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Comment On "Cancellation Of Internal Forces"

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argument. However, one then faces two problems. First of all we are teaching a course on quantum mechanics and we have made a particular point of the fact that superconductivity and the related phenomena are directly due to the fact that the carriers of charge are no longer fermions but have been transformed into bosons by means of a lattice coupling. And it is just this fact which is so very important and illustrative of the quite different behavior of fermions and bosons in quantum statistics. It therefore seems a pity to disregard this feature and "beg the question" by reverting to a less realistic model using single electrons.

The second problem one faces concerns the Meissner effect. How can the magnetic field in the interior of the ring be neutralized when only one current on the interior wall of the ring exists? It can't. And thus another question must be "begged." Using internal and external wall currents composed of coupled Cooper pairs not only is a more realistic situation, but also it begs neither of these questions and obtains the correct answer into the bargain.

Regarding Professor Firth's second paragraph where he says that the current on the outer surface of the ring does not contribute to the flux through the hole I can only observe that not only does Professor Firth disagree with me on this point but with Professors Maxwell and Ampère as well. If we integrate around a line of magnetic flux, the integral receives contributions from both the inner and outer currents. So in this sense the flux through the hole is due to both currents as I originally stated.

Regarding Professor Firth's alternative derivation I would only say that the more different derivations the better. However, when putting forward a plausibility argument of this type I personally feel that one should strive to be as "realistic" as possible with the framework of the particular course one is giving.

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COMMENT ON "CANCELLATION OF INTERNAL FORCES"

A brief note by J. W. McClain[1] brings up the very useful horse and cart and Newton III, i.e., if the horse and cart exert equal and opposite forces on each other, why is there any acceleration? This is a very useful example that everyone has used to remind students that the f in Newton II is the force *on* a body.

Unfortunately, the continuation of this note by McClain considerably muddies the clarity of the argument. When considering a system of particles, the correct equations are written down so that finally the rate of change of momentum of the system equals the external force, the internal forces canceling in pairs, by Newton III.

McClain then confuses this last statement invoking the horse and cart example again and concludes that the argument should go "that the internal forces are irrelevant to the motion of the center of mass of the system."

What does McClain think the underlined statement above says? It proves what he wants to take as an assumption (namely, his quote above) and it is that proof that is the point of the whole business.

[1] J. W. McClain, Am. J. Phys. **47**, 1005 (1980).

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REPLY TO "COMMENT ON 'CANCELLATION OF INTERNAL FORCES' "

There is, of course, no dispute about the first part of the underlined statement in Professor Brown's letter, which says that the rate of change of momentum equals the external force. The second part, however, speaks of the internal forces canceling in pairs by Newton III, and that is precisely the idea with which I take issue.

It is clear that in order to arrive at the principle expressed by the first part of the statement, we must replace the sum of forces by the sum of external forces. What reason shall we give for eliminating the sum of internal forces? I maintain that "the cancellation of internal forces in pairs" is not an acceptable reason, because the lesson of the horse-and-cart parable is that two action–reaction forces, acting as they do on different bodies, cannot cancel.

I suggest that a physically acceptable reason is available in the fact that the internal forces have no effect on the motion of the center of mass. This is not intended as an assumption (as Professor Brown believes I intend it), but as a consequence of Newton's laws of motion.

If two particles of a system exert equal and opposite forces on each other, then an application of Newton II shows that their resulting displacements are such that their center of mass is exactly where it would be if the two forces had been zero. Since the same is true for every pair of interacting particles in the system, we can conclude that internal forces do not affect the motion of the center of mass.

In this way the sum of internal forces can be eliminated and the equality established between rate of change of momentum and external force without contradicting the lesson of the horse and cart.

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COMMENT ON "INTUITIVE UNDERSTANDING OF PAULI'S σ MATRICES"

Following the interesting comments on the Pauli σ matrices by Levinger and Lichtenstein,[1] one may notice that the unit value of σ^2 along any axis, defined by unit vector $\hat{n}$, follows by putting $\mathbf{A} = \mathbf{B} = \hat{n}$ in the following identity.

$$(\sigma \cdot \mathbf{A})(\sigma \cdot \mathbf{B}) = \mathbf{A} \cdot \mathbf{B} + i\sigma \cdot (\mathbf{A} \wedge \mathbf{B})$$

Thus one may trust one's intuition.

[1] J. S. Levinger and R. M. Lichtenstein, Am. J. Phys. **47**, 744 (1979).

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