8.20 Engine oil flows through a 25-mm-diameter tube at a rate of 0.5 kg/s. The oil enters the tube at a temperature of 25°C, while the tube surface temperature is maintained at 100°C.

(a) Determine the oil outlet temperature for a 5-m and for a 100-m long tube. For each case, compare the log mean temperature difference to the arithmetic mean temperature difference.

$$Re_D = \frac{4\dot{m}}{\pi D \mu} = \frac{4 \cdot 0.5 \ kg/s}{\pi \cdot 0.025 m \cdot 28.6 \times 10^{-2} \frac{Ns}{m^2}}$$

$$= 52.4$$

$$Pr = 6400$$

$$k = 145 \times 10^{-3} \ \frac{W}{mK}$$

$$\bar{h} = \frac{k}{D} \overline{Nu_D} = \frac{k}{D}\left(3.66 + \frac{0.0683 \frac{D}{L} Re_D Pr}{1 + 0.04\left(\frac{D}{L} Re_D Pr\right)^{2/3}}\right) = \frac{145 \times 10^{-3}}{0.025}\left(3.66 + \frac{0.0683 \frac{0.025}{5} 52.4 \cdot 6400}{1 + 0.04\left(\frac{0.025}{5} 52.4 \cdot 6400\right)^{2/3}}\right)$$

$$= 122 \ \frac{W}{m^2 K}$$

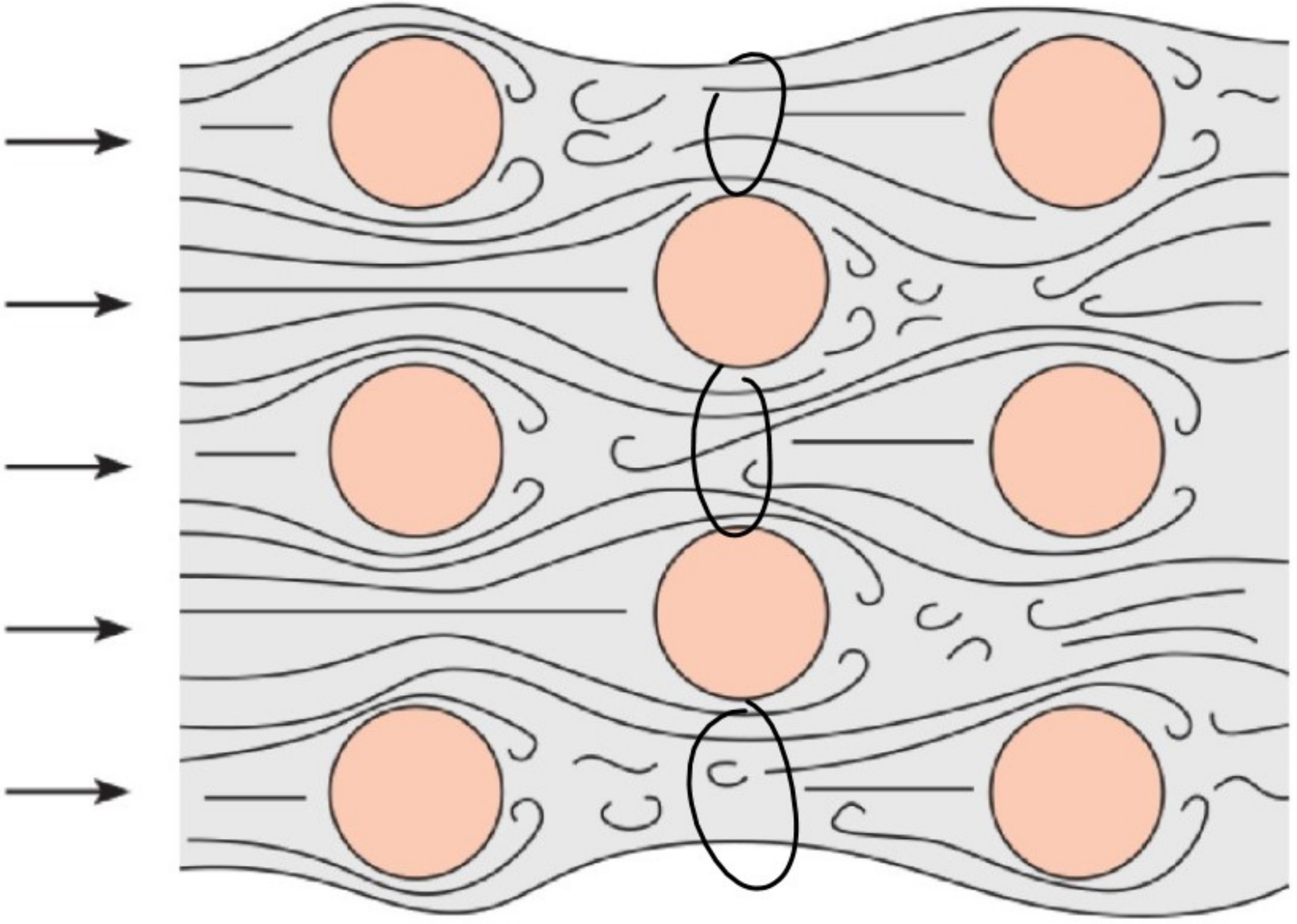
$$\frac{T_s - T_{mo}}{T_s - T_{mi}} = \exp\left(-\frac{PL}{\dot{m} c_p} \bar{h}\right)$$

$$\frac{100°C - T_{mo}}{100°C - 25°C} = \exp\left(-\frac{\pi \, 0.025 \cdot 5}{0.5 \cdot 1907} \, 122\right) = 0.95$$

$$100°C - T_{mo} = 0.95 \quad (100°C - 25°C)$$

$$-T_{mo} = 0.95 \quad (75°C) - 100°C = -28.7°C$$

$$\boxed{T_{mo} = 28.7°C}$$



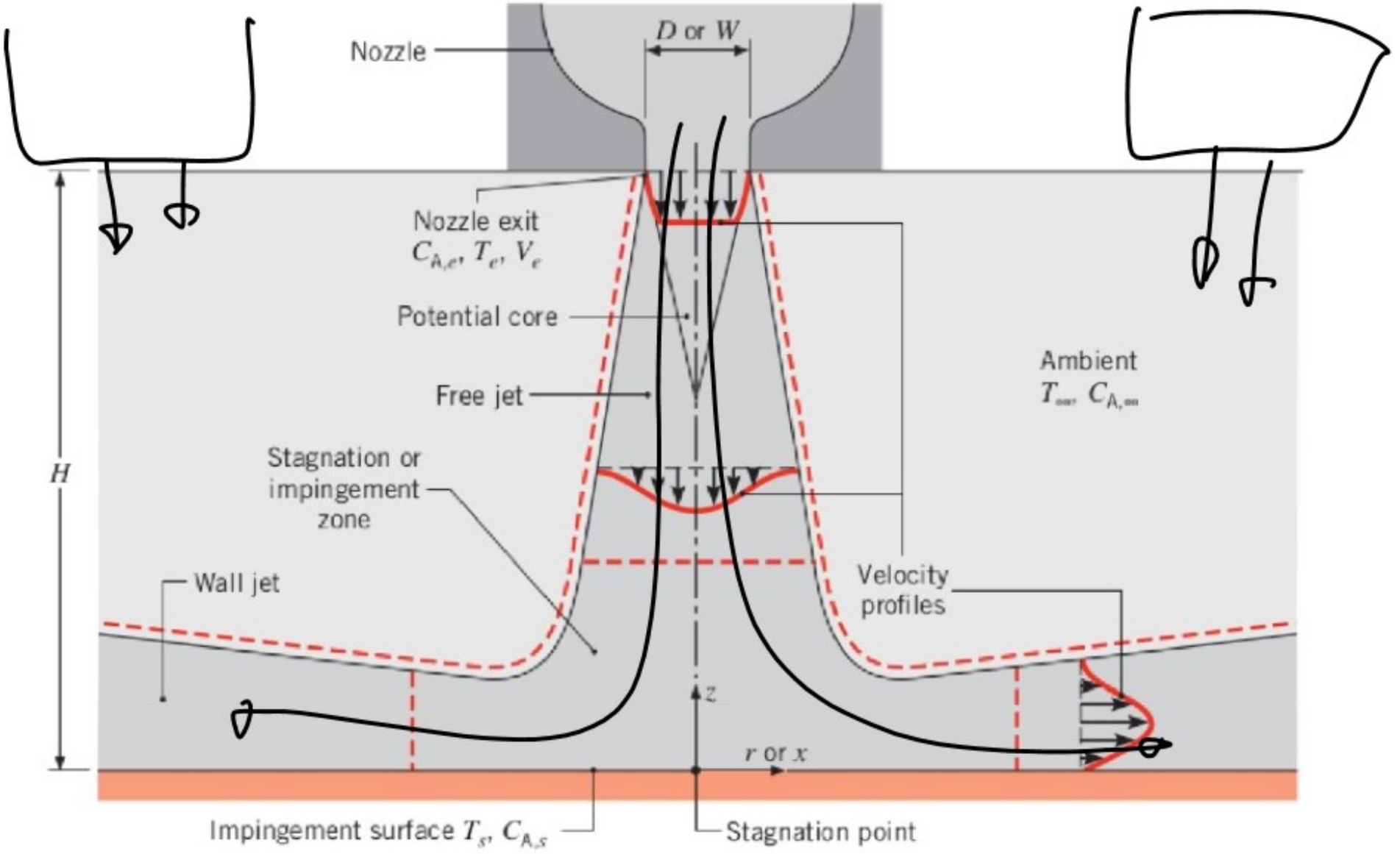

Nozzle
D or W
Nozzle exit
$C_{A,e}$, T_e, V_e
Potential core
Free jet
Stagnation or
impingement
zone
Wall jet
Velocity
profiles
Ambient
T_∞, $C_{A,\infty}$
H
z
r or x
Impingement surface T_s, $C_{A,s}$
Stagnation point

TABLE 8.1 Nusselt numbers and friction factors for fully developed laminar flow in tubes of differing cross section

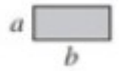
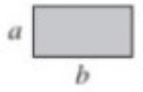
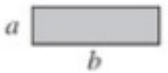
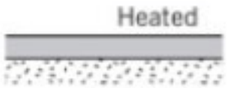
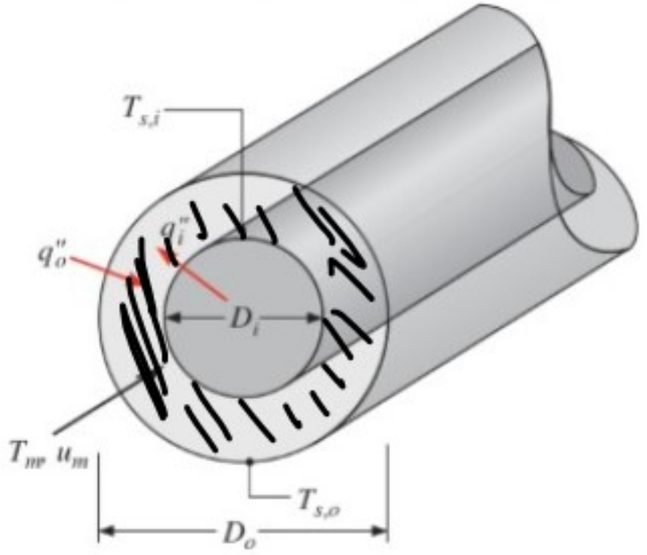
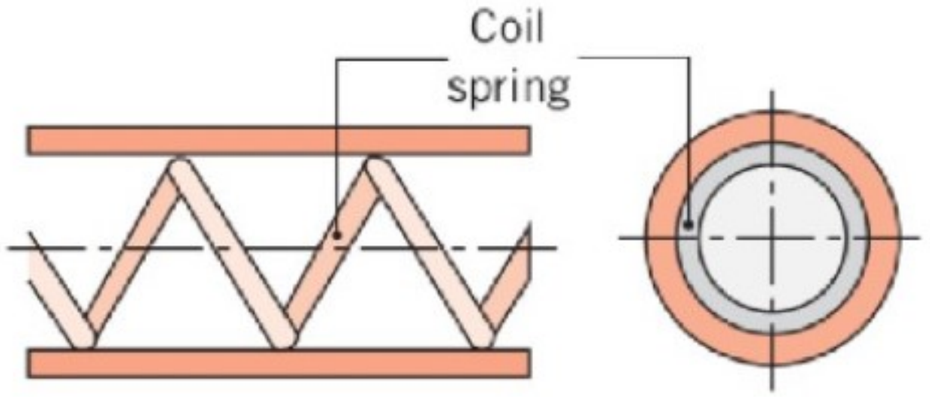
Cross Section	$\frac{b}{a}$	$Nu_D \equiv \frac{hD_h}{k}$ (Uniform q_s'')	$Nu_D \equiv \frac{hD_h}{k}$ (Uniform T_s)	fRe_{D_h}
	—	4.36	3.66	64
	1.0	3.61	2.98	57
	1.43	3.73	3.08	59
	2.0	4.12	3.39	62
	3.0	4.79	3.96	69
	4.0	5.33	4.44	73
	8.0	6.49	5.60	82
	∞	8.23	7.54	96
 Heated / Insulated	∞	5.39	4.86	96
	—	3.11	2.49	53

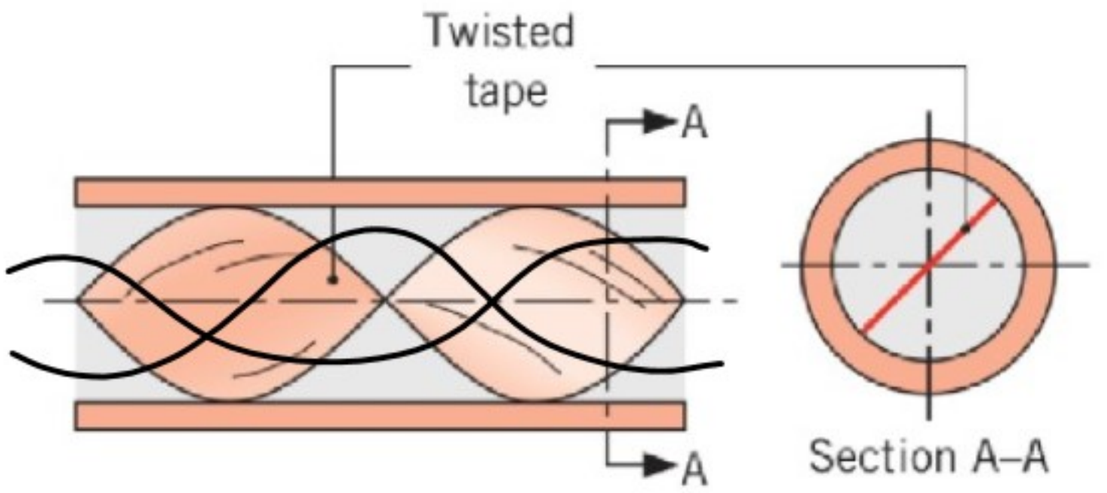
TABLE 8.2 Nusselt number for fully developed laminar flow in a circular tube annulus with one surface insulated and the other at constant temperature

D_i/D_o	Nu_i	Nu_o	*Comments*
0	—	3.66	See Equation 8.55
0.05	17.46	4.06	
0.10	11.56	4.11	
0.25	7.37	4.23	
0.50	5.74	4.43	
≈1.00	4.86	4.86	See Table 8.1, $b/a \rightarrow \infty$

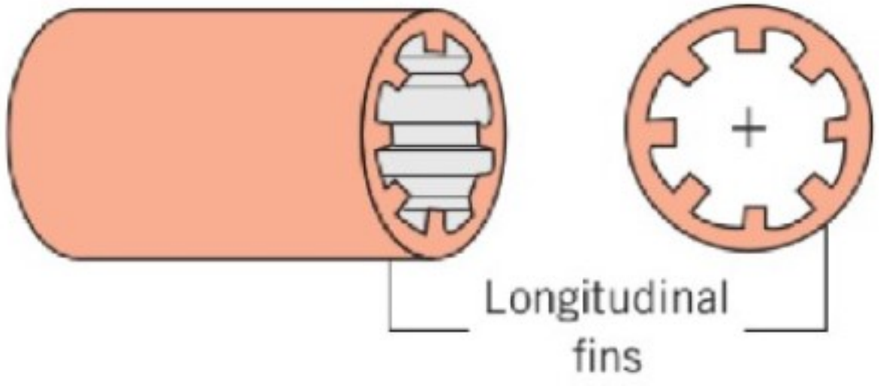



Coil
spring

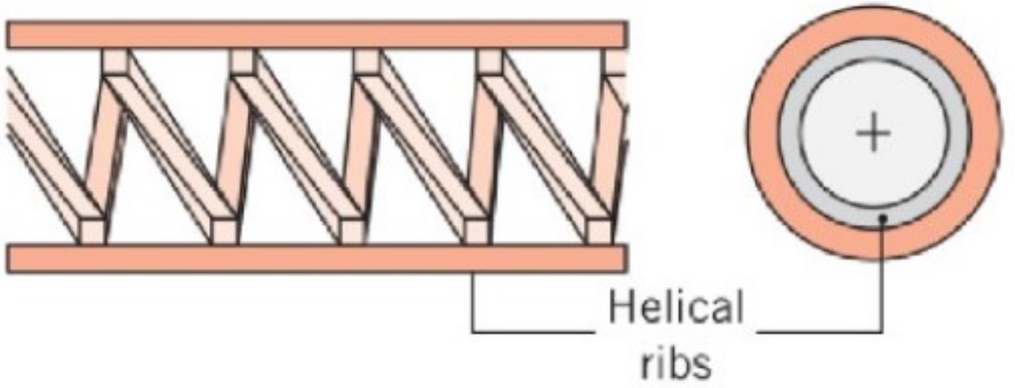
(a)


Twisted
tape
A
A
Section A–A

(b)

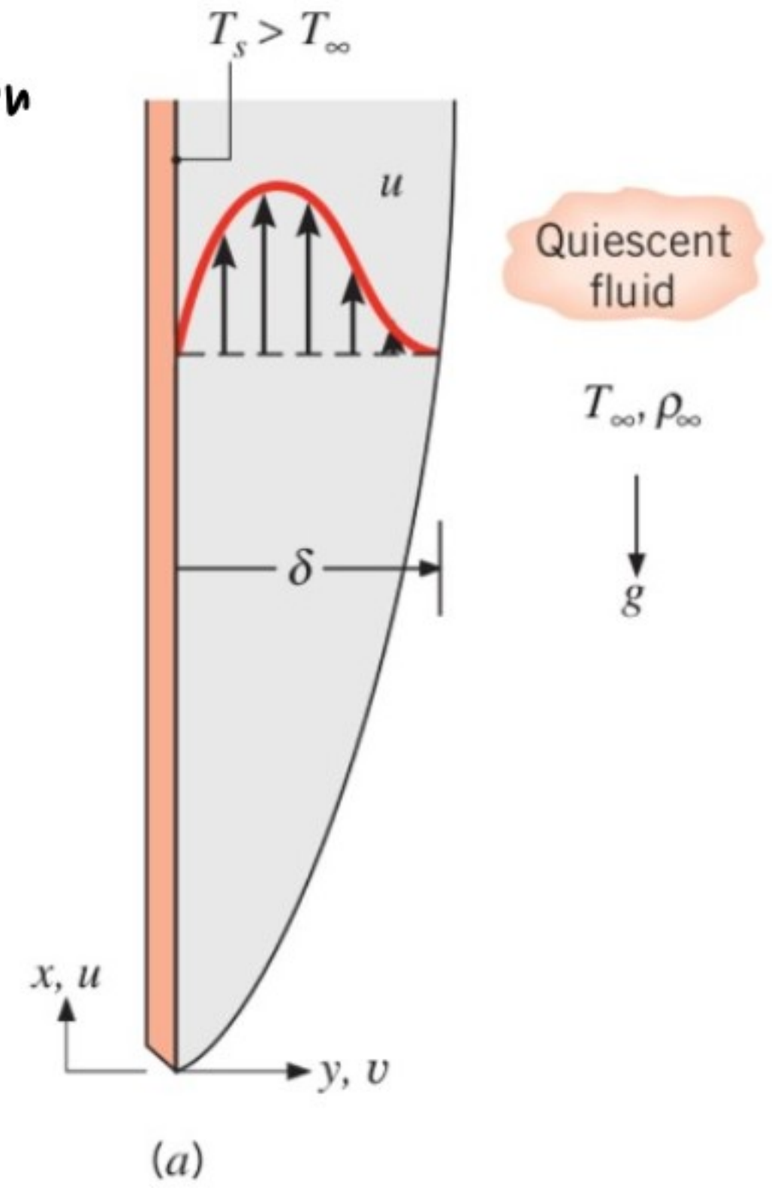

Longitudinal
fins

(c)

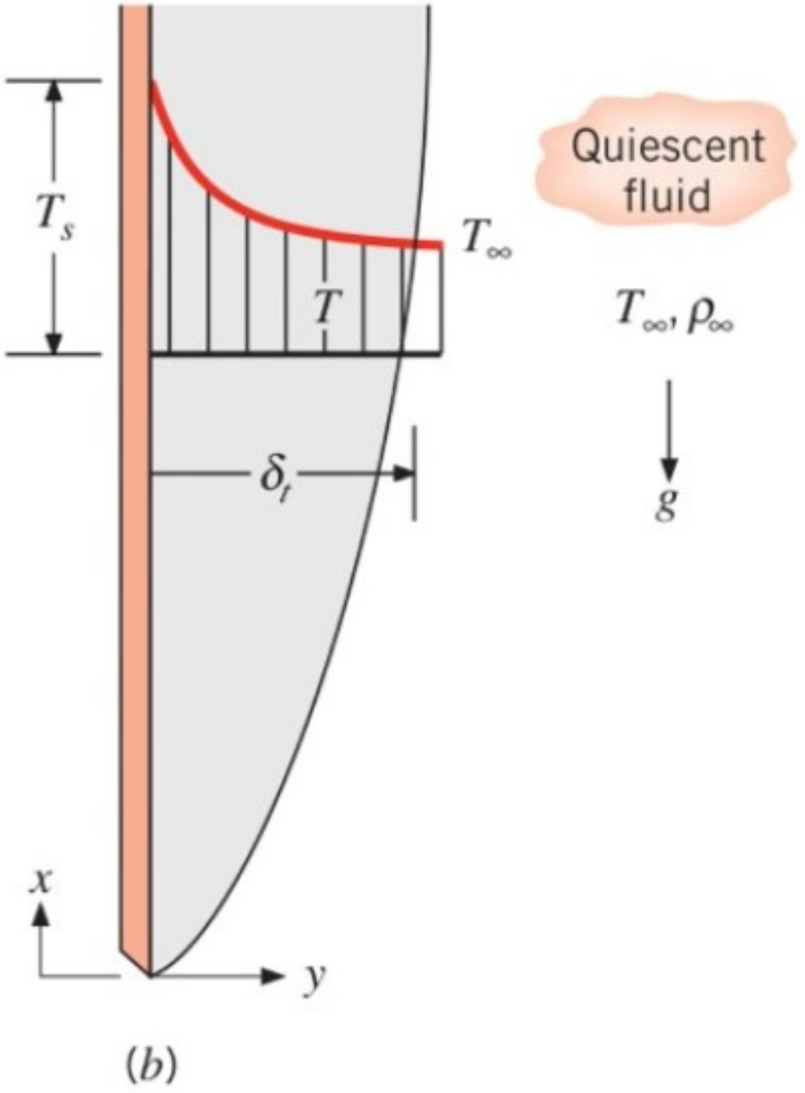

Helical
ribs

(d)

Free Convection



(a)



(b)