PHYS. 131 Final Exam

A comprehensive cheat sheet covering fluids, waves, sound, light interference, simple harmonic motion and nuclear physics, providing key formulas and concepts.

Fluids: Statics and Dynamics

Fluid Properties

Density (ρ): Mass per unit volume
`ρ = m/V`
Water Density: 1000 kg/m³
Air Density: 1.29 kg/m³

Pressure (P): Force per unit area
`P = F/A`
Units: Pascals (Pa) = N/m²

Macroscopic Differences:
Solids: Fixed shape and volume.
Liquids: Fixed volume, variable shape.
Gases: Variable shape and volume.

Microscopic Differences:
Solids: Atoms/molecules tightly packed.
Liquids: Atoms/molecules closely packed, can move past each other.
Gases: Atoms/molecules widely dispersed, move randomly.

Absolute Pressure: Total pressure including atmospheric pressure.
`P_absolute = P_gauge + P_atm`

Gauge Pressure: Pressure relative to atmospheric pressure.
`P_gauge = P - P_atm`

Pressure in a Static Fluid:
$P = P_0 + \rho g h$
where:
P_0 = pressure at surface,
`ρ` = density,
`g` = gravity,
`h` = depth.

Suction: Created by pressure difference. Fluid moves from high to low pressure.

Manometers: Measure pressure differences using fluid columns.

Barometers: Measure atmospheric pressure.

Pascal's Principle & Buoyancy

Pascal's Principle: Pressure applied to a confined fluid is transmitted undiminished throughout the fluid.
$F_1/A_1 = F_2/A_2$

Hydraulic Systems: Utilize Pascal's Principle for force amplification.

Blood Pressure: Measured using a sphygmomanometer. Systolic/Diastolic pressure (e.g., 120/80 mmHg).

Buoyancy: Upward force exerted by a fluid on an immersed object.

Archimedes' Principle: Buoyant force equals the weight of the fluid displaced by the object.
`F_buoyant = ρ_fluid * V_displaced * g`

Apparent Weight:
`W_apparent = W_true - F_buoyant`

Floating Objects: Buoyant force equals object's weight.

Immersed Objects: Buoyant force can be greater than, less than, or equal to object's weight (determining if object floats, sinks, or is neutrally buoyant).

Fluid Dynamics

Streamlines: Paths of fluid particles in steady flow.

Flow Rate (Q): Volume of fluid passing a point per unit time.
`Q = Av`
where `A` is cross-sectional area and `v` is flow speed.

Equation of Continuity: Conservation of mass in fluid flow.
$A_1 v_1 = A_2 v_2$

Bernoulli's Equation: Conservation of energy in fluid flow.
$P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$

Viscosity: Resistance to flow. Increases energy losses.

Turbulence: Irregular flow with eddies. Increases energy losses.

Simple Harmonic Motion & Waves

Simple Harmonic Motion (SHM)

SHM Definition: Periodic motion where restoring force is proportional to displacement.

Displacement: $x(t) = A\cos(\omega t + \varphi)$
where:
A = Amplitude
ω = Angular frequency
φ = Phase constant

Velocity: $v(t) = -A\omega\sin(\omega t + \varphi)$

Acceleration: $a(t) = -A\omega^2\cos(\omega t + \varphi) = -\omega^2 x(t)$

Hooke's Law: $F = -kx$
where:
k = Spring constant

Natural Frequency: $\omega = \sqrt{k/m}$

Elastic Potential Energy: $U = \frac{1}{2}kx^2$

Conservation of Energy: $\frac{1}{2}kA^2 = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

Pendulum Period: $T = 2\pi\sqrt{L/g}$
where:
L = Length
g = Gravity

Damped Oscillations: Amplitude decreases over time due to damping force.

Critical Damping: Returns to equilibrium fastest without oscillation.

Resonance: Large amplitude oscillations when driving frequency matches natural frequency.

Traveling Waves

Transverse Waves: Particle motion perpendicular to wave direction.

Longitudinal Waves: Particle motion parallel to wave direction.

Wave Speed on a String: $v = \sqrt{T/\mu}$
where:
T = Tension
μ = Linear density

Wave Speed: $v = \lambda f$
where:
λ = Wavelength
f = Frequency

Snapshot Graph (D vs. x): Displacement as a function of position at a given time.

History Graph (D vs. t): Displacement as a function of time at a given position.

1D Sinusoidal Wave: $D(x, t) = A\cos(kx - \omega t + \varphi)$
where:
$k = 2\pi/\lambda$ (wave number)

Phase: Argument of the cosine function $(kx - \omega t + \varphi)$
Phase Constant: φ

Standing Waves

Superposition: Waves combine linearly.

Constructive Interference: Waves add in phase; larger amplitude.

Destructive Interference: Waves add out of phase; smaller amplitude.

Reflection at a Boundary: Wave pulse can be inverted upon reflection if going from less dense to more dense medium.

Standing Waves: Superposition of two waves traveling in opposite directions, creating stationary nodes and antinodes.

String Fixed at Both Ends: $\lambda_n = 2L/n$
$f_n = nv/(2L)$ (n=1, 2, 3...)

Open-Open Tube: $\lambda_n = 2L/n$
$f_n = nv/(2L)$ (n=1, 2, 3...)

Open-Closed Tube: $\lambda_n = 4L/n$
$f_n = nv/(4L)$ (n=1, 3, 5...)

Overtones: Frequencies above the fundamental frequency.

Musical Instruments: Standing waves produce specific tones based on instrument geometry.

Sound & Light: Interference

Sound Waves

Loudness: Subjective perception of sound intensity.

Power (P): Energy per unit time.
Intensity (I): Power per unit area.
$I = P/A$ (W/m²)

Sound Intensity Level (dB): $\beta = 10\log_{10}(I/I_0)$
where:
$I_0 = 10^{-12}$ W/m²

Intensity vs. Distance: Intensity decreases with the square of the distance from the source.
$I \propto 1/r^2$

Doppler Effect: Change in frequency due to relative motion between source and observer.
$f' = f(v \pm v_o) / (v \pm v_s)$
where:
v = speed of sound,
v_o = observer speed,
v_s = source speed

Use (+) when moving toward and (-) when moving away. Apply consistently for observer and source.

Interference

Constructive Interference: Path difference is an integer multiple of the wavelength.

Destructive Interference: Path difference is a half-integer multiple of the wavelength.

Beats: Periodic variations in amplitude due to interference of two sound sources with slightly different frequencies.
$f_{beat} = |f_1 - f_2|$

Similarities: Both sound and light exhibit interference phenomena.

Differences: Light interference involves electromagnetic waves, while sound interference involves mechanical waves.

Index of Refraction (n): Ratio of speed of light in vacuum to speed of light in the material.
$n = c/v$

Optical Path Length: Product of the physical distance and the index of refraction.
$OPL = n \cdot d$

Young's Double-Slit Experiment: Demonstrates interference of light waves.

Bright Fringes (Constructive Interference): $d\sin\theta = m\lambda$ (m = 0, ±1, ±2,...)

Dark Fringes (Destructive Interference): $d\sin\theta = (m + \frac{1}{2})\lambda$ (m = 0, ±1, ±2,...)

Nuclear Physics

Nuclear Structure & Binding Energy

Standard Notation: AZX
`A` = Mass number (protons + neutrons)
`Z` = Atomic number (protons)
`X` = Chemical symbol

Nuclide Mass: Actual mass of the nucleus.
Atomic Mass: Mass of the neutral atom (nucleus + electrons).

Mass Defect (Δm): Difference between the mass of the nucleus and the sum of the masses of its individual nucleons.
`Δm = (Zm_p + Nm_n) - m_nucleus`

Binding Energy (BE): Energy required to separate a nucleus into its constituent nucleons.
`BE = Δmc²`

Binding Energy per Nucleon:
`BE/A`
Roughly constant for most nuclei, indicating nuclear stability.

Nuclear Stability: Related to the balance between the strong nuclear force and the electromagnetic force.

Radioactive Decay

Decay Rate (λ): Probability of decay per unit time.

Activity (A): Number of decays per unit time.
`A = λN`
where `N` is the number of radioactive nuclei.

Decay Equation:
`N(t) = N₀e^(-λt)`
`A(t) = A₀e^(-λt)`

Half-Life ($T_1/_2$): Time for half of the radioactive nuclei to decay.
`T₁/₂ = ln(2) / λ`

Lifetime (τ): Average time for a nucleus to decay.
`τ = 1/λ`

Conservation of Energy: Used to determine if a decay process is energetically possible.

Alpha Decay: Emission of an alpha particle (^4_2He).
Reduces mass number by 4 and atomic number by 2.

Beta Decay: Emission of a beta particle (electron or positron).
Changes the atomic number by 1 (either +1 or -1).

Gamma Decay: Emission of a gamma ray (high-energy photon).
Does not change mass number or atomic number.

Radiation Dose: Measure of energy absorbed by biological tissue.

Radiation Effects: Can cause damage to DNA and other biological molecules.

Dose Equivalent: Measure of biological effect of radiation, taking into account the type of radiation.
Measured in Sieverts (Sv).