Section 8.5: Properties of Sound Waves

Research This: Using Ultrasound Technology in Medicine, page 392

A. This technology uses waves to break apart cancerous masses. The technology surgically removes previously inoperable tumours, such as brain tumours.
B. The ultrasound waves are at a specific frequency (about 23 kHz) that breaks up tumours without harming surrounding body tissue. The broken pieces are then easily removed through a hollow probe.
C. This technology is preferred over traditional surgery because it reduces blood loss. In addition, the tumour can be removed without causing serious damage to healthy surrounding tissue.

Tutorial 1 Practice, page 393

1. Given: $T = 32$ °C
Required: v
Analysis: $v = 331.4\text{ m/s} + (0.606\text{ m/s/°C})T$
Solution:

$$\begin{aligned}v &= 331.4\text{ m/s} + (0.606\text{ m/s/°C})T \\ &= 331.4\text{ m/s} + \left(0.606\ \frac{\text{m/s}}{\cancel{\text{°C}}}\right)(32\ \cancel{\text{°C}}) \\ &= 331.4\text{ m/s} + 19.4\text{ m/s} \\ v &= 351\text{ m/s}\end{aligned}$$

Statement: The speed of sound in 32 °C air is 351 m/s.

2. Given: $v = 333$ m/s
Required: T
Analysis: $v = 331.4\text{ m/s} + (0.606\text{ m/s/°C})T$

$$T = \frac{v - 331.4\text{ m/s}}{0.606\text{ m/s/°C}}$$

Solution:

$$\begin{aligned}T &= \frac{v - 331.4\text{ m/s}}{0.606\text{ m/s/°C}} \\ &= \frac{333\text{ m/s} - 331.4\text{ m/s}}{0.606\text{ m/s/°C}} \\ &= \frac{1.6\ \cancel{\text{m/s}}}{0.606\ \frac{\cancel{\text{m/s}}}{\text{°C}}} \\ T &= 2.64\text{ °C}\end{aligned}$$

Statement: The ambient temperature is 2.64 °C.

3. Given: $v = 350$ m/s
Required: T
Analysis: $v = 331.4\text{ m/s} + (0.606\text{ m/s/°C})T$

$$T = \frac{v - 331.4\text{ m/s}}{0.606\text{ m/s/°C}}$$

Solution:

$$\begin{aligned}T &= \frac{v - 331.4\text{ m/s}}{0.606\text{ m/s/°C}} \\ &= \frac{350\text{ m/s} - 331.4\text{ m/s}}{0.606\text{ m/s/°C}} \\ &= \frac{18.6\ \cancel{\text{m/s}}}{0.606\ \frac{\cancel{\text{m/s}}}{\text{°C}}} \\ T &= 31\text{ °C}\end{aligned}$$

Statement: The ambient temperature is 31 °C.

Tutorial 2 Practice, page 394

1. Given: $v_{\text{sound}} = 344$ m/s; $v_{\text{aircraft}} = 910$ km/h
Required: M
Analysis: $M = \dfrac{v_{\text{aircraft}}}{v_{\text{sound}}}$
Solution:

$$\begin{aligned}M &= \frac{v_{\text{aircraft}}}{v_{\text{sound}}} \\ &= \frac{910\text{ km/h}}{344\text{ m/s}} \\ &= \frac{910\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}}}{344\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}}\left(\frac{1000\ \cancel{\text{m}}}{1\ \cancel{\text{km}}}\right)\left(\frac{1\ \cancel{\text{h}}}{3600\ \cancel{\text{s}}}\right) \\ M &= 0.73\end{aligned}$$

Statement: The Mach number is 0.73.

2. Given: $v_{\text{sound}} = 320$ m/s; $M = 0.93$
Required: v_{airplane}
Analysis:

$$M = \frac{v_{\text{airplane}}}{v_{\text{sound}}}$$

$$v_{\text{airplane}} = Mv_{\text{sound}}$$

Solution:

$$\begin{aligned}v_{\text{airplane}} &= Mv_{\text{sound}} \\ &= (0.93)(320\text{ m/s}) \\ &= 297.6\text{ m/s} \\ &= \left(297.6\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)\left(\frac{1\ \cancel{\text{km}}}{1000\ \cancel{\text{m}}}\right)\left(\frac{3600\ \cancel{\text{s}}}{1\ \cancel{\text{h}}}\right) \\ v_{\text{airplane}} &= 1100\text{ km/h}\end{aligned}$$

Statement: The speed of the airplane is 1100 km/h.

3. Given: v_{airplane} = 850 km/h; M = 0.81
Required: v_{sound}

Analysis: $M = \dfrac{v_{\text{airplane}}}{v_{\text{sound}}}$

$$v_{\text{sound}} = \frac{v_{\text{airplane}}}{M}$$

Solution:
$$\begin{aligned} v_{\text{sound}} &= \frac{v_{\text{airplane}}}{M} \\ &= \frac{850\ \text{km/h}}{0.81} \\ &= 1049\ \text{km/h} \\ v_{\text{sound}} &= 1.0 \times 10^3\ \text{km/h} \end{aligned}$$

Statement: The local speed of sound is 1.0×10^3 km/h, or 1000 km/h.

Mini Investigation: Testing Loudness, page 396

A. Answers may vary. Students' reports should include results of their measurements of the car stereo and include a warning about the hazards of listening to loud sounds for too long.

Section 8.5 Questions, page 397

1. (a) Cyanobacteria are also known as blue-green algae. It is important to control cyanobacteria because they are harmful if eaten.
(b) Cyanobacteria are traditionally controlled by chemicals such as copper sulphate. But using copper sulphate also kills any plants and animals in the water.
(c) The treatment proposes using low frequencies because such frequencies will immobilize the cyanobacteria. This is preferable to using high frequencies because high frequencies will break down the cell walls and spill the toxins into the water supply.
2. An aircraft flying at Mach 2 means that it is travelling at a speed equal to double the speed of the sound at that temperature.
3. Given: M = 0.83; T = 10 °C
Required: v_{airplane}
Analysis: $v_{\text{sound}} = 331.4\ \text{m/s} + (0.606\ \text{m/s/°C})T$;

$$M = \frac{v_{\text{airplane}}}{v_{\text{sound}}}$$

$$v_{\text{airplane}} = Mv_{\text{sound}}$$

Solution: Determine the local speed of sound:

$$\begin{aligned} v_{\text{sound}} &= 331.4\ \text{m/s} + (0.606\ \text{m/s/°C})T \\ &= 331.4\ \text{m/s} + \left(0.606\ \frac{\text{m/s}}{\cancel{\text{°C}}}\right)(10\ \cancel{\text{°C}}) \\ &= 331.4\ \text{m/s} + 6.06\ \text{m/s} \\ &= 337.46\ \text{m/s} \\ v_{\text{sound}} &= 337.5\ \text{m/s (two extra digits carried)} \end{aligned}$$

Determine the speed of the aircraft:

$$\begin{aligned} v_{\text{airplane}} &= Mv_{\text{sound}} \\ &= (0.83)(337.46\ \text{m/s}) \\ &= 280.09\ \text{m/s} \\ &= \left(280.09\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)\left(\frac{1\ \text{km}}{1000\ \cancel{\text{m}}}\right)\left(\frac{3600\ \cancel{\text{s}}}{1\ \text{h}}\right) \\ &= 1008\ \text{km/h} \\ v_{\text{airplane}} &= 1000\ \text{km/h} \end{aligned}$$

Statement: The speed of the airplane is 1000 km/h.
4. The speed of sound varies by temperature and density of the medium, both of which depend on the molecular structure of various particles.
5. (a) Sound intensity is a measure of energy per unit area due to a sound wave.
(b) Loudness is a measure of the sound intensity. It can also be defined as a human perception of sound energy.
(c) The decibel is the unit of measurement of sound level used to describe sound intensity.
6. Loudness is expressed in a logarithmic scale using decibels (dB). Decibels are a more convenient measurement unit than watts per square metre (W/m^2). The watt per square metre values for loudness can vary from 1.0×10^{-12} (the threshold of human hearing) to 1.0×10^{13} (an atomic bomb).
7. Sound intensity is a measure of energy flowing through the unit area due to a sound wave.
8. (a) Yes, the greater the loudness, the less time it is safe to listen.
(b) Answers may vary. Sample answer: One website suggested listening to no more than 2 h of 100 dB sound a day. This corresponds to a volume of 8 on the scale given.

9. The power saw operates at 120 dB, which is 1.0 W/m^2. The sound level of the city street is 90 dB, which is 1.0×10^{-3} W/m^2.

$$\frac{1.0 \text{ W/m}^2}{1.0 \times 10^{-3} \text{ W/m}^2} = \frac{1000}{1}$$

The ratio of the sound intensity the power saw compared to the city street is 1000:1.

10. Yes, the burglar's cough is louder than 1.0×10^{-7} W/m^2, or 50 dB, so it will be detected because it is more than 30 dB greater than the detection threshold of 1.0×10^{-10} W/m^2, or 20 dB.

11. (a) Barriers can be made of several materials. Barriers have been made of earth, wood, metal, concrete, and other materials.

(b) Sound barriers provide a physical barrier between highways and residential areas. The barriers absorb some of the sound waves, reflect some, and limit the sound waves that get by it to those that pass over the barrier.

(c) The barriers can be very effective at reducing residential noise. One website suggests that they can reduce traffic noise levels by 5 to 10 dB, cutting the loudness of the noise by as much as 50 %.

