Heisler Charts

General methodology for using the charts in chapter 9-2:
Use a plane wall of thickness 2L as an example

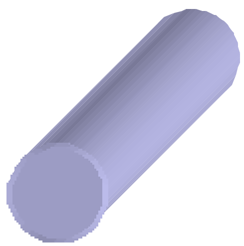
- Use figure 9-13(a) to determine the midplane temperature as a function of time: $T_O=T(x=0,t)$ for given Biot numder

- Use figure 9-13(b) to determine the temperature distribution $T(x,t^*)$ at a given point x and a given time t* by relating to the midplane temperature at the given time, $T_O(t^*)$. That is, to determine $(T(x,t^*)-T_\infty)/(T_O(t^*)-T_\infty)$ for given x/L using figure 9-13(b)

- Internal energy change should first be calculated: $Q_O=\rho cV(Ti-T_\infty)$. Based on this, the total heat transfer at a given time, Q, can be determined from figure 9-13(c) at a given Biot number by finding Q/Q_O. A new variable $Bi^2\tau$ is used to represent the time variation.

Unsteady HT Example

A 2-m long 0.2-m-diameter steel cylinder (k=40 W/m.K, $\alpha=1\times10^{-5}$ m^2/s, $\rho=7854$ kg/m^3, c=434 J/kg.K), initially at 400 C, is suddenly immersed in water at 50 C for quenching process. If the convection coefficient is 200 $W/m^2.K$, calculate after 20 minutes: (a) the center temperature, (b) the surface temperature, (c) the heat transfer to the water.



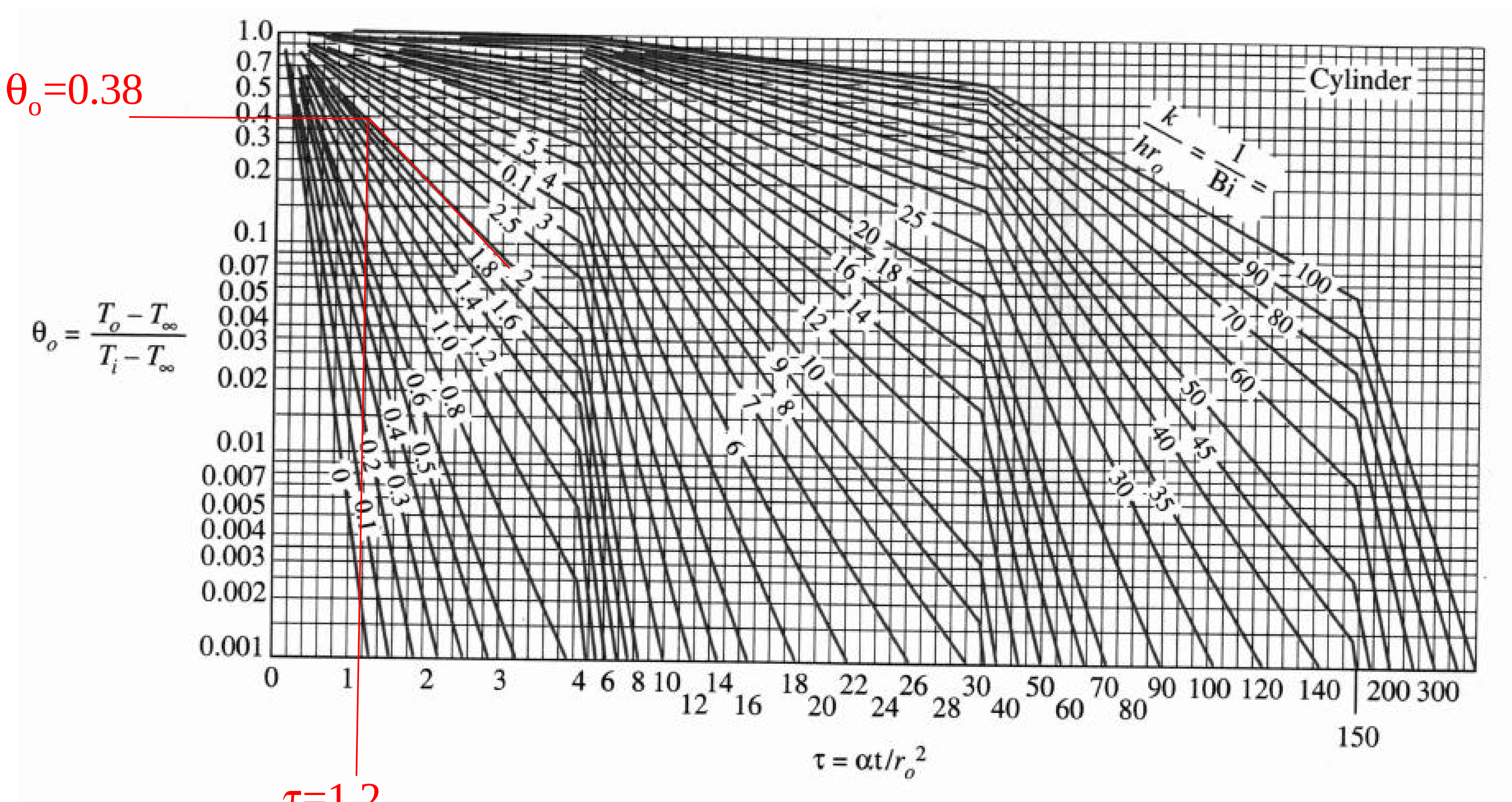
- L/D=2/0.2=10, assume infinitely long cylinder
- Check Lumped Capacitance Method (LCM) assumption: $Bi=h(r_o/2)/k=(200)(0.1)/2/40=0.25>0.1$, can not use LCM, instead use Heisler charts.
- Redefine $Bi=hr_o/k=0.5$

Define Fourier number (Fo or τ): $\tau = \dfrac{\alpha t}{r_O^2} = \dfrac{(10^{-5})(20)(60)}{(0.1)^2} = 1.2$

$Bi^2\tau = (0.5)^2(1.2) = 0.3$

Example (cont.)

(a) The centerline temperature: $Bi^{-1}=2$, $\tau=1.2$, from figure 9-14(a),
$(T_O-T_\infty)/(T_i-T_\infty)=0.38$, $(T_i-T_\infty)=400-50=350$
Center line Temp. T_O(t=20 min.)=(0.38)(350)+50=183° C.



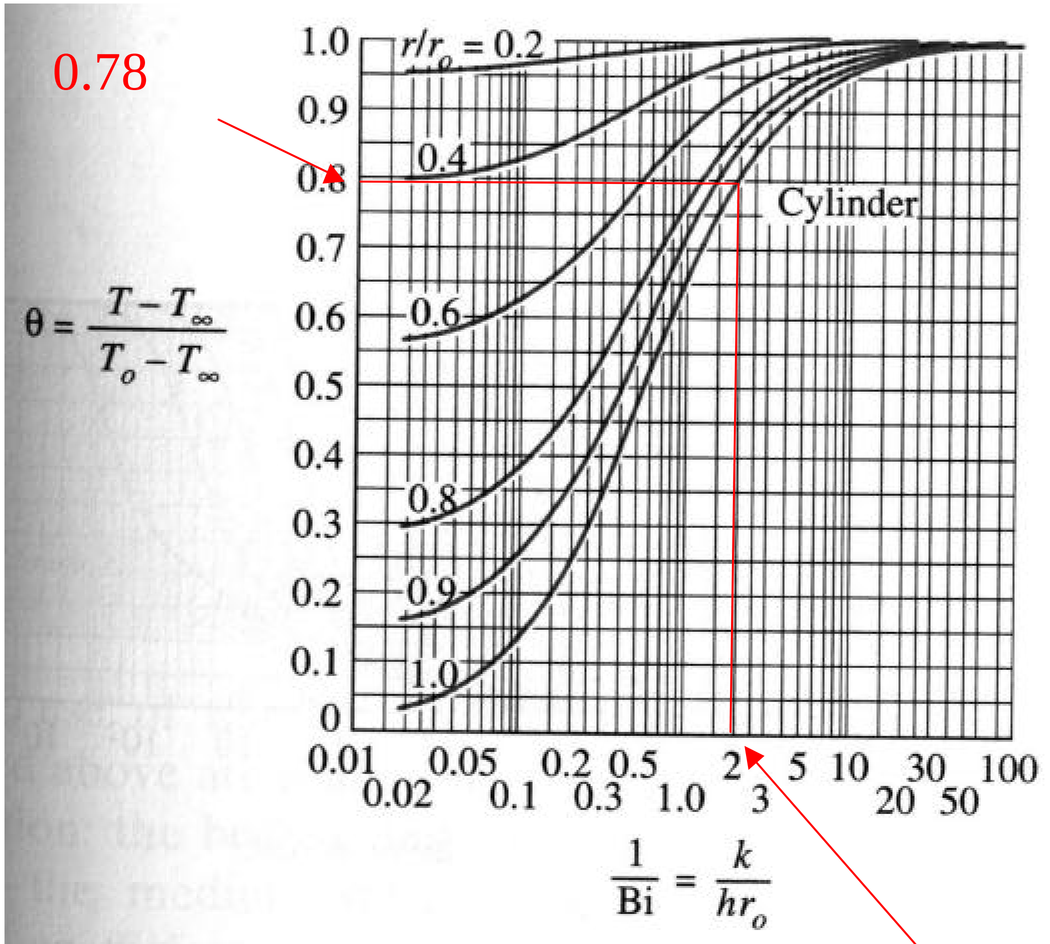
(a) Midplane temperature (from M. P. Heisler)

Example (cont.)

(b) The surface temperature should be evaluated at $r/r_O=1$, for $Bi^{-1}=2$, $(T-T_\infty)/(T_O-T_\infty)=0.78$ from figure 9-14(b)

$$\frac{T-T_\infty}{T_i-T_\infty}=\frac{T-T_\infty}{T_O-T_\infty}\frac{T_O-T_\infty}{T_i-T_\infty}$$
$$=(0.78)(0.38)=0.296$$

$$T(r=r_O,t=20\text{min.})$$
$$=50+(0.296)(350)=153.6°C$$



(b) Temperature distribution (from M. P. Heisler)

Example (cont.)

(c) Total heat transfer: $\mathrm{Bi}^2 t = 0.3$, $Bi = 0.5$, From figure 9-14(c), $Q/Q_O = 0.6$,

$$Q_O = r\,cV(T_i - T_\infty) = 3.75\times 10^8 (J)$$

$$Q = (0.6)(3.75\times 10^8) = 2.25\times 10^8 (J)$$

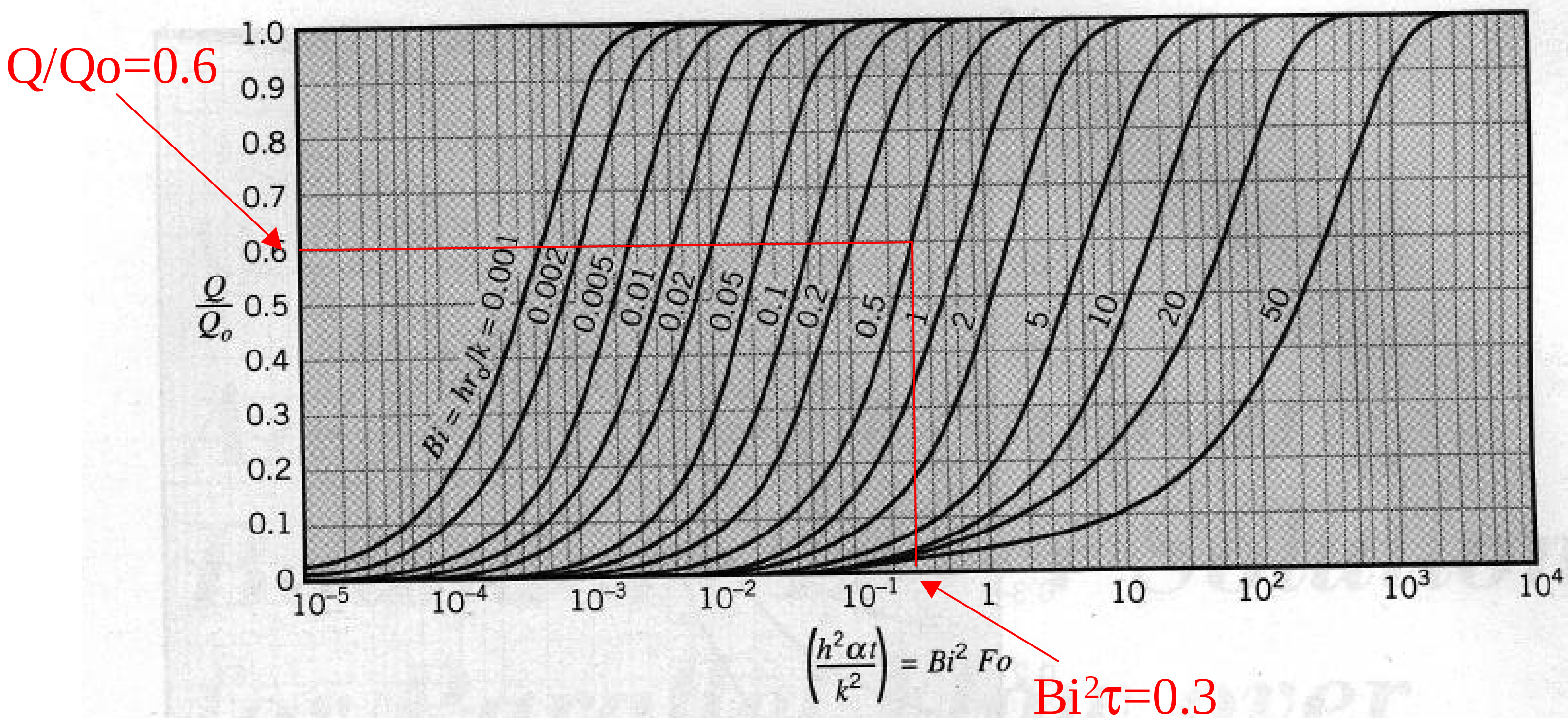


FIGURE D.6 Internal energy change as a function of time for an infinite cylinder of radius r_o [2]. Adapted with permission.