

## CONTENTS

1. Introduction	1
1.1 Historical Review of the Problem	2
1.1.1 Unbounded Beam-Plasma Systems	3
1.1.2 Bounded Beam-Plasma Systems	4
1.1.3 Absolute Instabilities and Amplifying Waves	5
1.2 Assumptions and Mathematical Models	6
2. Criteria for Identifying Amplifying Waves and Absolute Instabilities	8
2.1 Statement of the Problem	8
2.2 Green's Function Formalism for the Response to a Localized Source	11
2.3 Proof of Criteria on Amplifying Waves and Absolute Instabilities	15
2.3.1 $F(\omega, z)$ as a Sum of Normal Modes	16
2.3.2 Analytic Continuation of $F(\omega, z)$	17
2.3.3 Amplifying and Evanescent Waves	19
2.3.4 Absolute Instabilities	20
2.3.5 Response to a Pulse in Time	23
2.4 Propagation of Pulse Disturbances and Relations Between Temporal and Spatial Growth Rates of Convective Instabilities	23
2.4.1 Propagation of a Pulse Disturbance	24
2.4.2 Connection Between Amplifying Waves and Convective Instabilities	27
2.5 Comments on the Application of the Criteria and Some Physical Interpretations	29
2.5.1 Amplifying Waves	29
2.5.2 Absolute Instabilities	30
2.5.3 Application of the Criteria in Simple Cases	32
2.6 Discussion	33
2.6.1 Group Velocity of Propagating Waves	33
2.6.2 Comparison with Previous Work	34
2.6.3 Usefulness of Criteria	37
2.6.4 Amplifying Waves in the Presence of an Absolute Instability	38
2.7 Examples	39
2.7.1 Weak-Coupling Dispersion Equations	39
2.7.2 Double-Stream Interactions	42

3. Beam-Plasma Interactions in a One-Dimensional System	47
A. Longitudinal Interactions	48
3.1 Cold Plasma	48
3.2 Dispersion Equation for a Warm Plasma	49
3.3 Weak-Beam Theory	53
3.4 General Criteria for a Reactive-Medium Instability with Ions	59
3.4.1 Cold Ions	59
3.4.2 Warm Ions	61
3.5 Strong Reactive-Medium Amplification with Ions	63
3.5.1 Kinetic Power	67
3.5.2 Finite Ion Temperature	68
3.5.3 Relativistic Temperatures	70
B. Transverse Interactions	71
3.6 Dispersion Equation for Transverse Waves	71
3.7 Transverse Waves on Electron Beams and Weak-Coupling Predictions	73
3.7.1 Electron-Beam Waves	74
3.7.2 Weak-Coupling Predictions	75
3.8 Interaction at the Ion Cyclotron Frequency	76
3.8.1 Cold Plasma	76
3.8.2 Warm Plasma	78
3.9 Alfvén Wave Instability	81
4. Interactions with a Cold Plasma in Systems of Finite Transverse Dimensions	84
4.1 Interactions in a Waveguide Filled with a Weak Beam and a Plasma	85
4.1.1 Space-Charge Wave Interactions	88
4.1.2 Cyclotron-Wave Interactions	92
4.2 Thin-Beam Interactions	97
4.2.1 $n = 0$ Modes	99
4.2.2 $n = \pm 1$ Modes	102
4.3 Interactions in an Infinite Magnetic Field	108
4.3.1 Filled Waveguide	108
4.3.2 Unfilled Waveguide	112
5. Interaction with Ions in a Hot-Electron Plasma	118
5.1 Plasma Dispersion and Weak-Beam Interactions	119
5.1.1 Plasma Dispersion	120
5.1.2 Interaction with a Weak Beam	121
5.1.3 Resistive-Medium Amplification	123
5.2 Strong Interaction with Ions	124
5.2.1 Absolute Instability	125
5.2.2 Infinite Amplification at $\omega_{pi}$	129
5.2.3 Summary of Results	132
5.2.4 Extension to Lower Temperatures	133

Appendix A Comparison of the Method of Fainberg, Kurilko, and Shapiro	139
Appendix B The Landau Contour and the Stability Criteria for a Hot Plasma	143
Appendix C Derivation of One-Dimensional Dispersion Equation	148
Appendix D Classification of Longitudinal Weak-Beam Instabilities	156
Appendix E An Instability Condition for Lossless Systems	158
Appendix F Transverse Beam Waves	160
Appendix G Quasi-static Dispersion Equation	162
Appendix H Absolute Instability of Space-Charge Waves	165
Appendix I Monotonically Decreasing Character of the $p^2$ vs. $q^2$ Relation	168
Appendix J Dispersion Equation for Resistive-Medium Amplification	171
Appendix K Condition for an Absolute Instability	172
Glossary of Common Symbols	175
References	178
Index	185