MIT World Peace University

Physics
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Physics Formulas and Definitions

Notes

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Contents

1 Basics

1.1 Classical Physics

1. Kinetic Energy is defined as the energy gained by the virtue of motion of the particle:

$$K.E = \frac{1}{2}mv^2 \tag{1}$$

$$K.E = \frac{p^2}{2m} \tag{2}$$

2. Momentum

$$p = mv \tag{3}$$

$$p = \sqrt{2mK.E} \tag{4}$$

3. Work is on an object when an external force is applied and it moves.

$$W = F \cdot s = F \cdot s \cos\theta \tag{5}$$

4. Work Energy Theorem:

$$W = K.E_f - K.E_i = \Delta K.E \tag{6}$$

5. Power

$$P = \frac{E}{t} \tag{7}$$

$$P = F \cdot v \tag{8}$$

6. Potential Energy: Work done to move an object from infinity to a point.

$$P.E = qW \tag{9}$$

7. Electric Potential

$$V = \frac{W}{q} \tag{10}$$

8. Law of Conservation of Energy

$$K.E + P.E = 0 \tag{11}$$

1.2 Vibrations and Wave Theory

1. In any type of wave, matter is never propagated, it is only the momentum and Energy that are propagated, be it longitudinal (Sound, $\parallel$ to direction of Propagation), or Transverse (EM Waves, $\perp$ to Direction of Propagation)

2. Wavelength, is the distance travelled by the wave in the time in which the particle of the medium completes 1 Vibration. (λ)

3. Frequency is given as the number of vibrations made by the source particle in 1 Second

$$\nu = \frac{1}{T} \tag{12}$$

   where T is the time Period for 1 Oscillation

4. Amplitude (A) is the maximum displacement of the particle from its mean position.

5. Phase (ϕ), is the Angle swept by the radius vector (in the phasor diagram) since the last vibrating particle crossed its mean position of rest.

6. Basic Relation between Speed, frequency and Wavelength

$$c = \nu \times \lambda \tag{13}$$

7. Relation between path difference and phase difference

$$\phi = \frac{2\pi}{\lambda} \times \Delta \tag{14}$$

8. Wave number is given by:

$$\bar{\nu} = \frac{1}{\lambda} \tag{15}$$

9. Wave Equation is given by:

$$\Psi(x,t) = A\sin(\omega t - kx) = A\sin\frac{2\pi}{\lambda}(vt - x) \tag{16}$$

   where
   x = distance travelled by the wave
   v = velocity of the wave
   t = time
   A = Amplitude of the wave
   k = $\frac{2\pi}{\lambda}$
   $\omega = \frac{2\pi}{T}$
   T = Time Period

Here, Ψ represents the displacement of the particle. It is a function of x and t. the point being, that to represent an entire wave, all you need to know is where exactly the particle producing the wave is, at any given point of time, so to represent an entire wave, a function describing the displacement of its source particle at a given time, and at a given position is enough, and also the shortest way.

10. Differential Equation of the Wave

$$\frac{d^2\Psi}{dt^2} = v^2 \frac{d^2\Psi}{dx^2} \tag{17}$$

1.3 Optics

1. Relation between Refractive index of Material and given light wavelength (simplified, not accurate)

$$n \propto \frac{1}{\lambda} \tag{18}$$

so Red has a high wavelength (700 nm) and therefore material has a lower value of n for red, voilet has a low wavelength, and therefore material has a higher value of n for violet. This is why Red color disperses the least, naturally, and Violet disperses the most. This is Cauchy's Relation

2. Stokes Law: States that phase change of π or a path difference of $\lambda/2$ will take place when a light ray reflects fat the surface of a denser medium. Nothing happens when they reflect off the surface of a rare medium.

   Essentially,
   Rarer: Denser= Light transmitted is same phase, reflected is out of phase
   Denser: Rarer= Light Transmitted is same phase, and reflected is also same phase.

3. A *wavefront* is defined as the continuous locus of all such particles of the medium which are vibrating in the same phase at any instant.

4. *Coherent* sources of light are those that have the same phase difference.

5. Snells Law

$$\frac{n_2}{n_1} = \frac{\sin i}{\sin r} \tag{19}$$

1.4 Interference and Diffraction

1. When two light waves of save ν and having a constant phase difference traverse simultaneously in the same region of a medium and cross each other then there is a modification in the intensity of light in the region of superposition, which is in general different from the sum of the intensities due to individual waves. *This modification in intensity of light resulting from the superposition of two ore more waves of light is called **interference**.*

2. To get interference, you need to either

   (a) Division of wavefront: where you need a slit or something to divide the incoming wavefront into more waves that then cause interference. *Eg. Lasers, Fresnel Mirrors, Young's Double slit experiment, etc.*

   (b) Division of amplitude: amplitude is divided here by phenomena like partial reflection, refraction, etc. So coherent beams are produced but they all travel different paths, and are brought together. *Eg. Thin film interference, Newton's Rings, Michelson's interferometer etc.*

1.5 Quantum Mechanics and Atomic Structure

1. Planck's Quantum Theory Stated:
$$E = h\nu \tag{20}$$

2. PhotoElectric Effect:
$$W_0 = h\nu_0 - \frac{1}{2}mv_e^2 \tag{21}$$

3. De-Broglie's Principle:
$$\lambda = \frac{h}{mv} \tag{22}$$
$$\lambda_s = \frac{h}{\sqrt{2m_s \times K.E}} \tag{23}$$
$$\tag{24}$$

   As Work done on the electron is e × the Potential Difference applied (V)
$$\lambda = \frac{h}{\sqrt{2meV}} \tag{25}$$
$$\lambda_e = \frac{12.27}{\sqrt{V}}\text{Å} \tag{26}$$
$$\lambda_p = \frac{0.28}{\sqrt{V}}\text{Å} \tag{27}$$

1.6 Constants

1. Mass of Proton = 1.6×10^{-27} Kg
2. Mass of Neutron = 1.6×10^{-27} Kg
3. Mass of Electron = 9.1×10^{-31} Kg
4. Planck's Constant = 6.6×10^{-34} Js
5. Charge on an Electron = -1.6×10^{-19} C

2 Interference

2.1 Young's Double Slit Experiment

1. Constructive Interfernce Condition:

$$\Delta = n\lambda \tag{28}$$

2. Destructive Interference Condition:

$$\Delta = (n + \frac{1}{2}) \times \lambda \tag{29}$$

3. Expressions for Path difference

$$\Delta = \frac{\lambda}{2\pi} \times \phi = \frac{xd}{D} \tag{30}$$

   where,
   x = distance from the center of the screen to the the point in question
   d = distance between the 2 slits
   D = Distance from slits to the Screen

4. Position of Bright Fringes:
   From the above equations, for constructive interference *(bright fringes)* you will get:

$$x = \frac{nD\lambda}{d} \tag{31}$$

   which gives,

$$\textit{For m = 0, } x_0 = 0, \textit{ Central Bright Fringe} \tag{32}$$

$$\textit{For m = 1, } x_1 = \frac{(1)D\lambda}{d}, \textit{ First Bright Fringe} \tag{33}$$

$$\ldots \textit{and so on} \tag{34}$$

   and for Dark Fringes

$$\textit{For m = 1, } x'_0 = \frac{(1)D\lambda}{2d}, \textit{ First Dark Fringe} \tag{35}$$

$$\textit{For m = 2, } x'_1 = \frac{(3)D\lambda}{2d}, \textit{ Second Dark Fringe} \tag{36}$$

$$\ldots \textit{and so on} \tag{37}$$

5. Fringe Width:

$$\beta = \frac{D\lambda}{d} \tag{38}$$

6. Angular Fringe Width:

$$\theta = \frac{\lambda}{d} \tag{39}$$

2.2 Interference in Thin Film

1. Reflected System

   (a) Condition for Maxima

$$2\mu t\cos(r) = (n + \frac{1}{2})\lambda \tag{40}$$

   (b) Condition for Minima

$$2\mu t\cos(r) = n\lambda \tag{41}$$

2. Transmitted System

   (a) Condition for Maxima

$$2\mu t\cos(r) = n\lambda \tag{42}$$

   (b) Condition for Minima

$$2\mu t\cos(r) = (n + \frac{1}{2})\lambda \tag{43}$$

2.3 Interference in Wedge Film

1. Condition for Maxima

$$2\mu t\cos(r + \alpha) = (n + \frac{1}{2})\lambda \tag{44}$$

2. Condition for Minima

$$2\mu t\cos(r + \alpha) = n\lambda \tag{45}$$

3. Fringe Width

$$x_{n+1} - x_n = \beta = \frac{\lambda}{2\alpha} \tag{46}$$

2.4 Newtons Rings

1. Nth Dark Ring is given by:

$$D_n^2 = \frac{4Rn\lambda}{\mu} \tag{47}$$

2. Mth Bright Ring is given by:

$$D_m^2 = \frac{2R\lambda}{\mu}(2m \pm 1) \tag{48}$$

3. Radius of Curvature when Diameter of m and nth dark ring is given

$$R = \frac{\mu(D_m^2 - D_n^2)}{4(m-n)\lambda} \tag{49}$$

4. Refractive Index of the lens when air wedge and lens wedge Diameter of rings is given

$$\mu = \frac{D_{air}^2}{D_{lens}^2} \tag{50}$$

5. Thickness of Anti Reflective Coating

$$t = \frac{\lambda}{4\mu} \tag{51}$$

3 Diffraction

$$\alpha = \frac{\pi a \sin\theta}{\lambda} \tag{52}$$

$$I_\theta = I_m(\frac{\sin\alpha}{\alpha})^2 \tag{53}$$

3.1 Diffraction through a single slit

1. Condition for Central Maxima

$$I_\theta = I_m \tag{54}$$

$$\alpha = 0 \tag{55}$$

$$\theta = 0 \tag{56}$$

2. Condition for Minima

   Intensity

$$I_\theta = 0 \tag{57}$$

$$\alpha = m\pi \tag{58}$$

   Main Equation

$$a\sin\theta = n\lambda \tag{59}$$

3. Condition for Secondary Minima
   Path Difference is

$$\Delta = n\lambda \tag{60}$$

   Intensity

$$I_\theta = \textit{very small} \tag{61}$$

$$\alpha = (n + \frac{1}{2})\pi \tag{62}$$

$$a\sin\theta = (n + \frac{1}{2})\lambda \tag{63}$$

4. Width of Central or Principle Maxima

$$W = \frac{2D\lambda}{a} \tag{64}$$

5. Angular Width of Central Maxima

$$\theta = \frac{2\lambda}{a} \tag{65}$$

3.2 Diffraction through a Diffraction Grating

$$d = a + b \tag{66}$$

$$N = \frac{1}{a+b} \tag{67}$$

$$\beta = \frac{\pi d \sin\theta}{\lambda} \tag{68}$$

1. Condition for principle Maxima

$$I_\theta = N^2 I_m (\frac{\sin\alpha}{\alpha})^2 \tag{69}$$

$$\beta = n\pi \tag{70}$$

$$(a+b)\sin\theta = n\lambda \tag{71}$$

2. Condition for Minima

$$(a+b)\sin\theta = \frac{n}{N}\lambda \tag{72}$$

3. Highest visible power is (or maximum order)

$$n_{\max} = \frac{a+b}{\lambda} \tag{73}$$

4. Absent Spectra

$$m = \frac{a+b}{a} n \tag{74}$$

5. Total number of lines in the grating

$$\textit{total number of lines} = 2 \times N \tag{75}$$

6. Resolving Power

$$\frac{\lambda}{d\lambda} = n \times N \tag{76}$$

4 Polarization

1. Law of Malus
$$I_\theta = I_m \times \cos^2\theta \tag{77}$$

2. Brewster's Law: When Unpolarized light falls on a reflective surface, if the Angle of incidence is the angle of polarization (i_p) then the reflected light is fully polarized. r is angle of refraction.
$$i_p + r = 90^\circ \tag{78}$$
$$\mu = \tan i_p = \frac{1}{\sin c} \tag{79}$$

5 Quantum Mechanics

1. Phase Velocity
$$v_p = \frac{E}{p} = \frac{c^2}{v} = \frac{\omega}{k} \tag{80}$$

2. Group Velocity of a de Broglie Wave of a particle travels with the same velocity as the particle.
$$v_g = v_p - \frac{dv_p}{d_\lambda} \tag{81}$$

3. Heisenberg's Uncertainity Principle: You cannot simultaineously determine the momentum and the position of a microparticle at an instant with exactness.
$$\Delta x \cdot \Delta p_x = \frac{h}{2\pi} \tag{82}$$

   This is important, coz it sets an inherent, built-in, unavoidable, inevitable limit of nature itself to the accuracy with which we can make measurements.