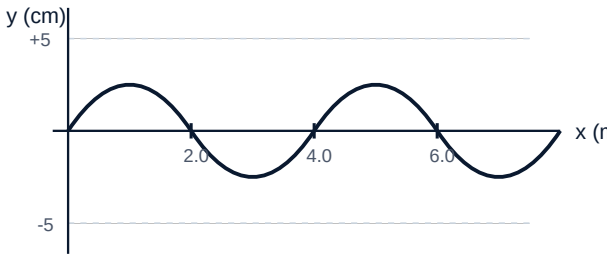
Topic: Waves & Optics (Progressive Waves)

Instructions: Choose the best answer for each of the following 30 questions. Diagrams are purely physical representations. Assume ideal conditions unless otherwise stated. Calculators are permitted, but analytical derivations may be required.

1 The graph below shows the displacement y of particles in a medium against their distance x from a source at time $t = 0$. What is the exact phase difference between a particle at $x = 1.0\ \text{m}$ and a particle at $x = 2.5\ \text{m}$?



A. $\frac{3\pi}{4}\ \text{rad}$

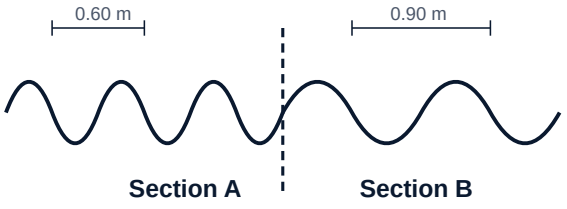
B. $\frac{3\pi}{2}\ \text{rad}$

C. $\frac{\pi}{4}\ \text{rad}$

D. $\frac{4\pi}{3}\ \text{rad}$

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2 A continuous progressive wave travels along a composite string composed of two distinct sections, A and B. The diagram shows a snapshot of the wave crossing the boundary. If the wave speed in section A is $12\ \text{m s}^{-1}$, what is the wave speed in section B?



A. $8.0\ \text{m s}^{-1}$

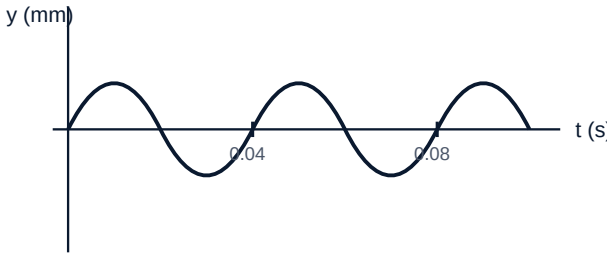
B. $12.0\ \text{m s}^{-1}$

C. $18.0\ \text{m s}^{-1}$

D. $24.0\ \text{m s}^{-1}$

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3 The graph represents the displacement y of a single particle in a medium over time t as a progressive wave passes through it. The wave propagates at a constant speed of $15.0\ \text{m s}^{-1}$. What is the wavelength of this wave?



A. $0.60\ \text{m}$

B. $1.50\ \text{m}$

C. $2.40\ \text{m}$

D. $3.75\ \text{m}$

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4 A continuous progressive transverse wave travels along a horizontal rope. The physical structure of the rope changes abruptly from a thin uniform cross-section to a thicker uniform cross-section. The mass per unit length of the thick section is four times that of the thin section. Assuming tension is perfectly uniform throughout, how does the wavelength change as the wave enters the thick section?



A. The wavelength decreases by a factor of 4.

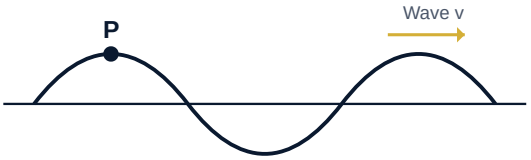
B. The wavelength decreases by a factor of 2.

C. The wavelength remains unchanged.

D. The wavelength increases by a factor of 2.

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5 A snapshot of a progressive transverse wave propagating to the right along a string is shown. At the precise instant depicted, what is the direction of the instantaneous particle velocity for the particle located exactly at position P?



A. Vertically upwards.

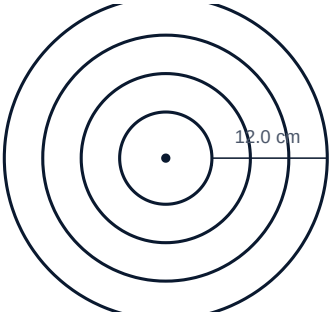
B. Vertically downwards.

C. Horizontally to the right.

D. The instantaneous velocity is zero.

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6 A small dipper oscillates on the surface of a ripple tank, producing progressive circular surface waves. The diagram shows a top-down view of the wave crests. The distance between the 1st crest (closest to the source) and the 4th crest is measured to be $12.0\ \text{cm}$. If the dipper oscillates at $15.0\ \text{Hz}$, calculate the propagation speed of the waves.



A. $0.45\ \text{m s}^{-1}$

B. $0.60\ \text{m s}^{-1}$

C. $1.35\ \text{m s}^{-1}$

D. $1.80\ \text{m s}^{-1}$

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7 A longitudinal wave passes through a uniform fluid. The instantaneous positions of maximum compression (C) and maximum rarefaction (R) are plotted below. The physical distance between consecutive points of maximum compression and maximum rarefaction is $0.85\ \text{m}$. What is the exact phase difference between a fluid particle at a compression and a fluid particle at the adjacent rarefaction?



A. $\frac{\pi}{4}\ \text{rad}$

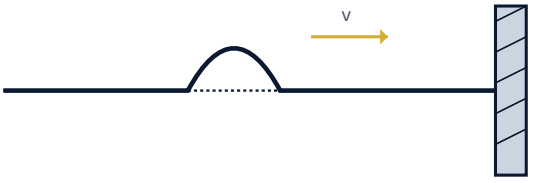
B. $\frac{\pi}{2}\ \text{rad}$

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

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

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8 A single Gaussian-shaped transverse wave pulse is travelling to the right along a taut string toward a rigidly fixed boundary. Which of the following correctly describes the properties of the reflected pulse immediately after reflection?



A. It travels to the left with an upright profile (phase change of 0).

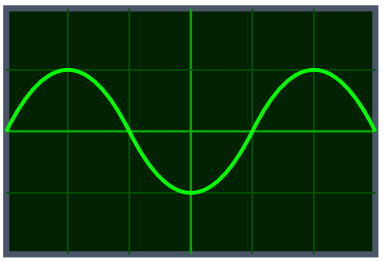
B. It travels to the left with an inverted profile (phase change of π).

C. It travels to the left with an inverted profile (phase change of $\frac{\pi}{2}$).

D. It forms a standing wave instantly without returning.

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9 The screen of a Cathode Ray Oscilloscope (CRO) displays the waveform of an AC electrical signal. The time-base setting of the CRO is $2.5\ \text{ms div}^{-1}$ and the Y-gain is $0.5\ \text{V div}^{-1}$. Based on the displayed trace, what is the frequency of the incoming signal?



A. $50\ \text{Hz}$

B. $100\ \text{Hz}$

C. $250\ \text{Hz}$

D. $400\ \text{Hz}$

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10 Two identical mechanical progressive waves, P and Q, propagate through the same uniform medium. Wave P has an amplitude of A, while Wave Q has an amplitude of $3A$. What is the exact ratio of the average rate of energy transfer (power) of Wave Q to Wave P?



A. $3:1$

B. $\sqrt{3}:1$

C. $9:1$

D. $27:1$

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11 The mathematical equation describing a 1-dimensional progressive wave travelling through a medium is given by $y = 0.050\sin(40\pi t - 2.5\pi x)$, where y and x are in meters, and t is in seconds. Calculate the phase speed of this wave.

A. $16\ \text{m s}^{-1}$

B. $32\ \text{m s}^{-1}$

C. $100\ \text{m s}^{-1}$

D. $125\ \text{m s}^{-1}$

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12 A point source emits a spherical progressive sound wave uniformly in all directions in a non-absorbing medium. At a distance of $r_1 = 4.0\ \text{m}$ from the source, the displacement amplitude of the air molecules is A_1. What is the displacement amplitude at a distance of $r_2 = 12.0\ \text{m}$?

A. $\frac{A_1}{9}$

B. $\frac{A_1}{3}$

C. $\frac{A_1}{\sqrt{3}}$

D. A_1

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13 Seismic waves from a distant earthquake are recorded at an observation station. The primary (P) waves are longitudinal and travel at $8.0\ \text{km s}^{-1}$ through the crust. The secondary (S) waves are transverse and travel at $5.0\ \text{km s}^{-1}$. If the S-waves arrive at the station exactly $3.0\ \text{minutes}$ after the P-waves, what is the approximate distance from the station to the epicenter?

A. $576\ \text{km}$

B. $1200\ \text{km}$

C. $2400\ \text{km}$

D. $4000\ \text{km}$

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14 Consider a transverse wave propagating along a taught string described by $y(x,t) = A\cos(kx - \omega t)$. What is the exact ratio of the maximum transverse speed of a particle on the string to the propagation speed of the wave itself?

A. ωA

B. kA

C. $\frac{A}{\lambda}$

D. $2\pi f A$

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15 A continuous progressive sound wave travels through air at standard temperature and pressure. Which of the following statements completely and accurately describes the energy transfer characteristics of this wave?

A. Energy is transferred parallel to the direction of propagation, with particles permanently displacing from their equilibrium positions.

B. Energy is transferred perpendicular to the direction of propagation.

C. Energy is transferred continuously in the direction of propagation, while the time-averaged displacement of any single particle is strictly zero.

D. No net energy is transferred because the medium exerts restoring forces that perform zero net work over one full cycle.

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16 Monochromatic light of wavelength $600\ \text{nm}$ travels through a vacuum and enters a block of dense flint glass with an absolute refractive index of $n = 1.60$. What is the frequency of the light while it is inside the glass block? $(c = 3.00 \times 10^8\ \text{m s}^{-1})$

A. $3.13 \times 10^{14}\ \text{Hz}$

B. $5.00 \times 10^{14}\ \text{Hz}$

C. $8.00 \times 10^{14}\ \text{Hz}$

D. $4.80 \times 10^{15}\ \text{Hz}$

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17 A longitudinal sound wave in a fluid has a frequency of $440\ \text{Hz}$ and a speed of $1450\ \text{m s}^{-1}$. What is the shortest physical distance between two fluid particles that are oscillating exactly $\frac{\pi}{3}\ \text{rad}$ out of phase?

A. $0.55\ \text{m}$

B. $1.10\ \text{m}$

C. $1.65\ \text{m}$

D. $3.30\ \text{m}$

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18 A transverse sinusoidal wave propagates along a horizontal string. At a specific instant t_0, a point P on the string is at its maximum positive vertical displacement. Exactly $0.15\ \text{s}$ later, point P reaches its maximum negative vertical displacement for the very first time. What is the frequency of the wave?

A. $3.33\ \text{Hz}$

B. $6.67\ \text{Hz}$

C. $15.0\ \text{Hz}$

D. $30.0\ \text{Hz}$

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19 The electromagnetic spectrum consists of various progressive transverse waves. Which of the following ranks the waves correctly in order of strictly decreasing wavelength in a vacuum?

A. Gamma Rays, X-Rays, Ultraviolet, Visible, Microwave.

B. Microwave, Infrared, Visible, Ultraviolet, X-Rays.

C. Radio, Visible, Infrared, Ultraviolet, Gamma Rays.

D. X-Rays, Ultraviolet, Infrared, Microwave, Radio.

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20 A progressive transverse wave is given by the function $y(x,t) = A\sin(kx + \omega t + \phi)$. Which physical characteristic of this wave implies that it is travelling in the negative x-direction?

A. The presence of the phase constant ϕ.

B. The positive sign between the kx and ωt terms.

C. The fact that it is a sine function rather than a cosine function.

D. The magnitude of the wave number k.

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21 Two particles on a continuous progressive wave are separated by a distance $\Delta x = \frac{5\lambda}{4}$. What is the magnitude of the phase difference between the oscillations of these two particles?

A. $\frac{\pi}{4}$ rad

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

C. $\frac{5\pi}{4}$ rad

D. $\frac{5\pi}{2}$ rad

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22 A wire of un-stretched length L and uniform cross-sectional area A is under a tension T, allowing transverse waves to propagate at speed v. The tension is subsequently increased by 44%. Assuming the material obeys Hooke's Law but the physical elongation and thinning of the wire are entirely negligible, what is the new wave speed?

A. $1.20v$

B. $1.44v$

C. $1.69v$

D. $2.44v$

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23 A source emits a progressive sound wave with a power of P. An observer at distance R measures an intensity I_0. If the source power is doubled to $2P$ and the observer moves to a distance of $4R$, what is the new measured intensity in terms of I_0?

A. $\frac{I_0}{8}$

B. $\frac{I_0}{4}$

C. $\frac{I_0}{2}$

D. $2I_0$

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24 Which of the following physical phenomena fundamentally requires the existence of a progressive wave, and cannot be achieved solely by a pure stationary (standing) wave?

A. The generation of distinct nodes and antinodes.

B. The transfer of linear momentum from a source to an absorber.

C. The storage of macroscopic kinetic and potential energy.

D. The continuous oscillation of particles at the wave frequency.

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25 A harmonic progressive wave on a string has an amplitude of 2.0 mm and a frequency of 50 Hz. What is the maximum transverse acceleration of any piece of the string?

A. $0.31\ \mathrm{m\ s^{-2}}$

B. $19.7\ \mathrm{m\ s^{-2}}$

C. $31.4\ \mathrm{m\ s^{-2}}$

D. $197\ \mathrm{m\ s^{-2}}$

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26 In the rigorous formulation of the wave equation for a 1D string, the wave speed v is determined by $v = \sqrt{\frac{T}{\mu}}$. This formulation fundamentally relies on the assumption that:

A. The amplitude of the wave is infinitely large.

B. The string's mass is zero.

C. The transverse displacement of the string is very small compared to its length (small angle approximation).

D. The tension in the string varies sinusoidally.

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27 A progressive electromagnetic wave travels in a vacuum. The instantaneous electric field is oriented in the +y direction, and the wave is propagating in the +x direction. According to Maxwell's equations, what is the direction of the instantaneous magnetic field vector?

A. $+y$ direction

B. $-y$ direction

C. $+z$ direction

D. $-z$ direction

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28 A plane progressive wave is normally incident upon a boundary between Medium 1 (speed v_1) and Medium 2 (speed v_2, where $v_2 < v_1$). Which statement concerning the transmitted wave in Medium 2 is mathematically absolutely true?

A. Its frequency is lower than in Medium 1.

B. Its wavelength is strictly shorter than in Medium 1.

C. Its amplitude is greater than the incident amplitude.

D. Its phase velocity vector reverses direction.

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29 The Doppler effect for a progressive sound wave implies that an observer moving directly towards a stationary continuous point source will measure:

A. An increased wave speed relative to the observer, but an unchanged wavelength in the medium.

B. A decreased wavelength in the medium, but an unchanged wave speed relative to the observer.

C. An increased wavelength in the medium, and a decreased wave speed.

D. An unchanged wave frequency, but an increased wave amplitude.

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30 Consider a progressive wave packet (a pulse) displaying dispersion as it travels through a specific non-vacuum medium. The physical definition of 'dispersion' in this context means:

A. The wave loses energy to the medium exponentially as it propagates.

B. The spatial width of the medium itself fluctuates periodically.

C. Waves of different frequencies propagate at different phase velocities.

D. The wave perfectly reflects back upon itself creating a standing wave.

Answer Key

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