



AP[®] Physics B 2003 Sample Student Responses Form B

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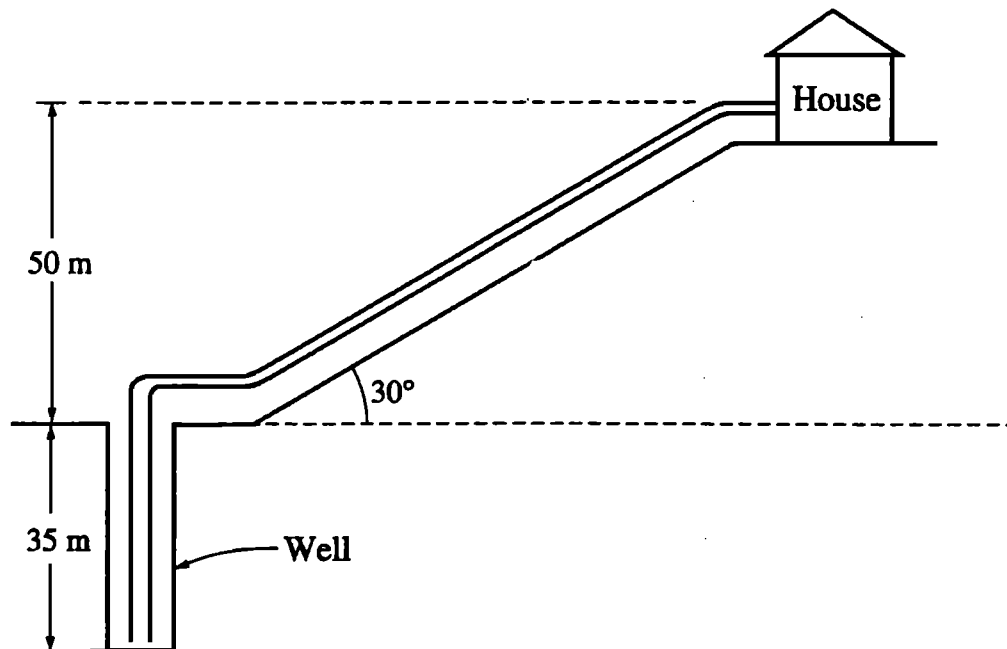
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6. (10 points)

A pump, submerged at the bottom of a well that is 35 m deep, is used to pump water uphill to a house that is 50 m above the top of the well, as shown above. The density of water is $1,000 \text{ kg/m}^3$. All pressures are gauge pressures. Neglect the effects of friction, turbulence, and viscosity.

(a) Residents of the house use 0.35 m^3 of water per day. The day's pumping is completed in 2 hours during the day.

i. Calculate the minimum work required to pump the water used per day

$$\begin{aligned} \text{mass of water pumped per day} &= 1000 \times 0.35 \\ &= 350 \text{ kg.} \end{aligned}$$

$$\begin{aligned} \text{minimum work done} &= mgh = 350 \times 9.8 \times (50 + 35) \\ \text{per day.} & \\ &= 291550 \text{ J.} \end{aligned}$$

ii. Calculate the minimum power rating of the pump.

$$\begin{aligned} \text{minimum power} &= \frac{W}{\Delta t} = \frac{291550}{2 \times 60 \times 60} \\ &= 40.493 \text{ W.} \end{aligned}$$

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(b) The average pressure the pump actually produces is $9.20 \times 10^5 \text{ N/m}^2$. Within the well the water flows at 0.50 m/s and the pipe has a diameter of 3.0 cm . At the house the pipe diameter is 1.25 cm .

i. Calculate the flow velocity when a faucet in the house is open.

$$\begin{aligned} \text{area of cross-section of pipe at well} &= \pi \left(\frac{3 \times 10^{-2}}{2} \right)^2 \\ &= (1.5 \times 10^{-2})^2 \pi \text{ m}^2 \end{aligned}$$

$$\begin{aligned} \text{area of cross-section of pipe at house} &= \pi \left(\frac{1.25 \times 10^{-2}}{2} \right)^2 \\ &= (0.625 \times 10^{-2})^2 \pi \text{ m}^2 \end{aligned}$$

since $Av = \text{constant}$, $A \propto \frac{1}{v}$, $A_1 v_1 = A_2 v_2$,

$$\begin{aligned} \therefore (1.5 \times 10^{-2})^2 \pi (0.5) &= (0.625 \times 10^{-2})^2 \pi v \\ v &= 2.88 \text{ m/s.} \end{aligned}$$

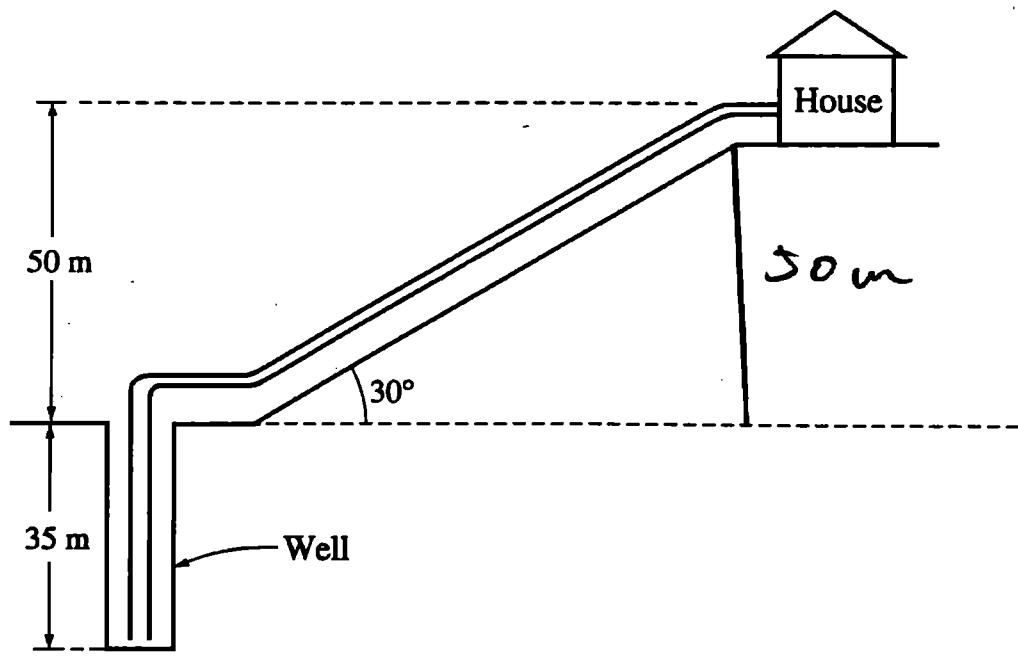
ii. Explain how you would calculate the minimum pressure at the faucet.

$$p + \rho g y + \frac{1}{2} \rho v^2 = \text{constant},$$

$$\text{thus } (9.20 \times 10^5) + \frac{1}{2} (1000) (0.5)^2 = p + 1000g(85) + \frac{1}{2} (1000) (2.88)^2$$

$$p = 83102.8 \text{ N/m}^2$$

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6. (10 points)

A pump, submerged at the bottom of a well that is 35 m deep, is used to pump water uphill to a house that is 50 m above the top of the well, as shown above. The density of water is $1,000 \text{ kg/m}^3$. All pressures are gauge pressures. Neglect the effects of friction, turbulence, and viscosity.

- (a) Residents of the house use 0.35 m^3 of water per day. The day's pumping is completed in 2 hours during the day.
 - i. Calculate the minimum work required to pump the water used per day

$$W = mgh = \rho V g h$$

$$= 1000 (0.35) (9.8) (85)$$

$$= 285750 \text{ J}$$

$$\boxed{8.6 \times 10^4 \text{ J}}$$

$$\textcircled{1} U_g = mgh$$

$$= 1000 (0.35) (9.8) (50)$$

$$= 171500 \text{ J}$$

- ii. Calculate the minimum power rating of the pump.

$$P = \frac{W}{t}$$

$$= \frac{285750}{(2 \times 60 \times 60)}$$

$$= 11.9$$

$$\boxed{12 \text{ W}}$$

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(b) The average pressure the pump actually produces is $9.20 \times 10^5 \text{ N/m}^2$. Within the well the water flows at 0.50 m/s and the pipe has a diameter of 3.0 cm . At the house the pipe diameter is 1.25 cm .

i. Calculate the flow velocity when a faucet in the house is open.

$$A_1 V_1 = A_2 V_2$$

$$V_2 = \frac{A_1 V_1}{A_2}$$

$$V_2 = \frac{\left(\left(\frac{0.03}{2}\right)^2 \pi\right) (0.50)}{\left(\left(\frac{0.0125}{2}\right)^2 \pi\right)} = 2.88$$

ii. Explain how you would calculate the minimum pressure at the faucet.

$$2.9 \text{ m/s}$$

$$P = \frac{F}{A}$$

$$= \frac{9.20 \times 10^5}{\text{m}^2}$$

$$A = \pi r^2$$

$$= \pi \left(\frac{1.25}{2}\right)^2$$

$$= \frac{9.20 \times 10^5}{\left(\left(\frac{0.0125}{2}\right)^2 \pi\right)}$$

$$= 7.5 \times 10^9 \text{ Pa}$$

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