'OPTICS' deals with the Science and Technology which involve the propagation of Light.

- The range of phenomena (or effects) and practical applications are very wide

- from most common application like spectacles for correction of vision, to modern high-speed optical fiber communication for transmission of multi-gigabits of information/data —

 Optics plays an important role!

Three different approaches:

Optics
→ Ray Optics ⎤
→ Wave Optics ⎦ In this Course
→ Quantum Optics
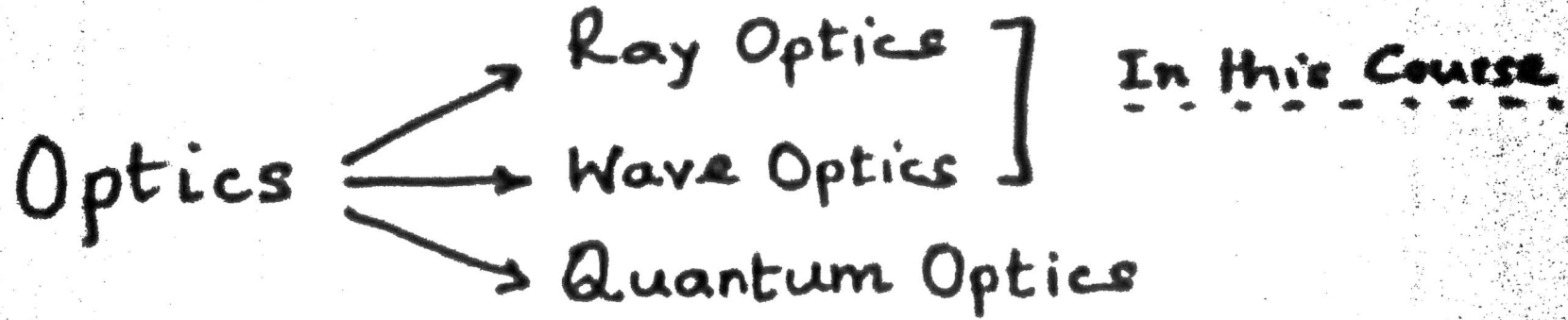
Why is it necessary to follow different approaches?

In 'Ray Optics'

- Propagation of Light is represented by 'rays'
- A 'ray' is a 'light path' along which the optical energy flows; the direction of energy flow is indicated by the arrow sign.

$$\longrightarrow \qquad \text{Ray path}$$

- In a homogeneous medium,
    (i.e. a medium of uniform refractive index)
  Ray paths are straight lines.

- Does this mean . . . .

$n(x)$

Graded index medium
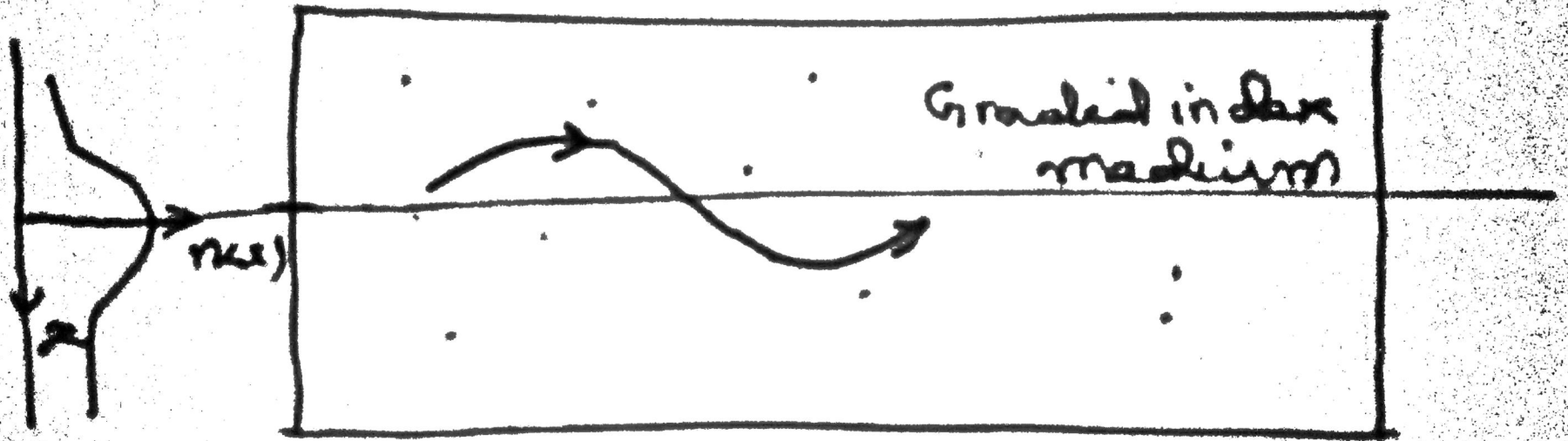
- Propagation of a beam of light
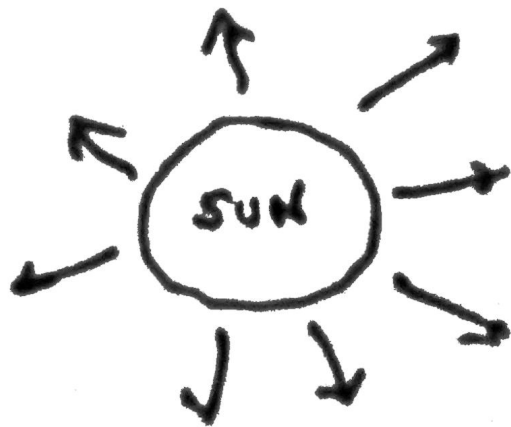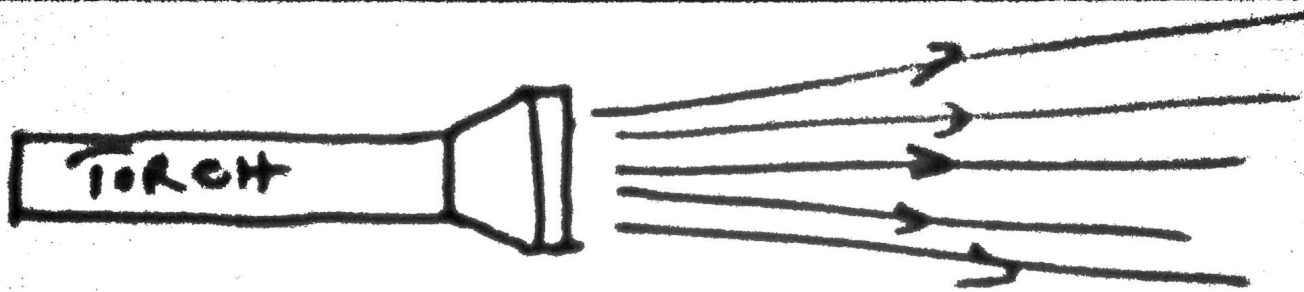$$\downarrow$$
" bunch of rays "

- For example,
  Light beam from
  a battery torch }   Sun rays,   A Laser beam

- Elementary experiments show that
  'Light travels in straight line paths'

TORCH

LASER

SUN
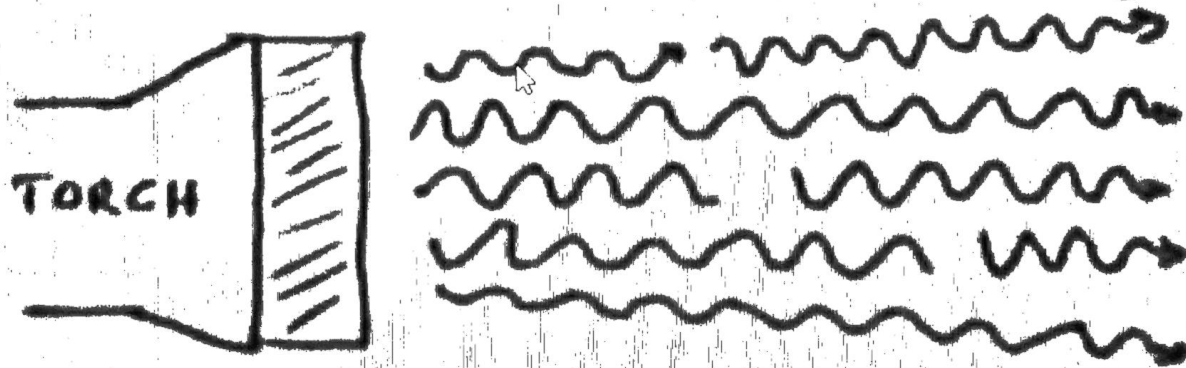
Tracing Ray paths Through a Medium

$n_1 = 1.0$

Glass
$n_2 = 1.5$
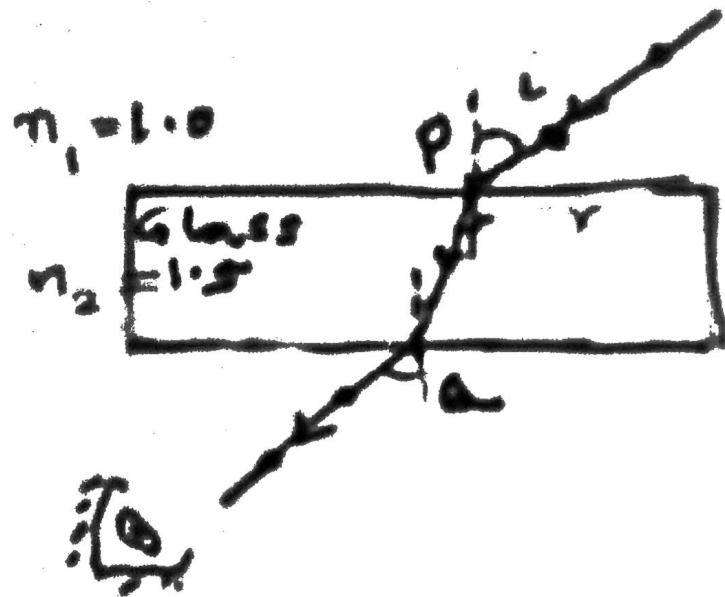
Snell's Law:

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

$\longrightarrow$ Wave Optics

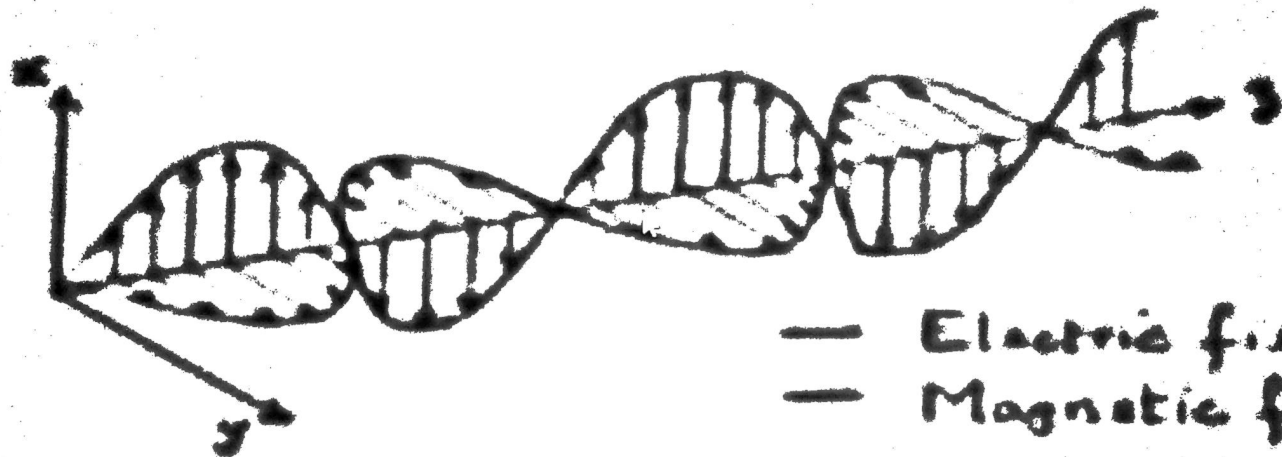Snell's Law comes out analytically

In 'Wave Optics'

A beam of light comprises of large number of propagating waves
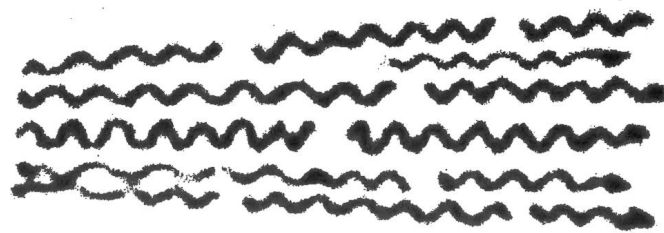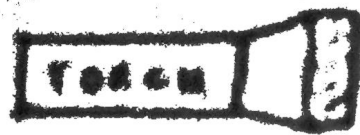— "a bunch of propating waves"

TORCH

What type of waves?
— Electromagnetic Waves

Electromagnetic Waves

— Electric field
— Magnetic field

$$\vec{E} = \hat{z} A \sin(\omega t - kx)$$

$$= \hat{z} \underline{A} \sin\left(2\pi \underline{f} t - \frac{3\pi}{2} x\right)$$

$$= \hat{z} A \sin k(\underline{v} t - x)$$

'Light Waves' emanating from different sources

TORCH 〰〰〰〰〰 'Incoherent Waves'

LASER 〰〰〰〰〰 'Coherent Waves'

SUN
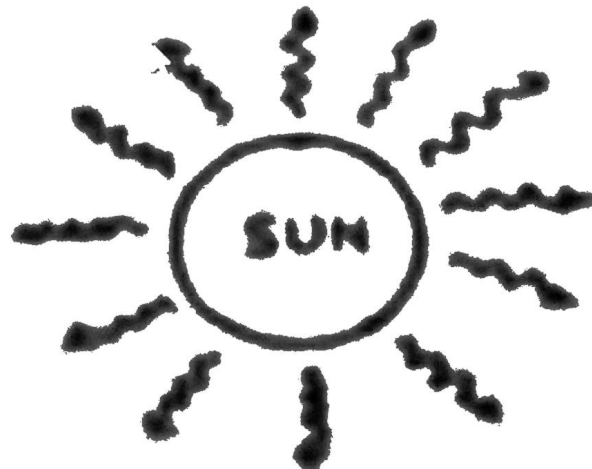
In 'Quantum Optics'

- Propagation of Light is described in terms of propagation of large number of tiny <u>particle-like packets</u> of optical energy called "<u>Photons</u>", which travel with the speed of light, c.

- The energy of a photon corresponding to light of a particular colour, with wavelength λ, is given by

$$E = h\frac{c}{\lambda} = h\nu$$

h — Planck's constant
(named after Max Planck)

'Bunch of Photons' amanating from different sources
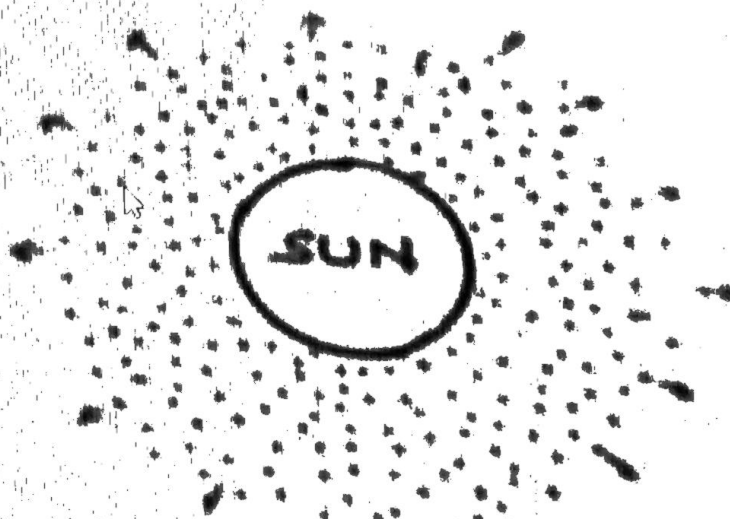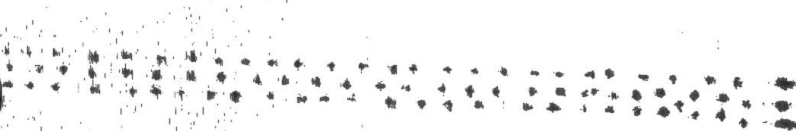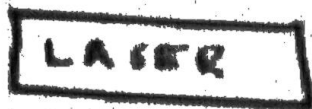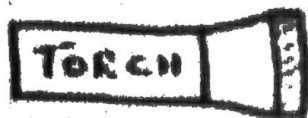
What is the energy of a photon corresponding to visible light?

$$E = \frac{hc}{\lambda}$$

$h = 6.6 \times 10^{-34}$ J.s

$c = 3 \times 10^{8}$ m s^{-1}

$\lambda = 600$ nm, say for yellow light

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{600 \times 10^{-9}}$$

$$\underline{E = 3.3 \times 10^{-19} \text{ J}} \; !$$

Extremely small!

What does this mean?

If 10^{19} photons are incident on a screen or a photodetector, in 1 sec., it would correspond to a power of 3.3 W.

$$(E = 3.3 \times 10^{-19} \text{ J}) \times 10^{19} \text{ s}^{-1}$$

$$= 3.3 \text{ J s}^{-1}$$

$$\text{Power} = 3.3 \text{ W}$$

At extremely low powers,
$\sim 10^{-15} W$ or less,
it is possible to count the no. of photons
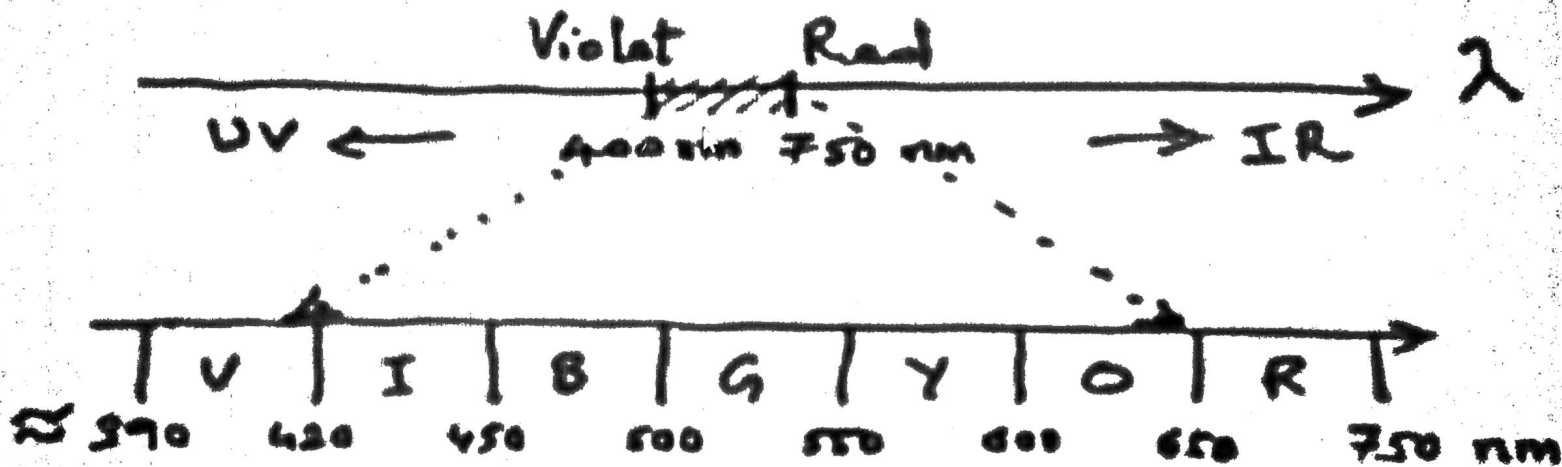incident on a detector — "Photon counters"

[rectangle] ·· ········ ·· ··· ··→

"Single photon sources"

The output photons follow certain distributions
                                    and statistics
    with applications!

1. Light is an electromagnetic radiation

- 'Visible Light' corresponds to a small portion of the spectrum of e.m. radiation

Common Light Sources

- Tungsten Bulb
- Fluorescent Tube
- LED bulbs

100 nm — 2000 nm

Broad spectrum

- LEDs
  - Red ~ 650 nm
  - Yellow ~ 550 nm
  - Blue ~ 420 nm

- LASERs
  - Orange-red ~ 633 nm (H_e–N_e)
  - Green ~ 532 nm
  - Blue

2. The speed of light in vacuum

$$c_0 = 3 \times 10^8 \text{ m/s } (\text{m.s}^{-1})$$

(Precise value of $c_0 = 2.99792458 \times 10^8 \text{ ms}^{-1}$)

In a material medium, light travels at a slower speed, given by

$$c = \frac{c_0}{n}$$

n — refractive index of the medium

$$n = \frac{c_0}{c} > 1$$

e.g. glass $n \approx 1.5$, water $n = 1.33$

3. The speed of light in any material medium depends on the wavelength

i.e. $c \equiv c(\lambda)$

$$\Rightarrow n = \frac{c_0}{c(\lambda)} \equiv n(\lambda)$$

i.e. Refractive index of an optical medium depends on the wavelength of light

— leads to the phenomenon called "Dispersion"

1. **Ray Optics**   – 3 important phenomena

    (i) Reflection   (of light)
    (ii) Refraction   "
    (iii) Dispersion   "

2. **Wave Optics**   – 3 important aspects

    (i) Interference   "
    (ii) Diffraction   "
    (iii) Polarization   "

Some Optical Components

1. Double Convex Lens
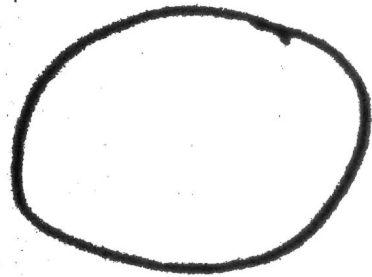
Front view
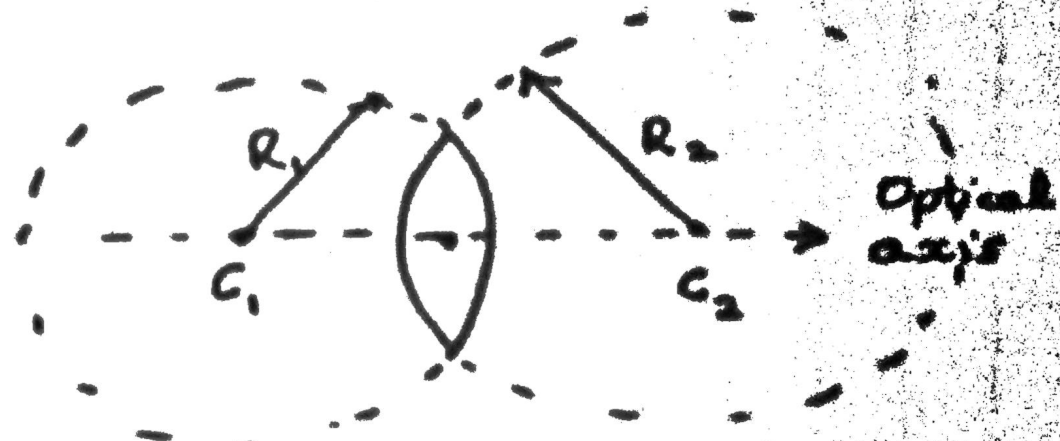
Side view

The surfaces of the lens form parts of spheres of radius R_1 & R_2

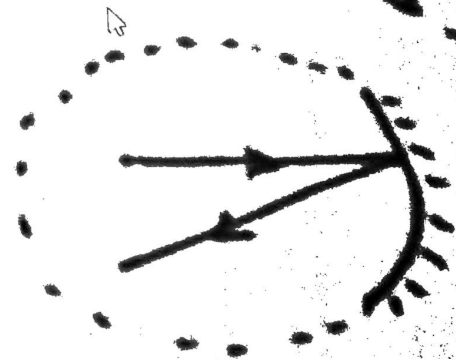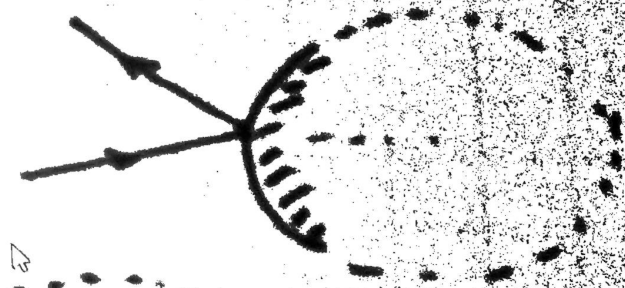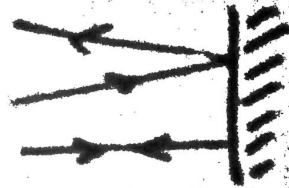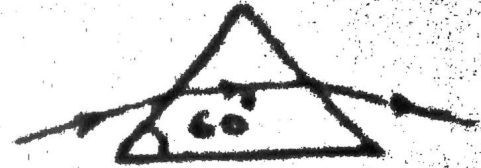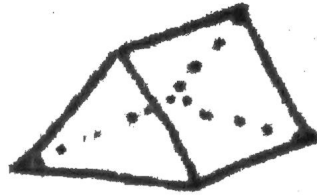## 2. Double Concave Lens
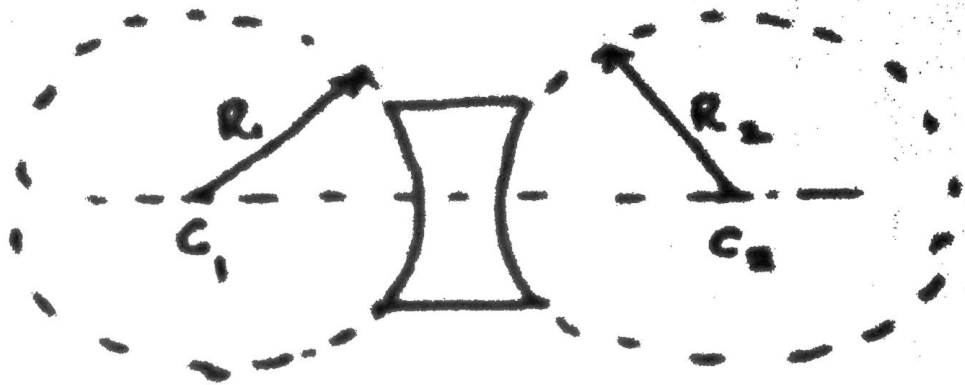
3. Others

Plano-convex

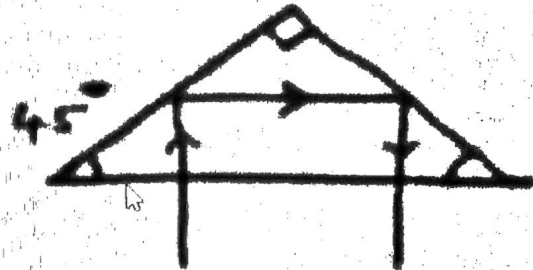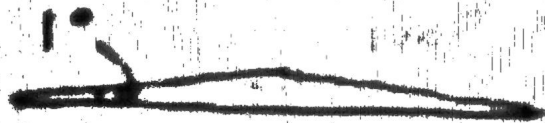Plano-concave

+ combinations

4. Mirrors

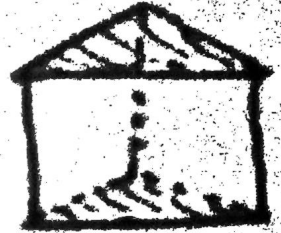- Plane mirror
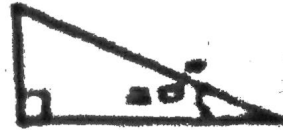
- Convex mirror

- Concave mirror

5. Prisms

110°   35°

Isosceles

1°

45°

Practical Applications (of Optical Components)

- Looking mirrors
- Magnifying glass
- Rear-view mirrors (in cars)
- Spectacles
- Camera
- Microscopes
- Telescopes
- Periscopes