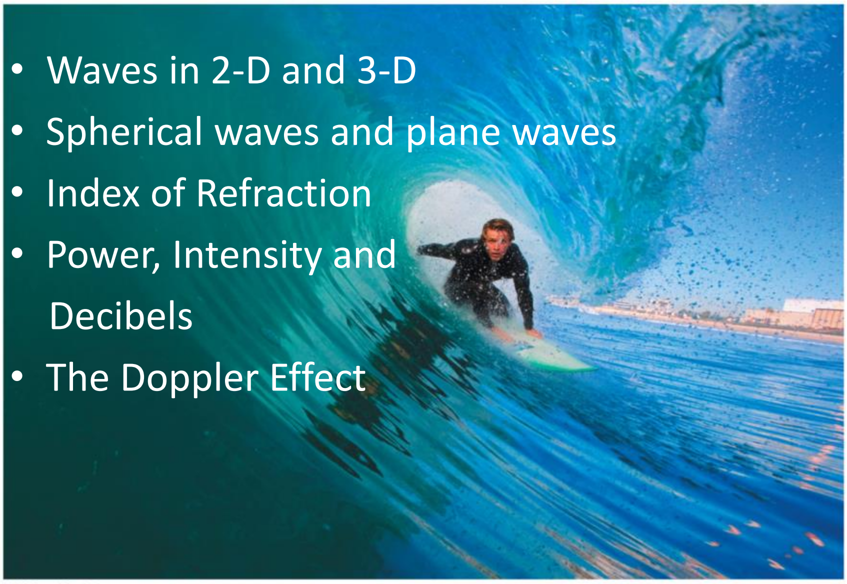
PHY132 Introduction to Physics II

Class 2 – Outline:



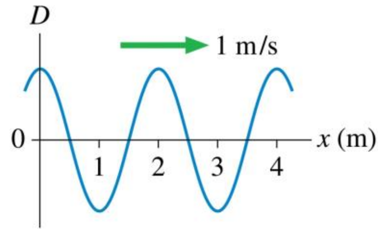
Last Time

- Mechanical Waves: waves that require a medium
- The wave travels through the medium. The wave speed is relative to that medium
- Many waves: “transverse” or “longitudinal”
- Sinusoidal waves
  - Source: Simple Harmonic Motion
  - Periodic in time (period T) and space (wavelength λ)

Clicker Question 1

Sinusoidal Wave Review

The period of this wave is



A. 1 s.

B. 2 s.

C. 4 s.

D. Not enough information to tell.

The postal code of University of Toronto is M5S1A1.

Class 2 Preclass Quiz on MasteringPhysics

- This was due this morning at 8:00am
- 651 students submitted the quiz on time
- 56% of students answered correctly: The "phase" of a sinusoidal wave is the argument of the sine function (what is in the brackets)
- 91% answered correctly: The speed of light in a material is determined by the **index of refraction**.
- 93% answered correctly: When a source is moving away from an observer, the observed frequency is changed due to the motion (also the wavelength, but that was not a choice listed)
- 94% answered correctly: The sound intensity level in decibels is related to the **logarithm** of the intensity.
- 95% answered correctly: Human ears can detect frequencies in the range 20 Hz up to 20,000 Hz

Class 2 Preclass Quiz on MasteringPhysics

- Some common or interesting student comments/feedback:
- *"Phi is the argument of the sin function correct? But why is there also a phi in the brackets?"*

"phase" = ϕ

$$D(x, t) = A \sin(kx - \omega t + \phi_0)$$

(sinusoidal wave traveling in the positive x-direction)

phase constant.

Short form:

$D(x,t) = A \sin \phi$

Class 2 Preclass Quiz on MasteringPhysics

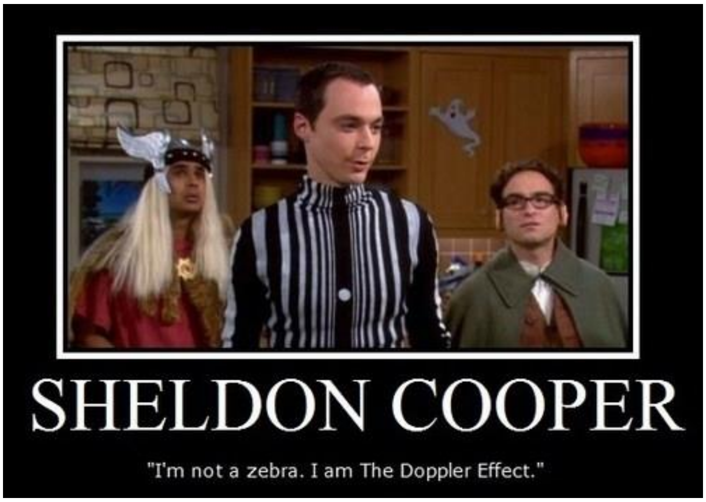
- *"Doppler effect. don't quite understand this. will it just have a higher or lower pitch as it's moving away/towards you?"*
- **Harlow answer:** Right! But it's higher if it's moving toward you, lower if it's moving away.
- *"Are we being marked on whether we get the right answer on these preclass quizzes? I'm slightly confused."*
- **Harlow answer:** Yes. You can always click on "Grading Policy" to see exactly how the marks are determined for any MasteringPhysics assignment.

Class 2 Preclass Quiz on MasteringPhysics

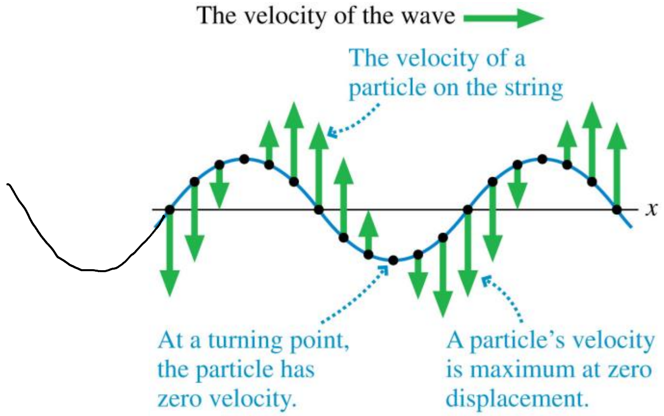
- *“The equations related to "Wave Motion on a String." Should we have to know the proof for v = sqrt (T/u) ? Or any part of that proof? I started seeing Ts and got confused.”*
- **Harlow answer:** We do not generally ask “proof” questions on tests and exams. However, I do think it is good to work through these so you can see where equations are coming from them, and understand and apply them better.
- *“That preclass quiz was "intense".”*
- *“Didn't actually read, since there's no way ur reading this unless u have no life, which i hope u do have one.”*
- *“How does intensity relates with numbers of sound sources? Is it directly proportional?”*
- **Harlow answer:** Yes. If you have N identical sources. The intensity at a certain distance will be N times the intensity from one of them.

Class 2 Preclass Quiz on MasteringPhysics

- The Doppler Effect. EEEEEEEEEEEeeeeeeeeeeeeeee
- The explanation on the doppler effect was really interesting, especially having pre-exposed to it in the Big Bang Theory!



Sinusoidal Waves

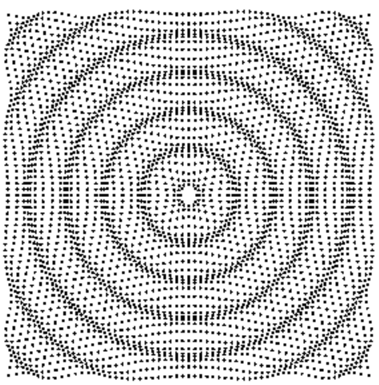


As the wave moves along x, the velocity of a particle on the string is in the y-direction.

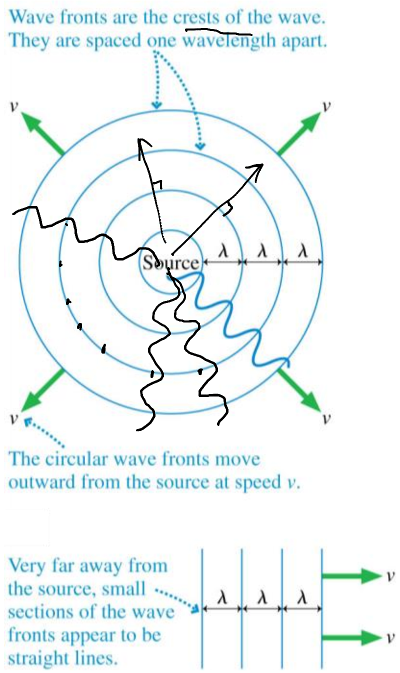
$$v_y = \frac{dy}{dt} = -\omega A\cos(kx - \omega t + \phi_0)$$

$$a_y = \frac{dv_y}{dt} = -\omega^2 A\sin(kx - \omega t + \phi_0)$$

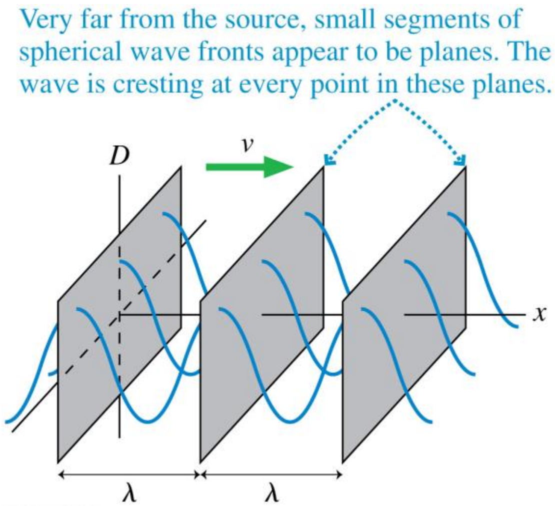
Waves in Two and Three Dimensions



[Animation courtesy of Dan Russell, Penn State]

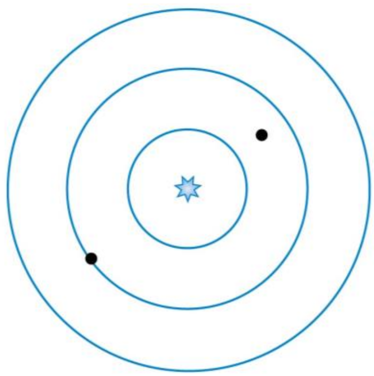


Waves in Two and Three Dimensions



Clicker Question 2

A spherical wave travels outward from a point source. What is the phase difference between the two points on the wave marked with dots?



A. $\pi/4$ radians.

B. $\pi/2$ radians.

C. π radians.

D. $7\pi/2$ radians.

E. 7π radians.

The Index of Refraction

- Light waves travel with speed *c* in a vacuum, but they slow down as they pass through transparent materials such as water or glass or even, to a very slight extent, air.
- The speed of light in a material is characterized by the material's index of refraction *n*, defined as

$$n = \frac{\text{speed of light in a vacuum}}{\text{speed of light in the material}} = \frac{c}{v}$$

The Index of Refraction

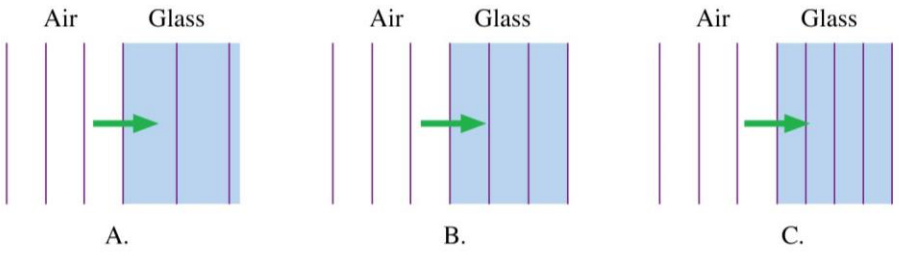
TABLE 20.2 Typical indices of refraction

Material	Index of refraction
Vacuum	1 exactly
Air	1.0003
Water	1.33
Glass	1.50
Diamond	2.42

Clicker Question 3

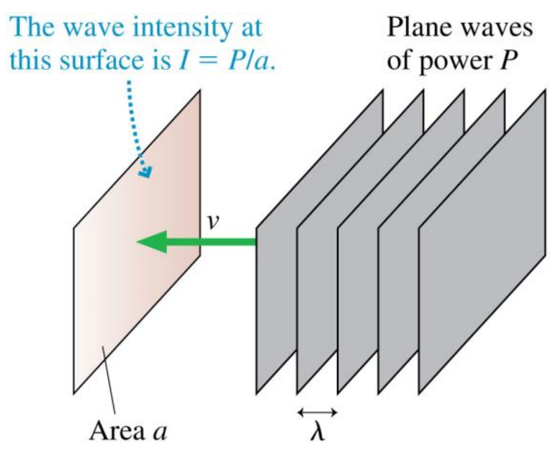
$v = f\lambda$

A light wave travels, as a plane wave, from air ($n = 1.0$) into glass ($n = 1.5$). Which diagram shows the correct wave fronts?



Power and Intensity

- The *power* of a wave is the rate, in joules per second, at which the wave transfers energy.
- When plane waves of power P impinge on area a, we define the **intensity** I to be:



$$I = \frac{P}{a} = \text{power-to-area ratio}$$

← units: $\frac{\text{Watts}}{m^2} = \frac{J}{s\,m^2}$

Example 20.9.
A laser pointer emits 1.0 mW of light power into a 1.0 mm diameter laser beam. What is the intensity of the laser beam?

$A = \pi r^2$

$r = 0.5 \times 10^{-3}\, m$

$I = \frac{P}{A} = \frac{P}{\pi r^2}$

$I = \frac{10^{-3}\, W}{3.14 \times (0.5 \times 10^{-3})^2}$

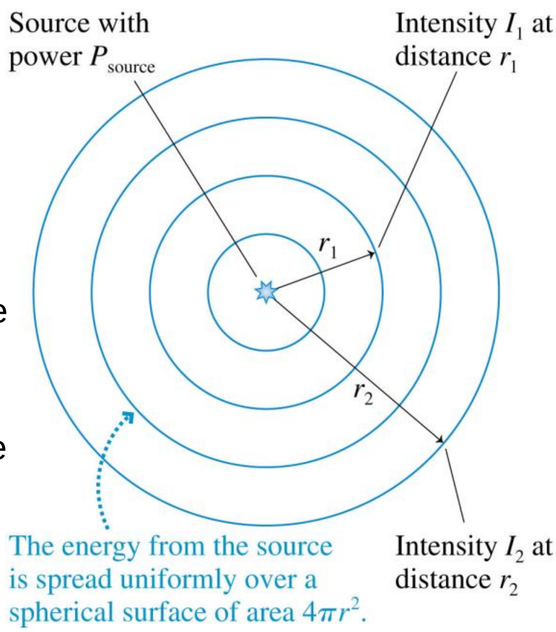
$= 1273$

$I = 1300\, \frac{W}{m^2}$

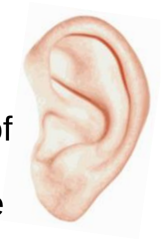
Intensity of Spherical Waves

- If a source of spherical waves radiates uniformly in all directions, then the power at distance *r* is spread uniformly over the surface of a sphere of radius *r.*
- The intensity of a uniform spherical wave is:

$$I = \frac{P_{source}}{4\pi r^2}$$



Intensity and Decibels



- Human hearing spans an extremely wide range of intensities, from the *threshold of hearing* at $\approx 1 \times 10^{-12}$ W/m^2 (at midrange frequencies) to the *threshold of pain* at ≈ 10 W/m^2.
- If we want to make a scale of loudness, it's convenient and logical to place the zero of our scale at the threshold of hearing.
- To do so, we define the **sound intensity level**, expressed in **decibels** (dB), as:

$$\beta = (10\text{ dB})\log_{10}\left(\frac{I}{I_0}\right)$$

where $I_0 = 1 \times 10^{-12}$ W/m^2.

$\beta = 10 \log\left(\frac{I_0}{I_0}\right) = 10 \log 1 = 0$

TABLE 20.3 Sound intensity levels of common sounds

Sound	β (dB)
Threshold of hearing	0
Person breathing, at 3 m	10
A whisper, at 1 m	20
Quiet room	30
Outdoors, no traffic	40
Quiet restaurant	50
Normal conversation, at 1 m	60
Busy traffic	70
Vacuum cleaner, for user	80
Niagara Falls, at viewpoint	90
Snowblower, at 2 m	100
Stereo, at maximum volume	110
Rock concert	120
Threshold of pain	130

each step of $\Delta\beta = 10$ corresponds to an increase of a factor of 10 in I.

Clicker Question 4

- A sound level of 10 decibels has 10 times more intensity than a sound level of zero decibels.
- A sound level of 20 decibels has ___ times more intensity than a sound level of zero decibels.

A. 10
B. 20
C. 50
D. 100
E. 200

Clicker Question 5

- When you turn up the volume on your ipod, the sound originally entering your ears at 50 decibels is boosted to 80 decibels. By what factor is the intensity of the sound has increased?

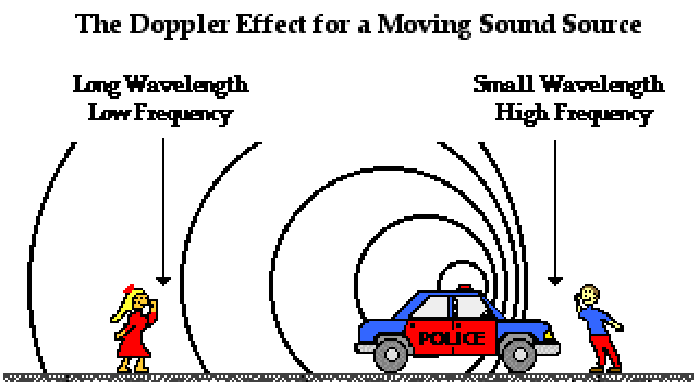
A. 1 (no increase)
B. 30
C. 100
D. 300
E. 1000

Doppler Effect

- If a sound source is not moving relative to you, you hear the “rest frequency” of the emitted sound.
- If the source is moving toward you, you will hear a frequency that is higher than the rest frequency.
- If the source is moving away from you, you will hear a frequency that is lower than the rest frequency.

- By measuring the difference between the observed and known rest frequencies, you can determine the speed of the source.

Doppler Effect



[image from http://www.physicsclassroom.com/class/waves/u10l3d.cfm]

Clicker Question 6

Which statement is true?

Valerie is standing in the middle of the road, as a police car approaches her at a constant speed, v. The siren on the police car emits a "rest frequency" of f_0.

A. The frequency she hears rises steadily as the police car gets closer and closer.
B. The frequency she hears steadily decreases as the police car gets closer and closer.
C. The frequency she hears does not change as the police car gets closer.

Clicker Question 7

Which statement is true?

Valerie is standing in the middle of the road, listening to the siren of a police car approaching her at a constant speed, v. Daniel is listening to a similar siren on a police car that is not moving.

A. The frequency Daniel hears is lower than the frequency Valerie hears.
B. The frequency Daniel hears is higher than the frequency Valerie hears.
C. The frequencies that Daniel and Valerie hear are exactly the same.

The Doppler Effect

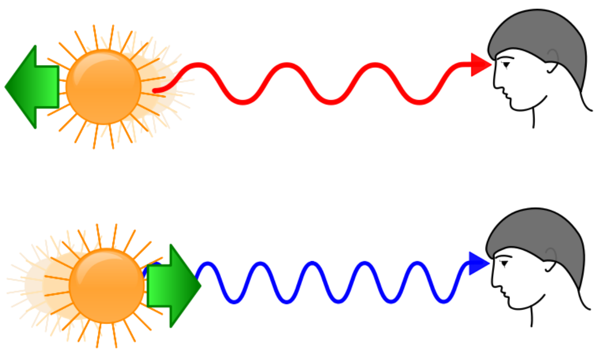
The frequencies heard by a stationary observer when the sound source is moving at speed v_0 are

$$f_+ = \frac{f_0}{1 - v_s/v} \quad \text{(Doppler effect for an approaching source)}$$
$$f_- = \frac{f_0}{1 + v_s/v} \quad \text{(Doppler effect for a receding source)} \qquad (20.39)$$

The frequencies heard by an observer moving at speed v_0 relative to a stationary sound source emitting frequency f_0 are

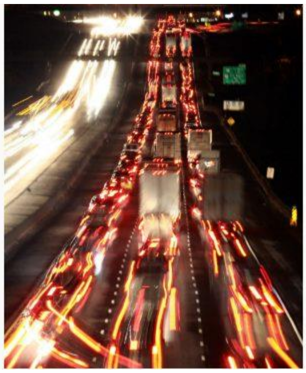
$$f_+ = (1 + v_o/v)f_0 \quad \text{(observer approaching a source)}$$
$$f_- = (1 - v_o/v)f_0 \quad \text{(observer receding from a source)} \qquad (20.40)$$

Doppler Shift for Light



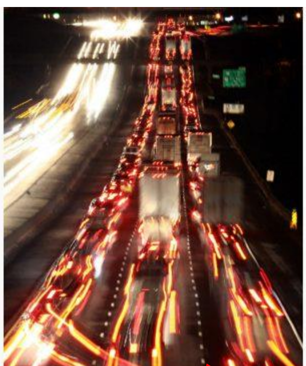
- When a light source is moving away from you, the spectrum is shifted toward the red.
- When a light source is moving toward you, the spectrum is shifted toward the blue.

Doppler Shift for Light



- The Doppler shift can be observed in the headlights of cars on the highway.
- The cars moving away from you appear more red, while the cars moving toward you appear more blue-ish or white.

Doppler Shift for Light

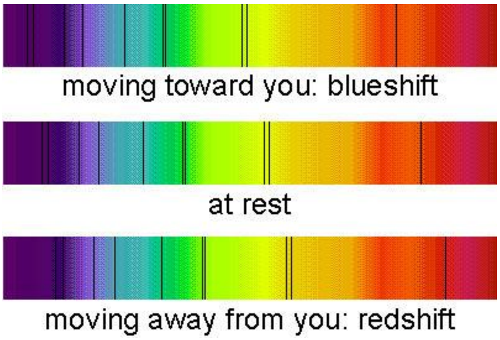


wthhh hhhhh hhhh??

- The Doppler shift can be observed in the headlights of cars on the highway.
- The cars moving away from you appear more red, while the cars moving toward you appear more blue-ish or white.

wrong

Doppler Shift for Light (yes, really!)



- The Doppler shift can be observed with carefully obtained spectra of very fast moving objects like stars
- There is a slight shift in “absorption lines”

Before Class 3 on Monday

- Please read Knight pages 591-603: Ch. 21, sections 21.1-21.4
- Please do the short pre-class quiz on MasteringPhysics by Sunday evening.
- Something to think about: What is the difference between a traveling wave and a standing wave. Does a standing wave really stand still?