Light: Interference and Optics

I. Light as a Wave
- wave types, parameters, and graphs
- electromagnetic radiation

II. Diffraction and Interference
- diffraction, Huygen's principle
- superposition, interference
- standing waves, slits & gratings

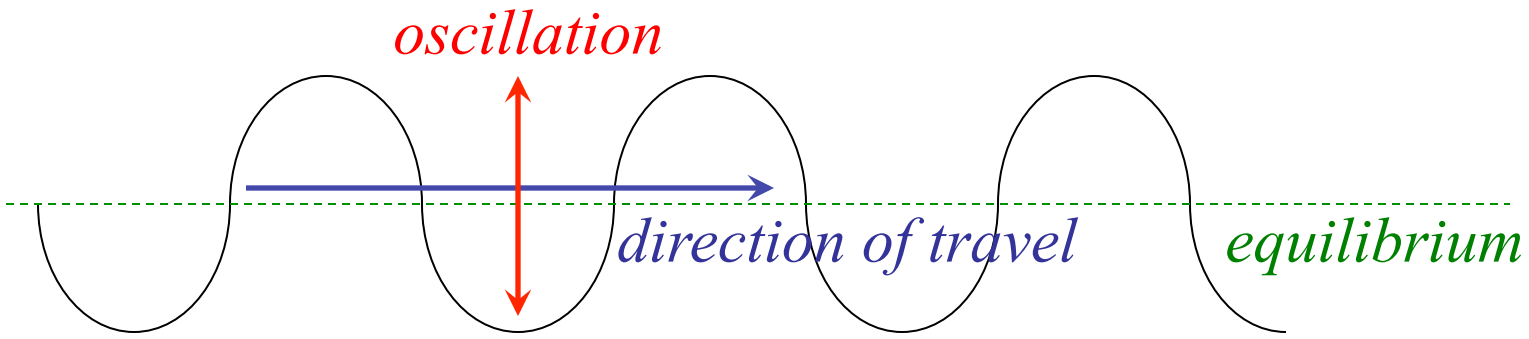
III. Geometric Optics
- reflection, refraction, Snell's Law
- images, lenses, and mirrors

A **wave** is a disturbance propagating through a medium.

- Whatever it is that is being disturbed is called the **medium**.
- A **disturbance** is a change in the equilibrium state of the medium.
- **Propagation** implies that the wave is "self sustaining" and that the pattern of disturbance is reproduced at progressive points through the medium.
- All waves involve the transfer of energy and require a **source** that initiates the wave and supplies energy to the medium.

Transverse Waves

In a **transverse wave** the oscillation of the medium is perpendicular to the direction the wave travels.

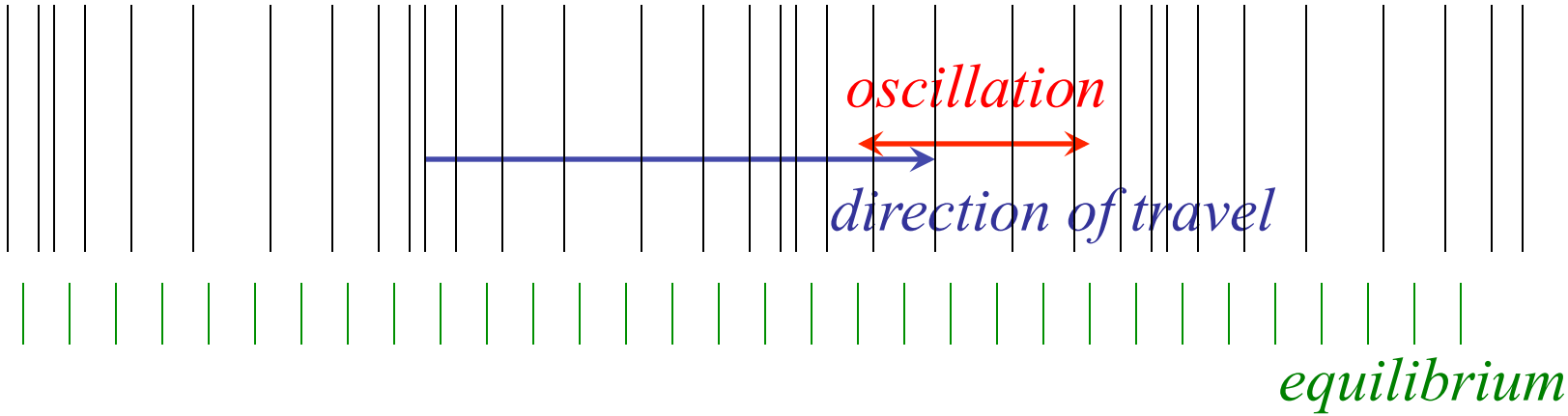


Crest = upward or positive displacement or change of the medium

Trough = downward or negative displacement or change of medium

Longitudinal Waves

In a **longitudinal wave** the oscillation of the medium is parallel to the direction the wave travels.

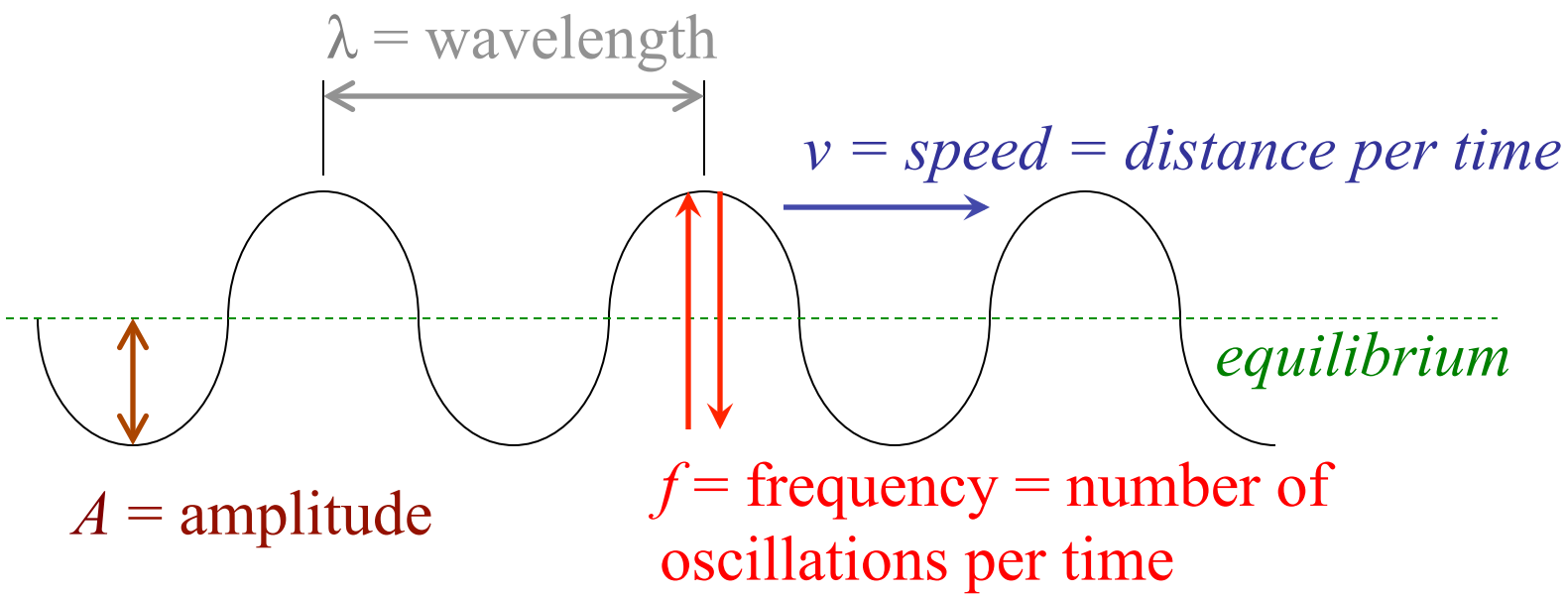


Compression = medium is more tightly spaced than normal

Rarefaction = medium is less tightly spaced than normal

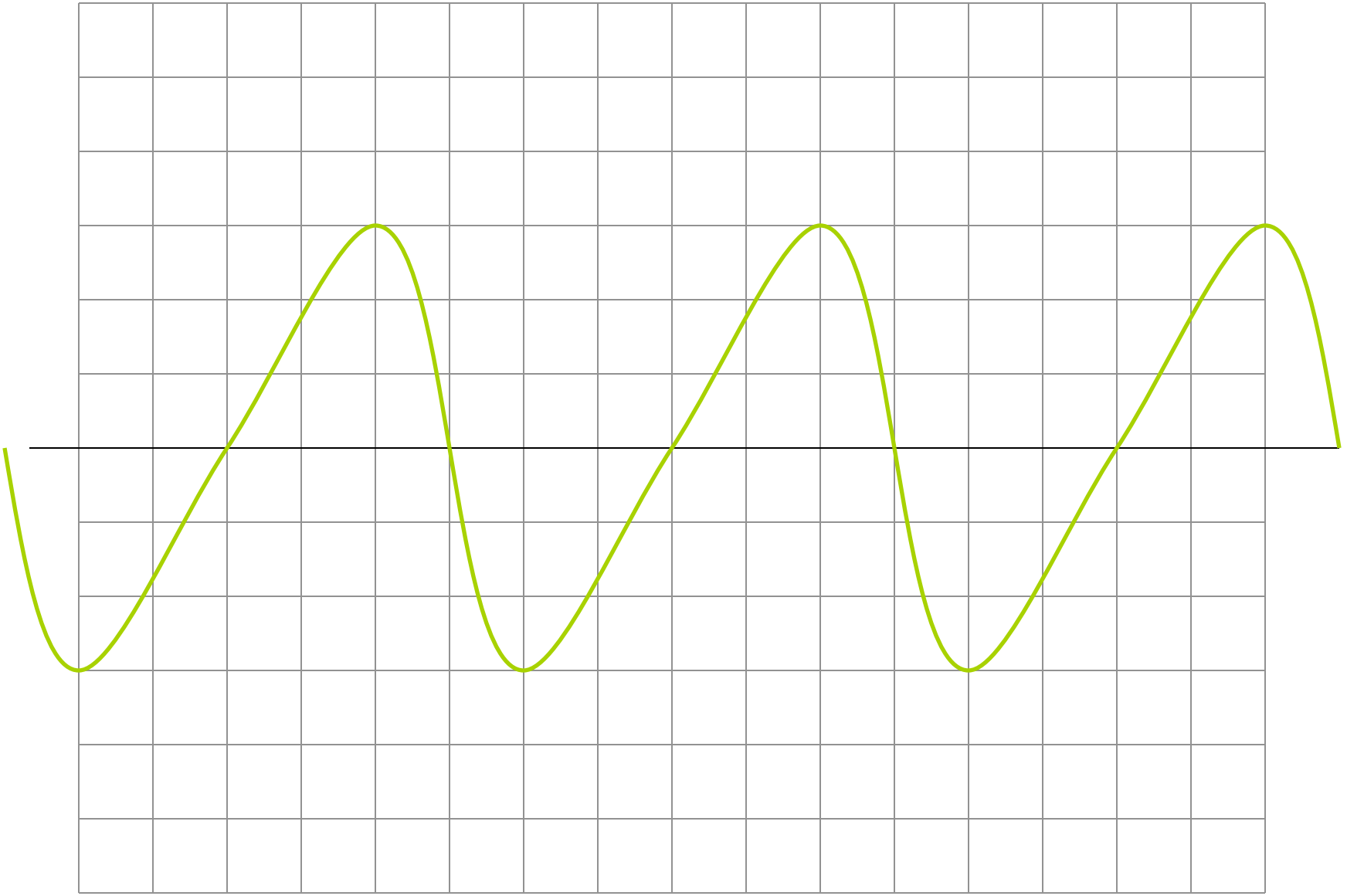
Wave Parameters

- The **speed** of a wave is the rate at which the disturbance travels through the medium.
- The **amplitude** is the maximum level of disturbance, measured from equilibrium.
- **Period** is the time for one complete cycle.
- **Frequency** is the number of cycles per unit time.
- **Wavelength** is the length of one complete cycle (measured along a line parallel to the direction of wave travel)



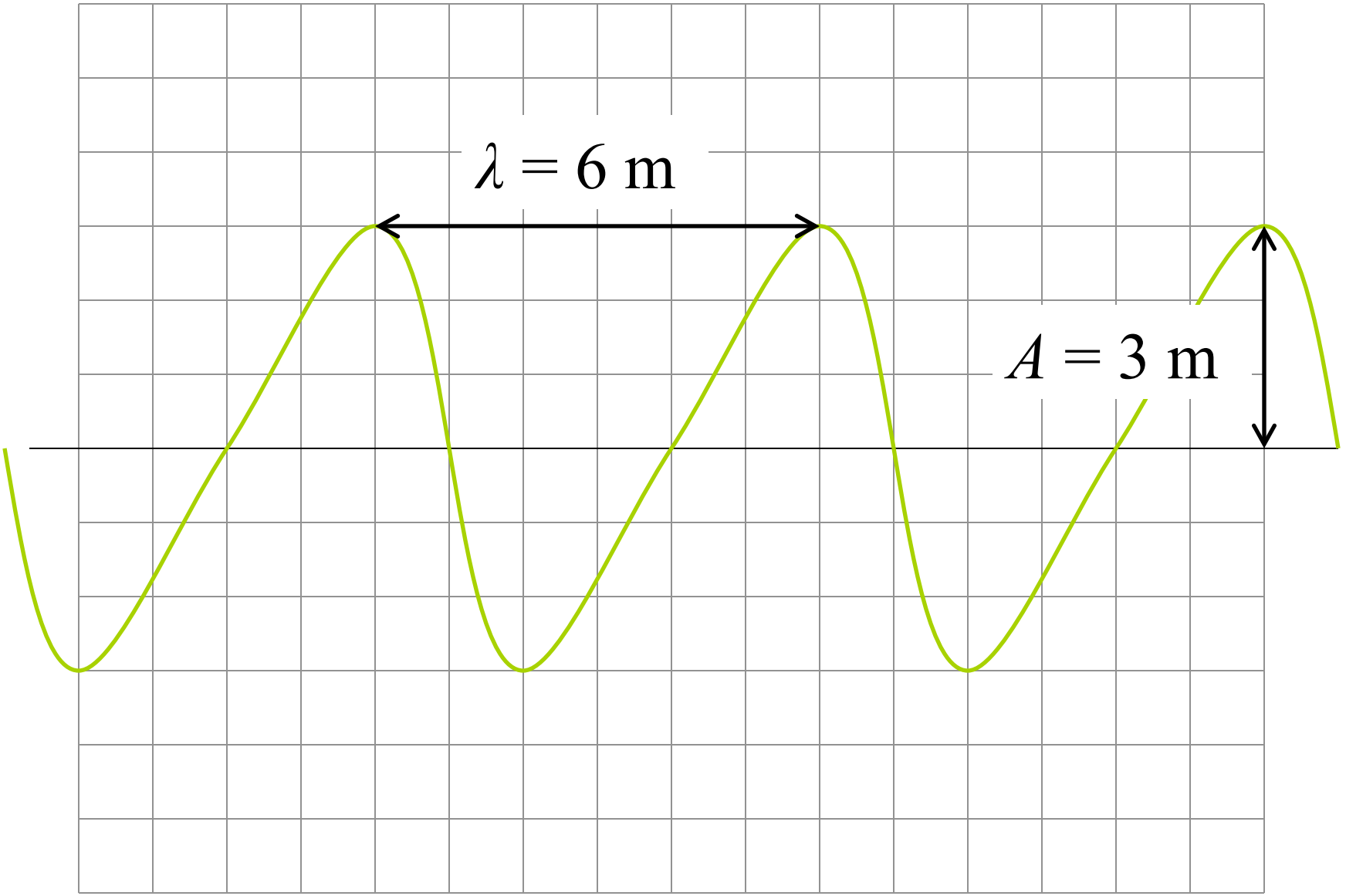
$$v = f \cdot \lambda$$

Find wavelength and amplitude.



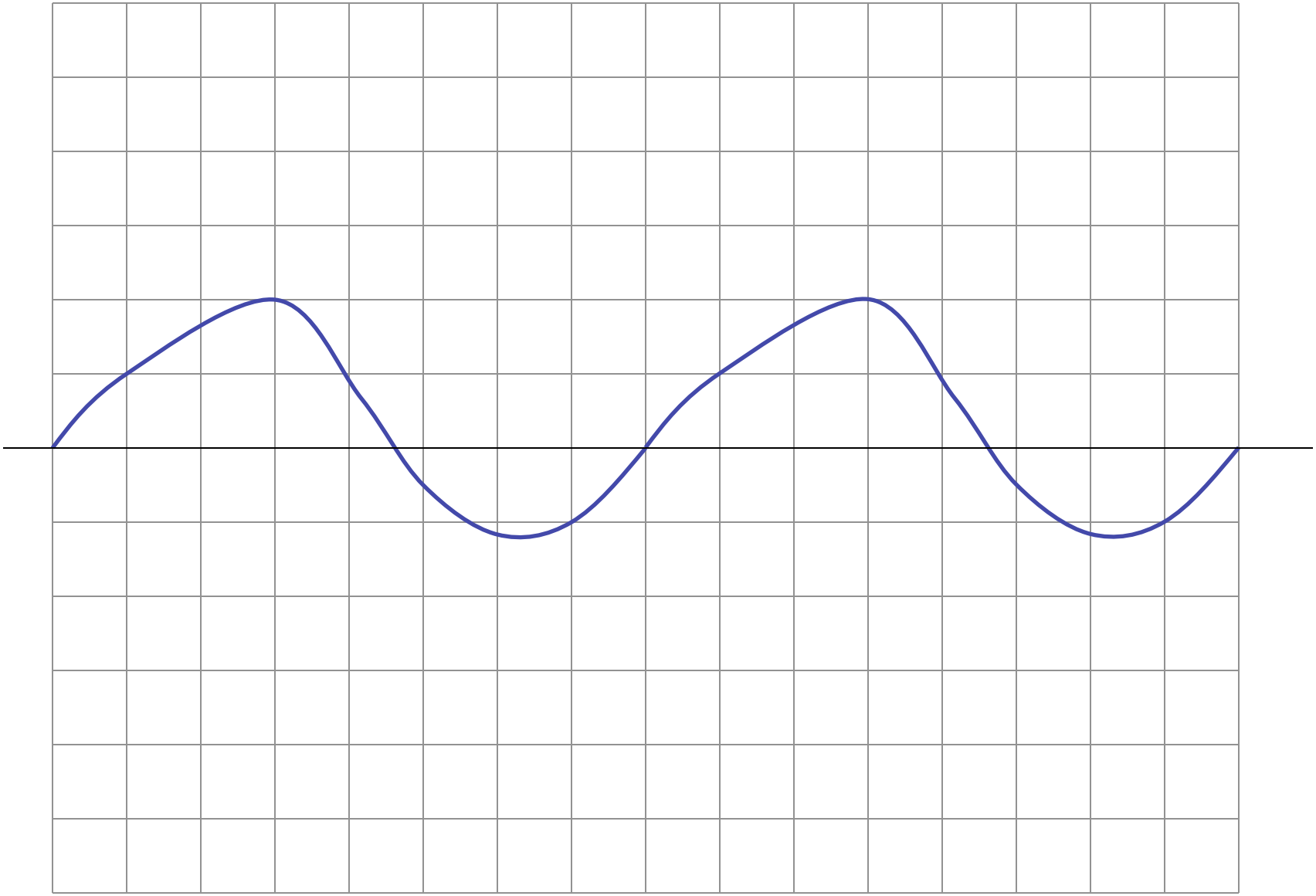
Scale: each square is 1 meter wide.

Find wavelength and amplitude.



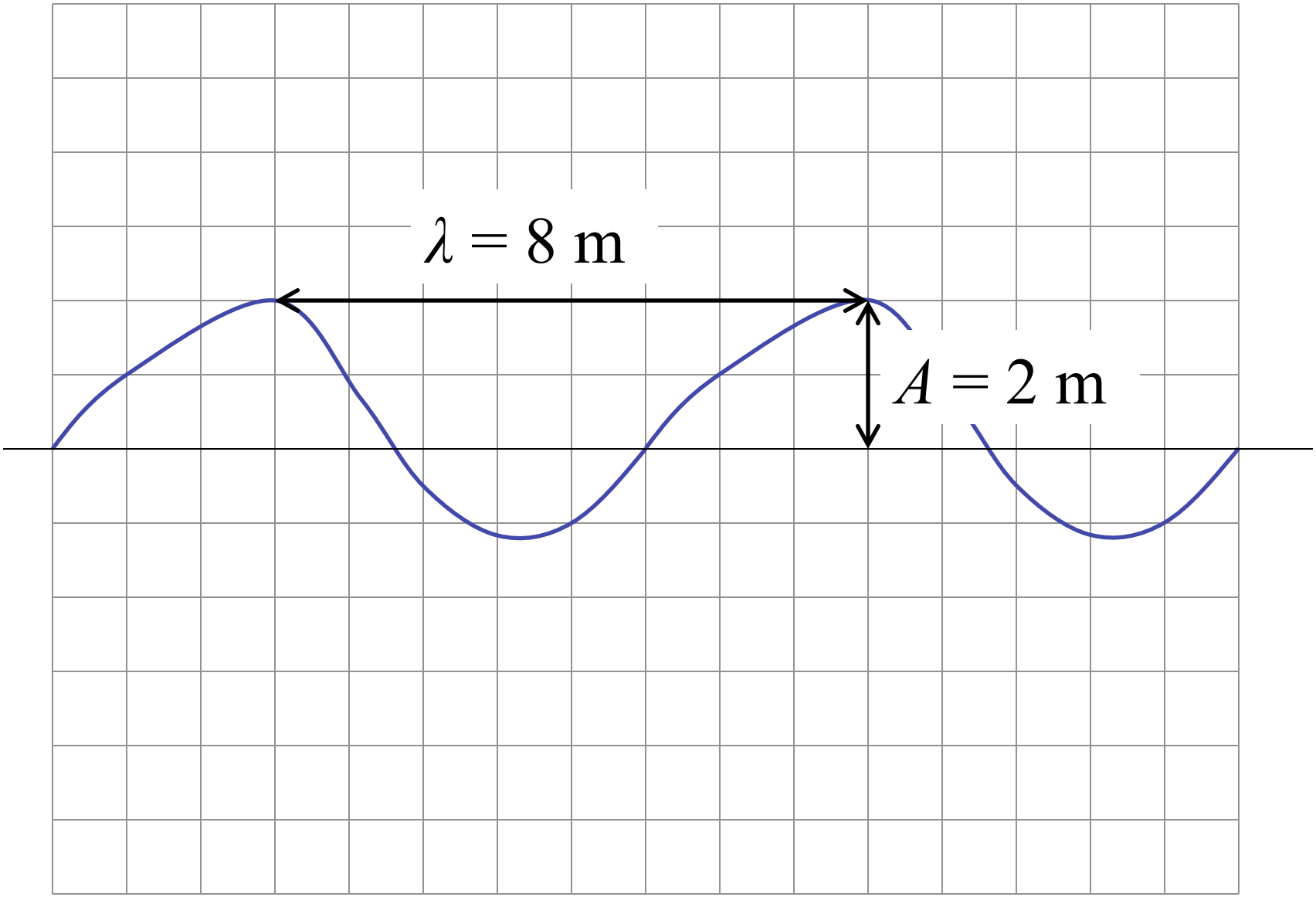
Scale: each square is 1 meter wide.

Find wavelength and amplitude.



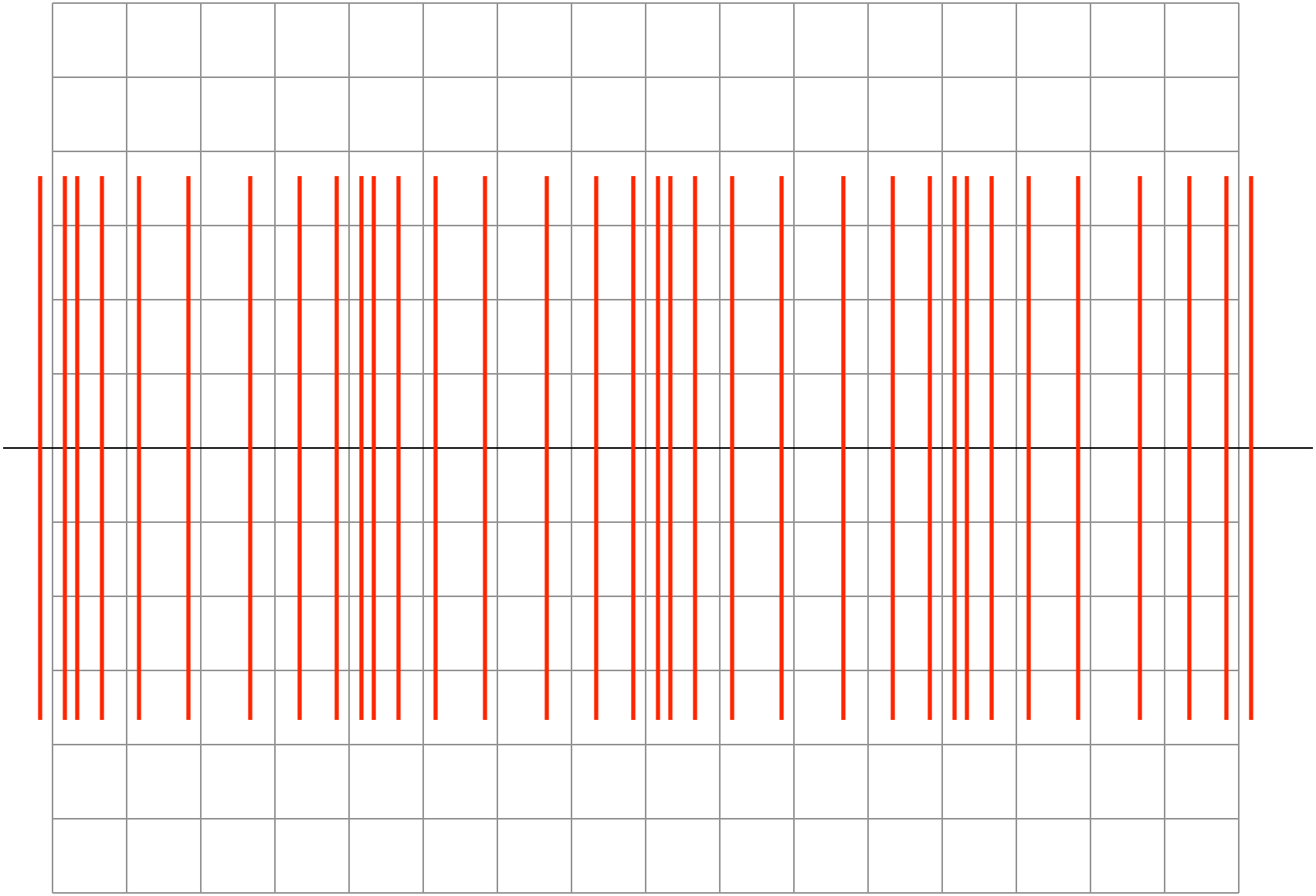
Scale: each square is 1 meter wide.

Find wavelength and amplitude.



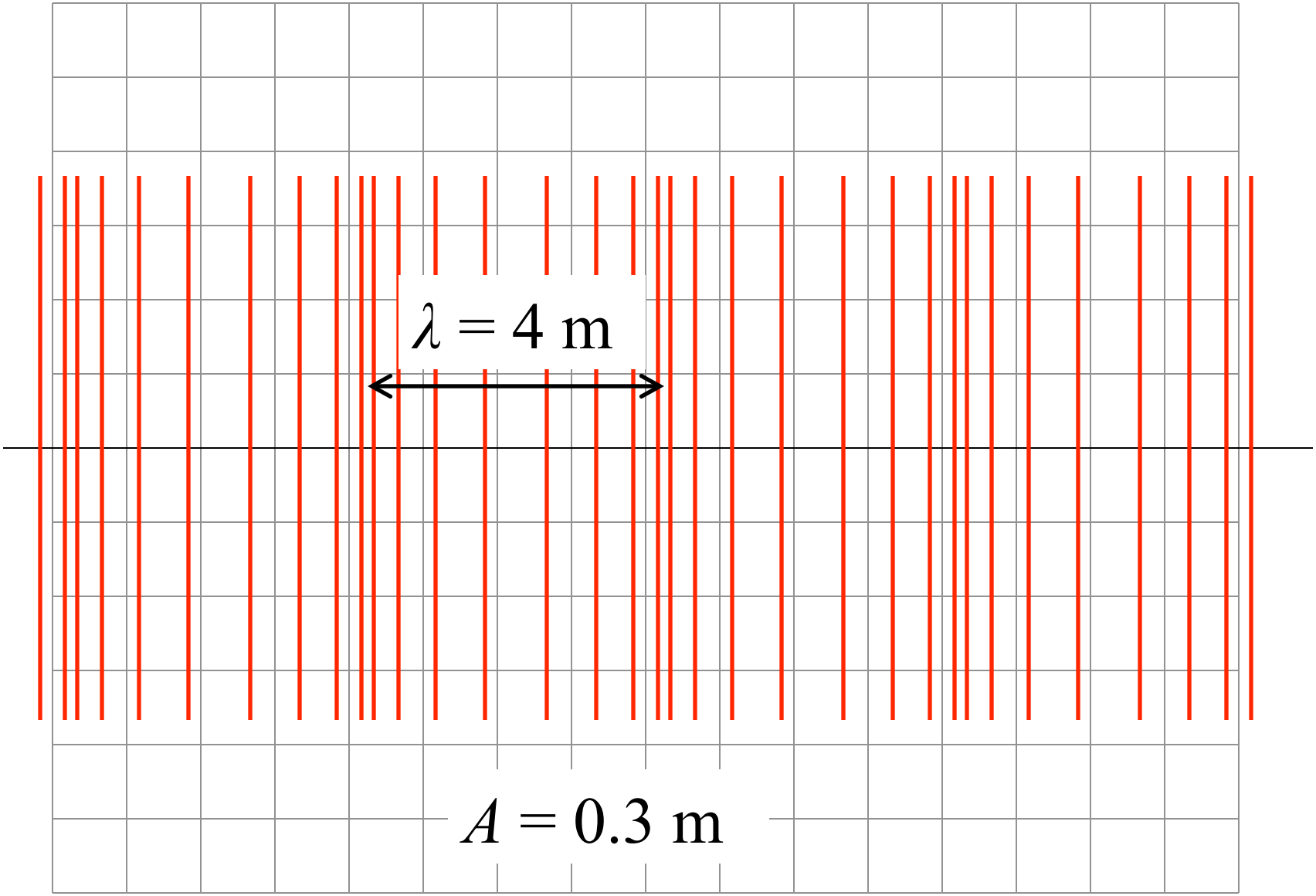
Scale: each square is 1 meter wide.

Find wavelength an amplitude.



Scale: each square is 1 meter wide.

Find wavelength and amplitude.



Scale: each square is 1 meter wide.

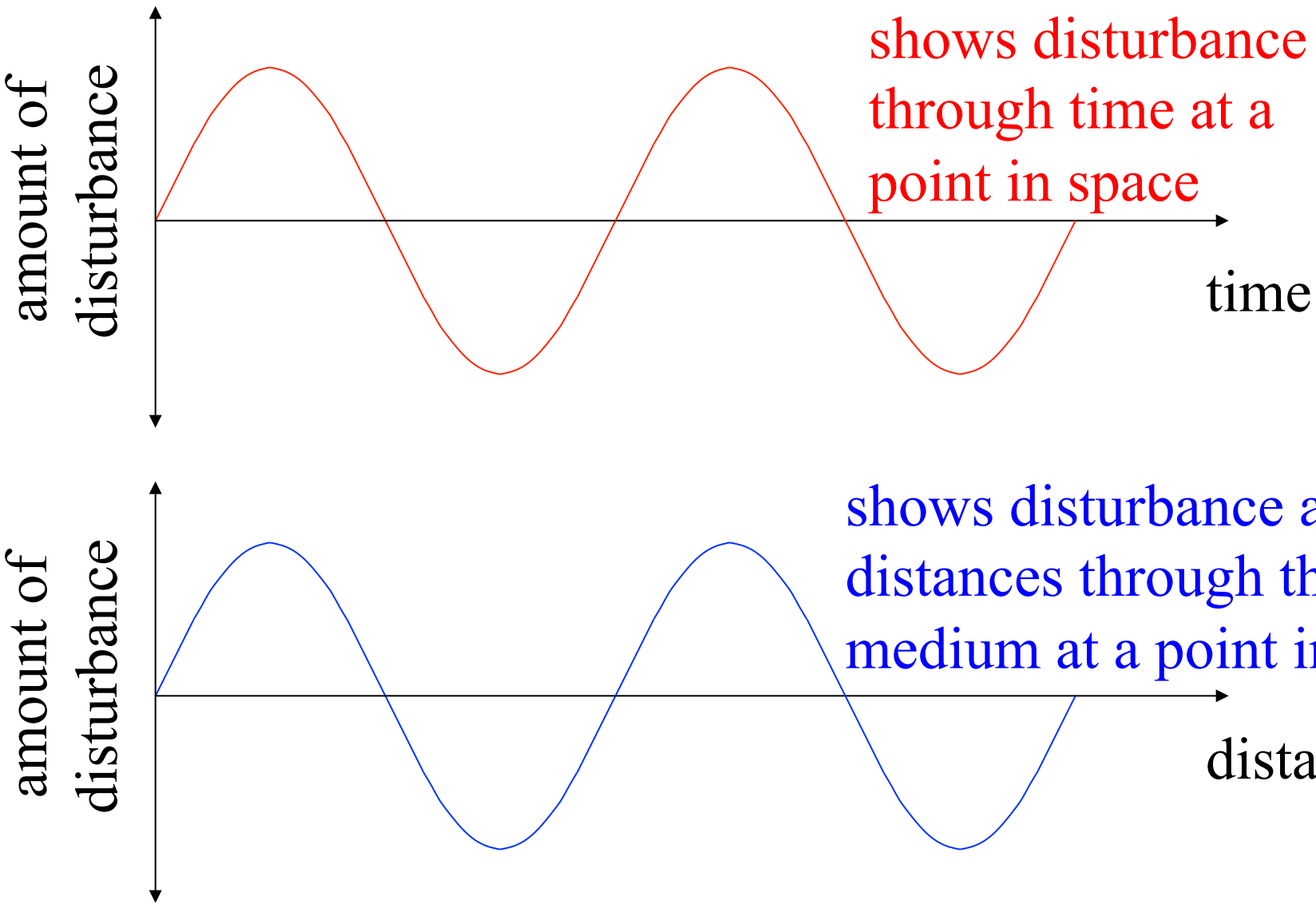
Source vs. Medium

- The source of a wave has no effect on the speed of the wave.
- The speed is determined by the properties of the medium.
- The medium of the wave has no effect on its frequency or period.
- The frequency and period of a wave are determined by (and equal) the frequency and period of the source.
- Wavelength is determined by speed (medium) and frequency (source) so that: $v = f\lambda$.

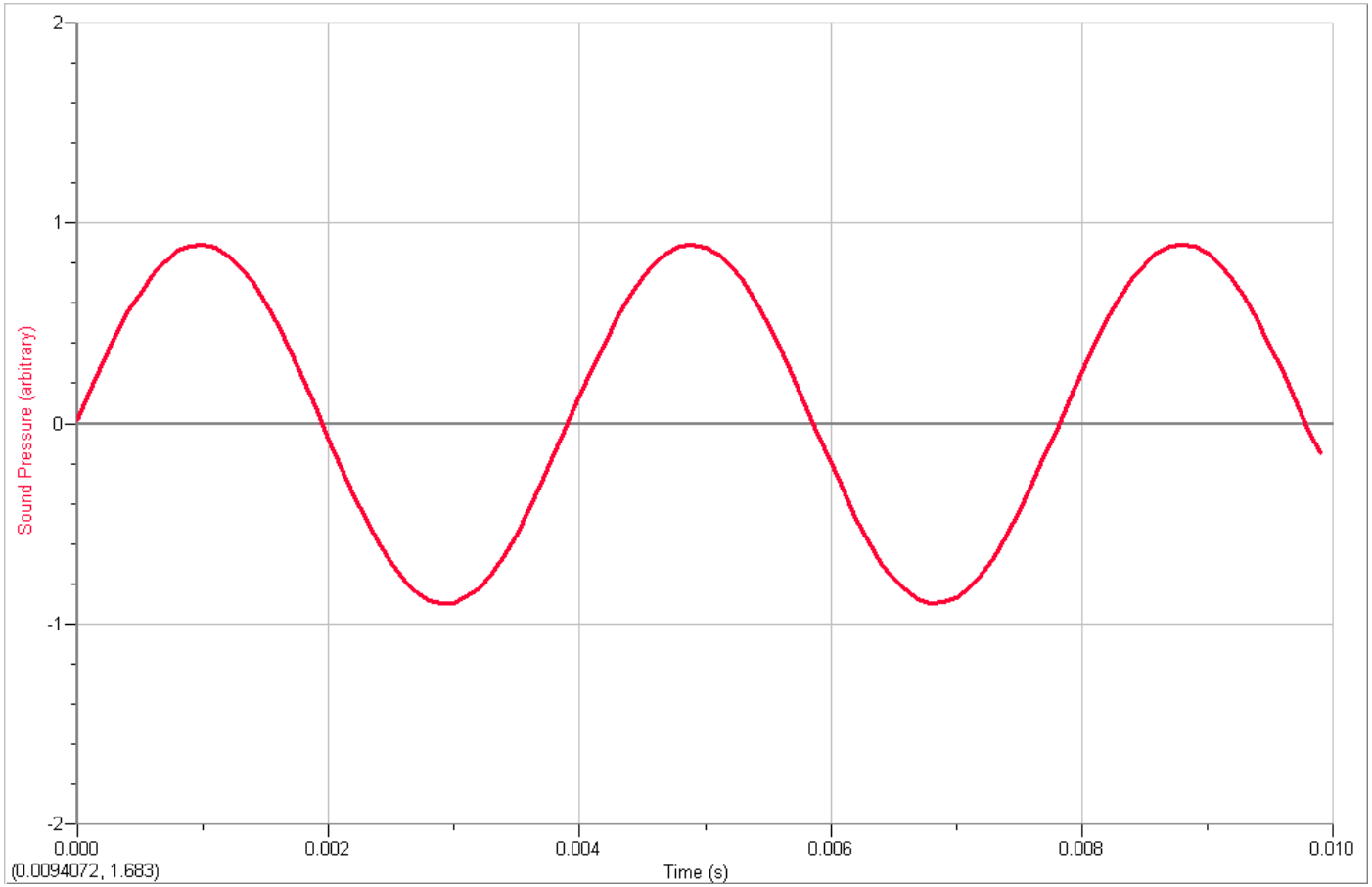
Wave Graphs

- Aside from wavelength, frequency, speed, and amplitude a wave can be unique in its shape or form.
- The shape or form of the wave is the pattern of disturbance.
- A common type of pattern is a sinusoidal wave (or more simply a "sine wave"). This is a wave pattern that has the same curved shape as the graph of the sine function.

Two Types of Wave Graphs

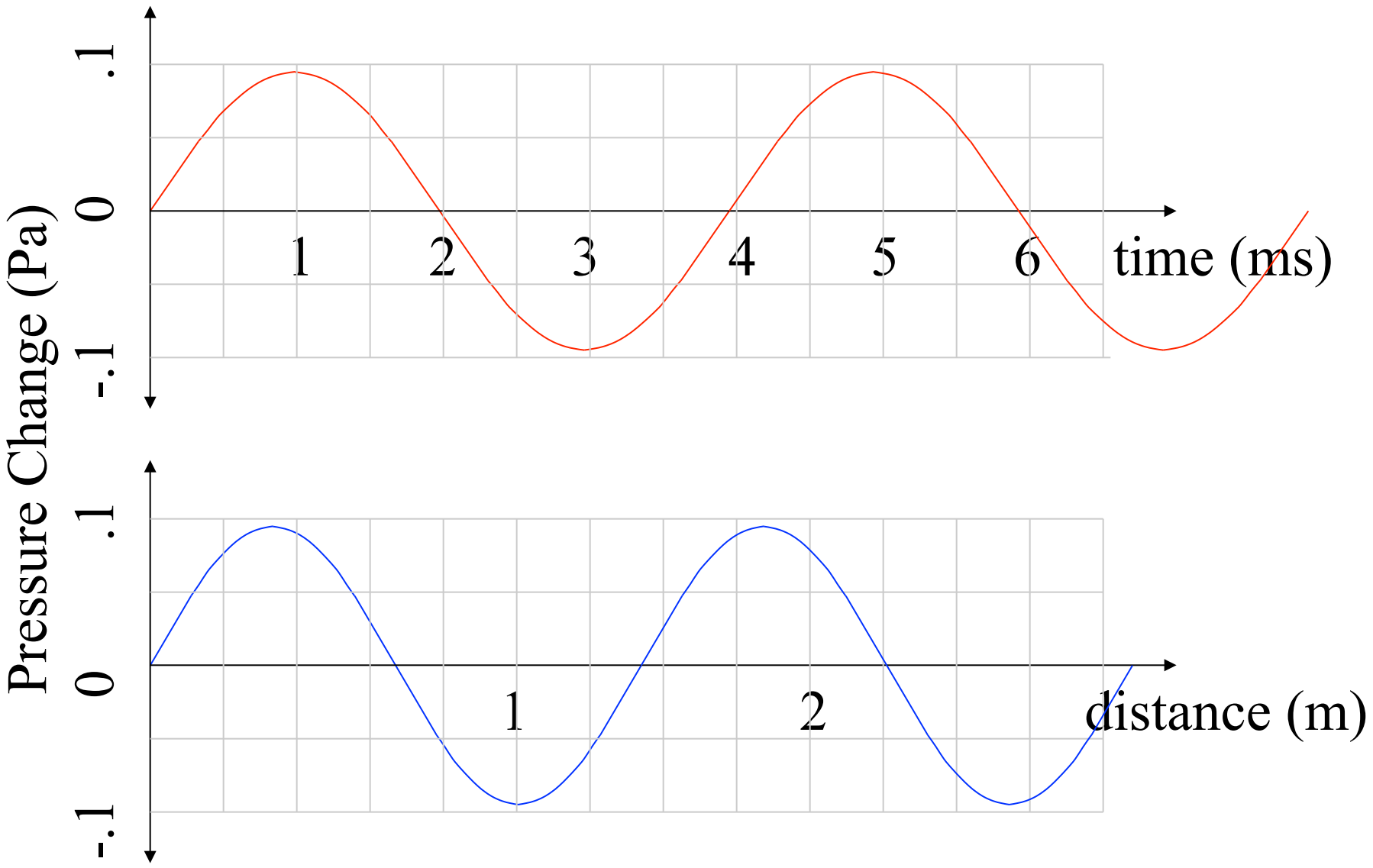


Graph of Sound Wave Made by Tuning Fork:



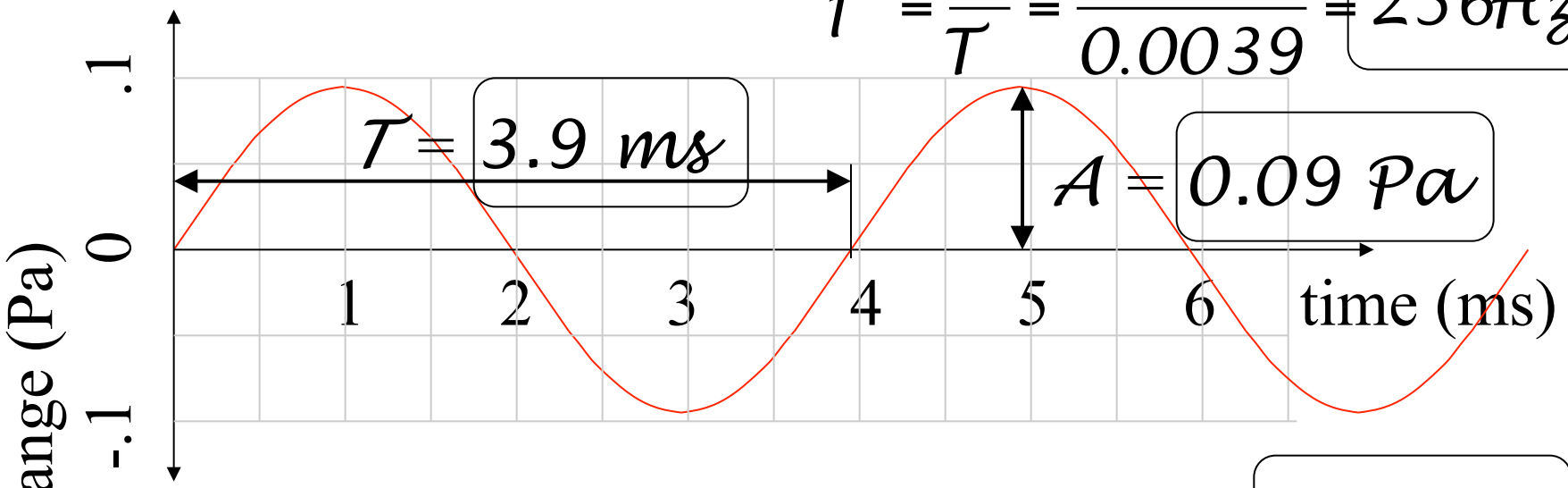
This is the output of an **oscilloscope**. An oscilloscope displays voltage vs. time – in this case the voltage output of a microphone.

Example – Find the Parameters A, f, T, λ, v

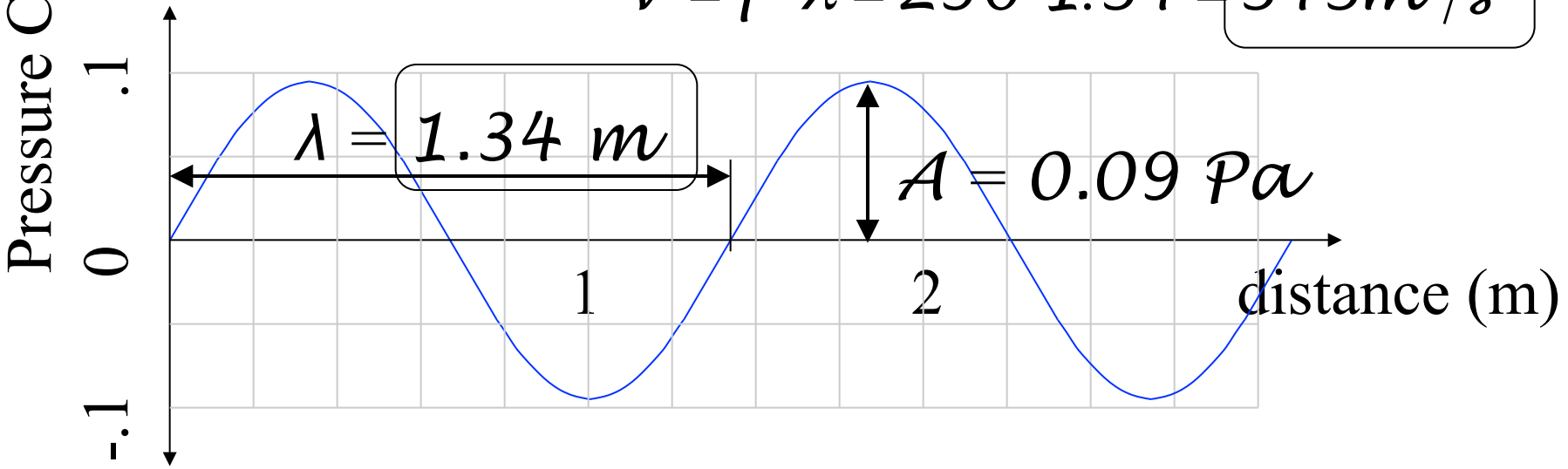


Find the Parameters A, f, T, λ, v:

$$f = \frac{1}{T} = \frac{1}{0.0039} = 256\,Hz$$

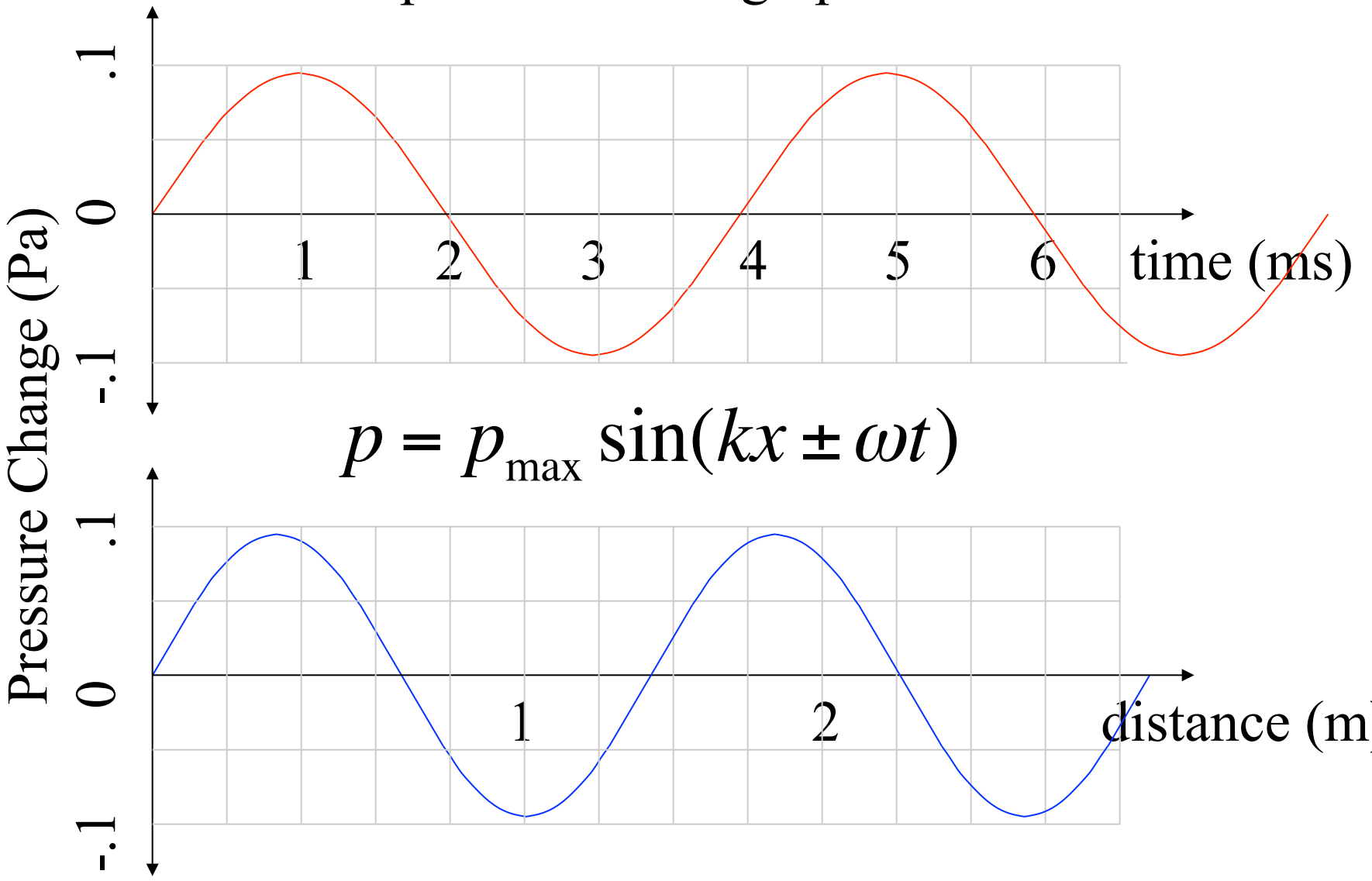


$$v = f\,\lambda = 256 \cdot 1.34 = 343\,m/s$$



Function form describing the wave: $p = p_{\max} \sin(kx \pm \omega t)$

This one function produces both graphs!



Example tuning fork sound wave:

$f = 256$ Hz, $\lambda = 1.34$ m, $A = 0.09$ Pa, $v = 343$ m/s

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{1.34\,\text{m}}$$

wave number: $k = 4.69\,\frac{1}{\text{m}}$

$$\omega = \frac{2\pi}{T} = 2\pi f = 2\pi \cdot 256\,\frac{1}{\text{s}}$$

angular frequency: $\omega = 1608\,\frac{1}{\text{s}} = 1.61\,\frac{1}{\text{ms}}$

pressure deviation: $p = 0.09 \cdot \sin(4.69x - 1.61t)$

This equation gives the pressure change p in the atmosphere caused by sound wave as a function of position x and time t.

Example tuning fork sound wave:

$f = 256$ Hz, $\lambda = 1.34$ m, $A = 0.09$ Pa, $v = 343$ m/s