(b) Doppler Effect and Beats

(i) Stationary Source, Moving Object

The frequency detected by the source after reflection, f_r, from an object moving away at speed v_{obj} is:

$$f_r = f_s \left(\frac{v_{\text{sound}} - v_{\text{obj}}}{v_{\text{sound}} + v_{\text{obj}}} \right)$$

Given $f_s = 256$ Hz, $v_{\text{sound}} = 340$ m/s, and $f_{\text{beat}} = 7$ Hz. The reflected frequency is $f_r = f_s - f_{\text{beat}} = 256 - 7 = 249$ Hz.

$$249 = 256 \left(\frac{340 - v_{\text{obj}}}{340 + v_{\text{obj}}} \right)$$

Solving for v_{obj} gives: $v_{\text{obj}} \approx 4.71\,\text{m/s}$.

(ii) Moving Source, Moving Object

The source moves towards the object with $v_s = 5.0$ m/s. The reflected frequency f_r' is:

$$f_r' = f_s \left(\frac{v_{\text{sound}} - v_{\text{obj}}}{v_{\text{sound}} - v_s} \right) \left(\frac{v_{\text{sound}} + v_s}{v_{\text{sound}} + v_{\text{obj}}} \right)$$

Using $v_{\text{obj}} = 4.71$ m/s from our calculation:

$$f_r' = 256 \left(\frac{340 - 4.71}{340 - 5} \right) \left(\frac{340 + 5}{340 + 4.71} \right) \approx 256.44\,\text{Hz}$$

The new beat frequency is $f'_{\text{beat}} = |f_r' - f_s| = |256.44 - 256| = 0.44$ Hz.