If D'_m and D'_{m+k} are the diameters of the mth and (m + k)th dark rings in the presence of liquid, then

For liquid the diameter of the mth dark ring $D'^2_m = \frac{4\,m\lambda R}{n}$

and for(m + k)th dark ring $D'^2_{m+k} = \frac{4(m+k)\lambda R}{n}$

Thus $D'^2_{m+k} - D'^2_m = \frac{4(m+k)\lambda R}{n} - \frac{4\,m\lambda R}{n}$

or $D'^2_{m+k} - D'^2_m = \frac{4\,k\lambda R}{n}$

The refractive index of the liquid is calculated as $\boldsymbol{n = \frac{4\,k\lambda R}{D'^2_{m+k} - D'^2_m}}$ .... (2)

Also n can be determined by dividing (2) by (1), i.e. $\boldsymbol{n = \frac{D^2_{m+k} - D^2_m}{D'^2_{m+k} - D'^2_m}}$

Part A : Eight mark Questions

1 (a) Explain Huygens' wave theory.
(b) Verify the law of refraction for a spherical wavefront incident on a plane surface using Huygens' wave theory.

2 (a) Explain Huygens' principle.
(b) Verify the law of reflection for a spherical wavefront incident on a plane surface using Huygens' wave theory.

3 (a) What is interference of light? Explain
(b) Mention the conditions required for constructive and destructive interference of light.

5 (a) Explain how interference fringes are produced using biprism.
(b) Describe Fresnel's biprism method for the determination of wavelength of light.

6 (a) State and explain Huygens' principle
(b) Obtain an expression for band width of interference fringes produced by biprism.

7 Discuss the effect of introducing a thin transparent plate in the path of the interfering beams in a biprism. Deduce an expression for the displacement of the fringes. Briefly explain how thin can be used to determine the thickness of a mica sheet.

8 (a) State the conditions for the sustained interference
(b) Write a note on production colours in thin films

9 (a) Explain any two methods of obtaining coherent sources.
(b) Describe with theory the formation of bright and dark interference fringes in the light reflected from a thin film.

10 (a) What are the methods used to get coherent sources.
(b) Describe with theory the formation of bright and dark interference fringes in the light transmitted from a thin film.

11 (a) What are Newton's rings?
(b) Show that the radii of the dark rings are in the ratio of square root of natural numbers.

12 Describe an experiment to determine the refractive index of water using Newton's rings.

13 (a) Explain with a diagram and necessary theory the interference in a wedge shaped thin film. Derive an expression for the fringe width.
(b) Why does the centre of Newton's ring pattern appear dark in reflected light?

Part B : Numerical problems

1 The distance between the two coherent sources of lightis 0.16 mm. Interference fringes are obtained on a screen placed at a distance of 1.2 m from the sources. It is found that for a certain monochromatic source of light the second bright fringe is at a distance of 9.6 mm from the central fringe. What is the wavelength of the source?

[Hint : $x_m = \frac{m\,\lambda\,D}{d}$, $here\ m = 2,\ \lambda = 6.4\ \times 10^{-7}\ m$]

2 The distance between two coherent sources is 1 mm and the screen is 1 m away from the sources. The second dark band is 0.1 cm from the central bright fringe. Find the wavelength and the distance of the second bright band from the central bright band.

[Hint : $x_m = \frac{(2m+1)\,\lambda\,D}{2d}$, $here\ for\ second\ dark\ m = 1,\ \lambda = 6.667\ \times 10^{-7}\ m$

For second bright fringe m = 2, $x_m = \frac{m\,\lambda\,D}{d} = 1.33\ \times 10^{-3}\ m$]

3 A beam of light consisting of two wavelengths 650 nm and 520 nm is used to obtain interference fringes in a Young's double slit experiment. (a) Find the distance of the third bright fringe on the screen from the central maximum for the wavelength 650 nm, (b) What is the least distance from the central maximum when the bright fringes due to both the wavelengths coincide. Assume d = 2 mm, D = 1.2 m. [Hint : $x_m = \frac{m\,\lambda\,D}{d}$, $here\ m = 3,\ x_3 = 0.177\ \times 10^{-2}\ m,\ \frac{m\,\lambda_1\,D}{d} = \frac{(m+1)\,\lambda_2\,D}{d},\ thus\ m = 4,\ x = \frac{m\,\lambda_1 D}{d} = 0.156\ \times 10^{-2}\ m$

4 In a biprism experiment interference fringes are obtained in the focal plane of an eye-piece at a distance of 1m from slit. The separation between the images for conjugate positions of a convex lens are 3.17mm and 1.75 mm. If the width of the fringes is 0.025 cm, find the wavelength of light used.

[Hint : $d = \sqrt{d_1 d_2},\ where\ d_1 = 3.17mm, d_2 = 1.75mm,\ \beta = \frac{\lambda\,D}{d}$, $Hence\ \lambda = \frac{\beta\,d}{D} = 5.888\ \times 10^{-7}\ m$]

5. In a biprism experiment fringes of width 0.02 cm are observed at a distance of 1m from the slit. Distance between coherent sources is 3mm. Find the wavelength of light. On placing a thin transparent sheet of refractive index 1.5 in the path of

one of the interfering beams the central bright fringe was found to be shifted through a distance equal to width of 10 fringes. Calculate the thickness of the sheet.

[Hint : $\beta = \frac{\lambda D}{d}$, $\lambda = 6 \times 10^{-7}\, m$, $t = \frac{m\lambda}{n-1}$, here m = 10, t = $1.2 \times 10^{-5}\, m$]

6 Interference fringes at an air wedge are formed by using sodium light of wavelength 589.3nm. While viewing normally 10 fringes are observed in a distance of 1cm. calculate the angle of wedge.

[Hint : $\beta = \frac{x}{k} = \frac{0.01}{10}$, $\beta = \frac{\lambda}{2\theta}$, $\theta = 2.94 \times 10^{-4}\, radian$]

7. An air wedge of angle 0.01 radian is illuminated by light of wavelength 600nm falling normally on it. At what distance from the edge of the wedge, will the 10th dark fringe be observed by the reflected light.

[Hint : $2t = m\lambda$ $(dark\ fringe)$, $\theta = \frac{t}{l}$, $or\ \ t = l\,\theta$, $thus\ 2l\theta = m\lambda$, $l = \frac{m\lambda}{2\theta} = 0.3\ cm$]

8. In a biprism experiment, with sodium light bands of width 0.02 cm are observed at 1m from the slit. On introducing a convex lens 0.3m away from the slit, two images of the slit are seen at 0.7×10^{-2}m apart at one metre distance from the slit .Calculate the wave length of light.

[Hint : $\frac{size\ of\ image}{size\ of\ object=} = \frac{v}{u}$, $\frac{0.7 \times 10^{-2}}{d} = \frac{0.7}{0.3}$, $d = 0.3 \times 10^{-2}, here\ u + v = 1$, $i.e.$ $0.3 + v = 1$, $\beta = \frac{\lambda D}{d}$, $\lambda = 600\ nm$]

9 A biprism is placed 0.05m from a slit illuminated by sodium light (λ=589nm). The width of the fringes obtained on a screen placed 0.75m from the biprism is 9.424×10^{-2}cm. What is the distance between the two coherent sources?

[Hint : $\beta = \frac{\lambda D}{d}$ $Here\ \ D = 0.05 + 0.75$, $d = 5 \times 10^{-4}\ m$]

10 Interference fringes are observed with a biprism of refracting angle of 1^0 and refractive index 1.5 on a screen 1 m away from it. If the distance between the source and the biprism is 0.1m ,calculate the fringe width when the wavelength of light used is 590nm.

[Hint : $\beta = \frac{\lambda D}{d}$, $d = 2(n-1)\alpha y_1 = 2\,(1.5-1)1 \times \frac{180}{\pi} \times 0.1$, $D = y_1 + y_2 = 0.1 + 1$, $\beta = 3.7 \times 10^{-4} m$]

11 In a biprism experiment the eyepiece was placed at a distance of 1.2m from the source. The distance between the two virtual sources was found to be 0.075cm. Find the wavelength of light of the source if the eyepiece has to be moved through a distance 1.883cm for 20 fringes to cross the field of view.

[Hint : $\beta = \frac{0.01883}{20}$, $\beta = \frac{\lambda D}{d}$, $\lambda = 588.4\ nm$]

12 When a thin sheet of a transparent material of refractive index 1.52 is introduced in the path of one of the interfering beams the central fringe shifts to a position occupied by the sixth bright fringe. If the wavelength of the light used is 546.1nm, calculate the thickness of the material.

[Hint : $t = \frac{m\lambda}{n-1}$, here m = 6, t = $6.3 \times 10^{-6}\ m$]

13 A transparent plate of thickness 10μm is placed in the path of one of the interfering beams of a biprism experiment using light of wavelength 500nm. If the central fringe shifts by a distance equal to the width of ten fringes, calculate the refractive index of the material of the plate

[Hint : $t = \frac{m\lambda}{n-1}$, $n = 1.5$]

14 A parallel beam of sodium light of wavelength 589.3nm is incident on a thin glass plate of refractive index 1.5 at an angle 60^0. Calculate the smallest thickness of the plate which makes it dark by reflection.

[Hint : $2\,nt\cos r = m\,\lambda$, $t = \frac{m\,\lambda}{2\,n\cos r}$, $here\ n = 1$, $t = 3.92 \times 10^{-7}\ m$

15 Interference fringes are produced by monochromatic light falling normally ona wedge shaped film of cellophane of refractive index 1.4. If the angle of wedge is 20 seconds of an arc and the distance between successive fringes is 0.25 cm, calculate the wavelength of light.

[Hint : $\theta = 20 \times \frac{\pi}{180} \times \frac{1}{60\times60}\ radian$, $\beta = \frac{\lambda}{2\theta n}$, ($n = 1.4$), $\lambda = 679\ nm$]

16 Newton's ring arrangement is used with a source emitting the wavelengths λ_1=600nm λ_2=450nm . It is found that the mth dark ring due to λ_1 coincides with the (m+1)th dark ring due to λ_2. Find the diameter of mth dark ring for the wavelength λ_1. Radius of curvature of the lens is 0.9m. [Hint :$D_m^2 = 4\,m\lambda_1 R$ and $D_{m+1}^2 = 4\,(m+1)\lambda_2 R$, $4\,m\lambda_1 R = 4\,(m+1)\lambda_2 R$, $m = 3$, $D_m^2 = 4\,m\lambda_1 R$, $D_m = 2.5\ mm$

17 The diameter of the third dark ring from the light of wavelength 589nm in a Newton's ring experiment is 3.2mm. Calculate the radius of curvature of the lens. What will be the radius of the ring if the air gap is filled with few drops of water (R.I of Water=1.3) Ans R=1.45m , r_3 =1.2x10^{-2}m.

[Hint : $D^2 = \frac{4m\lambda R}{n}$, ($here\ m = 3$, $n = 1$), $thus$ $R = 1.45\ m$, $r^2 = \frac{m\lambda R}{n} = 1.2 \times 10^{-2}\ m$ ($here\ n = 1.3$)]

18 In Newton's rings experiment, the diameters of third and ninth rings are 0.3 cm and 0.5 cm respectively. Calculate the diameter of the 15^{th} ring.

[Hint : $D_m^2 - D_n^2 = 4(m-n)\lambda R$, $D_9^2 - D_3^2 = 4(9-3)\lambda R$, $D_{15}^2 - D_3^2 = 4(15-3)\lambda R$

Dividing above two equations, $D_{15} = 0.64\ m$]

19 Two glass plates enclose a wedge shaped air film touching at one edge and are separated by a thin wire of 0.06 mm diameter at a distance of 0.18 m from the edge. Calculate the fringe width if wavelength is 600 nm.

[Hint : $\theta = \frac{t}{l} = \frac{0.06\times10^{-3}}{0.18}$, $\beta = \frac{\lambda}{2\theta} = 9 \times 10^{-4}\ m$]

20 A soap film of 0.4 μm thick is observed at 50^0 to the normal. Find the wavelengths of light in the visible spectrum which will be absent from the reflected light. n = 1.33.

[Hint : $n = \frac{\sin i}{\sin r}$, $r = 35^0 4'$, $\cos r = 0.8185$, $2nt\cos r = m\lambda$, $for\ m = 1$, $\lambda_1 = 8.7 \times 10^{-7} m$, $for\ m = 2$, $\lambda_2 = 4.35 \times 10^{-7} m$, $for\ m = 3$, $\lambda_3 = 2.97 \times 10^{-7} m$]

21 Newton's rings are formed by light of wavelength 589.3 nm between a convex lens and a plane glass plate with a liquid between them. The diameter of the 5th and the 15th rings in the reflected system are 2.18 mm and 4.51 mm respectively. If the radius of curvature of the lens is 0.9 m, calculate the refractive index of the lens.

[Hint : $r_k^2 - r_m^2 = \frac{4(k-m)\lambda R}{n}$, $n = 1.361$]

22 On placing a sheet of mica of refractive index 1.5 in the path of one of the interfering beams in a biprism arrangement, it is found that the central bright fringe shifts a distance equal to the width of a bright fringe. Calculate the thickness of the mica sheet (wavelength of light = 600 nm).

[Hint : $t = \frac{m\lambda}{n-1}$. $here\ m = 1,\ \ t = 1.2 \times 10^{-6}\ m$]

PART C : Two Mark Questions

1 Can interference be obtained by using two independent sources? Explain.

Ans : No, The two independent sources of light may emit light of different amplitudes, wavelengths and the phase difference between the two sources may vary with time. Thus interference of light cannot be obtained by two independent sources of light.

2 Does the phenomenon of interference obey the law of conservation of energy? Explain.

Ans : Yes, In interference there is only transfer of energy from points of minimum intensity to the points of maximum intensity. At maxima, the intensity due to two waves is $4a^2$ instead of $2a^2$. The intensity varies from 0 to $4a^2$ but the average is still $2a^2$ which is equal to uniform intensity $2a^2$ when there is no interference. Thus formation of interference fringes is in accordance to the law of conservation of energy.

3 Why are Newton's Rings circular and the fringes due to air wedge straight?

Ans : Interference in wedge shaped film is due to interference of light from reflected rays from two surfaces of the film of increasing thickness in a specific direction as the two glass plates touch each other at one of the edges.Thus fringes are straight. But in case of Newton's rings, the point of contact between the lens and glass plate is at the centre and thickness of the film increases in all directions and thus fringes are circular.

4 The interference pattern of the reflected rays and transmitted rays are complimentary Explain.

Ans : The condition for maxima and minima found in case of transmitted pattern are opposite to those found in case of reflected pattern. Under the same condition the film looks dark in the reflected pattern and bright in transmitted pattern. In case of white light, the colours found due to reflected pattern is absent in *transmitted pattern and vice versa. Thus the fringes in the two patterns are complementary.*

5 What will happen in Newton's ring experiment if few drops of water are introduced between the lens and the plate?

Ans : The diameter of a dark ring is given by $D^2 = \frac{4m\lambda R}{n}$*. By introducing a liquid in between the lens and the glass plate will decrease the diameter of the ring. This will bring the rings closer.*

6 The centre of Newton's ring pattern in the reflected system is dark. Explain.

Ans : In case of interference due to reflected pattern, the light is getting reflected at the surface of denser medium and undergoes a phase change of 180^0*. Thus the interfering at the centre are opposite in phase. Thus the centre appears dark.*

7. A thin film illuminated by monochromatic light appears bright in the transmitted system. Explain

Ans : In case of interference due to transmitted pattern, the light getting refracted at the surface of denser medium to rarer medium and does not undergo any phase change. Thus the interfering at the centre are in same phase. Thus the centre appears bright.

8. What happens to Newton's ring pattern if a monochromatic source of light is replaced by white light?

Ans: When white light which is the combination of different colours, is used the fringes are coloured.

9. A thin film of oil on the surface of water appears coloured. Explain.

Ans : A film of oil is a thin film and the light getting reflected from the lower and upper surface of the film superpose on each other resulting in interference. As light incident on it white light, the pattern appears coloured.

10. Why do the fringes in Young's double-slit experiment become indistinct if one of the slits is covered with a cellophane?

Ans : When of the slits is covered by cellophane, the intensity of light coming from that slit will decrease. The bright fringe which is constructive interference will not be that bright and the dark fringe will not be very dark. No constras in fringes is found and the fringes become indistinct.

11 What type of fringes are observed in a double slit experiment with a white source?

Ans : When white light is used, the fringe pattern is coloured. Only those colours are visible that satisfy the condition for constructive interference.

12 Is laser an example for coherence? Explain.

Ans : Yes, It arises from the stimulated emission process which provides amplification. The emitted photons have a definite phase relation to each other.

13 What happens to the fringe width in double slit experiment if the distance between the coherent sources is reduced to half and distance between the sources and screen is doubled?

Ans :From the relation $\beta = \frac{\lambda D}{d}$, *d is reduced to half and D is doubled, then the fringe width becomes four times the original width.*

14 What happens to the fringe system if a thin transparent film is placed in the path of one of the interfering beams?

Ans : The fringe system gets shifted. This can be observed as the central fringe which is white gets shifted.

15 In the biprism experiment, what happens to the fringe width if a monochromatic light of shorter wavelength is used?

Ans : *From the relation* $\beta = \frac{\lambda D}{d}$ *it is observed that by using light of shorter wavelength, the fringe width decreases as the fringe width is directly proportional to the wavelength of light.*

16 Explain why the fringes formed by a biprism disappear when the slit is made wide?

Ans : To observe interference fringes, it is required to have two coherent sources. In biprism, two virtual sources formed by the biprism act as coherent sources. When the slit is widened, it is not possible to get two narrow coherent sources which could broaden, Thus the fringes disappear.

17 What is the principle at interference due to thin films?

Ans : It is based on division of amplitude where there is partial reflection and partial refraction resulting in formation of two coherent source. The light from these sources superpose and produce interference.

18 On what factors colours observed on a soap bubble depend?

Ans : The colours on a soap bubble depend on the angle of refraction and the thickness of the film.