Dimensionless Numbers

3.185

November 24, 2003

Note: you are not responsible for knowing the different names of the mass transfer dimensionless numbers, just call them, e.g., "mass transfer Prandtl number", as many people do. Those names are given here because some people use them, and you'll probably hear them at some point in your career.

<table>
<tr><td>Heat Transfer</td><td>Mass Transfer</td></tr>
<tr><td>Biot Number
Ratio of conductive to convective H.T. resistance
Determines uniformity of temperature in solid
$\mathrm{Bi} = hL/k_{solid}$</td><td>M.T. Biot Number
Ratio of diffusive to reactive or conv MT resistance
Determines uniformity of concentration in solid
$\mathrm{Bi} = kL/D_{solid}$ or $h_D L/D_{solid}$</td></tr>
<tr><td colspan="2">Fourier Number
Ratio of current time to time to reach steady-state
Dimensionless time in temperature curves, used in explicit finite difference stability criterion</td></tr>
<tr><td>$\mathrm{Fo} = \alpha t/L^2$</td><td>$\mathrm{Fo} = Dt/L^2$</td></tr>
<tr><td colspan="2">Knudsen Number:
Ratio of gas molecule mean free path to process lengthscale
Indicates validity of line-of-sight (> 1) or continuum (< 0.01) gas models
$\mathrm{Kn} = \frac{\lambda}{L} = \frac{kT}{\sqrt{2}\pi\sigma^2 PL}$</td></tr>
<tr><td colspan="2">Reynolds Number:
Ratio of convective to viscous momentum transport
Determines transition to turbulence, dynamic pressure vs. viscous drag
$\mathrm{Re} = \rho UL/\mu = UL/\nu$</td></tr>
<tr><td>Prandtl Number
Ratio of momentum to thermal diffusivity
Determines ratio of fluid/HT BL thickness
$\mathrm{Pr} = \nu/\alpha = \mu c_p/k$</td><td>M.T. Prandtl (Schmidt) Number
Ratio of momentum to species diffusivity
Determines ratio of fluid/MT BL thickness
$\mathrm{Pr} = \nu/D = \mu/\rho D$</td></tr>
<tr><td>Nusselt Number
Ratio of lengthscale to thermal BL thickness
Used to calculate heat transfer coefficient h
$\mathrm{Nu} = hL/k_{fluid}$</td><td>M.T. Nusselt (Sherwood) Number
Ratio of lengthscale to diffusion BL thickness
Used to calculate mass transfer coefficient h_D
$\mathrm{Nu} = h_D L/D_{fluid}$</td></tr>
<tr><td colspan="2">Grashof Number
Ratio of natural convection buoyancy force to viscous force
Controls the ratio of lengthscale to natural convection boundary layer thickness</td></tr>
<tr><td>$\mathrm{Gr} = g\beta\Delta T L^3/\nu^2$</td><td>$\mathrm{Gr} = g\beta_C \Delta C L^3/\nu^2$</td></tr>
<tr><td colspan="2">Peclet Number
Ratio of convective to diffusive heat/mass transport in a fluid
Used to determine plug flow/perfect mixing (CSTR) continuous flow model validity</td></tr>
<tr><td>$\mathrm{Pe} = \mathrm{RePr} = UL/\alpha$</td><td>$\mathrm{Pe} = \mathrm{RePr} = UL/D$</td></tr>
<tr><td colspan="2">Rayleigh Number
Ratio of natural convective to diffusive heat/mass transport
Determines the transition to turbulence</td></tr>
<tr><td>$\mathrm{Ra} = \mathrm{GrPr} = g\beta\Delta T L^3/\nu\alpha$</td><td>$\mathrm{Ra} = \mathrm{GrPr} = g\beta_C \Delta C L^3/\nu D$</td></tr>
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