Topic 4.3

Wave characteristics
# Subject guide

**Understandings:**
- Wavefronts and rays
- Amplitude and intensity
- Superposition
- Polarization

**Applications and skills:**
- Sketching and interpreting diagrams involving wavefronts and rays
- Solving problems involving amplitude, intensity and the inverse square law
- Sketching and interpreting the superposition of pulses and waves
- Describing methods of polarization
- Sketching and interpreting diagrams illustrating polarized, reflected and transmitted beams
- Solving problems involving Malus’s law

**Guidance:**
- Students will be expected to calculate the resultant of two waves or pulses both graphically and algebraically
- Methods of polarization will be restricted to the use of polarizing filters and reflection from a non-metallic plane surface

**Data booklet reference:**
- \( I \propto A^2 \)
- \( I \propto x^{-2} \)
- \( I = I_0 \cos^2 \theta \)
Wave fronts and rays

- A **wavefront** is a surface that travels with a wave and is perpendicular to the direction in which the wave travels – the ray.

- A **ray** is a line showing the direction in which a wave transfers energy and is, of course, perpendicular to a wavefront.
Wave fronts using phet

Go to www.phet.colorado.edu and look for the physics simulation named “wave interference” and then “waves”

1. What do the black and blue strips represent?

2. Use the ruler tool to measure the wavelength of the wave and the timer to measure the time.

3. Find the speed of
   1. The sound wave
   2. The water wave
6 \((IB)\)

a) By referring to the energy of a travelling wave, explain what is meant by:

(i) a ray
(ii) wave speed.
1. The diagram below is a snapshot of wave fronts of circular waves emitted by a point source S at the surface of water. The source vibrates at a frequency $f = 10.0 \text{ Hz}$.

The speed of the wave front is

A. $0.15 \text{ cm s}^{-1}$  \quad B. $1.5 \text{ cm s}^{-1}$  \quad C. $15 \text{ cm s}^{-1}$  \quad D. $30 \text{ cm s}^{-1}$.  


You are painting two spheres blue. Unfortunately you can only use one can of paint for each sphere.

The “blueness” of the sphere depends on the thickness of the paint (more layers → more blue)

The radius of the large sphere is 3 times the radius of the small sphere.

• What is the ratio of their surface areas?
• How much less “blue” is the large sphere?
1. This question is about intensity and amplitude.

At a distance of 15m from the source, the intensity of a loud sound is \(2.0 \times 10^{-4} \text{W} \cdot \text{m}^{-2}\).

(a) Show that the intensity at 120 m from the source is approximately \(3.0 \times 10^{-6} \text{W} \cdot \text{m}^{-2}\).

(b) Deduce how the amplitude of the wave changes.
Superposition with a slinky

In your teams:

• Send out two wave pulses in opposite directions but “on the same side of the slinky”

• Send out two wave pulses in opposite directions and “on opposite sides of the slinky”

• Record both situations with slow motion. Watch the video and pay close attention to what happens when they meet.

• One is called **constructive** interference and the other situation is called **destructive** interference. Which one is which and why are they called constructive and destructive?
3. Two waves meet at a point in space. Which of the following properties always add together?

A. Displacement
B. Amplitude
C. Speed
D. Frequency
Superposition cards

- In your groups match the letter with corresponding number (e.g. 4 – B)
- All letter cards show two waves meeting.
- All number cards show a resultant wave.
- Your task is to match each letter with it’s corresponding number

![Graphs showing waves](image)
Answers...
4a. Outline what is meant by the principle of superposition of waves. [2 marks]

2. (a) the net displacement of the medium / particles (through which waves travel); is equal to the sum of individual displacements (produced by each wave); 2 max

Award a good understanding [2 max] and a reasonable one [1 max]

when 2 waves meet the resultant displacement is the «vector» sum of their individual displacements

Displacement should be mentioned at least once in MP 1 or 2.
b) The following graph shows the variation with time $t$ of the displacement $x_A$ of wave A as it passes through a point P.

(i) Calculate the frequency of the waves.

(ii) The waves pass simultaneously through point P. Use the graphs to determine the resultant displacement at point P of the two waves at time $t = 1.0 \text{ ms}$ and at time $t = 8.0 \text{ ms}$.
Two pulses travel towards each other on the same taut rope. The two graphs show the pulses before and after the collision. The speed of the black pulse is $15 \text{ m s}^{-1}$. The left diagram shows the pulses at $t = 0$.

a. State the principle of superposition.

b. State the speed of the grey pulse.

c. i. Determine the time after which the two pulses completely overlap.
   ii. Draw the shape of the rope at the time of complete overlap.

d. i. Suggest whether any energy was lost during the collision of the two pulses.
   ii. Comment on the shape of the rope in c ii by reference to your answer in d i.
5. The diagram below shows two wave pulses moving towards one another.

Which **one** of the following diagrams shows the resultant pulse when the two pulses are superposed?

A.  
B.  
C.  
D.
4. The two graphs show the variation with time of the individual displacements of two waves as they pass through the same point.

The displacement of the resultant wave at the point at time $T$ is equal to

A. $x_1 + x_2$.
B. $x_1 - x_2$.
C. $A_1 + A_2$.
D. $A_1 - A_2$. 
6. The diagram below shows two pulses on a string travelling toward each other.

Which of the following diagrams best shows the shape of the string after the pulses have passed through each other?

A.  

B.  

C.  

D.  