394(1): Magnetic Dipole Field in the Zitterbewegung Theory

Consider Fig. (1):

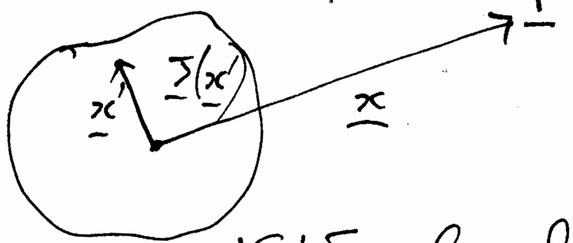

Fig (1)

A general current distribution localized in a small region of space, denoted $\underline{J}(\underline{x}')$, produces a magnetic induction at point P with coordinate $\underline{x}$. The vector potential is:

$$\underline{A}_0(\underline{x}) = \frac{\mu_0}{4\pi} \int \frac{\underline{J}(\underline{x}')}{|\underline{x}-\underline{x}'|} d^3x' \quad -(1)$$

which can be expanded in terms of the vector spherical harmonics. If:

$$|\underline{x}| >> |\underline{x}'| \quad -(2)$$

then:

$$\frac{1}{|\underline{x}-\underline{x}'|} = \frac{1}{|\underline{x}|} + \frac{\underline{x}\cdot\underline{x}'}{|\underline{x}|^3} + \dots \quad -(3)$$

Defining the magnetic dipole moment by:

$$\underline{m} = \frac{1}{2}\int \underline{x}' \times \underline{J}(\underline{x}')\, d^3x' \quad -(4)$$

the second term on the right hand side of eq. (3) gives the magnetic dipole vector potential:

$$\underline{A}_0(\underline{x}) = \frac{\mu_0}{4\pi} \frac{\underline{m}\times\underline{x}}{|\underline{x}|^3} \quad -(5)$$

The magnetic flux density outside the localized

2) Source is:

$$\underline{B}_0 = \underline{\nabla} \times \underline{A}_0 \quad -(6)$$

in the hypothetical absence of the vacuum. So:

$$\underline{B}_0 = \frac{\mu_0}{4\pi}\left(\frac{3\underline{n}(\underline{n}\cdot\underline{m}) - \underline{m}}{|\underline{x}|^3}\right) \quad -(7)$$

where

$$\underline{n} = \frac{\underline{x}}{|\underline{x}|} \quad -(8)$$

The effect of the vacuum is:

$$\underline{x} \rightarrow \underline{x} + \delta\underline{x} \quad -(9)$$

where $\delta\underline{x}$ is the shivering or zitterbewegung due to the vacuum. The magnetic flux density in the presence of the vacuum is:

$$\underline{B} = \frac{\mu_0}{4\pi}\left(\frac{3\underline{n}(\underline{n}\cdot\underline{m}) - \underline{m}}{|\underline{x} + \delta\underline{x}|^3}\right)$$

$$= \underline{\nabla} \times \underline{A}_0 - \underline{\omega} \times \underline{A}_0 \quad -(10)$$

$$= \underline{\nabla} \times \underline{A}$$

Here $\underline{\omega}$ is the vector spin connection or "vacuum map", and

$$\underline{n} = \frac{\underline{x} + \delta\underline{x}}{|\underline{x} + \delta\underline{x}|} \quad -(11)$$

The shivering magnetic dipole potential is

3)

$$\underline{A}(\underline{x}+\delta\underline{x}) = \frac{\mu_0}{4\pi}\frac{\underline{m}\times(\underline{x}+\delta\underline{x})}{|\underline{x}+\delta\underline{x}|^3} \quad -(12)$$

Therefore the magnetic flux density in the presence of the vacuum is:

$$\boxed{\underline{B} = \underline{B}_0 - \underline{\omega}\times\underline{A}_0} \quad -(13)$$

Similarly, as in UFT393:

$$\boxed{\underline{E} = \underline{E}_0 + \underline{\omega}\,\underline{\Phi}_0} \quad -(14)$$

In both cases, the vector spin connection can be calculated, giving the relevant vacuum map.

Note carefully that the experimentally observed electric and magnetic dipole fields are always $\underline{E}$ and $\underline{B}$, because the vacuum is always present.

From eqs. (7), (10) and (13):

$$\frac{3\underline{n}(\underline{n}\cdot\underline{m})-\underline{m}}{|\underline{x}+\delta\underline{x}|^3} = \frac{3\underline{n}_0(\underline{n}_0\cdot\underline{m})-\underline{m}}{|\underline{x}|^3} - \underline{\omega}\times\left(\frac{\underline{m}\times\underline{x}}{|\underline{x}|^3}\right) \quad -(15)$$

where

$$\underline{n} = \frac{\underline{x}+\delta\underline{x}}{|\underline{x}+\delta\underline{x}|}\,; \quad \underline{n}_0 = \frac{\underline{x}}{|\underline{x}|} \quad -(16)$$

4) Eq. (15) gives the vector spin connection $\underline{\omega}$.

The magnetic dipole moment $\underline{m}$ is a molecular or elementary particle property and appears in tables of data.

Fields far from a Current Loop

In this case, in the absence of the vacuum:

$$\underline{B}_0 = B_r \underline{e}_r + B_\theta \underline{e}_\theta \quad -(17)$$

$$= \frac{\mu_0}{2\pi r^3} (I\pi a^2) \left( \cos\theta \underline{e}_r + \sin\theta \underline{e}_\theta \right)$$

where $I$ is the current in the loop, and $a$ is its radius.

In the presence of the vacuum:

$$\underline{B} = \frac{\mu_0}{2\pi |\underline{r} + \delta\underline{r}|^3} (I\pi a^2) \left( \cos\theta \underline{e}_r + \sin\theta \underline{e}_\theta \right) \quad -(18)$$

As in UFT393:

$$\underline{B} = \frac{\mu_0 (I\pi a^2)}{2\pi r^3 (1+x)^{3/2}} \left( \cos\theta \underline{e}_r + \sin\theta \underline{e}_\theta \right) \quad -(19)$$

where

$$x = \frac{1}{r^2} \left( 2\underline{r} \cdot \delta\underline{r} + \delta\underline{r} \cdot \delta\underline{r} \right). \quad -(20)$$

We have used:

$$|\underline{r} + \delta\underline{r}| = \left( r^2 + 2 r \delta r + (\delta r)^2 \right)^{1/2}$$

$$= \left( r^2 + 2\underline{r} \cdot \delta\underline{r} + \delta\underline{r} \cdot \delta\underline{r} \right)^{1/2} \quad -(21)$$

) Using the binomial expansion:

$$\underline{B} = \frac{\mu_0}{4\pi} \frac{(I\pi a^2)}{r^3} \left(1 - \frac{3x}{2} + \frac{15x^2}{8} + \dots\right) \left(\cos\theta \, \underline{e}_r + \sin\theta \, \underline{e}_\theta\right) \quad -(22)$$

for

$$x \ll 1 \quad -(23)$$

The ensemble averaged magnetic flux density to first order in $x$ is:

$$\langle \underline{B} \rangle = \frac{\mu_0}{4\pi} \frac{(I\pi a^2)}{r^3} \left(1 - \frac{3}{2} \langle x \rangle\right) \left(\cos\theta \, \underline{e}_r + \sin\theta \, \underline{e}_\theta\right) \quad -(24)$$

where:

$$\langle x \rangle = \frac{1}{r^2} \langle 2\underline{r} \cdot \delta\underline{r} + \delta\underline{r} \cdot \delta\underline{r} \rangle \quad -(25)$$

$$= \frac{1}{r^2} \langle \delta\underline{r} \cdot \delta\underline{r} \rangle$$

So:

$$\langle \underline{B} \rangle = \frac{\mu_0 \, I\pi a^2}{4\pi \, r^3} \left(1 - \frac{3}{2r^2} \langle \delta\underline{r} \cdot \delta\underline{r} \rangle\right) \left(\cos\theta \, \underline{e}_r + \sin\theta \, \underline{e}_\theta\right) \quad -(26)$$

Similarly:

$$\langle \underline{E} \rangle = \frac{p}{4\pi\epsilon_0 r^3} \left(1 - \frac{3}{2r^2} \langle \delta\underline{r} \cdot \delta\underline{r} \rangle\right) \left(2\cos\theta \, \underline{e}_r + \sin\theta \, \underline{e}_\theta\right) \quad -(27)$$

6) The magnetic dipole moment is:

$$m = \pi I a^2 \quad -(28)$$

and is not affected by the vacuum. Similarly the electric and magnetic dipole moments of atoms and molecules, and of elementary particles, are not affected by the vacuum. The effect of the vacuum is always:

$$\underline{r} \rightarrow \underline{r} + \delta \underline{r} \quad -(29)$$

as in the well known Lamb shift theory.

Finally the spin connection vector can be worked out from:

$$\underline{B} = \underline{B}_0 - \underline{\omega} \times \underline{A}_0 \quad -(30)$$

So

$$\langle \underline{B} \rangle = \underline{B}_0 - \langle \underline{\omega} \rangle \times \underline{A}_0 \quad -(31)$$

Far from a current loop:

$$\underline{A}_0 = \frac{\mu_0 I a^2}{4 r^2} \sin\theta \, \underline{e}_\phi \quad -(32)$$

So:

$$\langle \underline{\omega} \rangle \times \underline{A}_0 = \underline{B}_0 - \langle \underline{B} \rangle \quad -(33)$$

From eqs. (17), (26) and (32), the mean spin connection or vacuum may can be worked out:

$$\frac{\langle \delta\underline{r}\cdot\delta\underline{r}\rangle}{r^5}\left(\cos\theta\,\underline{e}_r+\sin\theta\,\underline{e}_\theta\right)=\frac{\langle\underline{\omega}\rangle\times\underline{e}_\phi}{r^2}\quad-(28)$$

so $\langle\underline{\omega}\rangle$ can be evaluated.

In the next note the conservation of antisymmetry will be considered, and also methods for the evaluation of $\langle\delta\underline{r}\cdot\delta\underline{r}\rangle$ in an ensemble made up of vacuum particles.

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