Self Study Series

Few Notes

of the Textbook

PHYSICS XI

Ross Nazir Ullah

GENERAL PREFACE

This book is one of the volume from a set of FIVE books. It is not a substitute for the text book. Instead it is a helping book to understand the text more clearly.

Our standard of education is deteriorating very fast. The major factors are hand-books, keys, made-easy books, notes, and finally tuition. I know there is a war in progress. This Self Study Series is an attempt to enhance the level of education. It is to be reminded that this set of FIVE Books is simply a guide to help the text book. Without prescribed text book these books are nothing.

It's a new idea in the field of F. Sc. Physics. It is a sincere effort for making prescribed text more important than any other helping books.

Comments, suggestions and criticisms are invited for the sake of education to improve this book.

F. C. College, Ross Nazir Ullah
Lahore.

Introduction

The articles of this book is written in a special style. In the question paper, usually one question is asked to write a note on a particular topic. This book "Few Notes" will be helpful for that purpose. It is not the question whether it is important or not. I wrote it because I like to write that!

Definitely you'll find some helping material for a right method of writing an answer to the question.

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August 15, 2003

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1- Linear Momentum

Definition:

Momentum (p) : *In a moving body, the product of its mass and velocity.*

Linear momentum (p) : *In a body moving along a straight line, the product of its mass and linear velocity.*

Mathematically

$$p = m v \qquad .....(1)$$

It is a vector quantity and is directed along the velocity.

Units of Momentum:

i) kilogram x meter / sec ($kg.m.S^{-1}$)

ii) Newton x second (N-S)

Momentum and Second Law of Motion:

According to 2^{nd} Law of motion:

$$F = m a$$

$$\text{or} \quad F = \frac{mv_f - mv_i}{\Delta t} \qquad \left[a = \frac{v_f - v_i}{\Delta t} \right.$$

$$\text{or} \quad F = \frac{p_f - p_i}{\Delta t} \qquad [p = mv$$

$$\text{or} \quad F = \Delta p / \Delta t \qquad .....(2)$$

$$\text{or} \quad F \times \Delta t = \Delta p \qquad .....(3)$$

From eq. (2), we can express Newton's second law of motion as :

The rate of change of momentum of a body is equal to the force applied to it, and the change of momentum takes place in the direction of force.

Definition of Impulse:

The product of force and the duration of impact.

Mathematically,

$$I = F \times \Delta t \qquad .....(4)$$

From eqs. (3) & (4), we have

$$I = \Delta p \qquad .....(5)$$

Law of conservation of linear momentum:

Statement: *If there is no external force applied to a system the total linear momentum of that system remains constant in time.*

Proof:

We have from eq. (2),

$$F = \Delta p / \Delta t$$

and the instantaneous force as

$$F = \text{Lim}_{\Delta t \to 0} \frac{\Delta p}{\Delta t} = \frac{d\,p}{d\,t} \qquad .....(6)$$

For isolated system, the net force will be zero, so from eq. (6),

$$0 = dp / dt$$

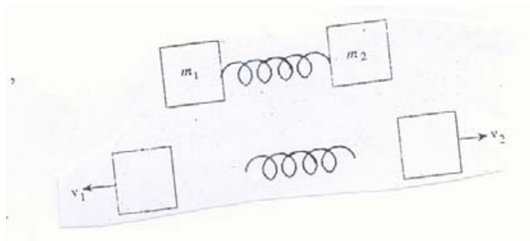
$$\text{or} \quad dp / dt = 0 \qquad \text{.....(7)}$$

Integrating equation (7) w.r.t. 't', we get

$$p = \text{constant}$$

i.e. the total momentum of an isolated system of bodies is constant.

Illustration:



Consider two masses m_1 and m_2 , both are at rest, connected by a compressed spring.
It is making an isolated system.
Let the spring is released and the two objects move apart with velocities v_1 and v_2
We have

$$\text{Initial momentum} = 0$$

$$\text{Final momentum} = m_1v_1 + m_2v_2 = p_1 + p_2$$

According to the Law of conservation of momentum,

$$0 = m_1v_1 + m_2v_2$$

$$\text{or} \quad m_1v_1 + m_2v_2 = 0 \qquad \text{.....(8)}$$

$$\text{or} \quad m_1v_1 = - m_2v_2 \qquad \text{.....(9)}$$

i.e. when released, one of the mass moves to the right whereas the other moves to the left.

2- Terminal velocity

Terminal velocity: *"At the end, the extreme, or maximum velocity reached by certain object"*.
Density (ρ): *"The ratio of the mass of a substance to its volume"*.
Stokes' law: *In fluid resistance, the drag force F of a sphere of radius r moving with a velocity v through a fluid of infinite extent is*

$F = 6 \pi \eta r v$, where η is the viscosity.

Terminal velocity of water droplet moving in air:
The dragging force experienced by a tiny water droplet (of fog or mist) falling freely will be given by Stokes Law as:

$$F_D = 6\pi\eta rv \qquad \text{.....(1)}$$

The weight of the droplet is given by

$$w = mg \qquad \text{.....(2)}$$

so the net downward force will be

$$F = w - F_D$$

$$\text{or} \quad F = mg - 6\pi\eta rv \qquad \text{.....(3)}$$

From 2nd Law of motion,

$$F = ma \qquad \text{.....(4)}$$

From eqs. (3) & (4), we have

$$ma = mg - 6\pi\eta rv$$

$$\text{or} \quad a = \frac{mg - 6\pi\eta rv}{m} \quad \text{or} \quad a = g - \frac{6\pi\eta rv}{m}$$

At terminal velocity $v = v_T$ & $a = 0$, so

$$0 = g - \frac{6\pi\eta r v_T}{m}$$

$$\text{or} \quad 6\pi\eta r v_T = mg$$

$$\text{or} \quad v_T = mg / 6\pi\eta r \qquad \text{.....(5)}$$

$$\text{or} \quad v_T = \frac{(4/3\pi r^3)\,\rho\, g}{6\pi\eta r} \qquad \left[\rho = \frac{\text{mass}}{\text{vol.}} = \frac{m}{4/3\pi r^3}\right.$$

$$\left[\text{or } m = (4/3)\,\pi r^3)\,\rho\right.$$

$$\text{or} \quad v_T = \frac{(4/3\,\pi r^3)\,\rho\, g}{6\pi\eta r}$$

$$\text{or} \quad \boxed{v_T = \frac{2\rho g r^2}{9\eta}} \qquad \text{.....(6)}$$

$$\text{since} \quad \frac{2\rho g}{9\eta} = \text{constant},$$

$$\text{so} \quad \boxed{v_T \propto r^2} \qquad \text{.....(7)}$$

i.e. The terminal velocity of a sphere of given material varies directly with the square of the radius.

3- Angular Momentum

Definition: *The angular momentum of a body is the cross product of position vector and its linear momentum. Mathematically*

$$L = r \times p \qquad \text{.....(1)}$$

The direction of L is perpendicular to r and p and can be determined by applying right-hand-rule.

Right-hand-rule:

Different mathematical forms of L:

We have

$$L = r \times p$$

$$= r \times mv \qquad [\, p = mv$$

$$\text{or} \quad L = m\, r \times v \qquad \text{.....(2)}$$

For a particular case when p and r are perpendicular to each other, then the magnitude of L is,

$$L = r\, p \sin 90^o = r\, p$$

$$\text{or} \quad L = r\, p \qquad \text{.....(3)}$$

$$L = r\, m\, v \qquad \text{.....(4)} \quad [p = mv$$

$$\text{or} \quad L = m\, r^2\, \omega \qquad \text{.....(5)} \quad [\, v = r\, \omega$$

$$\text{or} \quad L = I\, \omega \qquad \text{.....(6)} \quad [\, I = m\, r^2$$

Now we have

$$F = m\, a = m\, \Delta v / \Delta t = \Delta p / \Delta t \qquad \text{.....(7)}$$

$$\& \quad \tau = r\, F \sin 90^o = r\, F$$

$$\text{or} \quad \tau = r\, F = r\, \Delta p / \Delta t = \Delta L / \Delta t$$

$$\text{or} \quad \tau = \Delta L / \Delta t \qquad \text{.....(8)}$$

From eq. (8) we see that the rate of change of angular momentum is equal to the applied torque.

Examples:

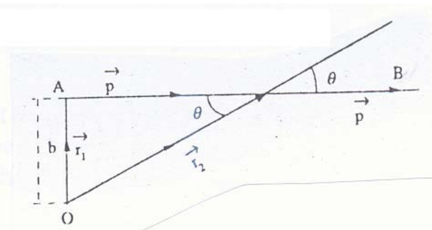
1. The earth rotating about its axis.
2. A satellite orbiting round the earth.
3. The wheels of a car rotating on their axles.

To prove that:

<u>For a particular with constant linear momentum has a constant angular momentum</u>,

Consider

A particle having mass m moving along the path AB with a constant momentum p



Then angular momentum at the position r_1 is,

$$L_1 \;=\; r_1 \text{ x } p \qquad \text{.....(9)}$$

And at the position r_2 is

$$L_2 \;=\; r_2 \text{ x } p \qquad \text{.....(10)}$$

Both have same directions i.e., inside the paper (from the knowledge of right-hand-rule).
And their magnitudes are

$$L_1 \;=\; r_1\, p \sin 90^o \;=\; m\, v\, r_1 \;=\; m\, v\, b \quad (\, r_1 \;=\; b$$

$$\text{and} \quad L_2 \;=\; r_2\, p \sin 90^o \;=\; m\, v\, r_2 \;=\; m\, v\, b \quad (\, r_2 \sin\theta = b$$

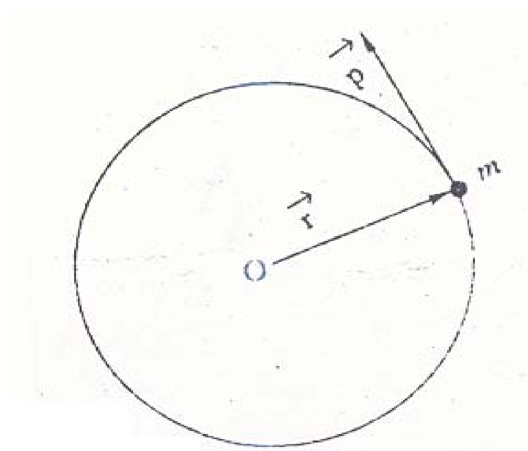
Therefore

$$L_1 \;=\; L_2 \quad m\, v\, b \qquad \text{.....(11)}$$

<u>As the direction and magnitude is constant, so the angular momentum is constant.</u>

To prove that:

<u>A particle moving in a circular orbit with constant speed has constant angular momentum:</u>



Consider

A particle of mass m moving with velocity v along a circle or radius r in anti-clockwise direction then its linear momentum P is

$$P \;=\; m\, v \qquad \text{.....(12)}$$

And angular momentum L is

$$L \;=\; r \text{ x } p \qquad \text{.....(13)}$$

From the knowledge of right-hand-rule, its direction will be out of the paper, and magnitude is

$$L \;=\; r\, p \sin 90^o \;=\; r\, p \;=\; m\, v\, r \qquad \text{.....(14)}$$

Since the particle is moving with constant speed v and having constant radius r , so from eq. (14) we conclude that <u>it has constant angular momentum.</u>

4- Weightlessness in Satellites

Definitions:
Inertial mass: *The mass of an object as measured by the property of inertia. It is equal to the ratio force/acceleration when the object is accelerated by a constant force.*
Gravitational mass: *The mass of a body as measured by the force of attraction between masses, the value being given by Newton's Law of Universal Gravitation.*
<u>Inertial and gravitational masses are equal in a uniform gravitational field.</u>

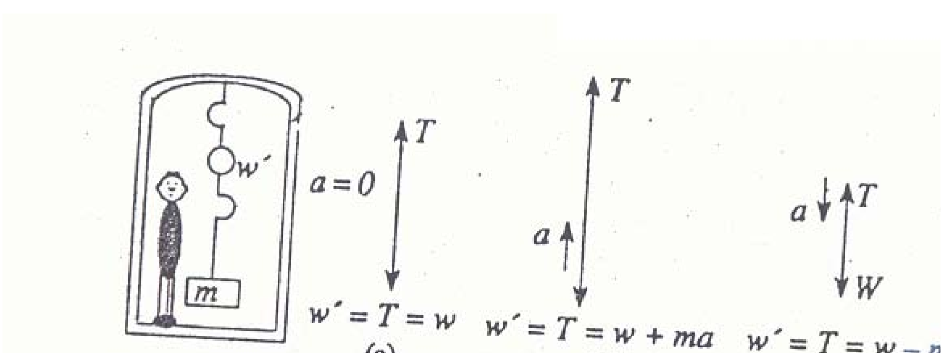
Weight: *A measure of the gravitational force acting on a substance.*
Lift (or elevator): *A cabin or chamber to carry a bunch of people or goods to upper or lower floors by electrical system.*
Satellite: *A smaller body that revolves around a larger body.*

Variation of weight:
Where gravitational forces are involved we can take gravitational mass equal to the inertial mass, i.e.,

$$m_i = m_g = m$$

In an inertial frame i.e., a frame at rest or moving with uniform velocity, the weight of the body is equal to the force of gravity experienced by the body but in an accelerated frame of reference, the weight of the body depends upon the acceleration of frame of reference.

Weight of a body in a lift (or elevator):
Consider a body of mass m tied to a spring balance that is attached to the ceiling of a lift. The reading of the spring balance indicates the tension in the string, related to weight w of mass m.
The reading of the spring balance by w′, the apparent weight.



a) Lift at Rest (or moving with uniform velocity):
In this case the tension is equal and opposite to the weight mg , so

$$w' = T = w \qquad \text{.....(1)}$$

b) Lift moving upward with uniform acceleration:

When the lift move upward with acceleration a , we have

Resultant force (in upward direction) $= F = T = T - w$ …..(2)

From 2nd Law of motion ,

$$F = m a \qquad \text{…..(3)}$$

From eqs. (2) & (3) , we get

$$T - w = m a$$

or $$T = w + m a$$

or The apparent weight $= w' = T = w + ma = mg + ma$

or $$\underline{\mathbf{w' = T = m(g + a)}} \qquad \text{…..(4)}$$

i.e. <u>The apparent weight increases by a factor ma for upward motion.</u>

c) Lift moving downward with uniform acceleration:

When the lift moves downward with acceleration a , we have (taking the upward direction positive)

$$T - w = -m a$$

or the apparent weight $= w' = T = w - ma = mg - ma$

or $$\underline{\mathbf{w' = T = m(g - a)}} \qquad \text{…..(5)}$$

i.e. <u>The apparent weight decreases by a factor ma for downward motion.</u>

Weightlessness:

If the lift starts moving down with an acceleration equal to g i.e., it falls freely, then from eq. (5) , we have

$$w' = T = m(g - g) = 0$$

thus according to the observer in the lift, the body appears to be weightless. The spring balance will read zero, the apparent weight is zero or the body seems to be weightless.

Weightlessness in satellite:

When a satellite moves around the earth with an orbital (or tangential) speed and downward force along a curved path. The curvature of this path is such that the earth curves around by the same amount as the moving object and therefore does not touch the surface of the earth. The body continues to fall during its orbit around the earth. This (free fall) gives the feeling of weightlessness.

Artificial Gravity:

To overcome the feeling of "weightlessness", an artificial gravity can be created in the space ship. To achieve this the space craft is set into rotation around its own axis. Any point on the outer rim experiences a centripetal force,

$$F_c = mv^2 / R$$

The astronaut is pressed towards the outer rim and exerts a force on the floor of the space station in the same manner as on the earth.

5- Various Sources of Energy

In the world the present annual consumption of energy is estimated as 6×10^{13} kilowatt hours. The ultimate source of most forms of the energy that we use today is the sun. The following are the various sources of energy.

1. Water Power Hydal energy:

Water wheels of many kinds have been used to produce mechanical power for milling grain, sugar cane crushing. In hydroelectric plant, water power drive turbines whose rotating shafts are connected to electric generators that produce electric power.
Hydroelectric plants are installed at big dams.
Tarbala Dam produces 1750 mega watt.
Mangla Dam produces 900 mega watt.
Total installed hydroelectric generating capacity is 3000 mega watt.
The planned capacity of Tarbela Dam is 4678 mega watt. And its number is 12th in World's Largest-Capacity Hydro Plants.
In World's Largest-Volume Embankment Dams, Tarbela is number 1st having volume capacity 1.485×10^{8} m^3 . Mangla comes 13th having volume capacity 6.3379×10^{7} m^3 and Tanda is 17th having volume capacity 5.725×10^{7} m^3.

2. Fossil Fuels:

The fossil fuels are mainly coal, wood, petroleum and natural gas.
Coal occurs widely throughout the world. The largest deposits are in Russia where 60 % of the world's coal reserves are located.
Oil deposits are widely distributed in coastal areas of the world. e.g. in south-west U.S.A., Sahara deserts, Kuwait, Iran, Iraq, U.A.E. and Saudi Arabia.
In Pakistan oil is being extracted in Pothohar Punjab and Sind.
Natural gas called Sui gas has huge reserves at Sui in Baluchistan.

3. Nuclear Energy:

Definitions:

Nuclear fission: *The splitting of a heavy nucleus into nuclei of medium mass, with the release of nuclear energy.*
Nuclear fusion: *A reaction in which light nuclei combine to form a nucleus with medium mass, with the release of nuclear energy.*
Nuclear Reactor: *A device in which the controlled fission of radioactive material produces new radioactive substances & energy.* Nuclear power reactors have been producing electricity all over the world since 30 years. In Pakistan we have one power reactor at Karachi generating 137 mega watts of electricity.

4. Geothermal Energy:

Geothermal energy is generated by tapping the energy of the hot, molten areas inside the earth crust.
These power plants are in U.S.A., Iceland, Mexico, Italy, Japan, Phillipines and New Zealand.
Geothermal power is used in two ways.

i) Piping of steam from naturally occurring reserves of steam deep in earth, and using that steam to operate turbines that generate electricity.

ii) Tapping of very hot water which is sometimes found deep in the earth.

5. Wind Energy:

In the windy regions, mechanical energy is obtained from wind mills installed to produce and used in the tube wells or flour mills.
In Pakistan Chitral, Gilgit coastal areas are suitable for wind power.

6. Tidal Energy:

The water rises along coasts due to the gravitational interaction of the moon and the earth.
Electricity is obtained from the power plant that uses the ‘heat’ of water created by the rise and fall of the ocean tides to spin the water turbines.
Tidal power stations have been installed in France, Alaska, Argentine and Russia.

7. Solar Energy:

Solar energy is produced by nuclear fusion. Mirrors and lenses have been used to concentrate the energy of the Sun’s rays into small spots.
Another way is to use <u>solar cells</u>. A solar cell is a device which converts solar energy into electrical energy. A panel of solar cells are used to drive radio, TV and vehicles.
In Pakistan solar energy electricity is used in some villages.

6- Resonance

Definition: i) *A specific response of a system which is able to oscillate with a certain period, to an external force acting with the same period.*

ii) *The vibratory motion produced in a body by the influence of another body when their time periods are exactly equal.*

Natural period and frequency:

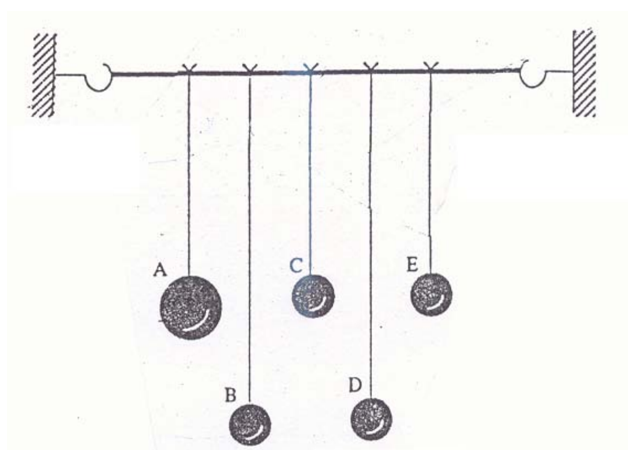
When a body vibrates freely under the action of its own elastic or gravitational force, it always vibrate with the same frequency f , called natural frequency of that body and the time period T as its natural period. In case of simple pendulum it is

$$T = 2\pi \sqrt{l/g}$$

Explanation:

When a periodic force of frequency equal to the natural frequency of a body is applied on the body, it slowly gains in amplitude and finally begins to vibrate with a very large amplitude. This is known as resonance.

Illustration:



Consider a number of simple pendulums.
Pendulums C & E have the same Length, pendulums B & D have same length and so same natural time period. Pendulum A is suspended in such a way that its lengthcan be changed. Adjust the length of A equal to C & E .
Then vibrate pendulum A.
We will see only C & E vibrate.
Now make length of A equal to B and D. On vibrating the pendulum A, the pendulums B & D will vibrate, being the same periods as that of A.
When pendulum A is set into vibration, a small periodic force acts upon the suspension and is communicated to all the pendulums. This cumulative effect takes place in case of pendulums have same natural periods.

Condition:

The phenomenon of resonance holds good for all bodies capable of vibrations. It will also occur if the period of the applied force is any integral multiple of the natural period of the body.

Applications:

1. Phenomenon of resonance is employed to determine the natural frequencies of many bodies.
2. The art of singing or speaking and the wonderful mechanism of the human ear are excellent natural applications of resonance.

Examples (Uses):

1. While crossing the bridges the soldiers are ordered to break their steps in order to avoid resonance.
2. In order to raise the swing to a great height, we must give it a push at the right moment and in the right direction.
3. Tuning a radio is an example of electrical resonance. By tuning a dial, the natural frequency of AC current in the receiving set is made equal to the frequency of the transmitter.
4. Employed in the improvements of the designs of microphones, loud-speakers, studios, etc.

7- Stationary Waves (or Standing Waves)

Definitions:

Stationary waves: i) *The resultant of two wave trains of the same wavelength, frequency and amplitude travelling in opposite directions through the same medium.*

ii) *Waves apparently standing still resulting from two similar wave trains travelling in opposite directions.*

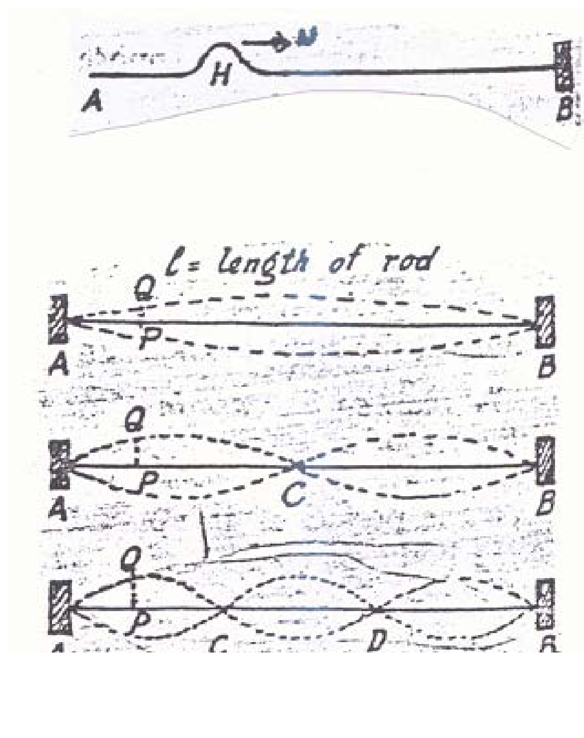
Node: *A point of no disturbance of a stationary wave.*

Antinode: *A point which oscillate with the maximum amplitude in stationary waves.*

Formation of Stationary waves:

Consider a rubber cord with one end held in hand and the other end tied to a fixed support. If we wiggle it from the end in our hand, at a particular frequency, say f_1 , the cord continues to oscillate as shown in fig. (a).

If we increase the wiggling frequency beyond f_1 , up to the frequency of the motion of the hand $2f_1$. This time the cord will oscillate in two loops. Similarly as the wiggling frequency is further increased, stationary waves are set up at the frequency $3f_1$. Now the cord oscillate in three loops. Generalizing it, if the frequency is nf_1, stationary waves with n loops will be formed.



Production of Nodes and Antinodes:

The points on the cord which do not oscillate at all (e.g. N_1 , N_2 , N_3 & N_4) are called <u>nodes</u>, and the point which oscillate with the maximum amplitude (e.g. A_1 , A_2 and A_3) are called <u>antinodes.</u> The distance between two nodes or antinodes is always equal to ½ λ.

Reason of production:

Stationary waves are set up as a result of super-position of two exactly similar waves moving along the same line but in opposite directions.

Condition for production:

The phenomenon of stationary waves takes place in any medium wherever its particles are simultaneously agitated by two similar waves moving along the same line in opposite directions.

Detection:

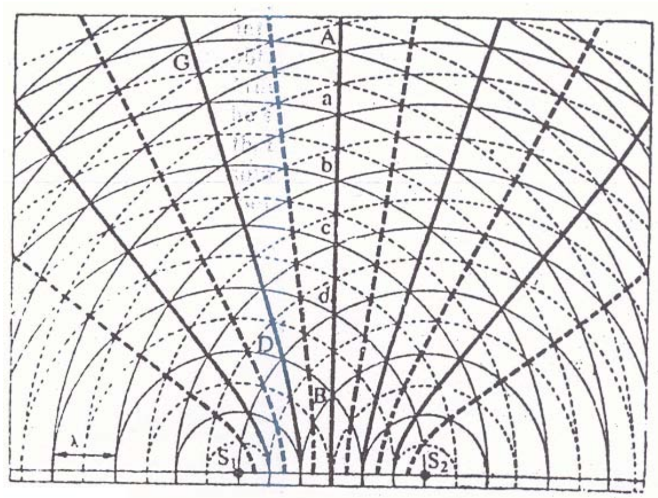
The presence of stationary waves in a medium can be easily detected by the fact that the particles at the nodal points will be at rest and the particles at the antinodes will be vibrating quite strongly.

Quantization of frequencies:

In any medium stationary waves of all frequencies cannot be set up. The waves having a discrete set of frequencies only, can be set up in the medium.

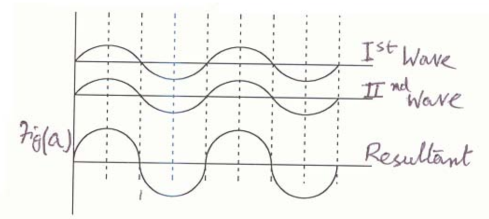
8- Interference of Sound Waves

Interference: *The phenomenon in which the two waves support each other at some points and cancel at others.*

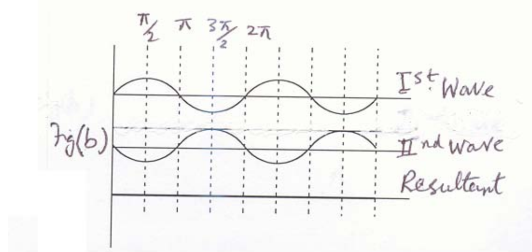


In the fig. when two waves arrive at a point in the same phase, i.e. two crests or two troughs super-pose, then resultant amplitude make constructive interference ,e.g. points on the lines AB & GD. While at some other points where they arrive in opposite phase, i.e. crest of one falls over the trough of the other, then the resultant amplitude make destructive interference , e.g. points on the dotted lines.

Constructive Interference:
The interference of two waves, so that they reinforce one another.



Condition for constructive interference:
The phase difference—or path difference between two waves is zero or an integral multiple of λ.
or $s = n\lambda$, $n = 0, 1, 2, 3, 4, \ldots$



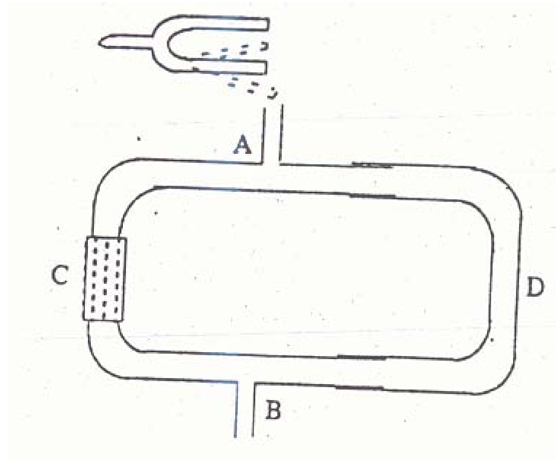
Destructive Interference:
The interference of two waves, so that they cancel one another.

Condition for destructive interference:
The phase difference or path difference between two waves should be an odd multiple of $\lambda/2$.
or $s = (n + \frac{1}{2})\lambda$, $n = 0, 1, 2, 3, \ldots$

Experimental demonstration:
Interference of sound waves can be demonstrated from the following simple experiment.

Quincke's Interference tube:
The apparatus is shown in the fig. A vibrating tuning fork is placed in front of the opening A. The sound waves on entering A will split, half the intensity goes through tube C and the other half through tube D. The two waves reunite at B and can be heard.

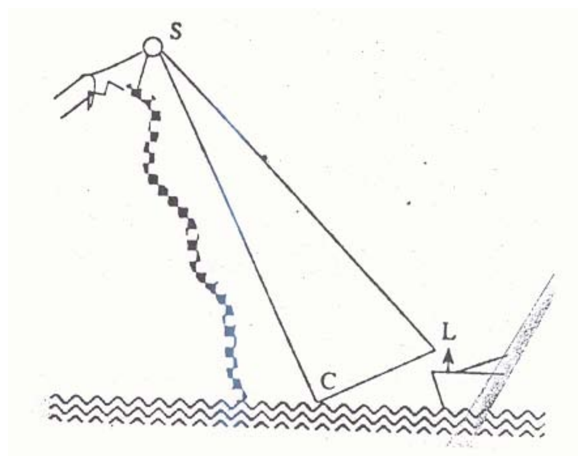
If the sliding tube D is adjusted to make both paths equal, then their path difference is zero and waves interfere constructively. If the tube D is drawn out, so that path ADB becomes longer. When path difference becomes half a wave-length they interfere destructively and no sound is heard at B.
Now if the rubber portion of C is closed, the ear will again hear the sound. This proves that silence is due to the destructive interference of the two sound waves.



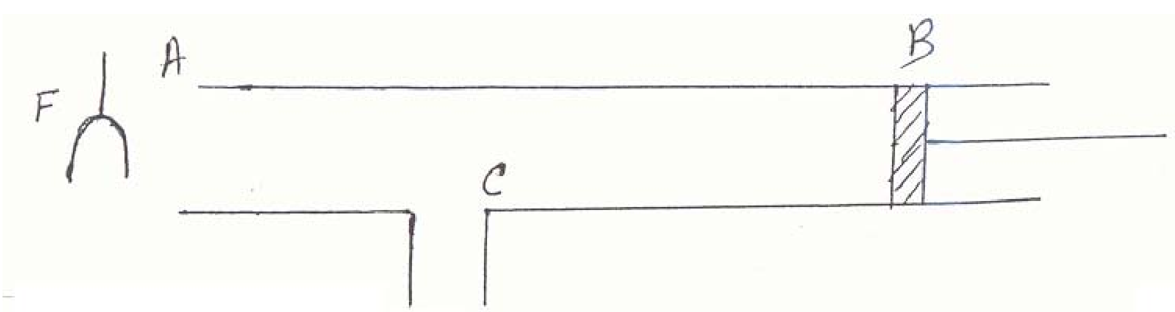
Other Examples:

1. Fog Siren:

If a fog siren is placed on the top of a peak. A ship approaching it may find itself in a silence zone, as it moves the sound again becomes audible.
The listener L is receiving sound waves through two paths, SL and SCL. When these two path differ by half integral multiple of λ, destructive interference or silence zone occurs. And when path difference is $n\lambda$, the sound is heard.



2. Seebeck's tube:



Interference by Seebeck's tube.

9- Beats

Definition:

i) *The periodic alternations of sound between maximum and minimum loudness.*

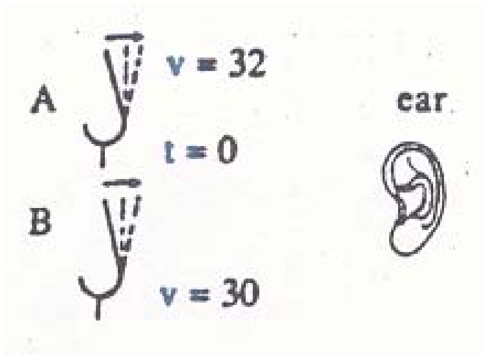
ii) *The condition whereby two sound waves form an outburst of sound followed by an interval of comparative silence.*

Explanation:

If two sources of nearly equal frequencies are sounded at the same time, then only a single note is heard. This note rises and falls in loudness alternately.

Illustration:

Consider two tuning forks, having frequencies 30 and 32, be sounded together and placed upon a table. Suppose at a certain time t = 0, the right hand prongs of both the forks are moving towards right.
After t = ¼ Sec, the fork A completes 8 vibrations and just starts moving to the right sending out a compression.
And fork B completes 7 ½ vibrations and just starts moving to the left sending out a rarefaction. The compression from A and rarefaction from B reach the ear at the same time. They cancel the effect of each other and no sound is heard.



After t = ½ seconds, fork A completes 16 vibrations and fork B 15 vibrations. The right hand prongs of both the forks Just start moving to the right sending out compressions.
These compressions arrive at the ear together and a loud sound is heard.
During this interval <u>one beat</u> is heard.
After t = ¾ seconds, the fork A completes 24 vibrations and fork B 22 ½ vibrations. Again compression from A and the rarefaction from B cancel each other and no sound is heard.
After t = 1 second, the fork A completes 32 vibrations and fork B 30 vibrations. Both these forks will be sending compressions and again a loud sound will be heard.
During this interval <u>another beat</u> is heard. So the total number of beats heard is 2, which is also equal to the frequency difference of two forks.

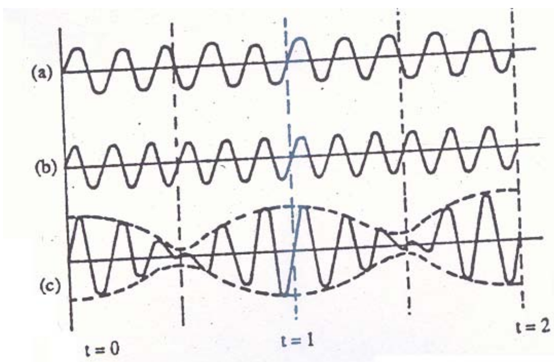
Conclusion:

The number of beats per second is equal to the difference between the frequencies of the forks.

Displacement curves:

From the principle of superposition, the resultant displacement of any particle will be the sum of the displacements due to each of the two waves.

The resultant wave which is produced from two waves a and b are shown in fig. The variations of amplitude give rise to variations of loudness which is called beats.



Applications:

1. The phenomenon of beats is used in tuning the musical instruments, e.g. pianos, organs.
2. It is used in finding the unknown frequencies.
3. The presence of dangerous gases in mines is sometimes detected by means of beats.
4. It is also made use in the Heterodyne method of radio reception.

[Heterodyne: *Having alternating currents of two different frequencies that are combined to produce two new frequencies the sum and difference of the original frequencies, either of which may be used in radio or TV receivers.*]

10- Acoustics

Definitions:

Acoustics: *Applications of the results of scientific study of the production, properties and propagation of sound waves in the design of buildings, halls and concert rooms.*

Echo: *The repetition of a sound or of sounds already heard, caused by the throwing back of sound waves.*

Reverberation: *Persistence of sound after the source has stopped.*

Reverberation time: *The time it takes for sound to diminish until it is no longer audible.*

Explanation:

In an acoustically well-designed hall, speech or music is distinctly audible at all its places. In many halls this quality is usually lacking. One may hear loud sound or loud spots at some places and very weak or dead spots at other places.

Acoustical defects:

The following factors adversely affect the acoustics.

1. Echoes
2. Reverberation
3. Focussing of sound at some spots

Echo depends on the distance of the reflecting surface from the source. The minimum distance of the wall must be about 17 m for an echo. It is heard if time interval between sounds is less than 0.1 second.

When reflecting surface is less than 17 meters, reverberation occurs. It cause the impressions on the ear that the original sound has been prolonged and cause the confusion.

Large curved walls produce a focussing of the sound waves at certain spots only and sound is not heard clearly at other places.

Empty hall exhibits these defects more strongly than the same hall full of audience.

Remedies:

The formation of echoes and reverberation in the public halls can be remedied by:

i) Selecting proper dimensions.
ii) Avoiding continuous flat and smooth walls.
iii) Introducing a number of windows.
iv) Introducing irregularities in the surface of walls, e.g. a) artistic engraving, b) suspending thick curtains
v) In designing a hall, large curved walls should be avoided.

Human bodies and the clothes serve also as good absorbents of sound of sound which in the absence of audience would have been reflected.

11- Dual Nature of Light

<u>Properties of Light</u>

Definitions:

Interference: *The phenomenon in which two waves support each other at some points and cancel at others.*

Diffraction: *The bending or spreading of waves around the edge of an opening or obstacle.*

Polarization (of light): *The limiting of the vibrations of light, usually to vibrations in one plane.*

Photoelectric effect: *The emission of electrons by a substance when illuminated by electromagnetic radiation.*

Compton effect: *The phenomenon in which a photon is scattered by an electron and the scattered photon has a frequency less than its original frequency.*

Theories of light:

Several theories have been given to explain the properties of light. We will consider the following four theories.

1. **Newton's Corpuscular theory:**
   According to it light consists of streams of minute particles in motion.

2. **Huygen's wave theory:**
   According to it light travels from one place to another in the form of waves.

3. **Maxwell's Electromagnetic wave theory:**
   According to it light waves are electromagnetic in nature and they consist of an oscillating electric field and an oscillating magnetic field, both are perpendicular to each other and have the same frequency and phase.

4. **Quantum theory of light:**
   According to it light is carried from one place to another in wave packets called 'quanta' or 'photons', each having a definite energy and momentum.

Duel nature of light:

Our present view about the nature of light is that light possesses both wave and particle properties. Sometimes it behaves like waves and sometimes it behave like particles. However, both these behaviors cannot be studied simultaneously.

i) Interference, diffraction and polarization shows its wave nature and can be explained by classical wave theory.

ii) Photoelectric effect and Compton effect exhibit its particle nature and can be explained by quantum theory.

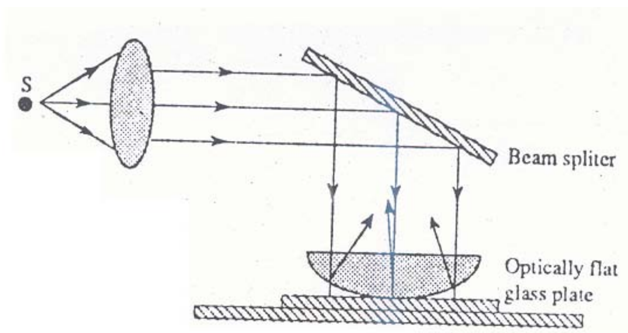
12- Newton's Rings

Definition: *Coloured rings produced by the interference of light waves.*

Explanation:

If a convex lens is placed upon a flat glass plate, we enclose an air film between the lens and the glass plate. If such a film is illuminated by a parallel beam of monochromatic light from the top falling normally on the film and also viewed from the same direction, we will see dark and bright circular rings. Such rings were first studied by Newton and are known as Newton's rings.

Experimental arrangement:



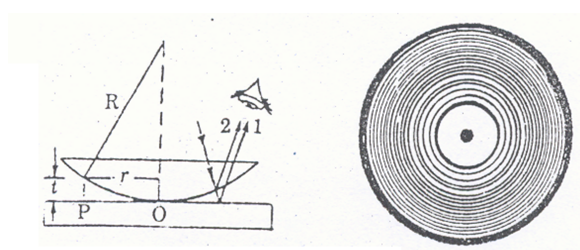
A plano convex lens is placed in contact with a plane glass surface, shown in the fig. When this arrangement is Illuminated from above by a parallel beam of mono-chromatic light, a series of concentric rings are observed. They are formed due to the interference between the rays reflected by the top and bottom surfaces of the air gap between the convex lens and the plane glass.

The air gap, equivalent to a thin film, increases in width from the central contact point out to the edges, corresponds to constructive and destructive interference and results in series of bright and dark rings, shown in the fig.

For dark rings, we have the formula,

$$r = \sqrt{m\lambda R}$$

where



- r = distance between central spot and the dark fringe
- m = number of order
- R = radius of curvature of the lens
- λ = wavelength of light used

We can calculate the wavelength λ, from the above formula.

Circular rings:

The fringes are circular because the air film is symmetrical about the points of contact of the lens and the glass plate. That is , it will have the same thickness at all points which lie on the circumference of a circle drawn with centre O and radius OP. The whole circle will therefore appear dark. These alternate bright and dark circular fringes can be observed by a low power travelling microscope.

Black central spot:

The point of contact between the two glass surfaces is dark. It is because of the fact that the two reflected parts of the incident wave (although air gap is zero) at the central spot are in opposite phase which is equivalent to a path difference of $\lambda/2$.

Transmitted light:

If the fringes are seen with the help of transmitted light central spot will look bright. Because the path difference between the two paths of the wave is zero at the centre and they are in the same phase.

13- Diffraction

Definitions:

Diffraction: *The bending or spreading of light waves around the edge of an opening or obstacle.*

Fraunhofer diffraction: *Diffraction of a parallel beam at an aperture observed effectively at infinity, i.e. when the wave fronts are plane.*

Fresnel diffraction: *Diffraction at an aperture, when either the source of radiation or the point of observation, or both, are at finite distance from the aperture, i.e. when the wave fronts are spherical.*

Diffraction grating: *An optical surface, either transmitting or reflecting with several thousand equally spaced and parallel grooves ruled in it.*

[**Groove:** *A long narrow hollow, especially one cut by a tool for something to fit into or work in.*]

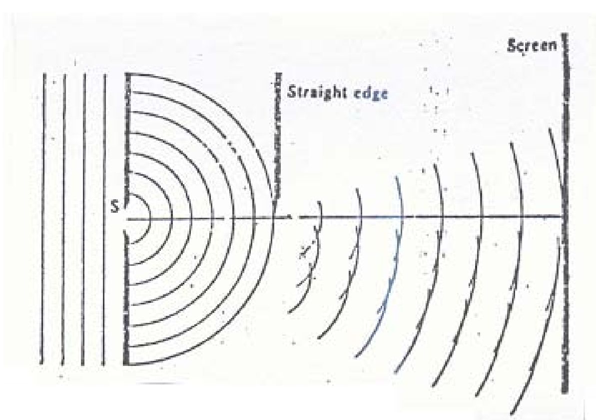
Introduction:

When light is incident over a sharp edge, it bends towards the geometrical shadow. The condition for diffraction is that the size of the obstructing object or slit must be comparable with the wavelength of the incident light.

The minute study or careful inspection of light shadow shows a series of bright and dark bands with the shadow which is due to diffraction.

Illustration:

Consider the light passing through A slit S and spherical wavefronts Crossing a straight edge. Applying Huygen's principle, if We draw secondary wavelets, Some of their portion will pass to The geometrical shadow. And Interference give rise to fringes.



Common factor between interference & diffraction:

In both interference and diffraction superposition of waves occur.

Difference between interference & diffraction:

1.Interference is the superposition of few secondary wavelets.	1. Diffraction is the superposition of very large number of secondary waves.
2. Interference fringes are equally spaced.	2. Diffraction fringes are wide near the obstacle and go on becoming narrow towards the shadow region.
3. Interference is the result of interaction of two different wave fronts originating from the same source.	3. Diffraction is the result of interaction from different parts of the same wave front.
4. Points of minimum intensity are perfectly dark.	4. Points of minimum intensity are not perfectly dark.
5. All bright bands are of uniform intensity.	5. All bright bands are not of the same intensity.

Difference between deviation & diffraction:

We define

Deviation: *The turning of a ray during reflection or refraction.*
Diffraction: *The bending or spreading of light waves around the edge of an opening or obstacle.*

In deviation two mediums viz. denser and rarer are required.
In diffraction no change of medium is involved.

14- Interference

Definitions:

Interference: *The phenomenon in which the two phase coherent light waves support each other at some points and cancel at the others due to superposition is known as interference.*

Superposition: *Combining the displacements of two or more wave motions algebraically to produce a resultant.*

Principle of linear superposition: *When two waves act upon a body simultaneously they pass each other without disturbing each other, and act upon the particles of the quite independent of each other, and their resultant displacement is the resultant of all individual waves.*

Phase coherence: *Producing of two waves of same wavelength and time period at the same instant.*

Phase: *The phase of a vibrating particle at any instant is its state or condition as regards its position and direction of motion with respect to the mean position.*

Coherent sources: *Sources which are emitting light waves continuously of the same wavelength, time period and amplitude. They must maintain a constant phase difference between them.*

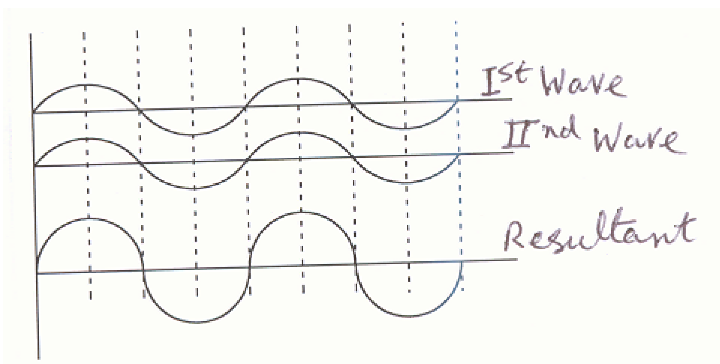
Monochromatic: *Light consisting of only one colour.*

Constructive Interference: *The phenomenon in which two waves superimpose so as to reinforce each other effect and results in bright band.*

Condition:

For constructive interference, the path difference between the two waves must be integral multiple of λ, i.e.

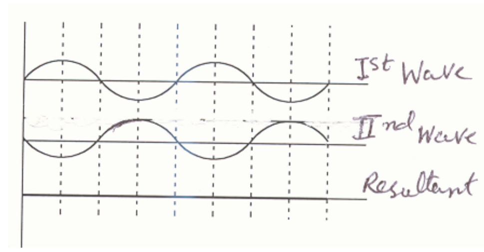
$$d = n\lambda , n = 0, 1, 2, 3, . .$$



Destructive Interference: *The phenomenon in which two waves superimpose to cancel each other effect and result in dark band.*

Condition:

For constructive interference, the path difference between the two waves must be half odd integral multiple of λ , i.e.



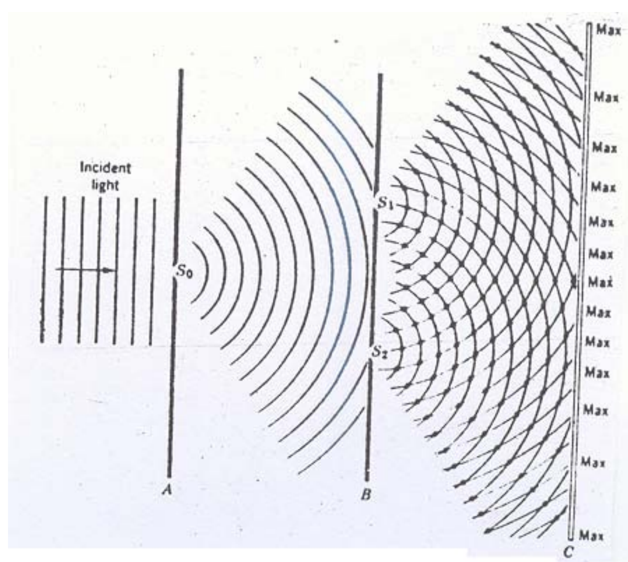
$$d = (n + ½)\lambda, n = 0, 1, 2, 3, \ldots$$

Conditions for interference:

1. The sources should be monochromatic.
2. The sources should be coherent, and close together.
3. The principle of linear superposition should be applicable.

Arrangement to demonstrate interference of light:

The interference of light can be demonstrated by using a single light source and then to split the light from it into two parts by slits A and B. The regions of the screen where the waves reinforce each other become bright and the region where the waves cancel each other become dark. These bright and dark bands are called <u>interference fringes.</u>



15- Interference in thin films

Thin film: *The transparent membrane, such as layer of oil or soap bubble.*

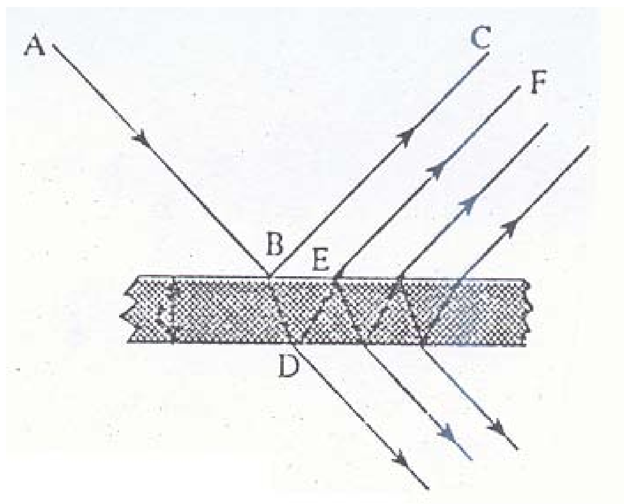
Principle of reflection: *When reflection takes place from a denser medium, then reflected rays suffers a phase change of 180^o or a path difference of $\lambda/2$. When reflection takes place from a rarer medium, there is no change of phase.*

Introduction:

The multiple reflection of light between the surfaces of transparent medium gives rise to beautiful effects of interference.

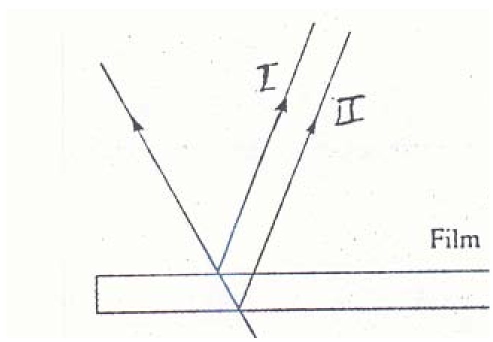
Illustration:

Consider a thin film. Let a monochromatic light be incident on the upper surface. A part of ray AB is reflected as ray BC and the rest of it is transmitted as ray BD. At D a part of it is again reflected , which emerges as ray EF.
The rays BC and EF are superimposed to produce interference fringes.

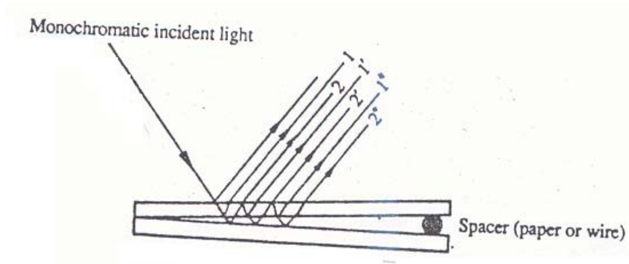


The following two cases will be discussed.

1. Thin parallel film:
A monochromatic beam of light of wavelength λ is incident. Part I of this beam is reflected from the upper surface and the remaining portion refracted into the film, after reflection from the second face, it emerges out as part II.
As the film is thin, so the separation between part I and II is very small and they superimpose on each other. The portions I and II, being the parts of same beam, will have phase coherence. So the effect of their interference can be detected. This results in the formation of circular rings.



2. Wedge-shaped film:



The wedge-shaped film may be made by placing a paper or a thin wire between the two flat surfaces. Here the reflected light from the upper and lower surfaces of the air film have a path difference. When emerging from the top they are superimposed to produce interference fringes. The fringes in this case are straight lines and parallel to the edge of wedge.

The first dark fringe:

The fringe at the point where the thickness is zero will be dark. It is because the two parts of the beam are being reflected from denser (upper surface) and rarer (lower surface) medium. From the consideration of principle of reflection, destructive interference is formed.

Dependence of path difference:

It depends upon;

1. Thickness of the film.
2. Angle of incidence.
3. Index of refraction, n.

Examples:

1. Coloured fringes formed in soap bubbles.
2. Formation of colours in thin layer of oil on water.
3. Formation of colours on metal sheets during welding.

Fringe pattern for transmitted rays:

Here the pattern is just opposite to the reflected rays due to no phase change.