List of Figures

1 Thermalization distance of deuterons Vs. plasma temperature in a deuterium plasma of ion number density $10^{26}$/cm$^3$ for the three cases of energy loss: 1. only to electrons, 2. electrons and ions and 3. including nuclear scattering. 3

2 Energy leakage probability of deuterons Vs. pellet radius in a deuterium plasma at temperature 0.1 MeV and ion number density $10^{26}$/cm$^3$ for the three cases of energy loss: 1. only to electrons, 2. electrons and ions and 3. including nuclear scattering. 4

3 Tritium breeding Vs. time for the DT pellet. Curve-1 refers to bremsstrahlung loss only, Curve-2 includes inverse bremsstrahlung as well, Curve-3 includes, in addition, inverse Compton scattering and Curve-4 is similar to curve-3, but without photon losses. 6

4 Yield vs. density for 10 $\mu$g DT pellets having various initial temperatures. 7

5 Transient analytical (symbols) and numerical (line) radiation energy densities in a spherical shell with radiation incident on the inner surface. 9

6 Linear plot of the radiation energy density and material energy density as functions of position in the slab at different times. The symbols represent the analytical solutions. 12

7 Flowchart of the radiation hydrodynamics code. 13

8 Profiles of the scaled thermodynamic variables at $t = 4.879$ ns for the point explosion problem including radiation interaction for $\gamma = 5/4$. Total energy $16.9 \times 10^{16}$ ergs is deposited at $t = 0$ in the innermost mesh. 15

1.1 Target sector of a typical ICF pellet. 34
1.2 Various stages followed in Inertial Confinement Fusion. ................................. 37
1.3 Maxwell-averaged reactivity Vs. temperature for reactions of interest to inertial con-
finement fusion. Reproduced with permission from reference [9]. .......................... 38
1.4 Hydrodynamic variables behind and ahead of a shock wave in a) fixed frame of refer-
ence and b) frame of reference moving with the shock. ........................................ 41
1.5 P-V diagram for shock and adiabatic compression. ............................................ 42
1.6 Radial distribution function (RDF) of Cu before and after melting. ...................... 50
1.7 Jump in the diffusion coefficient (D) of Cu at melting point. ............................... 51
2.1 Charged particle leakage probability ................................................................. 64
2.2 Energy of deuteron Vs. distance traversed in a deuterium plasma at temperature 0.1
MeV and ion number density $10^{26}/cm^3$ for the three cases of energy loss: 1. only to
electrons, 2. electrons and ions and 3. including nuclear scattering. ....................... 65
2.3 Thermalization distance of deuterons Vs. plasma temperature in a deuterium plasma of
ion number density $10^{26}/cm^3$ for the three cases of energy loss: 1. only to electrons,
2. electrons and ions and 3. including nuclear scattering. ................................. 65
2.4 Thermalization distance of deuterons Vs. plasma ion density in a deuterium plasma at
a temperature of 0.1 MeV for the three cases of energy loss: 1. only to electrons, 2.
electrons and ions and 3. including nuclear scattering. ........................................ 66
2.5 Energy leakage probability of deuterons Vs. pellet radius in a deuterium plasma at
temperature 0.1 MeV and ion number density $10^{26}/cm^3$ for the three cases of energy
loss: 1. only to electrons, 2. electrons and ions and 3. including nuclear scattering. .... 66
2.6 (a) Fraction of charged particle (deuteron) energy deposited to the ions in deuterium
plasma as a function of plasma temperature and logarithm of the number density. (b)
Thermalization distance of a 3.5 MeV deuteron in deuterium plasma as a function of
plasma temperature and logarithm of the number density. ............................... 68
2.7 Range of alpha particles Vs. electron temperature for various densities. ............... 69
2.8 Plasma temperature Vs. fraction of alpha energy deposited to ions for various plasma densities.

3.1 Fraction of a) charged particle energy deposited to the ions as the pellet burns. Curve-1 shows the case when energy deposition to ions and electrons due to small angle Coulomb scattering alone is considered. Curve-2 considers energy deposition via large angle Coulomb scattering, collective effects and nuclear interactions using the improved Maxwell averaged reaction rates. b) neutron energy deposited to the ions as the pellet burns. Curve-1 is obtained using the fitted formula and Curve-2 is that for the model discussed in this chapter using the improved Maxwell averaged reaction rates.

3.2 Ion temperatures Vs. time in the DT pellet for a) the model used by Eliezer et al and b) the model described in this chapter. Curve-1 refers to bremsstrahlung loss only, Curve-2 includes inverse bremsstrahlung as well, Curve-3 includes, in addition, inverse Compton scattering and Curve-4 is similar to Curve-3, but without photon losses.

3.3 Tritium breeding Vs. time for the DT pellet for a) the model used by Eliezer et al and b) the model described in this chapter. Curve-1 refers to bremsstrahlung loss only, Curve-2 includes inverse bremsstrahlung as well, Curve-3 includes, in addition, inverse Compton scattering and Curve-4 is similar to curve-3, but without photon losses.

3.4 Fusion power generated Vs. time for the case of energy exchanged via bremsstrahlung, inverse bremsstrahlung and Compton scattering. Curve-1 is for the model used by Eliezer et al and Curve-2 for the model described in this chapter.

3.5 (a) Tritium breeding ratio versus time for DT$_x$ pellets having different initial pellet densities. (b) Deuterium burn fraction as a function of the pellet density.

3.6 (a) Tritium breeding ratio versus time for DT$_x$ pellets having different initial plasma temperatures. (b) Deuterium burn fraction as a function of the initial plasma temperatures.

3.7 (a) Tritium breeding ratio versus time for DT$_x$ pellets having different initial tritium fraction ($x$). (b) Deuterium burn fraction as a function of the initial tritium fraction ($x$).
3.8 Yield Vs. density for 10 µg DT pellets having various initial temperatures.

3.9 Yield Vs. density for 1 µg DT pellets having various initial temperatures.

3.10 Yield Vs. temperature for 10 µg DT pellets having various initial densities.

4.1 Flux incident on the left surface of a slab of thickness $z = l$.

4.2 Finding the roots of the transcendental equation $\tan(\beta(s)) = f(\beta) = \frac{4\sqrt{3}\beta(s)}{4\beta^2(s)-3}$.

4.3 Flux incident on the inner surface of a spherical shell of inner radius $R_1$ and outer radius $R_2$.

4.4 Radiation flux incident on the outer surface of a sphere.

4.5 Scaled radiation energy density $u_r(x, \tau)$ Vs. position $(x)$ in the slab of scaled thickness $b = 1$ at different times for $\varepsilon = 0.1$.

4.6 Scaled material energy density $u_m(x, \tau)$ Vs. position $(x)$ in the slab at different times for $\varepsilon = 0.1$.

4.7 Space derivative of scaled radiation energy density $\partial u_r(x, \tau) / \partial x$ Vs. position $(x)$ in the slab at different times.

4.8 Space derivative of scaled material energy density $\partial u_m(x, \tau) / \partial x$ Vs. position $(x)$ in the slab at different times.

4.9 Leakage currents $J_-(\tau)$ and $J_+(\tau)$ from the left and right surfaces of the slab respectively.

4.10 Integrated radiation ($\psi_r(\tau)$) and material energy densities ($\psi_m(\tau)$) in the slab as a function of scaled time $\tau$.

4.11 Percentage error in the radiation energy density $u_r(x, \tau)$ in the slab as a function of number of roots considered $(N)$.

4.12 Scaled radiation energy density $u_r(x, \tau)$ Vs. position $(x)$ in the slab of scaled thickness $b = 1$ at different times for $\varepsilon = 0.0$.

4.13 Scaled radiation energy density $u_r(x, \tau)$ Vs. position $(x)$ in a spherical shell of scaled inner radius $X_1 = 1$ and outer radius $X_2 = 2$ at different times for $\varepsilon = 0.1$.  

4.14 Scaled material energy density $u_m(x, \tau)$ Vs. position in a spherical shell of scaled inner radius $X_1 = 1$ and outer radius $X_2 = 2$ at different times for $\varepsilon = 0.1$. 121

4.15 Space derivative of scaled radiation energy density $\partial u_r(x, \tau)/\partial x$ Vs. position (x) in the spherical shell at different times. 121

4.16 Space derivative of scaled material energy density $\partial u_m(x, \tau)/\partial x$ Vs. position (x) in the spherical shell at different times. 122

4.17 Leakage currents $J_-(\tau)$ and $J_+(\tau)$ from the inner and outer surfaces of the spherical shell respectively. 122

4.18 Integrated radiation ($\psi_r(\tau)$) and material energy densities ($\psi_m(\tau)$) in the spherical shell as a function of scaled time $\tau$. 123

4.19 Percentage error in the radiation energy density $u_r(x, \tau)$ in the spherical shell as a function of number of roots considered (N). 123

4.20 Scaled radiation energy density $u_r(x, \tau)$ Vs. position (x) in a sphere of scaled radius $X= 0.5$. 124

4.21 Scaled material energy density $u_r(x, \tau)$ Vs. position (x) in a sphere of scaled radius $X= 0.5$. 125

5.1 Grid structure. 129

5.2 (a) The (x,t) diagram in a shock tube. (b) Velocities of the fronts relative to the shock tube and (c) Illustrative pressure profiles at time t. 134

5.3 Comparison of the variables obtained from the simulation data in the pure hydrodynamic case (points) with the analytical solutions (lines) for the shock tube problem. 138

5.4 Comparison of the scaled variables obtained from the simulation data in the pure hydrodynamic case (points) with the self similar solutions (lines) for the point explosion problem. Specific internal energy $E = 10^5$ Tergs/gm is deposited in the inner two meshes and $\gamma = 1.4$. 141
5.5 Comparison of a) the velocities from the simulation data with the analytical solutions for the Noh problem in spherical geometry and b) the pressures in cylindrical geometry at time $t = 0.6 \mu\text{sec.}$

5.6 Scaled radiation energy density $u_r(x, \tau)$ Vs. position (x) in the slab of scaled thickness b=1 at different times for $\epsilon = 0.1$. The symbols stand for analytical values whereas lines represent the results obtained from finite difference method.

5.7 Scaled material energy density $u_m(x, \tau)$ Vs. position (x) in the slab at different times for $\epsilon = 0.1$. The symbols stand for analytical values whereas lines represent the results obtained from finite difference method.

5.8 Scaled radiation $u_r(x, \tau)$ and material energy density $u_m(x, \tau)$ Vs. slab depth at different times for $\epsilon = 0.1$. The symbols stand for analytical values whereas lines represent the results obtained from finite difference method.

5.9 Scaled radiation energy density $u_r(x, \tau)$ Vs. position (x) in a spherical shell of scaled inner radius $X_1 = 1$ and outer radius $X_2 = 2$ at different times for $\epsilon = 0.1$. The symbols stand for analytical values whereas lines represent the results obtained from finite difference method.

5.10 Scaled material energy density $u_m(x, \tau)$ Vs. position in a spherical shell of scaled inner radius $X_1 = 1$ and outer radius $X_2 = 2$ at different times for $\epsilon = 0.1$. The symbols stand for analytical values whereas lines represent the results obtained from finite difference method.

5.11 Linear plot of the radiation energy density and material energy density as functions of position in the slab at different times. The symbols represent the analytical solutions.

5.12 Linear plot of the scaled radiation temperature density $(T_r/T_{inc})^4$ as functions of position in the slab at different times. The symbols represent the analytical solutions.

5.13 Linear plot of the scaled material temperature density $(T_m/T_{inc})^4$ as functions of position in the slab at different times. The symbols represent the analytical solutions.
5.14 Radiation flux Vs. position at consecutive times. The symbols represent the solutions generated by Wilson [104] ........................................ 160

5.15 Radiation energy density Vs. position in the slab at consecutive times. The symbols represent the solutions generated by Wilson [104] ........................................ 161

5.16 Radiation temperature Vs. position at consecutive times. The symbols represent the solutions generated by Wilson [104] ........................................ 161

5.17 Radiation and material energy densities in a sphere at consecutive times. ............ 164

5.18 Steady state radiation temperatures within a sphere with no emission. ................. 164

6.1 Section of a cylindrical hohlraum with a hole in the wall on which an aluminium foil is placed. ................................................................. 172

6.2 Flowchart for the Implicit 1D Radiation Hydrodynamics. Here, ‘nh’ is the time step index and ‘dt’ is the time step taken. The iteration indices for electron temperature and total pressure are ‘npt’ and ‘npp’ respectively. ‘Error1’ and ‘Error2’ are the fractional errors in pressure and temperature respectively whereas ‘eta1’ and ‘eta2’ are those acceptable by the error criterion. ........................................ 175

6.3 Comparison of simulation data (points) with scaling law (line) relating shock velocity with the radiation temperature for aluminium. ................................. 176

6.4 Profiles of the thermodynamic variables: (a) velocity, (b) pressure, (c) density and (d) temperature in the region behind the shock as a function of position at t = 2.5 ns. The region ahead of the shock is undisturbed and retain initial values of the variables. The incident radiation temperature on the Al foil is shown in figure 6.5. ..................... 177

6.5 Radiation temperature profile in the hohlraum for strong shock propagation in aluminium. 178

6.6 Distance traversed by the shock front Vs. time in Al foil for incident radiation temperature shown in figure 6.5. The two slopes correspond to the two plateaus in the radiation profile. ............................................................ 178
Profiles of the scaled thermodynamic variables at $t = 4.879$ ns for the point explosion problem including radiation interaction for $\gamma = 5/4$. Total energy $16.9 \times 10^{16}$ ergs is deposited at $t=0$ in the innermost mesh.

Profiles of the scaled thermodynamic variables at $t = 0.5145$ ns for the point explosion problem including radiation interaction for $\gamma = 5/4$. Total energy $235 \times 10^{16}$ ergs is deposited at $t=0$ in the first mesh.

(a) Spatial convergence rate for the $L_1$ norm (b) Temporal convergence rate for the $L_1$ norm (c) Spatial convergence rate for the $L_2$ norm and (d) Temporal convergence rate for the $L_2$ norm obtained for the error in the thermodynamic variable internal energy (E) for the problem of shock propagation in Al foil.

(a) Spatial and (b) Temporal convergence rate for the $L_1$ norm obtained for the error in the thermodynamic variable internal energy (E) for the problem of point explosion with radiation interaction (Total energy $235 \times 10^{16}$ ergs is deposited).

$L_2$-Error/mesh in velocity Vs. time step for the shock wave propagation problem in aluminium with $\Delta t/\Delta x = 5 \times 10^{-3}$ $\mu$s/cm. Convergence rate is higher for the implicit scheme.

CPU cost Vs. time step for the shock wave propagation problem in aluminium with mesh width $\Delta x = 2 \times 10^{-4}$ cm.

Schematic of slopes for fourth order Runge Kutta Method.

Melting curve for Cu.

Melting curve for Al.

Random doping of Cu with (a) 5% and (b) 25% Ti.

Negative octant of supercell with (a) single microstructure of 5.5973% Ti and (b) 9 microstructures of Ti, each of radius 7 Å with 19.6% Ti.
D.3 Selective doping of Cu with 25% Ti for two Ti-arrangements, namely, (a) atom1 and (b) atom4. ................................................................. 206

D.4 Linear variation of the lattice parameter as a function of the atomic weight percent of the dopant Ti in Cu. ......................................................... 208

D.5 RDFs for Cu-Cu bond in the case of random doping of Cu with Ti. Inset shows linear variation in melting point (M.P.) as a function of the number percent of the dopant Ti in Cu. ......................................................... 208

D.6 RDFs for Cu-Cu bond in case of single microstructure doping of Cu with Ti. Inset shows linear variation in melting point as a function of the number percent of the dopant Ti in Cu. ......................................................... 209

D.7 RDFs for Cu-Cu bond in case of 8 microstructure doping of Cu with Ti. Inset shows linear variation in melting point as a function of the number percent of the dopant Ti in Cu. ......................................................... 210

D.8 RDFs for Cu-Cu bond in case of selective doping of Cu with Ti (atom1). Inset shows variation in melting points as a function of the number percent of the dopant Ti in Cu. ......................................................... 211

D.9 First three peaks of the Cu-Cu RDF for selective substitutional doping of Cu with 25% Ti doping. Inset shows variation in melting points for different Ti arrangements having 25% Ti concentration. ......................................................... 212

D.10 Melting points obtained for different types of substitutional doping of Cu with Ti. ......................................................... 213

D.11 First Cu-Cu RDF peaks for natural phases of CuTi alloy. Inset shows variation in melting point. ......................................................... 214