

Physics EOT Exam Final - Grade 10 Advanced



تم تحميل هذا الملف من موقع المناهج الإماراتية

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

تاريخ إضافة الملف على موقع المناهج: 2026-06-10 17:27:09

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المزيد من مادة
فيزياء:

إعداد: عبدالرحمن عصام عيد

التواصل الاجتماعي بحسب الصف العاشر المتقدم



صفحة المناهج
الإماراتية على
فيسبوك

الرياضيات

اللغة الانجليزية

اللغة العربية

التربية الاسلامية

المواد على تلغرام

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

بريدج شرح هيكل الامتحان أسئلة تدريبية

1

بريدج هيكل الامتحان أسئلة تدريبية

2

الجزء الأول نواتج التعلم من 1 إلى 6 انكسار الضوء

3

ملزمة مراجعة تكويني وفق الهيكل

4

شرح التداخل في الأغشية الرقيقة والحيود - الجزء الثاني

5

فـسـوـرـيـن
بـالـإـمـارـات

PROUD OF UAE



الفيزياء

20
25

ACADEMIC YEAR
2025 - 2026



PHYSICS

EOT EXAM FINAL

GRADE **10**

ADV
ADVANCED



شرح وتغطية كاملة للهيكل



اسئلة الكتاب



اسئلة امتحانات وزارية



تدريبات مطابقة لمخرجات الاختبار النهائي

TERM

3

مصدرك الأول للعلامة الكاملة - Your First Source for Full Marks

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هذا المحتوى مدفوع ولا أبيع نسخه أو إعادة نشره أو تداوله بأي شكل دون إذن مسبق
ولن أسامح أي شخص يستخدمه أو يشاركه بدون موافقة صريحة

 Learning Outcomes Table

No.	Learning Outcome / Performance Criteria	Student Book Reference	Pages
1	Describe refraction of light (or a wave) as it crosses the boundary between two different mediums and represent that in a ray diagram.	Figures (18,19)	90–91
2	Identify that during refraction, the wavelength and speed of light change but frequency remains the same.	Student Book	92–93
3	State and apply Snell's law of refraction.	Example (4), Practice Problems (30,32,33)	91–93
4	Calculate the refractive index of a medium using: $n = \frac{c}{v}$	Check Your Progress (38)	93, 96
5	Define the critical angle as the angle of incidence at which the refracted ray lies along the boundary.	Figure (21)	94
6	Apply concepts of refraction, critical angle, and total internal reflection to solve numerical problems.	Check Your Progress (36,37,39,40,41)	92–96
7	Identify the principal axis, focal points, and focal length of convex and concave lenses.	Figures (28),(31)	98–99
8	Draw ray diagrams for objects at different distances from a convex lens and determine image properties.	Figures (28,29,30), Practice Problem (47)	98–101
9	Describe how a convex lens acts as a magnifier.	Student Book	99
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11	Define coherent and incoherent light and explain how coherent light is generated.	Student Book	112–113
12	Explain how bright and dark interference fringes are formed in a double-slit experiment.	Figure (5)	113–114

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13	Apply the relation: $\lambda = \frac{xd}{L}$ to calculate wavelength or unknown distances.	Student Book	115
14	Explain constructive interference using: $m\lambda = \frac{x_m d}{L}$	Student Book	115
15	Solve problems on interference of light.	Example (1), Practice Problems (1,2,3), Check Your Progress (13)	116–120
16	Define and explain thin-film interference.	Student Book	117
17	Define diffraction and explain diffraction of light.	Student Book	121–122
18	Apply the single-slit diffraction equation: $2x_1 = \frac{2\lambda L}{w}$	Practice Problems (15,17,18), Check Your Progress (28)	123 129
19	Compare Young's Double Slit pattern with Single Slit Diffraction pattern.	Student Book	121 122
20	Define diffraction grating, reflection grating, and grating spectroscope.	Student Book	124–126
21	Explain constructive interference in diffraction gratings using: $m\lambda = d \sin \theta$	Student Book	126
22	Explain how a grating spectroscope works and its applications.	Student Book	126
23	Define a frame of reference.	Figure (13)	148
24	Calculate relative velocity in one dimension using vector addition/subtraction.	Figure (13), Practice Problems (25,27)	148 152
25	Calculate relative velocity in two dimensions graphically and mathematically.	Figure (13), Example (4), Practice Problems (28,29), Check Your Progress (33,35)	150–152

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1	Describe refraction of light (or a wave) as it crosses the boundary between two different mediums and represent that in a ray diagram.	Figures (18,19)	90-91
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اینشتاین فی الفیزیا
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1	Describe refraction of light (or a wave) as it crosses the boundary between two different mediums and represent that in a ray diagram.	Figures (18,19)	90-91
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"Refraction" refers **both** to the **crossing** of light from **one medium to another medium** with different refractive index, and the **change of direction** that occurs **on crossing** the boundary

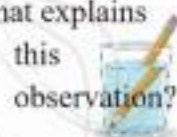
Light travels through a **vacuum** at a speed $c = 3.00 \times 10^8$ m/s

Light travels through **materials** at a speed **less** than its speed in a vacuum.



1. When a pencil is placed in a cup containing water, the pencil appears broken at the surface of the water, as in the figure. What is the name of the phenomenon that explains

- (a) The mirage phenomenon (b) Total internal reflection phenomenon
(c) The refraction phenomenon (d) The reflection phenomenon

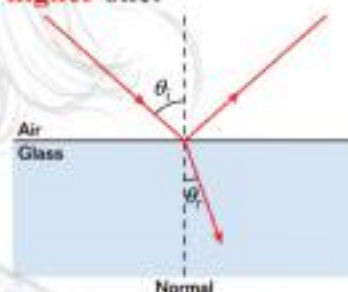


2. It is the phenomenon of a sudden change that occurs in the path of light rays when they pass at an angle through the surface separating two different transparent media. What is the name of this phenomenon?

- (a) The mirage phenomenon (b) Total internal reflection phenomenon
(c) The refraction phenomenon (d) The reflection phenomenon

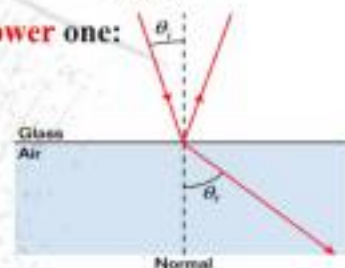
When light travels from a medium with a **lower refractive index to a higher one**:

- The speed of light decreases.
- The wavelength shortens.
- The frequency remains unchanged.
- The light refracts toward the normal.
- The angle of refraction is smaller than the angle of incidence.



When light travels from a medium with a **higher refractive index to a lower one**:

- The speed of light increases.
- The wavelength becomes longer.
- The frequency remains unchanged.
- The light refracts away from the normal.
- The angle of refraction is greater than the angle of incidence.



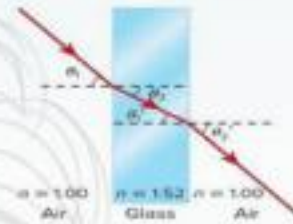
When light strikes the boundary between two media **perpendicularly** it passes straight through without refraction.



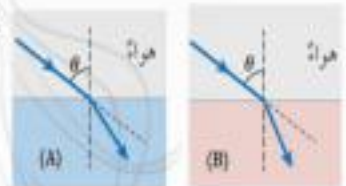
3. What **happens** to the refracted beam when light passes through **air to glass and then back to air**?

Hint: $n_{\text{glass}} > n_{\text{air}}$

- (a) It refracts **away** and then **toward** the normal.
 (b) It refracts **toward** and then **toward** the normal.
 (c) It refracts **toward** and then **away from** the normal.
 (d) It refracts **away** and then **away from** the normal.

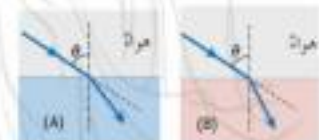


4. The Figure shows a light ray traveling from the air to a transparent medium (A) and to another transparent medium (B), at the same angle of incidence. Which medium (A) or (B) has the speed of light greater?



- (a) Medium (A) (b) Medium (B)
 (c) It depends on the speed of light in air (d) Speed of light does not depend on the medium

5. The Figure shows a light ray traveling from the air to a transparent medium (A) and to another transparent medium (B), at the same angle of incidence. Which medium (A) or (B) has the greater refractive index?



- (a) Medium (A) (b) Medium (B)
 (c) It depends on the speed of light in air (d) Speed of light does not depend on the medium

6. What happens when a light ray travels from air ($n=1.0$) into water ($n=1.3$)?

- (a) The ray bends **away from the normal**, and the speed **decreases**
 (b) The ray bends **away from the normal**, and the speed **increases**
 (c) The ray bends **toward the normal**, and the speed **decreases**
 (d) The ray bends **toward the normal**, and the speed **increases**

7. What happens when a light ray travels from Diamond ($n = 2.42$) into air ($n = 1.0$)?

- (a) The ray bends **away from the normal**, and the speed **decreases**
 (b) The ray bends **away from the normal**, and the speed **increases**
 (c) The ray bends **toward the normal**, and the speed **decreases**
 (d) The ray bends **toward the normal**, and the speed **increases**

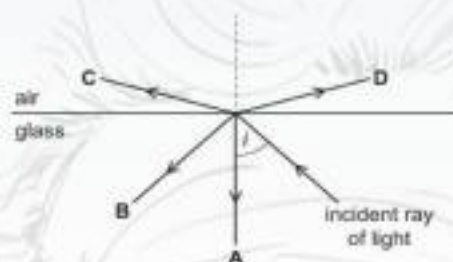
8. A ray of light traveling from air into several mediums as shown in the figures below. Which medium has the greatest index of refraction n ?



- (a) $n_A > n_B > n_D > n_C$ (b) $n_C > n_D > n_B > n_A$ (c) $n_D > n_C > n_B > n_A$ (d) $n_A > n_B > n_C > n_D$
 (a) $v_A > v_B > v_D > v_C$ (b) $v_C > v_D > v_B > v_A$ (c) $v_D > v_C > v_B > v_A$ (d) $v_A > v_B > v_C > v_D$

9. The diagram shows light incident at a glass–air boundary. The angle of incidence (θ_i) of the ray is less than the critical angle.

Which line shows the path of the light after it meets the boundary?



- (a) A (b) C
(c) B (d) D

10. The diagrams compare refraction from air into water, glass, and diamond.

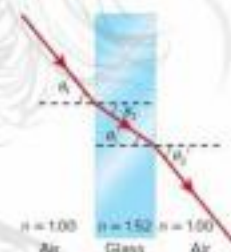
Which statement is correct about the refractive index?



- (a) $n_{\text{water}} < n_{\text{glass}} < n_{\text{diamond}}$ (b) $n_{\text{glass}} < n_{\text{water}} < n_{\text{diamond}}$
(c) $n_{\text{diamond}} < n_{\text{glass}} < n_{\text{water}}$ (d) $n_{\text{water}} = n_{\text{glass}} = n_{\text{diamond}}$

11. The light ray enters glass at angle θ_1 and leaves at angle θ_2 .

What is true about θ_1 and θ_2 ?



- (a) $\theta_1 = 0^\circ$ (b) $\theta_1 > \theta_2$
(c) $\theta_1 < \theta_2$ (d) $\theta_1 = \theta_2$

12. A light ray is incident **perpendicular** to the boundary separating two transparent media with different refractive indices.

Assume that $n_r > n_i$

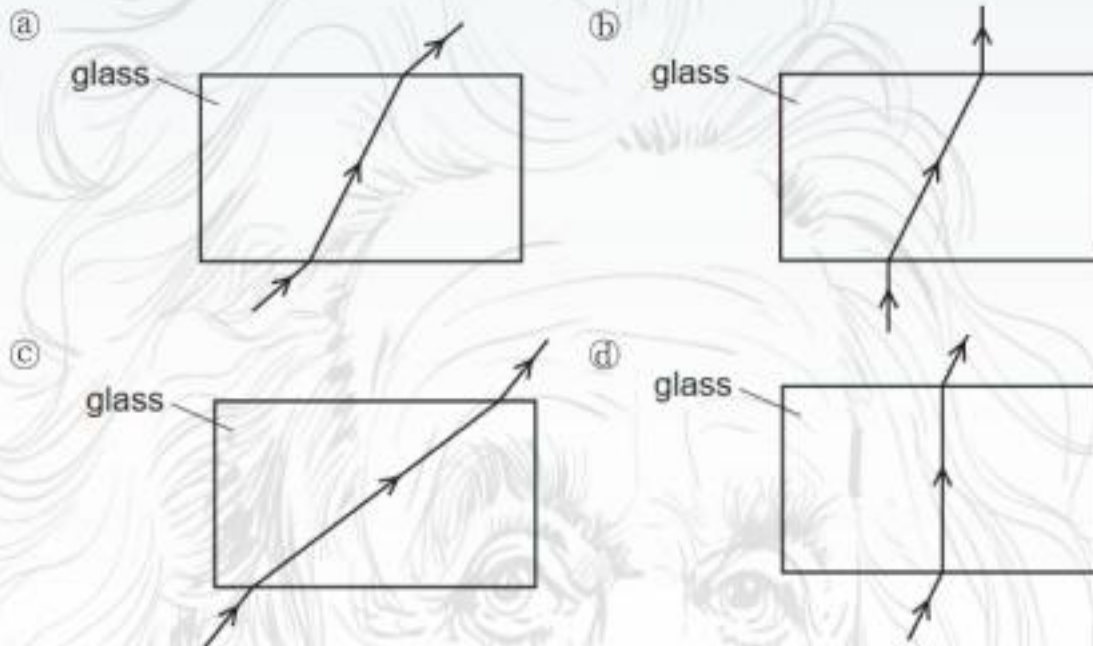
Which of the following relationships correctly describes the incidence angle (θ_i) and the refraction angle (θ_r)?

- (a) $\theta_i > \theta_r$ (b) $\theta_i = \theta_r = 90^\circ$
(c) $\theta_i < \theta_r$ (d) $\theta_i = \theta_r = 0^\circ$



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13. Which diagram shows how a ray of light could pass through a glass block in air?



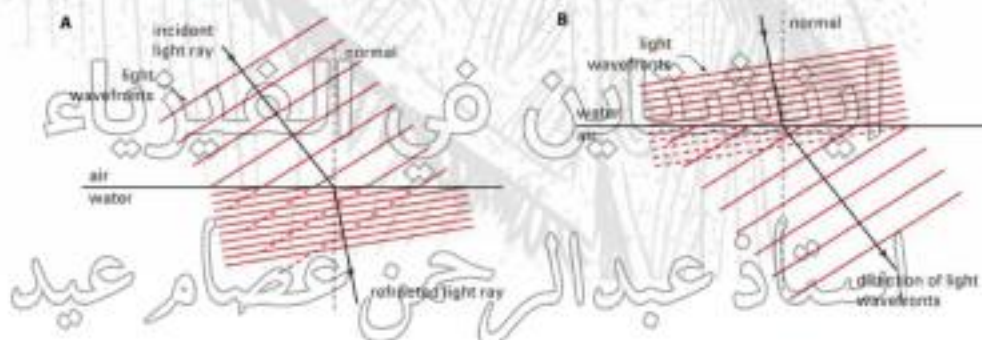
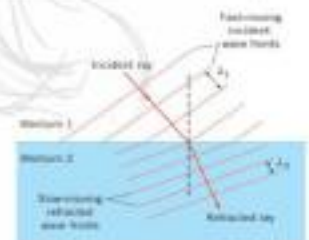
- 2 Identify that during refraction, the wavelength and speed of light change but frequency remains the same.

Student Book

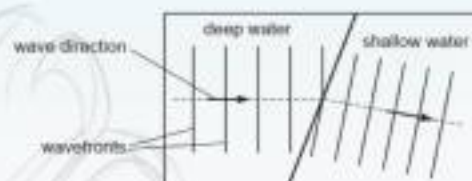
92 93

Wave Model of Refraction

- Before entering the new medium (air $\rightarrow$ glass):**
 - The wave fronts travel at a higher speed in air.
 - The wavelength is longer in air.
- As light enters the new medium (glass):**
 - The wave fronts **slow down** due to the higher refractive index.
 - The wave fronts that have already entered the glass move slower than those still in air.
 - This causes the wave to **change direction** — this is refraction.
- Inside the new medium:**
 - The **wavelength becomes shorter** because the **speed** of light is **lower**.
 - The **frequency remains constant** (it is determined **by the source** and does not change across media).



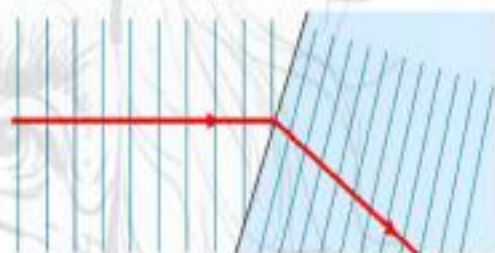
14. Water waves may be used to demonstrate refraction by making them pass into water of a different depth. Why does the water wave change direction as it passes into the shallow water?



- (a) The speed of the wave decreases. (b) The speed of the wave increases.
(c) The frequency of the wave decreases. (d) The frequency of the wave increases.

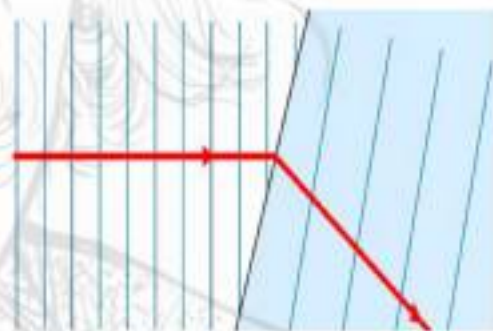
15. A light beam with frequency f and wavelength λ travels from one transparent medium to another. If its speed in the first medium is v_1 and its speed in the second medium is v_2 , which row in the following table **correctly** shows the frequency and wavelength of the beam in the second medium?

Row	Frequency in the second medium	Wavelength in the second medium
(a)	$f/2$	λ
(b)	f	2λ
(c)	f	λ
(d)	$2f$	$\lambda/2$



16. A light beam with frequency f and wavelength λ travels from one transparent medium to another. If its speed in the first medium is v_1 and its speed in the second medium is v_2 , which row in the following table **correctly** shows the frequency and wavelength of the beam in the second medium?

Row	Frequency in the second medium	Wavelength in the second medium
(a)	$f/2$	λ
(b)	f	2λ
(c)	f	λ
(d)	$2f$	$\lambda/2$



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- 3 State and apply Snell's law of refraction. Example (4), Practice Problems (30,32,33) 91-93

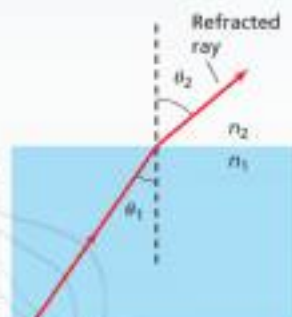
Snell's Law

The product of the refractive index of the incident medium and the sine of the angle of incidence is equal to the product of the refractive index of the refracting medium and the sine of the angle of refraction:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Quantities and Units

Symbol	Quantity	SI Unit
n_1	Index of refraction of the incident medium	Unitless
θ_1	Angle of incidence	Degrees (not an SI unit)
n_2	Index of refraction of the refracting medium	Unitless
θ_2	Angle of refraction	Degrees (not an SI unit)



Important note:

✓ All angles are measured with respect to the normal (the perpendicular to the boundary between the two media), not from the surface itself.

17. As shown in the figure, a light beam travels from air into a selected medium.

Based on the angle of refraction and the refractive index values, what is the **medium** used?

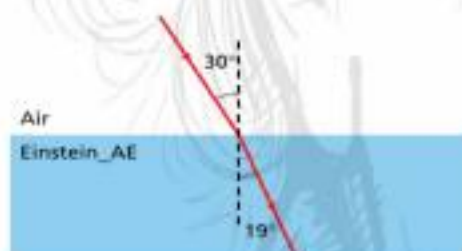


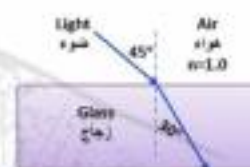
Table of Refractive Indices:

Medium	Index of Refraction
Water	1.33
Ethanol	1.36
Quartz	1.54
Diamond	2.42

- (a) Quartz (b) Diamond (c) Water (d) Ethanol

18. According to the figure, what is the **velocity** of light in the glass?

- (a) 1.4×10^8 m/s (b) 4.2×10^8 m/s
(c) 3.0×10^8 m/s (d) 2.1×10^8 m/s



19. The figure shows a light ray traveling from air to a transparent medium. Using the attached table; What is **the transparent medium** through which the light ray travels?



Transparent Medium	Refractive Index (n)
Air	1.00
Water	1.33
Glass	1.62
Diamond	2.42

- (a) Water (b) Diamond (c) Glass (d) Air

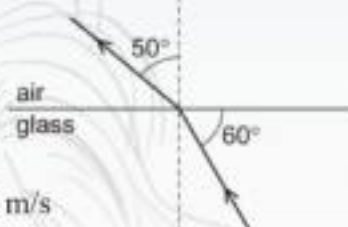
20. The diagram shows a ray of light passing from air into diamond.
What is the refractive index of the diamond?

- (a) 0.89 (b) 1.1
(c) 2.4 (d) 2.5



21. A ray of light is refracted as it enters air from glass, as shown.
What is the speed of light in the glass?

- (a) 2.0×10^8 m/s (b) 2.3×10^8 m/s
(c) 2.2×10^8 m/s (d) 2.7×10^8 m/s



- 4 Calculate the refractive index of a medium using: $n = \frac{c}{v}$ Check Your Progress (38) 93, 96

DEFINITION OF THE INDEX OF REFRACTION n (or refractive index)

The index of refraction of a material is the **ratio** of the speed of light in a **vacuum** to the speed of light in the **material**:

$$n = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in the material}} = \frac{c}{v} \quad \text{Unit Analysis} \quad \frac{\text{metres per second}}{\text{metres per second}} = \text{no unit}$$

22. What quantity do we get when dividing the speed of light in a vacuum by the speed of light in a medium?

- (a) the wavelength of the light in the medium (b) the index of refraction of the medium
(c) the frequency of the light in the medium (d) the critical angle

Notes:

The refractive index is always greater than 1 for any material other than vacuum.

The speed of light decreases when it travels from air (or vacuum) into any other medium.



The speed of light through air is about 3×10^8 m/s.



The speed of light through water is about 2.27×10^8 m/s.



The speed of light through glass is about 1.97×10^8 m/s.

Diamond

The speed of light through diamond is about 1.25×10^8 m/s.

Speed of Light in Different Media

Medium	Refractive Index (n)	Speed of Light (v)
Vacuum	1.00	3.00×10^8 m/s
Water	1.33	2.27×10^8 m/s
Ethanol	1.36	2.21×10^8 m/s
Float glass	1.52	1.97×10^8 m/s
Quartz	1.54	1.95×10^8 m/s
Flint glass	1.62	1.85×10^8 m/s
Diamond	2.42	1.25×10^8 m/s

Note:

- Frequency **never changes** during refraction because it is determined by the source.
- The **change in speed** causes the change in direction and wavelength.

23. The speed of light in diamond is $(1.24 \times 10^8 \text{ m/s})$. What is the index of refraction of diamond?

- (a) 0.042 (b) 0.413 (c) 1.24 (d) 2.42

24. If the speed of light in a material is $2.5 \times 10^8 \text{ m/s}$, what is the refractive index of this material?

- (a) 3.0 (b) 0.83 (c) 1.5 (d) 1.2

25. What is the speed of light in a medium with a refractive index of 2.0, if its speed in vacuum is C ?

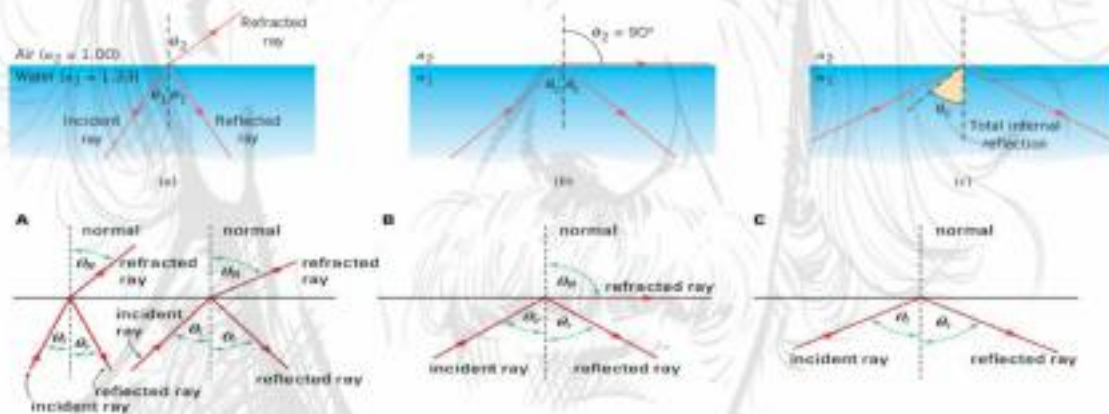
- (a) $C/4$ (b) C (c) $C/2$ (d) $2C$

26. What is the speed of light in chloroform ($n = 1.51$)?

- (a) $4.53 \times 10^8 \text{ m/s}$ (b) $1.99 \times 10^8 \text{ m/s}$ (c) $2.50 \times 10^8 \text{ m/s}$ (d) $3.00 \times 10^8 \text{ m/s}$

5. Define the critical angle as the angle of incidence at which the refracted ray lies along the boundary. Figure (21) 94

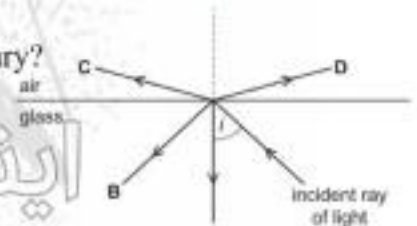
Important Notes:



1. If the angle of incidence is less than the critical angle, refraction occurs.
2. If the angle of incidence is equal to the critical angle, the refracted ray travels along the boundary between the two media.
3. If the angle of incidence is greater than the critical angle, total internal reflection occurs.

27. The diagram shows light incident at a glass-air boundary. The angle of incidence i of the ray is greater than the critical angle.

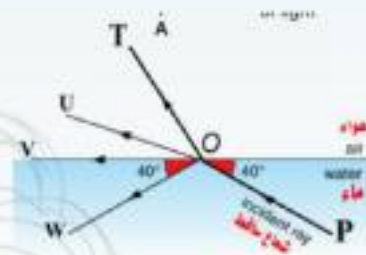
Which line shows the path of the light after it meets the boundary?



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28. The figure shows a ray of light (PO) passing from water into air. Given the refractive indices of $n_{\text{water}} = 1.325$, $n_{\text{air}} = 1.0$ which is the **correct** path of the ray?



- (a) POW (b) POV
(c) POU (d) POT

29. The figure shows a light ray passing through a transparent medium. If the refractive index of air ($n_{\text{air}} = 1.0$), calculate the refractive index of the transparent medium



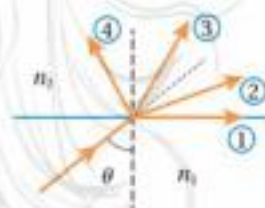
- (a) $n = 1.31$ (b) $n = 0.81$
(c) $n = 1.69$ (d) $n = 1.91$

30. What happens to the light ray when it falls from water to air at an angle of 50.0° ? (Given: $n_{\text{air}} = 1.0$, $n_{\text{water}} = 1.33$)

- (a) It refracts in the air at an angle greater than 50° (b) It reflects totally internally
(c) It refracts parallel to the surface (d) It refracts in the air at an angle less than 50°

31. Which path represents the correct behavior when light moves from a medium with a small refractive index to a medium with a large refractive index?

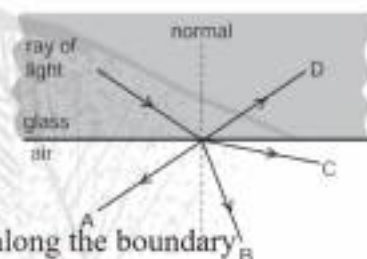
- (a) 1 (b) 2
(c) 3 (d) 4



32. The diagram shows a ray of light incident on the edge of a piece of glass. The angle i is greater than the critical angle.

Which arrow shows the direction of the ray after it leaves the edge of the glass?

- (a) A (b) C
(c) B (d) D



33. What is the angle of incidence at which the refracted ray travels along the boundary between two media called?

- (a) Angle of dispersion (b) Angle of refraction (c) Angle of reflection (d) Critical angle

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- 6 Apply concepts of refraction, critical angle, and total internal reflection to solve numerical problems.

Check Your Progress
(36,37,39,40,41)

92-96

34. The figure below shows light rays emitted from a luminous source located in water.

Given that the refractive index of water is $n_1 = 1.33$,



- (1) What is the value of θ_1 ?

(a) 60° (b) 48° (c) 40.63° (d) 50°

- (2) What is the value of θ_2 ?

(a) 60° (b) 48.8° (c) 90 (d) 32°

- (3) What is the value of θ_3 ?

(a) 60° (b) 48.8° (c) 90 (d) 50°

Critical Angle

The **critical angle** exists only when light travels from a medium with a **higher refractive index** to a medium with a **lower refractive index**.

$$\sin \theta_c = \frac{n_2}{n_1}$$

- From **glass to water**:
Glass has a higher refractive index than water, so a **critical angle exists**.
- From **water to glass**:
Water has a lower refractive index than glass, so **no critical angle exists**.

The critical angle for light passing from a glass block into another medium is 45.0° .

What is the refractive index of the medium into which the light travels?

(Assume the refractive index of glass is 1.41)

(a) 1.73 (b) 1.41 (c) 1.20 (d) 1.00

35. When does a **critical angle** occur?

(a) From low to high refractive index (b) From high to low refractive index
(c) In vacuum only (d) In all materials

36. Which transition can produce total internal reflection?

Material	Refractive Index (n)
Air	(1.00)
Water	(1.33)
Glass	(1.52)

(a) Air $\rightarrow$ Water (b) Air $\rightarrow$ Glass (c) Glass $\rightarrow$ Air (d) Water $\rightarrow$ Glass

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37. Why is there no critical angle from water to glass?

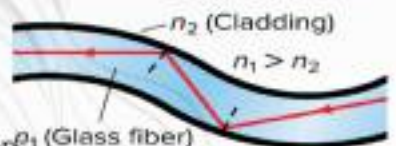
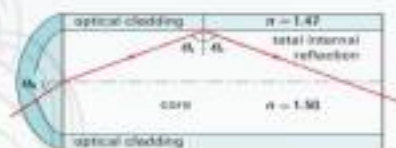
- (a) Water absorbs light (b) Light is entering a denser medium
(c) Glass is transparent (d) The angle is always zero

Total Internal Reflection

Optical fibres use **total internal reflection** to keep light inside the core.

The cladding must have a **lower refractive index** than the core.

- Quartz has a lower refractive index than float glass.
- Therefore, quartz is better for the cladding.



38. Why is quartz suitable as cladding?

- (a) It has a higher refractive index (b) It reflects all colors
(c) It has a lower refractive index (d) It absorbs light

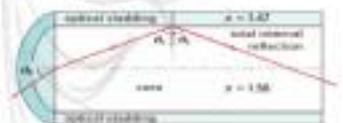
39. Optical fibres work based on:

- (a) Polarization (b) Total internal reflection (c) Interference (d) Diffraction

40. The diagram shows an optical fibre with a core refractive index of $n_1 = 1.50$ and cladding refractive index of $n_2 = 1.47$.

Calculate the critical angle θ_c for total internal reflection at the core-cladding boundary.

- (a) 68° (b) 80°
(c) 78.52° (d) 88°



Speed of Light

The refractive index is related to the speed of light by:

$$n = \frac{c}{v}$$

Since light travels fastest in vacuum:

$$n \geq 1$$

If $n < 1$, this would mean light travels faster than light in vacuum, which is not possible in normal materials.

41. What does the refractive index depend on?

- (a) Density only (b) Speed of light in the medium (c) Color only (d) Temperature only

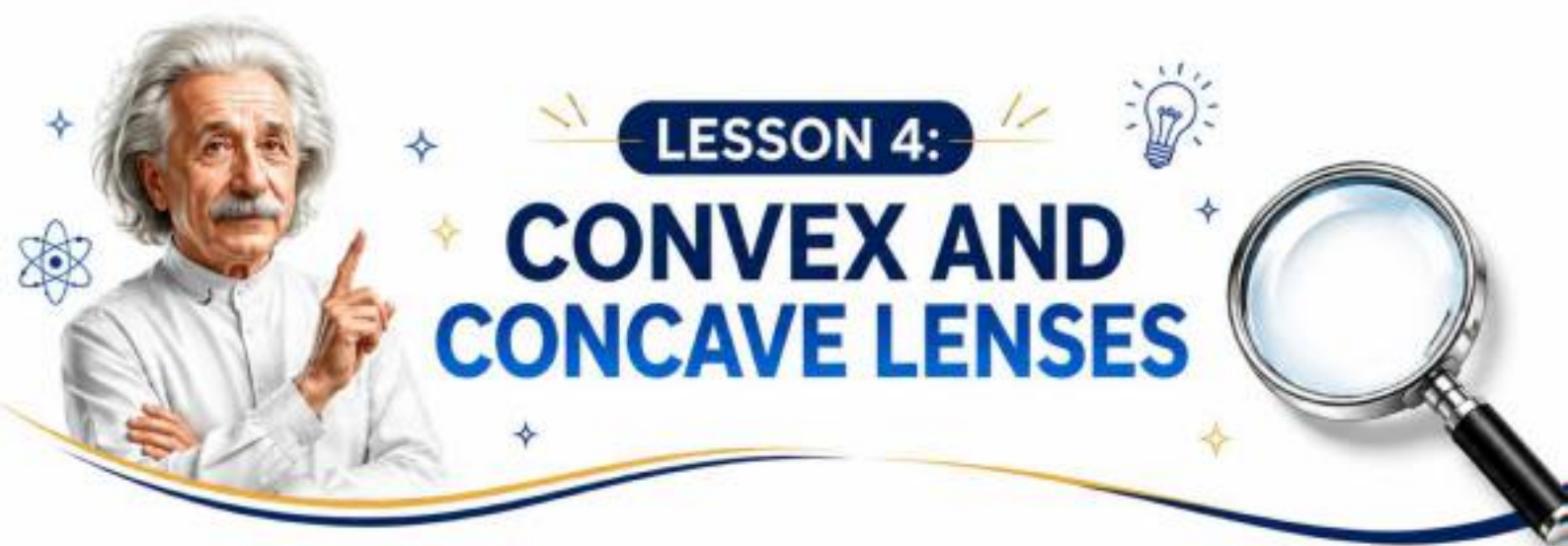
42. If the refractive index increases, the speed of light in the medium:

- (a) Increases (b) Decreases (c) Stays constant (d) Becomes zero

43. Why can the refractive index not normally be less than 1?

- (a) The speed of light in the medium is greater than in vacuum.
(b) The speed of light in the medium is less than in vacuum.
(c) The speed of light in the medium is equal to the speed in vacuum.
(d) The speed of light becomes zero in the medium.

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7	Identify the principal axis, focal points, and focal length of convex and concave lenses.	Figures (28),(31)	98 99
8	Draw ray diagrams for objects at different distances from a convex lens and determine image properties.	Figures (28,29,30), Practice Problem (47)	98 101
9	Describe how a convex lens acts as a magnifier.	Student Book	99
10	Apply the thin lens equation to calculate image distance, object distance, or focal length.	Example (5), Practice Problems (43,44,45,33), Check Your Progress (51,55,56)	100 106

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- 7 Identify the principal axis, focal points, and focal length of convex and concave lenses.

Figures (28),(31)

98-99

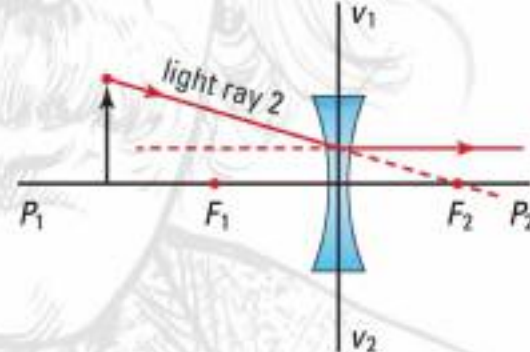
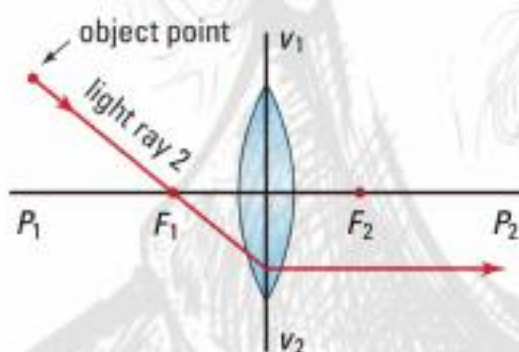
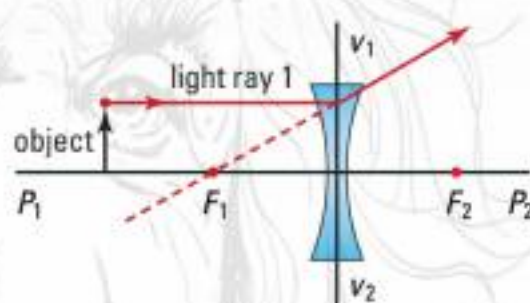
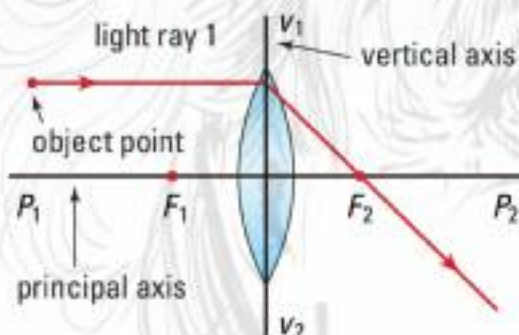
Principal Axis

The straight horizontal line passing through the center of the lens.

Focal Point (F)

The point where light rays:

- **Convex lens:** parallel rays converge after refraction.
- **Concave lens:** rays appear to diverge from after refraction.



Focal Length (f)

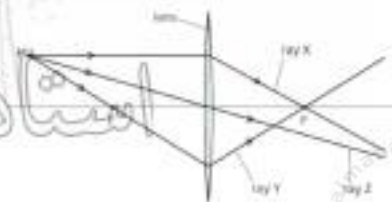
The distance between the center of the lens and the focal point F .

$$f = \text{distance between lens center and focal point } F$$

44. A student draws three light rays starting from point (P) through a convex lens.

Which of the rays is drawn incorrectly?

- (a) Ray (X) and Ray (Y)
(b) Ray (Y) and Ray (Z)
(c) Ray (X) only
(d) Ray (Z) only

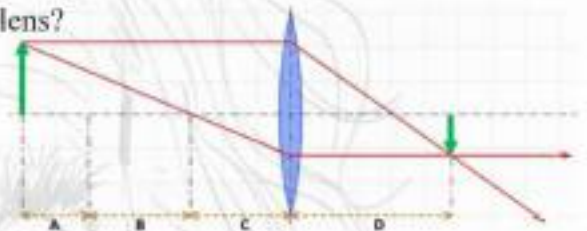


45. Which of the following ray diagrams is **incorrect**?



46. The diagram shows a ray diagram of a lens forming an image of an object. Which of the following represents **the focal length** of the lens?

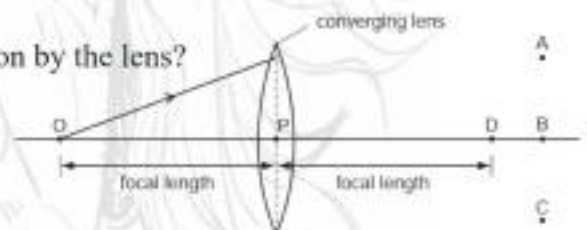
- (a) A (b) C
(c) B (d) D



47. In the diagram, the distance OP is the focal length of the converging lens. One ray of light from O is shown.

Through which point will this ray pass, after refraction by the lens?

- (a) A (b) C
(c) B (d) D

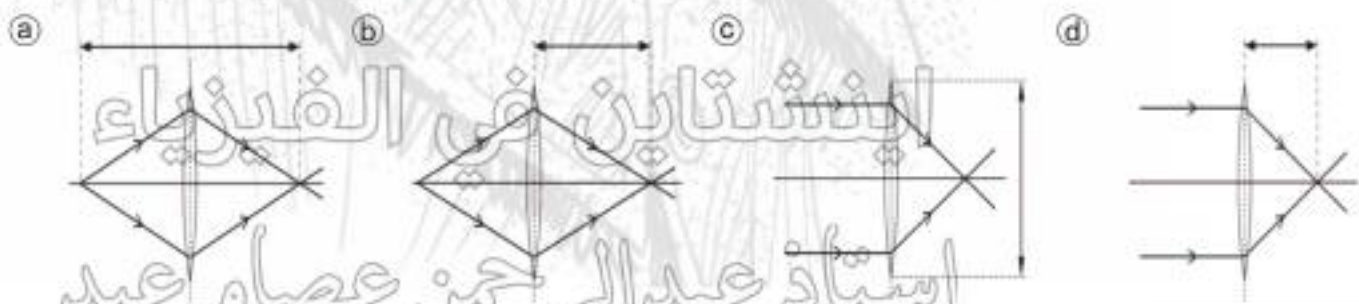


48. A parallel beam of light falls on a converging lens.

Which diagram shows what happens to the beam of light?



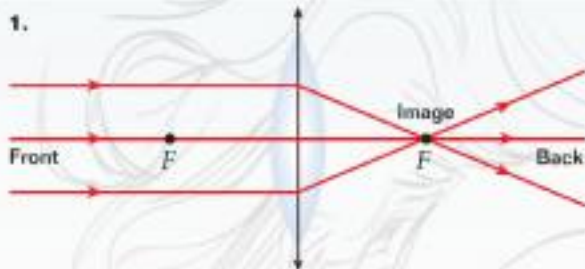
49. Which labelled distance is the focal length of the lens?



8 Draw ray diagrams for objects at different distances from a convex lens and determine image properties.

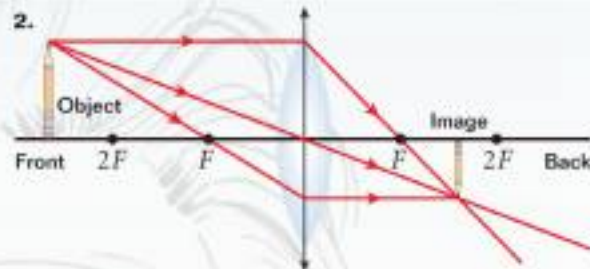
Figures (28,29,30),
Practice Problem (47)

98-101



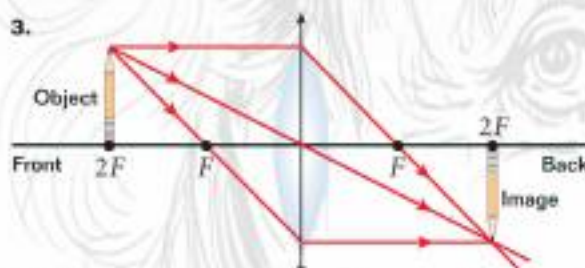
Configuration: object at infinity; point image at F

Applications: burning a hole with a magnifying glass



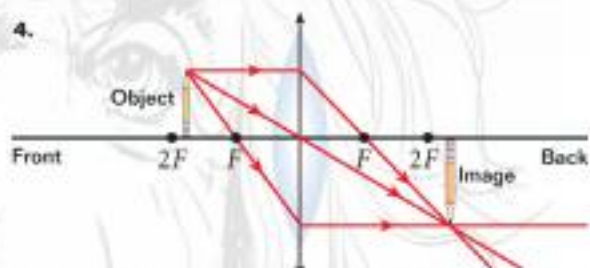
Configuration: object outside $2F$; real, smaller image between F and $2F$

Applications: lens of a camera, human eyeball lens, and objective lens of a refracting telescope



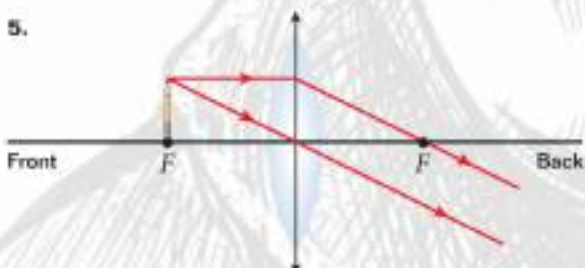
Configuration: object at $2F$; real image at $2F$ same size as object

Applications: inverting lens of a field telescope



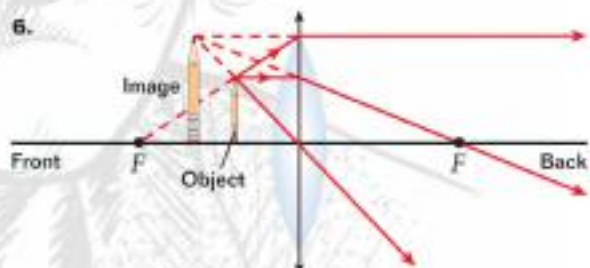
Configuration: object between F and $2F$; magnified real image outside $2F$

Applications: motion-picture or slide projector and objective lens in a compound microscope



Configuration: object at F ; image at infinity

Applications: lenses used in lighthouses and searchlights



Configuration: object inside F ; magnified virtual image on the same side of the lens as the object

Applications: magnifying with a magnifying glass; eyepiece lens of microscope, binoculars, and telescope

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❖ Image Formation by Convex Lens

Object Position x_o	Image Position	Side of Image	Image Properties	Image Size
At Infinity	At F	Opposite side	Real, Inverted	Highly Reduced
Beyond $2F$ $x_o > 2f$	Between F and $2F$	Opposite side	Real, Inverted	Reduced
At $2F$ $x_o = 2f$	At $2F$	Opposite side	Real, Inverted	Same Size
Between F and $2F$ $f < x_o < 2f$	Beyond $2F$	Opposite side	Real, Inverted	Magnified
At F $x_o = f$	At Infinity		No image formed (rays are parallel)	
Between F and Lens $x_o < f$	Same side as object	Same side	Virtual, upright	Magnified

❖ Images Formed by Concave Lenses

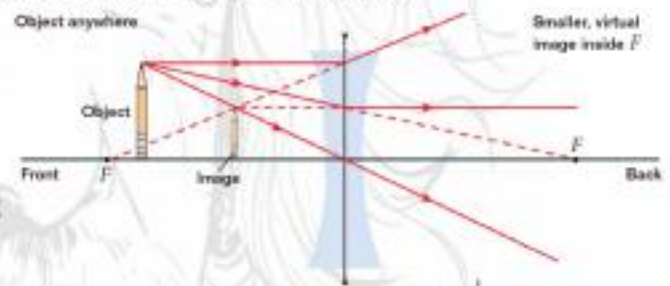
- The image properties do not change, regardless of the object's position.

Image Characteristics:

- Virtual
- Upright
- Smaller than the object

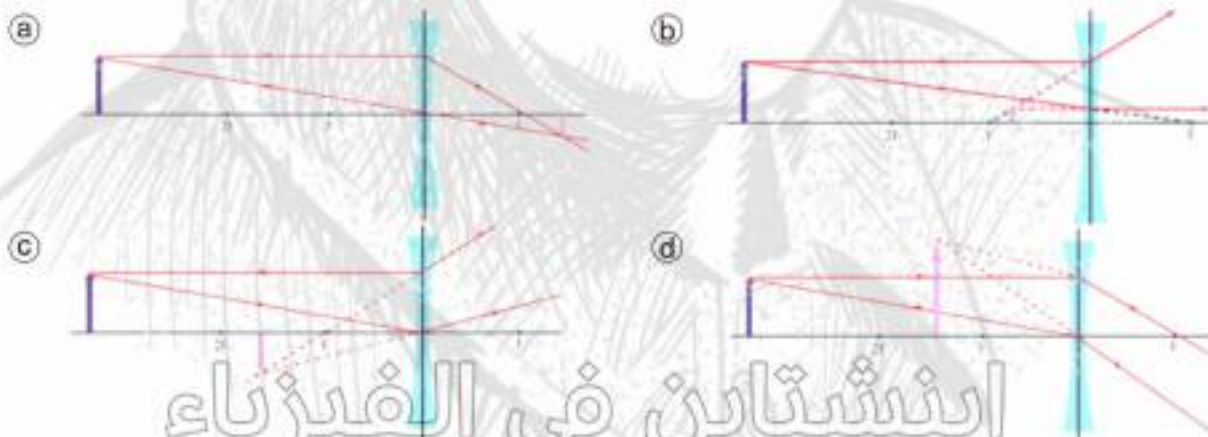
Image Location:

- On the same side of the lens as the object
- At a distance less than the focal length



50. An object is placed near a lens, as shown in the figure.

Which of the following diagrams **correctly** shows the image formed by the lens?

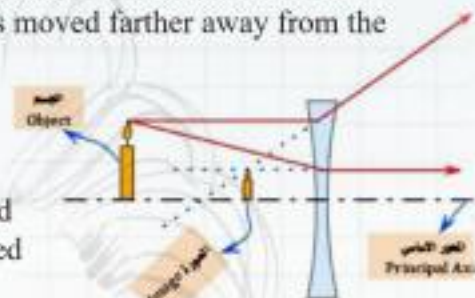


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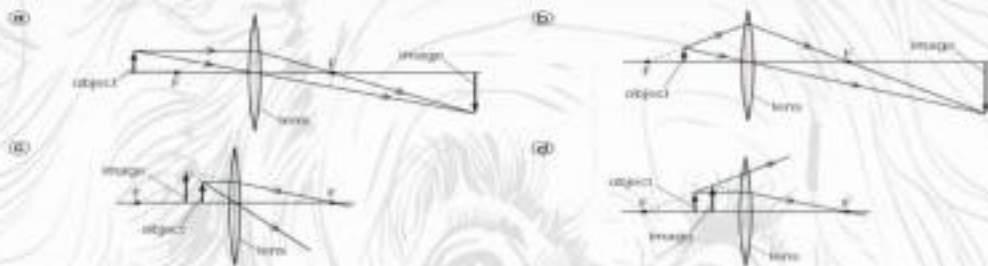
51. When a candle is placed in front of a concave lens as shown in the figure, an upright, virtual, and diminished image is formed. If the candle is moved farther away from the lens,

what happens to the image formed by the lens?

- (a) The image becomes inverted, real, and magnified
- (b) The image remains upright, virtual, and diminished
- (c) The image becomes inverted, virtual, and magnified
- (d) The image becomes upright, real, and diminished



52. Which diagram shows how a converging lens is used as a magnifying glass?

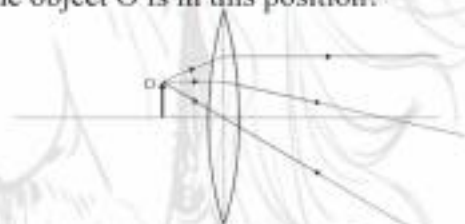


53. An object O is placed close to a thin converging lens.

The diagram represents three rays from the top of O passing through the lens.

Which type of image is produced by the lens when the object O is in this position?

- (a) real and diminished
- (b) real and enlarged
- (c) virtual and diminished
- (d) virtual and enlarged



54. A lit candle is placed in front of a convex lens at a distance **greater than twice its focal length**, as shown in the diagram. A sharp image is formed on a screen placed on the opposite side of the lens.

Which of the following **correctly** represents the image formed on the screen as seen by an observer?



55. a candle is placed in front of a convex lens **at twice its focal length (2f)**, as shown in the diagram. A sharp image is formed on a screen placed on the opposite side of the lens.

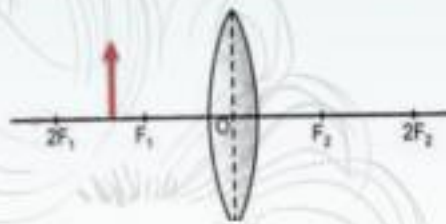
Which of the following **correctly** represents the image formed on the screen as seen by an observer?



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56. What are the image characteristics formed for the object shown in the figure?

- (a) Enlarged and real
- (b) Enlarged and upright
- (c) Enlarged and virtual
- (d) Reduced and inverted



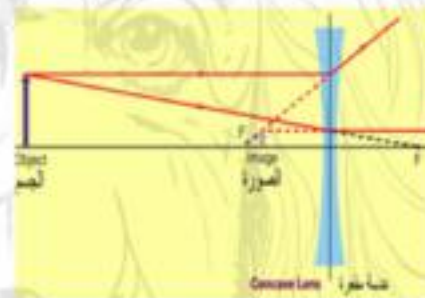
As shown in the figure, an object is placed in front of a convex lens. Determine the location of the image (if any).

- (a) Position B
- (b) No image is found
- (c) Position D
- (d) Position A



As shown in the figure, an object is placed in front of a concave lens. What happens to the image as the object gets closer to the lens?

- (a) Stay the same
- (b) Appear behind the lens
- (c) Become enlarged
- (d) Become inverted



9 Describe how a convex lens acts as a magnifier.

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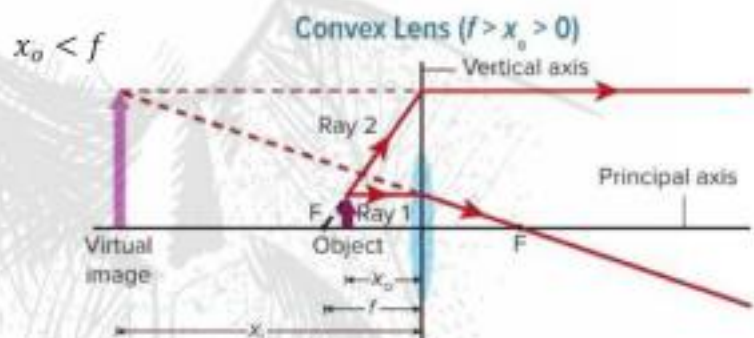
99

A convex lens acts as a magnifier when the object is placed at a distance less than the focal length of the lens ($x_o < f$).

In this case, the lens forms a:

- virtual image
- upright image
- enlarged image

on the same side of the lens as the object.



57. When does a convex lens act as a magnifier?

- (a) $x_o > 2f$
- (b) $x_o = 2f$
- (c) $x_o < f$
- (d) $x_o = f$

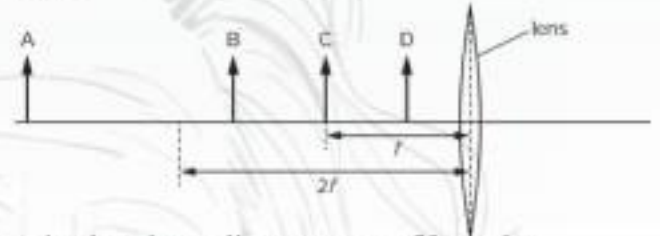
58. When a convex lens is used as a magnifier, the image formed is:

- (a) Real, inverted, and reduced (b) Real and upright
(c) Virtual, upright, and enlarged (d) Virtual and reduced

59. An object is placed in front of a converging lens. The lens has a focal length f . The lens produces a Virtual, enlarged image of the object.

In which labelled position is the object placed?

- (a) A (b) C
(c) B (d) D



60. A convex lens acts as a magnifier when the object is placed at a distance $x_o < f$ from the lens. What is the magnification of the image in this case?

- (a) 1 (b) 2 (c) 0.2 (d) 0.5

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10	Apply the thin lens equation to calculate image distance, object distance, or focal length.	Example (5), Practice Problems (43,44,45,33), Check Your Progress (51,55,56)	100–106
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Thin Lens Equation

The inverse of the focal length of a spherical lens is equal to the sum of the inverses of the image position and the object position.

$$\frac{1}{f} = \frac{1}{x_i} + \frac{1}{x_o}$$

- x_o = object position (distance from the lens)
- x_i = image position (distance from the lens)
- f = focal length of the lens

Note:

- For convex lens, the focal length (f) is positive.
- For concave lens, the focal length (f) is negative.

Magnification m

The magnification of an object by a spherical lens, defined as the image height divided by the object height, is equal to the negative of the image position divided by the object position.

$$\text{Magnification (m)} = \frac{h_i}{h_o} = \frac{-x_i}{x_o}$$

Where:

- h_i = height of the image
- h_o = height of the object
- x_i = image distance
- x_o = object distance

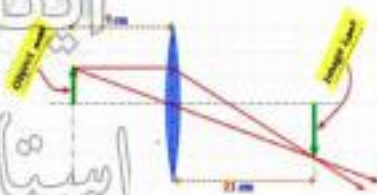
The behaviours of convex and concave types is opposite in mirrors and lenses.

Lens	Focal length (f)	Object distance (x_o)	Image distance (x_i)		Height of object (H_o)	Height of image (H_i)	
			Real	Virtual		Real (Inverted)	Virtual (Upright)
Convex	Positive (+)	Positive (+)	Positive (+)	Negative (–)	Positive (+)	Negative (–)	Positive (+)
Concave	Negative (–)	Positive (+)	Image does not form	Negative (–)	Positive (+)	Image does not form	Positive (+)

61. An image of an object was formed using a **convex lens** as shown in the adjacent figure.

If the object's height is 3.0 cm, what is **the height of the image**?

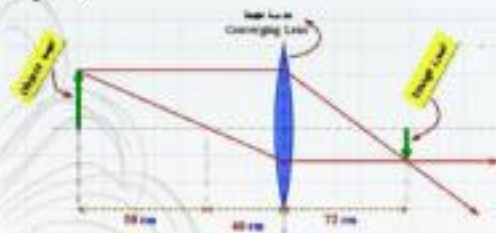
- (a) 5.0 cm (b) 1.0 cm
(c) 1.5 cm (d) 7.0 cm



62. The diagram shows a converging lens forming an image of an object.

What is the **focal length** of the lens?

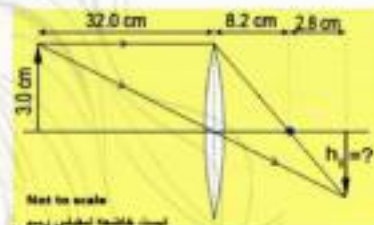
- (a) $f = 90 \text{ cm}$ (b) $f = 50 \text{ cm}$
(c) $f = 72 \text{ cm}$ (d) $f = 40 \text{ cm}$



63. The diagram shows how an image is formed by a **converging lens**.

What is **the height of the image** (h_i) formed in the diagram?

- (a) 0.34 cm (b) 2.24 cm
(c) 1.03 cm (d) 2.73 cm



64. An object is placed at a distance of 90 cm from a convex lens with a focal length of 30.

Calculate the **image distance** x_i from the lens.

- (a) 90 cm (b) 30 cm (c) 60 cm (d) 45 cm

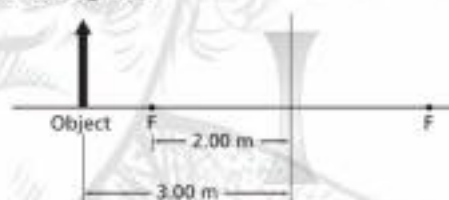
65. A researcher observes a bee using a Converging lens. If the bee is placed 12 cm from the lens and a virtual, upright image is formed at a distance of 20 cm from the lens, what is **the focal length** of the Converging lens?

- (a) +7.5 cm (b) -30 cm
(c) -12 cm (d) +30 cm



66. What is the image position for the situation shown in the figure?

- (a) 6.00 m (b) 0.167 m
(c) 1.20 m (d) 0.833 m



Example (5)

An object is placed 32.0 cm from a convex lens that has a focal length of 8.0 cm.

- Where is the image formed?
- If the object is 3.0 cm high, what is the height of the image?
- What is the orientation of the image?

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43. A 2.25-cm-tall object is 8.5 cm to the left of a convex lens whose focal length is 5.5 cm. Find:

- the image position
- the image height

44. An object near a convex lens produces an image that is 10.4 cm from the lens and inverted. If the focal length of the lens is 6.8 cm, determine:

- the object position
- the image height

45. An object is placed to the left of a convex lens with a 25-mm focal length so that its image is the same size as the object.

Determine:

- the image position
- the object position

51. Image Position and Height

An object is placed 1.5 m from a convex lens with a focal length of 1.0 m.

Use the thin lens equation to determine:

- the distance of the image from the lens
- the image height

If the object height is 2.0 m, determine whether the image is:

- real or virtual
- inverted or upright

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55. Image Position and Height

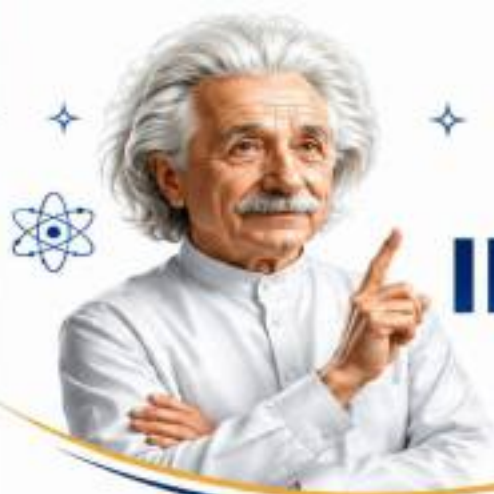
A 6.0-cm-tall object is placed 5.0 cm from a convex lens with a focal length of 4.0 cm. Draw a ray diagram to determine the image location and size. Confirm your results using the thin lens equation and the magnification equation.

56. Diverging Lens

A 6.5-cm-tall salt shaker is viewed through a diverging lens with a focal length of 5.0 cm.

- If the shaker is 6.0 cm from the lens, what is the image distance from the lens? Is the image virtual or real?
- What is the magnification? Is the image smaller or larger than the object?
- The salt shaker is now 4 cm from the lens. What is the distance of the image from the lens? What is the magnification? Is the image now smaller or larger than the object?

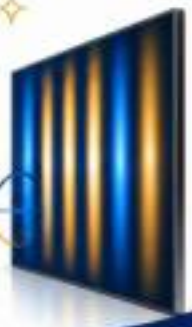
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LESSON 1



INTERFERENCE



11	Define coherent and incoherent light and explain how coherent light is generated.	Student Book	112–113
12	Explain how bright and dark interference fringes are formed in a double-slit experiment.	Figure (5)	113 114
13	Apply the relation: $\lambda = \frac{xd}{L}$ to calculate wavelength or unknown distances.	Student Book	115
14	Explain constructive interference using: $m\lambda = \frac{x_m d}{L}$	Student Book	115
15	Solve problems on interference of light.	Example (1), Practice Problems (1,2,3), Check Your Progress (13)	116–120
16	Define and explain thin-film interference.	Student Book	117

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- 11 Define coherent and incoherent light and explain how coherent light is generated.

Student
Book

112-113

Coherent Light

Coherent light is light made up of waves that:

- have the same frequency
- have the same wavelength
- are in phase with each other



LASER: One color (monochromatic) and waves in phase (coherent)

A regular wavefront is produced by coherent light.

Examples:

- Laser light
- Light from a single point source

Incoherent Light

Incoherent light is light made up of waves that:

- have different frequencies
- have different wavelengths
- are not in phase with each other



Sunlight (many different colors)

White light from a light bulb is an example of incoherent light.

Monochromatic Light

Monochromatic light is light that has:

- one frequency
- one wavelength



LED: one color (monochromatic) and waves not in phase (non-coherent)

However, the waves are not necessarily in phase.

How Coherent Light Is Generated

Coherent light can be generated using:

- a laser
- a single point source

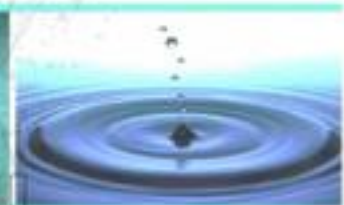
67. These sources produce waves with the same wavelength and constant phase difference.

Which of the following table rows correctly describes coherent light waves in terms of wavelength and phase?

	Wavelength	Phase
(a)	Have the same wavelength	Not in phase
(b)	Have different wavelengths	In phase
(c)	Have the same wavelength	In phase
(d)	Have different wavelengths	Not in phase



Incoherent Wave



Coherent Wave

68. Which light source produces waves that are in phase and have the same wavelength?

Which of the following sources can produce coherent light?

- (a) Laser (b) Candle
(c) Light bulb (d) Sunlight

- 12 Explain how bright and dark interference fringes are formed in a double-slit experiment.

Figure (5)

113–114

Bright Fringes (Constructive Interference)

Bright fringes are formed when:

- the two waves arrive in phase
- crest meets crest
- trough meets trough

The amplitudes add together, producing maximum intensity (bright bands).

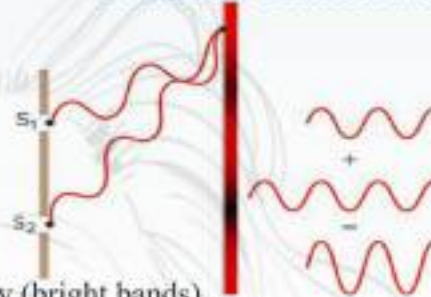
Condition for bright fringes:

$$\Delta L = m\lambda$$

where:

- ΔL = path difference
- m = order number (0, 1, 2, ...)
- λ = wavelength

Constructive interference



Dark Fringes (Destructive Interference)

Dark fringes are formed when:

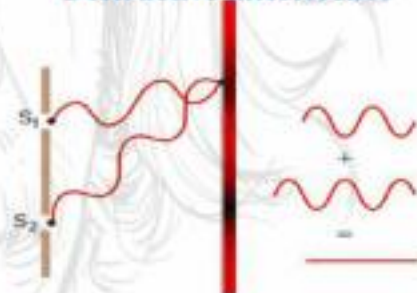
- the two waves arrive out of phase
- crest meets trough

The amplitudes cancel each other, producing minimum intensity (dark bands).

Condition for dark fringes:

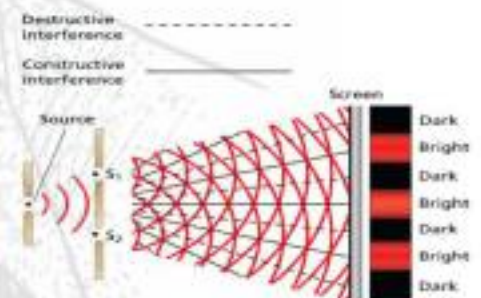
$$\Delta L = \left(m + \frac{1}{2}\right)\lambda$$

Destructive interference



Important Notes

- The central bright fringe occurs at $m = 0$.
- Bright and dark bands alternate on the screen.
- Coherent monochromatic light is required for a stable pattern.



69. What is the type of interference?



70. What band resulted from the **interference** shown in the image?

- a. Random bands
b. Dark bands
c. Bright bands
d. Dim band



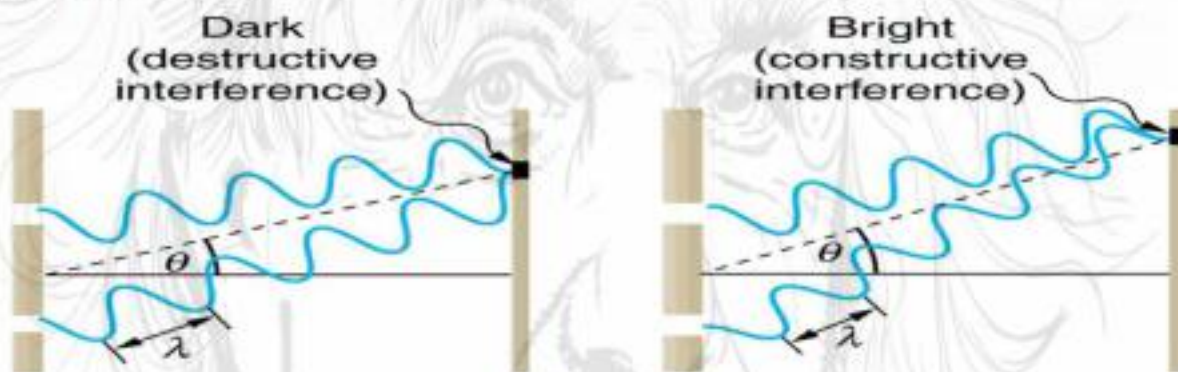
71. What band resulted from the **interference** shown in the image?

- a. Random bands
b. Dark bands
c. Bright bands
d. Dim band



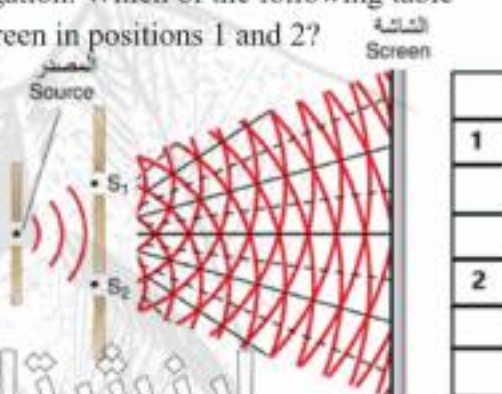
72. In **Young's double-slit experiment** using **monochromatic light**, the interference pattern consists of:

- a. A **bright central band** with alternating **dark and bright bands** on either side.
b. A **dark central band** with **multi-coloured bands** on either side.
c. A **dark central band** with alternating **bright and dark bands** on either side.
d. A **white central band** with **multi-coloured bands** on either side.



73. The figure shows a top view of a double-slit investigation. Which of the following table rows describes correctly the bands formed on the screen in positions 1 and 2?

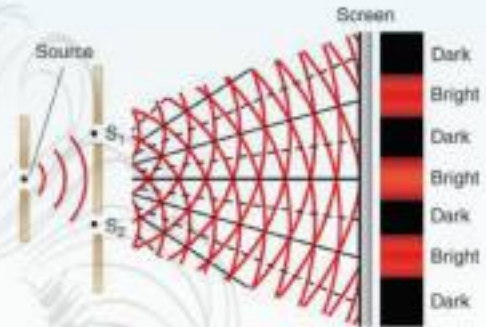
- | | Band (1) | Band (2) |
|-----|----------|----------|
| (a) | Dark | Bright |
| (b) | Bright | Bright |
| (c) | Dark | Dark |
| (d) | Bright | Dark |



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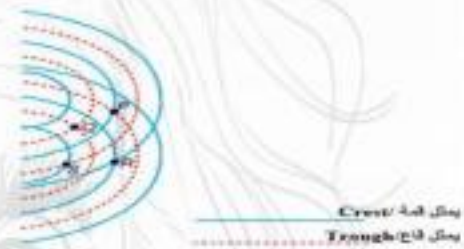
74. The figure below shows the double slit experiment.

- | | | |
|-----|------------------|----------------|
| | the bright bands | the dark bands |
| (a) | constructive | destructive |
| (b) | destructive | constructive |
| (c) | constructive | constructive |
| (d) | destructive | destructive |



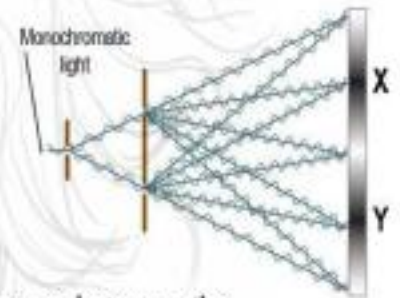
75. The diagram shows the pattern of interference produced by two coherent light waves sources. Which of the following table rows is **correct**?

- | | | |
|-----|---------------------------|--------------------------|
| | Constructive interference | Destructive interference |
| (a) | S | Q |
| (b) | P | R |
| (c) | R | S |
| (d) | P | Q |



76. The diagram shows monochromatic light passing through two openings. What do the areas labeled X and Y represent?

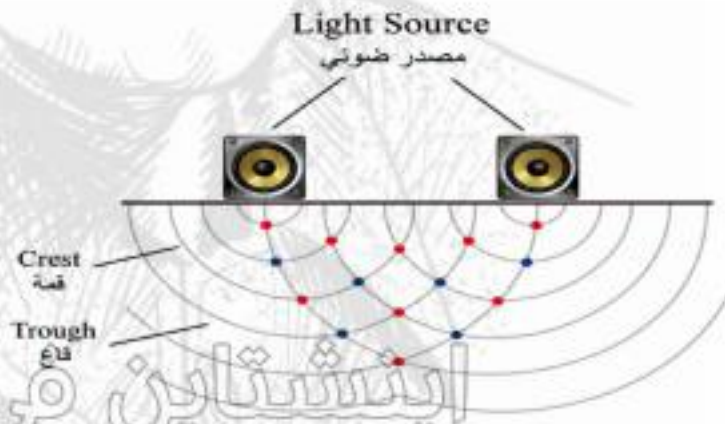
- | | |
|-----|--|
| (a) | constructive interference in which waves cancel each other out |
| (b) | constructive interference in which waves strengthen each other |
| (c) | destructive interference in which waves cancel each other out |
| (d) | destructive interference in which waves strengthen each other |



77. Two light sources are placed a certain distance apart, causing interference between the emitted waves.

What is the type of interference at the blue meeting points ● and the red meeting points ● respectively?

- | | |
|-----|-----------------------------|
| (a) | ● Constructive interference |
| | ● Constructive interference |
| (b) | ● Constructive interference |
| | ● Destructive interference |
| (c) | ● Destructive interference |
| | ● Constructive interference |
| (d) | ● Destructive interference |
| | ● Destructive interference |

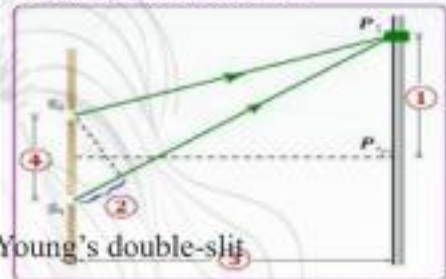


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13	Apply the relation: $\lambda = \frac{xd}{L}$ to calculate wavelength or unknown distances.	Student Book	115
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78. Which number on the figure indicates the wavelength of the light used in the double-slit experiment?

- (a) 1 (b) 2
(c) 3 (d) 4



Distance from the Central Bright Band to a Bright Band

The distance x from the central bright fringe to any bright fringe in Young's double-slit experiment depends on:

$$x = \frac{\lambda L}{d}$$

Factors Affecting x

1. Wavelength λ

- x is directly proportional to wavelength.

$$x \propto \lambda$$

Therefore:

- Increasing wavelength $\rightarrow$ increases fringe distance.
- Decreasing wavelength $\rightarrow$ decreases fringe distance.

Example:

- Red light produces wider fringe spacing than blue light.

2. Screen Distance L

- x is directly proportional to the screen distance.

$$x \propto L$$

Therefore:

- Increasing the distance between the screen and slits $\rightarrow$ increases fringe spacing.
- Bringing the screen closer $\rightarrow$ decreases fringe spacing.

3. Slit Separation d

- x is inversely proportional to slit separation.

$$x \propto \frac{1}{d}$$

Therefore:

- Increasing slit separation $\rightarrow$ decreases fringe spacing.
- Decreasing slit separation $\rightarrow$ increases fringe spacing.

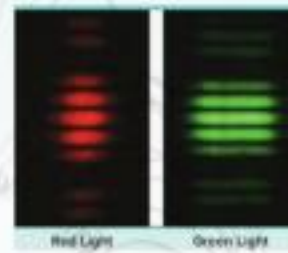
79. The distance between bright fringes increases when:

- (a) The slit separation increases (b) The screen distance decreases
(c) The wavelength decreases (d) The wavelength increases

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80. In Young's double-slit investigation, what change will be noticed when using red light instead of green light?

- (a) Patterns of all the colors of the spectrum appear
- (b) The width of the bright central band decreases
- (c) No change will be noticed
- (d) The width of the bright central band increases



14 Explain constructive interference using: $m\lambda = \frac{x_m d}{L}$

Student Book

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Bright Fringes (Constructive Interference)

Bright fringes are formed when:

- the two waves arrive in phase
- crest meets crest
- trough meets trough

The amplitudes add together, producing maximum intensity (bright bands).

Condition for bright fringes:

$$\Delta L = m\lambda$$

where:

- ΔL = path difference
- m = order number (0, 1, 2, ...)
- λ = wavelength

Dark Fringes (Destructive Interference)

Dark fringes are formed when:

- the two waves arrive out of phase
- crest meets trough

The amplitudes cancel each other, producing minimum intensity (dark bands).

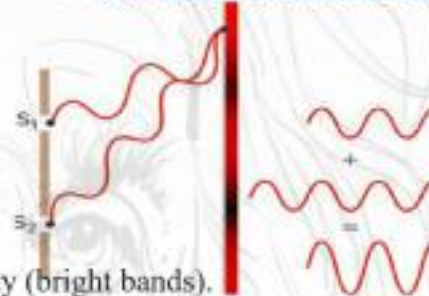
Condition for dark fringes:

$$\Delta L = \left(m + \frac{1}{2}\right)\lambda$$

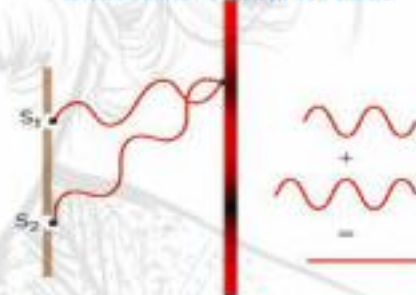
Important Notes

- The central bright fringe occurs at $m = 0$.
- Bright and dark bands alternate on the screen.
- Coherent monochromatic light is required for a stable pattern.

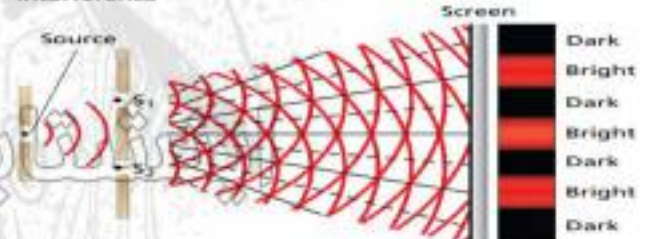
Constructive interference



Destructive interference



Destructive interference
Constructive interference



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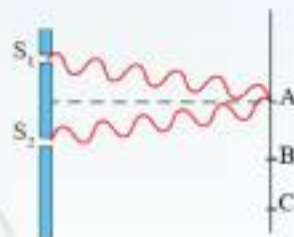
Determining the Phase Difference Between the Two Waves

1. Point A

A **bright fringe** is formed at point A due to **constructive interference** between two waves that are **in phase**.

This occurs because the distances traveled by the two waves are **equal**, so the **path difference is zero**.

This bright fringe is called the **central bright fringe**.

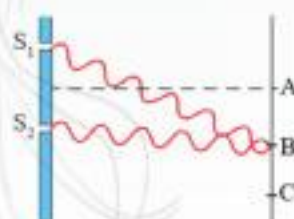


2. Point B

A **dark fringe** is formed at point B due to **destructive interference** between two waves that are **out of phase**.

This happens because the path difference between the two waves is $\frac{\lambda}{2}$

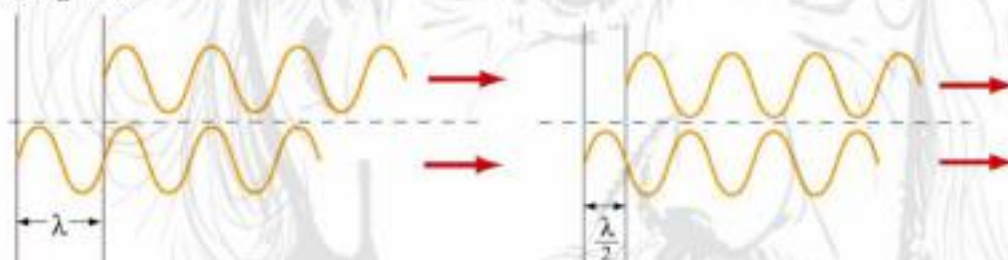
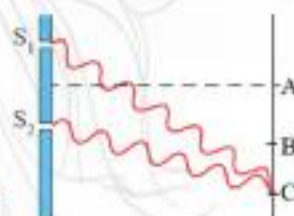
which corresponds to a **phase difference of π** .



3. Point C

A **bright fringe** is formed at point C due to **constructive interference**.

At this point, the path difference between the two waves is λ so the waves are **in phase again**.



Bright and Dark Fringes and Path Difference in Young's Experiment

Fringe type	Order (n)	Path difference	Phase difference
Central bright	0	0	0
First dark	—	$\frac{\lambda}{2}$	π
First bright	1	λ	0
Second dark	—	$\frac{3\lambda}{2}$	π
Second bright	2	2λ	0

81. In a double-slit interference pattern, the first bright band is formed when the path difference between the two waves is equal to:

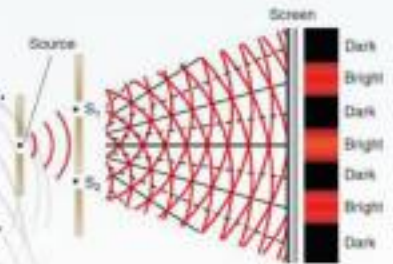
- (a) Half wavelength ($\frac{\lambda}{2}$) (b) Two wavelengths (2λ)
 (c) One wavelength (λ) (d) Zero wavelength

82. For destructive interference to occur between two waves of the same wavelength and amplitude, the path difference between the two waves must be:

- (a) Half wavelength ($\frac{\lambda}{2}$) (b) Two wavelengths (2λ)
 (c) One wavelength (λ) (d) Zero wavelength

83. In an interference pattern of a double-slit experiment, why does a bright band occur where constructive interference takes place?

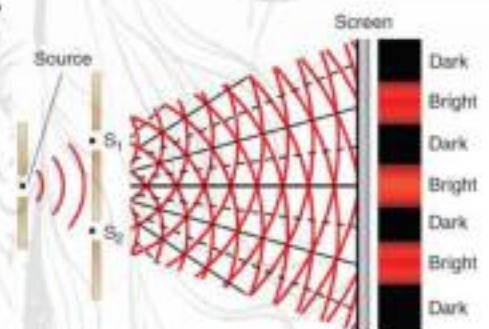
- (a) The two wavefronts have a phase difference of **one wavelength**.
- (b) The two wavefronts have a phase difference of a **quarter-wavelength**.
- (c) The two wavefronts have a phase difference of **one-half wavelength**.
- (d) The two wavefronts have a phase difference of **one-third wavelength**.



84. All light rays emerge from the two slits and are in phase. However, when two light rays meet on the screen, either constructive interference or destructive interference occurs.

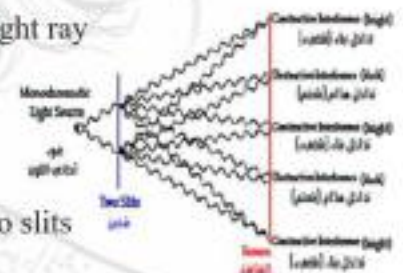
What causes the appearance of bright and dark bands on the screen?

- (a) The difference in the path length traveled by each light ray
- (b) The difference in the emission time of the two light rays
- (c) The difference in phase of the rays when leaving the two slits
- (d) The difference in wavelength of the rays exiting each slit



85. What causes **a difference in the interference pattern**, such that bright (light) bands and dark bands appear on the screen?

- (a) The difference in the length of the path(distance) traveled by each light ray
- (b) The difference in the emission time of each of the two light rays
- (c) The difference in wavelength of each ray when exiting each slit
- (d) The difference in phase of each of the two rays when leaving the two slits

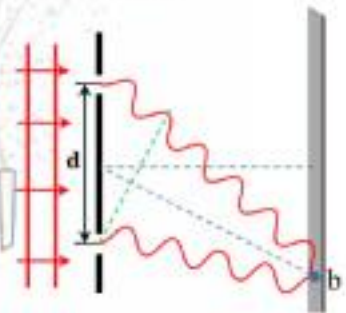


86. Two narrow slits separated by a distance d are illuminated with **monochromatic light**, producing a pattern of **bright and dark fringes** on a screen.

One of the fringes is observed at point **b**, as indicated in the adjacent figure.

What is the type of the fringe formed at point **b**?

- a. Random bands
- b. Dark bands
- c. Bright bands
- d. Dim band



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15 Solve problems on interference of light.

Example (1), Practice Problems (1,2,3), Check Your Progress (13)

116–120

The equation of the wavelength from the Double-Slit Experiment

$$m\lambda = \frac{x_m \cdot d}{L}$$



	The symbol	The physical quantity
1	m	The order of the fringe
2	x_m	The Distance from the central bright band to the bright band
3	λ	The wavelength of the light
4	d	The distance between the slits
5	L	The distance to the screen

Note: all the quantities are measured in meter except m which is dimensionless quantity

Convert all values into SI units before substitution.

$$1 \text{ mm} = 10^{-3} \text{ m}$$

$$1 \mu\text{m} = 10^{-6} \text{ m}$$

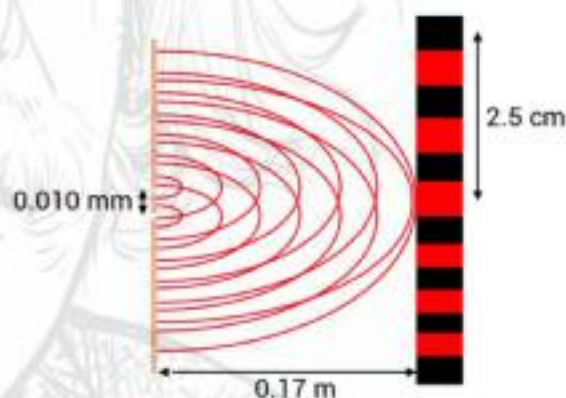
$$1 \text{ nm} = 10^{-9} \text{ m}$$

An **interference pattern** is formed on a screen that is located 0.17 m away from a barrier. The **two slits** of the barrier are separated by a distance of 0.010 mm. The **center of the third dark band** is found to be 2.5 cm away from the center of the **central bright band**.

What is the wavelength of the light used?

Choose the correct answer:

- ☐ $3.2 \times 10^{-7} \text{ m}$
☒ $4.2 \times 10^{-7} \text{ m}$
☐ $5.2 \times 10^{-7} \text{ m}$
☐ $6.2 \times 10^{-7} \text{ m}$



The wavelength of the light is calculated using the relation for dark fringes:

$$\lambda = \frac{x_m d}{\left(m + \frac{1}{2}\right) L}$$

$$\lambda = \frac{(2.5 \times 10^{-2} \text{ m})(0.010 \times 10^{-3} \text{ m})}{\left(3 + \frac{1}{2}\right)(0.17 \text{ m})} = 4.2 \times 10^{-7} \text{ m}$$

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87. Light falls on two slits separated by a distance of 2.4×10^{-5} m. A screen is placed 0.80 m away. The first-order bright band is 14 mm from the central bright band. What is the wavelength of the incident light?

- (a) 420 nm (b) 480 nm (c) 460 nm (d) 440 nm

88. Aisha Saif performed Young's double-slit experiment using laser light of wavelength 550 nm. The screen is 2.4 m from the slits, which are separated by $14 \mu\text{m}$.

What is the distance between the central bright band and the first-order bright band?

- (a) 9.4×10^{-2} m (b) 3.6×10^{-2} m (c) 6.6×10^{-2} m (d) 1.2×10^{-2} m

89. He-Ne laser light of wavelength 630 nm is aimed at two slits separated by $2.5 \mu\text{m}$. The screen is placed 1.2 m from the slits.

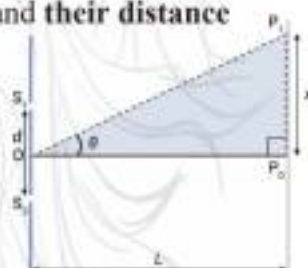
What is the distance between the central bright band and the first-order bright band?

- (a) 0.30 m (b) 0.10 m (c) 0.40 m (d) 0.20 m

A student performs Young's double-slit experiment to find the wavelength of light.

What is the relationship between the distance between the two slits (d) and their distance from the screen (L)?

- a. $d \gg L$
b. $d = L$
c. $d \ll L$
d. This has no effect on the experiment results



Young's Double-Slit Experiment

Young's double-slit experiment can be used to measure the wavelength of a given light.

In the figure below: The separation between the slits is $(1.90 \times 10^{-5} \text{ m})$ The screen is placed (0.60 m) away from the slits. The distance of the first-order bright band from the central bright band is $(2.11 \times 10^{-2} \text{ m})$



Answer the following questions:

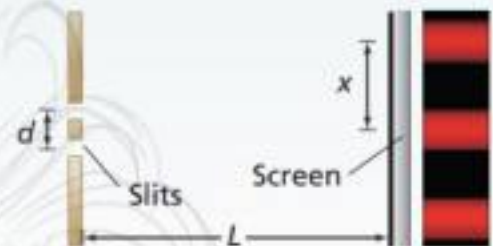
(a) Calculate the wavelength of red light.

(b) What happens to the intensity of the bright bands as we move away from the central band?

(c) What would happen if white light were used instead of red light?

A. Young's Double-Slit Experiment

Yellow-orange light from a sodium lamp of wavelength $(5.96 \times 10^{-7} \text{ m})$ is aimed at two slits that are separated by $(1.90 \times 10^{-5} \text{ m})$. If the screen is placed (60 cm) from the slits



answer the following:

(a) Calculate the distance from the central band to the first-order yellow band.

.....

.....

(b) When performing the previous experiment, what condition must be met for the value of the distance between the two slits (d) and their distance from the screen (L)?

.....

.....

Example (1) — Wavelength of Light

A double-slit investigation is performed to measure the wavelength of red light.

The slits are separated by 0.0190 mm .

A screen is placed 0.600 m away, and the first-order bright band is 21.1 mm from the central bright band.

Determine the wavelength of the red light.

.....

.....

1. Violet light falls on two slits separated by $1.90 \times 10^{-5} \text{ m}$. A first-order bright band appears 13.2 mm from the central bright band on a screen 0.600 m from the slits.

Required

Determine the wavelength of the violet light.

.....

.....

2. Yellow-orange light of wavelength 596 nm from a sodium lamp is aimed at two slits separated by $1.90 \times 10^{-5} \text{ m}$. The screen is 0.600 m from the slits.

Determine the distance from the central bright band to the first-order yellow band.

.....

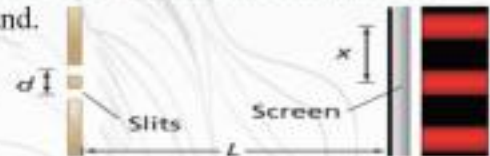
.....

Fatma Khalfan Al-Saeedi use a laser with wavelength 632.8 nm. A screen is placed 1.0m from the slits, and the first-order bright band is 65.5 mm from the central line.

Determine the slit separation.

Light of wavelength 542 nm falls on a double slit. The screen is 1.20 m from the slits, and the first-order bright band is 4.00 cm from the central bright band.

Determine how far apart the slits are.



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16 Define and explain thin-film interference.

Student Book

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Thin-Film Interference

Thin-film interference is an interference phenomenon produced when light reflects from the upper and lower surfaces of a very thin film.

The reflected light waves interfere with each other, producing:

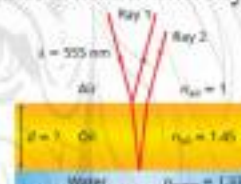
- constructive interference
- destructive interference

This creates colourful patterns such as:

- soap bubbles
- oil films on water

Direction of propagation	Index of second medium	Speed of light	Reflection behaviours
From lower (n) to higher (n)	Higher refractive index	Lower speed	Reflected with inversion
From higher (n) to lower (n)	Lower refractive index	Higher speed	Reflected without inversion

90. You observed colored rings on the surface of water and concluded that a thin layer of oil exists on the surface.



Which of the following correctly describes the phase change of the reflected waves at the two surfaces?

a

	Inversion	No inversion
First reflection	✓	
Second reflection	✓	

b

	Inversion	No inversion
First reflection		✓
Second reflection		✓

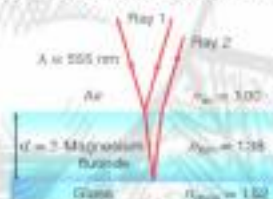
c

	Inversion	No inversion
First reflection		✓
Second reflection	✓	

d

	Inversion	No inversion
First reflection	✓	
Second reflection		✓

91. You observed colored rings on the surface of water and concluded that a thin layer of oil exists on the surface.



Which of the following correctly describes the phase change of the reflected waves at the two surfaces?

a

	Inversion	No inversion
First reflection	✓	
Second reflection	✓	

b

	Inversion	No inversion
First reflection		✓
Second reflection		✓

c

	Inversion	No inversion
First reflection		✓
Second reflection	✓	

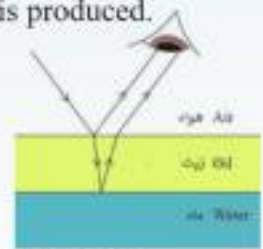
d

	Inversion	No inversion
First reflection	✓	
Second reflection		✓

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92. When light falls on a thin film of oil on the top of water, a spectrum of colors is produced. Which of the following wave properties is **not** involved in this phenomenon?

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



93. When an **oily film** floating on the surface of a **water puddle** in a parking lot is exposed to **bright sunlight**, it forms **colors in the spectrum** (appears colored), as shown in the adjacent figure.

What phenomenon explains this?

- (a) Interference of light (b) Dispersion of light
(c) Diffraction of light (d) Polarization of light



Constructive and Destructive Interference in Thin Films

When light falls on a thin film, part of the light is reflected from the top surface and another part is reflected from the bottom surface.

These reflected waves interfere with each other.

1) Constructive Interference

Constructive interference occurs when the reflected waves are **in phase**.

This produces:

1. Bright reflected light
2. Bright colorful bands

Thin-film thickness condition

If one reflected wave undergoes phase inversion:

$$d = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}, \dots$$

2) Destructive Interference

Destructive interference occurs when the reflected waves are **out of phase**.

This produces:

1. Weak reflected light
2. Dark regions
3. Reduced reflection

Thin-film thickness condition

$$d = \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}, \dots$$

94. Camera lenses are coated with a thin layer of a transparent material (thin film) that has a refractive index lower than the refractive index of the lens glass.

This results in the rays reflected from the outer and inner coating sides **destructively** interfering, which reduces the reflection of light from the lens by a very large percentage. It increases the amount of light that passes through the lens and improves photography efficiency.

What is the relationship between the thickness of the coating (thin film) (d) and the wavelength of light (λ)?

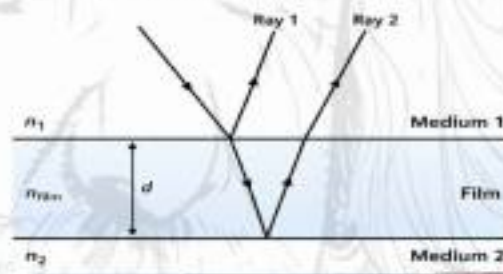
- (a) $d = \lambda/2$ (b) $d = 2\lambda$
(c) $d = \lambda/4$ (d) $d = 2\lambda$



95. A thin film of refractive index n_{film} is placed between two media of refractive indices n_1 and n_2 , as shown in the figure. Ray 1 is reflected from the upper surface of the film, while Ray 2 is reflected from the lower surface.

Under which condition will **both reflected rays undergo phase inversion**?

- (a) $n_1 < n_{film} < n_2$
(b) $n_1 > n_{film} > n_2$
(c) $n_1 < n_{film} > n_2$
(d) $n_1 > n_{film} < n_2$



Thin-Film Interference

When light of wavelength λ falls on a thin film of oil on water, colorful patterns appear because of constructive interference.

Which thickness of the oil film produces the strongest reflection?

- (a) $d = 3\lambda$ (b) $d = \frac{\lambda}{4}$
(c) $d = 4\lambda$ (d) $d = \frac{\lambda}{3}$



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17	Define diffraction and explain diffraction of light.	Student Book	121–122
18	Apply the single-slit diffraction equation: $2x_1 = \frac{2\lambda L}{w}$	Practice Problems(15,17,18), Check Your Progress (28)	123 129
19	Compare Young's Double Slit pattern with Single Slit Diffraction pattern.	Student Book	121–122
20	Define diffraction grating, reflection grating, and grating spectroscope.	Student Book	124–126
21	Explain constructive interference in diffraction gratings using: $m\lambda = d \sin \theta$	Student Book	126
22	Explain how a grating spectroscope works and its applications.	Student Book	126

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17 Define diffraction and explain diffraction of light.

Student Book

121-122

Definition of Diffraction

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

Diffraction of Light

When light passes through a very small slit whose width is comparable to the wavelength of light, the light spreads out instead of traveling in straight lines only.

This spreading produces a **diffraction pattern** consisting of:

- a wide bright central band
- alternating dark and dim bright bands on both sides

The pattern is formed because of:

constructive interference
destructive interference

between Huygens' wavelets coming from different parts of the slit.

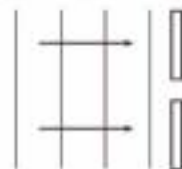
96. The process by which a beam of light is **spread out as a result of passing through a narrow opening** is called _____.

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

97. The diagram below shows a series of waves approaching an opening in a barrier.

Point P is located on the opposite side of the barrier.

The waves reach point P as a result of _____.



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

Which diagram best represents the **shape and direction** of a series of waves **after they have passed through a small opening in a barrier**?



(1)

(2)

(3)

(4)

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Diffraction Pattern Characteristics

A single-slit diffraction pattern consists of:

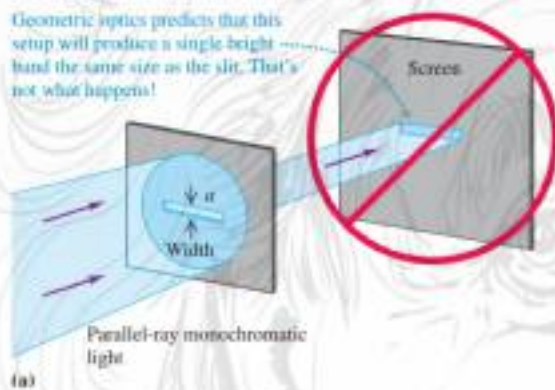
- One wide, bright central band
- Narrower, dimmer bands on both sides

Compared to the double-slit pattern, the single-slit pattern has:

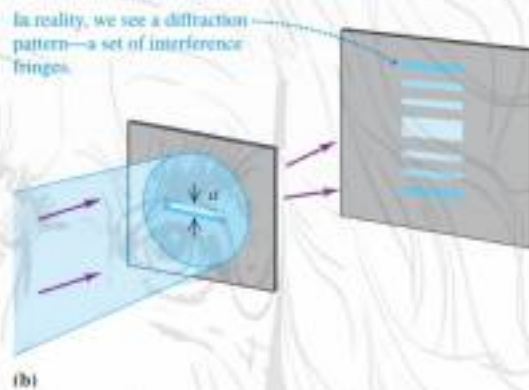
- A broader central maximum
- Less evenly spaced bright bands



Geometric optics predicts that this setup will produce a single bright band the same size as the slit. That's not what happens!

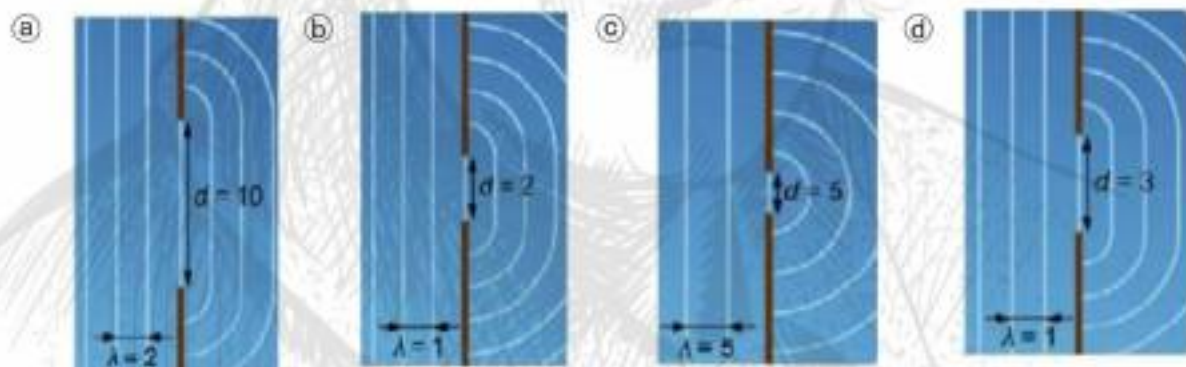


In reality, we see a diffraction pattern—a set of interference fringes.



According to Huygens' principle, a light source propagates as spherical waves. Each point on the wavefront acts as a point source. When light passes through a slit, a diffraction pattern is formed due to the constructive and destructive interference of Huygens' wavelets.

In which of the following cases is the diffraction pattern most clearly visible?



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18	Apply the single-slit diffraction equation: $2x_1 = \frac{2\lambda L}{w}$	Practice Problems(15,17,18), Check Your Progress (28)	123–129
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The width of the central bright band in single-slit diffraction is given by:

$$2x_1 = \frac{2\lambda L}{w}$$

$$2x_1 = \frac{2\lambda L}{w} \Rightarrow \lambda = \frac{x_1 w}{L}$$

Where:

Symbol	Physical Quantity
x_1	The distance between the first dark band and the central bright band
$2x_1$	The width of the central bright band
λ	The wavelength of the used light
w	The width of the single slit
L	The distance from the slit to the screen

Notes:

- This equation is valid when the distance to the screen is **much larger than the slit width** ($L \gg w$).

Distance Between First-Order Dark Bands

Monochromatic green light of wavelength **546 nm** falls on a **single slit** of width **0.080 mm**. The slit is located **68.0 cm** from a **screen**.

What is the separation of the first dark bands on each side of the central bright band?

$$2x_{\min} = \frac{2\lambda L}{w}$$

$$2x_{\min} = \frac{(2)(546 \times 10^{-9} \text{ m})(68.0 \times 10^{-2} \text{ m})}{0.080 \times 10^{-3} \text{ m}} = 9.3 \text{ mm}$$

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Monochromatic light passes through a single slit with a width of 0.010 cm and falls on a screen 100 cm away, as shown in Figure 19-18.

If the width of the central bright band is 1.20 cm, what is the wavelength of the light?

Given

- Slit width, $w = 0.010$ cm
- Distance to screen, $L = 100$ cm
- Width of central bright band, $2x_1 = 1.20$ cm

$$x_1 = 0.60 \text{ cm}$$

$$2x_1 = \frac{2\lambda L}{w} \Rightarrow \lambda = \frac{x_1 w}{L}$$

$$\lambda = \frac{(0.60 \times 10^{-2})(0.010 \times 10^{-2})}{100 \times 10^{-2}} = 600 \text{ nm}$$

What is the width of the slit?

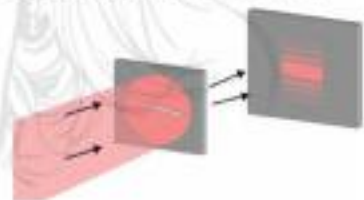
A laser beam of wavelength 650 nm passes through a narrow slit of unknown width.

A screen is placed 4.0 m from the slit.

The distance from the center of the central bright band to the first dark band is 1.0 mm.

Given

- Wavelength: $\lambda = 650 \text{ nm} = 650 \times 10^{-9} \text{ m}$
- Distance to screen: $L = 4.0 \text{ m}$
- Distance to first dark band: $x_1 = 1.0 \text{ mm} = 1.0 \times 10^{-3} \text{ m}$



For the first dark band:

$$x_1 = \frac{\lambda L}{w}$$

Rearranging for slit width w :

$$w = \frac{\lambda L}{x_1}$$

$$w = \frac{(650 \times 10^{-9})(4.0)}{1.0 \times 10^{-3}} = 2.6 \times 10^{-3} \text{ m}$$

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98. Monochromatic green light of wavelength **546 nm** falls on a single slit with a width of **0.095 mm**. The slit is located **75 cm** from a screen.

How wide will the central bright band be?

.....

.....

.....

99. Yellow light with a wavelength of **589 nm** passes through a slit of width **0.110 mm** and forms a pattern on a screen.
If the width of the central bright band is **2.60×10^{-2} m**, how far is the slit from the screen?

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.....

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100. Light from a **He-Ne laser** ($\lambda = 632.8 \text{ nm}$) falls on a slit of unknown width.
A pattern is formed on a screen **1.15 m** away, on which the central bright band is **15 mm** wide. **How wide is the slit?**

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.....

.....

101. Yellow light falls on a single slit of width **0.0295 mm**.
On a screen that is **60.0 cm** away, the central bright band is **24.0 mm** wide.

What is the wavelength of the light?

.....

.....

.....

102. White light falls on a single slit that is **0.050 mm** wide. A screen is placed **1.00 m** away.

A student first places a **blue-violet filter** ($\lambda = 441 \text{ nm}$) over the slit, then a **red filter** ($\lambda = 622 \text{ nm}$). The student measures the width of the central bright band.

- a. Which filter produces the wider band?
b. Calculate the width of the central bright band for each filter.

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103. Monochromatic light passes through a single slit with a width of 0.010 cm and falls on a screen 100 cm away, as shown in **Figure**. If the width of the central band is 1.20 cm,

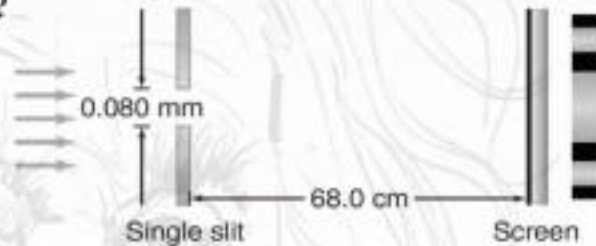
What is the wavelength of the light?



104. Monochromatic green light with a wavelength of 546 nm falls on a single slit of width 0.080 mm. The slit is located 68.0 cm from a screen, as shown in the figure.

What is the width of the central bright band?

- (a) 7.78 mm
(b) 9.28 mm
(c) 1.08 mm
(d) 1.28 mm



105. An unknown light falls on a single slit that is 0.080 mm wide. A screen is placed 75 cm away from the slit where a central bright band is observed. The width of the central bright band is 12 mm.

What is the color of this light?

- (a) green (b) yellow
(c) red (d) blue

Color	Wavelength (nm)
Blue	440-520
Green	520-560
Yellow	560-590
Red	630-740

106. A monochromatic light of wavelength: $\lambda = 5.0 \times 10^{-7} \text{ m}$ falls on a single slit of width:

$$w = 1.0 \times 10^{-4} \text{ m} \text{ The screen is placed: } L = 0.75 \text{ m}$$

What is the width of the central bright band?

- (a) 0.0075 m (b) 0.0038 m (c) 0.0150 m (d) 0.0019 m

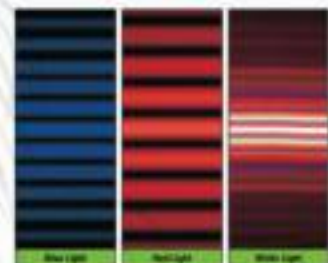
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19	Compare Young's Double Slit pattern with Single Slit Diffraction pattern.	Student Book	121-122
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Young's Double-Slit Pattern

- Produced by interference between light coming from two coherent slits.
- Forms equally spaced bright and dark fringes.
- Bright fringes have nearly equal spacing.
- Central bright fringe is not much wider than the others.

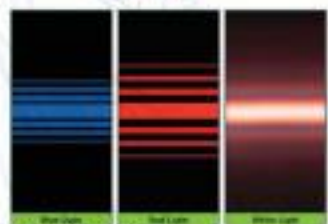
Double slit



Single-Slit Diffraction Pattern

- Produced when light passes through one narrow slit and spreads out.
- Forms one wide central bright band with dimmer side bands.
- Bands are not equally intense.
- Central maximum is much wider than side maxima.

single slit



You can compare this pattern with the double-slit interference pattern shown in the figure.

Importance of Single-Slit Diffraction

- Single-slit diffraction makes the wave nature of light observable.
- It is not very precise for measuring wavelength.
- More slits (diffraction grating) provide higher precision.

107. When coherent light passes through a single slit, the light is diffracted, producing a pattern of bright and dark bands on a distant screen.

Which statement correctly describes the diffraction pattern?

- A wide, bright central band with dimmer, narrower bands on either side.
- A narrow, bright central band with dimmer, wider bands on either side.
- A wide, dim central band with brighter, narrower bands on either side.
- A narrow, dim central band with brighter, wider bands on either side.

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20	Define diffraction grating, reflection grating, and grating spectroscope.	Student Book	124–126
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Diffraction Grating

A **diffraction grating** is an optical device made of a very large number of closely spaced slits or lines that diffract light and produce an interference pattern.

Key Features

- Produces very sharp and bright interference patterns.
- Used for accurate wavelength measurements.
- Has thousands of slits per centimeter.

Examples

- Transmission grating
- CDs and DVDs
- Spectroscopes

Reflection Grating

A **reflection grating** is a diffraction grating that reflects light instead of transmitting it.

How it works

- Made by engraving many fine parallel lines on a reflective surface.
- The reflected light undergoes diffraction and interference.
- Different wavelengths are reflected at different angles, producing spectrum colors.

Examples

- CDs
- DVDs
- Blu-ray discs

Grating Spectroscope

A **grating spectroscope** is an instrument that uses a diffraction grating to measure or analyze wavelengths of light.

Main Parts

- Slit
- Collimator
- Diffraction grating
- Telescope

Function

- Separates light into its component wavelengths.
- Used to identify elements and measure wavelengths accurately.

108. CDs can act as diffraction gratings because they produce colorful spectra when white light falls on their surfaces.

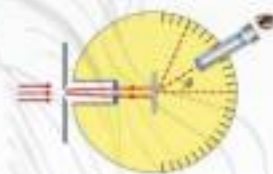
What type of diffraction grating do CDs represent?

- (a) Reflection grating (b) Grating spectroscope
(c) Transmission grating (d) Holographic diffraction grating



109. What is the instrument shown in the figure, which is used to measure light wavelengths of light using a diffraction grating?

- (a) Reflection grating (b) Grating spectroscope
(c) Transmission grating (d) Holographic diffraction grating



110. Which of the following best describes a **diffraction grating**?

- (a) A device made of many closely spaced slits that diffract light and produce an interference pattern.
(b) A single narrow slit used to refract light.
(c) A lens used to magnify diffraction patterns.
(d) A mirror used to absorb light.

111. What is a reflection grating?

- (a) A grating that transmits light through narrow slits.
(b) A diffraction grating that reflects light from a reflective surface.
(c) A lens that reflects all wavelengths equally.
(d) A prism used to separate colors.

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21 Explain constructive interference in diffraction gratings using:

$$m\lambda = d \sin \theta$$

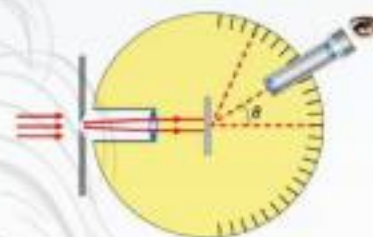
Student Book

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Measuring Wavelength Using a Diffraction Grating

A grating spectroscope is used to measure light wavelengths.

- Light passes through a slit and collimator
- Then passes through a diffraction grating
- The diffraction pattern is observed through a telescope



15. Diffraction Grating Equation

$$m\lambda = d \sin \theta_m$$

where:

- $m = 0, 1, 2, 3, 4 \rightarrow$ order of the bright fringe

Note

There are some important equations used in diffraction grating numerical problems:

- To find the distance between the slits of the grating: $d = \frac{1}{N}$
- To find the number of slits per unit length: $N = \frac{1}{L}$
- To find the angle of the bright fringe: $\theta = \tan^{-1} \left(\frac{x}{L} \right)$

Blue light of unknown wavelength shines on a CD. A screen is placed 0.85 m away from the CD, and the distance between two consecutive bright dots is 55 cm.

Assume the distance between grooves on the CD surface is 750 nm.

What is the wavelength of the light?

- (a) 410 nm (b) 480 nm (c) 550 nm (d) 440 nm

A diffraction grating has 4500 grooves per centimeter.

What is the distance between any two consecutive slits in nanometers?

- (a) 4500 nm (b) 5600 nm (c) 3200 nm (d) 2200 nm

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Diffraction Grating Problem

A diffraction grating has 4500 grooves per centimetre.

What is the distance between any two consecutive slits?

Given

- Number of grooves per centimetre : $N = 4500$ grooves/cm

The distance between consecutive slits (grating spacing) is:

$$d = \frac{1}{N}$$

$$d = \frac{1}{4500} \text{ cm}$$

$$d = \frac{1}{4500} \times 10^{-2} \text{ m} = 2.22 \times 10^{-6} \text{ m}$$

Aisha Saif uses a green laser on a CD.

The distance between the slits is 2000 nm.

The first bright line is observed at an angle of 14.5° .

What is the wavelength of this green light?

Given

- Slit spacing: $d = 2000 \text{ nm} = 2.0 \times 10^{-6} \text{ m}$
- Angle of first-order bright line: $\theta = 14.5^\circ$
- Order number: $m = 1$

$$m\lambda = d \sin \theta$$

For the first-order maximum ($m = 1$):

$$\lambda = d \sin \theta$$

$$\lambda = (2.0 \times 10^{-6}) \sin 14.5^\circ = 5.0 \times 10^{-7} \text{ m}$$



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A monochromatic helium–neon laser of wavelength 630 nm falls on a diffraction grating that has 4000 grooves per centimeter.

What is the angle at which the first-order bright band appears?

Step 1: Find slit spacing

$$d = \frac{1}{4000} \text{ cm} = 2.5 \times 10^{-6} \text{ m}$$

Step 2: Use the diffraction grating equation

$$m\lambda = d \sin \theta$$

For first order ($m = 1$):

$$\begin{aligned} \sin \theta &= \frac{\lambda}{d} \\ \sin \theta &= \frac{6.30 \times 10^{-7}}{2.5 \times 10^{-6}} = 0.252 \\ \theta &= \sin^{-1}(0.252) = 15^\circ \end{aligned}$$

EXAMPLE: Using a DVD as a Diffraction Grating

A student noticed the beautiful spectrum reflected off a DVD.

She directed a beam from her teacher's green laser pointer at the DVD and observed three bright spots reflected on the wall.

The label on the laser pointer indicates that the wavelength is 532 nm.

The spacing between the spots on the wall is 1.29 m, and the wall is 1.25 m away.

What is the spacing between the rows on the DVD?

Known:

- $x = 1.29 \text{ m}$
- $L = 1.25 \text{ m}$
- $\lambda = 532 \text{ nm} = 532 \times 10^{-9} \text{ m}$

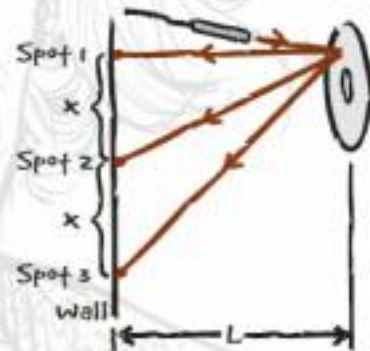
Unknown:

- d = spacing between the rows on the DVD

2. Solve for the Unknown

Step 1: Find the diffraction angle

$$\begin{aligned} \tan \theta &= \frac{x}{L} \\ \theta &= \tan^{-1} \left(\frac{1.29}{1.25} \right) \\ \theta &= 45.9^\circ \end{aligned}$$



Step 2: Use the diffraction grating equation

For first-order maximum:

$$\lambda = d \sin \theta$$

Rearranging for d :

$$d = \frac{\lambda}{\sin \theta}$$

Step 3: Substitute the values

$$d = \frac{532 \times 10^{-9}}{\sin 45.9^\circ} = 7.41 \times 10^{-7} \text{ m}$$

A monochromatic light source shines on a diffraction grating of 10 000 lines/cm, producing a first-order antinode at an angle of 40.5° from the central line.

What is the wavelength of the light?

Given

- $\theta = 40.5^\circ$
- $n = 1$
- Number of lines = 10 000 lines/cm

Slit Spacing

$$d = \frac{1}{10000} = 1.0 \times 10^{-6} \text{ m}$$

Diffraction Grating Equation

$$\lambda = \frac{d \sin \theta}{n}$$

$$\lambda = \frac{(1.0 \times 10^{-6})(\sin 40.5^\circ)}{1} = 649 \text{ nm}$$

Angle Difference Between Two Bright Bands

Monochromatic light of wavelength 670 nm falls normally on a diffraction grating.

The slit separation is 4500 nm.

What is the angle difference between the fourth-order and sixth-order bright bands?

Given

- $\lambda = 670 \text{ nm} = 6.70 \times 10^{-7} \text{ m}$
- $d = 4500 \text{ nm} = 4.50 \times 10^{-6} \text{ m}$
- Orders: $m_4 = 4, m_6 = 6$

Step 1: Find angle for the 4th order

$$\theta_4 = \sin^{-1} \left(\frac{m_4 \lambda}{d} \right)$$

$$\theta_4 = \sin^{-1} \left(\frac{4(6.70 \times 10^{-7})}{4.50 \times 10^{-6}} \right) = 36.6^\circ$$

Step 2: Find angle for the 6th order

$$\theta_6 = \sin^{-1} \frac{6(6.70 \times 10^{-7})}{4.50 \times 10^{-6}} = 62.6^\circ$$

Step 3: Find the angle difference

$$\Delta\theta = \theta_6 - \theta_4 = 62.6^\circ - 36.6^\circ = 26^\circ$$

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Using a DVD as a Diffraction Grating

A student pointed a beam from a teacher's **green laser pointer** at a **DVD** and noticed a beautiful **spectrum** reflected from the DVD.

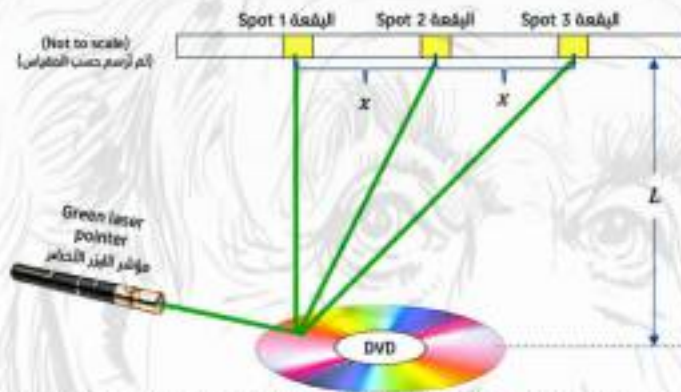
She observed **three bright spots** reflected on the ceiling.

The label on the laser pointer indicates that the **wavelength** is: $\lambda = 532\text{nm}$

She also found that the **spacing between the bright spots** on the wall is: $x = 1.29\text{ m}$

The wall is located at a distance of: $L = 1.25\text{ m}$

from the DVD, as shown in the figure below.



(Diagram: DVD acting as a diffraction grating producing three bright spots on a wall)

Required

Find the spacing (d) between the rows on the DVD.

.....

.....

.....

4	$d = 7.41 \times 10^{-7} \text{ m} = 741 \text{ nm}$	1
3	$d = \frac{532 \times 10^{-9} \text{ m}}{\sin(45.9^\circ)}$	1
2	$\tan \theta = \frac{L}{x} \Rightarrow \theta = \tan^{-1} \left(\frac{1.25}{1.29} \right) = 45.9^\circ$	1
1	$\lambda = d \sin \theta \Rightarrow d = \frac{\lambda}{\sin \theta}$	1
Step	Marking Guidelines	Mark

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If blue light of wavelength **434 nm** shines on a diffraction grating and the spacing of the resulting lines on a screen that is **1.05 m** away is **0.55 m**, what is the spacing between the slits in the grating?

A diffraction grating with slits separated by $8.60 \times 10^{-7} \text{ m}$ is illuminated by violet light with a wavelength of **421 nm**.

If the screen is **80.0 cm** from the grating, what is the separation of the lines in the diffraction pattern?

Blue light shines on the **DVD** in Example Problem 3.

If the dots produced on a wall that is **0.65 m** away are separated by **58.0 cm**, what is the wavelength of the light?

Light of wavelength **632 nm** passes through a diffraction grating and creates a pattern on a screen that is **0.55 m** away.

If the first bright band is **5.6 cm** from the central bright band, how many slits per centimeter does the grating have?

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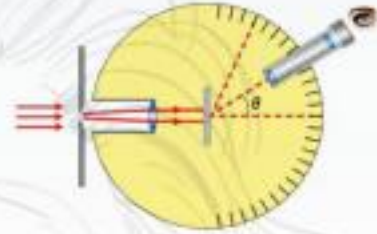
22	Explain how a grating spectroscope works and its applications.	Student Book	126
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Grating Spectroscope Works

A **grating spectroscope** is an instrument used to measure and analyze the wavelengths of light using a **diffraction grating**.

Working Principle

1. Light from a source enters through a **slit**.
2. A **collimator** makes the light rays parallel.
3. The parallel light reaches the **diffraction grating**, which contains many closely spaced lines.
4. The grating diffracts the light and produces an interference pattern of bright lines.
5. A **telescope** is used to observe the bright diffraction lines at different angles.



Applications of a Grating Spectroscope

1. Measuring Wavelengths

Used to determine the wavelength of monochromatic light accurately.

2. Spectral Analysis

Separates white light into its component colors to study spectra.

3. Identifying Elements

Each element produces unique spectral lines, so spectroscopes are used to identify substances.

4. Gemstone Analysis

Used by gemologists to analyze gemstones by studying their light spectra.

5. Scientific Research

Used in physics, chemistry, and astronomy to study light emitted by stars and materials.

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23	Define a frame of reference.	Figure (13)	148
24	Calculate relative velocity in one dimension using vector addition/subtraction.	Figure (13), Practice Problems (25,27)	148–152
25	Calculate relative velocity in two dimensions graphically and mathematically.	Figure (13), Example (4), Practice Problems (28,29), Check Your Progress (33,35)	150–152

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23 Define a frame of reference.

Figure (13)

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A **frame of reference** is a coordinate system or point of view from which motion is observed and measured.

Notes

The measured motion of an object depends on the observer's reference frame.



Relative motion depends on:

1. Who is observing?
2. What are we trying to find?

1) For each situation below, what is $v_{\text{you relative to street}}$?

(Use a solid line for velocities relative to the street and a dashed line for velocities relative to the street.)



A bus is moving east at 15 m/s relative to the street. You walk toward the front of the bus at 4 m/s relative to the bus.

What is $v_{\text{you relative to street}}$?

- (A) 11 m/s east
(B) 19 m/s east
(C) 15 m/s east
(D) 4 m/s east



A train is moving north at 20 m/s relative to the ground. You walk toward the rear of the train at 6 m/s relative to the train.

What is $v_{\text{you relative to ground}}$?

- (A) 14 m/s north
(B) 26 m/s north
(C) 20 m/s north
(D) 6 m/s north

112. A car moving on the road appears at rest to the driver inside the car, but appears moving to a stationary observer on the pavement.

This occurs because:

- (a) the weather is not good (b) the observer has farsightedness
(c) motion is relative (d) the observer has near-sightedness

A(n) _____ is a coordinate system from which motion is observed.

- (a) origin (b) frame
(c) axis (d) reference frame

- 24 Calculate relative velocity in one dimension using vector addition/subtraction.

Figure (13), Practice Problems (25,27)

148–152

Sometimes we want the motion relative to the **ground**, and sometimes relative to **another moving object**.

That is why we sometimes add and sometimes subtract.

1) Same Direction Relative to the Ground → ADD

Idea

Two motions help each other in the same direction.

So the total motion becomes larger.

Example

- A bus moves east at 8 m/s
- A student walks inside the bus toward the front at 1 m/s

We want:

the student's velocity relative to the ground.

The student is already inside a moving bus.

So:

- Bus motion helps the student move forward.
- Student walking also helps move forward.

Both motions are in the same direction.

Therefore we add:

$$v_{\text{student,ground}} = v_{\text{bus}} + v_{\text{student,bus}}$$

$$8 + 1 = 9 \text{ m/s}$$

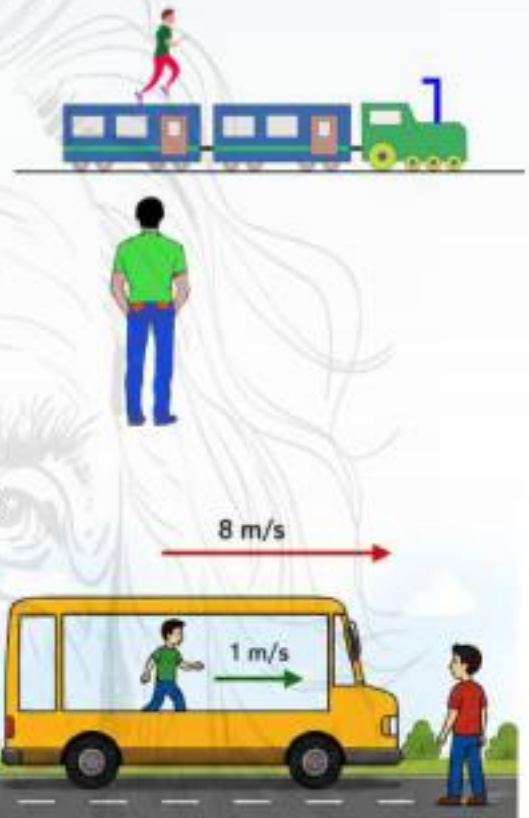
Student velocity relative to ground = 9 m/s

Physical Meaning

Imagine standing on the road.

You see:

- the bus moving,
- and the student also walking forward inside it.
- So the student moves even faster relative to you.



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2) Opposite Direction Relative to the Ground → SUBTRACT

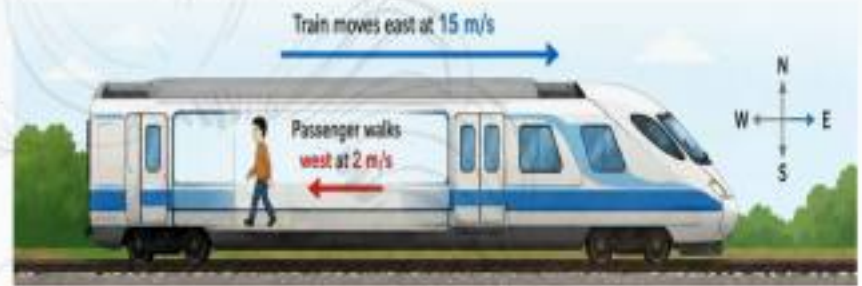
Idea

One motion opposes the other.

So, the final motion becomes smaller.

Example

- A train moves east at 15 m/s
- A passenger walks west inside the train at 2 m/s



We want:

passenger velocity relative to the ground.

Now:

- Train pushes passenger east.
- Passenger walks west.

The two motions oppose each other.

So we subtract:

$$\begin{aligned} v_{\text{passenger, ground}} &= 15 - 2 \\ &= 13 \text{ m/s} \end{aligned}$$

Passenger velocity relative to ground = 13 m/seast.

Physical Meaning

The passenger still moves east because the train is faster.

But walking backward reduces the total speed.

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3) Same Direction Relative to Another Moving Object → SUBTRACT

Idea

Now we are NOT finding motion relative to the ground.

We are comparing one moving object to another moving object.

Since both already move together, we care only about the difference.

Example

- Car A = 20 m/s
- Car B = 30 m/s



Both move east.

We want:

velocity of B relative to A.

Observer is inside Car A.

From inside A:

- A appears stationary to its driver.
- Driver compares only how much faster B moves.

So:

$$v_{B/A} = 30 - 20 = 10 \text{ m/s}$$

B appears to move at 10 m/s relative to A.

Physical Meaning

Even though B moves at 30 m/s relative to the road, A is already moving at 20 m/s.

So A only notices the extra 10 m/s.

Important Observation

If both cars move at the same speed:

- $40 - 40 = 0$
1. They appear stationary relative to each other.
 2. That is why cars moving side by side seem not to move.

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4) Opposite Direction Relative to Another Moving Object → ADD

Idea

Now the objects move toward each other.

The distance between them changes very quickly.

So the relative speed increases.

Example

- Car A moves east at 20 m/s
- Car B moves west at 30 m/s



We want:

velocity of B relative to A.

Now both cars approach each other.

So we add:

$$v_{\text{relative}} = 20 + 30 = 50 \text{ m/s}$$

Relative speed = 50 m/s

Physical Meaning

From inside Car A:

- B does not appear to move slowly.
- B rushes toward A very fast.

Because both cars move toward each other simultaneously.

You are riding in a bus moving slowly through heavy traffic at 2.0 m/s .

You hurry to the front of the bus at 4.0 m/s relative to the bus.

Question

What is your speed relative to the street?

Solution

Both motions are in the same direction, so we add:

$$\begin{aligned} v_{\text{person,street}} &= v_{\text{bus}} + v_{\text{person,bus}} \\ v_{\text{person,street}} &= 2.0 + 4.0 = 6.0 \text{ m/s} \end{aligned}$$

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Aisha Saif is pulling a toy wagon through a neighborhood at a speed of **0.75 m/s**. A caterpillar in the wagon is crawling toward the rear of the wagon at **2.0 cm/s**.

Question

What is the caterpillar's velocity relative to the ground?

Convert Units

$$2.0 \text{ cm/s} = 0.020 \text{ m/s}$$

Solution

The caterpillar moves opposite the wagon's motion, so we subtract:

$$v_{\text{caterpillar/ground}} = 0.75 - 0.020 = 0.73 \text{ m/s}$$

A boat moves directly upriver at **2.5 m/s relative to the water**.

Viewers on the shore see that the boat is moving at only **0.5 m/s relative to the shore**.

Questions

- What is the speed of the river?
- Is the river moving with or against the boat?

Solution

The river current opposes the boat's motion, so:

$$v_{\text{boat/shore}} = v_{\text{boat/water}} - v_{\text{river}}$$

$$0.5 = 2.5 - v_{\text{river}}$$

$$v_{\text{river}} = 2.0 \text{ m/s}$$

113. One car is following another car in **the same direction at the same speed v** .

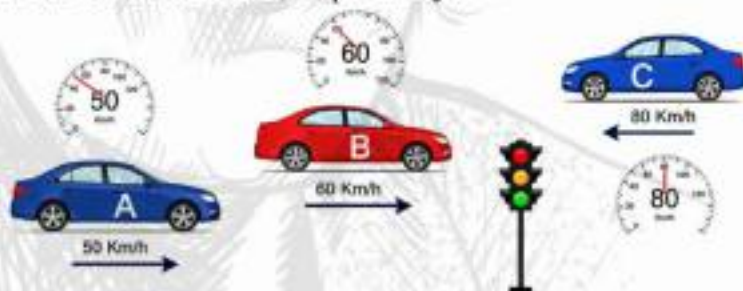
What is the speed of one car relative to the other?

- (a) $0v$ (b) $0.5v$ (c) $2v$ (d) v

114.

What is the speed of car B relative to car A and car C, respectively?

- Car A: 50 km/h east
- Car B: 60 km/h east
- Car C: 80 km/h west



- (a) $(v_{B/A} = 60 \text{ km/h}), (v_{B/C} = 60 \text{ km/h})$ (b) $(v_{B/A} = 70 \text{ km/h}), (v_{B/C} = 80 \text{ km/h})$
 (c) $(v_{B/A} = 130 \text{ km/h}), (v_{B/C} = 20 \text{ km/h})$ (d) $(v_{B/A} = 10 \text{ km/h}), (v_{B/C} = 140 \text{ km/h})$

115. An airplane flies due east at 400 km/h relative to the ground.

A wind blows at 90 km/h toward the west.

What is the plane's velocity relative to the air?

- (a) 310 km/h West (b) 490 km/h East
 (c) 490 km/h West (d) 310 km/h East



116. A river flows from west to east with velocity 1.0 m/s .

A boat moves north with velocity 2.40 m/s .

What is the boat's resultant velocity relative to the river?

- (a) 2.6 m/s (b) 6.8 m/s
(c) 2.8 m/s (d) 1.5 m/s

117. You walk on a moving walkway at 2.0 m/s in the same direction as the walkway.

The walkway moves relative to the ground at 1.5 m/s .

What is your speed relative to the ground?

- (a) 0.5 m/s (b) 3.5 m/s
(c) 2.0 m/s (d) 1.8 m/s

118. A bus moves east at 12 m/s relative to the street.

A student walks toward the front of the bus at 3 m/s relative to the bus.

What is the student's velocity relative to the street?

- (a) 9 m/s east (b) 3 m/s east
(c) 15 m/s east (d) 12 m/s west

119. A train moves east at 20 m/s relative to the ground.

A passenger walks west inside the train at 5 m/s relative to the train.

What is the passenger's velocity relative to the ground?

- (a) 25 m/s east (b) 15 m/s west
(c) 15 m/s east (d) 5 m/s east

120. Car A moves east at 18 m/s .

Car B moves east at 25 m/s .

What is the velocity of Car B relative to Car A?

- (a) 25 m/s east (b) 7 m/s east
(c) 7 m/s west (d) 43 m/s east

121.

A motorcycle moves north at 14 m/s .

A truck moves south at 16 m/s .

What is the velocity of the truck relative to the motorcycle?

- (a) 16 m/s (b) 14 m/s
(c) 30 m/s (d) 2 m/s

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25	Calculate relative velocity in two dimensions graphically and mathematically.	Figure (13), Example (4), Practice Problems (28,29), Check Your Progress (33,35)	150–152
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Relative Motion in Two Dimensions (2D)

Definition

Relative motion in two dimensions occurs when an object moves in two perpendicular directions at the same time.

In 2D motion:

- velocities are treated as vectors
- both magnitude and direction are important

Key Idea

To solve relative motion problems in two dimensions:

Draw a vector diagram

Combine the velocity vectors

Find:

- the resultant speed
- the resultant direction

Reference frame moving relative to ground



1) Find the Resultant Speed

When two velocities are perpendicular (north/south with east/west), use the Pythagorean theorem:

$$v_{\text{resultant}} = \sqrt{v_x^2 + v_y^2}$$

Where:

- v_x = horizontal velocity
- v_y = vertical velocity

2) Find the Resultant Direction

Use tangent:

$$\tan \theta = \frac{v_y}{v_x}$$

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Example — Boat Crossing a River**Question**

A boat is crossing a river.

- The boat's engine moves the boat north at 3.0 m/s relative to the water.
- The river current pushes the boat east at 2.0 m/s relative to the ground.

**Required**

Find:

1. The resultant speed of the boat relative to the ground.
2. The direction of the boat's motion.

Given

Boat velocity north:

$$v_{\text{boat/water}} = 3.0 \text{ m/s north}$$

River current east:

$$v_{\text{water/ground}} = 2.0 \text{ m/s east}$$

Solution**Step 1 — Find the Resultant Speed**

Use the Pythagorean theorem:

$$v = \sqrt{v_x^2 + v_y^2}$$

Substitute the values:

$$v = \sqrt{3^2 + 2^2}$$

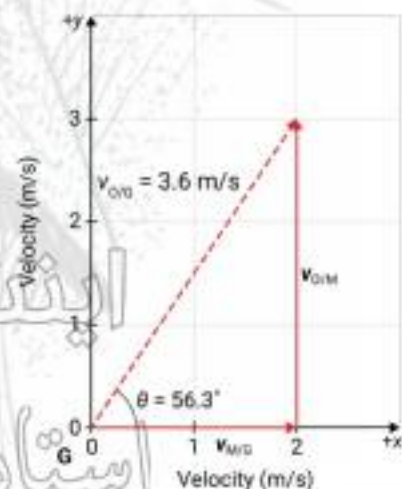
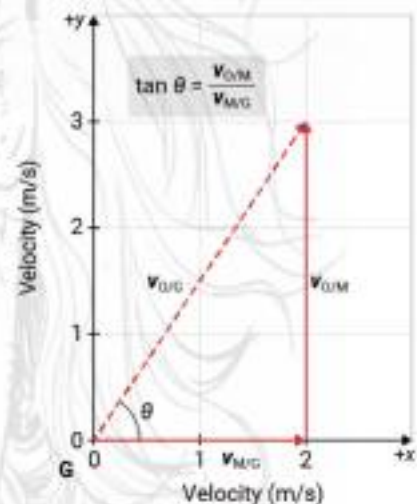
Calculation

$$v = \sqrt{9 + 4} = \sqrt{13} = 3.6 \text{ m/s}$$

Step 2 — Find the Direction

Use trigonometry:

$$\theta = \tan^{-1}\left(\frac{3}{2}\right) = 56^\circ$$



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You are standing on the shore observing a ship moving west at: $v_{ship/G} = 3.0 \text{ m/s}$ west

A child pushes a toy car north at: $v_{car/ship} = 1.0 \text{ m/s}$ north relative to the ship.

Required

Find:

1. The speed of the toy car relative to the ground.
2. The direction of the toy car relative to the positive x-axis.

Given

Horizontal velocity (west): $v_x = -3.0 \text{ m/s}$

Vertical velocity (north): $v_y = 1.0 \text{ m/s}$

Step 1 — Find the Resultant Speed

Use the Pythagorean theorem:

$$v = \sqrt{v_x^2 + v_y^2}$$

Substitute the values:

$$v = \sqrt{(-3)^2 + (1)^2} = \sqrt{10} = 3.2 \text{ m/s}$$

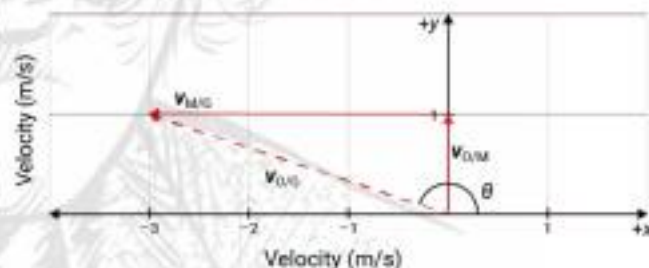
Step 2 — Find the Direction

Use trigonometry:

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right)$$

Substitute the values:

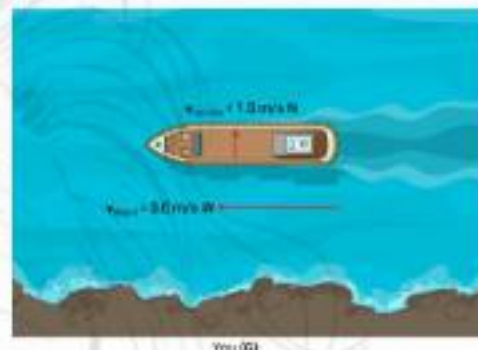
$$\theta = \tan^{-1}\left(\frac{1}{-3}\right)$$



Calculation

The vector lies in the second quadrant, so we add 180° :

$$\theta = 180^\circ + (-18.4^\circ) = 161.6^\circ = 162^\circ$$



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Fatima Khalfan Al-Saeedi is riding a train moving east at: 15 m/s relative to the ground.

Calculate Fatima's velocity relative to an observer on the ground in each of the following cases:

1. Standing Still in the Train

Fatima is standing still relative to the train.

2. Walking Toward the Front of the Train

Fatima walks toward the front of the train (east) at: 3 m/s relative to the train.

3. Walking Toward the Rear of the Train

Fatima walks toward the rear of the train (west) at: 3 m/s relative to the train.

4. Walking North

Fatima walks north at: 3 m/s relative to the train.

5. Walking Northeast

Fatima walks northeast at: 3 m/s relative to the train.

$$v = \sqrt{(15 + 2.12)^2 + (2.12)^2} = 17.25 \text{ m/s}$$

Resultant speed:

$$3 \sin 45^\circ = 2.12 \text{ m/s}$$

North component:

$$3 \cos 45^\circ = 2.12 \text{ m/s}$$

East component:

5. Walking Northeast

$$\theta = \tan^{-1} \left(\frac{15}{3} \right) = 11.3^\circ \text{ North of east}$$

Direction:

$$v = \sqrt{15^2 + 3^2} = 15.3 \text{ m/s}$$

4. Walking North

3. Walking Toward the Rear of the Train: $v_{fg} = 15 - 3 = 12 \text{ m/s east}$

2. Walking Toward the Front of the Train: $v_{fg} = 15 + 3 = 18 \text{ m/s east}$

1. Standing Still in the Train: $v_{fg} = 15 \text{ m/s east}$

Answers

122. Fatima Khalfan Al-Saeedi rides a boat moving east at:4 m/srelative to the water.
She throws a ball north at:0.75 m/srelative to the boat.

Required

Find **the velocity** of the ball relative to the water.

123. A swimmer moves north at:2 m/s across a river flowing east.

The swimmer's velocity relative to the riverbank is:3 m/s

What is **the velocity** of the river current?

- A) 2.2 m/s East
- B) 12.3 m/s South-West
- C) 6.4 m/s North-West
- D) 10.2 m/s South

A duck crosses a river moving north at:0.8 m/s while the river current moves east at:1.5 m/s

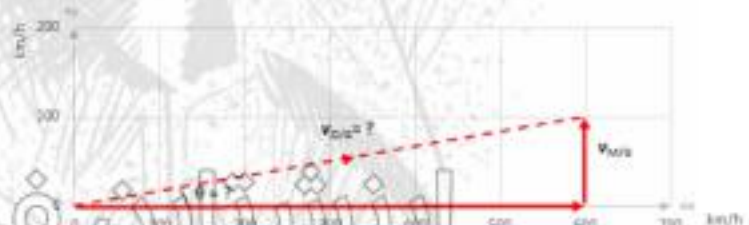
What is **the magnitude of the duck's velocity** relative to the beach?

- A) 2 m/s
- B) 8.5 m/s
- C) 29 m/s
- D) 1.7 m/s

124. A pilot needs to fly east at: 600 km/hto reach her destination.

However, a wind is blowing north at:100 km/h If the pilot points the airplane directly east,
what will be **the magnitude and direction of the airplane's** velocity relative to the ground?

- A) 369.664 km/h at 80.5° north of east
- B) 608 km/h at 80.5° north of east
- C) 608 km/h at 9.5° north of east
- D) 369.664 km/h at 9.5° north of east



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A boat is traveling **east** at a speed of **3.8 m/s**.

A person walks across the boat with a velocity of **1.3 m/s south**.

a) What is the person's **speed relative to the water**?

b) In what **direction relative to the ground** does the person walk?

An airplane flies due **north** at **150 km/h** relative to the air.

A wind blows at **75 km/h east** relative to the ground.

What is the airplane's **speed relative to the ground**?

A motorboat heads due **west** at **13 m/s** relative to a river that flows due **north** at **5.0 m/s**.

What is the velocity of the motorboat relative to the shore?

(Include both **magnitude and direction**.)

An airplane flies due **south** at **175 km/h** relative to the air.

A wind blows at **85 km/h** to the **east** relative to the ground.

What are the airplane's:

- **speed relative to the ground**
- **direction relative to the ground?**

THE END

Einstein AE

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