WAVE OPTICS — NEET PHYSICS

Comprehensive Formula Sheet for Revision

1. HUYGENS' PRINCIPLE & WAVE BASICS

Fundamental Relations

- **Speed of light in medium:** $v = \frac{c}{n}$ where n = refractive index, $c = 3 \times 10^8$ m/s
- **Wavelength in medium:** $\lambda_m = \frac{\lambda_0}{n}$ (λ_0 = wavelength in vacuum)
- **Frequency (constant):** $f = \frac{v}{\lambda} = \frac{c}{\lambda_0}$ (independent of medium)
- Optical path length: $L = n \times d$ (for distance d through medium with refractive index n)

Phase relation:

$$\phi = \frac{2\pi}{\lambda} \times (\text{path difference}) = \frac{2\pi}{c} \times (\text{optical path difference})$$

2. INTERFERENCE OF LIGHT

Young's Double Slit Experiment (YDSE)

Fringe width:

$$\beta = \frac{\lambda D}{d}$$

where D = distance to screen, d = separation between slits, λ = wavelength

Path Difference & Phase Difference

Path difference at point P: $\Delta x = S_2P - S_1P = \frac{x \cdot d}{D}$
(for small angles; x = position on screen from center)

- Relation: $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$ (phase difference)
- For n wavelengths path diff: $\Delta x = n\lambda$ (same for optical path)

Conditions for Maxima & Minima

Bright Fringes (Maxima): $\Delta x = n\lambda$ $(n = 0, \pm1, \pm2, ...)$
Dark Fringes (Minima): $\Delta x = (2n+1)\frac{\lambda}{2}$ $(n = 0, \pm1, \pm2, ...)$

- Position of n-th bright fringe: $x_n = n \cdot \beta = n \cdot \frac{\lambda D}{d}$
- Position of n-th dark fringe: $x_n = (2n+1) \cdot \frac{\beta}{2}$

Intensity Distribution

Resultant Intensity:

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos(\Delta\phi)$$

For equal intensities ($I_1 = I_2 = I_0$):

$$I = 4I_0\cos^2\left(\frac{\Delta\phi}{2}\right)$$

- **Max intensity (at bright fringe):** $I_{\max} = (I_1 + I_2 + 2\sqrt{I_1 I_2})$
- **Min intensity (at dark fringe):** $I_{\min} = (I_1 + I_2 - 2\sqrt{I_1 I_2})$

- For equal sources: $I_{\text{max}} = 4I_0$, $I_{\text{min}} = 0$

Coherent Sources (Conditions)

Same frequency (or wavelength in same medium)
Constant phase difference (or zero phase difference)
Preferably same amplitude
Small separation (for observable fringes)

3. DIFFRACTION

Single Slit Diffraction

Condition for Minima (Dark fringes):

$$a \sin\theta = n\lambda \quad (n = \pm 1, \pm 2, \pm 3, ...)$$

where a = slit width, θ = diffraction angle

Angular width of central maximum:

$$\Delta\theta = \frac{2\lambda}{a}$$

(for small angles, in radians; angular separation between first minima on either side)

- Linear width of central max on screen: $W = \frac{2\lambda D}{a}$ (D = distance to screen)
- Central max is always bright; contains about 90% of total intensity

Condition for Secondary Maxima

- Approximately at: $a \sin\theta \approx (2n+1)\frac{\lambda}{2} \quad (n = 1, 2, 3, ...)$
- Intensity of secondary maxima $\approx \frac{I_0}{(2n+1)^2}$ (very weak)

4. COMBINED INTERFERENCE & DIFFRACTION

Double Slit Diffraction Pattern

- Fringe visibility decreases as diffraction envelope modulates interference pattern
- Fringes disappear when diffraction minimum coincides with interference order
- Missing order condition: $n_{\text{missing}} = \frac{d}{a}$ (when diffraction min overlaps interference max)

5. POLARIZATION

Malus' Law

Intensity after polarization:

$$I = I_0 \cos^2\theta$$

where θ = angle between transmission axes of polarizer and analyzer, I_0 = incident intensity

- If two polarizers at angle θ: $I = I_0 \cos^2\theta$ (for unpolarized light: $I = \frac{I_0}{2}\cos^2\theta$)

Brewster's Angle (Polarization by Reflection)

Brewster's Angle:

$$\tan i_B = n$$

where n = refractive index of second medium, i_B = incident angle
At Brewster's angle, reflected light is completely polarized (perpendicular to plane of incidence)

- **For air-glass:** $n = 1.5 \Rightarrow i_B \approx 56.3$
- At Brewster's angle: $i_B + r = 90$ (incident + refracted angle)

Degree of Polarization

$$P = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

where $P = 0$ for unpolarized, $P = 1$ for completely polarized light

6. DIFFRACTION GRATING

Grating Equation

Condition for maxima (principal maxima):

$$d \sin\theta = n\lambda \quad (n = 0, 1, 2, 3, ...)$$

where d = grating spacing (distance between adjacent slits)

- Angular dispersion: $\frac{d\theta}{d\lambda} = \frac{n}{d\cos\theta}$
- Resolving power: $R = \frac{\lambda}{\Delta\lambda} = nN$ (N = total number of slits)
- Missing orders occur when: $d\sin\theta = m \times \lambda$ and $a\sin\theta = n\lambda$ overlap

7. IMPORTANT STANDARD RESULTS & SHORTCUTS

Path Difference to Phase Difference

$$\text{Path Diff} = \frac{\lambda}{2\pi} \times \text{Phase Diff} \quad \text{OR} \quad \text{Phase Diff} = \frac{2\pi}{\lambda} \times \text{Path Diff}$$

Quick Conversions for NEET MCQs

- Path diff of $\frac{\lambda}{4} \rightarrow$ Phase diff $= \frac{\pi}{2}$
- Path diff of $\frac{\lambda}{2} \rightarrow$ Phase diff $= \pi$ (out of phase by 180°)
- Path diff of $\lambda \rightarrow$ Phase diff $= 2\pi$ (in phase)

Effect of Medium on Fringe Pattern

- When transparent sheet (thickness t, refractive index n) placed before one slit:
  - Additional optical path $= (n-1)t$
  - Fringe pattern shifts by: $\Delta x = \frac{(n-1)t \cdot D}{d}$

Useful Standard Values

- Speed of light: $c = 3 \times 10^8$ m/s
- Visible spectrum: $\lambda \in [400 \text{ nm (violet)}, 700 \text{ nm (red)}]$

- Refractive index of glass: $n \approx 1.5$
- Refractive index of water: $n \approx 1.33$

8. SIGN CONVENTIONS & ASSUMPTIONS

- Path difference is measured from center (central maximum) outward
- For YDSE, positive x = above center, negative = below
- Small angle approximation: $\sin\theta \approx \tan\theta \approx \theta$ (in radians) valid for $\theta < 10$
- Optical path = geometric path $\times$ refractive index
- All wavelengths in formulas refer to wavelength in the medium unless specified as λ_0 (vacuum)

9. MOST IMPORTANT FORMULAS AT A GLANCE

Concept	**Key Formula**
Fringe Width (YDSE)	$\beta = \frac{\lambda D}{d}$
Path Diff (Bright)	$\Delta x = n\lambda$
Path Diff (Dark)	$\Delta x = (2n+1)\frac{\lambda}{2}$
Single Slit Minima	$a\sin\theta = n\lambda$
Central Max Width	$W = \frac{2\lambda D}{a}$
Malus' Law	$I = I_0\cos^2\theta$
Brewster's Angle	$\tan i_B = n$
Grating Maxima	$d\sin\theta = n\lambda$
Wavelength in Medium	$\lambda_m = \frac{\lambda_0}{n}$

Document optimized for NEET Physics revision — Print for quick reference during last-minute prep!