Solution to Problem 240A

From the Blasius solution for a laminar boundary layer on a flat plate with zero pressure gradient, the drag on one side of the flat plate is

$$D = \rho U^2 w \left[(\delta_M)_{\text{trailing edge}} - (\delta_M)_{\text{leading edge}} \right]$$

where w is the width of the plate and δ_M is the momentum thickness of the boundary layer defined as

$$\delta_M = \int_0^\infty \frac{u}{U} \left(1 - \frac{u}{U} \right) dy$$

At the leading edge of the plate $\delta_M = 0$.

Using the Blasius boundary layer solution, the momentum thickness evaluates to

$$\delta_M = 0.664 \left(\frac{\nu x}{U} \right)^{\frac{1}{2}}$$

and substituting this into the first equation yields

$$D = 0.664 \rho \sqrt{\nu} U^{\frac{3}{2}} \sqrt{L} w$$

which, after substituting $\rho = 10^3\ kg/m^3$, $\nu = 10^{-6}\ m^2/s$, $L = 10\ m$, and $w = 1\ m$, becomes

$$D \simeq \left(2.1 U^{\frac{3}{2}} \right)\ kg\ m/s^2$$

The total power generated by the eight rowers is

$$P = \frac{1}{2} (8 P_i)$$

where the factor of 1/2 comes from the fact that half of the power is uselessly dissipated. Each rower can produce $P_i = 0.1\ HP$, so that

$$P = 0.4\ HP = 298.4\ W$$

The power is related to the force necessary to move the boat by

$$P = D\ U = 2.1 U^{\frac{5}{2}}\ W$$

Thus, the boat can reach a top speed of

$$U = 7.26\ m/s$$