Subject Name & Code:

PHYSICS- BE01R00021

Assignment – 4

Remember Level

1. State Huygens' principle.
Huygens' principle states that every point on a given wavefront acts as a source of secondary spherical wavelets. These wavelets spread out in the forward direction with the same speed as the original wave. The new wavefront at any later time is the envelope (tangential surface) of all such secondary wavelets.

2. State the principle of superposition.
The principle of superposition states that when two or more waves overlap in a medium, the resultant displacement at any point is the vector sum of the individual displacements produced by each wave. Mathematically, $\vec{y} = \vec{y}_1 + \vec{y}_2 + \cdots$. This principle holds for linear waves (e.g., electromagnetic waves in vacuum).

3. State the difference between interference and diffraction.

Interference	Diffraction
Arises from superposition of waves coming from **two or more discrete sources** (or slits).	Arises from superposition of waves coming from **different parts of the same wavefront** (continuous source).
Fringe intensity is usually uniform (for two equal slits).	Fringe intensity decreases as we move away from the center.
Fringes are equally spaced (in YDSE).	Fringes are not equally spaced (central maximum is twice as wide).

4. State Rayleigh's criterion.
Rayleigh's criterion states that two point sources are just resolvable by an optical instrument when the central maximum of the diffraction pattern of one source coincides with the first minimum of the diffraction pattern of the other source. The angular separation for just resolution is $\theta = 1.22\frac{\lambda}{D}$ for a circular aperture.

Understand Level

5. Explain types of interference (constructive and destructive).

Constructive interference occurs when the phase difference δ between two waves is an even multiple of π, i.e., $\delta = 2m\pi$ (m = 0, 1, 2,…). The path difference is $m\lambda$. Amplitudes add, resulting in maximum intensity.

Destructive interference occurs when $\delta = (2m+1)\pi$. The path difference is $(m + \frac{1}{2})\lambda$. Amplitudes cancel partially or fully, resulting in minimum intensity.

6. Explain formation of Newton's rings in reflected light.
A plano-convex lens of large radius of curvature is placed on a flat glass plate. A thin air film of variable thickness is formed between the lens and the plate. Monochromatic light falls normally. Interference occurs between light reflected from the top and bottom surfaces of the air film.

- **Dark rings** form where the path difference = $m\lambda$ (destructive from reflection with phase change of π).
- **Bright rings** form where the path difference = $(m + \frac{1}{2})\lambda$.
  The rings are circular, centered at the point of contact, with decreasing spacing as radius increases.

7. Describe construction and working of Michelson's interferometer.

Construction: A beam splitter (half-silvered mirror) divides light from a source. The two beams travel to two movable mirrors M_1 and M_2, reflect back, and recombine at the beam splitter. The interference pattern is observed through a telescope.

Working: One mirror M_1 is moved slowly using a micrometer screw. The path difference changes, causing fringes to shift. By counting fringe shifts for a known mirror displacement, the wavelength of light can be measured accurately. Also used to measure refractive indices (gas cell in one arm) and small displacements.

8. Describe Fraunhofer diffraction at a single slit.

A plane wavefront is incident normally on a narrow slit of width a. A converging lens focuses diffracted light on a screen. The intensity pattern:

- **Central maximum** at $\theta = 0$ (bright, twice as wide as others).
- **Minima** (dark) occur at $a\sin\,\theta = m\lambda, m = \pm 1, \pm 2, \ldots$
- **Secondary maxima** occur at $a\sin\,\theta = (m + \frac{1}{2})\lambda$ approximately.

Intensity formula:

$$I = I_0 \left(\frac{\sin\beta}{\beta}\right)^2, \beta = \frac{\pi a \sin\,\theta}{\lambda}$$

The pattern is a central broad maximum with weaker, narrower side fringes.

Apply Level

9. Derive fringe width in Young's double slit experiment.

Given: Slit separation d, slit-to-screen distance D, wavelength λ.
To find: Fringe width β.

Formula: Path difference $\Delta = d\sin\,\theta \approx d\frac{y}{D}$ (for small θ).

Solution:
Constructive interference (bright fringe):

$$d\frac{y_m}{D} = m\lambda \Rightarrow y_m = \frac{m\lambda D}{d}$$

Destructive interference (dark fringe):

$$y_{m+\frac{1}{2}} = \frac{(m+\frac{1}{2})\lambda D}{d}$$

Fringe width $\beta = y_{m+1} - y_m = \frac{(m+1)\lambda D}{d} - \frac{m\lambda D}{d} = \frac{\lambda D}{d}$

Final Answer: $\boxed{\beta = \frac{\lambda D}{d}}$

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10. Derive intensity expression $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\,\delta$ for Young's double slit.

Given: Two waves with amplitudes A_1 and A_2, phase difference δ.
To find: Resultant intensity.

Formula: $y_1 = A_1\sin\,(\omega t)$, $y_2 = A_2\sin\,(\omega t + \delta)$.

Solution:
Resultant amplitude:

$$A_R = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\,\delta}$$

Intensity $I \propto A_R^2 \Rightarrow I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\,\delta$ (since $I \propto A^2$ and $\sqrt{I_1 I_2} \propto A_1A_2$).

Final Answer: $\boxed{I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\,\delta}$

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11. Prove Newton's ring diameters (dark rings ∝ natural numbers; bright ∝ odd numbers) in reflection.

Given: Radius of curvature R of lens, wavelength λ, air film thickness t.
To find: Diameter relation.

Formula: In reflection, path difference $= 2t + \frac{\lambda}{2}$ (due to phase change of π at lower surface of air film).
Condition for dark ring: $2t + \frac{\lambda}{2} = (2m)\frac{\lambda}{2} \Rightarrow 2t = (m - \frac{1}{2})\lambda$? Wait — standard formula:
For dark ring: $2t = m\lambda$ (since $\lambda/2$ extra path cancels for darkness) – correct:
Actually, dark: $2t = m\lambda$, $m = 0,1,2,...$
From geometry: $t = \frac{r^2}{2R} \Rightarrow \frac{r^2}{R} = m\lambda \Rightarrow r^2 = m\lambda R$

Diameter $D_m = 2r = 2\sqrt{m\lambda R} \Rightarrow D_m \propto \sqrt{m}$. Hence **dark ring diameters** $\propto \sqrt{\text{natural numbers}}$.

For bright ring: $2t = (m + \frac{1}{2})\lambda \Rightarrow r^2 = (m + \frac{1}{2})\lambda R \Rightarrow D_m \propto \sqrt{m + \frac{1}{2}} \Rightarrow \sqrt{\text{odd numbers / 2}} \Rightarrow$ hence $\propto \sqrt{\text{odd numbers}}$.

Final Answer: Dark: $D_m \propto \sqrt{m}$; Bright: $D_m \propto \sqrt{2m + 1}$ (odd numbers).

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12. Derive resolving power of a grating.

Given: Grating with N slits, slit width a, grating spacing d, wavelength λ, order m.
To find: Resolving power $R = \lambda/\Delta\lambda$.

Formula: From Rayleigh's criterion: The principal maximum of λ and first minimum of $\lambda + \Delta\lambda$ coincide in order m.

Solution:
For principal maximum: $d\sin\,\theta = m\lambda$
First minimum adjacent to this maximum occurs at phase difference $\delta = \frac{2\pi}{\lambda} d\sin\,\theta + \frac{2\pi}{N}$ for N slits — better:
The angular half-width of principal maximum:

$$\Delta\theta = \frac{\lambda}{Nd\cos\,\theta}$$

Change in wavelength $\Delta\lambda$ produces angular shift: differentiate grating equation:

$$d\cos\,\theta\,\Delta\theta = m\Delta\lambda$$

Set $\Delta\theta$ from half-width:

$$d\cos\,\theta \cdot \frac{\lambda}{Nd\cos\,\theta} = m\Delta\lambda$$
$$\frac{\lambda}{N} = m\Delta\lambda$$

Thus resolving power:

$$R = \frac{\lambda}{\Delta\lambda} = mN$$

Final Answer: Resolving power of grating = $\boxed{mN}$