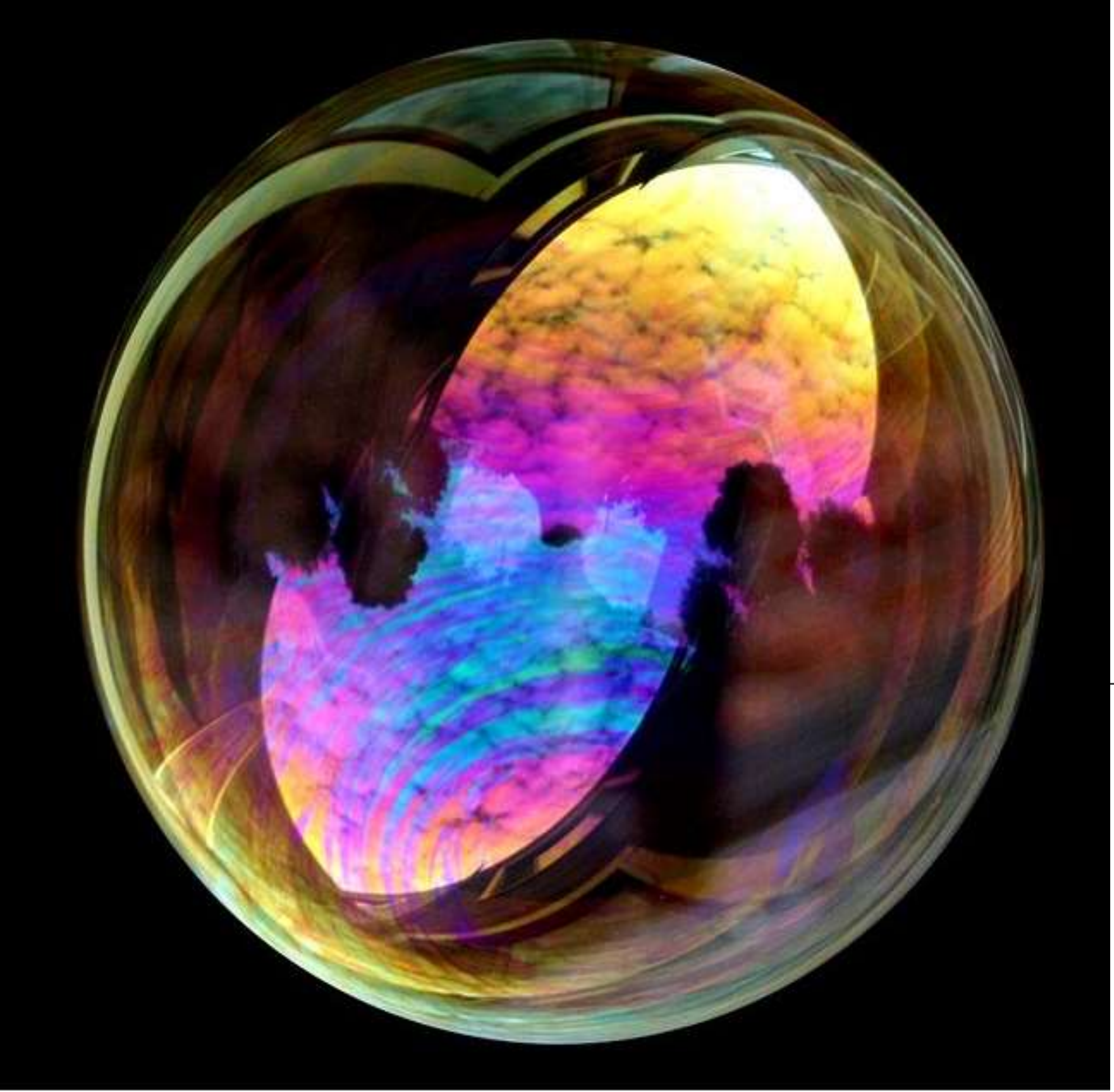


OPTICS

THE ART & SCIENCE

Major Topics

Physical Properties of light

INTERFERENCE.

DIFFRACTION.

POLARIZATION.

Are you still thinking that **PHYSICS** is

(1) **not beautiful**,

(2) **dull** &

(3) **boring**?!

The pictures in the coming slides might change your mind !!!!!!

THE ART OF DOING OPTICS

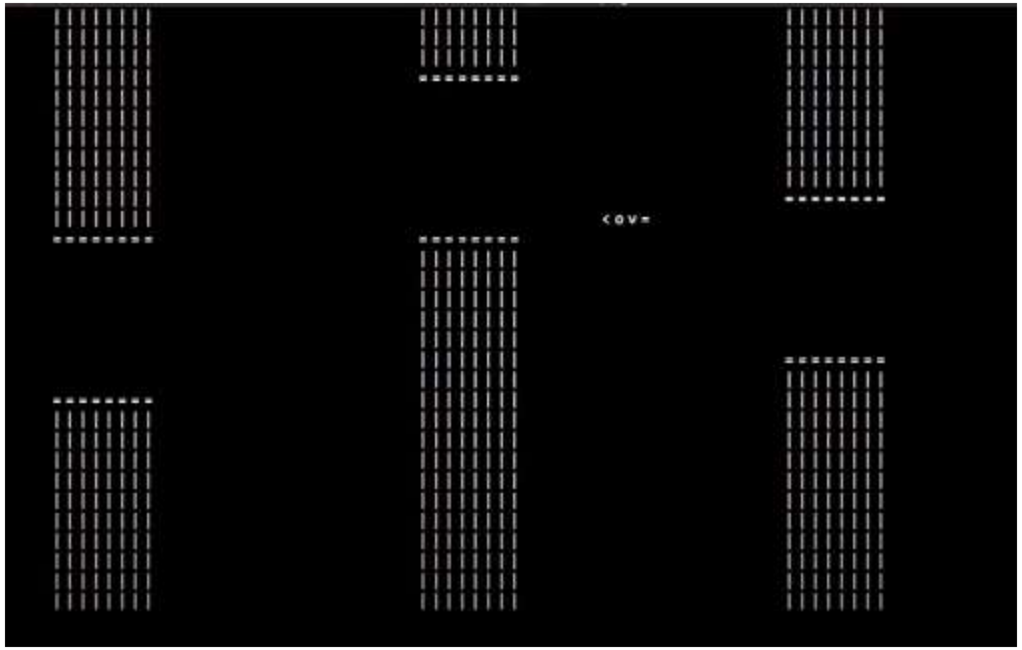
IS SAME AS THE ART OF CODING

This is **THE CODE**

AND

This is **the**

ART/GAME: The Flappy Bird



```
<script>//(c)2010 Oscar Toledo G.
var B,i,y,u,b,I=[],G=120,x=10,z=15,M=1e4,l=[5,3,4,6,2,4,3,5,1,1,1,1,1,1,1,1,9,9
,9,9,9,9,9,9,13,11,12,14,10,12,11,13,0,99,0,306,297,495,846,-1,0,1,2,2,1,0,-1,-
1,1,-10,10,-11,-9,9,11,10,20,-9,-11,-10,-20,-21,-19,-12,-8,8,12,19,21];function
X(w,c,h,e,S,s){var t,o,L,E,d,O=e,N=-M*M,K=78-h<<x,p,g,n,m,A,q,r,C,J,a=y?-x:x;
y^=8;G++;d=w||s&&s>=h&&X(0,0,0,21,0,0)>M;do{if(o=I[p=O]){q=o&z^y;if(q<7){A=q--&
2?8:4;C=o-9&z?[53,47,61,51,47,47][q]:57;do{r=I[p+=l[C]];if(!w|p==w){g=q|p+a-S?0
:S;if(!r&(!!q|A<3||!!g)||(r+1&z^y)>9&&q|A>2){if(m=!(r-2&7))return y^=8,I[G--]=
O,K;J=n=o&z;E=I[p-a]&z;t=q|E-7?n:(n+=2,6^y);while(n<=t){L=r?l[r&7|32]-h-q:0;if(
s)L+=(1-q?l[(p-p%x)/x+37]-l[(O-O%x)/x+37]+l[p%x+38]*(q?1:2)-l[O%x+38]+(o&16)/2:
!!m*9)+(!q?!(I[p-1]^n)+!(I[p+1]^n)+l[n&7|32]-99+!!g*99+(A<2):0)+!(E^y^9);if(s>h
||1<s&s==h&&L>z|d){I[p]=n,I[O]=m?(I[g]=I[m],I[m]=0):g?I[g]=0:0;L-=X(s>h|d?0:p,L
-N,h+1,I[G+1],J=q|A>1?0:p,s);if(!(h||s-1|B-O|i-n|p-b|L<-M))return W(),G--,u=J;
J=q-1|A<7||m||!s|d|r|o<z||X(0,0,0,21,0,0)>M;I[O]=o;I[p]=r;m?(I[m]=I[g],I[g]=0):
g?I[g]=9^y:0;}if(L>N||s>1&&L==N&&!h&&Math.random()<.5){I[G]=O;if(s>1){if(h&&c-L
<0)return y^=8,G--,L;if(!h)i=n,B=O,b=p;}N=L;}n+=J||(g=p,m=p<O?g-3:g+2,I[m]<z|I[
m+O-p]||I[p+=p-O])?1:0;}}}}while(!r&q>2||(p=O,q|A>2|o>z&!r&&++C*--A));}}}while(
++O>98?O=20:e-O);return y^=8,G--,N+M*M&&N>-K+1924|d?N:0;}B=i=y=u=0;while(B++<
120)I[B-1]=B%x?B/x%x<2|B%x<2?7:B/x&4?0:l[i++]|16:7;for(a=
"<table cellspacing=0 align=center>",i=18;i<100;a+=++i%10-9?
"<th width=60 height=60 onclick=Y("+i+") id=o"+i+
" style='line-height:50px;font-size:50px;border:2px solid #dde' bgcolor=#"+
(i*.9&1?"c0c":"f0f")+"0f0>":(i++,"<tr>"));
a+="<th colspan=8><select id=t style='font-size:20px'><option>&#9819;<option>";
document.write(a+"&#9820;<option>&#9821;<option>&#9822;</select></table>");
function W(){B=b;for(p=21;p<99;++p)if(q=document.getElementById("o"+p)){q.
innerHTML="\xa0\u265f\u265a\u265e\u265d\u265c\u265b  \u2659\u2654\u2658\u2657\u2656\u2655".charAt(I[p]&z);
q.style.borderColor=p==B?"red":"#dde";}}W();
function Y(s){i=(I[s]^y)&z;if(i>8){b=s;W();}else if(B&&i<9){b=s;i=I[B]&z;if((i&
7)==1&(b<29|b>90))i=14-document.getElementById("t").selectedIndex^y;X(0,0,0,21,
u,1);if(y)setTimeout("X(0,0,0,21,u,2/*ply*/),X(0,0,0,21,u,1)",250);}}
</script>
```

?

The **ART**


Toledo JavaScript Chess by Oscar Toledo G.
https://nanochess.org/chess.html

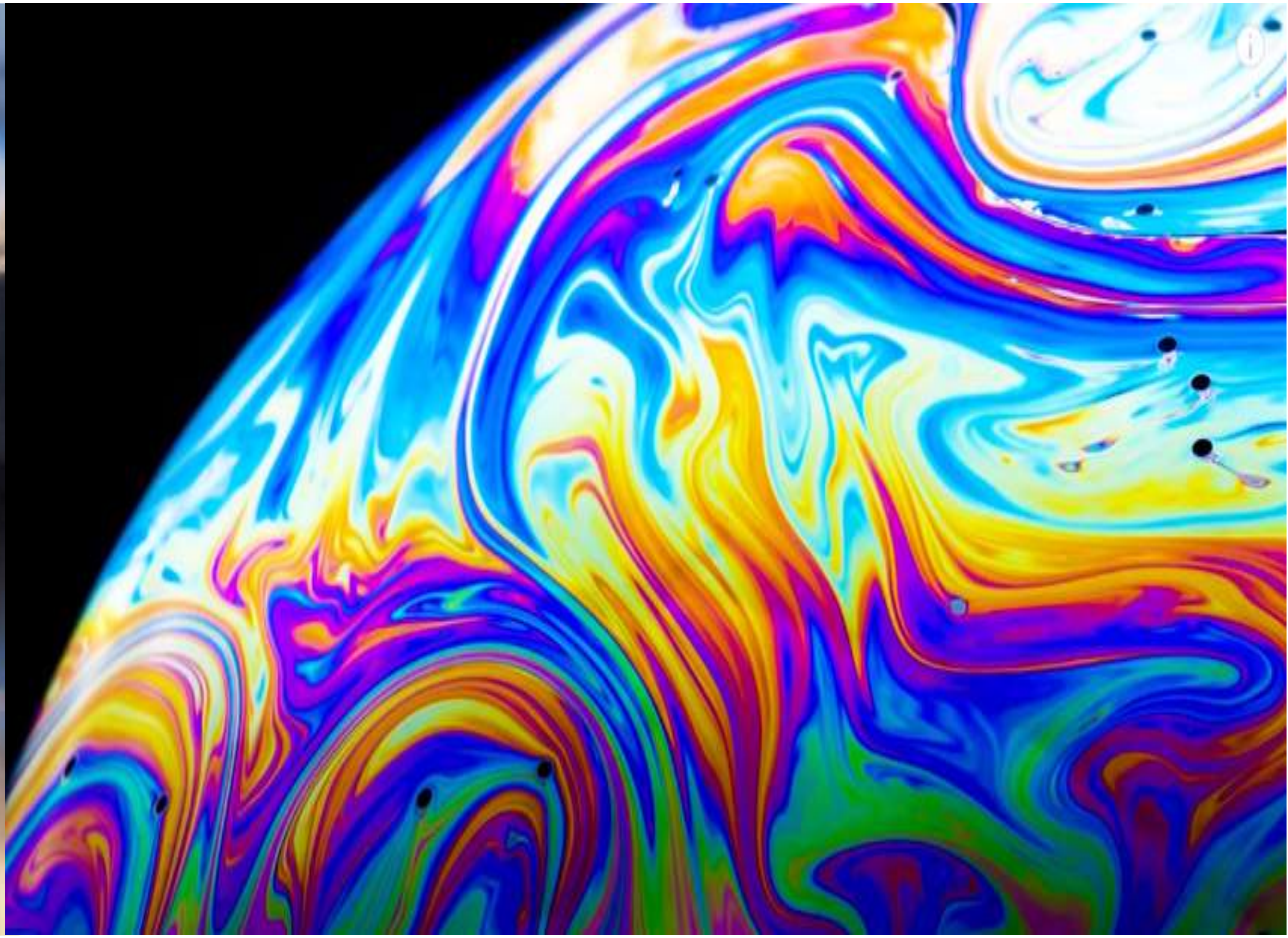
And in OPTICS……….

$2\mu t\cos r = n\lambda$, $n=0, 1, 2,\ldots\ldots$

&

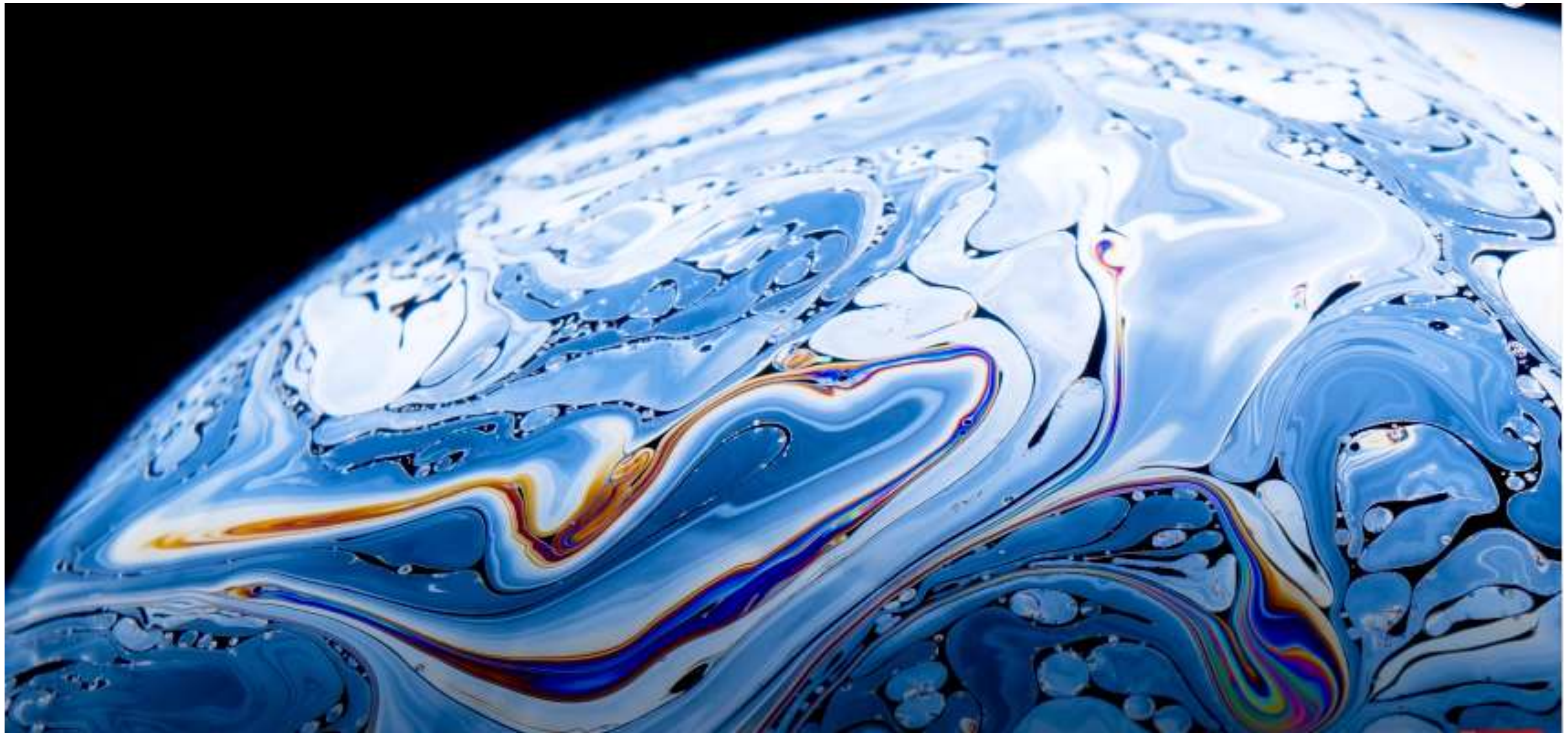
$2\mu t\cos r = (2n+1)\lambda/2$, $n=0, 1, 2,\ldots\ldots$

= ?

Courtesy: Khaled Youssef, ‘**The world in soap bubbles’**

Courtesy: Mike Smith



Courtesy: Mike Smith

INTERFERENCE

▲ *The colors in many of a hummingbird's feathers are not due to pigment. The iridescence that makes the brilliant colors that often appear on the throat and belly is due to an interference effect caused by structures in the feathers. The colors will vary with the viewing angle. (RO-MA/Index Stock Imagery)*

Butterfly, Thin-Film Interference

By: christopherconnock
18-01-2011

All these are the ART of

INTERFERENCE created by Arun Devkota_NCIT

AFTER THE ART OF

INTERFERENCE, LET'S ENTER

THE SCIENCE OF IT.

Terms in INTERFERENCE:

- Interference
- Condition of interference
- Coherent Sources
- Types of Interference
- Constructive Interference
- Destructive Interference
- Phase difference & Path difference
- Analytical Treatment of Interference

- Thin Film
  - Due to reflected light
  - Due to transmitted light
- Newton's Rings
  - Due to reflected light
  - Due to transmitted light
- Applications of Newton's Rings
  - To find λ
  - To find μ
- Numericals of Thin film and Newton's Rings
- Optical and geometrical path

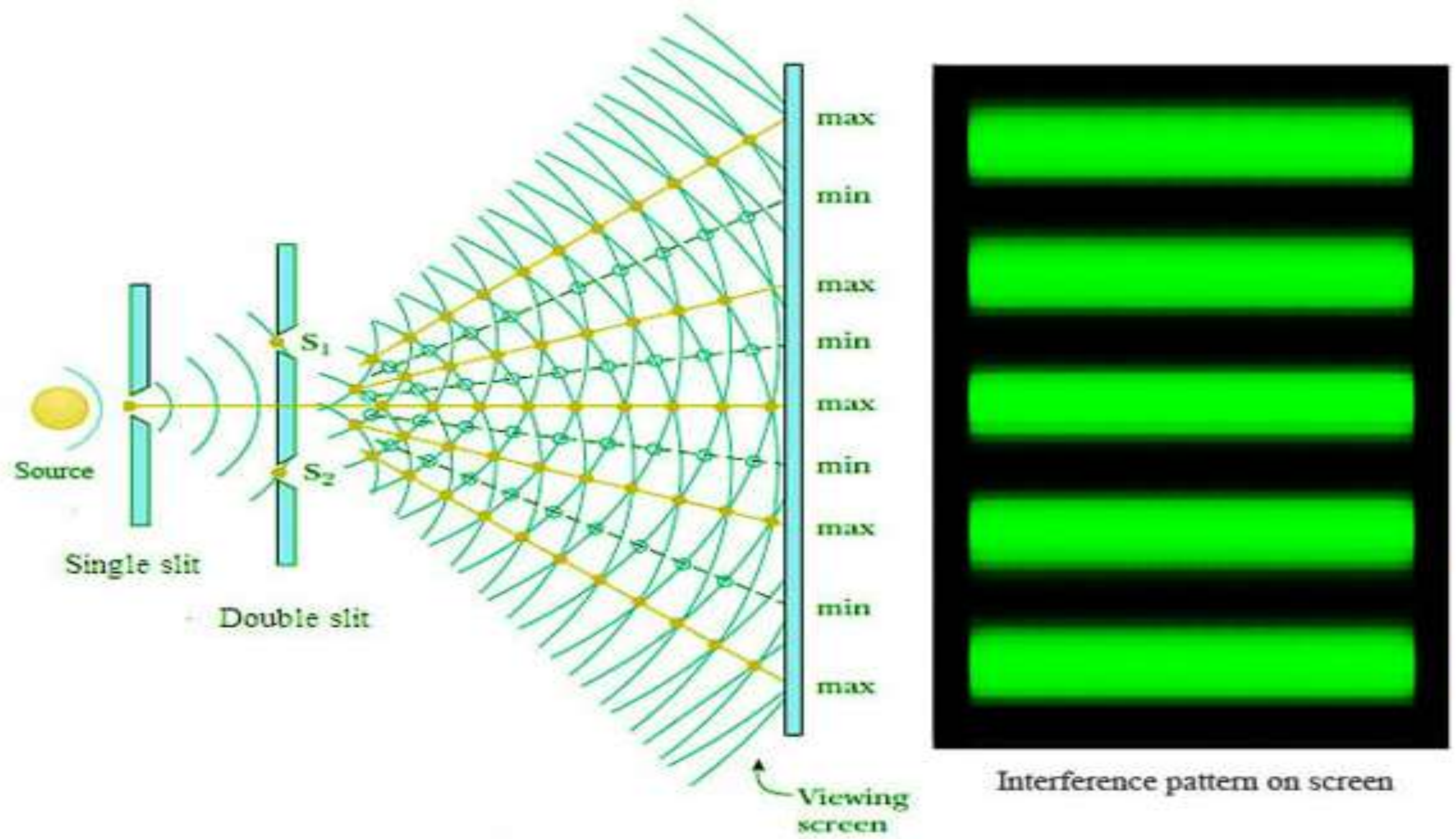
WATCH YOUTUBE CHANNEL: “VERITASIUM” titled The Original Double Slit Experiment.


Credit: Veritasium

Credit: Veritasium


Ve
Credit: Veritasium
5:37 / 7:39

By David Robison from Practical Law and Justice Nov 28, 2015



So, WHAT is INTERFERENCE ?

When two light waves from coherent sources meet together, then the distribution of energy due to one wave is disturbed by the other.

This modification in the distribution of light energy due to super-position of two light waves is called "Interference of light"

COHERENT SOURCES:

Those sources of light which emit light waves continuously of same wavelength, and time period, frequency and amplitude and have zero phase difference or constant phase difference are coherent sources.

There are two types of interference:

Constructive interference.

Destructive interference.

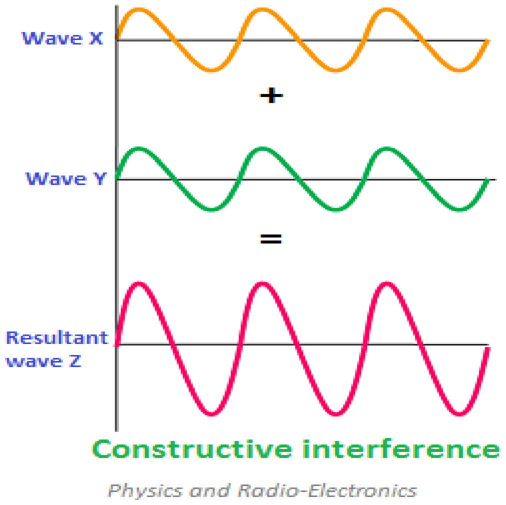
Difference between Constructive and Destructive Interference:

Constructive Interference

When two light waves superpose with each other in such away that the crest of one wave falls on the crest of the second wave, and trough of one wave falls on the trough of the second wave, then the resultant wave has larger amplitude and it is called constructive interference.

i.e.

Path difference $= n\,\lambda$, n=0,1,2….



Destructive Interference

When two light waves superpose with each other in such away that the crest of one wave falls on the trough of the second wave, and trough of one wave falls on the crest of the second wave, then the resultant wave has no amplitude and it is called destructive interference.

i.e.

Path difference $= (2n+1)\,\lambda/2$, n=0, 1, 2,…….

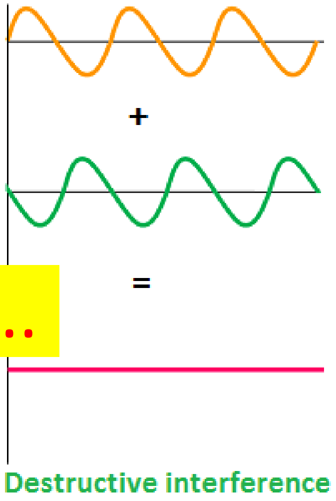
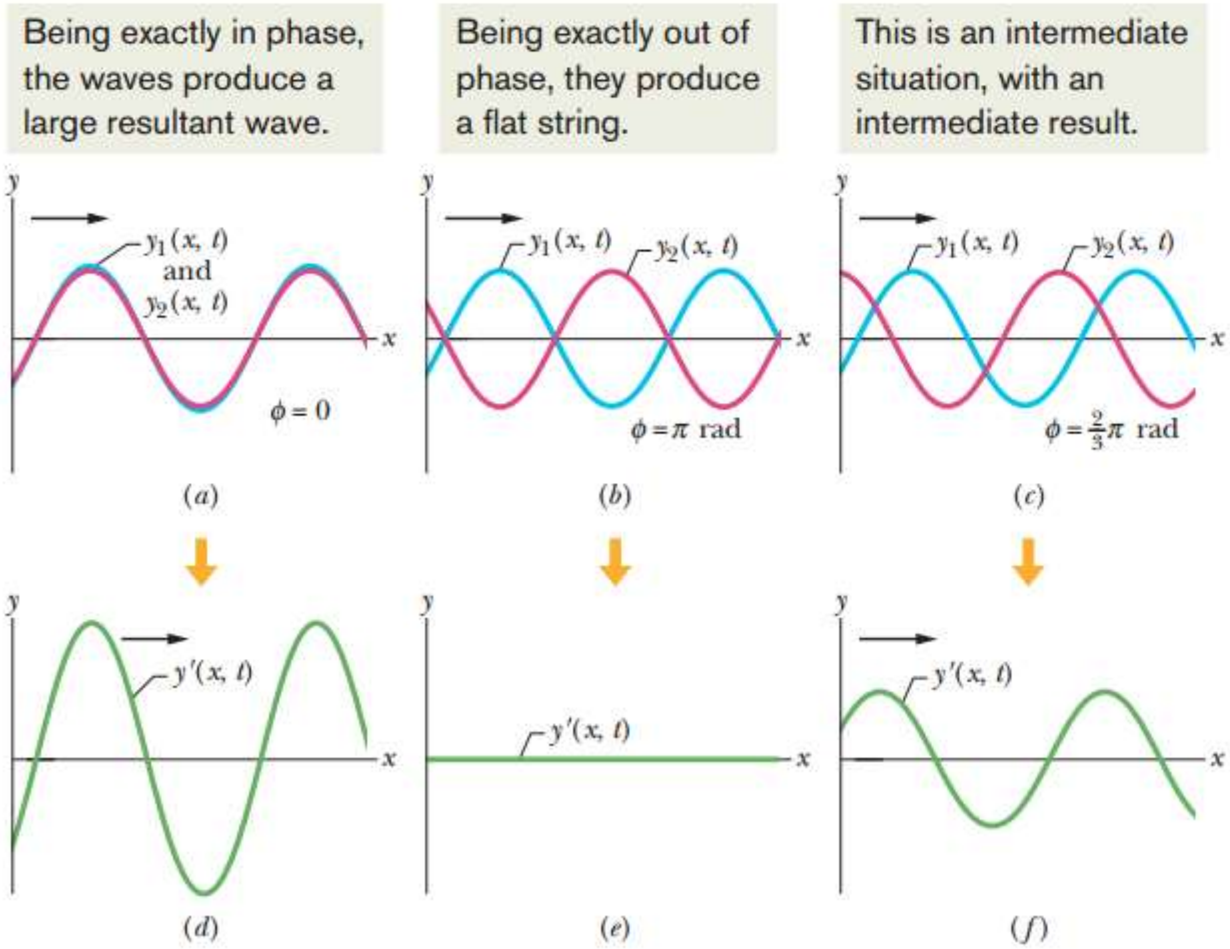


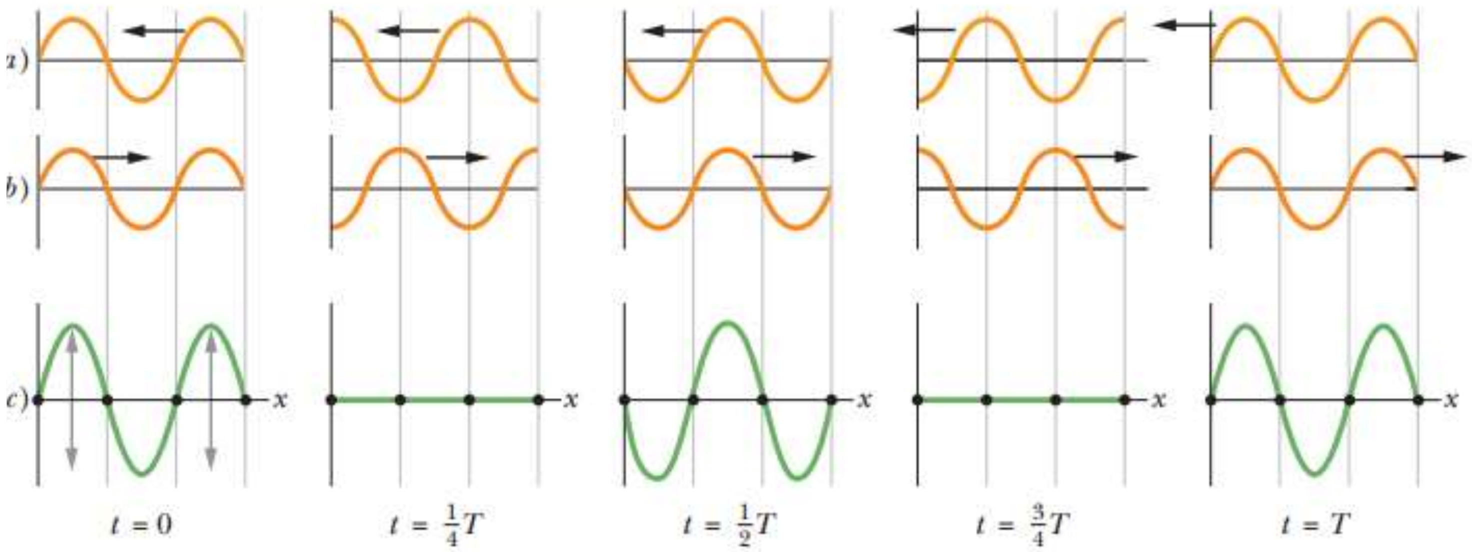
Figure 16-14 Two identical sinusoidal waves, $y_1(x, t)$ and $y_2(x, t)$, travel along a string in the positive direction of an x axis. They interfere to give a resultant wave $y'(x, t)$. The resultant wave is what is actually seen on the string. The phase difference ϕ between the two interfering waves is (a) 0 rad or 0°, (b) π rad or 180°, and (c) $\frac{2}{3}\pi$ rad or 120°. The corresponding resultant waves are shown in (d), (e), and (f).



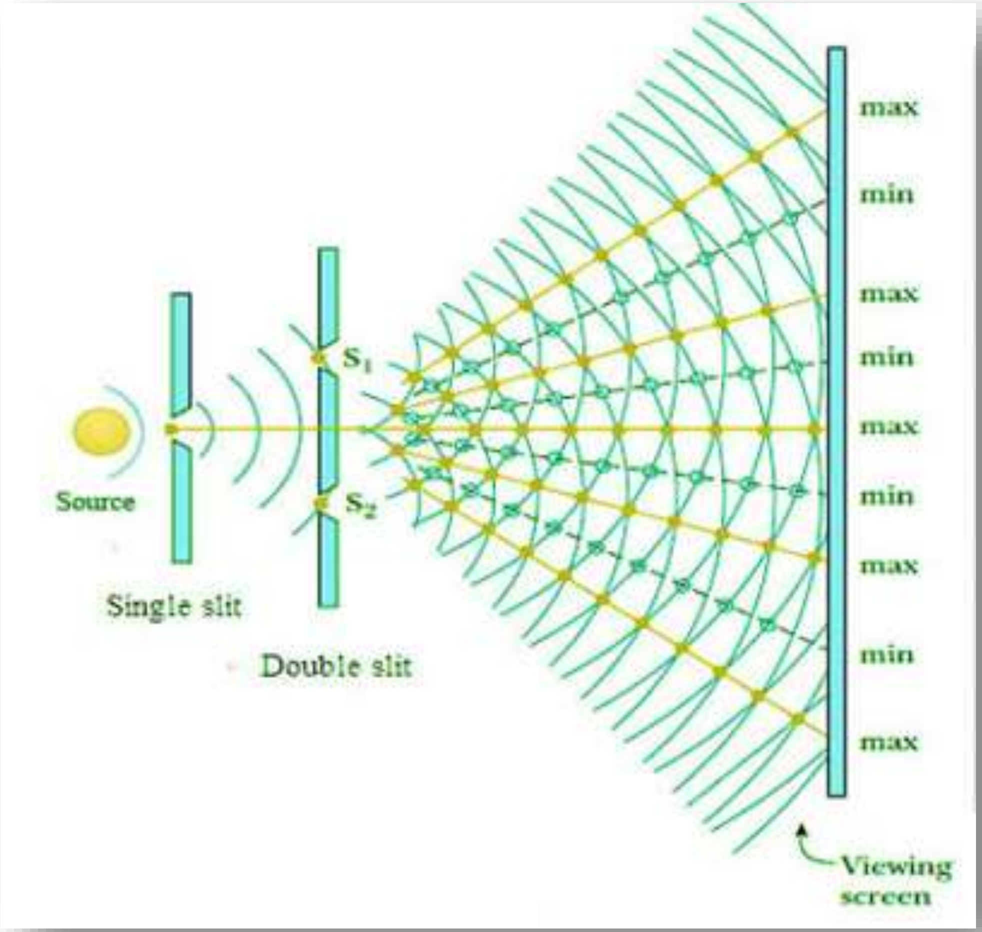
Credit: Resnick and Halliday

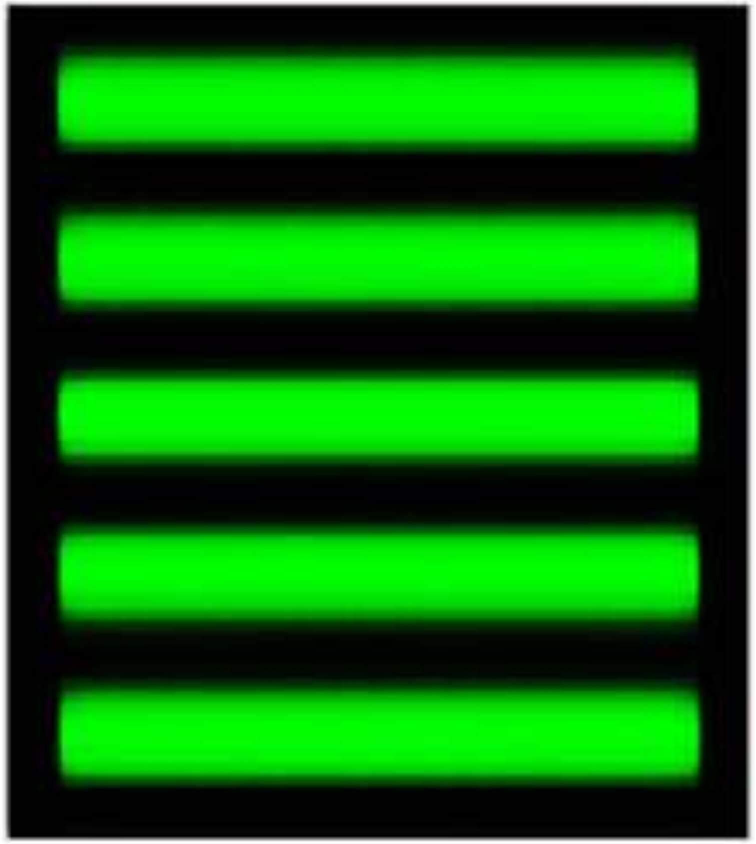
As the waves move through each other, some points never move and some move the most.

Figure 16-17 (*a*) Five snapshots of a wave traveling to the left, at the times t indicated below part (*c*) (T is the period of oscillation). (*b*) Five snapshots of a wave identical to that in (*a*) but traveling to the right, at the same times t. (*c*) Corresponding snapshots for the superposition of the two waves on the same string. At $t = 0, \frac{1}{2}T$, and T, fully constructive interference occurs because of the alignment of peaks with peaks and valleys with valleys. At $t = \frac{1}{4}T$ and $\frac{3}{4}T$, fully destructive interference occurs because of the alignment of peaks with valleys. Some points (the nodes, marked with dots) never oscillate; some points (the antinodes) oscillate the most.



Credit: Resnick and Halliday





Interference pattern on screen

Questions:

1. What is interference? What are the conditions for sustained interference?

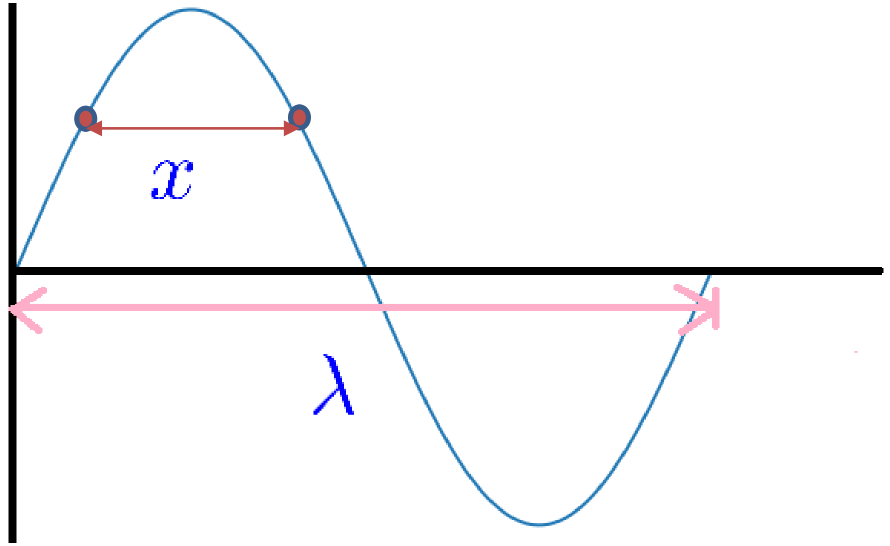
2. What are constructive and destructive interference? Analyze interference mathematically? (Long question: 9 marks)

or

3. What is the relation between path difference and phase difference? Give the analytical treatment of interference. (Long question: 9 marks)

Relation between Phase difference (ϕ) and Path difference (x):

$$\boxed{\phi = \frac{2\pi}{\lambda}x}$$



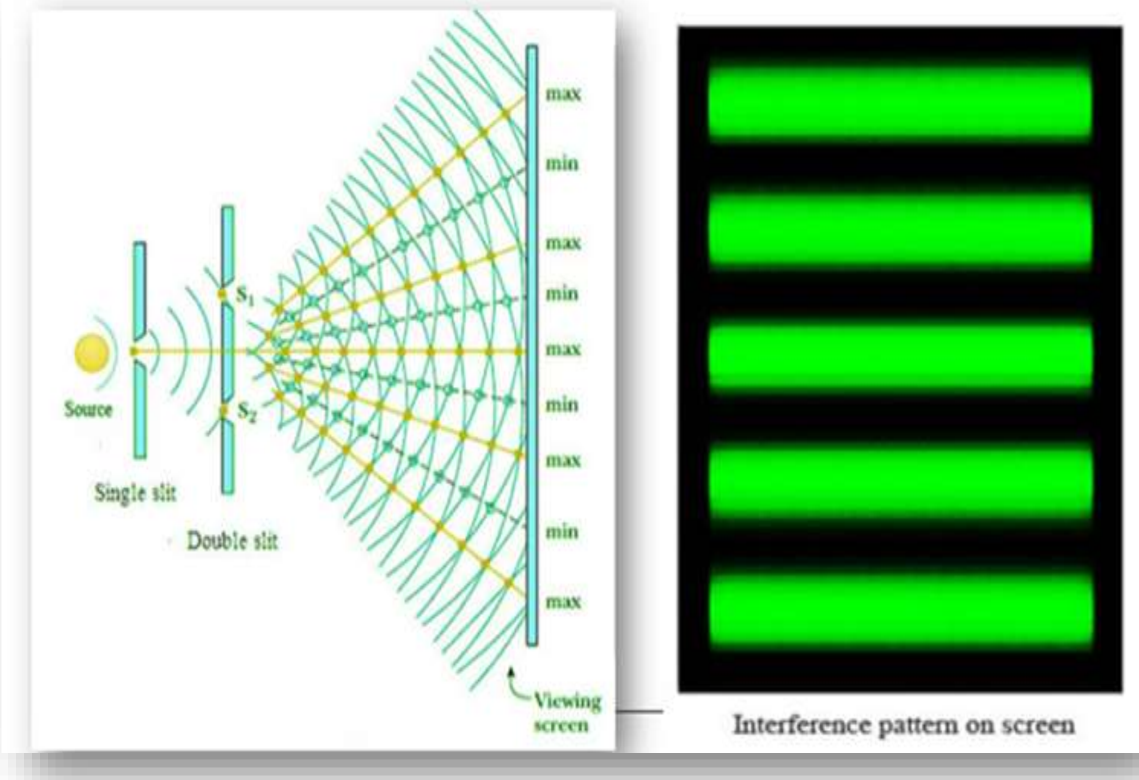
For λ Path difference, Phase difference $= 2\pi$

For 1 Path difference, Phase difference $= \dfrac{2\pi}{\lambda}$

For x Path difference, Phase difference $(\phi) = \dfrac{2\pi}{\lambda}x$

Mathematical or Analytical treatment of Interference:

(9 marks:Long Q)



Let the two light waves be represented by

$$y_1 = A \sin \omega t$$

& $$y_2 = A \sin(\omega t + \phi)$$

where $A,$ ω & ϕ are the amplitude, angular frequency and phase difference.

Now, the resultant wave is represented by

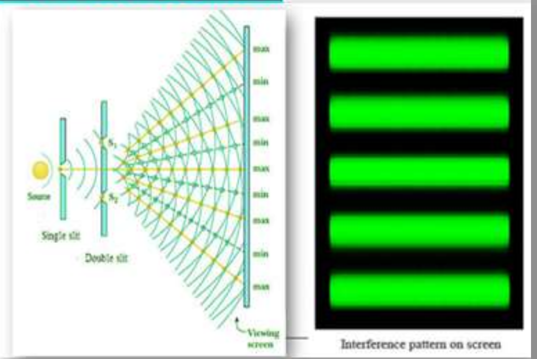
Mathematical or Analytical treatment of Interference:
(9 marks:Long Q)

Let the two light waves be represented by

$$y_1 = A\sin\omega t$$

& $$y_2 = A\sin(\omega t + \phi)$$

where $A,\ \omega$ & ϕ are the amplitude, angular frequency and phase difference.



Interference pattern on screen

Now, the resultant wave is represented by

$$y = y_1 + y_2$$
$$= A\sin\omega t + A\sin(\omega t + \phi)$$
$$= A[\sin\omega t + \sin(\omega t + \phi)]$$

Use the formula of $\sin(A + B)$

$$y = A[\sin\omega t + (\sin\omega t cos\phi + \cos\omega t sin\phi)]$$

$$y = A[\sin\omega t(1 + \cos\phi) + \cos\omega t sin\phi)] \quad \ldots\ldots\ \text{(i)}$$

Let $A(1 + \cos\phi) = R\cos\theta$ .... (ii)

and $A\sin\phi = R\sin\theta$ .... (iii)

where R and θ are the amplitude and the corresponding phase of the resultant wave.

From (i), (ii) and(iii),

$$y = R\cos\theta\sin\omega t + R\sin\theta\cos\omega t$$

$$= R[\cos\theta\sin\omega t + \sin\theta\cos\omega t]$$

$$= R\sin(\omega t + \theta)$$

which is the equation of S.H.M.

Squaring (ii) and (iii) and adding,

$$[A(1+\cos\phi)]^2 + A^2\sin^2\phi = R^2[\cos^2\theta + \sin^2\theta]$$

$$\implies A^2(1 + 2\cos\phi + cos^2\phi + sin^2\phi) = R^2$$

$$\implies A^2(2 + 2\cos\phi) = R^2$$

$$\Longrightarrow \; 2A^2(1+\cos\phi) = R^2$$

$$\Longrightarrow \; 2A^2.2\cos^2\frac{\phi}{2} = R^2$$

$$\Longrightarrow \; \boxed{R^2 = 4A^2\cos^2\frac{\phi}{2}}$$

Now, the intensity of the resultant wave is given by

$$I = R^2 = 4A^2\cos^2\frac{\phi}{2}$$

$$\Longrightarrow \; \boxed{I = I_0\cos^2\frac{\phi}{2}}$$ where $I_0 = 4A^2$, is the maximum intensity

Cases:

(i) For constructive interference,

$$I = I_0, \ maximum$$

$$\implies \phi = 0, 2\pi, 4\pi, 6\pi, ...$$

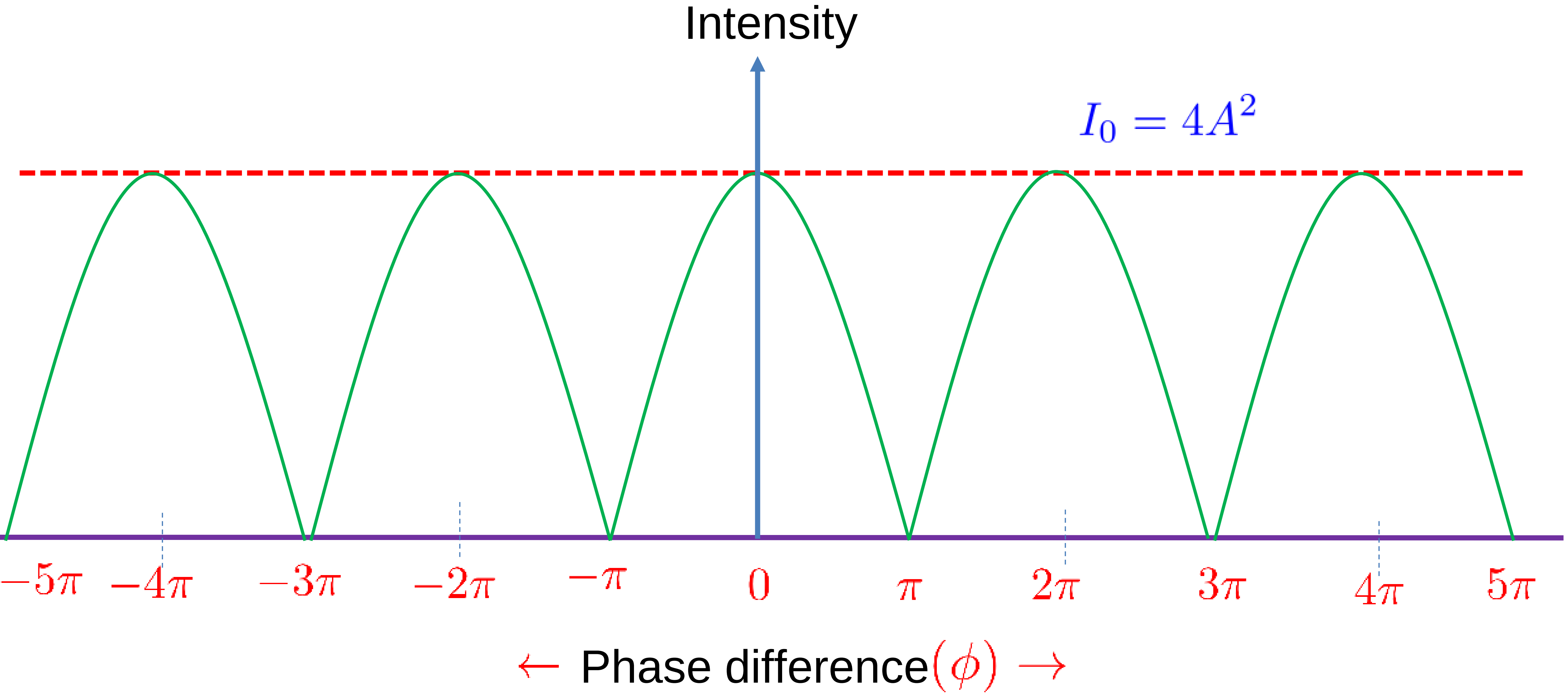
$$\implies path\ difference = n\lambda, n = 0, 1, 2, ...$$

(ii) For destructive interference,

$$I = 0, \ minimum$$

$$\implies \phi = \pi, 3\pi, 5\pi, 7\pi, ...$$

$$\implies path\ difference = (2n+1)\frac{\lambda}{2}, n = 0, 1, 2, ...$$



created by Arun Devkota_NCIT

Interference in thin film:

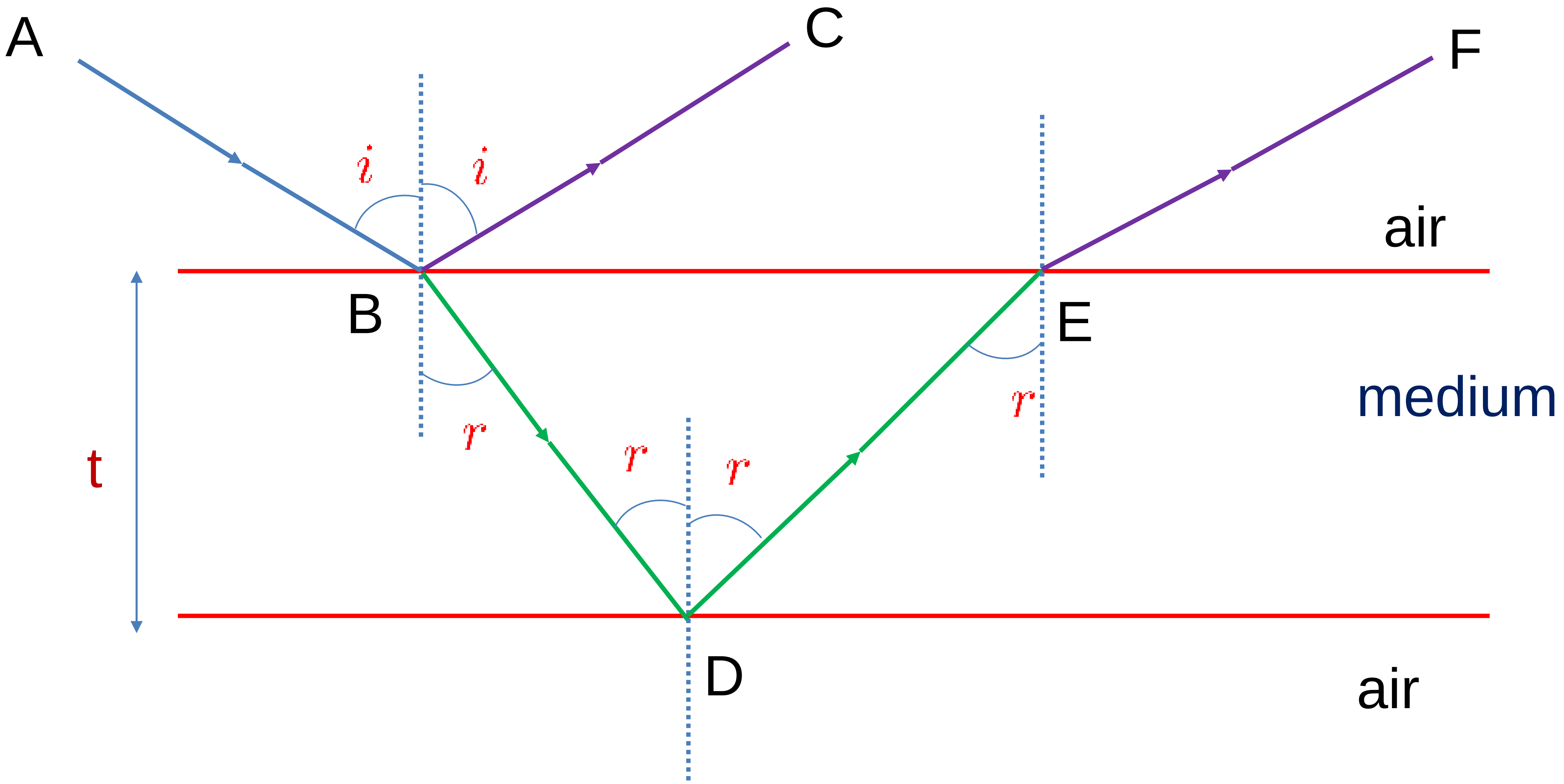
Thin film: A transparent medium of refractive index $\mu (\mu > 1)$ and of certain thickness t is called thin film. e.g. soap film, oil film.

Interference in thin film is of two types:

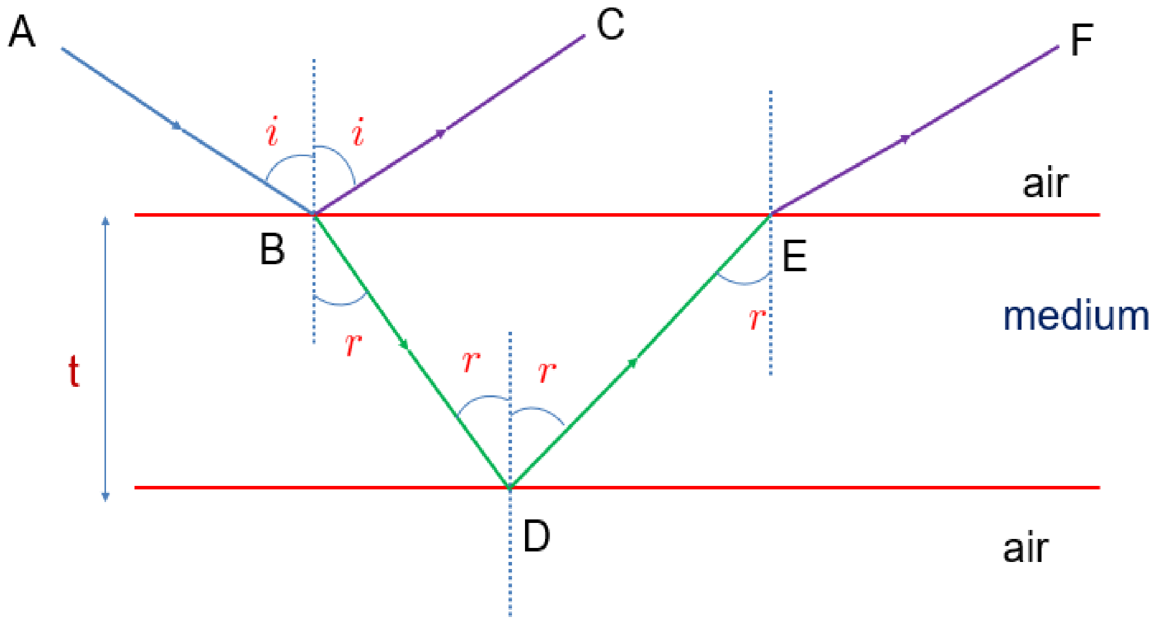
(i) Interference due to reflected light

(ii) Interference due to transmitted light

(i) Interference due to reflected light:



created by Arun Devkota_NCIT



Consider a thin film of refractive index μ and thickness t.

Let AB be the incident ray on the air - medium interface.

BC is the first reflected ray.

BD is the refracted ray which is reflected by the medium-air interface along DE and finally emerges along EF.

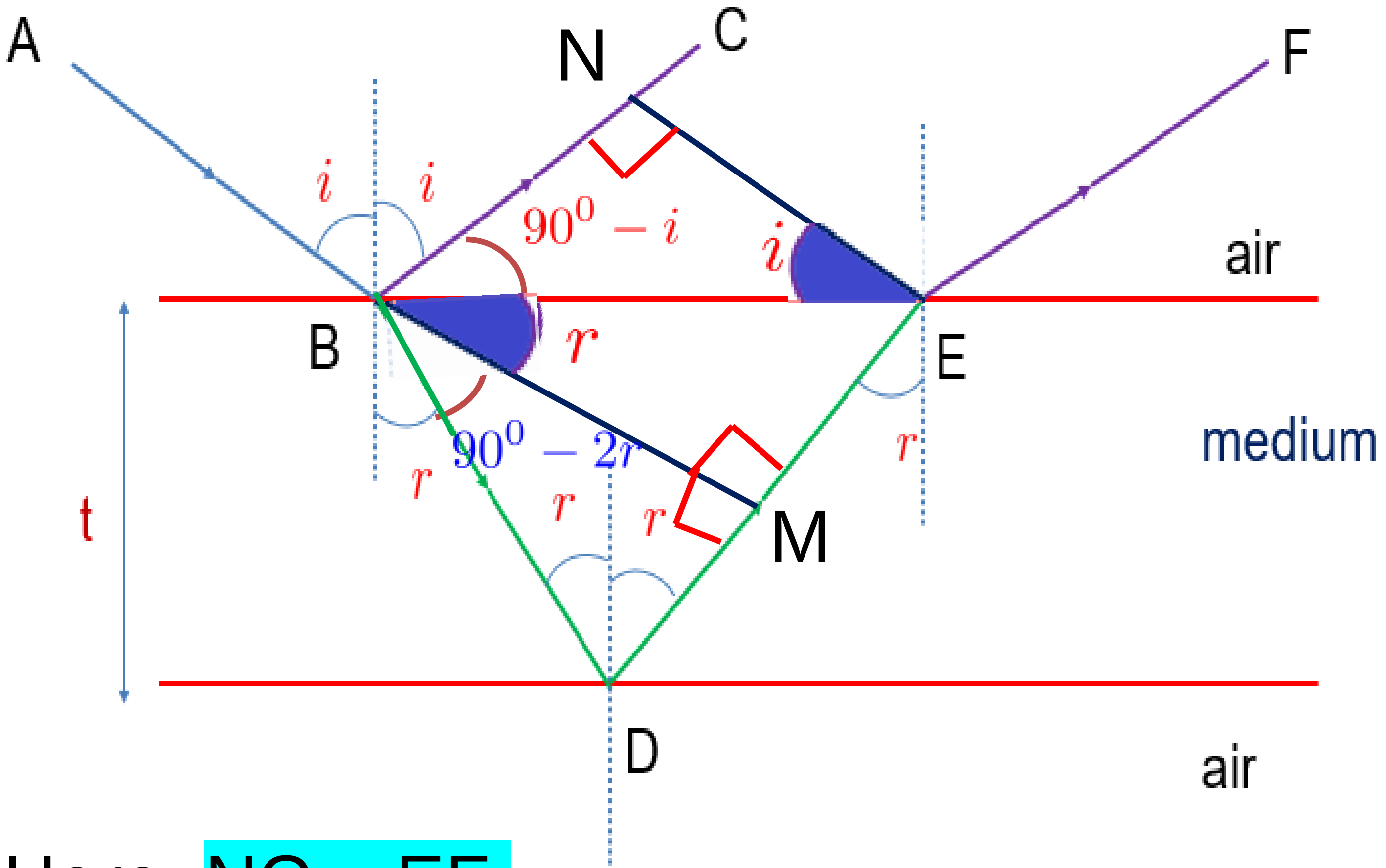
Now, the path difference between BC and EF is given by

$$x' = \mu(BD + DE) + EF - BC \quad \text{.....(i)}$$

The refractive index is given by

$$\mu = \frac{sin\ i}{sin\ r}$$

Now, draw EN and BM perpendicular to BC and DE.



Here, NC = EF

And BC = BN + NC

Then, equation (i) becomes

$$x' = \mu(BD + DE) - BN \quad \text{....(ii)}$$

In Δ BNE, $sin\ i = \dfrac{BN}{BE}$

In Δ BME,

$$sin\ r = \frac{ME}{BE}$$

Then,

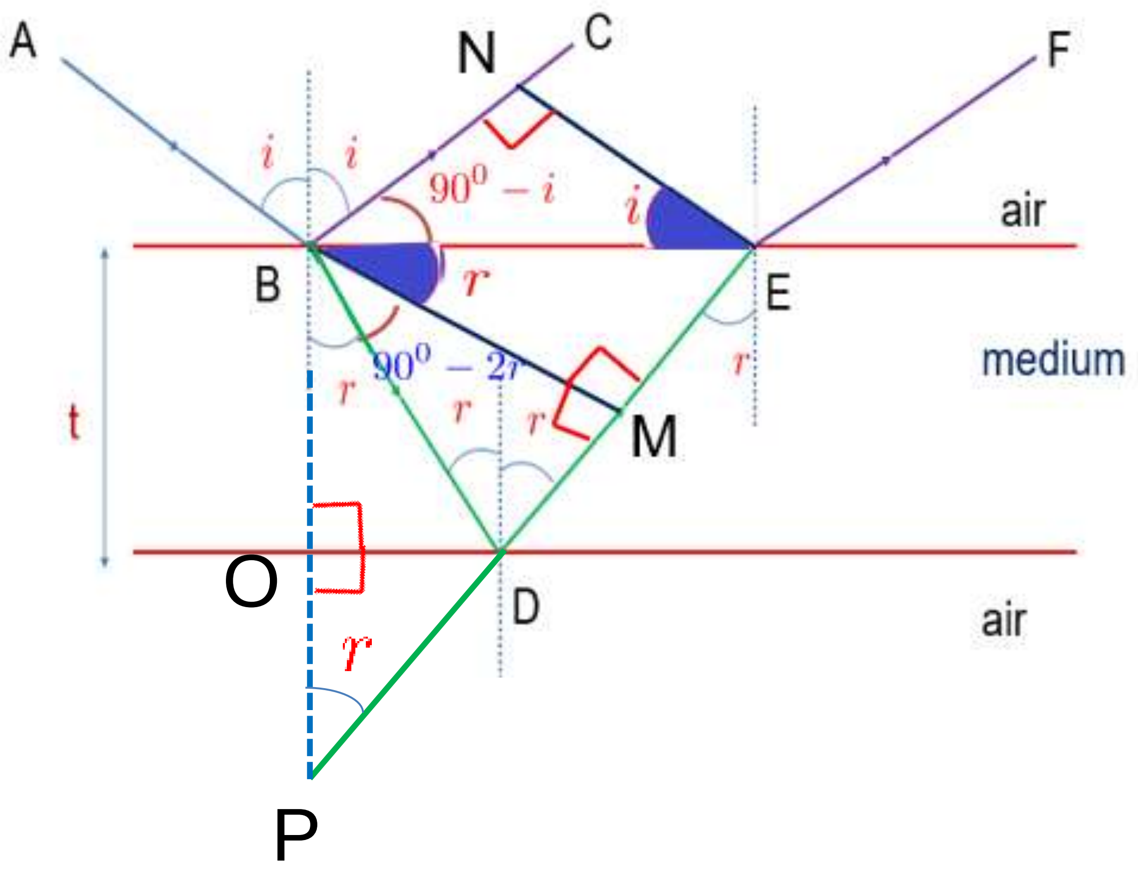
$$\mu = \frac{\sin\ i}{\sin\ r} = \frac{BN}{ME}$$

$$\Longrightarrow BN = \mu\ ME$$

So equation (ii) becomes

$$x' = \mu(BD + DE - ME)$$

$$\Longrightarrow \boxed{x' = \mu(BD + DM)}$$



Now produce ED back to the point P so as to meet the first normal.

Here,

$\Delta\, BOD \cong \Delta\, POD$ (by <u>A.A.S</u> axiom)

So, BD = PD & BO = OP = t

Then, equation

$$\boxed{x' = \mu(BD + DM)}$$ becomes

$$x' = \mu(PD + DM)$$

$$\Longrightarrow \boxed{x' = \mu PM} \quad \text{......(iii)}$$

In $\Delta\, BPM$, $\cos r = \dfrac{PM}{BP}$

$$\Longrightarrow PM = 2t\cos r$$

$$\Longrightarrow \boxed{x' = 2\mu t\cos r} \quad \text{....(iv)}$$

In case of reflection, there is additional path difference of $\lambda/2$ since a phase change of π radian occurs.

Hence, the actual path difference in thin film due to reflected light is given by

$$x = x' - \frac{\lambda}{2}$$

$$\Longrightarrow \boxed{x = 2\mu t cos r - \frac{\lambda}{2}}$$

Cases:

(i) For constructive interference, bright or maxima,

$$path\ difference = n\lambda,\ \ n = 0, 1, 2, 3, ...$$

$$\Longrightarrow \boxed{x = 2\mu t cos r - \frac{\lambda}{2} = n\lambda}$$

$$\implies \boxed{2\mu t cos r = n\lambda + \frac{\lambda}{2}}$$

$$\implies \boxed{2\mu t cos r = (2n+1)\frac{\lambda}{2}}, n = 0, 1, 2, 3, ...$$

(ii) For destructive interference, dark or minima,

$$path\ difference = (2n+1)\frac{\lambda}{2},\ n = 0, 1, 2, 3, ...$$

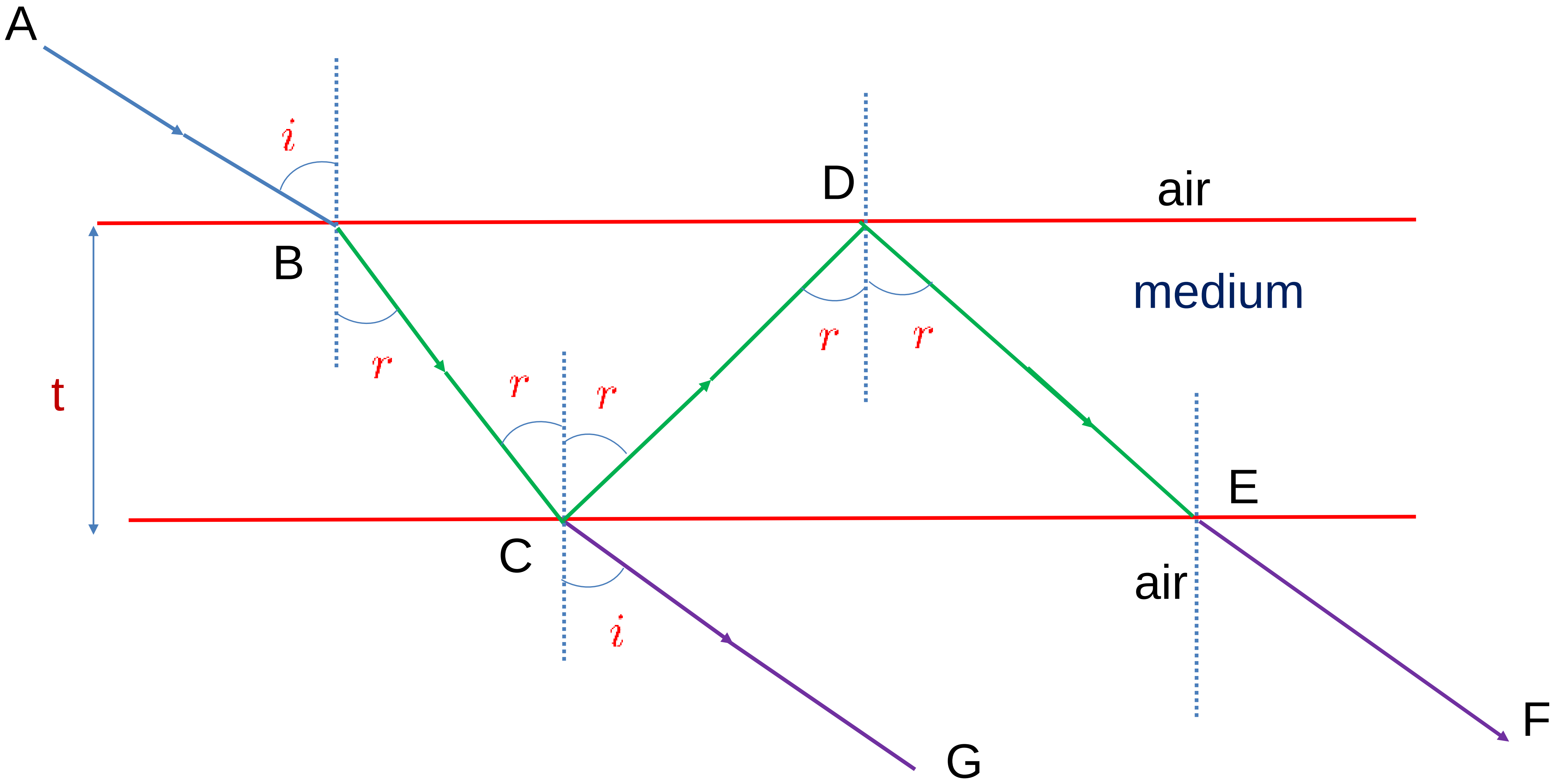
$$\implies x = 2\mu t cos r - \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$$

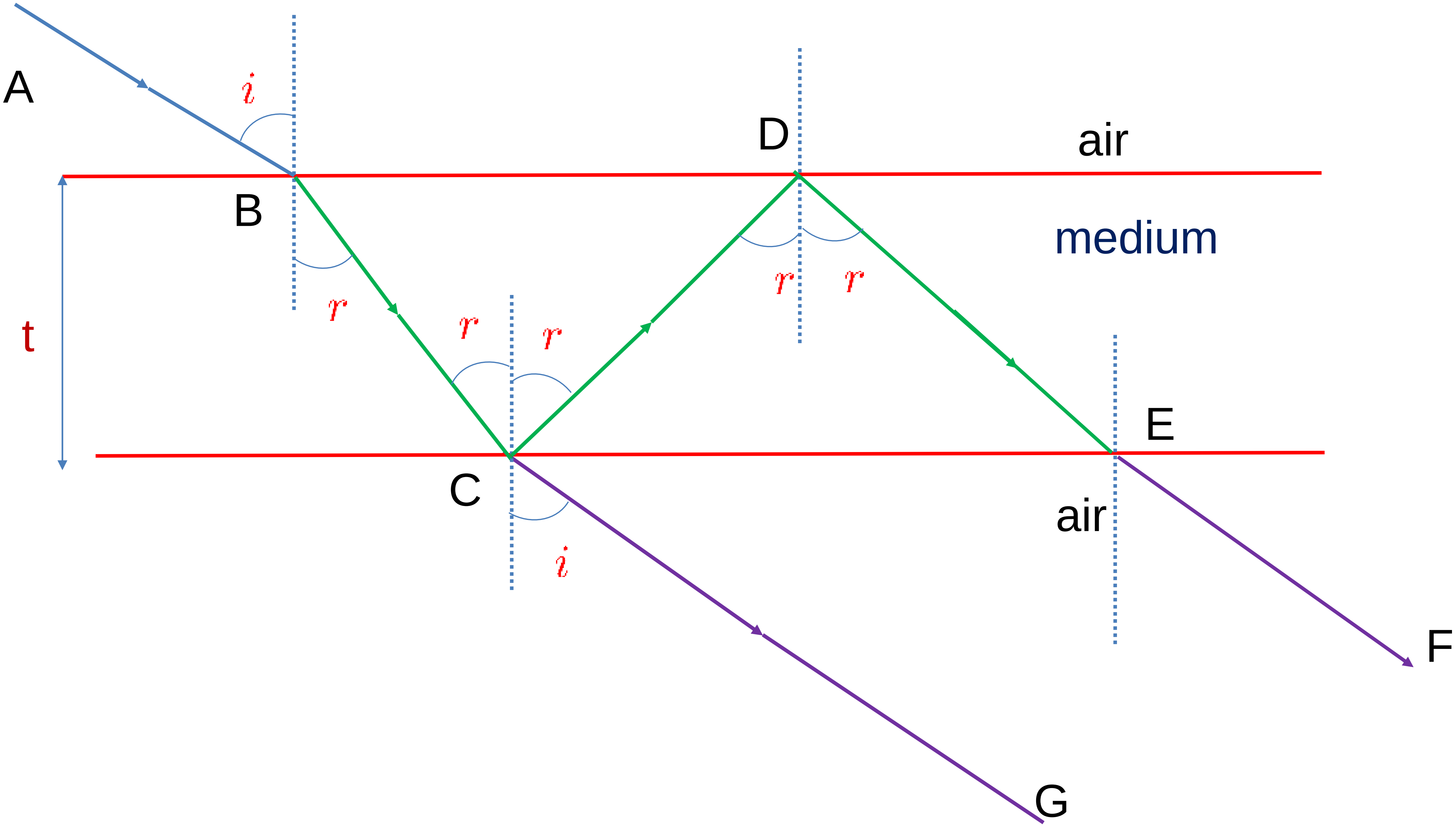
$$\implies x = 2\mu t cos r = (2n+2)\frac{\lambda}{2}$$

$$\implies x = 2\mu t cos r = (n+1)\lambda, n = 0, 1, 2, 3, ...$$

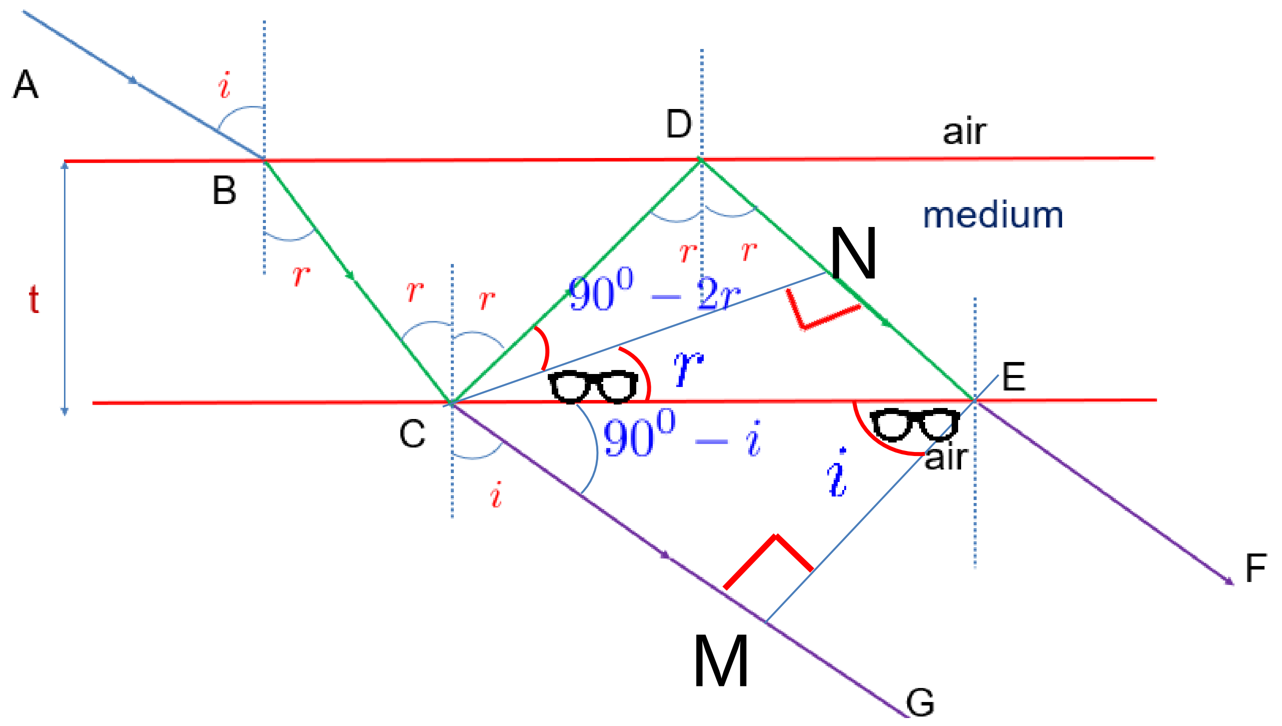
$$\implies \boxed{2\mu t cos r = n'\lambda}, n' = 1, 2, 3, ...$$

(ii) Interference due to transmitted light:





created by Arun Devkota_NCIT



Interference is due to two transmitted rays EF and CG.

The path difference between EF and CG is

$$x = \mu(CD + DE) + EF - CG$$

$$But,\ EF = MG\ and$$

$$CG = CM + MG$$

$$\Longrightarrow\ x = \mu(CD + DE) - CM \quad .....(1)$$

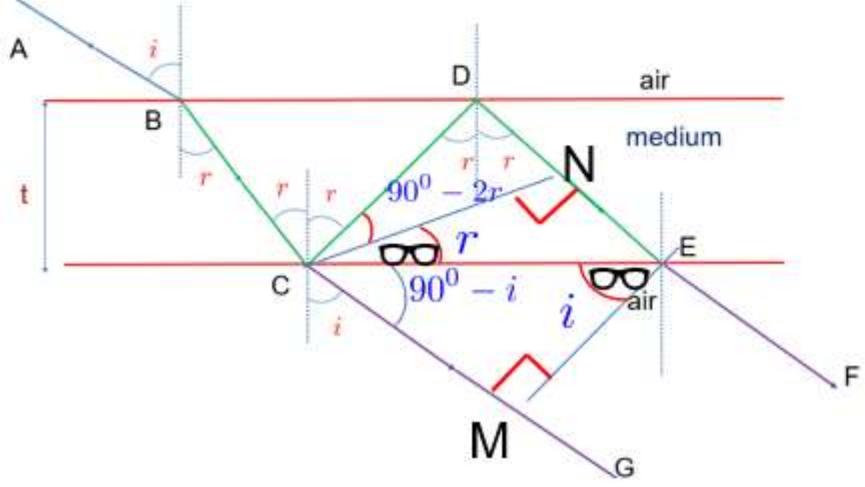
$$\mu = \frac{\sin i}{\sin r}$$

$$where\ \sin i = \frac{CM}{CE}$$

$$and\ \sin r = \frac{NE}{CE}$$

$$\Longrightarrow\ \mu = \frac{CM}{NE}$$

$$\Longrightarrow\ \boxed{CM = \mu NE} \quad .....(2)$$



Interference is due to two transmitted rays EF and CG.

The path difference between EF and CG is

$$x = \mu(CD + DE) + EF - CG$$

$$But,\ EF = MG\ and$$
$$CG = CM + MG$$

$$x = \mu(CD + DE) - CM \quad .....(1)$$

$$\mu = \frac{sin\ i}{sin\ r}$$

$$where\ sin\ i = \frac{CM}{CE}$$

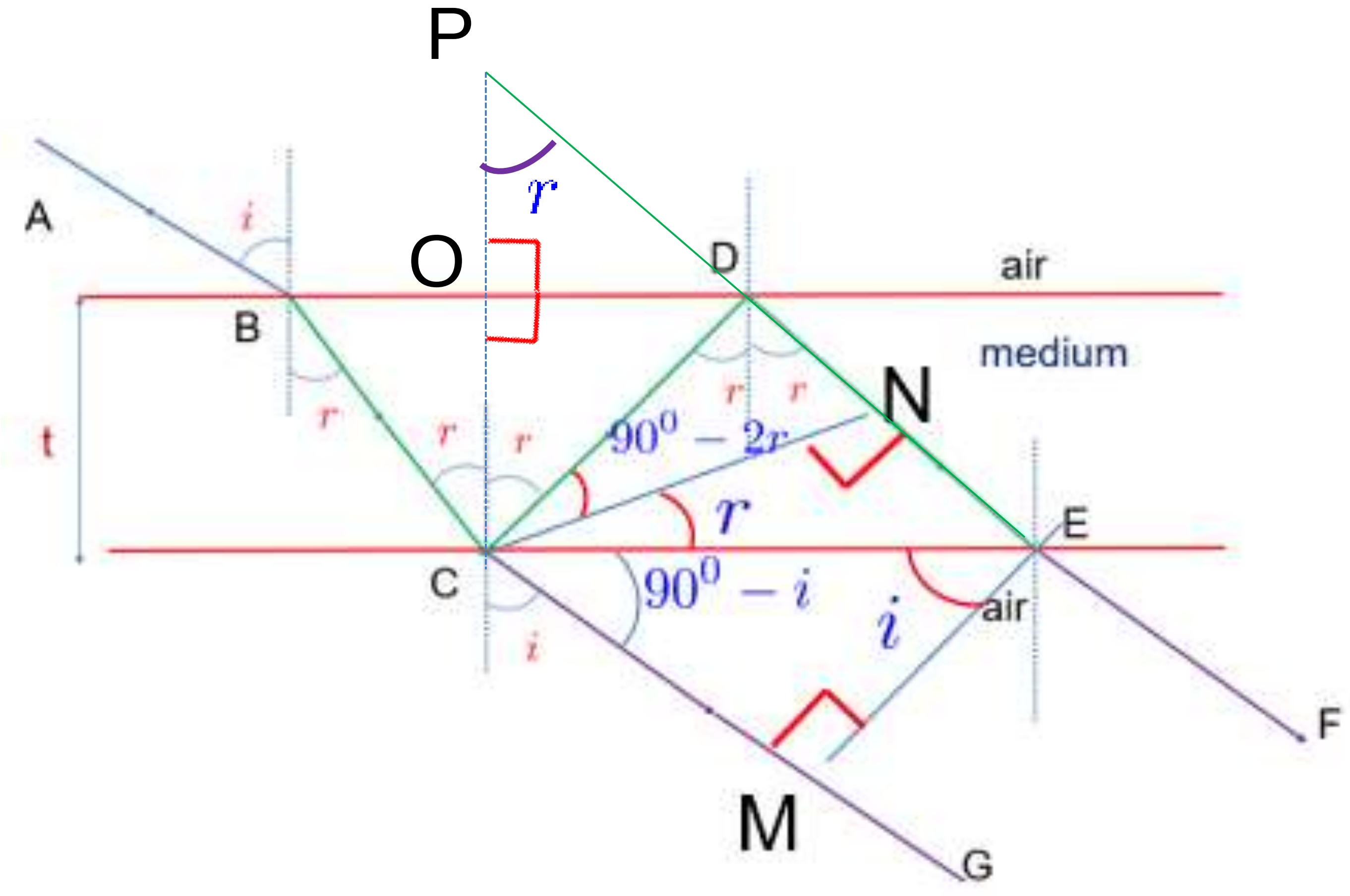
$$and\ sin\ r = \frac{NE}{CE}$$

$$\implies \mu = \frac{CM}{NE}$$

$$\implies \boxed{CM = \mu NE} \quad .....(2)$$

$$\implies x = \mu(CD + DE - NE)$$

$$\implies x = \mu(CD + DN) \quad .....(3)$$



Here,

$\Delta\, POD \cong \Delta\, COD$ (by A.A.S axiom)

So, PD = CD

And PO = OC = t

So

$$x = \mu(CD + DN) \quad .....(3)$$

becomes

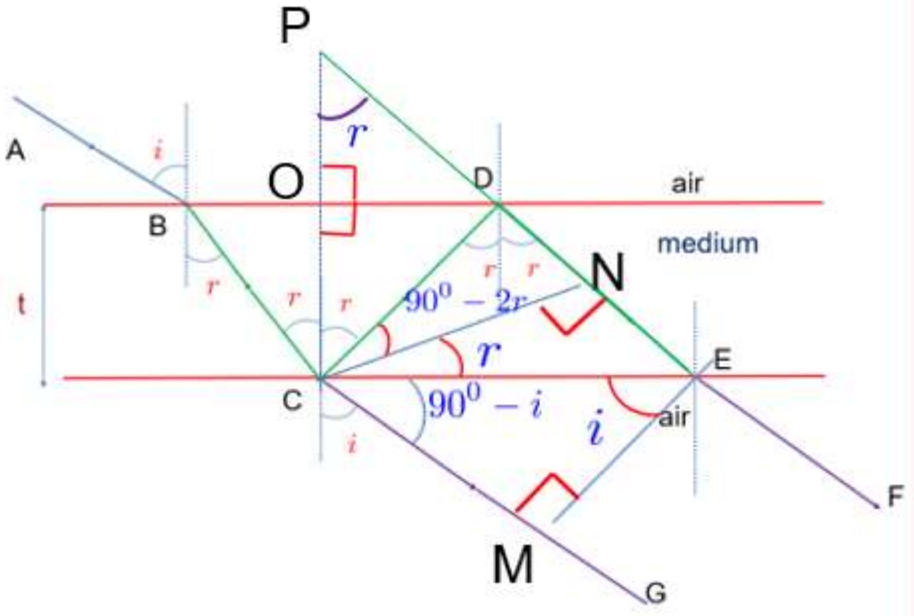
$$x = \mu(PD + DN)$$

$$\Longrightarrow \quad x = \mu PN \quad .....(4)$$

In $\Delta\, PCN$,

$$\cos r = \frac{PN}{PC}$$

$$\Longrightarrow \quad PN = 2t \cos r$$



Here,

$\Delta POD \cong \Delta COD$ (by A.A.S axiom)

So, PD = CD

And PO = OC = t

So

$x = \mu(CD + DN)$ .....(3)

becomes

$x = \mu(PD + DN)$

$\Longrightarrow x = \mu PN$ .....(4)

In ΔPCN, $\cos r = \dfrac{PN}{PC}$

$\Longrightarrow PN = 2t \cos r$

Hence, the path difference = $2\mu t \cos r$

In case of transmitted light, there is **no** additional path difference of $\lambda/2$.

Hence, the actual path difference = $2\mu t \cos r$

Cases:

(i) For constructive interference, bright or maxima,

$$path\ difference = n\lambda,\ \ n = 0, 1, 2, 3, ...$$

$$\implies \boxed{x = 2\mu t cos r = n\lambda}$$

(ii) For destructive interference, dark or minima,

$$path\ difference = (2n+1)\frac{\lambda}{2},\ \ n = 0, 1, 2, 3, ...$$

$$\implies \boxed{x = 2\mu t cos r = (2n+1)\frac{\lambda}{2}}$$

Hence, the interference pattern in thin film due to transmitted light and reflected light are opposite for bright and dark fringes.

Tricks to solve the numerical problems in thin film and Newton’s rings:

1. Firstly, confirm whether the light is reflected or transmitted in the question.

2. Secondly, confirm whether the fringes or rings or bands are bright or dark.

Problems in THIN FILM: Interference

1. A soap film $5\ x10^{-5}$ cm thick is viewed at an angle of 35^0 to the normal. Find the wavelengths of light in the visible spectrum which will be absent from the reflected light if the refractive index of the soap film is 1.33.

---

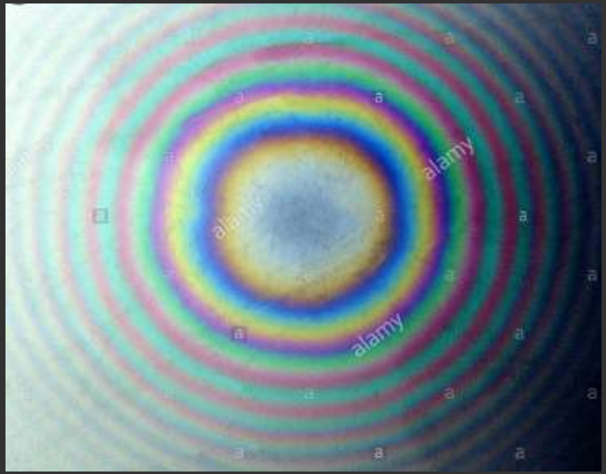
2. A beam of parallel rays is incident at an angle of 30^0 with the normal on a plane parallel film of thickness $4\ x10^{-5}$ cm and refractive index 1.50. Show that the reflected light whose wavelength is $7.539\ x10^{-5}$ cm, will be strengthened by reinforcement.

---

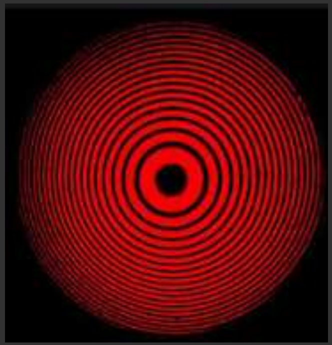
3. A thin film of soap solution is illuminated by white light at an angle of incidence $i = sin^{-1}\,(4/5)$. In reflected light, two dark consecutive overlapping fringes are observed corresponding to wavelengths $6.1\ x10^{-5}$ cm and $6.0x10^{-5}$ cm. μ for the soap solution is 4/3. Calculate the thickness of the film.

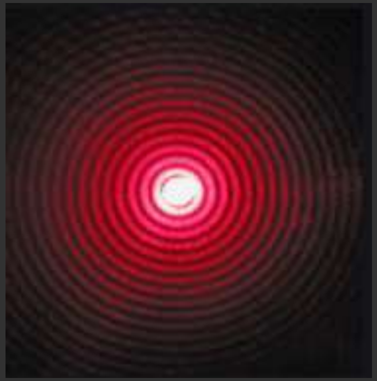
Newton’s rings:

NEWTON'S RINGS



Source: various pages from the Internet





The Souls of five hundred Newtons would be needed to make one Shakespeare:Coleridge

Reason and logic were the province of scientists and philosophers, whereas creativity and intuition were the domain of the artists.

Using a prism, Newton found that white light is actually composed of all the colors of the rainbow. He even provided a scientific explanation for the presence of rainbows. The artistic community was shocked. A scientist had taken a beautiful and magical experience and reduced it to the simple refraction of beams of light through the prism of a raindrop. A scientist had intruded into their sacred territory.

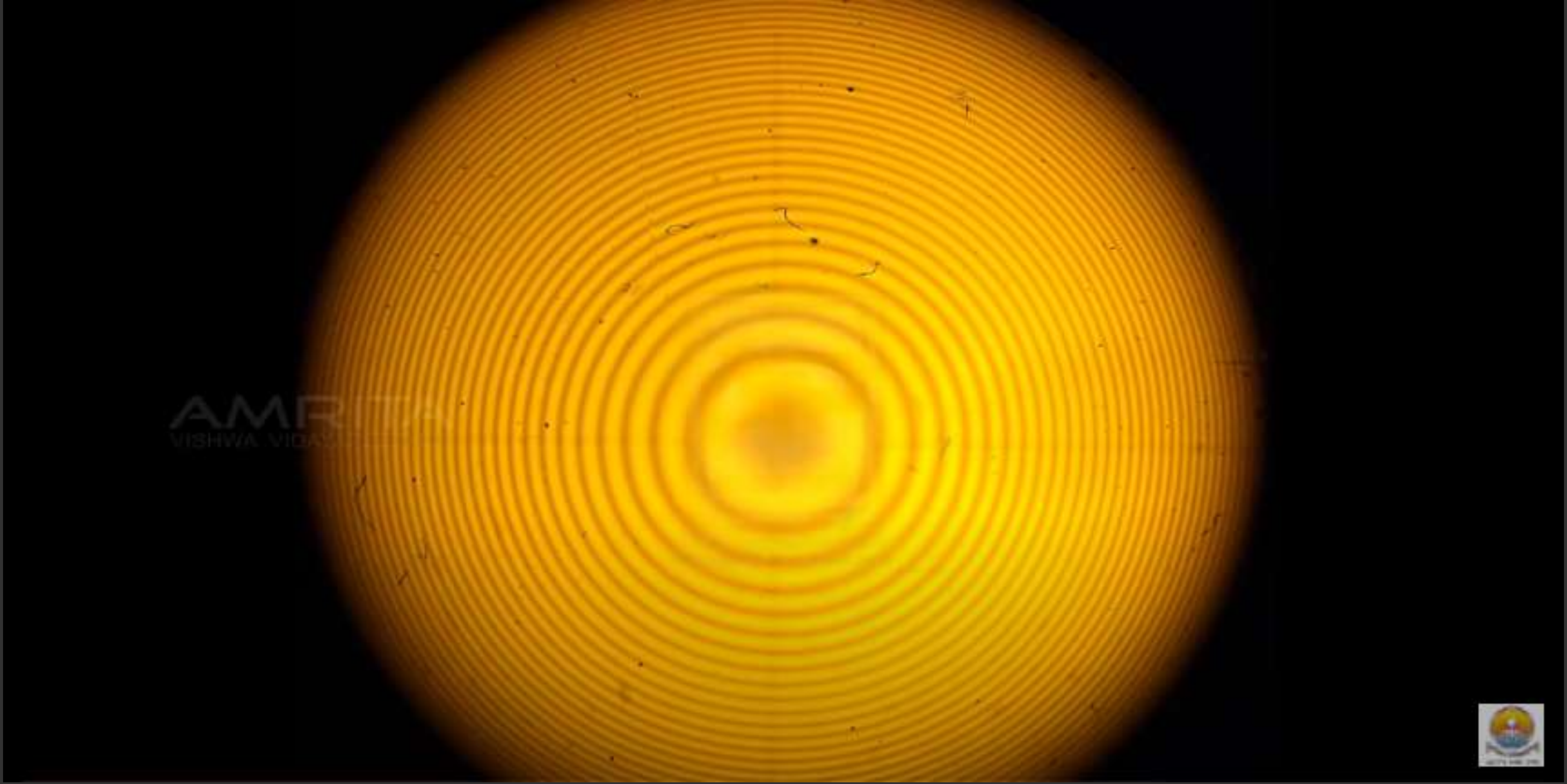
More than a hundred years later, John Keats, one of the most famous Romantic poets, accused Newton of diminishing beauty by "unweaving the rainbow." His colleague, Samuel Taylor Coleridge, famously remarked that the souls of five hundred Newtons would be needed to make one Shakespeare.

Coleridge

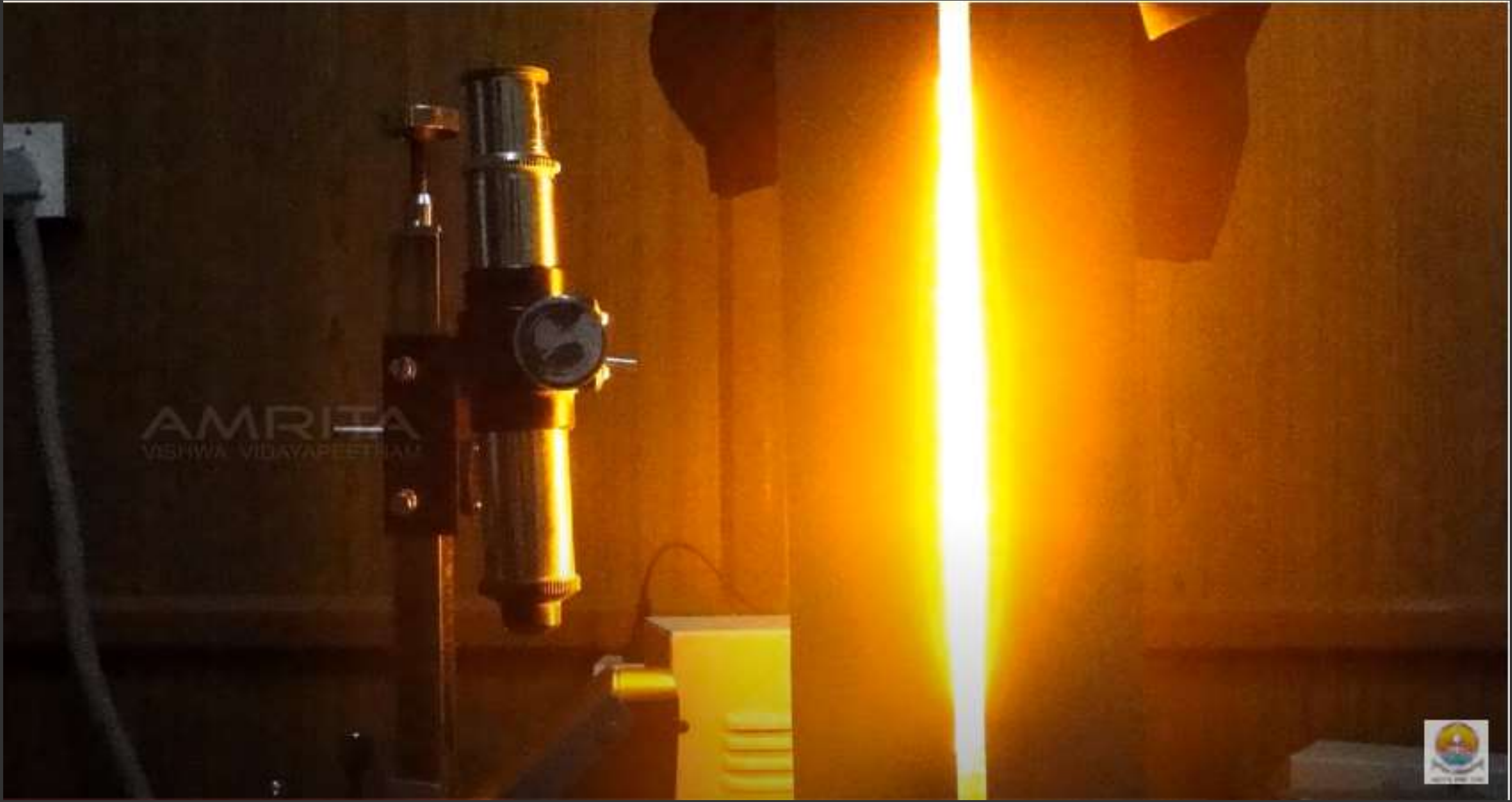
Newton

John Keats

Shakespeare



NEWTON'S RINGS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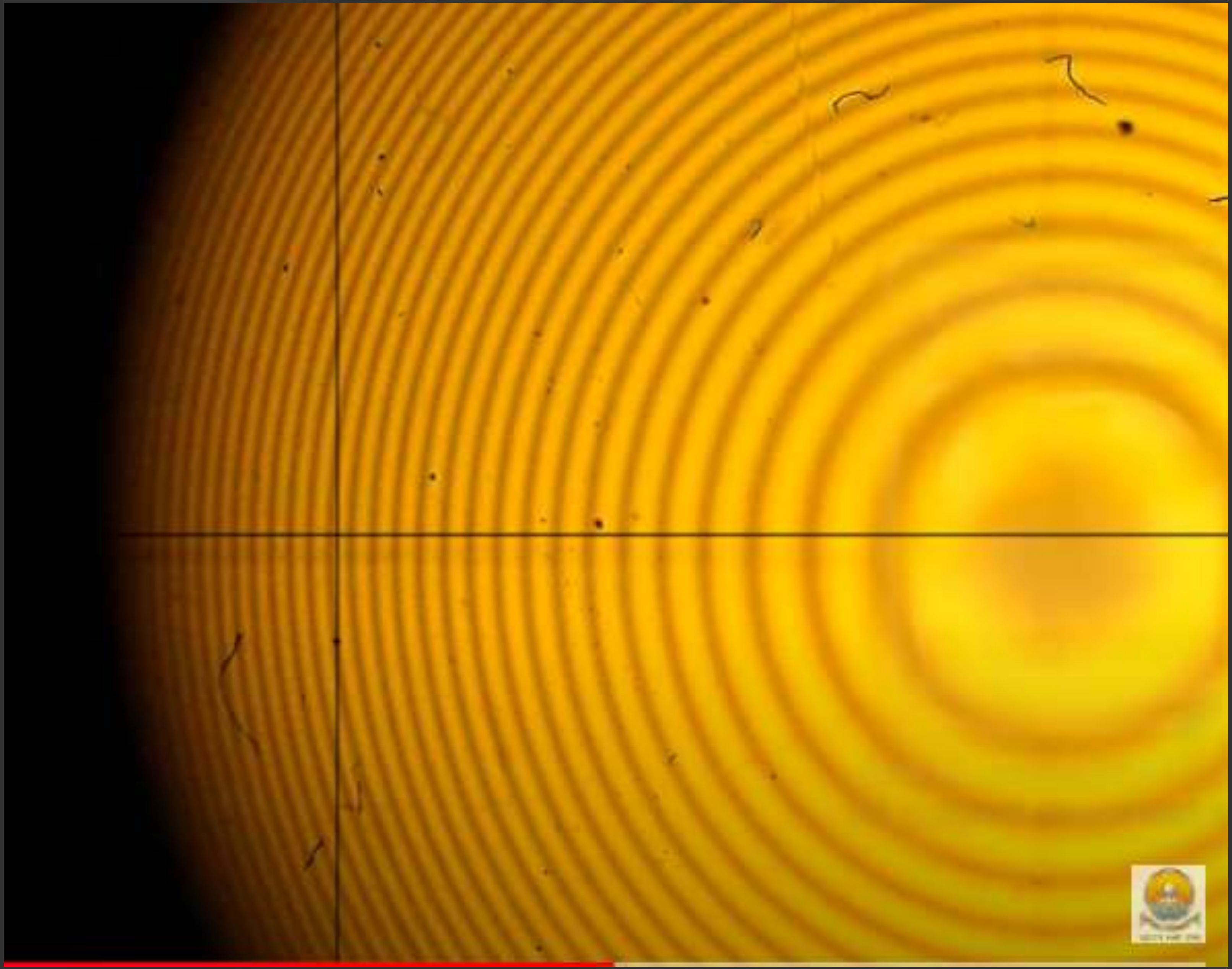
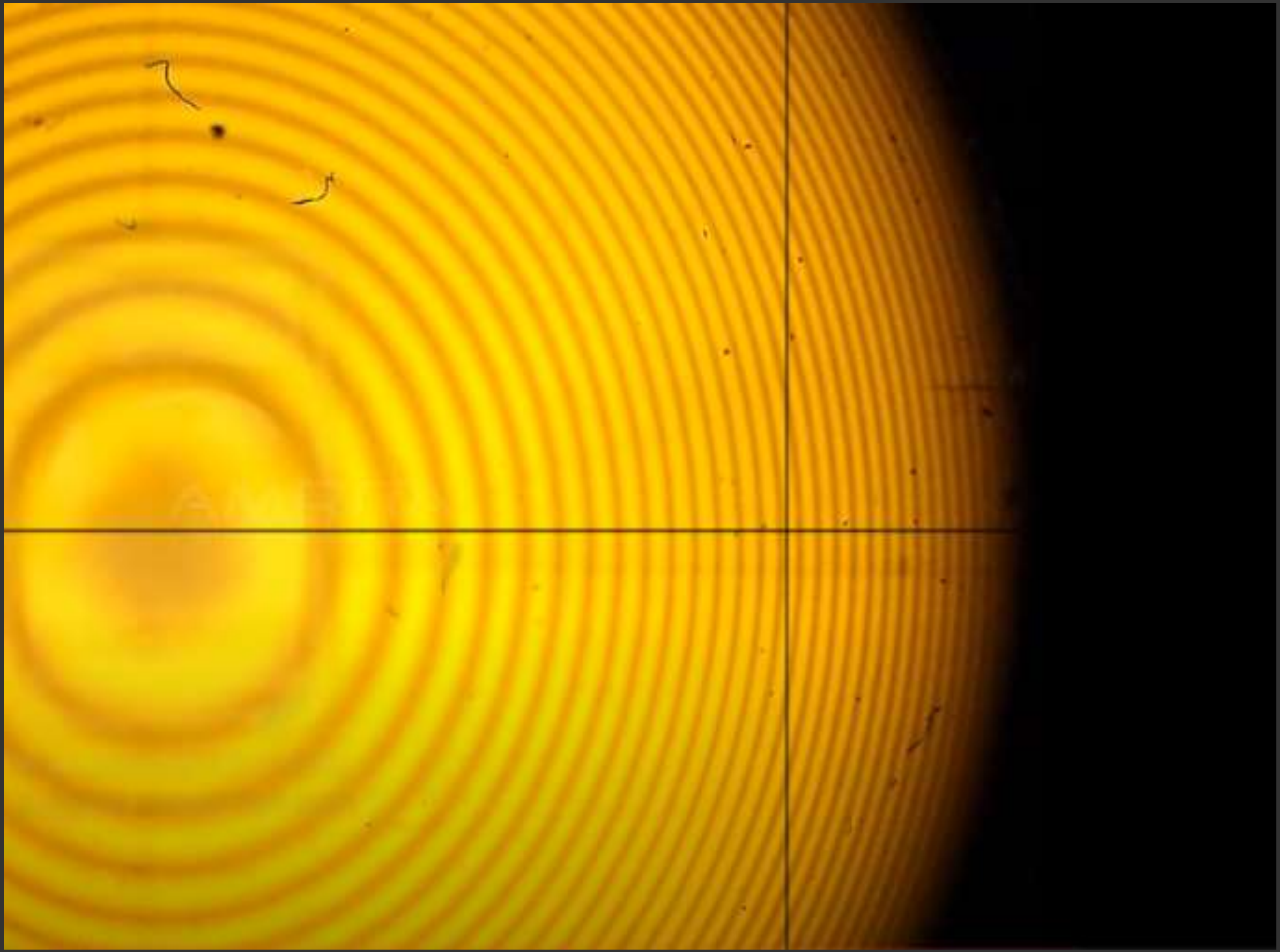




Newton's rings:

(i) Due to reflected light:

(ii) Due to transmitted light:

(i) Newton's rings due to reflected light:

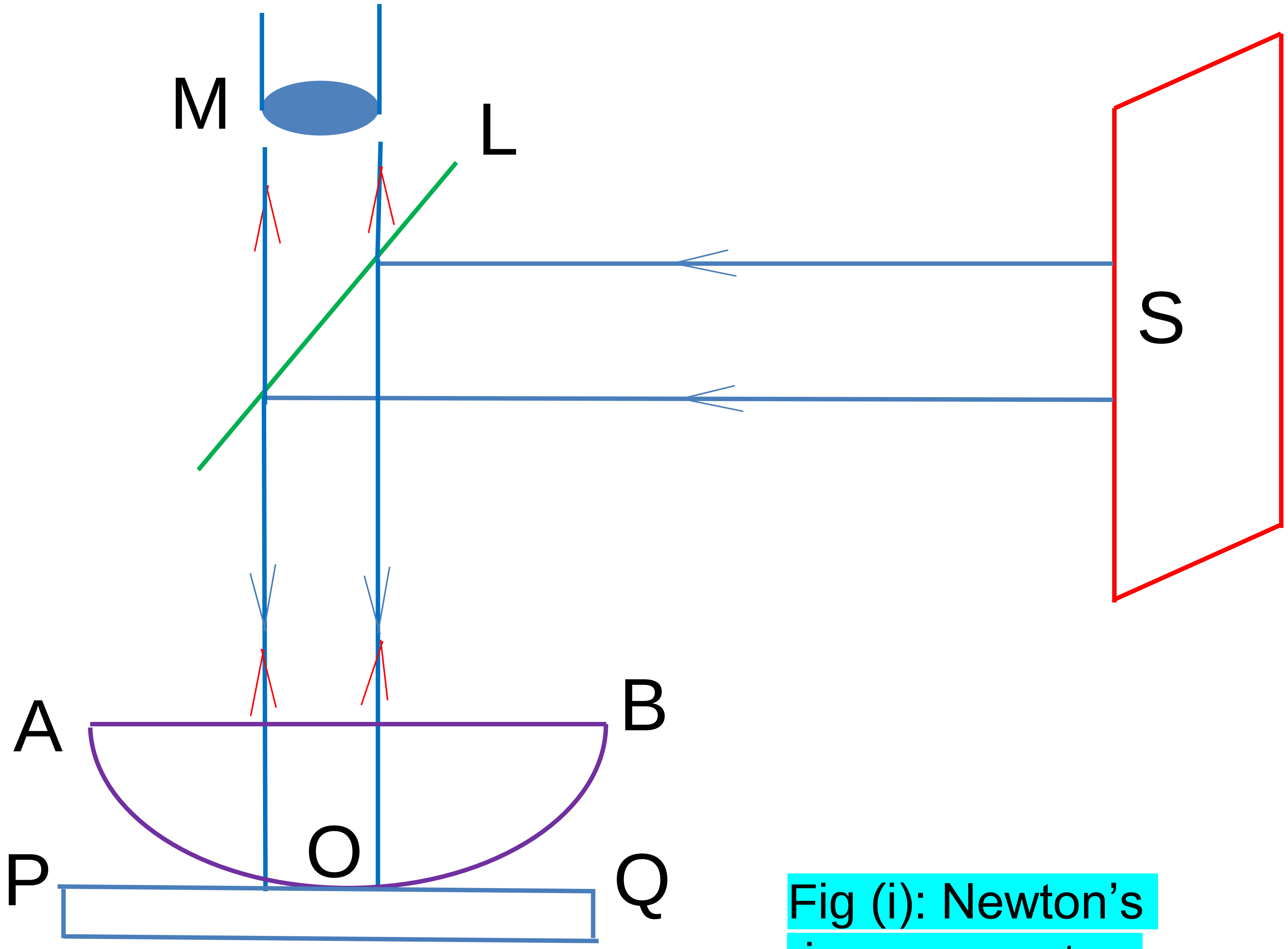


Fig (i): Newton's rings apparatus

(i) Newton's rings due to reflected light:

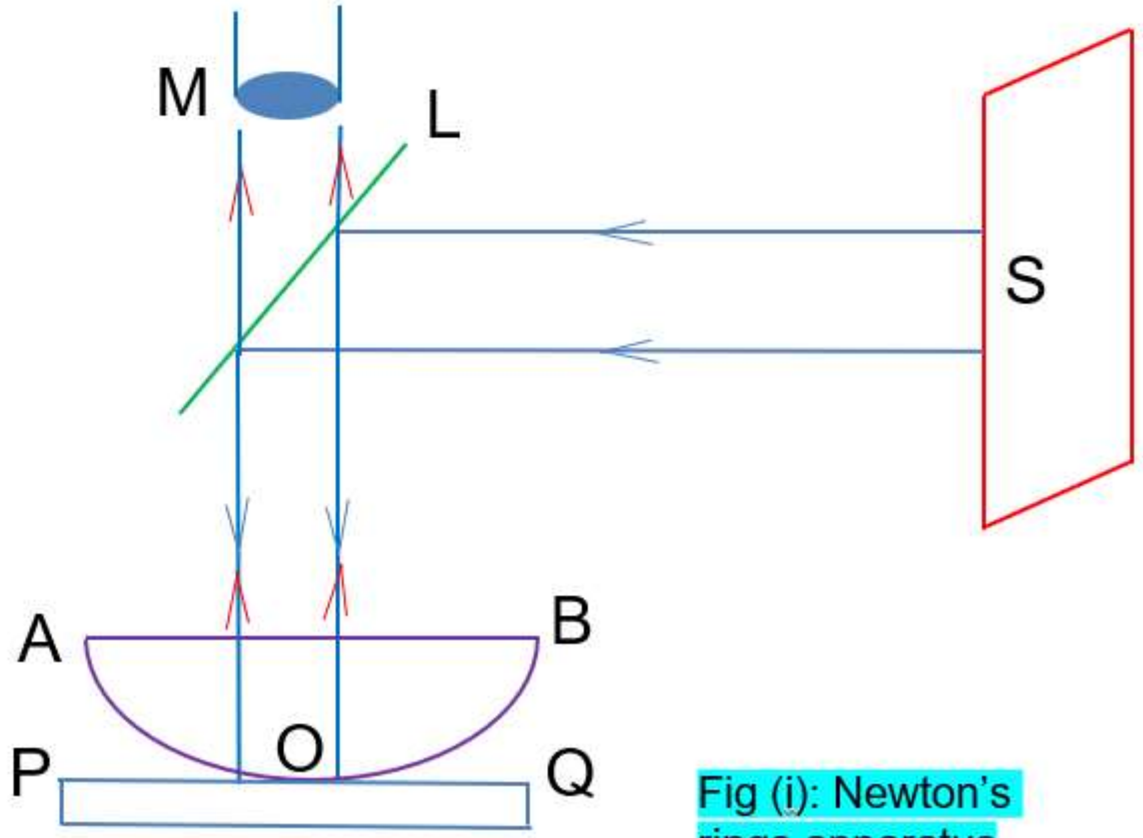


Fig (i): Newton's rings apparatus

Light from 'S' is reflected by the glass plate L to the plano-convex lens AOB placed over the glass plate POQ.

It is reflected by the two surfaces AOB and POQ back to L which transmits light to the travelling microscope M.

Here, S is the source of monochromatic light.

L is the partially silvered glass plate placed at an angle of 45^0 with the horizontal.

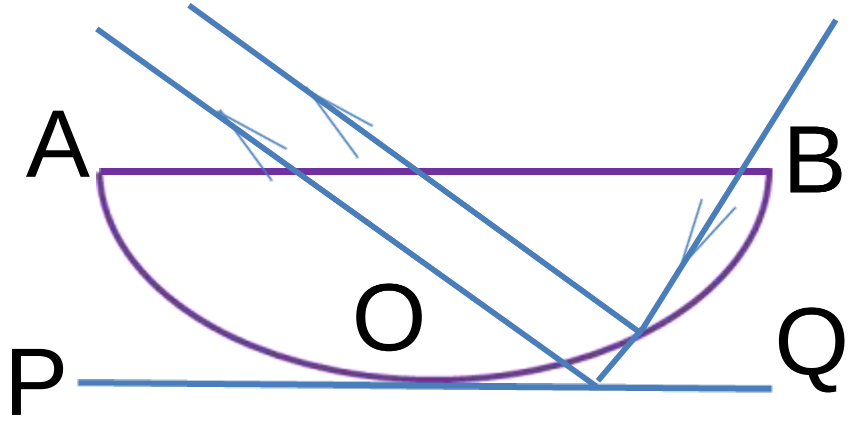


Fig (ii): Reflected light

Air is enclosed within AOB and POQ.

The thickness of air is zero at the point of contact O and increases on the either side..

Circular concentric rings are observed which are called the Newton's rings.

These rings include alternate bright and dark rings or fringes.

There are two types of Newton's rings:

(i) Newton's rings due to reflected light:

In case of reflected light, the center of Newton's rings is dark.

The dark rings due to reflected light are given by

$$\boxed{2\mu t\cos\theta = n\lambda}, n = 0, 1, 2, 3, ...$$

.....(1)

For air, $\mu = 1$

For normal incidence, $\theta \approx 0^0$

$$\implies \cos\theta \approx 1$$

So, equation (i) becomes

$$\boxed{2t = n\lambda} \quad .....(2)$$

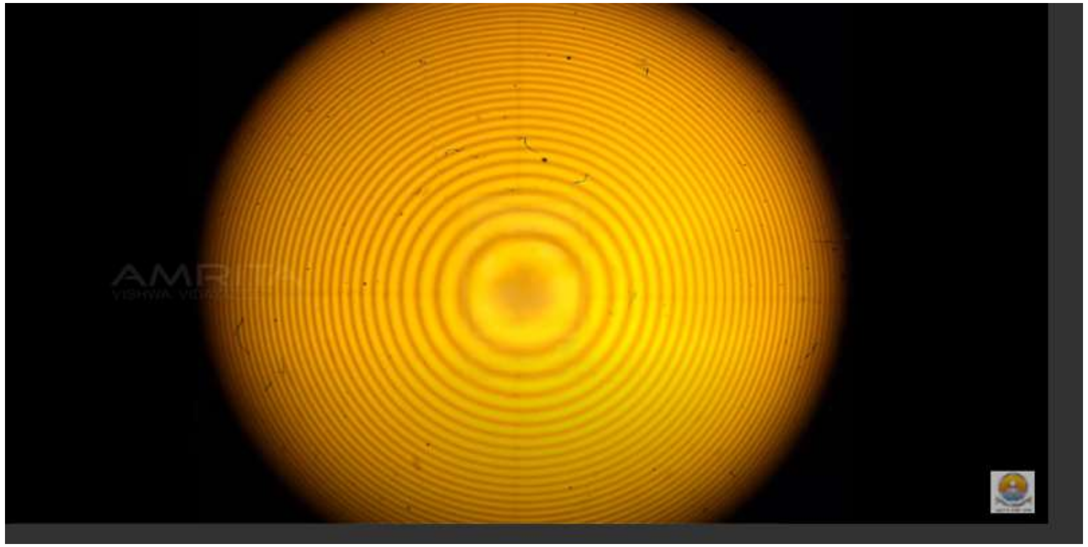


Fig (iii): Newton's rings due to reflected light (Center is dark)

To find t:

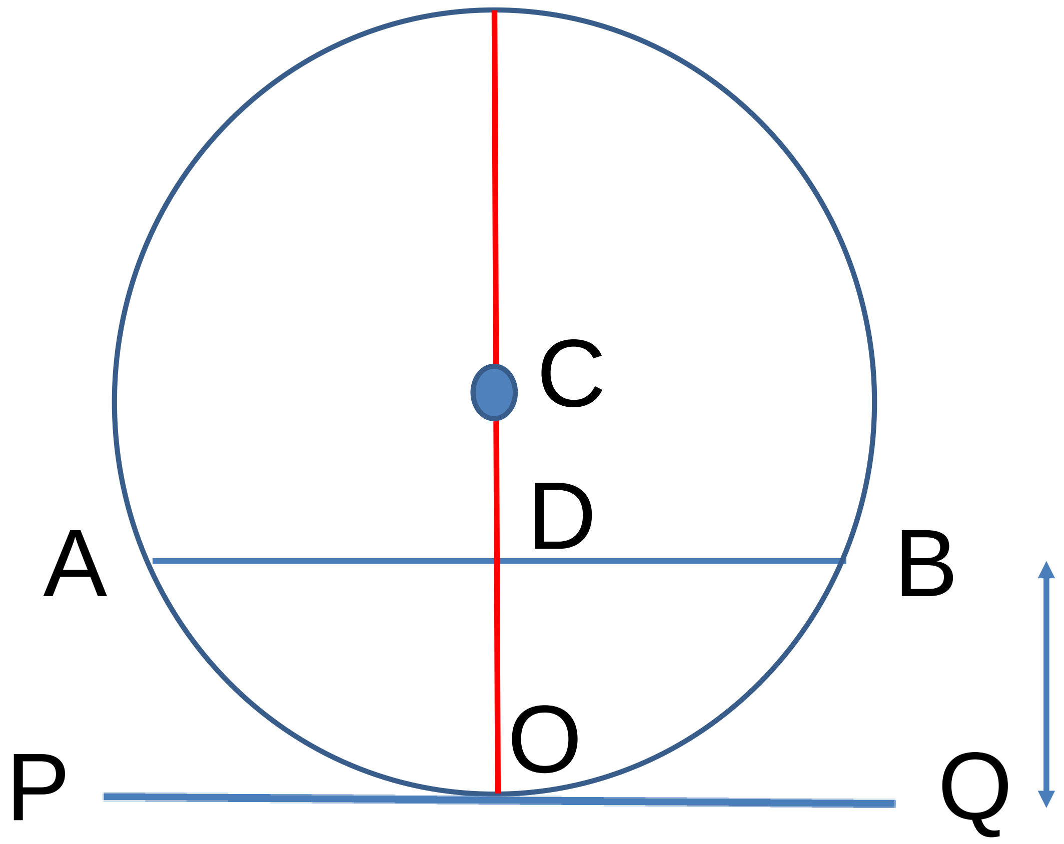
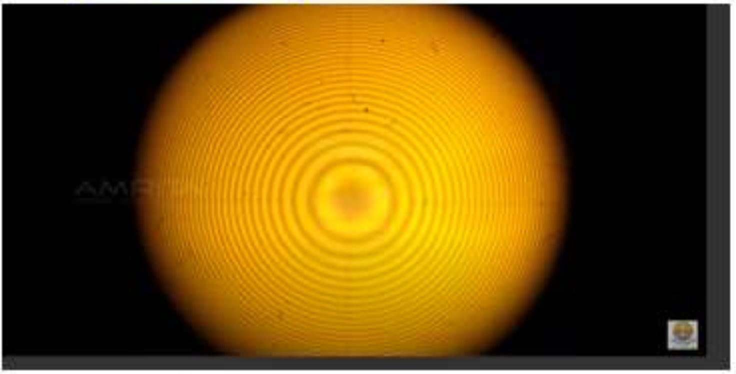


Fig (iv):

Let C be the center such that EC = R, Radius of curvature of the plano-convex lens.

So, equation (i) becomes

$\boxed{2t = n\lambda}$ .....(2)



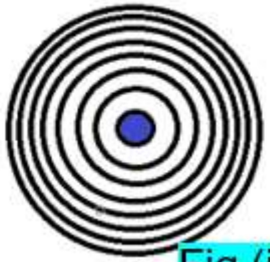


Fig (iii): Newton's rings due to reflected light (Center is dark)

To find t:

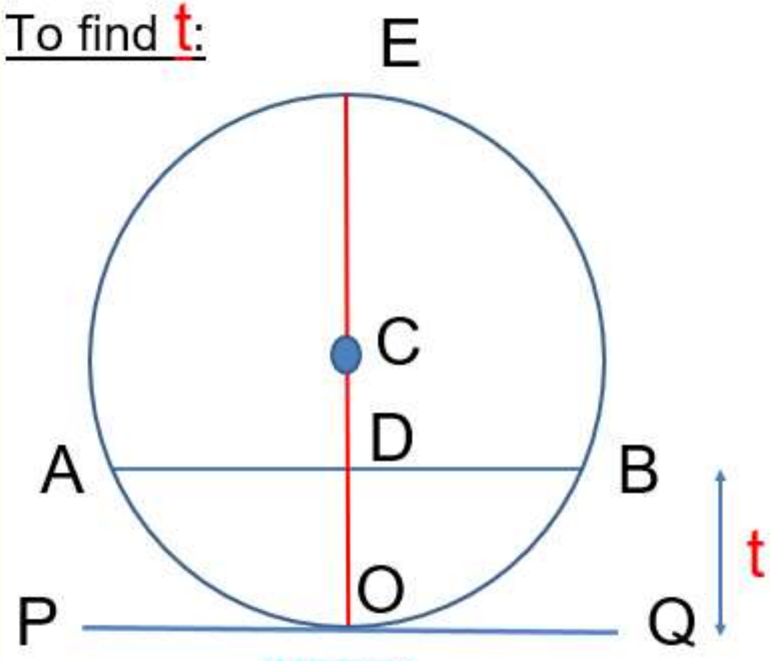


Fig (iv):

Let C be the center such that EC = R, Radius of curvature of the plano-convex lens.

Let AD = DB = r & OD = t

From geometry,

ED X DO = AD X DB → (2R-t) x t = r x r

$2Rt - t^2$ = r. r

Since R >> t,

$2Rt = r^2$

$$\Longrightarrow \boxed{2t = \frac{r^2}{R}} \quad .....(3)$$

From (2) & (3),

$$\boxed{2t = \frac{r^2}{R} = n\lambda}$$

So, equation (i) becomes

$\boxed{2t = n\lambda}$ .....(2)

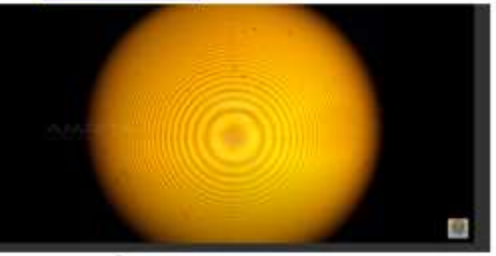
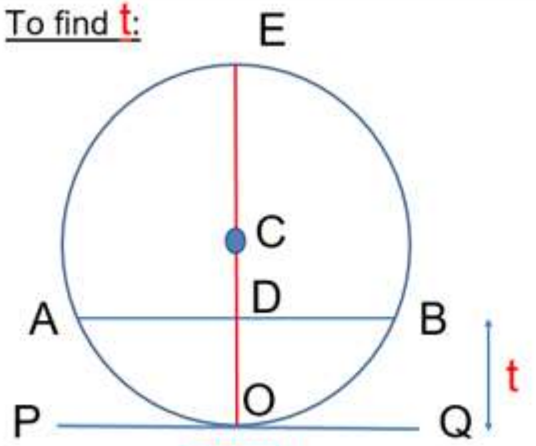


Fig (iii): Newton's rings due to reflected light (Center is dark)

To find t:



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From (2) & (3),

$$\boxed{2t = \frac{r^2}{R} = n\lambda}$$

$$\frac{r^2}{R} = n\lambda$$

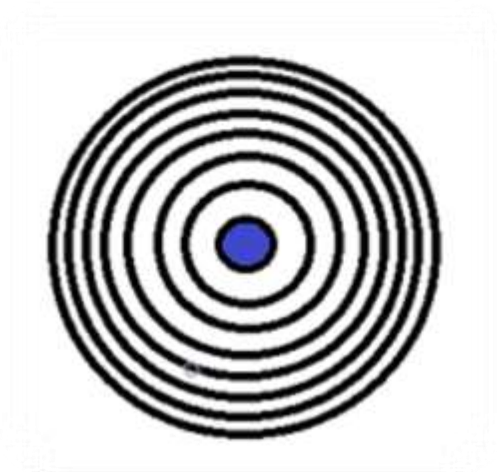
$$r = \sqrt{n\lambda R} \quad \Longrightarrow \quad \boxed{r_n = \sqrt{n\lambda R}}, n = 0, 1, 2, 3, \ldots..$$

$$\boxed{r_n = \sqrt{n\lambda R}} \quad , n = 0, 1, 2, 3, \ldots..$$

which gives the radius of the nth dark ring due to reflected light.

For n = 0, r_0 = 0

Hence, the center of Newton's ring due to reflected light is dark.



For bright rings due to reflected light,

$$2\mu t \cos\theta = (2n-1)\frac{\lambda}{2} \quad , n = 1, 2, 3, \ldots$$

For air, $\mu = 1$

For normal incidence, $\theta \approx 0^0$

$$\implies \cos\theta \approx 1$$

So,

$$\boxed{2t = (2n-1)\frac{\lambda}{2}} \quad , n = 1, 2, 3, \ldots$$

Also, $\boxed{2t = \frac{r^2}{R}}$

$$\implies \frac{r^2}{R} = (2n-1)\frac{\lambda}{2}$$

$$\implies r = \sqrt{(2n-1)\frac{\lambda R}{2}}$$

$$\implies \boxed{r_n = \sqrt{(2n-1)\frac{\lambda R}{2}}}\ ,$$

which gives the radius of the nth bright ring due to reflected light.

The diameter of the nth dark ring is given by

$$\boxed{D_n = 2r_n = 2\sqrt{n\lambda R}}\ , n = 0, 1, 2, 3, \ldots$$

And for the nth bright ring,

$$\boxed{D_n = 2r_n = 2\sqrt{(2n-1)\frac{\lambda R}{2}}}$$

$$, n = 1, 2, 3, \ldots$$

$$\boxed{D_n = \sqrt{2(2n-1)\lambda R}}$$

Q. Show that rings or fringes get closer or fringe width decreases as we move away from the center.

$$\Longrightarrow \frac{r^2}{R} = (2n-1)\frac{\lambda}{2}$$

$$\Longrightarrow r = \sqrt{(2n-1)\frac{\lambda R}{2}}$$

$$\Longrightarrow \boxed{r_n = \sqrt{(2n-1)\frac{\lambda R}{2}}},$$

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$$, n = 1, 2, 3, \ldots$$

Q. Show that rings or fringes get closer or fringe width decreases as we move away from the center.

Soln:

Since for the nth dark ring due to reflected light, diameter is given by

$$\boxed{D_n = 2\sqrt{n\lambda R}}$$

For the 1st dark ring, $n = 1$

$$D_1 = 2\sqrt{\lambda R}$$

And for the 4th , 9th and 16th dark rings,

$$D_4 = 2\sqrt{4\lambda R} = 4\sqrt{\lambda R}$$

$$D_9 = 2\sqrt{9\lambda R} = 6\sqrt{\lambda R}$$

$$D_{16} = 2\sqrt{16\lambda R} = 8\sqrt{\lambda R}$$

Hence,

$$D_4 - D_1 = 2\sqrt{\lambda R} = D_{16} - D_9$$

Hence, the rings or fringes get closer or fringe width decreases as we move away from the center.

(ii) Newton's rings: Due to transmitted light:

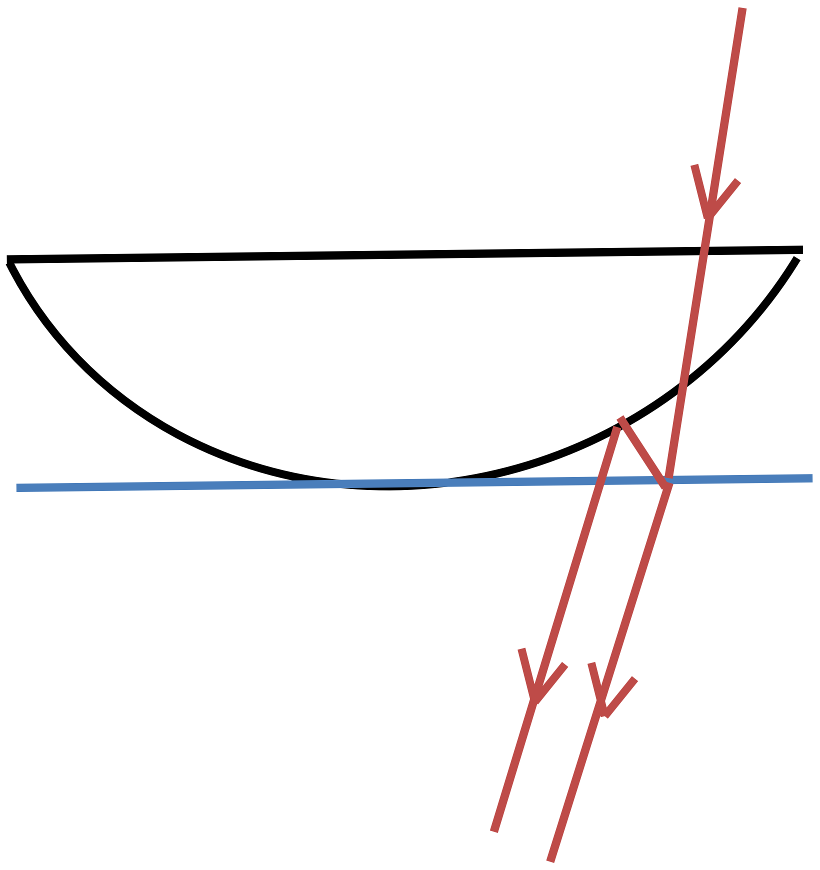

Fig: Transmitted light

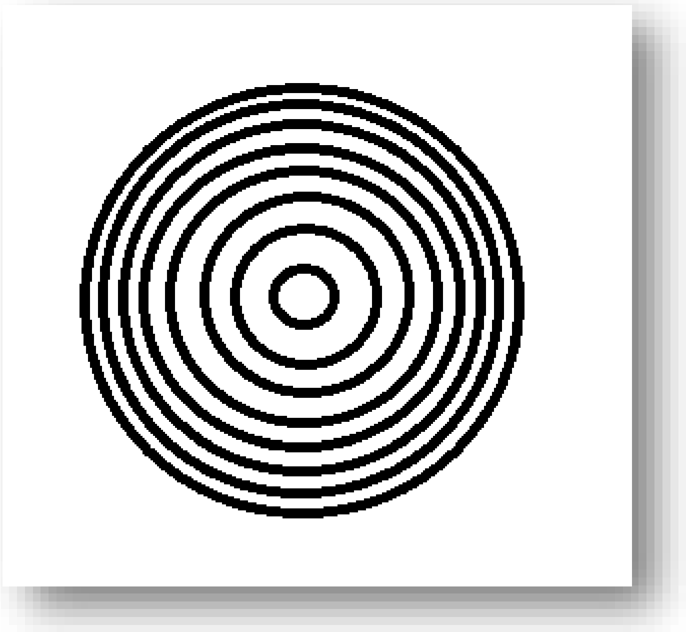

Fig: Newton's rings due to transmitted light (center is bright)

In case of transmitted light, the center of Newton’s rings is bright.

The bright rings due to transmitted light are given by

$$2\mu t \cos\theta = n\lambda \ , n = 0, 1, 2, 3, ...$$

For air, $\mu = 1$ & $\cos\theta \approx 1$

Then, $\boxed{2t = n\lambda}$ $, n = 0, 1, 2, 3, ...$

Also, $\boxed{2t = \frac{r^2}{R}}$ $\Rightarrow$ (Derive this formula)

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Also, $\boxed{2t = \frac{r^2}{R}}$ $\Rightarrow$ (Derive this formula)

Combining, we get

$$\frac{r^2}{R} = n\lambda$$

$$\Rightarrow \quad r = \sqrt{n\lambda R}$$

$$\Rightarrow \quad \boxed{r_n = \sqrt{n\lambda R}} \; ,$$

$$n = 0, 1, 2, 3, ...$$

This gives the radius of the nth bright ring due to transmitted light.

For dark rings due to transmitted light,

$$2\mu t\cos\theta = (2n - 1)\frac{\lambda}{2} \; , n = 1, 2, 3, ...$$

In case of transmitted light, the center of Newton's rings is bright.

The bright rings due to transmitted light are given by

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So, $\boxed{2t = (2n-1)\frac{\lambda}{2}}$, $n = 0, 1, 2, 3, ...$

Also, $\boxed{2t = \frac{r^2}{R}}$

So,

$$\frac{r^2}{R} = (2n-1)\frac{\lambda}{2}$$

$$r = \sqrt{(2n-1)\frac{\lambda R}{2}}$$

$$\boxed{r_n = \sqrt{(2n-1)\frac{\lambda R}{2}}} \;,$$

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$$\boxed{r_n = \sqrt{(2n-1)\frac{\lambda R}{2}}}\ , \quad n = 1, 2, 3, \ldots..$$

This gives the radius of the nth dark ring due to transmitted light.

Applications of Newton's ring: $(\ To\ find\ \lambda\ , \mu)$

$(i)\ To\ find\ the\ wavelength\ of\ monochromatic\ light(\lambda)$
$\quad by\ using\ Newton's\ rings\ method:$

$The\ radius\ of\ the\ n^{th}\ dark\ ring\ due\ to\ reflected\ light\ is\ given\ by$

$$r_n = \sqrt{n\lambda R}$$

$$or,\ D_n = 2r_n = 2\sqrt{n\lambda R}$$

$$or,\ D_n^2 = 4n\lambda R$$

$Similarly,\ for\ m^{th}\ dark\ ring,$

$$D_m^2 = 4m\lambda R$$

$Substracting,\ we\ get,$

$$D_n^2 - D_m^2 = 4(n-m)\lambda R$$

$$or, \boxed{\lambda = \frac{D_n^2 - D_m^2}{4(n-m)R}}$$

$(Note:\ For\ a\ single\ ring,\ say\ n^{th}\ ring,$

$$\lambda = \frac{D_n^2}{4nR})$$

(ii) *To determine the refractive index(μ) of a given liquid :*

In air, the diameters of the n^{th} and m^{th} dark rings are given by

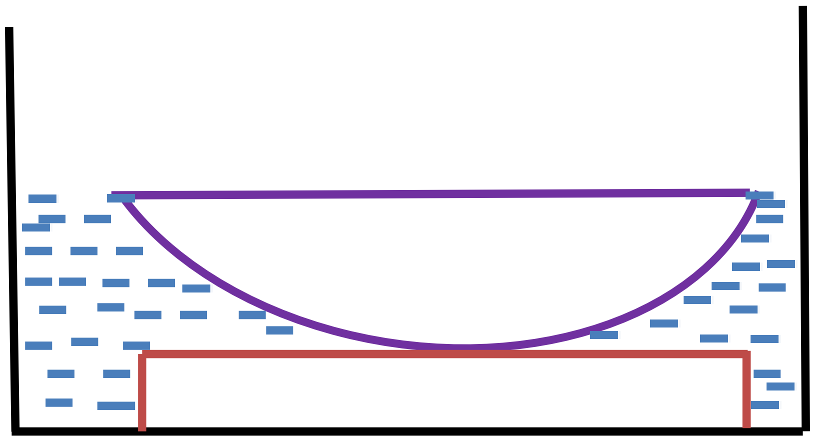
$$D_n^2 = 4n\lambda R$$

$$and\ D_m^2 = 4m\lambda R$$

Substracting, we get,

$$D_n^2 - D_m^2 = 4(n-m)\lambda R \qquad (1)$$

If a liquid is placed in between the plano-convex lens and the glass plate,



$the\ diameters\ of\ the\ n^{th}\ and\ m^{th}\ dark\ rings\ in\ the\ liquid\ become$

$$D_n'^2 = \frac{4n\lambda R}{\mu}$$

$$and\ \ D_m'^2 = \frac{4m\lambda R}{\mu}$$

$$D_n^2 - D_m^2 = 4(n-m)\lambda R$$

$Substracting,\ we\ get$

$$D_n'^2 - D_m'^2 = \frac{4(n-m)\lambda R}{\mu}$$

$Using\ (i),\ we\ get$

$$D_n'^2 - D_m'^2 = \frac{D_n^2 - D_m^2}{\mu}$$

$$\boxed{\mu = \frac{D_n^2 - D_m^2}{D_n'^2 - D_m'^2}}$$