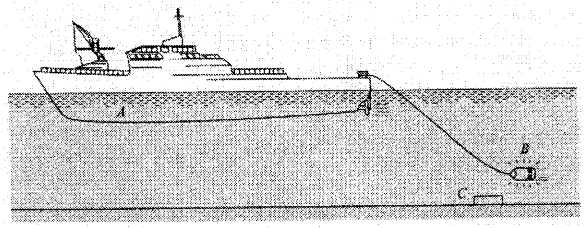
8.45 The "noisemaker" B is towed behind the minesweeper A to set off enemy acoustic mines such as that shown at C. The drag force of the "noisemaker" is to be studied in a water tunnel at a 1/5 scale (the model is 1/5 the size of the full scale). If the full-scale towing speed is 3 m/s, what should be the water velocity in the water tunnel for the two tests to be exactly similar? What will be the prototype drag force if the model drag force is found to be 868 N? Assume that sea water at the same temperature is used in both the full-scale and the model tests.



Solution $L_t/L_p = 1/5$ $V_p = 3\,m/s$ $V_m = ?$ $F_p = ?$ if $F_t = 868\,N$

Dynamic similarity based on Re

$$Re_t = Re_p \Rightarrow \frac{V_t L_t}{\nu_t} = \frac{V_p L_p}{\nu_p} \Rightarrow V_t = V_p \cdot (5/1)$$

$$\boxed{V_t = V_p \cdot 5 = 3 \times 5 = 15\,m/s}$$

Pressure coefficients are the same

$$C_{p,t} = C_{p,p}$$

$$(\Delta p/\rho V^2)_t = (\Delta p/\rho V^2)_{prop}$$

$$\frac{\Delta p_t}{\Delta p_p} = \frac{\rho_t}{\rho_p} \times \frac{V_t^2}{V_p^2}$$ multiple by $\frac{A_t}{A_p} = \frac{L_t^2}{L_p^2}$

$$\frac{F_t}{F_p} = (\rho_t/\rho_p) \cdot \left(\frac{V_t^2}{V_p^2}\right) \times \frac{L_t^2}{L_p^2}$$

$$= (1/1) \cdot (5)^2 \; (1/5)^2$$

$$F_t = F_p = \underline{868\,N}$$

8.45 **Information and Assumptions**

provided in problem statement

Find

velocity in water tunnel and force on prototype.

Solution

Dynamic similarity based on Reynolds number

$$
\begin{aligned}
\mathrm{Re}_{\text{tunnel}} &= \mathrm{Re}_{\text{prototype}} \\
V_{\text{tunnel}} &= V_{\text{prot.}}(4/1)(\nu_{\text{tunnel}}/\nu_{\text{prot.}}) \\
V_{\text{tunnel}} &= 3(5/1)(1) = 15 \text{ m/s}
\end{aligned}
$$

For dynamic similarity, the pressure coefficients are the same.

$$
\begin{aligned}
C_{p_{\text{tunnel}}} &= C_{p_{\text{prototype}}} \\
(\Delta p/\rho V^2)_{\text{tunnel}} &= (\Delta p/\rho V^2)_{\text{prototype}} \\
(\Delta p_{\text{tunnel}}/\Delta p_{\text{prot.}}) &= (\rho_{\text{tunnel}}/\rho_{\text{prot.}})(V_{\text{tunnel}}^2/V_{\text{prot.}}^2)
\end{aligned}
$$

Multiply both sides of the equation by $A_{\text{tunnel}}/A_{\text{prot.}} = L_t^2/L_p^2$

$$
\begin{aligned}
(\Delta p \times A)_{\text{tunnel}}/(\Delta p \times A)_{\text{prot.}} &= (\rho_{\text{tunnel}}/\rho_{\text{prot.}}) \times (V_{\text{tunnel}}^2/V_{\text{prot.}}^2) \times (L_t/L_p)^2 \\
F_{\text{tunnel}}/F_{\text{prot.}} &= (1/1)(5)^2(1/5)^2 \\
F_{\text{tunnel}} &= F_{\text{prot.}} = \underline{\underline{868\ N}}
\end{aligned}
$$