PROBLEM 9.54

GIVEN A COAL BARGE IS 1000 FT LONG, 100 FT WIDE, AND IS SUBMERGED IN 12 FT OF 60°F WATER. IT IS BEING TOWED AT A SPEED OF 12 MPH

FIND ESTIMATE THE FRICTION DRAG ON THE BARGE

SOLUTION THE PROPERTIES OF WATER AT TEMP = 60 °F, FROM TABLE B.1

$$\rho = 62.4 \text{ lbm/ft}^3 \quad \text{AND} \quad \nu = 1.21 * 10^{-5} \text{ ft}^2/\text{sec}$$

WE MUST DETERMINE WHETHER THE BOUNDARY LAYER FLOW IS LAMINAR OR TURBULENT. TRANSITION TO TURBULENT FLOW OCCURS AT $Re_x = 5 * 10^5$

$$Re_x = \frac{V\,X}{\nu} = \frac{(12 * 1.47 \text{ ft/sec})\,X}{1.21 * 10^{-5} \text{ ft}^2/\text{sec}} = 5 * 10^5 \Rightarrow X = 0.343 \text{ ft}$$

THEREFORE THE FLOW IS ASSUMED TURBULENT OVER THE ENTIRE LENGTH OF THE BARGE. THE REYNOLDS NUMBER AT THE END OF THE BARGE IS

$$Re_x = \frac{V\,L}{\nu} = \frac{(12 * 1.47 \text{ ft/sec})\,1000 \text{ ft}}{1.21 * 10^{-5} \text{ ft}^2/\text{sec}} = 1.46 * 10^9$$

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From Table 9.3, assuming turbulent smooth plate,

$$C_{D_f} = 0.455 / (\log Re_L)^{2.58}$$

Thus, $$D = \frac{1}{2} \rho C_{D_f} U^2 A = \frac{1}{2} \rho \left(0.455 / (\log Re_L)^{2.58}\right) U^2 A$$

$$D = \frac{1}{2} \left(62.4 \frac{lb_m}{ft^3}\right) \left(0.455 / (\log (1.46 \times 10^9))^{2.58}\right) \left(12 * 1.47 \frac{ft}{sec}\right)^2 (1000 ft)(100 + 12 + 12 ft)$$

$\left(\frac{lb_f \cdot sec^2}{32.2\ lb_m \cdot ft}\right)$

$$\boxed{D = 56{,}100\ lb}$$