Fisika Dasar I (FI-321)

Topik hari ini (minggu 14)

Optik

- Pemantulan dan Pembiasan Cahaya
- Cermin dan Lensa

Pemantulan dan Pembiasan Cahaya

Dualisme Cahaya

- Bersifat sebagai gelombang (classical E & M – penjalaran cahaya)
- Bersifat sebagai partikel (efek fotolistrik)
- Einstein memformulasikan teori tentang cahaya:

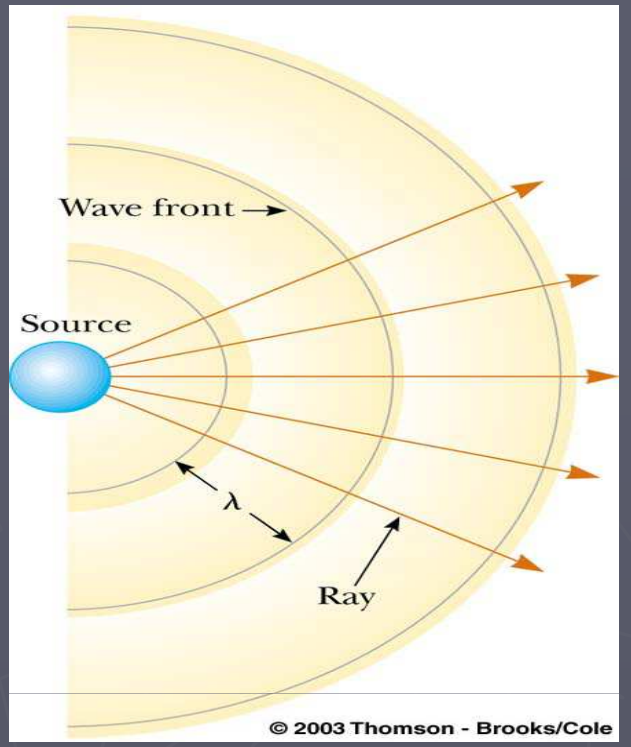
$$E = hf$$

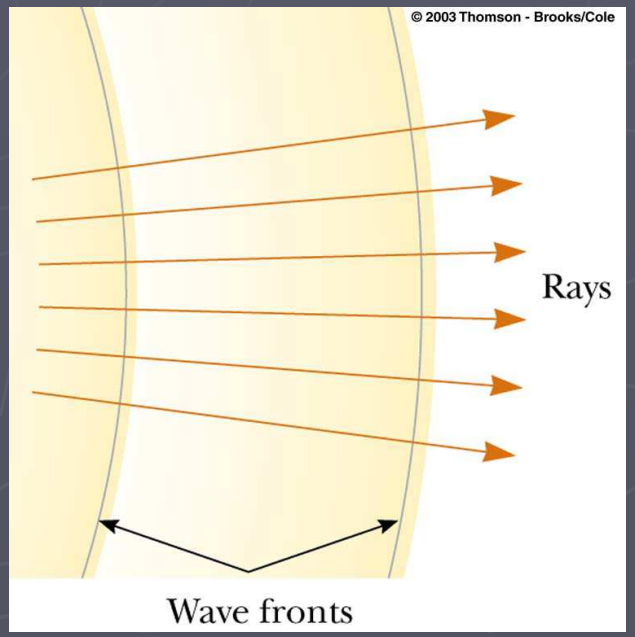
$$h = 6.63 \times 10^{-34}\ J \cdot s$$

Konstanta Plank

Optik

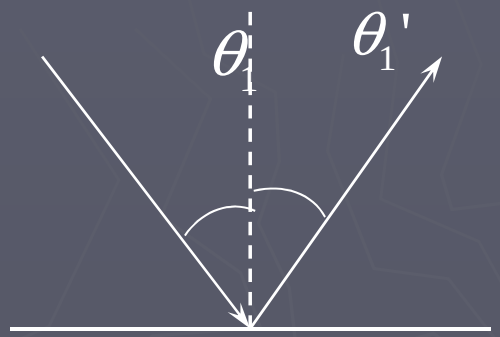
- Kecepatan cahaya
  - 3.00×10^8 m/s dalam vakum
    - Menjalar lebih lambat dalam cairan atau padatan (cocok dengan prediksi dari teori partikel)
- Untuk menjelaskan penjalaran: Metoda Huygens
  - Semua titik pada muka gelombang diambil sebagai titik sumber untuk penjalaran gelombang sferis
- Asumsi gelombang bergerak melalui medium dalam garis lurus searah sinar





Pemantulan Cahaya

- Ketika cahaya melewati batas antar medium, bagian dari sinar yang datang dipantulkan



$$\theta_1 = \theta_1'$$

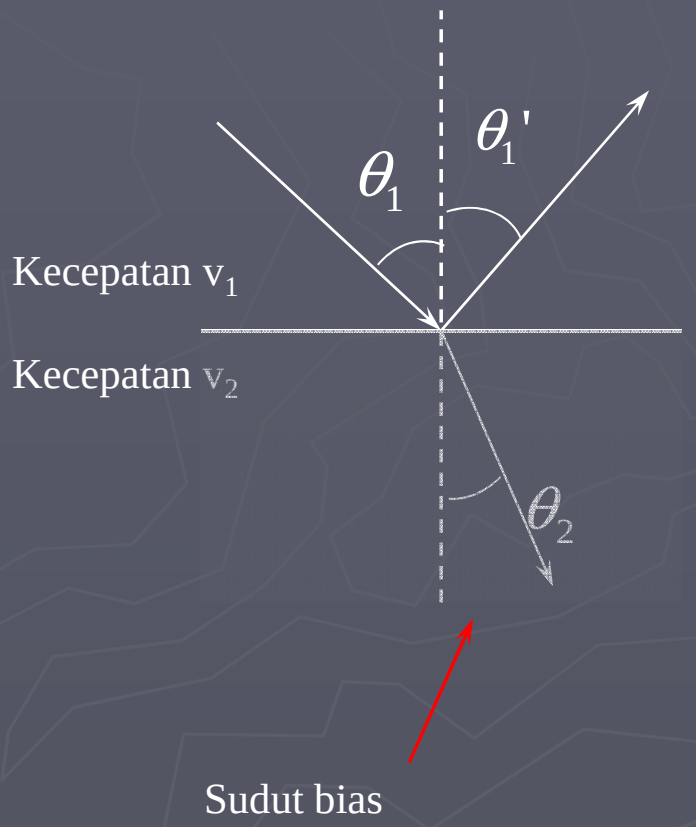
- Permukaan yang rata:

Sudut datang =
Sudut pantul

- Permukaan tidak rata:

Pembiasan Cahaya

- Hal yang sama, ketika cahaya melewati batas dua medium, bagian sinar yang datang memasuki medium yang kedua dan dikatakan dibiaskan

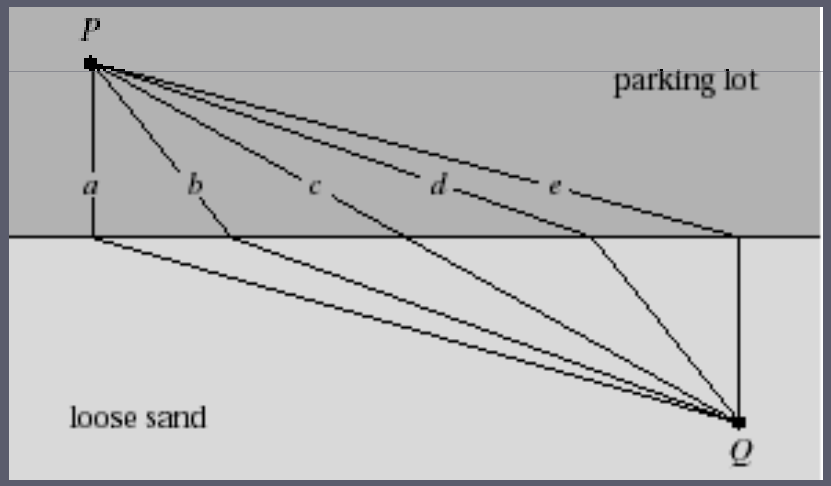


$$\frac{\sin \vartheta_2}{\sin \vartheta_1} = \frac{v_2}{v_1} = const$$

Jika kecepatan turun: $\theta_2 < \theta_1$
Jika kecepatan naik : $\theta_2 > \theta_1$

Tes Konsep 1

Para pelari berada pada titik P yaitu pada sebuah taman berbatasan dengan pantai. Mereka harus berlari melewati taman tersebut dan menuju titik Q yang berada di pantai secepat mungkin. Lintasan manakah dari P ke Q yang membutuhkan waktu tercepat? Anda harus meninjau laju relatif para pelari pada permukaan yang keras (taman) dan pada permukaan yang licin (pantai).



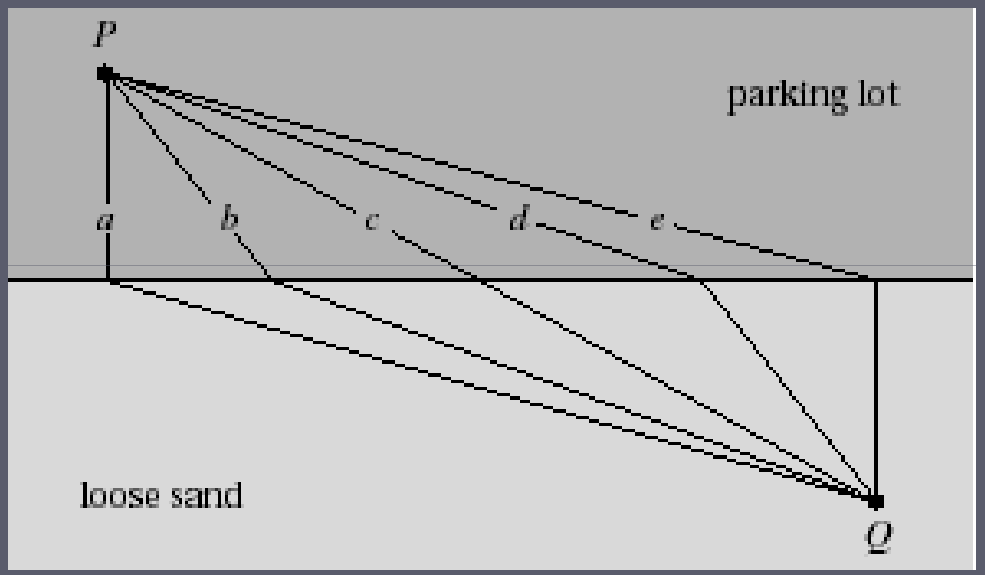
1. *a*
2. *b*
3. *c*
4. *d*
5. *e*
6. Semua lintasan memberikan waktu yang sama

Jawab 4

Note: Anybody can run faster on a hard surface than on loose sand. While the sand distance is smaller for e, the run over the parking lot is much longer.

Tes Konsep 2

Andaikan para pelari berada pada titik Q dan menuju titik P. Lintasan manakah yang memberikan waktu tercepat?



1. *a*
2. *b*
3. *c*
4. *d*
5. *e*
6. Semua lintasan memberikan waktu yang sama

Jawab 4

Hukum Pembiasan

- Perkenalkan konsep *indeks bias dalam medium*

$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}} = \frac{c}{v}$$

- *Catatan:* n tidak berdimensi dan *n>1*

  semakin besar indeks bias, laju cahaya dalam medium tersebut lebih lambat
- Ketika cahaya bergerak dari medium satu ke medium yang lain, frekuensinya ***tidak berubah.***

Hukum Pembiasan (Lanjutan)

- Hukum pembiasan dituliskan dalam indeks bias:

$$\frac{v_1}{v_2} = \frac{c/n_1}{c/n_2}, \text{thus}$$

$$\frac{\sin\vartheta_1}{\sin\vartheta_2} = \frac{n_2}{n_1}, \text{or}$$

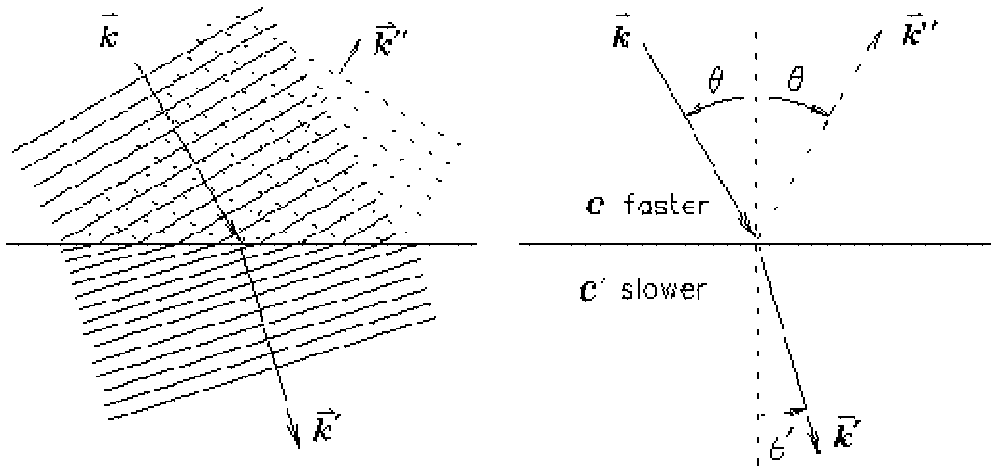
$$\mathbf{n}_1 \sin\vartheta_1 = \mathbf{n}_2 \sin\vartheta_2$$

Hukum Snell

intan	2.42
kaca	1.52
zircon	1.92
aor	1.33
udara	1.000293

Example: angle of refraction in glass

A light ray of wavelength 589 nm (produced by a sodium lamp) traveling through air is incident on a smooth, flat slab of crown glass at an angle of 30.0º to the normal, as sketched in the figure. Find the angle of refraction.



Example:

Given:

indexes of refraction:
air: $n_1 = 1.00$
glass: $n_2 = 1.52$
wavelength: $\lambda = 589\ nm$

Find:

$\theta_2 = ?$

Let's rewrite Snell's law as

$$\sin\vartheta_2 = \frac{n_1}{n_2}\sin\vartheta_1 \qquad (1)$$

Inserting the table data for n in the air and in glass the unknown refraction angle can be determined as

$$\sin\vartheta_2 = \frac{1.00}{1.52}\sin 30^\circ = 0.329 \qquad (2)$$

$$\vartheta_2 = \sin^{-1}(0.329) = \underline{19.2^\circ}$$ ✓

Note: the ray is bent *toward* the normal, as expected.

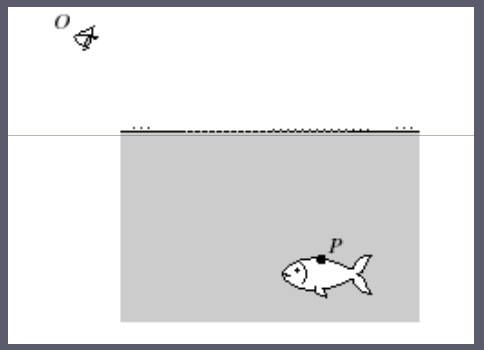
Q: What is the wavelength of this light in glass?

$$\lambda_n = \frac{\lambda_0}{n} = \frac{589\,nm}{1.52} = 387.5\,nm$$ ✓

Tes Konsep 3

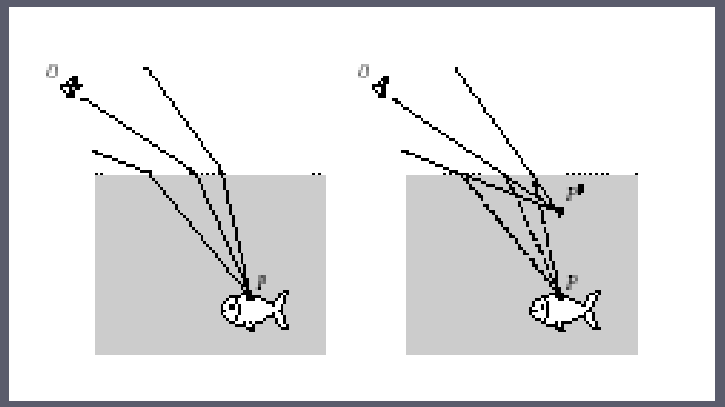
Seekor ikan berenang dibawah permukaan air pada titik P. Seorang pengamat yang berada pada posisi Q akan melihat ikan

1. Lebih dalam dari yang sebenarnya.
2. Kedalaman yang sama.
3. Lebih dangkal dari yang sebenarnya.



Jawab 3

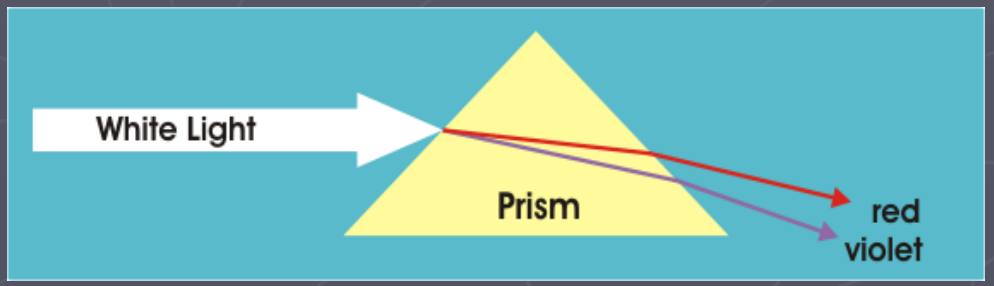
Note: The rays emerging from the water surface converge to a point above the fish.



Dispersi dan prisma

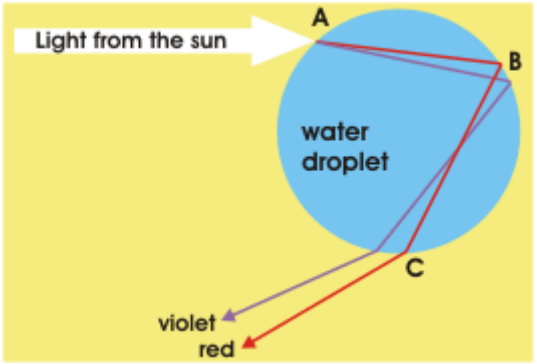
- Salah satu sifat yang penting dari indeks bias : nilainya dalam medium apapun kecuali vakum, bergantung pada gelombang cahaya. Fenomena ini dinamakan *dispersi*.
- Hukum Snell mengindikasikan: cahaya berpanjang gelombang berbeda dibiaskan dengan sudut yang berbeda ketika dibiaskan oleh material.

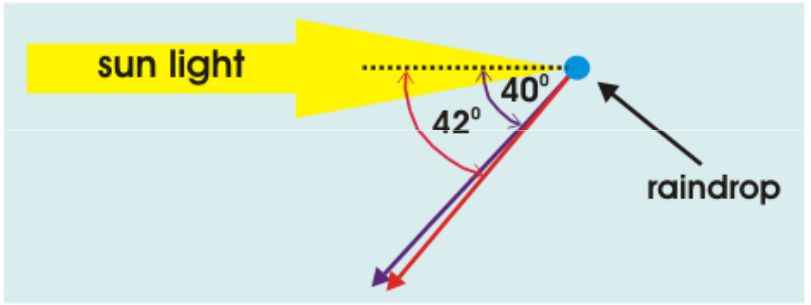
  - Prisma
  - Pelangi

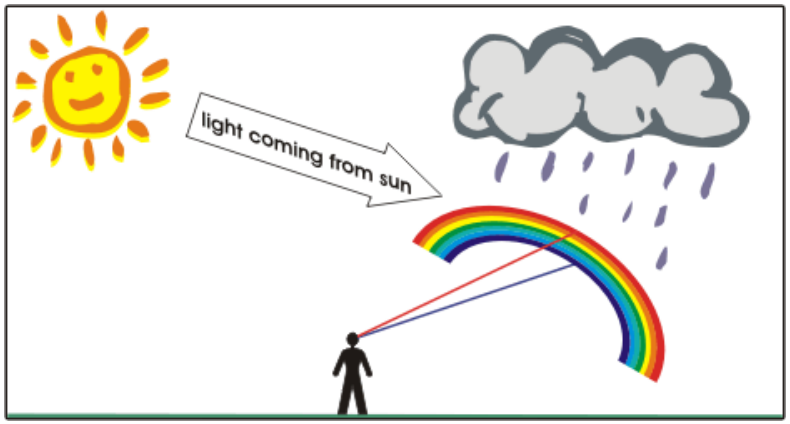


Pelangi

- Terjadinya pelangi: *butiran air hujan* berprilaku seperti *prisma kecil*. Cahaya sampai pada butiran di A, dibiaskan menuju B, kemudian dipantulkan di B dan meninggalkan butiran di C. Pada proses tersebut, sinar matahari dipecah menjadi spektrum sama seperti pada prisma.
- Sudut antara sinar matahari yang datang dan yang keluar adalah 42^0 untuk merah dan 40^0 untuk ungu.
- Perbedaan sudut yang kecil antara sinar-sinar ini mengakibatkan kita dapat melihat pelangi.

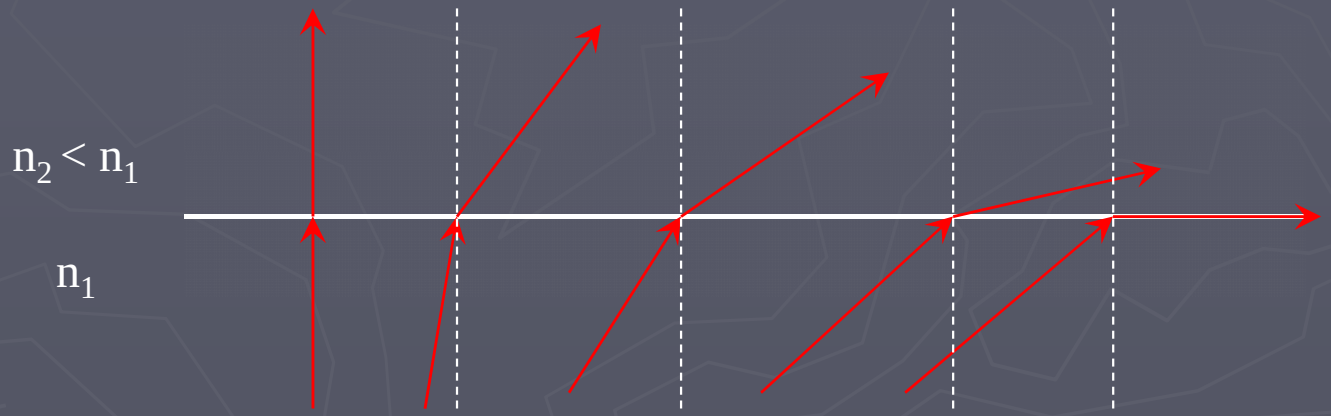






Pemantulan internal total

- Tinjau cahaya yang bergerak dari medium yang berindeks bias lebih *tinggi* ke medium yang berindeks bias lebih *rendah*.



- Pada Sudut tertentu, θ_c, pantulan cahaya bergerak sejajar pada bidang batas:

Pemantulan internal total

$$n_1 \sin \vartheta_c = n_2 \sin 90^\circ = n_2$$

$$\sin \vartheta_c = n_2 / n_1$$

Penerapan :

- Intan

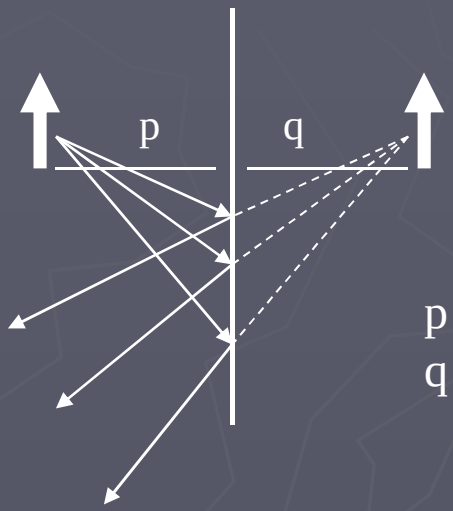
- Fiber optik

- Mikroskop, periskop…

Cermin dan Lensa

Cermin datar

- Bayangan dibentuk pada titik dimana sinar-sinar cahaya yang sebenarnya saling memotong atau sinar-sinar or at which they appear to originate.
- Bayangan dapat berupa
  - Nyata (light rays actually intersect – can be displayed on a screen)
  - Maya (where light rays appear to come from)



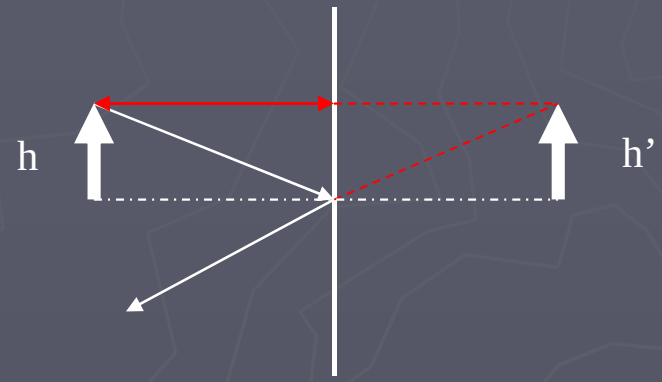
p = object distance
q = image distance

Q: What kind of image does the plane mirror have?

A: virtual

Pembentukan Bayangan: Cermin Datar

- Use two (or more) rays to construct an image



- Note: the image formed by an object placed in front of a flat mirror is as far behind the mirror as the object is in front of it.

- Lateral magnification

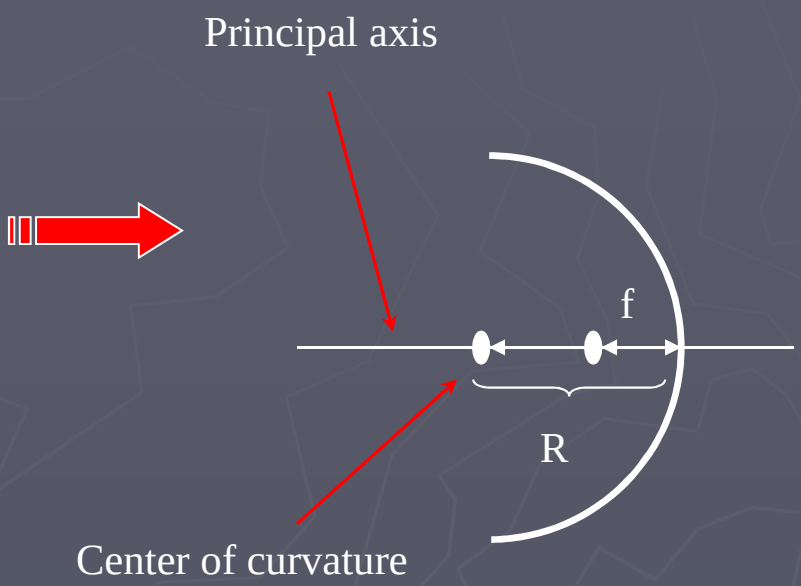
$$M = \frac{image\ height}{object\ height} = \frac{h'}{h}$$

Cermin datar: rangkuman

1. The image is as far behind the mirror as the object is in front.
2. The image is unmagnified, virtual and upright (i.e. if the object arrow points upward, so does the image arrow. The opposite of an upright image is an inverted image.)

Bola Cermin

- Spherical mirrors can be concave (light reflecting from its silvered inner) or convex (light reflecting from its silvered outer surface).
- Useful property: all light rays parallel to the principal axis will reflect through the *focal point* (where the image will be located).



R = radius of curvature
f = focal length = R/2

We will use it to build images…

Persamaan Cermin

- Can use geometry to compute image magnification and image position.

$$\frac{1}{p}+\frac{1}{q}=\frac{2}{R}=\frac{1}{f}$$

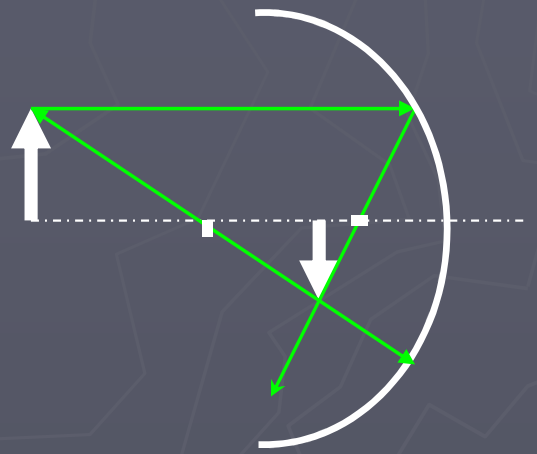
$$M=\frac{h'}{h}=-\frac{q}{p}$$

p = object distance
q = image distance

- Note:
  - both q and p are positive when both image and object are on the same side of the mirror (q<0 if "inside the mirror").
  - *f* is positive for concave mirror and negative for convex mirror.
  - Plane mirror: q=-p, so M=-q/p=1 (virtual and upright image).

Pembentukan bayangan : cermin cekung

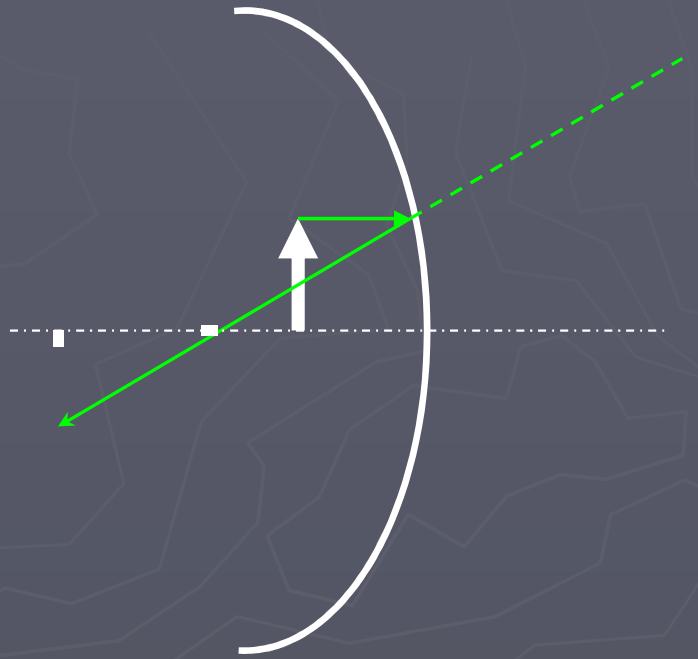
- Use two (or more) rays to construct an image
- Case 1: p>R
  - Light ray parallel to the principal axis will be reflected through the focal point
  - Light ray passing through the curvature center will be reflected back
  - Light ray passing through the focal point will be reflected parallel to the principal axis.



Note: image is real and inverted

Pembentukan bayangan Construction of images: cermin konkap concave mirrors

- Use two (or more) rays to construct an image
- Case 2: p<f
  - Light ray parallel to the principal axis will be reflected through the focal point



Pembentukan bayangan Construction of images: cermin konkap concave mirrors

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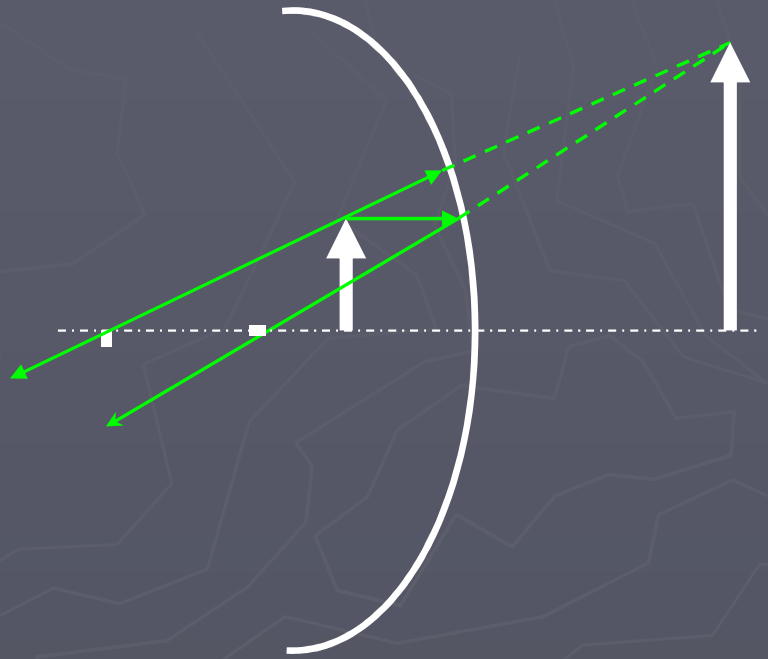

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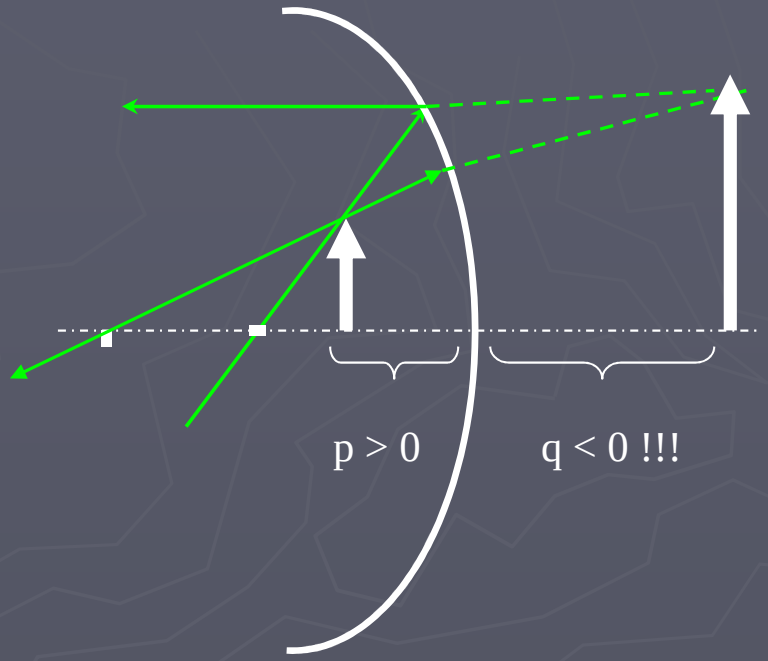


Note: image is virtual and upright

Contoh Example 1: cermin konkap concave mirrors

An object is placed in front of a concave mirror at the distance of 80.0 cm. Find (a) distance between the image and the mirror (b) lateral magnification if the focal distance of the mirror is 20.0 cm.

Contoh 1

Given:

mirror parameters:
focal distance: f = 20.0 cm
radius: R = 2 f = 40.0 cm
p = 80.0 cm

Find:

q = ?
M = ?

(a) Use mirror equation:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \qquad (1)$$

Inserting the available data for f and p the unknown image distance can be determined as

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{20cm}-\frac{1}{80cm}=\frac{3}{80cm} \qquad (2)$$

$$q=80cm/3=+26.7cm$$

✓

(b) Lateral magnification can be found from

$$M=-\frac{q}{p}=-\frac{26.7cm}{80.0cm}=-0.33$$

✓

The image is smaller than the object!

Contoh 2: cermin konkap concave mirrors

An object is placed in front of a concave mirror at the distance of 10.0 cm. Find (a) distance between the image and the mirror (b) lateral magnification if the focal distance of the mirror is 20.0 cm.

Contoh 2

Given:

mirror parameters:
focal distance: f = 20.0 cm
radius: R = 2 f = 40.0 cm
p = 10.0 cm

Find:

q = ?
M = ?

(a) Use mirror equation:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \qquad (1)$$

Inserting the available data for f and p the unknown image distance can be determined as

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{20cm}-\frac{1}{10cm}=-\frac{1}{20cm}$$

$$q=20cm/1=-20cm \qquad (2)$$

✓

(b) Lateral magnification can be found from

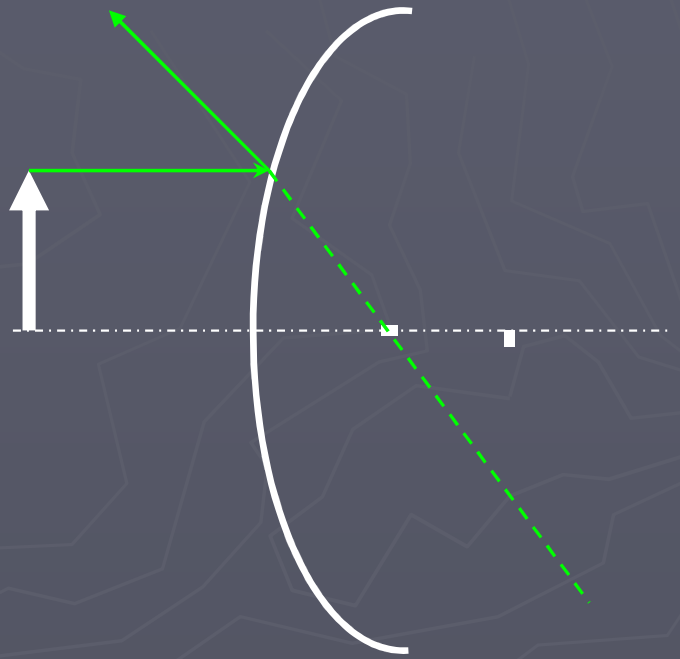
$$M=-\frac{q}{p}=-\frac{(-20.0cm)}{80.0cm}=+2.00$$

✓

The image is larger than the object!

Pembentukan Bayangan Construction of images: cermin cekung convex mirrors

- Use two (or more) rays to construct an image
- Same method:
  - Light ray parallel to the principal axis will be reflected through the focal point



Pembentukan Bayangan Construction of images: cermin cekung convex mirrors

- Use two (or more) rays to construct an image
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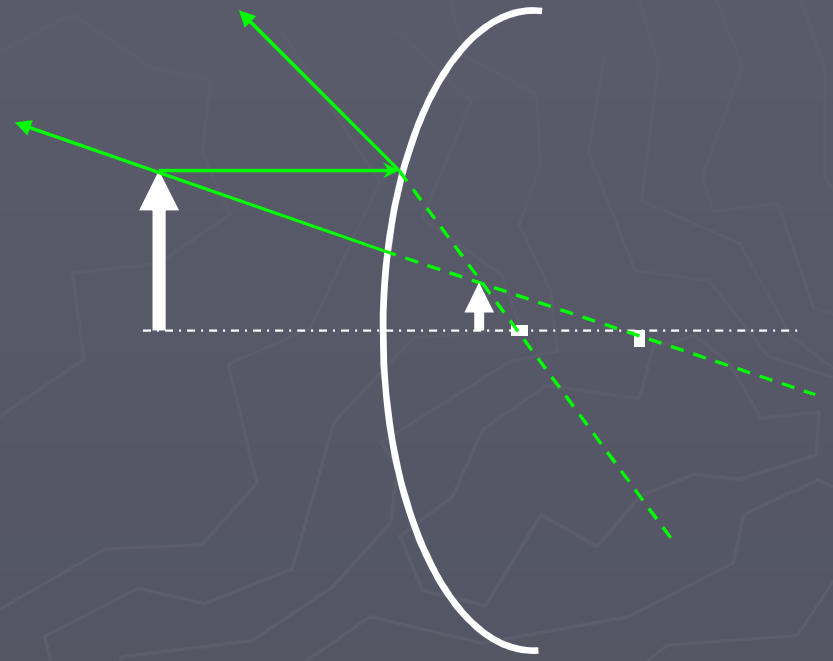
  - Light ray passing through the curvature center will be reflected back



Pembentukan Bayangan Construction of images: cermin cekung convex mirrors

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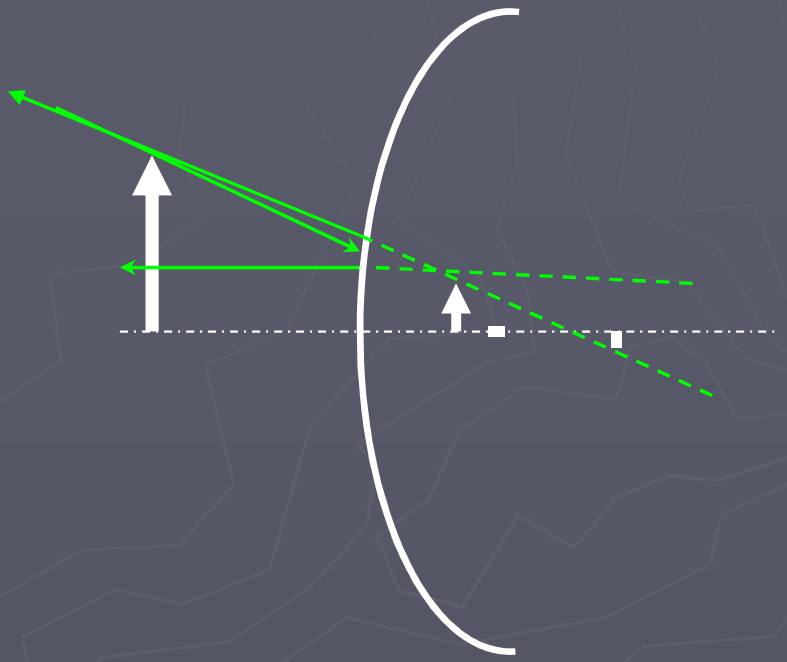


Note: image is virtual and upright

Contoh: cermin cekung convex mirrors

An object is placed in front of a convex mirror at the distance of 30.0 cm. Find (a) distance between the image and the mirror (b) lateral magnification if the focal distance of the mirror is 20.0 cm.

Contoh:

Given:

mirror parameters:
focal distance: f = 20.0 cm
radius: R = 2 f = 40.0 cm
p = 30.0 cm

Find:

q = ?
M = ?

(a) Use mirror equation:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \qquad (1)$$

Inserting the available data for f and p the unknown image distance can be determined as

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{-20cm}-\frac{1}{80cm}=-\frac{5}{60cm}$$

$$q=-60cm/5=-12cm \qquad (2)$$

✓

(b) Lateral magnification can be found from

$$M=-\frac{q}{p}=-\frac{-12cm}{-20cm}=+0.40$$

✓

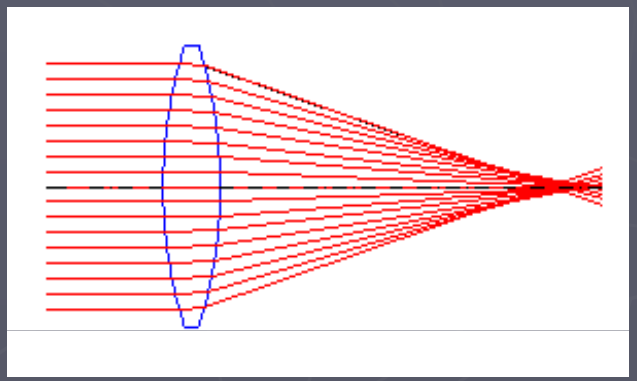
The image is smaller than the object!

Pemantulan dan Refraksi Cahaya pada Lensa tipis Reflection and Refraction of Light

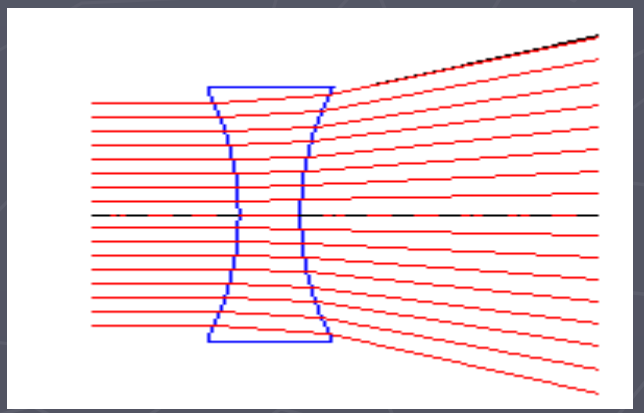
Thin lenses

Pendahuluan Introduction

- Thin lens consists of piece of glass or plastic ground so each of its two refracting surfaces is segment of sphere or plane.
- Examples:



Converging lens



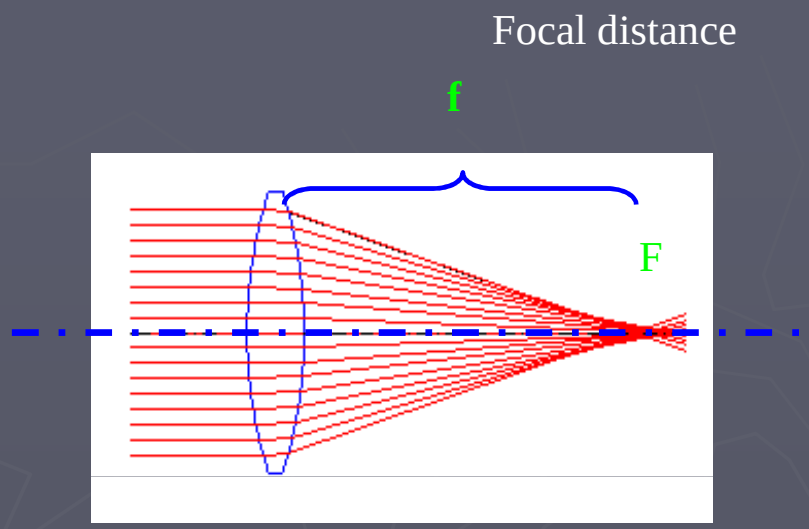
Diverging lens

Definisi Definitions

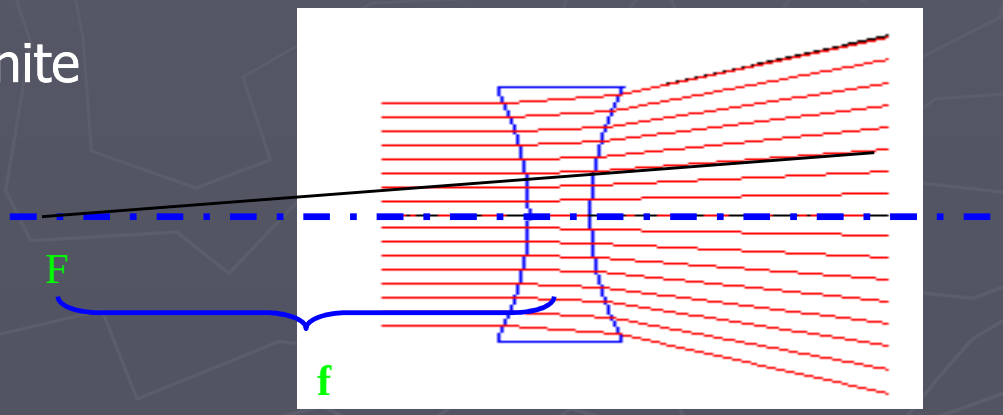
- Just as for mirrors, define principal axis
  - line passing through the "center" of the lens

and focal length,

- image distance that corresponds to an infinite object distance



Converging lens



Diverging lens

Persamaan Lensa Lens equations

Similar to mirror equations

- Can use geometry to compute image magnification and image position.

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

$$M=\frac{h'}{h}=-\frac{q}{p}$$

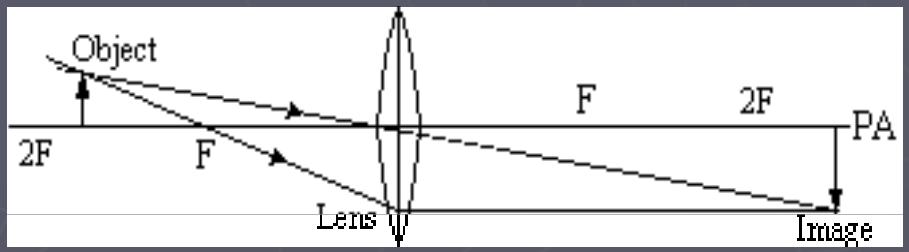
p = object distance
q = image distance

- Note on sign conventions:
  - p is always positive
  - q is positive when image and object are on the different sides of the lens and negative otherwise.
  - *f* is positive for converging lens and negative for diverging lens.

Pembentukan Bayangan Construction of images: lensa konvergen convergent lenses

- Use two (or more) rays to construct an image
- Same method (mirrors):
  - Light ray parallel to the principal axis will be refracted through the focal point
  - Light ray passing through the center of the lens will be refracted undeviated
  - Light ray passing through the focal point will be refracted parallel to the principal axis.

Example 1: p>f



Contoh Example 1: lensa konvergen converging lens

An object is placed in front of a convergent lens at the distance of 40.0 cm. Find (a) distance between the image and the lens (b) lateral magnification if the focal distance of the lens is 20.0 cm.

Contoh 1:

Given:

lens parameters:
focal distance: f = 20.0 cm
p = 40.0 cm

Find:

q = ?
M = ?

(a) Use lens equation:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \qquad (1)$$

Inserting the available data for f and p the unknown image distance can be determined as

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{20cm}-\frac{1}{40cm}=+\frac{1}{40cm} \qquad (2)$$

$$q=40cm/1=+40cm$$

✓

(b) Lateral magnification can be found from

$$M=-\frac{q}{p}=-\frac{(+40.0cm)}{40.0cm}=-1$$

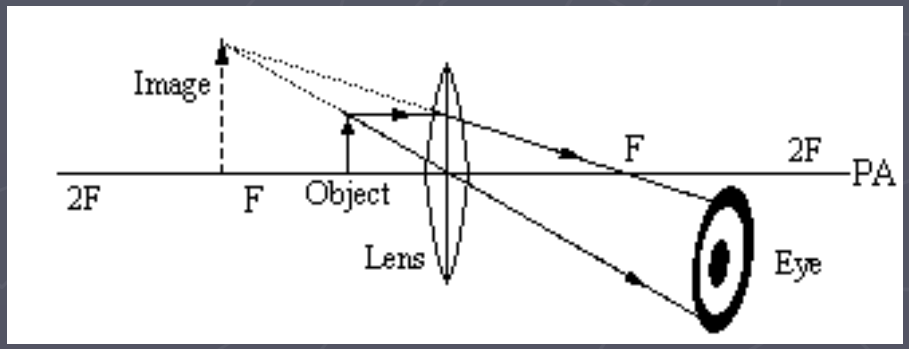
✓

The image is real and inverted!

Pembentukan Bayangan Construction of images: lensa konvergen convergent lenses

- Use two (or more) rays to construct an image
- Same method:
  - Light ray parallel to the principal axis will be refracted through the focal point
  - Light ray passing through the center of the lens will be refracted undeviated
  - Light ray passing through the focal point will be refracted parallel to the principal axis.

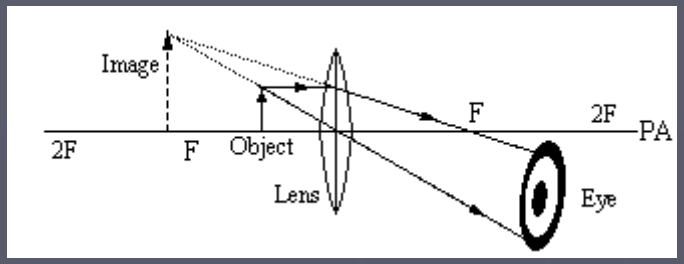
Example 2: p<f



Contoh 2: lensa konvergen converging lens

An object is placed in front of a convergent lens at the distance of 10.0 cm. Find (a) distance between the image and the lens (b) lateral magnification if the focal distance of the lens is 20.0 cm.

Contoh 2:



Given:

lens parameters:
focal distance: f = 20.0 cm
p = 10.0 cm

Find:

q = ?
M = ?

(a) Use lens equation:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \quad (1)$$

Inserting the available data for f (>0) and p (>0) the unknown image distance can be determined as

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{20cm}-\frac{1}{10cm}=-\frac{1}{20cm} \quad (2)$$

$$q=-\frac{20cm}{1}=-20cm$$

(b) Lateral magnification can be found from

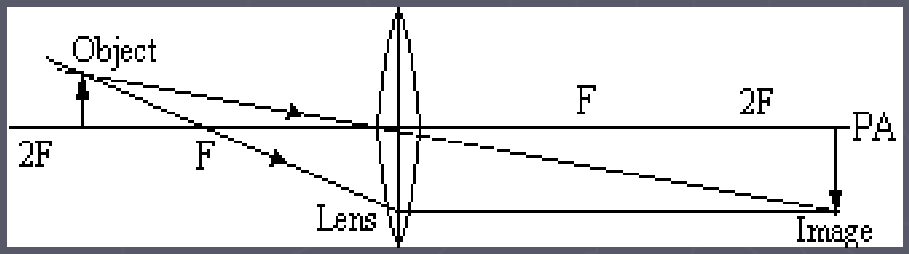
$$M=-\frac{q}{p}=-\frac{(-20.0cm)}{10.0cm}=+2$$

The image is virtual and upright!

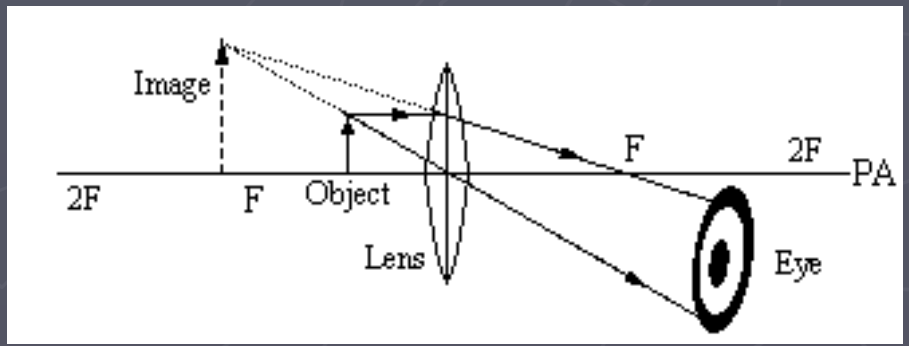
Pembentukan Bayangan Construction of images: lensa konvergen convergent lenses

- Use two (or more) rays to construct an image
- Same method:
  - Light ray parallel to the principal axis will be refracted through the focal point
  - Light ray passing through the center of the lens will be refracted undeviated
  - Light ray passing through the focal point will be refracted parallel to the principal axis.

Example 1: p>f



Example 2: p<f



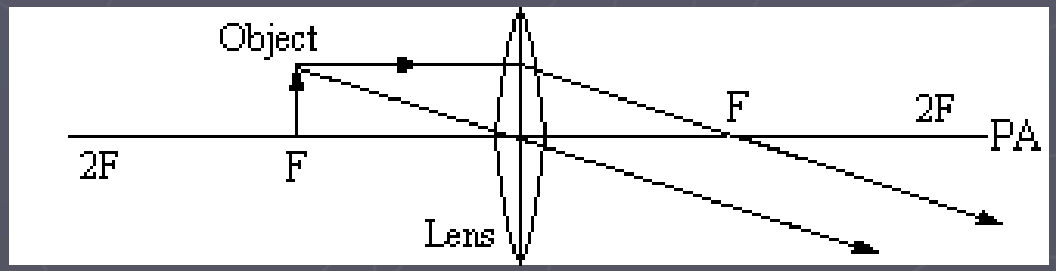
Thus, the question:

Pertanyaan Question

What happens if the object is placed at the distance that is equal to the focal distance?

Pertanyaan Question

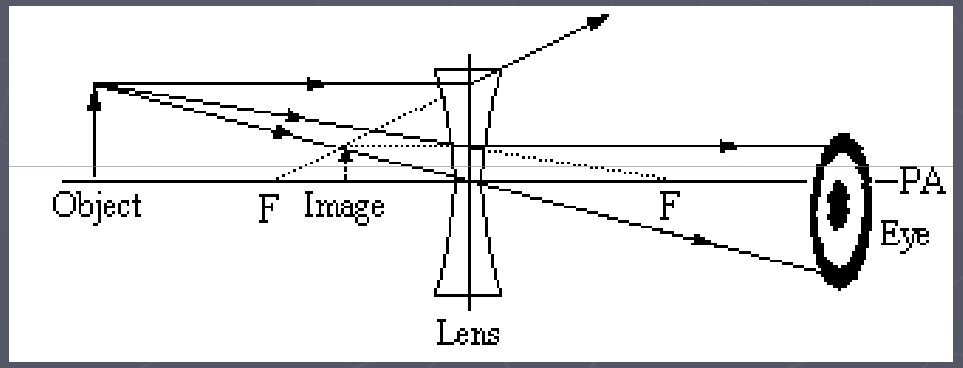
What happens if the object is placed at the distance that is equal to the focal distance?



The image will not be formed: light rays are parallel!

Pembentukan Bayangan Construction of images: lensa divergen divergent lenses

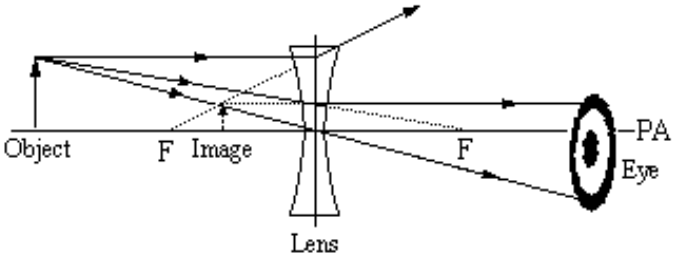
- Use two (or more) rays to construct an image
- Same method:
  - Light ray parallel to the principal axis will be refracted through the focal point
  - Light ray passing through the center of the lens will be refracted undeviated
  - Light ray passing through the focal point will be refracted parallel to the principal axis.



Contoh 3: Lensa divergen diverging lens

An object is placed in front of a divergent lens at the distance of 40.0 cm. Find (a) distance between the image and the lens (b) lateral magnification if the focal distance of the lens is 20.0 cm.

Contoh 3:



Given:

lens parameters:
focal distance: f = 20.0 cm
p = 10.0 cm

Find:

q = ?
M = ?

(a) Use lens equation:

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f} \qquad (1)$$

Inserting the available data for f (<0) and p (>0) the unknown image distance can be determined as

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{-20cm}-\frac{1}{40cm}=-\frac{3}{40cm} \qquad (2)$$

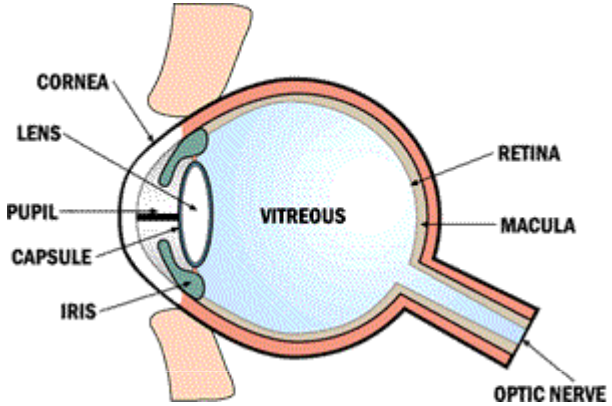
$$q=-40cm/3=-13.3cm$$

(b) Lateral magnification can be found from

$$M=-\frac{q}{p}=-\frac{(-13.3cm)}{40.0cm}=+0.33$$

The image is virtual and upright!

Mata ManusiaHuman Eye



Pupil - the opening in the center of the iris.
Iris - the colored membrane between the lens and the cornea - its color determines the color of the eye. It separates the anterior and posterior chambers of the eyeball. It contracts and dilates to regulate the entry of light.
Lens - the normally transparent structure behind the pupil. Tiny muscles attached to it cause it to contract or relax, thereby focusing light rays to form an image on the retina.
Cornea - the clear outer covering of the eye.
Optic nerve - the nerve carrying impulses for sight from the retina to the brain.
Retina - The innermost layer of the eye. The light sensitive structure on which light rays come to focus.
Capsule - the transparent membrane that surrounds and encloses the lens.

HOW THE EYE WORKS

Light rays enter the eye through the cornea, which is the main focusing element of the eye. The cornea bends the light rays through the pupil. The light rays then pass through the lens, which adjusts their path in order to bring them to focus on the retina at the back of the eye. The retina contains nerve cells which convert the light rays into electrical impulses. The impulses are sent through the optic nerve to the brain, where they are interpreted as an image.

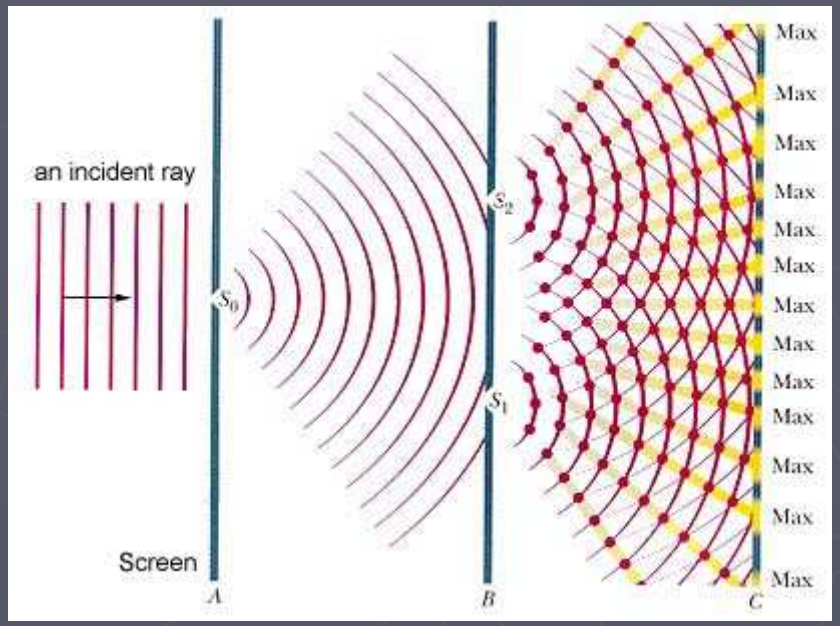
Wave optics
(interference, diffraction, polarization..)

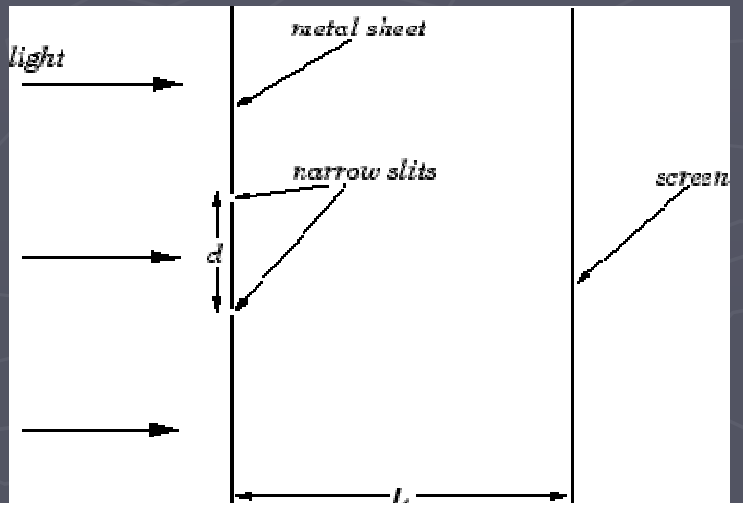
1. Interference

- Conditions for interference:
  - light sources must be coherent (must maintain a constant phase wrt each other)
  - sources must have identical wavelength
  - superposition principle must apply

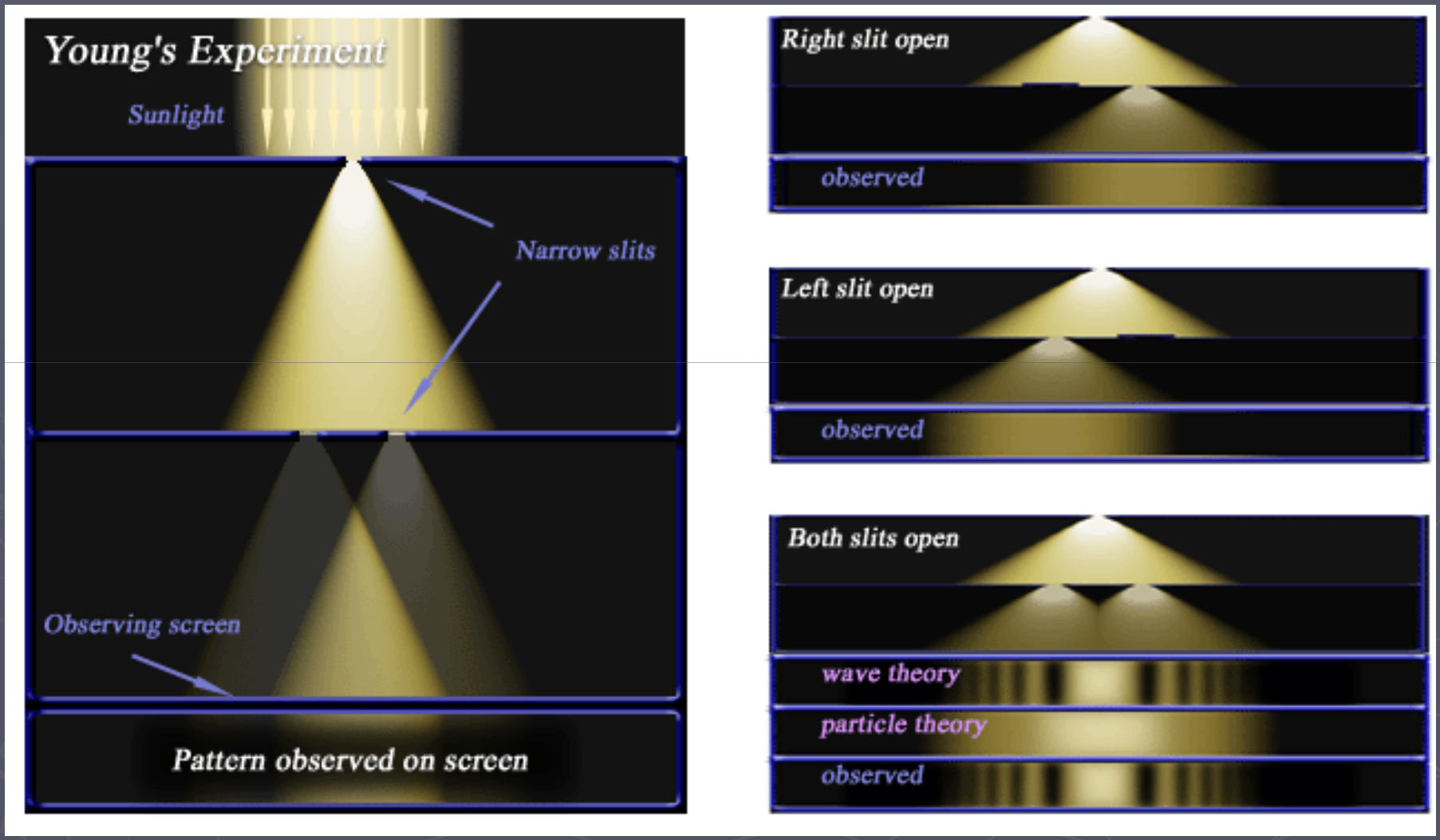
Young's double-slit interference

- Setup: light shines at the plane with two slits
- Result: a series of parallel dark and bright bands called fringes





Young's double-slit interference



Young's double-slit interference

- Path difference:

$$\delta = d \sin\theta$$

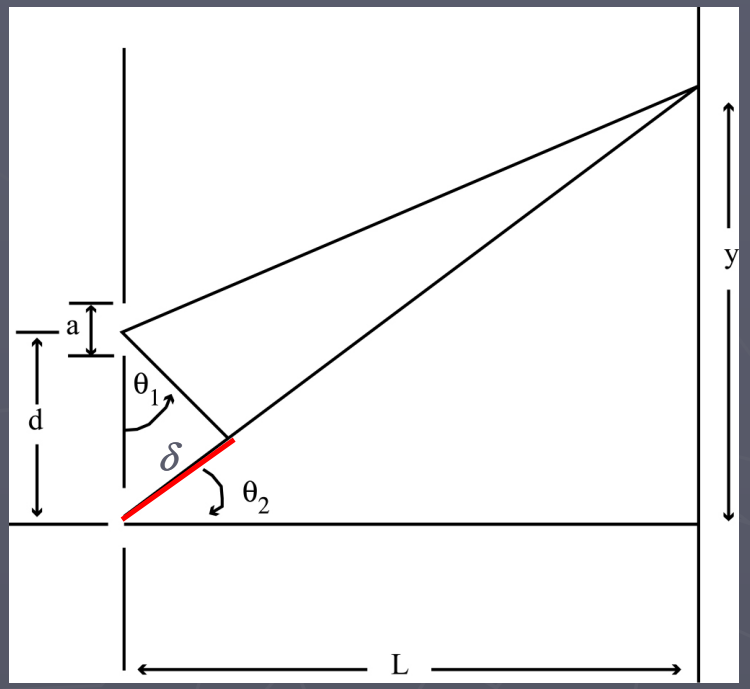
If: $\delta = m\,\lambda$: constructive interference

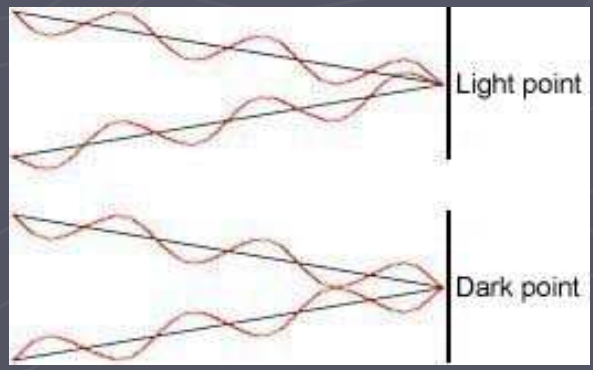
If: $\delta = (m+1/2)\,\lambda$: destructive int.

$$\sin\vartheta \approx \tan\vartheta = \frac{y}{L}, \text{ thus :}$$

$$y_{bright} = L\sin\vartheta = \frac{\lambda L}{d}m,\ m = 0,\pm1,\pm2,\ldots$$

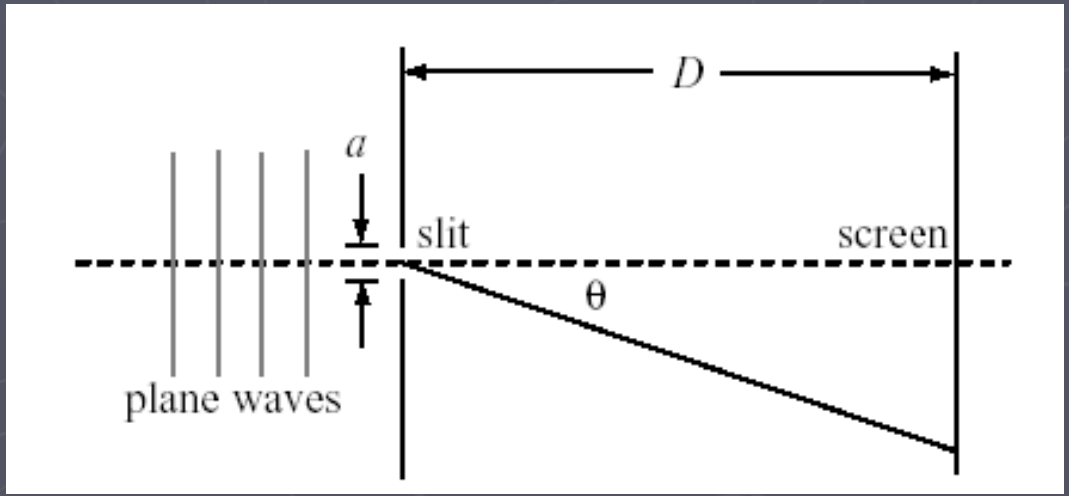
$$y_{dark} = L\sin\vartheta = \frac{\lambda L}{d}\left(m+\frac{1}{2}\right),\ m = 0,\pm1,\pm2,\ldots$$





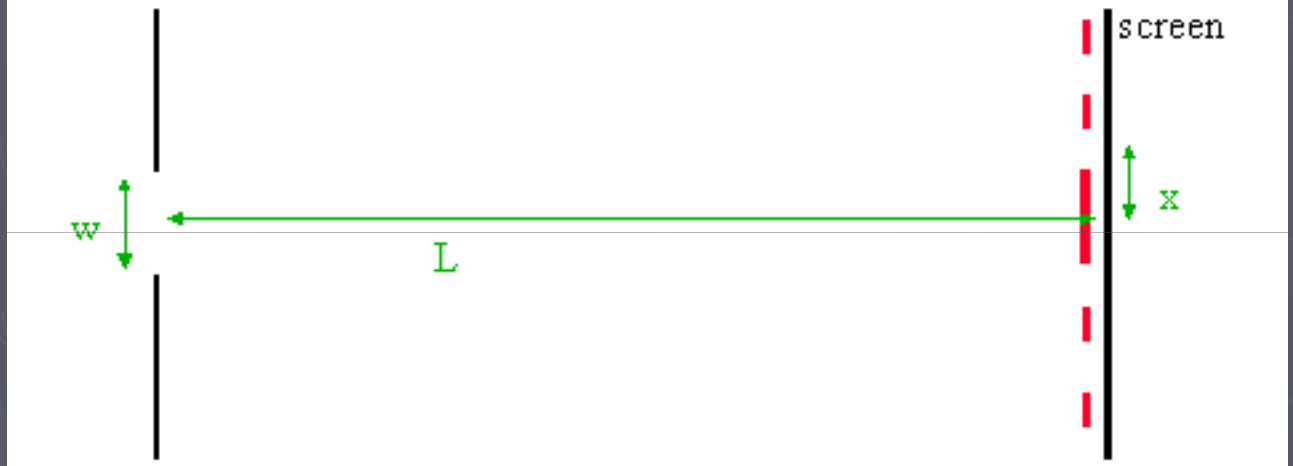
2. Diffraction

- Diffraction occurs when light deviates from a straight line path and enters a region that would otherwise be shadowed.
  - "bending of light around corner"
- Single-slit diffraction
  - Each portion of the slit acts as a source of waves: interference



Diffraction: single slit

How can we explain the pattern from light going through a single slit?



1. Divide: each source width *a/2n*
2. Find path difference *for destructive interference:*

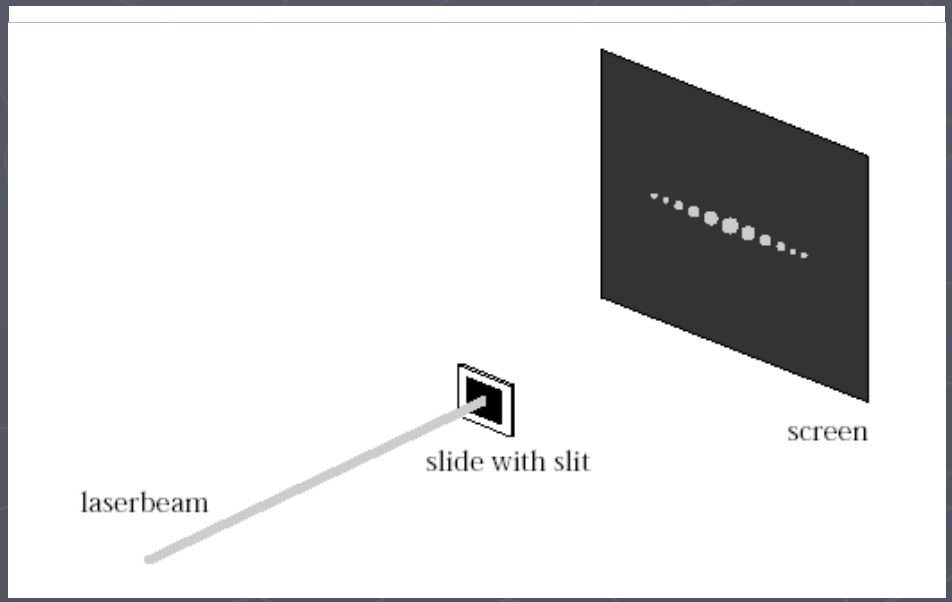
d = λ/2 = (a/2) sin θ, so λ = a sin θ, or

$$\sin\vartheta = m\frac{\lambda}{2},\ m = \pm 1, \pm 2, \ldots$$

THE FINAL Question

The pattern on the screen is due to a narrow slit that is

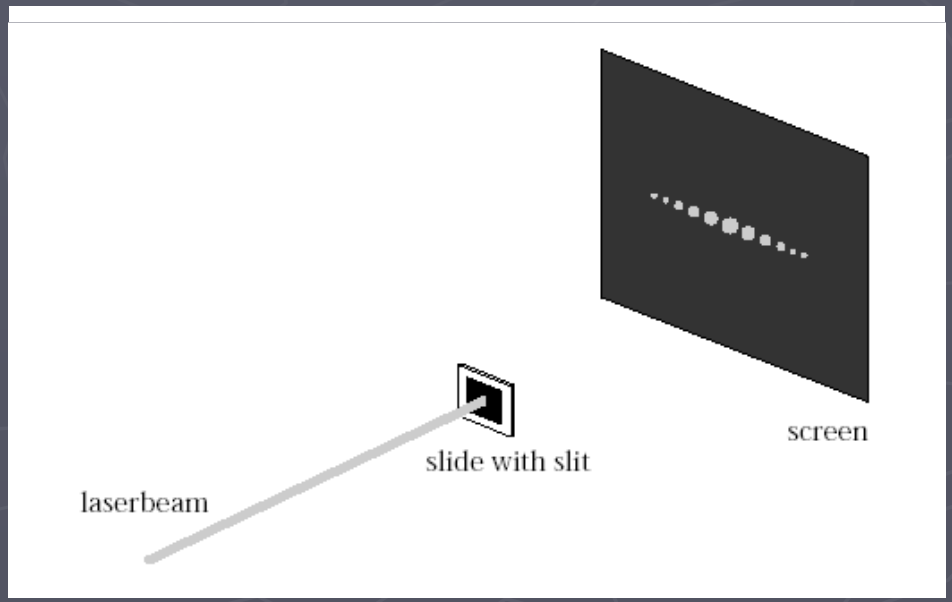
1. horizontal
2. vertical



THE FINAL Question

The pattern on the screen is due to a narrow slit that is

1. horizontal
2. ✓ vertical



Note: diffraction is most pronounced for small apertures, and hence diffraction occurs in the direction of the smallest dimension of the slit.