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4.3. Entanglement Entropy and the Page Curve

The entanglement entropy S of particle B is:

$$S = -\text{Tr}_B (\rho_B \log \rho_B),$$

with $\rho_B = \text{Tr}_A (|\Psi_{AB}\rangle\langle\Psi_{AB}|)$.

The **Page curve** describes how S evolves over time, initially increasing as entanglement builds and decreasing as the black hole evaporates, suggesting information is eventually released back into the universe.

5. Detailed Calculations

5.1. Entanglement Entropy Calculation

Step 1: Write the Density Matrix

$$|\Psi_{AB}\rangle\langle\Psi_{AB}| = \frac{1}{2} (|0\rangle_A|1\rangle_B + |1\rangle_A|0\rangle_B) (\langle 0|_A\langle 1|_B + \langle 1|_A\langle 0|_B).$$

Step 2: Partial Trace over Particle A

Compute $\rho_B = \text{Tr}_A (|\Psi_{AB}\rangle\langle\Psi_{AB}|)$:

$$\rho_B = \frac{1}{2} (|1\rangle_B\langle 1|_B + |0\rangle_B\langle 0|_B) = \frac{1}{2} I_B,$$

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