It may be noted that the Weber-Wesley (1990, 1997) field theory, being valid in absolute space, is not a relativity theory. It is not immediately compatible with the theory of induction presented here. It is not clear what approximation of the absolute space theory is needed to derive the relativity induction theory.

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TRANSVERSE, LONGITUDINAL, AND MIXED ELECTRODYNAMIC WAVES

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ABSTRACT

Oscillating current loop sources with no surface charges produce transverse waves prescribed by the magnetic vector potential **A** field alone. Oscillating surface charges produce longitudinal waves prescribed by the electric scalar potential Φ field alone. An oscillating source of unshielded charges, obeying the equation of continuity for charge, produces mixed, transverse and longitudinal, waves.

1. BACKGROUND

Despite the failure of the Maxwell theory in so many ways [1-6], it is still commonly believed that electrodynamic waves are necessarily transverse, as predicted by the usual Maxwell theory. Transverse electrodynamic waves are readily excited and have been observed. However, with care, as described below, longitudinal waves can also be excited and observed. A general source of unshielded charges, where the equation of continuity for charge is applicable, can produce a mixed wave with both transverse and longitudinal properties, as discussed below.

The Maxwell theory [7] is generally presented as an axiomatic theory, that postulates Maxwell's differential equations and the fields **E, B, D,** and **H**. In this way it can be assumed that "potentials" can be defined to fit different arbitrary "gauges." In contrast, Weber-Wesley (8) electrodynamics is a fundamental theory based upon the forces between two moving point charges. The magnetic vector potential **A** and the electric potential Φ are then *uniquely* defined in terms of the source current density **J** and the source charge density ρ by

$$\mathbf{A}(\mathbf{r}, t) = \int d^3\mathbf{r'}\, \mathbf{J'}(\mathbf{r'},t)/c\,|\mathbf{r} - \mathbf{r'}|,$$
$$\Phi(\mathbf{r}, t) = \int d^3\mathbf{r'}\, \rho'(\mathbf{r'},t)/|\mathbf{r} - \mathbf{r'}|, \qquad (1)$$

where the integrations are taken over all **r'** space containing the sources and **r** is a point of observation. These potentials, being defined directly in terms of the sources represent the true fundamental physical electrodynamic field. Force fields such as **E** and **B**, depending not only upon the electrodynamic field **A** and Φ, but also upon the mode of observation, are necessarily secondary derived quantities, such as $\mathbf{E} = -\nabla F - \partial\mathbf{A}/\partial tc$ and $\mathbf{B} = \nabla \times \mathbf{A}$, which lack the full physical information contained in the **A** and Φ fields themselves.

2. THE TRANSVERSE MAGNETIC WAVE

From the definition of the **A** field, the first of Eqs. (1), it may be proved [9] that

$$\nabla \times (\nabla \times \mathbf{A}) = 4\pi\mathbf{J}/c \qquad (2)$$

For the case of interest here oi may be assumed that the source currents form closed current loops; so

$$\nabla \bullet \mathbf{A} = 0 \qquad (3)$$

Taking the gradient of Eq. (3), subtracting from Eq. (2), and noting that

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$$\nabla^2\mathbf{A} = \nabla(\nabla\bullet\mathbf{A}) - \nabla \times (\nabla \times \mathbf{A}) \tag{4}$$

where on the left the ∇^2 operator operates on each cartesian component of **A** treated as a scalar, Eq. (2) becomes a Poisson's equation

$$\nabla^2\mathbf{A} = -4\pi\mathbf{J}/c \tag{5}$$

If the effect of the source **J** is transmitted with the finite velocity of action c in the **r** – space, the del squared operator ∇^2 in the Poisson equation (5) is to be replaced by the wave operator; thus,

$$\nabla^2 \rightarrow \nabla^2 - \partial^2/\partial t^2 c^2, \tag{6}$$

which takes into account the retarded time involved [10]. Equation (5) then becomes the inhomogeneous wave equation for **A**; thus,

$$\nabla\mathbf{A} - \partial^2\mathbf{A}/\partial t^2c^2 = -4\pi\mathbf{J}/c. \tag{7}$$

Multiplying Eq. (7) by the force of induction per unit charge, $-\partial\mathbf{A}/\partial tc$, using Eq. (4), where $\nabla\bullet\mathbf{A} = 0$, and employing the vector identity for any two vectors **a** and **b**,

$$\mathbf{a}\bullet(\nabla \times \mathbf{b}) = \nabla\bullet(\mathbf{a} \times \mathbf{b}) - \mathbf{b}\bullet(\nabla \times \mathbf{a}), \tag{8}$$

an expression for the conservation of energy per unit volume is obtained; thus,

$$\nabla\bullet\mathbf{S}_m + \partial E_m/\partial t = \mathbf{J}\bullet\partial\mathbf{A}/\partial tc, \tag{9}$$

where the wave energy flux $\mathbf{S}_m$ and the wave energy density E_m are given by

$$\mathbf{S}_m = -c(\partial\mathbf{A}/\partial tc) \times (\nabla \times \mathbf{A})/4\pi$$
$$E_m = [(\nabla \times A)^2 + (\partial A/\partial tc)^2]/8\pi. \tag{10}$$

The right side of Eq. (9) is the rate per unit volume that the current density J does work on the field under the action of -the force of induction per unit charge $-\partial A/\partial tc$. Thus. Eq. (9) reads that the rate of increase in the wave energy per unit volume $\partial E_m/\partial t$ equals the rate of work done by the current **J** on the field $\mathbf{J}\bullet\partial A/\partial tc$ minus the outflow of energy $-\nabla\bullet\mathbf{S}_m$. In regions where $\mathbf{J} = 0$ Eq. (9) becomes the equation of continuity for the conservation of the wave energy.

(Defining an "electric field" as $\mathbf{E}\ -\partial\mathbf{A}/\partial tc$ and .a "magnetic: field" as $\mathbf{B} = \nabla \times \mathbf{A}$, Eqs. (10) yield the more usual appearing result:

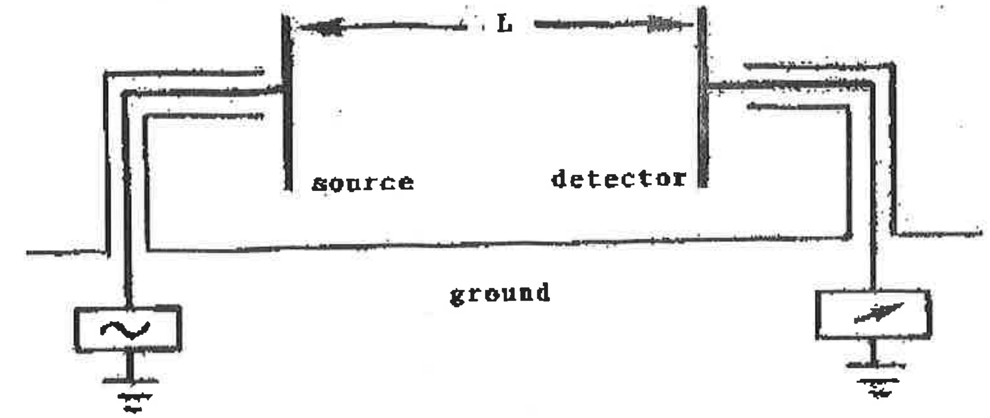
$$\mathbf{S}_m = c(\mathbf{E} \times \mathbf{B})/4\pi, \quad E_m = (E^2 + B^2)/8\pi$$

where the rate of doing work on the field is $-\mathbf{J}\bullet\mathbf{E}$. But no "electromagnetic wave" is actually involved; since only the single fundamental physical field vector **A** is involved.)

Since the force of induction $-q\,\partial\mathbf{A}/\partial tc$ on a stationary detector charge q is perpendicular to $\mathbf{S}_m$, as indicated by the first of Eq. (10); the magnetic wave is a transverse wave. The source current **J** of this magnetic wave involves no unshielded charges; so $\rho = 0$. Thus, no actual "electric field" defined in terms of unshielded charges and Coulomb's law exists, $\mathbf{E} = -\nabla\Phi = 0$ in this case.

3. THE LONGITUDINAL ELECTRIC WAVE

The inhomogeneous wave equation for the scalar electric potential Φ for a time varying electric charge density ρ may be similarly derived from the definition of Φ as given by the second of Eq. (1). Again assuming a finite velocity of action c, Poisson's equation, making the replacement (6), yields



Fig, 1, Setup to detect longitudinal electric waves.

$$\nabla^2\Phi - \partial^2\Phi/\partial t^2c^2 = -4\pi\rho. \tag{11}$$

Multiplying Eq. (11) by $\partial\Phi/\partial tc$ yields an expression for the conservation of energy,

$$\nabla\bullet\mathbf{S}_e + \partial E_e/\partial t = \rho\,\partial\Phi/\partial t, \tag{12}$$

where the wave energy flux $\mathbf{S}_e$ and wave energy density E_e are given by

$$\mathbf{S}_e = -c(\partial\Phi/\partial tc)\nabla\Phi/4\pi,$$
$$E_e = [(\nabla\Phi)^2 + (\partial\Phi/\partial tc)^2]/8\pi. \tag{13}$$

The term on the right of Eq. (12), $\rho\,\partial\Phi/\partial t$, is the time rate of gain of the field energy due to the source ρ per unit volume; since the energy per unit volume of the charge density ρ in the field Φ is $\rho\Phi$.

In a region where $\rho = 0$ Eq. (12) yields the equation of continuity for the conservation of the field energy.

Since the electric field force, $-q\nabla\Phi$, on a stationary detector charge q is parallel to $\mathbf{S}_e$, as indicated by the first of Eq. (13); the electric wave is a longitudinal wave.

4. TO DETECT LONGITUDINAL ELECTRIC WAVES

As is well known, energy is transmitted between the plates of a parallel plate condenser, where the electric field is perpendicular to the plates and parallel to the direction of the energy transmission. In particular, one plate may be driven by an alternating voltage to constitute the "source", as indicated in Fig. 1. The other plate may be connected to a passive detector of an alternating voltage to constitute the "detector," as also indicated in Fig. 1.

The plates may then be separated a distance L to investigate the signal received as a function of the distance L. The power detected should, for example, decrease as the inverse square of the distance, if the ground and other material in the environment are much farther away than the distance L.

The wavelength characteristics of the wave can be investigated by driving the source at a frequency v large enough to establish a wavelength less than the separation distance L; or

$$\nu > c/L \tag{14}$$

For example for L = 1 m the frequency should be chosen as $\nu > 300$ megahertz.

5. UNSHIELDED CHARGES RADIATE MIXED WAVES

Systems composed of an equal number of positive and negative moving charges, as in an atom, are subject to the equation of continuity for charge,

$$\nabla \cdot \mathbf{J} + \partial \rho / \partial t = 0. \tag{15}$$

The pure magnetic and pure electric waves, treated in Sections 2. and 3. above, were not subject to this condition (15). The The present problem is thus reduced to finding the wave satisfying Eqs. (7) and (11) subject to the coupling condition (15).

From the definitions of **A** and **Φ**, Eqs. (1), it may be readily proved, using Eq. (15), that **A** and **Φ** are not independent, but are subject to the condition

$$\nabla \cdot \mathbf{A} + \partial \Phi / \partial tc = 0. \tag{16}$$

Using this Eq. (16) the inhomogeneous wave Eq. (7) may be written as

$$(\partial / \partial tc)(\nabla \Phi) + \partial \mathbf{A} / \partial tc) + \nabla \times (\nabla \times \mathbf{A}) = 4 \pi \mathbf{J} / c. \tag{17}$$

Multiplying this Eq. (17) by

$$\nabla \Phi + \partial A / \partial tc = -E, \tag{18}$$

which defines the "electric field" E, and using the identity (8) yields

$$c \nabla \cdot [\mathbf{E} \times (\nabla \times \mathbf{A})] / 4\pi + (\partial / \partial tc)[E^2 + (\nabla \times A)^2) / 8\pi = -\mathbf{J} \cdot \mathbf{E}, \tag{19}$$

which is the same as Eqs.(9) and (10) with $\partial A / \partial tc$ replaced by Eq. (18). The energy flux, the "Poynting vector," $\mathbf{S}_p$ and the energy density E_p for the field become

$$\mathbf{S}_p = c\mathbf{E} \times (\nabla \times \mathbf{A}) / 4\pi,$$
$$E_p = [E^3 \times (\nabla \times \mathbf{A})^2] / 4\pi. \tag{20}$$

Equation (19) represents the conservation of energy for this field, where $-\mathbf{J} \cdot \mathbf{E}$ is the rate the current density **J** does work on the field.

This result, Eqs. (7), (19) and (20), letting $\mathbf{B} = \nabla \times \mathbf{A}$, is seen to be the usual traditional Maxwell result [11]. But this result is not sufficient; because a static charge density p can also do work on a time changing Φ field per unit time per unit volume given by $\rho\, \partial\Phi / \partial t$, as already indicated on the right side of Eq. (12). This energy must also be included to conserve energy for all of the effects involved. Here Eqs. (11) through (13) remain valid. However, for the present case of interest the field is not independent of the A field; as they are coupled, as indicated by the condition (16). The total energy flux **S** and the total energy density E are then given by

$$\mathbf{S} = -c[(\nabla\Phi + \partial A / \partial tc) \times (\nabla \times . A) + \nabla\Phi\, \partial\Phi / \partial tc] / 4\pi, \tag{21}$$

$$E = [(\nabla\Phi + \partial \mathbf{A} / \partial tc) + (\nabla \times A)^2 + (\nabla\Phi)^2 + (\partial\Phi / \partial tc)^2 / 8\pi, \tag{22}$$

which satisfies the conservation of energy,

$$\nabla \cdot \mathbf{S} + \partial E / \partial t = \partial \mathbf{W} / \partial t, \tag{23}$$

where the time rate per unit volume that the sources do work on the field is given by

$$\partial W / \partial t = - J \cdot (\nabla\Phi) + \partial A / \partial tc) + \rho\partial\Phi / \partial tc. \tag{24}$$

The wave described by the inhomogeneous wave Eqs. (7) and (11), subject to the coupling condition (16), is neither transverse nor longitudinal. The field $-\nabla\Phi$ is longitudinal; while the field $-(\nabla\Phi + \partial A / \partial tc)$ is transverse to **S**, as indicated by the first of Eqs. (22). It is a mixed wave, having both transverse and longitudinal properties.

6. DISCUSSION

Only limited situations are discussed here. Only sources involving and **J** are considered. It is not clear that other possible sources for an electrodynamic field, such as $\partial J / \partial tc$ or $\nabla\rho$ might not also exist to yield additional special waves. Moreover, the waves considered here are limited to fields that can produce a force on a static detector charge. Other fields and other waves might be detected using forces on moving detector charges. For example, a detector charge q with an acceleration **a** can detect the electric potential Φ itself; since the reaction force of induction is given by

$$-q\mathbf{a}\,\Phi, \tag{25}$$

as verified by Lenz' law for the back emf (A force that does not exist in the Maxwell-Lorentz theory) [8].

Electrodynamics is still not a mature empirical science [1]. More experiments are needed, such as the one suggested in Section 4 above. And, of course, a completely adequate theory that fits all of the observations consistently is still needed.

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