DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS
IB PHYSICS

LSN 4-2: TRAVELING WAVES

Questions From Reading Activity?

Essential Idea:

- There are many forms of waves available to be studied. A common characteristic of all travelling waves is that they carry energy, but generally the medium through which they travel will not be permanently disturbed.

Nature Of Science:

- Patterns, trends and discrepancies: Scientists have discovered common features of wave motion through careful observations of the natural world, looking for patterns, trends and discrepancies and asking further questions based on these findings.

International-Mindedness:

- Electromagnetic waves are used extensively for national and international communication

Theory Of Knowledge:

- Scientists often transfer their perception of tangible and visible concepts to explain similar non-visible concepts, such as in wave theory.
- How do scientists explain concepts that have no tangible or visible quality?

Understandings:

- Travelling waves
- Wavelength, frequency, period and wave speed
- Transverse and longitudinal waves
- The nature of electromagnetic waves
- The nature of sound waves

Applications And Skills:

- Explaining the motion of particles of a medium when a wave passes through it for both transverse and longitudinal cases
- Sketching and interpreting displacement–distance graphs and displacement–time graphs for transverse and longitudinal waves
- Solving problems involving wave speed, frequency and wavelength
- Investigating the speed of sound experimentally

Guidance:

- Students will be expected to derive $c = f\lambda$
- Students should be aware of the order of magnitude of the wavelengths of radio, microwave, infra-red, visible, ultraviolet, X-ray and gamma rays

Data Booklet Reference:

$$c = \lambda f$$

Utilization:

- Communication using both sound (locally) and electromagnetic waves (near and far) involve wave theory
- Emission spectra are analyzed by comparison to the electromagnetic wave spectrum (see Chemistry topic 2 and Physics sub-topic 12.1)
- Sight (see Biology sub-topic A.2)

Aims:

- Aim 2: there is a common body of knowledge and techniques involved in wave theory that is applicable across many areas of physics
- Aim 4: there are opportunities for the analysis of data to arrive at some of the models in this section from first principles

Aims:

- Aim 6: experiments could include (but are not limited to): speed of waves in different media; detection of electromagnetic waves from various sources; use of echo methods (or similar) for determining wave speed, wavelength, distance, or medium elasticity and/or density

Transition Video:

Physics of Waves

INTRODUCTORY VIDEOS

- Cool Waves
- Bad Waves
- Properties of Waves

What is a wave?

- **A wave is a way of transferring energy and momentum from one place to another, *but without the actual large-scale motion of a material body***

What is a wave?

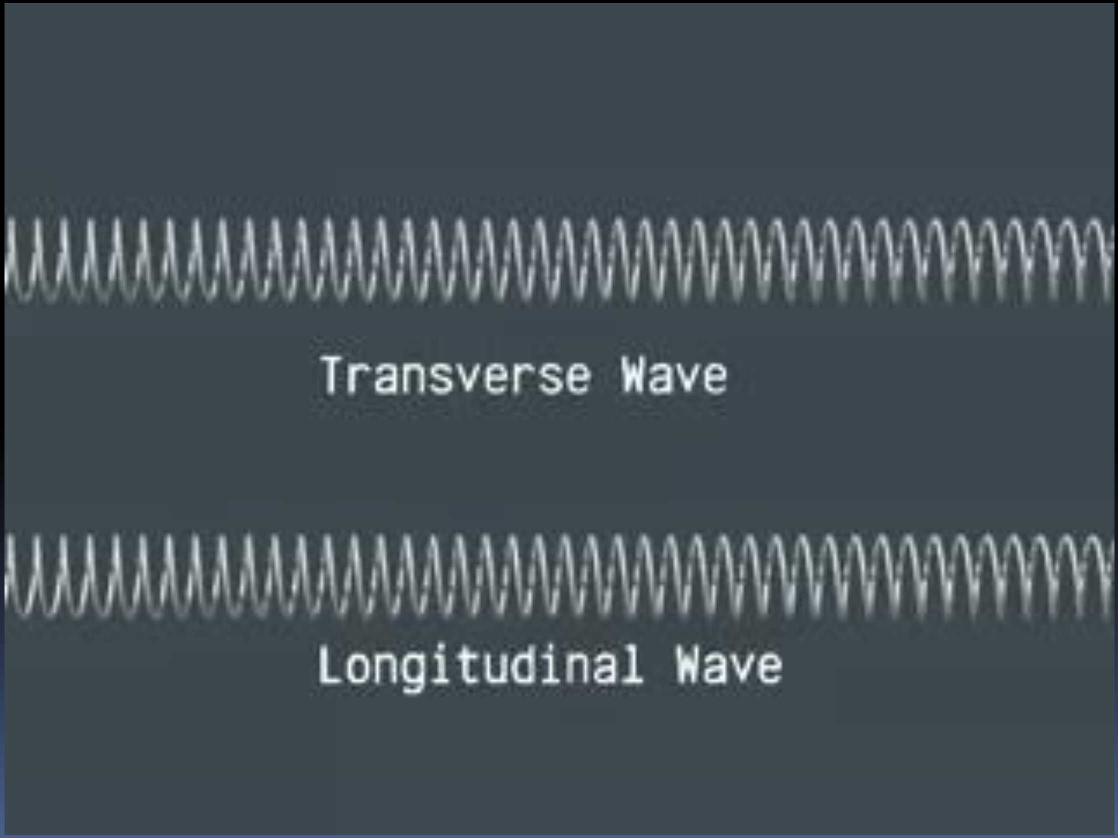
- Examples:
  - Life is a beach
  - Light from the sun
  - Soprano breaking a glass
  - Light travels in a vacuum – no medium required – an <u>*electromagnetic*</u> wave
  - Sound and water require a medium – <u>*mechanical*</u> waves

What is a wave?

- Waves occur because something is disturbed
- *A wave is a disturbance that travels, transferring energy and momentum from one place to another, but without the actual large-scale motion of a material body. The direction of energy transfer is the direction of propagation of the wave.*

Transverse and Longitudinal Waves

- [Video: Longitudinal and Transverse Waves]



Transverse and Longitudinal Waves

- ***<u>Transverse</u>*** **– waves in which the disturbance is at right angles to the direction of energy transfer**
  - **rope tricks**

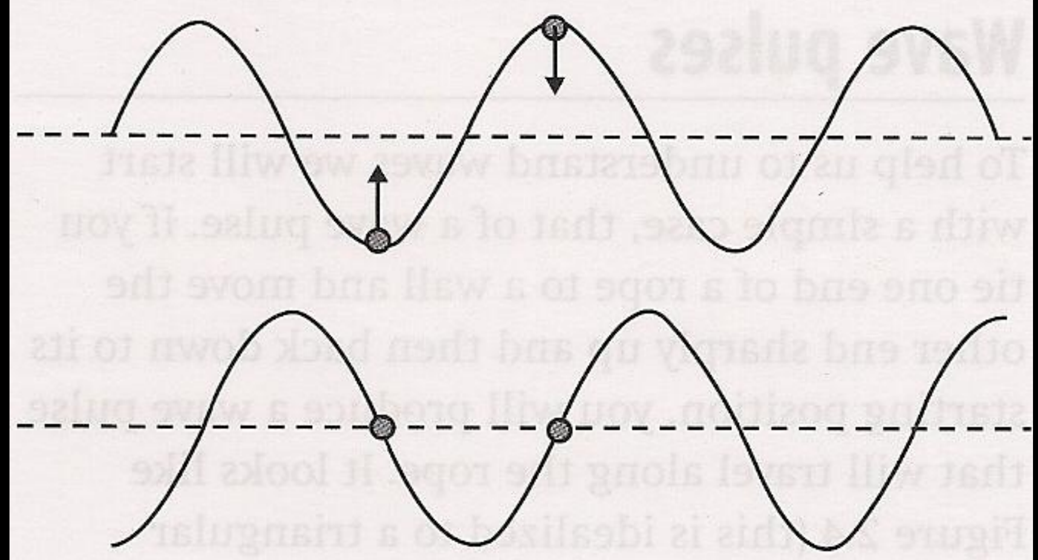


Figure 2.1 A transverse wave on a string travelling to the right. At the early time of the top picture, the parts of the string marked are at their maximum displacement above and below the equilibrium position of the string. Some time later the left part has moved up and the right part down – their motion is at right angles to the direction of motion of the wave.

Transverse and Longitudinal Waves

- ***Transverse*** – waves in which the disturbance is at right angles to the direction of energy transfer
  - rope tricks
  - electromagnetic waves

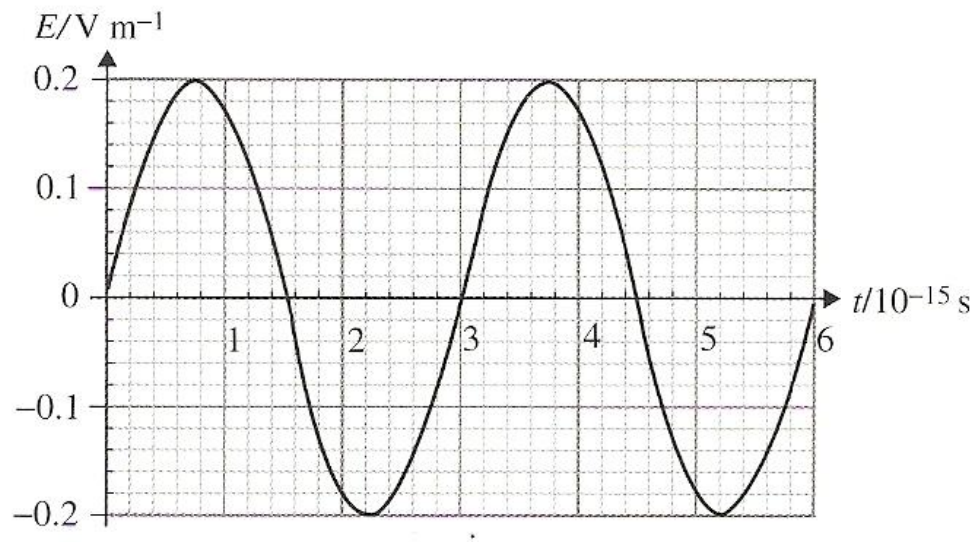


Figure 2.14 An electromagnetic wave as a function of time.

Transverse and Longitudinal Waves

- ***Longitudinal*** **-- waves in which the disturbance is along the direction of energy transfer**
  - ***dominos***
  - **sound waves**
- **energy propagated through a series of *compressions* (region of higher than normal density) and *rarefactions* (region of lower than normal density)**

Transverse and Longitudinal Waves

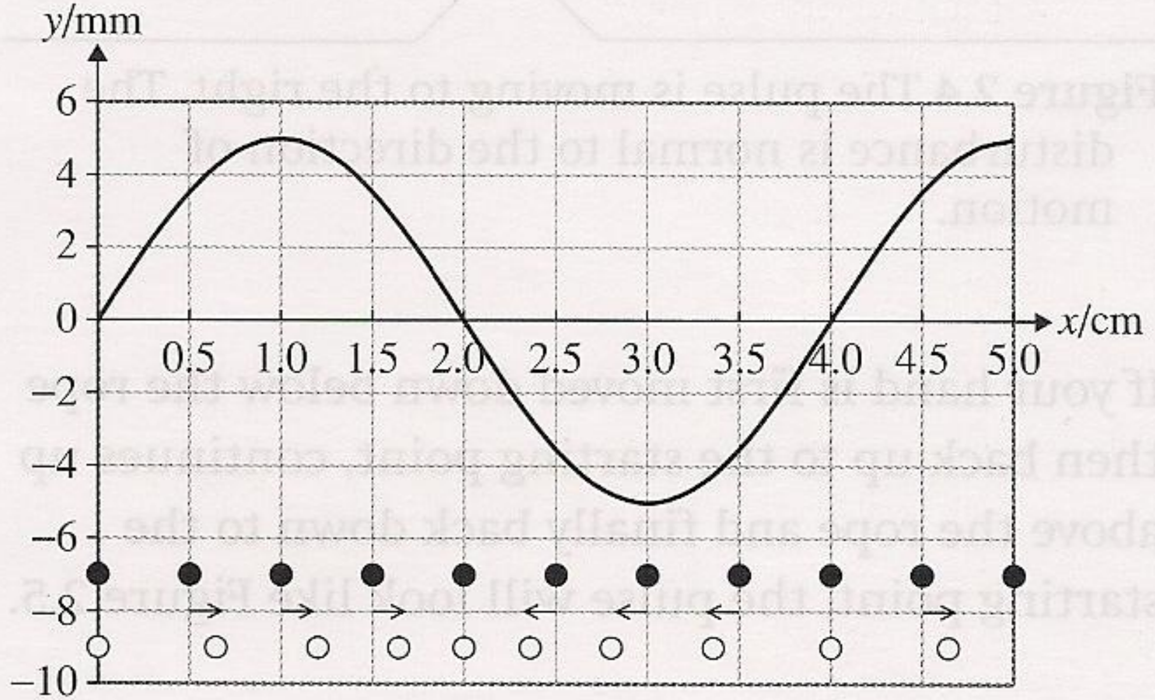
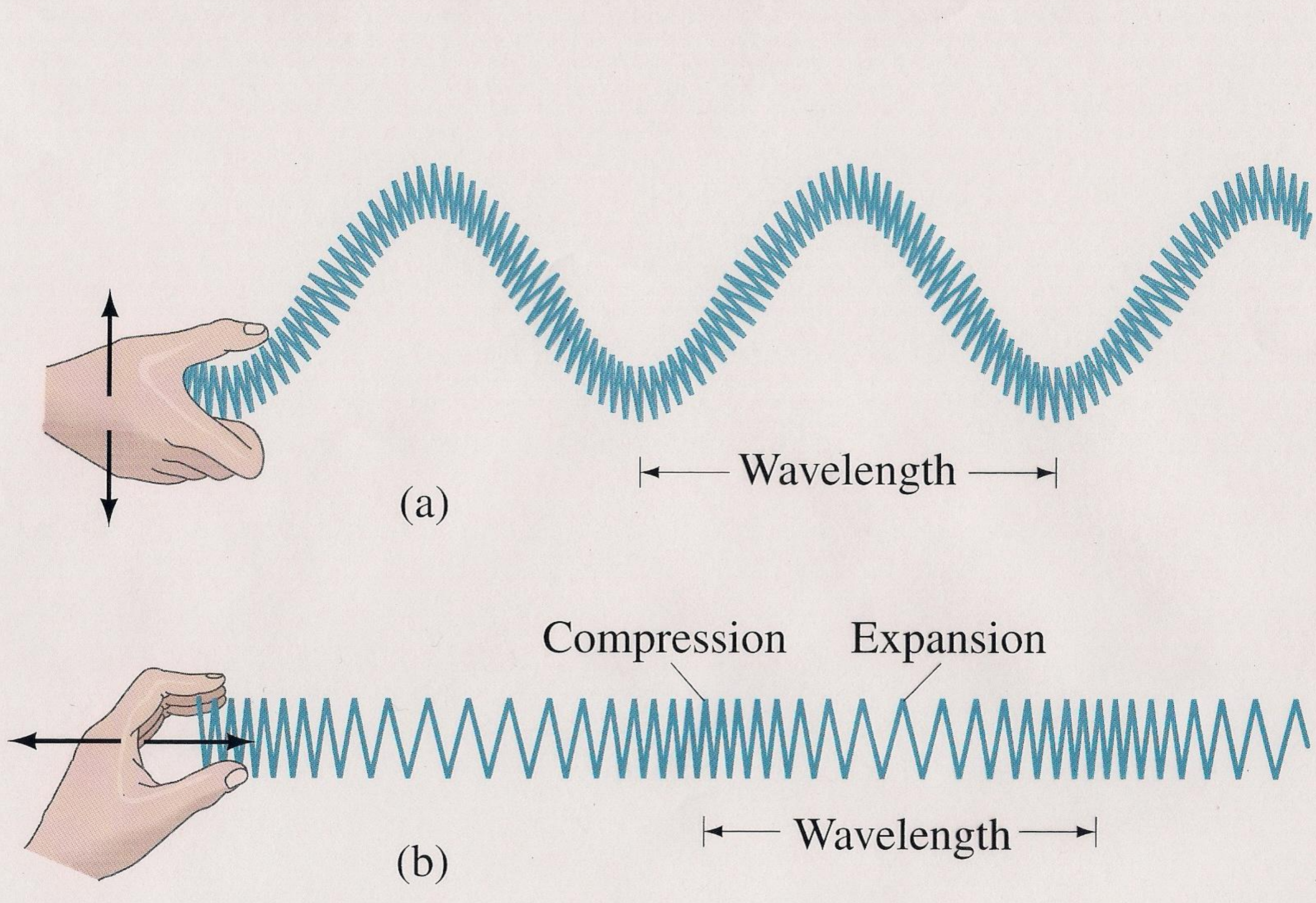


Figure 2.2 The black dots represent air molecules when no wave is present. The uncoloured dots below represent the positions of these molecules at the instant the wave shown by the graph passes.

Transverse and Longitudinal Waves

Figure 11-24 (a) Transverse wave; (b) longitudinal wave

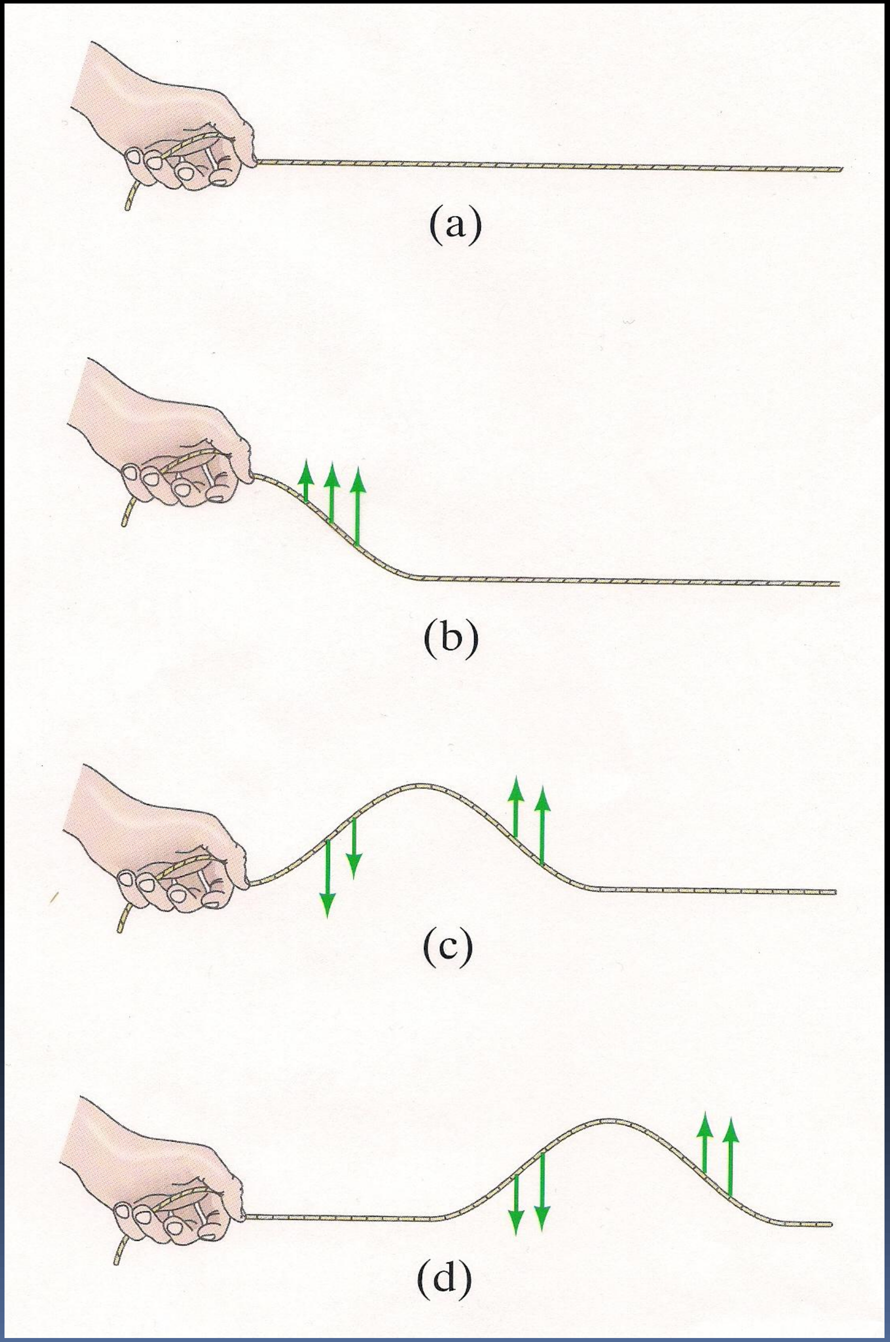


Wave pulses

- Video: Pulses and Waves

Wave pulses

- Rope Tricks
  - half-pulse vs. full pulse



Wave pulses

- Rope Tricks
  - wave pulses travel with a given speed determined by the tension in the rope and mass per unit length, $\mu = m/L$

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{TL}{m}}$$

Wave Pulses

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{TL}{m}}$$

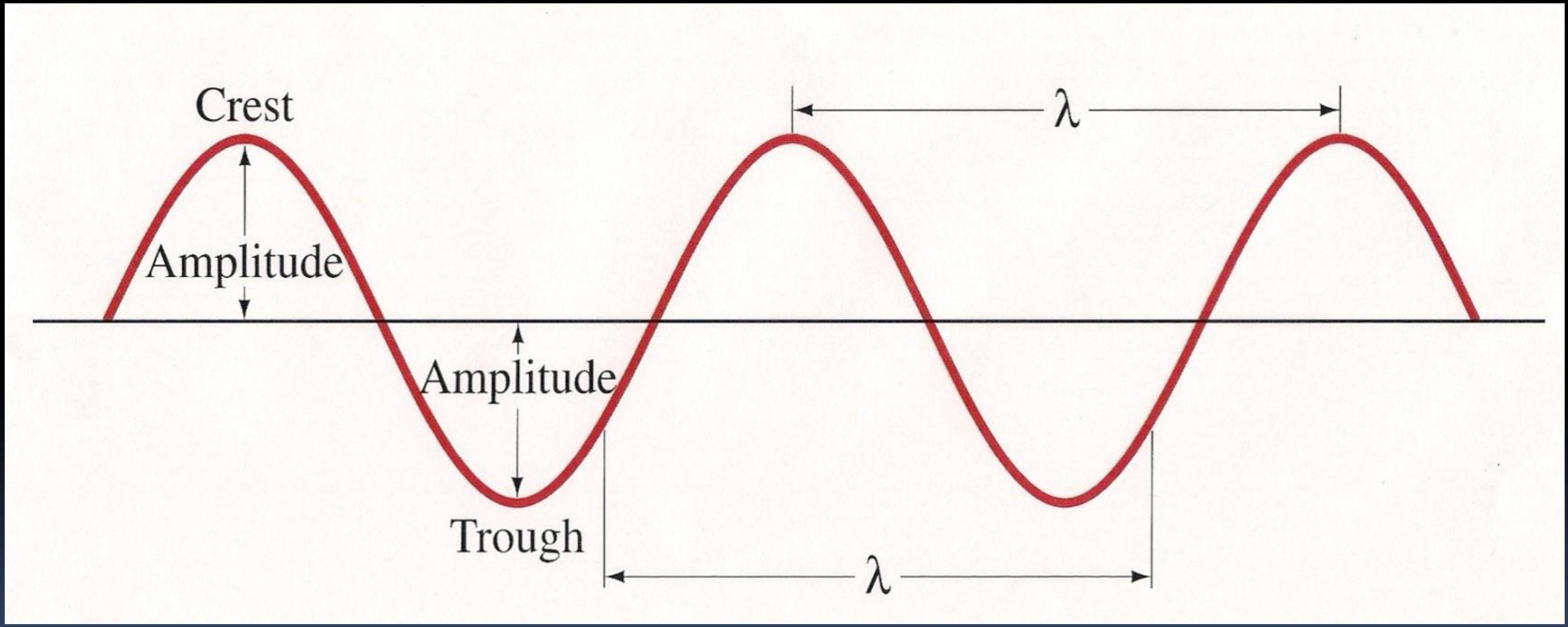
- Rope Tricks
  - the speed of the wave is determined by the properties of the medium and not by how the wave is created,
  - i.e. independent of shape or how fast you produced it

Travelling Waves

- ~~those that take more than one step before dribbling (N/A NBA)~~
- when pulses are repetitiously produced
- if the wave driver demonstrates SHM, the wave produced will exhibit SHM and the wave will look like a sine wave (also called a harmonic wave)

Harmonic waves

- **exhibit SHM**



Harmonic waves

- ***period (s)*** – time to complete one full wave, unit is s
- ***wavelength ()*** – length of a wave (surprise!)

Harmonic waves

- ***velocity (v)*** – equal to one wavelength (m) per the period (s)
- ***frequency (f)*** – number of waves per unit time, equal to 1/T, unit is s^{-1} or Hz

The Marvels of Algebra!!!

$$v = \frac{\lambda}{T}$$

$$T = \frac{1}{f}$$

$$v = \lambda f$$

Harmonic waves

- ***displacement (y)*** – height obtained above or below the undisturbed point due to the disturbance, it is a function of the distance (x) and time (t)
  - When wave movement is dependent on the medium (like for sound [compression] waves), displacement is given in terms of density:

$$y_{\rho} = \rho - \rho_0$$

Harmonic waves

- *displacement (y)* – **height obtained above or below the undisturbed point due to the disturbance, it is a function of the distance (x) and time (t)**
  - **or in terms of pressure**

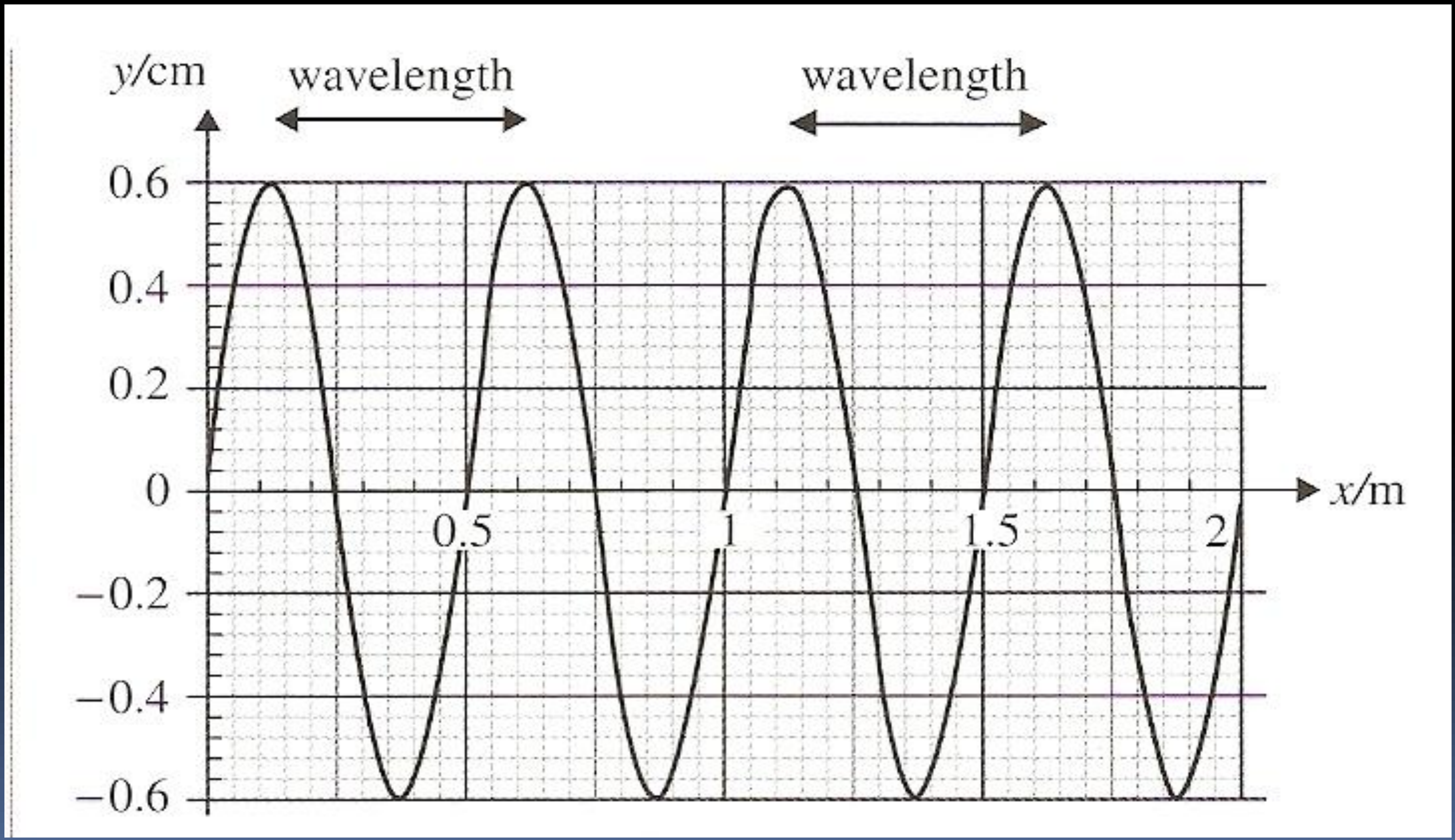
$$y_p = p - p_0$$

Harmonic waves

- displacement is a function of distance and time for any wave regardless of whether the displacement is vertical (transverse) or horizontal (longitudinal)

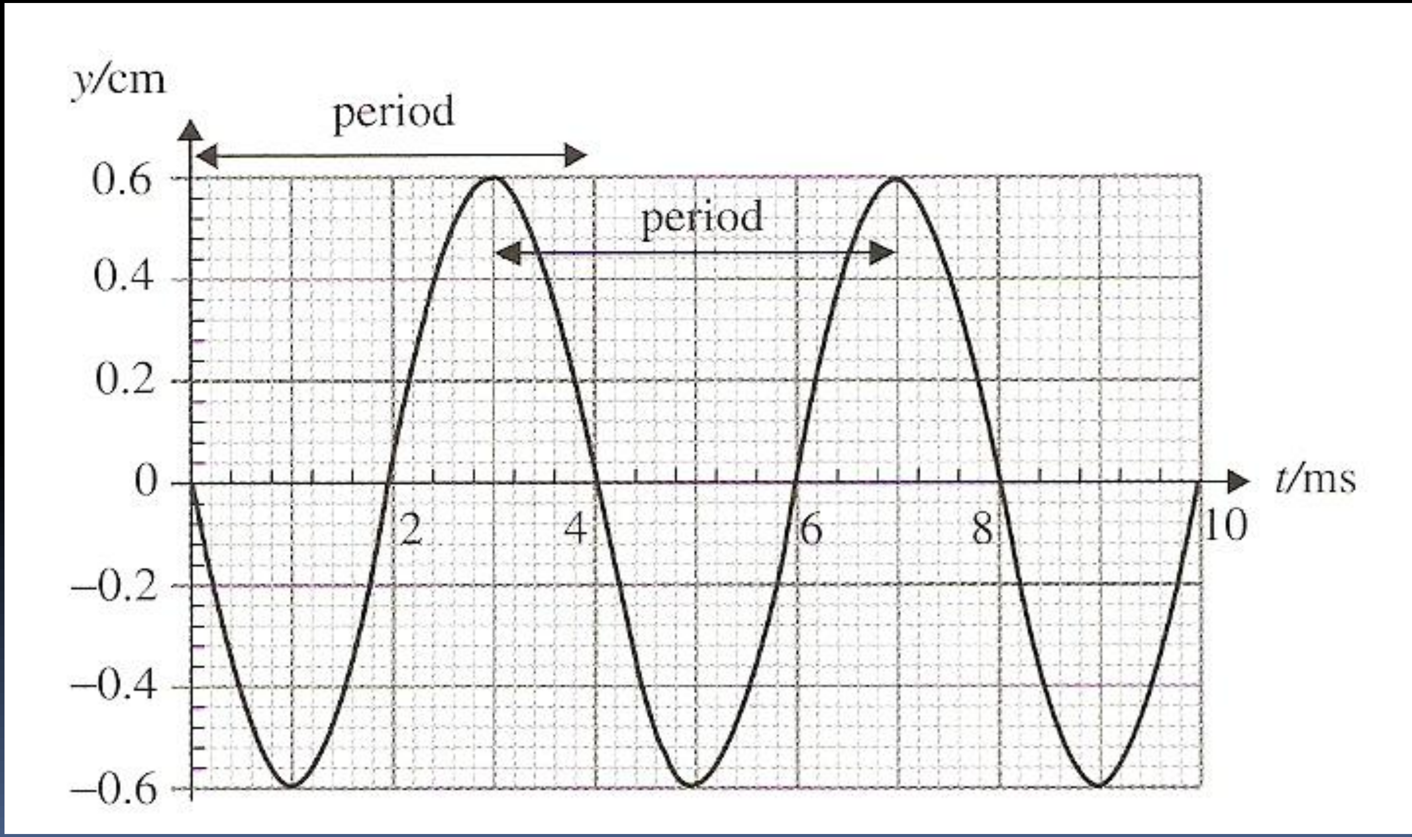
Displacement Versus *Position* Graph

- **determines *wavelength***



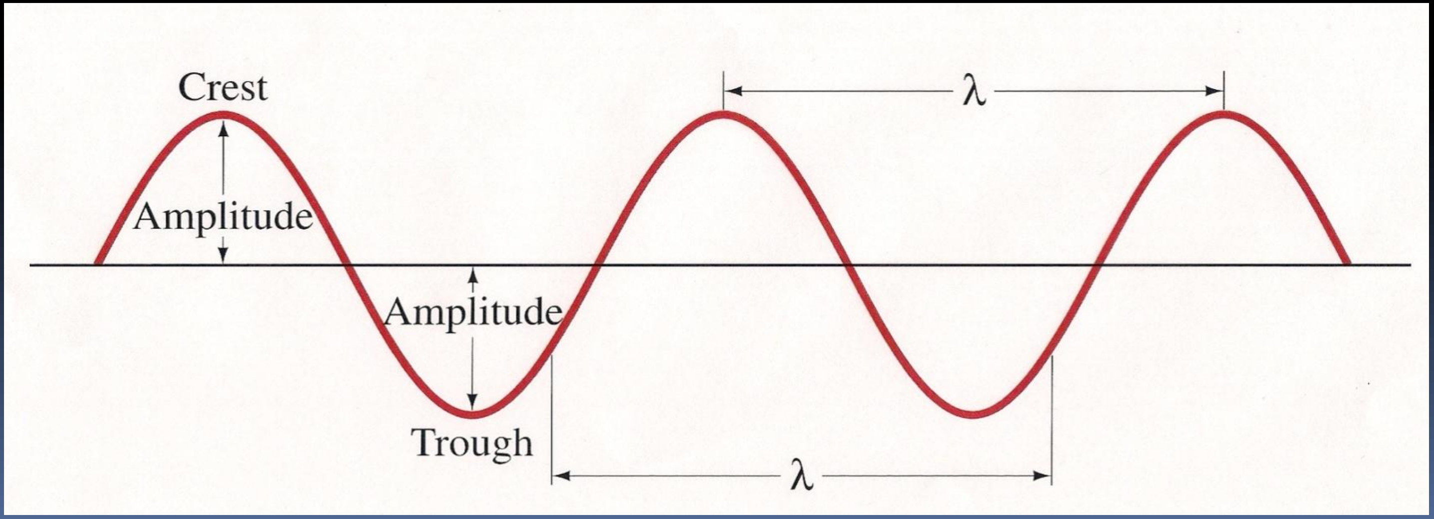
Displacement Versus *Time* Graph

- **determines *period***



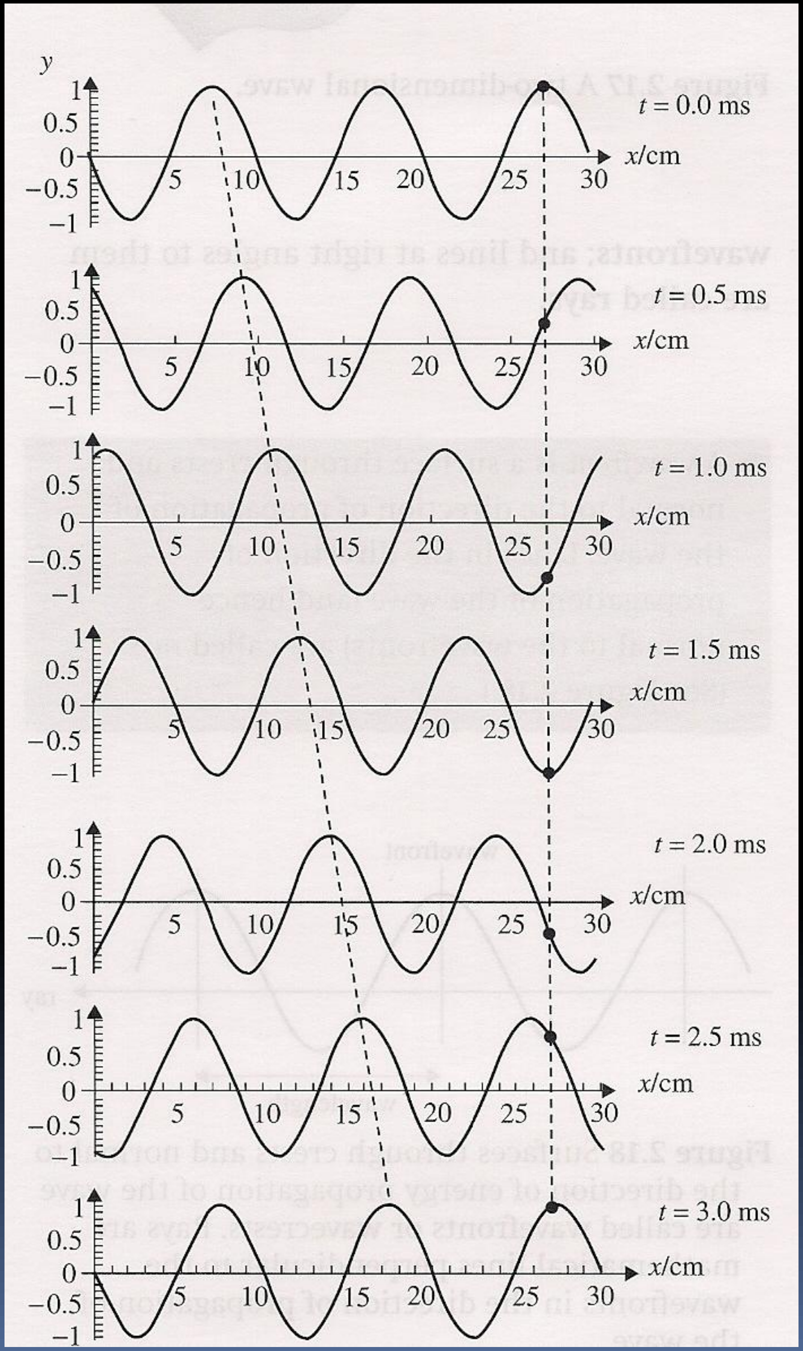
Other Wave Stuff

- **Points on the wave with maximum displacement are call *crests* and those at the minimum displacement are called *troughs***



Other Wave Stuff

- **In a travelling wave, the crests will steadily move forward until the period is reached which is where the wave will look like it originally did when it was disturbed**



Example Questions:

- *A radio station emits at a frequency of 90.8 MHz. What is the wavelength of the waves emitted?*

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- ***A radio station emits at a frequency of 90.8 MHz. What is the wavelength of the waves emitted?***
  - Since they are electromagnetic waves, they travel at the speed of light, $3x10^8$ m/s
  - $f = 90.8x10^6\ s^{-1}$

$$v = \lambda f$$

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{3x10^8}{90.8x10^6}$$

$$\lambda = 3.3m$$

Example Questions:

- *A sound wave of frequency 450Hz is emitted from A and travels towards B, a distance of 150m away. Take the speed of sound to be 341 m s^{-1} . How many wavelengths fit in the distance from A to B?*

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- *A sound wave of frequency 450Hz is emitted from A and travels towards B, a distance of 150m away. Take the speed of sound to be 341 m s^{-1} . How many wavelengths fit in the distance from A to B?*
  - f = 450 s^{-1}
  - v = 341 m s^{-1}

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{341}{450} = 0.758$$

$$\frac{150m}{0.758m} = 198$$

Example Questions:

- *The noise of thunder is heard 3 s after the flash of lightning. How far away is the place where the lightning struck? (Use 340 m s^{-1} for the speed of sound)*

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- *The noise of thunder is heard 3 s after the flash of lightning. How far away is the place where the lightning struck? (Use 340 m s^{-1} for the speed of sound)*
  - Since light travels so fast, you can assume you saw it instantaneously.
  - v x t = d
  - (340 m s^{-1})(3 s) = 1020 m
  - 1609 m = 1 mi

Wavefronts and Rays

- If you consider a wave to be moving horizontally, a ***wavefront*** is a plane perpendicular to the wave and perpendicular to the direction the wave is travelling

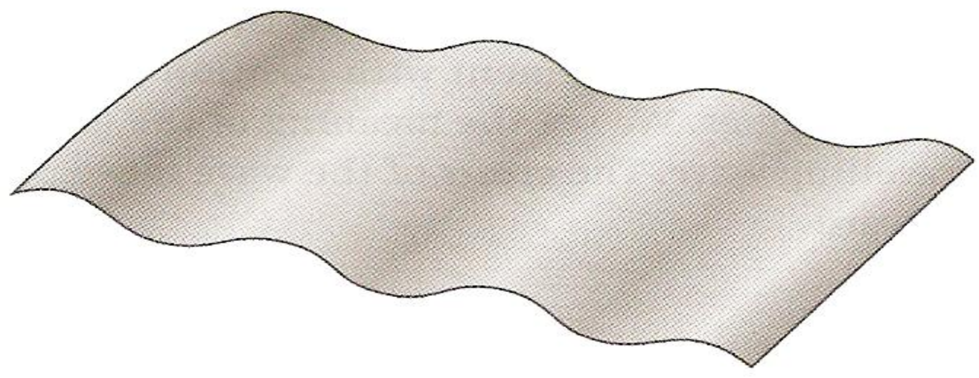
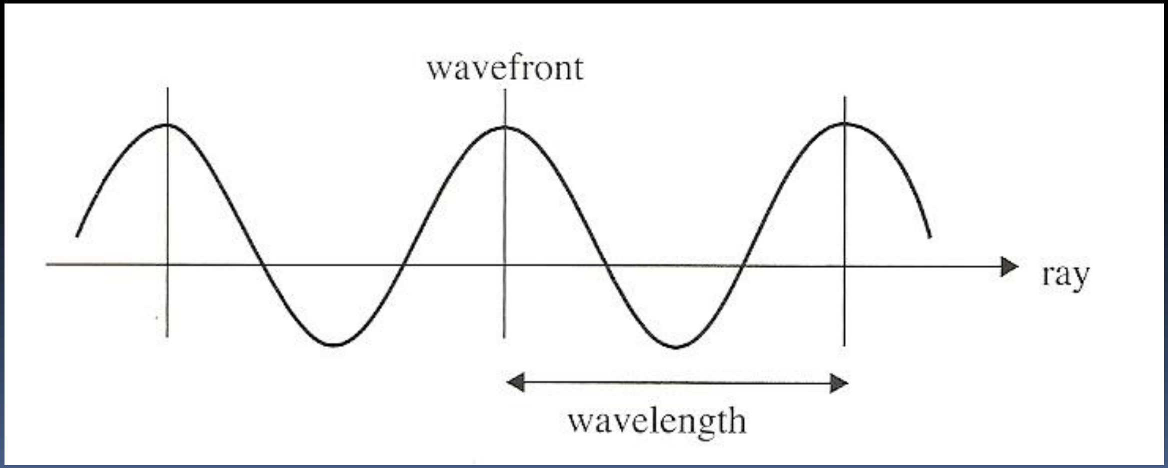


Figure 2.17 A two-dimensional wave.

Wavefronts and Rays

- Rays are a pretty good baseball team
- They are also lines perpendicular to the wavefronts in the direction the wave is travelling



Wavefronts and Rays

- Examples:
  - The waves on the beach would have a rectangular wavefront
  - If you drop a stone in the water, the wavefront would be cylindrical
  - Light waves from a point source would have spherical wavefronts

Wavefronts and Rays

- **Example Question: Why do waves from a rock thrown into a lake eventually die out?**

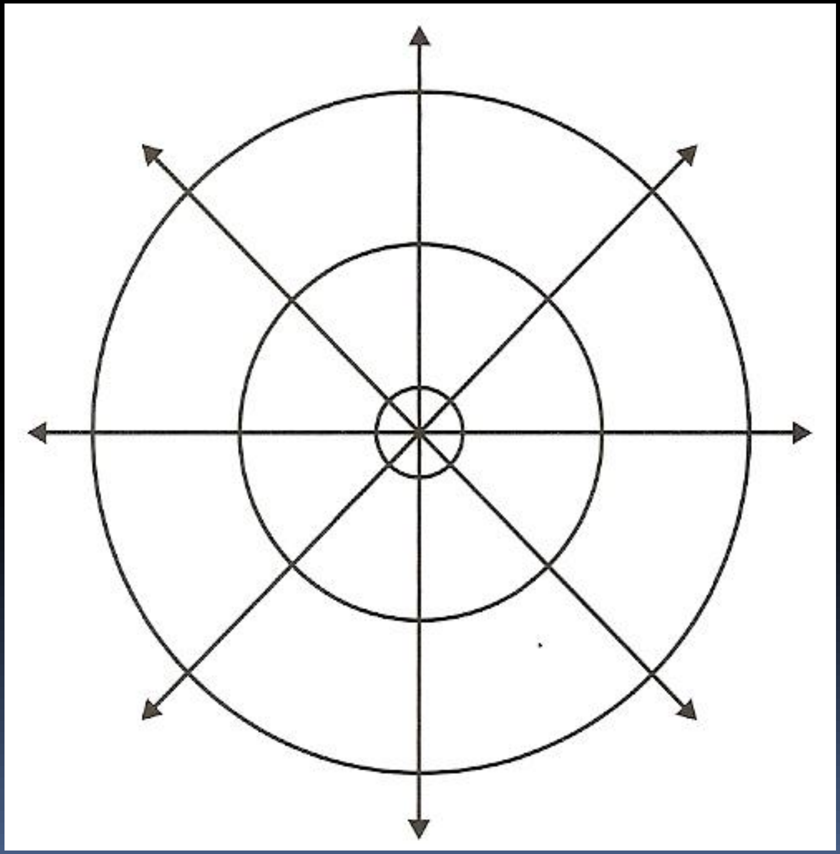
Example question

Q7

A stone dropped in still water creates circular ripples that move away from the point of impact. The initial height of the ripple is about 2.4 cm and the wavelength is 0.5 m. Draw a sketch of the displacement of the ripples as a function of the distance from the point of impact.

Wavefronts and Rays

- **Example Question: Why do waves from a rock thrown into a lake eventually die out?**



Wavefronts and Rays

- **Example Question: Why do waves from a rock thrown into a lake eventually die out?**

Answer

The energy carried by the wave is distributed along the (circular) wavefronts. As the wave moves away from the point of impact, the length of the wavefront increases and so the energy per unit wavefront length decreases. Thus, the amplitude has to decrease as well. So we get the graph shown in Figure 2.20.

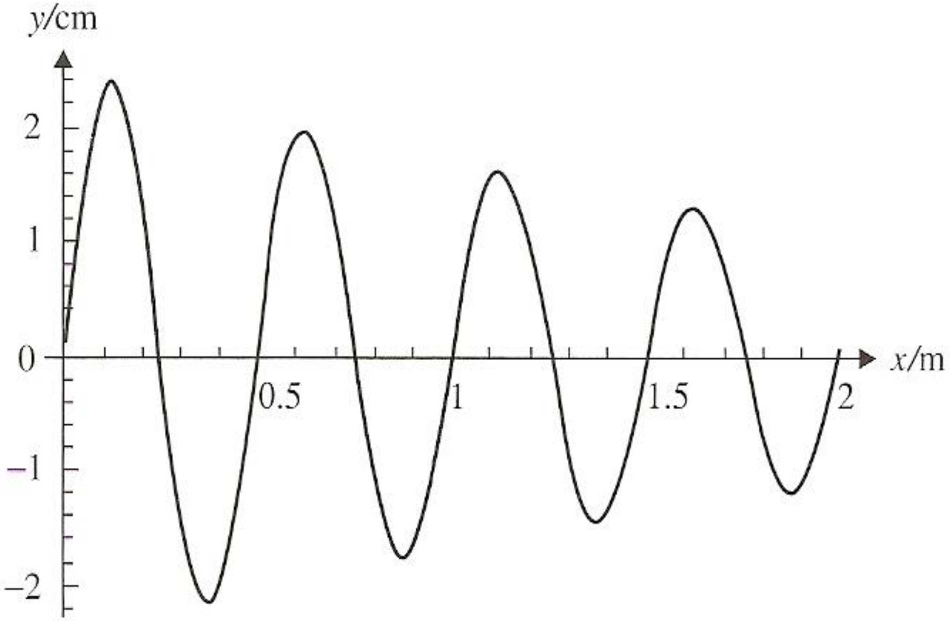


Figure 2.20.

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Essential Idea:

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QUESTIONS?

Homework

#6-14