Magnetic fields
from the second order perturbation theory

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Magnetic fields are observed ubiquitously even on large scales.
- galaxy, cluster scales $\sim O(10^{-6})$ Gauss,
- Intergalactic scales (or voids?) $> O(10^{-22})$ Gauss

Cosmological magnetic fields $= \text{seed fields} + \text{dynamo mechanism}$

**Question.**
Can we generate *seed fields* in the standard cosmology?

$\Rightarrow 2^{\text{nd}} \text{order perturbation theory}$
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**Harrison mechanism**

Primordial plasma in the early universe
→ Thomson scattering induces the relative velocity between protons and electrons
→ The rotational currents induce magnetic fields.

\[
\frac{d B^i}{dt} = \frac{4 \sigma_T \rho_\gamma^{(0)} a}{3e} \epsilon^{ijk} \left[ \frac{1}{2} \delta v^{(2)}_{\gamma bj,k} - \delta^{(1)}_{\gamma j} \delta v^{(1)}_{\gamma bk} - \frac{3}{4} \left( v^{(1)}_{el} \Pi^{(1)l} \right)_{,k} \right]
\]

2\text{nd order Slip term}

Slip term  Anisotropic stress
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Magnetic field spectrum at cosmological recombination:

![Graph showing magnetic field spectrum at different k values.

Remark
- Bump at $k \sim 0.5 \, h\text{Mpc}^{-1}$
- Non-trivial cancellation!}