香 港 中 文 大 學 研 究 院
Graduate School * The Chinese University of Hong Kong

碩士學位考試論文評閱報告
Master's Degree Thesis Assessment Report

學生姓名
Name: 吳仲生 Mr. Ng Chung-sang

學 部
Division: Physics

論文題目
Thesis Title: Characteristics of Far Field and Energy Flow Due to a Moving Radiating Source in Various Media

評 語
Remarks:

The master's thesis, "Characteristics of Far Field and Energy Flow due to a Moving Radiating Source in Various Media", submitted by Ng Chung-Sang, is an outstanding piece of work. Addressing the question of the spatial and temporal dependencies of frequency, wave-number, and field intensity for the radiation from a moving radiation source, the author extends previous knowledge in this area by a very significant amount. Lighthill (1960) and Giles (1978) laid the groundwork for this field, examining these same questions for radiation from a stationary source. Including magnetic-field immersed plasmas among the media through which the radiation might propagate, the problem takes on a fascinating complication stemming from the strongly anisotropic nature of the plasma's dielectric characteristics. Lai and Chan (1986) laid out the methods by which the work of Lighthill and Giles could be extended to the case of a moving source. Ng, in the present paper, has applied the Lai-Chan methods to an impressive multiplicity of cases, has extended the calculation to cover sources moving with relativistic velocity, and has insightfully resolved a number of results which, at first look, surprise one's intuition.

One is impressed by a number of facets of this work. The author time and again shows both skill and elegance in his mathematical treatments, and carries through a large number of complicated analyses with enormous energy. In many instances he has been able to apply his derived formulae to recover results that are already known -- those pertaining to the simplest dielectric media. He has paid particular attention to the occurrence of Cerenkov radiation, where the velocity of the source exceeds the velocity of the wave in the medium, and to the question of propagation through a cold magnetoplasma.

The present work, as a master's thesis, is unusual for its scientific maturity and for the range and depth of its analysis. In summary, it constitutes an excellent piece of research and makes an interesting and significant contribution to our knowledge in this field.

給分標準 Grading System

A	Excellent	
A-	Very good	
B+	Good	
B		
B-		
C+	Pass	
C		
C-		
D	Failure	
F	Bad Failure	

評閱分數
Grade: Excellent

考試委員簽署
Examiner's Signature: [signature]

姓名
Name: Thomas H Stix
(正楷 in block letters)

日期
Date: 23 June 1988

$$u(\mathbf{r},t) = \frac{(2\pi)^{1/2}e^{-i\omega t}}{r} \sum \frac{CF(\mathbf{k})e^{i\mathbf{k}\cdot\mathbf{r}}}{|\partial G/\partial \mathbf{k}||K|^{1/2}} + O\left(\frac{1}{r^2}\right) \tag{50}$$

as $\mathbf{r} \to \infty$ *along any radius vector l, if the sum* Σ *is over all points* (k_x,k_y,k_z) *of the surface* $G(\mathbf{k})=0$ *where the normal to the surface is parallel to l and* $\mathbf{r}\cdot\mathbf{v}_g > 0$ *; provided that the surface has nonzero Gaussian curvature K at each of these points; that C is (a)* $\pm i$ *where* $K<0$ *and* $\partial G/\partial \mathbf{k}$ *is in the direction of* $\pm r$*, (b)* ± 1 *where* $K>0$ *and the surface is convex to the direction of* $\pm \partial G/\partial \mathbf{k}$*, and that*

$$F(\mathbf{k}) = \frac{1}{(2\pi)^{3/2}} \int d^3\mathbf{r}\, e^{-i\mathbf{k}\cdot\mathbf{r}} f(\mathbf{r}). \tag{51}$$

$G(\omega,\mathbf{k})$ is given by Eq. (42), $\mathbf{v}_g$ by Eq. (48). The Gaussian curvature K—a quantity that will reappear in Sec. 10—is the reciprocal of the product of the principal radii of curvature of the wave-number surface, $G(\omega,\mathbf{k}) = 0$, for ω fixed, and is evaluated in Eq. (80). K is positive when the curvatures have the same sign (e.g., an ellipsoid), negative when they are of opposite sign (e.g., a saddle surface). The case of zero Gaussian curvature, to which Lighthill's theorem does not apply, corresponds to the interesting phenomenon of "resonance cones" and is studied separately in Sec. 6-8. Lighthill's work has been expanded by M. J. Giles (1978) and extended to the case of a moving radiating source by H. M. Lai and P. K. Chan (1986), and H. M. Lai and C. S. Ng (1990).

instability cannot occur. The two complex roots for real ω correspond to one amplifying wave ($k_i < 0, z > 0$) and one evanescent ($k_i > 0, z > 0$) wave.

(d) $+\ +$. k is real for all real ω, but ω may be complex for real k. The k roots lie in opposite half-planes for large positive σ, and absolute instability can occur.

Show, for case (d), that a double root for k occurs at the frequency and wave number

$$\omega_0 = 2ik_c\left(\frac{1}{V_1} + \frac{1}{V_2}\right)^{-1},$$
$$k_0 = -ik_c\frac{V_1 - V_2}{V_1 + V_2}. \tag{36}$$

Sketch the loci of the roots in the complex-k plane in each example for $\omega = \omega_r + i\sigma$ and $V_1 > V_2$, for the case $\omega_r = 0$ as σ goes from ∞ to $-\infty$ (R. J. Briggs, 1964).

3. **Oscillating Source.** Consider the excitation of plasma waves by an oscillating source. Let the source, Eq. (10), be a dipole represented, for $t > 0$, by $S(z,t) = \exp(-i\omega_0 t)\delta(z)$. Choose a model dispersion function, $\Delta(\omega,k) = \omega - ku + i\epsilon$, where $u > 0$ is a constant. Then invert $E(\omega, k)$, Eq. (13), to find $E(z,t)$ for *all* z and t. Show that your answer is independent of the order in which the Laplace and Fourier inversions are performed. What is the character of the waves for $\epsilon > 0$? For $\epsilon < 0$?

4. **Moving Source.** Generalize the previous problem in two ways. First, let the oscillating source move, with constant velocity, V, through the plasma. Represent it by $S(z,t) = \exp(-i\omega_0 t)\delta(z - Vt)$. Then expand the dispersion function, $\Delta(\omega, k)$, around the points $\omega = \omega_0 + k_0 V$, $k = k_0$, where k_0 is such that $\Delta(\omega_0 - k_0 V, k_0) = 0$,

$$\Delta(\omega, k) = 0 + (\omega - \omega_0 - k_0 V)\partial\Delta/\partial\omega + (k - k_0)\partial\Delta/\partial k + \ldots$$
$$= (\partial\Delta/\partial\omega)[\omega - \omega_0 - k_0 V - (k - k_0)v_{group}] + \ldots \tag{37}$$

where $\partial\Delta(\omega, k)/\partial\omega$ is evaluated at $\omega = \omega_0 + k_0 V$, $k = k_0$. Would you expect k_0 to be real? If not, what physical arguments can determine the sign of Im (k_0)? Find $E(z,t)$.

For the analysis of three-dimensional stable electromagnetic waves radiated by a moving oscillating source, see H. M. Lai and P. K. Chan (1986); also H. M. Lai and C. S. Ng (1990).