Interference & Superposition

Creating Complex Wave Forms

Waves & Interference

I. Definitions and Types
II. Parameters and Equations
III. Sound
IV. Graphs of Waves
V. Interference
- superposition
- standing waves

	The student will be able to:	HW:
1	Define, apply, and give examples of the following concepts: wave, pulse vs. continuous wave, source, medium, longitudinal wave, transverse wave, surface wave, crest, trough, compression, rarefaction. ✓	1 – 11
2	Define, apply and give examples of the following wave parameters: speed, wavelength, frequency, period, and amplitude and state the influence of source and medium on each wave parameter. ✓	
3	Identify the wave type, medium, and speed of mechanical waves and sound. State the relation between speed, wavelength, and frequency for a wave, and use this relation to solve related problems. ✓	12 – 18
4	Solve problems analyzing graphs to determine a wave's parameters. ✓	19 – 21
5	Define and apply the following concepts: superposition, constructive and destructive interference, phase, beat frequency and solve related problems.	22 – 24
6	Explain the requirements for the creation of a standing wave. Define and identify nodes and antinodes in standing wave patterns. Solve problems involving harmonics for strings or pipes.	25 – 38
7	Define resonance and identify and give examples of this phenomenon.	39 – 41

Interference

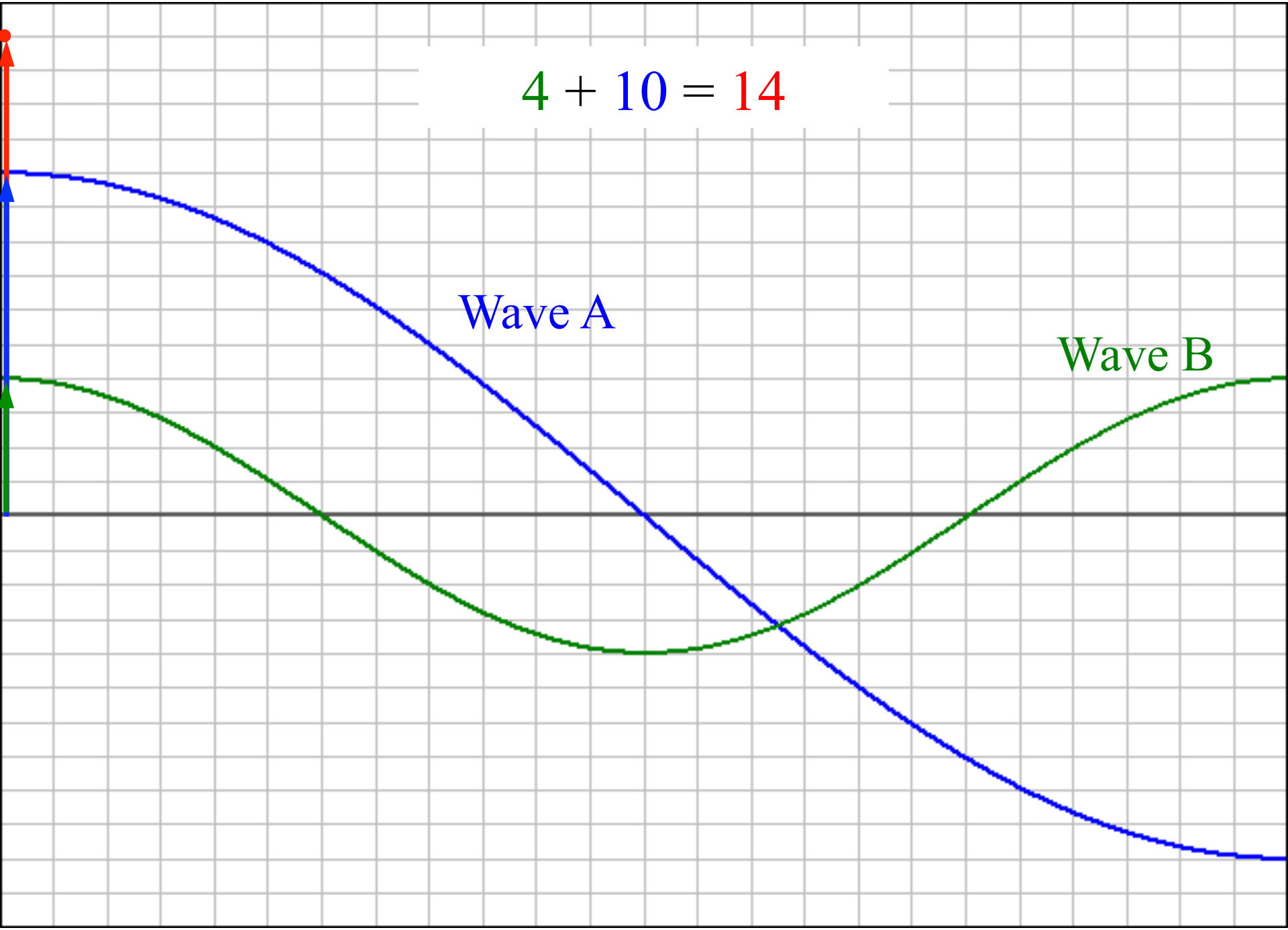
- Two or more waves of the same type can exist simultaneously in the same medium.
- Interference refers to the combined effect of two or more waves.
- If the resulting amplitude is increased it is called constructive interference.
- If the resulting amplitude is decreased it is called destructive interference.

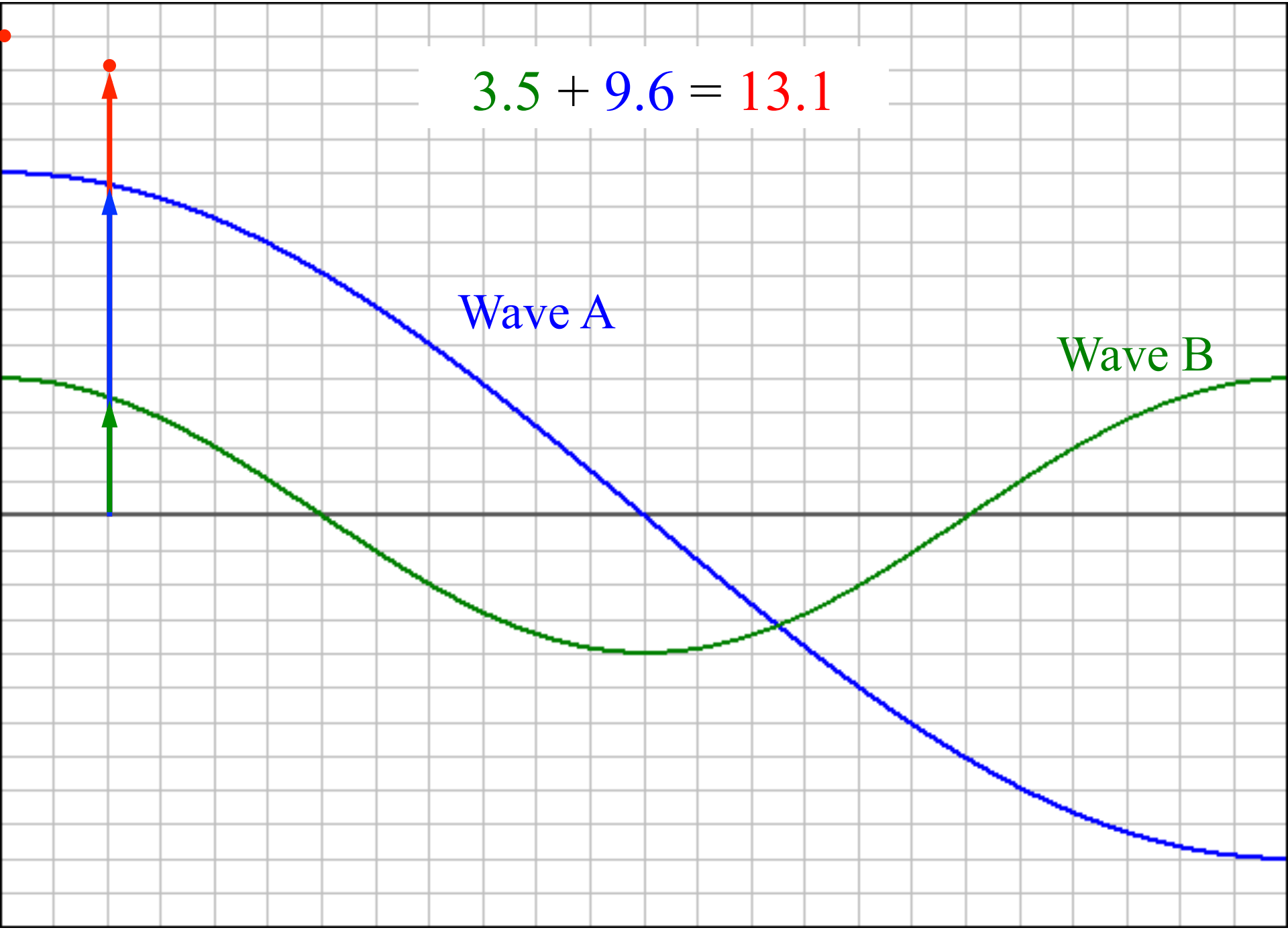
Phase

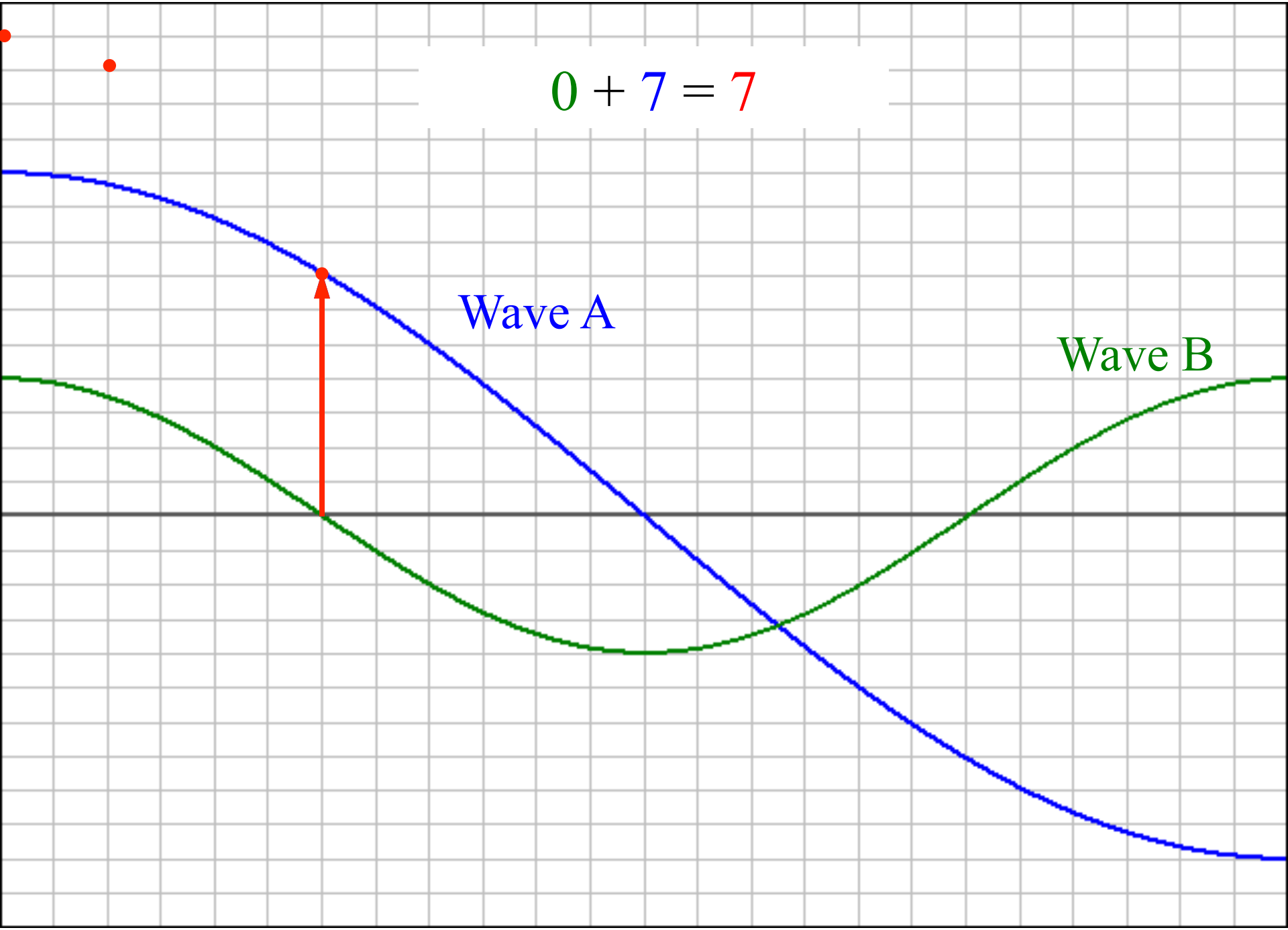
- Phase refers to the degree to which behaviors are synchronized. (Or in some cases phase refers to a certain part of a cycle.)
- Waves with the same behavior are said to be "in phase". This results in constructive interference.
- Waves with the opposite behaviors are said to be "out of phase". This results in destructive interference.

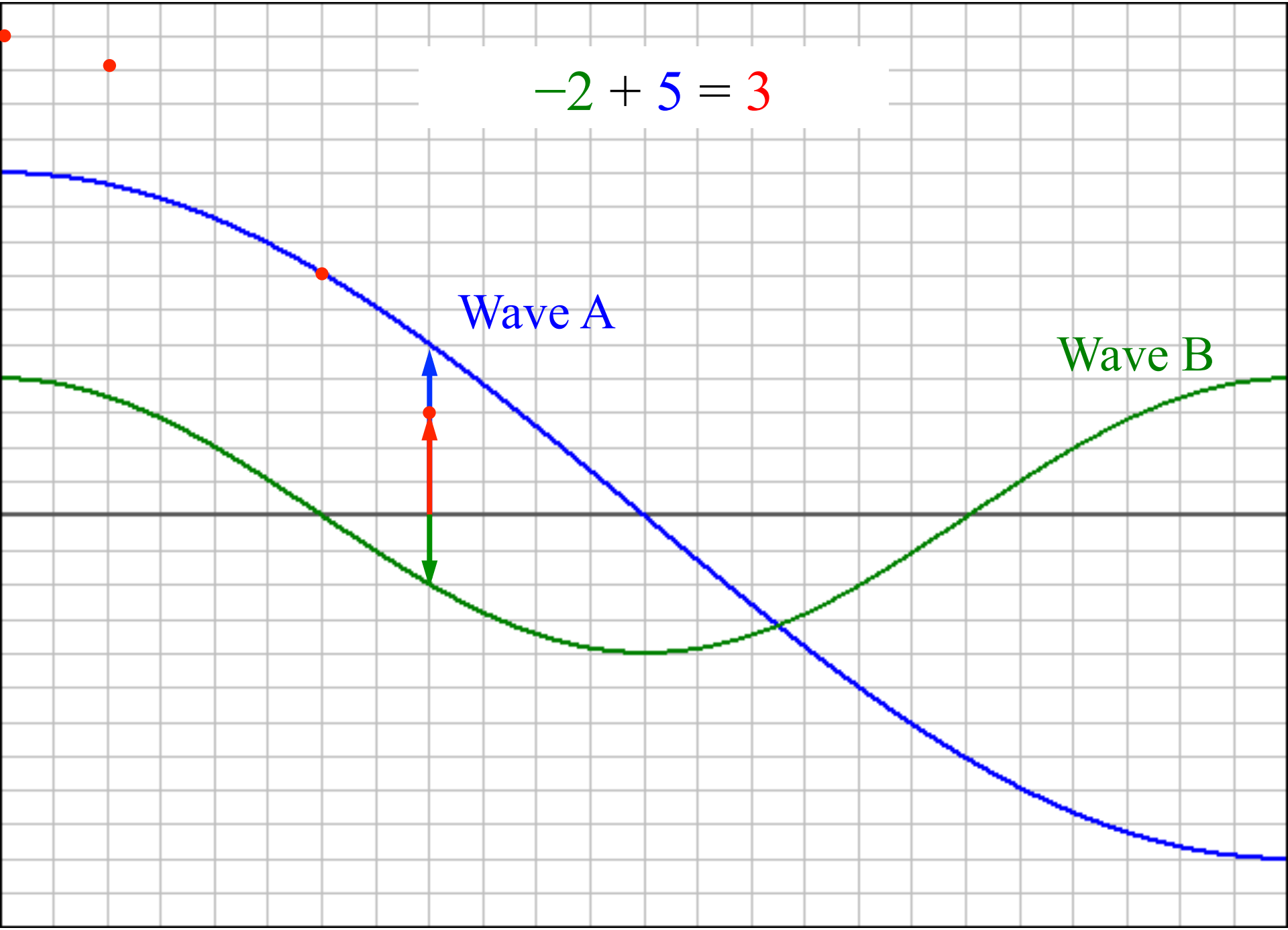
Superposition

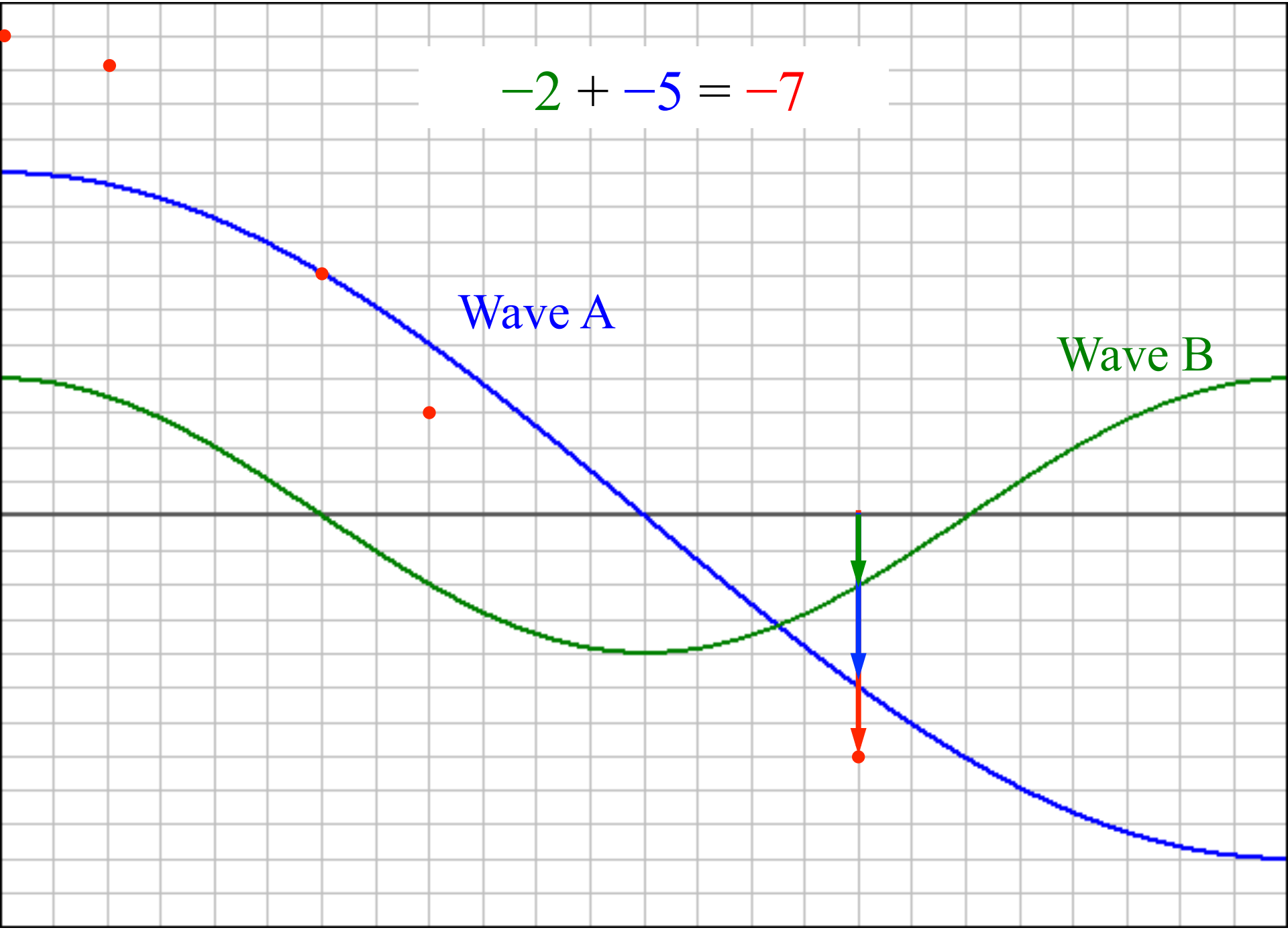
- Superposition is the method for finding the combined effect of two or more waves.
- The superposition is simply the sum of the levels of disturbance of the individual waves.

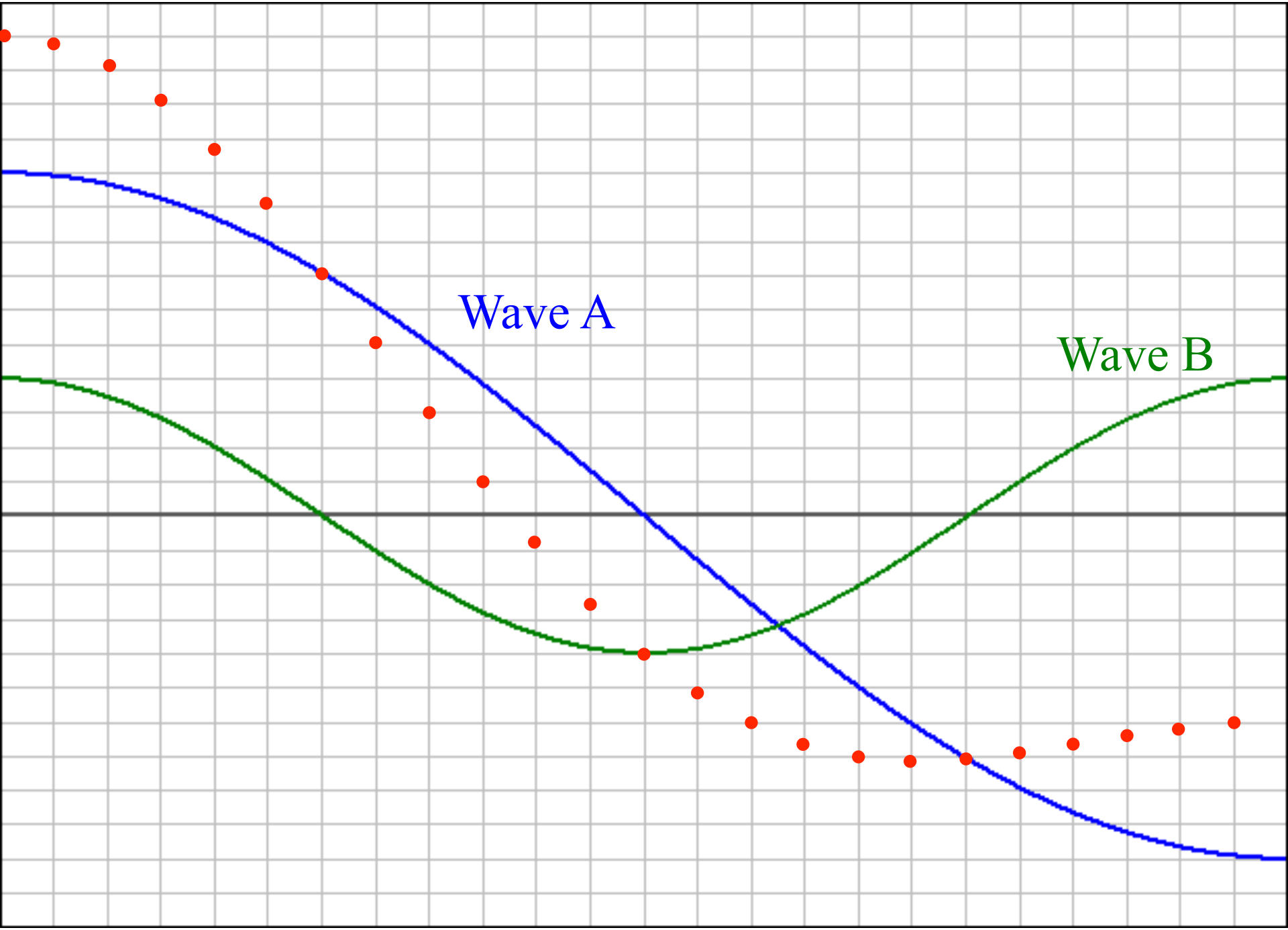

4 + 10 = 14
Wave A
Wave B

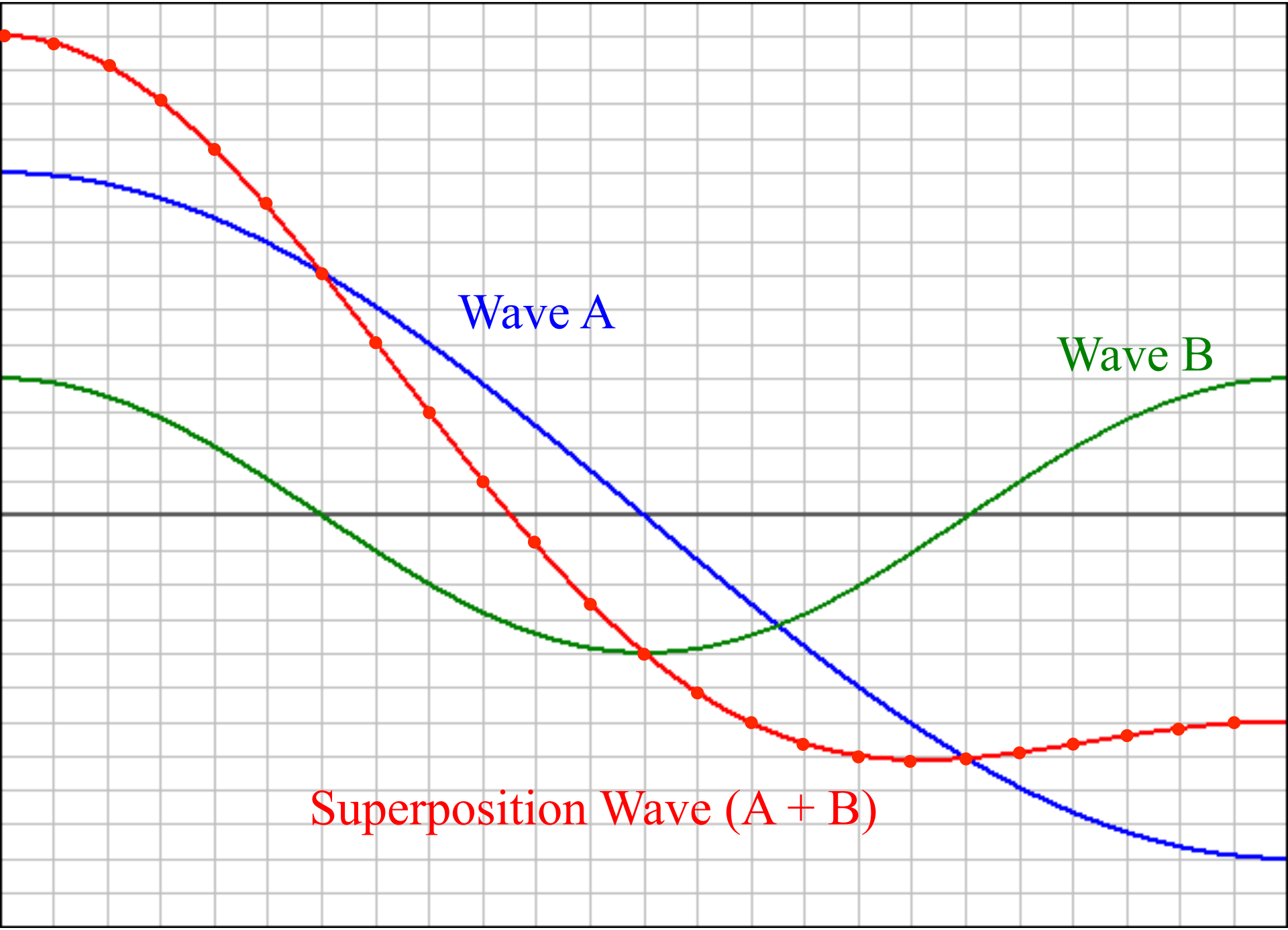

3.5 + 9.6 = 13.1
Wave A
Wave B

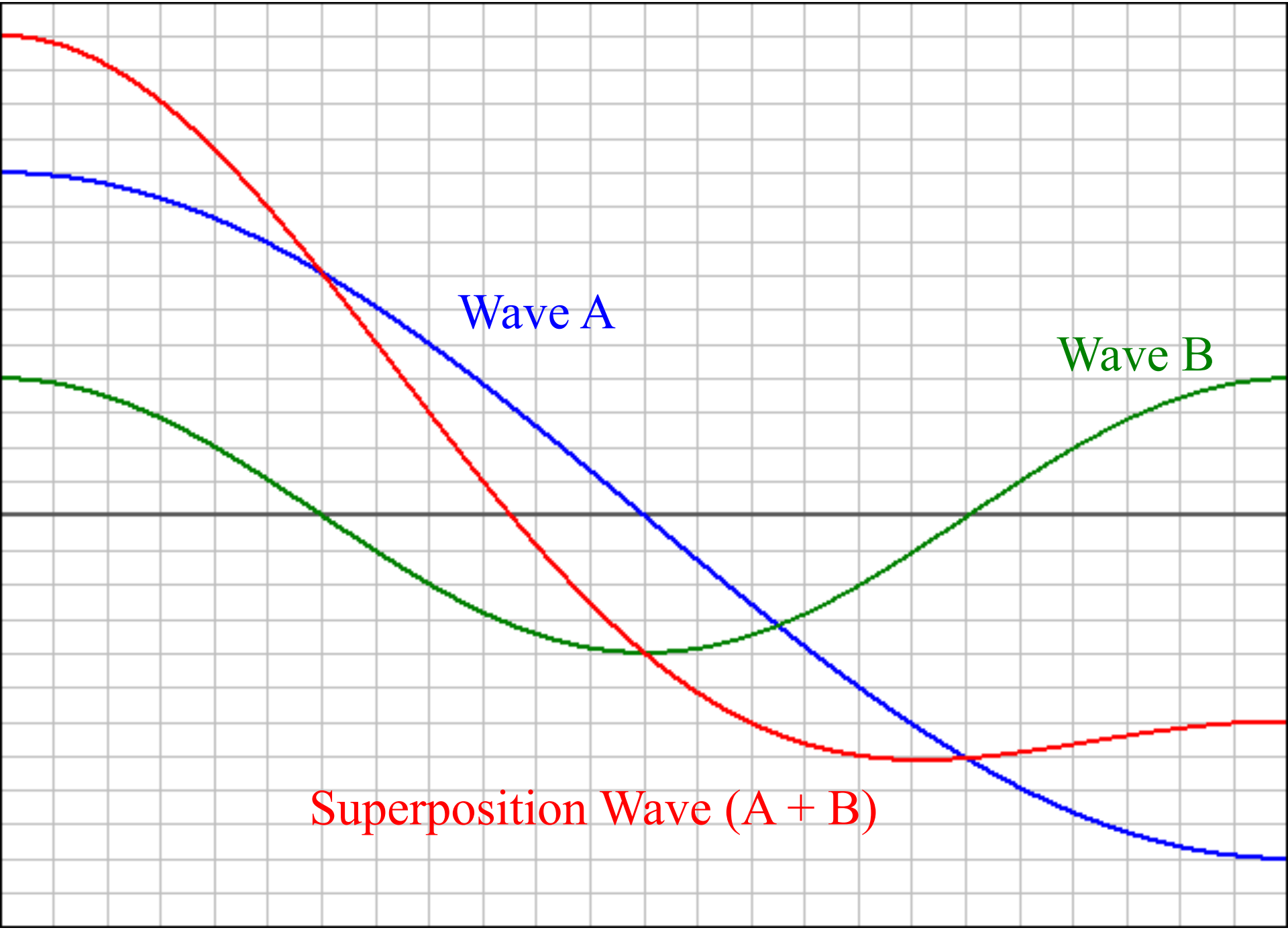

0 + 7 = 7
Wave A
Wave B

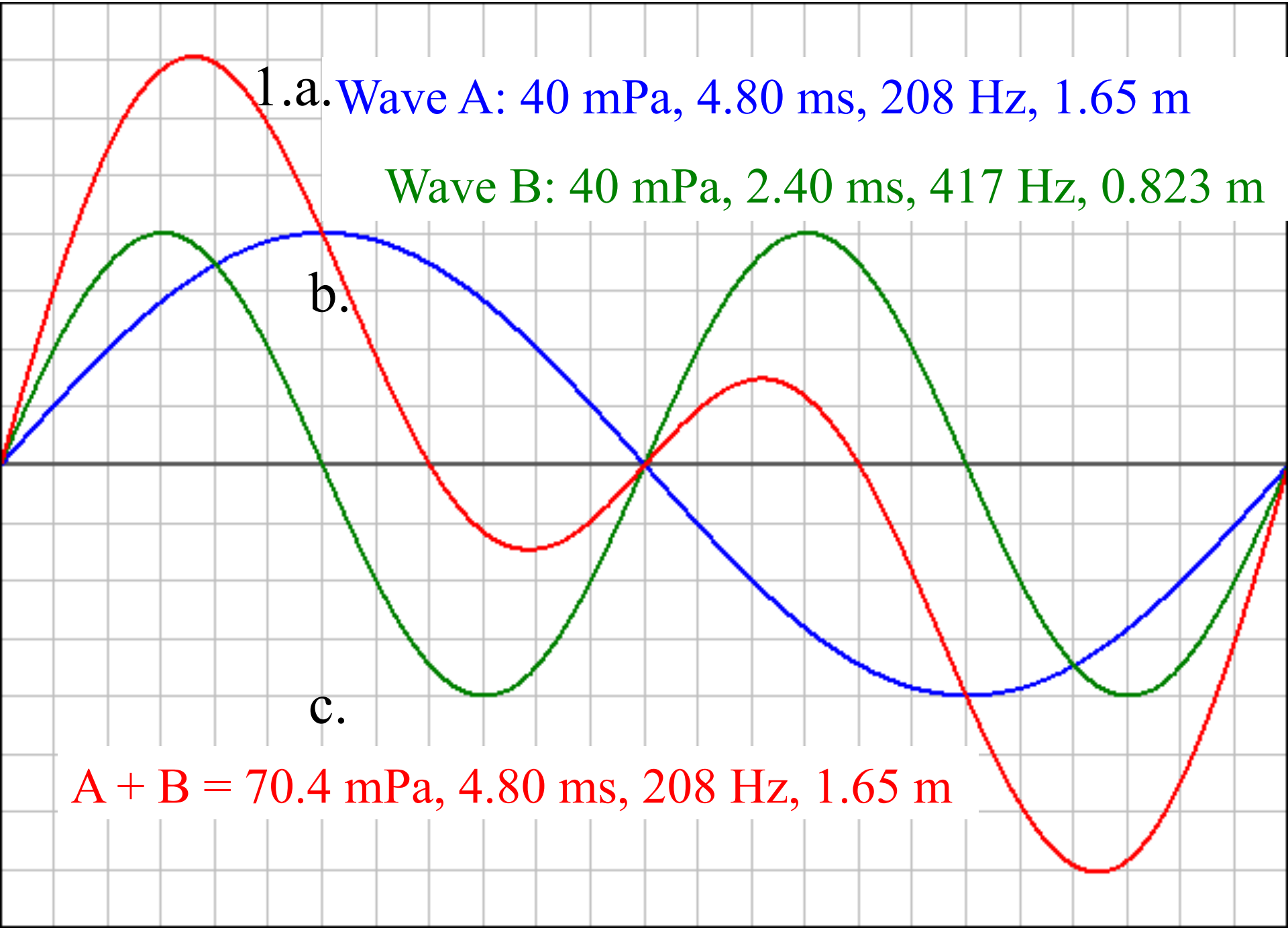

−2 + 5 = 3
Wave A
Wave B


−2 + −5 = −7
Wave A
Wave B

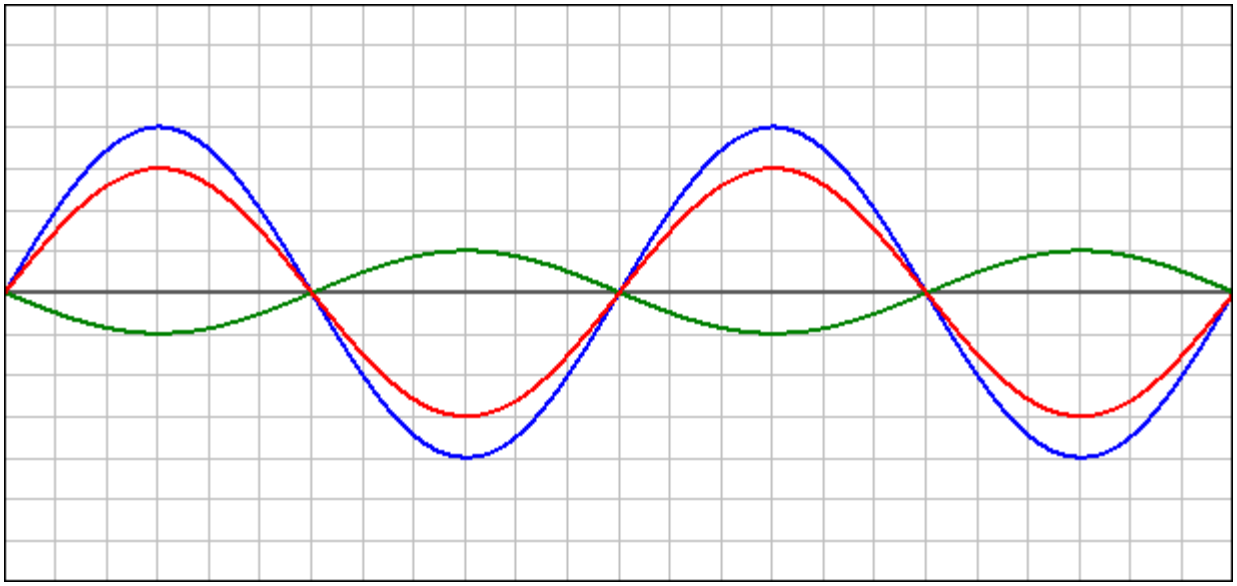

Wave A
Wave B


Wave A
Wave B
Superposition Wave (A + B)


Wave A
Wave B
Superposition Wave (A + B)


1.a.
Wave A: 40 mPa, 4.80 ms, 208 Hz, 1.65 m
Wave B: 40 mPa, 2.40 ms, 417 Hz, 0.823 m
b.
c.
A + B = 70.4 mPa, 4.80 ms, 208 Hz, 1.65 m

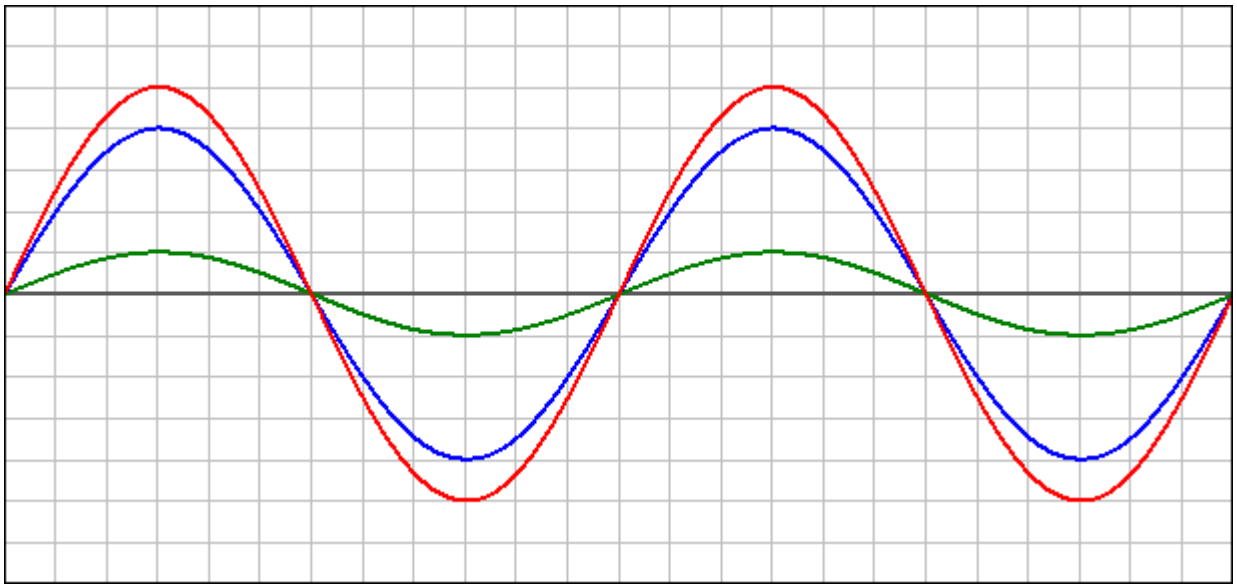
2.



Superposition:
A = 3 cm
λ = 12 cm

Out of Phase,
Destructive
Interference

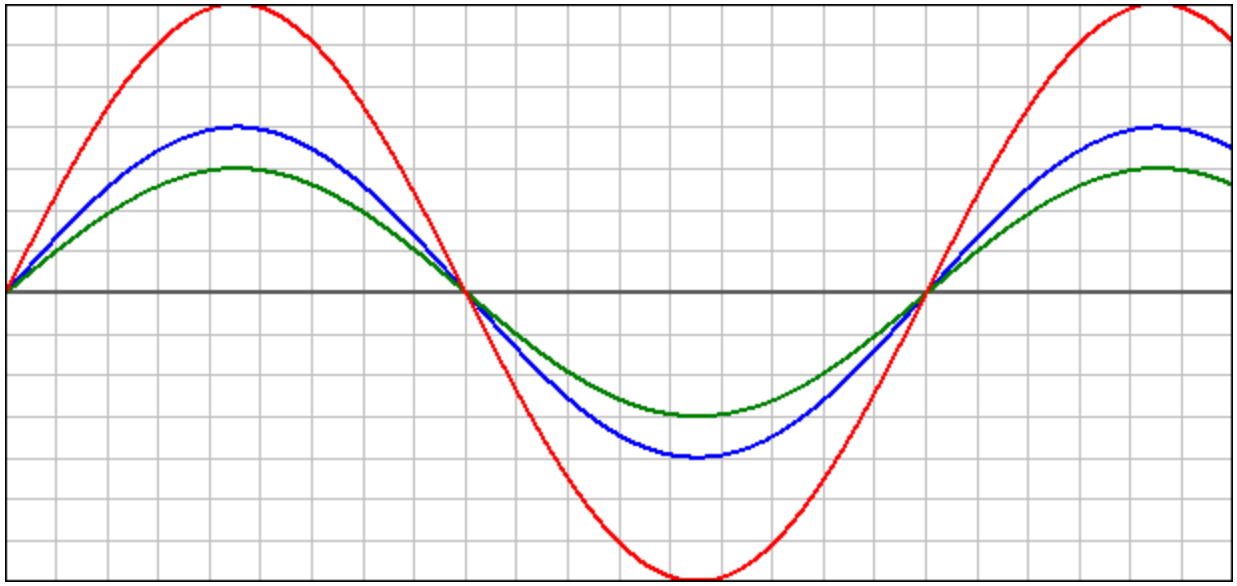
3.



Superposition:
A = 5 cm
λ = 12 cm

In Phase,
Constructive
Interference

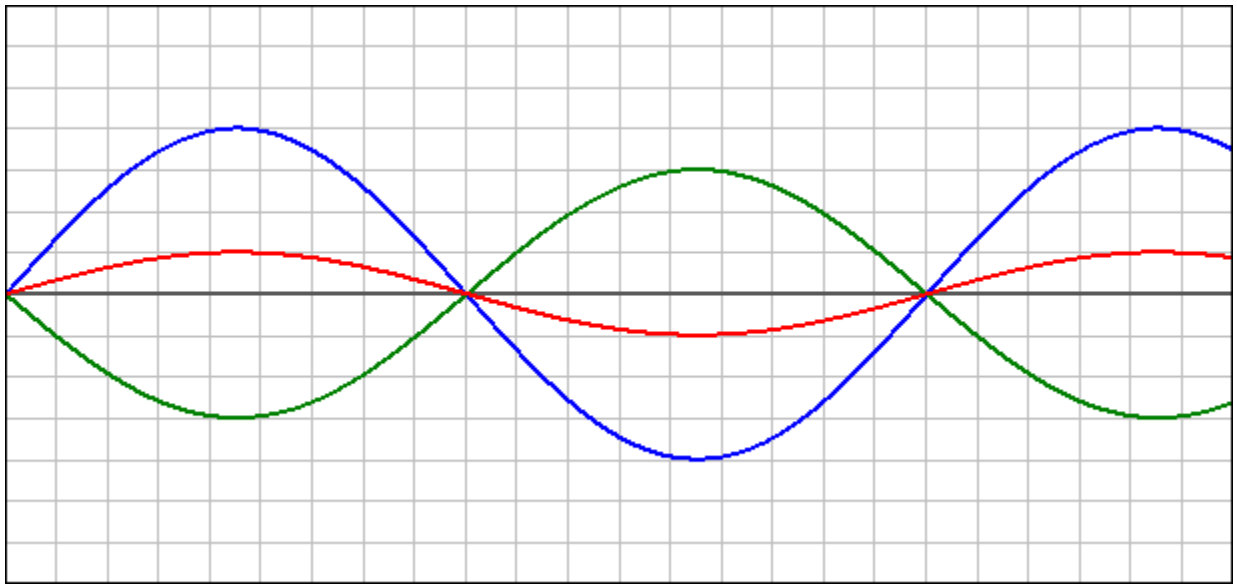
4.



Superposition:
A = 7 cm
λ = 18 cm

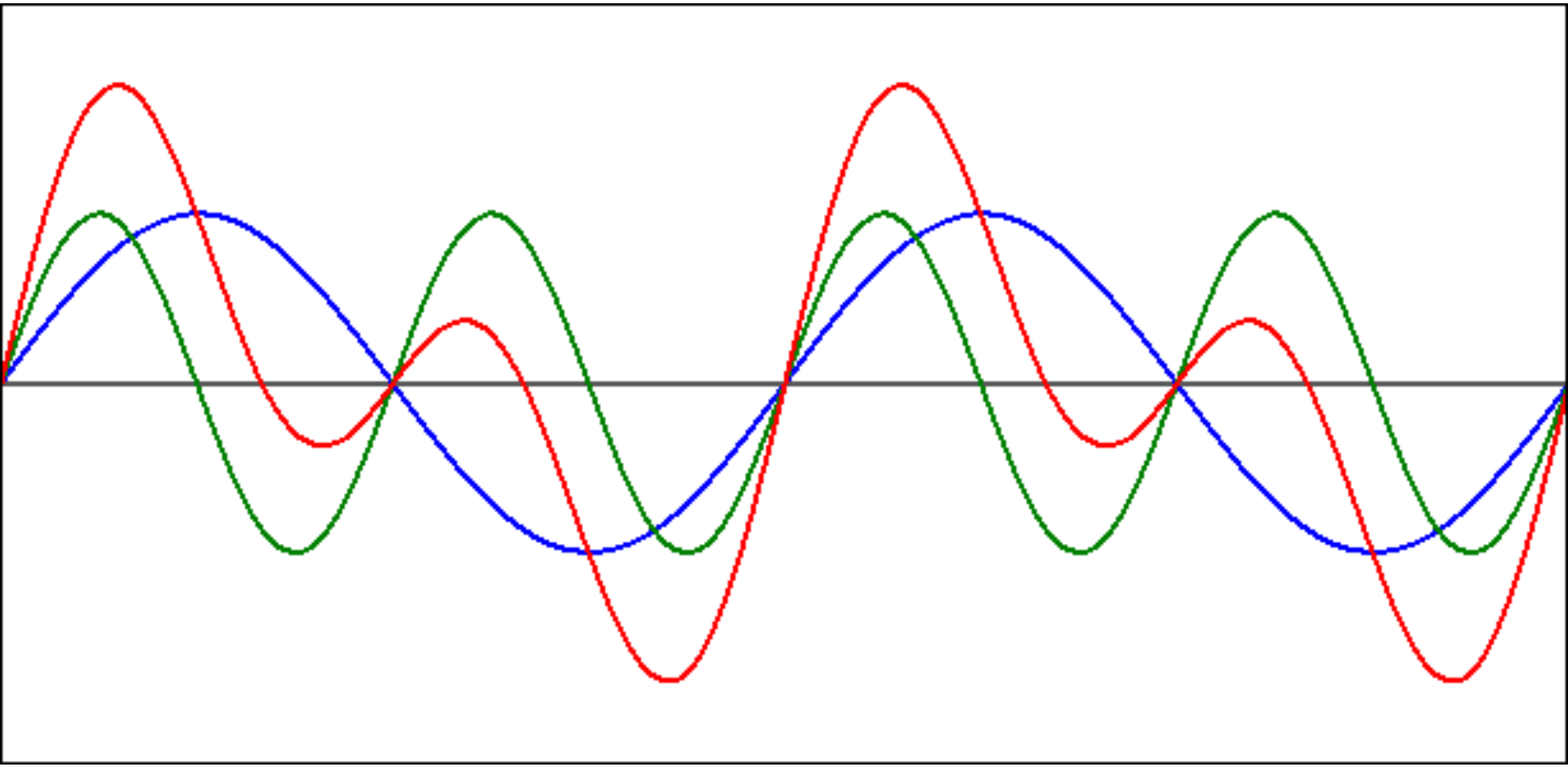
In Phase,
Constructive
Interference

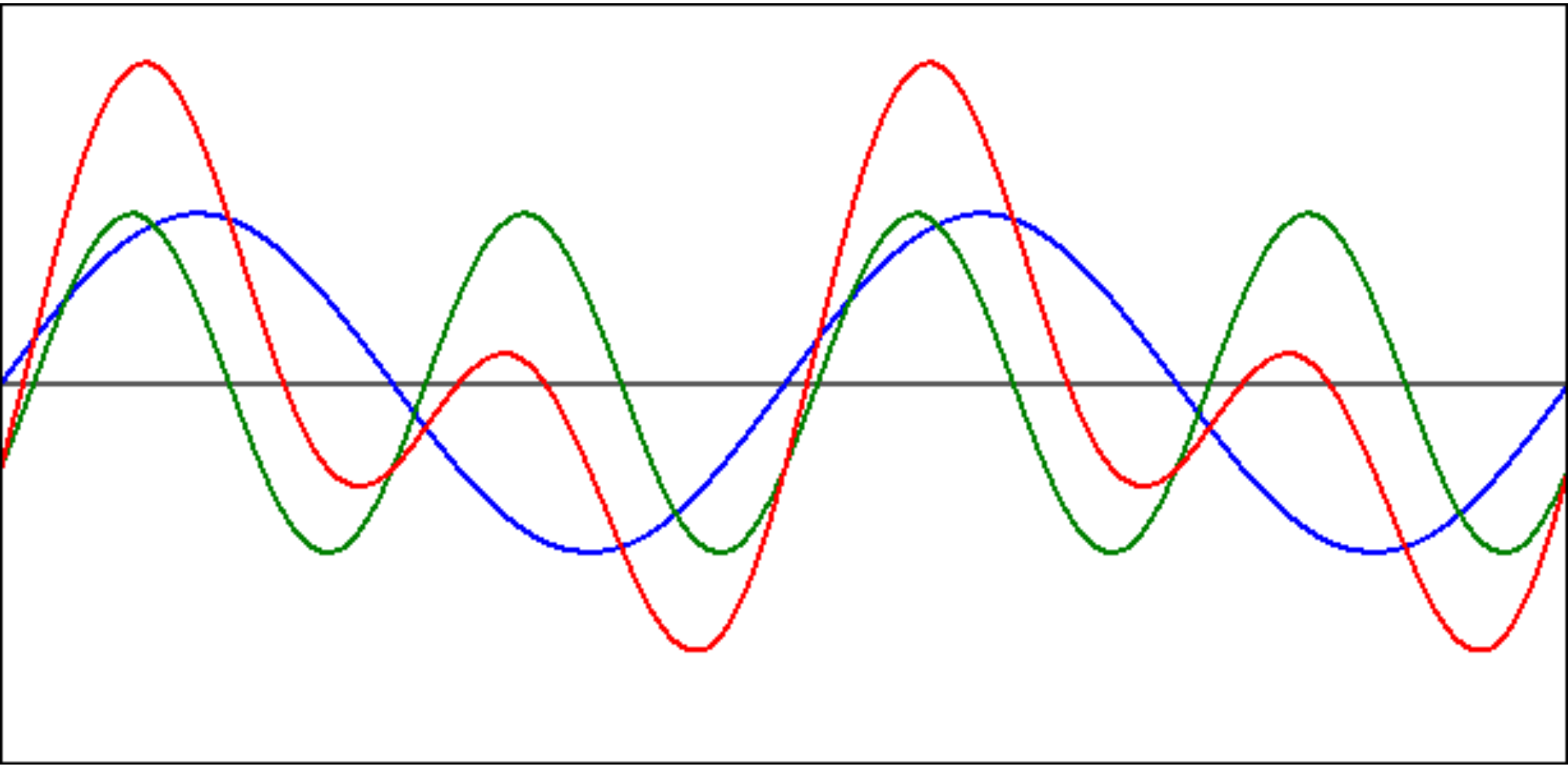
5.

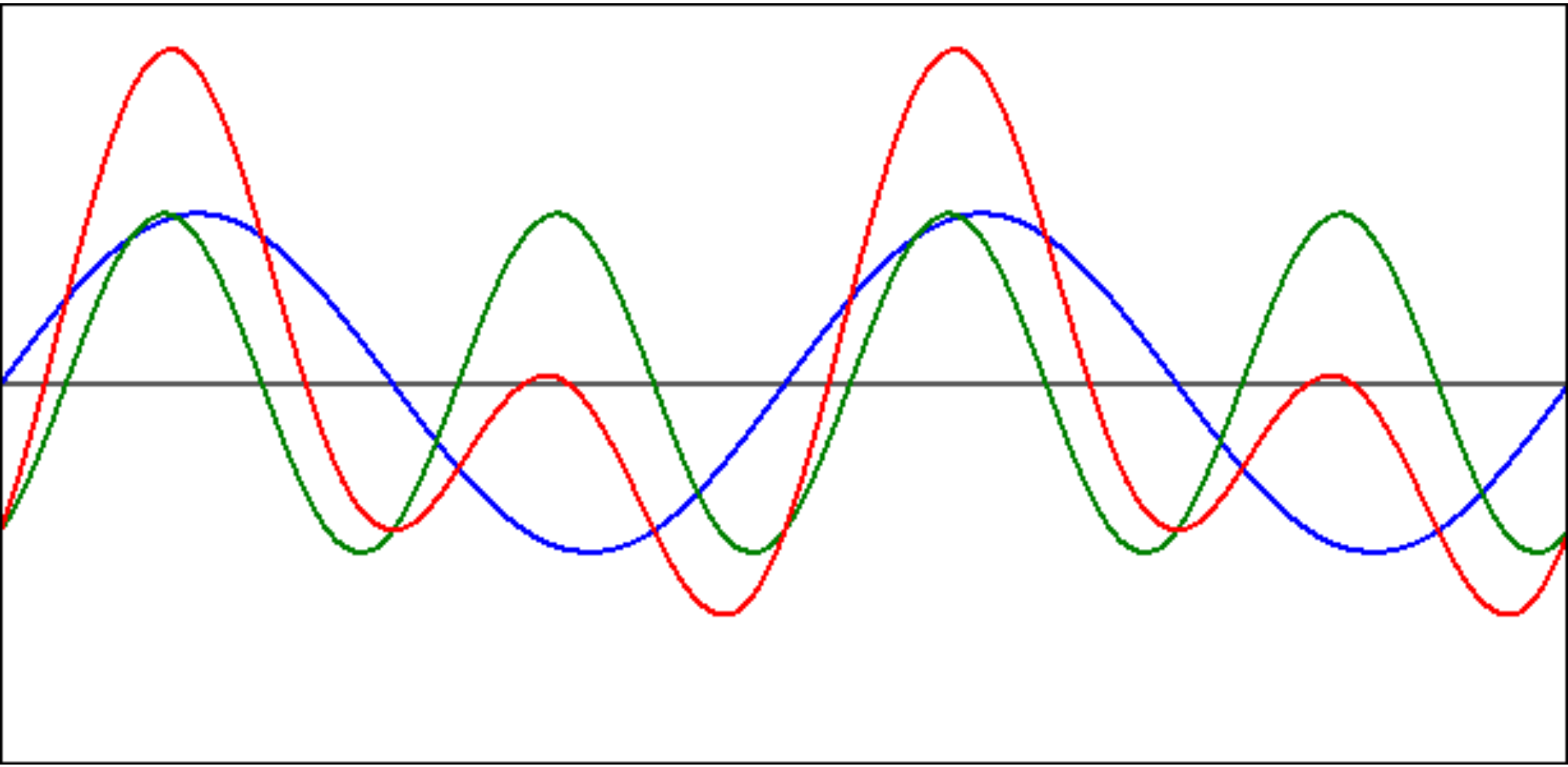


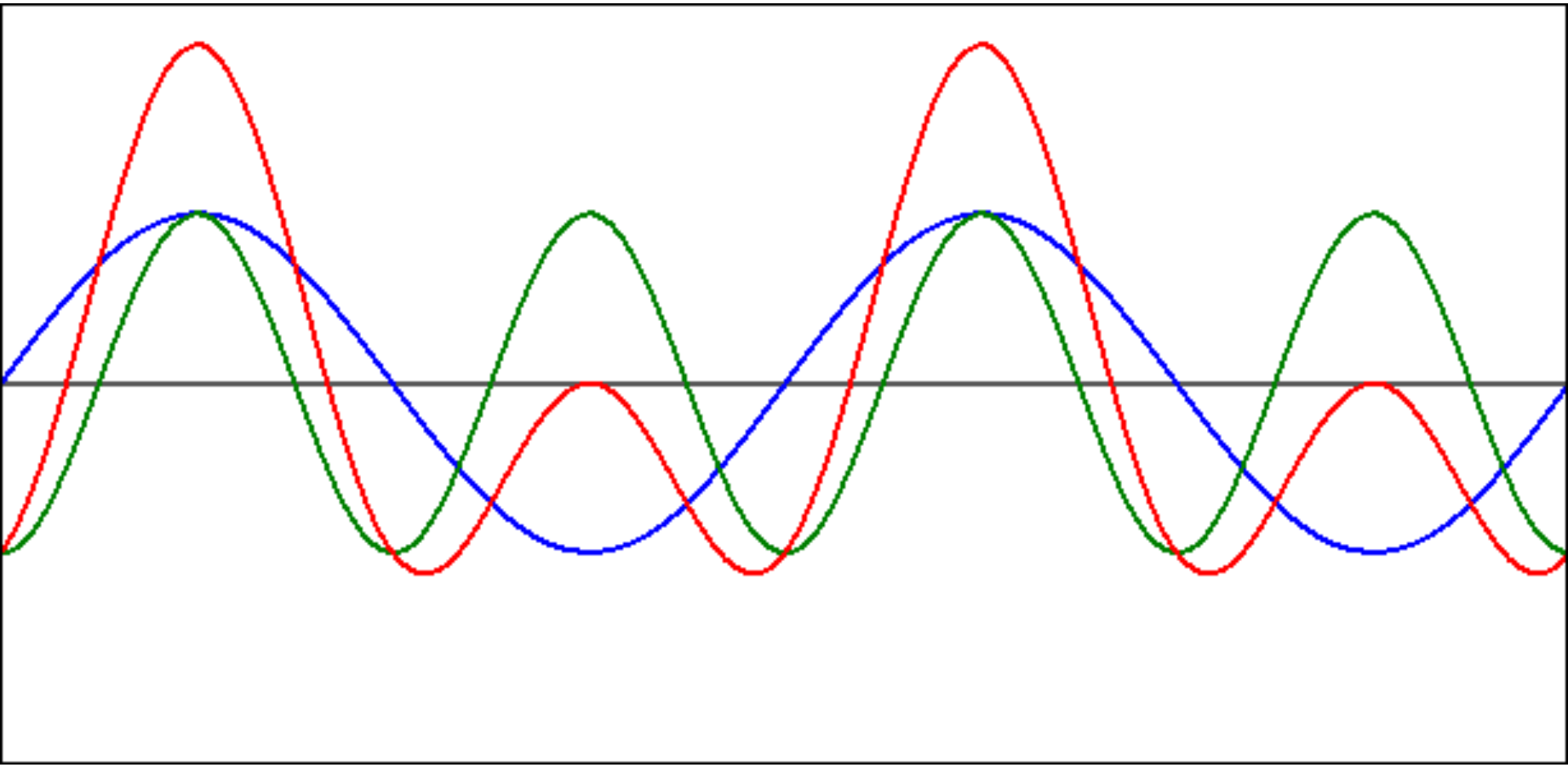
Superposition:
A = 1 cm
λ = 18 cm

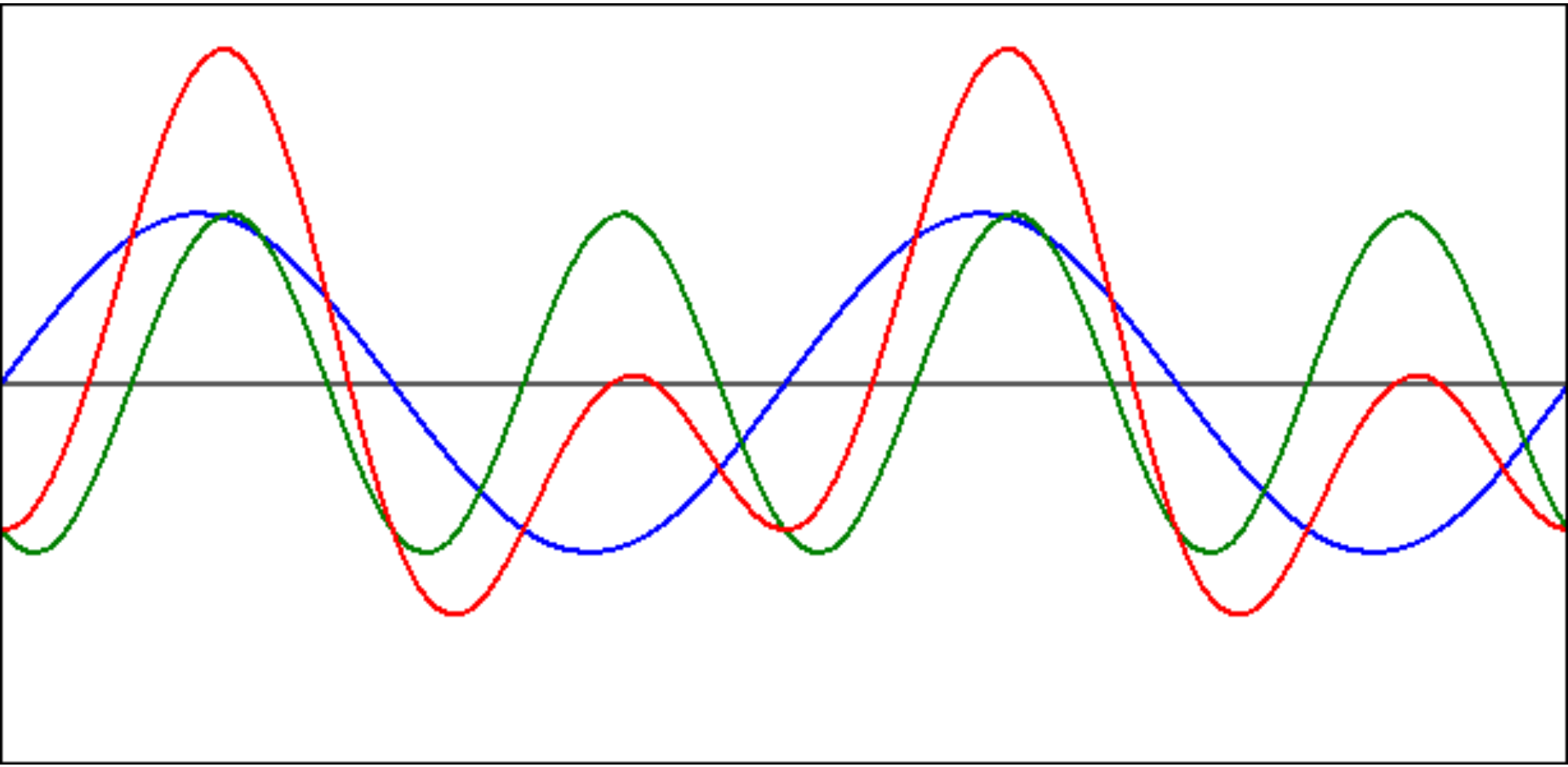
Out of Phase,
Destructive
Interference

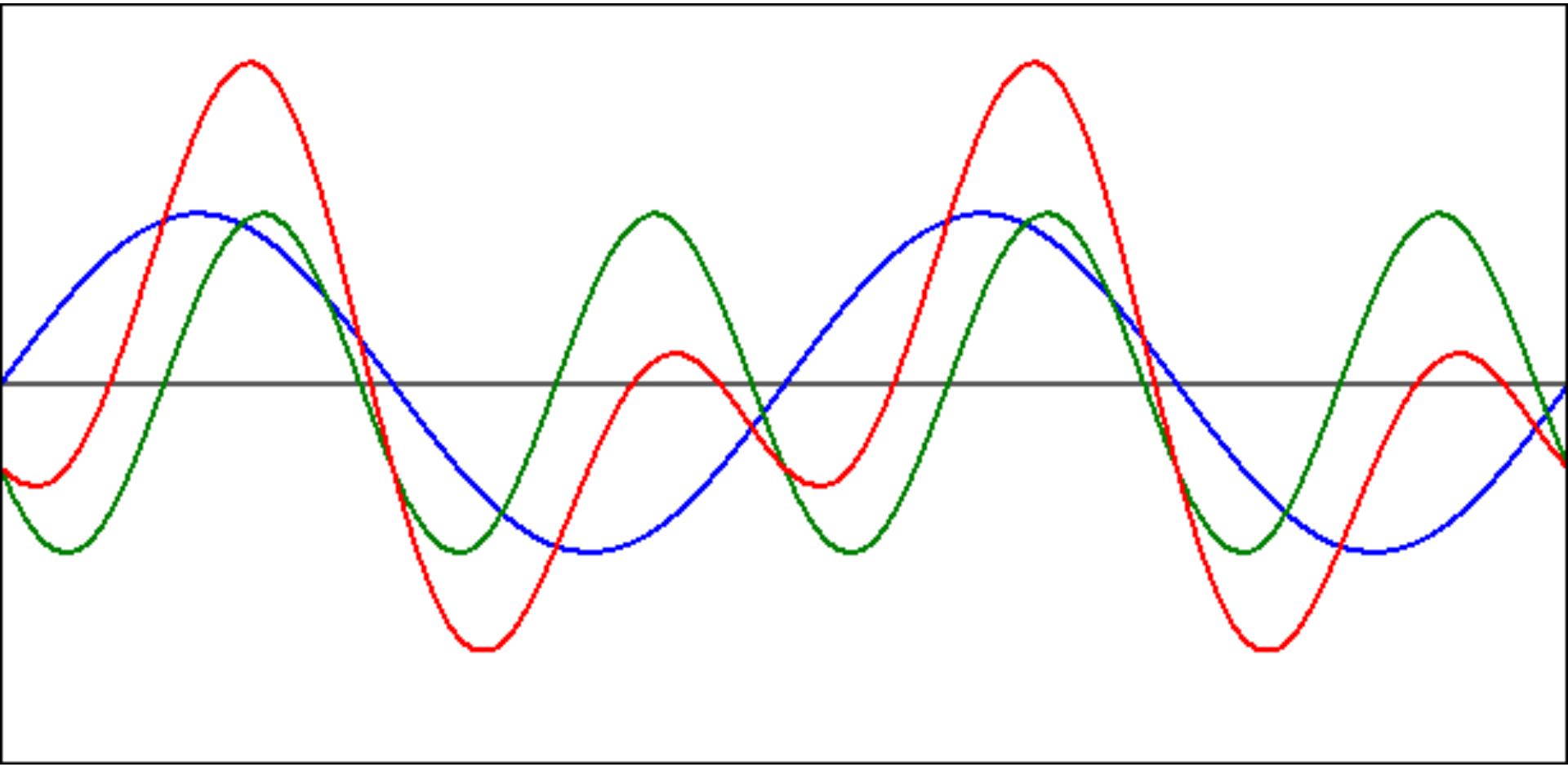


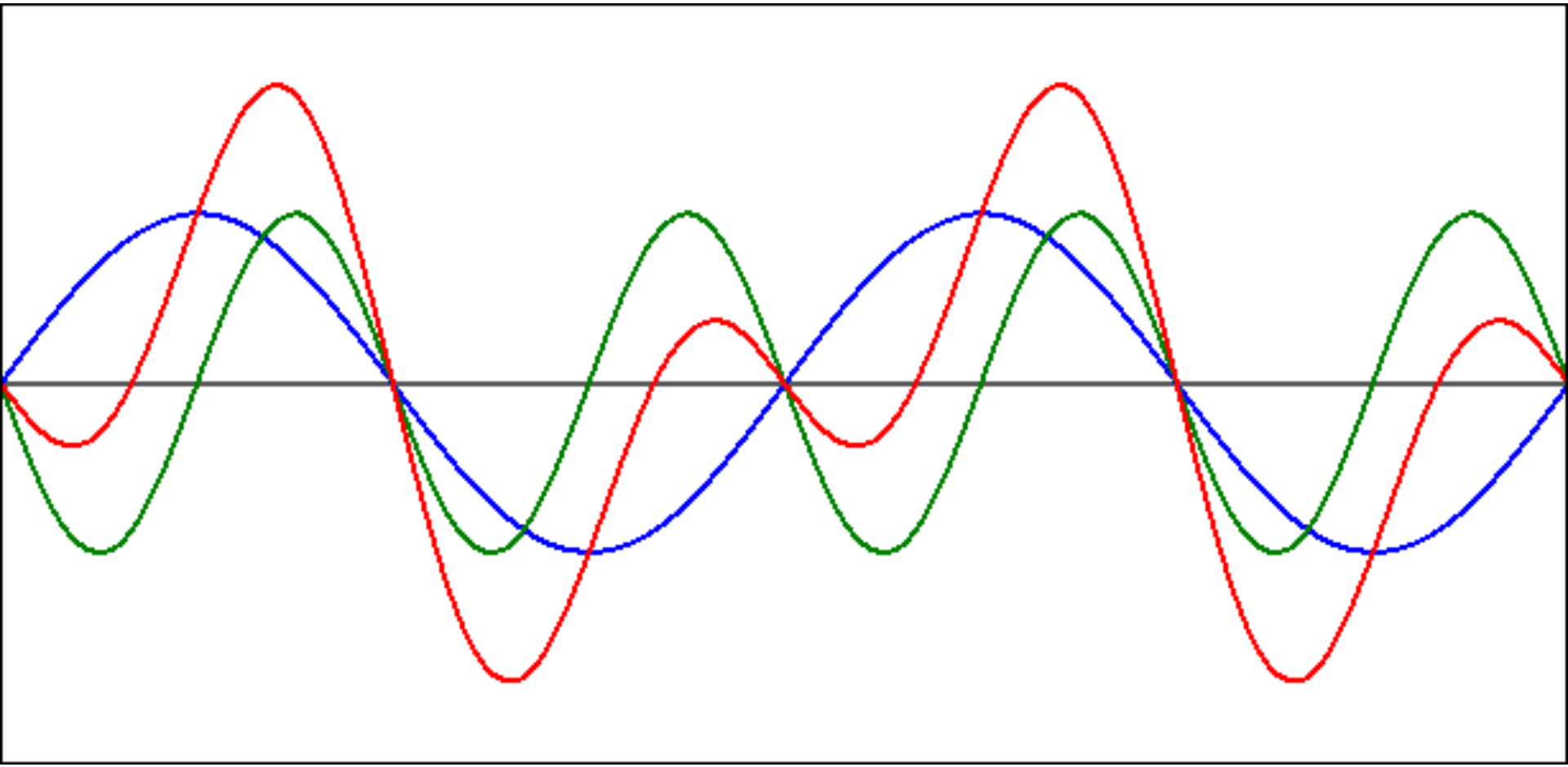




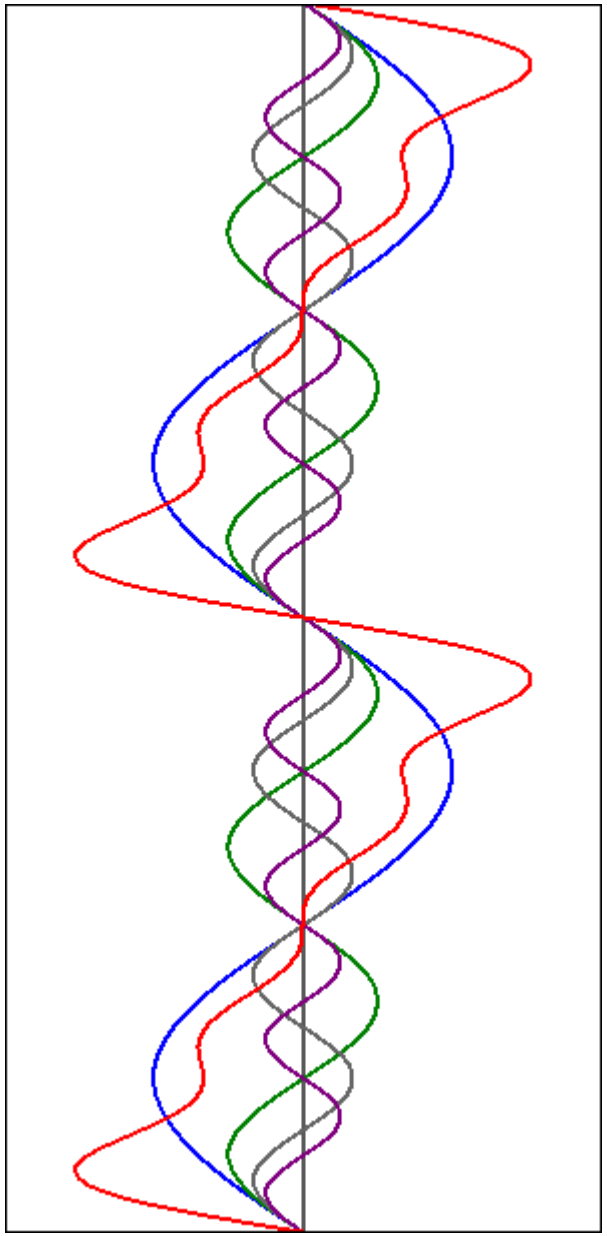


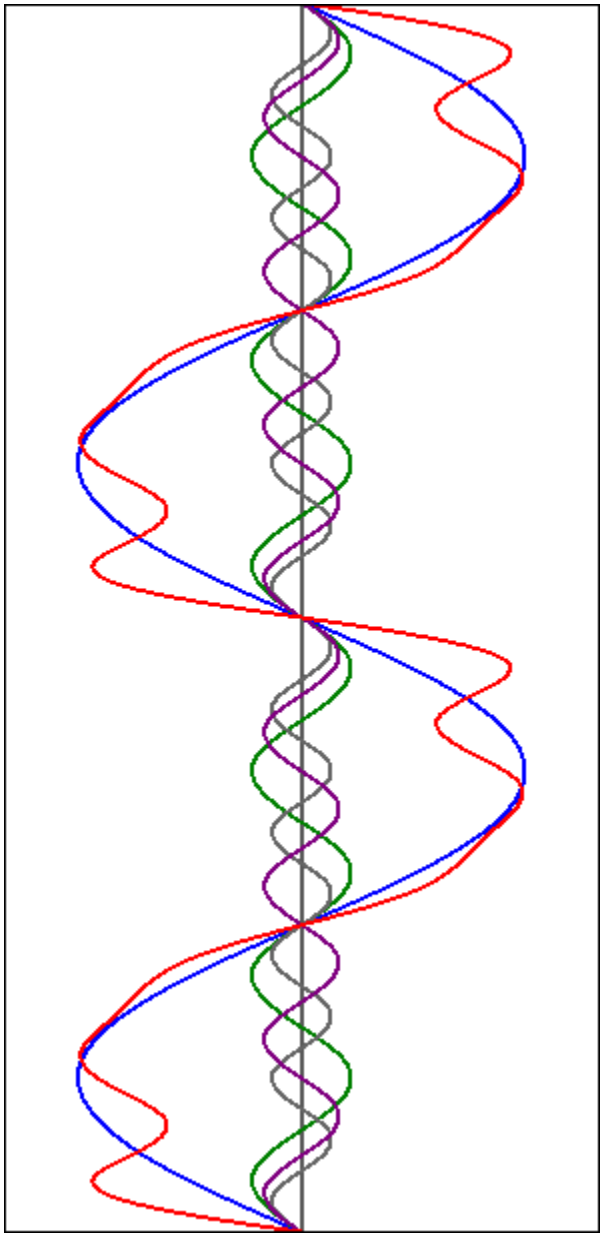


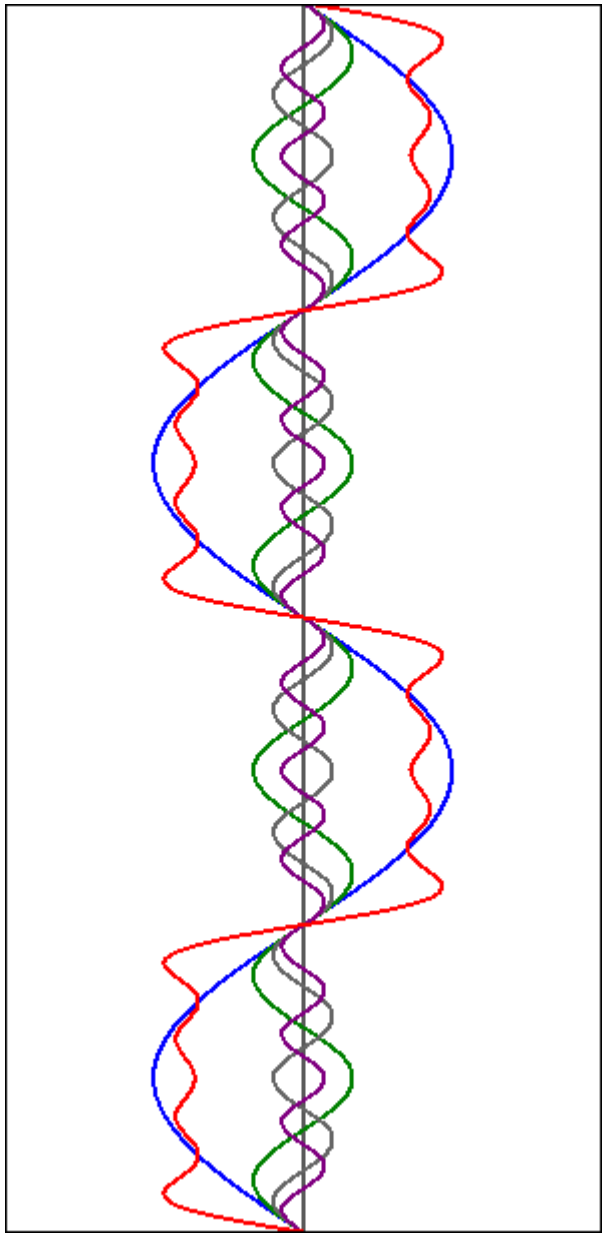




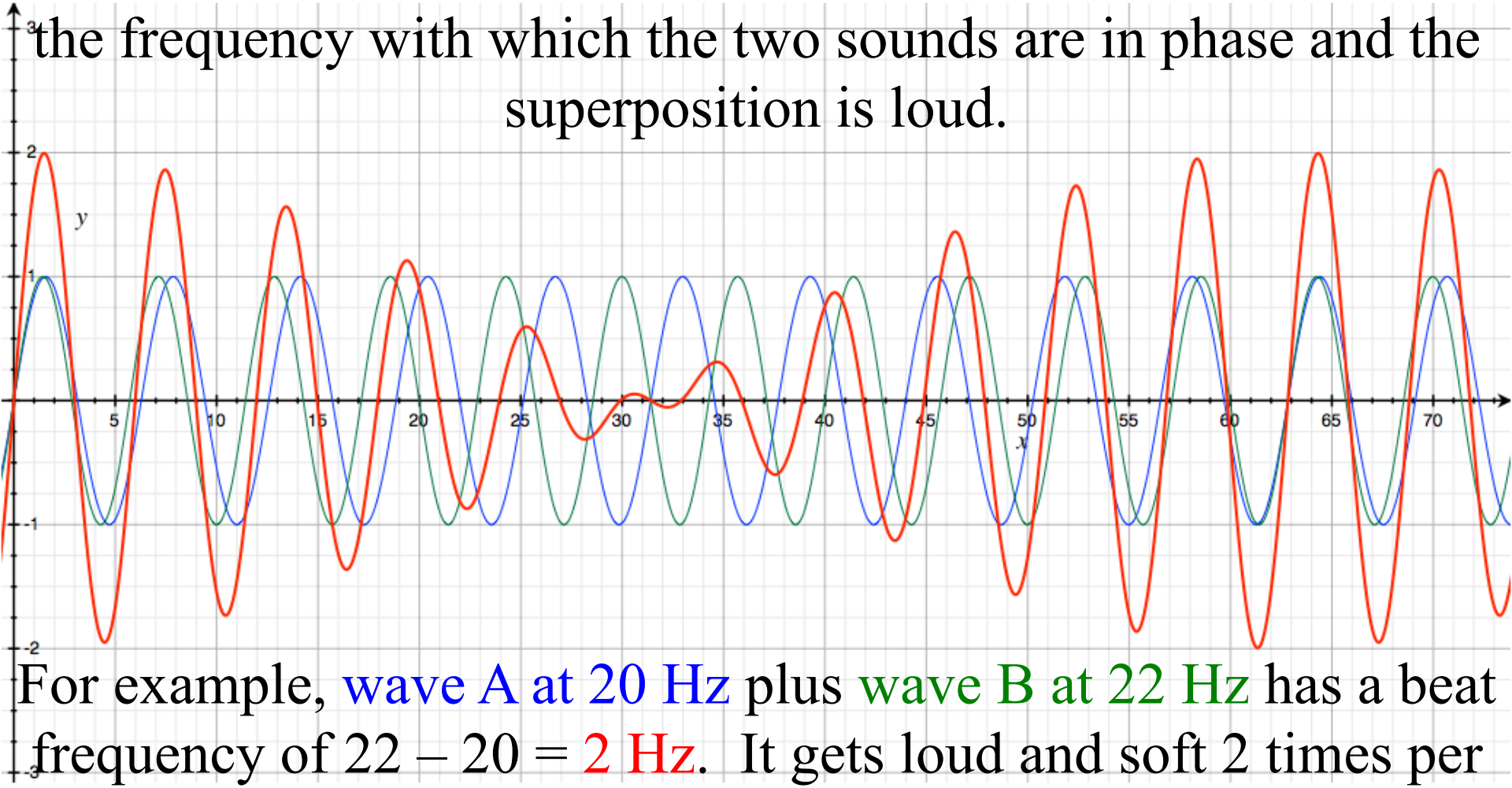
Theoretically complex waves of *any* shape may be formed…







Beat frequency is simply the difference in the frequencies of two waves that occur at the same time. This difference gives the frequency with which the two sounds are in phase and the superposition is loud.



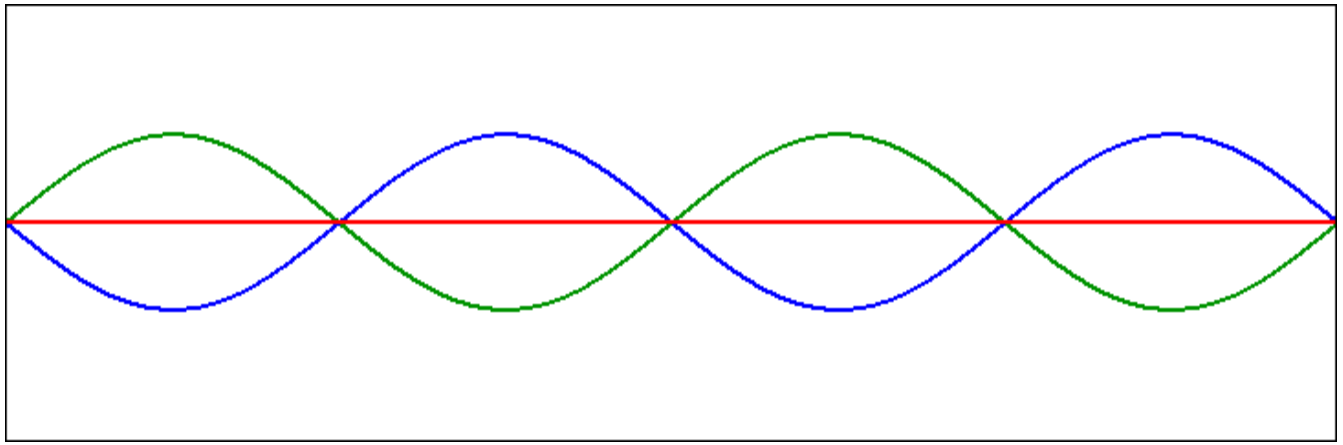
For example, wave A at 20 Hz plus wave B at 22 Hz has a beat frequency of 22 – 20 = 2 Hz. It gets loud and soft 2 times per second as constructive interference occurs 2 times per second.

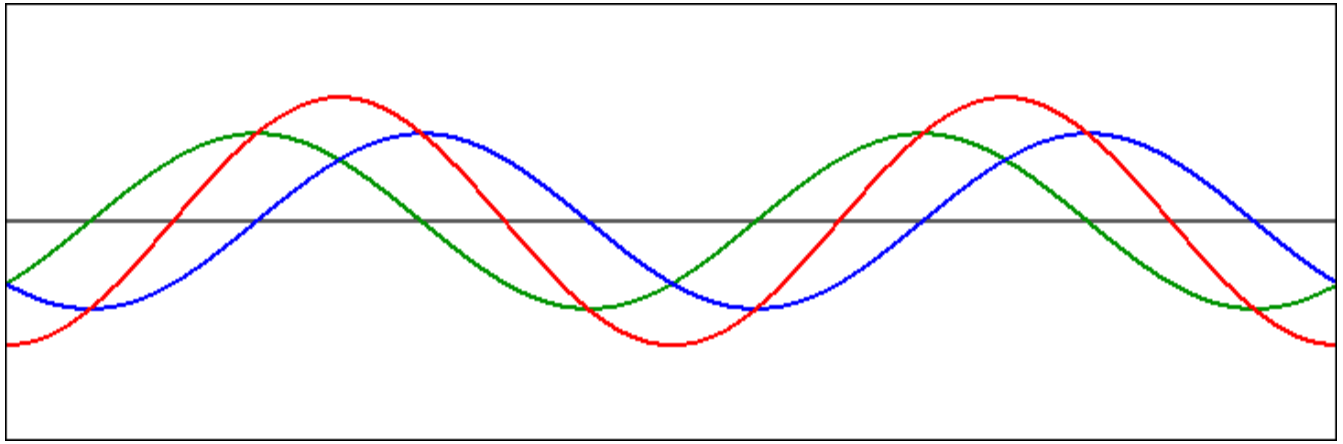
Waves & Interference

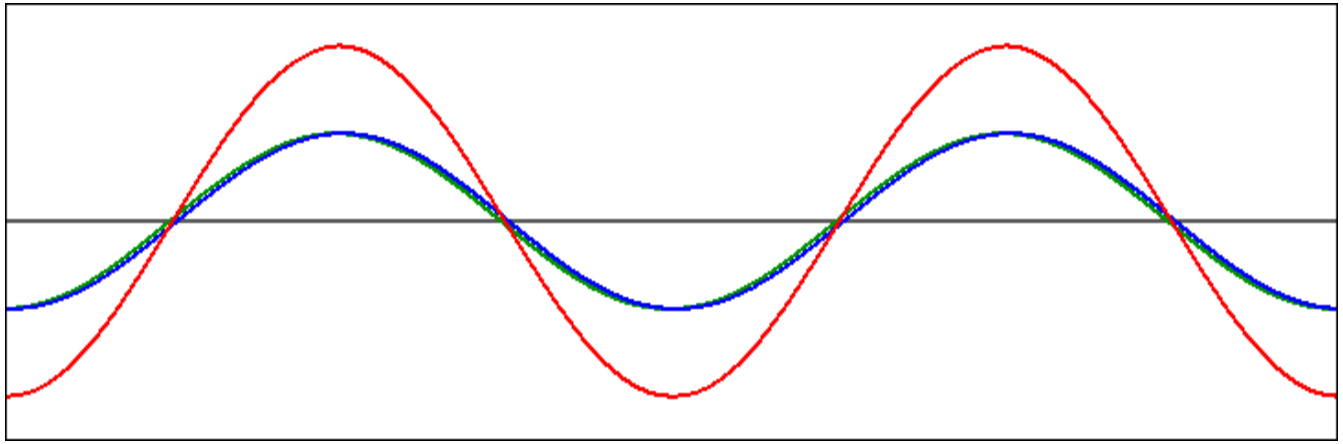
I. Definitions and Types
II. Parameters and Equations
III. Sound
IV. Graphs of Waves
V. Interference
- superposition
- standing waves

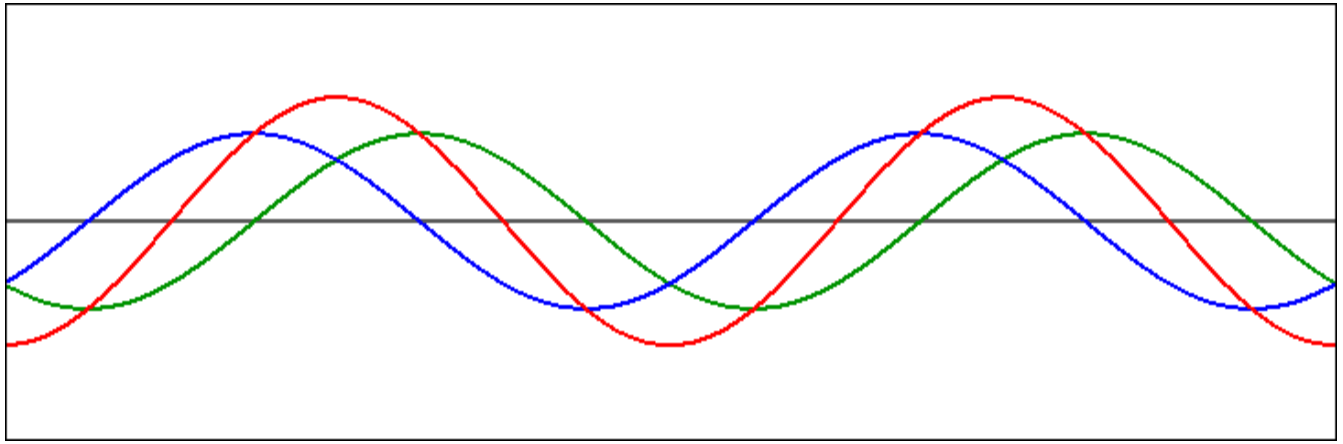
	The student will be able to:	HW:
1	Define, apply, and give examples of the following concepts: wave, pulse vs. continuous wave, source, medium, longitudinal wave, transverse wave, surface wave, crest, trough, compression, rarefaction. ✓	1 – 11
2	Define, apply and give examples of the following wave parameters: speed, wavelength, frequency, period, and amplitude and state the influence of source and medium on each wave parameter. ✓	
3	Identify the wave type, medium, and speed of mechanical waves and sound. State the relation between speed, wavelength, and frequency for a wave, and use this relation to solve related problems. ✓	12 – 18
4	Solve problems analyzing graphs to determine a wave's parameters. ✓	19 – 21
5	Define and apply the following concepts: superposition, constructive and destructive interference, phase, beat frequency and solve related problems. ✓	22 – 24
6	Explain the requirements for the creation of a standing wave. Define and identify nodes and antinodes in standing wave patterns. Solve problems involving harmonics for strings or pipes.	25 – 38
7	Define resonance and identify and give examples of this phenomenon.	39 – 41

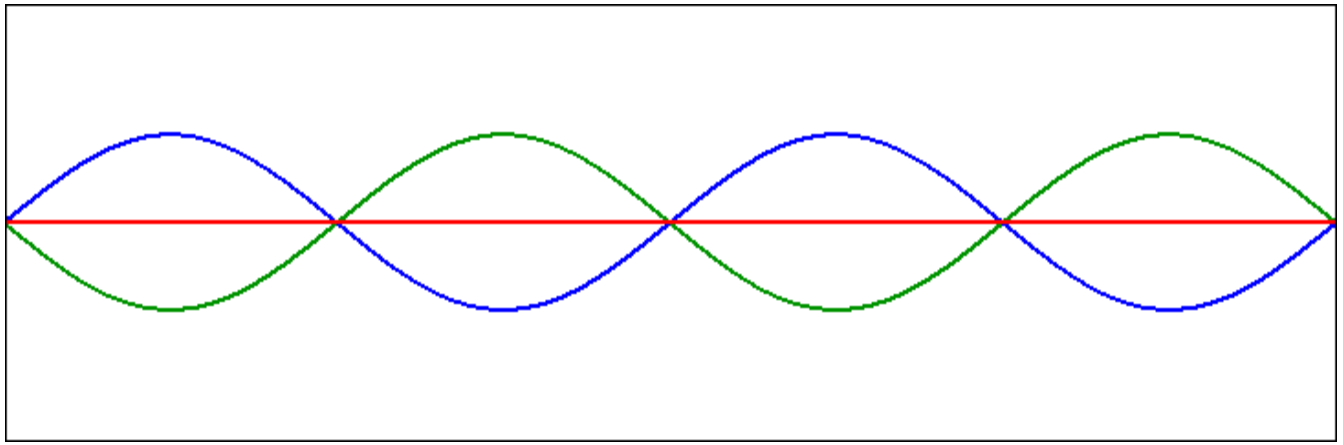
Flip through the following nine pages to create a “movie” that shows the superposition (red) of two identical waves (blue and green) moving in opposite directions. This works best if you can use a key press to “page down” (do not scroll through the pages).

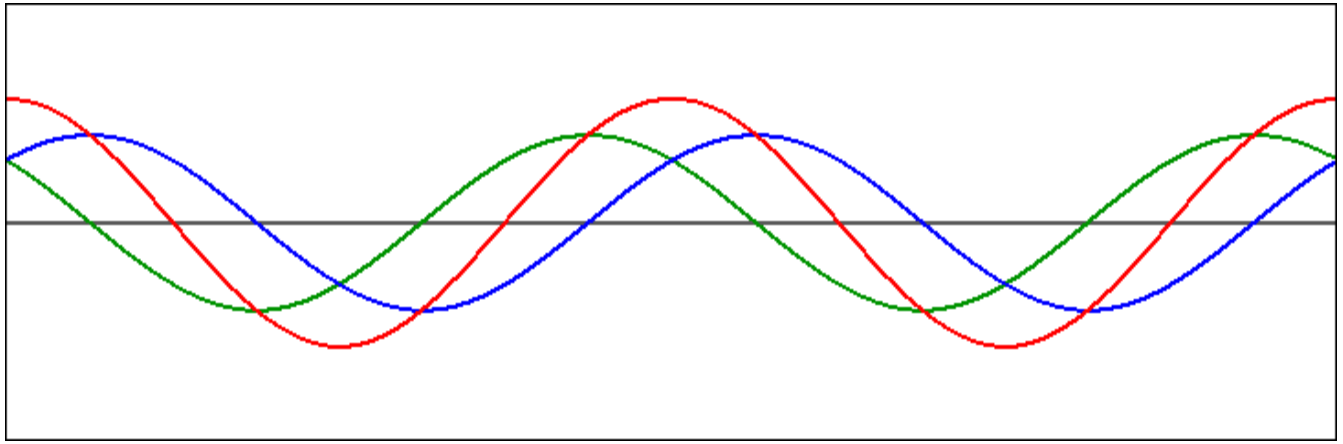


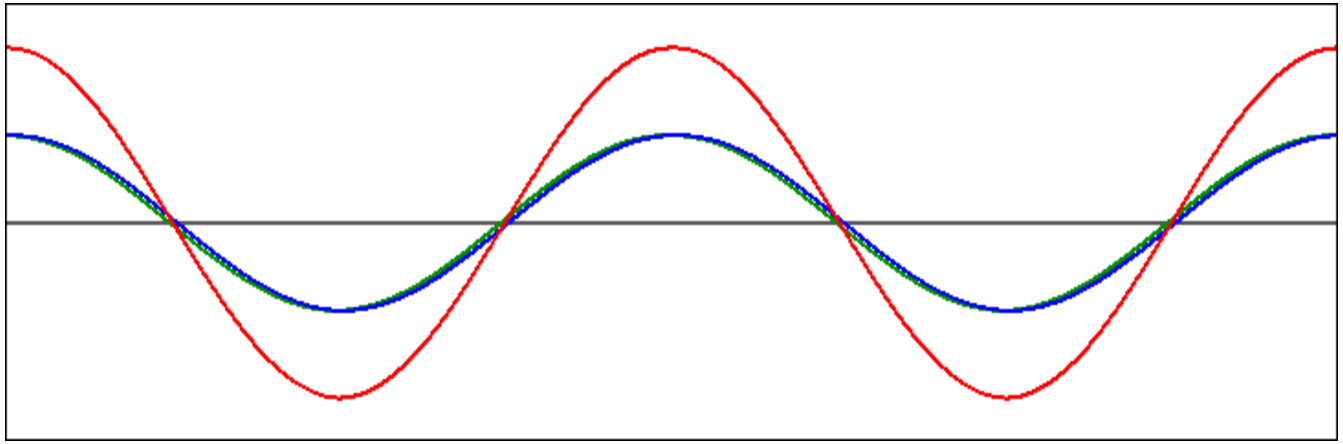


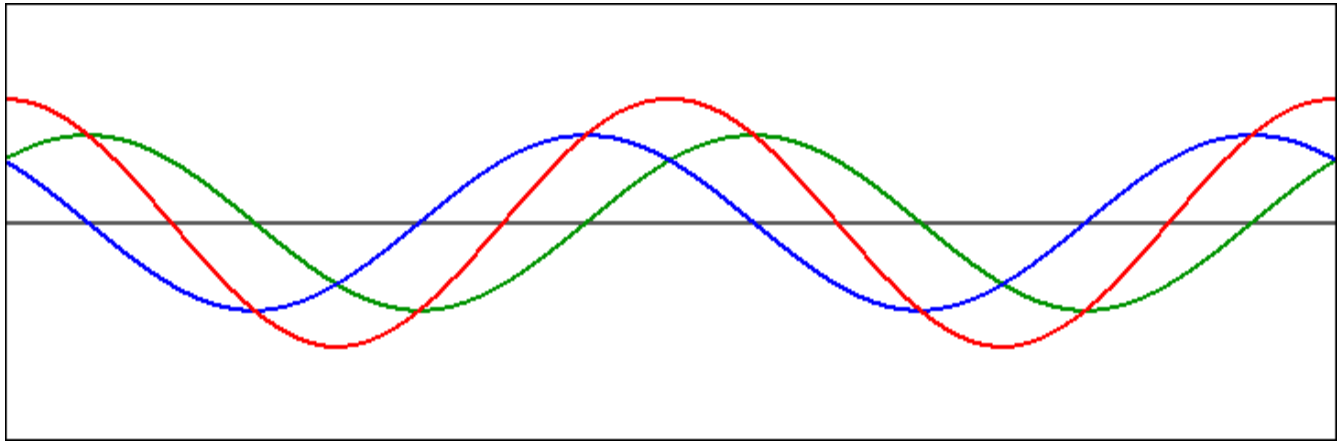


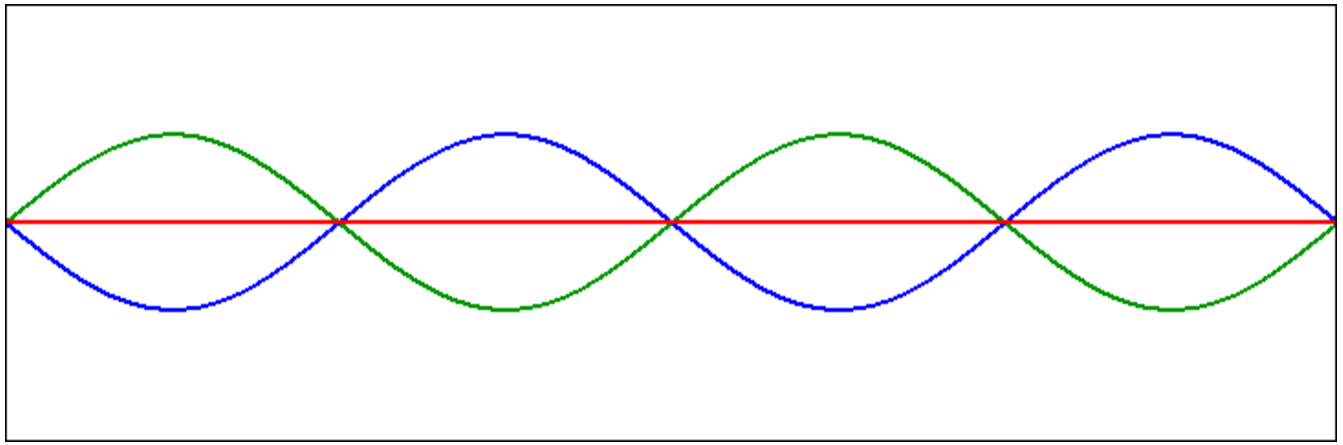










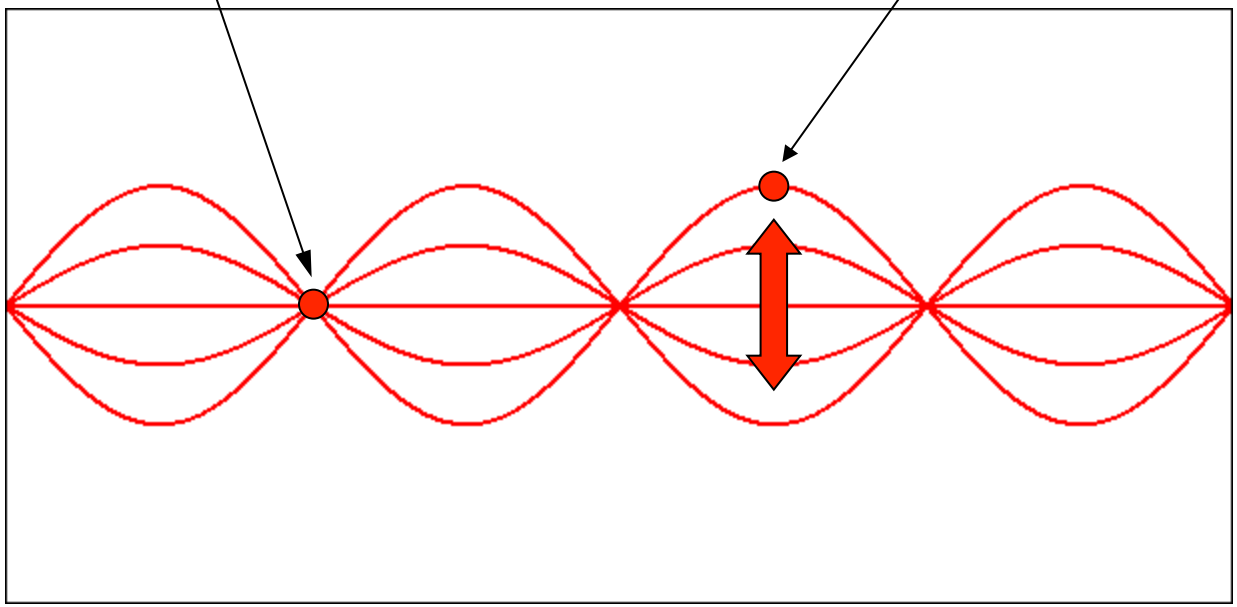


Standing Wave

- A **standing wave** is a pattern of interference caused by two identical waves traveling in opposite directions.
- The resulting pattern is stationary, hence the term “standing”.
- Most often standing waves are caused by reflection of a wave back upon itself.
- Standing waves are the basis for all musical instruments.

A **node** is a point of zero disturbance.

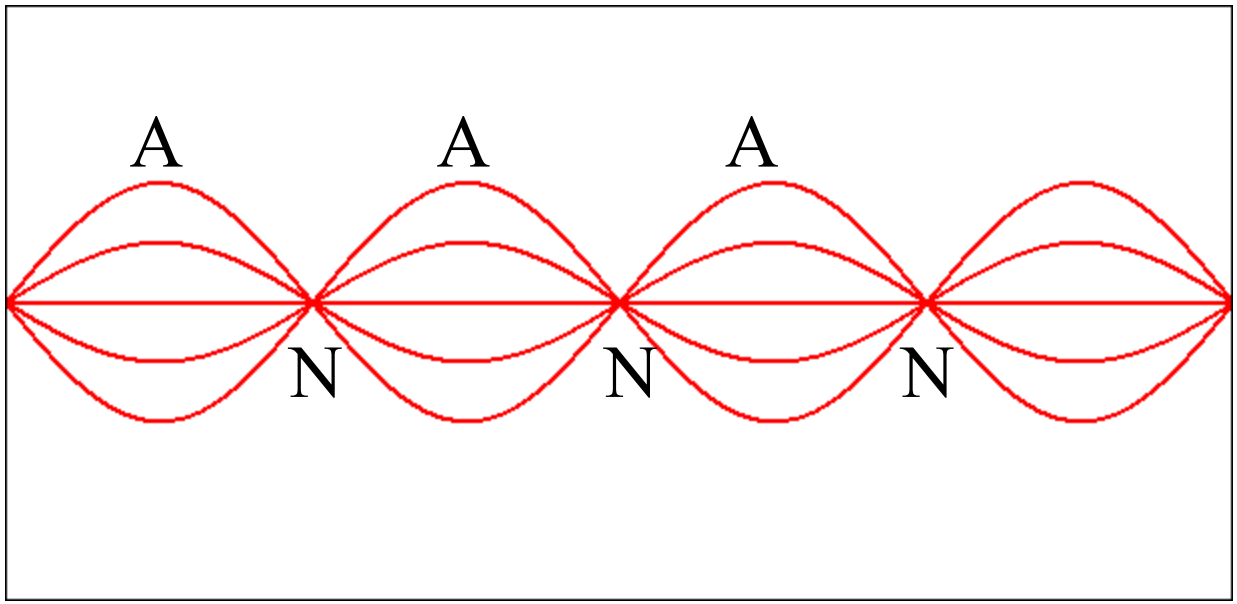
An **antinode** is a point that has maximum oscillation.



Destructive interference occurs at each node.

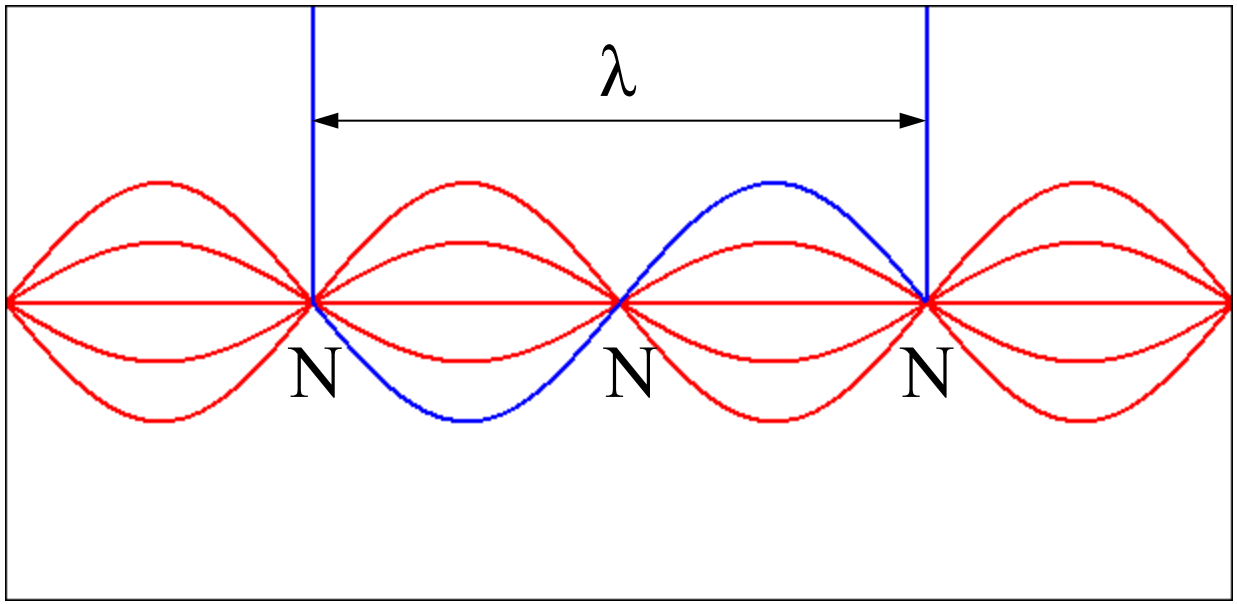
Constructive interference occurs at each antinode.

What is the wavelength of a standing wave?



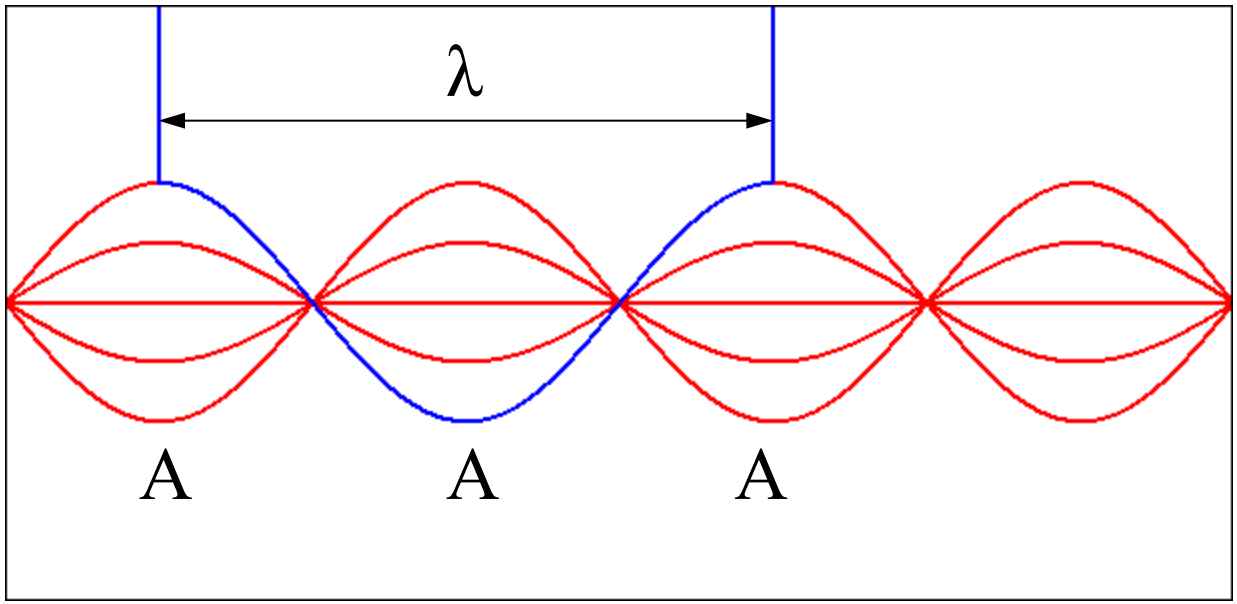
It relates to the spacing of nodes and antinodes …

What is the wavelength of a standing wave?



The wavelength of a standing wave is twice the distance between successive nodes.

What is the wavelength of a standing wave?



The wavelength of a standing wave is twice the distance between successive antinodes.

What is the Speed of a Standing Wave?

- Although the pattern of nodes and antinodes is stationary, the waves that cause the pattern do travel at a certain speed.
- The speed of the individual waves is taken to be the speed of the standing wave.
- This speed depends on the properties of the medium.
- $v = f \cdot \lambda$ = a particular constant for a given medium.

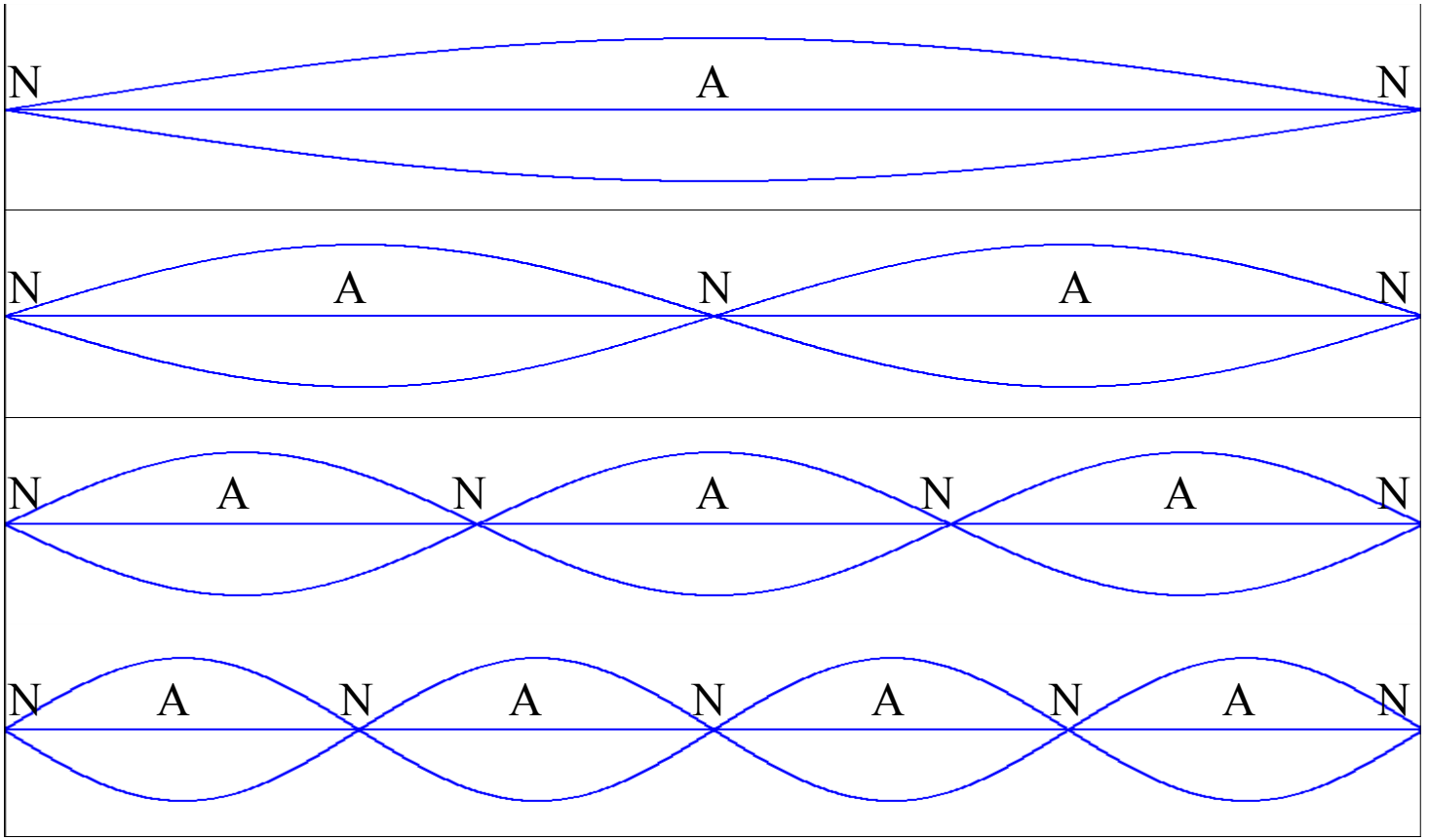
Harmonics

- Only certain standing wave patterns can exist for a given physical system.
- These unique patterns are called **harmonics** and occur at particular frequencies and wavelengths.
- The frequencies and wavelengths of the harmonics are determined by the medium and the type of reflection at each end.

Harmonics

- The harmonic with the lowest frequency is called the “fundamental” or “first harmonic”.
- Harmonics with higher frequencies are multiples of the fundamental and are referred to by number.

Harmonics for String, Length *L*, Fixed at Each End



$n = 1$

$n = 2$

$n = 3$

$n = 4$

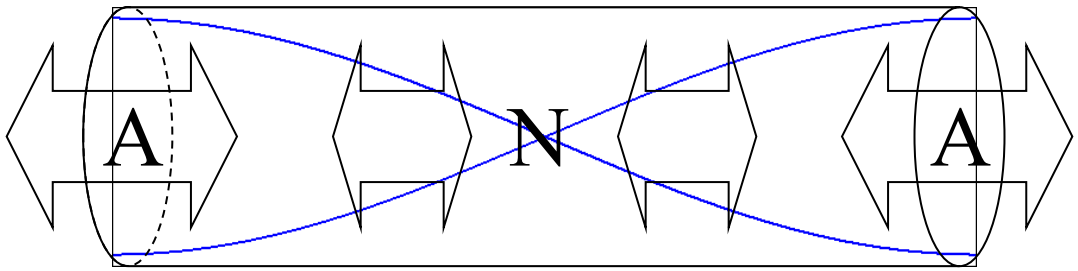
etc.

$$\lambda_n = \frac{2L}{n}$$

$$f_n = n f_1$$

Harmonics for a Pipe

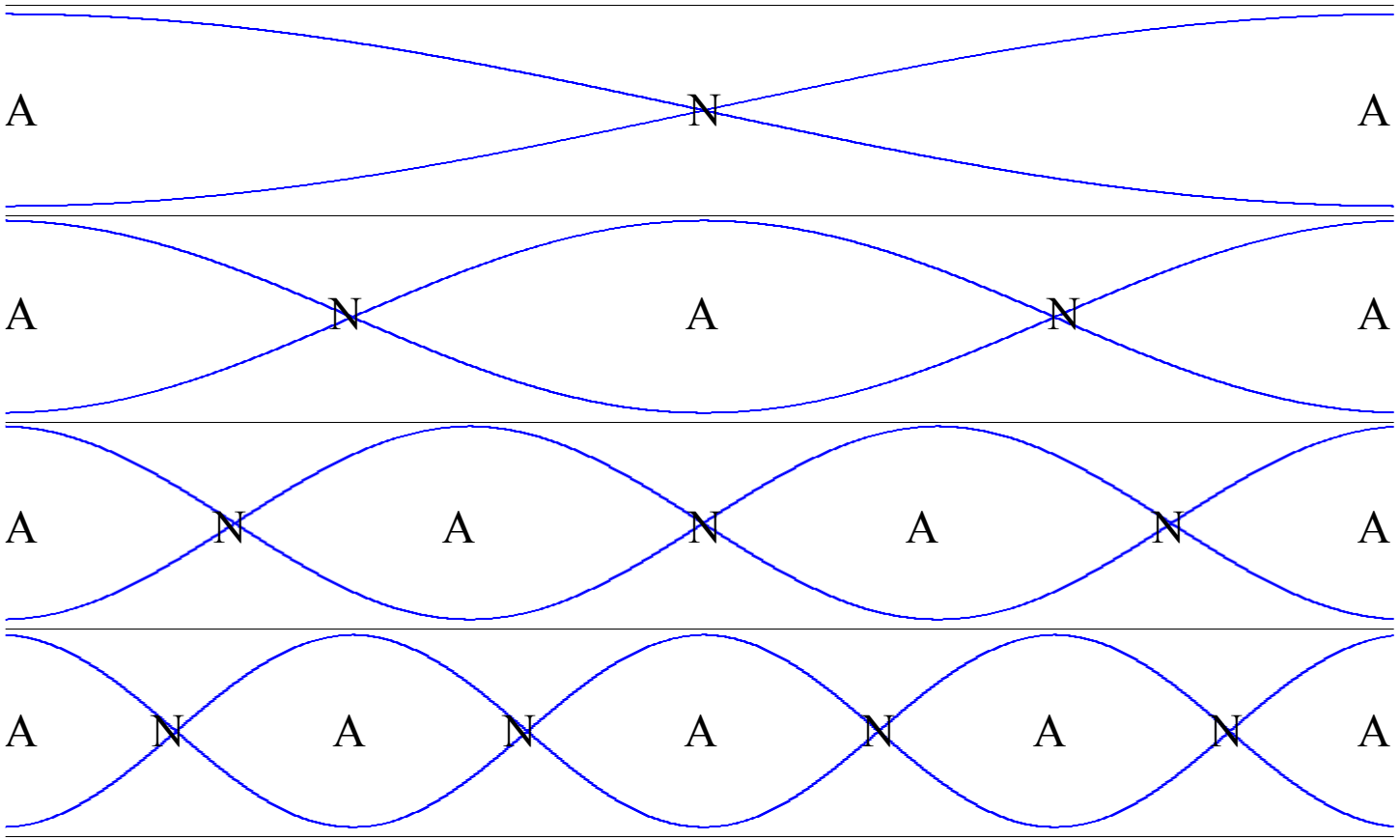
Sound waves travel back and forth through the "column of air" inside the pipe. A standing wave occurs in the air inside the pipe.



Although this is a longitudinal wave, it is often depicted as a transverse wave or "wave graph" for convenience.

Notice that at an open end of a pipe an antinode is formed as air "rushes in and out" of the pipe.

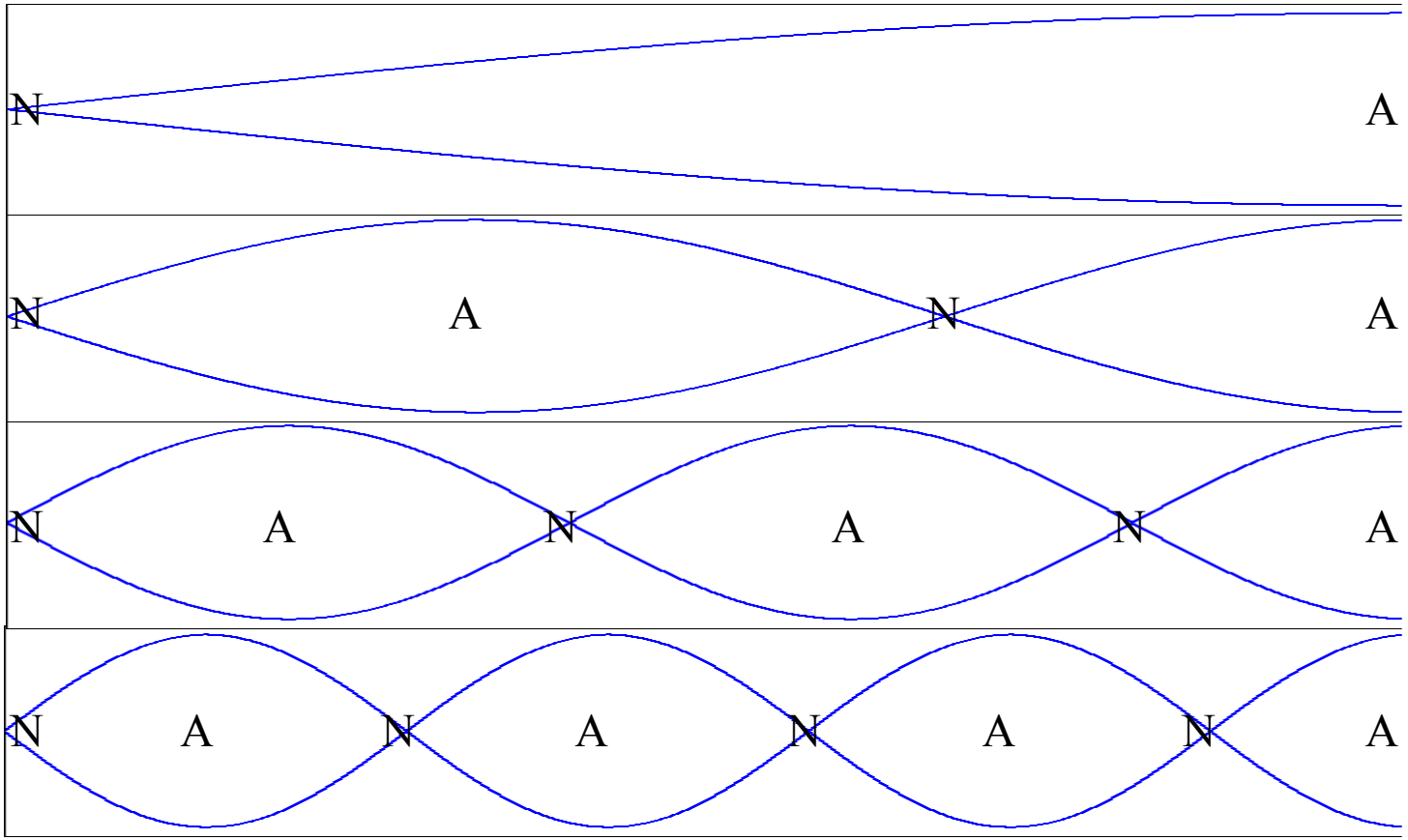
Harmonics for Pipe, Length L, Open at Each End



$$\lambda_n = \frac{2L}{n}$$

$$f_n = n f_1$$

Harmonics for Pipe, Length L, Closed at One End



$n = 1$

$n = 3$

$n = 5$

$n = 7$

etc.

$$\lambda_n = \frac{4L}{n}$$

$$f_n = n f_1$$

Only the **odd** harmonics occur!

Resonance

- Resonance occurs when a source of vibration has a frequency that matches a “natural frequency” (or harmonic frequency).
- Any medium that is set into motion like this is said to resonate with the source.
- Vibrations of a source can be “amplified” by a resonator (because constructive interference occurs).
- Resonance is usually undesirable in structures.