Phase 12 – Quantization & Coupling  
Part 4: ψ Coupling to Matter Fields

ψ as an interaction mediator  
I extend ψ-gravity into the quantum regime by introducing couplings between ψ and matter fields.  
General form of interaction Lagrangian:

Plain text:  
Lint = g\_s ψ φ² + g\_f ψ χ̄χ + g\_A ψ Fμν Fμν.

Where:

* ϕ = scalar field
* χ = fermion field
* Fμν = gauge field strength
* g\_s, g\_f, g\_A = coupling constants

Scalar–ψ coupling  
Equation of motion for scalar with ψ coupling:

Plain text:  
(□ + mφ²) φ(x) + 2 g\_s ψ(x) φ(x) = 0.

Effective mass shift:

Plain text:  
mφ,eff²(x) = mφ² + 2 g\_s ψ(x).

Fermion–ψ coupling  
Interaction Hamiltonian density:

Plain text:  
Hint(f) = − g\_f ψ χ̄χ.

The Dirac equation becomes:

Plain text:  
(iγμ ∂μ − mχ − g\_f ψ) χ = 0.

ψ thus acts as a dynamical mass contribution for fermions.

Gauge–ψ coupling  
Gauge field interaction term:

Plain text:  
Lint(A) = −1/4 (1 + g\_A ψ) Fμν Fμν.

This induces ψ-dependent variation of the effective gauge coupling.

ψ-mediated interaction between matter fields  
At tree-level, ψ exchange generates a potential between two matter sources :

Plain text:  
V(r) ~ − (g1 g2 / 4π) e^(−mψ r) / r.

Thus ψ quanta act as mediators of a Yukawa-type force.

Path integral with matter couplings  
Extended generating functional:

Plain text:  
Z[…] = ∫ Dψ Dφ Dχ DA exp{ i/ħ ∫ d⁴x [ Lψ + Lmatter + Lint + sources ] }.

Feynman rules for ψ exchange  
Propagator:

Plain text:  
Gψ(k) = iħ / (k² − mψ² + iε).

Vertex couplings:

* Scalar–ψ: factor .
* Fermion–ψ: factor .
* Gauge–ψ: factor .

Simulation: ψ-mediated scalar scattering amplitude  
I simulate the leading-order ψ-exchange contribution to 2 → 2 scalar scattering.

# simulations/phase12\_part4\_scalar\_scattering.py  
import numpy as np  
  
# Define momentum transfer q²  
def scattering\_amplitude(q2, gs, mpsi, hbar=1.0):  
 # ψ propagator contribution  
 return (1j \* gs\*\*2 \* hbar) / (q2 - mpsi\*\*2 + 1j\*1e-6)  
  
# Parameters  
gs = 0.5  
mpsi = 1.0  
  
# Sample q² values  
q2\_vals = np.linspace(-5, 5, 50)  
amp\_vals = [scattering\_amplitude(q2, gs, mpsi) for q2 in q2\_vals]  
  
print("Sample scattering amplitudes (real part):", np.real(amp\_vals[:10]))  
print("Sample scattering amplitudes (imag part):", np.imag(amp\_vals[:10]))