25. (I) An organ pipe is 112 cm long. What are the fundamental and first three audible overtones if the pipe is (*a*) closed at one end, and (*b*) open at both ends?

26. (I) (*a*) What resonant frequency would you expect from blowing across the top of an empty soda bottle that is 18 cm deep, if you assumed it was a closed tube? (*b*) How would that change if it was one-third full of soda?

27. (I) If you were to build a pipe organ with open-tube pipes spanning the range of human hearing (20 Hz to 20 kHz), what would be the range of the lengths of pipes required?

28. (II) A tight guitar string has a frequency of 540 Hz as its third harmonic. What will be its fundamental frequency if it is fingered at a length of only 60% of its original length?

29. (II) An unfingered guitar string is 0.73 m long and is tuned to play E above middle C (330 Hz). (*a*) How far from the end of this string must a fret (and your finger) be placed to play A above middle C (440 Hz)? (*b*) What is the wavelength on the string of this 440-Hz wave? (*c*) What are the frequency and wavelength of the sound wave produced in air at 20°C by this fingered string?

30. (II) (*a*) Determine the length of an open organ pipe that emits middle C (262 Hz) when the temperature is 21°C. (*b*) What are the wavelength and frequency of the fundamental standing wave in the tube? (*c*) What are λ and f in the traveling sound wave produced in the outside air?

31. (II) An organ is in tune at 20°C. By what percent will the frequency be off at 5.0°C?

32. (II) How far from the mouthpiece of the flute in Example 12–10 should the hole be that must be uncovered to play D above middle C at 294 Hz?

33. (II) (*a*) At $T = 20°\text{C}$, how long must an open organ pipe be to have a fundamental frequency of 294 Hz? (*b*) If this pipe is filled with helium, what is its fundamental frequency?

34. (II) A particular organ pipe can resonate at 264 Hz, 440 Hz, and 616 Hz, but not at any other frequencies in between. (*a*) Show why this is an open or a closed pipe. (*b*) What is the fundamental frequency of this pipe?

35. (II) A uniform narrow tube 1.80 m long is open at both ends. It resonates at two successive harmonics of frequencies 275 Hz and 330 Hz. What is (*a*) the fundamental frequency, and (*b*) the speed of sound in the gas in the tube?

36. (II) A pipe in air at 20°C is to be designed to produce two successive harmonics at 240 Hz and 280 Hz. How long must the pipe be, and is it open or closed?

37. (II) How many overtones are present within the audible range for a 2.14-m-long organ pipe at 20°C (*a*) if it is open, and (*b*) if it is closed?

38. (III) The human ear canal is approximately 2.5 cm long. It is open to the outside and is closed at the other end by the eardrum. Estimate the frequencies (in the audible range) of the standing waves in the ear canal. What is the relationship of your answer to the information in the graph of Fig. 12–6?

12–6 Interference; Beats

39. (I) A piano tuner hears one beat every 2.0 s when trying to adjust two strings, one of which is sounding 440 Hz. How far off in frequency is the other string?

40. (I) What is the beat frequency if middle C (262 Hz) and C$^\#$ (277 Hz) are played together? What if each is played two octaves lower (each frequency reduced by a factor of 4)?

41. (I) A certain dog whistle operates at 23.5 kHz, while another (brand X) operates at an unknown frequency. If neither whistle can be heard by humans when played separately, but a shrill whine of frequency 5000 Hz occurs when they are played simultaneously, estimate the operating frequency of brand X.

42. (II) A guitar string produces 4 beats/s when sounded with a 350-Hz tuning fork and 9 beats/s when sounded with a 355-Hz tuning fork. What is the vibrational frequency of the string? Explain your reasoning.

43. (II) Two violin strings are tuned to the same frequency, 294 Hz. The tension in one string is then decreased by 2.0%. What will be the beat frequency heard when the two strings are played together? [*Hint*: Recall Eq. 11–13.]

44. (II) How many beats will be heard if two identical flutes each try to play middle C (262 Hz), but one is at 5.0°C and the other at 25.0°C?

45. (II) You have three tuning forks, A, B, and C. Fork B has a frequency of 441 Hz; when A and B are sounded together, a beat frequency of 3 Hz is heard. When B and C are sounded together, the beat frequency is 4 Hz. What are the possible frequencies of A and C? What beat frequencies are possible when A and C are sounded together?

46. (II) Two loudspeakers are 1.80 m apart. A person stands 3.00 m from one speaker and 3.50 m from the other. (*a*) What is the lowest frequency at which destructive interference will occur at this point? (*b*) Calculate two other frequencies that also result in destructive interference at this point (give the next two highest). Let $T = 20°\text{C}$.

47. (III) Two piano strings are supposed to be vibrating at 132 Hz, but a piano tuner hears three beats every 2.0 s when they are played together. (*a*) If one is vibrating at 132 Hz, what must be the frequency of the other (is there only one answer)? (*b*) By how much (in percent) must the tension be increased or decreased to bring them in tune?

48. (III) A source emits sound of wavelengths 2.64 m and 2.76 m in air. How many beats per second will be heard? (Assume $T = 20°\text{C}$.)

12–7 Doppler Effect

49. (I) The predominant frequency of a certain fire engine's siren is 1550 Hz when at rest. What frequency do you detect if you move with a speed of 30.0 m/s (*a*) toward the fire engine, and (*b*) away from it?

50. (I) You are standing still. What frequency do you detect if a fire engine whose siren emits at 1550 Hz moves at a speed of 32 m/s (*a*) toward you, or (*b*) away from you?

51. (II) (*a*) Compare the shift in frequency if a 2000-Hz source is moving toward you at 15 m/s, versus you moving toward it at 15 m/s. Are the two frequencies exactly the same? Are they close? (*b*) Repeat the calculation for 150 m/s and then again (*c*) for 300 m/s. What can you conclude about the asymmetry of the Doppler formulas?

52. (II) Two automobiles are equipped with the same single-frequency horn. When one is at rest and the other is moving toward the first at 15 m/s, the driver at rest hears a beat frequency of 5.5 Hz. What is the frequency the horns emit? Assume $T = 20°\text{C}$.

53. (II) A bat at rest sends out ultrasonic sound waves at 50.0 kHz and receives them returned from an object moving directly away from it at 25.0 m/s. What is the received sound frequency?