Waves and the particle nature of light: the 6-mark questions

The long-answer questions in this topic come in a few types, and each type gets marked against the same points every time. Choose one, learn its chain, then fill in the details from the question.

6-MARK PROSE

Standing waves

1. How to spot one

THE TRIGGER WORDS

“Explain how a standing (stationary) wave is set up…”

…or a question about **nodes or antinodes**, or waves that **reflect back to where they came from**. And the biggest clue of all: **a musical instrument**.

Watch out for **structures that oscillate dangerously** too, like a bridge, a tall chimney or a cable in the wind. The wind sets up waves that travel along the structure and reflect off its fixed ends, so a standing wave forms on the structure itself.

Every musical instrument makes its note with a standing wave. So if the question shows an instrument, start thinking “standing wave” straight away. The wave travels along the string or the air inside the pipe, reflects at the end, and comes back on itself.



Strings
Guitar, violin, harp, piano. The wave reflects at the two **fixed ends** of the string (the bridge and the nut on a guitar).



Pipes
Organ, flute, recorder, trumpet. The **air column** inside vibrates, and the sound wave reflects at the ends of the pipe.



Drums
The stretched skin vibrates. The wave reflects at the fixed rim, giving a standing wave in two dimensions.

Only certain frequencies fit a whole number of loops between the ends. That’s why each string or pipe plays its own note.

	Standing wave	Interference pattern
The waves	Two **coherent** waves on the **same line**, travelling in **opposite directions**. One is usually the reflection of the other	Waves from **two or more coherent sources** (or two paths) meeting at a point
Clue words	string, pipe, instrument, reflected back, a bridge or structure in the wind, nodes, antinodes	two slits, two speakers, bright and dark lines, louder and quieter places, path difference
What you see	Nodes and antinodes at fixed places, half a wavelength apart	Maxima and minima, set by the path difference to each point

Both need coherent waves: the same frequency and a **constant phase difference**. That keeps the nodes and antinodes (or the maxima and minima) in the same places, so you get a steady pattern.

Both use superposition, so the mark schemes overlap. The difference is **where the two waves come from**: one wave and its own reflection (standing wave), or two separate sources (interference).

2. The standing wave chain: six links, six marks

THE STANDING WAVE CHAIN reflect → superpose

Two waves first, then where the nodes and antinodes form

Say it until it sticks: **opposite directions · superpose · in phase · antiphase · nodes and antinodes form · min and max**

1. **Two waves, opposite directions**
   The wave reflects at the end, so two coherent waves travel in opposite directions.
2. **Superpose**
   Where they meet, the two waves superpose (interfere).
3. **In phase → constructive**
   Where the waves are in phase (path difference nλ), they interfere constructively.

4 **Antiphase → destructive**
Where the waves are in antiphase (path difference (n + ½)λ), they interfere destructively.

5 **Nodes and antinodes form**
Nodes form at the points of destructive interference; antinodes at the points of constructive interference.

6 **Min and max**
Nodes are points of minimum (zero) amplitude; antinodes are points of maximum amplitude.

The trap: the result without the reason. “The waves cancel out to make nodes” misses two marks. Say **why** (the waves are in antiphase) and **what kind** of interference (destructive). The same goes for the antinodes: in phase, constructive.

No spare link this time. The guitar mark scheme has exactly six points for six marks, so you need every link. Nodes and antinodes are easy to swap over: a **N**ode has **N**o movement.

3. Before you write: mark up the question

Ring two things and underline the trigger. The question doesn’t always say where the wave reflects: if it doesn’t, you supply it.

RING · V
What vibrates
The string, the air in the pipe, the air between the loudspeaker and the board.

RING · R
Where it reflects
The fixed ends of the string, the end of the pipe, the fixed ends of a bridge or cable.

UNDERLINE
The trigger
“standing wave”, “stationary wave”, a musical instrument, nodes or antinodes, a structure oscillating in the wind.

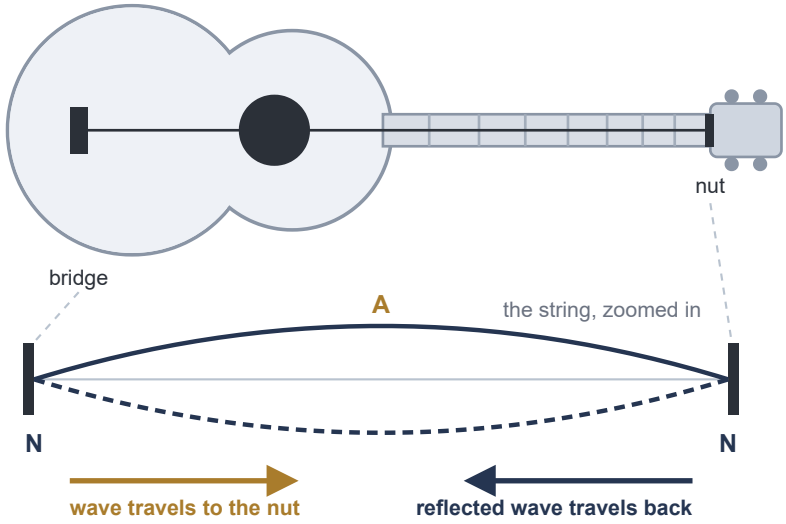
If the question shows…	What vibrates	Where it reflects (link 1)
a stringed instrument (guitar, violin, harp)	The string	The two fixed ends of the string
a wind instrument or pipe (organ, flute, tube)	The air column	The ends of the pipe
a structure in the wind (bridge, tall chimney, cable)	The structure itself	Its fixed ends

4. Worked example: the guitar

A standing wave on a guitar string

Edexcel A Level Physics past paper · 6 marks

The photograph shows a guitar. The strings of the guitar are at the same tension.



The first harmonic: the note you hear. The wave reflects at both fixed ends and the two coherent waves superpose: a node (N) at each end, where they are in antiphase, and an antinode (A) in the middle, where they are in phase.

When a string (V) is **plucked**, a **standing wave** is set up on the string.

(a) * Explain how a **standing wave is set up** on a string. **(6)**

THE TRIGGER

"standing wave", and a musical instrument. Run the standing wave chain.

VIBRATES AND REFLECTS

V = the string. R isn't in the question, so **you add it**: the wave reflects at the fixed ends (the bridge and the nut).

SIX MARKS

- the * means your writing is marked too
- six marks, six links: none spare

STEP 1 Run the chain in note form

1. reflects at fixed ends: 2 coherent waves, opposite directions
2. superpose
3. in phase → constructive
4. antiphase → destructive
5. nodes at destructive, antinodes at constructive
6. node = min amplitude, antinode = max

STEP 2 Write it in full sentences

1. When the string is plucked, a wave travels along the string and **reflects at the fixed ends**, so there are **two coherent waves travelling in opposite directions** along the string. ✓ 1 mark
2. Where the two coherent waves meet, they **superpose (interfere)**. ✓ 1 mark
3. At points where the two waves are **in phase** (path difference nλ), there is **constructive interference**. ✓ 1 mark
4. At points where the two waves are **in antiphase** (path difference (n + ½)λ), there is **destructive interference**. ✓ 1 mark
5. **Nodes** form at the points of **destructive** interference, and **antinodes** form at the points of **constructive** interference. ✓ 1 mark
6. Nodes are points of **minimum (zero) amplitude**, and antinodes are points of **maximum amplitude**. The fixed ends are always nodes. ✓ 1 mark

Six marking points, six marks available: every link earns its mark.

▼ Check it against the mark scheme

Mark scheme says	Link	
Two waves travelling in opposite directions	1	(1)
Superpose / interfere	2	(1)
Constructive (interference) if waves in phase, or if path difference = nλ	3	(1)
Destructive (interference) if waves in antiphase, or if path difference = (n + ½)λ	4	(1)
Nodes are formed from points of destructive (interference) or antinodes are formed from points of constructive (interference)	5	(1)
Nodes are points with min amplitude and antinodes are points with max amplitude	6	(1)

6 marks. Indicative content, so quality of written communication counts: write it in order, and the chain does that for you. Always say the waves are **coherent** (same frequency, constant phase difference): that word earns credit, “the same frequency” on its own doesn’t.

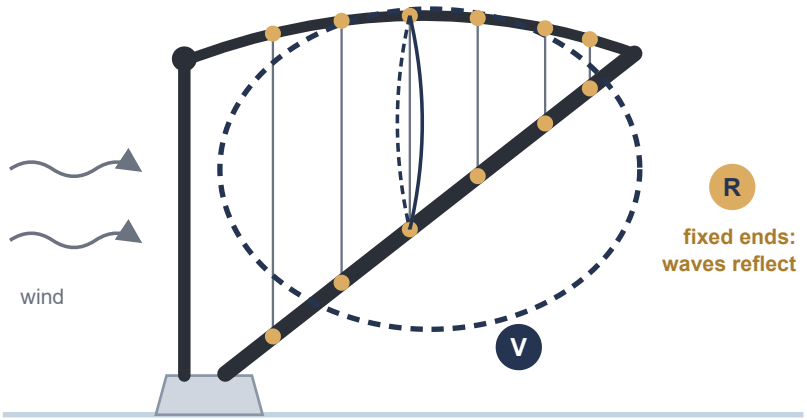
5. Your turn: practise the chain

Same chain, different set-ups. Mark up the question first (ring what vibrates, ring where it reflects, underline the trigger), write your answer, then open the answer to see the mark-up, the chain and the mark scheme.

Practice 1 · The Aeolian harp

Edexcel A Level Physics past paper · 2 marks

An Aeolian harp is a stringed **musical instrument** that is 'played' by the wind.



Each string is fixed at both ends, like a guitar string. The wind blows at right angles to the strings and makes them vibrate; the waves reflect at the fixed ends. The middle string shows its first harmonic.

As air passes (the strings) V, it forces them to vibrate, creating **stationary waves** on the strings.

(a) Explain how **stationary waves are formed** on the strings. **(2)**

THE TRIGGER
"stationary waves", and "musical instrument". Standing wave chain.

VIBRATES AND REFLECTS
V = the strings. R = the fixed ends of each string (not in the question: you add it).

TWO MARKS
- two marks = **links 1 and 2**
- the first two links are always the same

STEP 1 Run the chain in note form

1 reflects at fixed ends: 2 coherent waves, opposite directions → 2 superpose

2 marks: stop here

STEP 2 Write it in full sentences

1 Waves travel along each string and **reflect at the fixed ends**, so there are **two coherent waves travelling in opposite directions** along the string. ✓ 1 mark

2 The two waves **superpose (interfere)**, producing nodes and antinodes: a stationary wave. ✓ 1 mark

Two marks, two links. Writing links 3–6 won't lose marks, but it costs time you need for the rest of the paper.

▼ Check it against the mark scheme

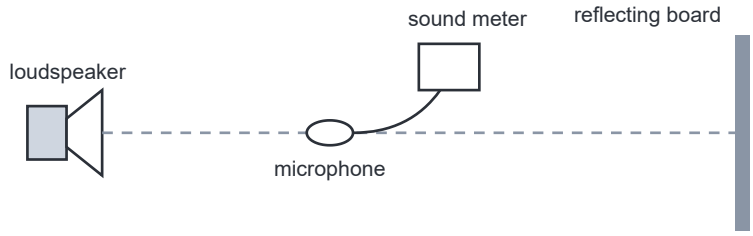
Mark scheme says	Link	
(Two) waves travelling in opposite directions, or wave reflected back on itself	1	(1)
Superposition / interference occurs	2	(1)

2 marks. Always say the waves are **coherent** (same frequency, constant phase difference): that word earns credit, "the same frequency" on its own doesn't.

Practice 2 · Loudspeaker and reflecting board

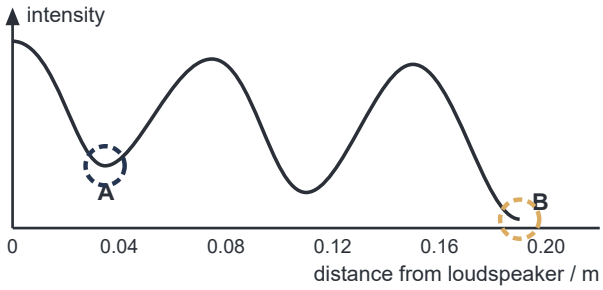
Edexcel A Level Physics past paper · 3 marks

(c) An alternative method to determine a value for the speed of sound is shown in the diagram.



A: waves very different sizes → only partly cancel

B: waves similar sizes → cancel almost completely



A and B are both nodes. Near the loudspeaker the reflected wave has travelled much further than the wave from the speaker, so it is much weaker.

A loudspeaker is placed at a distance from a vertical reflecting board (R). Sound waves (V) reflect off the board and set up a **standing wave** between the loudspeaker and the

THE TRIGGER

"standing wave". Loudspeakers usually mean interference, but here the sound reflects back off the board: one wave and its own reflection. Use links 4 and 5: A and B are nodes.

VIBRATES AND REFLECTS

V = the sound waves (the air).
R = the reflecting board.

THE EXTRA IDEA

- amplitude **falls with distance** travelled
- at B both waves have travelled about the same distance

board. A microphone connected to a sound meter is moved in a straight line from the loudspeaker to the board.

As the microphone is moved, the sound meter records the varying intensity of the standing wave. The sketch graph shows how the intensity varies with distance from the loudspeaker.

(i) Explain why **the intensity at point B is less than the intensity at point A**. **(3)**

STEP 1 Run the chain in note form

1. A and B are nodes: antiphase, destructive
2. amplitude falls with distance travelled
3. at A: very different amplitudes
4. at B: similar distances, similar amplitudes
5. B cancels more: lower intensity

STEP 2 Write it in full sentences

1. A and B are both **nodes**, where the wave from the loudspeaker and its reflection (two coherent waves) are in antiphase and **interfere destructively**. ✓ 1 mark
2. The **amplitude (and intensity) of the sound decreases with the distance travelled**. ✓ 1 mark
3. At A, the wave from the loudspeaker has travelled only a short distance but the reflected wave has travelled much further, so their amplitudes are very different and they **only partly cancel**. goes with 4
4. At B, near the board, the two waves have **travelled similar distances**, so they have **similar amplitudes**. ✓ 1 mark
5. So at B the waves **cancel almost completely**, and the intensity is lower than at A. answers the question

The answer isn't "B is further away so it's quieter". It's about how well the two waves cancel.

Check it against the mark scheme

Mark scheme says	Link	
Amplitude/energy/intensity of the sound wave reduces with distance travelled	**2**	**(1)**
Appreciate that at A or B two waves are interfering destructively, or at A and B there are nodes	**1**	**(1)**
At B the waves have travelled similar distances so have similar amplitudes	**4**	**(1)**

6-MARK PROSE

Interference

1. How to spot one

THE TRIGGER WORDS

“Explain why there is a bright line / a quiet spot / colours…”

…with waves arriving at a point from **two or more coherent sources**, or by **two different paths**: two slits, two loudspeakers, sound bouncing off the walls of a hall, light scattering off the tracks of a CD. Some places get a **maximum** (bright, loud) and some a **minimum** (dark, quiet).

Not a standing wave? A standing wave is one wave and its own reflection travelling in opposite directions along the same line. Here, the waves come from **separate sources** and meet at a point. If you’re asked about positions in a room or on a screen, think interference. (Compare the two.)

2. The interference chain: six links

THE INTERFERENCE CHAIN sources → path difference

Where the waves come from, then how far each one travels

Say it until it sticks: **two sources · superpose · path difference · nλ constructive · (n + ½)λ destructive · so…**

1. **Two sources**
   Waves reach the point from two (or more) coherent sources (same frequency, constant phase difference), or by different paths. Name them from the question.
2. **Superpose**
   At the point, the waves superpose (interfere).
3. **Path difference**
   The waves travel different distances, so there is a path difference, and so a phase difference.
4. **nλ → constructive** BRIGHT / LOUD
   Path difference a whole number of wavelengths (phase difference 0, 2π…): in phase, constructive interference, maximum.

5 **(n + ½)λ → destructive** DARK / QUIET

Path difference an odd number of half wavelengths (phase difference π, 3π…): antiphase, destructive interference, minimum.

6 **So…**

Link it back to the question: the bright line, the quiet seat, the colours.

The trap: mixing up path and phase. Path difference is a distance (in wavelengths); phase difference is an angle (in radians). “A path difference of π” scores nothing. Keep the pairs together: **nλ ↔ 0, 2π, 4π** and **(n + ½)λ ↔ π, 3π, 5π**.

Use the chain for part questions too. A 3-mark “why is it bright here?” is links 3, 4 and 6. The longer questions want the whole chain, plus whatever extra the question asks for, like a fix for the problem.

3. Before you write: mark up the question

Ring the sources and the point, underline what happens there. The sources aren’t always named: reflections off walls count as sources too.

RING · S

The sources

Two slits, two speakers, the walls that reflect, the tracks of a CD.

RING · P

The point

Where the waves meet: O or P on a screen, a seat in the audience, your eye.

UNDERLINE

What happens there

Bright or dark, loud or quiet, colours. That tells you which link (4 or 5) you need.

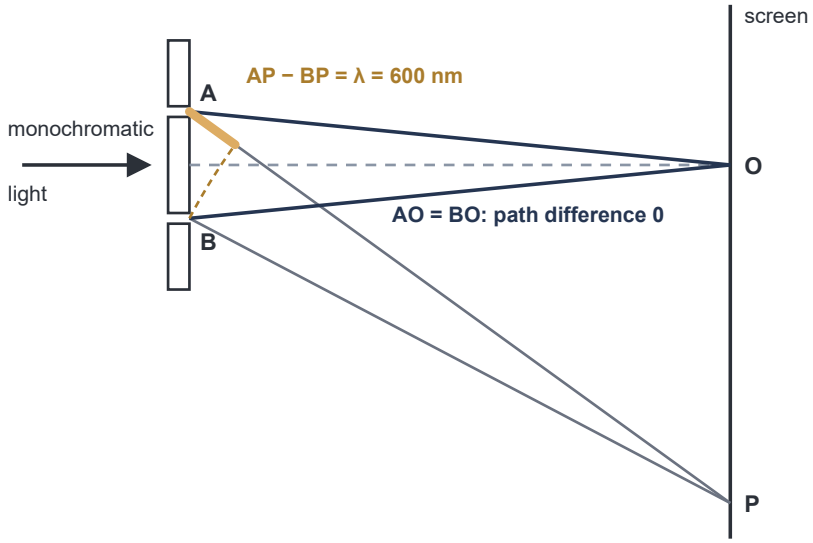
If the question says it’s…	Path difference	So your answer says
bright, loud, a maximum	nλ (phase difference 0, 2π…)	In phase, constructive interference
dark, quiet, a minimum	(n + ½)λ (phase difference π, 3π…)	Antiphase, destructive interference
coloured, from white light	nλ happens at a different angle for each wavelength	Each wavelength has constructive interference at a different angle, so a spectrum

4. Worked example: two slits

The bright lines from two slits

Edexcel A Level Physics past paper · 4 marks

The experiment was carried out with laser light of wavelength 600 nm. The diagram below shows two paths taken by the light after it has passed through the two slits A and B (S). The diagram is not to scale.



To O the two paths are the same length. To P, AP is one wavelength longer than BP (the gold bit).

(i) Point O (P) is a point **equidistant from the two slits**. Explain why there is a **bright line** at this point. **(3)**

(ii) The **next bright line** is observed on the screen at point P. Lines AP and BP show the path of the light from each slit to the screen at P. State the **difference in the lengths of the paths** AP and BP. **(1)**

THE CLUE
"equidistant" and "difference in the lengths of the paths": this is all about path difference.

SOURCES AND POINT
S = the two slits A and B. P = point O, then point P.

WHAT HAPPENS THERE
- "bright line" = constructive, **link 4**
- "next bright line" = n = 1

STEP 1 Run the chain in note form

1. 2 coherent sources: slits A and B
2. superpose at O
3. equidistant: path difference 0
4. in phase → constructive
6. maximum intensity: bright line
(ii) next bright line: n = 1, so λ

STEP 2 Write it in full sentences

(i)

1. Light from the two slits is **coherent**, and the waves **superpose** at O. — sets it up
2. O is equidistant from the slits, so the **path lengths AO and BO are equal**: the **path difference is zero**. — ✓ 1 mark
3. So the waves **arrive in phase** (phase difference zero). — ✓ 1 mark
4. They undergo **constructive interference**, giving maximum intensity: a **bright line**. — ✓ 1 mark

(ii)

5. P is the next bright line, so the path difference is **one wavelength**: AP − BP = **600 nm** (6.0×10^{-7} m). — ✓ 1 mark

For (ii) give the number. “nλ” on its own scores nothing: the mark scheme says so.

▼ Check it against the mark scheme

Mark scheme says	Link	
(i) Path lengths (A–O and B–O) are equal, or path difference is zero	2	(1)
(i) Will arrive in phase, or phase difference is zero	3	(1)
(i) (Bright line is position of) constructive interference/superposition	4	(1)
(ii) 600 nm, or 600×10^{-9} m, or 6.0×10^{-7} m, or one wavelength, or λ. Do not accept nλ	5	(1)

4 marks. “Constructive” needs underlining in your head: it’s the word the mark is for. Always say the waves are **coherent** (same frequency, constant phase difference): that word earns credit, “the same frequency” on its own doesn’t.

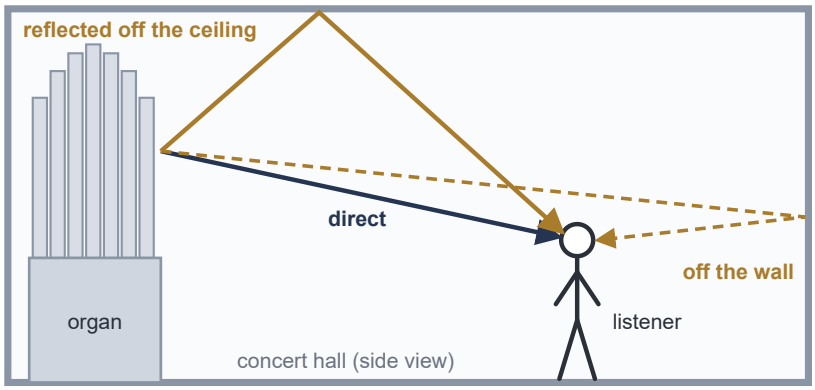
5. Your turn: practise the chain

Same chain, harder set-ups. Ring the sources, ring the point, underline what happens there, then write your answer before you open it.

Practice 1 · The pipe organ in a concert hall

Edexcel A Level Physics past paper · 6 marks

* The photograph shows a pipe organ in a concert hall.



Sound reaches the listener by several paths of different lengths. The walls and ceiling act like extra sources.

When the organ is played, sound travels through the air to a person in the audience (P) as a wave. It is found that there are some positions in the concert hall where **particular frequencies are quieter than others**.

Explain why this might be the case and **give an action** that could be taken to eliminate this problem. **(6)**

TWO JOBS
Explain it with the interference chain, **then** give an action. The action is a mark of its own.

SOURCES AND POINT
S isn't named: it's the organ **and** the walls and ceiling that reflect the sound. P = the person in the audience.

WHAT HAPPENS THERE
- "quieter" = destructive, **link 5**
- other frequencies louder = constructive, **link 4**

STEP 1 Run the chain in note form

1. reflect off walls: waves arrive by different paths
2. superpose
3. some frequencies: (n + ½)λ, odd multiple of π
4. destructive → quieter
5. others: nλ, 0 or 2π
6. constructive → louder
7. absorbing material on walls

STEP 2 Write it in full sentences

1. Sound waves from the organ **reflect off the walls, ceiling and other surfaces**, so coherent waves reach a listener by different paths. ✓ 1 mark
2. The waves arriving from different directions **superpose** at the listener. goes with 3
3. For some frequencies the **path difference is an odd number of half wavelengths**, so the waves arrive with a **phase difference of an odd multiple of π** (antiphase). ✓ 1 mark
4. They interfere **destructively**, so those frequencies are **quieter**. ✓ 1 mark
5. For other frequencies the **path difference is a whole number of wavelengths** (phase difference zero or a multiple of 2π), so the waves arrive in phase. ✓ 1 mark
6. They interfere **constructively**, so those frequencies are **louder**. ✓ 1 mark
7. The problem comes from reflections, so cover the walls and ceiling with **sound-absorbing material** (soft panels, curtains) to **reduce the reflections**. ✓ 1 mark

Why only *some* frequencies? At one seat the path difference is fixed, but the wavelength depends on the frequency. So whether the path difference comes out as nλ or (n + ½)λ depends on the frequency.

▼ Check it against the mark scheme

Mark scheme says	Link	
Sound waves incident upon surfaces within the concert hall will be reflected	**1**	**(1)**
Some frequencies arrive from different directions with a phase difference of (any odd multiple of) π radians, or path difference is an odd number of half wavelengths	**2–3**	**(1)**
Destructive superposition/interference will occur, causing the waves with those frequencies to be quieter than others	**4**	**(1)**
Other frequencies arrive with a phase difference of zero or (any multiple of) 2π radians, or a whole number of wavelengths	**5**	**(1)**

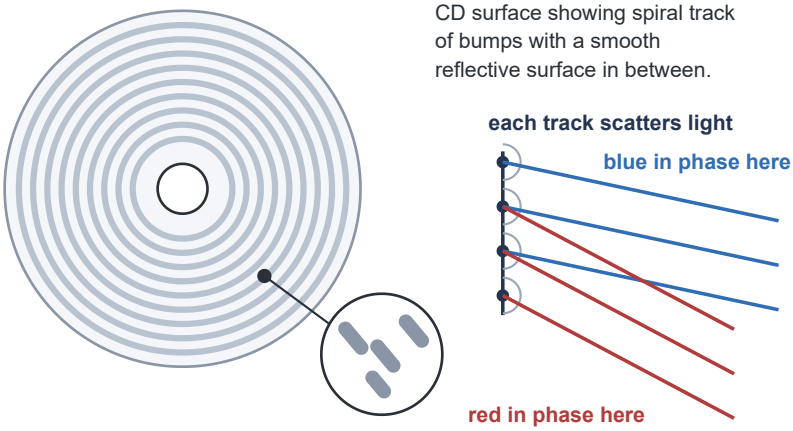
Constructive superposition/interference will occur, causing waves with those frequencies to be louder than others	**6**	**(1)**
Problem arises due to reflections from walls, so use absorbing material on surfaces to reduce reflections	**7**	**(1)**

Indicative content, so your writing is marked too. The organ *pipes* make their notes with standing waves, but this question is about the hall: that's interference. Always say the waves are **coherent** (same frequency, constant phase difference): that word earns credit, "the same frequency" on its own doesn't.

Practice 2 · Colours from a CD

Edexcel A Level Physics past paper · 6 marks

* The light from a lamp is reflected from the surface of a CD, which consists of a spiral track of elongated bumps (S).



CD surface showing spiral track of bumps with a smooth reflective surface in between.

Each track scatters light in all directions. Light from many tracks superposes, and each wavelength has constructive interference at its own angle.

A physics student notices that although the light from the lamp is **white**, **different colours are seen** in the reflected light. He suggests that the colours are produced when **diffraction** occurs at the surface of the CD.

Discuss the extent to which the student's suggestion explains the presence of colours in the light reflected from the surface of the CD. **(6)**

"DISCUSS THE EXTENT"

Is the student right, and is it the whole story? Diffraction is only half of it: you need **interference** too.

SOURCES AND POINT

S = every bit of the track: each one scatters light, so there are many sources. P = the eye looking at the CD.

WHAT HAPPENS THERE

- "white" = a mix of wavelengths
- "colours" = each wavelength has constructive interference at a different angle

STEP 1 Run the chain in note form

1. yes, diffraction at the CD surface
2. each ring = a source, scatters in all directions
3. superpose: interference
4. nλ (even multiple of π) → constructive
5. white light = range of λ
6. each λ constructive at a different angle: spectrum

STEP 2 Write it in full sentences

1. The student is partly right: **diffraction does occur** when light is reflected from the CD surface. ✓ 1 mark
2. **Each ring of the track acts as a source**, diffracting (scattering) the light **in all directions**. ✓ 1 mark
3. The coherent light from the many rings **superposes**, so **interference** occurs. ✓ 1 mark
4. In directions where the **path difference is a whole number of wavelengths** (phase difference an even multiple of π), the waves are in phase and interfere **constructively** (reinforce). ✓ 1 mark
5. **White light is a mixture of wavelengths.** ✓ 1 mark
6. So **each wavelength has constructive interference at a different angle**, separating the colours into a **spectrum**. ✓ 1 mark
7. So diffraction on its own doesn't explain the colours: it's **diffraction followed by interference**, just as in a diffraction grating. answers "discuss"

"Discuss the extent" wants a verdict. Start by saying how far the student is right, and finish by saying what's missing.

▼ Check it against the mark scheme

Mark scheme says	Link

Analyses and interprets the text to conclude that diffraction occurs when light is reflected from the CD surface	**1**	**(1)**
Each ring on the CD acts as a diffraction centre scattering light in all directions	**2**	**(1)**
Interference occurs (superposition of light from the multiple light sources)	**3**	**(1)**
In directions with a phase difference equal to an even multiple of π rad, or a path difference equal to a whole number of wavelengths, constructive interference (reinforcement) occurs	**4**	**(1)**
White light is a range (mixture) of wavelengths	**5**	**(1)**
Hence each wavelength of light reinforces in a different direction, which explains why a spectrum is seen	**6**	**(1)**

6 marks, indicative content. Same chain as the organ, plus links 5 and 6 for the colours. Always say the waves are **coherent** (same frequency, constant phase difference): that word earns credit, “the same frequency” on its own doesn’t.