Topic 4: Oscillations and Waves

Formulæ

- $T = \frac{1}{f}$
- $E_k + E_p = \text{CONST} \ (N.D.B.)$
- $v = \frac{\lambda}{T}$, wave speed
- $I = \frac{A}{4\pi}$, intensity \ (N.D.B.)
- $I \propto \frac{A}{r^2}$, $r$ = distance from source
- $\text{For spherical waves, } I = \frac{\text{Power}}{4\pi r^2} = \frac{I}{(4\pi)^{\frac{1}{2}}}$ \ (N.D.B.)

- $I \propto A^2$, $A = \text{amplitude}$
- $\theta_{\text{incident}} = \theta_{\text{reflection}}$ \ (N.D.B.)
- $I = I_0 \cos^2 \theta$ \ (Polarization, Malus' Law) \ (For Analyzer usually)
- $I \propto E^2$, $E$ = electric field \ (Polarization)
- $\theta = \text{Angle between transmission axis of polarizer or analyzer, and direction of electric field. Can be angle between polarizer and analyzer.}$
- $\lambda = \text{Length between maxima or minima.}$
- $d = \text{Distance between fringes.}$

Required Definitions

1. Isochronous oscillations – oscillations that repeat in the same time period, regardless of amplitude changes.
2. Period \ (T) – time duration of one oscillation, \ (sec)
3. Frequency \ (f) – number of oscillations per unit time, \ (Hz)
4. Amplitude – refers to maximum displacement, \ (m)
5. Phase difference – the fraction of the wave cycle that has elapsed relative to the origin, \ (rad)
7. Transverse waves – waves with direction of oscillation perpendicular to direction of energy propagation.
8. Longitudinal waves – waves with direction of oscillation parallel to direction of energy propagation.
9. Wavefront – wavefront is a surface that travels with a wave, and is perpendicular to its direction of travel, or energy propagation.
10. Ray – rays are lines showing the direction of energy propagation, and are perpendicular to wavefronts.
11. Superposition – when two or more waves superimpose, the sum of their individual amplitudes becomes the amplitude of the resultant wave. They are constructive or destructive interference.
12. Polarization – polarization restricts direction of oscillation of electric field of a wave to a plane perpendicular to the direction of propagation.
13. Refractive index – fraction of speed of light in vacuum \ (c) to speed in medium \ (v).
15. Standing waves – when coherent travelling waves superimpose, they form standing waves.

Common Diagrams

- [Diagram of oscillations and waves with various types of waves and their characteristics]
- [Diagram with labeled parts such as amplitude, frequency, and phase difference]
- [Diagram of standing waves with critical angles and density indication]
- [Diagram of wavefronts and ray paths]

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**Common Graphs**

- **Similar to $F=kx$ and Kinematics graphs in Mechanics notes**
  - **Hooke's Law**
    - Gradient = $k$
    - Area under graph = Work done = $F_{max}x_{max} = \frac{1}{2} MV^2_{max}$

- **Standing Waves**
  - Not transferred
  - Same for all points
  - SHM & same $f$
  - Phase: Different, all points adjacent are shifted (180°)
  - Wave Pattern: Does not move

- **Travelling Waves**
  - Transferred
  - Same for all points
  - SHM & same $f$
  - Phase: Same for each point in a lobe, adjacent lobes
  - Wave Pattern: Moves

**Experiment Summaries**

- **Brewster's Law (polarization)**
  - If reflected & refracted ray are at 90°
  - Plane, the reflected ray will be totally polarized.
  - $\theta_{reflection} + \theta_{refraction} = 90°$, Brewster's angle

- **Other Notes**
  - Period and Amplitude are independent. (Spring or pendulum) in terms of magnitude
  - Conditions for SHM (2): Acceleration is proportional to displacement. The direction of acceleration is opposite the direction of displacement. (Restoring)
  - Electromagnetic spectrum: All transverse waves
  - $c = 3.0 \times 10^8 \text{ m/s}$, constant for entire electromagnetic spectrum.
  - Sound waves cannot travel through vacuum. Light can. Electromagnetic spectrum can.
  - In longitudinal waves, compressions are wavefronts. In transverse, crests are wavefronts.
  - Refraction, speed and $n$ change, $\lambda$ and period $T$ no change.
  - Polarization is only for transverse waves.
  - Remember that if $I_0$ is incident intensity on a polarizer, then only $\frac{I_0}{2}$ is transmitted to analyzer.
  - $\theta$ in reflection or refraction diagrams is always against the normal, not plane.
  - A HARMONIC is named by ratio of its frequency to that of First HARMONIC.
  - Revise tuning fork. For $440$ Hz: $\lambda$ = 108 cm.
  - If $s = \frac{AD}{d}$, remember $\frac{AD}{d} = \frac{(n+\frac{1}{2})AD}{d}$, where $n$ shows which maxima order $s = minima$ order.