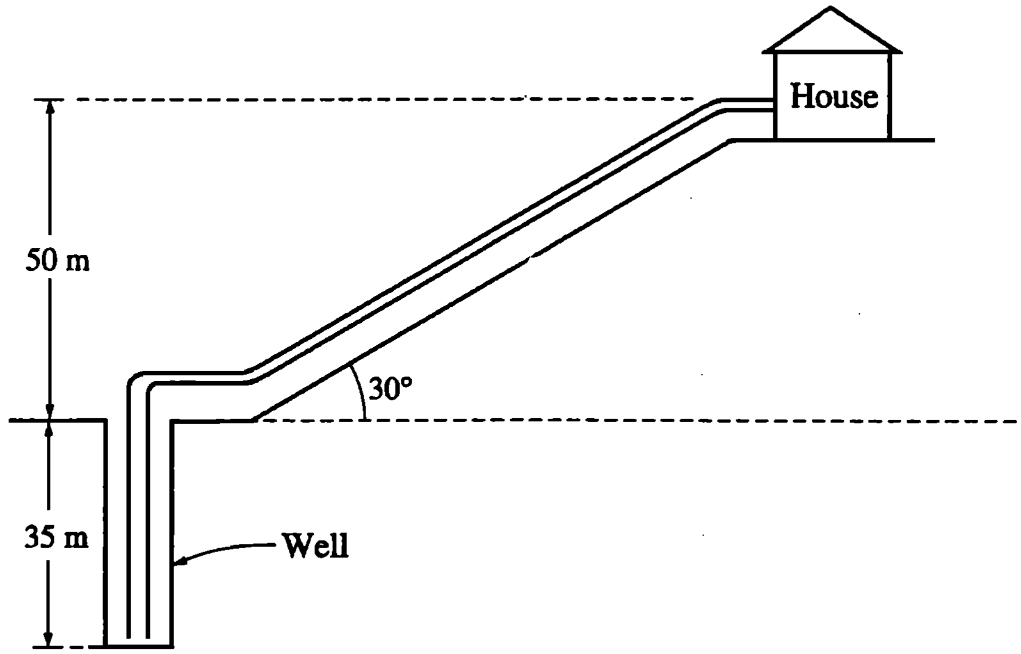
AP® Physics B
2003 Sample Student Responses
Form B



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 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

mass of water pumped per day $= 1000 \times 0.35$
$= 350\,kg$.

minimum work done per day $= mgh = 350 \times 9.8 \times (50+35)$
$= 291550\,J$.

ii. Calculate the minimum power rating of the pump.

minimum power $= \frac{W}{\Delta t} = \frac{291550}{2 \times 60 \times 60}$
$= 40.493\,W$.

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(b) The average pressure the pump actually produces is 9.20×10^5 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.

area of cross-section of pipe at well $= \pi\left(\frac{3\times10^{-2}}{2}\right)^2$

$= (1.5\times10^{-2})^2\pi$. m^2

area of cross-section of pipe at house $= \pi\left(\frac{1.25\times10^{-2}}{2}\right)^2$

$= (0.625\times10^{-2})^2\pi$. m^2.

since $Av =$ constant, $A \propto \frac{1}{v}$, $A_1v_1 = A_2v_2$,

$\therefore (1.5\times10^{-2})^2\pi(0.5) = (0.625\times10^{-2})^2\pi\, v$

$v = 2.88$ m/s.

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

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

thus $(9.20\times10^5) + \frac{1}{2}(1000)(0.5) = p + 1000g(85) + \frac{1}{2}(1000)(2.88)^2$.

$p = 83102.8$ N/m^2

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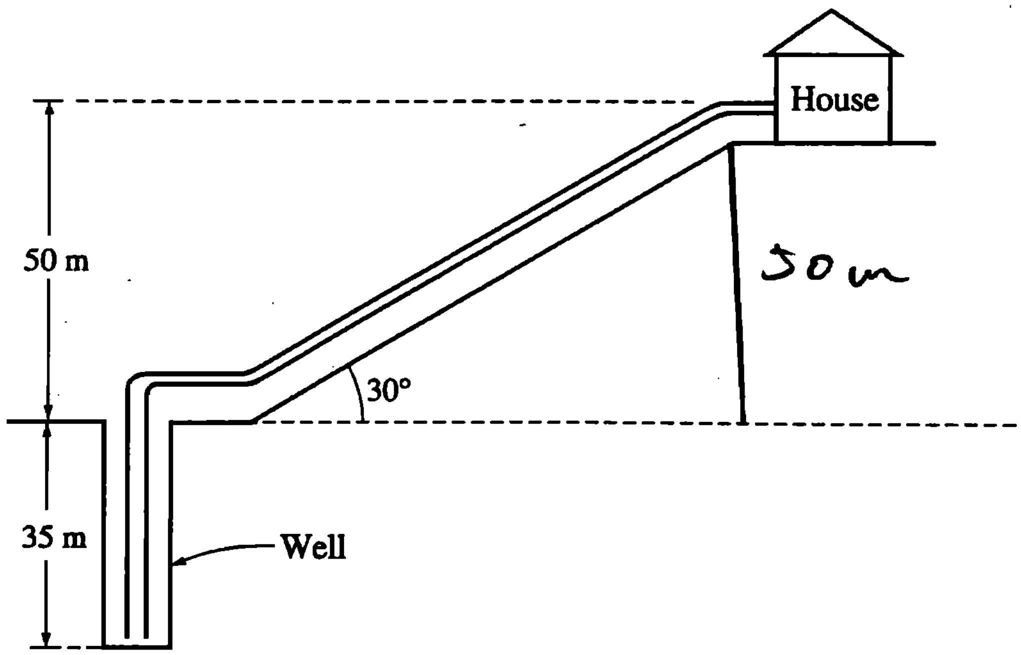

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A pump, submerged at the bottom of a well that is 35 m deep, is used to pump water uphill to a house that is 50 m above the top of the well, as shown above. The density of water is 1,000 kg/m^3. All pressures are gauge pressures. Neglect the effects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

$171500 \sin(30)$

$= 85750\ J$

$8.6 \times 10^4\ J$

① $U_g = mgh$

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

$= 171500\ J$

ii. Calculate the minimum power rating of the pump.

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

$= \frac{85750}{(2 \times 60 \times 60)}$

$= 11.9$

$12\ W$

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(b) The average pressure the pump actually produces is 9.20×10^5 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.

$$A_1 V_1 = A_2 V_2$$

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

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

2.9 m/s

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

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

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

$$A = \pi r^2$$

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

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

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

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