CHAPTER 10 PRACTICE PASSAGE

Sound waves propagate away from a source in spherical wavefronts, lines that connect the points on sound wave that were emitted at the same time. When the source is stationary, these wave fronts are concentric spheres centered about the source. However, when the source begins to move with a velocity v_0, the wavefronts get closer together in the direction of v_0 and are spread farther apart in the opposite direction.

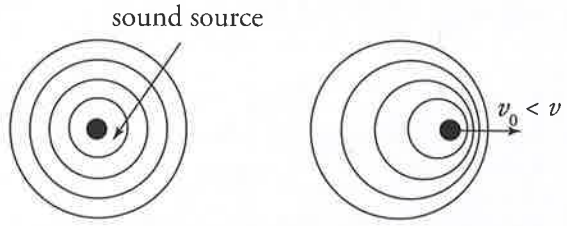

Figure 1 Wavefronts generated by sound sources that are stationary and moving with a speed less than the speed of sound.

As a result of the change in the distance between wavefronts, a listener standing ahead or behind the object will hear a frequency different from the original emitted frequency, a phenomenon known as the Doppler effect, according to the equation:

$$f_D = f_S \frac{v \pm v_D}{v \mp v_S}$$

Equation 1

where f_D and f_S are the detected and emitted frequencies, respectively, v is the speed of sound, and v_D and v_S are the velocities of the detector and the source, respectively.

Some jets have been designed to fly at speeds greater than the speed of sound. There speeds are usually given as a Mach number, $M = v_0/v$, which indicates the jet's speed relative to the speed of sound in the surrounding air. Because the speed of sound in air increases as the temperature increases, the jets flying with the same Mach number can be travelling at different speeds. When a jet flies at exactly Mach 1, the wavefronts build up just in front of the object, creating an intense shock wave. Flight at this speed is incredibly turbulent. Interestingly, in this case an observer ahead of the jet would not hear it until the jet itself arrived, since the first wavefront and the jet arrive at the same time. Jets can also fly faster than the speed of sound, at supersonic speeds. When this happens, the jet actually advances ahead of the shock wave it creates. The intense sound heard when a shockwave passes by an observer is known as a sonic boom.

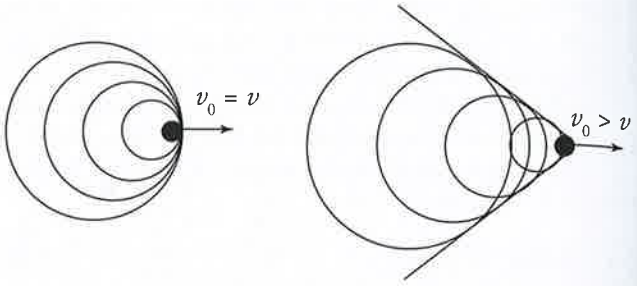

Figure 2 Wavefronts created by a jet flying at the speed of sound and at a supersonic speed.

1. Two jets are flying at Mach 3, one close to sea level, the other at 50,000 ft where the air temperature is cooler. Compared to the jet at sea level, the one flying at 50,000 ft is travelling:

A) at the same speed.
B) at a lower speed because the speed of sound decreases at altitude due to the lower air temperature.
C) at a greater speed because the speed of sound decreases at altitude due to the lower air temperature.
D) at a greater speed because the speed of sound increases at altitude due to the greater air temperature.

2. While driving down the road at 10 m/s, a driver hears 330 Hz siren from police car approaching from behind. If the frequency emitted by the siren is 300 Hz, how fast is the police car going?

A) 9 m/s
B) 10 m/s
C) 20 m/s
D) 40 m/s

3. A stationary observer is standing on a sidewalk when a police car emitting a 300 Hz siren passes by on the road at 20 m/s. Just as the police car passes her, what is the frequency she hears?

A) 283 Hz
B) 300 Hz
C) 318 Hz
D) 340 Hz

4. If the sonic boom that the jet produces when it goes supersonic is 60 dB louder than acceptable limits for the people on the base below, at minimum how many times farther away should it be from the base when it goes supersonic?

A) 10^3
B) 10^4
C) 10^5
D) 10^6

5. As a siren approaches an observer at a constant velocity, the observer hears a sound that is:

A) increasing in frequency.
B) at a constant frequency that is higher than the emitted frequency.
C) at a constant frequency that is lower than the emitted frequency.
D) decreasing in frequency.

6. What is a possible explanation for why flying at Mach 1 results in incredibly turbulent flight?

A) The transverse motion of the air molecules of the sound wave jostle the vessel up and down.
B) The transverse motion of the air molecules of the sound wave make it difficult for the pilot to steer.
C) The build-up of sound waves in front of the jet creates an extreme pressure front.
D) Jets are increasingly structurally unstable the faster they travel.

7. A jet flying at Mach 2 flies directly over a ship in the ocean. When the observers on the ship hear the jet, the jet is:

A) approaching the ship.
B) directly overhead.
C) already past the ship.
D) somewhere in the vicinity of the ship, but it is impossible know where it is in its path over the ship.