Lecture 01: **01/16/2024**

- Goals
- Announcements
  - Recitation
  - Labs
  - Grading
  - Syllabus
  - Homework
  - Text
  - Clickers
  - Questions

- Waves (Chapter 16, Volume 1)

Goals

- Learn about Electricity, Magnetism and Electromagnetism

- Why?

  - It's useful
    Computers, Cell Phones
    Motors, Generators, Transformers
    Lasers, particle beams

  - It's beautiful
    Four equations describe all there is to know

  - It's verifiable and tested
    In a world of misinformation, it is a stable place to stand

Maxwell's Equations

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \times \vec{B} = \mu_0 \vec{J}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{B} = 0$$

Recitation

- Homework help and problem solving practice
- This week –
  - Assessment Exam
  - Setup Expert TA
  - Bring a laptop/tablet or smartphone

- Requirements / What to expect
  - Attendance required (10% of grade)
  - TA works 2-3 selected problems
  - Groups of 3-4, each assigned at least one homework problem
  - Group representative presents problem at the board
  - Every member of every group must present in rotation
  - Ticket to leave: Submit worked version of your problem to TA

Lab

- There will be a brief lab meeting this week.
- Full time labs start next week

Grading

Spring 2024 - PHYS-1320-04-Calculus-based Physics II

Jump to Today Edit

Physics 1320 introduces electromagnetism. Almost everything about biology and chemistry can be described by a combination of electromagnetism and quantum mechanics. All electronic, computing and communications devices are applications of electromagnetism. Electromagnetism gives you the tools to understand how the climate crisis can be solved. Electromagnetism can be completely described by four equations called Maxwell's equations. Einstein's relativity was inspired by Maxwell. Particle physicists who seek a "Theory of Everything" are jealous of the beauty of Maxwell's equations.

Instructor: Richard Sonnenfeld

Office: Workman 341

E-mail: richard.sonnenfeld@nmt.edu

Office hours: 30 minutes immediately after class or by Appointment (Make appointment via e-mail)

Lectures: Sections 4, 5, 6 Tuesdays and Thursdays, 11:00 - 12:15, Workman 101

Recitations:

Section 4, Tuesday,	17:00 – 18:50	Workman 113	TA: Roberto Niardi (Roberto.Niardi@student.nmt.edu)
Section 5, Wednesday	19:00 – 20:50	Workman 113	TA: Rebecca Proni (Rebecca.Proni@student.nmt.edu)
Section 6, Thursday,	19:00 – 20:50	Workman 113	TA: Chamindri Hemendra (Chamindri.Hemendra@student.nmt.edu)

Full Textbook: OpenStax University Physics, *University Physics Volume 2*

https://openstax.org/details/books/university-physics-volume-2

OpenStax University Physics, *University Physics Volume 1 (Only for Waves unit)*

https://openstax.org/details/books/university-physics-volume-1

Director's Cut: Dr. Sonnenfeld's edited version that highlights specifically the material you need to know.

Marking:

30% - Homework

10% - Class Participation (half clickers / half presence)

10% - Recitation (attendance and board work)

30% - 2 x “mid-term” exams (the highest exam grade will count 20% and the lowest 10%)

20% - Final exam

*Note that students must achieve at least 50% in each of the categories

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This class has an idiosyncratic grading scheme (The Aussie System!) This is NOT the standard NM Tech grading scheme.

Grading Scheme:

Numerical Ave.	Grade
90-100	A
80-90	A-
77-79	B+
73-76	B
70-72	B-
67-69	C+
63-66	C
60-62	C-
55-59	D+
51-54	D
<=50	F

Syllabus

Week	Date (Monday)	Lectures	Key topics	Lab
1	Jan 15	Volume 1 Ch16	Introduction, Waves	lab intro
2	Jan 22	Volume 2 Ch 5	Electric Charges and Coulomb's Law	Wave Superposition
3	Jan 29	Ch 5	Electric Field and Field Lines	Oscilloscopes
4	Feb 5	Ch 6	Gauss's Law	Coulomb's Law
5	Feb 12	Ch 7	Electric Potential & Potential Diff	E-field and Superposition principl
6	Feb 19	Test 1		Electric Field Mapping
7	Feb 26	Ch 8	Capacitance	Capacitors and Dielectrics
8	Mar 4	Ch 9	Current and Resistance	Ohm's Law
9	Mar 11	Ch 10	DC Circuits	Kirchhoff's Laws
10	Mar 18		SPRING BREAK	
11	Mar 25	Ch 11	Magnetic Forces and Fields	Magnetic Forces
12	Apr 1	Test 2		Magnetic Forces II
13	Apr 8	Ch 12	Sources of Magnetic Fields	Faraday's Law
14	Apr 15	Ch 13	Electromagnetic Induction	Mutual Inductance
15	Apr 22	Ch 16	Maxwell's Equations & EM Waves	Displacement Current

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{B} = \mu_0 \vec{J}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

Homework

- Every week there will be online homework with ExpertTA
- There will also be written homework … on paper, which you will upload to Canvas.

Text

- The text is wordy, but backs up the lecture
- It is likely that there will be “required” items that I cannot cover sufficiently in lecture.
- I have edited the text to eliminate sections that we will skip entirely.
- The edited text is available as the “Director’s Cut”

B1Ch16_Waves_RSedit.pdf

File Edit View Go Bookmarks Help

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Key Equations

Wave speed	$v = \frac{\lambda}{T} = \lambda f$
Linear mass density	$\mu = \frac{\text{mass of the string}}{\text{length of the string}}$
Speed of a wave or pulse on a string under tension	$\lvert v \rvert = \sqrt{\frac{F_T}{\mu}}$
Speed of a compression wave in a fluid	$v = \sqrt{\frac{B}{\rho}}$
Resultant wave from superposition of two sinusoidal waves that are identical except for a phase shift	$y_R(x,t) = \left[2A\cos\left(\frac{\phi}{2}\right)\right]\sin\left(kx - \omega t + \frac{\phi}{2}\right)$
Wave number	$k \equiv \frac{2\pi}{\lambda}$
Wave speed	$v = \frac{\omega}{k}$

A periodic wave	$y\,(x, t) = A \sin\,(kx \mp \omega t + \phi)$
Phase of a wave	$kx \mp \omega t + \phi$
The linear wave equation	$\frac{\partial^2 y(x,t)}{\partial x^2} = \frac{1}{v_w^2}\frac{\partial^2 y(x,t)}{\partial t^2}$
Power averaged over a wavelength	$P_{\text{ave}} = \frac{E_\lambda}{T} = \frac{1}{2}\mu A^2 \omega^2 \frac{\lambda}{T} = \frac{1}{2}\mu A^2 \omega^2 v$
Intensity	$I = \frac{P}{A}$
Intensity for a spherical wave	$I = \frac{P}{4\pi r^2}$
Equation of a standing wave	$y\,(x, t) = [2A \sin\,(kx)] \cos\,(\omega t)$
Wavelength for symmetric boundary conditions	$\lambda_n = \frac{2}{n}L, \quad n = 1, 2, 3, 4, 5...$
Frequency for symmetric boundary conditions	$f_n = n\frac{v}{2L} = nf_1, \quad n = 1, 2, 3, 4, 5...$

Summary

iClicker

- We will start using iClicker cloud next week.
- You should have been invited to join or update your account. It costs $16.
- Let me know if you have any issues at all or did not receive the invitation.

Blue

Albus

Romana

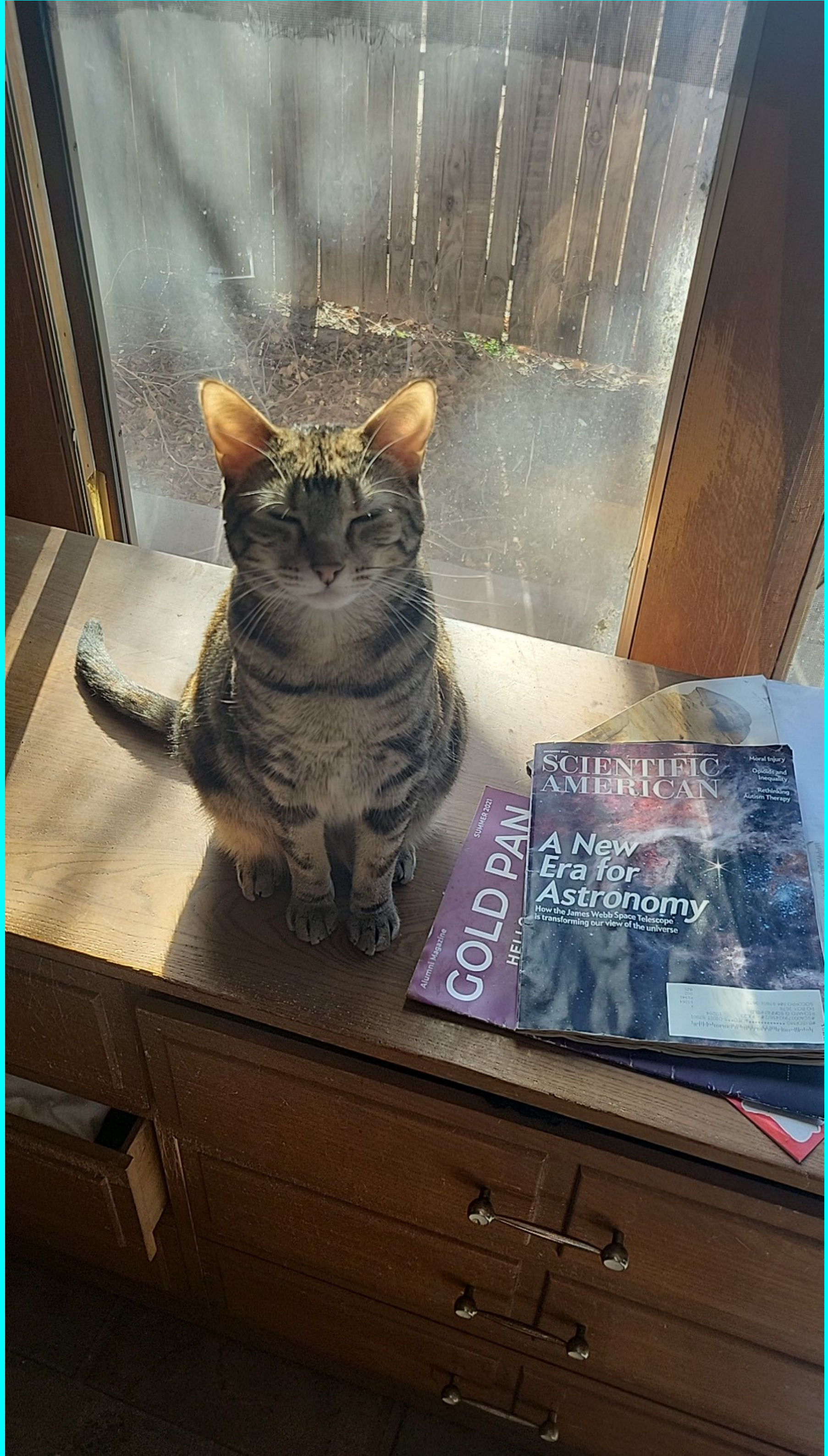
River Soong

cycles/s

$f = \text{Hz}$ $\quad \frac{1}{s}$

$\omega = \text{rad/s}$

$\omega = 2\pi f$



Waves Outline (Ch 16, Vol 1)

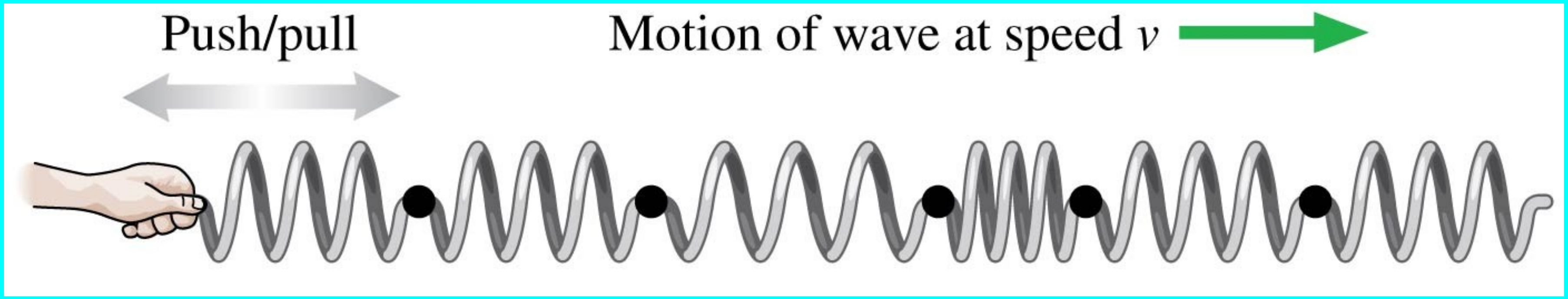
Transverse and Longitudinal Waves

$$v = f\lambda$$
$$y = A\sin k(x - vt)$$
$$y = A\sin(kx - \omega t)$$
$$v = \sqrt{\frac{T}{\mu}}$$

Relation of wave and simple harmonic oscillator

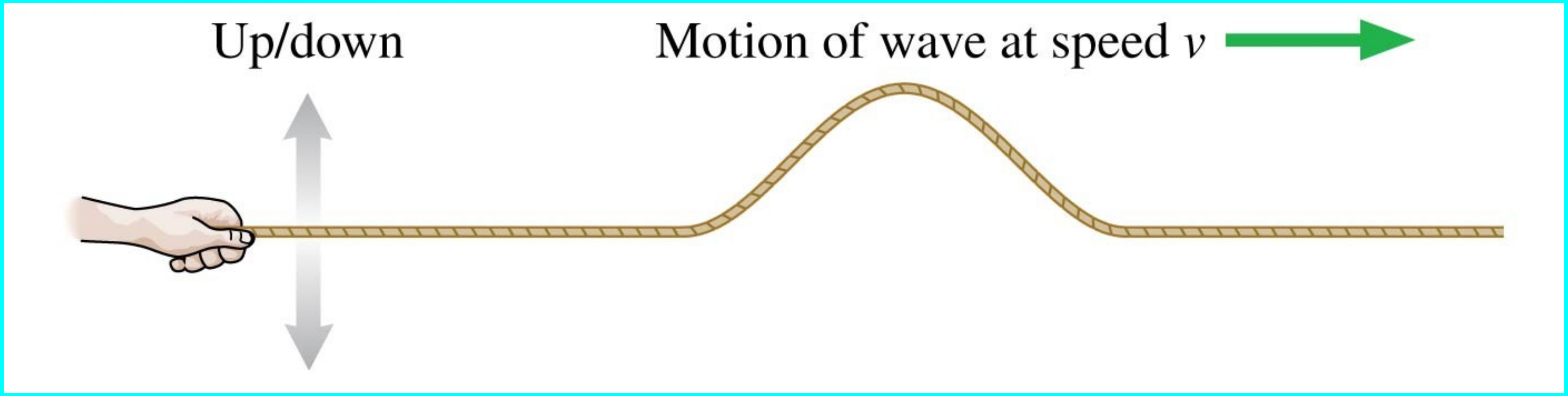
A Longitudinal Wave

- In a **longitudinal wave**, the particles in the medium move *parallel* to the direction in which the wave travels.
- Here we see a chain of masses connected by springs.
- If you give the first mass in the chain a sharp push, a disturbance travels down the chain by compressing and expanding the springs.



A Transverse Wave

- A **transverse wave** is a wave in which the displacement is *perpendicular* to the direction in which the wave travels.
- For example, a wave travels along a string in a horizontal direction while the particles that make up the string oscillate vertically.



What type of wave is this?

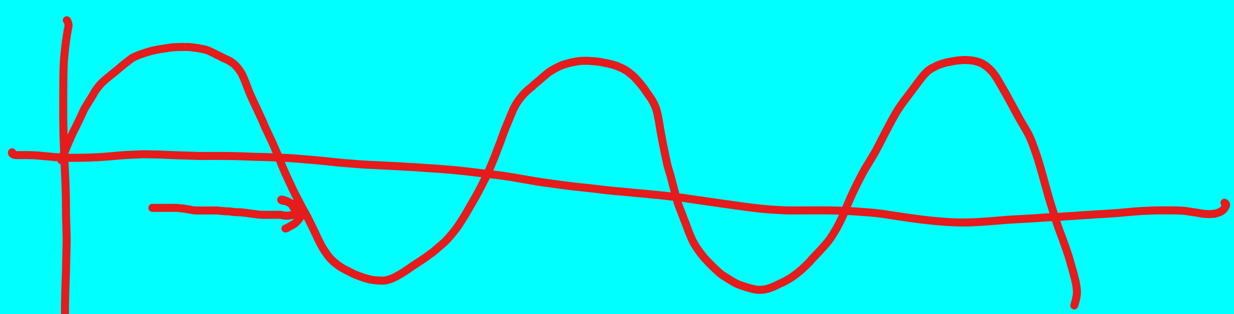
Meow Longit

Bark Transverse

Sound — L: Sound

Ocean — T: ✓

Slinky — L: ✓ — T: ✓ ✓



Math of Waves

A wave is any function of the form

$$y = A\,f(x - v\,t)$$

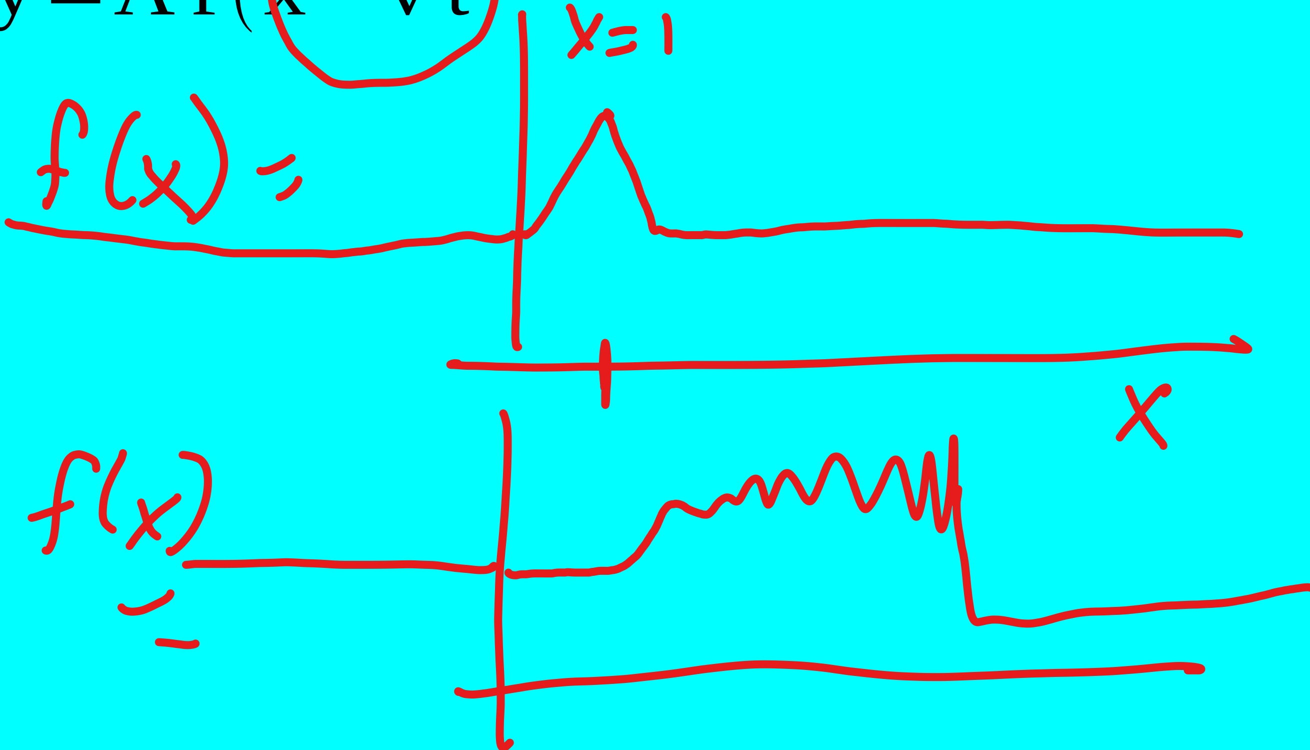
$v = f\lambda$

$x - vt = 1$

$x = vt + 1$

$x - 1 = vt$

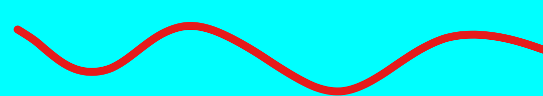
$\frac{x-1}{v} = t$



$x = 4$

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

sine(kx − ωt)

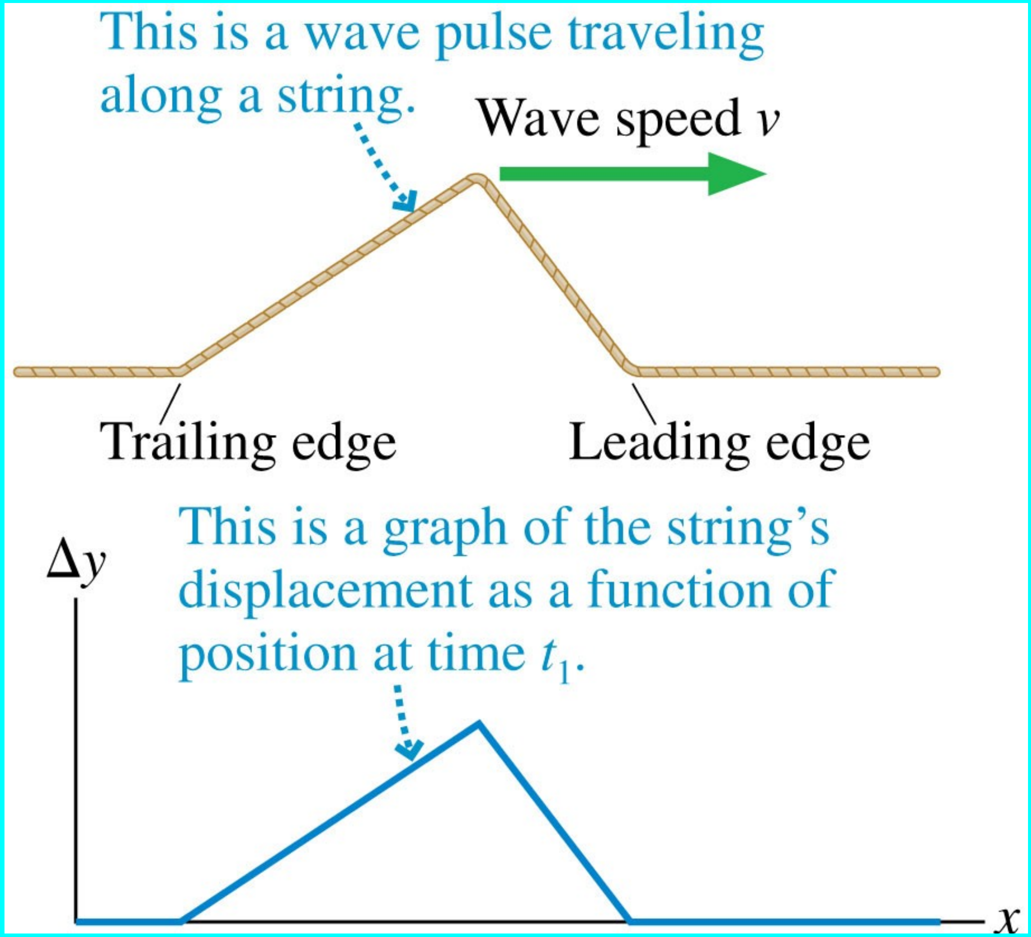


END LECTURE

Snapshot Graph

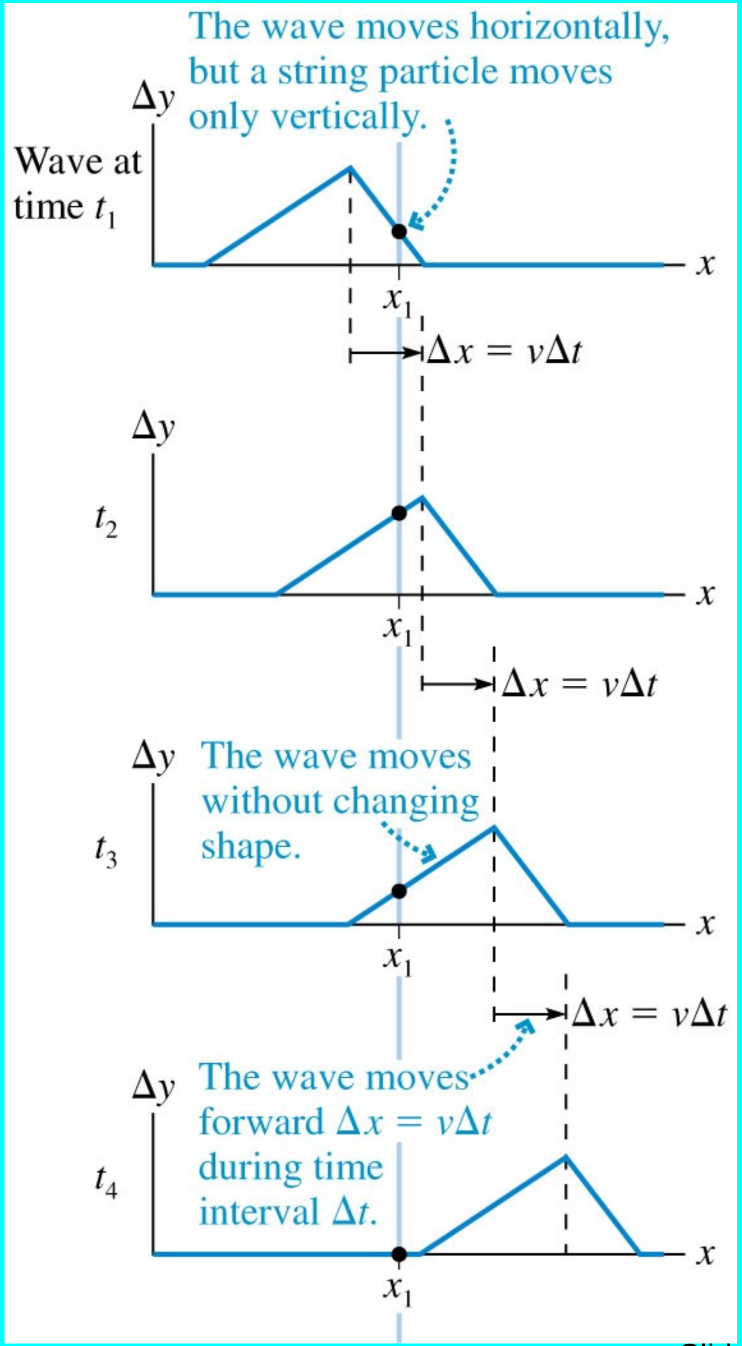
- A graph that shows the wave's displacement as a function of position at a single instant of time is called a **snapshot graph**.

- For a wave on a string, a snapshot graph is literally a picture of the wave at this instant.



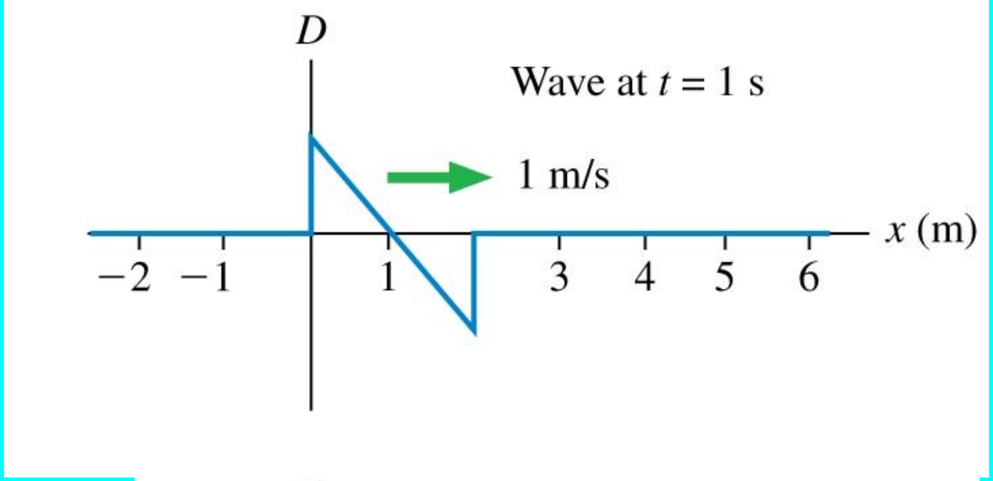
Math of One-Dimensional Waves

- The figure shows a sequence of snapshot graphs as a wave pulse moves.
- These are like successive frames from a movie.
- Notice that the wave pulse moves forward distance $\Delta x = v\Delta t$ during the time interval Δt.
- That is, the wave moves with *constant speed.*

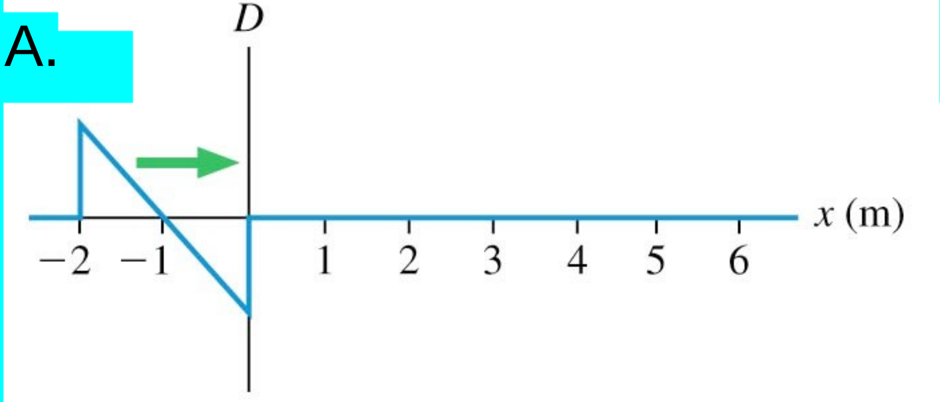


Clicker Question

This is a snapshot graph at $t = 1$ s of a wave pulse traveling to the right at 1 m/s. Which graph below shows the wave pulse at $t = –1$ s?



A.



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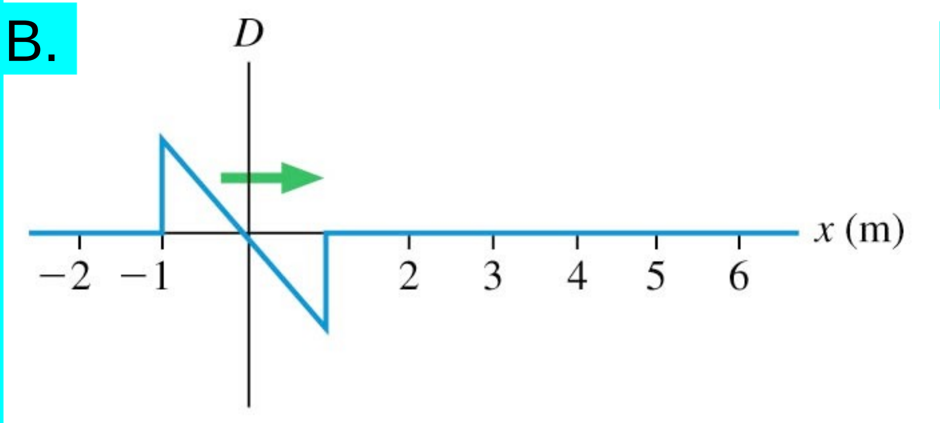

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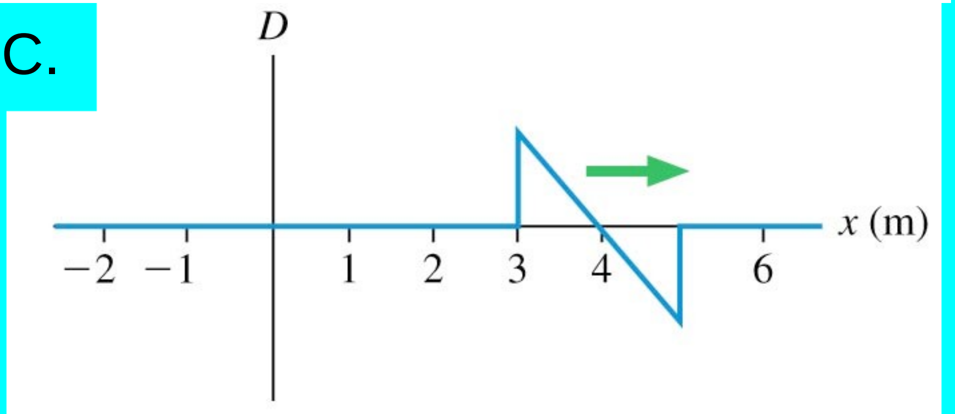
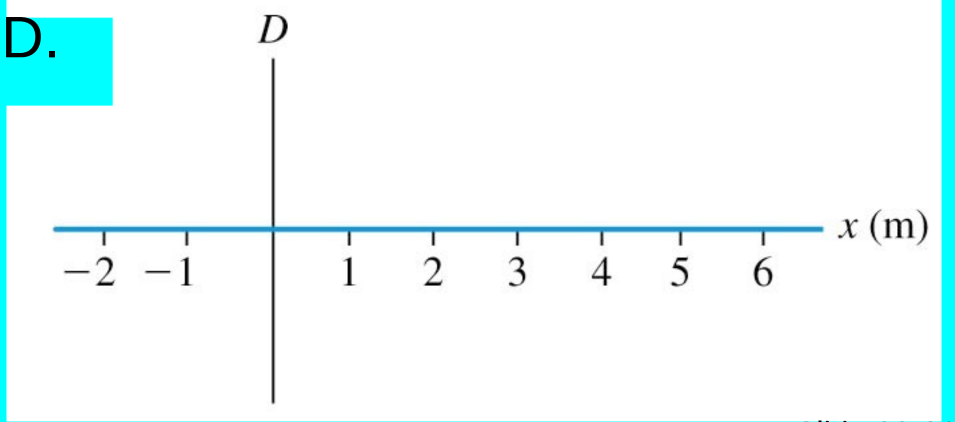


D.



Math of Waves

A wave is any function of the form

$$y = A\,f\left(x - v\,t\right)$$

But frequently we let the function "f" be a sine or cosine.

$$y = A \sin k\left(x - v\,t\right)$$

$v = f\lambda$

$v = \sqrt{T/\mu}$

$f = \text{const}$

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

set $f = 1$

$\lambda \sim v$

Math of Waves

What is the period of

$$y = A\sin(k v t)$$

$(A) \quad T = 2\pi$

$(B) \quad T = \pi$

$(C) \quad T = 2\pi k v$

$(D) \quad T = \frac{2\pi}{k v}$

Math of Waves

What is the wavelength of

$$y = A\sin(kx)$$

$(A)\quad \lambda = 2\pi$

$(B)\quad \lambda = \pi$

$(C)\quad \lambda = \dfrac{2\pi}{k}$

$(D)\quad \lambda = \dfrac{2\pi}{kv}$

Important relationships for Waves

Homework problem 48 (ish)

$$y = (2\ \text{cm})\sin\left(0.2\,\text{m}^{-1}x + 3\,\text{s}^{-1}t + \pi/10\right)$$

$T?\ \ v? \lambda ?, \phi ?$

pHeT time?

Homework problem 72 (ish)

$$y = (2\ \text{cm})\sin\left(0.2\,\text{m}^{-1}x + 3\,\text{s}^{-1}t + \pi/10\right)$$

Maximum vertical speed of string?

SHO vs. Wave

- Simple harmonic oscillator
  - One quantity (length of a spring, angle of a pendulum) varies in time.

$$L = L_0 \sin(\omega t)$$

- Wave
  - Continuous medium (e.g. air, string, water)
  - Each piece of string, or volume of air vibrates but not “in phase”
  - For sound, when one piece of air is compressed, another piece is rarefied

$$p = p_0 \sin(k x - \omega t)$$

Next Class:

Show that $$v = \sqrt{\frac{T}{\mu}}$$

And explain standing waves