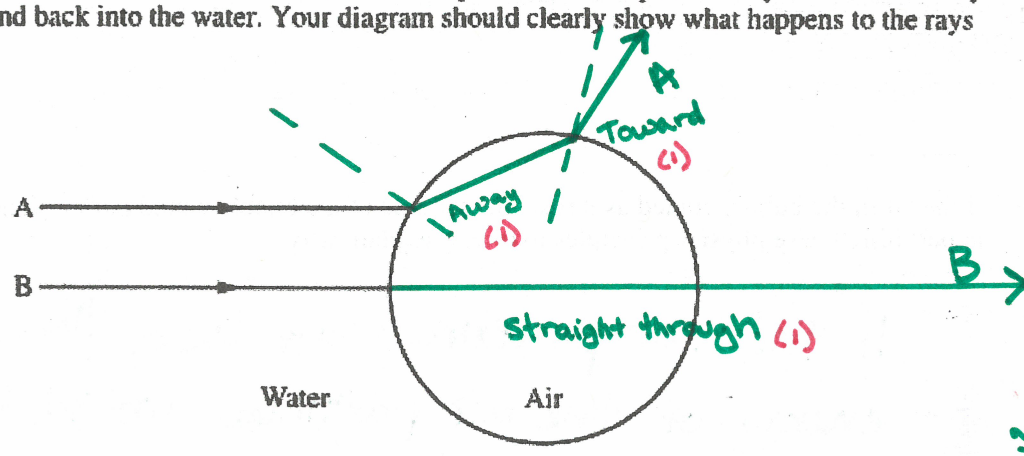
Name ______________________ Date ______________________
AP Physics AP Review # 12
Period __________ Mrs. Nadworny

AP Review # 12

4. (10 points, suggested time 20 minutes)

A student notices many air bubbles rising through the water in a large fish tank at an aquarium.

3 (a) In the figure below, the circle represents one such air bubble, and two incoming rays of light, A and B, are shown. Ray B points toward the center of the circle. On the diagram, draw the paths of rays A and B as they go through the bubble and back into the water. Your diagram should clearly show what happens to the rays at each interface.



3 (b) The bubble has a volume V_1, the air inside it has density ρ_A, and the water around it has density ρ_W. The bubble starts at rest and has a speed v_f when it has risen a height h. Assume that the change in the bubble's volume is negligible. Derive an expression for the mechanical energy dissipated by drag forces as the bubble rises this distance. Express your answer in terms of the given quantities and fundamental constants, as appropriate.

(1) $\Delta K = W_{net} = W_B - W_g - W_{diss}$
(1) $W_B = \rho_w V g h$
(1) correct sub w/ signs

① $F_{net} = ma$

$F_B - F_d - F_g = ma$

$F_{drag} = F_B - F_g - ma$

$= \rho_w g V_1 - \rho_A g V_1 - ma$

$F_{drag} = \rho_w g V_1 - \rho_A g V_1 - \frac{m v_f^2}{2h}$

② $a = \frac{v_f^2 - v_i^2}{2d}$ ($v_i = 0$)

③ $W_{drag} = F_{drag} d$

$= (\rho_w g V_1 - \rho_A g V_1 - \frac{mv^2}{2h})h$

$= \rho_w g V_1 h - \rho_A g V_1 - \frac{mv^2}{2}$

$= \rho_w g V_1 h - \rho_A g V_1 h - \frac{1}{2}\rho_A V_1 v_f^2$

(c) At a particular instant, one bubble is 4.5 m below the water's surface. The surface of the water is at sea level, and the density of the water is $1000\ \mathrm{kg/m^3}$.

1 i. Determine the absolute pressure in the bubble at this location.

$P = P_0 + \rho g h = 1\times10^5\ \mathrm{Pa} + (1000\ \mathrm{kg/m^3})(9.81\ \mathrm{m/s^2})(4.5\ \mathrm{m})$

$= 144{,}000\ \mathrm{Pa}$ (1) w/units

2 ii. The bubble has a volume V_1 when it is 4.5 m below the water's surface. Assume that the temperature of the air in the bubble remains constant as it rises. In terms of V_1, calculate the volume of the bubble when it is just below the surface of the water.

(1) sub P

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad V_2 = \frac{P_1V_1}{P_2} = \frac{(144{,}000\ \text{Pa})(V_1)}{(1\times10^5\ \text{Pa})} = 1.44V_1$$

(1) eqn

1 iii. If the air in the bubble cooled as it rose, the volume of the bubble would be less than the value calculated in part (c)(ii). Use physics principles to briefly explain why.

(1) If the temperature was less, the kinetic energy of the air particles would be lower, so the collisions would be less energetic, causing the volume to be lower.