


"Analogue" relativity in condensed matter

Relativistic energy: \( E = \sqrt{\left(\hbar c k\right)^2 + (mc^2)^2} \)

If \( m \) finite

<table>
<thead>
<tr>
<th>Case</th>
<th>bare mass</th>
<th>effective mass</th>
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</thead>
<tbody>
<tr>
<td>Semiconductors</td>
<td>( \epsilon_0 = \hbar c</td>
<td>k</td>
</tr>
<tr>
<td>Massless case</td>
<td>( \epsilon_0 = \hbar c</td>
<td>k</td>
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Due to the interaction of the electrons with the lattice atoms, usually \( m \) is finite. In graphene it actually vanishes.

Graphene

The corresponding Dirac equations are mapped to each other by parity: around the \( K \)-point the pseudospin directions are just opposite to the \( K' \)-point. For \( \gamma \) this could be reproduced by a parity mapping the two supergravity Chern-Simons theories of the Achucarro-Townsend formulation into each other.

The reciprocal lattice of graphene is also a honeycomb lattice, featuring two inequivalent types of Dirac points: \( K \) and \( K' \).

The graphene Dirac cone

The electron band structure of graphene

At the Dirac points (for a range of 1eV) the spectrum is linear: \( E \sim \pm \hbar c |k| \) where

\( m \) is the bare mass and \( v_F \) is the Fermi velocity.

\( m \) = 11 supergravity. By studying a self-duality condition \( K_3 \mid K_4 \rangle \rangle \langle \eta \mid K_3 \rangle \rangle \) of the AdS3 boundary, starting from \( V^T \rightarrow 2 \) pure supergravity theory in the AdS3 bulk.

This top-down approach to graphene is more predictive than the more common bottom-up one, because it is constrained from the properties of the \( Z = 3 \rightarrow 1 \) supergravity theory.

BRST quantization: We have explained the relation between the propagating spinor in the AVZ model and the supersymmetry parameter as a particular unconventional gauge-fixing of a Chern-Simons theory in the framework of a BRST quantization. Indeed, supergravity in \( D = 3 \) is topological, and coincides with difference of two \( \tilde{\gamma} \) Chern-Simons forms. The corresponding Dirac equation is:

\( \gamma \partial \gamma = \frac{1}{2} \epsilon_0 \sqrt{\left(\hbar c k\right)^2 + (mc^2)^2} \)