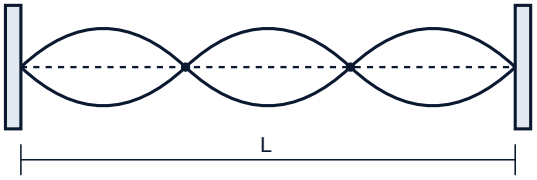
Topic: Waves & Optics (Superposition & Standing Waves)

Instructions: Choose the best answer for each of the following 30 questions. Diagrams are physical representations (not drawn to scale unless a grid is provided). Assume ideal conditions, small angle approximations where physically appropriate, and non-dispersive media unless otherwise stated.

1 A taut string of length L is fixed at both ends. It is driven by an external oscillator and resonates in the stationary wave pattern shown in the diagram. If the wave speed on the string is $120\ \text{m s}^{-1}$ and $L = 1.80\ \text{m}$, what is the frequency of the oscillator?



A. $33.3\ \text{Hz}$

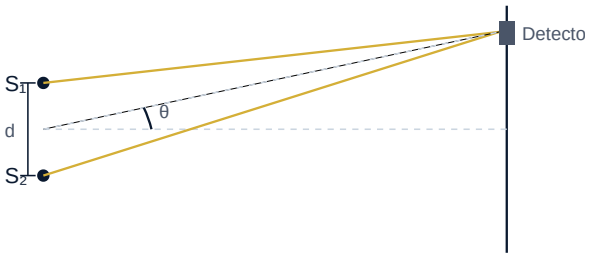
B. $66.7\ \text{Hz}$

C. $100\ \text{Hz}$

D. $200\ \text{Hz}$

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2 Two coherent microwave transmitters, S_1 and S_2, are placed a distance d apart. They emit waves of wavelength λ in phase. A detector is moved along a line parallel to the sources at a large distance D. The diagram shows the physical setup. If the detector records the first minimum at an angle θ, which equation correctly relates these parameters?



A. $d \sin\theta = \lambda$

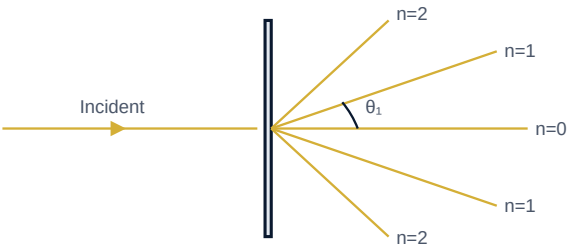
B. $d \sin\theta = \frac{\lambda}{2}$

C. $D \sin\theta = \lambda$

D. $d \tan\theta = \lambda$

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3 A diffraction grating with N lines per meter is illuminated normally by monochromatic light of wavelength λ. The diagram depicts the diffracted beams. Which of the following expressions correctly yields the maximum number of completely visible orders, n_{max}, observed on a hemispherical screen?



A. The greatest integer strictly less than $\frac{1}{N\lambda}$

B. The greatest integer less than or equal to $\frac{1}{N\lambda}$

C. The greatest integer less than or equal to $N\lambda$

D. The greatest integer less than or equal to $\frac{\lambda}{N}$

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4 A narrow vertical pipe of length L is closed at the bottom end and open at the top. A tuning fork is held above the open end, exciting the fundamental mode (first harmonic) of a stationary acoustic wave in the air column. Assuming the end correction is negligible, which physical property must strictly be zero at the closed end?



A. Pressure variation from equilibrium

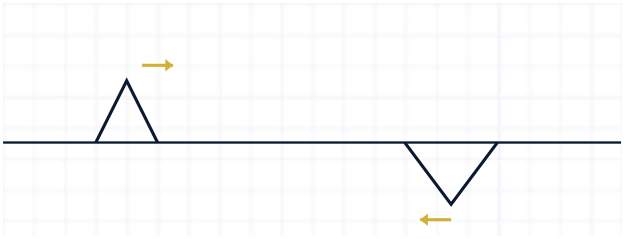
B. Acoustic intensity

C. Displacement of air molecules

D. Density of the air

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5 The diagram illustrates the transverse superposition of two ideal triangular wave pulses travelling towards each other on a uniform string at a speed of $2.0\ \text{m s}^{-1}$. Each grid square represents $1.0\ \text{cm}$. What will be the maximum vertical displacement of the string during their interaction?



A. $0\ \text{cm}$

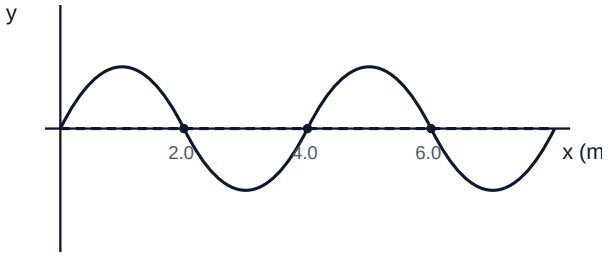
B. $1.0\ \text{cm}$

C. $2.0\ \text{cm}$

D. $4.0\ \text{cm}$

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6 A stationary wave is formed on a string. The graph shows the displacement y of the string at time $t = 0$ (solid line) and at $t = \frac{T}{4}$ (dashed line), where T is the period of oscillation. What is the phase difference between a particle at $x = 1.0\ \text{m}$ and a particle at $x = 3.0\ \text{m}$?



A. $0\ \text{rad}$

B. $\frac{\pi}{2}\ \text{rad}$

C. $\pi\ \text{rad}$

D. $2\pi\ \text{rad}$

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7 A plane microwave beam of wavelength $3.0\ \text{cm}$ is directed normally at a flat metal plate. A stationary wave pattern is established in the space between the transmitter and the plate. A small detector is moved from the plate towards the transmitter. What is the physical distance between the first maximum (antinode) and the third minimum (node) detected?



A. $2.25\ \text{cm}$

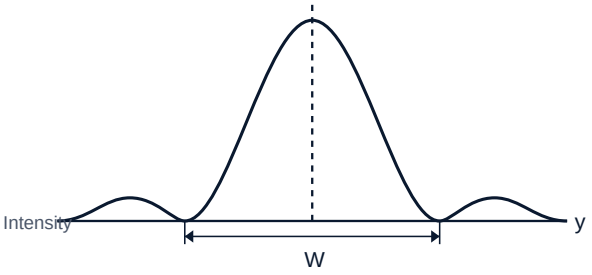
B. $3.00\ \text{cm}$

C. $3.75\ \text{cm}$

D. $4.50\ \text{cm}$

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8 Light of wavelength λ passes through a single slit of width a. The diffraction pattern is projected onto a screen a large distance L away. The diagram shows the intensity I as a function of the transverse distance y from the central axis. If the slit width a is halved, how does the width of the central maximum, W, change?



A. It halves.

B. It remains the same.

C. It doubles.

D. It quadruples.

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9 A glass tube, open at both ends, is vibrating in its second harmonic (first overtone) resonance mode. The diagram represents the amplitude of the longitudinal displacement of the air molecules. If the length of the tube is $0.60\ \text{m}$ and the speed of sound is $340\ \text{m s}^{-1}$, what is the frequency of the sound?



A. $283\ \text{Hz}$

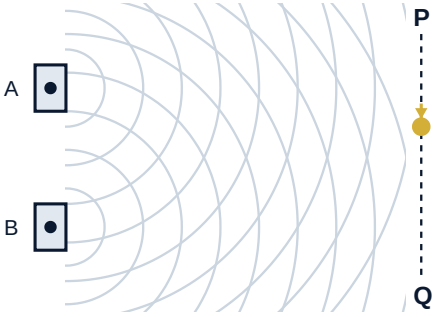
B. $567\ \text{Hz}$

C. $850\ \text{Hz}$

D. $1133\ \text{Hz}$

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10 Two identical loudspeakers, A and B, are driven by the same oscillator at a frequency of $680\ \text{Hz}$. A student walks along a straight line PQ that is parallel to the line connecting the speakers. The setup is shown from above. What is the physical phenomenon that causes the student to hear alternating loud and quiet sounds?



A. Diffraction of sound around the student

B. Acoustic beats due to frequency differences

C. Two-source interference due to path differences

D. Formation of a longitudinal standing wave between the speakers

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11 In Young's double-slit experiment, if the entire apparatus is immersed in water (refractive index $n = 1.33$) rather than vacuum, what happens to the spacing between the interference fringes on the screen?

A. It increases by a factor of 1.33.

B. It decreases by a factor of 1.33.

C. It remains exactly the same, as the slit geometry is unchanged.

D. It decreases by a factor of 1.33^2.

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12 Two coherent light sources emit waves that meet at a point P on a screen. Source 1 has an amplitude of A and Source 2 has an amplitude of $2A$. If the path difference at P results in a phase difference of π radians, what is the resultant intensity at P in terms of the intensity I_0 of Source 1?

A. I_0

B. $3I_0$

C. $5I_0$

D. $9I_0$

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13 A composite string consists of a light section and a heavy section, joined together. A transverse sinusoidal wave travels from the light section into the heavy section. At the boundary, some energy is reflected and some is transmitted. Which of the following parameters must be identical for the incident, reflected, and transmitted waves?

A. Amplitude

B. Wave speed

C. Wavelength

D. Frequency

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14 A diffraction grating has $500\ \text{lines per mm}$. It is illuminated by light containing two distinct spectral lines: red light of wavelength $660\ \text{nm}$ and blue light of wavelength $440\ \text{nm}$. Which order of the blue light will perfectly overlap with the second order of the red light?

A. First order

B. Second order

C. Third order

D. Fourth order

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15 Two identical tuning forks are struck simultaneously. Fork A has a frequency of $256.0\ \text{Hz}$. Fork B has a small piece of Blu-tack attached to one of its prongs. When sounded together, a beat frequency of $4.0\ \text{Hz}$ is heard. What is the exact frequency of Fork B?

A. $252.0\ \text{Hz}$

B. $260.0\ \text{Hz}$

C. $256.0\ \text{Hz}$

D. Either $252.0\ \text{Hz}$ or $260.0\ \text{Hz}$, it is impossible to determine.

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16 A stationary wave on a stretched string has an equation $y(x,t) = 0.04\sin(5\pi x)\cos(40\pi t)$, where y and x are in meters and t is in seconds. What is the speed of the progressive waves that superpose to form this stationary wave?

A. $4.0\ \mathrm{m\ s^{-1}}$

B. $8.0\ \mathrm{m\ s^{-1}}$

C. $16.0\ \mathrm{m\ s^{-1}}$

D. $32.0\ \mathrm{m\ s^{-1}}$

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17 In a Young's double-slit experiment setup, white light (ranging from $400\ \mathrm{nm}$ to $700\ \mathrm{nm}$) is used instead of monochromatic light. What will be the appearance of the central fringe (zero-order maximum) on the viewing screen?

A. It will be dark due to destructive interference of all wavelengths.

B. It will be a spectrum of colors with red on the inside and violet on the outside.

C. It will be a spectrum of colors with violet on the inside and red on the outside.

D. It will be white.

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18 Consider the principle of superposition applied to two scalar waves in a linear medium. The waves are described by $\Psi_1(\vec{r},t)$ and $\Psi_2(\vec{r},t)$. The total energy density of the combined wave field is proportional to the square of the total amplitude. Which statement is generally true about the total energy density U_{total} of the superimposed waves?

A. U_{total} is always exactly equal to the sum of the individual energy densities, $U_1 + U_2$, at all points in space.

B. U_{total} can be greater or less than $U_1 + U_2$ at specific points, but the total energy integrated over all space is strictly conserved.

C. U_{total} is everywhere greater than $U_1 + U_2$ due to constructive interference.

D. Superposition strictly violates local energy conservation without transferring energy to the medium.

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19 Monochromatic light of wavelength $550\ \mathrm{nm}$ is incident normally on a single slit. The angular width of the central maximum (from the first minimum on one side to the first minimum on the other) is observed to be $0.10\ \mathrm{radians}$. Using the small-angle approximation, calculate the width of the slit.

A. $5.5\ \mu\mathrm{m}$

B. $11.0\ \mu\mathrm{m}$

C. $22.0\ \mu\mathrm{m}$

D. $55.0\ \mu\mathrm{m}$

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20 An open organ pipe and a closed organ pipe are sounded together. The open pipe is vibrating in its fundamental mode. The closed pipe is vibrating in its fundamental mode. If they have exactly the same fundamental frequency, what is the ratio of the length of the open pipe to the length of the closed pipe?

A. $1:1$

B. $1:2$

C. $2:1$

D. $4:1$

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21 Two continuous wave sources emit waves of the exact same frequency f, but the second source has a constant, fixed phase lead of $\frac{\pi}{2}$ radians over the first source. At a point P strictly equidistant from both sources, what will be the phase difference between the arriving waves?

A. 0 radians

B. $\frac{\pi}{4}$ radians

C. $\frac{\pi}{2}$ radians

D. π radians

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22 A student observes a two-slit interference pattern. They then cover one of the two slits with a very thin piece of transparent glass of refractive index n and thickness t. What is the primary macroscopic change observed on the viewing screen?

A. The fringe spacing decreases.

B. The fringe spacing increases.

C. The entire fringe pattern shifts laterally.

D. The interference fringes completely vanish, leaving only a single-slit diffraction pattern.

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23 A long, uniform string under tension T is fixed at both ends and plucks, causing it to vibrate in its third harmonic. The total energy stored in the string's vibration is E. If the tension is increased to $4T$, and the string is plucked to vibrate in its fundamental mode with the exact same maximum amplitude, what is the new total stored energy?

A. $\frac{E}{9}$

B. $\frac{4E}{9}$

C. E

D. $4E$

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24 Which of the following is a necessary, fundamental condition for two wave sources to produce a stable, observable interference pattern over a prolonged period of time?

A. They must be emitting waves of completely identical amplitude.

B. They must be physically close together relative to their wavelength.

C. They must maintain a constant phase relationship over time (coherence).

D. They must emit transverse waves exclusively; longitudinal waves cannot interfere.

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25 A radio telescope array consists of two antennas separated by a distance $d = 2.0\ \text{km}$. They are detecting signals of wavelength $21\ \text{cm}$ emitted by a distant hydrogen cloud. To mathematically resolve two close point sources within the cloud using the principle of interference (similar to a double-slit), the angular resolution $\Delta\theta$ of this baseline is approximately governed by $\frac{\lambda}{d}$. What is this limiting angular resolution?

A. $1.05 \times 10^{-4}\ \text{rad}$

B. $1.05 \times 10^{-5}\ \text{rad}$

C. $2.10 \times 10^{-4}\ \text{rad}$

D. $2.10 \times 10^{-5}\ \text{rad}$

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26 Light from a Helium-Neon laser ($\lambda = 633\ \text{nm}$) is directed normally onto a diffraction grating. The screen is placed $2.00\ \text{m}$ away. The distance between the central maximum and the first-order principal maximum on the screen is measured to be $0.40\ \text{m}$. Calculating without the small angle approximation, what is the grating spacing d?

A. $1.6\ \mu\text{m}$

B. $3.2\ \mu\text{m}$

C. $3.8\ \mu\text{m}$

D. $5.0\ \mu\text{m}$

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27 In the context of the superposition of waves, a 'beat' is heard when two sound sources are played simultaneously. Mathematically, this is the result of superposing two sinusoidal waves of:

A. Identical frequency but differing amplitudes.

B. Slightly different frequencies, causing a time-varying phase difference.

C. Identical frequency but differing initial phases.

D. Vastly different frequencies, creating a static geometric interference pattern.

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28 Consider a stationary (standing) wave set up on a string. Which of the following statements concerning the instantaneous kinetic and potential energies of a tiny string element between two adjacent nodes is strictly correct?

A. Kinetic energy is maximum when the string element reaches its maximum transverse displacement.

B. The total mechanical energy of the element remains constant at every instant during a cycle.

C. Potential energy is minimum when the string element passes rapidly through its equilibrium position.

D. Energy flows continuously and uniformly in the direction of the progressive waves that formed it.

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29 A musical instrument consists of a tube open at one end and closed at the other. It is filled with a unique gas where the speed of sound is v_g. The third harmonic (first overtone) of this tube has a frequency f. If the gas is suddenly replaced by air (speed of sound v_a, where $v_a > v_g$), what will be the frequency of the exact same physical resonant mode?

A. $f\left(\frac{v_g}{v_a}\right)$

B. $f\left(\frac{v_a}{v_g}\right)$

C. $3f\left(\frac{v_a}{v_g}\right)$

D. $\frac{f}{3}\left(\frac{v_g}{v_a}\right)$

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30 Two point sources of water waves, operating in phase at the exact same frequency, generate a stable interference pattern in a ripple tank. A student traces a continuous line representing a specific nodal curve (a line of zero displacement). Which geometric property strictly defines this nodal line?

A. It is a straight line equidistant from both sources.

B. It is a hyperbola along which the difference in distance to the two sources is a constant half-integer multiple of wavelengths.

C. It is a parabola with its focus at one source and directrix through the other.

D. It is an ellipse where the sum of the distances to both sources is constant.

Answer Key

Q1: **C**	Q2: **B**	Q3: **B**	Q4: **C**	Q5: **B**
Q6: **C**	Q7: **C**	Q8: **C**	Q9: **B**	Q10: **C**
Q11: **B**	Q12: **A**	Q13: **D**	Q14: **C**	Q15: **A**
Q16: **B**	Q17: **D**	Q18: **B**	Q19: **B**	Q20: **C**
Q21: **C**	Q22: **C**	Q23: **B**	Q24: **C**	Q25: **A**
Q26: **B**	Q27: **B**	Q28: **C**	Q29: **B**	Q30: **B**