2.13

Calculate the thermal conductivity of air, hydrogen, and carbon dioxide at 300 K, assuming ideal gas behavior. Compare your calculated values to values from Table A.4.

$$K = \frac{9\gamma - 5}{4} \frac{c_v}{\pi d^2} \sqrt{\frac{m k_B T}{N \pi}} \quad \text{eq. } 2.12$$

$$\gamma = c_p / c_v$$

c_p heat capacity if pressure is const

c_v heat capacity if volume is const

$$PV = nRT \quad R = 8.314 \frac{J}{K\ mol}$$

Mayer's Relation

$$C_{pm} - C_{vm} = R$$

M molar mass $\frac{Kg}{Kmol}$

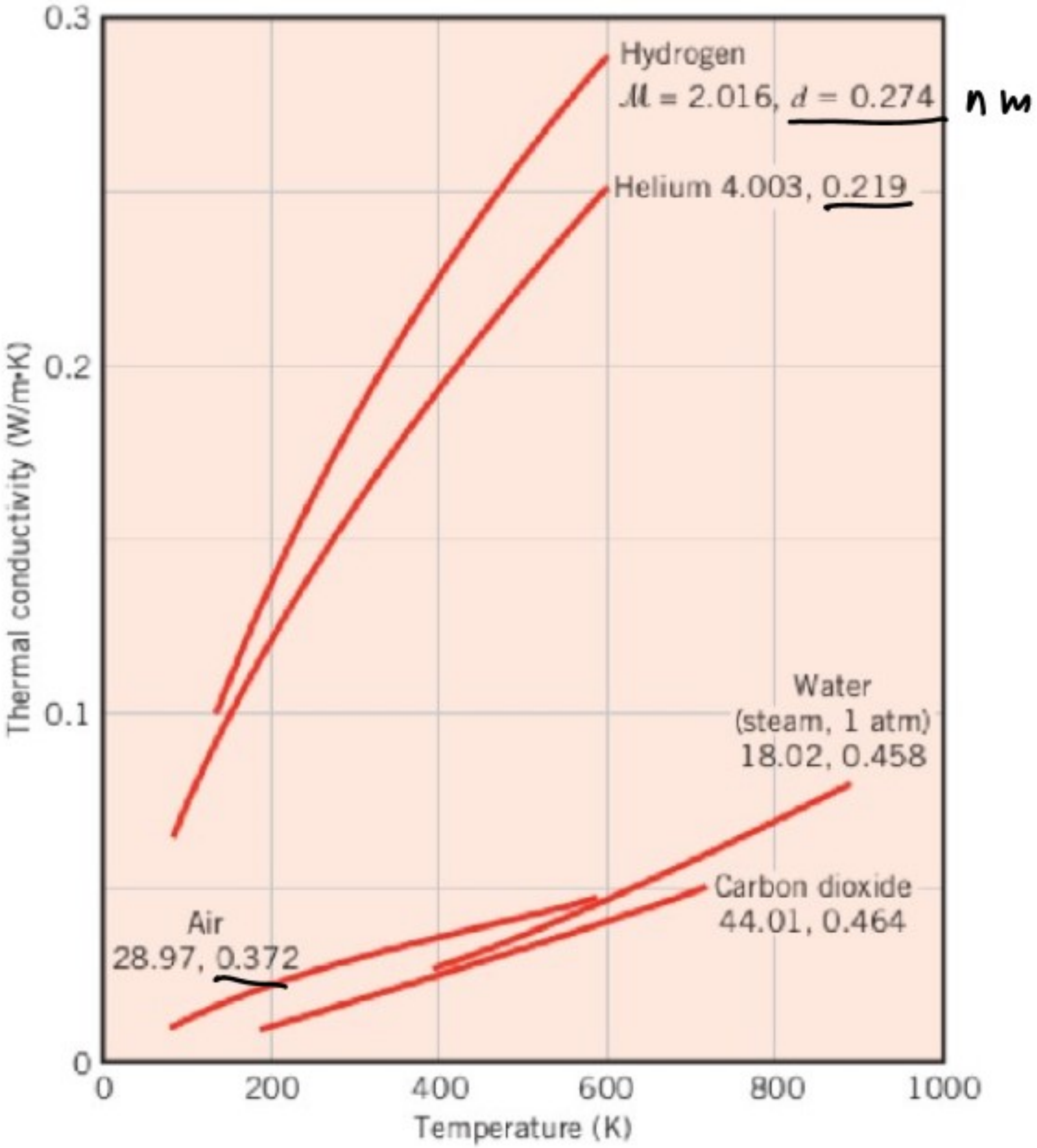
$C_p \quad \frac{KJ}{Kg\ K}$

$C_{pm} \quad \frac{KJ}{Kmol\ K}$

$$\frac{C_{pm}}{M} - \frac{C_{vm}}{M} = \frac{R}{M}$$

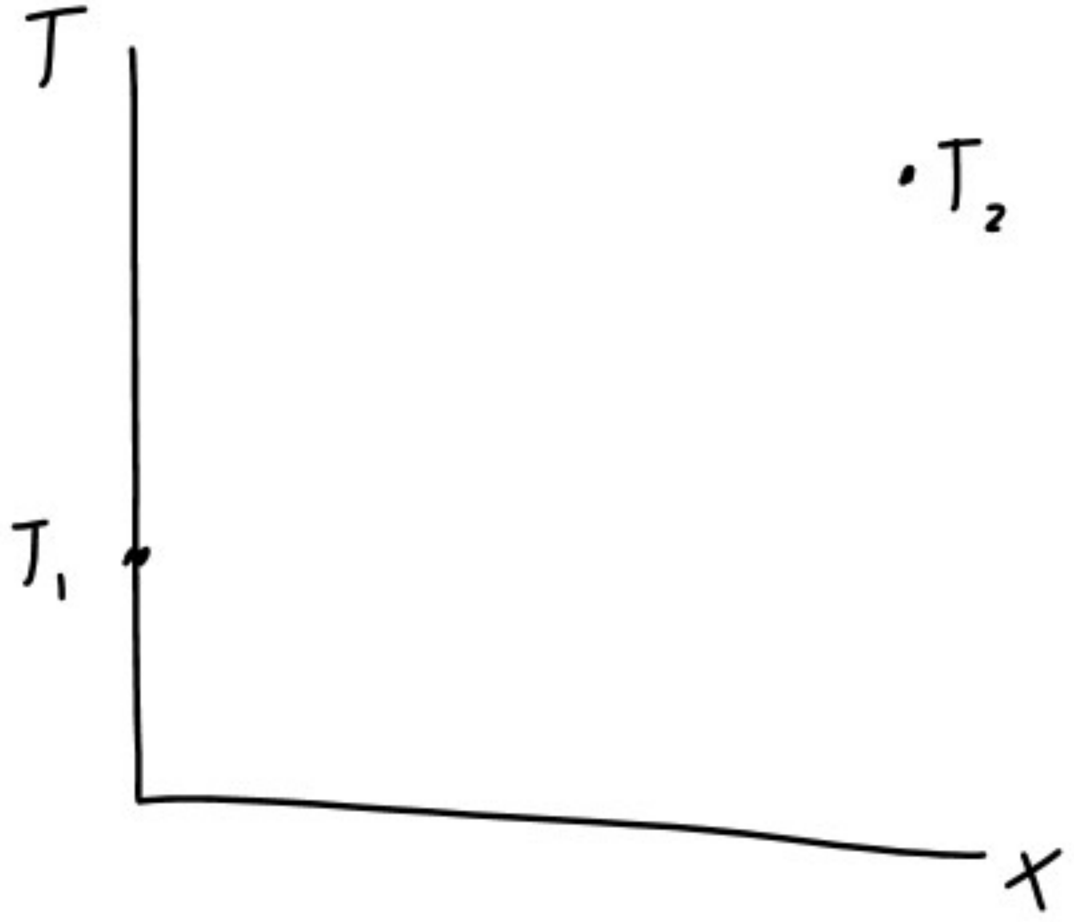
$$\boxed{C_p - C_v = \frac{R}{M}}$$

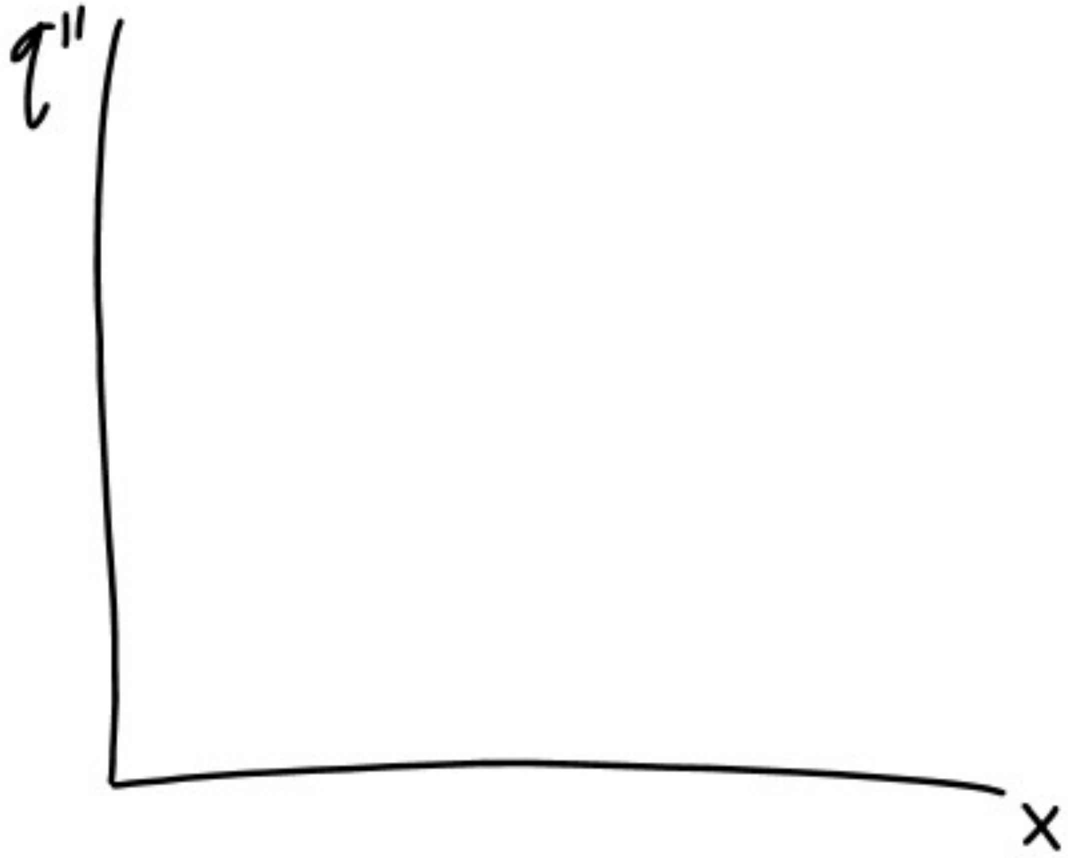
Fig 2.8

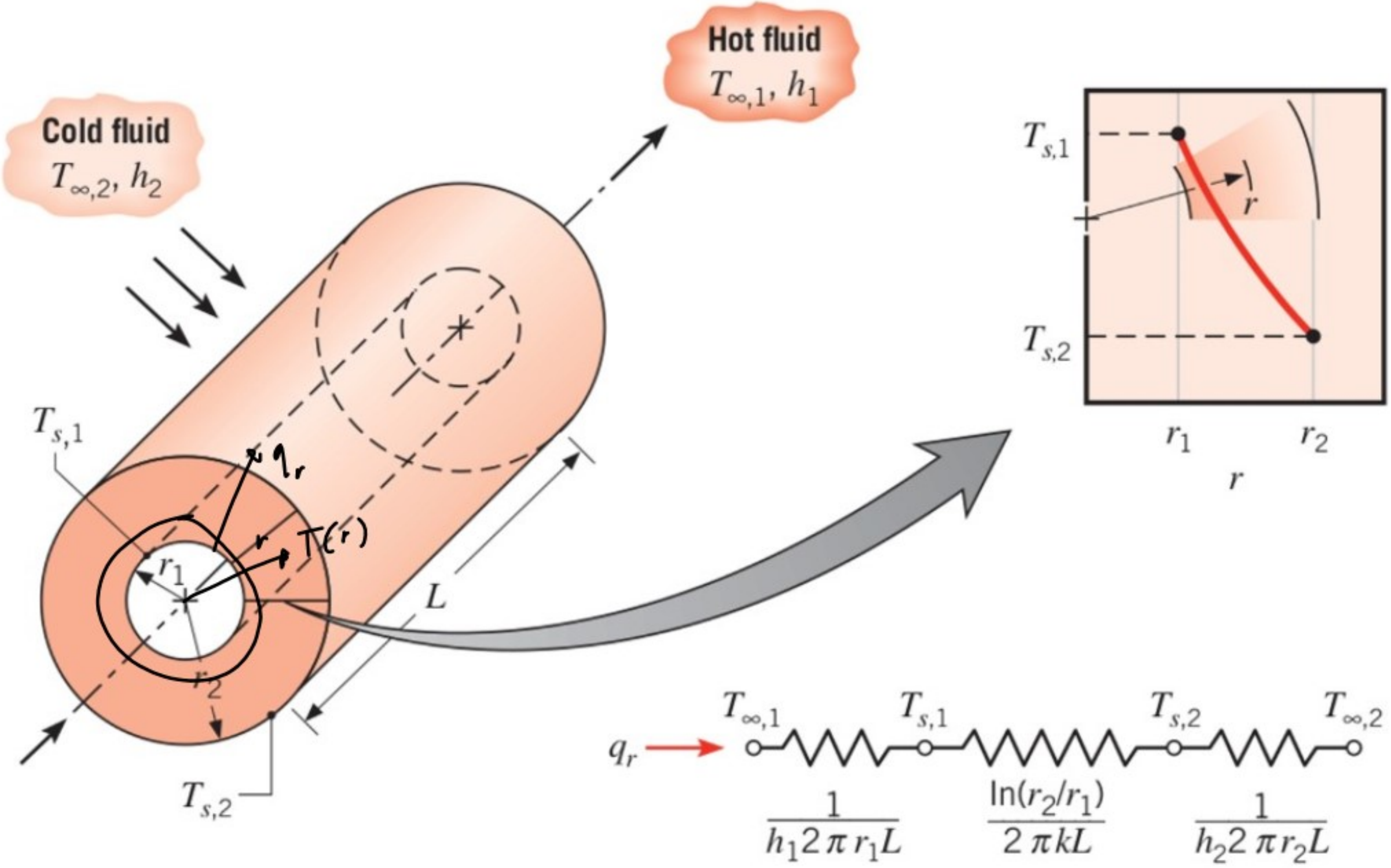


Hydrogen
$\mathcal{M}$ = 2.016, d = 0.274
nm
Helium 4.003, 0.219
Water
(steam, 1 atm)
18.02, 0.458
Carbon dioxide
44.01, 0.464
Air
28.97, 0.372
Thermal conductivity (W/m·K)
Temperature (K)
0.3
0.2
0.1
0
0
200
400
600
800
1000

2.25







Hot fluid
$T_{\infty,1}$, h_1
Cold fluid
$T_{\infty,2}$, h_2
$T_{s,1}$
q_r
r
$T(r)$
r_1
r_2
L
$T_{s,2}$
$T_{s,1}$
$T_{s,2}$
r
r_1
r_2
r
q_r
$T_{\infty,1}$
$T_{s,1}$
$T_{s,2}$
$T_{\infty,2}$
$\frac{1}{h_1 2\pi r_1 L}$
$\frac{\ln(r_2/r_1)}{2\pi k L}$
$\frac{1}{h_2 2\pi r_2 L}$

$$q_r = -kA\frac{dT}{dr} = -k(2\pi r L)\frac{dT}{dr}$$

q''_r not constant

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \cancel{\frac{1}{r^2}\frac{\partial^2 T}{\partial \phi^2}} + \cancel{\frac{\partial^2 T}{\partial z^2}} + \cancel{\frac{\dot{q}}{k}} = \frac{1}{\alpha}\cancel{\frac{\partial T}{\partial t}}$$

0 0 0 no generation 0 SS

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) = 0$$

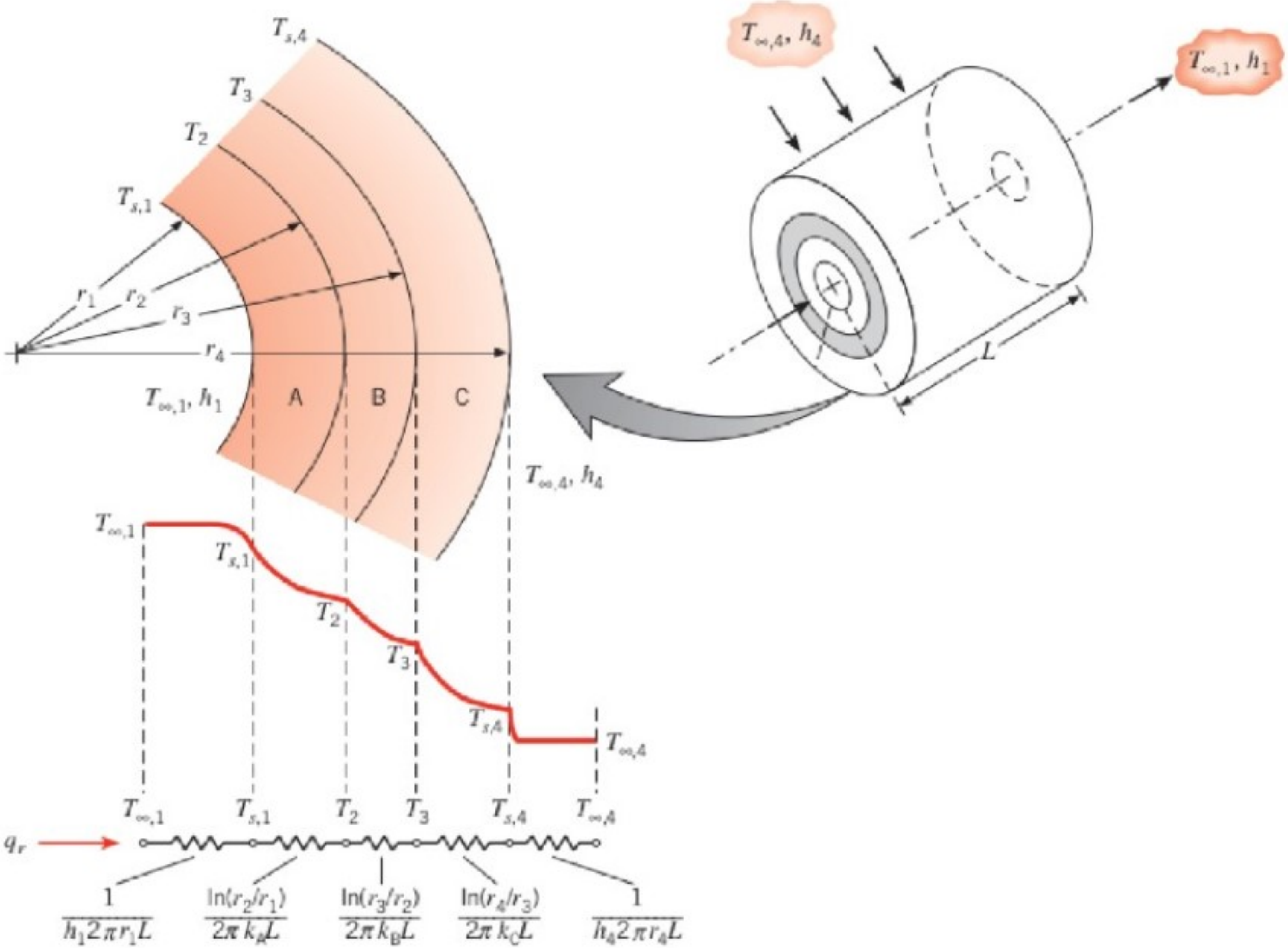
$$T(r) = C_1 \ln(r) + C_2$$

$T(r_1) = T_{s1}$ $T(r_2) = T_{s2}$

$$\boxed{T(r) = \frac{T_{s1} - T_{s2}}{\ln(r_1/r_2)}\ln(r/r_2) + T_{s2}}$$

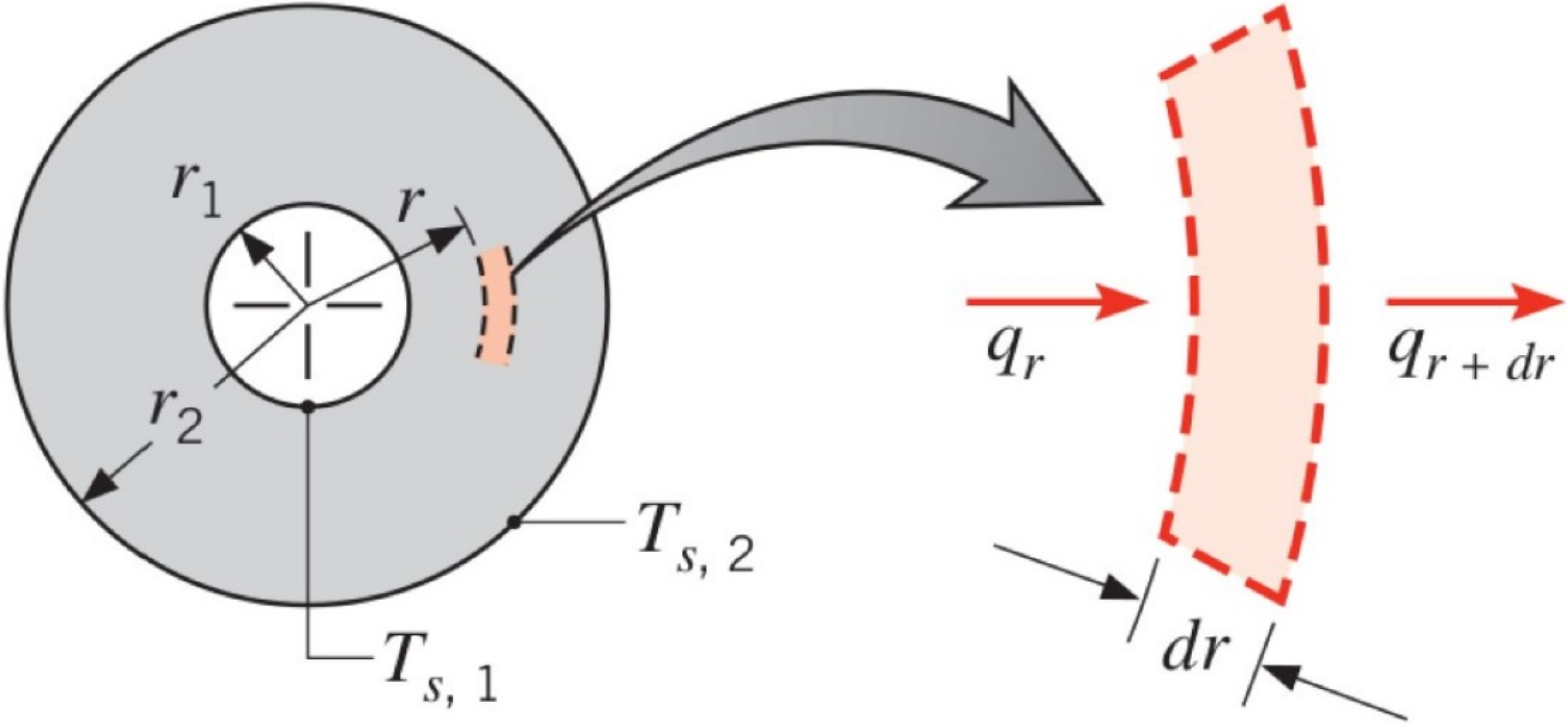
$$\boxed{q_r = \frac{2\pi L k (T_{s1} - T_{s2})}{\ln(r_2/r_1)}}$$

$$\boxed{R_{cond} = \frac{\ln(r_2/r_1)}{2\pi L k}}$$



$T_{\infty,4}$, h_4
$T_{\infty,1}$, h_1
L
$T_{s,4}$
T_3
T_2
$T_{s,1}$
r_1
r_2
r_3
r_4
$T_{\infty,1}$, h_1
A
B
C
$T_{\infty,4}$, h_4
$T_{\infty,1}$
$T_{s,1}$
T_2
T_3
$T_{s,4}$
$T_{\infty,4}$
$T_{\infty,1}$ $T_{s,1}$ T_2 T_3 $T_{s,4}$ $T_{\infty,4}$
q_r
$\frac{1}{h_1 2\pi r_1 L}$
$\frac{\ln(r_2/r_1)}{2\pi k_A L}$
$\frac{\ln(r_3/r_2)}{2\pi k_B L}$
$\frac{\ln(r_4/r_3)}{2\pi k_C L}$
$\frac{1}{h_4 2\pi r_4 L}$

1D Spherical Conduction



$$q_r = -k\,A\,\frac{dT}{dr} = -k\,4\pi r^2\,\frac{dT}{dr}$$

$$\int \frac{q_r}{4\pi r^2}\,dr = \int -k\,dT$$

$$\frac{q_r}{4\pi}\int_{r_1}^{r_2}\frac{1}{r^2}\,dr = -k\int_{T_{s1}}^{T_{s2}} dT$$

$$\boxed{q_r = \frac{4\pi k\,(T_{s1} - T_{s2})}{(1/r_1) - (1/r_2)}}$$

$$\boxed{R_{cond} = \frac{1}{4\pi k}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)}$$