3.1.1. INTRODUCTION

_ Sunlight, as the rainbow shows us, is a composite of all colors of visible spectrum. The colors reveal themselves in the rainbow because the incident wave lengths are bent through different angles as they pass through raindrops that produce a bow. However, soap bubbles and oil slicks can also show striking colors produced not by refraction but by constructive and destructive interference of light. The interfering waves combine either to enhance or to suppress certain colors in the spectrum of sun light. Interference of light waves is thus a superposition phenomenon.

This selective superposition of wavelengths has many applications. When light encounters an ordinary glass surface, for example about 4% of incident light energy is reflected, thus weakening the transmitted beam by the amount. This unwanted loss of light can be a real problem in optical systems with many components. A thin transparent “interference film” deposited on glass surface, Can reduce the amount of reflected light by destructive interference. The bluish cast of camera lens reveals the presence of such a coating. Interference coatings can also be used to enhance –rather than reduce- the ability of a surface to reflect light.

To understand interference, we must go beyond the restrictions of geometrical optics and employ the full power of wave optics. In fact, as you will see, the existence of interference phenomena is perhaps our most convincing evidence that light is a wave-because interference cannot be explained other than with waves.

OBJECTIVES:

After going through this chapter we should able to: know

1) About light wave.
2) The relation between path difference and phase difference.
3) About interference.
4) About the interference phenomenon takes place in thin films.
5) Determination of thickness of a paper using wedge method.
6) Determination of wavelength of monochromatic light using Newton’s rings.

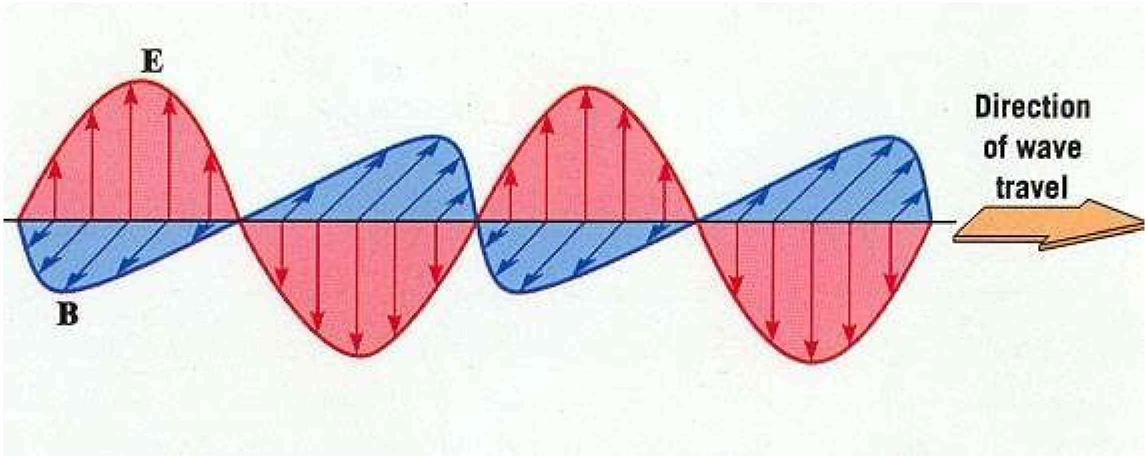
3.1.2) LIGHT AS A WAVE:

Light has dual nature. It has both particle nature and wave nature but it cannot act as a wave and particle simultaneously. Light is also having the properties such as reflection, refraction, interference, diffraction, polarization. Light is also having two most famous effects like photoelectric effect and Compton Effect. To explain the properties like interference diffraction and polarization we need to adopt wave nature for light.
Light is a transverse wave.

The first person to advance a convincing wave theory for light was DUTCH PHYSICIST CHRISTIAN HUYGENS, in 1678.

Light wave should be represented as follows.

Figure1



Whose displacement is given b

$$y = asin\omega t \quad or \quad y = \mathrm{asin}\,(\omega t + \delta)$$

Where ' a' is amplitude of wave.

'ωt' is Phase, Which gives the position and direction of wave at a time 't'

3.1.3) PHASE DIFFERENCES:

The angular separation between two points of wave is called Phase difference. It is measured in radians or degrees.

3.1.4) PATH DIFFERENCE:

The linear separation between two points of wave is called Path Difference
It is measured in mm or cm.

Fig.

3.1.5) RELATION BETWEEN PHASE DIFFERENCE AND PATH DIFFERENCE:

Figure

2π Phase Difference = λ Path Difference

π Phase Difference = $\frac{\lambda}{2}$ Path Difference

$\frac{\pi}{2}$ Phase Difference = $\frac{\lambda}{4}$ Path Difference

Therefore for

2π Phase Difference = λ (Path Difference)

Phase Difference (δ)= What is the Path Difference(X)

$$\frac{\delta}{2\pi} = \frac{x}{\lambda}$$

$$\delta = (\frac{2\pi}{\lambda}) \text{ x path difference}$$

$$\text{Phase Difference} = (\frac{2\pi}{\lambda}) \text{ x Path Difference}$$

Path Difference = $(\frac{2\pi}{\lambda})$ x Phase Difference

3.1.6) COHERENCE:

Two light waves are said to be coherent if they are having

1) Same Frequency
2) Almost Same Amplitude
3) Moving in a medium with either zero or constant Phase Difference
4) S

3.1.7) INTERFERENCE:

Interference is the optical phenomenon in which brightness and darkness are produced by the combination of two similar light waves.

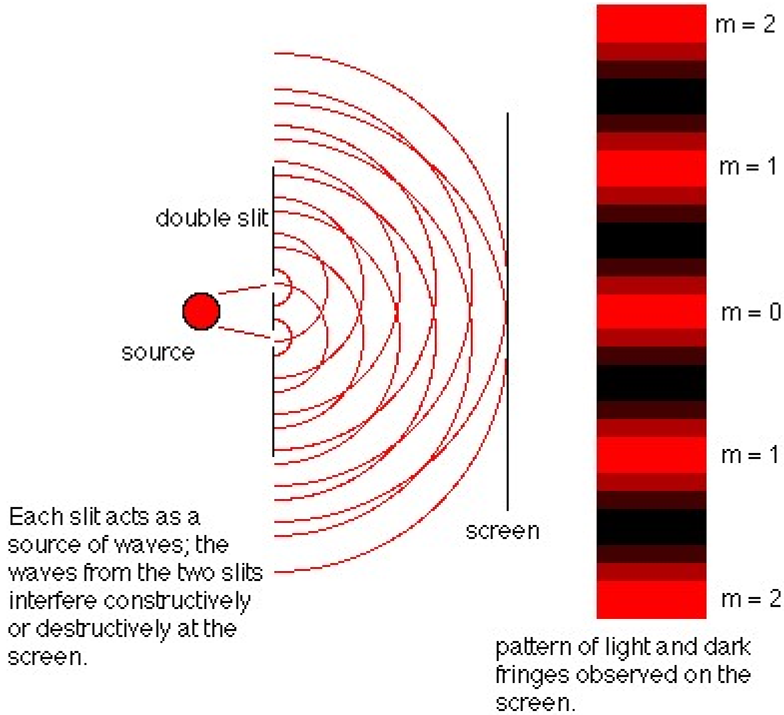
DEFINITION:

When two light waves of same frequency having constant phase difference coincide in space and time. There is modification in the intensity of light.

The resultant intensity at any point depends upon amplitudes and phase relationships between two waves.

This modification in the intensity is due to superposition of two light waves are called Interference.

And the pattern dark and bright fringes produced are called Interference pattern.



(i)PRINCIPLES OF SUPERPOSITION:

When two or more waves reach a point simultaneously, the resultant displacement at that point is the algebraic sum of the displacements produced by the individual waves in absence of others.

Explanation: Let us consider the two waves of same frequency "ν" is $\frac{\omega}{2\pi}$

If y_1 is the displacement produced by one wave and
y_2 is the displacement produced by second wave
δ is the phase difference between these two waves

The resultant displacement produced by the superposition of these waves is

$$y = y_1 + y_2 \rightarrow (1)$$

Let $$y_1 = a_1 \sin \omega t \rightarrow (2)$$

$$y_2 = a_2 \sin(\omega t + \delta) \rightarrow (3)$$

Where a_1 and a_2 are the amplitudes of these two waves

Substitute equation (2) and (3) in (1), we get

$$y = y_1 + y_2$$

$$y = a_1 \sin \omega t + a_2 \sin(\omega t + \delta)$$

$$y = a_1 \sin \omega t + a_2 \sin \omega t \cos \delta + a_2 \cos \omega t \sin \delta$$

$$y = (a_1 + a_2 \cos\delta)\sin\omega t + (a_2 \sin\delta)\cos\omega t \rightarrow (4)$$

$$\text{Let } (a_1 + a_2 \cos\delta) = A\cos\theta \quad \rightarrow (5)$$

$$a_2 \sin\delta = A\sin\theta \quad \rightarrow (6)$$

Sub eq(5) and eq(6) in (4) then

$$y = A\sin\omega t\cos\delta + A\cos\omega t\sin\delta$$

$$\mathrm{y} = \mathrm{A}\sin(\omega t + \delta) \quad \rightarrow (7)$$

This is an equation for resultant displacement.

Where A is resultant amplitude which can be calculated as follows.

By squaring and Adding equation (5) and equation (6)

$$A^2cos^2\delta = (a_1 + a_2cos\delta)^2$$

$$A^2sin^2\delta = (a_2sin\delta)^2$$

$$A^2(cos^2\delta + sin^2\delta) = (a_1 + a_2cos\delta)^2 + (a_2sin\delta)^2$$

$$A^2 = {a_1}^2 + {a_2}^2cos^2\delta + 2a_1a_2cos\delta + {a_2}^2sin^2\delta$$

$$A^2 = {a_1}^2 + {a_2}^2 + 2a_1a_2cos\delta$$

Square of the amplitude (A^2) = Intensity of light (I)

$$I = {a_1}^2 + {a_2}^2 + 2a_1a_2cos\delta$$

$$If\ a_1 = a_2 = a$$

$$I = 4a^2cos^2\frac{\delta}{2}$$

$$A^2 = 4a^2cos^2\frac{\delta}{2}$$

$$A = 2acos\frac{\delta}{2}$$

(2)TYPES OF INTERFERENCE:

Interference is of two types.

1. Constructive interference / constructive superposition
2. Destructive interference / destructive superposition

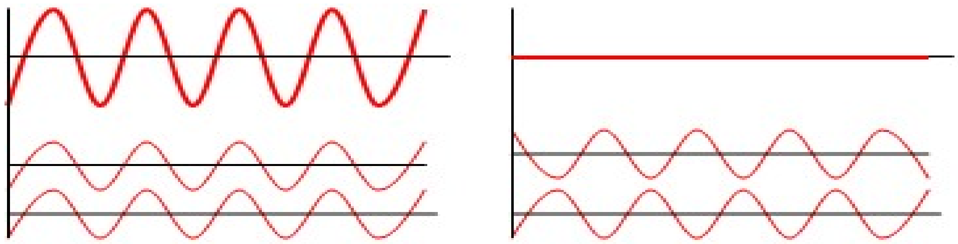
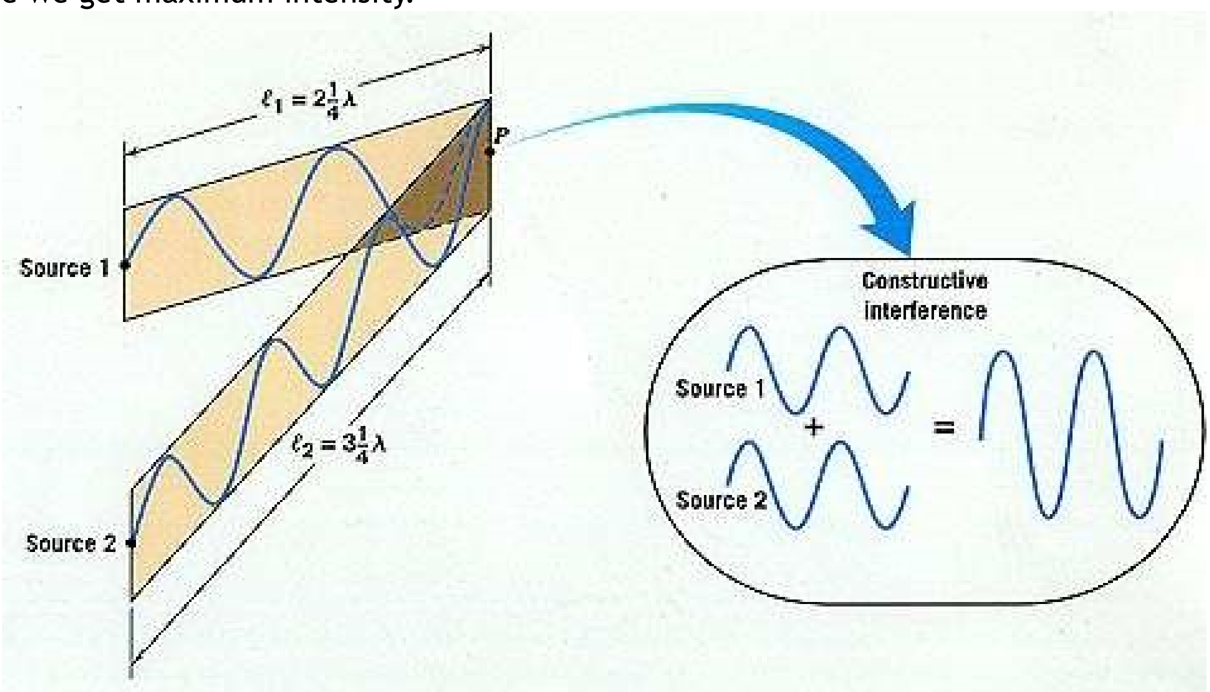


Figure: Constructive and Destructive Interference

(A)CONSTRUCTIVE INTERFERENCE:

When crust of one light wave falls on the crust of another wave then the resultant intensity increases and this type of interference is called constructive interference.

Here we get maximum intensity.



The intensity becomes maximum $(I = 4a^2 cos^2 \frac{\delta}{2}$) when $cos^2 \frac{\delta}{2} = 1$

$$cos \frac{\delta}{2} = \pm 1$$

$$cos \frac{\delta}{2} = cos n\pi$$

$\delta = 2n\pi$, n=0, 1, 2, 3...............

For δ=0, 2π, 4π.............we get bright band

Path Difference =($\frac{\lambda}{2\pi}$) X Phase Difference

Path Difference=($\frac{\lambda}{2\pi}$) x2nπ

Path Difference=$n\lambda$

This is the condition for constructive interference.

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For δ=0, 2π, 4π......... $cos\delta = 1$

$$I = {a_1}^2 + {a_2}^2 + 2a_1a_2cos\delta$$

$$I = (a_1 + a_2)^2$$

$$A^2 = (a_1 + a_2)^2$$

s$A = (a_1 + a_2)$

(B)DESTRUCTIVE INTERFERENCE:

When crust of one light wave falls on the trough of another wave then the resultant intensity decreases. This type of interference is called destructive interference. Here we get minimum intensity.

The intensity becomes minimum $(I = 4a^2cos^2\frac{\delta}{2})$ when $cos^2\frac{\delta}{2} = 0$

$$cos\frac{\delta}{2} = 0$$

$$cos\frac{\delta}{2} = \cos(2n \pm 1)\,\pi/2$$

$\delta = (2n \pm 1)\pi$, n=0, 1, 2, 3...............

For $\delta = \pi, 3\pi, 5\pi$.............we get dark band.

Path Difference =($\frac{\lambda}{2\pi}$)X Phase Difference

Path Difference=$\left(\frac{\lambda}{2\pi}\right) * (2n \pm 1)\pi$

Path Difference=$(2n \pm 1)\lambda/2$

This is the condition for constructive interference.

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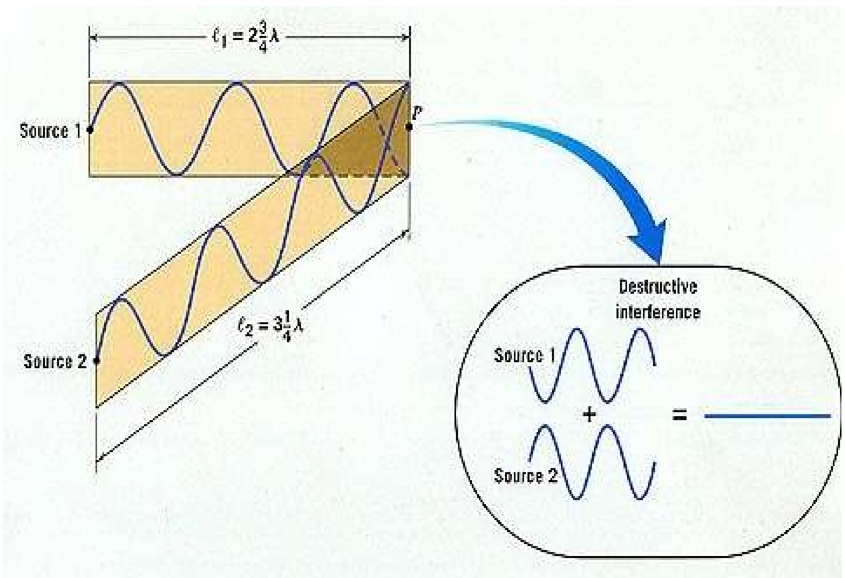
For δ=π, 3π, 5π……… $cos\delta = -1$

$$I = {a_1}^2 + {a_2}^2 - 2a_1a_2cos\delta$$

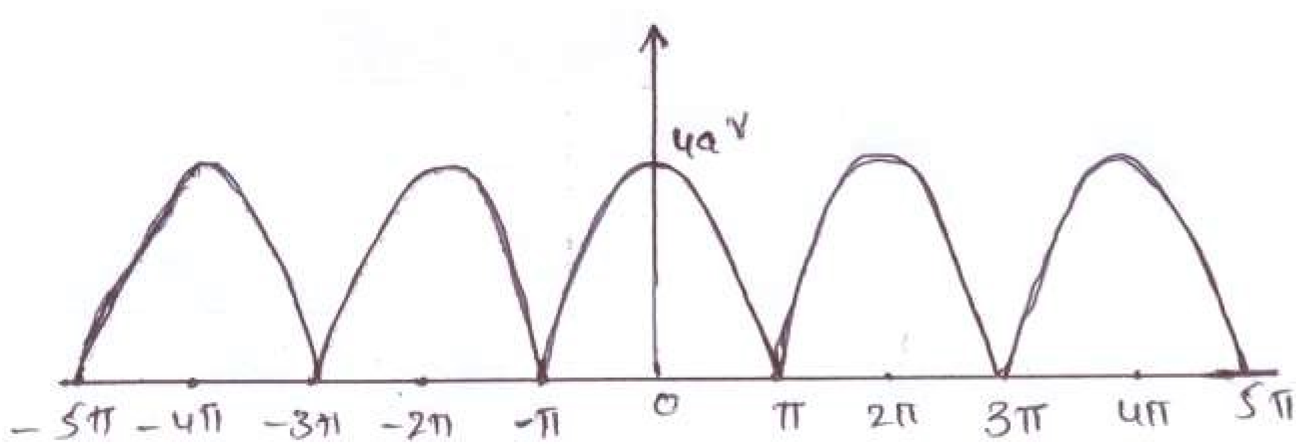
$$I = (a_{1-}a_2)^2$$

$$A^2 = (a_1 - a_2)^2$$

$$A = (a_1 - a_2)$$

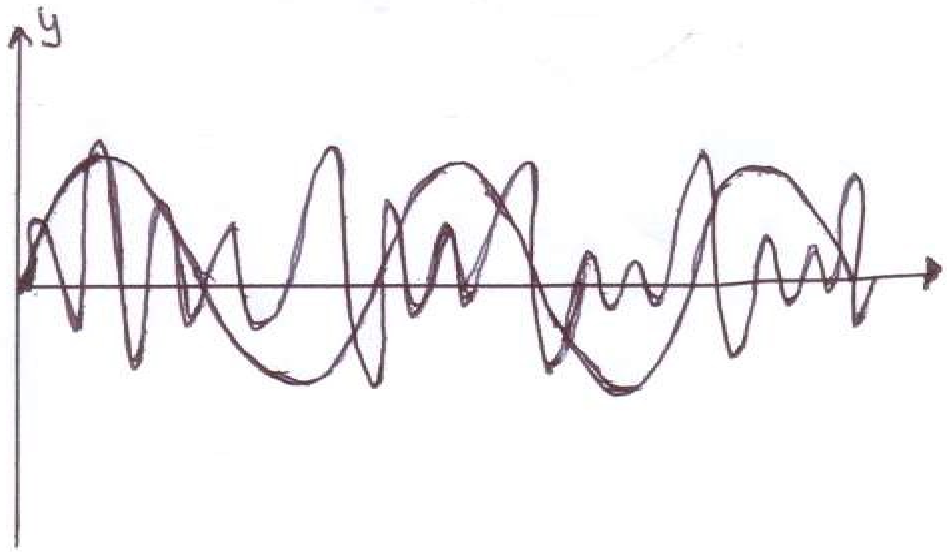


<u>Variation of Intensity with phase</u>:-



3) <u>When two light waves having different frequencies and varying phase difference:</u>

If two light waves have different frequencies and the phase difference between light waves is not constant then we get unsustained interference pattern i.e., Uniform illumination is observed i.e., bright and dark bands cannot be seen.



4)When two light waves having equal frequencies and constant phase difference:

If two light waves having equal frequencies and constant phase difference then we get sustained interference pattern. i.e we get alternative bright and dark fringes. Here the bright fringe becomes very bright and dark fringe becomes very dark.

To get sustained interference light waves has to be satisfying the following conditions.

5)Conditions for sustained or Good interference pattern :

1) We require two monochromatic light sources.
2) These two sources must be coherent i.e., they constant phase difference.
3) The frequency must be the same.
4) The amplitude must be the same.
5) They must travel in the same directions.
6) The two sources must be the same
7) These two sources must be as near as possible and the screen must be as far from them as possible.

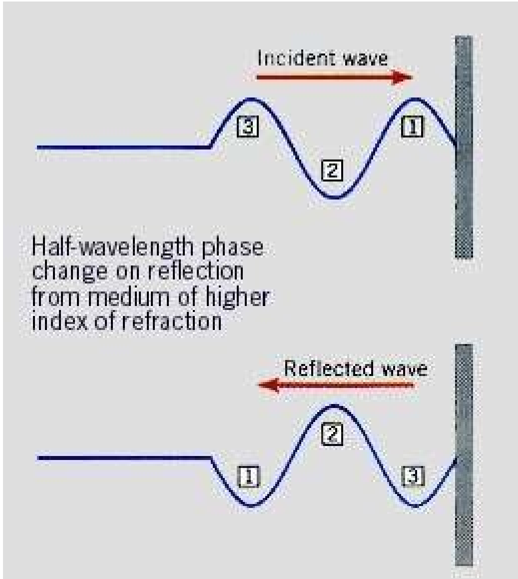
3.1.9) INTERFERENCE IN THIN FILMS:

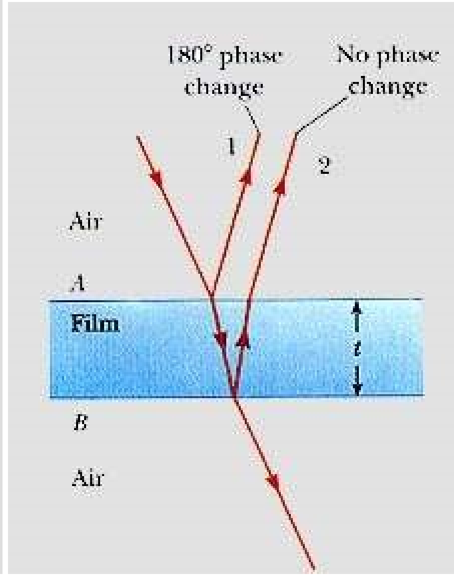
To understand interference in thin films first of all we have to understand some basic concepts like stokes principle and optical path.

1) STOKE'S PRINCIPLE:

STATEMENT:-

According to stoke principle, a light beam which is initially passing through a rarer medium reflects back into the same rare medium from denser medium suffering sudden phase change of π or path change of $\lambda/2$.Such a phase change cannot be observed for a light beam light beam which is initially passing through denser medium and reflects back into the same medium.





2) The second basic point is Optical Path:

The optical path travel led by a light beam in a medium of refractive index 'μ' is not equal to actual path travel led by the light beam.

Optical path travelled by light beam =μ X Actual path travelled by light

Thin films are of two types
1) Thin films which have uniform thickness
2) Thin films which have non uniform thickness

Striking colors observed on thin films due to interference