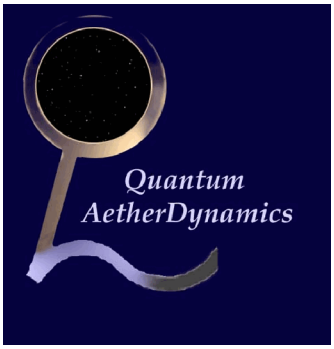


**Quantum AetherDynamics Institute (QADI)**

# Electrodynamics and Circuit Theory in Quantum Measurement Units: Resonance, Impedance Partitioning, and Quantum Hall Response

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It develops the Aether Physics Model (APM)

**Abstract**

This paper develops electrodynamics directly in the Quantum Measurement Units (QMU) conventions of the Aether Physics Model (APM), with no reliance on conventional-unit heuristics. The starting point is the QMU ledger, defined by two charge channels $(e^2, {e_{\text{emax}}}^2)$, the Aether seat-map occupancy $(A_u/k_C = 16\pi^2)$, and the rotational–torsional closure $A_u\,\text{curl} = {F_q}^2\,{\lambda_C}^2$. We adopt the QMU field dictionary that distinguishes flux-density fields from strength fields, and we use the exception-class substrate operators $\{\text{perm}, \text{ptty}, \text{indc}, \text{capc}, \text{cond}\}$ as the primitive constitutive layer. On this foundation we (i) state the APM field system in QMU-native integral form, (ii) define circuit observables and element laws so that dimensional closure holds in QMU, (iii) derive resonance conditions in both distributed and lumped limits, and (iv) express quantum Hall quantization directly in the QMU conductance primitive $\text{cond} = \text{mflx}^{-1}$ with the channel-factor reduction $e^2/h = (8\pi\alpha)\text{cond}$. We close the system with a QMU-native energy–power ledger that respects conjugate pairing and exception-class semantics.

**Keywords:** QMU; APM; electrodynamics; circuit theory; resonance; quantum Hall; perm; ptty; Au; curl

# 1 Scope and design constraints

This paper is written *QMU-first*: every definition and equation is required to close in QMU dimensional analysis as tabulated in the QMU reference tables Thomson [2025b]. The charge conversion factor (CCF) rules, including the no-CCF exception class $\{\text{perm}, \text{ptty}, \text{indc}, \text{capc}, \text{cond}\}$, are treated as axioms of admissible modeling Thomson [2025a]. The field dictionary and constitutive reconstruction adopted here follow the QMU-native development in Thomson Thomson III [2025b], but the present paper is structured as a standalone APM electrodynamics module aimed at circuit theory, resonance theory, and quantum Hall response.

# 2 Ledger primitives and geometry-first closures

## 2.1 Base set and the Aether rotational identity

The QMU base set is $\{m_\text{e}, \lambda_C, F_q, e^2, {e_{\text{emax}}}^2\}$. A canonical closure used throughout the APM electromagnetic sector is:

$$A_u\,\text{curl} = {F_q}^2\,{\lambda_C}^2, \tag{1}$$

which fixes the Aether rotational self-identity and ensures that wave-sector propagation remains purely geometric.

### 2.2 Three closures used in this paper

We adopt the standard APM electromagnetic closures:

$$\text{velc} = F_q\,\lambda_C, \tag{2}$$

$$\frac{e^2}{{e_{\text{emax}}}^2} = 8\pi\alpha, \tag{3}$$

$$\frac{A_u}{k_C} = 16\pi^2. \tag{4}$$

Equation (2) is the propagation closure; Eq. (3) is the electric-to-magnetic channel conversion factor; and Eq. (4) encodes the Aether seat-map occupancy.

### 2.3 Substrate operators: perm and ptty

QMU treats perm (torsional response) and ptty (rotational response) as substrate ratios rather than empirical medium constants. In the uniform-Aether vacuum closure they reduce to

$$\text{perm} = \frac{1}{\text{curl}}, \qquad \text{ptty} = \frac{1}{A_u}, \tag{5}$$

so that the propagation product is

$$\text{perm}\,\text{ptty} = \frac{1}{A_u\,\text{curl}} = \frac{1}{(F_q\lambda_C)^2}. \tag{6}$$

The complementary ratio

$$Z^2 \equiv \frac{A_u}{\text{curl}} \tag{7}$$

is the impedance-like partitioning invariant used for wave/circuit matching.

## 3 Field variables: flux-density vs strength (QMU dictionary)

QMU distinguishes two operational layers in each channel Thomson III [2025b]:

$$(\boldsymbol{D}, \boldsymbol{B}): \text{ flux-density layer (Gauss/Faraday accounting)}, \tag{8}$$

$$(\boldsymbol{E}, \boldsymbol{H}): \text{ operational strength layer (local forcing scale)}. \tag{9}$$

The table-grounded field units are

$$[\boldsymbol{E}] = \text{elfs}, \quad [\boldsymbol{D}] = \text{dvef}, \quad [\boldsymbol{B}] = \text{mfxd}, \quad [\boldsymbol{H}] = \text{magr}, \tag{10}$$

and the fundamental geometric lift is the $\lambda_C$-mapping

$$\boldsymbol{E} = \lambda_C\,\boldsymbol{D}, \qquad \boldsymbol{H} = \lambda_C\,\boldsymbol{B}, \tag{11}$$

valid in uniform-Aether states.

### 3.1 Conjugate strengths for constitutive operator pairing

For boundary-value problems and material response, QMU introduces conjugate strengths $(\boldsymbol{E}^\star, \boldsymbol{H}^\star)$ defined by the exception-class operators:

$$D_i = \mathrm{ptty}_{ij}(\omega)\, E^\star_j, \qquad B_i = \mathrm{perm}_{ij}(\omega)\, H^\star_j. \tag{12}$$

In isotropic vacuum, Eqs. (5)–(12) imply

$$\boldsymbol{E}^\star = \mathrm{ptty}^{-1}\boldsymbol{D} = A_u\, \boldsymbol{D} = \frac{A_u}{\lambda_C}\, \boldsymbol{E}, \qquad \boldsymbol{H}^\star = \mathrm{perm}^{-1}\boldsymbol{B} = \mathrm{curl}\, \boldsymbol{B} = \frac{\mathrm{curl}}{\lambda_C}\, \boldsymbol{H}. \tag{13}$$

The partitioning ratio of conjugate strengths is therefore fixed by $Z$:

$$\frac{\|\boldsymbol{E}^\star\|}{\|\boldsymbol{H}^\star\|} = \frac{A_u}{\mathrm{curl}} = Z^2. \tag{14}$$

## 4 APM field system in QMU-native integral form

The APM electromagnetic sector is expressed in integral form over a closed surface $S$ with boundary loop $\partial S$:

$$\oiint_S \boldsymbol{D} \cdot \mathrm{d}\boldsymbol{S} = q_e, \tag{15}$$

$$\oiint_S \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S} = q_m, \tag{16}$$

$$\oint_{\partial S} \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{\ell} = -\frac{\mathrm{d}}{\mathrm{d}t} \oiint_S \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S}, \tag{17}$$

$$\oint_{\partial S} \boldsymbol{H} \cdot \mathrm{d}\boldsymbol{\ell} = \frac{\mathrm{d}}{\mathrm{d}t} \oiint_S \boldsymbol{D} \cdot \mathrm{d}\boldsymbol{S} + \oiint_S \boldsymbol{J}_e \cdot \mathrm{d}\boldsymbol{S}. \tag{18}$$

Equations (15)–(18) are the QMU-native transport statements; they are closed by the dictionary relations (11) and the constitutive operators (12).

## 5 QMU energy and power accounting

Electrodynamics in QMU is closed not only by transport laws (Eqs. (15)–(18)) but also by an explicit energy–power ledger that respects the exception-class semantics. The energetic pairing is performed with the conjugate strengths $(\boldsymbol{E}^\star, \boldsymbol{H}^\star)$ because these are the operator-duals of the flux-density fields $(\boldsymbol{D}, \boldsymbol{B})$ via Eq. (12).

### 5.1 Energetic pairing and stored energy seat

Define the QMU electromagnetic energy density $u$ as

$$u \;\equiv\; \frac{1}{2}\Big(\boldsymbol{D} \cdot \boldsymbol{E}^\star + \boldsymbol{B} \cdot \boldsymbol{H}^\star\Big), \tag{19}$$

so that the total stored energy seat in a volume $V$ is

$$\mathcal{U} \equiv \iiint_V u \, \mathrm{d}V. \tag{20}$$

Equation (19) is QMU-first: it is written in the same operator pairing as Eq. (12) and does not import conventional-unit forms.

## 5.2 Energy transport (Poynting-like flux) and work term

Define the operational energy-flux vector [Poynting, 1884] (energy transport density) as

$$\boldsymbol{S} \equiv \boldsymbol{E} \times \boldsymbol{H}, \tag{21}$$

which is the unique bilinear flux built from the operational forcing fields $(\boldsymbol{E}, \boldsymbol{H})$ that appear in the loop integrals Eqs. (17)–(18). In QMU the mechanical work density performed on charge transport is taken in the conjugate pairing:

$$p_{\mathrm{work}} \equiv \boldsymbol{J}_e \cdot \boldsymbol{E}^\star, \tag{22}$$

because $\boldsymbol{E}^\star$ is the constitutive dual of $\boldsymbol{D}$ and is therefore the energetic driver in the $(\boldsymbol{D}, \boldsymbol{E}^\star)$ pairing.

**Electric transport current density.** The vector field $\boldsymbol{J}_e$ denotes the electric-channel charge-current density: the rate of transport of electric charge $q_e$ through oriented area. For any surface $S$,

$$I_e(S) \equiv \oiint_S \boldsymbol{J}_e \cdot \mathrm{d}\boldsymbol{S}, \tag{23}$$

so $\boldsymbol{J}_e$ is the surface-density seat whose flux gives the transported current seat $I_e$. Dimensionally in QMU,

$$[\boldsymbol{J}_e] = \frac{\text{chrg freq}}{\text{area}}, \tag{24}$$

i.e., charge-per-clock per area. (Analogously, $\boldsymbol{J}_m$ is the magnetic-channel charge-current density for $q_m$.)

## 5.3 Integral energy balance (QMU statement)

With the definitions above, the QMU energy balance over a control volume $V$ with boundary $\partial V$ is stated as

$$\frac{\mathrm{d}}{\mathrm{d}t} \iiint_V u \, \mathrm{d}V + \oiint_{\partial V} \boldsymbol{S} \cdot \mathrm{d}\boldsymbol{A} = -\iiint_V \boldsymbol{J}_e \cdot \boldsymbol{E}^\star \, \mathrm{d}V, \tag{25}$$

which is the QMU conservation statement used throughout the circuit reductions that follow. Equation (25) is the operational criterion that determines when a reduced element law is admissible: it must preserve the exception-class semantics and must reproduce the correct sign and scaling of the work term in the conjugate pairing. [Poynting, 1884]

(Here the negative sign indicates energy transfer from the electromagnetic field seats to the charge-carrier sector, i.e., work done by the field on the transport current within $V$.)

### 5.4 From field seats to element seats

For a reduced branch (element) occupying a localized region, the volume energy seat $\mathcal{U}$ is mapped to the element energy unit enrg of Sec. 6 by a geometry reduction that preserves Eq. (25). In practice, the reduction identifies a dominant branch clock freq (or resonance seat rson) and uses the QMU closures of Sec. 6 to express storage and loss strictly in the primitives $\{\mathrm{indc}, \mathrm{capc}, \mathrm{cond}\}$.

## 6 Circuit primitives and element laws in QMU

Circuit theory in APM is built from the same observables that appear in the field integrals:

$$\Phi_E \equiv \oiint_S \boldsymbol{D} \cdot \mathrm{d}\boldsymbol{S}, \qquad \Phi_B \equiv \oiint_S \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S}, \tag{26}$$

together with QMU energy and charge book-keeping. In particular, we treat resonance as a *ledger primitive* rather than an emergent SI mnemonic: the resonant seat rson and the frequency seat freq are fundamental QMU variables that determine how inductive and capacitive operators enter reduced circuit models.

### 6.1 Resonance-seat identities (QMU unit closures)

In QMU, the inductive and resonant primitives are related by unit identities that are used throughout this paper as *dimensional closures*:

$$\mathrm{mflx} = \mathrm{indc}\,\mathrm{freq}, \tag{27}$$

$$\mathrm{minr} = \mathrm{indc}\,\mathrm{chrg}, \tag{28}$$

$$\mathrm{rson} = \mathrm{freq}^2, \tag{29}$$

$$\mathrm{temp} = \mathrm{freq}^2\,\mathrm{area} \;=\; \mathrm{rson}\,\mathrm{area}. \tag{30}$$

Equation (27) is the defining flux–clock relation for the QMU inductance primitive. Equation (28) defines the corresponding inertia seat minr induced by charge occupancy. Equation (29) defines the resonance seat rson, and Eq. (30) is the thermal-area closure used when coupling resonant electrodynamics to temperature observables.

### 6.2 Potential and capacitance (QMU definitions)

In QMU, potential is defined by

$$\mathrm{potn} \equiv \frac{\mathrm{enrg}}{\mathrm{chrg}}, \tag{31}$$

and the capacitance primitive is

$$\mathrm{capc} \equiv \frac{1}{\mathrm{potn}}. \tag{32}$$

Equations (31)–(32) are definitions; they are not imported from conventional-unit circuit heuristics. In particular, any expression proportional to chrg/potn is dimensionally distinct from capc and is inadmissible in QMU.

A QMU-consistent resonance energy seat is defined by the inertia–resonance product

$$\mathrm{enrg} \equiv \mathrm{minr}\,\mathrm{rson}. \tag{33}$$

Using Eqs. (28) and (29), this yields the QMU potential closure

$$\mathrm{potn} = \frac{\mathrm{enrg}}{\mathrm{chrg}} = \frac{\mathrm{minr}\,\mathrm{rson}}{\mathrm{chrg}} = \mathrm{indc}\,\mathrm{rson} = \mathrm{mflx}\,\mathrm{freq}, \tag{34}$$

and therefore

$$\mathrm{capc} = \frac{1}{\mathrm{potn}} = \frac{1}{\mathrm{indc}\,\mathrm{rson}} = \frac{1}{\mathrm{mflx}\,\mathrm{freq}}. \tag{35}$$

The QMU lumped-resonance closure is then stated directly in seat variables as

$$\mathrm{rson} = \frac{1}{\mathrm{indc}\,\mathrm{capc}}, \tag{36}$$

which is the APM/QMU resonance law used in the lumped eigenproblem of Sec. 8.

## 6.3 Conductance and magnetic flux

The no-CCF exception-class conductance is the reciprocal magnetic flux:

$$\mathrm{cond} = \mathrm{mflx}^{-1}, \tag{37}$$

and the magnetic flux unit admits the action-charge representation [Tiesinga et al., 2021]

$$\mathrm{mflx} = \frac{h}{{e_{\mathrm{emax}}}^2}. \tag{38}$$

Thus $\mathrm{cond} = {e_{\mathrm{emax}}}^2/h$ is the QMU conductance quantum, and the electric-channel conductance reduction follows from Eq. (3).

## 6.4 Inductance as the flux–clock operator

The inductance primitive indc is a no-CCF substrate operator. In QMU it is fixed dimensionally by the two unit identities $\mathrm{mflx} = \mathrm{indc}\,\mathrm{freq}$ and $\mathrm{minr} = \mathrm{indc}\,\mathrm{chrg}$ (Eqs. (27)–(28)). Operationally, a reduced circuit model assigns a branch clock freq (or resonance seat rson) and interprets the linked magnetic flux observable $\Phi_B$ as a flux seat consistent with mflx. In the resonant regime this implies the directly measurable mapping

$$\Phi_B \sim \mathrm{indc}\,\mathrm{freq}, \tag{39}$$

where the proportionality becomes equality when $\Phi_B$ is evaluated in the same branch clock normalization used to define freq for the reduced eigenproblem.

Eliminating indc between Eqs. (27) and (28) yields the flux–inertia bridge

$$\mathrm{minr}\,\mathrm{freq} = \mathrm{chrg}\,\mathrm{mflx}, \tag{40}$$

which is the QMU statement that charge–flux book-keeping is equivalent to rotational impulse book-keeping in the inductive channel. Equation (40) provides a direct geometric interpretation of indc: magnetic flux is to the branch clock what inertia is to charge. Equivalently, the inductive channel trades chrg-occupancy against freq-occupancy via mflx, with minr acting as the rotational seat that ensures the exchange closes dimensionally in QMU. In this sense, indc is not a material "constant" but a geometry-dependent operator that encodes how boundary conditions convert charge seats into flux seats under a chosen clock normalization.

# 7 Distributed reduction: lines, matching, and QMU impedance partitioning

Circuit theory in QMU is a boundary-value reduction of the same operator content as the field transport system. The reduction is most transparent in distributed structures (waveguides, transmission lines, cavities), where the wave-sector product perm ptty fixes the propagation seat while the ratio $Z^2 = A_u/\mathrm{curl}$ fixes the partitioning of electric and magnetic strength seats.

## 7.1 Propagation seat and partitioning seat

In uniform Aether, the propagation product is $\mathrm{perm}\,\mathrm{ptty} = 1/(F_q\lambda_C)^2$ (Eq. (6)), and the impedance-like partitioning invariant is $Z^2 = A_u/\mathrm{curl}$ (Eq. (7)). These two seats are the distributed "boundary conditions" that reduced circuit models must inherit.

## 7.2 Effective per-length operators

For a line-like geometry parameterized by coordinate $z$, define effective per-length operators $\mathrm{indc}_\ell$ and $\mathrm{capc}_\ell$ as the geometry-reduced storage primitives that reproduce the correct field energy seat (Eq. (19)) per unit length. They are not conventional-unit parameters; they are QMU operators that summarize the boundary-value reduction of $\mathrm{perm}_{ij}(\omega)$ and $\mathrm{ptty}_{ij}(\omega)$ for the chosen cross-section and material state.

In the lossless limit, a distributed eigenproblem inherits a QMU resonance-seat closure of the form

$$\mathrm{rson} \;\sim\; \frac{1}{\mathrm{indc}_\ell\,\mathrm{capc}_\ell}\,\mathrm{wavn}^2, \tag{41}$$

where wavn is the QMU wavenumber and the proportionality constant is fixed by the exact boundary geometry. Equation (41) is the distributed analogue of the lumped resonance closure $\mathrm{rson} = (\mathrm{indc}\,\mathrm{capc})^{-1}$ (Eq. (36)) and makes explicit the route by which the wave-sector eigenvalue problem reduces to element seats.

## 7.3 Matching as a QMU partition problem

For line termination and cavity coupling, the matching condition is a statement about partitioning of conjugate strengths (Eq. (14)) rather than a conventional-unit impedance ratio. In the reduced description, the line inherits a partitioning ratio schematically

$$Z^2_{\mathrm{line}} \;\sim\; \frac{\mathrm{indc}_\ell}{\mathrm{capc}_\ell}, \tag{42}$$

and admissible matching is achieved when the geometry-reduced partitioning $Z^2_{\mathrm{line}}$ reproduces the substrate partitioning seat $Z^2$ up to the known geometry factor of the structure. This framing keeps matching QMU-first: it is a statement about seat partitioning, not a conventional-unit mnemonic.

# 8 Resonance in the APM electromagnetic sector

## 8.1 Distributed resonance (wave-sector reduction)

From Eq. (6), the wave-sector dispersion in uniform Aether has the form

$$\omega^2 = \frac{1}{\text{perm}\,\text{ptty}}\,k^2 = (F_q\lambda_C)^2 k^2, \tag{43}$$

so any geometry that quantizes $k$ defines resonance frequencies purely in QMU.

## 8.2 Lumped resonance as a reduced eigenproblem

A lumped resonator is defined as a geometry-reduced eigenproblem of the same operator content as Eq. (43), with element primitives $\{\text{capc}, \text{indc}, \text{cond}\}$ representing the coarse-grained response of the boundary geometry. The key modeling requirement is that every reduced law preserve the QMU exception-class semantics. In particular, the resonance seat closure $\text{rson} = 1/(\text{indc}\,\text{capc})$ (Eq. (36)) is used as the fundamental lumped eigenvalue condition, rather than importing conventional-unit LC mnemonics.

## 8.3 Worked QMU example: single-mode lumped resonator closure

A minimal lumped resonator in QMU is specified by a storage pair $(\text{indc}, \text{capc})$ and a selected mode (single branch clock freq). The resonant eigenvalue is the resonance seat $\text{rson} = \text{freq}^2$ (Eq. (29)). The QMU closure derived in Sec. 6 is

$$\text{rson} = \frac{1}{\text{indc}\,\text{capc}}, \tag{44}$$

which fixes the mode frequency as

$$\text{freq} = \sqrt{\text{rson}} = \frac{1}{\sqrt{\text{indc}\,\text{capc}}}. \tag{45}$$

The energetic seat is $\text{enrg} = \text{minr}\,\text{rson}$ (Eq. (33)) and the potential seat is $\text{potn} = \text{indc}\,\text{rson} = \text{mflx}\,\text{freq}$ (Eq. (34)). Therefore, for a calibrated resonant mode, any two of the observables $\{\text{freq}, \text{potn}, \text{mflx}\}$ determine the third without leaving QMU.

**Flux–clock inference of** indc**.** From $\text{mflx} = \text{indcfreq}$ (Eq. (27)), measuring the branch clock freq and evaluating the linked flux seat in the same normalization yields

$$\text{indc} = \frac{\text{mflx}}{\text{freq}}. \tag{46}$$

In resonant metrology this is the preferred route because it avoids importing any potential-based heuristic into the inductive primitive.

**Thermal coupling via** temp = rson area**.** If the resonator is operated in a regime where the temperature observable is coupled to the resonant seat, the QMU thermal-area closure temp = rson area (Eq. (30)) yields

$$\text{area} = \frac{\text{temp}}{\text{rson}} = \frac{\text{temp}}{\text{freq}^2}, \tag{47}$$

which provides a direct scaling discriminator: at fixed temp, increasing the mode clock increases rson and therefore reduces the effective area seat required to maintain the same thermal coupling. In boundary-limited resonators (including Casimir-constrained gaps and cavity inserts) [Casimir, 1948], the effective area seat is set by accessible boundary geometry; therefore Eq. (47) implies a geometric ceiling on high-freq operation at fixed temp: increasing the clock pushes the admissible thermal-coupling area toward smaller boundary domains.

# 9 Quantum Hall response in QMU

The quantum Hall sector is naturally expressed in QMU because cond is a ledger primitive. [von Klitzing et al., 1980, von Klitzing, 1986, Thouless et al., 1982, Laughlin, 1981] From Eqs. (37)–(38) we have the QMU conductance quantum

$$\text{cond} = \frac{e_{\text{emax}}{}^2}{h}. \tag{48}$$

Using the channel conversion factor (3) [Tiesinga et al., 2021], the electric-channel conductance quantum reduces to

$$\frac{e^2}{h} = (8\pi\alpha)\,\text{cond}. \tag{49}$$

Therefore the integer-plateau Hall conductance is stated QMU-first as

$$\sigma_H = \nu\,(8\pi\alpha)\,\text{cond}, \qquad \nu \in \mathbb{Z}, \tag{50}$$

and the corresponding Hall resistive plateau is

$$\rho_H = \frac{1}{\sigma_H} = \frac{\text{mflx}}{\nu\,(8\pi\alpha)}. \tag{51}$$

Equations (50)–(51) are QMU-native: they remain meaningful without any conventional-unit intermediate and they make explicit the role of the channel conversion factor in translating between electric and magnetic charge book-keeping.

## 9.1 Operational plateau metrology as a QMU ratio

The utility of the quantum Hall response in QMU is that it realizes the conductance primitive cond = $\text{mflx}^{-1}$ as a reproducible laboratory standard without any conventional-unit intermediate.

From Eq. (50), the plateau conductance satisfies

$$\frac{\sigma_H}{\text{cond}} = \nu\,(8\pi\alpha), \tag{52}$$

which is a QMU-first statement: the left-hand side is a pure ratio against the ledger conductance primitive, and the right-hand side isolates the integer occupancy $\nu$ and the channel conversion factor $8\pi\alpha$.

**Plateau extraction.** Operationally, one determines the plateau index by measuring $\sigma_H$ as a device response and forming the ratio $\sigma_H/\mathrm{cond}$. The APM bookkeeping is explicit: cond is a magnetic-channel primitive ($e_{\mathrm{emax}}{}^2/h$), while the appearance of the electric-channel conductance reduction $(8\pi\alpha)\mathrm{cond}$ in Eq. (49) is entirely due to the channel factor Eq. (3). The plateau ratio Eq. (52) therefore separates (i) integer occupancy $\nu$, (ii) channel bookkeeping, and (iii) the flux/action primitive mflx.

**Hall resistance seat.** The resistive plateau (Eq. (51)) may be restated as a direct flux-seat expression:

$$\rho_H = \frac{\mathrm{mflx}}{\nu\,(8\pi\alpha)}, \tag{53}$$

which makes explicit that the Hall resistance is an inverse occupancy of the flux seat modulated only by the channel conversion factor.

## 9.2 Superconducting flux seats and the Josephson clock law (QMU)

A key advantage of the QMU circuit closures is that the Josephson-type clock law [Josephson, 1962] is not imported as a conventional-unit relation; it is an immediate consequence of the QMU potential closure (Eq. (34)). From

$$\mathrm{potn} = \mathrm{mflx}\,\mathrm{freq}, \tag{54}$$

the branch clock is

$$\mathrm{freq} = \frac{\mathrm{potn}}{\mathrm{mflx}}. \tag{55}$$

Equation (55) states that a junction (or any phase-coherent resonant element) acts as a *potential-to-clock transducer*, with slope set by the flux seat mflx.

**General occupancy scaling of the flux seat.** Because QMU charge primitives are square-charges, coherent multi-carrier transport is naturally represented by an integer occupancy factor on the relevant magnetic square-charge seat. Write

$$\begin{aligned} e_{\mathrm{emax},n}{}^2 &\equiv n\, e_{\mathrm{emax}}{}^2, \\ \mathrm{mflx}^{(n)} &\equiv \frac{h}{e_{\mathrm{emax},n}{}^2} = \frac{1}{n}\,\mathrm{mflx}. \end{aligned} \tag{56}$$

Thus, in QMU, coherent pairing or multi-channel coherence is detected as an *integer slope change* in the freq–potn relation, referenced directly to the primitive mflx.

**Pairing expectation (square-charge semantics).** If the coherent carrier corresponds to a doubled unsquared charge in the underlying seat bookkeeping, then the associated square-charge occupancy scales by a factor of four. In that case the natural QMU pair occupancy is $n = 4$, yielding $\mathrm{mflx}^{(\mathrm{pair})} = \mathrm{mflx}/4$ and therefore

$$\mathrm{freq}_{\mathrm{pair}} = 4\,\frac{\mathrm{potn}}{\mathrm{mflx}}. \tag{57}$$

The factor $n$ is therefore an experimentally accessible discriminator of the correct QMU pairing bookkeeping: it is determined by a pure ratio measurement of slopes, without leaving QMU.

**Metrological hook.** A practical test is to compare the measured freq/potn slope of a phase-coherent junction against the reference slope implied by the magnetic flux primitive mflx (Eq. (55)). Any departure by an integer factor $n$ identifies the effective magnetic square-charge occupancy ${e_{\mathrm{emax},(n)}}^2$ of the coherent transport channel.

## 10 Experimental hooks and metrological strategy

- **Impedance-like partitioning.** The ratio $Z^2 = A_u/\mathrm{curl}$ can be inferred from conjugate-strength partitioning observables (Eq. (14)) in controlled waveguide or cavity geometries.
- **QHE plateau as a conductance standard.** The integer plateau $\sigma_H$ provides a direct operational realization of cond (Eq. (48)) and isolates the channel factor via Eq. (49).
- **Flux–clock inductance.** Resonant measurements that determine freq and $\Phi_B$ in a calibrated loop directly constrain indc via the QMU flux–clock closure $\mathrm{mflx} = \mathrm{indc}\,\mathrm{freq}$ (Eq. (27)).
- **Non-uniform Aether response.** Tensor generalizations of $\mathrm{perm}_{ij}(\omega)$ and $\mathrm{ptty}_{ij}(\omega)$ predict birefringence and polarization eigenmode shifts in non-uniform rmfd states, supplying a wave-sector discriminator for Aether anisotropy Thomson III [2025b].

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