# 4.4 Wave Behaviour

## Mark Schemes

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| Course | DP IB Physics |
| Section | 4. Waves |
| Topic | 4.4 Wave Behaviour |
| Difficulty | Medium |



To be used by all students preparing for DP IB Physics SL
Students of other boards may also find this useful

1

The correct answer is **C** because:

- Interference is caused by waves interacting constantly with a constant phase difference
  - If the waves had a phase difference that was changing, the interference pattern would be blurred and no longer observed

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| **A** is incorrect as | equal amplitude implies that the waves are incident at point X with the same intensity, but not that they create interference that can be observed. For example, they could have a non-constant phase difference leading to lack of observable interference |
| **B** is incorrect as | waves solely of the same wavelength will not necessarily have constructive or destructive interference that can be observed. They may have different intensities that may fluctuate based on the changing interaction due to the different intensity of waves arriving at point X |
| **D** is incorrect as | all light waves are electromagnetic in nature, but other waves can also interfere such as sound waves or even waves on the surface of water. Being an electromagnetic wave is not necessary for interference to occur |

The main concept needed to answer this question is that constant interference and interference patterns only occur with a single wavelength of light (monochromatic light) and a constant phase shift. In all other cases, a visible interference pattern will not occur.

2

The correct answer is **D** because:

- This is the point where neither wave crest occurs and is directly between the two maximum from the individual slits therefore this is a minimum

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| **A** is incorrect as | point A is where a maximum from the highest slit occurs and therefore this cannot be a minimum for this double-slit diffraction |
| **B** is incorrect as | point B is where a maximum from the both of the slits occurs and therefore this cannot be a minimum for this double-slit diffraction |
| **C** is incorrect as | point C is where a maximum from the lowest slit occurs and therefore this cannot be a minimum for this double-slit diffraction |

3



The correct answer is **C** because:

- The speed of light within a medium is directly related to the refractive index
- The higher the refractive index, the greater the slowing effect of the material on the speed of light
- $v = \frac{c}{r_i}$ where
  - $v$ is the velocity of the light within the medium
  - $c$ is the speed of light in a vacuum
  - $r_i$ is the refractive index of the medium
- Substituting in values: $v = \frac{(3.0 \times 10^8)}{1.52} = 1.97 \times 10^8 \text{ m s}^{-1}$

4

The correct answer is **B** because:

- As the light enters into a denser medium than the one it is currently traveling in, then it will be absorbed and re-emitted slowing it down
  - This slowing effect means that the speed of light within the medium will decrease
  - The wavelength of the light will also decrease
  - The frequency will remain the same
  - If the frequency of a wave (any wave, not just electromagnetic radiation) crossing a boundary changed, then that would cause a phase shift which would lead to constantly changing wave mechanics over the boundary which is not allowed

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| **A** is incorrect as | the speed of the light is indicated to speed up, but this is incorrect for a denser medium and so A cannot be correct. The frequency is indicated to change which also cannot be the case and the wavelength remains the same which is also untrue |
| **C** is incorrect as | the speed of the light is indicated to remain constant, but this is not true due to absorption and re-emission of light which slows it down in the medium so C cannot be correct. The frequency is indicated to change which also cannot be the case |
| **D** is incorrect as | the speed of the light is indicated to speed up, but this is incorrect for a denser medium and so D cannot be correct. The frequency is indicated to change which also cannot be the case and the wavelength remains the same which is also untrue |

This problem can be directly related to the wave equation: $v = f\lambda$ where $v$ is the velocity of the wave, $f$ is the frequency and $\lambda$ is the wavelength. If one side of the equation changes, so must the other; this already eliminates options A and C. Only option B and D can be considered based on the mathematics and then understanding the physical situation allows elimination of option D.

5

The correct answer is **D** because:

- The fringe separation equation is given by
  - $s = \frac{\lambda D}{d}$
- The fringe spacing $s$ is directly proportional to the wavelength $\lambda$ and the distance between the slits and the screen $D$ and inversely proportional to the distance between the slits, $d$
- Therefore, this means if the distance $s$ is decreased, this will increase the fringe separation $s$
- When you divide by a smaller number then the value of the equation is bigger
- Therefore the correct answer is **D**

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| **A** is incorrect as | The width of each slit is not a quantity in the fringe spacing equation |
| **B** is incorrect as | Moving the screen closer to the double-slit will decrease the value of $D$ and hence the value of fringe spacing $s$ will decrease |
| **C** is incorrect as | Using light of a higher frequency will result in a smaller wavelength $\lambda$, and hence cause a decrease in fringe spacing $s$ |

6

The correct answer is **D** because:

- These processes of reflection, refraction and diffraction can alter the speed and wavelength of waves, but they do not change the frequency of waves
  - Reflection will only change the phase of the wave
  - Refraction changes a waves speed and wavelength, but not the frequency
  - Diffraction does not change the speed, wavelength or phase of the wave, but does change the direction

This question is a rare occurrence where none of the above can apply. While often the *none of the above* option is included as an extra option that is not correct, it can occasionally be used to test students and attempt to cause uncertainty in responses. Having good general knowledge of physics is the best way to deal with such situations.

7



The correct answer is **B** because:

- A double-slit creates two sources of light which are coherent
  - This is because each source originates from the same 'mother' source, the single-slit
  - Therefore, their phase difference is fixed – i.e., they are coherent
  - Without coherent light that is in phase and monochromatic, then it is not possible to have double-slit interference

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| **A** is incorrect as | while equal intensity is preferable on both slits, it is not necessary for double-slit interference to occur. The single slit is not there to equalize the intensity on the double-slits |

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| **C** is incorrect as | a bright intensity upon double-slits will cause an interference pattern, a lower intensity is not necessary to have this phenomenon occur |
| **D** is incorrect as | any wave undergoing diffraction does not change wavelength, therefore this option is incorrect. However, it is also important to know that there is no optimal wavelength of light that creates a double-slit interference pattern and so there is no need to reduce the wavelength |

8

The correct answer is **A** because:

- The phase difference between the two sources at point X is exactly one half of an integer of the wavelength
    - The distance between the first source and point X will fit exactly 6 full wavelengths
    - The distance between the second source and point X will fit exactly 3.5 wavelengths
    - Since the path difference travelled by each wave at point X is: 6 – 3.5 = 2.5 wavelengths, which is a half-integer number of wavelengths, there will be complete destructive interference at point X

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| **B** is incorrect as | partial destructive interference would only occur close to points where the phase difference is half of an integer value of a wavelength (i.e., 0.5λ, 1.5λ, 2.5λ and so on). Since point X is exactly where one of these half integer wavelength values occurs, it cannot be partial destructive interference occurring here |

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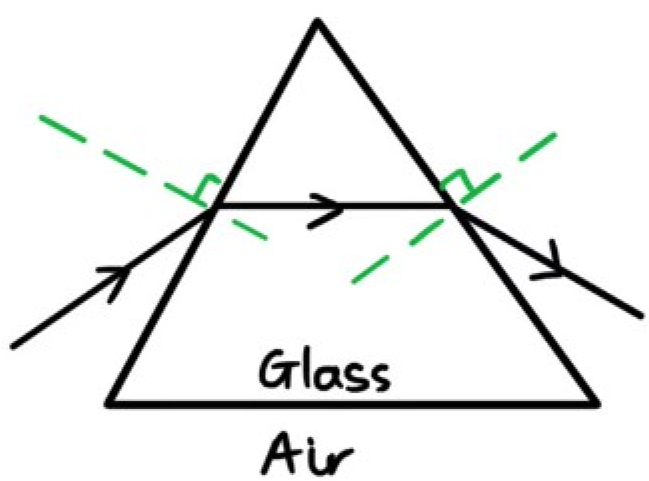
| **C** is incorrect as | partial constructive interference would only occur close to, but not actually at points where the phase difference is a full integer of an integer value of a wavelength (i.e., 0λ, 1λ, 2λ and so on). Since point X is where half integer wavelength values occurs, it cannot be partial constructive interference occurring here |
| **D** is incorrect as | complete constructive interference would only occur at points where the phase difference is an integer value of a wavelength (i.e., 0λ, 1λ, 2λ and so on). Since point X is where half integer wavelength values occurs, it cannot be complete constructive interference occurring here |

9

The correct answer is **D** because:

- The ray of light enters the glass prism which has a higher refractive index than air:
  - The light therefore slows down and bends towards the normal
- Then as the light ray passes from the glass prism into the air, which has a lower refractive index:
  - The light speeds up and bends away from the normal
- This is shown below, with the normal lines to each boundary shown:





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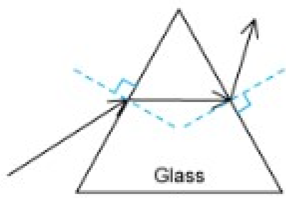
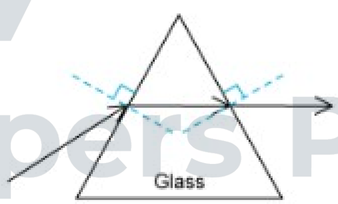
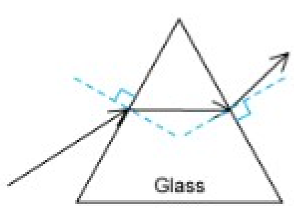
| **A** is incorrect as | as the light passes into the glass prism initially it follows the correct direction and bends towards the normal. However, as the light passes out of the glass prism it 'reflects' against the normal line, as shown below. This is incorrect   |
| **B** is incorrect as | as the light passes into the glass prism initially it follows the correct direction and bends towards the normal. However, as the light passes out of the glass prism it enters a medium of lesser refractive index, so it should bend toward the normal. This is not shown in option B   |
| **C** is incorrect as | as the light passes into the glass prism initially it follows the correct direction and bends towards the normal. However, as the light passes out of the glass prism it goes partially up and away from the normal which is incorrect   |

The shape of the triangle is also part of the reason that the light follows the path as shown since this changes the direction of the interface of the medium (i.e., the angles of incidence and the angles of refraction), both as the light enters and then leaves the triangular prism.

10

The correct answer is **B** because:

- The angle of incidence is always measured relative to the incoming ray for any wave that is undergoing refraction or reflection
  - Therefore, it is not related to the outgoing ray
- The angle will be formed between the ray and the normal because the normal is the point of reference for both the incoming and outgoing ray

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| **A** is incorrect as | the angle of incidence will never be for an outgoing ray (i.e., the reflected or refracted ray) as when a physical object is **incident** upon another, it has moved into the other object and is therefore incoming, so this option is incorrect |
| **C** is incorrect as | the key point around which the information is organized for reflection and refraction is the normal. Using both rays to measure the angle of incidence does not work as that would then require always knowing information about the outgoing ray before considering the angle for the incident ray |
| **D** is incorrect as | the normal already takes into account the second medium as it will be perpendicular to the surface of this medium. Making the angle of incidence lie between the incident ray and the surface of the second medium will result in an that is the opposite of the true of angle of incidence which lies between the incident ray and the normal |