Wave Phenomena

Mark Schemes

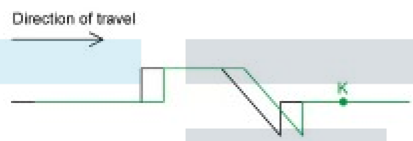
Course	HL IB Physics
Section	Wave Behaviour
Topic	Wave Phenomena
Difficulty	Medium

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

1

The correct answer is **B** because:

- The wave formed along the rope is a transverse wave
  - The oscillations are perpendicular to the direction of travel
- Direction of travel is to the right, as shown in the diagram
- The particles can only oscillate in a vertical motion (up and down)
- The diagram below shows the wave an instant later, moving the wave to the right



- The particle K will move according to the form of the wave:
  - A sudden negative peak
  - A gradual increase to maximum
  - A high value of displacement
  - And a final sudden jump down
- Therefore the correct answer is **B**

A is incorrect as the graph shows a long negative displacement with a positive peak, this is the opposite direction to what would happen to particle K

C is incorrect as the graph shows a long positive displacement followed by a gradual decrease and a final negative peak which is the opposite order to what would happen to particle K

D is incorrect as the graph shows a long negative displacement with a positive peak, this is the opposite direction to what would happen to particle K

2

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

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.

3

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

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

4

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: $v = \frac{(3.0 \times 10^8)}{1.52} = 1.97 \times 10^8$ m s^{-1}

5

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

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 λ 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.

6

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 λ 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**

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 *λ*, and hence cause a decrease in fringe spacing *s*

7

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.

8

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

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

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

9

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

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

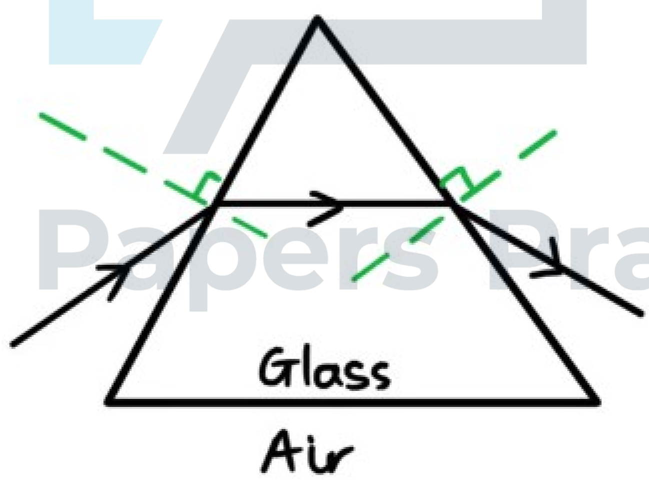
C is incorrect as partial constructive interference would only occur close to, but not actually at points where the phase difference is a full integer of an integer value of a wavelength (i.e., 0λ, 1λ, 2λ and so on). Since point X is where half integer wavelength values occurs, it cannot be partial constructive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

10

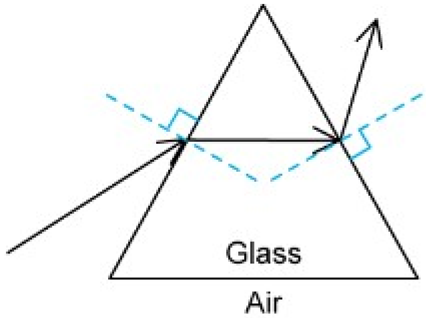
The correct answer is **D** because:

- 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:



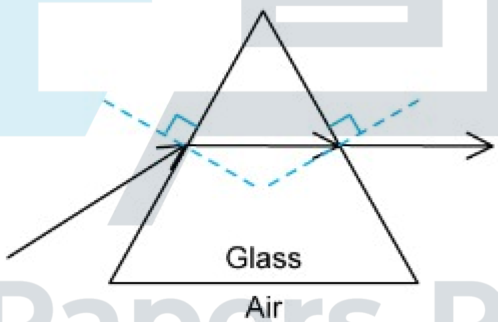
A is incorrect as as the light passes into the glass prism initially it follows the correct direction and bends towards the normal. However, as the light passes out of the glass prism it 'reflects' against the normal line, as shown below. This is incorrect

A



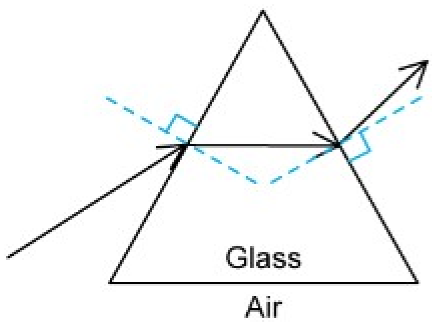
B is incorrect as the light passes into the glass prism initially it follows the correct direction and bends towards the normal. However, as the light passes out of the glass prism it enters a medium of lesser refractive index, so it should bend toward the normal. This is not shown in option B

B



C is incorrect 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

C



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.

11

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

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

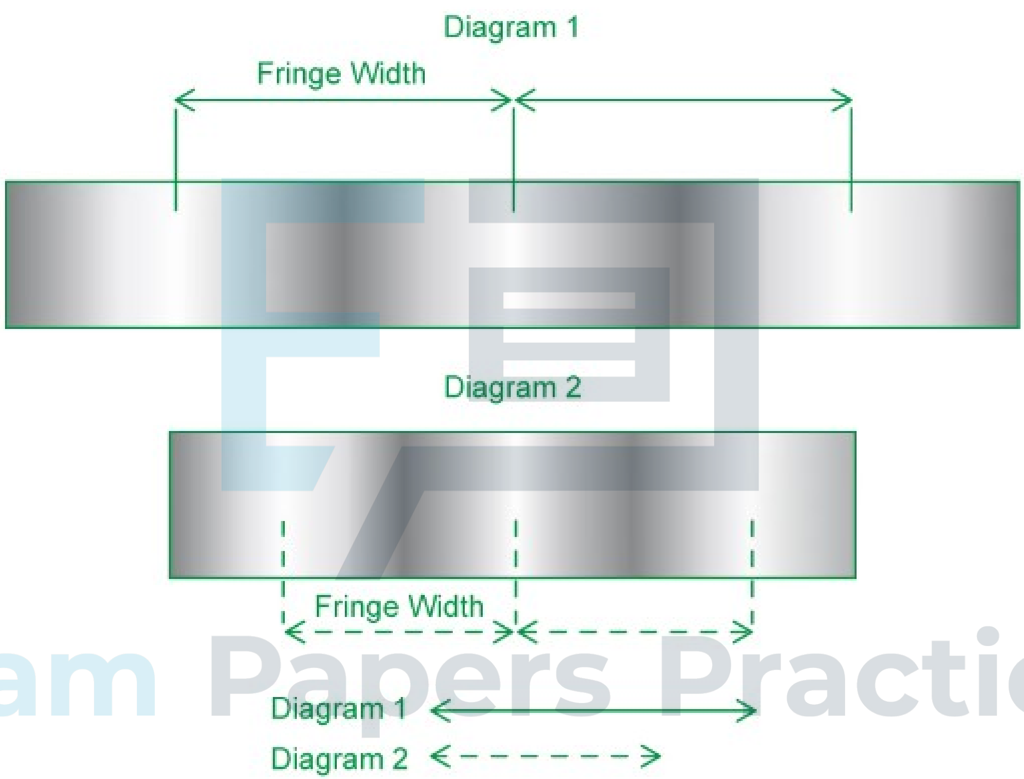
C is incorrect as the key point around which the information is organized for reflection and refraction is the normal. Using both rays to measure the angle of incidence does not work as that would then require always knowing information about the outgoing ray before considering the angle for the incident 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

12

The correct answer is **C** because:

- The interference pattern is affected by both the slit width b and the wavelength of light λ
- Diagram 1 has a larger fringe spacing:
  - In other words, the distance between the centre of the bright fringes is larger than in diagram 2
  - The larger fringe spacing means that the angle of diffraction θ of light is also larger



- So, since $\theta = \frac{\lambda}{b}$, then:
  - For θ_1 to be larger than θ_2, $\frac{\lambda_1}{b_1}$ must be larger than $\frac{\lambda_2}{b_2}$
  - So, the correct answer is C: $\frac{\lambda_1}{b_1} > \frac{\lambda_2}{b_2}$

A and **B** are incorrect as both wavelength and slit width need to be considered in the expression

D is incorrect as

$\frac{\lambda_1}{b_1} > \frac{\lambda_2}{b_2}$ and not $\frac{\lambda_1}{b_1} < \frac{\lambda_2}{b_2}$ because

- λ_1 will be longer than λ_2
- b_1 will be narrower than b_2

Remember that when dividing fractions, if the denominator is bigger then the fraction itself will be smaller.

13

The correct answer is **C** because:

- Consider the equation for the angle of diffraction of the first minimum, $\theta = \frac{\lambda}{b}$
  - Where λ is the wavelength of the light and b is the width of the single slit
- The wavelength of blue light is shorter than the wavelength of red light
  - In the equation, when λ is smaller and b is constant then θ is also smaller
  - So statement I is false
- The smaller the slit width b then the bigger the diffraction angle θ when λ is constant
  - So statement II is true
- So, the correct answer is **C**

A, **B** and **D** are incorrect as only II. is correct. Red light creates a diffraction pattern with a bigger angle of diffraction, θ than blue light.

It is important to memorise how the diffraction pattern changes with changes in wavelength, slit width and distance from slit to screen.

14

The correct answer is **B** because:

- A 10-slit diffraction grating is the grating with the most slits, so it will have the most number of subsidiary maxima between the highest intensity maxima, / in the interference pattern
  - There are 8 equally spaced subsidiary maxima between the highest intensity maxima
  - The subsidiary maxima decrease in intensity from the highest intensity maxima to halfway along to the next highest intensity maxima
  - The intensity of the first subsidiary maxima are 1/15 th of the intensity of the highest intensity maxima and 1/3 rd of the width
- Single slit interference has:
  - A central maximum with the highest intensity, /
  - Equally spaced subsidiary maxima, successively smaller in intensity and half the width of the central maximum
- Double slit interference has:
  - Equally spaced maxima
  - All maxima are of equal intensity, /
- Five-slit interference has:
  - The highest intensity maxima, all have the same intensity, /
  - There are three equally spaced subsidiary maxima between the highest intensity maxima
  - The central subsidiary maxima has a slightly smaller intensity than the subsidiary maxima on either side
  - The intensity of the first subsidiary maxima are 1/10th of the highest intensity maxima and 2/3 rd of the width

It is important to remember the features of the intensity pattern of light when diffracted through a single slit, different sized diffraction gratings, and a double slit. Being able to describe the intensity patterns in terms of maxima and subsidiary maxima can help with structured questions too.

15

The correct answer is **C** because:

- When the slit width is increased:
  - The central peak intensity is increased, so there is a higher central peak on the graph
  - Fringe spacing between subsequent maxima is reduced

- So, the correct answer is **C**

A is incorrect as the fringe spacing has been increased and not reduced

B is incorrect as,

- The central peak intensity is not increased, the new pattern is not drawn higher than the original pattern
- The new spacing between subsequent maxima has been increased and not reduced

D is incorrect as the central peak intensity is not increased, the new pattern is not drawn higher than the original pattern

Remember that slit width affects the **maximum intensity** of the central fringe on an intensity pattern. If the slit width increases, the maximum intensity **increases**, because more light is incident through the slit. You should also remember, if the slit width increases, the fringe spacing decreases, such that each bright fringe is closer together. This makes sense: if the slit width increases to infinity (i.e., there is no more slit!) then diffraction reduces to zero: the intensity observed will simply be a central area of brightness which fades away on both sides of the maximum.

16

The correct answer is **C** because:

- For the first minima, the angle of diffraction, $\theta = \frac{Wavelength\ of\ light}{slit\ width} = \frac{\lambda}{b}$
- Use the graph to find the diffraction angle from the central maximum to the first minima = 1×10^{-2} rad
- Convert the slit width from mm to m: 2×10^{-3} m
- Rearrange the equation for the angle of diffraction to find the wavelength, $\lambda = \theta \times b$
    - $\lambda = (1 \times 10^{-2}) \times (2 \times 10^{-3}) = 2 \times 10^{-5}$ m $= 20 \times 10^{-6}$ m $= 20$ μm
- So, the correct answer is **C**

17

The correct answer is **C** because:

- The maximum amount of constructive interference occurs at the central maxima
  - So the central maxima is all white
- When white light diffracts through a single slit:
  - longer wavelengths (red light) have a larger angle of diffraction
  - shorter wavelengths (violet light) have a smaller angle of diffraction
- So violet light appears closer to the central maximum and red light further away
- This gives option **C**

A is incorrect as the central maximum is white and not coloured

B is incorrect as this shows the positions of violet and red light the wrong way around. Red light should be diffracted the most and violet light the least

D is incorrect as the central maximum is white and the outer fringes coloured, this is the opposite to what is shown in this diagram

This question is not tricky but requires you to look carefully at each diagram to identify the correct interference pattern.

18

The correct answer is **A** because:

- Decreasing the wavelength of the light will decrease the width of the central maximum peak
- According to the equation for the angle of diffraction of the first minima, $\theta = \frac{\lambda}{b}$ for wavelength λ and slit width b
  - When λ is smaller for constant b then θ will also be smaller
  - θ is proportional to λ
- Red light has a longer wavelength than blue light, so changing the colour will decrease the wavelength of the light

B is incorrect as increasing the wavelength of the light will increase the width of the central maximum and not decrease it

C is incorrect as making the slit width narrower will

- decrease the intensity of the central maximum
- increase the fringe spacing

D is incorrect as moving the screen further away will increase and not decrease the width of the central maximum

You should memorise the properties that affect the width of the central maxima.

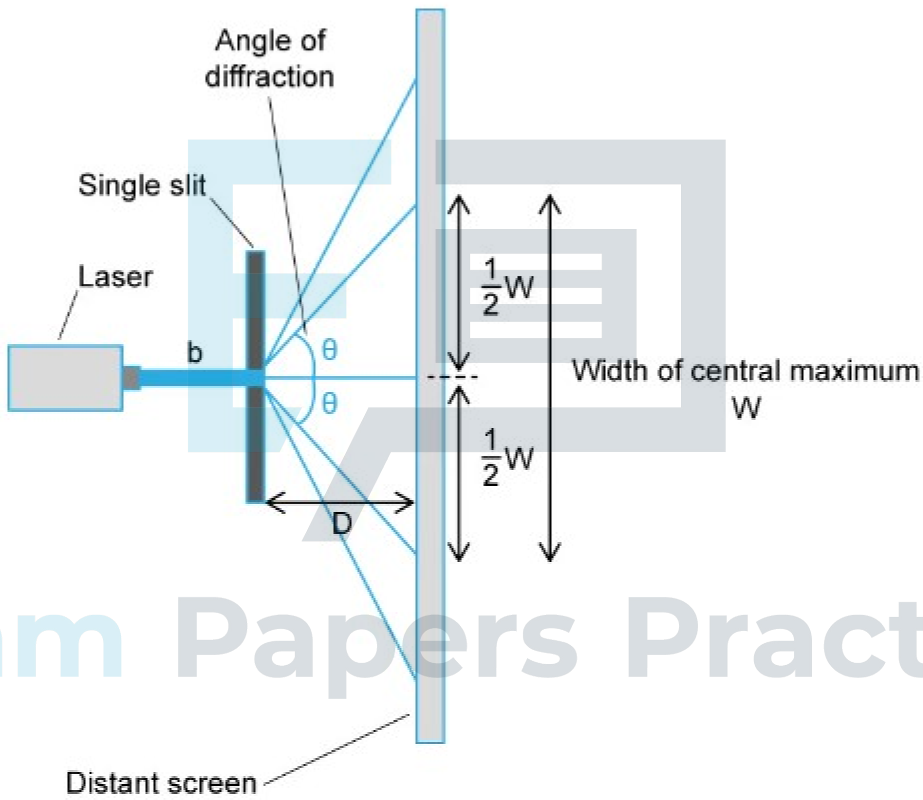
19

The correct answer is **D** because:

- Let the width of the central maxima be given by w
  - So half the central maximum width = $\frac{1}{2}w$
- Using trigonometry:
  - $\tan\theta = \frac{opposite}{adjacent}$
- Using the small-angle approximation for the angle of diffraction, $\tan\theta \approx \theta$ for very small θ
  - Therefore, $\tan\theta \approx \theta = \frac{opposite}{adjacent} = \frac{\frac{1}{2}w}{D}$
  - Rearranging this gives: $\theta D = \frac{1}{2}w$
- Therefore, the width of the central maximum $w = 2\theta D$
- The angle of diffraction for the first minimum, $\theta = \frac{\lambda}{b}$
- Substituting θ into the expression for the central maximum gives:
  - $2\theta D = w$
  - $2 \times \frac{\lambda}{b} \times D = w$
  - So, the width of the central maximum $w = \frac{2\lambda D}{b}$

A, **B** and **D** are incorrect as they are the incorrect rearrangement and substitution of the angle of diffraction of the first minima and the trigonometry of this angle of diffraction

This question requires very careful consideration of the geometry and equations involved in single slit diffraction and what this means for the width of the central maximum., Make sure you write down all the equations you know and draw a diagram to make it easier to understand what is happening.



20

The correct answer is **B** because:

- Reducing the single slit width will reduce the intensity, /of the central maximum

- The angle of diffraction, θ to the first minima will increase, so the fringe spacing will be wider
  - This can be shown using the equation for the angle of diffraction for the first minima $\theta = \frac{\lambda}{b}$
  - b is the slit width and λ the wavelength, which remains the same
  - when b is made smaller then θ is made bigger

A, **B** and **C** are incorrect as the intensity, I will decrease and the angle of diffraction, θ increase, and not any other combination of these options.

You should confidently know how changing the slit width affects the angle of diffraction and the intensity of the central maxima on the screen.

21

The correct answer is **C** because:

- Using the equation for wave speed, frequency, and wavelength: $c = f\lambda$
  - So, $f = \frac{c}{\lambda}$
- When the frequency is doubled this means the wavelength is halved (as c is the speed of light and is the same for any frequency of light)
  - So, $2f = \frac{c}{\frac{1}{2}\lambda}$
- Using the equation for the angle of diffraction to the first minima: $\theta = \frac{\lambda}{b}$
    - So the angle of diffraction, $Y = \frac{\lambda}{b}$

- When the slit width is halved, $b \rightarrow \frac{1}{2}b$
- Combining the change in slit width and wavelength $Y = \frac{\frac{1}{2}\lambda}{\frac{1}{2}b} = \frac{\lambda}{b}$
  - So, the new angle of diffraction of the first minimum = Y

A is incorrect as 4Y is the value of the new angle of diffraction if the wavelength was double and not halved and the slit width was still halved

B is incorrect as $\frac{1}{2}$ Y is the value of the new angle of diffraction if the frequency was doubled, so the wavelength was halved and the slit width remained the same

D is incorrect as $\frac{1}{4}$ Y is the value of the new angle of diffraction if the frequency was quadrupled, so the wavelength was now $\frac{1}{4}\lambda$

Use what you know to carefully substitute the correct values into the equation for angular diffraction of the first minimum and obtain the correct new angle Y.

22

The correct answer is **C** because:

- For destructive interference path difference = $(n + \frac{1}{2})\lambda$ = 0.3 m
  - Where n is the number of the maxima away from the central order of n = 0
  - This means the path difference has to be a multiple of half wavelengths
- Now consider the wavelength at different values of n
  - A is not equidistant between V and W, so it is not the central maxima of the interference pattern, so we know $n \neq 0$

- For the first order maxima at $n = 1$
  - $(1 + \frac{1}{2})\lambda = 0.3$
  - $\frac{3}{2}\lambda = 0.3$
  - $3\lambda = 0.6$
  - $\lambda = 0.2$ m

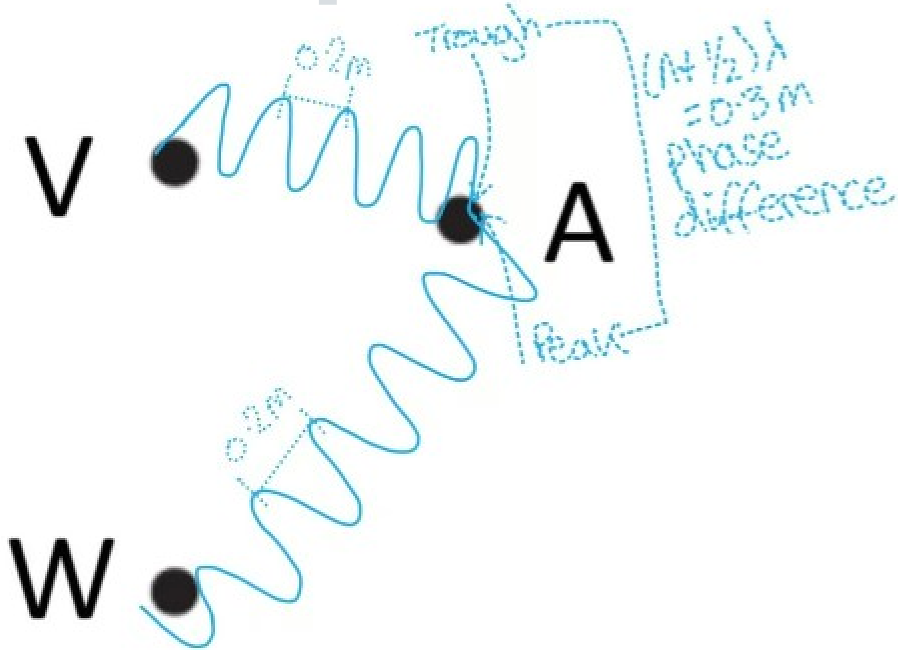
- Hence, the answer is **C**: $\lambda = 0.20$ m

A is incorrect as this is when $n = 0$, but A is not near the central maximum

B is incorrect as this is the path difference given in the question and not the wavelength of the wave. It would also be λ for $n = 1$ if constructive interference ($n\lambda$ = path difference) took place, not destructive

D is incorrect as this would be λ for $n = 2$, but the question asks for the maximum possible wavelength i.e. the smallest value of n that gives one of the possible values
It is important you remember the path difference equations for both constructive and destructive interference and can spot when you need to use them.

The diagram below shows a possible destructive interference pattern of waves coming from V and W.

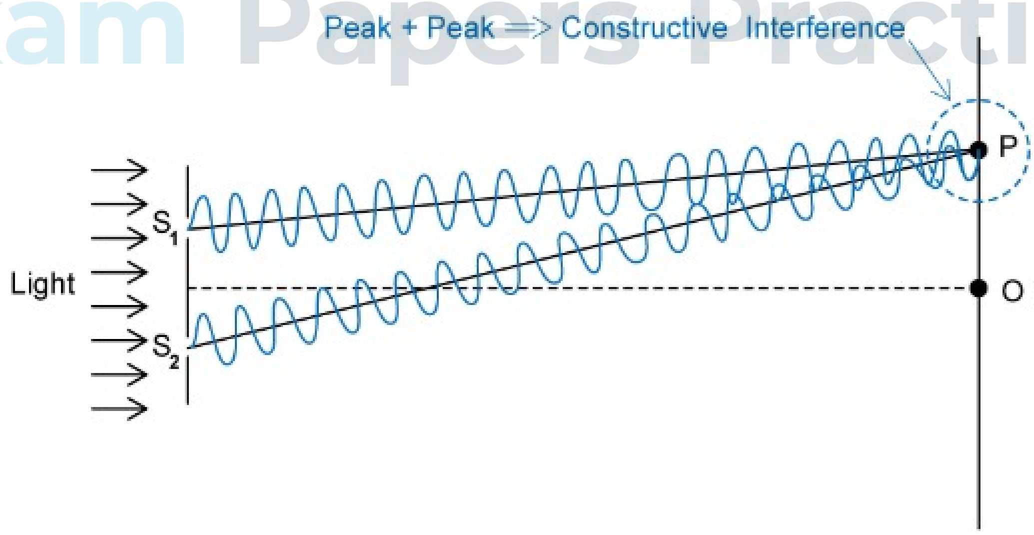


23

The correct answer is **C** because:

- P is the next bright fringe, so it is the next point of constructive interference on the screen from O
- Constructive interference at P means that $S_2P - S_1P = n\lambda$
- As P is the next point of constructive interference then P is the first order maximum, so $n = 1$
  - Therefore, $S_2P - S_1P = \lambda$
- Recall the wave equation:
  - $c = f\lambda$
- Rearrange for λ gives:
  - $\lambda = \dfrac{c}{f}$
- Therefore:
  - $S_2P - S_1P = \dfrac{c}{f}$

This question requires you to remember the conditions for constructive interference. This is when two **crests** or two **troughs** that meet at the same point and their amplitudes add accordingly.



24

The correct answer is **A** because:

- The maximum intensity of the light will be present at the central maxima O
- The intensity of the light on the screen will oscillate from zero intensity where there are dark fringes, to high intensity where there are bright fringes
- All the fringes will have an **equal** intensity in a double slit interference pattern

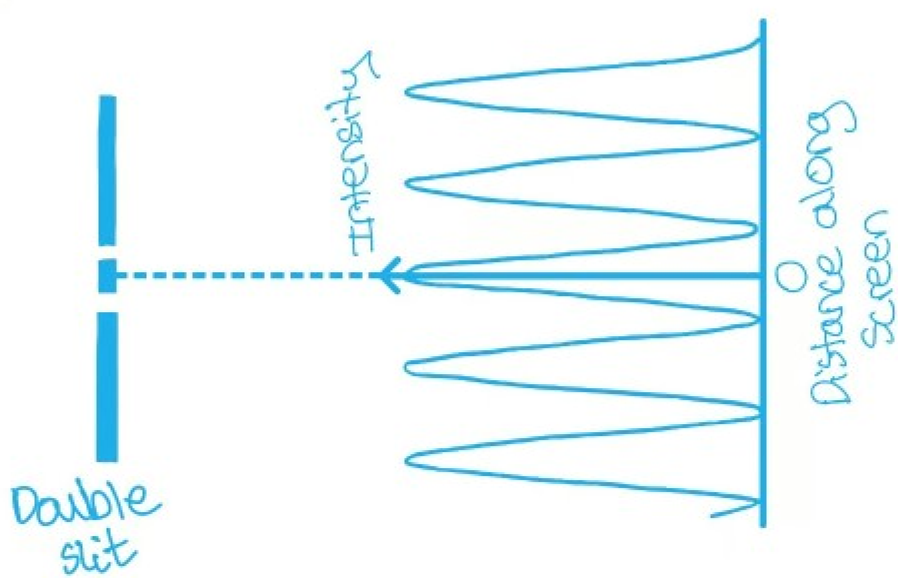
B is incorrect as this is the intensity, distance graph for a single slit interference pattern

C is incorrect as O is the central maximum so should have the maximum intensity and not an intensity of zero

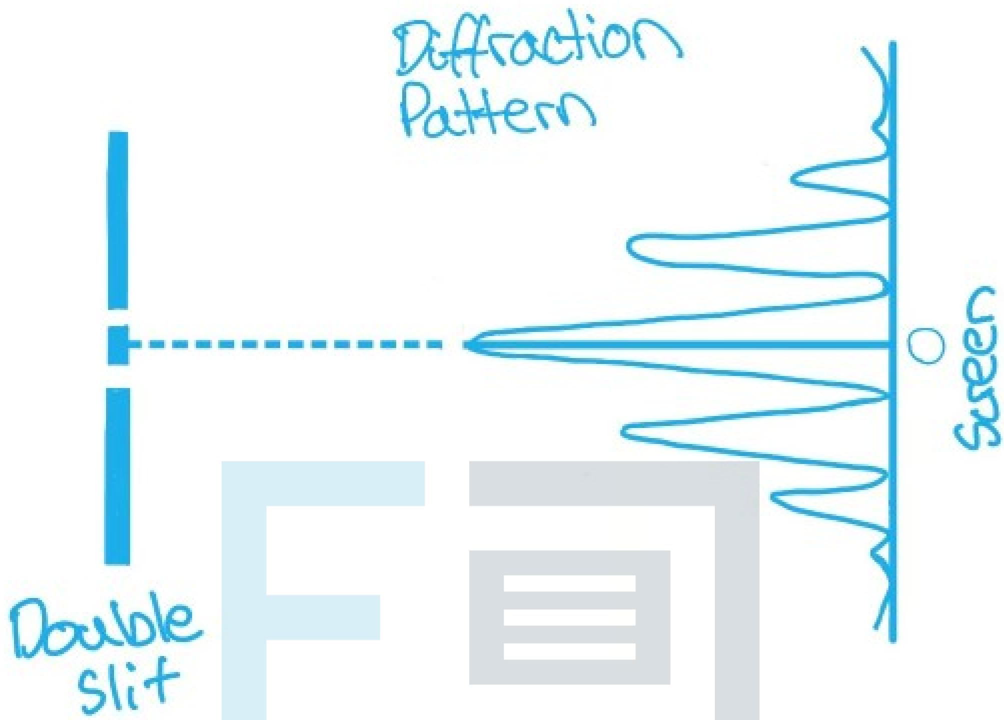
D is incorrect as the intensity pattern should have a sinusoidal shape and not wide fringes of zero intensity

It is important to know and recognise the difference between the intensity, distance graph of a double slit diffraction pattern and the diffraction pattern that will be observed on the screen.

The graph of intensity is shown here:



The image of the diffraction pattern on the screen is shown here:



This is why the answer is graph **A** and **not** graph **D**.

25

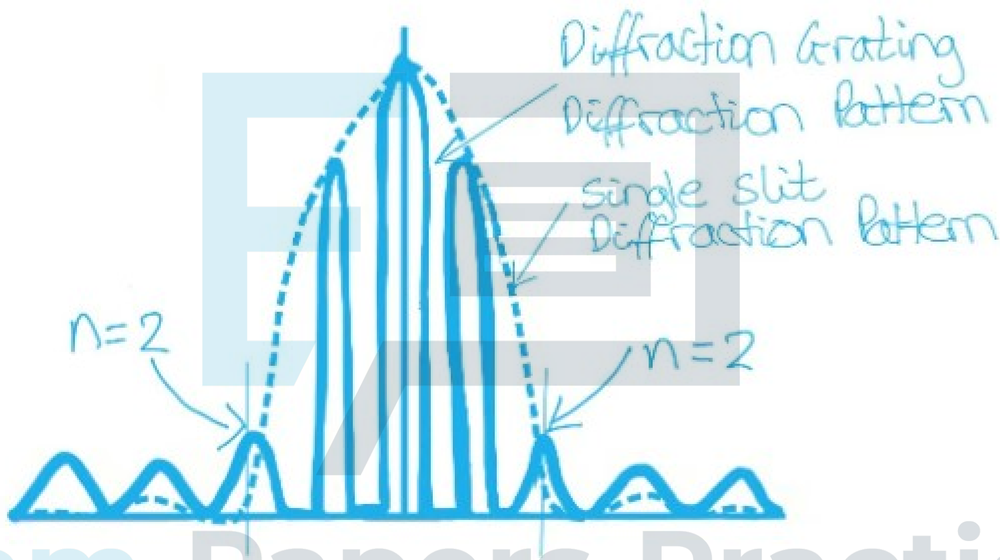
The correct answer is **A** because:

- For the diffraction pattern
  - n = 2
  - for $n\lambda = d\sin\theta$
- For the single slit
  - The diffraction angle of the first minimum, $\theta = \frac{\lambda}{b}$
- For the angle of the first minimum of the single slit $\sin\theta \cong \theta$ due to small angle approximation
- Substitute θ into the diffraction grating equation for $\sin\theta$:

- $n\lambda = d\frac{\lambda}{b}$
- $\frac{n\lambda}{\lambda} = \frac{d}{b}$

- So, $nb = d$
  - When $n = 2$, $d = 2b$
- So the correct answer is **A**

Sketching an image, like the one below, of the two diffraction patterns in the correct places will help understand what this question is asking.



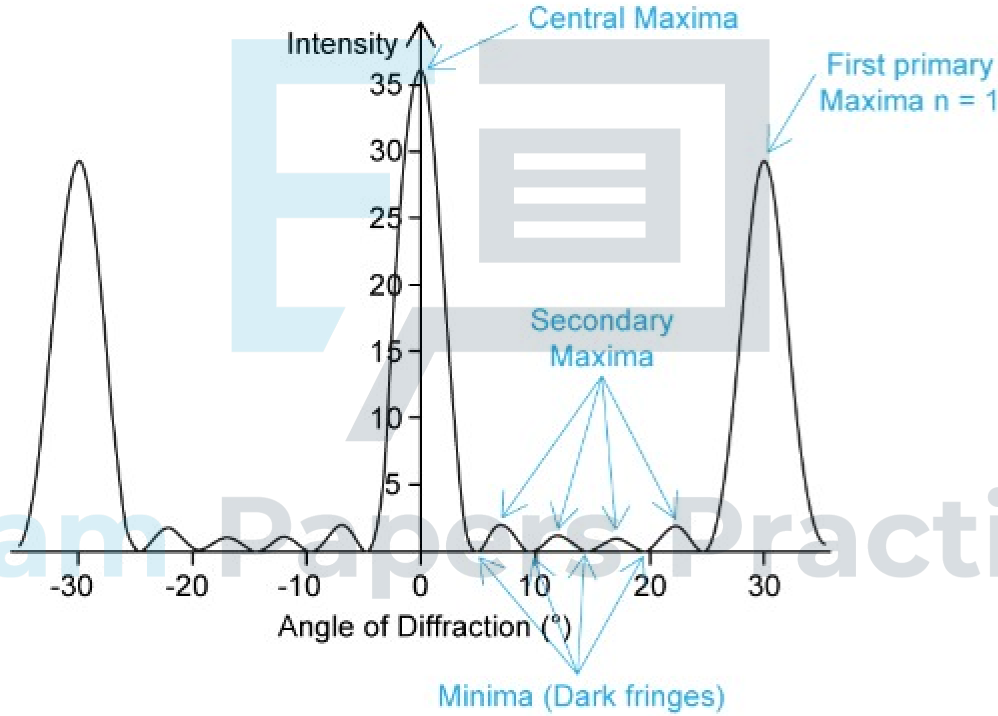
26

The correct answer is **B** because:

- The number of slits N is related to the number of secondary maxima between the primary maxima
  - Number of secondary maxima = $N - 2$
- There are 4 secondary maxima, so there must be 6 slits in the diffraction grating
  - This eliminates options **C** and **D**
- The relationship between slit separation, d and wavelength λ is given by the diffraction grating equation:
  - $n\lambda = d\sin\theta$

- The angle of the first maxima $n = 1$ is 30°
- So, the diffraction grating equation becomes:
  - $1 \times \lambda = d\sin(30)$
  - $\lambda = d\frac{1}{2}$
  - So, $d = 2\lambda$
- Therefore, option **B** is correct

Understanding and using the correct terminology for primary and secondary maxima and minima is key to understanding the graph for this question. Check your knowledge against the diagram below.



There are some key trigonometric values for you to remember in this topic:

- $\text{Sin}(30) = \frac{1}{2}$
- $\text{Sin}(90) = 1$

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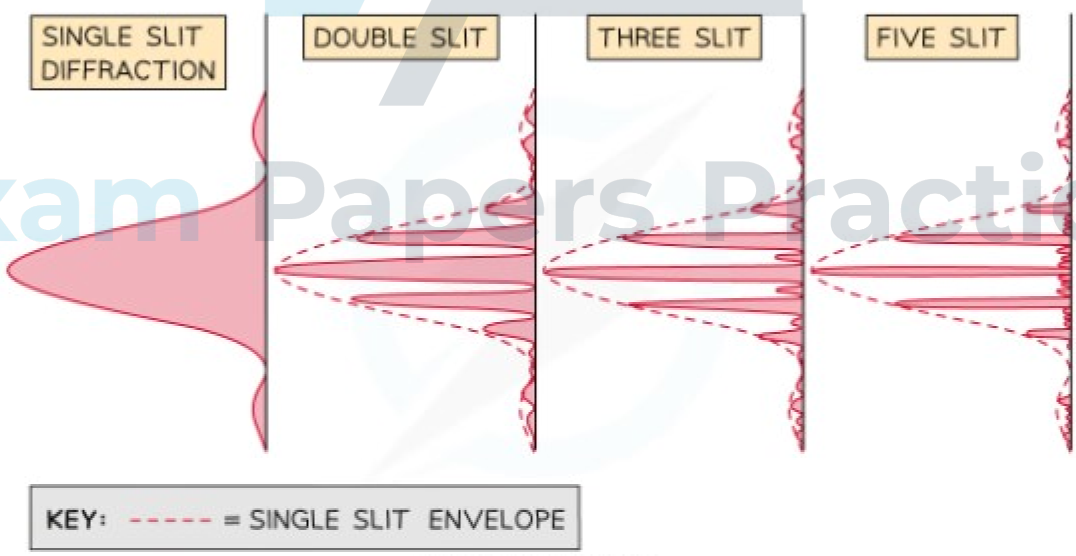
The correct answer is **B** because:

- p shows a pattern that is e**qually spaced** maxima of similar relative intensity and brightness
    - This is characteristic of a double slit diffraction pattern
- q shows a pattern that has one central maximum with the highest intensity. This fringe is much wider than the secondary maxima
    - This is characteristic of a single slit diffraction pattern
- r shows a pattern that consists of many equally spaced very thin maxima of equal intensity
    - This is characteristic of a diffraction grating
- Therefore, row **B** is correct

It is important to remember how a diffraction pattern changes depending on the number of slits. You can see clearly in the diagram below that as the number of slits increases, the width of the slit decreases and so does the width of the maxima fringes.



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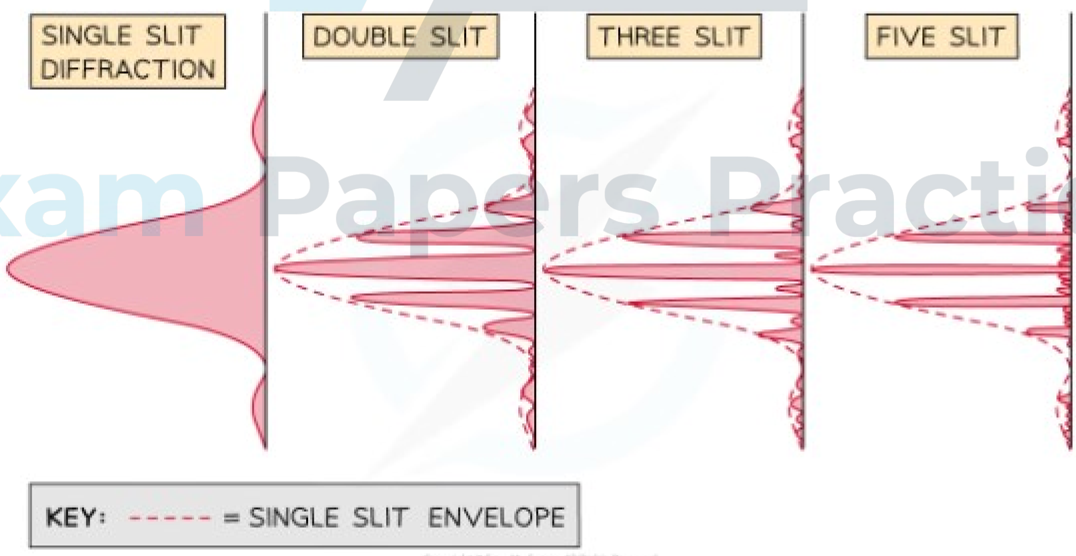
The correct answer is **C** because:

- The width of the primary maxima, and other subsidiary maxima, increases with a decrease in the number of slits in the diffraction grating:
- When the number of slits is < 20, there are now secondary maxima visible between the primary maxima
- So, statements II and III are correct

It is important to know from memory exactly how an intensity graph will change as the number of slits in the diffraction grating changes.

- As the number of slits increases:
  - Between the maxima, secondary maxima appear
  - The intensity of the central and other larger maxima increases
  - The central maxima and subsequent bright fringes become narrower

The diagram below shows the relative intensity for a single slit, a double slit, a three slit grating and a five slit grating.



The changes that can be observed are summarised below:

- When there are 3 slits, 1 secondary maxima can be seen between the primary maxima

- When there are 5 slits, 3 secondary maxima can be seen between the primary maxima
    - Therefore, with N slits (when N > 2), there are **(N – 2) secondary maxima**
- Since the overall amount of light being let through is increased, the pattern increases in intensity by a factor of $N^2 I_0$
    - Where I_0 is the intensity of the central maximum by a single slit
- Once the number of slits increases to **N > 20**:
    - The primary maxima will become thinner and sharper (since slit width, $d \propto \frac{1}{N}$)
    - The (N – 2) secondary maxima will become unobservable

So, statement I is incorrect because:

- The intensity of the primary maxima decreases with a decrease in the number of slits.
- There is less interference, as there are fewer slits for the light to diffract through

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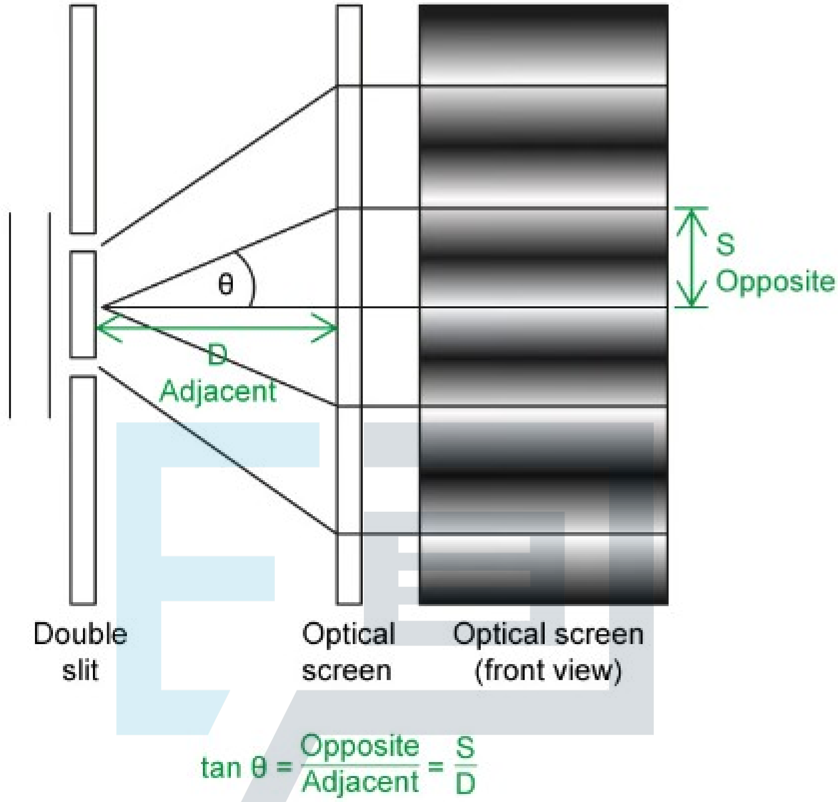
The correct answer is **D** because:

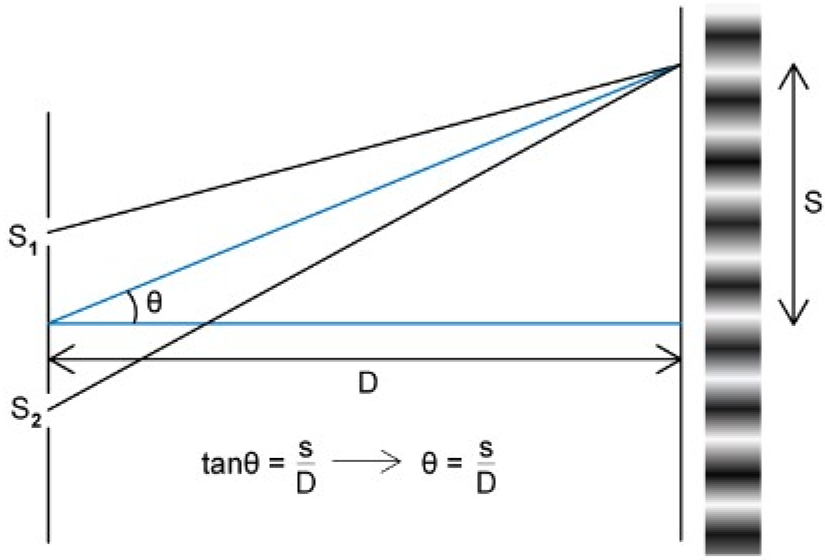
- The equation for the fringe spacing in a double-slit interference pattern:
    - $s = \frac{\lambda D}{d}$
    - Where s is the fringe spacing, λ is the wavelength of the light, D is the distance from the double slit to the screen and d is the slit separation
- Rearranging the equation for λ gives:
    - $\lambda = \frac{sd}{D}$
- Considering the trigonometry of the double-slit diffraction pattern we can see that 'tan' of the angle of diffraction θ is:

- $\tan\theta = \frac{opposite}{adjacent} = \frac{s}{D}$



- Using the small-angle approximation for the double-slit diffraction pattern $\tan\theta \approx \theta$
- Substituting $\theta = \frac{s}{D}$ into the equation for λ gives:
  - $\lambda = \theta d$
- So, the correct answer is **D**

Reading this question carefully and considering the trigonometry involved in the angle of diffraction will enable you to find a suitable equation for $\sin\theta$. You must also remember the small-angle approximation of $\sin\theta \approx \theta$. You can see this in the diagram below.



Small angle approximation: tanθ ≈ sinθ ≈ θ