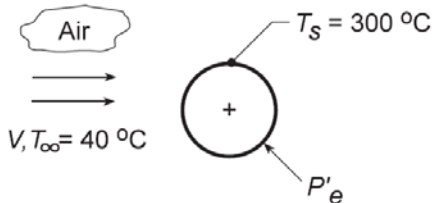


### PROBLEM 1.13

**KNOWN:** Power required to maintain the surface temperature of a long, 25-mm diameter cylinder with an imbedded electrical heater for different air velocities.

**FIND:** (a) Determine the convection coefficient for each of the air velocity conditions and display the results graphically, and (b) Assuming that the convection coefficient depends upon air velocity as  $h = CV^n$ , determine the parameters  $C$  and  $n$ .

**SCHEMATIC:**



$V$ (m/s)	1	2	4	8	12
$P'_g$ (W/m)	450	658	983	1507	1963
$h$ (W/m <sup>2</sup> ·K)	22.0	32.2	48.1	73.8	96.1

**ASSUMPTIONS:** (1) Temperature is uniform over the cylinder surface, (2) Negligible radiation exchange between the cylinder surface and the surroundings, (3) Steady-state conditions.

**ANALYSIS:** (a) From an overall energy balance on the cylinder, the power dissipated by the electrical heater is transferred by convection to the air stream. Using Newton's law of cooling on a per unit length basis,

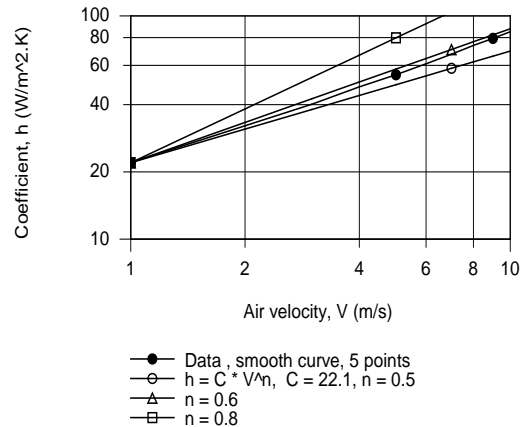
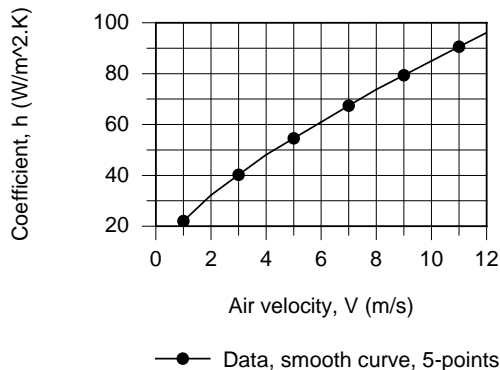
$$P'_e = h(\pi D)(T_s - T_\infty)$$

where  $P'_e$  is the electrical power dissipated per unit length of the cylinder. For the  $V = 1$  m/s condition, using the data from the table above, find

$$h = 450 \text{ W/m} / \pi \times 0.025 \text{ m} (300 - 40)^\circ \text{C} = 22.0 \text{ W/m}^2 \cdot \text{K}$$

Repeating the calculations, find the convection coefficients for the remaining conditions which are tabulated above and plotted below. Note that  $h$  is not linear with respect to the air velocity.

(b) To determine the  $(C, n)$  parameters, we plotted  $h$  vs.  $V$  on log-log coordinates. Choosing  $C = 22.12 \text{ W/m}^2 \cdot \text{K}(\text{s/m})^n$ , assuring a match at  $V = 1$ , we can readily find the exponent  $n$  from the slope of the  $h$  vs.  $V$  curve. From the trials with  $n = 0.8, 0.6$  and  $0.5$ , we recognize that  $n = 0.6$  is a reasonable choice. Hence,  $C = 22.12$  and  $n = 0.6$ .



**COMMENTS:** Radiation may not be negligible, depending on surface emissivity.