<u>Syllabus for Test 10</u>: L23 (partial), L24 and L 25 (partial)

L23: Sinusoidal wave, general form of a sinusoidal wave; wavelength, frequency, time period, wave number, angular frequency and phase constant or epoch angle of a sinusoidal wave. Energy transport in a wave, instantaneous velocity of a particle or element of the medium carrying a wave; kinetic energy, potential energy and total energy per wavelength in the medium carrying a wave; Power of wave motion, Intensity of a wave, intensity of sound wave; Energy density in an electromagnetic wave, Power and intensity of an electromagnetic wave.

Interference of waves, Young's double-slit experiment, interference by the method of division of wave front, production of coherent sources in Young's double-slit experiment, Conditions of constructive and destructive interferences in Young's double-slit experiment, Intensity Distribution of the double-Slit Interference Pattern, Numerical problems on Young's double-slit experiment.

L24: Review of:
Energy transport in a wave, energy stored per wavelength in the medium, Power and intensity of wave motion, intensity of sound, intensity of electromagnetic wave, Definition of interference, coherent sources, interference by the division of wave front, Young's double-slit experiment, conditions of maxima and minima in terms of angular and linear position on the screen, Intensity distribution of Young's double-slit experiment.

Interference in thin films, definition of a thin film, examples of interference in thin films; 180° phase change upon reflection from thin film, conditions for constructive and destructive interferences in thin films, different types of thin films and corresponding conditions for constructive and destructive interferences; Numerical problems on interference in thin films, Reflective and anti-reflective coatings using interference phenomena; Newton's ring, equations for dark and bright rings in Newton's ring setup determination of wavelength of light using Newton's ring experiment.

L25: Review of:
Interference in thin films, ; 180° phase change upon reflection from thin film, conditions for constructive and destructive interferences in thin films, different types of thin films and corresponding conditions for constructive and destructive interferences; Newton's ring, equations for dark and bright rings in Newton's ring setup determination of wavelength of light using Newton's ring experiment.

Michelson interferometer, Michelson-Morley Experiment, LIGO
(The rest of the materials of L25 i.e. topics of diffraction will put in the next test.)

1.
For a sinusoidal wave if the wavelength is λ and the time period is T, then in a half cycle, the sinusoidal wave executes or moves:

$\pi/2$ radians in phase
π radians in phase
T time in seconds
λ time in seconds
2λ distance in meters

Ans: π radians in phase. Explanation: The period of a sine wave is 360º or 2π radians. So, a sine wave takes 180º or π radians to complete a half cycle.

2.
For a given medium, the wavelength of a sinusoidal wave is:

independent of frequency
proportional to frequency
inversely proportional to frequency
proportional to amplitude
inversely proportional to amplitude

Ans: inversely proportional to frequency. Explanation: Since in a medium the speed of a sinusoidal wave is constant (the speed depends on the property of the medium only), the wavelength is inversely proportional to the frequency.

3.
If two sine waves of the same frequency have a phase difference of π radians, then

Both will reach their minimum values at the same instant
Both will reach their maximum values at the same instant
When one wave reaches its maximum value, the other will reach its minimum value
When one wave reaches its maximum value, the other will reach zero value
None of the mentioned

Ans: When one wave reaches its maximum value, the other will reach its minimum value.

Explanation: If the phase difference is 180 degrees (π radians), then the two sine waves are said to be opposite in phase. As a result, when one wave reaches its maximum value, then other will reach its minimum value.

4.
A stretched string is carrying a sinusoidal wave. The maximum speed of the particles of the string is vm. Consider a point on the string where the displacement is half its maximum. The speed of the point is:

vm/2
2 vm
vm/4
3vm/4
(√3)vm/2

Ans: (√3)vm/2 . Explanation: For a wave $y(x,t) = A \sin(kx - \omega t + \varphi)$ on a stretched string, the instantaneous speed of an element of the string is: $uy = -A\omega \cos(kx - \omega t + \varphi)$ which gives $vm = A\omega$. Now, at a point x' on the string $y(x',t) = A/2 \Rightarrow \sin(kx' - \omega t + \varphi) = 1/2 = \sin(30 \text{ degrees}) \Rightarrow kx' - \omega t + \varphi = \pi/6$. Then, we get $uy(x',t) = -A\omega \cos(kx' - \omega t + \varphi) = -A\omega \cos(\pi/6) = -\sqrt{3}\ vm/2$ and in magnitude the speed is $\sqrt{3}\ vm/2$

5.
Two identical but separate strings, with the same tension, carry sinusoidal waves with the same amplitude. Wave A has a frequency that is twice that of wave B, and transmits energy at a rate that is ___________ of wave B.

half
twice
one-fourth
four times
eight times

Ans: four times. Explanation: The power transmitted by a wave on a string (mechanical wave) is proportional to the square of the amplitude and square of the frequency: $P \propto f^2 A^2$. Hence, as the frequency doubles, the power (energy/time) transmitted becomes four times larger.

6.
Two waves may be coherent if they have:

same wavelength but different initial phase angles
same amplitude but different frequencies
same amplitude but different wavelengths
same initial phase angles but different wavelengths
same initial phase angles but different frequencies

Ans: same wavelength but different initial phase angles. Explanation: Coherent sources are sources which have the same frequency and hence the same wavelength but are in a phase relationship with each other. The difference of their phases must be constant and hence the phases may be different.

7.
Two sinusoidal waves of the same type in the same medium having the same frequency but of two different amplitudes and two phase angles are subtracted. The resultant is

A sinusoidal wave of the same frequency
A sinusoidal wave of half the original frequency
A sinusoidal wave of double the frequency
A sinusoidal wave of half the wavelength
Not a sinusoidal wave

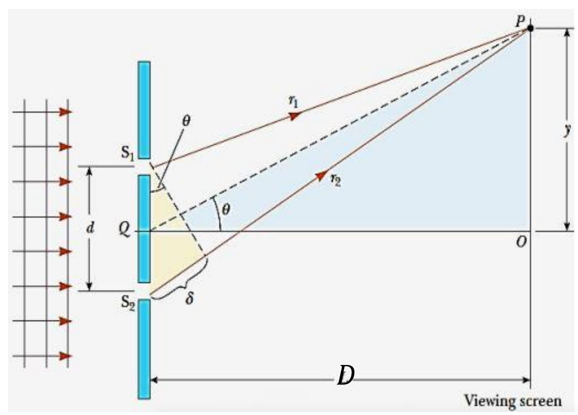
Ans: A sinusoidal wave of the same frequency. Explanation: If the sinusoidal waves are of the same type and moving in the same medium, their speeds are the same. If the frequency is the same for the waves, then the wavelength would be the same also.

Hence, adding two sinusoidal waves of the same frequency would produce superposition of the same frequency as well.
For example, $y1 = A \sin(kx - \omega t)$, $y2 = B \sin(kx - \omega t + \varphi)$ gives:
$y = y1 + y2 = A \sin(kx - \omega t) + B [\sin(kx - \omega t) \cos(\varphi) + \cos(kx - \omega t) \sin(\varphi)]$
$= \sin(kx - \omega t) [A + B \cos(\varphi)] + \cos(kx - \omega t) [B \sin(\varphi)]$
$= C [\sin(kx - \omega t) \cos(\delta) + \cos(kx - \omega t) \sin(\delta)]$
$= C \sin(kx - \omega t + \delta)$ where, $C \cos(\delta) = A + B \cos(\varphi)$ and $C \sin(\delta) = B \sin(\varphi)$ giving,
$C = \text{sqrt}(A^2 + B^2 + 2AB \cos(\varphi))$
and $\tan(\delta) = B \sin(\varphi)/(A + B \cos(\varphi))$

8.
Two sinusoidal waves in the same medium travel in the same direction. They have the same frequency and their amplitudes are A and B, respectively. The smallest possible amplitude of the resultant wave is:

A+B and occurs when the waves are 180 degrees out of phase
|A-B| and occurs when the waves are 180 degrees out of phase
A+B and occurs when the waves are in phase
|A-B| and occurs when the waves are in phase
|A-B| and occurs when the waves are 90 degrees out of phase

Ans: |A-B| and occurs when the waves are 180 degrees out of phase. Explanation: The amplitude of the resultant wave is $C= \text{sqrt}(A^2 + B^2 + 2AB \cos(\varphi))$, where φ is the phase difference between the waves. Obviously, C becomes the minimum when $\varphi=180$ so that $\cos(\varphi)= -1$.



9.
Consider two sources of sinusoidal waves having the same wavelength λ and are in phase at the respective sources. One travels a distance l1 to get to the observation point and the other wave travels a distance l2. The amplitude is a minimum at the observation point if l1-l2 = ?

an odd multiple of $\lambda/2$
an odd multiple of $\lambda/4$
a multiple of λ
an even multiple of $\lambda/2$
an even multiple of $\lambda/4$

Ans: an odd multiple of $\lambda/2$. Explanation: For minimum amplitude, the path difference must be an odd multiple of half the wavelength.

10.
Consider a monochromatic light source that illuminates a double-slit. The resulting interference pattern is observed on a distant screen. Let, d=center-to-center slit-spacing ; a=slit width of both the slits; D=perpendicular distance from the slits to the screen; l= fringe width in interference pattern. The wavelength of light is given by:

ld/D
ld/a
da/D
lD/a
Dd/l

Ans: ld/D. Explanation: Condition for dark fringe : d $\sin(\theta\_dark\text{-}m) = (m + 1/2)\lambda$.
For large D i.e. D >> y, where y is the position on the screen of a minimum (center of a dark fringe), we get: $\sin(\theta\_dark\text{-}m) \approx \tan(\theta\_dark\text{-}m) = y\_m/D$ => $y\_m = D \sin(\theta\_dark\text{-}m) = (D/d)(m + 1/2)\lambda$
Hence, fringe width is: $\Delta y\_m = \Delta [(D/d)(m + 1/2)\lambda] = (D/d)\{ \Delta(m + 1/2) \} \lambda = (D/d)(m+1+1/2 - m-1/2)\lambda$
=> $l= \Delta y\_m = (D/d)\lambda$; Hence, $\lambda = ld/D$.

11.
In Young's double-slit experiment, let d=center-to-center slit-spacing and D=perpendicular distance from the slits to the screen and λ=wavelength of light. The slit-separation is doubled. To maintain the same fringe width on the screen, D must be changed to:

D/2
D/√2
D√2
2D
D2√2

Ans: 2D. Explanation: In Young's double-slit experiment, the fringe width $l=\lambda(D/d)$. Since λ is fixed, if d is doubled i.e. d -> 2d, then D has to be doubled too, i.e. D -> 2D.

12.
Coherent light of a single frequency passes through a double slit with a separation d, to produce a pattern on a screen as distance D from the slits. What would cause the separation between adjacent minima on the screen to increase?

increase the index of refraction of the medium in which the setup is immersed
increase the separation d between the slits
decrease the distance D
increase the frequency of the incident light
increase the slit width

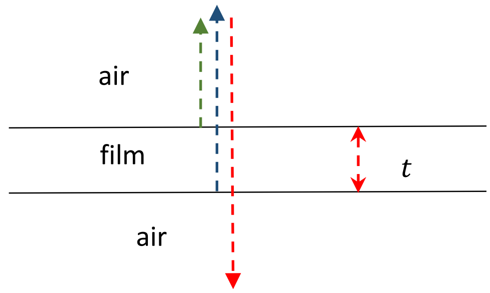
Ans: increase the separation d between the slits. Explanation: In Young's double-slit experiment, the fringe width $l=\lambda(D/d)$. Increasing the frequency of the light would decrease the wavelength and would decrease the fringe width or the separation between adjacent minima. l may be increased by increasing D or λ or by decreasing d.

13.
What is the ratio of fringe widths in dark and bright fringes in Young's double-slit experiment i.e. l_dark/l_bright = ?

0.5
√2
1.0
2.0
1/√2

Ans: 1.0 Explanation: In Young's double slit experiment, the dark and bright fringes are equally spaced. Therefore the ratio of the fringe width for dark and bright fringes is 1.0.

14.
Consider a thin film inside air. Light of wavelength λ coming from the air is incident normally (i.e. in the perpendicular direction) on the thin film. Let λ' denote the wavelength in the thin film material. What is the minimum width of the thin film for which the reflected light will be a MAXIMUM?



Much less than λ'
λ'/4
λ'/2
3λ'/4
λ'

Ans: λ'/4. Explanation: 1.At normal incidence, upon reflection, there is a phase change of π on the upper surface.

15. A second ray is reflected at the lower surface of the film but this time there is NO phase change upon reflection.

Path difference between the rays reflected upon the upper and the lower surface of the thin film is: 2t , where t= thickness of the film.

Total phase difference between the two reflected rays = $\pi + 2\pi\,(2t/\lambda')$
For a MAXIMUM we need $\Delta\varphi = 2m\pi$, where m is an integer => $2m\pi = \pi + 2\pi\,(2t/\lambda')$ => $2m = 1 + 4t/\lambda'$
Thus, $4t = \lambda'(2m-1)$ which for the MINIMUM WIDTH gives, m=1 (since λ' >0) giving $t_{min}=\lambda'/4$

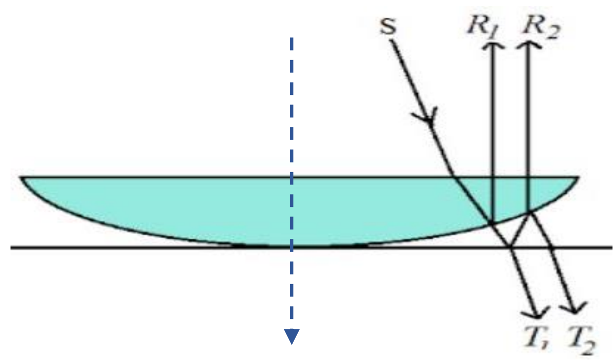
16.
Newton's rings are formed because of interference between the light rays reflected from:

upper surface of plano-convex lens and lower surface of plane glass plate
lower surface of plano-convex lens and upper surface of plane glass plate
lower and upper surfaces of the plano-convex lens
lower and upper surfaces of the plane glass plate
lower surfaces of the plane glass plate and that of the plano-convex lens

Ans: lower surface of plano-convex lens and upper surface of plane glass plate.

17.
In refracted light the central fringes of Newton's ring is

dark
bright
uniform
diffused
cannot be observed.



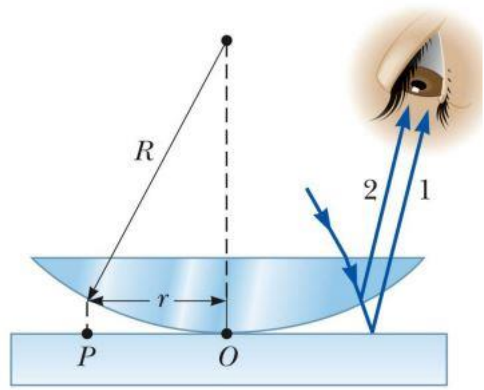
Ans: Bright. Explanation: In refracted light, one ray passes directly through the lens at the central point.

Another ray is reflected TWICE inside the air film and gets phase shift of π two times upon reflection once from the base plate and again from the lower and outside surface of the lens. As a result, there is no net effect due to phase change at reflection.
The path difference is zero at the center and hence there is direct passage of light at the center resulting in bright spot (no interference occurs there).

18.
In Newton's ring experiment, the central spot is dark when viewed from above because of destructive interference created by:

reflected light rays from the top surface of the lens and that at the bottom surface
reflected light rays from the bottom surface of the lens and that at the base plate
reflected light rays from the top surface of the lens and that at the base plate
path difference of $\lambda/2$ between the reflected light rays from the bottom surface of the lens and that at the base plate
path difference of 2t between the reflected light rays from the top surface of the lens and that at the bottom surface

Ans: reflected light rays from the bottom surface of the lens and that at the base plate.
There is no geometrical and hence optical path difference between the reflected light rays from the bottom surface of the lens and that at the base plate as the thickness of air just at the center is ZERO.



In spite of this, there are two light rays reflected from the bottom surface of the lens and that at the base plate because the LENS IS NOT PHYSICALLY JOINED WITH THE BASE PLATE. Hence, the path difference or thickness of air film is NOT STRICTLY ZERO but very much negligible.
Interference cannot occur between the reflected light rays from the top surface of the lens and that at the bottom surface because the thickness of the lens is very much large than the coherence length of ordinary monochromatic light coming from discharge tubes.

19.
In Newton's ring experiment, the diameter of the 15th ring was found to be 0.590 cm and that of the 5th ring was 0.336 cm. If the radius of plano-convex lens is 100 cm, compute the wavelength of light used.

5850 angstrom
5880 angstrom
5885 angstrom
5890 angstrom
5900 angstrom

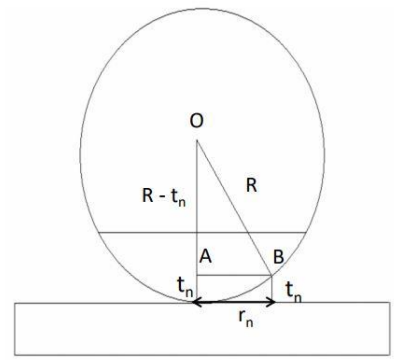
Ans: 5880 angstrom. Explanation: λ= [D_(n+m)^2 - D_n^2]/(4mR) = [(0.590)^2 - (0.336)^2] cm^2/(40R)
=> λ= [(0.590)^2 - (0.336)^2]/(40*100) cm = 5.880 x 10^(-5) cm = 5880 angstrom

20.
In Newton's Ring experiments , the diameter of dark rings is proportional to

square root of odd natural numbers
natural numbers
even natural numbers
square root of natural numbers
square root of even natural numbers

Ans: square root of natural numbers. Explanation: The formula for the radius of the dark rings in Newton's ring experiment is r_n = sqrt(n λR), where R is the radius of curvature of the convex surface of the plano-convex lens.

21.
Newton's rings experiment is performed with air gap between lens and plate. Now that gap is filled with water. What will be effect on radius (or diameter)?



Radius (or diameter) will remain constant but there will be more brightness
Radius (or diameter) will remain constant but there will be less brightness
Radius (or diameter) will increase
Radius (or diameter) will decrease
There will be no effect

Ans: Radius (or diameter) will decrease. Explanation: We know for dark ring in Newton's ring experiment $2t\mu$ = path difference = $n\lambda$ (dark ring; there is an extra phase difference due to reflection at the base plate.)

But from geometry: t = r_n^2/2R
Hence, $2\mu(Dn^2)/(8R) = n\lambda \Rightarrow Dn^2 = 4nR\lambda/\mu \Rightarrow$ Hence as μ is increased, Dn decreases.

22.
Which of the following were one of the conclusions of the Michelson-Morley experiment?

Laws of physics remain invariant in all inertial frames.
Light propagates with different speeds in different directions.
The hypothesis of stationary ether was wrong.
The velocity of light in free space is constant.
None of the mentioned.

Ans: The hypothesis of stationary ether was wrong.

Explanation: In Michelson Morley experiment, the aim was to find the time difference from which the relative velocity between ether and the earth could be estimated. However, no shift was observed.

Hence from the Michelson-Morley experiment it was shown that light propagates with the same speed in all directions, and hence the hypothesis of ether was shown to be wrong.