Given: Data for one operating condition of a pump test

Measured values: $h = 30$ in, $m = 500$ g, $\Delta t = 30$ s

pump voltage = 12V, pump current = 1A

physical constants:

$d = 3/16"$ = I.D. of tubing

$\rho = 1000$ kg/m³ = density of water

Analysis:

1. Compute velocity of water

mass flow rate $= \dot{m} = \rho A v \Rightarrow v = \frac{\dot{m}}{\rho A}$

A = cross-sectional area of the tubing $= \frac{\pi}{4} d^2$

v = average velocity

From measurements: $\dot{m} = \frac{\text{mass collected}}{\text{time of collection}} = \frac{m}{\Delta t}$

$$v = \frac{\dot{m}}{\rho A} = \frac{m}{\Delta t} \frac{1}{\rho} \frac{4}{\pi d^2}$$

$$= \underbrace{\frac{500\text{ g}}{30\text{ s}} \times \frac{1\text{ kg}}{1000\text{ g}}}_{0.0167\ \text{kg/s}} \times \frac{1}{1000\ \text{kg/m}^3} \times \underbrace{\frac{4}{\pi\left(\frac{3}{16}\text{ inch} \times \frac{25.4\text{ mm}}{\text{inch}} \times \frac{1\text{ m}}{1000\text{ mm}}\right)^2}}_{\frac{1}{1.781\times10^{-5}\ \text{m}^2} = \frac{1}{A}}$$

$$\boxed{v = 0.936\ \frac{\text{m}}{\text{s}}}$$

Analysis, Continued

2. Calculate volumetric flow rate

$$Q = vA = \frac{m}{\Delta t}\frac{1}{\rho}$$

$$= \left(0.936\ \frac{m}{s}\right)\left[\frac{\pi}{4}\left(\frac{3}{16}\text{ inch} \times 25.4\ \frac{mm}{inch} \times \frac{1\ m}{1000\ m}\right)^2\right]$$

$$A = 1.781 \times 10^{-5}\ m^2$$

$$Q = 1.667 \times 10^{-5}\ \frac{m^3}{s} \times \frac{1\ L}{1000\ cm^3} \times \left(\frac{100\ cm}{m}\right)^3 \times \frac{60\ s}{min} = 1.00\ \frac{L}{min}$$

$$\boxed{Q = 1.667 \times 10^{-5}\ \frac{m^3}{s} = 1.00\ \frac{L}{min}}$$

3. Compute Efficiency

$$\eta = \frac{\text{Energy Output}}{\text{Energy Input}} = \frac{\text{Power Output}}{\text{Power Input}} = \frac{\dot{m}gh + \frac{1}{2}\dot{m}V^2}{VI} = \frac{\dot{m}\left(gh + \frac{V^2}{2}\right)}{VI}$$

$$\dot{m} = \frac{m}{\Delta t} = \frac{500\ g}{30\ s} \times \frac{1\ kg}{1000\ g} = 0.0167\ \frac{kg}{s}$$

$$\eta = \frac{\left(0.0167\ \frac{kg}{s}\right)\left[9.8\ \frac{m}{s^2} \times 30\text{ inch} \times \frac{25.4\ mm}{inch} \times \frac{1\ m}{1000\ mm} + \frac{1}{2}\left(0.936\ \frac{m}{s}\right)^2\right]}{(12\ V)(1\ A)}$$

$$= \frac{\left(0.0167\ \frac{kg}{s}\right)\left(7.468\ \frac{m^2}{s^2} + 0.438\ \frac{m^2}{s^2}\right)}{12\ W}$$

$$= \frac{0.132\ W}{12\ W}$$

$$= 0.011$$

$$\therefore \boxed{\eta = 1.1\%}$$