

## Difusão em Regime Transiente

**Quadro 5.1 — Distribuições da concentração adimensional de A para a difusão em regime transiente sem resistência externa**

	$\theta(\eta, Fo_M)$	$\gamma_n$	$z_1$
placa-plana infinita	$2 \sum_{n=0}^{\infty} \frac{(-1)^n}{\gamma_n} \cos(\eta \gamma_n) e^{(-\gamma_n^2 Fo_M)}$	$(2n+1) \frac{\pi}{2}$	a
esfera	$2 \sum_{n=1}^{\infty} \frac{(-1)^{n+1}}{\gamma_n} \text{sen}(\eta \gamma_n) e^{(-\gamma_n^2 Fo_M)}$	$(n\pi)$	R
cilindro infinito	$2 \sum_{n=1}^{\infty} \frac{1}{\gamma_n} \left[ \frac{J_0(\eta \gamma_n)}{J_1(\gamma_n)} \right] e^{(-\gamma_n^2 Fo_M)}$	tab.(5.1)	s

**Quadro 5.2 — Concentrações médias adimensionais de A para a difusão em regime transiente sem resistência externa**

	$\bar{\theta}(Fo_M)$	$\gamma_n$	$z_1$
placa-plana infinita	$2 \sum_{n=0}^{\infty} \frac{1}{\gamma_n^2} e^{(-\gamma_n^2 Fo_M)}$	$(2n+1) \frac{\pi}{2}$	a
esfera	$6 \sum_{n=1}^{\infty} \frac{1}{\gamma_n^2} e^{(-\gamma_n^2 Fo_M)}$	$(n\pi)$	R
cilindro infinito	$4 \sum_{n=1}^{\infty} \frac{1}{\gamma_n^2} e^{(-\gamma_n^2 Fo_M)}$	tab.(5.1)	s

<sup>a</sup> Tabela 5.1 — Raízes de  $J_0(\gamma_n) = 0$

$\gamma_1$	$\gamma_2$	$\gamma_3$	$\gamma_4$	$\gamma_5$	$\gamma_6$
2,4048	5,5201	8,6537	11,7915	14,9309	18,0711

<sup>a</sup> Fonte: M. R. Spiegel, *Manual de fórmulas e tabelas matemáticas*. São Paulo: McGraw-Hill do Brasil, 1973.

**Tabela 5.1b – Raízes de  $J_1(\gamma_n)$**

$\gamma_1$	$\gamma_2$	$\gamma_3$	$\gamma_4$	$\gamma_5$	$\gamma_6$
3,8317	7,0156	10,1735	13,3237	16,4706	19,6159

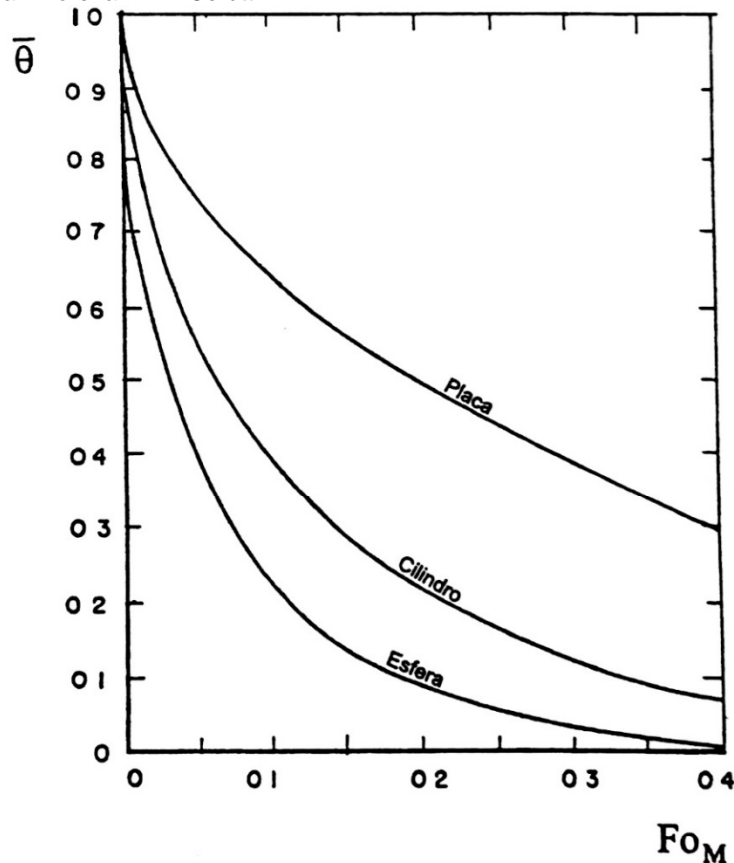


Figura 5.8: Curvas para a difusão em regime transiente com resistência externa desprezível.  
 (Fonte: Skelland, A. H. P. *Diffusional Mass Transfer*, New York, John Wiley, 1974, p. 28.)

Quadro 5.3 — Distribuições das concentrações adimensionais de A para a difusão em regime transiente com resistência externa

	$\theta = \theta(\eta, Fo_M)$	$\gamma_n$	$z_1$
placa-plana infinita	$2 \sum_{n=1}^{\infty} \frac{Bi_M}{\left[ \gamma_n^2 + Bi_M^2 + Bi_M \right]} \frac{\cos(\gamma_n \eta)}{\cos(\gamma_n)} e^{-\gamma_n^2 Fo_M}$	tab.(5.3)	a
esfera	$\frac{2}{\eta} \sum_{n=1}^{\infty} \frac{Bi_M}{\left[ \gamma_n^2 + Bi_M(Bi_M - 1) \right]} \frac{\text{sen}(\gamma_n \eta)}{\text{sen}(\gamma_n)} e^{-\gamma_n^2 Fo_M}$	tab.(5.4)	R
cilindro infinito	$2 \sum_{n=1}^{\infty} \frac{Bi_M}{\left( \gamma_n^2 + Bi_M^2 \right)} \left[ \frac{J_0(\gamma_n \eta)}{J_0(\gamma_n)} \right] e^{-\gamma_n^2 Fo_M}$	tab.(5.5)	s

Quadro 5.4 — Concentrações médias adimensionais de A para a difusão em regime transiente com resistência externa

	$\bar{\theta} = \bar{\theta}(Fo_M)$	$\gamma_n$	$z_1$
placa-plana infinita	$2 \sum_{n=1}^{\infty} \frac{Bi_M^2}{\gamma_n^2 (\gamma_n^2 + Bi_M^2 + Bi_M)} e^{-\gamma_n^2 Fo_M}$	tab.(5.3)	a
esfera	$6 \sum_{n=1}^{\infty} \frac{Bi_M^2}{\gamma_n^2 [\gamma_n^2 + Bi_M(Bi_M - 1)]} e^{-\gamma_n^2 Fo_M}$	tab.(5.4)	R
cilindro infinito	$4 \sum_{n=1}^{\infty} \frac{Bi_M^2}{\gamma_n^2 (\gamma_n^2 + Bi_M^2)} e^{-\gamma_n^2 Fo_M}$	tab.(5.5)	s

<sup>a</sup> Tabela 5.3 — Raízes da eq. **PLACA**

$Bi_M$	$\gamma_1$	$\gamma_2$	$\gamma_3$	$\gamma_4$	$\gamma_5$	$\gamma_6$
0	0	3,1416	6,2832	9,4248	12,5664	15,7080
0,01	0,0998	3,1448	6,2848	9,4258	12,5672	15,7086
0,1	0,3111	3,1731	6,2991	9,4354	12,5743	15,7143
0,2	0,4328	3,2039	6,3148	9,4459	12,5823	15,7207
0,5	0,6533	3,2923	6,3616	9,4775	12,6060	15,7397
1,0	0,8603	3,4256	6,4373	9,5293	12,6453	15,7713
2,0	1,0769	3,6436	6,5783	9,6296	12,7223	15,8336
5,0	1,3138	4,0336	6,9096	9,8928	12,9352	16,0107
10,0	1,4289	4,3058	7,2281	10,2003	13,2142	16,2594
100,0	1,5552	4,6658	7,7764	10,8871	13,9981	17,1093
$\infty$	1,5708	4,7124	7,8540	10,9956	14,1372	17,2788

<sup>a</sup> Fonte: J. Crank, *The mathematics of diffusion*. Londres: Oxford University Press, 1956.

<sup>a</sup> Tabela 5.4 — Raízes da eq. **ESFERA**

$Bi_M$	$\gamma_1$	$\gamma_2$	$\gamma_3$	$\gamma_4$	$\gamma_5$	$\gamma_6$
0	0	4,4934	7,7253	10,9041	14,0662	17,2208
0,01	0,1730	4,4956	7,7256	10,9050	14,0669	17,2213
0,1	0,5423	4,5157	7,7382	10,9133	14,0733	17,2266
0,2	0,7593	4,5379	7,7511	10,9225	14,0804	17,2324
0,5	1,1656	4,6042	7,7899	10,9499	14,1017	17,2498
1,0	1,5708	4,7124	7,8540	10,9956	14,1372	17,2788
2,0	2,0288	4,9132	7,9787	11,0856	14,2075	17,3364
5,0	2,5704	5,3540	8,3029	11,3349	14,4080	17,5034
10,0	2,8363	5,7172	8,6587	11,6532	14,6870	17,7481
100,0	3,1102	6,2204	9,3309	12,4414	15,5522	18,6633
$\infty$	3,1416	6,2832	9,4248	12,5664	15,7080	18,8496

<sup>a</sup> Fonte: J. Crank, *The mathematics of diffusion*. Londres: Oxford University Press, 1956.

<sup>a</sup> Tabela 5.5 — Raízes da eq. **CILINDRO**

$Bi_M$	$\gamma_1$	$\gamma_2$	$\gamma_3$	$\gamma_4$	$\gamma_5$	$\gamma_6$
0	0	3,8137	7,0156	10,1735	13,3237	16,4706
0,01	0,1412	3,8343	7,0170	10,1745	13,3244	16,4712
0,1	0,4417	3,8577	7,0298	10,1833	13,3312	16,4767
0,2	0,6170	3,8835	7,0440	10,1931	13,3387	16,4828
0,5	0,9408	3,9594	7,0864	10,2225	13,3611	16,5010
1,0	1,2558	4,0795	7,1558	10,2710	13,3984	16,5312
2,0	1,5994	4,2910	7,2884	10,3658	13,4719	16,5910
5,0	1,9898	4,7131	7,6177	10,6223	13,6786	16,7630
10,0	2,1795	5,0332	7,9569	10,9363	13,9580	17,0099
100,0	2,3809	5,4652	8,5678	11,6747	14,7834	17,8931
$\infty$	<sup>12</sup> 2,4048	5,5201	8,6537	11,7915	14,9309	18,0711

<sup>a</sup> Fonte: J. Crank, *The mathematics of diffusion*. Londres: Oxford University Press, 1956.

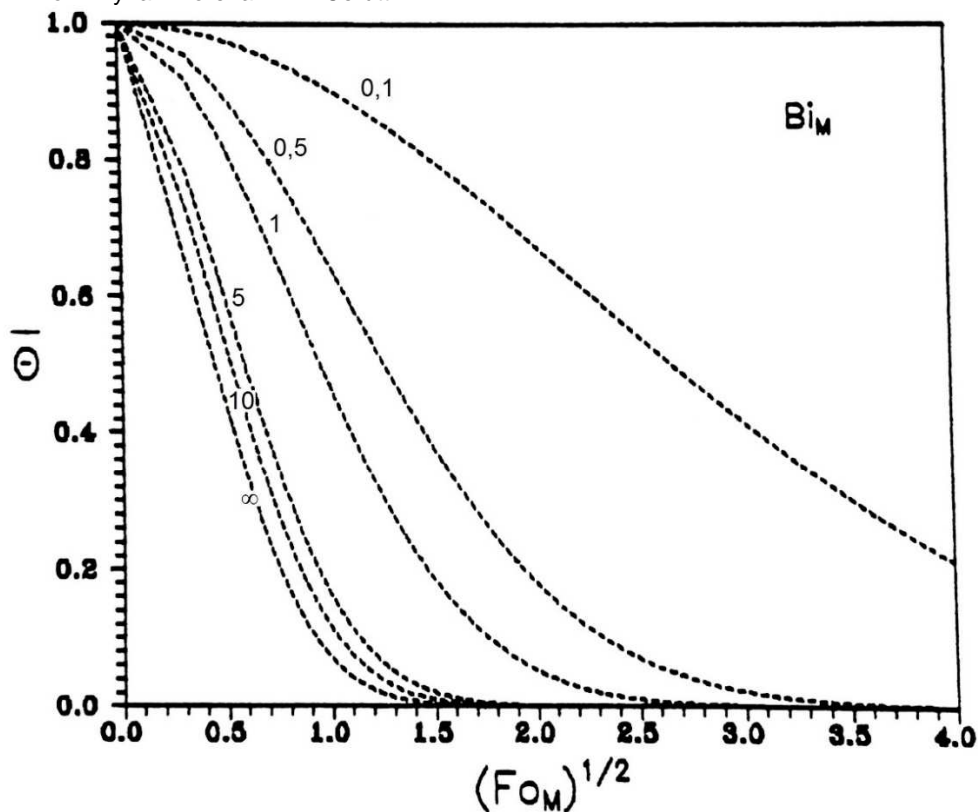


Figura 5.12: Distribuição da concentração média adimensional com resistência externa: *placa-plana infinita*.

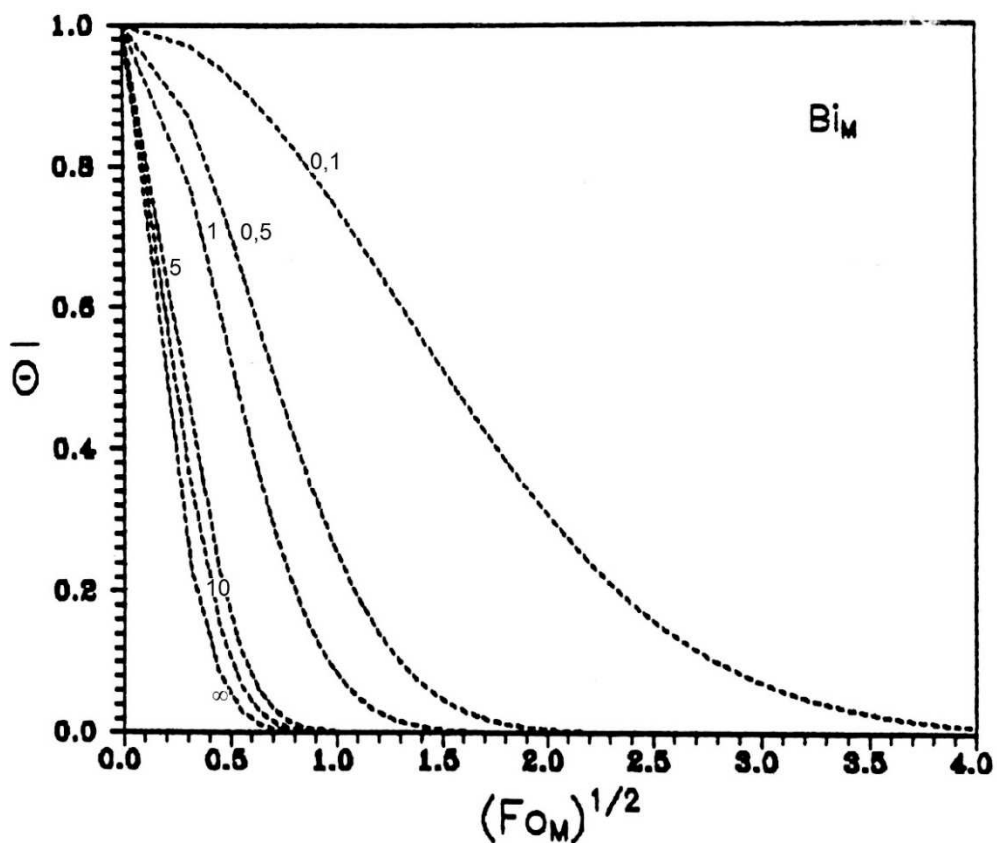


Figura 5.13: Distribuição da concentração média adimensional com resistência externa: *esfera*.



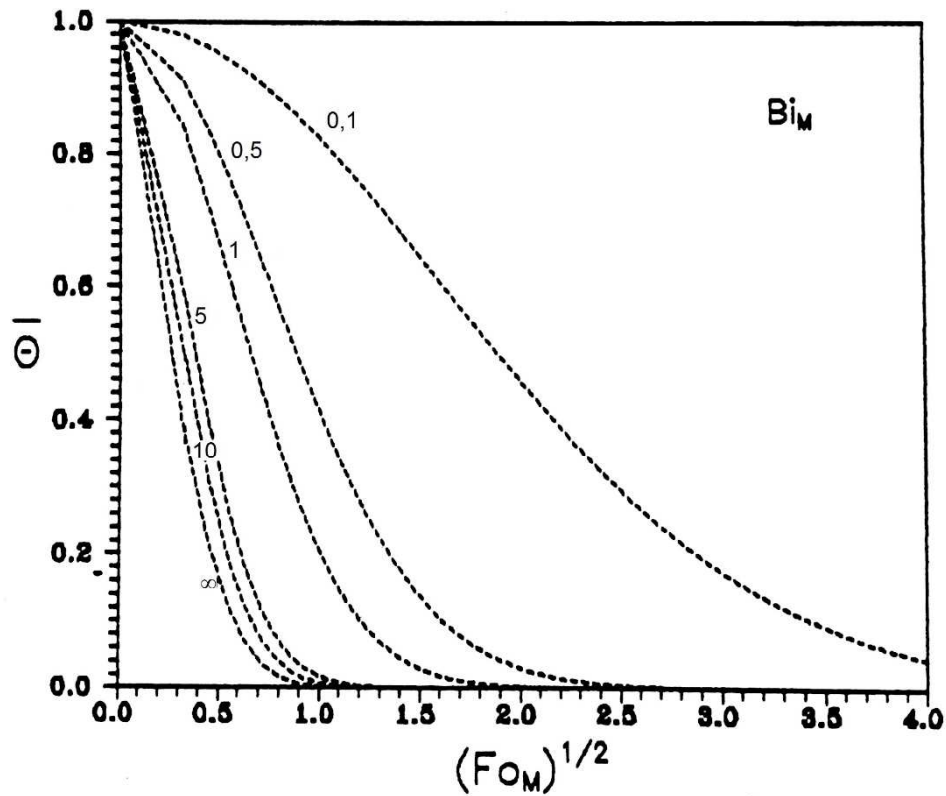


Figura 5.14: Distribuição da concentração adimensional com resistência externa: *cilindro infinito*.

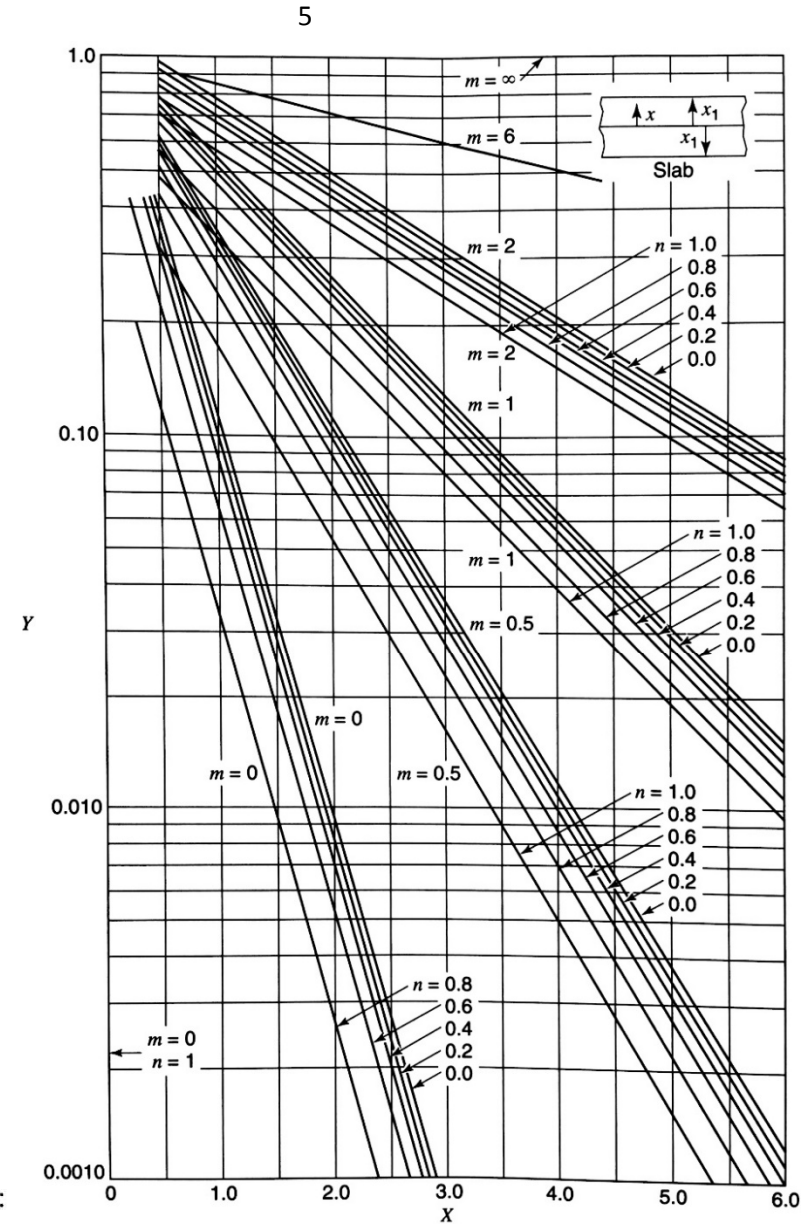
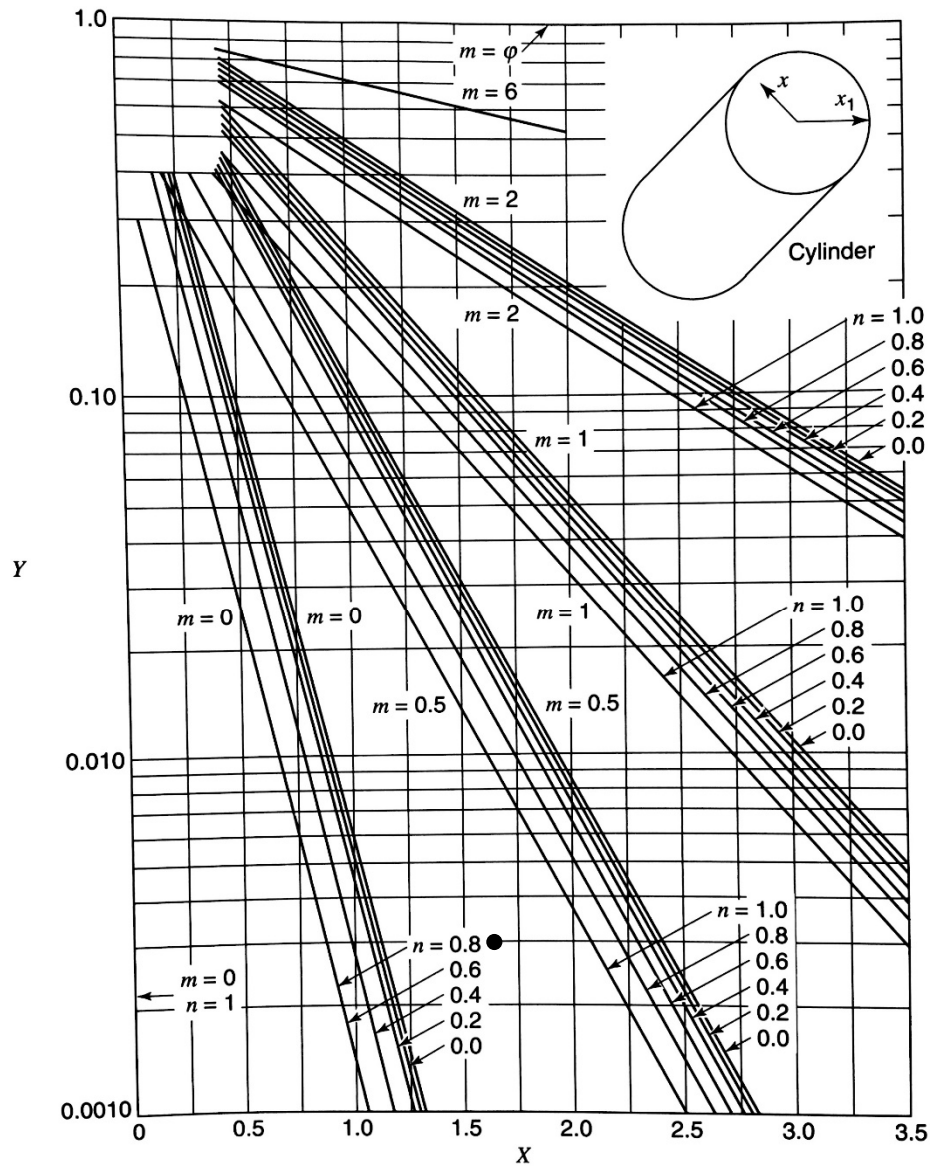
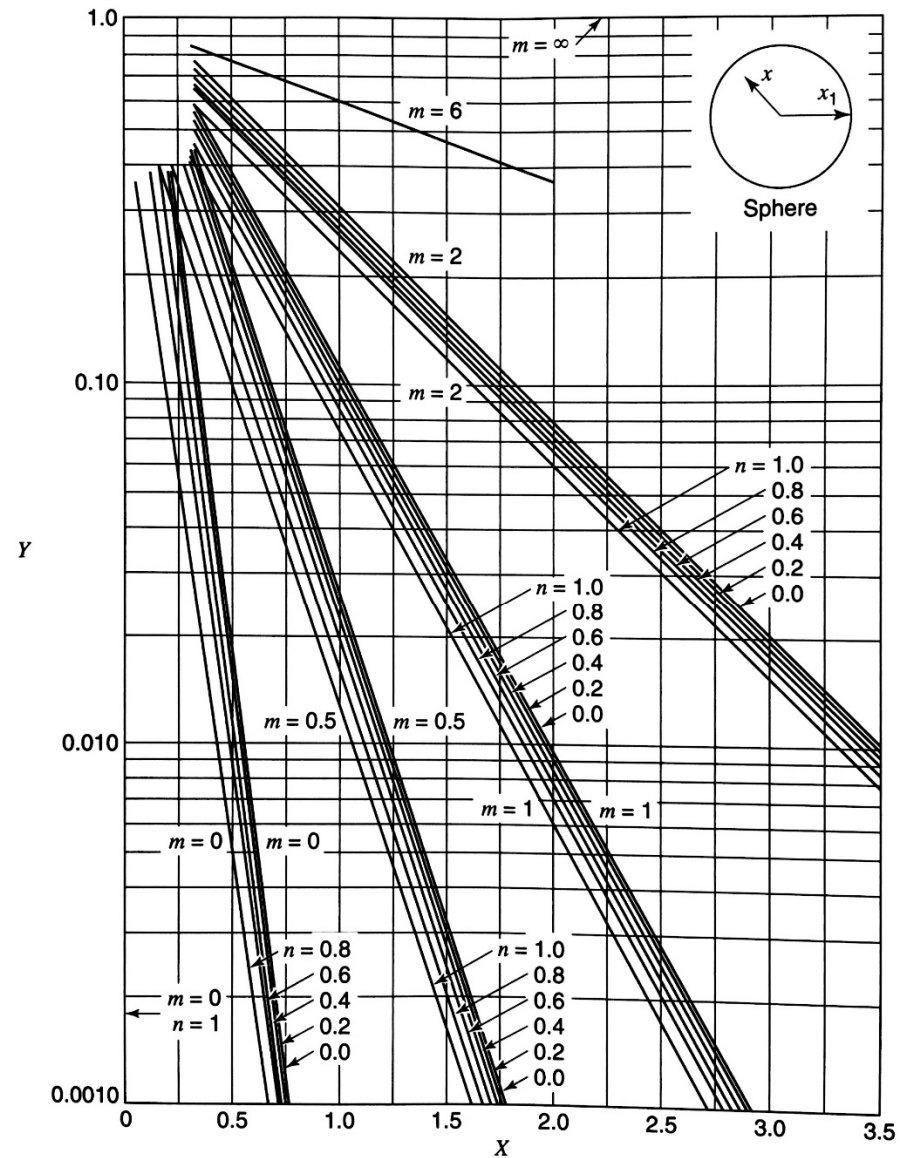


Figure F.1 Unsteady-state transport in a large flat slab.



**Figure F.2** Unsteady-state transport in a long cylinder.

● OBS: erro na indicação das linhas do grupo  $m=0$ . Primeira linha  $n=0.8$ ; segunda linha  $n=0.6$ ; terceira linha  $n=0.4$ ; quarta linha  $n=0.2$  e quinta linha  $n=0.0$ .



**Figure F.3** Unsteady-state transport in a sphere.