Chapter One

FIRST AND SECOND LAWS

We might reason, a priori, that such absolute destruction of living force cannot possibly take place; because it is manifestly absurd to suppose that the powers with which God has endowed matter can be destroyed, any more than that they can be created by man’s agency; but we are not left with this argument alone, decisive as it must be to any unprejudiced mind. . . . Experiment has enabled us to answer these questions in a satisfactory manner, for it has shown that wherever living force is apparently destroyed, an equivalent is produced which, in process of time, may be reconverted into living force.

James P. Joule, 1847

NOTATION

\[ A \text{ Free energy density } \text{kcal kg}^{-1} \]
\[ B \text{ A body} \]
\[ \partial B \text{ External surface of the body} \]
\[ b \text{ Field acceleration } \text{m s}^{-2} \]
\[ f() \text{ Constitutive function for pressure } \text{atm} \]
\[ F \text{ Force } \text{kg m s}^{-2} \]
\[ J_r \text{ Rate of entropy supply } \text{kcal kg}^{-1} \text{s}^{-1} \]
\[ J \text{ Radiant entropy supply } \text{kcal kg}^{-1} \text{s}^{-1} \]
\[ j \text{ Entropy flux } \text{kcal m}^{-2} \text{s}^{-1} \text{K}^{-1} \]
\[ K \text{ Kinetic energy } \text{kcal kg}^{-1} \]
\[ L \text{ Any constitutive quantity} \]
\[ l() \text{ Constitutive function for } L \]
\[ m \text{ Mass } \text{kg} \]
\[ n_t \text{ Total number of moles } \text{kmol} \]
\[ p \text{ Pressure } \text{atm} \]
\[ P \text{ Power } \text{kcal s}^{-1} \]
\[ P() \text{ A process} \]
Chapter One

Q Radiant heat supply kcal kg⁻¹ s⁻¹
Q Rate of heating kcal s⁻¹
Q⁺ Rate of heat supply kcal s⁻¹
Q⁻ Rate of heat removal kcal s⁻¹
q Local rate of heating kcal kg⁻¹ s⁻¹
q Conductive heat flux kcal m⁻² s⁻¹
R Gas constant kcal kmol⁻¹ K⁻¹
S Entropy density kcal kg⁻¹ K⁻¹
ds Surface element m²
\( t \) Time s
\( T \) Temperature K
\( T^+ \) Highest temperature at which heat is supplied K
\( T^- \) Lowest temperature at which heat is removed K
\( U \) Internal energy density kcal kg⁻¹
\( U_t \) Total internal energy kcal
\( V_t \) Volume m³
\( v \) Velocity ms⁻¹
\( W_t \) Net work rate kcal s⁻¹
\( w \) Local work rate kcal kg⁻¹ s⁻¹
\( Z \) Dissipation rate kcal kg⁻¹ s⁻¹
\( Z_T \) Thermal dissipation rate kcal kg⁻¹ s⁻¹
\( Z_M \) Nonthermal dissipation rate kcal kg⁻¹ s⁻¹
\( \Gamma \) Efficiency of a heat engine
\( \Phi \) Density kg m⁻³
\( \sigma \) State
\( \phi \) Potential of body force s⁻²
\( \phi_t \) Potential energy kcal

Subscripts
B From body forces
E From external forces
cond By conduction
rad By radiation
t Total

Superscripts
. Time derivative
+ Where heat flows in
− Where heat flows out
0 Adiabatic