11.31 A centrifugal pump with backward-curved blades has the following measured performance when tested with water at 20°C:

Q, gal/min:	0	400	800	1200	1600	2000	2400
H, ft:	123	115	108	101	93	81	62
P, hp:	30	36	40	44	47	48	46

(a) Estimate the best efficiency point and the maximum efficiency. (b) Estimate the most efficient flow rate, and the resulting head and brake horsepower, if the diameter is doubled and the rotation speed increased by 50%.

Solution: (a) Convert the data above into efficiency. For example, at $Q = 400$ gal/min,

$$\eta = \frac{\gamma QH}{P} = \frac{(62.4\text{ lbf/ft}^3)(400/448.8\text{ ft}^3\text{/s})(115\text{ ft})}{(36\times 550\text{ ft·lbf/s})} = 0.32 = 32\%$$

When converted, the efficiency table looks like this:

Q, gal/min:	0	400	800	1200	1600	2000	2400
η, %:	0	32%	55%	70%	80%	85%	82%

So maximum efficiency of **85%** occurs at $\boldsymbol{Q = 2000}$ **gal/min.** *Ans.* (a)

(b) We don't know the values of C_Q^* or C_H^* or C_P^*, but we can set them equal for conditions 1 (the data above) and 2 (the performance when n and D are changed):

$$C_Q^* = \frac{Q_1}{n_1 D_1^3} = \frac{Q_2}{n_2 D_2^3} = \frac{Q_2}{(1.5n_1)(2D_1)^3},$$

$$\text{or:}\quad Q_2 = 12Q_1 = 12(2000\text{ gpm}) = \mathbf{24,000\ \frac{gal}{min}} \quad \textit{Ans. (b)}$$

$$C_H^* = \frac{gH_1}{n_1^2 D_1^2} = \frac{gH_2}{n_2^2 D_2^2} = \frac{gH_2}{(1.5n_1)^2(2D_1)^2},$$

$$\text{or:}\quad H_2 = 9H_1 = 9(81\text{ ft}) = \mathbf{729\ ft} \quad \textit{Ans. (b)}$$

$$C_P^* = \frac{P_1}{\rho n_1^3 D_1^5} = \frac{P_2}{\rho n_2^3 D_2^5} = \frac{P_2}{\rho(1.5n_1)^3(2D_1)^5},$$

$$\text{or:}\quad P_2 = 108P_1 = 108(48\text{ hp}) = \mathbf{5180\ hp} \quad \textit{Ans. (b)}$$
