What is the Absorber Theory of Radiation?

A model for electromagnetic radiation that allows for the elementary process of radiation by an accelerated charge to be symmetric in time.

Why is this desired?

Noether's Theorem: Conservation of energy _ Symmetric in Time

Isotropic coordinates

Maxwell Equations are Time-Symmetric

Einstein 1909 paper

The Goal:

Given the temporal symmetry of elementary radiative processes, can the obvious physical manifestation of the asymmetric nature of macroscopic process be accounted for?

From which problems did the Absorber Theory arise?

Known by several names, the radiation reaction problem has caused many pains in the formulation of a complete classical electrodynamics. The difficulties associated with it, in part, prompted the development of the absorber theory. While a surface inspection of the problem leaves one feeling not terrible worried, the radiation reaction issue extends to the very heart of physics, namely, the nature of the fundamental particles. Stated briefly: if a charged particle accelerates, it emits a field. The field must then, by the standard equations of electromagnetic interaction, affect the motion of the accelerated particle, thereby creating a radiation damping effect. What however, is the precise nature of this damping force?

H.A. Lorentz, in a very classical way, attempted to consider the electron as an entity with a finite size. "We have now to bethink ourselves of the extreme smallness of the electrons." [page 47 theory of electrons] Oh really? How small should we be bethinking of Mr. Lorentz? His answer of 1.5 X 10^{-13} cm is not very convincing. By summing up the contributions from various parts of the spherical electron, a series whose first term matches the expected $(2/3)*(e^2/c^3)*v''$ was given for the force. WF point out the flaws: 1) the other terms in the series depend upon the structure of the electron, that is, its exact geometry; 2) how can the repulsive forces of the identically charged parts of the electron hold it together. Thus more was needed to address this problem.

1938 saw the publication of Dirac's paper *Classical Theory of Radiating Electrons*. His goal was "not so much to get a model of the electron as to get a simple scheme of equations which can be used to calculate all the results that can be obtained from experiment." [page 149 Dirac 1938] By considering the electron as a point charge and also using both the retarded and advanced fields in the construction of the radiation field, his formulation produced self-consistent results in agreement with experiment. WF find the following problems: 1) the field is defined for times before and after the moment of acceleration, thus yielding the phenomenon of pre-acceleration; 2) the field has no singularity at the position of the particle and must therefore come from sources other than the charge itself. On these grounds, WF seek other models for their absorber theory.

The 1945 Paper

The first publication of the absorber theory appeared in 1945's Reviews of Modern Physics; *Interaction with the Absorber as the Mechanism of Radiation* was the title. After some preliminary introductory materials that essentially state the problem and its background, the paper then presents four derivations of the absorber model, each with increasing generality and therefore complexity. All of the derivations rely on four assumptions:

1) An accelerated point charge in otherwise charge-free space does not radiate electromagnetic energy.

This assumption can be traces to Tetrodes assertion of 1922 in which he writes "the sun would not radiate if it were alone in space and no other bodies could absorb its radiation." Thus radiation is not quite an elementary process but rather a consequence of the interaction between a source and absorber. Here we can feel the pressing hand of the direct action theory upon our shoulder.

2) The fields which act on a given particle arise only from other particles.

This clears away the troubling radiation reaction problem as illustrated above.

3) These fields are represented by one-half the retarded plus one-half the advanced Liénard-Wiechart solutions of Maxwell's Equations. This law of force is symmetric with respect to past and future.

This statement brings with it some important implications. Foremost, that the laws of physics are indeed symmetric with respect to time. Considering the multitude of time *asymmetric* phenomena in nature, clearly some explaining needs to happen. How can reversible mechanisms combine to form irreversible processes? The absorber theory seeks to address this question.

4) Sufficiently many particles are present to absorb completely the radiation given off by the source.

Claiming this is a means of describing the nature of the universe in the cosmological sense. Essentially, as Davies puts it, "Is the universe transparent or opaque?" [p. 143 Davies 1975] The consequence of such a question will be important in the evaluation of the plausibility of the notion of Direct Action electrodynamics.

Using these four assumptions (postulates?) the absorber theory of radiation can begin to take shape. Prior to this however, vagueness must be first clarified. Specifically, the dichotomy between the theories incorporating fields and those theories that do not: Maxwellian electrodynamics being of the former type; Newtonian action at a distance gravitation being of the latter. In which camp should the absorber theory be placed? It would be a mistake to say that it, as described in the 1945 paper, clearly lies in either. In fact, the 1945 paper seems to be more a reconciliation between the two sides, that is, an attempt to establish a "complete correspondence … between action at a distance and the useful formulation of field theory in the completely absorbing system." [p. 181 WF 1945]

Let us start with a simplified version of the absorber mechanism in which the radiative reaction will be somewhat evinced. In a severe reduction, the mechanism can be described in the following way. A charged particle (the source) is caused to accelerate by some force. Retarded waves are emitted by the source (ignore the advanced waves here). The retarded emission causes a particle at the boundary (the absorber) to accelerate. The acceleration by the absorber then creates retarded and advanced waves that propagate outward. The advanced wave reaches the source at the same time the original acceleration occurred, thereby providing the expecting 'self-action' force. Such a description can be easily modified to portray the effect of a large number of absorber particles at the boundaries.

After assuming a simple primary acceleration, ($a = \mathrm{U}e^{-iwt}$), as well as accounting for the phase discrepancies between the different waves, the standard equation was reached:

$$F=(2/3)(e^2/c^3)(da/dt) \quad .$$

This derivation only accepts non-relativistic motions of the electrons. Additionally, it was assumed that the absorber was far from the source, a simplification that permitted using the standard form for the E field in the far field,

$$(eU/rc^2)\sin(\mathbf{U}\cdot\mathbf{r})$$

The second derivation allows for the presence of the absorber particles to be in the neighborhood of the source. From this, some new results are found. A particle being accelerated emits a radiation field that is comprised in equal parts of the advanced field and the retarded field. Such radiation accelerates the absorber particles, which in turn emit fields equal to _ the retarded field minus _ the advanced field of the source. This produces the proper radiation field required by Dirac to explain the damping effect. Here it is the interaction between the fields emitted by the absorber and the field of the source. All of the other advanced waves are found to cancel each other through destructive interference.

The third and fourth derivations account for relativistically moving charges and complete absorption by the universe, respectively. They conclude with the following:

> "We have shown that the half-advanced, half-retarded fields of the action at a distance lead to a satisfactory account of the mechanism of radiative reaction an to a description of the action of one particle on another in which no evidence of the advanced fields is apparent."