AP® Physics B
2003 Sample Student Responses
Form B

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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 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.

$$mgh = 350 \times 9.8 \times (50 + 35)$$

= 291,550 J.

ii. Calculate the minimum power rating of the pump.

$$\text{minimum power} = \frac{W}{\delta t} = \frac{291,550}{2 \times 60 \times 60}$$

= 40.493 W.
(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.

\[
\text{area of cross-section of pipe at well} = \pi \left( \frac{3 \times 10^{-2}}{2} \right)^2 = (1.5 \times 10^{-2})^2 \pi. \text{ m}^2
\]

\[
\text{area of cross-section of pipe at house} = \pi \left( \frac{1.25 \times 10^{-2}}{2} \right)^2 = (0.625 \times 10^{-2})^2 \pi. \text{ m}^2
\]

Since \( A_1 v_1 = A_2 v_2 \),

\[
(1.5 \times 10^{-2})^2 \pi (0.5) = (0.625 \times 10^{-2})^2 \pi v
\]

\[
v = 2.88 \text{ m/s}
\]

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

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

Thus

\[
(9.20 \times 10^5) + \frac{1}{2} (1000) (0.5) = p + 1000g(0.5) + \frac{1}{2} (1000)(2.88)^2
\]

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

\[ W_g = mgh = 1000 \times (0.35 \times 9.8 \times 50) \]
\[ = 175000 \text{ J} \]
\[ = 8.6 \times 10^4 \text{ J} \]

ii. Calculate the minimum power rating of the pump.

\[ P = \frac{W}{t} \]
\[ = \frac{85750}{(2 \times 60 \times 60)} \]
\[ = 1.19 \text{ kW} \]

GO ON TO THE NEXT PAGE.
(b) The average pressure the pump actually produces is $9.20 \times 10^5$ 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}
= \frac{(\frac{0.03}{2})^2 \pi}{(\frac{0.0125}{2})^2 \pi}
= \frac{0.000875}{0.0005625}
= 1.55556

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

\[
p = \frac{F}{A}.
= \frac{9.20 \times 10^5}{\pi \frac{(1.25)}{2}^2}
= \frac{9.20 \times 10^5 \left(\frac{0.0125}{2}\right)^2 \pi}{\pi}
= 7.5 \times 10^7 \text{ Pa}
\]