• **PT-Symmetric Theories** are a new class of field theories which are non-Hermitian, but have positive spectra because of the existence of PT (parity-time reversal) symmetry. Such theories could be important phenomenologically because they permit the existence of nontrivial vacuum expectation values of field, even perturbatively, while maintaining asymptotic freedom. Thus, PT-symmetric theories may offer a new route toward understanding the Higgs mechanism. In 2003 Milton showed that the PT-symmetric quantum electrodynamics which he and Bender had proposed six years ago is inconsistent because of anomalies, but an alternative, based on a photon field which transforms as an axial vector, may permit a nontrivial solution of the eigenvalue condition for the fine structure constant α, based on the quenched beta function, and exhibit strikingly different predictions from ordinary QED. This new theory is based on the interaction $ij^{\mu}A_{5}^{\mu}$, where $j^{\mu}$ is the usual vector current constructed from Dirac fields, but $A_{5}^{\mu}$ is odd under PT. Milton, Bender, and Wang are currently studying the nature of vacuum decay in such schemes (the analogue of Schwinger’s mechanism for the production of electron-positron pairs through a strong constant electric field) and how unitarity is achieved through the use of a “charge conjugation” operator $C$. Milton’s group has just completed the construction of that operator pertubatively. The next step will be the calculation of the unitary $S$-matrix using this new $C$ operator.

• The Casimir effect has been receiving increasing attention in the last few years. In part, this has been driven by new, unambiguous experimental proofs of the phenomenon. Milton has been a leader in the theoretical developments, as evidenced by his monograph, published to much praise in 2001, and the review article this year, which already seems to have had a major impact. Because of advances in nanotechnology and nanoelectronics, the Casimir effect will increasingly play an important role in technological developments. Recent developments by Milton’s group include an impressive demonstration that the Casimir energy of a dilute dielectric cylinder is zero, and that the divergences in the local quantum energy associated with surfaces correspond to the energy contained within those surfaces. This is done by moving beyond the consideration of ideal surfaces, to ones with continuously varying properties. Understanding the nature of the infinities encountered in calculations of quantum vacuum energy should permit us to reach an
intuitive understanding of the sign of the effect, that is, whether it be attractive or repulsive. He has also contributed to the still controversial issue of the temperature dependence of the Casimir force between real materials. All this will help us improve our understanding of the application of quantum field theory to macroscopic situations.

- In 2000 Kalbfleish, Luo, Milton, Smith, and Strauss published first results from an experiment looking for magnetic monopoles produced at the Tevatron. The final experimental limits have now been given in a paper in Physical Review D, which lead to a factor of three improvement in mass limits. Theoretically, Milton have begun the reformulation of the quantum field theory of magnetic charge, which has never been brought to a computationally useful state. This is because the interaction between electric and magnetic currents,

\[
W(j, j^\ast) = \int (dx)(dx')(dx'')^\ast j^\mu (x)\epsilon_{\mu\nu\sigma\tau} \partial^\nu f^\sigma (x - x') D_+ (x' - x'') j^\tau (x'') ,
\]

involves the arbitrary gauge-dependent string function \( f^\mu \), which is subject only to the constraint

\[
\partial_\mu f^\mu (x) = \delta (x) .
\]

To date, no one has been able to do better than to calculate in the eikonal approximation. These improvements will be essential to the extraction of reliable mass limits, because they are based on models of the production process, which are, at present, somewhat ad hoc. Milton hopes to provide some more definitive theoretical results this year.

- A new experiment to improve limits on the electric dipole moment of the electron is being designed, led by Neil Shafer-Ray in our department. This proposed experiment is of obvious interest to the high-energy community. Beyond studying fundamental physics issues, Milton has been involved in considering the trapping of cold molecules to make the measurements, and a first joint paper on the trapping mechanism, based on the Stark effect, involving the construction of a novel electrostatic trap with \( E^2 \) minimum without \( E = 0 \), has appeared in Physical Review A in 2003. It is hoped to be able to improve the sensitivity to the edm of the electron by two orders of magnitude, which should be sufficient to either detect this phenomenon, or to largely rule out low-energy supersymmetry.