Mesh Model Equations Cheat Sheet

Overview

This cheat sheet summarizes key equations from the Mesh Model framework, covering discrete mesh mechanics, quantum field emergence, and geometric structure. It reflects the core pipeline developed in the Mesh-Field Transformer and its alignment with both classical and quantum field theory.

Legend

q_i	Generalized coordinate
$\dot{q}_i$	Time derivative of q_i
T	Kinetic energy
V	Potential energy
m	Mass
R	Radial or rotational coordinate
θ	Angular position
G	Gravitational constant
M	Mass of a black hole or object
r	Radial coordinate
c	Speed of light
$\rho(x)$	Energy density at position x
$\hbar$	Reduced Planck's constant
ω	Angular frequency
$\hat{H}$	Hamiltonian operator
$\hat{p}$	Momentum operator
$\hat{x}$	Position operator
E_n	Energy of the n-th quantum state
ϕ_i	Field value at node i
$\phi(x)$	Continuous field approximation
$\pi(x)$	Canonical momentum density
a	Lattice spacing
$\mathcal{L}$	Lagrangian density
ds	Line element in spacetime
$f(x)$	Emergent metric factor
S	Action
ΔS	Change in action across a curvature gradient

1 Lagrangian Mechanics

1.1 Generalized Coordinates

$$L(q_i, \dot{q}_i, t) = T - V$$

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q_i} = 0$$

1.2 Particle on a Circle

$$L = \frac{1}{2} m R^2 \dot{\theta}^2$$

2 General Relativity Integration

2.1 Schwarzschild Metric

$$ds^2 = -\left(1 - \frac{2GM}{r}\right) c^2 dt^2 + \left(1 - \frac{2GM}{r}\right)^{-1} dr^2 + r^2 d\Omega^2$$

2.2 Mesh-Emergent Metric

$$ds^2 = -f(x)^2 dt^2 + dx^2, \quad f(x) = \sqrt{1 - \frac{2G\rho(x)}{c^2}}$$

3 Quantum Mechanics

3.1 Quantum Harmonic Oscillator

$$\hat{H} = \frac{\hat{p}^2}{2m} + \frac{1}{2} k \hat{x}^2$$

$$E_n = \hbar\omega\left(n + \frac{1}{2}\right)$$

4 Field Theory on a Mesh

4.1 Discrete Scalar Field (Lattice)

$$L = \sum_i \left[\frac{1}{2}\dot{\phi}_i^2 - \frac{1}{2a^2}(\phi_{i+1} - \phi_i)^2\right]$$

4.2 Continuum Limit (Wave Equation)

$$m\frac{\partial^2\phi}{\partial t^2} = k\frac{\partial^2\phi}{\partial x^2}$$

4.3 Lagrangian Density (Continuum)

$$\mathcal{L} = \frac{1}{2}m\left(\frac{\partial\phi}{\partial t}\right)^2 - \frac{1}{2}k\left(\frac{\partial\phi}{\partial x}\right)^2$$

4.4 Canonical Quantization

$$[\hat{\phi}(x), \hat{\pi}(y)] = i\hbar\delta(x-y)$$

5 Mesh Drive and Coherence Gradient

5.1 Curvature Propulsion

$$\Delta S = S_{\text{front}} - S_{\text{rear}} < 0$$

Motion arises from asymmetry in the mesh curvature gradient.

6 Core Equations of the Mesh Model

6.1 1. Coupled Lagrangian (Structure + Curvature + Coherence)

$$\mathcal{L} = -T_0\sqrt{1-\frac{1}{T_0}g^{\mu\nu}\partial_\mu\phi\,\partial_\nu\phi} - V(\phi) + \frac{1}{2}K^{\mu\nu\alpha\beta}\nabla_\mu h_{\alpha\beta}\nabla_\nu h^{\alpha\beta} - \frac{1}{2\kappa}\phi^2 g^{\mu\nu}h_{\mu\nu}$$

Tagline: "Spacetime emerges when coherence meets resistance."

6.2 2. Mesh–Field Transformer (Curved-Compatible)

$$\phi(x) = \sum_i \phi_i\,\psi_i(x), \quad \text{with} \quad \psi_i(x) = \frac{\exp\left(-\frac{d^2(x,x_i)}{\sigma^2}\right)}{\sum_j \exp\left(-\frac{d^2(x,x_j)}{\sigma^2}\right)}$$

$$V_{\text{field}} = \int \frac{1}{2}k\,g^{\mu\nu}(x)\,\partial_\mu\phi(x)\,\partial_\nu\phi(x)\,\sqrt{-g(x)}\,d^4x$$

Tagline: "Structure becomes field — the mesh becomes physics."

6.3 3. Inversion Equation (Structure Defines Geometry)

$$g^{\mu\nu}(x) \propto \frac{1}{\mathcal{E}(x)}\sum_{i,j}\phi_i\phi_j\,\partial^\mu\psi_i(x)\,\partial^\nu\psi_j(x)$$

Tagline: "Curvature is structure. Geometry is earned."