Name: _____

Learning Intention

- Learn some of the properties of sound waves.

Definitions

1. _Natural_ frequency is the frequency at which an object with vibrate if struck.

2. _Forced_ vibration occurs when an object is physically touched to an object that is vibrating.

   a. _Resonance_ occurs when an object undergoes _forced_ vibration at its natural frequency.

3. In a _standing_ wave, there is _constructive_ and _destructive_ interference between the initial waves and the reflected waves.
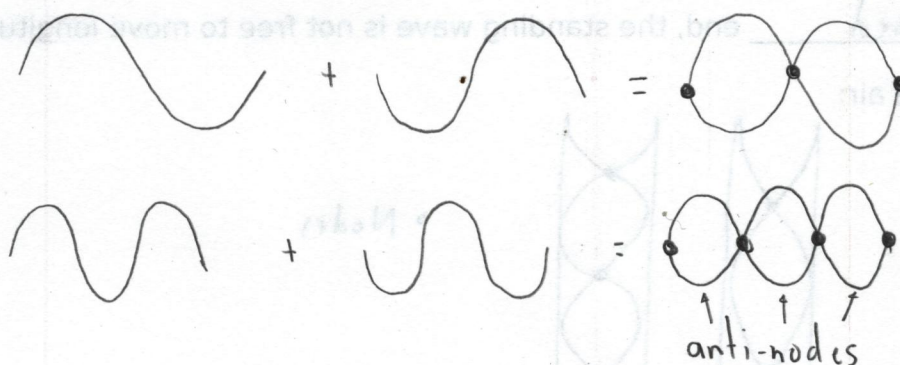

   a. A _node_ is the point in a standing wave where, due to _destructive_ interference, the medium does not undergo any displacement.

   b. An _anti-node_ is the point in a standing wave where, due to _constructive_ interference, the medium undergoes the maximum displacement in each direction.

4. In music, the term _loudness_ is used to refer to the amplitude of a sound wave.

5. In music, the term _pitch_ is used to refer to the frequency of a sound wave.

6. When a guitar string is plucked, it produces ___standing___ waves in the string.

   a. Each standing wave is called a ___harmonic___.

   b. The lowest frequency is known as the ___fundamental___ frequency, or the ___first___ ___harmonic___.

   c. The second lowest frequency standing wave is known as the ___first___ ___overtone___, or the ___second___ ___harmonic___.

   d. The third lowest frequency standing wave is known as the ___second___ ___harmonic___, or the ___third___ ___harmonic___.

7. An air column is a tube that is open at either ___one___ end or ___both___ ends.

   a. At a ___closed___ end, the standing wave is not free to move longitudinally through the air:

   • Nodes
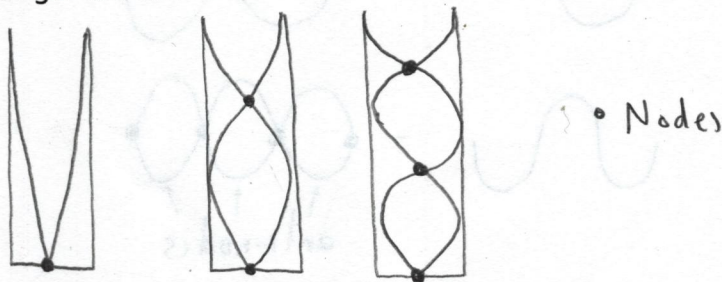
   b. At an ___open___ end, the standing wave is free to move longitudinally through the air:

   • Nodes
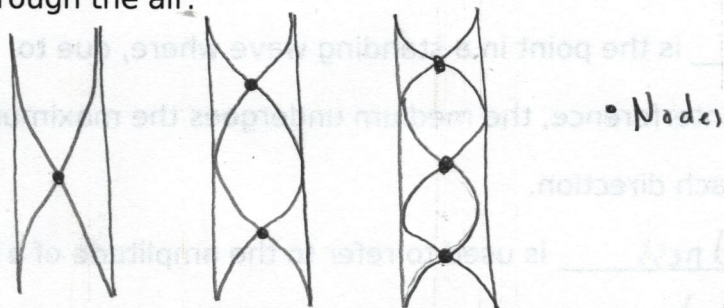
8. Young humans can generally hear sounds from around ___20___ Hz to ___20___ kHz.

a. Dog whistles make a noise at 23 to 54 kHz, which is considered the

__ultrasonic__ range.

9. In air, at sea level (normal atmospheric pressure), the speed of sound is given by:

$$V = 331 \text{ m/s} + 0.600 \frac{\text{m/s}}{°C} \times T$$

V: speed of sound (m/s)

T: temperature (°C)

10. A __supersonic__ plane can fly faster than the speed of sound in air.

a. The __Mach__ number indicates how fast the plane is flying.

b. When a plane breaks the __sound__ barrier (Mach 1.0), a __sonic__ __boom__ is generated.

11. The loudness of sounds is measured using the __decibal__ scale.

a. An increase of 10 dB results in __2__ times as much power in the sound wave.

b. __0__ dB: Limit of human hearing

c. __60__ dB: Human voice

d. __110__ dB: Rock concert

e. __140__ dB: Painful to the ears, can cause permanent damage

Questions

1. For a 440 Hz tone

    1. What is the first harmonic?

    2. What is the first overtone?

    3. What is the second overtone?

    4. What is the third overtone?

2. What is the fundamental frequency, if the first overtone is 680 Hz?

3. What is the first harmonic, if the second overtone is 680 Hz?

4. What is the second harmonic, if the third overtone is 680 Hz?

5. How fast will sound travel at:

    1. 0.00 °C

    2. 25.0 °C

    3. 0 K

6. A camper sees a flash of lightning, and immediately begins counting until they hear the sound of the thunder. The air is 21 °C. How far from the lightning is the camper if the thunder arrives in:

    1. 9.0 seconds?

    2. 6.0 seconds?

    3. 3.0 seconds?

7. What is the rule of thumb for finding the distance from a lightning strike?

8. How fast is a plane travelling, in m/s, if it is going at a speed of:

    1. Mach 3.0 in 21 °C air.

    2. Mach 10.0 in -55 °C air.

9. How many times louder than a 40 dB library is a 110 dB concert?

10. How many times louder than a 60 dB air conditioner is a 120 dB jet engine?

Answers

1. 1. 440 Hz
   2. 880 Hz
   3. 1300 Hz
   4. 1800 Hz
2. f_0 = 340 Hz
3. f_0 = 230 Hz
4. f_1 = 340 Hz
5. 1. v = 331 m/s
   2. v = 346 m/s
   3. v = 167 m/s
6. 1. d = 3,100 m = 3.1 km
   2. d = 2,100 m = 2.1 km
   3. d = 1,000 m = 1.0 km
7. The distance in kilometers is equal to the time in seconds between the lightning and the thunder, divided by 3.
8. 1. v = 1,000 m/s = 1.0 km/s
   2. v = 3,000 m/s = 3.0 km/s
9. 130 times
10. 64 times

1. 1. The first harmonic is the tone's frequency.

$$f_0 = 440 \text{ Hz}$$

2. $f_1 = 2f_0 = 2 \times 440 \text{ Hz} = 880 \text{ Hz}$

3. $f_2 = 3f_0 = 3 \times 440 \text{ Hz} = 1320 \text{ Hz} \rightarrow 1300 \text{ Hz}$

4. $f_3 = 4f_0 = 4 \times 440 \text{ Hz} = 1760 \text{ Hz} \rightarrow 1800 \text{ Hz}$

f_0: fundamental (harmonic 1)

f_1: 1st overtone (harmonic 2)

f_2: 2nd overtone (harmonic 3)

f_3: 3rd overtone (harmonic 4)

2. $f_0 = \frac{1}{2} f_1 = \frac{1}{2} \times 680 \text{ Hz} = 340 \text{ Hz}$

3. $f_0 = \frac{1}{3} f_2 = \frac{1}{3} \times 680 \text{ Hz} = 226.7 \text{ Hz} \rightarrow 230 \text{ Hz}$

4. $\left.\begin{array}{c} f_0 = \frac{1}{2} f_1 \\ f_0 = \frac{1}{4} f_3 \end{array}\right\}$ $\frac{1}{2} f_1 = \frac{1}{4} f_3$

$f_1 = \frac{2}{4} f_3 = \frac{1}{2} \times 680 \text{ Hz} = 340 \text{ Hz}$

5. 1. $V = 331 \text{ m/s} + 0.6 \frac{\text{m/s}}{°C} \times T = 331 \text{ m/s}$

2. $V = 331 \text{ m/s} + 0.6 \frac{\text{m/s}}{°C} \times (25\,°C) = 346 \text{ m/s}$

3. $V = 331 \text{ m/s} + 0.6 \frac{\text{m/s}}{°C} (-273.15\,°C) = 167 \text{ m/s}$

6. 1. $V = 331 \text{ m/s} + 0.6 \frac{\text{m/s}}{°C} (21°C) = 343.6 \text{ m/s}$

$d = V \cdot t = 343.6 \text{ m/s} \times 9.0 \text{ s} = 3092.4 \text{ m}$

$d = 3100 \text{ m} = 3.1 \text{ km}$

2. $d = V \cdot t = 343.6 \text{ m/s} \times 6.0 \text{ s} = 2061.6 \text{ m}$

$d = 2100 \text{ m} = 2.1 \text{ km}$

3. $d = V \cdot t = 343.6 \text{ m/s} \times 3.0 \text{ s} = 1030.8 \text{ m}$

$d = 1000 \text{ m} = 1.0 \text{ km}$

8.1 $M = \dfrac{v}{v_{sound}} \implies v = Mv_{sound} = 3.0 \times \left[331 \, m/s + 0.6 \frac{m/s}{°C} \times (21°C) \right] = 1030.8 \, m/s$

$v = 1,000 \, m/s$

2. $v = Mv_{sound} = 10.0 \times \left[331 \, m/s + 0.6 \frac{m/s}{°C} (-55°C) \right] = 2980 \, m/s$

$v = 3,000 \, m/s$

9. 110 dB - 40 dB = 70 dB

Every 10 dB is a doubling of power

$2^7 = 128 \rightarrow 130 \text{ times}$

10. 120 dB - 60 dB = 60 dB

$2^6 = 64$