Problem 59a

Since the two submarines are moving towards each other, we must make the fraction in the Doppler effect formula as large as possible. This means we must use a plus sign in the numerator, and a minus sign in the denominator. So, we have:

f_L = (1000 Hz)(5470 + 70) / (5470 – 50), where the US submarine is the listener v_L, and the French submarine is the sound source v_S, and all speeds are in km/hr. The calculation gives: f_L = 1022 Hz.

Problem 59b

We deal with this problem by assuming that the sound being reflected from the US submarine is 1022 Hz, as calculated in part a, *and* that this reflection is now a frequency source, moving with a speed of 70 km/hr. We thus have v_S = 70 km/hr, while the 50 km/hr speed of the French submarine becomes the velocity of the listener. Again we must use a plus sign in the numerator and a minus in the denominator because the French and US subs are moving towards each other. We have: f_L = (1022)(5470 + 50) / (5470 – 70) = 1045 Hz.

The solution given by the textbook has a misprint. It shows the correct final answer, but if you actually compute the numbers shown in the last formula then you get f_L = 1031 Hz, not 1045 Hz. I think the factor in the denominator which is shown as (5470) should actually be (5470 – 70).

Problem 63

We start off with the burglar as a listener. He or she is walking away from the frequency source, so the sign in front of v_L must be negative. The alarm is not moving, so v_S = 0. We have:

f_L = (28 kHz)(343 – 0.95) / (343 + 0) = 27,922.5 Hz.

This frequency will be reflected back to the alarm. If, as in the submarine problem above, we assume that the reflection is now a sound source moving with the burglar (the alarm is now a stationary listener), then we need to compute the Doppler effect a second time. Since he or she is moving away from the alarm, his/her speed will lower the Doppler fraction, so we must put a plus sign in front of v_S:

f_L = (27,922.5 Hz)(343 – 0) / (343 + 0.95) = 27,845.4 Hz.

The difference is $f_{beat} = f_S - f_L$ = 28,000 – 27,845.4 = 154.6 Hz.

In its solution, the textbook opts to do the problem algebraically. In other words, it starts by multiplying together the above two formulas for the coming/going f_L, to get:

f_L = (28 kHz)[(343 – 0.95)/(343)][(343)/(343 + 0.95)] = (28 kHz)(343 – 0.95)/(343 + 0.95).

The textbook then divides the top and bottom of the fraction by 343 to get:
f_L = (28 kHz)(1 – x)/(1 + x), where x = u/v = 0.95/343.

Rather than just calculating this out, the textbook then applies the binomial theorem, which says that $(1 + x)^n \approx 1 + nx$, if x is much less than one. Since u/v = 0.00277 in this case, the theorem is satisfied. So, we have $f_L \approx$ (28 kHz)(1 – x)(1 – x), because $(1 + x)^{-1} \approx 1 - x$.

Multiplying out $(1 - x)(1 - x) = 1 - 2x + x^2$, but because x is small we can neglect x^2 and just use 1 – 2x. We thus come to: $f_L \approx$ (28 kHz)(1 – 2x) = 28 kHz – 2(28 kHz)(0.95 /343).

$f_{beat} = |f_L - f_S|$ = 2(28 kHz)(0.95 /343) = 155.1 Hz