

مراجعة الهيكل الوزاري لمادة الفيزياء



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: 18:20:10 2026-06-10

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: عبدالرحمن عصام عيد

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

Fundamentals of Light: Illumination

1

هيكل امتحان أوراق عمل الموجات

2

بريدج شرح هيكل الامتحان أسئلة تدريبية

3

بريدج هيكل الامتحان أسئلة تدريبية

4

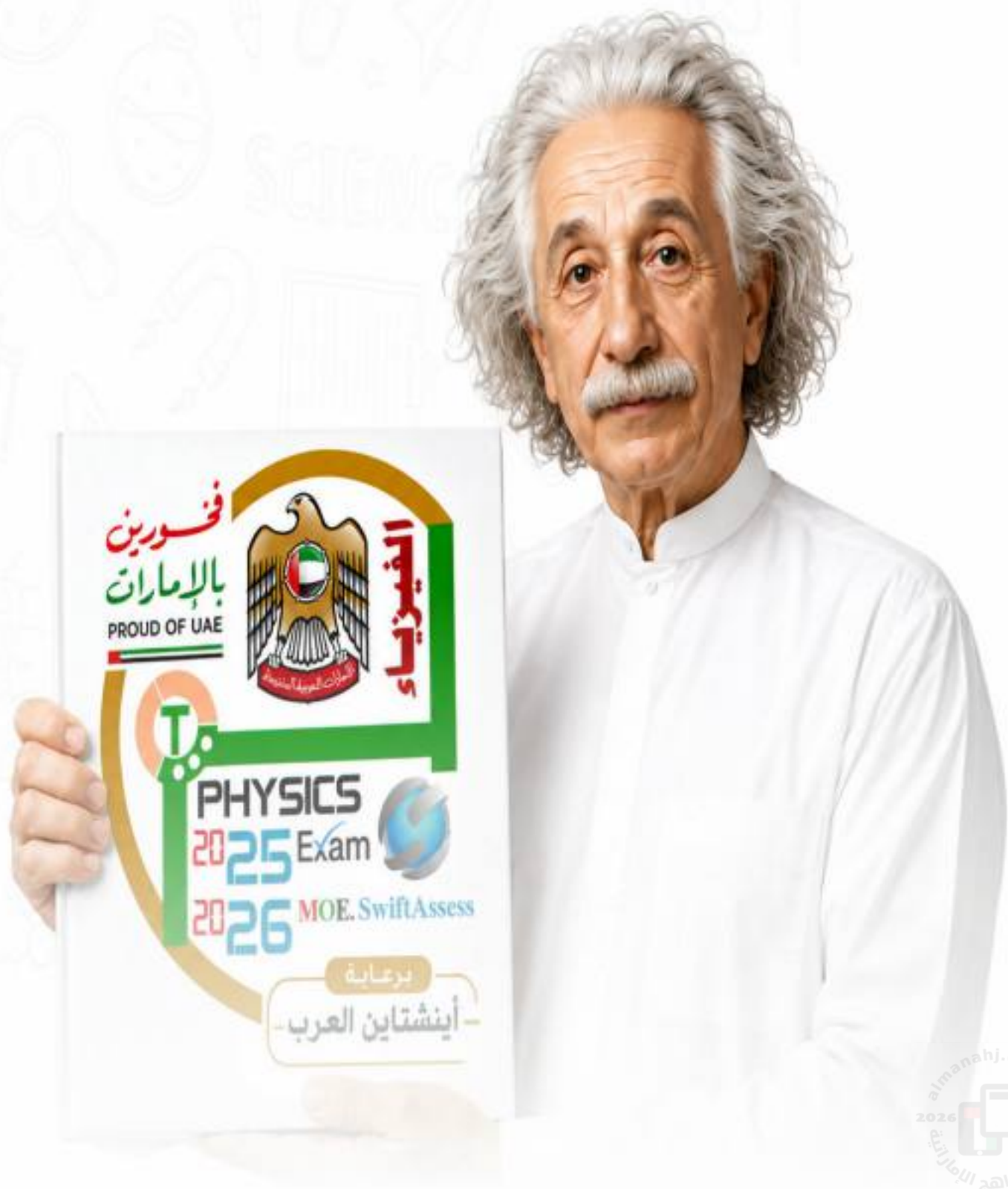
Physics Inspire - Mechanical Waves

5

Einstein_AE

PHYSICS

END OF TERM 3 COVERAGE (2025–2026)



اينشتاين العرب

مراجعة الهيكل الوزاري
END OF TERM 3 COVERAGE

الهيكل الوزاري

شرح واضح للمخرجات



شرح تفصيلي ومنظم لكل مخرج من مخرجات المنهج
بلغة سهلة وأمثلة تطبيقية توضح الفهم

تدريبات شاملة



تدريبات متنوعة تغطي
جميع أنواع الأسئلة
على كل مخرج

تغطية الهيكل



كل مخرج في مكانه
وفقاً للمواصفات الرسمية
للهيكل

أسئلة وزارية سابقة



تجميع لأهم الأسئلة
الوزارية السابقة
مع الحل النموذجي

اختبارات تجريبية



نماذج اختبارات شاملة
على الهيكل بالكامل
تحاكي الامتحان الحقيقي

Mr.Abdulrahman Esam Eid

استاذ عبدالرحمن عصام عيد

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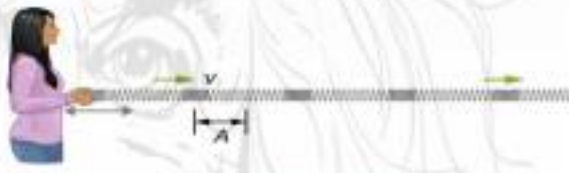
Einsteinabdo

هذه الملازم متاحة حصرياً للمشتركين

Academic Year العام الدراسي	2025-2026	Type نوع	Questions أسئلة	Learning Outcome/Performance Criteria** معايير الأداء	المراجع في كتاب الطالب والمعلم (الانجليزية) Reference(s) in the Student Book (English Version)	Page, صفحة
Term/المصطلح	T3	المرجع	1		Example/Exercise مثال/تمرين	
Subject الموضوع	Physics (Inspire)		1	Differentiate between transverse, longitudinal, and surface waves and give examples	St. textbook	115-116
Grade الصف	9		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	St. textbook Example problem 3 Practice problem(14 to 23)	118 119 120
Stream. المسار	Advanced المتقدم		3	Describe that a mechanical wave is inverted if reflected from a fixed end and remains upright if reflected from a free end	St. textbook	122-121
Number Of MCQ عدد الأسئلة الموضوعية	25		4	Describe wave properties like amplitude, energy of a wave, wavelength, speed, phase, period and frequency	St. textbook	118-118
Marks of MCQ درجة الأسئلة الموضوعية	4		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	St. textbook	122-123
Type of All Questions نوع كافة الأسئلة	MCQ/ الموضوعية		6	Define nodes and antinodes and describe how they are formed.	St. textbook	123
Maximum Overall Grade الدرجة القصوى الممكنة	100		7	Determine the wavelengths required for the first several harmonics on a string under tension in terms of string length ($\lambda_n = \frac{2L}{n}$).	St. textbook	124
Exam Duration مدة الامتحان	120 min		8	Define sound as pressure oscillation that is transmitted through matter. Explain that sound is a longitudinal wave that has frequency, wavelength, and speed	St. textbook	132
Mode of Implementation طريقة التطبيق	Swift Assess.		9	Explain that the speed of sound varies with different mediums and temperatures.	St. textbook	133-134
Calculator الآلة الحاسبة	Allowed مسموحة		10	Define sound pitch and relate it to the frequency of a sound wave.	St. textbook	135
			11	Define loudness and relate it to the amplitude of a sound wave.	St. textbook	135
			12	Describe the sound level and define the decibel (dB) as a unit of measuring sound level.	St. textbook	135
			13	Apply the Doppler effect equation ($f_A = f_s \left[\frac{v \pm v_o}{v \pm v_s} \right]$) to calculate different frequencies and velocities.	Example Problem/ Practice problems	138
			14	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.	St. textbook	141
			15	Differentiate between luminous and non-luminous sources of light, giving examples. Differentiate between opaque, translucent and transparent mediums, giving examples	St. textbook	157-158
			16	Define quantities of light like luminous flux and illuminance, specifying their SI units. Define luminous intensity, specifying its SI units	St. textbook	158-161
			17	Apply the equation for illuminance of a point source to numerical problems	Example Problem/ Practice problems	162
			18	Define quantities of light like luminous flux and illuminance, specifying their SI units.	St. textbook	158-161
			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.	St. textbook	158
			20	Define diffraction as the bending of a wave as it passes the edge of a barrier	St. textbook	165
			21	Describe that the color of light is related to its wavelength and frequency.	St. textbook	166
			22	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.	St. textbook	167
			23	Describe primary and secondary pigments and the effects of mixing pigments or dyes	St. textbook	168
			24	Explain the polarization of light by filtering using a polarizing filter. Describe the polarization of light by reflection	St. textbook	169
			25	Apply Malus's law to light filtered by polarizer and analyzer filters	St. textbook	170
الأسئلة الموضوعية - MCQ						
Questions might appear in a different order in the actual exam, or on the exam paper. كما تظهر الأسئلة بترتيب مختلف في الامتحان الفعلي.						
As it appears in the textbook, LMS, and (Math_IP) LMS. كما وردت في كتاب الطالب والمعلم.						

Learning Outcome 1:

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

Transverse Wave	Longitudinal Wave
Particles vibrate perpendicular ($\perp$) to the direction of wave travel	Particles vibrate parallel ($\parallel$) to the direction of wave travel
Particles move up and down	Particles move back and forth
Consists of crests and troughs	Consists of compressions and rarefactions
 (a) Transverse wave	 (b) Longitudinal wave
Energy moves forward while particles oscillate vertically	Energy and particles oscillate in the same direction
Example: rope waves, light waves	Example: sound waves, spring waves

Surface Waves**Definition:**

A **surface wave** is a wave in which particles move in a **circular path**, combining characteristics of both transverse and longitudinal waves.

**Characteristics:**

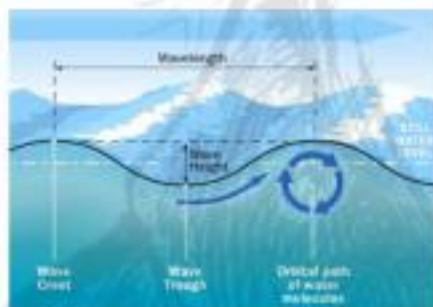
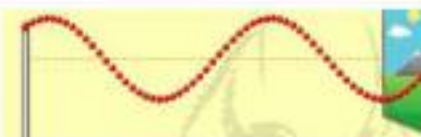
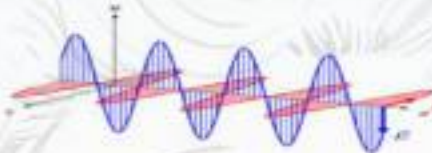
- Particle motion is **both parallel and perpendicular** to wave direction.
- Contains:
 - Transverse motion $\rightarrow$ up and down
 - Longitudinal motion $\rightarrow$ forward and backward
- Particles follow a **circular motion**.

Which of the following is an **example** of a **transverse wave**?

- Ⓐ Vibration of a rope Ⓑ Waves in a spring Ⓒ Deep waves of the ocean Ⓓ Water surface waves

Which shape shown below represents a surface wave?

أي الأشكال المبينة أدناه يُمثل موجة سطحية؟



في هذا النوع من الموجات، تتبع جسيمات الوسط مسارا دائريا يكون في بعض الأحيان موازيا وفي أحيان أخرى متعامدا مع اتجاه انتقال الموجة. كما هو موضح في الشكل. ما اسم هذا النوع من الموجات؟

In this type of waves, the medium's particles follow a circular path that is at times parallel and at other times perpendicular to the direction of wave travel, as shown in the Figure. What is the name of this type of waves?

Primary waves

موجات أولية

Longitudinal waves

موجات طولية

Transverse waves

موجات مستعرضة

Surface waves

موجات سطحية

يتم وضع مكبر صوت بجوار لهب شعلة مضادة، كما في الشكل. ويتم تشغيل موجة صوتية بصوت عال باتجاه لهب الشعلة فينتج أي المصطلح التالية بين بشكل صحيح نوع الموجات الصادرة من مكبر الصوت واتجاه حركة لهب الشعلة؟

A speaker is placed next to a flame, a loud sound wave is played through the speaker causing the flame to vibrate. Which of the following rows describes, correctly, the type of the wave and the direction of the flame movement?

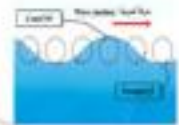
	Type of waves	اتجاه حركة اللهب	نوع الموجة
		Direction of flame movement	
A	Longitudinal		طولية
B	Transverse		مستعرضة
C	Longitudinal		طولية
D	Transverse		مستعرضة

Which of the following is an example of a transverse wave?

- (a) Vibration of a rope (b) Waves in a spring
(c) Deep waves of the ocean (d) Water surface waves

1. The adjacent figure shows the movement of water particles at the surface, where they follow a circular path, sometimes parallel to the direction of travel, and other times perpendicular to the direction of wave travel. What is **this type of wave** named?

- (a) Longitudinal Waves (b) Transverse Waves
(c) Standing Waves (d) Surface Waves



2. In this type of waves, the medium's particles follow a circular path that is at times parallel and at other times perpendicular to the direction of wave travel, as shown in the Figure.

What is the name of **this type** of waves?

- (a) Longitudinal Waves (b) Transverse Waves
(c) Standing Waves (d) Surface Waves



3. A wave disturbs objects in the medium perpendicular to its direction of motion. What type of **wave** is this?

- (a) Circular wave (b) Sound wave (c) Longitudinal wave (d) Transverse wave

4. A wave disturbs objects in the medium parallel to its direction of motion.
What type of wave is this?

(a) Circular wave (b) Sound wave (c) Longitudinal wave (d) Transverse wave

5. In the figure, what **type** of wave is propagating in the spring and in which direction is it traveling?



(a) Longitudinal and propagating to the right (b) Longitudinal and propagating to the left
(c) Transverse and propagating to the right (d) Transverse and propagating to the left

6. The figures below show two different waves produced in a rope and a spring.
Which of the statements **correctly** describes the waves?



- (a) Wave 2 is a transverse wave and disturbs the particles in the medium perpendicular to the direction of the wave's travel
(b) Wave 1 is a transverse wave and disturbs the particles in the medium perpendicular to the direction of the wave's travel
(c) Wave 1 is a longitudinal wave and disturbs the particles in the medium parallel to the direction of the wave's travel
(d) Wave 2 is a longitudinal wave and disturbs the particles in the medium perpendicular to the direction of the wave's travel

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Learning Outcome 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 wave speed, wavelength, or frequency

Wave Equations Revision Summary**1. Frequency and Period**

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

T is period; f is frequency.

Rules

- If Period increases → Frequency decreases
- If Period decreases → Frequency increases

2. Wave Speed Equation

$$v = \lambda f$$

Where:

- v = Wave speed (m/s)
- λ = Wavelength (m)
- f = Frequency (Hz)

Derived Equations (Important)

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

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

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Example Problem 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 changes to **442 Hz**, what are the new wavelength and period?

.....

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14. A sound wave produced by a clock chime is heard **515 m** away after **1.50 s**. The wave has a frequency of **436 Hz**. What is the **wavelength**?

- Ⓐ 0.85 m Ⓑ 1.77 m Ⓒ 2.25 m Ⓓ 3.00 m

15. Which equation correctly describes the relationship between **wave speed**, **wavelength**, and **frequency**?

- Ⓐ $v = \frac{f}{\lambda}$ Ⓑ $v = \lambda f$ Ⓒ $\lambda = vf$ Ⓓ $f = v\lambda$

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**?

- Ⓐ 0.20 m/s Ⓑ 2.45 m/s Ⓒ 4.20 m/s Ⓓ 5.00 m/s

17. If the wavelength of a wave on a rope increases by **50%** while the wave speed remains constant, what happens to the frequency?

- Ⓐ Increases by 50% Ⓑ Remains constant Ⓒ Decreases Ⓓ Doubles

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

- (a) 1.50 m (b) 2.50 m (c) 3.00 m (d) 90.0 m

19. Five wavelengths are generated every **0.100 s** in a water tank. If the wavelength is **1.20 cm**, what is the speed of the wave?

- (a) 0.06 m/s (b) 0.60 m/s (c) 6.00 m/s (d) 12.0 m/s

20. A periodic longitudinal wave has a frequency of **20.0 Hz** and the distance between successive compressions is **0.600 m**. What is the wave speed?

- (a) 6.0 m/s (b) 12.0 m/s (c) 20.0 m/s (d) 30.0 m/s

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

- (a) Doubles (b) Decreases to half (c) Remains constant (d) Becomes four times

22. If the period of a wave is reduced to **one-half**, what happens to the wavelength?

- (a) Decreases to half (b) Remains constant (c) Doubles (d) Becomes zero

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

- (a) Remains constant (b) Decreases (c) Increases by 1.5 times (d) Doubles

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When the frequency of a wave is doubled, and the velocity of the wave does not change. What happens to the **wavelength** of the wave?

عندما يزداد تردد الموجة لمثل ما كان عليه ولا تتغير سرعتها. ماذا يحدث لل**طول الموجي** للموجة؟

Decreases by half

يقل للتصاف

It does not change

لا يتغير

It increases by a factor of four

يصبح طولها الموجي أربع أمثال ما كان عليه

It doubles

يصبح طولها الموجي مثل ما كان عليه



A fire whistle emits a tone of **170 Hz**. The speed of sound in air is **340 m/s**. What is the **wavelength** of this sound?

جهاز إذار الحريق يصدر صوتاً تردده **170 Hz** . سرعة الصوت في الهواء تساوي **340 m/s** .
ما **الطول الموجي** للصوت الصادر من الجهاز؟

2.0 m

0.5 m

0.2 m

3.4 m

Direction of travel wave اتجاه تنقل الموجة



A water wave travels from deep water to shallow water, as shown in the figure, so its speed decreases. Which row of the following table rows is **correct for this wave**?

تنتقل موجة مائية من موضع فيه عمق الماء كبير، إلى موضع فيه الماء ضحل كما في الشكل فتقل سرعتها.
أي صف من صفوف الجدول التالي **صحيح لموجة الماء**؟

Wave length (λ) الطول الموجي	The period (T) الزمن الدوري	frequency (f) التردد	
Remains the same/ لا يتغير	Remains the same/ لا يتغير	Decreases/ يقل	(A)
Remains the same/ لا يتغير	Decreases/ يقل	Increases/ يزداد	(B)
Decreases/ يقل	Remains the same/ لا يتغير	Remains the same/ لا يتغير	(C)
Increases/ يزداد	Remains the same/ لا يتغير	Remains the same/ لا يتغير	(D)

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إذا كان مقدار التردد لـبندول بسيط على سطح الأرض (0.263 Hz) ،
ما مقدار الزمن الدوري لهذا البندول في نفس المكان على سطح الأرض؟

If a magnitude of frequency of simple pendulum on Earth surface was (0.263 Hz)
What is the **period** for this pendulum at the same place on Earth surface?



3.80 s

1.80 s

0.80 s

7.60 s

يولد مصدر للموجات موجات مستعرضة طولها الموجي (20 m) ، بتردد (10 موجات كاملة في الثانية الواحدة) . ما مقدار سرعة الموجة؟

A source of waves produces longitudinal wave of wavelength 20 m ,with a frequency of (10 complete waves in a second). What is the **speed** of the wave.?

0.50 $\frac{m}{s}$

200 $\frac{m}{s}$

2.00 $\frac{m}{s}$

20.0 $\frac{m}{s}$

A sound wave has a wavelength of (4.0m) and travels with a speed of (340m/s). What is the period of the wave?

موجة صوتية طولها الموجي (4.0m) وتنتقل بسرعة (340m/s) . ما الزمن الدوري للموجة؟

85.0s

0.006s

0.024s

0.012s

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What is **the frequency** of a wave with a period of (3.0 s) ?

ما تردد موجة تبلغ زمنها الدوري (3.0 s) ؟

$$\frac{\pi}{3}\text{ Hz}$$

$$3\pi\text{ Hz}$$

$$0.3\text{ Hz}$$

$$3\text{ Hz}$$

What is **the period** of a wave with a frequency of (0.3 Hz) ?

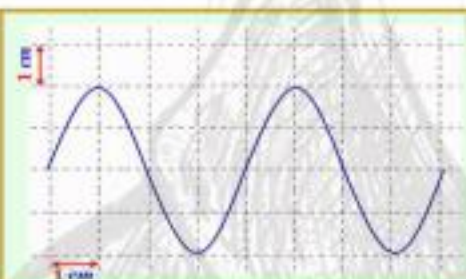
ما الزمن الدوري لموجة ترددها (0.3 Hz) ؟

$$\frac{\pi}{3}\text{ s}$$

$$3\pi\text{ s}$$

$$\frac{10}{3}\text{ s}$$

$$\frac{3}{\pi}\text{ s}$$



يوضح الشكل الموجود موجة تم الحصول عليها من مولد موجات بتردد $(f = 60\text{ s}^{-1})$. ما هي سرعة انتقال هذه الموجة (v) ؟

Figure on the left shows a wave obtained from a wave's generator with frequency $(f = 60\text{ s}^{-1})$. , what is the **velocity** (v) of this wave?

$$360\text{ cm. s}^{-1}$$

$$160\text{ cm. s}^{-1}$$

$$240\text{ cm. s}^{-1}$$

$$240\text{ cm. s}$$

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Learning Outcome 3

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

Wave Reflection**Fixed End Reflection (Rigid Boundary)**

When a mechanical wave reaches a **fixed end**, the reflected wave becomes **inverted**.

Rule:

Fixed End → Reflected Wave is Inverted

Example:

- Crest → Trough
- Trough → Crest

Free End Reflection

When a mechanical wave reaches a **free end**, the reflected wave remains **upright**.

Rule:

Free End → Reflected Wave Remains Upright

Example:

- Crest → Crest
- Trough → Trough

When a wave crosses a boundary between two media thin rope and thick rope, as shown in Figure. Which of the following is correct to the wave?

عندما تعبر موجة هذا بين وسطين حبل رفيع وحبل سميك، كما هو موضح في الشكل. أي مما يلي صحيح للموجة؟



its wavelength, speed and frequency change.
طول الموجة وسرعتها يتغيران وكذلك ترددها يتغير

its wavelength and speed change, but its frequency does not.
طول الموجة وسرعتها يتغيران لكن ترددها لا يتغير

its frequency and speed change, but its wavelength does not.
تردد الموجة وسرعتها يتغيران لكن طولها الموجي لا يتغير

its wavelength and frequency change, but its speed does not.
طول الموجة وترددها يتغيران لكن سرعتها لا تتغير

A wave pulse reaches an end that is fixed as shown below.

The wave is ____ in the opposite direction.



- Ⓐ inverted and maintains the same shape Ⓑ not inverted and maintains the same shape
Ⓒ inverted and gets bigger in shape Ⓓ not inverted and gets bigger in shape

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Learning Outcome 4

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

Wave Properties

Property	Definition
Amplitude (A)	Maximum displacement from the equilibrium position
Energy of a Wave	Energy carried by a wave and depends on amplitude
Wavelength (λ)	Distance between two successive corresponding points (crest crest or trough trough)
Wave Speed (v)	Distance travelled by the wave per unit time
Phase	Position of a particle in one complete cycle of motion
Period (T)	Time required for one complete cycle
Frequency (f)	Number of complete oscillations per second



الشكل يبين موجتين تتحركان في وسط واحد بالسرعة نفسها. أي مما يأتي **صحيح**؟

The figure shows two waves moving at the same speed. Which of the following is **true**?

Wave A has less frequency than wave B

الموجة A لها تردد أقل من الموجة B.

Wave A has a greater frequency than wave B

الموجة A لها تردد أكبر من الموجة B.

Wave A has less energy than wave B

الموجة A تمتلك طاقة أقل من الموجة B.

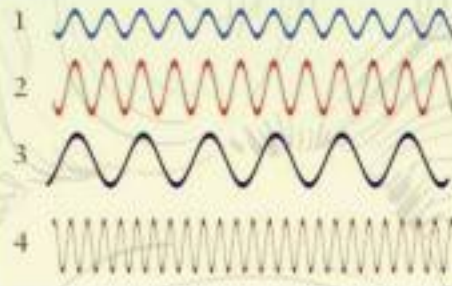
Wave A has a greater energy than wave B

الموجة A تمتلك طاقة أكبر من الموجة B.

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Which wave in the diagram has the greatest frequency?



أي موجة في الشكل لها أكبر تردد؟

1

2

3

4

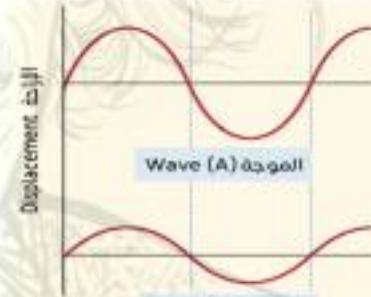
The figure shows two waves (A) and (B) propagating in the same medium. The properties of each of them are written in the table shown below;

Which of the four possibilities in the table most accurately describes the properties of each of the two waves (A) and (B)?

يُظهر الشكل موجتين (A) و (B) تنتشران في الوسيط نفسه. تم كتابة خصائص كل منهما في الجدول المبين أدناه:
أي الاحتمالات الأربع في الجدول تكون لخصائص كل من الموجتين (A) و (B) وصف أدق؟

Wave Frequency تردد الموجة	Wave Speed سرعة الموجة	Wave Energy طاقة الموجة	Wavelength طول الموجة	
$A > B$	$A < B$	$A > B$	$A > B$	1
$A > B$	$A > B$	$A = B$	$A > B$	2
$A = B$	$A = B$	$A = B$	$A = B$	3
$A = B$	$A = B$	$A > B$	$A = B$	4

الجدول Table



الموجة (B) Wave (B)

الموجة (A) Wave (A)

الشكل Figure

1

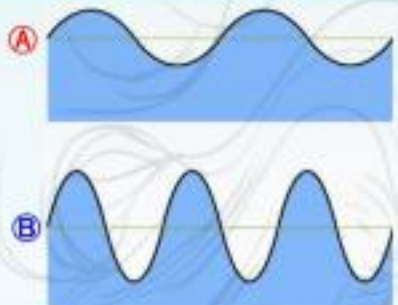
2

3

4

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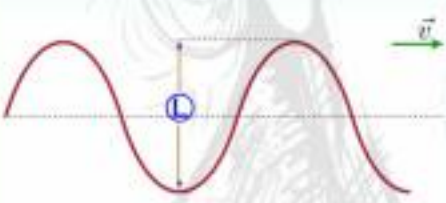
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The diagrams show two water waves (A) and (B) that are travelling at the same speed on the surface of a pond. The diagrams are on the same scale. Which of the following rows is **correct**?

يوضح الشكلان موجتين مائيتين (A) و (B) تتحركان بنفس السرعة على سطح بركة. الشكلان بنفس مقياس الرسم. أي من الصفوف التالية **صحيح**؟

Greater Amplitude/أكبر سعة (B)	Greater Energy/أكبر طاقة (B)	Smaller frequency/أقل تردد (A)
Greater Amplitude/أكبر سعة (A)	Greater Energy/أكبر طاقة (B)	Smaller frequency/أقل تردد (A)
Greater Amplitude/أكبر سعة (B)	Greater Energy/أكبر طاقة (A)	Smaller frequency/أقل تردد (B)
Greater Amplitude/أكبر سعة (A)	Greater Energy/أكبر طاقة (A)	Smaller frequency/أقل تردد (B)



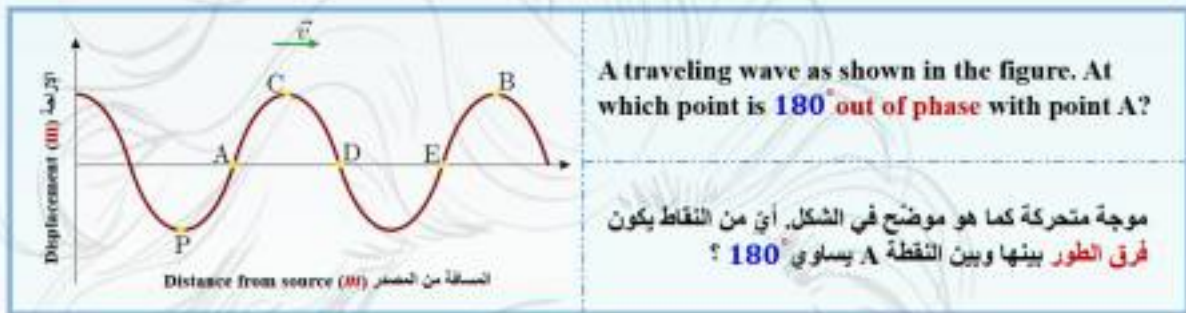
A transverse wave is traveling toward the right as shown in the figure, the amplitude of this wave is **0.6 m**. What is the magnitude of the **vertical distance** labeled by letter (L) on the figure?

موجة مستعرضة تنتقل نحو اليمين كما في الشكل، سعة هذه الموجة تساوي **0.6 m**. ما مقدار **المسافة العمودية** المُشار إليها بالحرف (L) المبين على الشكل؟

1.2 m
2.4 m
0.9 m
1.8 m

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D

E

P

C

According to the wave figure. What is the frequency of the wave?

وفقا للموجة في الشكل. ما تردد الموجة؟

0.2Hz

13Hz

50Hz

25Hz

According to the wave figure. Which of the following is correct?

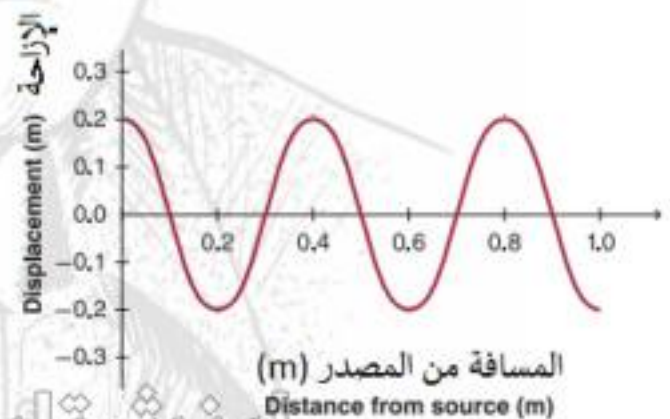
وفقا للموجة في الشكل. أي من التالي صحيح؟

The wavelength الطول الموجي	The amplitude السعة
0.2m	0.4m

The wavelength الطول الموجي	The amplitude السعة
0.2m	0.2m

The wavelength الطول الموجي	The amplitude السعة
0.4m	0.4m

The wavelength الطول الموجي	The amplitude السعة
0.4m	0.2m

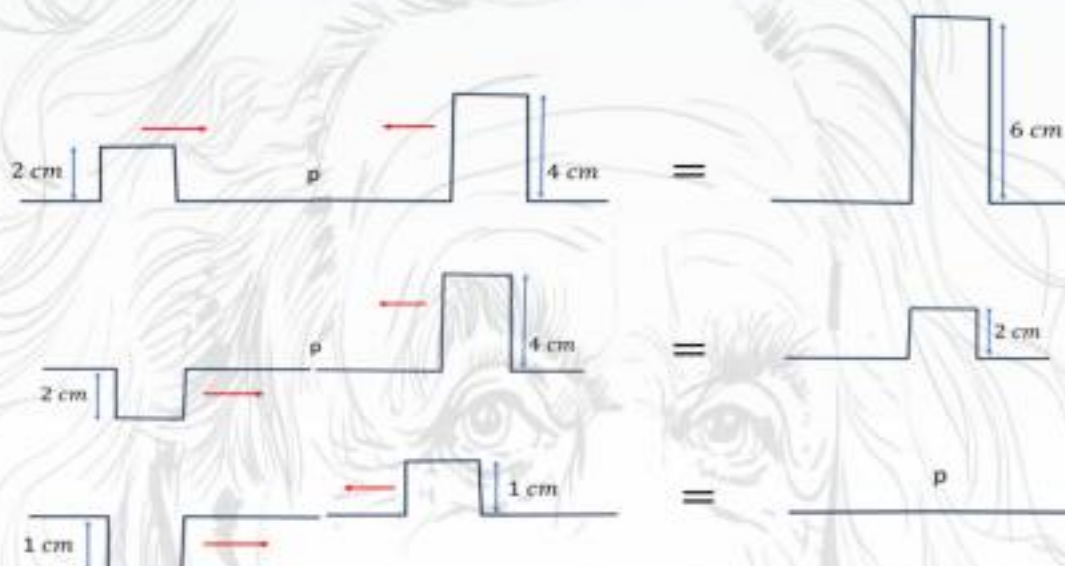


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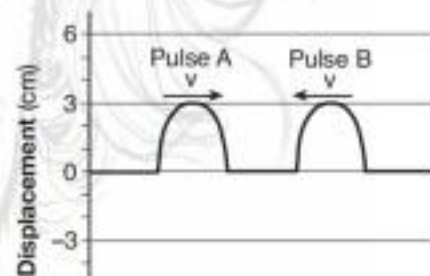
Learning Outcome 5

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.

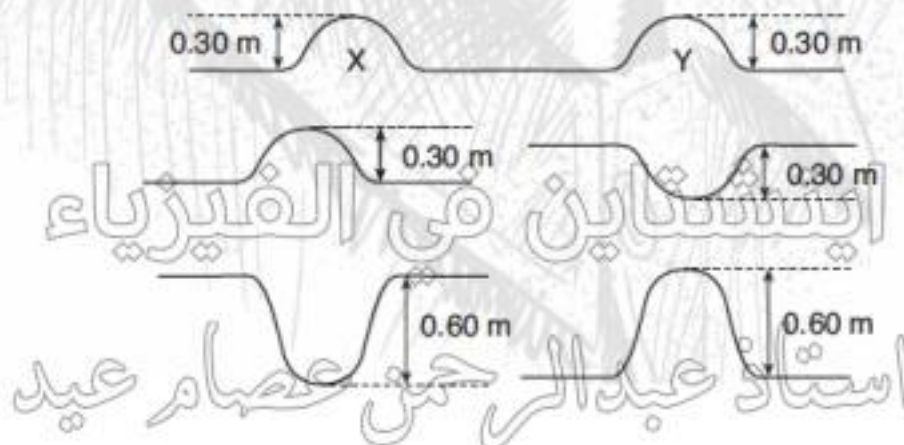


The diagram below represents two **identical wave pulses** approaching each other in a uniform medium. As the wave pulses meet and are superposed, what is the **maximum displacement** of the medium?



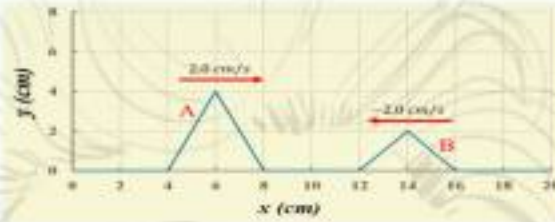
- Ⓐ 6 cm Ⓑ 0 cm Ⓒ 3 cm Ⓓ 6 cm

As represented in the diagram, two wave pulses **X** and **Y** are traveling toward each other in a rope. Both pulses have an amplitude of **0.30 m**. Which diagram shows the pulse produced due to superposition?



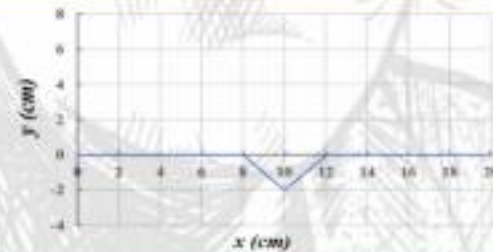
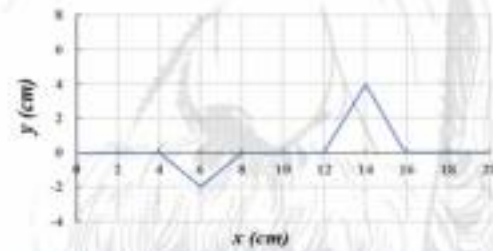
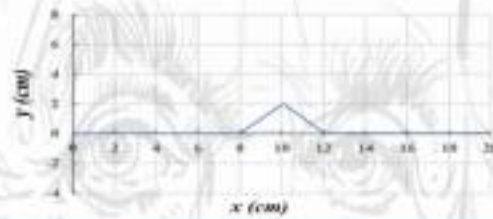
Two triangular wave pulses **A** and **B** are traveling toward each other on a stretched string, each pulse speed is (2.0 cm/s) , as shown in the Figure when $(t = 0 \text{ s})$.

What is the resulting shape of the interference of the two waves at time $(t = 2.0 \text{ s})$?



تتحرك نبضتان موجيتان مثلثيتان **A** و **B** باتجاه بعضهما البعض على وتر مشدود. وسرعة كل نبضة (2.0 cm/s) . كما يوضح الشكل عندما تكون $(t = 0 \text{ s})$.

ما الشكل الناتج لتداخل الموجتين عند الزمن $(t = 2.0 \text{ s})$.



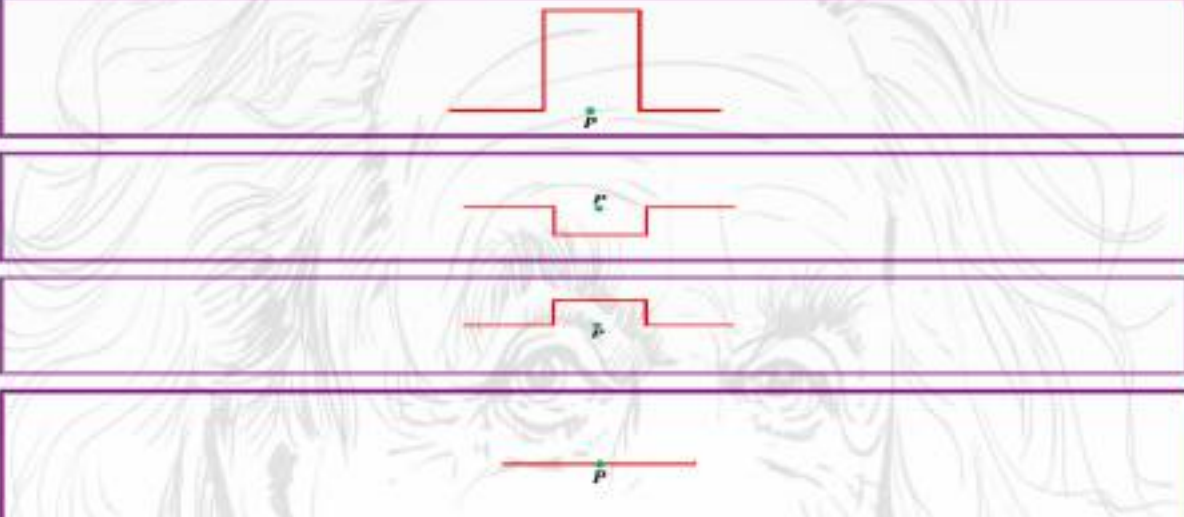
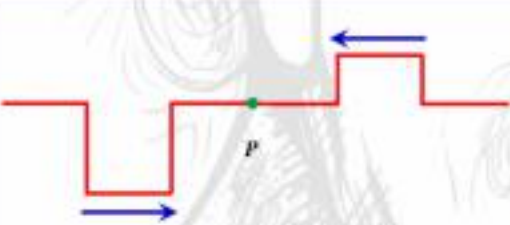
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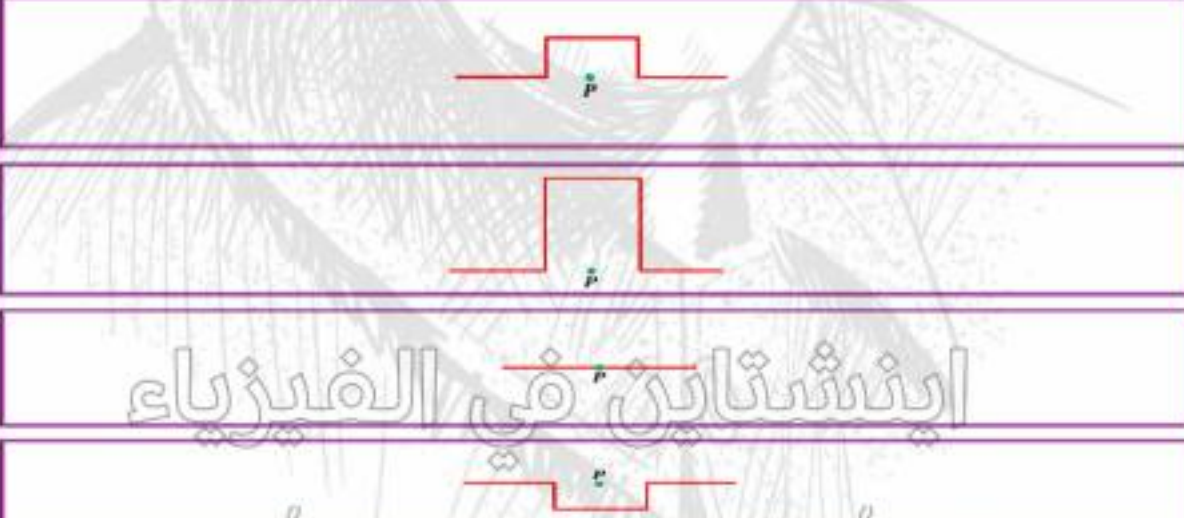
تتجه نبضتان موجيتان على نفس الوتر نحو بعضهما البعض كما هو موضح في الشكل .
عند تراكب الموجتين ، أي المخططات الآتية يصف شكل الموجة الناتجة؟

Two wave pulses on the same string are headed towards one another as shown. When both occupy the same space, which diagram best describes the **resulting** wave form?

تتجه نبضتان موجيتان على نفس الوتر نحو بعضهما البعض كما هو موضح .
عند تراكب الموجتين ، أي مخطط يصف شكل الموجة الناتجة؟

Two wave pulses on the same string are headed towards one another as shown. When both occupy the same space, which diagram best describes the **resulting** wave form?



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Learning Outcome 6

Define nodes and antinodes and describe how they are formed

1. Node (N)**Definition:**

A **node** is a point that **does not move** because the displacements cancel each other.

Formation:

- Two waves meet
- One crest overlaps with one trough
- Resultant displacement = 0

Type of Interference:**Destructive Interference****Rule:**

$$+A + (-A) = 0$$

2. Antinode (A)**Definition:**

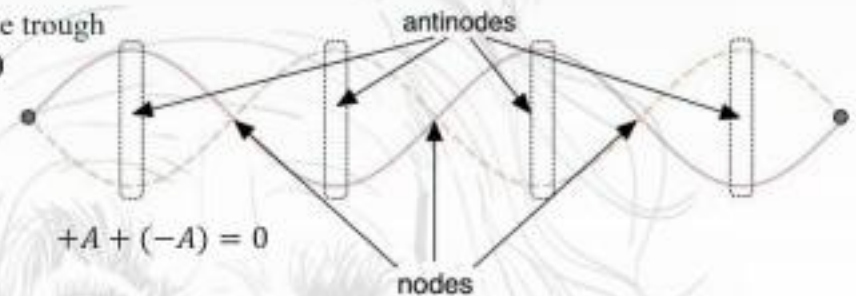
An **antinode** is the point with the **largest displacement**.

Formation:

- Two crests overlap
OR
- Two troughs overlap

Type of Interference:**Constructive Interference****Rule:**

$$A + A = 2A$$

**Nodes and Antinodes**

Term	Definition	How It Is Formed	Displacement
Node (N)	A point where the resultant displacement is zero	Formed by destructive interference when two waves overlap with opposite displacements	Minimum (0)
Antinode (A)	A point where the resultant displacement is maximum	Formed by constructive interference when two waves overlap in the same direction	Maximum

The diagram below represents a standing wave in a string. Maximum constructive interference occurs at the _____.

- (a) antinodes A, C and E (b) antinodes B and D
 (c) nodes A, C and E (d) nodes B and D



Learning Outcome 7

Determine the wavelengths required for the first several harmonics on a string under tension in terms of string length

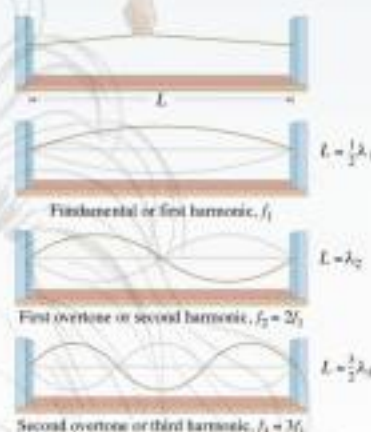
Standing Waves and Harmonics

For a string fixed at both ends:

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

Where:

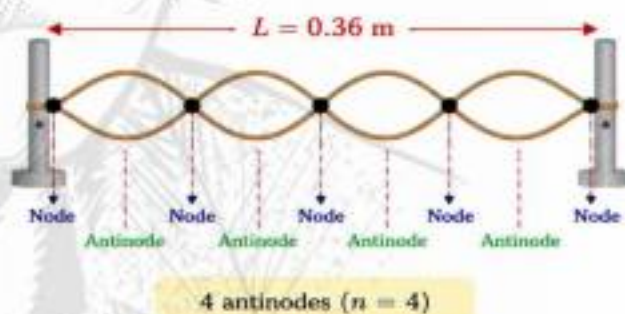
- λ_n = wavelength of harmonic n
- L = length of string
- n = harmonic number (1, 2, 3, ...)



Harmonic	Frequency Relation	Length Relation (L)	Wavelength (λ)	Number of Loops
Fundamental / First Harmonic	f_1	$L = \frac{1}{2} \lambda_1$	$\lambda_1 = 2L$	1
First Overtone / Second Harmonic	$f_2 = 2f_1$	$L = \lambda_2$	$\lambda_2 = L$	2
Second Overtone / Third Harmonic	$f_3 = 3f_1$	$L = \frac{3}{2} \lambda_3$	$\lambda_3 = \frac{2L}{3}$	3
Third Overtone / Fourth Harmonic	$f_4 = 4f_1$	$L = 2\lambda_4$	$\lambda_4 = \frac{L}{2}$	4

The diagram shows a rubber band fixed at both ends forming a standing wave. The rubber band length is 0.36 m, and the wave speed is 24.0 m/s. The standing wave has 4 antinodes. Based on the diagram, choose the correct wavelength and frequency.

	Wavelength (λ)	Frequency (f)
Ⓐ	0.09 m	65 Hz
Ⓑ	0.18 m	133 Hz
Ⓒ	0.72 m	520 Hz
Ⓓ	0.36 m	260 Hz



Step	Formula	Calculation	Result
1	$\lambda = \frac{2L}{n}$	$\lambda = \frac{2(0.36)}{4}$	$\lambda = 0.18 \text{ m}$
2	$f = \frac{v}{\lambda}$	$f = \frac{24.0}{0.18}$	$f = 133 \text{ s}^{-1}$ (133 Hz)

تتكون موجات مستقرة في أربعة أوتار متماثلة لها نفس الطول (l) كما هو مبين بالشكل. أي مما يلي يمثل الترتيب الصحيح لقدار تردد الموجات الناتجة في الأوتار الأربعة؟

Standing waves are created in four identical strings, as shown in the figure. The strings are of length (l). Which of the following is the correct ranking of the frequency produced in the four strings?

$$f_A > f_C > f_B > f_D$$

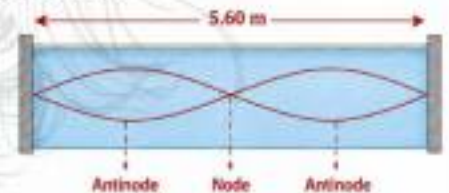
$$f_A < f_C < f_B < f_D$$

$$f_A \leq f_C > f_B \geq f_D$$

$$f_D > (f_A = f_B) > f_C$$

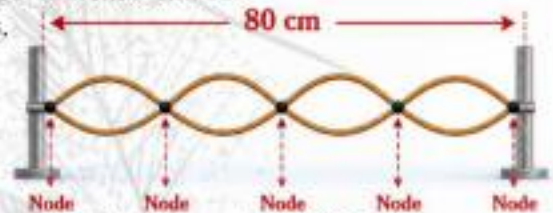
A standing wave is created in a swimming pool when a wave interferes with its reflection off the side of the pool. The standing wave is **5.60 m** long and has **2 antinodes**. What is the wavelength of the wave?

- (a) 2.80 m (b) 11.2 m
(c) 5.60 m (d) 1.40 m



A rope stretched between two fixed points 80 cm apart vibrates with 5 nodes. The speed of propagation of the wave in the rope is 20 m/s. What is the frequency of the vibrating rope?

- (a) 40 Hz (b) 60 Hz
(c) 20 Hz (d) 50 Hz



A string is **92.0 cm** long and its lowest frequency (fundamental frequency) is **92.0 Hz**. Which frequency will create a standing wave with 3 antinodes?

- (a) 46.0 Hz (b) 184 Hz (c) 276 Hz (d) 92.0 Hz

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Learning Outcome 8 – Sound Waves

Define sound as pressure oscillation transmitted through matter and explain that sound is a longitudinal wave with frequency, wavelength, and speed.

A **wave** is a disturbance that transfers **energy** through matter or space **without transferring matter**.

- **Sound** is a type of **mechanical wave** that travels through a **medium (matter)**.
- Sound waves are **longitudinal waves**, meaning the particles move **parallel** to the direction of wave travel.
- Sound is produced by **vibrations** that create **pressure variations** in the surrounding medium.

Examples of sound sources:

- Tuning forks
- Guitar strings
- Vocal cords
- Speakers

How Sound Waves Travel

When an object vibrates:

- It pushes air particles together → **Compression**
- It spreads particles apart → **Rarefaction**

Compression

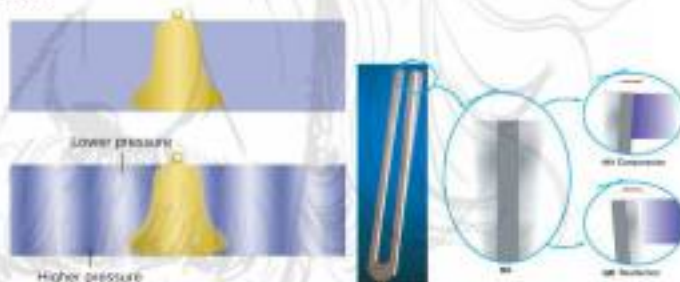
Region of a longitudinal wave where:

- Pressure → **maximum**

Rarefaction

Region of a longitudinal wave where:

- Pressure → **minimum**



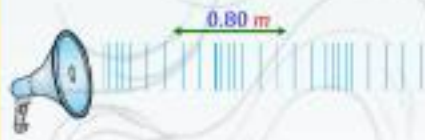


يمثل الرسم المجاور نبضات صوتية تنتقل في الهواء. النقطة الحمراء المبينة على الشكل تمثل أحد جزيئات الهواء. أي الرسوم التخطيطية الآتية تمثل حركة النقطة الحمراء أثناء حركة النبضات في الهواء؟

The diagram represents sound pulses traveling through air. The red point represents an air molecule. Which of the following diagrams represents the motion of the red point as the pulses pass through air?

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يوضح الشكل موجة صوتية يصدرها مكبر صوت. ينتشر الصوت في الهواء بسرعة (336 m/s) .
ما تردد الموجة الصوتية؟

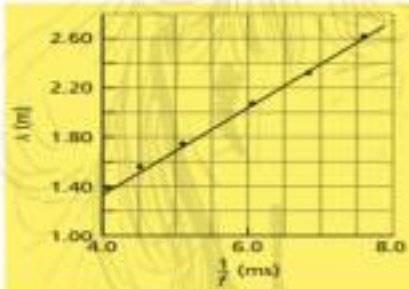
The figure shows a sound wave produced by a loudspeaker.
The sound propagates in the air at the speed of, (336 m/s) .
The **frequency** of the sound wave?

300 Hz

212 Hz

420 Hz

500 Hz



في مختبر بدرجة حرارة (20°C) أجريت تجربة باستخدام شوكة رنانة ذات ترددات مختلفة. وفي التجربة تم قياس الأطوال الموجية (λ) لكل منها. وتم تمثيل العلاقة بين الطول الموجي ومقلوب التردد $(\frac{1}{f})$ كما هو موضح في الشكل.

ما الكمية التي يمثلها ميل أفضل خط مستقيم في الرسم البياني؟

In a laboratory with a temperature of (20°C) , an experiment was conducted using tuning forks of different frequencies. In the experiment, the wavelength (λ) of each of them was measured, and the relationship between the wavelength and the inverse (reciprocal) of the frequency $(\frac{1}{f})$ was plotted as shown in the Figure.

What physical quantity is represented by the slope of the line of best fit on the graph?

Sound Amplitude

سعة الصوت

Sound Speed

سرعة الصوت

Sound Intensity

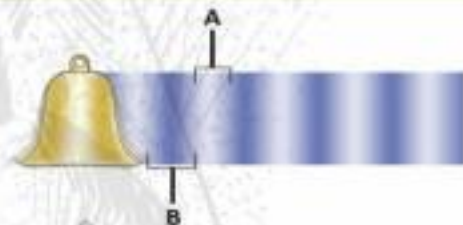
شدة الصوت

Sound Power

قدرة الصوت

The diagram shows waves move out from the bell after it has been struck in air. Which of the following is correct according to regions A and B?

يوضح الرسم التخطيطي موجات متباعدة عن جرس تم قرعه في الهواء. أي مما يلي صحيح بالنسبة للمنطقتين A و B؟



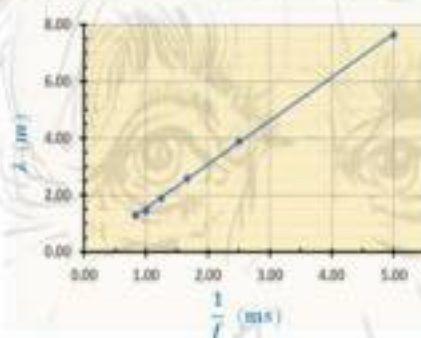
A High pressure ضغط مرتفع	B Low pressure ضغط منخفض	A High pressure ضغط مرتفع	B High pressure ضغط مرتفع
A Low pressure ضغط منخفض	B Low pressure ضغط منخفض	A Low pressure ضغط منخفض	B High pressure ضغط مرتفع

An experiment was conducted to find the speed of a sound wave in a medium, by sending sound signals at different frequencies, and measuring the wavelengths (λ) in meters for each frequency. In a graph, the relationship between the wavelength and the reciprocal of the frequency ($\frac{1}{f}$) was represented in milliseconds, and the best straight line was obtained as shown in the figure.

What is the **speed of sound** in that medium?

أجريت تجربة لإيجاد سرعة موجة صوتية في وسط ما، بإرسال إشارات صوتية بترددات مختلفة، وقياس الأطوال الموجية (λ) بوحدة المتر لكل تردد منها. وفي رسم بياني تم تمثيل العلاقة بين الطول الموجي ومقلوب التردد ($\frac{1}{f}$) بوحدة ملي ثانية، والحصول على أفضل خط مستقيم كما هو موضح في الشكل.

ما **سرعة الصوت** في ذلك الوسط؟



1560 m/s

340 m/s

5100 m/s

3450 m/s

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Learning Outcome 9 – Speed of Sound**Explain that the speed of sound varies with different mediums and temperatures****Speed of Sound**Sound is a **pressure wave** that travels through matter by particle collisions.The speed of sound is **not constant**; it changes depending on:

1. **The medium through which sound travels**
2. **The temperature of the medium**

1. Effect of the Medium

Sound travels at different speeds because particles are arranged differently in each medium.

General rule:

Solids > Liquids > Gases

- In **solids**, particles are tightly packed → sound travels fastest.
- In **liquids**, particles are less packed → medium speed.
- In **gases**, particles are far apart → slowest speed.
- Sound **cannot travel in a vacuum** because there are no particles.

Speed of Sound in Different Media

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

2. Effect of Temperature

For sound in air:

- Speed increases by approximately: 0.6 m/s for every 1°C

increase in temperature.

Formula:

Where:

- v → new speed of sound
- v_0 → initial speed
- ΔT → temperature change

$$v = v_0 + 0.6\Delta T$$

Example

Estimate the speed of sound in air at 25°C .

Given:

$$v_0 = 343 \text{ m/s}$$

$$\Delta T = 25 - 20 = 5^{\circ}\text{C}$$

Substitute:

$$v = 343 + (0.6 \times 5)$$

$$v = 346 \text{ m/s}$$

Answer:

$$\boxed{346 \text{ m/s}}$$

Important Relationship

The wave speed depends on wavelength and frequency:

$$v = f\lambda$$

f is frequency; λ is wavelength; v is wave speed.

Key Notes

- Sound is a **longitudinal wave**.
- Particle motion is **parallel** to wave direction.
- Frequency does **not change** when sound enters another medium.
- Wavelength changes because speed changes.
- Higher temperature $\rightarrow$ higher sound speed.

Which medium has the greatest speed of sound?

- (a) Air (b) Water (c) Helium (d) Iron

A sound wave takes about **0.02 s** to travel through a material that is **30.0 m** long.

Using the data in the table below, determine the material.

Speed of Sound in Different Materials

Material (20°C)	Speed (m/s)
Air	340
Cork	500
Steel	5800
Water	1500

- (a) Air (b) Cork (c) Steel (d) Water

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Learning Outcome 10 – Pitch of Sound**Define sound pitch and relate it to the frequency of a sound wave****Pitch**Pitch is the **highness or lowness of a sound** as perceived by the ear.Pitch depends directly on the **frequency of vibration**.**Relationship:**

Higher Frequency → Higher Pitch

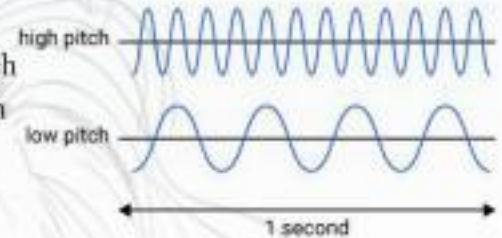
Lower Frequency → Lower Pitch

Examples:

- **High pitch** → whistle, bird sounds
- **Low pitch** → drum, thunder

Key Notes:

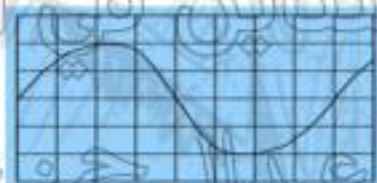
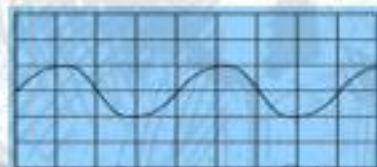
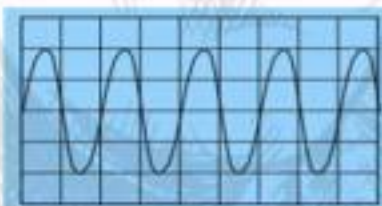
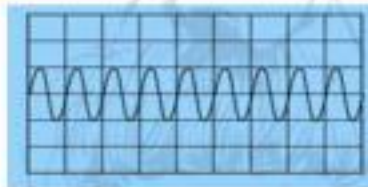
- Pitch depends on **frequency only**.
- Pitch does **not depend on amplitude**.



جهاز "راسم ذبذبات" يُبَيِّن موجات صوتية لأربعة من المصادر المختلفة.

أي الرسوم البيانية الآتية لموجة لها أعلى حدة صوتية؟

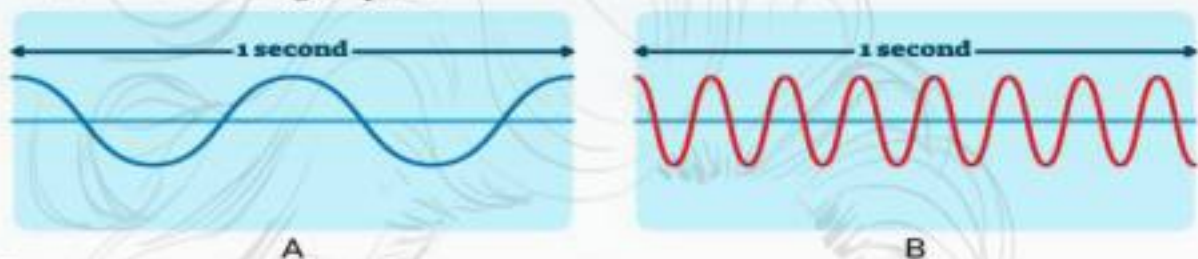
An oscilloscope displays four sound waves from different sources.

Which of the following graphs represents the wave with the **highest pitch**?

اينشتاين في الفيزياء

استاذ عبدالرحمن عصام عيد

The figure shows two sound waves A and B produced during the same time interval (1 second). Which wave has the **higher pitch**?



- (a) Wave A has a higher pitch because it has a lower frequency
 (b) Wave B has a higher pitch because it has a higher frequency
 (c) Wave A and Wave B have the same pitch
 (d) Pitch depends on amplitude, not frequency

Learning Outcome 11 – Loudness of Sound

Define loudness and relate it to the amplitude of a sound wave

Loudness

Loudness is the **intensity of sound as perceived by the ear and interpreted by the brain**.

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

Relationship:

Greater Amplitude → Louder Sound

Smaller Amplitude → Softer Sound

Sound Level Unit:

Decibel (dB)

Examples:

- Larger wave amplitude → louder sound
- Smaller wave amplitude → quieter sound



أي من الطيور التالية صوت له أعلى شدة؟

Which one of the following birds has the **loudest** sound?



استاذ عبدالرحمن عصام عيد

Which of the following is not correct for pitch and loudness of sound?

أي مما يلي غير صحيح بالنسبة لحدة الصوت وشدة؟

Pitch depends on the frequency of vibration.

حدة الصوت تعتمد على تردد الاهتزاز

Loudness depends primarily on the amplitude of the pressure wave

شدة الصوت تعتمد بشكل أساسي على سعة موجة الضغط

Pitch and loudness of sound are factors that determine the sound

حدة الصوت وشدة من العوامل التي تحدد الصوت

Pitch depends on the amplitude of the pressure wave

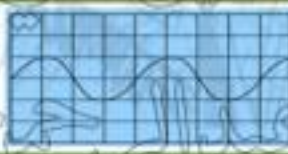
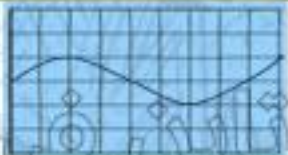
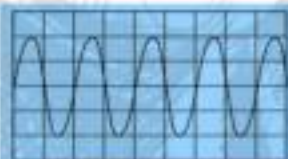
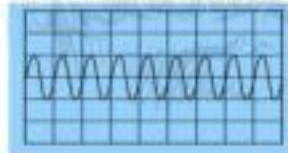
حدة الصوت تعتمد على سعة موجة الضغط

In the figure, an oscilloscope displays four sound waves from different sources.

Which of the following graphs represents the wave with the highest loudness (Intensity)?

في الشكل جهاز "رأس مذبذبات". يُبين موجات صوتية لأربعة من المصادر المختلفة.

أي الرسوم البيانية الأتية لموجة لها أعلى شدة صوتية (علو الصوت)؟



إينشنتي في الفيزياء

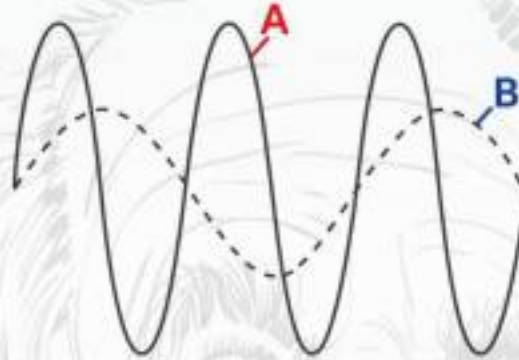
استاذ عبدالرحمن عصام عيد

If a sound wave's **intensity** is increased, how will it affect the sound's **loudness**?

- Ⓐ Loudness will increase Ⓑ Loudness will decrease
Ⓒ Loudness will remain unchanged Ⓓ Loudness will depend on the frequency of the wave

An engineer tests two sound waves:

Wave A with a frequency of **600 Hz** and **Wave B** with a frequency of **300 Hz**



Which statement best describes the relative **pitch** and **wavelength**?

- Ⓐ Wave A has a higher pitch and shorter wavelength than Wave B
Ⓑ Wave B has a higher pitch and shorter wavelength than Wave A
Ⓒ Wave A has a lower pitch and longer wavelength than Wave B
Ⓓ Wave B has a lower pitch and shorter wavelength than Wave A

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استاذ عبدالرحمن عصام عيد

12. Describe the sound level and define the decibel (dB) as a unit of measuring sound level

Sound Level (Loudness)

- **Sound level** is the perceived intensity (loudness) of a sound by the human ear.
- It depends mainly on the **amplitude (intensity)** of the sound wave.
- Because humans can hear a very wide range of sound intensities, sound level is measured using a **logarithmic scale**.

Decibel (dB)

- The **decibel (dB)** is the **unit of measurement of sound level**.
- It expresses sound intensity on a **logarithmic scale of sound intensities**.
- Larger dB values mean a **louder sound**.

Key idea

- **0 dB** → approximately the faintest sound humans can hear.
- Increasing decibels means the sound becomes much more intense:
 - **20 dB** → about **10×** more intense than **10 dB**
 - **40 dB** → about **100×** more intense than **20 dB**
 - **80 dB** → much louder than **40 dB**

Sound Level Scale (dB)



Decibel Scale

Sound Level (dB)	Sound Source
10	Barely audible
30	Whisper, 1 m away
50	Casual conversation, Alarm clock
70	Heavy traffic
90	Alarm clock
110	Rock concert
130	Jet engine

أي الكميات التالية يقاس بوحدة الديسيبل (dB) ؟

Which of the following quantities is measured in decibels (dB) ?

Energy of sound	طاقة الصوت
Pitch of sound	درجة الصوت
Loudness of sound	شدة الصوت
Sound level	مستوى الصوت

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أي الكميات الفيزيائية الآتية تقاس بوحدة الديسيبل (dB)؟

Which of the following physical quantities is measured in decibels (dB)?

Sound Pitch

حدة الصوت

Sound Loudness

علو (جهازة) الصوت

Sound Level

مستوى الصوت

Sound Amplitude

سعة الصوت

Which of the following physical quantities measure the **sound intensities** on a logarithmic scale?

أي الكميات الفيزيائية الآتية تقيس **شدة الصوت** على مقياس لوغاريتمي؟



Sound Pitch

حدة الصوت

Sound Loudness

علو (جهازة) الصوت

Sound Amplitude

سعة الصوت

Sound Level

مستوى الصوت

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استاذ عبدالرحمن عصام عيد

13. Doppler Effect

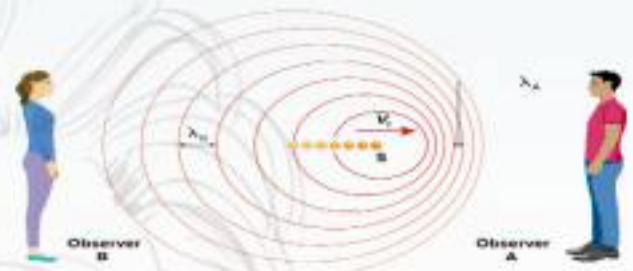
Doppler Effect — Organized Review

1. When Objects Move Toward Each Other

- Distance between wavefronts **decreases**
- Wavelength (λ) **decreases**
- Frequency (f) **increases**

2. When Objects Move Away From Each Other

- Distance between wavefronts **increases**
- Wavelength (λ) **increases**
- Frequency (f) **decreases**



13. Apply the Doppler Effect Equation to calculate different frequencies and velocities

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

Symbols:

- f_d = detected (observed) frequency
- f_s = source frequency
- v = speed of sound
- v_d = speed of detector (observer)
- v_s = speed of source

Motion	Observer (Detector)	Source
Toward		+
Away	+	-

A guitar player sounds C above middle C (523 Hz) while traveling in a convertible car at 24.6 m/s.

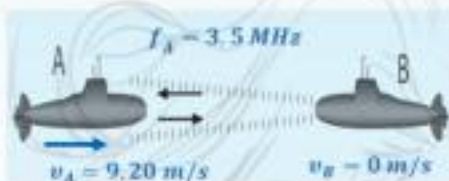
If the car is moving **toward the observer**, what frequency would the observer hear?

Assume:

- Speed of sound in air = 343 m/s
- Source frequency = 523 Hz
- Detector is at rest



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تتحرك الغواصة **A** بسرعة 9.20 m/s باتجاه غواصة أخرى **B** في حالة السكون، تُصدر الغواصة **A** إشارة سونار بتردد مقداره 3.50 MHz . إذا علمت أن سرعة الصوت في الماء 1482 m/s . ما التردد الذي سترصد الغواصة الثانية (B)؟

A submarine **A** is moving at (9.20 m/s) towards another submarine **B**, at rest. The Sub **A** sends out a sonar signal at (3.50 MHz) . If you know the speed of sound in water is (1482 m/s) . What frequency would the second submarine (B) detect?

5.22 MHz

A

4.32 MHz

B

3.48 MHz

C

3.52 MHz

D



قطار يتحرك بسرعة ثابتة $(0.25v)$ مقتربا من مراقب يقف على منصة، حيث (v) هي سرعة الصوت. يصدر القطار صوتا بتردد (f) . ما هو التردد الذي يرصده المراقب؟

A train is traveling with a constant speed $(0.25v)$ toward an observer standing on a platform, where (v) is the speed of sound. The train sounds whistle of a frequency (f) . What is the observed frequency?

$$\frac{7}{4}f$$

$$\frac{1}{2}f$$

$$\frac{8}{10}f$$

$$\frac{4}{3}f$$

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استاذ عبدالرحمن عصام عيد

A stationary siren wails a sound wave of 390Hz traveling in the air towards an observer who runs towards the siren at speed of (5.0m/s). If you know that the speed of sound in air is 345m/s, what is the wavelength of the sound wave received by the observer?

تطلق صافرة إنذار ثابتة موجة صوتية ترددها (390Hz) تنتقل في الهواء باتجاه مراقب يركض باتجاه صافرة الإنذار بسرعة (5.0m/s). إذا علمت أن سرعة الصوت في الهواء (345m/s)، فما الطول الموجي للموجة الصوتية التي يستقبلها المراقب؟

0.885m

0.621m

0.872m

0.898m

A ship's sonar uses a frequency of 22.5 kHz. The speed of sound in seawater is 1533 m/s. What is the frequency received on the ship that was reflected from a whale traveling at 4.15 m/s away from the ship? Assume that the ship is at rest.

- (a) 22.4 kHz (b) 21.9 kHz (c) 22.0 kHz (d) 23.1 kHz

A train moving toward a sound detector at 31.0 m/s blows a 305-Hz whistle. What frequency is detected on each of the following?

a. a stationary train

- (a) 278 Hz (b) 335 Hz (c) 305 Hz (d) 352 Hz

b. a train moving toward the first train at 21.0 m/s

- (a) 324 Hz (b) 357 Hz (c) 305 Hz (d) 388 Hz

A train moving away from a sound detector at 31.0 m/s blows a 305-Hz whistle. What frequency is detected on each of the following?

a. a stationary train

- (a) 280 Hz (b) 305 Hz (c) 331 Hz (d) 354 Hz

b. a train moving away from the first train at 21.0 m/s

- (a) 241 Hz (b) 263 Hz (c) 280 Hz (d) 305 Hz

You are in an auto traveling at 25.0 m/s 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.

- (a) 338 Hz (b) 392 Hz (c) 365 Hz (d) 418 Hz

استاذ عبدالرحمن عصام عيد

The following table shows data collected from an investigation into the relationship between the velocity of a moving sound source and the frequency detected by a stationary listener.

Experiment Number	Velocity of Sound Source (m/s)	Frequency Detected by Listener (Hz)
1	0	900
2	10	874
3	20	850
4	30	827

a) Was the sound source moving towards or away from the listener?

Answer:

The sound source was moving away from the listener.

Reason:

As the **velocity of the sound source increased**, the **detected frequency decreased**, which is a characteristic of the **Doppler Effect** when the source moves away.

b) Use the information in the table to calculate the speed of sound during the investigation.

Given:

- $f_s = 900 \text{ Hz}$
- $f_d = 874 \text{ Hz}$
- $v_s = 10 \text{ m/s}$
- $v_d = 0 \text{ m/s}$

Doppler Effect Equation

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

Substitute:

$$874 = 900 \left(\frac{v}{v - 10} \right)$$

Multiply both sides:

$$874(v - 10) = 900v$$

Expand:

$$874v - 8740 = 900v$$

Rearrange:

$$\begin{aligned} -26v &= 8740 \\ v &= -336.2 \end{aligned}$$

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The table below shows how the **detected frequency** changes with the **velocity** of a moving **sound source** approaching a **stationary observer**:

Experiment Number	Source Velocity (m/s)	Detected Frequency (Hz)
1	0	900
2	10	927
3	20	956
4	30	988

The **sound source** is **moving toward the observer**.

Using the **Doppler effect for sound waves**, estimate the **speed of sound** during the experiment.

- (a) 300 m/s (b) 320 m/s (c) 336 m/s (d) 343 m/s

The table below shows how the **detected frequency** changes as the **velocity** of a moving **sound source** increases while it is moving **away from a stationary observer**:

Experiment Number	Source Velocity (m/s)	Detected Frequency (Hz)
1	0	900
2	10	874
3	20	850
4	30	827

The **sound source** is **moving away from the observer**.

Using the **Doppler effect for sound waves**, estimate the **speed of sound** during the experiment.

- (a) 300 m/s (b) 320 m/s (c) 336 m/s (d) 343 m/s

The graph shows the relationship between the **velocity of a moving sound detector** and the **detected frequency** of sound emitted from a **stationary source**.

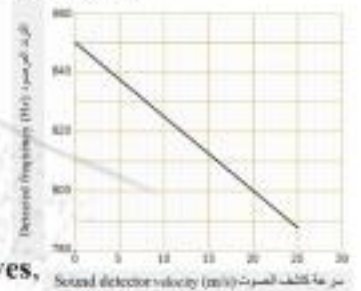
a) The **detected frequency** **decreases** as the **detector velocity** **increases**.

What does this indicate about the motion of the detector relative to the sound source?

- (a) The detector is **moving toward** the source
 (b) The detector is **moving away from** the source
 (c) The detector is **stationary**
 (d) The source and detector are **moving together**

b) Using the **data from the graph** and the **Doppler effect for sound waves**, estimate the **speed of sound**.

- (a) 300 m/s (b) 320 m/s (c) 336 m/s (d) 390 m/s



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 استاذ عبدالرحمن عصام عيد

14. Resonance in Air Columns

Learning Outcome

Recall that **resonance** is the increase in the amplitude of vibration that occurs when an object vibrates at its **natural frequency** due to an external periodic force.

Explain resonance in **air columns** and give examples of different instruments.

What is Resonance?

Resonance occurs when:

- An object is forced to vibrate at its **natural frequency**
- The amplitude of vibration becomes **larger**
- The sound becomes **louder**

Maximum vibration happens when the driving frequency equals the natural frequency.

Resonance in Air Columns

An **air column** is the air inside a tube or pipe that vibrates to produce sound.

When a sound source (such as a tuning fork or lips in a trumpet) produces vibrations:

- The air particles inside the tube begin vibrating
- If the vibration frequency matches the natural frequency of the air column:
 - ✓ **Resonance occurs**

The sound becomes stronger and louder

A resonant system has a fundamental frequency ($f_1 = 140 \text{ Hz}$). If the next frequencies that able to give resonance are (280 Hz) and (420 Hz). Figures (1-3) show musical instruments whose working principle is based on resonance.

Which musical instrument **achieves the resonant frequencies** in this system?



(3) Flute
الأنبوب المفتوح
Open Pipe



(2) Clarinet
الأنبوب مغلق الطرف
Closed Pipe



(1) Violin
وتر
String

نظام الرنين له تردد أساسي ($f_1 = 140 \text{ Hz}$). إذا كانت الترددات التالية القادرة على إعطاء الرنين هي (280 Hz) و (420 Hz). الأشكال (1-3) تُبين آلات موسيقية مبدأ عملها يقوم على الرنين. أي الآلات الموسيقية **تُحقق ترددات الرنين** في هذا النظام؟

2, 3

1, 3

1, 2

1, 2, 3



إذا كان التردد الأساسي لوتر جيتار (500 Hz) ، أي الترددات التالية يمكنه أن يجعل الوترية حالة رنين .

If a guitar string has a fundamental frequency of (500 Hz). which of the following frequencies can set the string into resonance?

750 Hz

1750 Hz

1500 Hz

1250 Hz



تحتوي حديقة هيلي الترفيهية في مدينة العين على ميزان خارجي لأنتابيب الأرغون المفتوحة، عندما ترتفع درجة حرارة الهواء، ماذا يحدث للتردد الأساسي للأنتابيب المغلقة؟

Hili Fun Park in Al-Ain city has an outer open organ pipe resonator. When the air temperature increases; What happened to the fundamental frequency of the closed pipes?

Goes up

ترتفع

Goes down

تنخفض

Stays the same

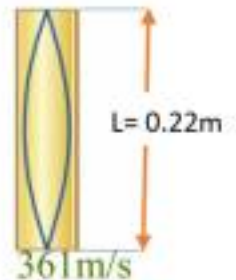
تبقى كما هي

Is impossible to determine

من المستحيل تحديد ذلك

The figure shows the first resonance length of an open air pipe. If the frequency of the sound is 820 Hz , what is the speed of the sound?

يوضح الشكل طول الرنين الأول لأنبوب هوائي مفتوح الطول 0.22 m إذا كان تردد الصوت 820 Hz فما سرعة الصوت؟



820 m/s

334 m/s

180 m/s



أنبوب مفتوح من كلا الطرفين يتذبذب برنين تردده الأساسي $f_{(open)}$. عندما يتم تغطية أحد طرفي الأنبوب وجعله يتذبذب مرة أخرى، يكون تردد رنينه الأساسي $f_{(closed)}$. أي من العبارات التالية تصف العلاقة بين ترددي الرنين في الحالتين؟

A pipe open at both ends resonates at a fundamental frequency $f_{(open)}$. When one end is covered and the pipe is again made to resonate, the fundamental frequency is $f_{(closed)}$. Which of the following expressions describes the relation between the two resonance frequencies?

$$f_{(closed)} = f_{(open)}$$

$$f_{(closed)} = \frac{1}{2} f_{(open)}$$

$$f_{(closed)} = \frac{3}{2} f_{(open)}$$

$$f_{(closed)} = 2 f_{(open)}$$

اينشتاين في الفيزياء
استاذ عبدالرحمن عصام عيد

15. Light Sources and Types of Materials

Learning Outcomes

- Differentiate between **luminous** and **non-luminous** sources of light.

Ray Model of Light

Light travels in:

- Straight lines** called **rays**

When light reaches a boundary, it may:

- Be **reflected**
- Be **refracted**
- Continue in a straight line

Sources of Light

1. Luminous Sources

Objects that **produce their own light**.

Examples:

- Sun
- Stars
- Light bulb
- Candle flame
- Fireflies
- Television screens

Luminous objects can be seen because they emit light.

2. Non-Luminous Sources

Objects that **do not produce light**.

They are seen because they:

- Reflect light** from luminous sources.

Examples:

- Moon
- Planets
- Books
- Tables
- People

The Moon appears bright because it reflects sunlight.

Comparison of Light Sources

Property	Luminous Source	Non-Luminous Source
Produces its own light	Yes	No
Needs external light	No	Yes
Visibility	Emits light	Reflects light
Examples	Sun, lamp	Moon, chair

أي من التالي من المصادر
المضيئة؟

Which of the following is a light
source?

	ايندشتاين في الفيزياء	Mars المريخ
		Moon القمر
	استاذ عبدالرحمن عصام عيد	Earth الأرض
		Polar star النجم القطبي

1. A(n) _____, like the Moon, reflects light.
 (a) laminated body (b) radiating body (c) reflecting body (d) illuminated body
2. Which of the following is a **luminous source**?
 (a) Moon (b) Planet (c) Sun (d) Earth
3. Which of the following is an **illuminated source**?
 (a) Star (b) Candle flame (c) Sun (d) Moon
4. Which of the following is a **light source**?
 (a) Mars (b) Earth (c) Polar star (d) Moon
5. Which sources appear bright due to **reflected light**?
 (a) Luminous sources (b) Illuminated sources
 (c) Opaque media (d) Transparent media
6. Which sources emit light **by themselves**?
 (a) Opaque media (b) Illuminated sources
 (c) Transparent media (d) Luminous sources

Differentiate between **transparent**, **translucent**, and **opaque** materials.

Light and Matter

Light can:

- Be **absorbed**
- Be **reflected**
- Pass through materials

Materials are classified into **three types**:

1. Transparent Materials

- Allow **most light** to pass through.
- Objects can be seen **clearly** through them.

Examples:

- Clear glass
- Air
- Clean water

Transparent: transmits most of the light that reaches it.



2. Translucent Materials

- Allow **some light** to pass through.
- Objects appear **blurred**.

Examples:

- Frosted glass
- Wax paper
- Foggy plastic
- Thin tissue paper

Translucent: transmits and reflects light but does not allow objects to be seen clearly through it.



3. Opaque Materials

- Do not allow light to pass through.
- Light is mostly:
 - ✓ Reflected
 - ✓ Absorbed

Examples:

- Wood
- Metal
- Brick
- Book



OPAQUE



Opaque: reflects and absorbs light but does not transmit it.

Quick Comparison

Type	Light Transmission	Visibility
Transparent	Most light passes	Clear image
Translucent	Some light passes	Blurred image
Opaque	No light passes	Cannot see through

1. A medium that allows light to pass through but does not allow the light source to be visible is _____.
 (a) transparent (b) translucent (c) opaque (d) translucent
2. Which objects reflect and absorb light but do not allow light to pass through?
 (a) Translucent media (b) Transparent media
 (c) Opaque media (d) None of the above
3. Which media allow most of the light to pass through, making objects clearly visible through them?
 (a) Translucent media (b) Transparent media
 (c) Opaque media (d) None of the above
4. Which media transmit and reflect light but do not allow clear visibility through them?
 (a) Translucent media (b) Transparent media
 (c) Opaque media (d) None of the above
5. Very thin, white tissue paper can best be described as _____.
 (a) opaque (b) luminous (c) transparent (d) translucent
6. Materials that do not allow any transmission of light are described as _____.
 (a) transparent (b) luminous (c) translucent (d) opaque

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استاذ عبدالرحمن عصام عيد

16. Define the following photometric quantities and state their SI units:

- Luminous flux
- Illuminance
- Luminous intensity

Luminous Flux (P)

Definition

The rate at which light energy is emitted from a luminous source.

Unit

- lumen (lm)

Important Note

- Luminous flux depends on the **source only**.
- It does **not** depend on:
 - ✓ distance
 - ✓ area size

Example

A 100-W light bulb emits about **1750 lm**.

Illuminance (E)

Definition

The rate at which light falls on a surface.

Unit

- lux (lx)

$$1 \text{ lx} = 1 \text{ lm/m}^2$$

Concept

Illuminance measures how much light reaches a surface.

Examples:

- desk
- book
- wall

Illuminance Equation

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

Where:

- E = illuminance (lx)
- P = luminous flux (lm)
- r = distance from source (m)

Key Notes

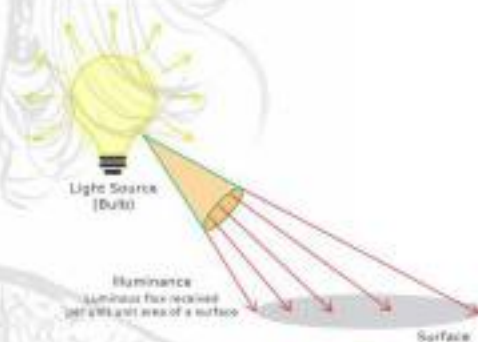
- Increasing distance decreases illuminance.
- The same luminous flux spreads over a larger area as distance increases.

1. _____ is the rate at which light falls on a surface.

- (a) Fluorescence (b) Illuminance flux (c) Luminous flux (d) Illuminance

2. What do we call the rate of light emission from a luminous source?

- (a) Luminous flux (b) Illuminance (c) Luminous intensity (d) Glare of light



3. The rate, in lumens, at which light is emitted from a lightbulb is the bulb's _____.
 (a) illuminance (b) frequency (c) luminous intensity (d) luminous flux

4. According to the equation

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

What is the unit of P ?

- (a) lx (b) lm (c) cd (d) cd/m²

5. What is the SI unit of illuminance?

- (a) lx (b) lm (c) cd (d) cd/m²

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According to the equation

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

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

ما وحدة قياس P ؟

?What is the unit of P

- ☐ a. N
- ☐ b. J
- ☐ c. lx
- ☒ d. lm



ماذا يسمى معدل انبعاث الضوء من المصدر المشع أو المصباح؟

What do we call the **rate of light emission** from the luminous source or lamp?

Luminous flux

التدفق الضوئي

Illuminance

الاستضاءة

Luminous intensity

شدة الانبعاث

glare of light

وهج الضوء

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Two light bulbs (A and B). Bulb A has a luminous flux of (1000 lm), while bulb B has a luminous intensity of (100 cd).

Which of the two bulbs **is more effective (greater luminous intensity)?**

- (a) Bulb A, because it provides greater luminous intensity.
- (b) Bulb B, because it provides greater luminous intensity.
- (c) Both bulbs have the same effectiveness.
- (d) Bulb A, because it provides greater luminous flux.



According to the equation

$$P = AI$$

What does the constant **A** represent?

- (a) 4π
- (b) $4\pi r^2$
- (c) r^2
- (d) πr^2

According to the equation

$$X = E \times 4\pi r^2$$

What does the symbol **X** represent, and what is its SI unit?

- (a) Luminance — cd/m^2
- (b) Luminous Flux — lm
- (c) Illuminance — lx
- (d) Luminous Intensity — cd

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17. Illuminance of a Point Source**Learning Outcome**

Apply the equation for illuminance of a point source to numerical problems.

Point-Source Illuminance Equation

$$\text{Illuminance (E)} = \frac{\text{Luminous Flux (P)}}{\text{Area(A)} \ 4\pi r^2} \text{ or } = \frac{\text{Luminous Intensity (I)}}{r^2}$$

**Relationship**

Illuminance is:

- directly proportional to luminous flux
- inversely proportional to the square of the distance

Units

Quantity	Symbol	SI Unit
Illuminance	E	lux (lx)
Luminous Flux	P	lumen (lm)
Distance	r	meter (m)

Example Problem

A lamp emits a luminous flux of **1750 lm** and is located **2.50 m** above a desk. Find the illuminance on the desk.

Given

- $P = 1750 \text{ lm}$
- $r = 2.50 \text{ m}$

Required

- $E = ?$

Solution

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

Substitute:

$$E = \frac{1750}{4\pi(2.50)^2} = 22.3 \text{ lx}$$

A lamp emits a luminous flux of **2400 lm** and is placed **3.0 m** above a table. What is the illuminance on the table?

- (a) 10.6 lx (b) 21.2 lx (c) 35.4 lx (d) 48.0 lx

A surface receives an illuminance of **50 lx** from a lamp located **2.0 m** away. What is the luminous flux of the lamp?

- (a) 400 lm (b) 800 lm (c) 1600 lm (d) 2510 lm

A lamp emits a luminous flux of **1800 lm** and produces an illuminance of **20 lx** on a desk. What is the distance between the lamp and the desk?

- (a) 1.9 m (b) 2.7 m (c) 3.5 m (d) 4.2 m

A light source emits **3200 lm** and is located **4.0 m** from a wall.
What is the illuminance on the wall?

- (a) 7.9 lx (b) 15.9 lx (c) 31.8 lx (d) 63.7 lx

A surface receives an illuminance of **15 lx** from a lamp emitting **2700 lm**.
What is the distance from the lamp to the surface?

- (a) 2.1 m (b) 3.8 m (c) 5.4 m (d) 6.7 m

A lamp placed **5.0 m** above the floor produces an illuminance of **8.0 lx**.
What is the luminous flux emitted by the lamp?

- (a) 800 lm (b) 1200 lm (c) 2510 lm (d) 4020 lm

A lamp has a luminous intensity of **180 cd** and is placed **3.0 m** from a surface.
What is the illuminance on the surface?

- (a) 10 lx (b) 20 lx (c) 30 lx (d) 60 lx

A surface receives an illuminance of **25 lx** from a lamp with luminous intensity **225 cd**.
What is the distance between the lamp and the surface?

- (a) 2 m (b) 3 m (c) 4 m (d) 5 m

A lamp produces an illuminance of **16 lx** on a wall located **5.0 m** away.
What is the luminous intensity of the lamp?

- (a) 80 cd (b) 160 cd (c) 320 cd (d) 400 cd



مصدر ضوئي نقطي شدة إضاءته (36 cd) - يقع على ارتفاع (2.0 m) فوق سطح مكتب.
ما مقدار الإضاءة الواقعة على سطح ذلك المكتب؟

A (36 cd) point source of light is (2.0 m) above the surface of a desk.
What is the illuminance on the desk's surface?

9.0 lx

3.2 lx

2.3 lx

17 lx

In the figure, if the illumination on screen 2 is (400 lm/m²).

What is the illuminance on screen 1 from the same Source?



- (a) 50 lm/m² (b) 400 lm/m² (c) 200 lm/m² (d) 100 lm/m²

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Learning Outcome 19

Show that the illuminance provided by a point source of light has:

- an **inverse-square relationship** with distance (r) from the source
- a **direct relationship** with luminous flux (P)

Inverse-Square Law of Illuminance

When a point light source emits light in all directions, the illuminance (E) on a surface depends on the distance (r) from the source:

If P is constant, then E is inversely proportional to r^2 . $E \propto \frac{1}{r^2}$

- When r^2 increases, E decreases.
- When r^2 decreases, E increases.

$$\frac{E_2}{E_1} \propto \frac{r_1^2}{r_2^2}$$

A light bulb emits 1750 lumens.

- If placed at the **center** of a **1-meter-radius** sphere:

$$\text{Surface area} = 4\pi r^2 = 4\pi(1)^2 = 12.57 \text{ m}^2$$

$$\text{Illuminance} = \frac{1750}{12.57} = 139 \text{ lx}$$

- If the sphere's **radius** increases to **2 meters**:

$$\text{Surface area} = 4\pi(2)^2 = 50.27 \text{ m}^2$$

$$\text{Illuminance} = \frac{1750}{50.27} = 34.8 \text{ lx}$$

$$\frac{E_2}{E_1} = \frac{r_1^2}{r_2^2} = \frac{(1)^2}{(2)^2} = \frac{1}{4}$$

The illuminance becomes **one-fourth** of the original value.

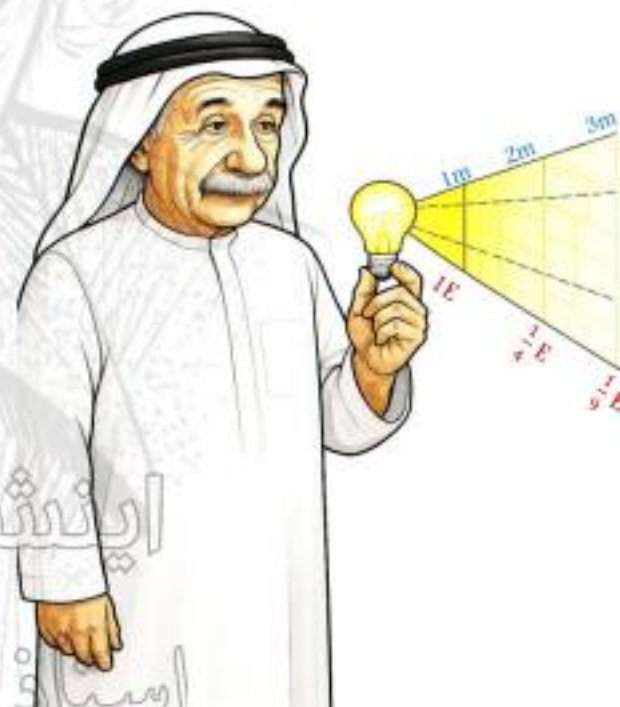
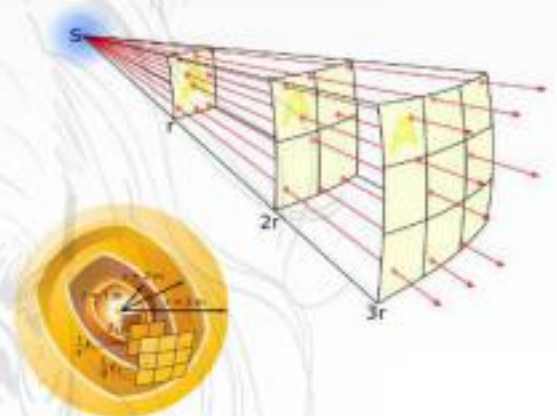
- If the sphere's **radius** increases to **3 meters**:

$$\text{Surface area} = 4\pi(3)^2 = 113.1 \text{ m}^2$$

$$\text{Illuminance} = \frac{1750}{113.1} = 15.5 \text{ lx}$$

$$\frac{E_2}{E_1} = \frac{r_1^2}{r_2^2} = \frac{(1)^2}{(3)^2} = \frac{1}{9}$$

The illuminance becomes **1/9** of the original value.



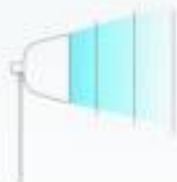
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Which best describes the relationship between distance and illuminance?

- (a) $E \propto r^2$ (b) $E \propto 1/r$ (c) $E \propto r$ (d) $E \propto 1/r^2$

Illuminance _____ as the light source moves away from the object.

- (a) increases with an inverse square relationship (b) decreases with an inverse relationship
(c) increases with an inverse relationship (d) decreases with an inverse square relationship



According to the principles of illuminance, when a surface is illuminated by a point light source, the illuminance decreases as the distance from the source increases.

Which of the following graphs **correctly** shows the relationship between illuminance and the distance between the light source and the surface?

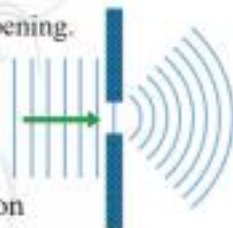


Learning Outcome 20

Define diffraction as the bending of a wave as it passes the edge of a barrier or through an opening.

Diffraction is the **bending of a wave** as it passes the **edge of a barrier** or through a narrow opening.

This bending causes the wave to spread out instead of continuing in a straight line.



The bending of light as it passes the edge of a barrier is called:

- (a) Reflection (b) Diffraction (c) Polarization (d) Refraction

The spreading out of a wave as it moves past the edge of a barrier is called

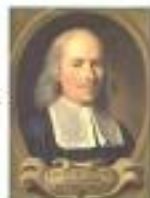
- (a) Reflection (b) Diffraction (c) Polarization (d) Refraction

According to Huygens' Principle, in order for a wave to be diffracted when it passes through an opening, the opening must be

- (a) at an angle (b) wide (c) narrow (d) very large

What types of waves can be diffracted?

- (a) Only light waves can be diffracted. (b) Only sound waves can be diffracted.
(c) All types of waves can be diffracted. (d) Only high energy waves can be diffracted.

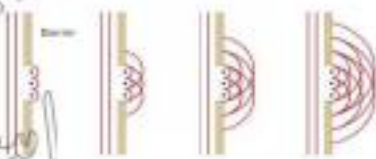


The scientist Francesco Grimaldi was the first to investigate the idea that light waves could

- (a) contract (b) move (c) expand (d) bend

Which of the following explains the **phenomenon** of the **waves after** passing the barrier as shown in the figure?

- (a) Doppler effect (b) Bernoulli's principle
(c) Malus's law (d) Huygens's principle



The figure shows waves before and after passing the barrier.

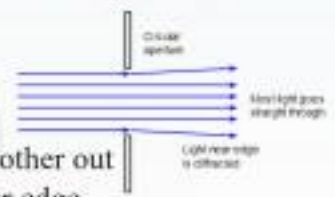
Which of the following is **true** for the waves after passing the barrier?

- (a) The wavelength is decreased (b) The direction of its propagation is changed
(c) The wavelength is increased (d) The frequency is decreased



What causes diffraction when a wave moves near an edge or through an opening?

- (a) wave reflects off a surface (b) two waves cancel each other out
(c) wave bends through a material (d) wave spreads at a gap or edge



Learning Outcome 21

Describe that the color of light is related to its wavelength and frequency.

RoyGBiv

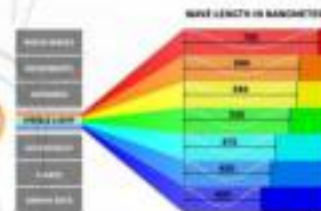
For light to behave as a **wave**, it must have both **wavelength** and **frequency**.

- The **colour of light** is directly related to its **wavelength** and **frequency**:

- Shorter wavelengths** (higher frequency) → **violet**
- Longer wavelengths** (lower frequency) → **red**

Visible light ranges approximately from **400 nm** (violet) to **700 nm** (red).

Color	Wavelength Range ($\times 10^{-9}\text{m}$)	Frequency Range ($\times 10^{14}\text{Hz}$)
Red	700 – 635	430 – 480
Orange	635 – 590	480 – 510
Yellow	590 – 560	510 – 540
Green	560 – 490	540 – 610
Blue	490 – 450	610 – 670
Indigo	450 – 425	670 – 705
Violet	450 – 400	670 – 750



ملحوظة ترتيب الألوان فقط حفظ بينما الأطوال الموجية والترددات ليست مطلوبة للحفظ

What determines the **color** of light?

- (a) Distance (b) Temperature (c) Wavelength (d) Surface

Which of these colors of light has the **longest** wavelength?

- (a) Red (b) Green (c) Black (d) Violet

Which of these colors of light has the **short wavelength**?

- (a) Red (b) Green (c) Black (d) Violet

Which of these colors of light has the **higher frequency**?

- (a) Red (b) Green (c) Black (d) Violet

Which of these colors of light has **Lowest frequency of Color**.

- (a) Red (b) Green (c) Black (d) Violet

Learning Outcome 22

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.

Primary Colors of Light (RGB):

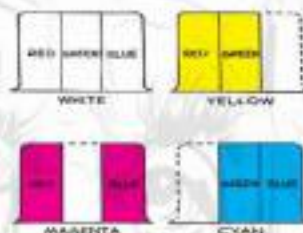
Red, Green, and Blue

Additive color mixing involves combining different colored **light rays** to produce new colors.

Secondary Colors of Light (YCM):

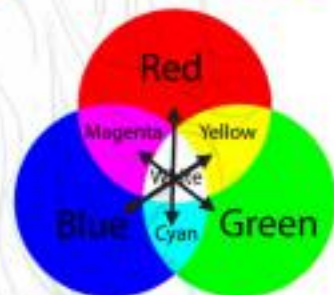
- Formed by mixing two primary colors:

- Red + Green = **Yellow**
- Green + Blue = **Cyan**
- Red + Blue = **Magenta**



Complementary Colors of Light:

- Two colors that combine to produce **white light**:
- Yellow + Blue
- Cyan + Red
- Magenta + Green



The diagram represents overlapping areas of light of the same intensity.

Which of the following indicates the colors that appear in areas (A, B, C)?

- | | | | |
|-----|--------------------|--------------------|--------------------|
| (a) | A [Yellow] | B [Cyan] | C [Magenta] |
| (b) | A [Magenta] | B [Yellow] | C [Cyan] |
| (c) | A [Yellow] | B [Magenta] | C [Cyan] |
| (d) | A [Cyan] | B [Yellow] | C [Magenta] |



Which of the following colors is **not** one of the primary colors of light?

- (a) Blue (b) Red (c) Green (d) Yellow

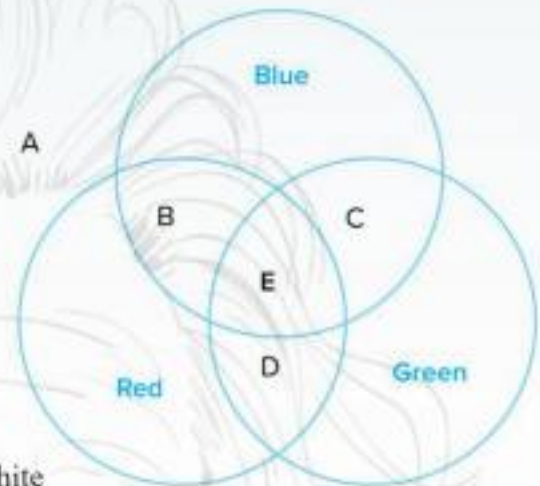
To make red light **white**, add

- (a) Magenta light (b) Green light (c) Yellow light (d) Cyan light

Red and **blue** light make

- (a) Magenta (b) Violet (c) Indigo (d) Purple

The diagram below represents three overlapping circles of equally intense colored light projected onto a white screen.



1. Why would region A be black?

- (a) Because it reflects all colors
- (b) Because it contains white light
- (c) Because it is outside all colored light sources
- (d) Because it absorbs blue light

2. What color would region B be?

- (a) Cyan
- (b) Yellow
- (c) Magenta
- (d) White

3. What color would region C be?

- (a) Red
- (b) Cyan
- (c) Green
- (d) Magenta

4. What color would region D be?

- (a) Yellow
- (b) Blue
- (c) White
- (d) Cyan

5. What color would region E be?

- (a) Black
- (b) White
- (c) Yellow
- (d) Green

6. The color in region B is complementary to which color?

- (a) Red
- (b) Blue
- (c) Green
- (d) Yellow

7. The color in region C is complementary to which color?

- (a) Green
- (b) Red
- (c) Blue
- (d) Cyan

8. The color in region D is complementary to which color?

- (a) Red
- (b) Green
- (c) Blue
- (d) Magenta

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Learning Outcome 23

Describe primary and secondary pigments and the effects of mixing pigments or dyes.

Primary Pigments (YCM):

- Yellow, Cyan, Magenta

Secondary Pigments:

- Formed by mixing two **primary colors of light** (RGB).

Complementary Pigments:

- Two pigments that combine to produce **black**:
 - Yellow + Blue
 - Green + Magenta
 - Cyan + Red



Color Mixing in Pigments

- Pigments follow **subtractive color mixing principles**. Paints, dyes, and inks contain pigments that absorb certain colors and **reflect** the remainder.

The presence of **dyes** within the material or **pigments** on its surface determines the color of the object.

- **Dyes** are substances that color materials by being absorbed into them.
- **Pigments** are substances applied to surfaces that absorb certain wavelengths and reflect others, giving the object its color.

Primary and Secondary Pigments

- **Primary Pigments:**

A primary pigment absorbs **only one primary color of light** and reflects the other two colors from white light.

Examples:

- ✓ Yellow pigment absorbs **blue light** and reflects **red and green light**.
- ✓ Cyan pigment absorbs **red light** and reflects **blue and green light**.
- ✓ Magenta pigment absorbs **green light** and reflects **red and blue light**.

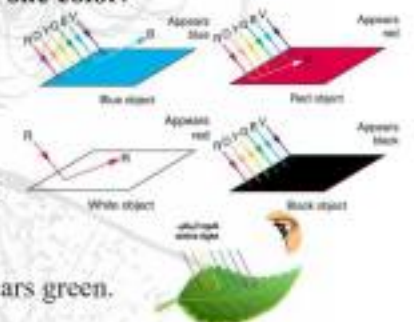
- **Secondary Pigments:**

A secondary pigment absorbs **two primary colors of light** and reflects **one color**.

Examples:

- ✓ Red pigment absorbs **green and blue light**, reflects **red**.
- ✓ Green pigment absorbs **red and blue light**, reflects **green**.
- ✓ Blue pigment absorbs **red and green light**, reflects **blue**.

White light (composed of its seven color components) falls on a green leaf.



Which of the following statements **describes what happens?**

- The eye sends a ray toward the leaf, which reflects it back, so it appears green.
- The pigment molecules in the green leaf absorb the green light and reflect all the other colors.
- The pigment molecules in the green leaf absorb all the colors and reflect only green light.
- The pigment molecules absorb all the colors, so the leaf appears light-coloured.

Which of the following is **not** correct?

- The primary pigment is a pigment that absorbs only one primary color and reflects two from white light.
- The secondary pigment is a pigment that absorbs two primary light colors and reflects one color.
- The primary pigment colors are the secondary colors of light.
- The primary pigment colors are red, green, and blue.

A **primary pigment** reflects **primary** colors from white light.

- (a) One (b) Three (c) Two (d) None

Based on the secondary colors indicated, determine the color of each spotlight.

What **color** occurs in the very center?



Learning Outcome 24

Explain the polarization of light by filtering using a polarizing filter.

Describe the polarization of light by reflection

"Light waves are electromagnetic waves consisting of electric and magnetic fields oscillating in two perpendicular planes."

Polarization is the process by which light waves are restricted to vibrate in a **single plane** perpendicular to the direction of propagation.

Unpolarized light vibrates in **multiple planes**, while polarized light vibrates in **one specific plane**.

2. Transverse Waves and Light

- **Transverse waves:** Oscillate perpendicular to their direction of travel.
- **Electromagnetic waves** (like light):
 - Have electric and magnetic fields oscillating in perpendicular planes.
 - Both fields are also perpendicular to the direction of wave motion.



- **Unpolarized light** (like from a lamp) vibrates in **multiple planes**.
- **Reflected light** (like from a road or glass) becomes **partially polarized**, mostly vibrating **parallel to the surface**.
- This is why **polarizing sunglasses** can block glare from roads or water.

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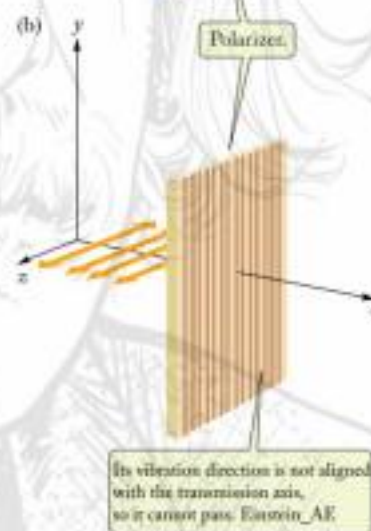
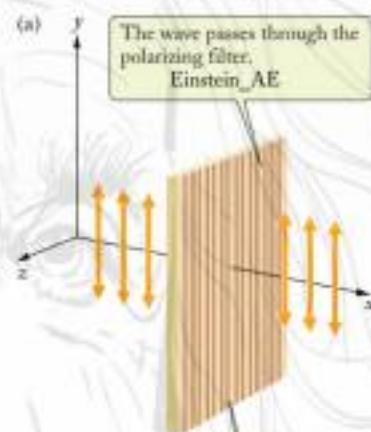
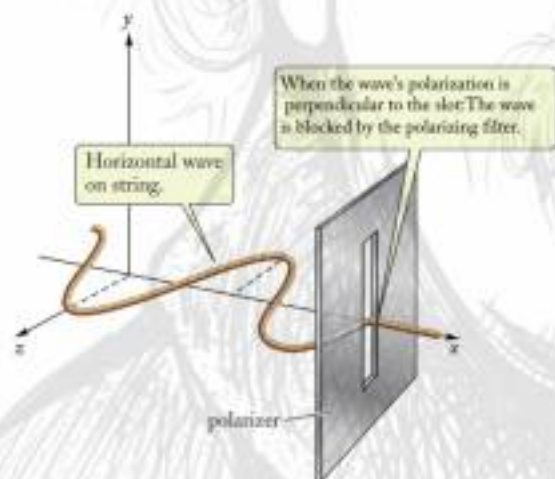
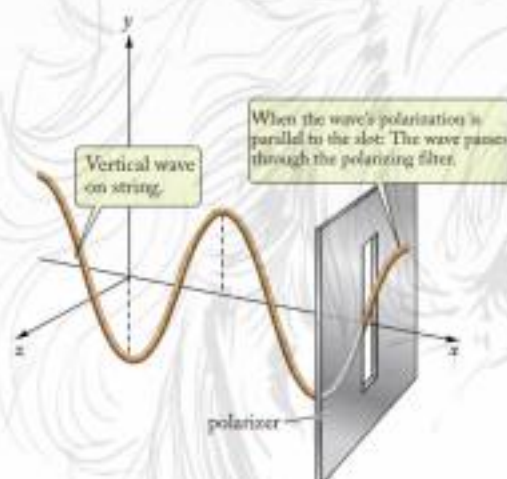
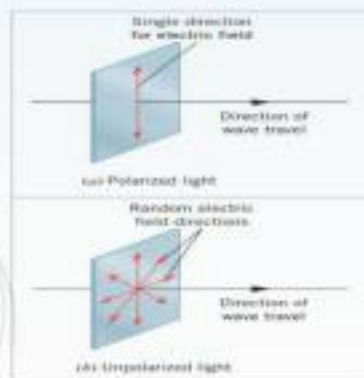
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Polarized Light

- Vibrates in **one specific plane** only.
- Produced by **polarizing filters, reflection, or scattering.**
- Contains light waves oscillating in a **single direction.**
- **Can be blocked or modified** using polarizing filters.

Unpolarized Light

- Vibrates in **multiple planes** perpendicular to the direction of travel.
- Found in **natural sources** like sunlight or lamps.
- Contains light waves oscillating in **all directions.**
- **Cannot be completely blocked** by a single polarizing filter.

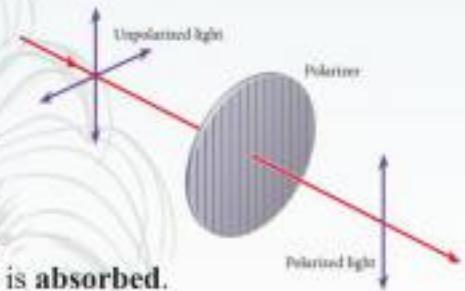


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Polarization by Filtering

Rope Model Analogy

- Imagine light waves as **transverse waves on a rope**.
- A **slot** represents the **polarizing axis** of a filter.
- If the wave is **parallel to the slot**, it **passes through**.
- If the wave is **perpendicular to the slot**, it is **blocked**.

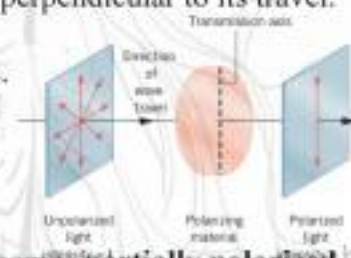


How Polarizing Filters Work

- Polarizing materials contain **long molecules**.
- Electrons in these molecules oscillate in **one direction**.
- Light vibrating **in the same direction** as the molecules is **absorbed**.
- Light vibrating **perpendicular** to the molecules is **transmitted**.
- The **polarizing axis** is **perpendicular** to the direction of the molecules.
- Only light waves **aligned with the polarizing axis** can pass through.

Effect on Ordinary Light

- Ordinary light contains waves vibrating in **all directions** perpendicular to its travel.
- When passed through a polarizing filter:
 - Only the component **aligned with the axis** passes.
 - Intensity is reduced by half**.
 - The output is **polarized light**.



2. Polarization by Reflection

Observation

- When light reflects off surfaces like **glass or roads**, it becomes **partially polarized**.
- Reflected light tends to vibrate **parallel to the surface**.

Applications

- Polarizing sunglasses** reduce glare by blocking horizontally polarized light.
- Photographers** use polarizing filters to eliminate reflections and improve image clarity.



3. Polarization Analysis with Two Filters

Using a Second Filter (Analyzer)

- When polarized light passes through a **second polarizing filter**, the amount of light that gets through depends on the **angle between the two filters**.

Case 1: **Parallel** Axes

- If the second filter's **polarizing axis is parallel** to the first:
 - Light passes through**.
 - The intensity remains **almost the same**.



Case 2: **Perpendicular** Axes

- If the second filter's **polarizing axis is perpendicular** to the first:
 - No light passes through**.
 - The intensity becomes **zero**.



The waves that **cannot pass** through a polarizing filter are those whose electric fields are vibrating to the polarizing axis.

Ⓐ Diagonal Ⓑ Circular Ⓒ Parallel Ⓓ Perpendicular

Learning Outcome 25

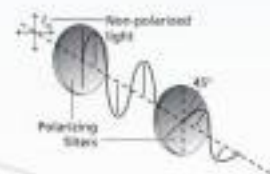
Apply Malus's law to light filtered by polarizer and analyzer filters

Malus's law describes how the **intensity of polarized light** changes when it passes through a polarizing filter at an angle.

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

Unpolarized light of intensity I_0 is incident on a polarizing filter, and the emerging light strikes a second polarizing filter, as shown in the figure. What is the light intensity emerging from the second polarizing filter?

- (a) $\frac{I_0}{2}$ (b) $\frac{I_0}{4}$ (c) I_0 (d) $4I_0$



In the figure, the intensity of the polarized light coming out from **Polarizer 2** is (75 W/m^2) . Calculate the **intensity** of the polarized light coming out from filter 1?

- (a) 228 W/m^2 (b) 112 W/m^2 (c) 92 W/m^2 (d) 130 W/m^2

The figure shows a light ray passing through two polarizing filters. The intensity of observed light is **36.0%** of the intensity coming out of the first filter.

What is the angle between the polarizing axes of the two filters?

- (a) 75.54° (b) 36.87° (c) 53.13° (d) 45.54°



Unpolarized light with an intensity of 200 W/m^2 is sent through a polarizer with a transmission axis in the vertical direction. The light then goes through an analyzer that has a transmission axis at a set angle from the vertical. What angle is required if the transmitted intensity is to be 25 W/m^2 ?

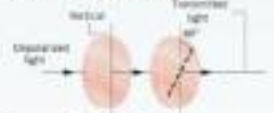
- (a) 90° (b) 60° (c) 45° (d) 30°

Unpolarized light passes through two polarizers whose transmission axes are at an angle θ with respect to each other. What should be the angle θ between the transmission axes of the polarizers if it is desired that **one-eighth of the incident intensity** be transmitted?

- (a) 90° (b) 60° (c) 45° (d) 30°

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Unpolarized light is sent through a vertical polarizer and an analyzer set at an angle of 60° from vertical. The light intensity transmitted from the analyzer is 18 W/m^2 . What was the original intensity of the light?



- (a) 288 W/m^2 (b) 144 W/m^2 (c) 72 W/m^2 (d) 36 W/m^2

In the adjacent figure, light passes through **Polarizer 2** with an intensity of 180 W/m^2 . Calculate the intensity of the light emerging from **Polarizer 1** if the angle between the polarizers is 45° .



- (a) 512 W/m^2 (b) 360 W/m^2 (c) 254.6 W/m^2 (d) 180 W/m^2

A beam of polarized light of intensity I_0 passes through a sheet of ideal polarizing material. The polarization axis of the beam and the transmission axis of the sheet differ by 30° . What is the intensity of the emerging light?

- (a) $0.25I_0$ (b) $0.50I_0$ (c) $0.75I_0$ (d) $0.87I_0$

What angle is needed between the direction of polarized light and the axis of a polarizing filter to reduce its intensity by 90% ?

- (a) 18.43° (b) 45° (c) 71.6° (d) 60°

A polarizer and analyzer will **block** all light if they are at _____ to each other.

- (a) 90° (b) 60° (c) 45° (d) 30°

If you were to place the polarizing axes of two polarizing filters at 90° to each other, What percent of light **intensity** would **pass** through?

- (a) 0 (b) 50% (c) 100% (d) 75%

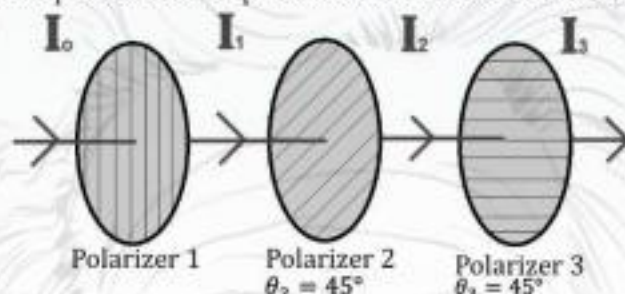
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If you were to place the polarizing axes of two polarizing filters at 45° to each other, What percent of **light intensity** would **pass** through?

- (a) 0 (b) 50% (c) 100% (d) 75%

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Unpolarized light is passed through polarizer 1. The light then goes through polarizer 2 with its plane of polarization at 45.0° to that of polarizer 1. Polarizer 3 is placed after polarizer 2. Polarizer 3 has its plane of polarization at 45° to the plane of polarization of polarizer 2 and at 90° to that of polarizer 1 as shown below.



What fraction of the intensity of the original light I_0 gets through:

- The polarizer 2? $\frac{I_0}{4}$
- The polarizer 3? $\frac{I_0}{8}$
- Suppose the second polarizer is removed. What is the intensity of light transmitted by the two (i.e., first and third) polarizers now? 0

- (a) $\frac{I_0}{2}$ (b) $\frac{I_0}{4}$ (c) $\frac{I_0}{8}$ (d) 0

If you were to place the polarizing axes of two polarizing filters at 90° to each other,

What percent of light **intensity** would **pass** through?

- (a) 0 (b) 50% (c) 100% (d) 75%

If you were to place the polarizing axes of two polarizing filters at 45° to each other, what percent of **light intensity** would **pass** through?

- (a) 0 (b) 50% (c) 100% (d) 75%

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