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General Physics-I, Quiz 4
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St. ID:______________________, Name:_________________

1. **Review.** A student holds a tuning fork oscillating at 256 Hz. He walks toward a wall at a constant speed of 1.33 m/s. (a) What beat frequency does he observe between the tuning fork and its echo? (b) How fast must he walk away from the wall to observe a beat frequency of 5.00 Hz?

Ans: The source moves toward the wall:

$$v_s = +v_{\text{student}}, \quad v_0 = 0, \quad \text{and}$$

$$f' = f\frac{(v+v_o)}{(v-v_s)} = f\frac{v}{(v-v_{\text{student}})}.$$

The wall acts as stationary source, reflecting the wave of frequency f'. The observe moves toward the source: $v_s = 0$, $v_0 = +v_{\text{student}}$, and

$$f'' = f'\frac{(v+v_o)}{(v-v_s)} = f'\frac{(v+v_s)}{v} = f\frac{v}{(v-v_{\text{student}})}\frac{(v+v_{\text{student}})}{v}$$
$$= f\frac{(v+v_{\text{student}})}{(v-v_{\text{student}})}$$

(a) When the student walks toward the wall f'' is larger than f; the beat frequency is

$$f_b = |f''-f| = f\frac{(v+v_{\text{student}})}{(v-v_{\text{student}})} - f = f\left[\frac{(v+v_{\text{student}})}{(v-v_{\text{student}})} - 1\right]$$
$$= f\frac{2v_{\text{student}}}{(v-v_{\text{student}})}$$

$$f_b = (256\text{ Hz})\frac{2(1.33\text{ m/s})}{(343\text{ m/s}-1.33\text{ m/s})} = \boxed{1.99\text{ Hz}}$$

(b) When he is moving away from the wall, the sign of v_{student} changes and f'' is smaller than f:

$$f_b = \left|f'' - f\right| = f - f\frac{\left(v - v_{\text{student}}\right)}{\left(v + v_{\text{student}}\right)} = f\left[1 - \frac{\left(v - v_{\text{student}}\right)}{\left(v + v_{\text{student}}\right)}\right]$$

$$= f\frac{2v_{\text{student}}}{\left(v + v_{\text{student}}\right)}$$

Solving for v_{student} gives

$$v_{\text{student}} = \frac{f_b v}{2f - f_b} = \frac{(5\text{ Hz})(343\text{ m/s})}{(2)(256\text{ Hz}) - 5\text{ Hz}} = \boxed{3.38\text{ m/s}}$$

2. (a) How much work is done on the steam when 1.00 mol of water at 100°C boils and becomes 1.00 mol of steam at 100°C at 1.00 atm pressure? Assume the steam to behave as an ideal gas. (b) Determine the change in internal energy of the system of the water and steam as the water vaporizes.

Ans:

(a) We choose as a system the H_2O molecules that all participate in the phase change. For a constant-pressure process,

$$W = -P\Delta V = -P\left(V_s - V_w\right)$$

where V_s is the volume of the steam and V_w is the volume of the liquid water. We can find them respectively from

$$PV_s = nRT \quad \text{and} \quad V_w = m/\rho = nM/\rho$$

Calculating each work term,

$$PV_s = (1.00\text{ mol})\left(8.314\frac{\text{J}}{\text{K}\cdot\text{mol}}\right)(373\text{ K}) = 3\ 101\text{ J}$$

$$PV_w = (1.00\text{ mol})(18.0\text{ g/mol})\left(\frac{1.013\times10^5\text{ N/m}^2}{1.00\times10^6\text{ g/m}^3}\right) = 1.82\text{ J}$$

Thus the work done is

$$W = -3\ 101\text{ J} + 1.82\text{ J} = \boxed{-3.10\text{ kJ}}$$

(b) The energy input by heat is

$$Q = L_v \Delta m = (18.0 \text{ g})(2.26 \times 10^6 \text{ J/kg}) = 40.7 \text{ kJ}$$

so the change in internal energy is

$$\Delta E_{\text{int}} = Q + W = 40.7 \text{ kJ} - 3.10 \text{ kJ} = \boxed{37.6 \text{ kJ}}$$