

EOT Solution Term 3 Physics Grade 9 Advanced



تم تحميل هذا الملف من موقع المناهج الإماراتية

موقع المناهج ← المناهج الإماراتية ← الصف التاسع المتقدم ← فيزياء ← الفصل الثالث ← ملفات متنوعة ← الملف

تاريخ إضافة الملف على موقع المناهج: 2026-06-07 13:12:41

ملفات اكتب للمعلم اكتب للطالب | اختبارات الكترونية | اختبارات | حلول | عروض بوربوينت | أوراق عمل
منهج انجليزي | ملخصات وتقارير | مذكرات وبنوك | الامتحان النهائي | للمدرس

المزيد من مادة
فيزياء:

إعداد: Jadhav Kailas

التواصل الاجتماعي بحسب الصف التاسع المتقدم



صفحة المناهج
الإماراتية على
فيسبوك

الرياضيات

اللغة الانجليزية

اللغة العربية

التربية الاسلامية

المواد على تلغرام

المزيد من الملفات بحسب الصف التاسع المتقدم والمادة فيزياء في الفصل الثالث

ملزمة الوحدة 13 الاهتزازات

1

ورقة عمل عن خصائص و سلوك الموجات مع الحل

2

أسئلة اختبار الدرس الأول خصائص الموجات من الوحدة 13 الاهتزازات والموجات

3

ملزمة جميع دروس ووحدات الفصل الثالث منهج بريدج Bridge

4

عرض بوربوينت شرح القسم الثاني خصائص الموجات من وحدة الاهتزازات والموجات

5



وزارة التربية والتعليم
MINISTRY OF EDUCATION

GRADE 9 ADVANCED

INSPIRE PHYSICS

UNITED ARAB EMIRATES
MINISTRY OF EDUCATION



الإمارات العربية المتحدة
وزارة التربية والتعليم

EOT SOLUTION TERM 3

2025-2026

SUBJECT TEACHER : MR. KAILAS JADHAV

Grade 9, Advanced stream
Term Three:

Module 13: Vibrations and Waves

Lesson 2: Wave Properties

Lesson 2: Wave Behavior

Module 14: Sound

Lesson 1: Properties and Detection of Sound

Lesson 2: The Physics of Music

Required: “Sources of Sound – Resonance in Air Columns (Standing pressure wave)” pages 140-142

For enrichment: the remaining content of the lesson

Module 15: Fundamentals of Light

Lesson 1: Illumination

Lesson 2: The Wave Nature of Light

Academic Year العام الدراسي	2025-2026
Term/الفصل	T3
Subject الموضوع	Physics (Inspire)
Grade الصف	9
Stream. المسار	Advanced المتقدم



Number Of MCQ عدد الأسئلة الموضوعية	25
Markes of MCQ درجة الأسئلة الموضوعية	4
Type of All Questions نوع كافة الأسئلة	MCQ الأسئلة الموضوعية
Maximum Overall Grade الدرجة القصوى الممكنة	100
Exam Duration مدة الامتحان	120 min

Mode of implementation طريقة التطبيق	Swift Assess.
Calculator الآلة الحاسبة	Allowed مسموحة

MULTIPLE CHOICE QUESTIONS (MCQ) (QUE. 1 TO QUE. 25)

قد تظهر الأسئلة بترتيب مختلف في الامتحان الفعلي. / Questions might appear in a different order in the actual exam.

كما وردت في كتاب الطالب وLMS والخطة الفصلية. / As it appears in the textbook, LMS, and (Main_IP).

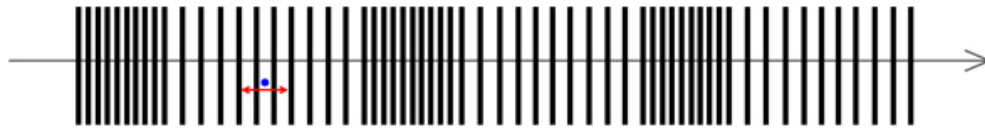
1

Differentiate between transverse, longitudinal, and surface waves and give examples

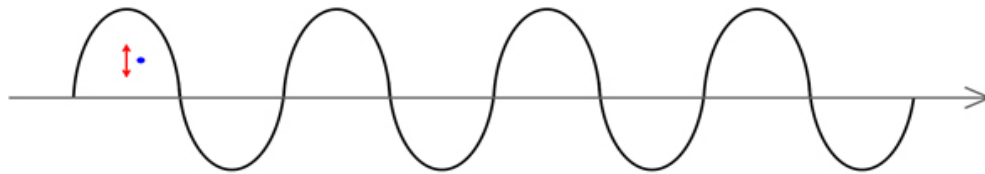
Students book,
Page 115-116

Types of Mechanical Waves

Longitudinal Wave: Particles vibrate parallel to the direction of propagation of the wave.

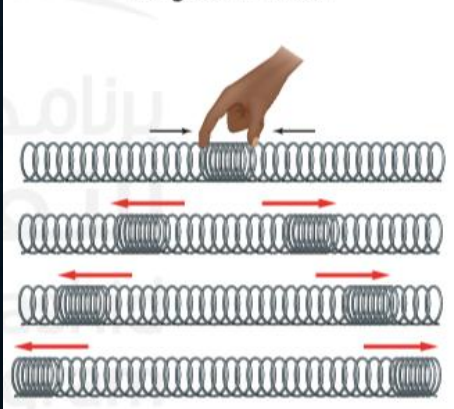


Transverse Wave: Particles vibrate perpendicular to the direction of propagation of the wave.

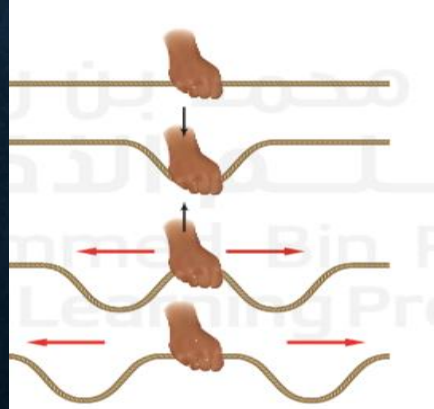


Science Facts.net

Longitudinal Wave

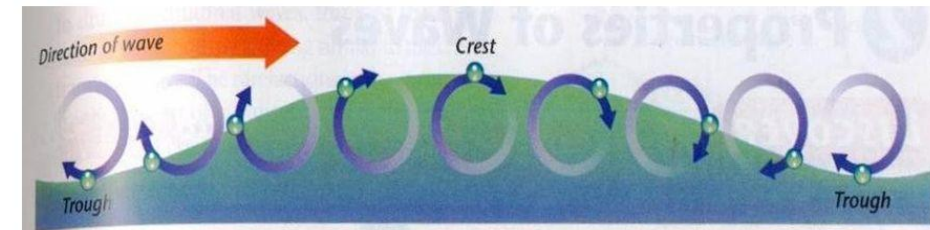


Transverse Wave



Surface Waves

- Combination of transverse and longitudinal waves
- Example: Water



Some examples of **transverse waves** are the ripples on the surface of water, vibrations on a guitar string, and electromagnetic waves such as light.
Some examples of **longitudinal waves** are sound waves and ultrasound waves

Feature	Transverse Wave	Longitudinal Wave	Surface Wave
Definition	A wave in which particles vibrate perpendicular to the direction of wave travel	A wave in which particles vibrate parallel to the direction of wave travel	A wave that travels along the surface between two different media (like water and air)
Particle Motion	Up and down	Back and forth	Circular or rolling motion
Direction of Vibration	At right angles to wave movement	Same direction as wave movement	Combination of transverse and longitudinal motion
Main Parts	Crest and trough	Compression and rarefaction	Crests, troughs, and circular motion
Medium Required	Can travel in solids or on surfaces; electromagnetic waves do not need a medium	Requires a material medium	Usually occurs at the boundary of two media
Example 1	Light waves	Sound waves in air	Ocean water waves
Example 2	Waves on a rope	Compression in a spring	Waves on the surface of a lake
Example 3	Seismic S-waves	Seismic P-waves	Ripple waves in water

2

Calculate the frequency of a wave from its period and vice-versa ($f = \frac{1}{T}$)

Apply the relation ($v = \lambda f$) to calculate the speed, wavelength, or frequency of a wave

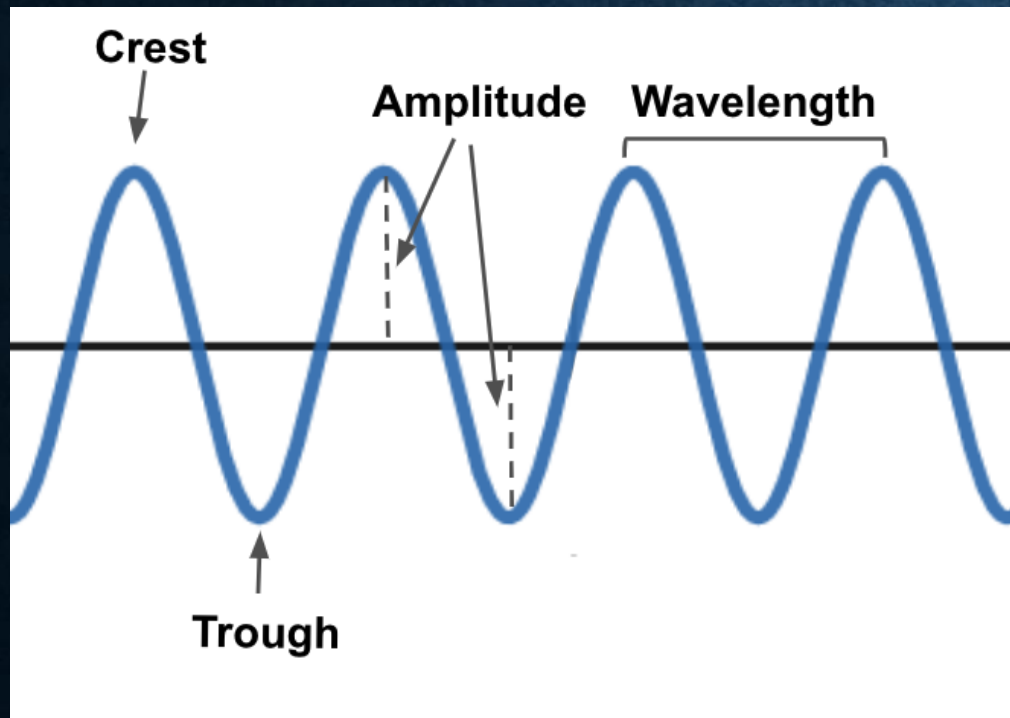
Students book Page 118

Example problem Q.3

Page 119

Practice problem

Q.14 to Q.23 Page 120



FREQUENCY OF A WAVE

The frequency of a wave is equal to the reciprocal of the period.

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

WAVELENGTH

The wavelength of a wave is equal to the velocity divided by the frequency.

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

EXAMPLE 3

CHARACTERISTICS OF A WAVE A sound wave has a frequency of 192 Hz and travels the length of a football field, 91.4 m, in 0.271 s.

- What is the speed of the wave?
- What is the wavelength of the wave?
- What is the period of the wave?
- If the frequency were changed to 442 Hz, what would be the new wavelength and period?

KNOWN

$$\begin{aligned}f &= 192 \text{ Hz} \\ \Delta d &= 91.4 \text{ m} \\ \Delta t &= 0.271 \text{ s}\end{aligned}$$

UNKNOWN

$$\begin{aligned}v &= ? \\ \lambda &= ? \\ T &= ?\end{aligned}$$

2 SOLVE FOR THE UNKNOWN

- a. Use the definition of velocity.

$$\begin{aligned}v &= \frac{\Delta d}{\Delta t} \\ &= \frac{91.4 \text{ m}}{0.271 \text{ s}} \\ &= 337 \text{ m/s}\end{aligned}$$

- b. Use the relationship between wave velocity, wavelength, and frequency.

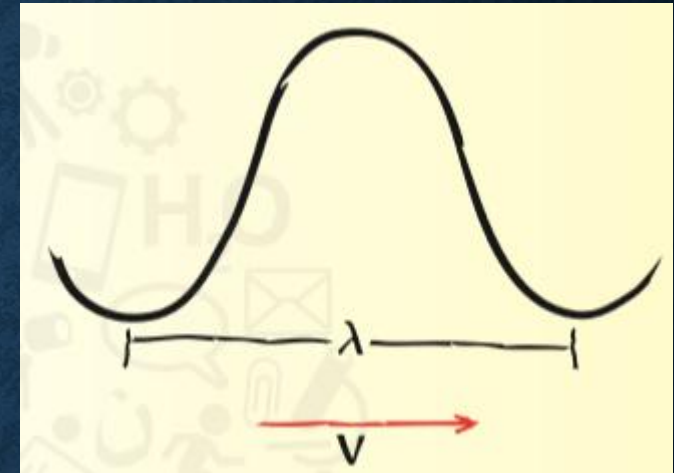
$$\begin{aligned}\lambda &= \frac{v}{f} \\ &= \frac{337 \text{ m/s}}{192 \text{ Hz}} \\ &= 1.76 \text{ m}\end{aligned}$$

- c. Use the relationship between period and frequency.

$$\begin{aligned}T &= \frac{1}{f} \\ &= \frac{1}{192 \text{ Hz}} \\ &= 0.00521 \text{ s}\end{aligned}$$

1 ANALYZE AND SKETCH THE PROBLEM

- Draw a diagram of the wave.
- Draw a velocity vector for the wave.



$$\begin{aligned}\text{d. } \lambda &= \frac{v}{f} \\ &= \frac{337 \text{ m/s}}{442 \text{ Hz}} \\ &= 0.762 \text{ m}\end{aligned}$$

$$\begin{aligned}T &= \frac{1}{f} \\ &= \frac{1}{442 \text{ Hz}} \\ &= 0.00226 \text{ s}\end{aligned}$$

3 EVALUATE THE ANSWER

Are the units correct? Hz has the unit s^{-1} , so $(\frac{\text{m}}{\text{s}})/\text{Hz} = (\frac{\text{m}}{\text{s}}) \cdot \text{s} = \text{m}$, which is correct for λ .

Are the magnitudes realistic? A typical sound wave travels at approximately 340 m/s in air, so 337 m/s is reasonable. The frequencies and periods are reasonable for sound waves. The frequency of 442 Hz is close to a 440 Hz A, which is A above middle-C on a piano.

**PRACTICE
PROBLEMS**

14. A sound wave produced by a clock chime is heard 515 m away 1.50 s later.

- a. Based on these measurements, what is the speed of sound in air?
- b. The sound wave has a frequency of 436 Hz. What is the period of the wave?
- c. What is its wavelength?

a.

$$\begin{aligned}v &= \frac{d}{t} \\&= \frac{515 \text{ m}}{1.50 \text{ s}} \\&= 343 \text{ m/s}\end{aligned}$$

b.

$$\begin{aligned}T &= \frac{1}{f} \\&= \frac{1}{436 \text{ Hz}} \\&= 2.29 \times 10^{-3} \text{ s}\end{aligned}$$

c.

$$\begin{aligned}\lambda &= \frac{v}{f} \\&= \frac{343 \text{ m/s}}{436 \text{ Hz}} \\&= 0.787 \text{ m}\end{aligned}$$

15. How are the wavelength, frequency, and speed of a wave related? How do they depend on the medium through which the wave is passing and the type of wave?

The wavelength of a wave is equal to the velocity divided by the frequency.

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

Frequency (f)

Constant in a Medium Change: Frequency remains the same when a wave moves from one medium to another. This is because frequency is determined by the source of the wave, not by the medium.

Wavelength (λ)

Varies with Medium: When a wave travels from one medium to another, its wavelength changes depending on the speed of the wave in the new medium.

Speed (v)

Depends on Medium: Wave speed depends on the properties of the medium, such as density and elasticity. For example:

- In general, waves travel faster in solids than in liquids, and faster in liquids than in gases, because particles are closer together in solids.

Formula: The speed of a wave is given by $v = f \times \lambda$.

16. What is the speed of a periodic wave disturbance that has a frequency of 3.50 Hz and a wavelength of 0.700 m?

SOLUTION:

$$v = \lambda f = (0.700 \text{ m})(3.50 \text{ Hz}) = 2.45 \text{ m/s}$$

17. How does increasing the wavelength by 50 percent affect the frequency of a wave on a rope?

SOLUTION:

The frequency decreases to two-thirds of its original value.

18. The speed of a transverse wave in a string is 15.0 m/s. If a source produces a disturbance that has a frequency of 6.00 Hz, what is its wavelength?

SOLUTION:

$$v = \lambda f, \text{ so } \lambda = \frac{v}{f} = \frac{15.0 \text{ m/s}}{6.00 \text{ Hz}} = 2.50 \text{ m}$$



19. Five wavelengths are generated every 0.100 s in a tank of water. What is the speed of the wave if the wavelength of the surface wave is 1.20 cm?

SOLUTION:

$$\frac{0.100 \text{ s}}{5 \text{ pulses}} = 0.0200 \text{ s/pulse, so}$$
$$T = 0.0200 \text{ s}$$

$$\lambda = vT, \text{ so}$$

$$v = \frac{\lambda}{T}$$
$$= \frac{1.20 \text{ cm}}{0.0200 \text{ s}}$$
$$= 60.0 \text{ cm/s} = 0.600 \text{ m/s}$$

20. A periodic longitudinal wave that has a frequency of 20.0 Hz travels along a coiled spring toy. If the distance between successive compressions is 0.600 m, what is the speed of the wave?

SOLUTION:

$$v = \lambda f = (0.600 \text{ m})(20.0 \text{ Hz}) = 12.0 \text{ m/s}$$

21. How does the frequency of a wave change when the period of the wave is doubled?

SOLUTION:

The wavelength is one-half of its original value.

22. Describe the change in the wavelength of a wave when the period is reduced by one-half.

SOLUTION:

The wavelength is one-half of its original value.

23. If the speed of a wave increases to 1.5 times its original speed while the frequency remains constant, how does the wavelength change?

SOLUTION:

The wavelength increases to 1.5 times its original length.

24. CHALLENGE A hiker shouts toward a vertical cliff as shown in **Figure 11**. The echo is heard 2.75 s later.

- a. What is the speed of sound of the hiker's voice in air?
- b. The wavelength of the sound is 0.750 m. What is its frequency?
- c. What is the period of the wave?

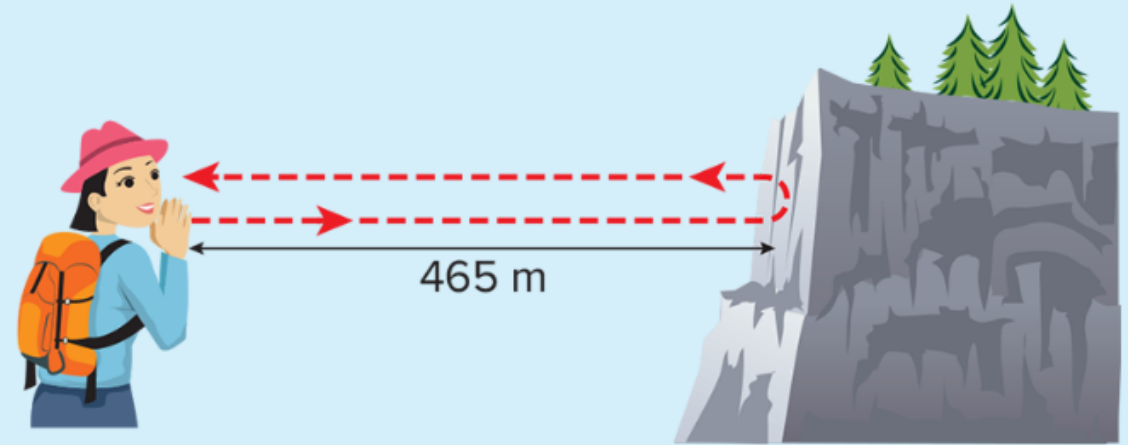


Figure 11

SOLUTION:

a.

$$v = \frac{d}{t} = \frac{(2)(465 \text{ m})}{2.75 \text{ s}} = 338 \text{ m/s}$$

b.

$$v = \lambda f, \text{ so } f = \frac{v}{\lambda} = \frac{338 \text{ m/s}}{0.750 \text{ m}} = 451 \text{ Hz}$$

c.

$$T = \frac{1}{f} = \frac{1}{451 \text{ Hz}} = 2.22 \times 10^{-3} \text{ s}$$

Describe that a mechanical wave is inverted if reflected from a fixed end and remains upright if reflected from a free end

Students book,
Page 121-122

Reflection of Waves at Boundaries

1. Fixed End — Inverted Reflection

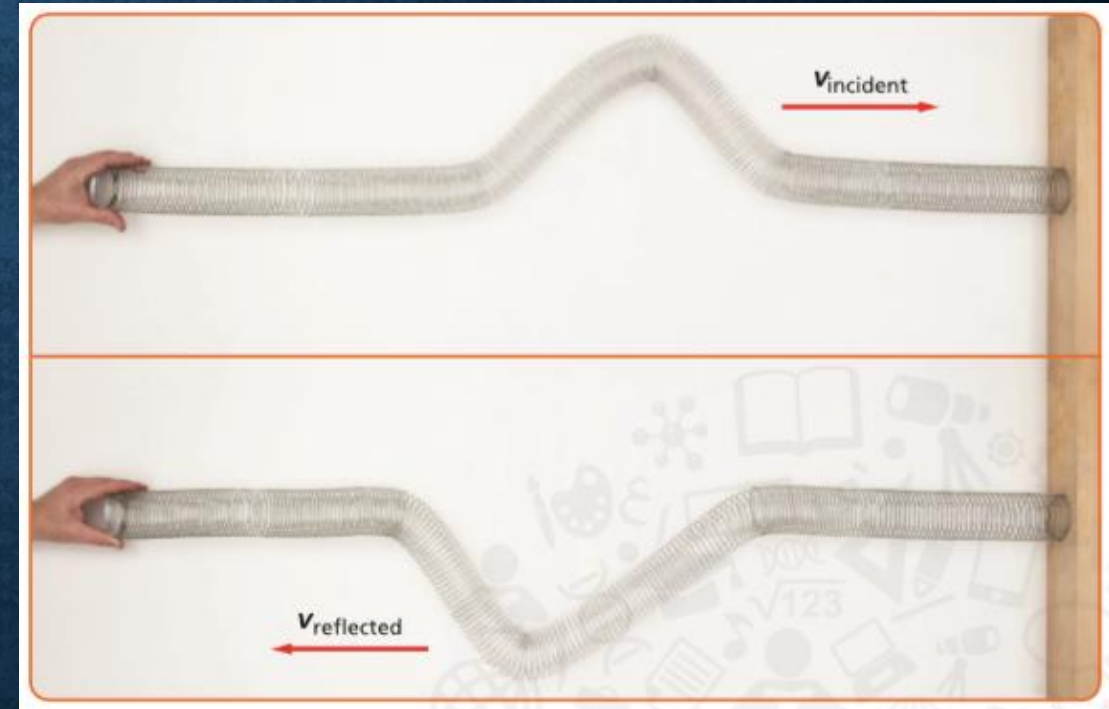
When a wave hits a **fixed end**, it reflects back **upside down** (inverted).

- Crest becomes trough
- Trough becomes crest

This happens because the end cannot move.

Example

A rope tied tightly to a wall produces an inverted reflected wave.



2. Free End — Upright Reflection

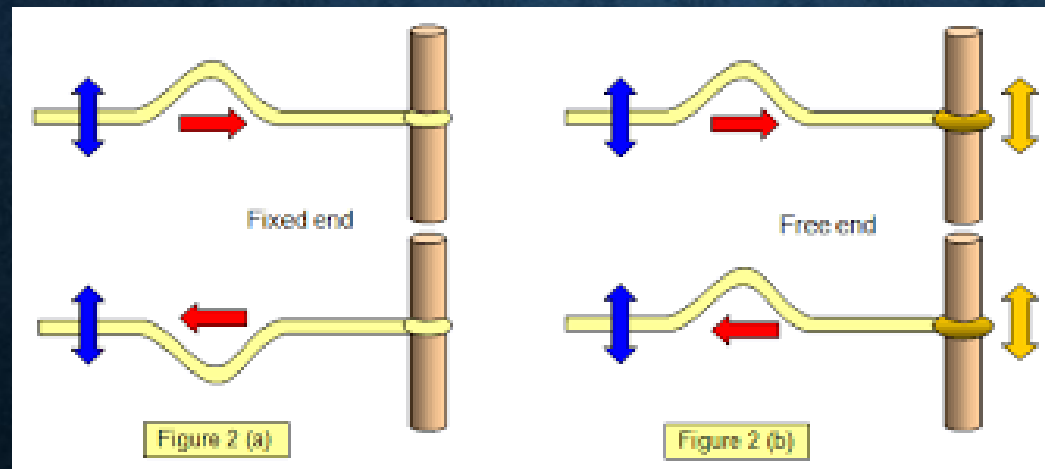
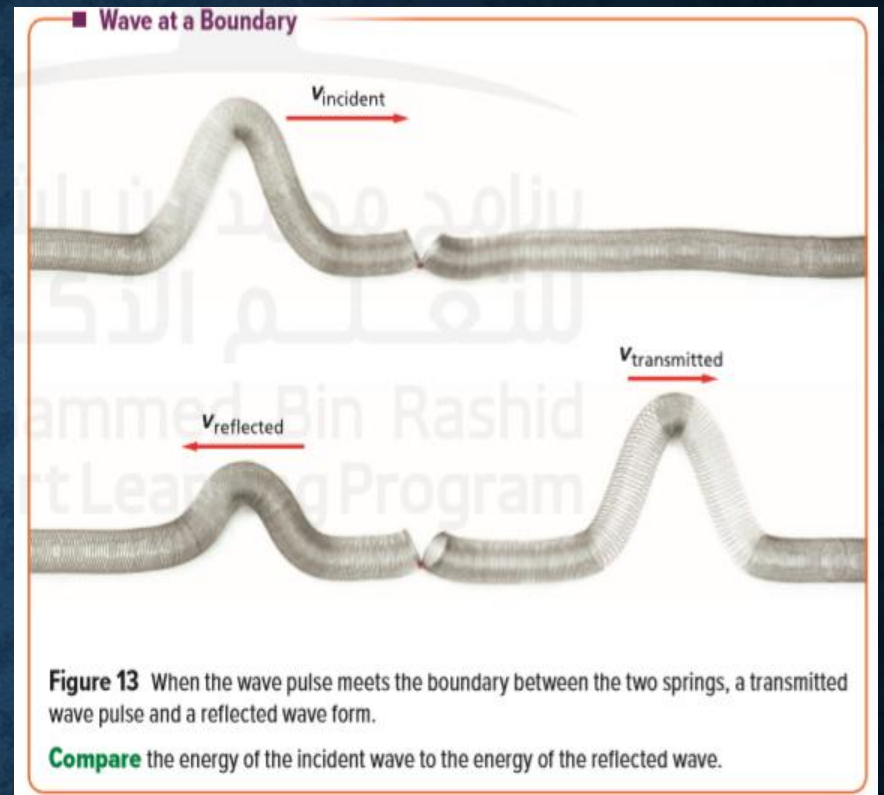
When a wave hits a **free end**, it reflects back **upright** (not inverted).

- Crest remains crest
- Trough remains trough

This happens because the end is free to move.

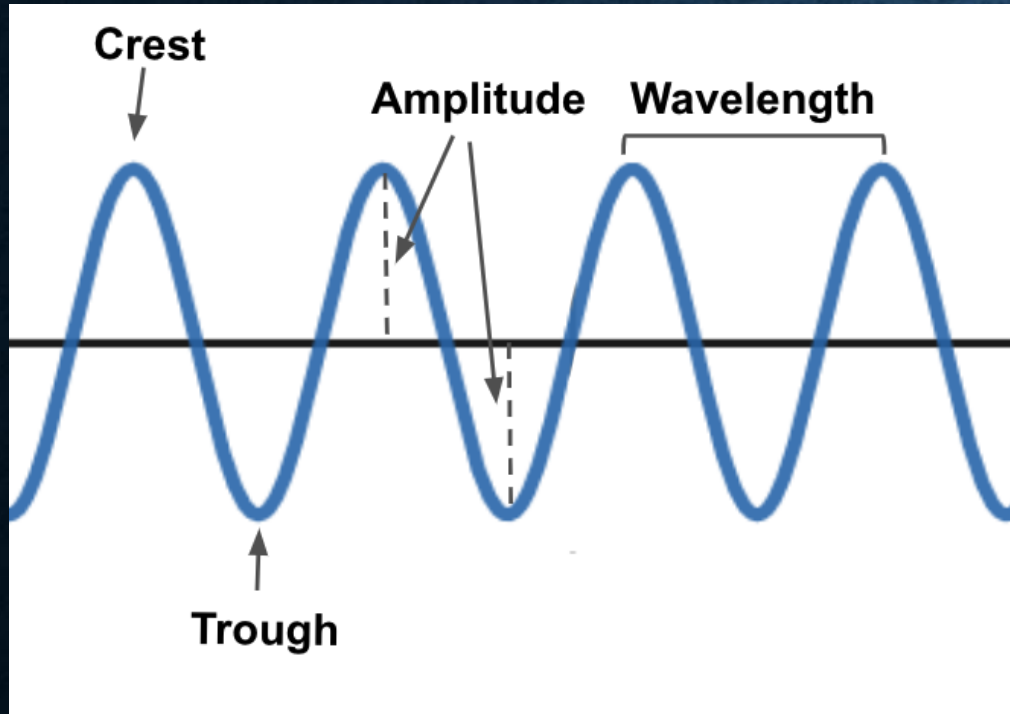
Example

A rope attached to a loose ring reflects the wave upright.



Describe wave properties like amplitude, energy of a wave, wavelength, speed, phase, period and frequency

**Students book,
Page 116-118**



Amplitude

The **amplitude** of a wave is the **maximum distance** a particle moves from its rest (mean) position.

Energy of a Wave

A wave transfers **energy** from one place to another without transferring matter.

The energy of a wave depends on its **amplitude**.

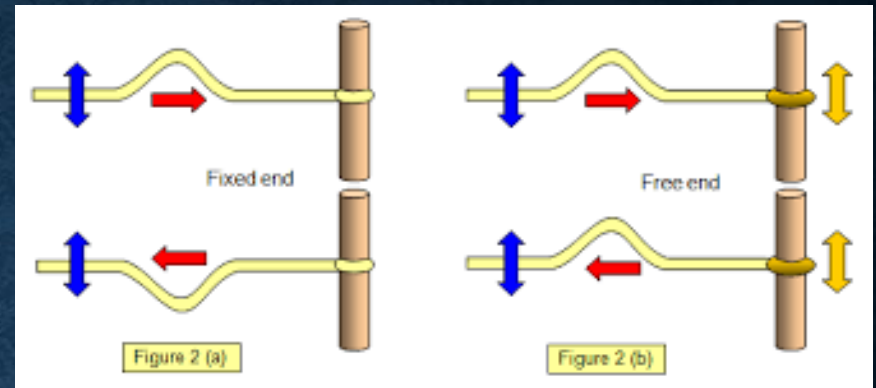
$$E \propto A^2$$

This means:

- Greater amplitude → more energy
- Smaller amplitude → less energy

Phase

The **phase** of a wave shows the **position** of a particle in its cycle of motion at a particular time.



WAVELENGTH

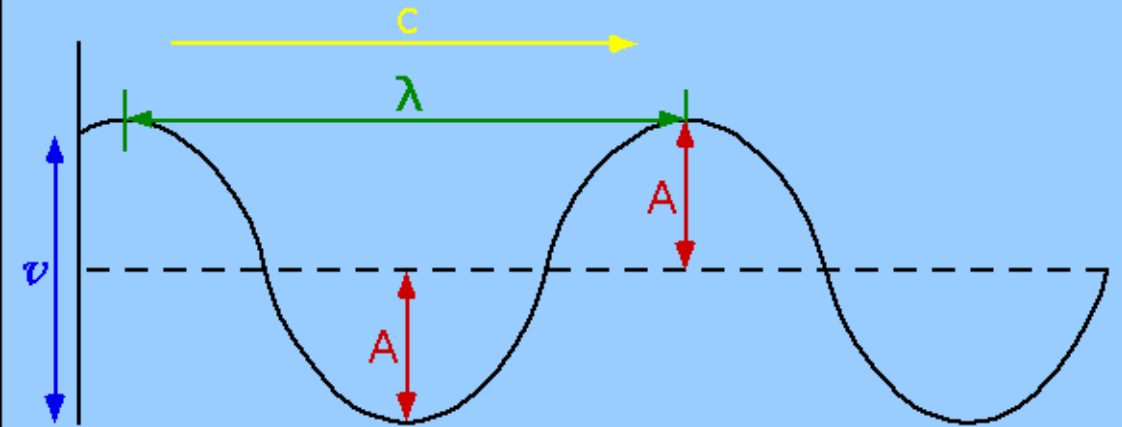
The wavelength of a wave is equal to the velocity divided by the frequency.

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

FREQUENCY OF A WAVE

The frequency of a wave is equal to the reciprocal of the period.

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



Properties of waves:

- λ Wave length – distance from crest to crest.
- C Speed of light, 300,000 km/sec – rate of motion of crests or troughs.
- T Period – Time between passage of successive crests.
- v Frequency – Number of crest passages per unit time.
- A Amplitude – Distance from level of crest to level of trough.

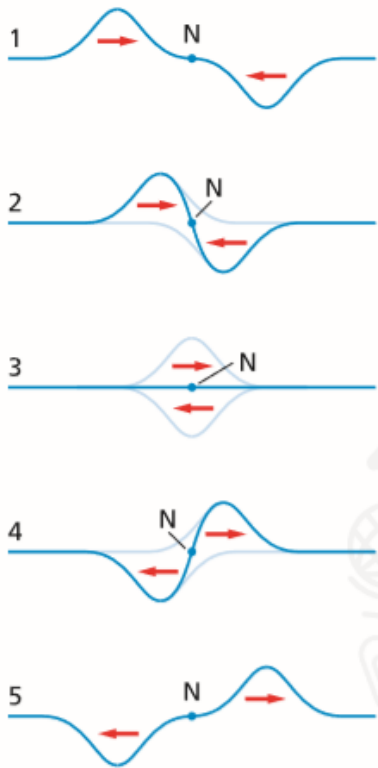
JDH/LP

5

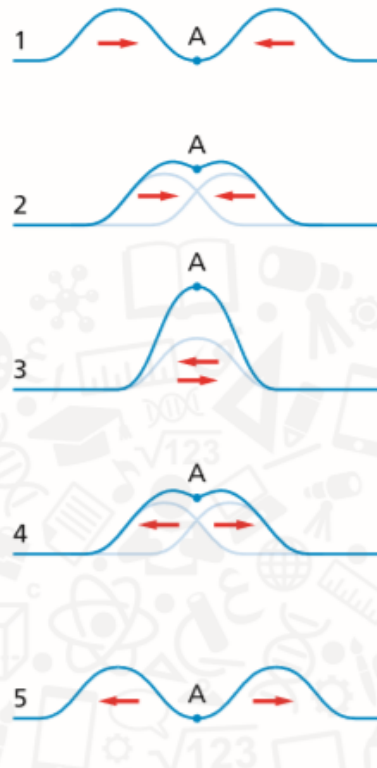
Sketch snapshots for the superposition of two overlapping wave pulses (same wavelength) traveling in opposite directions showing the resultant wave. Find the amplitude of the resultant wave in terms of the individual wave amplitude, for two overlapping waves (same wavelength) traveling in opposite directions

Students book,
Page 122-123

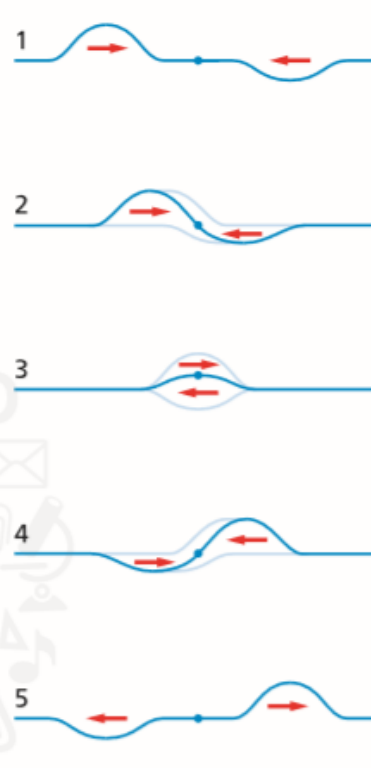
Destructive Interference



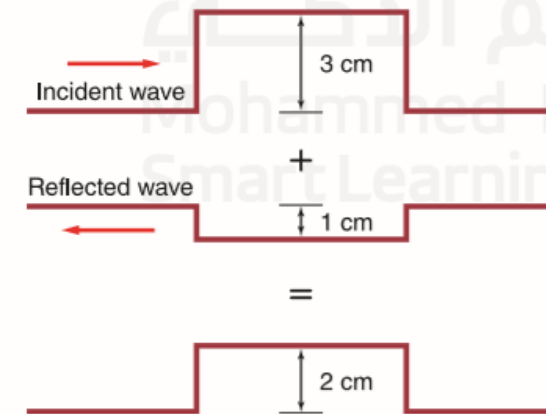
Constructive Interference



Different Amplitudes



Interference of Waves



Node

A **node** is a point in a standing wave where there is **no vibration or displacement**. The particles at the node always remain at rest.

Formation of Nodes

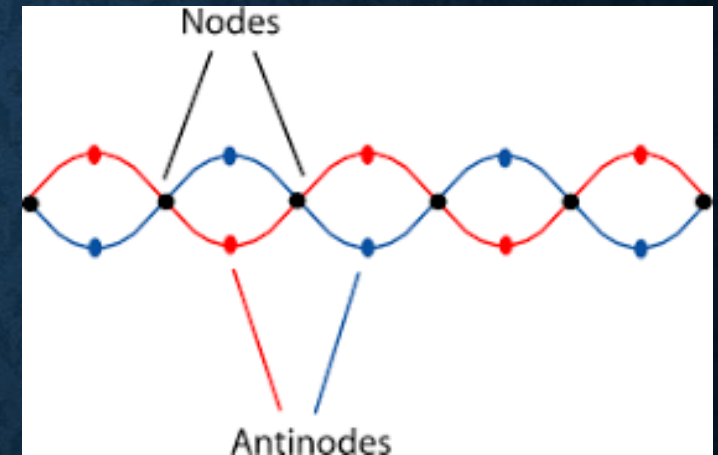
Nodes are formed when two waves of the same frequency and amplitude travel in opposite directions and meet in such a way that they undergo **destructive interference**. At these points, the crest of one wave meets the trough of another wave, cancelling each other completely.

Antinode

An **antinode** is a point in a standing wave where the vibration or displacement is **maximum**.

Formation of Antinodes

Antinodes are formed when two waves of the same frequency and amplitude meet and undergo **constructive interference**. At these points, two crests or two troughs meet together, producing maximum vibration.

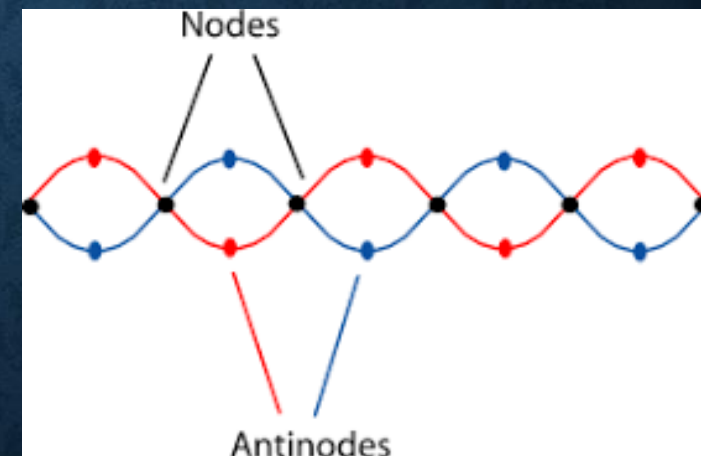


Feature	Node	Antinode
Vibration	No vibration	Maximum vibration
Displacement	Zero	Maximum
Type of Interference	Destructive interference	Constructive interference
Position in Standing Wave	Fixed resting point	Point of largest movement

Example

In a vibrating guitar string:

- The fixed ends of the string are **nodes**.
- The middle part moving the most is an **antinode**.



7

Determine the wavelengths required for the first several harmonics on a string under tension in terms of string length ($\lambda_n = \frac{2L}{n}$).

**Students book,
Page 124**

For a string fixed at both ends, standing waves are formed only when the string length L fits an integer number of half wavelengths.

The condition is:

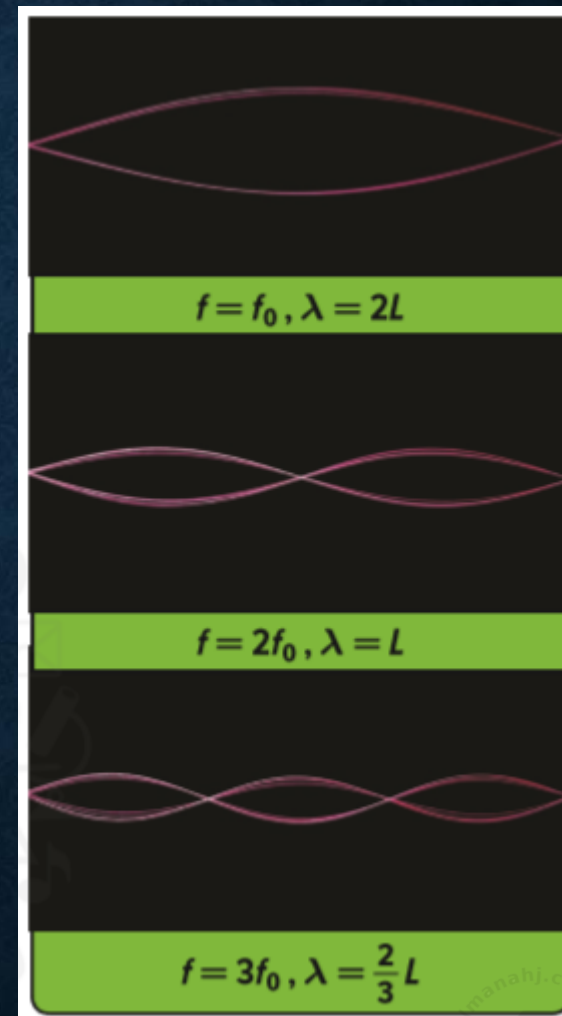
$$L = \frac{n\lambda}{2}$$

where:

- L = length of the string
- λ = wavelength
- n = harmonic number (1, 2, 3, ...)

Rearranging:

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



Harmonic	n	Wavelength
First harmonic (fundamental)	1	$\lambda_1 = 2L$
Second harmonic	2	$\lambda_2 = L$
Third harmonic	3	$\lambda_3 = \frac{2L}{3}$
Fourth harmonic	4	$\lambda_4 = \frac{L}{2}$
Fifth harmonic	5	$\lambda_5 = \frac{2L}{5}$

Explanation

- The **first harmonic** has one loop (one antinode) and two nodes at the ends.
- Higher harmonics contain more loops and shorter wavelengths.
- As harmonic number increases, wavelength decreases.



Define sound as pressure oscillation that is transmitted through matter.

Explain that sound is a longitudinal wave that has frequency, wavelength, and speed

Students book,
Page 132

Sound

Sound is a **pressure oscillation** that is transmitted through matter such as solids, liquids, or gases. It is produced when an object vibrates and causes the particles around it to vibrate.

Sound cannot travel through a vacuum because it needs a material medium.

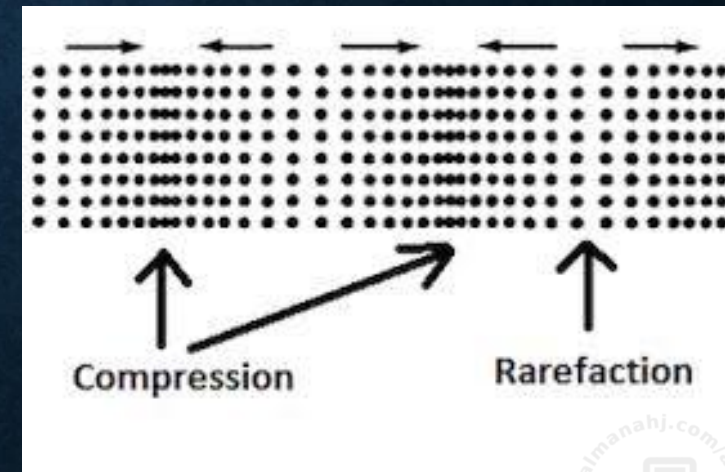
Sound as a Longitudinal Wave

Sound is a **longitudinal wave** because the particles of the medium vibrate **parallel** to the direction in which the wave travels.

In a sound wave:

- **Compressions** are regions where particles are close together.
- **Rarefactions** are regions where particles are spread apart.

These compressions and rarefactions move through the medium and carry sound energy.



Important Properties of Sound Waves

Property	Definition
Frequency	The number of vibrations or waves produced per second. It is measured in hertz (Hz). Higher frequency produces a higher pitch.
Wavelength	The distance between two consecutive compressions or two consecutive rarefactions.
Speed	The distance travelled by the sound wave per second. Sound travels fastest in solids, slower in liquids, and slowest in gases.

The relationship between them is:

$$v = f\lambda$$

Explain that the speed of sound varies with different mediums and temperatures.

Students book,
Page 133-134

1. Effect of Medium on Speed of Sound

Sound needs particles to travel. The closer and more elastic the particles are, the faster sound moves.

General Order

Speed in solids > Speed in liquids > Speed in gases

Reason

- In **solids**, particles are tightly packed, so vibrations pass quickly.
- In **liquids**, particles are less tightly packed.
- In **gases**, particles are far apart, so sound travels slowest.

Table 1
Speed of Sound in Various Media

Medium	Speed (m/s)
Air (0°)	331
Air (20°)	343
Helium (0°)	965
Water (25°)	1497
Seawater (25°)	1535
Copper (20°)	4760
Iron (20°)	4994

Just like any other wave, the speed of sound depends on the medium through which it travels. In air, the speed depends on the temperature, increasing by about 0.6 m/s for each 1°C increase in air temperature.

2. Effect of Temperature on Speed of Sound

In gases, increasing temperature increases the speed of sound.

When temperature rises:

- particles gain more kinetic energy,
- particles vibrate faster,
- sound waves travel more quickly.

For air:

$$v = 331 + 0.6T$$

where:

- v = speed of sound in air (m/s)
- T = temperature in °C

$$v = 331 + 0.6T$$

Example

At:

- $0^{\circ}\text{C}: v = 331 \text{ m/s}$
- $20^{\circ}\text{C}: v = 343 \text{ m/s}$

So sound travels faster in warm air than in cold air.

Conclusion

- Sound travels fastest in solids, slower in liquids, and slowest in gases.
- Increasing temperature increases the speed of sound, especially in gases like air.

Pitch of Sound (Definition)

Pitch is the characteristic of sound that allows us to distinguish between a **high sound** and a **low sound**.

In simple terms:

- High pitch = shrill sound (like whistle, bird chirp)
- Low pitch = deep sound (like drum, thunder)

Relation between Pitch and Frequency

Pitch is directly related to the **frequency** of a sound wave.

- Higher frequency → higher pitch
- Lower frequency → lower pitch

Mathematically:

$$\text{Pitch} \propto \text{Frequency}$$

Explanation

- Frequency is the number of vibrations per second.
- A sound with more vibrations per second reaches your ear more rapidly, so it is heard as **high pitch**.
- A sound with fewer vibrations per second is heard as **low pitch**.

Conclusion

Pitch depends on frequency:

- Increase frequency → pitch increases
- Decrease frequency → pitch decreases

Loudness of Sound (Definition)

Loudness is the characteristic of sound that determines how **strong, soft, or intense** a sound appears to the human ear.

In simple terms:

- Loud sound = high intensity (e.g., loud music, thunder)
- Soft sound = low intensity (e.g., whisper)

Relation between Loudness and Amplitude

Loudness depends on the **amplitude** of the sound wave.

- Greater amplitude → louder sound
- Smaller amplitude → softer sound

Mathematically:

$$\text{Loudness} \propto (\text{Amplitude})^2$$

Explanation

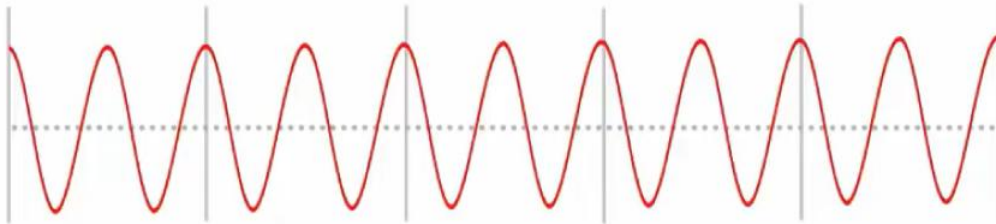
- Amplitude is the maximum displacement of particles in a medium from their rest position.
- When amplitude is large, particles vibrate more strongly, carrying more energy.
- More energy means the ear perceives the sound as **louder**.

Example

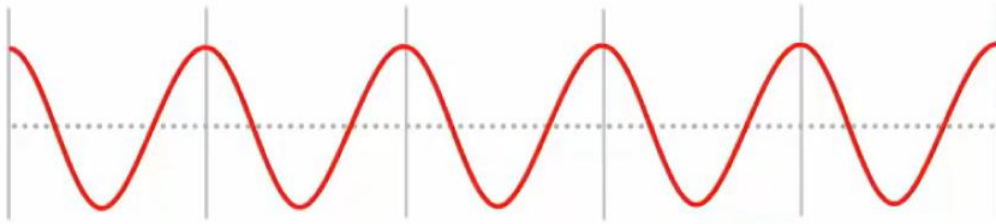
Sound	Amplitude	Loudness
Whisper	Small	Soft
Normal speech	Medium	Moderate
Loud music	Large	Loud

The Pitch of Sound

The pitch of sound tells us how **shrill** or **deep** it is.



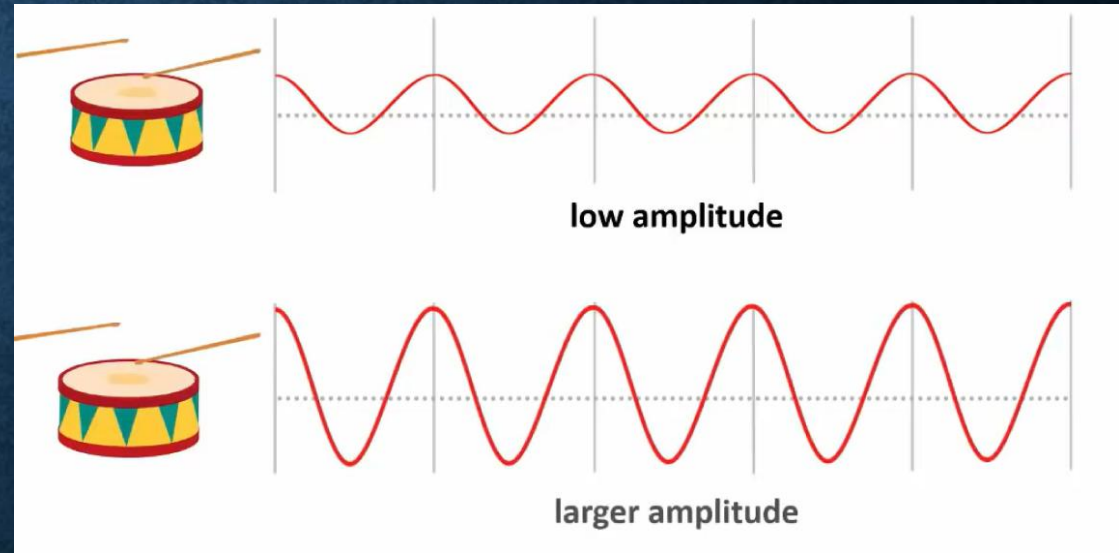
greater frequency → high pitch



lower frequency → low pitch

The Loudness of Sound

It tells us how **loud** or **soft** a sound is.



The human ear is extremely sensitive to variations in the intensity of sound waves. Recall that 1 atmosphere of pressure equals 1.01×10^5 Pa. The ear can detect pressure-wave amplitudes of less than one-billionth of an atmosphere, or 2×10^{-5} Pa. At the other end of the audible range, pressure variations of approximately 20 Pa or greater cause pain. It is important to remember that the ear detects pressure variations only at certain frequencies. Driving over a mountain pass changes the pressure on your ears by thousands of pascals, but this change does not take place at audible frequencies.

Because humans can detect a wide range of intensities, it is convenient to measure these intensities on a logarithmic scale called the **sound level**. The most common unit of measurement for sound level is the **decibel** (dB). The sound level depends on the ratio of the intensity of a given sound wave to that of the most faintly heard sound. This faintest sound is measured at 0 dB. A sound that is ten times more intense registers 20 dB. A sound that is another ten times more intense is 40 dB. Most people perceive a 10-dB increase in sound level as about twice as loud as the original level. **Figure 4** shows the sound level for a variety of sounds. In addition to intensity, pressure variations and the power of sound waves can be described by decibel scales.

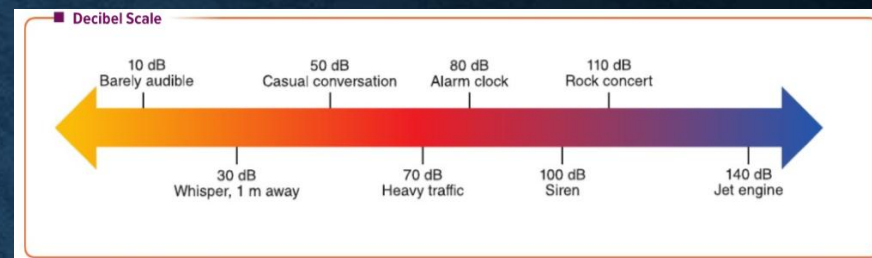


Figure 4 This decibel scale shows the sound level for a variety of sounds.

Decibels

The sound intensity I may be expressed in decibels above the standard threshold of hearing I_0 . The expression is

$$I(\text{dB}) = 10 \log_{10} \left[\frac{I}{I_0} \right] \quad \text{Intensity in decibels}$$

$$\text{dB} = 10 \log \frac{I}{10^{-12}}$$

decibels

intensity of the sound

intensity of the softest sound a healthy human ear can detect

Sound Level

Sound level is a measure of how **loud or intense** a sound is **perceived**, usually compared on a logarithmic scale because the human ear responds to sound in a wide range of intensities.

It tells us how strong a sound is in relation to a reference (minimum audible sound).

Decibel (dB)

The decibel (dB) is the unit used to measure **sound level (loudness intensity level)**.

It is a **logarithmic unit**, meaning that even small increases in dB represent large changes in actual sound intensity.

Formula for sound level:

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

- β = sound level in decibels (dB)
- I = intensity of the sound
- I_0 = reference intensity (threshold of hearing, 10^{-12} W/m^2)

Examples of Sound Levels

Sound Source	Sound Level
Whisper	~20 dB
Normal conversation	~60 dB
Busy traffic	~80–90 dB
Rock concert	~110–120 dB

Conclusion

- Sound level describes the perceived loudness of sound.
- It is measured in **decibels (dB)**.
- The decibel scale is logarithmic, making it suitable for the wide range of human hearing.

13

Apply the Doppler effect equation ($f_d = f_s \left[\frac{v - v_d}{v - v_s} \right]$) to calculate different frequencies and velocities.

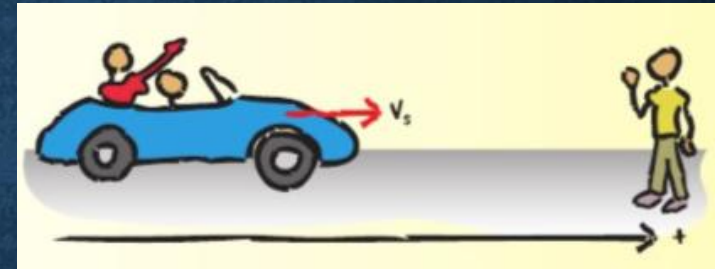
Example Q.1,
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EXAMPLE 1

THE DOPPLER EFFECT A guitar player sounds C above middle C (523 Hz) while traveling in a convertible at 24.6 m/s. If the car is coming toward you, what frequency would you hear? Assume that the temperature is 20°C.

1 ANALYZE AND SKETCH THE PROBLEM

- Sketch the situation.
- Establish a coordinate axis. Make sure that the positive direction is from the source to the detector.
- Show the velocities of the source and detector.



KNOWN

$$v = +343 \text{ m/s}$$

$$v_s = +24.6 \text{ m/s}$$

$$v_d = 0 \text{ m/s}$$

$$f_s = 523 \text{ Hz}$$

UNKNOWN

$$f_d = ?$$

2 SOLVE FOR THE UNKNOWN

Use $f_d = f_s \frac{v - v_d}{v - v_s}$ with $v_d = 0 \text{ m/s}$.

$$f_d = f_s \frac{1}{1 - \frac{v_s}{v}}$$

$$= 523 \text{ Hz} \left(\frac{1}{1 - \frac{24.6 \text{ m/s}}{343 \text{ m/s}}} \right)$$

$$= 564 \text{ Hz}$$

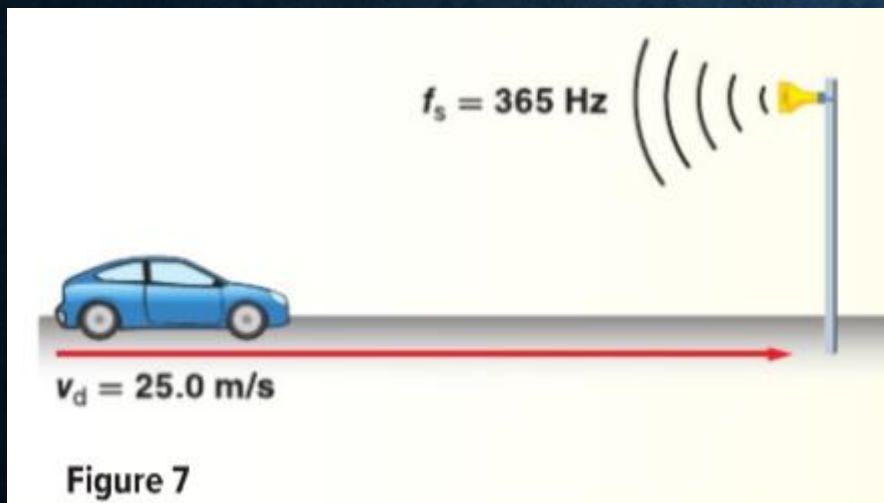
**PRACTICE
PROBLEMS**
Page 138

1. Repeat Example Problem 1, but with the car moving away from you. What frequency would you hear?

$$v_s = -24.6 \text{ m/s}$$

$$f_d = 524 \text{ Hz} \left(\frac{1}{1 - \frac{(-24.6 \text{ m/s})}{343 \text{ m/s}}} \right)$$
$$= 489 \text{ Hz}$$

2. You are in an automobile, like the one in **Figure 7**, traveling toward a pole-mounted warning siren. If the siren's frequency is 365 Hz, what frequency do you hear? Use 343 m/s as the speed of sound.



$$v = 343 \text{ m/s}, f_s = 365 \text{ Hz}, v_s = 0,$$

$$v_d = -25.0 \text{ m/s}$$

$$f_d = f_s \left(\frac{v - v_d}{v - v_s} \right)$$

$$= (365 \text{ Hz}) \left(\frac{343 \text{ m/s} + 25.0 \text{ m/s}}{343 \text{ m/s}} \right)$$

$$= 392 \text{ Hz}$$

3. You are in an automobile traveling at 55 mph (24.6 m/s). A second automobile is moving toward you at the same speed. Its horn is sounding at 475 Hz. What frequency do you hear? Use 343 m/s as the speed of sound.

$$v = 343 \text{ m/s}, f_s = 475 \text{ Hz}, v_s = +24.6 \text{ m/s}, \\ v_d = -24.6 \text{ m/s}$$

$$f_d = f_s \left(\frac{v - v_d}{v - v_s} \right) \\ = (475 \text{ Hz}) \left(\frac{343 \text{ m/s} + 24.6 \text{ m/s}}{343 \text{ m/s} - 24.6 \text{ m/s}} \right) \\ = 548 \text{ Hz}$$



4. A submarine is moving toward another submarine at 9.20 m/s. It emits a 3.50-MHz ultrasound. What frequency would the second sub, at rest, detect? The speed of sound in water at the depth the submarines are moving is 1482 m/s.

$$v = 1482 \text{ m/s}, f_s = 3.50 \text{ MHz},$$

$$v_s = 9.20 \text{ m/s}, v_d = 0 \text{ m/s}$$

$$f_d = f_s \left(\frac{v - v_d}{v - v_s} \right)$$

$$= (3.50 \text{ MHz}) \left(\frac{1482 \text{ m/s}}{1482 \text{ m/s} - 9.20 \text{ m/s}} \right)$$

$$= 3.52 \text{ MHz}$$



5. CHALLENGE A trumpet plays middle C (262 Hz). How fast would it have to be moving to raise the pitch to C sharp (277 Hz)? Use 343 m/s as the speed of sound.

$$v = 343 \text{ m/s}, f_s = 262 \text{ Hz}, f_d = 271 \text{ Hz},$$

$$v_d = 0 \text{ m/s}, v_s \text{ is unknown}$$

$$f_d = f_s \left(\frac{v - v_d}{v - v_s} \right)$$

Solve this equation for v_s .

$$v_s = v - \frac{f_s}{f_d}(v - v_d)$$

$$= 343 \text{ m/s} - \left(\frac{262 \text{ Hz}}{271 \text{ Hz}} \right) (343 \text{ m/s} - 0 \text{ m/s})$$

$$= 11.4 \text{ m/s}$$

Recall resonance as the increase in the amplitude of vibration that occurs when a system (or an object) is driven by an external periodic force, vibrating at the system's (or object's) own natural frequency.

Explain resonance in air columns and give examples on different instruments.

Resonance in air columns occurs when air inside a tube vibrates at its natural frequency because of an external sound source. This causes the amplitude of vibration to increase greatly, producing a loud sound.

For example, in musical instruments, resonance helps to make sounds louder and clearer:

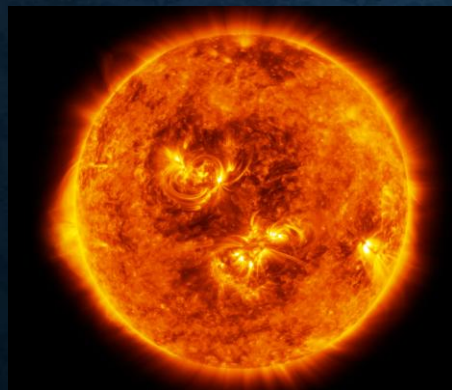
- In a **flute** or **open organ pipe**, the air column vibrates inside an open tube to produce musical notes.
- In a **clarinet** or **closed organ pipe**, resonance occurs in a tube closed at one end.
- In a **guitar** or **violin**, the vibrating strings cause the air inside the hollow body to resonate, making the sound louder.

Thus, resonance in air columns is very important in producing strong and pleasant sounds in musical instruments.

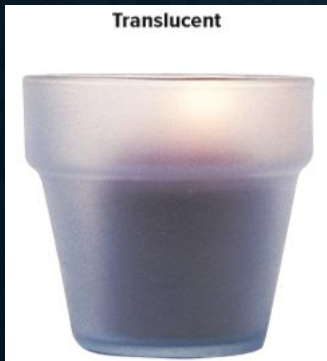
Differentiate between luminous and non-luminous sources of light, giving examples.
Differentiate between opaque, translucent and transparent mediums, giving examples

Difference between luminous and non-luminous sources of light

Luminous Sources	Non-luminous Sources
Objects that produce their own light.	Objects that do not produce their own light.
They can be seen because they emit light.	They are seen only when light falls on them and reflects.
Example: Sun, candle flame, electric bulb.	Example: Moon, book, chair, planets.



Difference between opaque, translucent and transparent mediums



Medium	Meaning	Example
Opaque	Does not allow light to pass through.	Wood, wall, metal
Translucent	Allows some light to pass through. Objects cannot be seen clearly.	Frosted glass, butter paper
Transparent	Allows almost all light to pass through. Objects can be seen clearly.	Clear glass, clean water, air

Luminous Flux (P)

Luminous flux is the total amount of visible light energy emitted by a light source per second.

•**SI Unit:** lumen (lm)

Illuminance (E)

Illuminance is the amount of luminous flux falling on a unit area of a surface.

•**SI Unit:** lux (lx) or

$$1 \text{ lux} = 1 \frac{\text{lumen}}{\text{meter}^2}$$

$$E = \frac{P}{4\pi r^2}$$

Luminous Intensity (I)

Luminous intensity is the amount of luminous flux emitted by a source in a particular direction.

•**SI Unit:** candela (cd)

EXAMPLE 1

ILLUMINATION OF A SURFACE What is the illuminance on your desktop if it is lit by a 1750-lm lamp that is 2.50 m above your desk?

1 ANALYZE AND SKETCH THE PROBLEM

- Assume the lightbulb is the point source.
- Diagram the position of the bulb and the desktop. Label P and r .

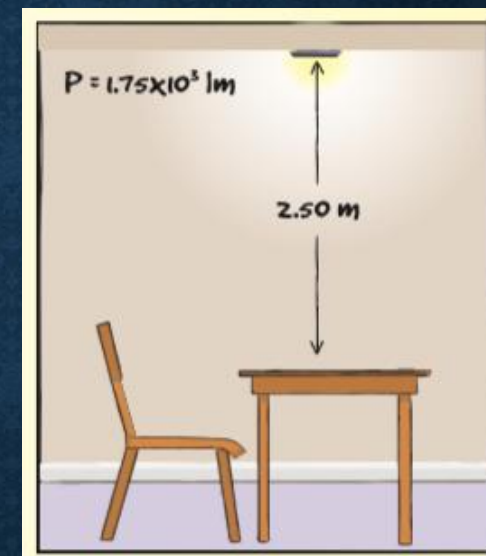
KNOWN

$$P = 1.75 \times 10^3 \text{ lm}$$

$$r = 2.50 \text{ m}$$

UNKNOWN

$$E = ?$$

**2 SOLVE FOR THE UNKNOWN**

The surface is perpendicular to the direction in which the light ray is traveling, so you can use the point-source illuminance equation.

$$E = \frac{P}{4\pi r^2}$$

$$= \frac{1.75 \times 10^3 \text{ lm}}{4\pi (2.50 \text{ m})^2}$$

$$= 22.3 \text{ lm/m}^2$$

$$= 22.3 \text{ lx}$$

**PRACTICE
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1. A lamp is moved from 30 cm to 90 cm above the pages of a book. Compare the illumination on the book before and after the lamp is moved.

$$\frac{E_{\text{after}}}{E_{\text{before}}} = \frac{\left(\frac{P}{4\pi d_{\text{after}}^2}\right)}{\left(\frac{P}{4\pi d_{\text{before}}^2}\right)} = \frac{d_{\text{before}}^2}{d_{\text{after}}^2}$$
$$= \frac{(30 \text{ cm})^2}{(90 \text{ cm})^2} = \frac{1}{9}; \text{ therefore, after}$$

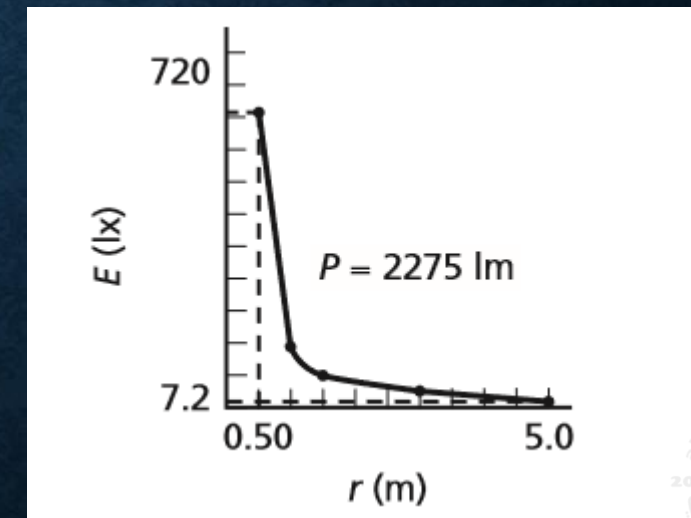
the lamp is moved the illumination is one-ninth of the original illumination.

2. Draw a graph of the illuminance produced by a lamp with a luminous flux of 2275 lm at distances from 0.50 m and 5.0 m.

Illuminance of a 150-W bulb

$P = 2275$, $d = 0.50, 0.75, \dots, 5.0$

$$E(d) = \frac{P}{4\pi d^2}$$



3. A 64-cd point source of light is 3.0 m away from a painting. What is the illumination on the painting in lux?

$$P = 4\pi(64 \text{ cd}) = 256\pi \text{ lm}$$

$$\text{so } E = \frac{P}{4\pi d^2} = \frac{256\pi \text{ lm}}{4\pi(3.0 \text{ m})^2} = 7.1 \text{ lx}$$

5. What is the illumination on a surface that is 3.0 m below a 150-W incandescent lamp that emits a luminous flux of 2275 lm?

$$E = \frac{P}{4\pi d^2} = \frac{2275 \text{ lm}}{4\pi(3.0 \text{ m})^2} = 2.0 \times 10^1 \text{ lx}$$

4. A screen is placed between two lamps so that they illuminate the screen equally, as shown in **Figure 9**. The first lamp emits a luminous flux of 1445 lm and is 2.5 m from the screen. What is the distance of the second lamp from the screen if the luminous flux is 2375 lm?

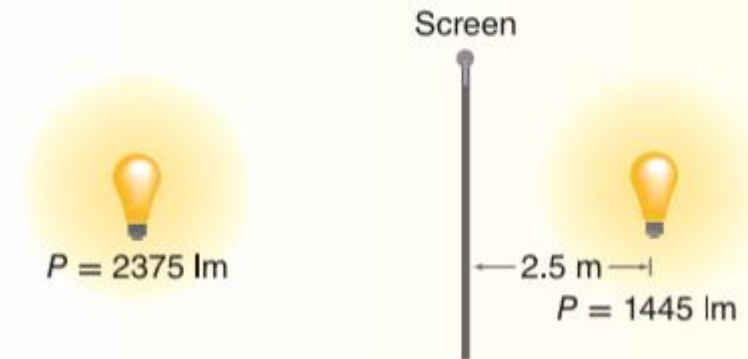


Figure 9

$$E_1 = E_2$$

$$\text{So } \frac{P_1}{d_1^2} = \frac{P_2}{d_2^2}$$

$$\begin{aligned} \text{or } d_2 &= d_1 \sqrt{\frac{P_2}{P_1}} \\ &= (2.5 \text{ m}) \sqrt{\frac{2375}{1445}} \\ &= 3.2 \text{ m} \end{aligned}$$

6. A public school law requires a minimum illuminance of 160 lx at the surface of each student's desk. An architect's specifications call for classroom lights to be located 2.0 m above the desks. What is the minimum luminous flux that the lights must produce?

$$E = \frac{P}{4\pi d^2}$$

$$P = 4\pi E d^2$$

$$= 4\pi(160 \text{ lm/m}^2)(2.0 \text{ m})^2$$

$$= 8.0 \times 10^3 \text{ lm}$$



7. CHALLENGE Your local public library is planning to remodel the computer lab. The contractors have purchased fluorescent lamps with a rated luminous flux of 1750 lm. The desired illumination on the keyboard surfaces is 175 lx. Assume a single lamp illuminates each keyboard. What distance above the surface should the lights be placed to achieve the desired illumination? If the contractors had also already purchased fixtures to hold the lights that when installed would be 1.5 m above the keyboard surface, would the desired illuminance be achieved? If not, would the illuminance be greater or less than desired? What change in the lamp's luminous flux would be required to achieve the desired illuminance?

Given:

- luminous flux of lamp = **1750 lm**
- desired illuminance = **175 lx**
- assume lamp is point-like over one keyboard
- relation:

$$I = \frac{P}{4\pi} \qquad E = \frac{I}{r^2}$$

1) What distance will give 175 lx with this lamp?

First convert flux → intensity:

$$I = \frac{1750}{4\pi} \approx 139.3 \text{ cd}$$

Now:

$$E = \frac{I}{r^2} \qquad 175 = \frac{139.3}{r^2}$$

$$r^2 = \frac{139.3}{175}$$

$$r \approx 0.89 \text{ m}$$

Answer:

The lamp should be about 0.9 m above the keyboard.

2) If the fixtures place the lamps at 1.5 m height, will the desired illuminance be achieved?

At 1.5 m:

$$E = \frac{139.3}{(1.5)^2} = \frac{139.3}{2.25} \approx 61.9 \text{ lx}$$

61.9 lx is **much less** than 175 lx.

So, the desired illuminance will NOT be achieved, and the illumination will be LESS than required.

3) What flux would be needed if lamps are fixed at 1.5 m?

We need:

$$175 = \frac{I}{(1.5)^2} \rightarrow I = 175 \times 2.25 = 393.75 \text{ cd}$$

Luminous Flux is:

$$P = I(4\pi) = 393.75 \times 4\pi \approx 4950 \text{ lm}$$

Luminous flux (P):

It is the total amount of *visible light energy* emitted by a source per second.

It tells how much light the light source produces.

SI unit: lumen (lm)

Illuminance (E):

It is the amount of luminous flux *falling on a unit area*.
It tells how brightly a surface is illuminated.

SI unit: lux (lx)

Relation:

1 lux = 1 lumen per square meter
 $1 \text{ lx} = 1 \text{ lm/m}^2$

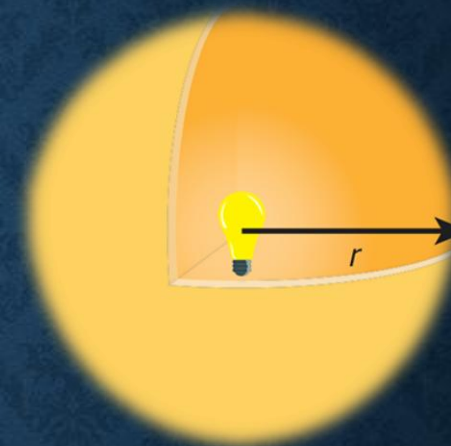


Figure 5 Luminous flux is the rate at which light rays are emitted from a luminous source.

$$E = \frac{P}{4\pi r^2}$$

19

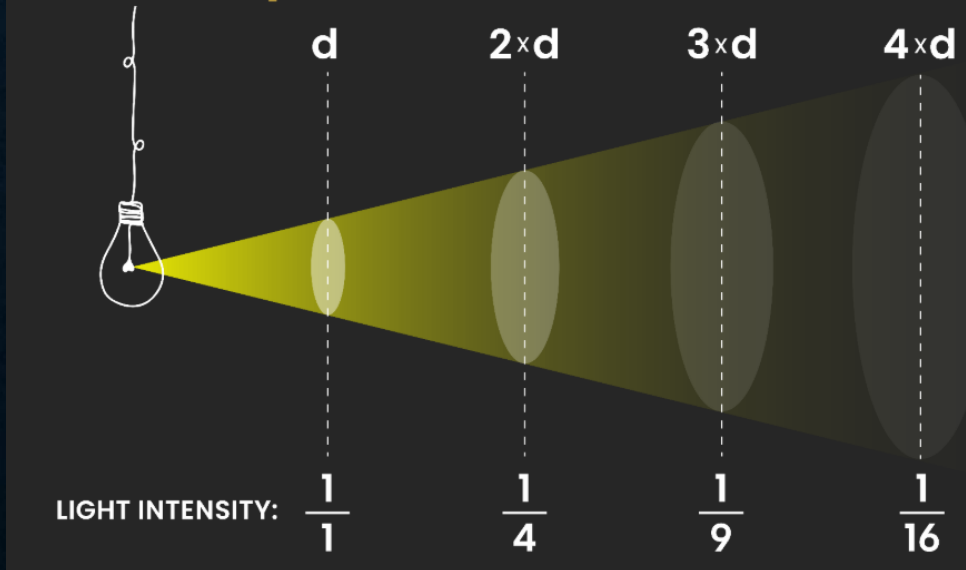
Show that the illuminance provided by a point source of light has an inverse-square relationship with distance (r) from the source and a direct relationship with luminous flux.

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The **illuminance inverse square law** states that the illuminance (E) of a surface is inversely proportional to the square of the distance (r) from a point light source. As light travels, it spreads out spherically, meaning a surface twice as far away receives exactly one-quarter of the light.

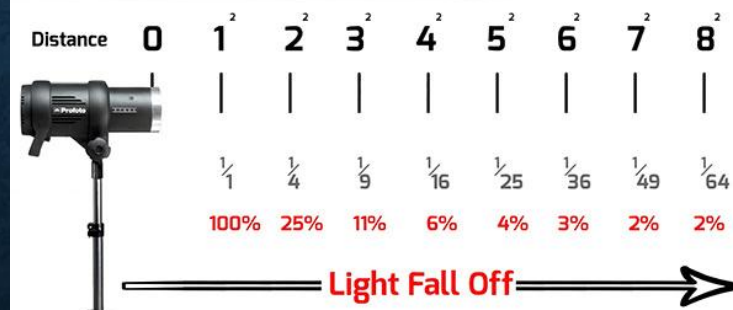
$$E \propto \frac{1}{r^2}$$

Inverse-Square Law



Inverse Square Law

$$\text{Intensity of Light} = \frac{1}{\text{Distance}^2}$$

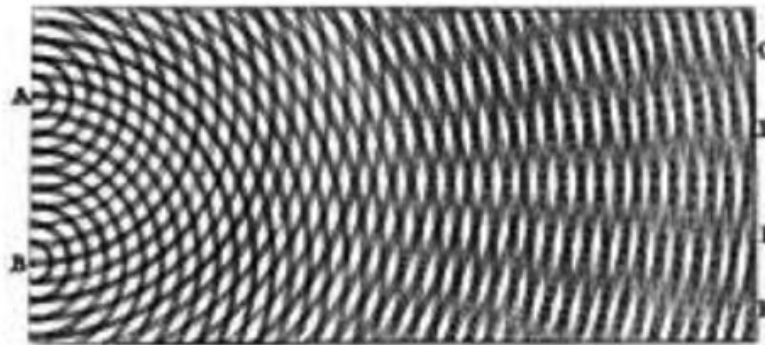


Diffraction is the **bending and spreading of waves** when they **pass around the edge of an obstacle or through a narrow opening (slit)**.

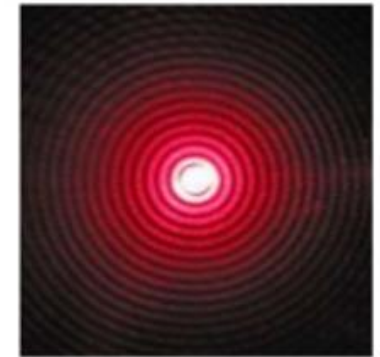
So instead of only “bending at the edge of a barrier,” remember it also includes **spreading out after passing through a gap or slit**.

Diffraction of Light

Diffraction refers to various phenomena that occur when a wave encounters an obstacle or a slit. It is defined as the bending of light around the corners of an obstacle or aperture into the region of geometrical shadow of the obstacle.



Thomas Young's sketch of two-slit diffraction, which he presented to the Royal Society in 1803.



Diffraction pattern of red laser beam made on a plate after passing through a small circular aperture in another plate.

The **color of light** is related to its **wavelength** and **frequency**.

Different colors have different wavelengths and frequencies.

- **Red light** has a **long wavelength** and **low frequency**.

- **Violet light** has a **short wavelength** and **high frequency**.

As the wavelength decreases, the frequency increases, producing different colors in the visible spectrum.

Different wavelengths Can the wave model of light explain Newton's observations? For light to be a wave, it must have wavelength and frequency. The work of Grimaldi, Huygens, Newton, and others suggested that the color of light is related to wavelength. Visible light falls within the range of wavelengths from about 400 nm (4.00×10^{-7} m) to 700 nm (7.00×10^{-7} m), as shown in **Figure 14**. The longest visible wavelengths are seen as red light and the shortest as violet.

As white light crosses the boundary from air into glass and back into air in **Figure 14**, its wave nature causes each different color of light to be bent at a different angle. The shorter the wavelength, the more the light is bent. This unequal bending of the different colors causes the white light to be spread into a spectrum.

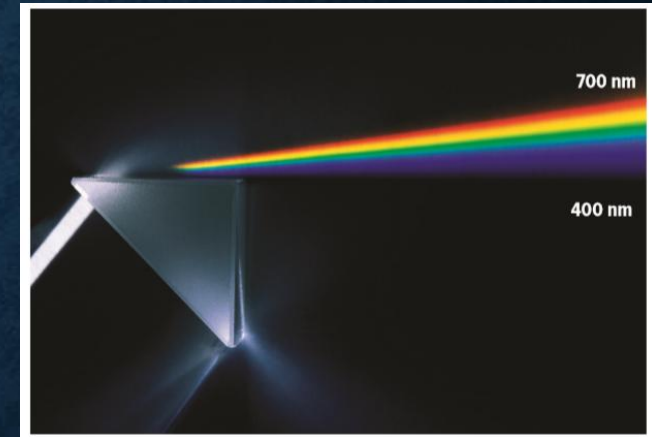


Figure 14 White light is separated into bands of color by a prism. Each color has a different wavelength.

Describe primary, secondary, and complementary colors of light and the effects of corresponding combinations.

Explain that the color of an object depends on the wavelengths present in incident light and on which wavelengths are absorbed or reflected by the object.

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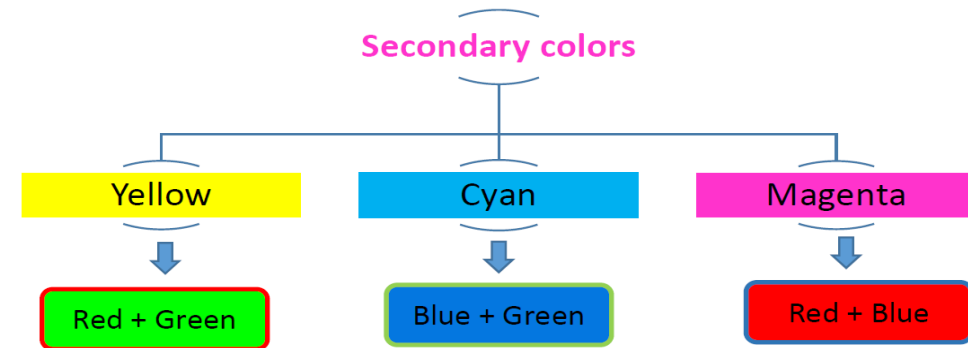
Primary colors



- ❖ The correct intensities of red, green, and blue light appear on a screen as white light when combined.

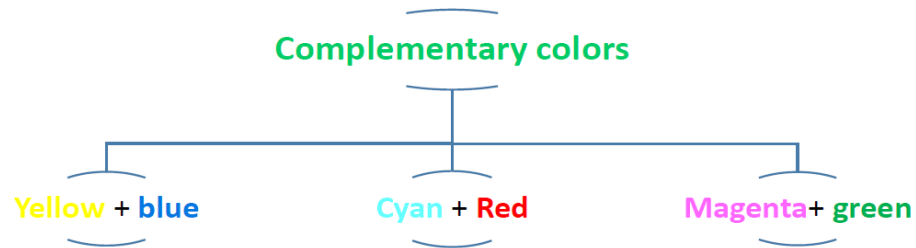
- ❖ **Secondary colors:** is a combination of two primary colors.

Secondary colors

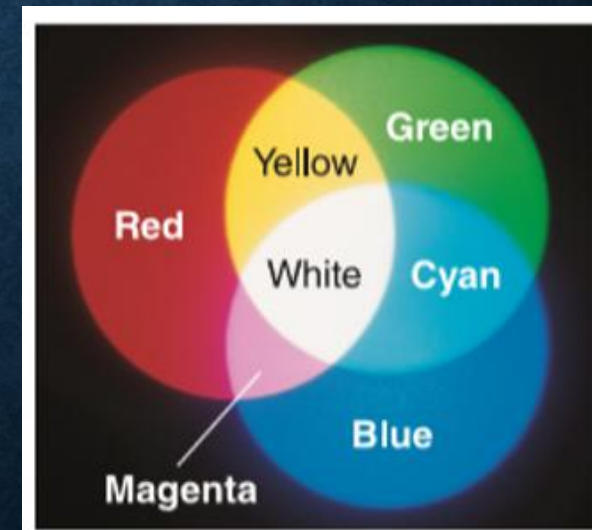


- ❖ **Complementary colors:** are two colors of light that can be combined to produce white light.

Complementary colors



- ❖ **A practical application:** yellowish laundry can be whitened with a bluing agent added to detergent. (yellow + blue = white)

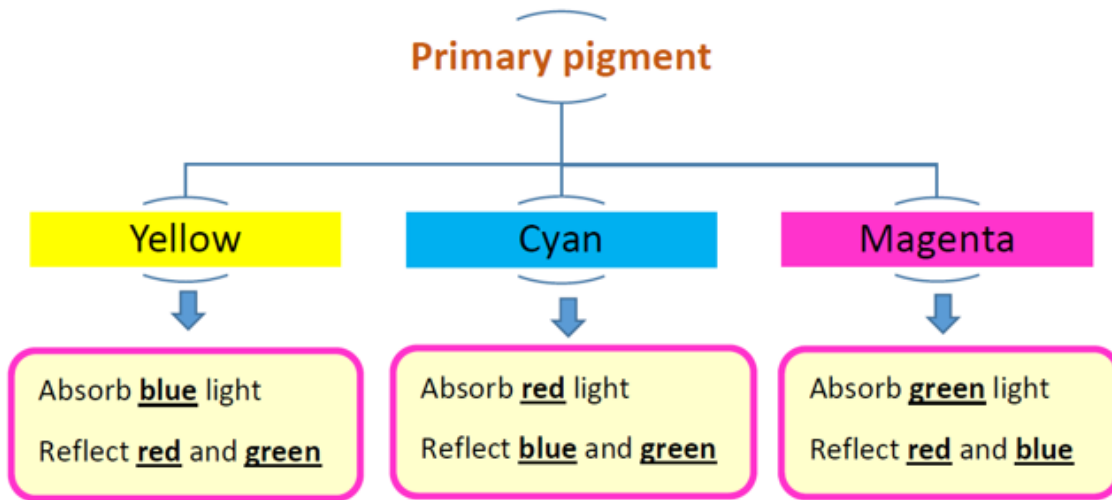


Explain that color of light depends on wavelength present in the incident light and on which wavelengths are absorbed or reflected by the object

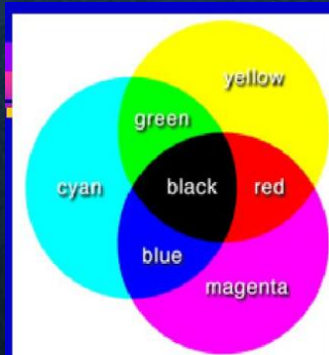
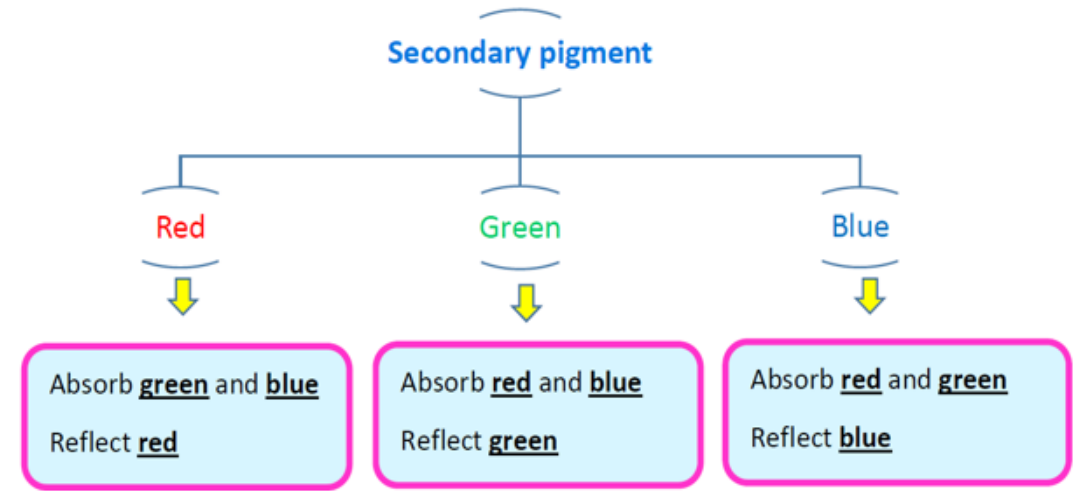
The **color of light seen from an object** depends on the **wavelengths present in the incident light** and on which wavelengths are **absorbed** or **reflected** by the object. An object appears a certain color because it reflects that color's wavelength and absorbs the other wavelengths. For example, a red object appears red because it reflects red light and absorbs most other colors. If there is no red light in the incident light, the object may not appear red.

Colors by Absorption	Colors by Reflection
An object absorbs certain wavelengths (colors) of light.	An object reflects certain wavelengths (colors) of light.
The absorbed colors are not seen by our eyes.	The reflected colors are seen by our eyes.
More absorption makes the object appear darker.	The reflected color determines the color of the object.
Example: A black shirt absorbs almost all colors of light.	Example: A green leaf reflects green light.

Primary pigments absorb one primary colors and reflect two primary color from white light.



Secondary pigments absorb two primary colors and reflect one primary color from white light.



Primary Pigments

Effects of mixing pigments or dyes:

When **pigments or dyes are mixed**, they follow the **subtractive color mixing process**, where different wavelengths of light are absorbed and fewer wavelengths are reflected.

- The mixture **absorbs more lights** and **reflects fewer wavelengths**.
- The color becomes **darker and less bright** with each addition of pigment.
- Mixing two pigments produces a **secondary color**.
- Mixing all primary pigments together results in **black or very dark brown** (because almost all light is absorbed).

Examples:

- Cyan + Yellow → Green
- Magenta + Yellow → Red
- Cyan + Magenta → Blue
- Cyan + Magenta + Yellow → Black (theoretically)

So, the main effect is : **more mixing → more absorption → darker color.**

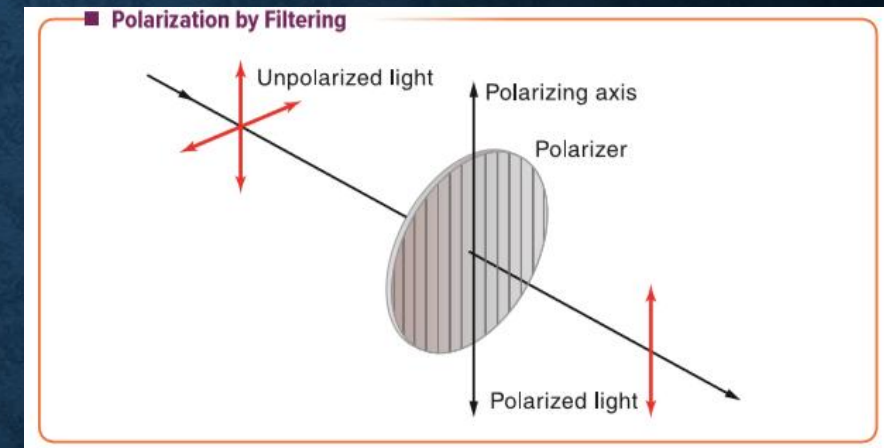
Polarization of light using a polarizing filter

Polarization is the process in which the vibrations of light waves are restricted to **one direction only**.

- Ordinary (unpolarized) light vibrates in **many directions** perpendicular to its direction of travel.
- A **polarizing filter** only allows vibrations in **one plane** to pass through.
- When unpolarized light passes through a polarizer, the emerging light becomes **polarized light**.

Example:

Sunglasses with polarizing filters reduce glare because they block unwanted directions of light vibrations, especially reflected light from roads or water.



Polarization by reflection

When light reflects from a **smooth surface** (like water, glass, or a road), it becomes partially polarized.

- The reflected light vibrations become mostly **parallel to the surface**.
- This reflected light can produce strong glare.
- A polarizing filter can reduce this glare by blocking these horizontal vibrations.

Example:

Sunlight reflected from water or a wet road becomes polarized, which is why polarized sunglasses help drivers and fishermen see more clearly.

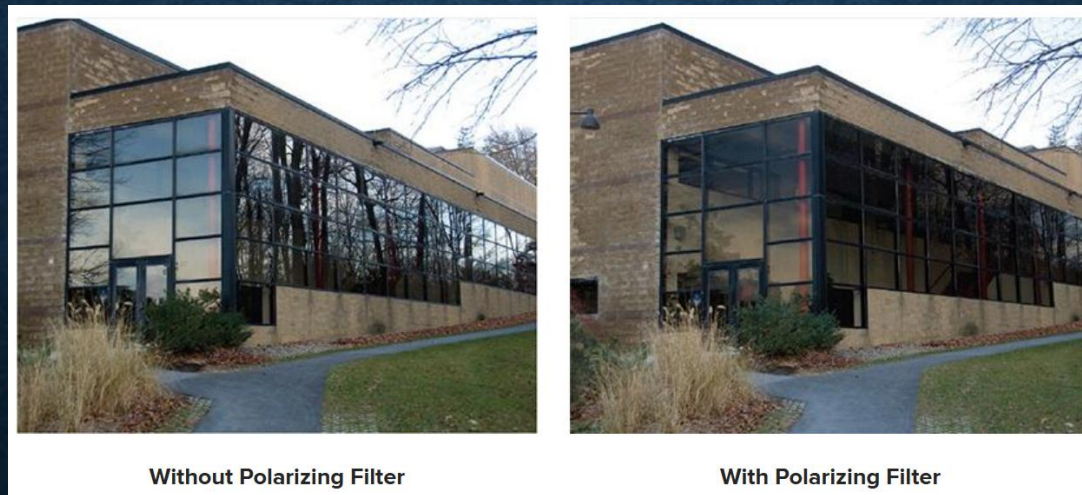


Figure 19 Glare is light that has been polarized by reflection. Photographers use polarizing filters to reduce glare.

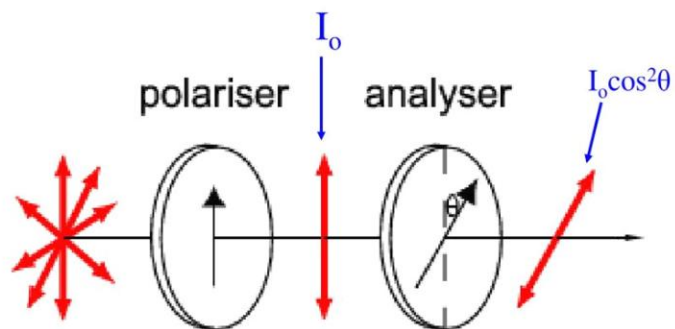
Malus's Law

The intensity of light coming out of a second polarizing filter is equal to the intensity of polarized light coming out of a first polarizing filter multiplied by the cosine, squared, of the angle between the polarizing axes of the two filters.

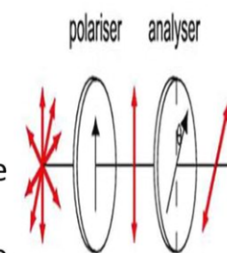
$$I_2 = I_1 \cos^2 \theta$$

Malus' law

$$I = I_0 \cos^2 \theta$$

**MALUS LAW**

- According to Malus, when completely plane polarized light is incident on the analyzer, the intensity I of the light transmitted by the analyzer is directly proportional to the square of the cosine of angle between the transmission axes of the analyzer and the polarizer.



$$A = A_0 \cos \theta$$

$$I \propto A^2$$

$$A^2 = A_0^2 \cos^2 \theta$$

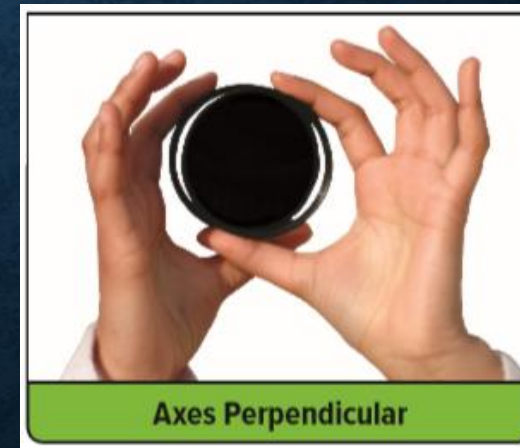
Explanation (Polarizer + Analyzer system)

1. **Unpolarized light** first passes through a **polarizer** → becomes **plane-polarized light**.
2. This polarized light then passes through an **analyzer**.
3. The analyzer allows only the component of light along its axis to pass.
4. The transmitted intensity follows Malus' law:
 1. Maximum transmission when $\theta = 0^\circ$ → axes parallel
 2. Zero transmission when $\theta = 90^\circ$ → axes perpendicular (crossed polarizers)

Key results:

- $\theta = 0^\circ \rightarrow I = I_0$ (maximum light passes)
- $\theta = 90^\circ \rightarrow I = 0$ (no light passes)
- Intermediate angles → partial transmission following $\cos^2\theta$ rule

$$I = I_0 \cos^2 \theta$$



**ALL THE BEST
FOR EXAM!**