Superconductivity: A Time Region Phenomenon

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1 Introduction

The chief characteristic of superconductivity is the complete absence of the electrical resistance. As the temperature is decreased, the change from the normal to the superconducting state takes place abruptly at a critical temperature T_c. Though the phenomenon was discovered as far back as 1911, it resisted all theoretical understanding and not until 1957 was the famous BCS theory (Bardeen, Cooper, and Schrieffer) propounded. According to this theory, superconductivity occurs when the repulsive interaction between two electrons is overcome by an attractive one, resulting from a mechanism which gives rise to electron pairs since then known to be called the "Cooper Pairs"—that behaved like bosons and moved without resistance.

The tunneling and flux quantization experiments firmly established the presence of electron pairs. However, the *phonon mechanism* of electron pairing remained experimentally unproven. Subsequent experimental work brought to light many anomalies and unexplained results which demonstrated the inadequacy of the BCS theory. The theoretical trend, in the past decade, has been toward invoking the quantum mechanical concept of "exchange interactions" for the explanation of the formation of the electron pairs.

The explanation of the phenomenon of superconductivity from the point of view of the *Reciprocal System*, however, has not yet been attempted. Larson himself refers to the phenomenon with nothing more than a passing remark.[1] As the present author sees, progress toward this end would not have been possible in the Reciprocal System, as it needed the discovery of a new development, which emerged only recently. This is the new light thrown by the study of the "photon controversy," leading to the discovery of *birotation*.[2] It has been shown there that the two equal, and opposite rotational components of a birotation manifest as a linear Simple Harmonic Motion (SHM). The knowledge of this now opens the way toward understanding the phenomenon of superconductivity.

2 The Origin of the Phenomenon

It has been well-recognized that superconductivity, from the abruptness of its occurrence at the temperature T_c, is a collective phenomenon—like that of ferromagnetism, for example—involving all particles co-operatively. We have shown that the ferromagnetic ordering is the phenomenon of the time region.[3] We now find that superconductivity is the result of the electron motion entering the time region. In fact, since in solids the atoms are already in the time region, the region inside unit space, it follows that superconductivity, like ferromagnetism, results when the motion concerned crosses another regional boundary, namely, the time region unit of space (which is a compound unit).

1 Larson, Dewey B., *Basic Properties of Matter*, the International Society of Unified Science, Utah, U.S.A., 1983, p. 104.
2 K.V.K. Nehru, "The Law of Conservation of Direction," *Reciprocity*, XVIII (3), Autumn 1989, pp. 3-6.
3 K.V.K. Nehru, "Is Ferromagnetism A Co-magnetic Phenomenon?", *Reciprocity*, XIX (1), Spring 1990, p. 6

2.1 The Perfect Conductor

Larson points out: "…the electron is essentially nothing more than a rotating unit of space."[4] He identifies the movement of the electrons (rotating units of space) through matter (a time structure) as the electric current. We might note that there is no electric charge associated with these electrons. One of the causes, according to Larson, of the resistance to the flow of current is the spatial component of the thermal motion of the atoms. "If the atoms of the matter through which the current passes are effectively at rest…, uniform motion of the electrons (space) through matter has the same general properties as motion of matter through space. It follows Newton's first law of motion… and can continue indefinitely… This situation exists in the phenomenon known as *superconductivity*."[1]

We would like to point out that the actual situation is somewhat different. Firstly, as we will see later, superconductivity is not solely a phenomenon of zero resistance which we shall call the *perfect conduction* (that is, infinite conductivity), which is what Larson seems to imply by "superconductivity" in the paragraph cited above. The second fact is concerning the resistance caused by the impurity atoms due to their space displacement. Since the current moves, according to the Reciprocal System, through all the atoms of the conductor (including the impurity atoms), and not through the interstices between the atoms, there is a large contribution by the impurity atoms to the resistance.[5] Mere reduction of the thermal motion, therefore, cannot serve to eliminate the cause of resistance to the current.

2.2 The Electron Pair as a Birotation

In the "uncharged state the electrons cannot move with reference to extension space, because they are inherently rotating units of space, and the relation of space to space is not motion. … In the context of the stationary spatial system the uncharged electron, like the photon, is carried outward by the progression of the natural reference system."[6] But as the temperature is decreased below the critical value T_c and the electrons in the solid enter the region of the inside of the compound unit of space, the direction of the electron motion changes from outward to inward from the point of view of the stationary reference system. Thus the electrons start moving toward each other, as if mutually attracting.

Remembering that the electron is a unit of rotational space, when two of them with antiparallel rotations approach each other to an effective distance of less than one compound unit of space, the two opposite rotations form into a birotation. As explained in detail elsewhere[2] a birotation manifests as a Simple Harmonic Motion (SHM). We might call this process the "pair condensation," following the conventional nomenclature. The formation into the birotation (that is, SHM) has two distinct effects which need to be noted:

i. the character of the motion changes from rotational (two-dimensional in extension space) to linear (one-dimensional in extension space);
ii. the magnitude of the motion changes from steady (constant speed in time) to undulatory (varying speed in time).

Let us call these two effects respectively the "dimension-reduction" and the "activation" for ease of future reference.

4 Larson, Dewey B., *Basic Properties of Matter*, *op. cit.*, p. 102.
5 *Ibid.*, p. 114.
6 *Ibid.*, p. 113.

2.3 The Zero Electrical Resistivity

The rotational space, that is the electron, may be regarded as a circular disk area. We see that the effect of the dimensional-reduction is to turn the disk area into a straight line element (of zero area). What causes the electrical resistance in normal conduction is the finiteness of the projected area of the electron in the direction of current flow. The vanishing of this projected area on pair formation eliminates the cause for the resistance and turns the material into a perfect conductor (zero resistivity). It should be emphasized that a dimension-reduction from a three-dimensional spatial extension (say, a spherical volume) to a two-dimensional spatial extension (a circular disk) could not have accomplished such an elimination of projected area. This is only possible when the reduction is from a two-dimensional spatial extension to the one-dimension.

In the conventional parlance we might say that while the single-electron (rotational) is a fermion, the electron pair (linear SHM) behaves as a boson. In the analogous case of a photon, we see that the photon is a linear SHM and is a boson. One can, therefore, conjecture that the circularly polarized photon[2] *ought to behave like a fermion*. I suppose that an experimental verification of this prediction could easily be borne out.

3 The Meissner Effect

This an interaction between superconductivity and magnetic field and serves to distinguish a superconductor from the so-called "perfect conductor." If we could place a perfect conductor in an external magnetic field, no lines of magnetic flux would penetrate the sample since the induced surface currents would counteract the effect of the external field. Now imagine a normal conductor, placed in the magnetic field and the temperature lowered, such that at T_c it turns into a perfect conductor while in that field (see top row Figure 1, which is adopted from Blackmore[7]). The field that was coursing through it would be continuing to do so (top center, Figure 1). If now the external field is removed (top right) the change in this field would induce electrical currents in it which would be persisting (as there is no resistance), and these currents produce the internal flux that gets locked in as shown.

But the situation is quite different in the case of the superconductor. As can be seen from the bottom row of Figure 1, a metal placed in an external magnetic field and cooled through the superconducting transition temperature T_c expels all flux lines from the interior (providing, of course, the field is less than a critical value, H_c) (see bottom center). This is called the *Meissner Effect*. In fact, the external field threading the superconductor generates persistent surface currents, and these currents generate an internal field that exactly counterbalances the external field resulting in the flux expulsion phenomenon. Termination of the external field induces an opposing surface current which cancels the previous one and leaves the superconductor both field-free and current free.

Now the crucial point that should be noted is that a constant magnetic flux threading a conductor that is stationary relative to it does not induce an electric current. What induces a current is a *change* in the magnetic field. In the case of a perfect conductor we considered above, the field is steady (that is, constant with time) and no induced currents appear (top center, Figure 1).

But in the case of the superconductor, the *steady field does induce an electric current.* This has been a recalcitrant fact that defied explanation in the conventional theory and forced the theorists to hazard weird conceptual contrivances like the exchange interactions. The development of the Reciprocal System has clearly demonstrated that in all such cases there is no need to devise extreme departures

7 Blackmore JS., *Solid State Physics*, Cambridge Univ. Press, 1985, p. 274.

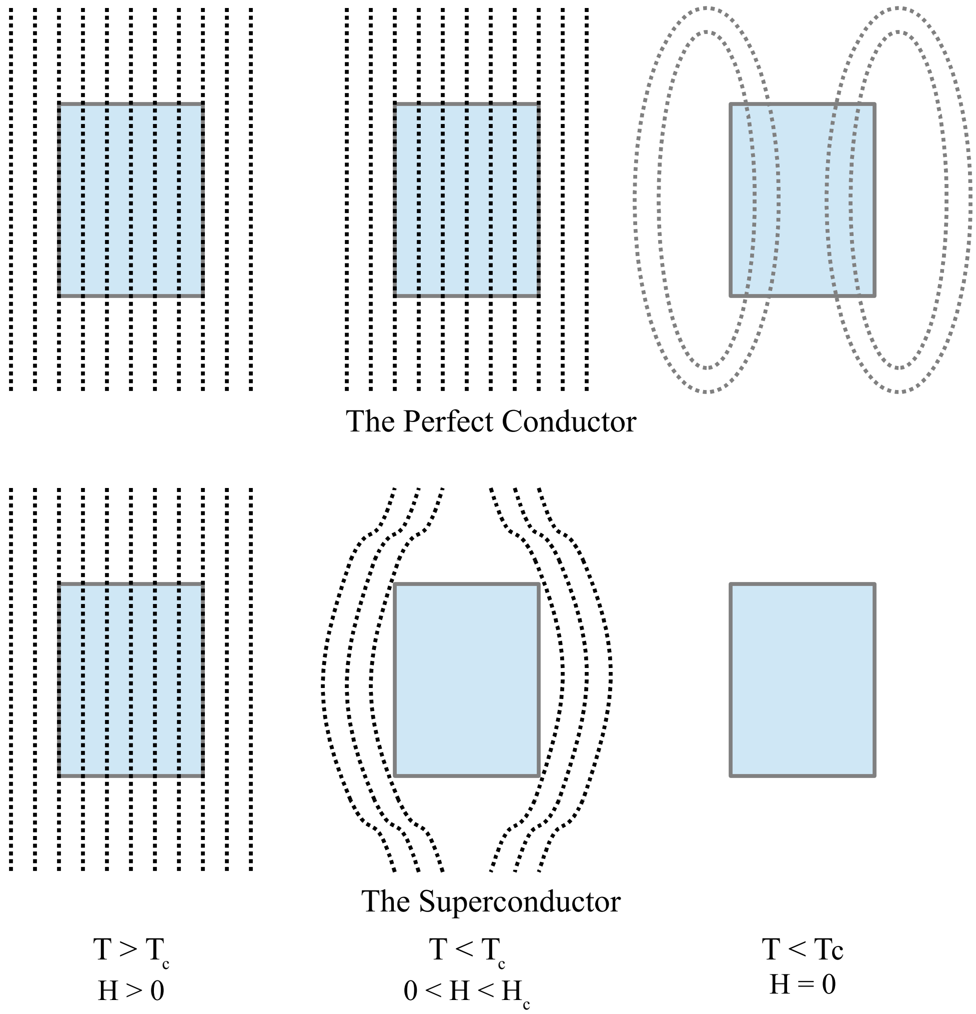

Figure 1: The Meissner Effect

from the otherwise understandable straightforward explanations. For instance, we have shown in the explanation of ferromagnetism there is no need to invoke the aid an "exchange interaction" at all.[3] It was shown that understanding of the origin and characteristics of that phenomenon follows from the recognition that it has crossed a regional boundary and entered the time region.

Exactly for identical reasons, we find that in the present too, there is no need to resort to the purely hypothetical exchange interaction explanation. The reason why a steady magnetic field threading the superconductor induces a current in it follows from the *activation* aspect of the electron pairing. That is, while in the case of the normal electron the rotational space is constant with time, in the case of the electron pair the space is sinusoidally varying with time. In normal conduction, electric current is induced if the magnetic flux threading the space of the electrons changes with time. In superconductivity, the electrical current is induced since the space of the electrons threading the magnetic flux varies with time. We may call this "superinduction," and the relevant current "activation current."

4 The Non-locality of the Pairing

It has been found that "the size of the electron pairs is on the order of 10^{-4} cm and the motion of electrons at different points of the metal shows correlations over distances of this order."[8] Richard Feynman points out: "I don't wish you to imagine that the pairs are really held together very closely like a point particle. As a matter of fact, one of the great difficulties of understanding this phenomenon originally was that that is not the way things are. The electrons which form the pair are really spread over a considerable distance; and the mean distance between pairs is relatively smaller than the size of a single pair. Several pairs are occupying the same space at the same time."[9] By any standard of conventional thinking this is rather a strange state of affairs.

From the point of view of the Reciprocal System, however, we see that the two electrons that form the pair are *adjacent in time*, and not in space, since the electron motion is in the time region as has already been noted. As the location of the particles in space is in no way correlated to their location in time, adjacency in time does not necessarily entail propinquity in space. Therefore, the components of a pair could be spatially separated while contiguous in time. Their maximum separation could be the natural unit of space multiplied by the interregional ratio (nearly 7×10^{-4} cm).

5 Superconductivity and Magnetic Ordering

As both magnetic ordering and superconductivity are the result of the respective motions entering the time region, it would be of interest to examine whether and how they affect each other. In the ferromagnetic arrangement of the directions of all the atomic dipoles are mutually parallel. Such a state of ordering precludes the electron pair formation required in superconductivity since the spins of the electrons are disposed to orient parallel to each other. As such, we can predict that superconductivity and ferromagnetism cannot coexist.

On the other hand, in the antiferromagnetic ordering, adjacent magnetic dipoles are oriented antiparallel to each other. Since the rotational space that is the electron will have greater chance of assuming the directions of these dipoles, adjacent electrons with opposite spin directions would be readily available for pairing. Consequently, we can conclude that the antiferromagnetic ordering can co-exist with or even promote the electron pairing that underlies superconductivity. If this is so, it might lead to the development of high T_c superconducting materials by exploiting the potential of the antiferromagnetic type of structures.

6 Thermodynamical Aspects

The observable relationships among the superconducting and the normal states follow directly from the quadratic nature of the relationship between the corresponding quantities of the time region and the outside region.[10]

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8 Narlikar AV. & Ekbote SN., *Superconductivity and Superconducting Materials*, South Asian Pub., New Delhi, India, 1983, p. 36.

9 Feynman RP., *The Feynman Lectures on Physics* – Vol. III, Narosa Pub. House, India, 1986, pp. 21-27.

10 Larson, Dewey B., *Nothing but Motion*, NPP, 1979, p. 155.

6.1 Specific Heat Relations

Quoting Larson, "…the relation between temperature and energy depends on the characteristics of the transmission process. *Radiation* originates three-dimensionally in the time region, and makes contact one-dimensionally in the outside region. It is thus four-dimensional, while temperature is only one-dimensional. We thus find that the energy of radiation is proportional to the fourth power of the temperature, $E_{rad} = K * T^4$."[11]

We have seen earlier that the phenomenon of birotation of the electron pair is identical to that of the birotation of photons (except for the absence of the rotational base in the latter). Consequently, the time region energy associated with the electron pairs is proportional to the fourth power of the temperature. Therefore, considering unit volume of the material, the expression for the thermal energy in the superconducting state can be written as

$$E_s = K_s \times T^4 \tag{1}$$

where K_s is a constant and suffix s denotes the superconducting state. Differentiating this equation one gets the expression for the specific heat in the superconducting state,

$$C_s = 4 \times K_s \times T^3 \tag{2}$$

This cubic relationship is confirmed experimentally.

Continuing the quotation from Larson: "The thermal motion originating inside unit distance is likewise four-dimensional in the energy transmission process. However, this motion is not transmitted directly though the thermal oscillation is identical with the oscillation of the photon, it differs in that its direction is collinear with the progression of the natural reference system rather than perpendicular to it. "The transmission is a contact process… subject to the general inter-regional relation previously explained. Instead of $E = KT^4$, as in radiation, the thermal motion is $E^2 = K'T^4$,"[12] that is,

$$E_n = K_n \times T^2 \tag{3}$$

where K_n is a constant and suffix n denotes the normal state. This, of course, gives the linear relationship between the normal specific heat C_n, and temperature that Larson uses in his calculations.[12]

$$C_n = 2 \times K_n \times T \tag{4}$$

We know that the entropy of both the states, S_n and S_s, must be equal both at T_c and at 0 kelvin (by the third law of thermodynamics). Using dS = dE/T, we have from Equations (1) and (3),

$$S_s(T) = \int_0^T 4 \times K_s \times T^2 \times dT = (4/3) \times K_s \times T^3 \tag{5}$$

$$S_n = \int_0^T 2 \times K_n \times dT = 2 \times K_n \times T \tag{6}$$

At $T = T_c$ we have $S_s(T_c) = S_n(T_c)$ which gives

$$K_s = \frac{(3 \times K_n)}{(2 \times T_c^2)} \tag{7}$$

11 Larson, Dewey B., *Basic Properties of Matter*, *op. cit.*, p. 57.
12 *Ibid.*, p. 58.

Using Equations (2), (4) and (7), we can now find that at the transition the excess specific heat is given by

$$C_s - C_n = 6 K_n T_c - 2 K_n T_c = 4 K_n T_c = 2 C_n \tag{8}$$

The above result is experimentally corroborated.

6.2 External Magnetic Field

Below the critical temperature T_c superconductivity is quenched by applying an external magnetic field of intensity greater than the critical value H_c. The fourth power and the second power relations, Equations (1) and (3) respectively, pertaining to the two regions across the boundary lead us to the result (see Section 7)

$$\frac{[H_c(T)]}{[H_c(0)]} = 1 - \left(\frac{T}{T_c}\right)^2 \tag{9}$$

where $H_c(T)$ is the critical magnetic field that quenches the superconductivity at the temperature T (less than T_c).

This is the well-known parabolic relation that is especially found to hold good in the case of all the soft (Type 1) superconducting materials. A more rigorous treatment should, of course, take into consideration the probability of existence of some unpaired electrons at temperatures greater than 0 kelvin. The Type II superconducting materials have a mixed state which we cannot consider in a preliminary study such as the present one.

7 Temperature Dependence of the Critical Field

At the transition temperature T, under an external magnetic field H_c, the condition of equilibrium is the equality of the free energies F_n and F_s of the normal and the superconducting states respectively.[13] Considering the variation of the free energies with temperature we can write

$$dF_n = dF_s \tag{10}$$

Since by definition

$$dF = -SdT - BdH \tag{11}$$

with S as entropy and B the magnetic induction, we have

$$-S_n dT - B_n dH = -S_s dT - B_s dH \tag{12}$$

or

$$(B_s - B_n) dH = (S_n - S_s) dT \tag{13}$$

We can take that the material is only weakly magnetic in the normal state and so omit the term B_n. Since in the superconducting state the material acts as a perfect diamagnetic, we can take

$$B_s = -\mu_0 H \tag{14}$$

where μ_0 is the permeability. Using Eqs. (14), (5), (6) and (7), we obtain from Equation (13)

13 Duzer TV. & Turner CW., *Principles of Superconducting Devices and Circuits*, Elsevier Pub., New York, USA, 1981, Chapter 6.

$$-\int_{H_c(T)}^{0} \mu_0 H \, dH = \int_{T}^{T_c} [2K_n T - \frac{(2 K_n T^3)}{T_c^2}] dt \tag{15}$$

since at the limit T = T_c, H_c = 0. Carrying out the integration and simplifying,

$$\mu_0 H_c^2(T) = K_n T_c^2 \left[1 - \left(\frac{T}{T_c}\right)^2\right]^2 \tag{16}$$

For T = 0° K this gives

$$\mu_0 H_c^2 = K_n T_c^2 \tag{17}$$

Substituting from Equation (17) in Equation (16) and taking the square root, we finally get

$$\frac{H_c(T)}{H_c(0)} = 1 - \left(\frac{T}{T_c}\right)^2 \tag{18}$$

8 Conclusion

The foregoing explanation of superconductivity adds one more item that demonstrates the coherence and generality of the *Reciprocal System* of theory. It has been shown that the apparent reversal of direction, from the point of view of the stationary three-dimensional spatial reference system, that takes place when the scalar motion constituting a phenomenon crosses a unit boundary of some sort underlies the explanation of such diverse phenomena as the white dwarfs, quasars, cohesion in solids, sunspots and ferromagnetism. In this present article we extend this explanation to the phenomenon of superconductivity as well. Superconductivity is the result of the electron motion (rotational space) entering the time region and turning into a birotation.

- The formation of electron pairs,
- the non-locality of the pairing,
- the zero electrical resistance,
- the expulsion of magnetic field,
- the abrupt change in the specific heat at the transition,
- the manner of variation of the critical field with temperature,

all of these are shown to follow logically from the theory.