AB and the Meaning of Multiply Connected Field Free Regions

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Let us examine the magnetic AB effect. The standard expression for the interaction of an electron with the vector potential A is (see [1], p. 48)

$$L_{int} = -e\mathbf{v}_{(e)}\cdot\mathbf{A}, \tag{1}$$

where -e, $\mathbf{v}_{(e)}$ denote the electronic charge and its velocity, respectively. Now, in the case of the magnetic AB effect, the vector potential is a sum of the vector potentials of the magnetic dipoles of the source. Therefore, (1) can be cast into a sum of 2-body interactions

$$L_{int} = -e\sum_i \mathbf{v}_{(e)}\cdot\mathbf{A}_i. \tag{2}$$

On the other hand, one may write the 2-body interaction not as an interaction of the traveling electron with the vector potential of the ith dipole but as an interaction of the ith dipole with the magnetic field of the traveling electron (see [2], p. 186)

$$L_{int} = -\sum_i \mathbf{B}_{(e)}\cdot\boldsymbol{\mu}_i. \tag{3}$$

Here $\mathbf{B}_{(e)}$ denotes the magnetic field of the traveling electron and $\boldsymbol{\mu}_i$ denotes the ith magnetic dipole at the source. In expression (3) for the interaction, the electron's magnetic field takes no null value throughout the entire space. Thus, there is no field free region and, a fortiori, no multiply connected field free region. Since (3) is a legitimate expression for the interaction, one concludes that the magnetic AB effect does not prove that topology plays an inherent role in quantum mechanics. See also[3].

References:

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