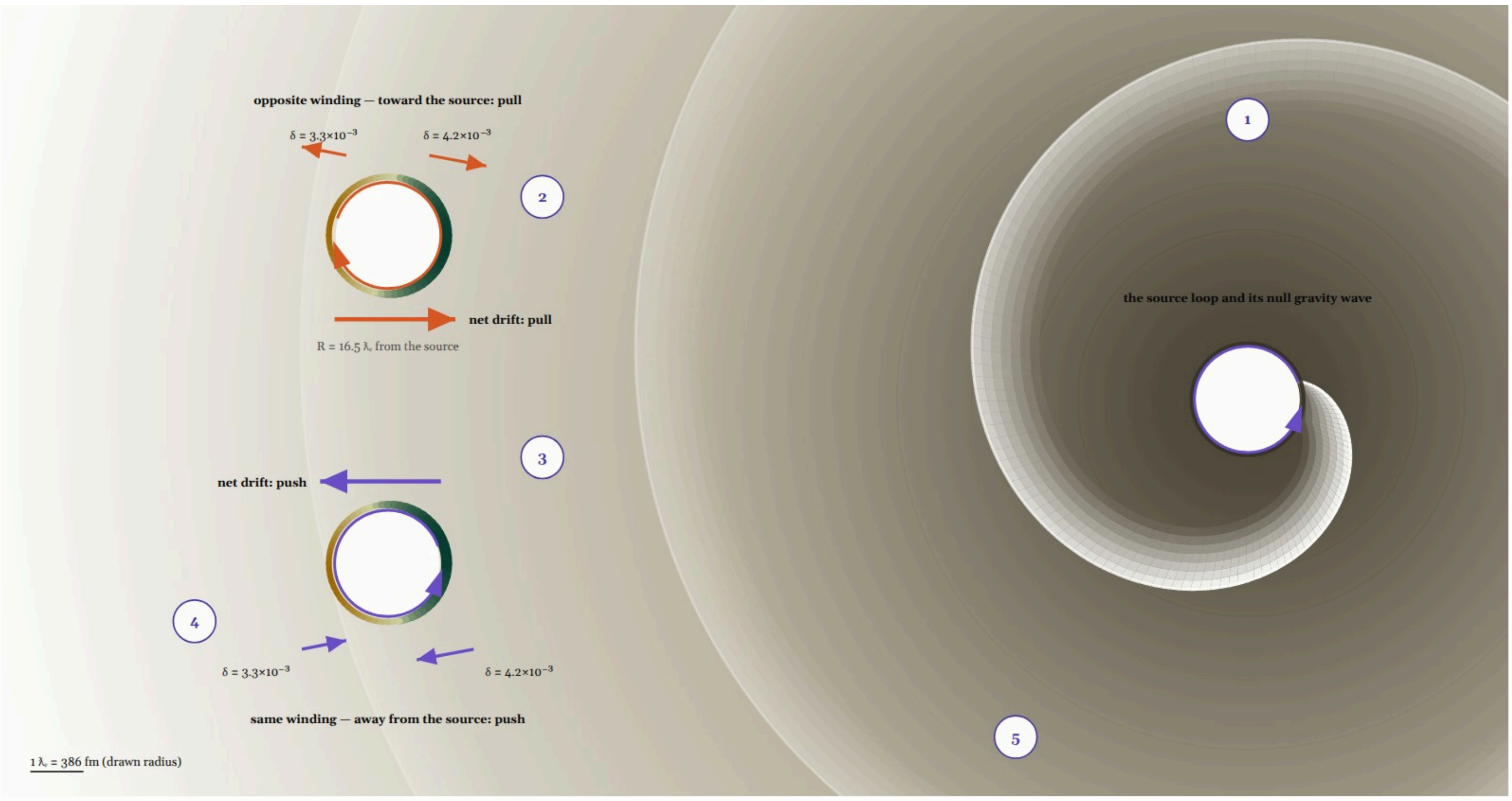
(the same line in the textbook's letters, with $q = \sigma e$: Coulomb's law and the field of a point charge; $k = 1/(4\pi\varepsilon_0)$ is a lock on the scale, not an input)

Mathematical Bridge Math Appendix (the map and δ), Particle Mechanics Math Appendix ($\Delta\varphi_{loop} = 2\pi n$), Particle Mechanics Narrative §7, Electromagnetism Narrative (What Is Charge; §6), Mathematical Bridge §4, Electromagnetism Math Walk-Through §2 (Coulomb).

Every element computed. The wave is the source loop's null gravity wave, drawn by the same rule as the previous page (release front dr/du = 1/(1−δ), hide front dr/du = 1, the drawing's own; contrast eased as √δ for printability); the base shading runs to the page edge. All three loops are at true size, radius ƛₑ. Both particles stand R = 16.5 ƛₑ from the source. The paired arrows are the local wave strength at each particle's two edges, δ = 4.2×10^{-3} near against 3.3×10^{-3} far, a ratio of 1.27, on one scale along the loop to source line, each pointing in that side's drift direction. The facing sets the sign, opposite windings toward, same windings away (Mathematical Bridge, section 4); the near side, on the stronger wave, sets the size. Boundary hue runs by the angle to the source line, ordered by computed route length and normalized per loop: darkest green at the nearest point (shortest routes, drawn heavier), darkest yellow at the farthest, pale at the two perpendicular points, which stand at equal distance from the source; the printed δ values carry the magnitudes. The net-drift arrows are summary indicators; the edge gauges lie on the true loop to source line. The impacted particles' own waves are omitted for clarity.

Why charges pull and push, and what that recovers: the full derivation

A photon is the smallest piece of light; this page follows one photon closed into a loop, and a second one standing in its wave, and derives what the high school page stated. The near side of the second loop rides the stronger wave, so it sets the size; the two facings set the sign. The drawing is the high school page's; each numbered circle is a panel below, and each panel a step of the derivation.



The case drawn.

$$F \propto \sigma_1\sigma_2 / r^2, \quad \sigma_i \in \{+1, -1\}$$

(opposite facing pulls, same facing pushes; Mathematical Bridge, section 4)

In the textbook's variables, with $q = \sigma e$, the same line is Coulomb's law, and the same two identities that give it give the rest of electromagnetism:

$$F = k_e\, q_1 q_2 / r^2, \quad k_e = 1/(4\pi\varepsilon_0)$$

(k_e a limit lock, not an input; Electromagnetism Math Walk-Through, Box 4)

Panels 1 to 5. The general case is not drawn on the high school page; it is derived in panels 6 to 11.

The general solution, and what it recovers, from dK = 0 and d⋆K = J and nothing else:

Gauss's law	**panel 6**
retarded potentials, causality at c	**panel 7**
the Lorentz force	**panel 8**
Coulomb's law	**panel 9**
Ampère's law, Biot–Savart	**panel 10**
all four Maxwell equations, continuity, the wave speed c	**panel 11**

Named only at the end, as the Math Appendix names them: "(E,B) are not primitives but simply the decomposition of K into radial and circulatory parts relative to the source's motion."

A. The case drawn, panels 1 to 5

1 the source loop and its wave, fading as δ
2 the particle's two edges: the size
3 the facing: the sign, $F \propto \sigma_1\sigma_2/r^2$
4 the surfer, and the one facing equation
5 why this is not gravity

B. The general solution, panels 6 to 11

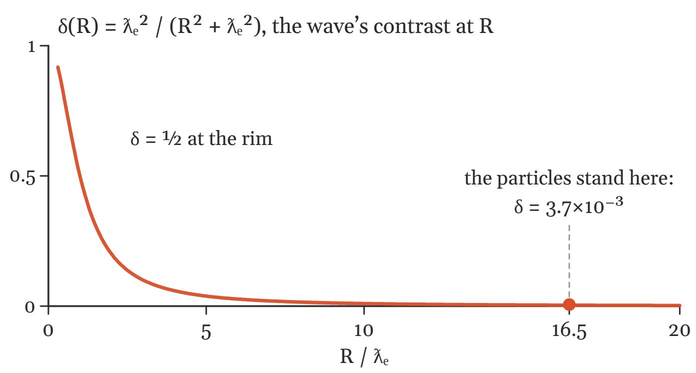
6 the source, $Q = \oint \star K$: Gauss
7 the retarded solution: causal at c
8 the coupling: the Lorentz force
9 the static limit: Coulomb
10 moving sources: Ampère, Biot–Savart
11 the whole set: Maxwell

Published documents used, and nothing else: the Mathematical Bridge (section 4) and its Math Appendix (Electromagnetism from Void Transport; Source Extension; Transport Circulation from Moving Sources; Magnetism from Moving Sources via Transport Calculus), with the Bridge's section 3 behind the mass pages' map; the Electromagnetism Narrative (What Is Charge; sections 1, 4, 6); the Electromagnetism Math Walk-Through (sections 1 and 2, Boxes 1 to 4) and Math Appendix (section 9); the Particle Mechanics Narrative (section 7) and Math Appendix (the closure phase); the Student Workbook ($q = \sigma e$). Only ratios enter; S_0 is the one scale; ε_0, μ_0, k_e and μ_{eff} are limit locks, not inputs.

> **A note on the mathematics.** As on the previous page, the general solution is written in differential forms (A, K = dA, ⋆, Stokes) and the observer split of a 2-form into its time–space and space–space parts, which is the standard way of writing electromagnetism covariantly (Flanders, *Differential Forms with Applications to the Physical Sciences*, 1963; Frankel, *The Geometry of Physics*, 3rd ed., 2011); the retarded Green's operator is textbook (Jackson, *Classical Electrodynamics*, 3rd ed., 1999, chapter 6). Nothing on this page needs more than that; the caustic asymptotics of the previous page enter only through the axis n̂.

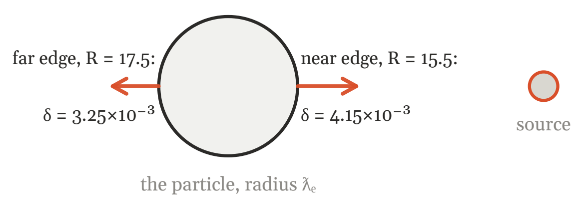
The case drawn (panels 1 to 5)

1. In this case: the source loop and its wave, fading as δ



the wave is the H3 page's null gravity wave, one turn per loop period; its contrast is δ at that radius (the drawing's rule), so far out it is faint: at 16.5 $ƛ_e$, δ = 0.0037, 0.7 % of the rim's ½. "Those ripples don't pile anything up, no net space-density change" (EM Narrative, What Is Charge in VMS?)

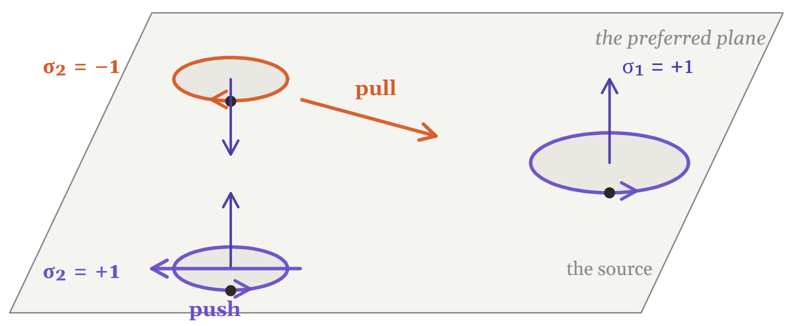
2. In this case: the particle's two edges set the size



ratio near/far = 1.27; difference = 8.9×10^{-4}: the unequal ride the drawing's arrows show

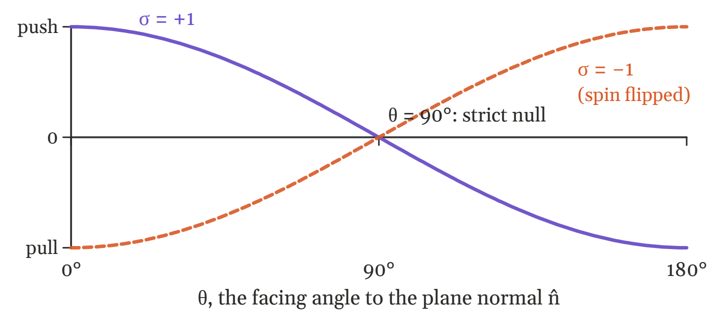
δ(15.5) and δ(17.5) from the mass pages' map, $R = \sqrt{r^2 - ƛ_e^2}$ (their construction; the Bridge gives the fixed missing volume and the $1/r^2$ far field): the two numbers printed on the H page.
The near side always rides the stronger wave, so it sets the size; "the side near the big drawing always rides a bigger wave than the side far away" is the same arithmetic on the kid page.

3. In this case: the facing sets the sign



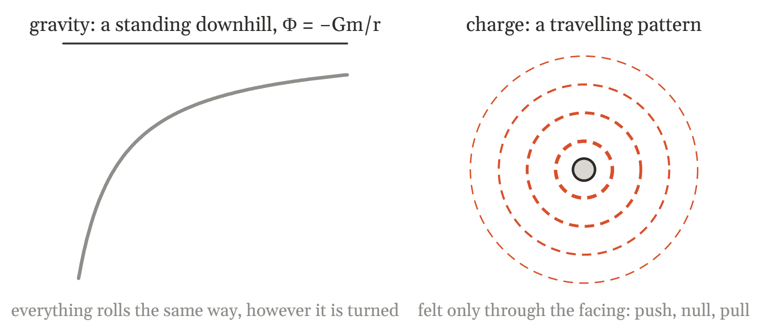
$F \propto \sigma_1\sigma_2 / r^2$, $\sigma_i \in \{+1, -1\}$ (Bridge, section 4): $\sigma_1\sigma_2 = -1$ pulls, +1 pushes
"Relative orientation determines the sign of far-field interaction. The far-field again follows a $1/r^2$ dependence, but its direction depends only on σ." The size is panel 2; the sign is this.

4. In this case: the surfer, and the one facing equation



$\langle \Delta p \rangle \propto \varepsilon \cdot \sigma \cdot \cos\theta$ (EM Math Appendix, Eq. 9.4, written for the neutral-rotor test): push, null, pull. "If the surfer angles the board into the swell the right way, the path bends and you 'catch' it. If you're misaligned, the chops ... average out, no net drift. If you're faced the other way, you get the opposite path change."

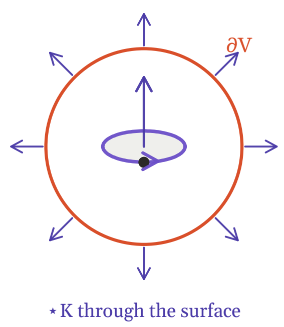
5. In this case: why this is not gravity



"Gravity behaves like a standing curvature gradient, a downhill. Anything with inertia 'rolls' the same way no matter how it's turned. Electromagnetism here is different: there's no standing downhill, just a traveling pattern, so the outcome depends completely on how you're oriented" (EM Narrative, section 6)

The general solution (panels 6 to 11), and what each recovers

6. The source, and the charge as a closed-surface flux



recovered: Gauss's law

$\mathbf{dJ = 0,\ dK = 0,\ d{\star}K = J}$

$\mathbf{Q[V] := \int_V J = \oint_{\partial V} {\star}K}$

surface independent, since $dJ = 0$

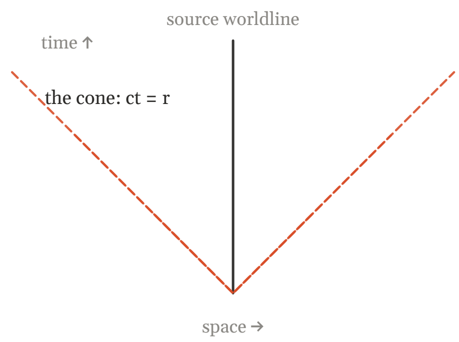
in local inertial coordinates:

$\mathbf{\nabla \cdot E = \rho}$

(E the time–space part of K)

"Thus Q is measured by the flux of ⋆K through any closed 2-surface surrounding the source." (Math Appendix, Source Extension, 13). The 3+1 split of $d{\star}K = J$ gives "$\nabla\cdot E = \rho$, (radial transport sourced by density ρ)" (Magnetism from Moving Sources, 3): Gauss's law, with E named only at the end.

7. The retarded solution: causal at c



recovered: retarded potentials

$\mathbf{\Box A = \mathscr{J}[J]}$

$A(x) = \int G_{ret}(x - x')\,\mathscr{J}[J](x')\,d^4x'$

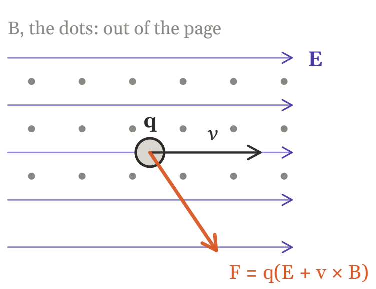
$K = dA$

far zone: amplitude $\propto 1/r$,
intensity $\propto 1/r^2$, transverse to $\hat{n}$

nothing arrives before r/c

"Solutions are obtained with the retarded Green's operator of □, guaranteeing causal propagation at speed c." (Source Extension, 14). "Using the retarded Green's operator G_ret of □, the causal solution is $A(x) = \int G\_ret(x - x')\,\mathscr{J}[J](x')\,d^4x'$, $K = dA$." (Magnetism from Moving Sources, 5)

8. The coupling: the force on a second loop



recovered: the Lorentz force

$\mathbf{S[A; J] = (1/2\sigma_s) \int K \wedge {\star}K + \int A \wedge J}$

the second loop's current J′ couples
to the first's transport A through $\int A \wedge J'$

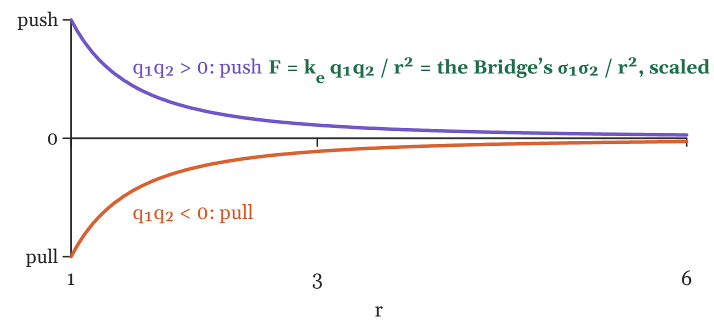
for a point charge that coupling is
$L = ½mv^2 + q\,v{\cdot}A - q\Phi$

$\mathbf{\Rightarrow m\,a = q(E + v \times B)}$

"$S[A; J] = (1/2\sigma\_s)\int K\wedge{\star}K + \int A\wedge J$ ... Variation $\delta S/\delta A = 0$ gives $d{\star}K = J$" (Source Extension, 12). "$L = ½mv^2 + q\,v{\cdot}A - q\Phi \Rightarrow m\,a = q(E + v \times B)$. Gauge choices (Coulomb/Lorentz) do not change observables." (EM Math Walk-Through, 2, Box 3). The sign of $q\,v{\cdot}A - q\Phi$ is σ of panel 3.

9. The static limit: Coulomb

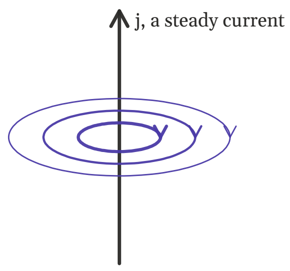
recovered: Coulomb's law



static: $\nabla\cdot E = \rho/\varepsilon_0$, $E = -\nabla\Phi$, $\nabla^2\Phi = -\rho/\varepsilon_0$; "Point charge $\rho = q\,\delta(x) \Rightarrow \Phi = k\_e\, q/r$ and $E = k\_e\, q\, r/r^2$ with $k\_e = 1/(4\pi\varepsilon_0)$" (EM Math Walk-Through, 2, Box 4: $F = k\_e\, q_1q_2/r^2$). k_e is a limit lock, not an input; $q = \sigma e$ (Student Workbook), so q_1q_2 carries the Bridge's $\sigma_1\sigma_2$ and the $1/r^2$ is the same $1/r^2$.

10. Moving sources: the flux leans, circulation appears

recovered: Ampère, Biot–Savart



$\oint_C A = \mu_{\mathrm{eff}} \cdot I_{\mathrm{enc}}$

d⋆K = J, split against motion (Appendix units):

$\nabla\times B - \partial E/\partial t = j$

steady current, $\nabla\cdot B = 0$:

$B(x) = (\mu_{\mathrm{eff}}/4\pi) \int j(x') \times (x - x') / |x - x'|^3 \, d^3x'$

μ_{eff} from the tension T_s (A3)

"motion of sources inevitably generates transverse circulation, the magnetic analogue." "This is the transport analogue of the Biot–Savart law." "The transport circulation law coincides with Ampère's law with a material constant μ_eff set by A3." (Math Appendix, Transport Circulation; Magnetism, 4 and 6)

11. The whole set, from two identities

recovered: Maxwell's equations

$dK = 0$ (geometric) $\longrightarrow$ $\nabla\cdot B = 0$, $\nabla\times E + \partial B/\partial t = 0$

Gauss for B; Faraday

$d\star K = J$ (the source law) $\longrightarrow$ $\nabla\cdot E = \rho$, $\nabla\times B - \partial E/\partial t = j$

Gauss; Ampère–Maxwell

continuity $dJ = 0$: $\partial\rho/\partial t + \nabla\cdot j = 0$

wave: $\Box A = 0$ in vacuum, $c = (\mu_0\varepsilon_0)^{-1/2}$

"dK=0 ⇒ ∇·B=0, ∇×E + ∂B/∂t = 0. d⋆K=J ⇒ ∇·E=ρ, ∇×B − ∂E/∂t = j." (Math Appendix, Magnetism, boxed). "(E,B) are not primitives but simply the decomposition of K into radial and circulatory parts relative to the source's motion." In the Appendix's units (the Walk-Through's SI set carries ε_0, μ_0).

A. The case drawn, step by step (the numbers are the circles in the figure)

1. In this case: the source loop and its wave, fading as δ

The source on the right is the electron loop of the previous page, and the wave it throws off is that page's null gravity wave, drawn by the same rule (release edge at drawn speed $c/(1-\delta)$, head edge at c; the drawing's own). Its contrast at radius R is the share of space missing there, from the mass pages' map, which is their construction of two lines of the Bridge (section 3): "The loop acts like a geometric anchor that removes a volume of available transverse area from the surrounding space, fixing the missing volume", and "This deficit propagates outward with profile $\Delta g(r) \sim 1/r^2$":

$\delta(R) = ƛ_e^2/(R^2 + ƛ_e^2) \rightarrow ƛ_e^2/R^2$ far from the loop; at $R = 16.5\,ƛ_e$, $\delta = 3.7\times10^{-3}$

The Electromagnetism Narrative: "A 'charged' thing here is a rotating void-loop that's constantly throwing off null-gravity waves (NGWs) ripples. Those ripples don't pile anything up, no net space-density change. Another loop only feels something if it's also spinning and its facing lines up with the ripple pattern. The effect is purely orientation-gated."

2. In this case: the particle's two edges set the size

Each particle is a loop of radius $ƛ_e$ standing at $R = 16.5\,ƛ_e$. Its near edge is at 15.5, its far edge at 17.5, and the wave is not the same at the two:

$\delta(15.5) = 4.2\times10^{-3}$, $\delta(17.5) = 3.3\times10^{-3}$, ratio 1.27, difference 9×10^{-4}

Those are the paired arrows on the drawing, at each particle's two edges, on one scale. The near side always rides the stronger wave, so the near side sets the size of what happens; the kid page says it in five words, "closest wins". What the size does not fix is which way: a difference is a number, not a direction.

3. In this case: the facing sets the sign

The direction is the Mathematical Bridge's line (section 4): "Relative orientation determines the sign of far-field interaction. The far-field again follows a $1/r^2$ dependence, but its direction depends only on σ. Binary polarity is therefore a direct geometric consequence of orientation."

$F \propto (\sigma_1\sigma_2)/r^2$, $\sigma_i \in \{+1, -1\}$: $\sigma_1\sigma_2 = -1$, opposite facing, pull; $\sigma_1\sigma_2 = +1$, same facing, push

On the drawing the upper particle turns opposite to the source and is pulled; the lower turns the same way and is pushed. The size of both is panel 2; the sign of each is this line. Nothing else is needed for the H page, and nothing else is claimed there.

4. In this case: the surfer, and the site's one facing equation

Why facing matters at all is the Narrative's surfer (section 1): "Think of the second loop as a surfer and the NGW pattern as ocean swell. The swell isn't a 'standing downhill', it's a traveling pattern. If the surfer angles the board into the swell the right way, the path bends and you 'catch' it. If you're misaligned, the chops shove you back and forth but average out, no net drift. If you're faced the other way, you get the opposite path change." The one place the site writes facing as an equation is the Electromagnetism Math Appendix's neutral-rotor test (section 9):

$\langle\Delta p\rangle \propto \varepsilon \cdot \sigma \cdot \cos\theta$ (Eq. 9.4): right facing → push; 90° → strict null; spin flip or opposite facing → pull

That equation is written for a neutral spinning body in the caustic plane, so it is quoted here for the shape of the facing dependence, not as the two-charge force; the two-charge law is panel 3. The Bridge gives the same handedness in its Waveform section: "reversing the loop's rotation flips the side toward which the transverse push acts, setting the handed response of the force."

5. In this case: why this is not gravity

The same loop has two far fields (matter page, step 11): its obscured volume makes a standing dent, gravity, always toward; its facing makes a travelling pattern, charge, with a sign. The Narrative (section 6): "Gravity behaves like a standing curvature gradient, a downhill. Anything with inertia 'rolls' the same way no matter how it's turned. Electromagnetism here is different: there's no standing downhill, just a traveling pattern, so the outcome depends completely on how you're oriented. Right facing → push. Wrong facing → it cancels. Opposite facing → pull."

gravity: $F = Gmm'/r^2$ (toward, no σ) charge: $F \propto \sigma_1\sigma_2/r^2$ (sign from the facings)

And the Math Appendix's remark on range: "Magnetism drops off faster than gravity because here the conserved flux is tied to transverse oscillations set by tension. Gravity, by contrast, is encoded in space curvature directly and dilutes differently."

B. The general solution: the force, and what it recovers

6. The source, and the charge as a closed-surface flux

recovered: Gauss's law

Now the general case, from the Mathematical Bridge Math Appendix. A closed loop is a transport that does not close perfectly, and that is a source: "Sources arise when Void transport fails to close perfectly (broken closures, defects, intersections), creating conserved transport currents." Introduce the current 3-form J with dJ = 0; the transport equations and the charge:

$$dJ = 0, \quad dK = 0, \quad d{\star}K = J; \quad Q[V] := \int_V J = \int_V d{\star}K = \oint_{\partial V} {\star}K \text{ (surface independent, by } dJ = 0)$$

3+1 split of $d{\star}K = J$, in the Appendix's units: $\nabla\cdot E = \rho$ "(radial transport sourced by density ρ)"

"Thus Q is measured by the flux of ⋆K through any closed 2-surface surrounding the source. Conservation dJ=0 implies Q is independent of the particular surface chosen (as long as it encloses the same sources)." (Source Extension, 13). With E named as the time–space part of K, that is Gauss's law: the charge inside any closed surface is the flux through it. The Workbook's q = σe is this Q for one loop.

7. The retarded solution: causal at c

recovered: retarded potentials

Apply d⋆ to K = dA with the source present, choose the relabelling ∇·A = 0, and the transport equation is the wave equation with a source; its solution is the retarded one (Math Appendix, Source Extension 14; Magnetism from Moving Sources 5):

$$\square A = \mathscr{J}[J]; \quad A(x) = \int G_{\text{ret}}(x - x')\,\mathscr{J}[J](x')\, d^4x', \quad K = dA$$

far zone: amplitude ∝ 1/r, intensity ∝ $1/r^2$, transverse to $\hat{n}$

"Solutions are obtained with the retarded Green's operator of □, guaranteeing causal propagation at speed c." Nothing a source does is felt before r/c: the wave of panel 1 is this solution for a rotating source, and the arrival of the wave at the particle in panel 2 is at c, as the H page says. These are the retarded potentials of the textbook, without the potentials having been postulated.

8. The coupling: the force on a second loop

recovered: the Lorentz force

The force is in the action (Math Appendix, Source Extension 12). One action produces the source law and the coupling: "$S[A; J] = (1/2\sigma_s) \int K \wedge {\star}K + \int A \wedge J$, with K:=dA. Variation δS/δA = 0 gives d⋆K = J." A second loop carries its own current J′, and the term ∫ A ∧ J′ is how the first loop's transport acts on it. For a point charge that coupling is the minimal-coupling Lagrangian of the Walk-Through (section 2):

$$L = \tfrac{1}{2}mv^2 + q\, v\cdot A - q\Phi \;\Rightarrow\; ma = q(E + v \times B) \text{ (Box 3)}$$

"Gauge choices (Coulomb/Lorentz) do not change observables." The q in front of v·A − Φ is the σ of panel 3 in the textbook's units, so the sign of the force is the relative orientation, as the Bridge says; the size is the wave at the particle, panel 2. That is the Lorentz force, recovered from the coupling term and nothing else.

9. The static limit: Coulomb

recovered: Coulomb's law

Hold everything still. The source law's time–space part becomes Poisson's equation and the point source gives the potential and the force (Electromagnetism Math Walk-Through, section 2):

$$\nabla\cdot E = \rho/\varepsilon_0, \quad E = -\nabla\Phi, \quad \nabla^2\Phi = -\rho/\varepsilon_0; \quad \rho = q\,\delta^3(x) \Rightarrow \Phi = k_e q/r, \quad E = k_e q r/r^2$$

$$F = k_e\, q_1 q_2/r^2, \quad k_e = 1/(4\pi\varepsilon_0) \text{ (Box 4; a limit lock, not an input)}$$

"Static point source solution of Poisson's equation gives Coulomb's law." With q = σe, q_1q_2 is $\sigma_1\sigma_2\, e^2$, and this is the Bridge's F ∝ $\sigma_1\sigma_2/r^2$ with its scale set: the same $1/r^2$, the same sign rule, now in coulombs and newtons. The H page's two particles are this law at R = 16.5 λ_e. The $1/r^2$ here is the static force from Poisson; the $1/r^2$ of panel 7 is the radiated intensity of a moving source; the documents keep them apart and so does this page.

10. Moving sources: the flux leans, circulation appears

recovered: Ampère, Biot–Savart

The H page draws still loops. Let the source move (Math Appendix, Transport Circulation from Moving Sources; Magnetism from Moving Sources via Transport Calculus): "When the source moves with velocity u (timelike worldline tangent), transport conservation requires that the flux lines 'lean' in the direction of motion. This tilt produces circulation of the transport 1-form A around the axis of motion." The same source law, split against the motion, and the steady-current case:

$$d{\star}K = J \;\Rightarrow\; \nabla\cdot E = \rho, \quad \nabla\times B - \partial E/\partial t = j \text{ (the Appendix's units); steady current: } \oint_C A = \mu_{\text{eff}} \cdot I_{\text{enc}}, \quad I_{\text{enc}} = \int_S j\cdot dS$$

$$B(x) = (\mu_{\text{eff}}/4\pi) \int j(x') \times (x - x')/|x - x'|^3\, d^3x' \text{ } (\mu_{\text{eff}} \text{ from the tension } T_s\text{, A3})$$

"This is the transport analogue of the Biot–Savart law. It shows that moving sources generate circulating transport proportional to their current strength." And: "The transport circulation law coincides with Ampère's law with a material constant μ_{eff} set by A3." Magnetism is not a second thing beside charge; it is the same transport seen from a source that moves, which is why a moving charge and a current loop act alike.

11. The whole set, from two identities

recovered: Maxwell's equations

Everything above came from two lines, the geometric identity dK = 0 and the source law d⋆K = J. Split against an observer's time direction (Math Appendix, Magnetism from Moving Sources, sections 1 to 3; boxed results), they are the four equations:

$$dK = 0 \;\Rightarrow\; \nabla\cdot B = 0, \quad \nabla\times E + \partial B/\partial t = 0$$

$$d{\star}K = J \;\Rightarrow\; \nabla\cdot E = \rho, \quad \nabla\times B - \partial E/\partial t = j$$

(the Appendix's units; the Walk-Through's SI set carries ε_0 and μ_0)

$$\text{with } dJ = 0 \Rightarrow \partial\rho/\partial t + \nabla\cdot j = 0; \quad \text{in vacuum } \square A = 0, \quad c = (\mu_0\varepsilon_0)^{-1/2} \text{ (Walk-Through, Boxes 1 and 2)}$$

"(E,B) are not primitives but simply the decomposition of K into radial and circulatory parts relative to the source's motion." "If one elects to adopt conventional names at the end, identify the observer-split components of K with (E, B). Then Sections 2–3 reproduce the standard magnetic sector exactly." The Narrative (section 5): "When you average these orientation-gated path nudges over time and over many loops, in smooth, weak-curvature conditions, the effective path law you recover is the same set engineers already use: the standard Maxwell equations." That is the recovery this page set out to show: the push and pull of the drawing, and the whole of vacuum electromagnetism, from a closed loop's orientation and the transport of the space it hides.

What is published, what is derived here, what is chosen, what is recovered

Line	Status	Where it stands
$F \propto \sigma_1\sigma_2/r^2$; direction depends only on σ; reversing the rotation flips the side	published	Mathematical Bridge, 4 and Waveform (steps 3, 4).
the map $R = \sqrt{(r^2 - ƛ_e^2)}$, $\delta(R) = ƛ_e^2/(R^2 + ƛ_e^2)$; $\delta(15.5) = 4.2\times10^{-3}$, $\delta(17.5) = 3.3\times10^{-3}$, ratio 1.27	the mass pages' construction + computed	The map is the mass figures' construction (thread 28) of two published lines, Mathematical Bridge section 3: a loop "removes a volume of available transverse area from the surrounding space, fixing the missing volume" (the map keeps $\pi ƛ_e^2$ missing at every radius) and "$\Delta g(r) \sim 1/r^2$" (its far field). Its exact form is not a line in any document. Values evaluated here and on the H page (steps 1, 2).
the wave's width rule $c/(1 - \delta)$; contrast eased $\sqrt{\delta}$; the particles at 16.5 $ƛ_e$; net-drift arrows as indicators	the drawing's rule / chosen	Declared here and on the H page; not a line in any document.
a charged loop throws off null-gravity waves; another loop feels them only through its facing; the surfer; not a standing downhill	published	Electromagnetism Narrative, What Is Charge, 1, 6 (steps 1, 4, 5).
$\langle\Delta p\rangle \propto \varepsilon\cdot\sigma\cdot\cos\theta$, push / null / pull	published (rotor test)	Electromagnetism Math Appendix, 9, Eq. 9.4; quoted for the facing dependence, not as the two-charge force (step 4).
the near side sets the size, the facing sets the sign	reading	The map's two δ values (published) beside the Bridge's sign law (published); the sentence joining them is this page's and the H page's.
$dJ = 0$; $dK = 0$, $d\star K = J$; $Q[V] = \oint \star K$; $\nabla\cdot E = \rho$	published; recovers Gauss	Math Appendix, Source Extension 10 to 13; Magnetism 3 (step 6).
$\Box A = \mathscr{I}[J]$; $A = \int G_{ret}\mathscr{I}[J]$; far zone $1/r$, $1/r^2$	published; recovers retarded potentials	Math Appendix, Source Extension 14; Magnetism 5 (step 7).
$S[A; J]$ with $\int A\wedge J$; $L = ½mv^2 + q\, v\cdot A - q\Phi \Rightarrow ma = q(E + v\times B)$	published; recovers Lorentz	Math Appendix, Source Extension 12; Walk-Through, 2, Box 3 (step 8).
$\nabla^2\Phi = -\rho/\varepsilon_0$; $\Phi = k_e q/r$; $F = k_e q_1 q_2/r^2$	published; recovers Coulomb	Walk-Through, 2, Box 4 (step 9).
$q_1q_2 = \sigma_1\sigma_2 e^2$, so Coulomb is the Bridge's line with its scale set	reading	$q = \sigma e$ (Workbook) put into Box 4; the two published lines side by side.
the lean; $\nabla\times B - \partial E/\partial t = j$; $\oint A = \mu_{eff} I_{enc}$; Biot–Savart	published; recovers Ampère, Biot–Savart	Math Appendix, Transport Circulation 2, 3; Magnetism 3, 4, 6 (step 10).
$dK = 0 \Rightarrow \nabla\cdot B = 0$, $\nabla\times E + \partial B/\partial t = 0$; $d\star K = J \Rightarrow \nabla\cdot E = \rho$, $\nabla\times B - \partial E/\partial t = j$; continuity; $\Box A = 0$, c	published; recovers Maxwell	Math Appendix, Magnetism boxed results; Walk-Through, Boxes 1 and 2 (step 11).
the wave's $1/r^2$ (step 7) and Coulomb's static $1/r^2$ (step 9) are two statements	published, kept apart	Radiated intensity of a moving source; static force from Poisson.
$S_0 = \hbar$; ε_0, μ_0, k_e, μ_{eff}	calibrations / limit locks	One scale and the acceptance locks the documents name; μ_{eff} "derived from A3's finite tension T_s and σ_s"; never derived here.

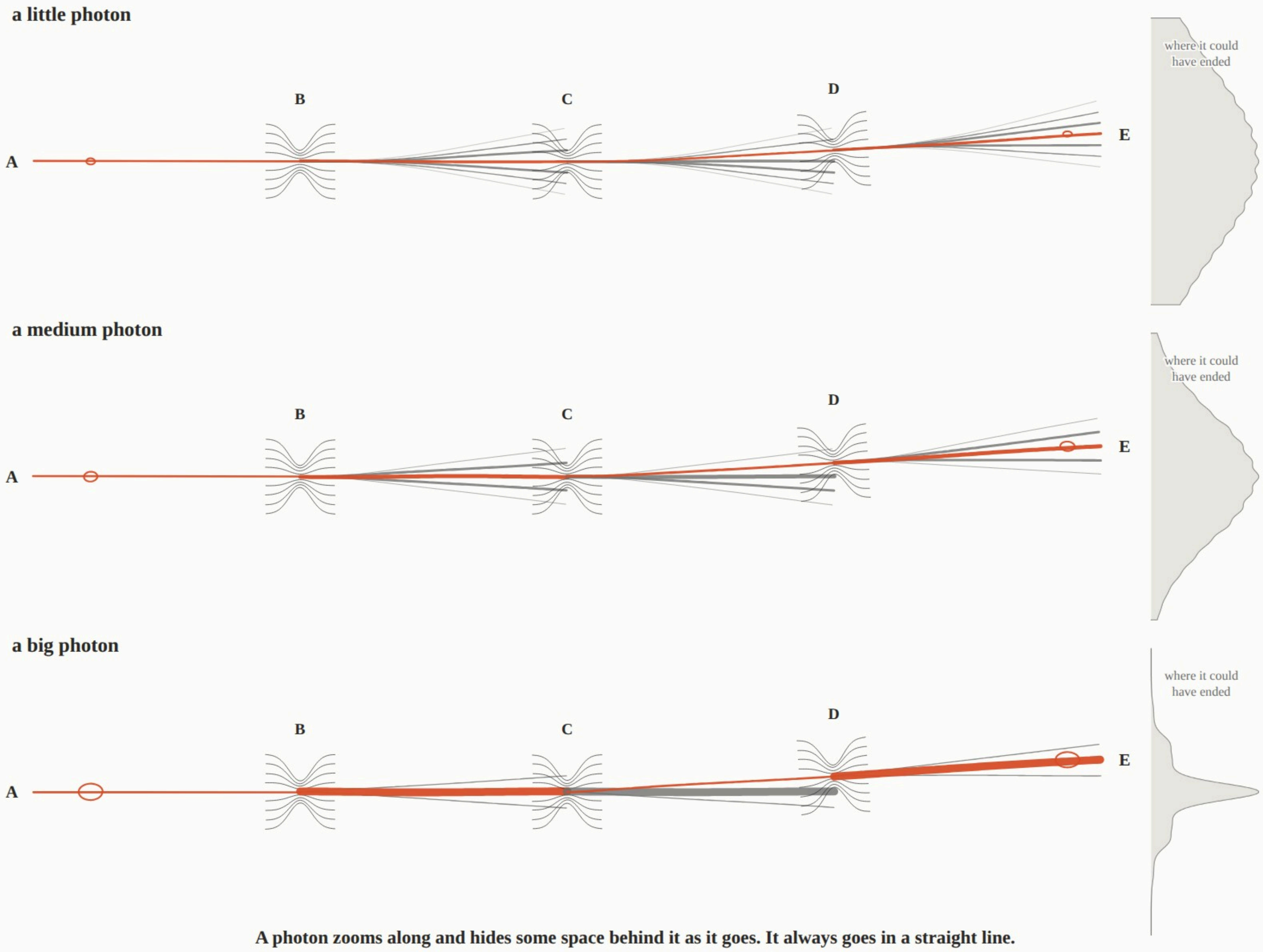
Chosen for the drawing, not from the framework. The two particles stand at $R = 16.5\ ƛ_e$, a drawing choice, and their net-drift arrows are summary indicators, not computed magnitudes; the wave's width rule (release edge at drawn speed $c/(1 - \delta)$, head edge at c) is the drawing's own, as on the previous page, and its contrast is eased as $\sqrt{\delta}$ to print. In panels 6 to 11 the closed surface, the light cone, the field pictures, the current and its loops, and the plotted ranges are drawing choices; the curves and the two δ values are the stated functions evaluated.

Computed from those choices. δ(R) on 0 to 20 $ƛ_e$; $\delta(15.5) = 4.15\times10^{-3}$, $\delta(17.5) = 3.25\times10^{-3}$, ratio 1.27, difference 9.0×10^{-4}, the arrows in panel 2 drawn proportional; $\langle\Delta p\rangle \propto \sigma \cos\theta$ for both σ; $\Phi = -Gm/r$; $\pm k_e q_1 q_2/r^2$ for the two signs.

Sources (vms-institute.org/theory). Proposed Mathematical Bridge: Loop Orientation to Electromagnetism ($F \propto \sigma_1\sigma_2/r^2$; direction depends only on σ); Waveform (reversing the rotation flips the side). Mathematical Bridge Math Appendix: Electromagnetism from Void Transport, 7 (the range remark); Source Extension, 10 to 17 (J, $dJ = 0$; $d\star K = J$; S[A; J]; $Q[V] = \oint\star K$; retarded $\Box A = \mathscr{I}[J]$); Transport Circulation from Moving Sources, 1 to 5 (the lean; $\oint A = \mu_{eff} I_{enc}$); Magnetism from Moving Sources via Transport Calculus, 1 to 6 and boxed results (the 3+1 split of K; $dK = 0$ and $d\star K = J$ as the four equations; Biot–Savart; the retarded solution; naming at the end); Mathematical Bridge, section 3 (the fixed missing volume; $\Delta g \sim 1/r^2$), of which the mass pages' map is a construction. Electromagnetism Narrative: What Is Charge in VMS?; sections 1 (the surfer), 5 (the Maxwell limit), 6 (how this is not gravity). Electromagnetism Math Walk-Through: section 1 (Boxes 1 and 2), section 2 (minimal coupling, Lorentz force, Poisson, Coulomb, Boxes 3 and 4). Electromagnetism Math Appendix: section 9, Eq. 9.4. Particle Mechanics Narrative: section 7 ($q = n\cdot q_0$). Electromagnetism Student Workbook: symbols ($q = \sigma e$). Generator: gen_charge_force_proofs3d.py.

How Light Moves

Light is made of photons. Many, many photons make up the light you see around you. This is one photon.



A photon zooms along and hides some space behind it as it goes. It always goes in a straight line.
But as we saw before, space it goes through can get bent. If space gets bent from two directions it can get squished for some time.
Where it is squished the photon can pick a nearby way out.
That leaves only a few ways out, depending on how big the photon is.

this page on its own

How light moves, and where the wave form comes from

A photon is the smallest piece of light; this page follows one photon.
The textbook wave form $\psi = A\cdot e^{i(kx - \omega t)}$, $I = |\Sigma\psi|^2$, and its intensity pattern come out of the VMS math and patterns below:
$\lambda = S_0/A_d$, $k = 2\pi/\lambda = 2\pi A_d/S_0$ (S_0 locked to $\hbar$ at the electron), and ψ is the sum over routes $\Sigma\ \sqrt{\text{weight}}\cdot e^{2\pi i S/S_0}$, weight the product of the route's shares (this page draws it, red, over the counted shape, grey).

The textbook wave form has no $\hbar$. It takes the wavelength as given. VMS gives the wavelength:
one step $\ell = S_0/A_d$, the distance in which the display action grows by one S_0 (one full turn of what the textbook calls the phase), is the wavelength λ.
That is where $\hbar$ lives: $S_0 = \hbar$. (Compare de Broglie's $p\lambda = h = 2\pi S_0$: with $\lambda = S_0/A_d$ the display action $\int A_d\, ds$ stands where $\oint p\cdot dl$ stands, and $2\pi A_d$ stands where p stands.)

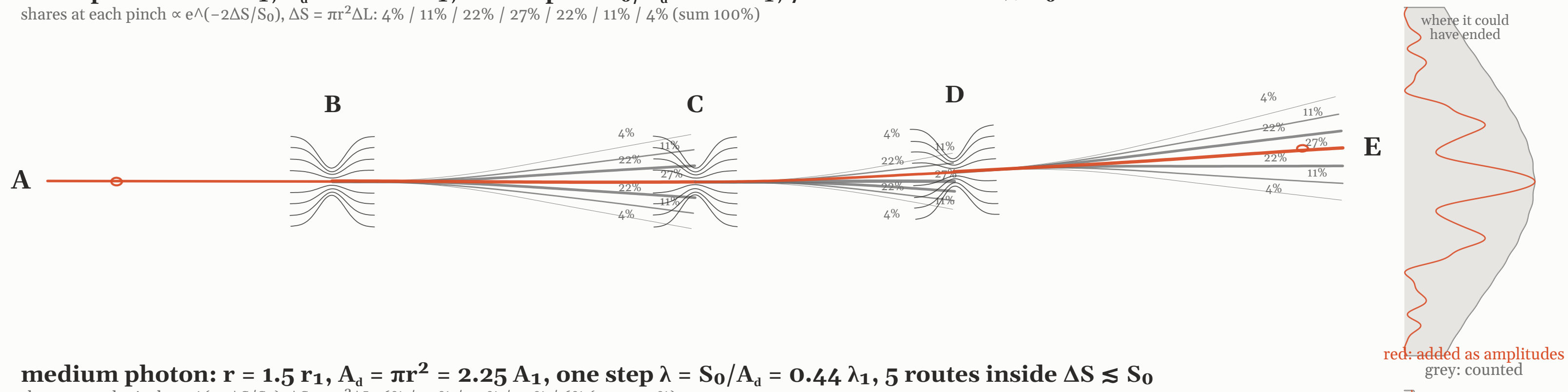
Here is how. A photon hides a patch of space as it goes, its display area $A_d = \pi r^2$. The size of that patch decides what the photon can do at every pinch (caustic): a big patch has few ways through, a small patch has many. Along the route the patch adds up to display action $S = \int A_d\, ds$, and the photon moves in steps of $\ell = S_0/A_d$ with $S_0 = \hbar$: big patch, short steps; small patch, long steps. On a straight route $S = A_d\cdot x$, so $2\pi S/S_0 = kx$ with $k = 2\pi A_d/S_0 = 2\pi/\ell$. That is the angle the textbook calls the phase, and one step is the wavelength λ. The step belongs to the photon and is the same in empty space. The pinches belong to the space, wherever it happens to be squished; their spacing has nothing to do with the wavelength.

A pinch (caustic) is where two fronts of bent space cross and the lattice is squeezed for a while (see the pinch figure). There a neighbouring route is an option while its extra action is small, $\Delta S = \pi r^2\cdot\Delta L \lesssim S_0$, and its amplitude is $e^{-\Delta S/S_0}$, its share the square, $e^{-2\Delta S/S_0}$. The grey shape at E is where the photon can end up: the average over many, and the textbook envelope. The red curve is the pattern for just these few example caustics.

So a bigger display area takes fewer, sharper turns and lands in a narrow pattern; a smaller display area spreads wide. That is the wavelength dependence that emerges as the wave form, and it came from the display area and the caustics, not from a wave form itself.

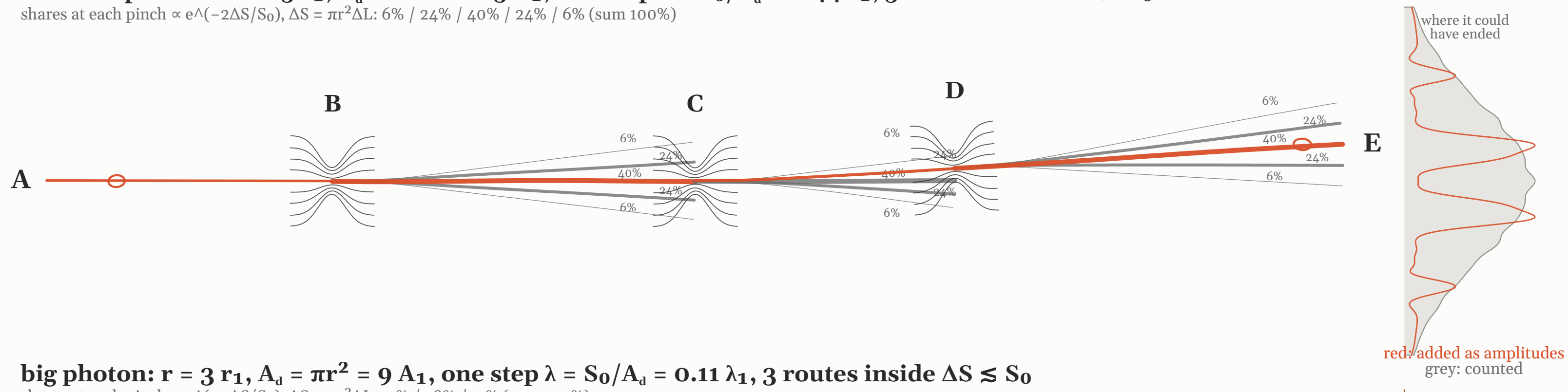
small photon: $r = 1\ r_1$, $A_d = \pi r^2 = 1\ A_1$, one step $\lambda = S_0/A_d = 1.00\ \lambda_1$, 7 routes inside $\Delta S \lesssim S_0$

shares at each pinch ∝ e^(−2ΔS/S₀), ΔS = πr²ΔL: 4% / 11% / 22% / 27% / 22% / 11% / 4% (sum 100%)



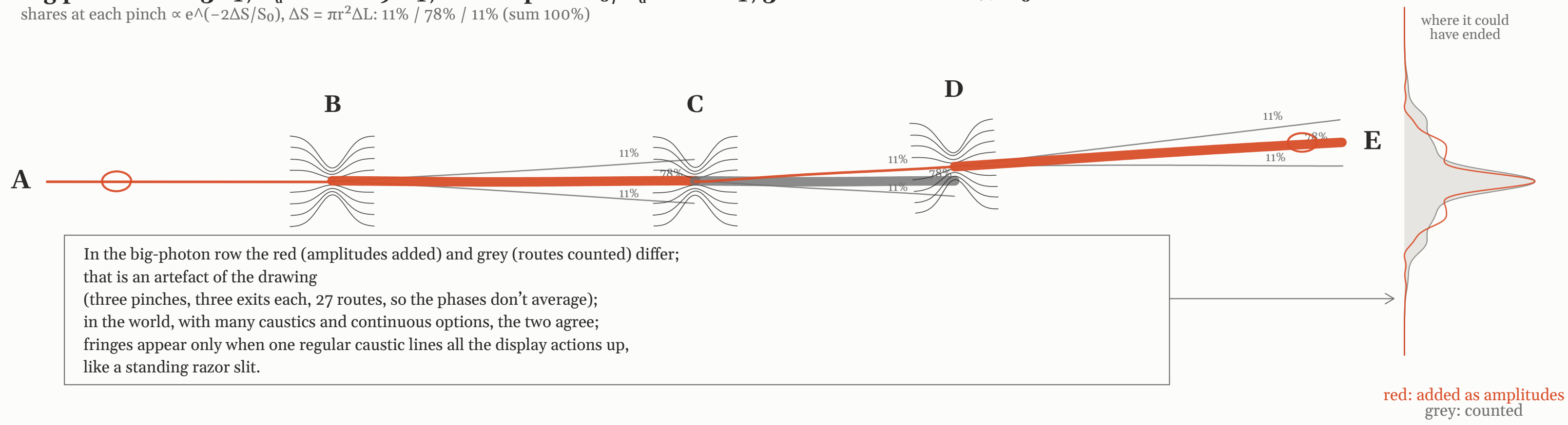
medium photon: $r = 1.5\ r_1$, $A_d = \pi r^2 = 2.25\ A_1$, one step $\lambda = S_0/A_d = 0.44\ \lambda_1$, 5 routes inside $\Delta S \lesssim S_0$

shares at each pinch ∝ e^(−2ΔS/S₀), ΔS = πr²ΔL: 6% / 24% / 40% / 24% / 6% (sum 100%)



big photon: $r = 3\ r_1$, $A_d = \pi r^2 = 9\ A_1$, one step $\lambda = S_0/A_d = 0.11\ \lambda_1$, 3 routes inside $\Delta S \lesssim S_0$

shares at each pinch ∝ e^(−2ΔS/S₀), ΔS = πr²ΔL: 11% / 78% / 11% (sum 100%)



Everything on this page is computed from five lines of the framework.

$A_d = \pi r^2$ $S = \int A_d\, ds$ $2\pi S/S_0$ (the textbook's phase), $S_0 = \hbar$, closure $\oint p \cdot dl = 2\pi n S_0$ $\ell = S_0/A_d = \lambda$ route amplitude $\propto e^{-\Delta S/S_0}$, share = its square

Display area, display action, closure (one S_0 of display action is one full turn of the textbook's phase), one step (the wavelength), and the route amplitude. Only the ratio S/S_0 enters; S_0 is the one scale.

At a pinch (caustic). The photon can leave on a nearby route instead of the entering path. A nearby route costs extra action ΔS. If that extra is less than about one S_0, the route is an option; the less extra it costs, the bigger its share of the odds:

option if $\Delta S = \pi r^2 \cdot \Delta L \lesssim S_0$

amplitude $\propto e^{-\Delta S/S_0}$, share $\propto e^{-2\Delta S/S_0}$

shares at one pinch add to 100%

ΔL is how much longer the tilted route is than the straight one on the way to the next pinch. Line width and the printed percentage are these shares.

Three sizes shown using one rule. Every pinch offers the same seven exit directions, 3.5° apart. A tilted exit costs extra action $\Delta S = \pi r^2 \cdot \Delta L$. A bigger photon pays r^2 times more for the same tilt, so fewer of the seven stay under S_0:

$r = r_1$: 7 routes

$r = 1.5\ r_1$: 5 routes

$r = 3\ r_1$: 3 routes

step $\ell = \lambda = S_0/A_d$: 1 : 0.44 : 0.11

The turn at a pinch is drawn as spread over one step λ (this page's reading of the linearised route), so a big photon corners and a small photon bends.

The grey shape at E. Every route from A to E, one option at each of B, C and D (7^3, 5^3, 3^3 routes), counted with its weight:

$$\text{weight} = \text{share}_B \cdot \text{share}_C \cdot \text{share}_D$$

$$\text{grey}(E) = \Sigma_{\text{routes}}\ \text{weight}$$

The red curve at E. The same routes, added as amplitudes instead of counted:

$$\psi(E) = \Sigma_{\text{routes}} \sqrt{\text{weight}} \cdot e^{2\pi i S/S_0}$$

$$I = |\psi|^2$$

S is the route's display action; dividing by S_0 counts it in turns, and $2\pi S/S_0$ is the angle the textbook calls the phase.

On a straight route $S = A_d \cdot x$, so $e^{2\pi i S/S_0} = e^{ikx}$ with $k = 2\pi A_d/S_0 = 2\pi/\lambda$.

Inside the window the routes differ by up to one S_0 of display action;

added as amplitudes they give the fringes of the textbook pattern inside the grey shape, its envelope.

Chosen for the drawing, not from the framework. Three pinches at 22%, 50% and 70% of the way from A to E (uneven on purpose to show random caustics).
Seven candidate tilts 3.5° apart. The three sizes 1 : 1.5 : 3, chosen so that each photon's outermost surviving route sits right at the window edge (ΔS grows as $(r\cdot\text{tilt})^2$, and r times the last tilt is 3 in every row). S_0 placed at the small photon's outermost option. Which option the photon takes at each pinch (middle, one up, middle; the same in every row). The shares at B, C and D are multiplied as independent choices: no memory carried from one pinch to the next.
The route counts 7, 5, 3 are relative to that S_0 placement; the r^2 scaling between them is the framework's.
The red curve and grey shape are smoothed by half a tilt step, because the drawn routes are 3.5° apart while real routes are continuous.

Sources (vms-institute.org/theory). Proposed Mathematical Bridge for the Standard Model and General Relativity: Display Area to Display Action ($A_d = \pi r^2$, $S = \int A_d\, ds$, ratios only), Open Path to Photon Sector (caustics mandate optionality; linearisation gives $\Box\psi = 0$). Mathematical Bridge Math Appendix: Caustic Formation and Ray Mapping (J = 0, Airy form near a fold), Loop Action Connection and the electron anchor ($S_0 = \oint A_d\, ds$, $\oint p\cdot dl = 2\pi n S_0$, $p\lambda = 2\pi S_0$, $S_0 = \hbar$). Particle Mechanics Math Appendix: Decays and Widths from Action Gaps (amplitude $e^{-\Delta S/S_0}$, probability $e^{-2\Delta S/S_0}$). VMS Closure Math Primer (optional paths, forced bottleneck, action gap $\Delta S/S_0$). Generator: gen_one_light_HS_LOCKED_v5.py (locked 2026-09-12).

 this page on its own

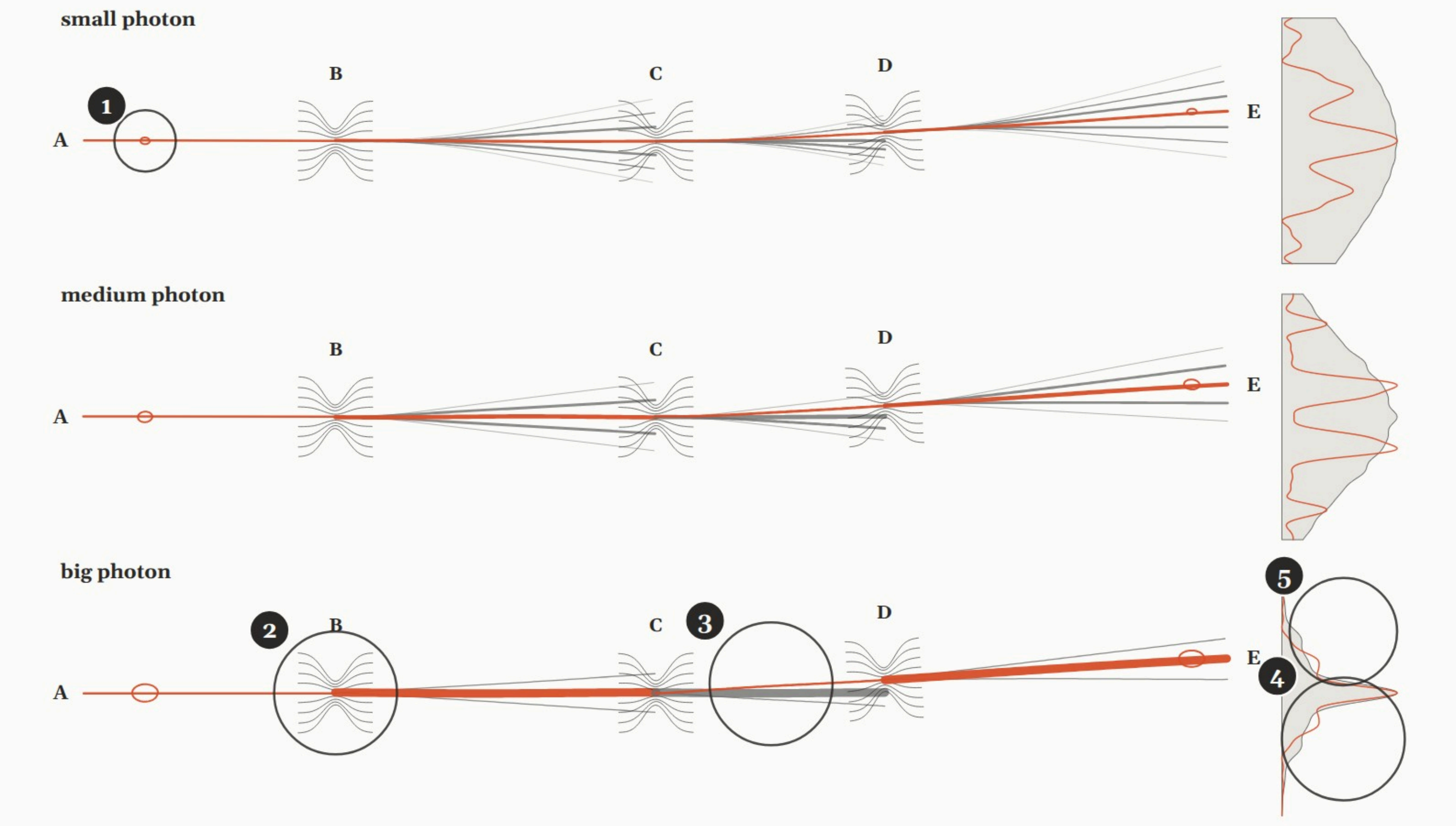
How light moves, and where the wave form comes from: the full derivation

A photon is the smallest piece of light; this page follows one photon.
The textbook wave form $\psi = A\cdot e^{i(kx - \omega t)}$, $I = |\Sigma\psi|^2$, and its intensity pattern come out of the VMS math and patterns below:
$\lambda = S_0/A_d$, $k = 2\pi/\lambda = 2\pi A_d/S_0$, and ψ is the sum over routes $\Sigma\, \sqrt{\text{weight}}\cdot e^{2\pi i S/S_0}$, weight the product of the route's shares (drawn in red over the counted shape, grey).

The textbook wave form has no ħ. It takes the wavelength as given. VMS gives the wavelength:
one step $\ell = S_0/A_d$, the distance in which the display action grows by one S_0 (one full turn of what the textbook calls the phase), is the wavelength λ.
That is where ħ lives: $S_0 = \oint A_d\, ds$, the n = 1 loop's own volume, locked to ħ at the electron. (Compare de Broglie's $p\lambda = h = 2\pi S_0$: the display action $\int A_d\, ds$ stands where $\oint p\cdot dl$ stands, and $2\pi A_d$ where p stands.)

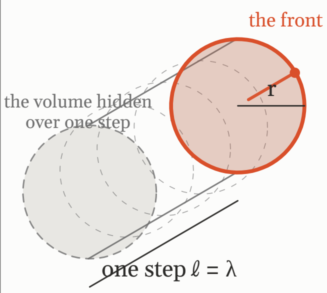
The small figure is the high school drawing: one photon from A to E through three caustics B, C, D, three sizes, one rule. Each numbered circle is exploded below as a zoom (1 to 3 drawn in depth, 4 and 5 enlarged), and each number is a step of the derivation further down. The derivation is the framework's own math, in order; step 5 ends at the textbook wave form. Nothing on this page is assumed about waves: the wave form is the last line, not the first.

A note on the mathematics. The derivations on the advanced pages draw on two bodies of work that are rigorous and long established but not widely taught: the classification of singularities of smooth maps (Arnold, Gusein-Zade and Varchenko, *Singularities of Differentiable Maps*, Vol. I, Birkhäuser, 1985) and the asymptotics of wave fields near caustics (Kravtsov and Orlov, *Caustics, Catastrophes and Wave Fields*, Springer, 2nd ed., 1998). Both have a strong pedigree; both are the province of a small specialist community. For scale, and as background only: SpringerLink records about 1,100 citations of the first book in forty years and about 110 of the second in thirty, and the field's own international workshops on singularities draw a few dozen participants. The number of people who work with this mathematics is at most in the hundreds, not the thousands.



The zooms (panels 1 to 5)

1 the photon: a front, its display area, one step



the front Σ (A1) advances at c (A2) and hides the patch behind it, the display area $A_d = \pi r^2$ (an area, m^2)

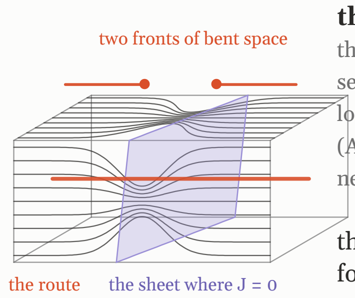
over one step it has hidden the volume $S = A_d \cdot \ell = S_0$ (a volume, m^3)

$S_0 = \oint A_d\, ds$ is the n = 1 loop's own volume, locked to ħ at the electron.

$\lambda = S_0 / A_d$ (volume over area)

the wavelength is the display area, inverted. Bigger patch, shorter step.

2 the caustic: two fronts of bent space cross



bent space arriving from two directions: the two fronts cross, and where they cross they form a caustic.

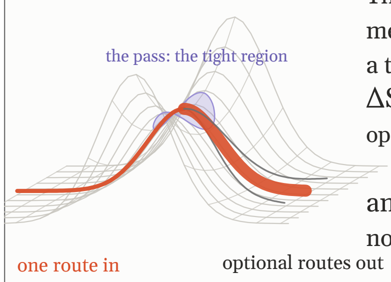
rays $x = X(q,t)$, $J = \det(\partial X/\partial q)$

the caustic: the sheet where J = 0

the sheet leans: expansion-driven caustics select a preferred plane (A3); the generic local caustic analysed here is the fold (Arnold; the Math Appendix's case); near it the field is Airy.

the photon meets a fold: a tight region, for a time.

3 one route in, optional routes out



every route from one basin to the next must cross the ridge; the pass is the forced bottleneck (Closure Math Primer). The tight region is where the photon meets the fold.

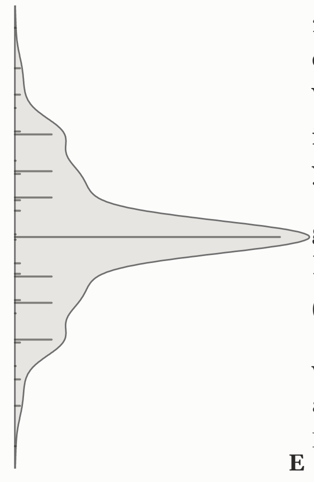
a tilted exit costs extra display action $\Delta S = \pi r^2 \cdot \Delta L$

open while $\Delta S \lesssim S_0$ (one S_0 of extra action);

amplitude $e^{-\Delta S/S_0}$, share $e^{-2\Delta S/S_0}$ normalised at the caustic.

big photon: 3 routes, 11 / 78 / 11.
same fold, small photon: 7 routes; medium: 5.
The patch decides.

4 the final distribution at E



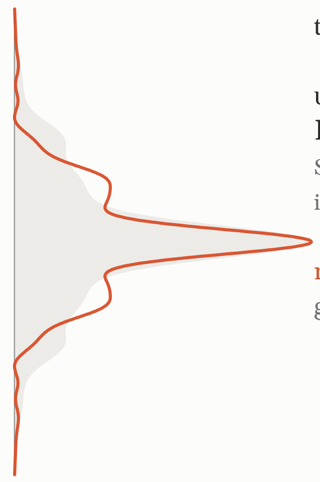
27 routes: 3 options at B × 3 at C × 3 at D. each stick is one route; its length is weight = $\text{share}_B \cdot \text{share}_C \cdot \text{share}_D$ its height is where the route ends, y_E from the three tilts

grey: every route counted, $P(y) = \Sigma\, \text{weight} \cdot \delta(y - y_E)$ (smoothed half a tilt step)

where the photon can end up: a probability of paths.

Nothing here is a wave.

5 the wave form: the same routes, added as amplitudes



the same 27 routes, each with its display action

$\psi(y) = \Sigma \sqrt{\text{weight}} \cdot e^{2\pi i S/S_0}$
$I(y) = |\psi(y)|^2$

$S = A_d \cdot L_{route}$: one S_0 of extra route
is one full turn of the textbook's phase

red: the fringes of the textbook pattern
grey: its envelope, the count from 4

on a straight stretch

$e^{2\pi i S/S_0} = e^{ikx}$, $k = 2\pi A_d/S_0 = 2\pi/\lambda$
carried at c: $kx - \omega t$, $\omega = kc$
each term is a textbook plane wave;
the sum is the textbook superposition;
each term and the sum solve $\Box\psi = 0$

the wave form is the last line, not the first.

The derivation, step by step (the numbers are the circles in the figure)

1. The photon

A photon is an advancing front that hides a patch of space as it goes. The patch is the display area (an area, m²); what it has hidden along its route is the display action (a volume, m³). Everything about the photon follows from these two.

$A_d = \pi r^2$ (display area: the orthogonal cross-section the front hides; m²)
$S = \int A_d \, ds$ (display action along a route: the volume hidden; only ratios of S carry meaning)
$S_0 = \oint A_d \, ds$ (the $n = 1$ loop's own volume, m³; the one scale, locked to ħ at the electron)
$2\pi S/S_0$ (closure $\oint p \cdot dl = 2\pi n S_0$: one loop, one S_0 of display action, one full turn; the angle the textbook calls the phase)
$\lambda = S_0/A_d$ (one step: the length over which the front hides one S_0)

On a straight route the display area is constant, so $S = A_d \cdot x$ and the display action grows evenly with distance:

$2\pi S/S_0 = (2\pi A_d/S_0) \cdot x = kx$, $k = 2\pi A_d/S_0 = 2\pi/\lambda$, $\lambda = S_0/A_d$ (compare $p\lambda = h = 2\pi S_0$: $2\pi A_d$ stands where p stands, under the same SI lock that maps S_0 to ħ)

This is already the angle the textbook calls the phase. The wavelength is not given; it is the display area, inverted (a volume over an area). Bigger patch, shorter step.

2. The caustic

Space bent from two directions: two fronts of bent space cross, and while they cross the lattice the photon rides is squeezed. How much the lattice is stretched or squeezed is the Jacobian J of the ray map (its local area transport); a caustic is where J = 0 (Mathematical Bridge Math Appendix, Caustic Formation and Ray Mapping). A caustic environment mandates optionality in the available paths (Mathematical Bridge, Open Path to Photon Sector). Expansion-driven caustics select a preferred plane in the surrounding space (Mathematical Bridge, Electromagnetism; axiom A3), and the generic local caustic analysed here is the fold (Arnold), the case the Math Appendix works through. The photon meets a fold: a tight region, for a time.

Leaving the fold on a route tilted by θ instead of straight on costs extra length over the next stretch L, and extra length costs extra display action:

$\Delta L = L(1/\cos\theta - 1) \approx L\theta^2/2$ $\Delta S = A_d \cdot \Delta L = \pi r^2 \cdot \Delta L$

4. The final distribution: a probability of paths

A route from A to E is one option at B, one at C, one at D. Its weight is the product of its three shares, and where it ends is set by the three tilts over the three stretches:

$\text{weight}(i,j,k) = \text{share}_B(i) \cdot \text{share}_C(j) \cdot \text{share}_D(k)$
$y_E(i,j,k) = L_{BC} \cdot \tan(\theta_i) + L_{CD} \cdot \tan(\theta_i+\theta_j) + L_{DE} \cdot \tan(\theta_i+\theta_j+\theta_k)$
$P(y) = \Sigma_{routes}$ weight $\cdot\ \delta(y - y_E)$ (the grey shape: every route counted)

P(y) is where the photon can end up: a probability of paths. Nothing here is a wave.

5. The wave form

Now add the same routes as amplitudes instead of counting them. Each route carries its display action as an angle, $2\pi S/S_0$; its amplitude is $e^{-\Delta S/S_0}$ at each caustic, the square root of its share, so that routes added without their angles reproduce the count:

$\psi(y) = \Sigma_{routes} \sqrt{\text{weight}} \cdot e^{2\pi i S_{route}/S_0}$, $S_{route} = A_d \cdot L_{route}$ $I(y) = |\psi(y)|^2$

On any straight stretch the amplitude factor is $e^{2\pi i S/S_0} = e^{ikx}$ with $k = 2\pi A_d/S_0$. The count $2\pi S/S_0$ is set where the front is launched and carried with it at c (A2), so the count found at x at time t is the one launched at $t - x/c$: $k(x - ct) = kx - \omega t$ with $\omega = kc$. Each term of the sum is a textbook plane wave; the sum is the textbook superposition; $I = |\Sigma\psi|^2$ is the textbook intensity.

$\psi = \Sigma\, A \cdot e^{i(kx - \omega t)}$, $k = 2\pi A_d/S_0$, $\lambda = S_0/A_d$, $\omega = kc$

Check against the wave equation: every term $e^{i(kx - \omega t)}$ with $\omega = kc$ satisfies $\partial_{tt}\psi - c^2\partial_{xx}\psi = 0$, and so does their sum, so the route sum built here is a solution of $\Box\psi = 0$. The framework reaches the same equation the other way round, by linearising the front's surface action about a straight path (Mathematical Bridge, Open Path to Photon Sector; Math Appendix, Perturbation Analysis: $\partial_{tt}u - c^2\Delta_\perp u = 0$). Near a fold the stationary-phase integral takes the uniform Airy form $u \approx \mathcal{A} \cdot \text{Ai}(\alpha\xi)$, $\alpha > 0$, ξ the signed distance to the caustic, oscillatory on the lit side (Math Appendix, Caustic Formation and Ray Mapping).

$\Box\psi = 0$ (the route sum satisfies it; the linearised front derives it) near a fold $\psi \to \mathcal{A} \cdot \text{Ai}(\alpha\xi)$

Inside the window the routes differ by up to one S_0 of display action, so $|\psi|^2$ carries the fringes of the textbook pattern and P(y) is their envelope: the red curve inside

A tilted route is an option while its extra action is within the one scale (this page's reading of the mandated optionality, with S_0 the one scale: a competing route is open while its extra action is within one S_0; the Closure Math Primer carries the optional-path and action-gap $\Delta S/S_0$ picture):

$$\text{option if } \Delta S = \pi r^2 \cdot \Delta L \lesssim S_0 \quad \Leftrightarrow \quad \theta^2 \lesssim 2\lambda/L$$

That window is the Fresnel-zone construction of optics written in routes (extra path counted against the one scale), with the window's edge at one S_0 of extra display action (one wavelength of extra route: the first two Fresnel zones). It closes as $1/r^2$: a bigger display area has fewer ways out of the same caustic.

3. The optional paths

Each option carries a share. The framework weights admissible routes exponentially in their action (Particle Mechanics Math Appendix: the admissible-route ensemble $W[r] \propto e^{-\beta S[r]}$; decays from action gaps, amplitude $e^{-\Delta S/S_0} \cdot A_0$ and probability $e^{-2\Delta S/S_0}$); carried over to one photon at one caustic:

$$\text{amplitude}_i \propto e^{-\Delta S_i/S_0} \quad \text{share}_i = e^{-2\Delta S_i/S_0} / \Sigma_j\, e^{-2\Delta S_j/S_0} \quad \text{(shares at one caustic add to 100\%)}$$

In the drawing the width of each option is its share. The cleanest route is the fattest; the outermost survivor sits at the window edge. Small photon 4/11/22/27/22/11/4, medium 6/24/40/24/6, big 11/78/11.

the grey shape. In ordinary space, with many caustics of many strengths and continuous options, the routes' display actions are uncorrelated; averaged over many such routes, the added intensity approaches the counted envelope. Fringes stay where one regular caustic sets all the display actions the same way. The wave form is the last line of this page, not the first: it emerged from the display area and the caustics, and ħ entered once, as the one scale S_0.

What is derived, what is carried over, what is chosen

Line	Status	Where it stands
$A_d = \pi r^2$, $S = \int A_d\, ds$, $S_0 = \oint A_d\, ds$ (m^3), $S_0 = \hbar$ at the electron	published	Mathematical Bridge; Math Appendix, Objects and Units and the electron anchor.
$2\pi S/S_0$ is the textbook's phase (one S_0 of display action is one full turn); $\lambda = S_0/A_d$; $k = 2\pi A_d/S_0$	reading of two published lines	Math Appendix p. 3: $S_0 = \oint A_d\, ds$, the loop's own display action; p. 27: $\oint p \cdot dl = 2\pi n S_0$ with the n = 1 loop identified as $2\pi S_0 = 2\pi\hbar$. Read together: the n = 1 loop is one S_0 of display action and one full turn of the textbook's phase. The compressed training notes carry $\varphi = S/S_0$ with closure $S_{loop}/S_0 = 2\pi n$, which would make one S_0 one radian; that is not what the published Appendix says, and this page follows the Appendix. The fringes in the red curve and λ (rather than $\lambda/2\pi$) depend on this reading.
J = 0 at a caustic; caustics mandate optionality; fold, Airy near it; $\Box u = 0$ from the linearised front	published	Mathematical Bridge, Open Path to Photon Sector; Math Appendix, Caustic Formation and Ray Mapping, Perturbation Analysis.
option if $\Delta S \lesssim S_0$ (window edge at exactly one S_0)	this page's reading	The Bridge mandates optionality and S_0 is the only scale; the Appendix uses $\lvert\Delta S\rvert/S_0$ as its dimensionless tolerance. The hard edge at one S_0 is where the drawn route set is cut; the exponential share already makes routes beyond it small.
amplitude $e^{-\Delta S/S_0}$, share $e^{-2\Delta S/S_0}$ at one caustic	carried over	Particle Mechanics Math Appendix, Decays and Widths from Action Gaps (a decay rule) and the admissible-route ensemble (β unspecified); applied here to one photon at one caustic, with $\beta = 2/S_0$ for the share ($1/S_0$ for the amplitude).
weight = product of three shares; y_E from the tilts; P(y); $\psi = \Sigma\sqrt{\text{weight}} \cdot e^{2\pi i S/S_0}$; $I = \lvert\psi\rvert^2$	computed	Arithmetic on the lines above; the figure is this computation.
$e^{i(kx - \omega t)}$ with $\omega = kc$; the route sum solves $\Box\psi = 0$	derived here	The count carried at c (A2) gives $k(x - ct)$; each such term and their sum satisfy the wave equation, the same one the Bridge derives from the linearised front.
three caustic positions, seven tilts 3.5° apart, sizes 1 : 1.5 : 3, S_0 at the small photon's outermost option, which option is taken, independent shares at B, C, D (no memory between pinches), half-tilt-step smoothing, the zoom drawings	chosen	See "Chosen for the drawing".

Chosen for the drawing, not from the framework. Three pinches at 22%, 50% and 70% of the way from A to E (uneven on purpose to show random caustics).
Seven candidate tilts 3.5° apart. The three sizes 1 : 1.5 : 3, chosen so that each photon's outermost surviving route sits right at the window edge (ΔS grows as $(r \cdot \text{tilt})^2$, and r times the last tilt is 3 in every row). S_0 placed at the small photon's outermost option. Which option the photon takes at each pinch (middle, one up, middle; the same in every row). The shares at B, C and D are multiplied as independent choices: no memory carried from one pinch to the next.
The route counts 7, 5, 3 are relative to that S_0 placement; the r^2 scaling between them is the framework's.
The red curve and grey shape are smoothed by half a tilt step, because the drawn routes are 3.5° apart while real routes are continuous.
The zooms are drawings of the same objects, not new claims: the tube in 1 is the volume hidden over one step; the slab in 2 is the pinch figure in depth with the J = 0 sheet drawn in; the pass in 3 is the Primer's bottleneck picture standing in for the fold, with the big photon's three exits; 4 and 5 are the big photon's E column enlarged.

Sources (vms-institute.org/theory). Proposed Mathematical Bridge for the Standard Model and General Relativity: Display Area to Display Action ($A_d = \pi r^2$, $S = \int A_d\, ds$, ratios only), Open Path to Photon Sector (caustics mandate optionality; linearisation gives $\Box\psi = 0$), Electromagnetism (expansion-driven caustics select a preferred plane). Mathematical Bridge Math Appendix: Objects and Units ($S_0 = \oint A_d\, ds$, units m^3; SI lock $S_0 = \hbar$), Perturbation Analysis ($\Box u = 0$), Caustic Formation and Ray Mapping ($x = X(q,t)$, J = 0, stationary phase, Airy), the electron anchor ($\oint p \cdot dl = 2\pi n S_0$, $p\lambda = 2\pi S_0$). Particle Mechanics Math Appendix: Conserved Charge and Families from Admissibility (route weights $\propto e^{-\beta S}$), Decays and Widths from Action

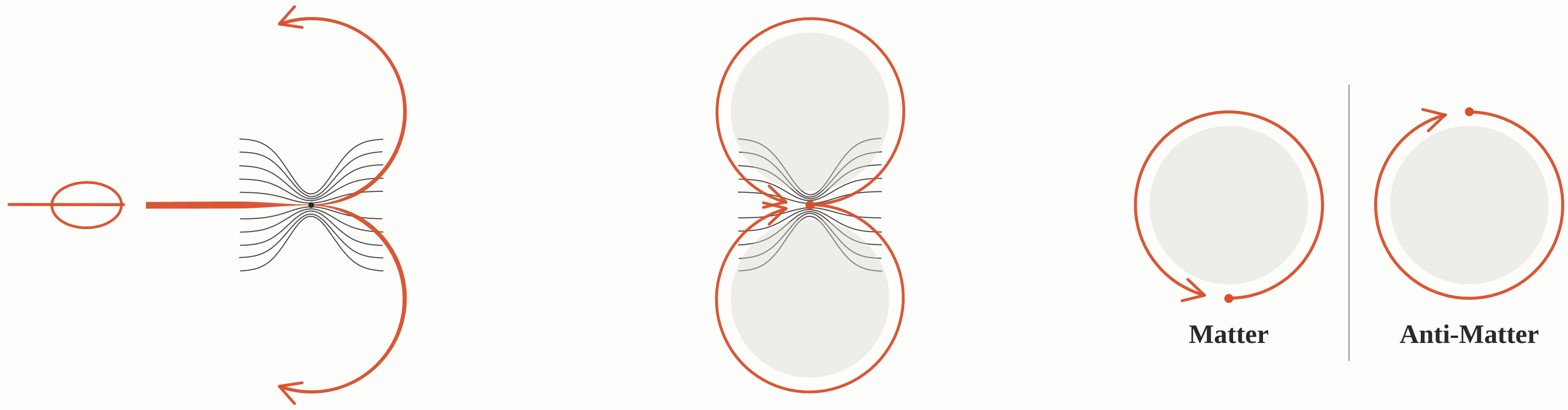
Gaps (amplitude $e^{-\Delta S/S_0}$, probability $e^{-2\Delta S/S_0}$). VMS Closure Math Primer (optional paths, forced bottleneck, action gap $\Delta S/S_0$, integer winding on a closed loop). Generator: gen_one_light_proofs3d_v5.py.

How Matter Is Made

Sometimes when a big photon hits a big squeeze it can't fit

If its head reaches its tail

They both have the same mass but opposite spin or "charges"



And it splits

Both parts get trapped to make mass or matter

How matter is made, and why it comes in pairs

A photon is the smallest piece of light; this page follows one photon. A photon becomes matter when it closes into a stable loop. It closes when a whole number of its steps is the length of the closed loop:

$$\ell = n\lambda, \text{ with } \lambda = S_0/A_\mathrm{d} \quad \text{(the step from the previous page)}$$

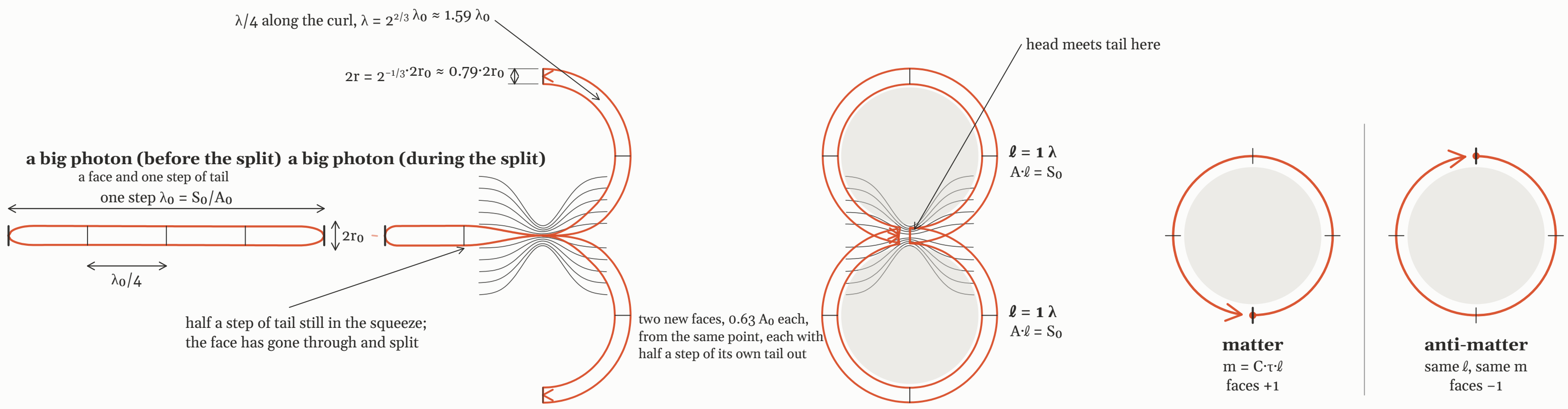
One loop hides a whole number of S_0 (here $n = 1$). Under the SI lock, $S_0 = \hbar$ at the electron, that same line in the textbook's variables is $p\cdot\ell = 2\pi\hbar n$, recovering Bohr's condition.

The math of the caustic determines whether the photon can fit. When it can't and splits, the math of the photon forces the display area of two equal parts to carry $2^{1/3} \approx 1.26$ times that of the whole. That display area expansion is what gives the caustic math the extra curvature needed to close.
Two parts have the same exiting loop length, so the same mass ($m = C\cdot\tau\cdot\ell$), and they face opposite ways, so opposite charge: matter and anti-matter.

A photon has a display area and a step, $\lambda = S_0/A_\mathrm{d}$. A photon that curls to where it started can be trapped: its head has reached its tail at the caustic:

Same mass, opposite charge: a particle and its anti-particle, made from one photon. One faces +1, the other −1.

1. A big photon hits a squeeze it cannot fit through, and splits **2. Each part closes: whole steps round the loop** **3. Same mass, opposite facing**



The two parts carry $2^{1/3} \approx 1.26$ times the display area of the whole (0.63 A_0 each).
The clock is display action: the rear half in ($S_0/2$)
and each part's head out ($S_0/2$) have advanced the same.

four ticks of $\lambda/4$ round each loop;
the fourth lands on the squeeze, meeting in the caustic:
one loop = one S_0 of display action, each.

drawn as routes again, as on the other pages:
panels 1 and 2 drew the display area side-on
to show the expansion and the closure

Everything on this page is computed from four lines of the framework. Only ratios enter; S_0 is the one scale.

closure: $\ell = n\lambda$, $n = 1, 2, 3 \ldots$ ($p\cdot\ell = 2\pi\hbar n$) $\lambda = S_0/A_\mathrm{d}$ split: $A_1 + A_2 = 2^{1/3}\cdot A_0$ mass: $m = C\cdot\tau\cdot\ell$ facing ±1 = charge

Closure. A loop of length ℓ holds only if a whole number of the photon's steps fits round back to the caustic. Mark the step off round the loop like ticks on a ruler: the head meets the tail only if the last tick lands on the start.

$$\ell = n\lambda \quad (n = 1 \text{ drawn: one step round})$$
$$A_d \cdot \ell = n \cdot S_0 \quad (\text{one loop = one } S_0 \text{ of display action})$$

Two closed parts need two closures, each one S_0. How big a photon must be to supply them is a ratio to the electron loop, fixed by the anchor; in the textbook's dictionary it is the 1.022 MeV minimum pair threshold. This page does not derive that ratio; it draws a photon big enough.

The split. The display area is the face of the photon. When one photon becomes two equal parts, what is shared equates to the photon's energy; but the faces of two half-size parts do not add up to the face of the whole. They add to $2\cdot(½)^{2/3} = 2^{1/3} \approx 1.26$ of it. The same way one sphere splits to two spheres of same volume (mass) but 1.26x the original surface area.

$$F_{split} = 2\cdot(½)^{2/3} = 2^{1/3} \approx 1.26$$
each part: half of what is enclosed, half the energy;
$$\text{display area } A = 2^{-2/3}\cdot A_0 \approx 0.63\, A_0$$

Of all the ways to cut into two, $a^{2/3} + (1 - a)^{2/3}$ is largest at a = ½: equal halves gain the most display area, so this split helps closure most; that is why the equal-mass pairs are the case drawn. This extra display area is what lets each part close where the caustic alone could not.

Same mass, opposite charge. The mass of a loop is set by its length ℓ and its loop-response budget τ, with one constant C fixed once at the electron:

$$m = C\cdot\tau\cdot\ell \qquad m_2/m_1 = (\tau_2/\tau_1)\cdot(\ell_2/\ell_1) = 1 \text{ for two identical parts}$$

Each loop faces one way or the other relative to the plane that the caustic resolution sets, and that facing is preserved (A3).
Facing is charge: the two parts of one split face opposite ways, so one is the particle and the other its anti-particle.
The split made the pair and that expansion enabled closure. The math resolves to face them opposite.

Chosen for the drawing, not from the framework. Three choices. The incoming photon is drawn big enough that each part closes at n = 1. The photon's display radius against its own step, r_0, is the drawing's choice: the framework fixes only ratios, and $r_0/\lambda_0 = \pi r_0^3/S_0$ needs S_0 as a length. The curls (up one, down the other) is the drawing's choice; that they curl opposite ways is the math. The loops are drawn as circles with quarter-step ticks; the exact route is set by the caustic.

The drawing is computed from those choices. The photon is one step long ($\lambda_0 = S_0/A_0$, the length in which it hides one S_0) and $2r_0$ high. Each part's loop is one of its own steps ($\ell = \lambda = S_0/A$), so with the split $A = 2^{-2/3}\cdot A_0$ the photon's step is $\lambda_0 = 2^{-2/3}\cdot\lambda \approx 0.63\ \lambda$ and its height is $2^{1/3} \approx 1.26$ times a part's; every tick is at exactly those spacings and at the full display extent ($2r_0$ in, 2r out); whole-step ticks differ only by line weight. The instant shown is fixed by display action, not distance: the rear half of the photon still in the caustic is $S_0/2$ ($A_0\cdot\lambda_0/2$), and each part's head has come half of its own step out, also $S_0/2$ ($A\cdot\lambda/2$); equal action, so the parts' heads are further along only because their step is longer. In panels 1 and 2 the photon and its parts are drawn side-on with their display area as height ($2r_0$, then 2r), so the expansion and the closure can be seen; a display area is really the face and once a loop has closed that side view no longer shows it, so panel 3 returns to drawing each loop as its route, the way every other page does.

Sources (vms-institute.org/theory). Particle Mechanics Math Appendix: Routes, Admissibility and Action Phase and Loop Closure ($\Delta\varphi_{loop} = 2\pi n$; $p\cdot\ell = 2\pi\hbar n$; $k_n = 2\pi n/\ell$), Mass Scaling from Bounded Loop Stability ($m = C\cdot\tau\cdot\ell$, ratio law), Conserved Charge (sign by class orientation). Treatise on Caustics Loop Closure thru Display Area Expansion and Contraction ($F_{split} = N^{1/3}$; photon collisions as particle creation channels). Proposed Mathematical Bridge: Closed Loop to Inertial Measure; Loop Orientation to Electromagnetism (orientation ±1 preserved under expansion, A3). Mathematical Bridge Math Appendix: Objects and Units ($S_0 = \oint A_d\, ds$, m^3; $S_0 = \hbar$ at the electron). Generator: gen_matter_HS_LOCKED_v2.py (locked 2026-09-12).

 this page on its own

How matter is made, and why it comes in pairs: the full derivation

A photon is the smallest piece of light; this page follows one photon, and derives what the high school page stated.
A photon becomes matter when it closes into a stable loop. It closes when a whole number of its steps is the length of the closed loop:

$$A_d\cdot\ell = n\cdot S_0, \quad n = 1$$
(one loop hides a whole number of S_0; under the SI lock, $S_0 = \hbar$ at the electron, this is $p\cdot\ell = 2\pi\hbar n$, recovering Bohr's condition)

The math of the caustic determines whether the photon can fit. When it can't and splits, the void's volume V is shared half and half, and because a face scales as $V^{2/3}$ the two faces total

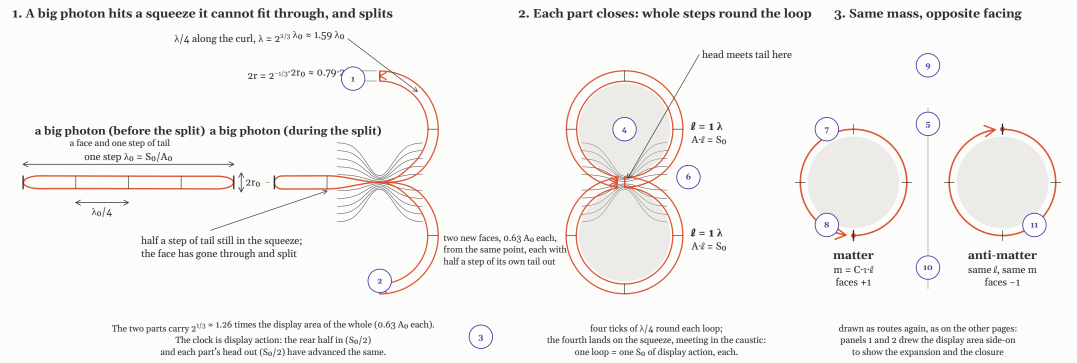
$$F_{split} = 2\cdot(½)^{2/3} = 2^{1/3} \approx 1.26$$
(Treatise on Caustics Loop Closure; equal halves are the maximum of $a^{2/3} + (1 - a)^{2/3}$)

That display area expansion is what gives the caustic math the extra curvature needed to close. Two parts have the same exiting loop length, so the same mass ($m = C\cdot\tau\cdot\ell$), and they face opposite ways, so opposite charge: matter and anti-matter.

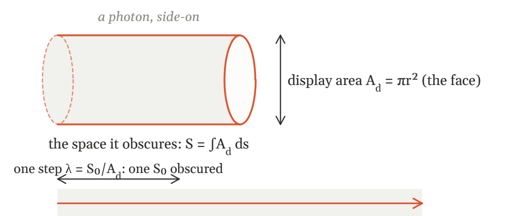
The general case, mass and gravity from any closed loop, is not drawn on the high school page; it is derived below (panels 7 to 11).

The small figure is the high school drawing. Each numbered circle is exploded below, and each number is a step of the derivation further down. Panels 1 to 6 are the case drawn: this split, on the treatise's sphere model, then closure and the pair. Panels 7 to 11 are the general solution: any closed loop, its mass, its gravity, and its sign. The derivation uses four published documents and nothing else: the Treatise on Caustics Loop Closure (the case), the Particle Mechanics Math Appendix (closure, mass, charge), the Mathematical Bridge and its Math Appendix (the general solution: mass and gravity from closed Void loops; orientation), and the VMS Closure Math Primer (why closure is an invariant). Only ratios enter; S_0 is the one scale.

> **A note on the mathematics.** The derivations on the advanced pages draw on two bodies of work that are rigorous and long established but not widely taught: the classification of singularities of smooth maps (Arnold, Gusein-Zade and Varchenko, *Singularities of Differentiable Maps*, Vol. I, Birkhäuser, 1985) and the asymptotics of wave fields near caustics (Kravtsov and Orlov, *Caustics, Catastrophes and Wave Fields*, Springer, 2nd ed., 1998). Both have a strong pedigree; both are the province of a small specialist community. For scale, and as background only: SpringerLink records about 1,100 citations of the first book in forty years and about 110 of the second in thirty, and the field's own international workshops on singularities draw a few dozen participants. The number of people who work with this mathematics is at most in the hundreds, not the thousands.



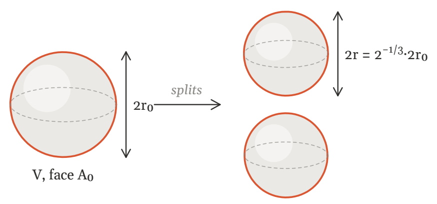
1. In this case: a photon, its display area, and the volume it obscures



a Void, or a photon, is a surface that obscures the space behind it

One volume on this page: the obscured space. The treatise's V in panels 2 and 3 is its sphere model of it.

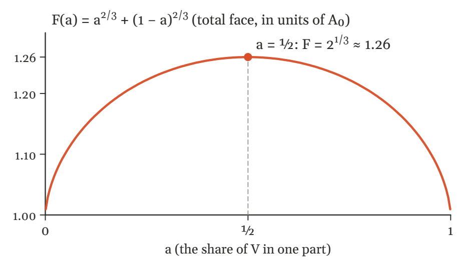
2. In this case: the split on the treatise's sphere model



faces: $A_0 \to 2 \cdot (½)^{2/3} A_0 = 2^{1/3} A_0 \approx 1.26\ A_0$

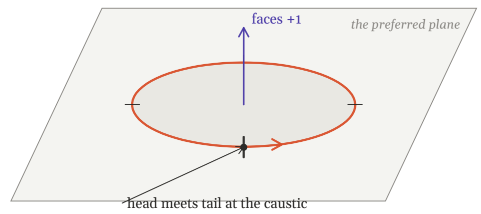
the treatise computes with a sphere: face ∝ $V^{2/3}$; a bound for other shapes (its note)

3. In this case: equal halves gain the most face



$F'(½) = 0$, $F''(½) < 0$: the maximum. N equal pieces: $F = N^{1/3}$ (1.26, 1.44, 1.59 ...)

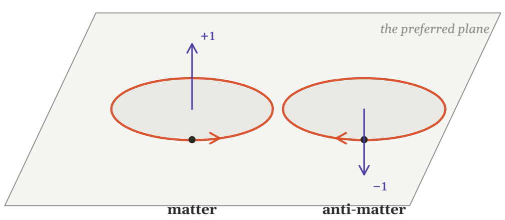
4. Closure: whole steps round, in the plane the expansion selects



$A_d \cdot \ell = n \cdot S_0$, n = 1: $\ell = \lambda = S_0/A_d$ (four ticks of λ/4; the fourth lands on the start)

admissibility is the integer condition, not a balance: the first loop a part can make is n = 1

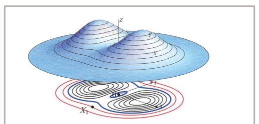
5. The pair: same loop, opposite facing



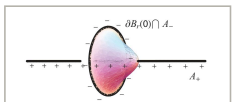
$m = C \cdot \tau \cdot \ell$, $m_2/m_1 = (\tau_2/\tau_1)(\ell_2/\ell_1) = 1$ for two identical parts

orientation ±1 is preserved under expansion (Bridge, A3); relative orientation sets the sign of the far field: charge

6. Closure is a named invariant: the pass is forced, the crossing cannot be erased



Bisgard, Fig. 3.1 (p. 279), mountain-pass geometry: "every path that begins at 0 and ends at x_1 passes through blue!"



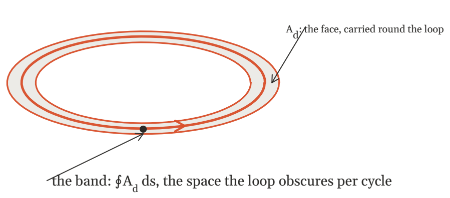
Bisgard, Fig. 7.3 (p. 286), forced intersection: the intersection "cannot be removed by deforming the surface if the deformation must decrease F".

Figures reproduced from James Bisgard, "Mountain Passes and Saddle Points", SIAM Review 57(2), 2015, as cited in the VMS Closure Math Primer. The mapping below follows the Primer's dictionary page; "the pass is the caustic" is this page's reading.

The landscape is the closure score; the basins are closed states; the pass is the caustic, the forced crossing; the invariant that survives every downhill move is the integer n on the loop. A part does not "nearly" close: n is an integer, so it closes at n = 1 or it does not close.

The general solution (panels 7 to 11)

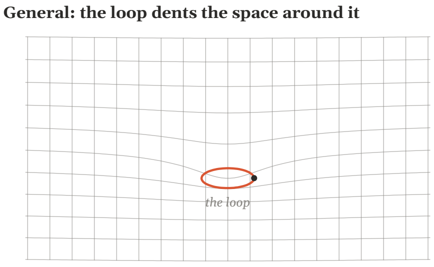
7. General: a closed loop obscures a volume, and that volume is its mass



$m \propto \oint A_d\,ds$; in static gauge $E = \sigma_\tau L$, $m = E/c^2 = (\sigma_\tau/c^2)\cdot L$

"the geometric consequence of how much space the Void loop obscures" (Math Appendix, Mass and Gravity, step 4)

8. General: the loop dents the space around it



$T^{\mu\nu} = -(2/\sqrt{-g})\,\delta S_{void}/\delta g_{\mu\nu}$, $G_{\mu\nu} = \kappa T_{\mu\nu}$; weak field: $\nabla^2\Phi = 4\pi G\rho$, $\Phi = -Gm/r$

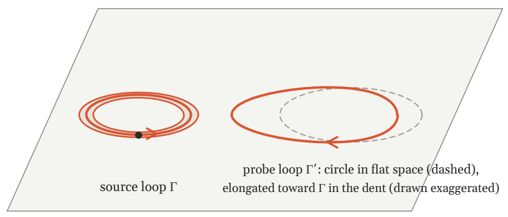
a deficit of transverse area, localised on the loop, spreading as $1/r^2$ (Math Appendix, steps 3, 5, 7)

Chosen for the drawing, not from the framework. The incoming photon is drawn big enough that each part closes at n = 1. The photon's display radius against its own step, r_0, is the drawing's choice: the framework fixes only ratios, and $r_0/\lambda_0 = \pi r_0^3/S_0$ needs S_0 as a length. The void is drawn as a sphere in panel 2 and as a short tube in panel 1: the treatise's scaling is the sphere's, and for any other shape the same power is a bound. The loops are drawn as circles lying in the preferred plane (a drawing choice); the exact route is set by the caustic. Which way each part curls, and which faces +1, is the drawing's choice; that they face opposite ways is the math. In panels 7 to 11 the loop sizes, the probe's distance from the source, and the amount of elongation are drawing choices (the elongation is exaggerated to be visible; the appendix gives the mechanism, not a number for a drawn pair); the dent in panel 8 is drawn with the −Gm/r profile softened at the loop so it can be seen.

Computed from those choices. $r = 2^{-1/3} r_0$, $A = 2^{-2/3} A_0 = 0.63\ A_0$, $\lambda = 2^{2/3}\lambda_0 = 1.59\ \lambda_0$, $\ell = \lambda$; the curve in panel 3 is $F(a) = a^{2/3} + (1 - a)^{2/3}$ evaluated; every tick is at its computed spacing.

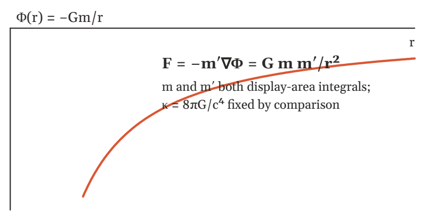
Sources (vms-institute.org/theory). Treatise on Caustics Loop Closure thru Display Area Expansion and Contraction (a void of conserved volume V; $F_{split} = \Sigma(V_i/V)^{2/3} = 2^{1/3}$; $N^{1/3}$; the sphere scaling $A \propto V^{2/3}$ and the isoperimetric bound; the extra curvature needed to close; photon collisions as particle creation channels). Particle Mechanics Math Appendix: Routes, Admissibility and Action Phase and Loop Closure ($\Delta\varphi_{loop} = 2\pi n$; $p\cdot\ell = 2\pi\hbar n$), Mass Scaling from Bounded Loop Stability ($m = C\cdot\tau\cdot\ell$, the ratio law), Conserved Charge (sign by class orientation; classes are not created or destroyed). Proposed Mathematical Bridge: Closed Loop to Inertial Measure and Gravity ($m \propto \oint A_d\,ds$; the void splits and inflates its display area, forming a stable harmonic loop; the loop obscures volume, interpreted as mass; $\Delta g \sim 1/r^2$; probe–source $F = G\,m\,m'/r^2$); Loop Orientation to Electromagnetism (orientation ±1 preserved under expansion, A3; expansion-driven caustics select a preferred plane). Mathematical Bridge Math Appendix: Objects and Units ($S_0 = \oint A_d\,ds$, m^3; $S_0 = \hbar$ at the electron); Canonical Derivation, Mass and Gravity from Closed Void Loops, steps 1 to 8, 6A and 7 expanded (worldsheet action, stress–energy, inertial mass, Einstein equations, geodesic response and elongation, Newtonian limit). Site audit package (vms-institute.org/audit): F0000, F0001, F0002. VMS Closure Math Primer (optional paths, forced bottleneck, closure as a named invariant; built on James Bisgard, "Mountain Passes and Saddle Points", SIAM Review 57(2), 2015, whose Figs. 3.1 and 7.3 are reproduced in panel 6). Generator: gen_matter_proofs3d_LOCKED_v2.py (locked 2026-09-12).

9. General: a second loop is deflected toward the first



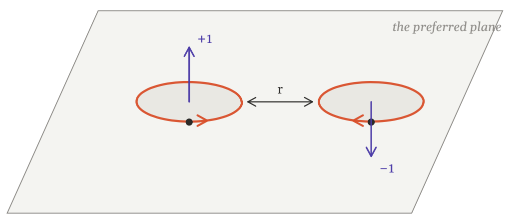
geodesic: $D^2x^\mu/D\tau^2 + \Gamma^\mu_{\alpha\beta}\dot{x}^\alpha\dot{x}^\beta = 0$; null segments: $g_{\mu\nu}u^\mu u^\nu = 0$ (runs at c)
$L_{eff} > L_{flat} \Rightarrow \oint A_d$ ds larger $\Rightarrow m_{obs}$ larger (Math Appendix, steps 6, 6A)

10. General: the weak field is Newton



$\Box\bar{h}_{\mu\nu} = -2\kappa T_{\mu\nu}$, $T_{00} \approx \rho c^2$, $h_{00} = -2\Phi/c^2 \Rightarrow \nabla^2\Phi = 4\pi G\rho$
checked: $\nabla^2(-Gm/r) = 0$ for $r > 0$, $F = -m'\, d\Phi/dr$ (sympy here; audit block F0002)

11. General: the same loop, two far fields



gravity: $F = -m'\nabla\Phi = G\, m\, m'/r^2$, from the obscured volume, always attractive
charge: $F \propto \sigma_1\sigma_2/r^2$, direction from orientation $\sigma = \pm1$ on the plane, preserved by expansion (Bridge, A3)
Bridge, sections 3 and 4: one loop, one $1/r^2$, two far fields; the pair has the same mass and opposite sign

A. The case drawn, step by step (the numbers are the circles in the figure)

1. In this case: the photon, its display area, the space it obscures

A Void, or a photon, is a surface with a display area A_d (an area, m^2) that obscures the space behind it. Along its route the obscured space is the display action $S = \int A_d$ ds (a volume, m^3), one S_0 per step. That is the one volume on this page: what the photon obscures, what the split shares, and, once a loop has closed, what the loop obscures per cycle, which the general solution below identifies with mass. Panels 2 and 3 work the split on the Treatise on Caustics Loop Closure's model, in which the obscured volume is treated as a sphere of conserved volume V; that is a model for this case, not a general theorem.

$\lambda = S_0/A_d$ one step, one S_0 obscured

closed loop: $\oint A_d\, ds = n\cdot S_0$ the volume it obscures per cycle

2. In this case: the split on the sphere model

The Treatise on Caustics Loop Closure takes the obscured volume as a sphere of conserved volume V and lets it split into two equal parts, V/2 each. On a sphere the face scales with volume as $V^{2/3}$ ($A = 4\pi(3V/4\pi)^{2/3}$), and the treatise notes that for other shapes the isoperimetric inequality makes the same power a bound. On that model the two new faces total

$F_{split} = \Sigma\, (V_i/V)^{2/3} = 2\cdot(½)^{2/3} = 2^{1/3} \approx 1.26$

each part: $A = 2^{-2/3}\cdot A_0 \approx 0.63\, A_0$, $r = 2^{-1/3}\cdot r_0 \approx 0.79\, r_0$

N equal pieces: $F_{split} = N^{1/3}$; merging two: $1/2^{1/3} \approx 0.79$

isoperimetric inequality, any shape: $A \geq (36\pi)^{1/3}\cdot V^{2/3}$, equality for the sphere;

so for the two parts $A_1 + A_2 \geq 2\cdot(36\pi)^{1/3}\cdot(V/2)^{2/3} = 2^{1/3}\cdot A_{sphere}(V)$

On the sphere model the parts' faces total at least $2^{1/3}$ times the face of a sphere holding the whole volume; the sphere is the least-face case and the treatise's number is its value. The volume is shared; the faces are not, they grow, by 26%. That growth is the treatise's lever: it provides the extra curvature needed to form a harmonically closed loop where the caustic alone is insufficient. This is the case drawn on the kid and high school pages, worked through; it is not promoted here to a general theorem.

3. In this case: equal halves gain the most face

For a two-way split into shares a and 1 − a of V, the total face is $F(a) = a^{2/3} + (1 - a)^{2/3}$. Two lines of calculus:

4. Closure is the integer condition

A route that closes is admissible when its display action round the loop is a whole number of S_0 (Particle Mechanics Math Appendix: $\Delta\varphi_{loop} = 2\pi n$; on a uniform ring $p\cdot\ell = 2\pi\hbar n$). With the photon page's step $\lambda = S_0/A_d$, that is

$A_d\cdot\ell = n\cdot S_0 \;\Leftrightarrow\; \ell = n\lambda$, $n = 1, 2, 3 \ldots$

under the SI lock ($S_0 = \hbar$, $2\pi A_d \leftrightarrow p$): $p\cdot\ell = 2\pi\hbar n$ (Bohr, recovered)

Closure is not a balance to be met by 26%; it is an integer. The split puts each part where the n = 1 loop is reachable, and that loop is one S_0 of display action by definition. The loop's facing is taken relative to the plane that the expansion-driven caustics select (Mathematical Bridge, Electromagnetism); drawing the loop in that plane is this page's choice; that the head meets the tail at the caustic is the high school page's reading. How big a photon must be for both parts to reach n = 1 is a ratio to the electron loop, fixed by the anchor; in the textbook's dictionary, the 1.022 MeV minimum pair threshold. Not derived here.

5. Same mass, opposite charge

Mass is set by the loop (Particle Mechanics Math Appendix, Mass Scaling from Bounded Loop Stability). Along an admissible closed loop of length ℓ the appendix carries a dimensionless loop-response budget $\mathcal{T}(s)$; its loop-average is τ, its energy is κ times its integral, and mass is that energy over c^2:

$\tau \equiv (1/\ell)\cdot\oint\mathcal{T}\, ds$, $E = \kappa\cdot\oint\mathcal{T}\, ds = \kappa\cdot\tau\cdot\ell$, $m = E/c^2 = (\kappa/c^2)\cdot\tau\cdot\ell \equiv C\cdot\tau\cdot\ell$

$\tau\ell = \oint\mathcal{T}\, ds$ is reparameterisation-invariant; C is fixed once at the electron, $m_e = C\cdot\tau_e\cdot\ell_e$;

$m_2/m_1 = (\tau_2/\tau_1)\cdot(\ell_2/\ell_1) = 1$ for two identical parts

Each closed loop carries an orientation, +1 or −1, preserved under expansion (Mathematical Bridge, A3), and the relative orientation sets the sign of the far-field interaction: charge. The appendix's Conserved Charge line says admissible dynamics do not create or destroy classes; read onto a split, two loops made from one photon are of opposite class. Two identical loops, opposite facing: a particle and its anti-particle, from one photon. The split made the pair, the expansion enabled closure, and orientation faces them opposite.

6. Why closure is an integer, not a balance (the Closure Math Primer)

The VMS Closure Math Primer says what "closed" means in the framework, in its own words: "When VMS says a structure is 'closed,' it means: there's a candidate space of routes, a closure score we want to minimize, refinement steps that legally only reduce that score, and a topological invariant that survives every legal refinement. That invariant is what the framework actually claims about reality."

$F'(a) = ⅔\cdot[a^{-1/3} - (1 - a)^{-1/3}] = 0 \Rightarrow a = ½$

$F''(a) = -(2/9)\cdot[a^{-4/3} + (1 - a)^{-4/3}] < 0 \Rightarrow$ a maximum

On the sphere model equal halves gain the most face, so the equal split is the one that helps closure most, and equal-mass pairs are the case drawn on every page of this section. Unequal splits gain less; they are not excluded by this line, only favoured against. Other channels (more pieces, a piece that leaks) are not drawn.

And on how a closure is proved: "define what moves are legal (refinement steps that reduce your closure score), then prove the target structure cannot be erased under those moves. That target structure is what you're actually 'closing.'"

the invariant here: $n \in \mathbb{Z}$, $\Delta\varphi_{\text{loop}} = 2\pi n$, $A_d\cdot\ell = n\cdot S_0$

legal moves change the route, not n: an integer cannot drift; a part closes at $n = 1$ or does not close

The Primer names the integer winding number on a closed loop as exactly this kind of invariant, and reads Bisgard's mountain pass as the geometry behind admissibility: optional routes exist, but between two basins every route crosses the ridge somewhere, and that forced crossing is the transition state. On this page the ridge is the caustic. The split's 26% is therefore not a payment against a closure defect; it moves each part into the basin where the $n = 1$ loop is reachable, and the integer does the rest. The figures in panel 6 are Bisgard's, reproduced as in the Primer.

B. The general solution: mass and gravity from any closed loop

7. The closed loop and the volume it obscures: mass

Now the general case, from the Mathematical Bridge (section 3) and its Math Appendix (Mass and Gravity from Closed Void Loops). A closed Void loop Γ sweeps a worldsheet W as it propagates, $X^\mu(\tau, \lambda)$ with λ round the loop and induced metric $\gamma_{ab} = g_{\mu\nu}\partial_a X^\mu \partial_b X^\nu$. Its display action per cycle is $S_\Gamma = \oint_\Gamma A_d\, ds$, the volume it obscures. The loop's action is the minimal-area principle applied to that obscured space, the Nambu–Goto form; "a Void loop accumulates action proportional to the space it obscures" (step 2). In static gauge, $X^0 = c\tau$, the energy is σ_s times the loop's length, and mass is that energy over c^2:

$S_{\text{void}}[W; g] = \sigma_s \int_W \sqrt{(-\gamma)}\, d^2\xi$

$E = \sigma_s \oint_\Gamma |\partial_\lambda X|\, d\lambda = \sigma_s L_\Gamma$, $m = E/c^2 = (\sigma_s/c^2)\cdot L_\Gamma$; with A_d varying round the loop, $m \propto \oint_\Gamma A_d\, ds$

"Mass is not an independent assumption; it is the geometric consequence of how much space the Void loop obscures" (step 4). For the electron loop the obscured volume per cycle is S_0, locked to ħ (Bridge, Calibration A); that is the one scale, and every other mass is a ratio to it. The Particle Mechanics Math Appendix's $m = C\cdot\tau\cdot\ell$ (Mass Scaling from Bounded Loop Stability) is the same statement with ℓ the loop length and τ carrying the variation of the face round the loop.

8. The dent: the loop as a source of curvature

Vary the loop's action with respect to the metric (Mathematical Bridge Math Appendix, Mass and Gravity from Closed Void Loops, step 3; full derivation there). The result is a stress–energy localised on the worldsheet, conserved by reparameterisation invariance and the Bianchi identity: "a closed loop makes a local dent in the fabric of space, proportional to the obscuration it carries" (step 3). Add the Einstein–Hilbert term and vary again:

$T^{\mu\nu}(x) = -(2/\sqrt{-g})\cdot\delta S_{\text{void}}/\delta g_{\mu\nu} = \sigma_s \int d^2\xi \sqrt{(-\gamma)}\, \gamma^{ab}\, \partial_a X^\mu\, \partial_b X^\nu\, \delta^{(4)}(x - X(\xi))$

$S_{\text{total}} = (1/2\kappa) \int R \sqrt{(-g)}\, d^4x + S_{\text{void}} \Rightarrow G_{\mu\nu} = \kappa T_{\mu\nu}$

That is the statement that a Void loop curves spacetime (step 5). Nothing was added to make it so: the same action that gave the loop its mass gives, by varying the metric instead of the path, its effect on the geometry. The Bridge describes the result as a deficit of available transverse area that propagates outward as $\Delta g \sim 1/r^2$ (section 3, recipe steps 2 and 3).

9. A second loop is deflected

Put a second loop Γ' in the geometry made by Γ (Mathematical Bridge Math Appendix, steps 6 and 6A; full derivation there). Its action is the same form, $S_{\text{void}}[W'; g]$, and in the small-loop limit its centre of energy follows the geodesic equation: "the second loop bends its trajectory toward the first" (step 6). Each

10. The weak field: Newton

Linearise the metric, $g = \eta + h$ with $|h| \ll 1$, in harmonic gauge (Mathematical Bridge Math Appendix, step 7 and its expanded deflection framing; full derivation there). For a static source the dominant component of the loop's stress–energy is $T_{00} \approx \rho c^2$, with ρ the mass density from the display-area integral. Writing $h_{00} = -2\Phi/c^2$ turns the linearised equation into Poisson's, and the pointlike loop's potential and the force on a probe loop follow (step 7):

$\Box\bar{h}_{\mu\nu} = -2\kappa T_{\mu\nu}$, $\nabla^2\Phi = 4\pi G\rho$, $\kappa = 8\pi G/c^4$ (fixed by comparison)

$\Phi(r) = -Gm/r$, $F = -m'\nabla\Phi = Gmm'/r^2$

Both masses are display-area integrals. G is fixed by comparison with Newton, as S_0 is fixed at the electron: two calibrations, one for the mass scale and one for the gravity scale, and the finite tension of space (the Math Appendix's A3, tension; the Bridge's A3 is expansion) is what makes a finite G exist at all. Checked here: $\nabla^2(-Gm/r) = 0$ away from the source, $F = -m'\, d\Phi/dr$; and in the site's audit package, F0001 (Newton from variational closure) and F0002 (the potential and the $1/r^2$ limit).

11. The sign: the same loop, two far fields

The loop that has mass also has an orientation, $\sigma = +1$ or -1, preserved under expansion (Bridge, A3), and the Mathematical Bridge's section 4 gives the second far field: the same $1/r^2$ dependence, with its direction set by the relative orientation. "When a void loop closes on the preferred expansion plane, the orientation of its rotation defines a polarity. This polarity is identified with electric charge."

gravity: $F = Gmm'/r^2$ charge: $F \propto \sigma_1\sigma_2/r^2$, $\sigma_i \in \{+1, -1\}$

So the pair of panel 5, two identical loops facing opposite ways, has the same mass by step 7 and opposite charge by this step, and both come from the one closed loop. That is the general solution behind the case drawn: matter is a closed loop, its mass is the volume it obscures, its gravity is the dent that volume makes, and its charge is which way it faces.

segment of the loop runs at c, so the loop's tangent is null; and the closed path that would be a circle in flat space is elongated toward the source, which increases its obscured volume per cycle and so its observed mass (step 6A):

$$D^2x^\mu/D\tau^2 + \Gamma^\mu{}_{\alpha\beta}\,(dx^\alpha/d\tau)(dx^\beta/d\tau) = 0,\quad g_{\mu\nu}u^\mu u^\nu = 0$$

$$L_{\mathrm{eff}} = \oint_{\Gamma'} \sqrt{(g_{ij}\,dx^i\,dx^j)} > L_{\mathrm{flat}},\quad m_{\mathrm{obs}} = (\sigma_s/c^2)\cdot L_{\mathrm{eff}}$$

Gravitational attraction is this deflection and nothing else: "not because of a pulling force, but because the geometry itself has changed what straight ahead means." The speed limit is the closure condition: a loop that tried to run faster than c would fail to close (6A, boxed remark).

What is published, what is derived here, what is chosen

Line	Status	Where it stands
A void of conserved volume V splits into V/2 + V/2; face ∝ $V^{2/3}$; $F_{split} = 2^{1/3}$; $N^{1/3}$; the extra curvature needed to close	the case drawn (treatise's sphere model)	Treatise on Caustics Loop Closure thru Display Area Expansion and Contraction: its statement, worked on its sphere model in panels 2 and 3; not a general theorem of the framework.
$F(a) = a^{2/3} + (1 - a)^{2/3}$ is largest at a = ½	the case drawn	Two lines of calculus on the sphere model (step 3).
$\Delta\varphi_{loop} = 2\pi n$; $p\cdot\ell = 2\pi\hbar n$; $A_d\cdot\ell = n\cdot S_0$ with $\lambda = S_0/A_d$	published + reading	Particle Mechanics Math Appendix (the first two); the display-action form is the photon page's mapping of $2\pi A_d$ to p under the SI lock.
$S_0 = \oint A_d\,ds$ (m^3); $S_0 = \hbar$ at the electron	published	Mathematical Bridge Math Appendix, Objects and Units; the anchor is a calibration.
$m = C\cdot\tau\cdot\ell$; $m_2/m_1 = (\tau_2/\tau_1)(\ell_2/\ell_1)$	published	Particle Mechanics Math Appendix, Mass Scaling from Bounded Loop Stability.
orientation ±1 preserved under expansion (Bridge, A3); expansion-driven caustics select a preferred plane; sign by class orientation, classes conserved	published	Mathematical Bridge, Loop Orientation to Electromagnetism; Particle Mechanics Math Appendix, Conserved Charge.
the head meets the tail at the caustic; the two new faces have their final display area from the instant of the split	reading of the drawing	Stated on the high school page as the framework's reading of the drawing; consistent with the sources, which give the closure condition without fixing where on the route the join sits.
$A \geq (36\pi)^{1/3}\,V^{2/3}$, equality for the sphere; $A_1 + A_2 \geq 2^{1/3}\cdot A_{sphere}(V)$	the case drawn	The isoperimetric inequality the treatise's note invokes, written out (step 2); it bounds the sphere model, it does not make it general.
$E = \kappa\oint\mathcal{T}\,ds = \kappa\tau\ell$, $m = E/c^2 = C\tau\ell$	published	Particle Mechanics Math Appendix, Mass Scaling from Bounded Loop Stability, derived there and copied here (step 5).
closure = a named invariant (integer winding n) surviving legal refinement; the pass is forced	published (the Primer's words)	VMS Closure Math Primer, quoted verbatim; Bisgard's figures reproduced as the Primer reproduces them (step 6). "The ridge is the caustic" is the Primer's mapping of the pass to admissibility, read onto this page.
a closed loop obscures a volume $\oint A_d\,ds$; that volume is its mass; $m \propto \oint A_d\,ds$, $m = (\sigma_s/c^2)L$ in static gauge	published	Mathematical Bridge, section 3; Math Appendix, Mass and Gravity from Closed Void Loops, steps 1, 2, 4 (step 7 here). CAS: static-gauge reduction, sympy here.
$S_{void} = \sigma_s\int\sqrt{(-\gamma)}\,d^2\xi$ (Nambu–Goto form); $T^{\mu\nu}$ from $\delta S/\delta g$; $G_{\mu\nu} = \kappa T_{\mu\nu}$	published	Math Appendix, steps 2, 3, 5 (step 8 here).
geodesic response of a second loop; null segments; elongation $L_{eff} > L_{flat} \Rightarrow m_{obs}$ larger; closure forbids v > c	published	Math Appendix, steps 6, 6A (step 9 here).
$\Box\bar{h} = -2\kappa T$, $\nabla^2\Phi = 4\pi G\rho$, $\Phi = -Gm/r$, $F = -m'\nabla\Phi = Gmm'/r^2$	published + CAS	Math Appendix, step 7; sympy here; audit blocks F0001, F0002 (pass).
$\kappa = 8\pi G/c^4$ fixed by comparison; $S_0 = \hbar$ at the electron	calibrations	Two locks, one for the mass scale and one for the gravity scale; the finite tension of space is what makes a finite G exist. Never derived.
$m = C\cdot\tau\cdot\ell$ (particle appendix) and $m \propto \oint A_d\,ds$ (Bridge) are one statement	reading	ℓ is the loop length; τ carries the variation of the face round the loop; both published.
the loops drawn in the preferred plane; the probe's elongation drawn exaggerated; loop sizes and the probe's distance	chosen	See "Chosen for the drawing".
the pair threshold (1.022 MeV)	anchor	A ratio to the electron loop, fixed by the calibration; never derived on these pages.
sphere for the void, circles for the loops, r_0, which part curls which way, n = 1	chosen	See "Chosen for the drawing".