V, mi/h:	2(	4(
Drag, lbf:	3]	11

The same car travels in Colorado at 65 mi/h at an altitude of 3500 m. Using dimensional analysis, estimate (a) its drag force and (b) the horsepower required to overcome air drag.

Solution: For sea-level air in BG units, take $\rho \approx 0.00238$ slug/ft^3 and $\mu \approx 3.72E{-}7$ slug/ft·s. Convert the raw drag and velocity data into dimensionless form:

V (mi/hr):	20	40	60
$C_D = F/(\rho V^2 L^2)$:	0.237	0.220	0.211
$Re_L = \rho VL/\mu$:	1.50E6	3.00E6	4.50E6

Drag coefficient plots versus Reynolds number in a very smooth fashion and is well fit (to ±1%) by the Power-law formula $\mathbf{C_D \approx 1.07 Re_L^{-0.106}}$.

(a) The new velocity is V = 65 mi/hr = 95.3 ft/s, and for air at 3500-m Standard Altitude (Table A-6) take $\rho = 0.001675$ slug/ft^3 and $\mu = 3.50E{-}7$ slug/ft·s. Then compute the new Reynolds number and use our Power-law above to estimate drag coefficient:

$$\mathbf{Re}_{Colorado} = \frac{\rho VL}{\mu} = \frac{(0.001675)(95.3)(8.0)}{3.50E{-}7} = 3.65E6, \quad hence$$

$$C_D \approx \frac{1.07}{(3.65E6)^{0.106}} = 0.2157, \quad \therefore \ \mathbf{F} = 0.2157(0.001675)(95.3)^2(8.0)^2 = \mathbf{210\ lbf} \quad Ans.\ \text{(a)}$$

(b) The horsepower required to overcome drag is

$$\text{Power} = FV = (210)(95.3) = 20030\ \text{ft·lbf/s} \div 550 = \mathbf{36.4\ hp} \quad Ans.\ \text{(b)}$$

5.6 SAE 10 oil at 20°C flows past an 8-cm-diameter sphere. At flow velocities of 1, 2, and 3 m/s, the measured sphere drag forces are 1.5, 5.3, and 11.2 N, respectively. Estimate the drag force if the same sphere is tested at a velocity of 15 m/s in glycerin at 20°C.

Solution: For SAE 10 oil at 20°C, take $\rho \approx 870$ kg/m^3 and $\mu \approx 0.104$ kg/m·s. Convert the raw drag and velocity data into dimensionless form:

V (m/s):	1	2	3
F (newtons):	1.5	5.3	11.2
$C_D = F/(\rho V^2 D^2)$:	0.269	0.238	0.224
$Re_L = \rho VD/\mu$:	669	1338	2008