an arbitrarily initial-shaped fluid region. The numerical problems that can arise in computing the curvature, in particular when this is varying rapidly, are discussed. A number of numerical examples are shown for simply connected regions which transform themselves into circles as time increases.

IMPLICIT PARTICLE SIMULATION OF ELECTROMAGNETIC PLASMA PHENOMENA. T. Kamimura, *National Institute of Fusion Science, Nagoya, Japan*; E. Montalvo, *Center for Fusion Engineering, The University of Texas 78712, USA*; D. C. Barnes, *Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA*; J. N. Leboeuf, *Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA*; T. Tajima, *Institute for Fusion Studies, The University of Texas 78712, USA.*

A direct method for the implicit particle simulation of electromagnetic phenomena in magnetized, multi-dimensional plasmas is developed. The method is second-order accurate for $\omega \Delta t < 1$, with ω a characteristic frequency and time step Δt. Direct time integration of the implicit equations with simplified space differencing allows the consistent inclusion of finite particle size. Decentered time differencing of the Lorentz force permits the simulation of strongly magnetized plasmas in the limit of zero perpendicular temperature. A Fourier-space iterative technique for solving the implicit field corrector equation, based on the separation of plasma responses perpendicular and parallel to the magnetic field and longitudinal and transverse to the wavevector, is described. Wave propagation properties in a uniform plasma are in excellent agreement with theoretical expectations. Applications to collisionless tearing and coalescence instabilities further demonstrate the usefulness of the algorithm.

MOMENTUM ADVECTION ON A STAGGERED MESH. David J. Benson, *University of California, San Diego, La Jolla, California 92093, USA.*

Eulerian and ALE (Arbitrary Lagrangian–Eulerian) hydrodynamics programs usually split a timestep into two parts. The first part is a Lagrangian step, which calculates the incremental motion of the material. The second part is referred to as the Eulerian step, the advection step, or the remap step, and it accounts for the transport of material between cells. In most finite difference and finite element formulations, all the solution variables except the velocities are cell-centered while the velocities are edge- or vertex-centered. As a result, the advection algorithm for the momentum is, by necessity, different than the algorithm used for the other variables. This paper reviews three momentum advection methods and proposes a new one. One method, pioneered in YAQUI, creates a new staggered mesh, while the other two, used in SALE and SHALE, are cell-centered. The new method is cell-centered and its relationship to the other methods is discussed. Both pure advection and strong shock calculations are presented to substantiate the mathematical analysis. From the standpoint of numerical accuracy, both the staggered mesh and the cell-centered algorithms can give good results, while the computational costs are highly dependent on the overall architecture of a code.

PARTICLE-METHOD SOLUTION OF TWO-DIMENSIONAL CONVECTION–DIFFUSION EQUATIONS. Aaron L. Fogelson, *University of Utah, Salt Lake City, Utah 84112, USA.*

We present a new method for solving two-dimensional convection-dominated convection–diffusion equations containing spatially and temporally localized source terms. The method uses grid-free transport: particles which carry point values of the concentration gradient move by convection and undergo random-walk to simulate diffusion. No numerical diffusion is introduced. Equations for the evolution of the gradient values are solved. The concentration is recovered from the particle data by solving Poisson equations. The method is applied to problems in rotational and elongational flow fields. Numerical results demonstrating convergence of the method are presented.

THE RAPID EVALUATION OF VOLUME INTEGRALS OF POTENTIAL THEORY ON GENERAL REGIONS. Anita Mayo, *IBM Research Division, T. J. Watson Research Division, Yorktown Heights, New York 10598, USA.*

We present a new method for the rapid, high order accurate evaluation of certain volume integrals in potential theory on general irregular regions. The kernels of the integrals are either a fundamental solution, or a linear combination of the derivatives of a fundamental solution of a second-order linear elliptic differential equation. Instead of using a standard quadrature formula or the exact evaluation of any integral, the methods rely on rapid methods of solving the differential equation of which the kernel is the solution. Therefore, the number of operations needed to evaluate the volume integral is essentially equal to the number of operations needed to solve the differential equation on a rectangular region with a regular grid, and the method requires no evaluation of the kernel.

VARIATIONAL CURVE AND SURFACE GRID GENERATION. Stanley Steinberg, *University of New Mexico, Albuquerque, New Mexico 87131, USA*; Patrick Roache, *Ecodynamics Research Associates, Inc., P.O. Box 8172, Albuquerque, New Mexico 87198, USA.*

Variational algorithms that control the lengths of grid lines, cell areas, and the orthogonality of grid lines can be used for generating boundary-conforming grids on surfaces. Additional geometric control is provided by using a reference grid, while solution adaptivity is achieved by using weights. In a typical application, the reference grid can be used to produce an exponential compression of the grid at a boundary, while the solution adaptive weights are used to make the grid spacing inversely proportional to the gradient (when the gradient is large) of some solution being computed on the grid. The grid is adapted on both the interior and boundary of the surface. The algorithm performs these tasks with exceptional precision, as demonstrated in the examples presented here.

A HIGH-RESOLUTION EULER SOLVER BASED ON MULTIGRID, SEMI-COARSENING, AND DEFECT CORRECTION. Wim A. Mulder, *University of California, Los Angeles, California 90024-1555, USA.*

In an earlier paper, an $O(N)$ method for the computation of stationary solutions to the Euler equations of inviscid compressible gas dynamics has been described. The method is a variant of the multigrid technique and employs semi-coarsening in all co-ordinate directions simultaneously. It provides good convergence rates for first-order upwind discretisations even in the case of alignment, the flow being aligned with the grid. Here we discuss the application of this scheme to higher-order discretisations. Two-grid analysis for the linear constant-coefficient case shows that it is difficult to obtain uniformly good convergence rates for a higher-order scheme, because of waves perpendicular to stream lines. The defect correction technique suffers from the same problem. However, convergence to a point where the residual of the total error (the sum of the iteration error and the discretisation error) is of the order of the truncation error can be obtained in about seven defect correction cycles, according to estimates for the linear constant-coefficient equations. This result is explored for the nonlinear case by some illustrative numerical experiments.