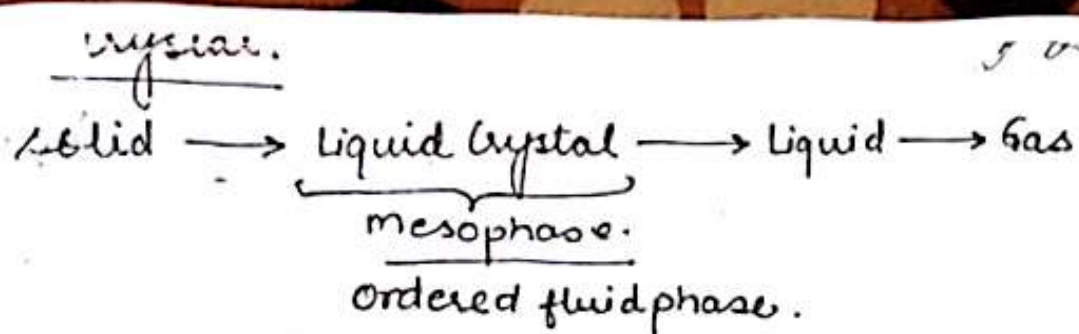




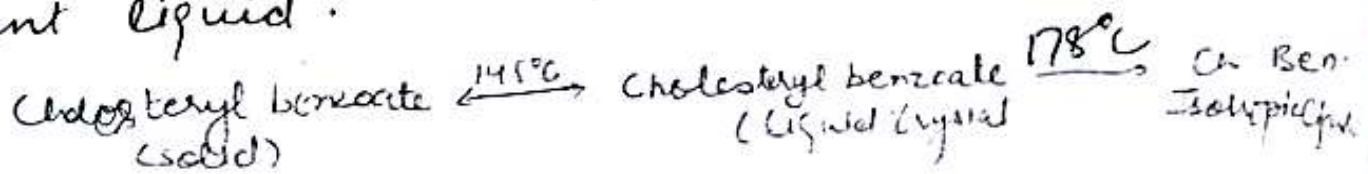
CHITKARA
UNIVERSITY



Generally, when a solid is heated, the thermal agitation gradually overcomes the cohesive forces of attraction; till at its melting point the solid changes into liquid form.

In long chain organic solids, kinetic energy (at transition temperature) is sufficient to disrupt the binding between end of molecules, but it is insufficient to overcome the strong lateral attraction b/w the long chain of molecules. Consequently, such long chain organic solids do not melt directly to give isotropic liquid, they first transform sharply to "turbid liquids" (mesophases) and then equally sharply to clear isotropic liquid at higher temperature.

The study of liquid crystals began in 1888, when an ~~australian~~ austrian botanist named Friedrich Reinitzer observed that a material known cholesteryl benzoate had two distinct melting points 145°C and 178°C . At 145°C , solid material converts into a tazy liquid and on further increasing the temperature (178°C) the material changes into a clear transparent liquid.



An ordered fluid mesophase of an ^{anisotropic} long chain molecule possessing both solid-like ^{order} molecular order and liquid like character is known as Liquid Crystal.



Solid

- Rigid arrangement of molecules
- fixed position
- fixed orientation



Liquid Crystal

- NO fixed position
- ~~have~~ orientation order



Liquid

- no fixed position
- no fixed orientation

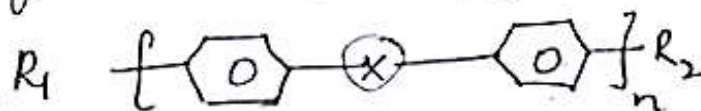
* positional order: Regularity in the distance b/w molecules

* Orientalional : Regularity in the orientation. \updownarrow

Characteristics of liquid crystal: molecules.

- ① Liquid crystal are long, rod-like ~~molecular structure~~
- ② LC are narrow, elongated molecules having sufficient molecular interactions due to ^{ne} presence of strong dipoles ^{namely} and ^{also having} easily polarisable grps. The most common liquid crystal are of type:

Substituent gp. { Aromatic gp. — Linkage gp. — Aromatic gp. } substituent gp.



where $n = 0, 1, 2, 3, \dots$

$R_1 = R_2 =$ para ester $=$ alkyl, alkoxy or aryl gp etc.

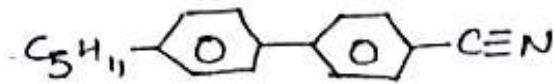
$X =$ rigid gp. $=$ $-\text{CH}=\text{N}-$ Schiff's base, $-\text{N}=\text{N}-$ diazo compound, $-\text{N}=\text{N}-$ Azoxy.

$-\text{CH}=\text{N}-$ Nitrosones, $-\text{CH}=\text{CH}-$ Stilbenes, $-\text{O}-\text{C}(=\text{O})-$ Ester

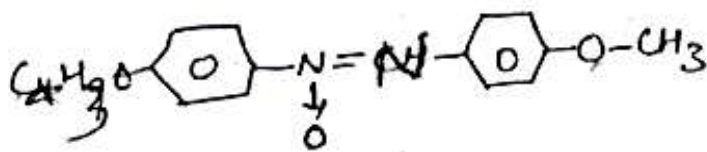
③ ~~Rigidity~~ Liquid crystal molecules are rigid in nature. The need of rigidity is satisfied by restricting the linkage gp. to those containing multiple bonds.

Examples of some liquid crystal molecules:

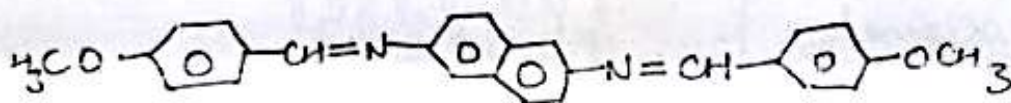
a) PCB [p-pentyl-p' cyanobiphenyl]



b) PAA [p-azoxy anisole]



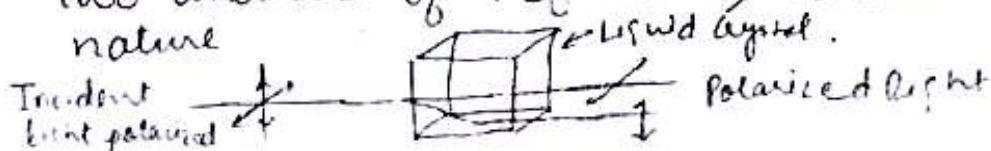
c) MBBA (4-methoxybenzylidene-4' butylaniline)



④ The most distinguish characteristics of liquid crystalline state is the tendency of molecules to point a common axis, called director (\hat{n}). Basically, director is average direction of the molecules. (Because of the elongated shape, under appropriate conditions, the molecules can exhibit orientational order, such that all axes line up in a particular direction.)

⑤ Liquid crystal are ^{shows} highly anisotropic physical (optical, mechanical, symmetrical etc) properties.

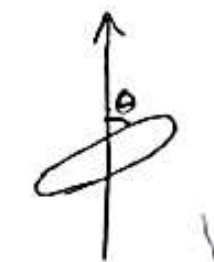
Also, Liquid crystal are found to be birefringent (having two indices of refraction) due to their anisotropic nature.



.. (6) Liquid crystal molecules exhibits the $\frac{3}{2}$ order because of their elongated shapes ~~are~~ under appropriate conditions. The "amount of order" is measured by the order parameter of the liquid crystal, which can be found represented by averaging the function.

$$\frac{3 \cos^2 \theta - 1}{2}$$

where ' θ ' \rightarrow angle of long axis of molecule in a particular direction.

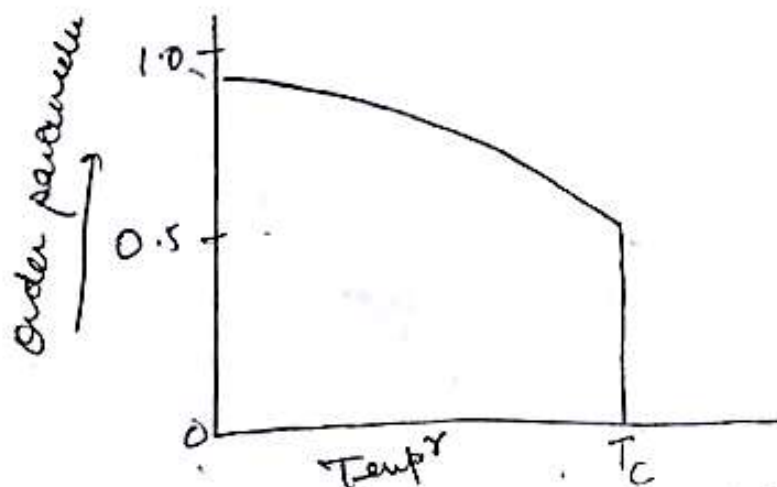


Original Orientation



Strong Electric field

Amount of order is in between 0 to 1 and is highly dependent on temperature of sample



$T_c \approx$ Temp. of Transition b/w LC and Liquid state.

Liquid crystals

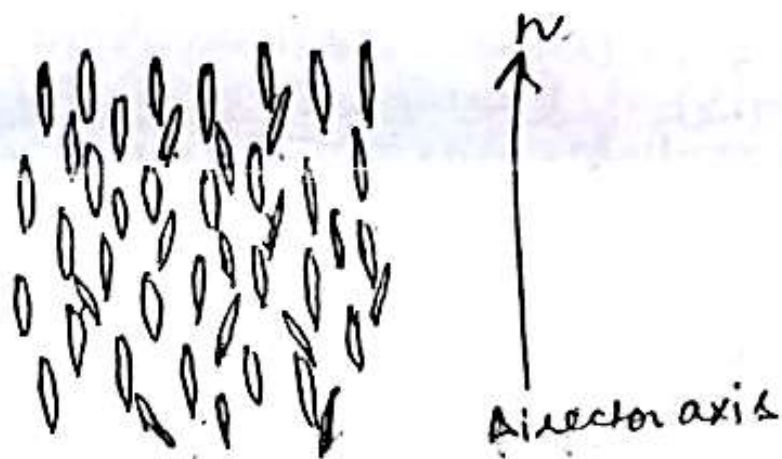
Thermotropic
LC

Lyotropic
LC

Thermotropic LC are established by adjustment of temperature. The phase transitions are effected by changing the temperature.

3 major class of LC (distinguished by molecular order they exhibits)

① Nematic LC: The molecules in nematic structure maintain a parallel or nearly parallel arrangement to each other along the molecular axis as shown in figure:



Salient features:

- Structure is one-dimensional, uniaxial symmetry.
- Molecules possess only orientational order but no positional long range order.
- Behaviour of Nematic LC are closer to true anisotropic liquid. (Newtonian flow)
- Nematic LC exhibits normal flow characteristics having low viscosity; they flow readily.
- Nematic LC appear to be "thread-like" when viewed through polarized light.

Example: (1) p-azoxyanisole $\rightarrow 116^\circ\text{C}$
T. Temp.

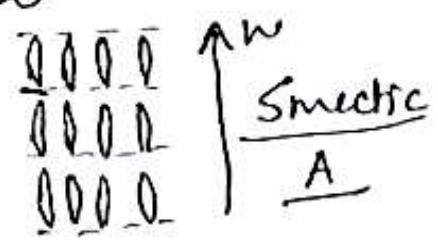
(2) p-azoxy phenetole $\rightarrow 137^\circ\text{C} \rightarrow 167^\circ\text{C}$
T. Temp. melting pt.

pre-hydrated
ethyl

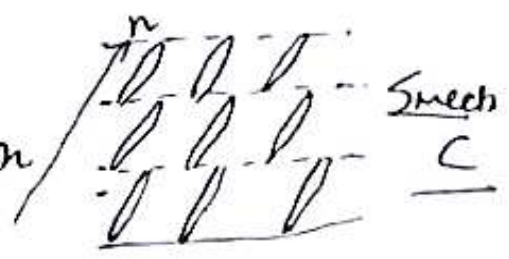
(B) Smectic Liquid Crystal \rightarrow The smectic state is another distinct mesophase of liquid crystal. Salient features of this phase are as follows:

- 1) Molecules in smectic phase show a certain degree of translational order along with the orientational order. This translation order is absent in nematic LC. Due to this order ~~like nematic~~ they tend to align themselves in layers or planes.
- 2) Due to increased order, smectic state is more solid-like than the nematic.
- 3) Smectic liquid crystal do not flow as normal liquids. They have limited mobility. They flow in layers i.e. if different planes or sheets are gliding over each other. (Now Newtonian flow)
- 4) Like nematic crystal, smectic liquid crystal are always uniaxial.
- 5) Under polarized light, they have fan-like appearance. (Slippery substance) - Soap Cast - bottom
- 6) Many compounds are observed to have more than one type of smectic phase.

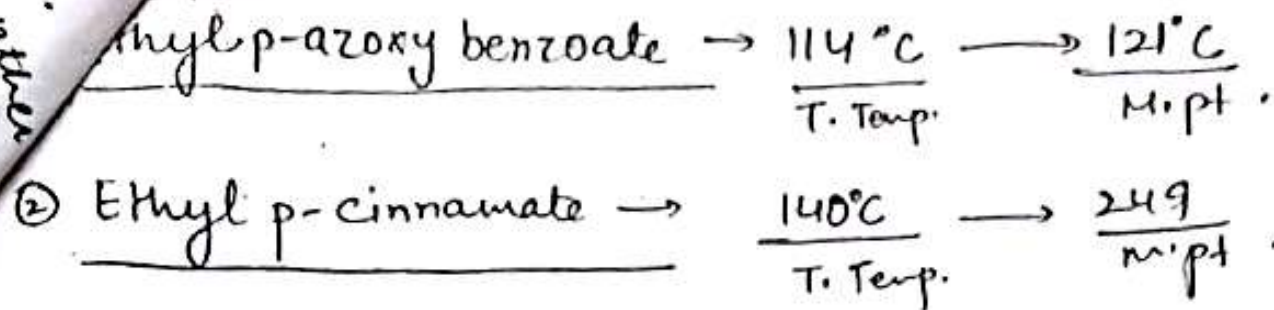
In Smectic A, the director is perpendicular to smectic plane and there is no particular positional order. (Uniaxial)



In Smectic C, molecules are arranged as in smectic-A, but director is at a constant tilt angle to smectic plane

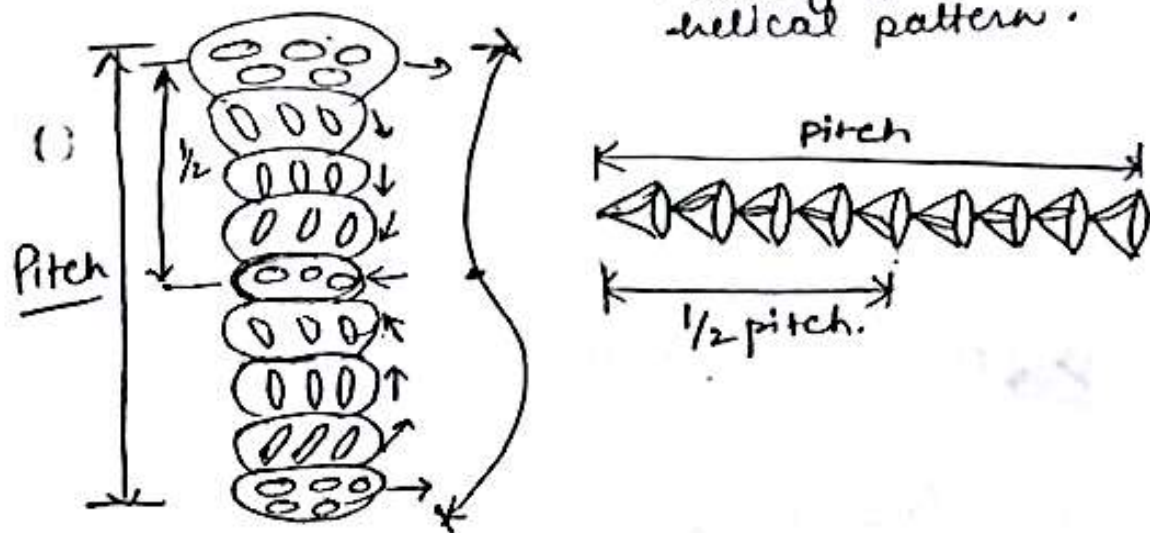


another



③. Cholestic Phase:

The cholestic (or chiral nematic) liquid crystal phase is typically composed of nematic mesogenic molecules containing a chiral center which produces intermolecular forces that favour alignment b/w molecules at slight angle to each other. This leads to formation of a layered structure (like smectic) in which director of each layer twisted with respect to above and below and form a stack as shown in figure. In this structure, the directors actually form in a continuous helical pattern.



* An important characteristic of the cholestic phase is the 'pitch'.

The pitch 'p' is defined as the distance it takes for the director to rotate one full turn in a helix.

Molecules of cholesteric phase has ability to selectively reflect light of wavelength equal to pitch, so that a colour will be reflected when pitch is equal to corresponding wavelength in visible spectrum.

The pitch is temperature sensitive also, it decreases with increase in temperature.

Polymorphism in Thermotropic Liquid Crystal

Polymorphism is a condition where more than one phase is observed in liquid crystalline state. The temperature at which they transform to another phase is known as its "phase transition temperature".

The stability of particular type of liquid crystal depends on to the extent of destruction of molecular order by increasing the temperature. Thus, more ordered LC phase is closer to solid state. Therefore, the order of stability among LC phases with increasing temperature will be

Solid \leftrightarrow Smectic C \leftrightarrow Smectic A \leftrightarrow Nematic

\downarrow
Isotropic
Liquid

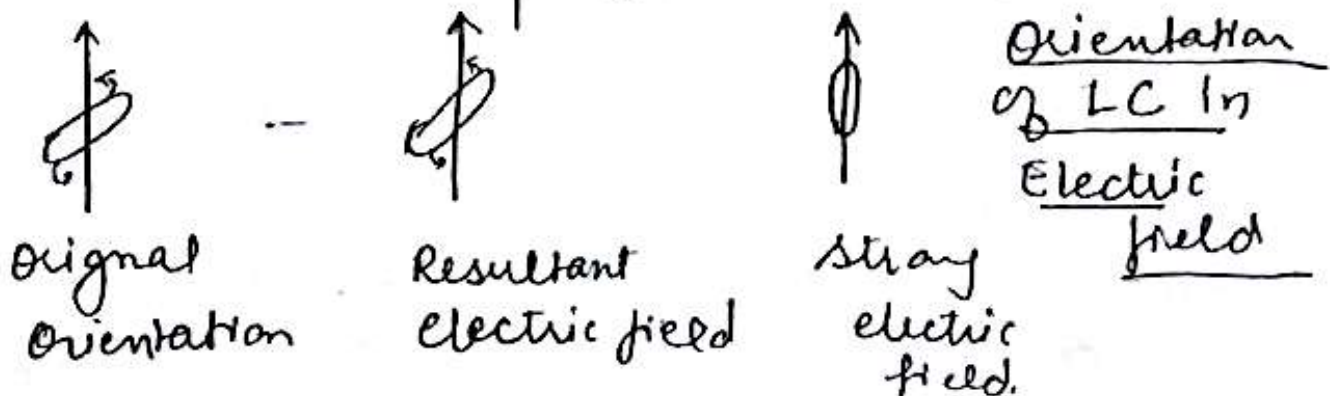
Lyotropic Liquid Crystal: Lyotropic mesophase occur in concentrated solutions of rod-like molecules in an isotropic solvent (usually water). The stability of these mesophase is as readily influenced by concentration of solution. Lyotropic mesophases are important in soaps, gels and colloids and are of great interest in biology.

Liquid C
in today's
optics

Principle of Liquid Crystal Display:

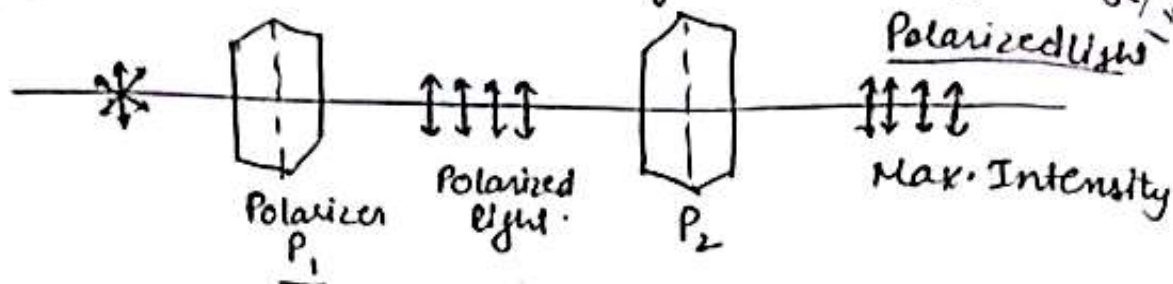
Liquid Crystal material are ~~key components~~ in today's technology as they possess unique optical properties. Liquid crystals are ideal for display devices because

- KC are light modifiers not light producers. So they consume very less power.
- The mesophase is fluid and therefore the molecules are easily moved by the application of an electric field.
- The alignment or orientation in a thin film of mesophase can be controlled by the application of electric field. The elongated LC molecules are aligned in one direction and give one optical property and when an electric field is applied, the ~~fluid~~ LC molecules reorient to give different optical properties. Hence the use in display.

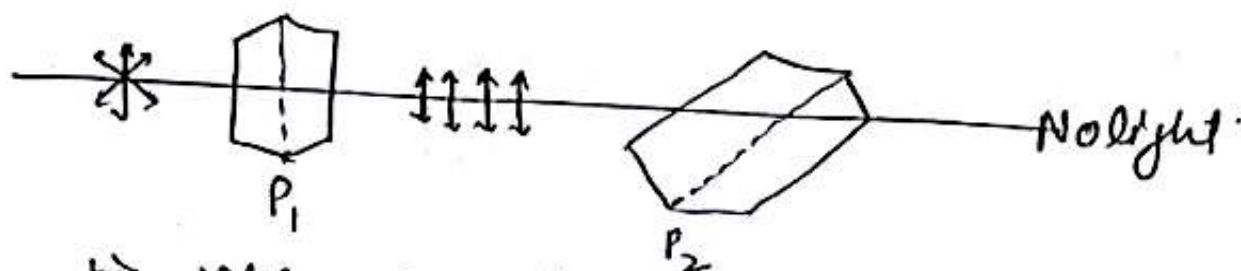


- Based on their alignment, due to their rod-shaped structure they can rotate the direction of polarised light ~~as~~ polarizers can do. Polarization phenomenon

can be understood by following diagram

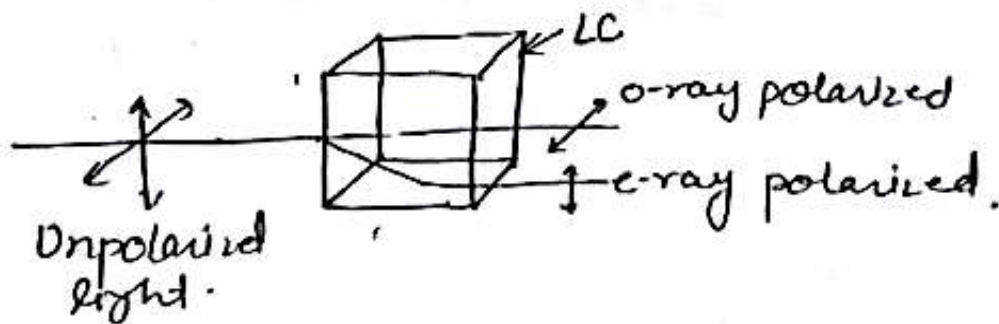


a) When P_2 and P_1 are \parallel ed.



b) when P_2 and P_1 are perpendicular.
Polarization in absence of any material.

In presence of Liquid crystal material which act as birefringent (having two indices of refraction), light travels as shown below:



In order to understand the principle of Liquid crystal display, we must understand the basic structure of liquid crystal display.

- A liquid crystal cell consists of thin layer (about $10\mu\text{m}$) of a liquid crystal molecules sandwiched b/w two glass sheets, each with conductive transparent coating (Indium tin oxide ITO) that act as an electrode.

Image

Spacers to control cell gap.

Two crossed polarizers (the polarizer and analyzer which are perpendicular to each other)

Working: In a display (as shown in fig.), LC material is sealed b/w two glass plates, each of which has polarizer on its outside. The transparent conductor (usually ITO) on inner surface of the glass sheet are used to control the electric field on the cell and thus the direction of liquid crystal molecule.

Basically, LCD made up of any number of colour or monochrome pixels. Each pixel consists of liquid crystal molecule which are suspended b/w two transparent perpendicular polarizers. In absence of anything ⁱⁿ b/w them, light passing through one would be blocked by another. The twisted LC changes the polarization of light entering one filter to allow it to pass through the other. By applying measured electrical charges to each pixel, the twist in nematic crystal can be controlled, allowing varying degree of light to pass through.



Working of LC Display

(a) when light or electric supply is off

(b) when electric supply is on

2/ Sep 12/21

When a voltage is applied to electrode, the liquid crystal molecules tend to align with resultant electric field 'E' and it would be perpendicular to polarizer which results into blockage of light. And the cell becomes dark.

When electric field is turned off, the molecules relax back to their twisted state and the cell becomes transparent again.

For colour LCD's in which picture display in colours, there are colour filter with three subpixels red, green and blue colour.

Different Liquid Crystal Display Material

In comparison to CRT, LCD displays are preferred ~~over~~ CRT. Because of

- (1) The first factor is size. There is no bulky tube as in CRT. So, LCD are compact and lighter in size.
 - (2) LCD's use much less power than CRT. They use only ambient light source to illuminate the display while in CRT, an electron ray is produced which consumes more power.
- So, LCD's are light modifiers not light producers.

Types of LCD's display

(15)

① Super Twisted Nematic (STN) and Twisted nematic (TN) display:

- Low molecular weight.
- TN configuration sets up 90° twist while STN molecules are twisted to $180-270^\circ$.
- Lower viscosity, larger ~~birefringence~~ birefringence and dielectric anisotropy.
- STN's require less power and less expensive.

Therefore, STN display are used in some inexpensive mobile phones, laptops and portable computers while TN used in watches & calculators.

Dis: ① Lower Image Quality.
advantage ② Slower response time.

② Ferroelectric LCD materials (FLC):

- Ferroelectric material used as LC material
- Faster Response time
- Reduced cost.

Dis: ① Easily destroyed by mechanical shock.
② Difficult to fabricate.

(3.3) Nematic Cholesteric Phase Transition display

Principle:

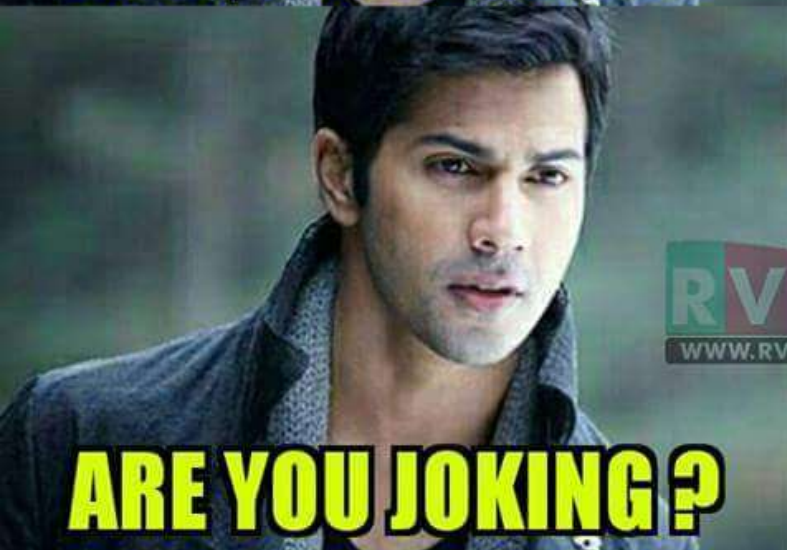
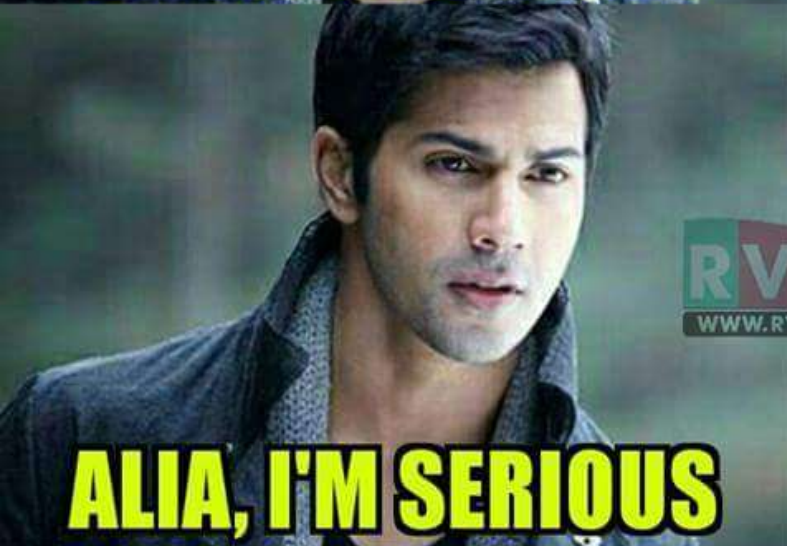
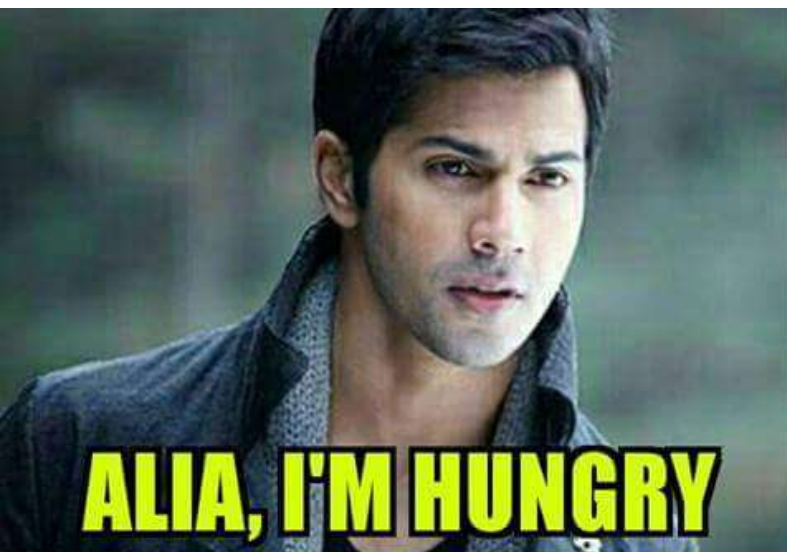
NCPT is a chiral material provides a very bright projection. With these materials it is possible to manufacture system with up to trillion pixels or even more.

(4) Polymer Dispersed Liquid Crystal (PDLC's) display

- Simplicity to fabricate.
- Improved brightness
- No polarizers used. ✓
- Used mostly in projection television
- Active matrix used. ✓
- High resolution

Nanotech
Gel





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