1. In the Young double-slit experiment, light passes through two narrow slits and a pattern of light is observed on a screen.

Which property of light is **not** demonstrated by this experiment?

A diffraction
B refraction
C wave nature
D superposition

Your answer ☐ **[1]**

2. In a Young double-slit experiment, electromagnetic radiation is incident on a double slit. The following results are obtained.

distance from slits to screen = 3.5 m
distance between slits = 1.5 mm
distance between central fringe and 6th order fringe = 9 mm

What is the wavelength of the radiation?

A 6.4×10^{-7} m
B 3.9×10^{-6} m
C 6.4×10^{-1} m
D 2.3×10^{-5} m

Your answer ☐ **[1]**

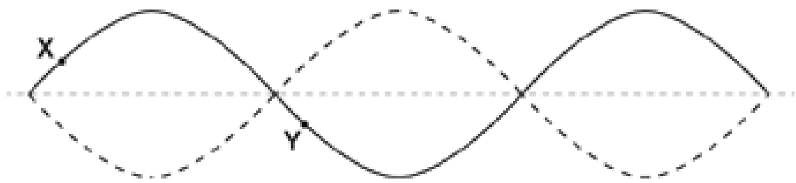
3. Two waves, of wavelength λ, undergo constructive interference.

What is a possible path difference between the two waves?

A $\frac{\lambda}{4}$
B $\frac{\lambda}{2}$
C $\frac{3\lambda}{2}$
D λ

Your answer ☐ **[1]**

4. The diagram shows a stationary wave on a string.



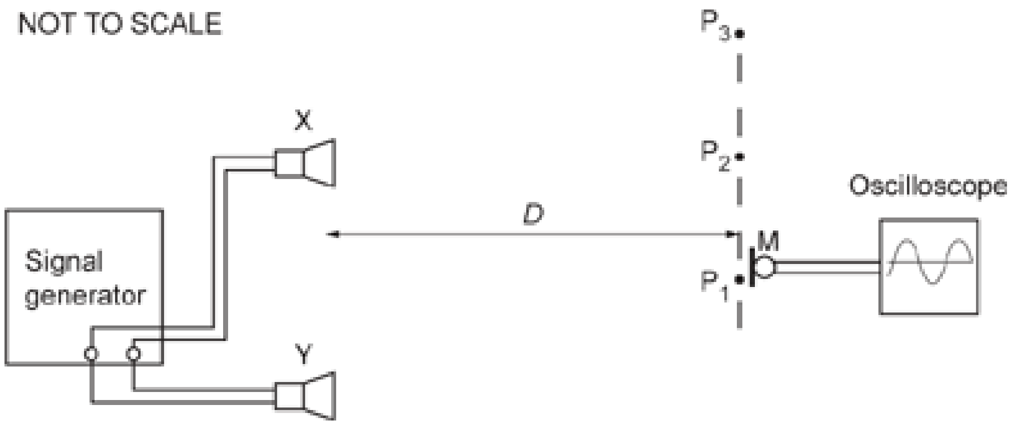
What is the phase difference between the points on the wave labelled **X** and **Y**?

A 0
B $\frac{\pi}{4}$
C $\frac{\pi}{2}$
D π

Your answer [1]

5(a). The diagram shows two identical loudspeakers X and Y connected to a signal generator. The loudspeakers emit sound waves of the same amplitude and frequency which are in phase.

A microphone M is moved along a line from P_1 to P_3 and the signal recorded on an oscilloscope.



As the microphone is moved along the line P_1 to P_3 the oscilloscope shows maximum signal at P_1, zero signal at P_2 and the next maximum signal at P_3.

Explain these observations.

[2]

(b). The distance between the centres of X and Y is 70.0 cm, the distance *D* (as shown in the diagram) is 4.00 m and the distance from P_1 to P_2 is 1.25 m.

Use the two source interference formula to calculate the frequency of the sound waves. (Speed of sound = 340 m s^{-1})

frequency = ... Hz **[3]**

(c). Loudspeaker Y is replaced with a loudspeaker that produces sound waves of twice the original amplitude.

Describe how the signal observed on the oscilloscope varies as the microphone is moved along the line P_1 to P_3.

[2]

(d).

i. Explain what is meant by the term *intensity*.

[1]

ii. Calculate the factor by which the intensity of the sound waves at P_1 in the previous question is larger than the intensity of the original sound waves at P_1.

factor = ... **[3]**

6. Two spherical dippers, **D1** and **D2** oscillate on a ripple tank as shown in **Fig. 5.1**.

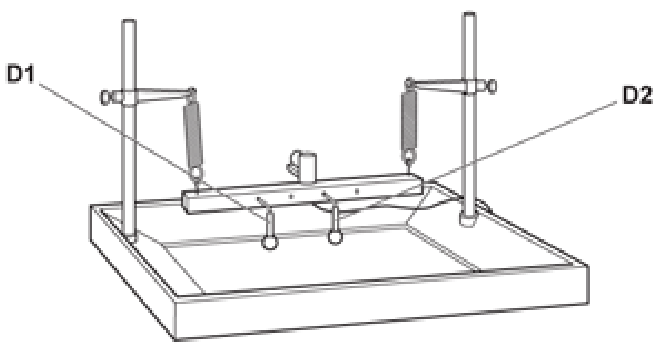


Fig. 5.1

Waves on the surface of the water are produced from each dipper. These waves are in phase with each other.

The water waves have a speed of 8.0 cm s^{-1} and a wavelength of 3.2 cm.

Fig. 5.2 shows the positions **D1** and **D2** of the two dippers in the ripple tank.

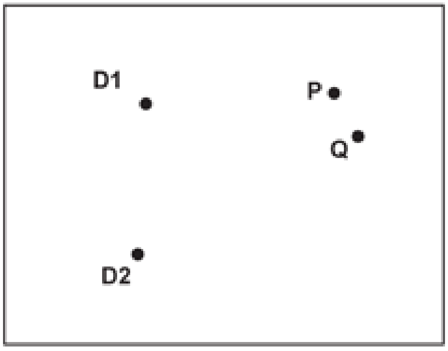


Fig. 5.2

P and **Q** are two points on the water.

i. The distance between **P** and **D1** is 12.2 cm.
The distance between **P** and **D2** is 20.2 cm.

Explain whether constructive or destructive interference occurs at **P**.

[3]

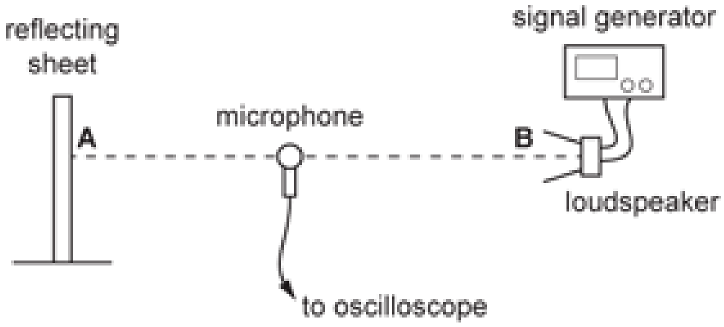
ii. The distance between **Q** and **D1** is 12.5 cm.
The distance between **Q** and **D2** is 19.7 cm.

Calculate the phase difference φ, in rad, between the waves arriving at point **Q** from **D1** and the waves arriving at **Q** from **D2**.

φ = ... rad **[3]**

7. Sound waves in air are longitudinal waves consisting of compressions and rarefactions.

A student investigates sound waves. They set up the following apparatus.



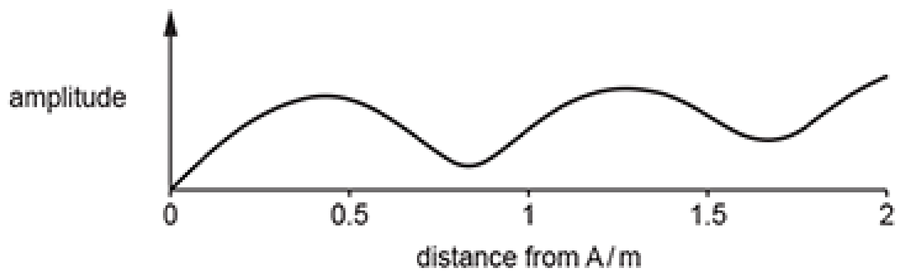
The sound wave emitted from the loudspeaker at **B** travels to the reflecting sheet at **A** and is reflected. A stationary wave is formed between the loudspeaker and the sheet.

The student moves a microphone along the line **AB**. The microphone is connected to an oscilloscope. The oscilloscope shows the relative amplitude of the stationary wave at each point along the line. The student observes a series of nodes and antinodes.

i. Explain how a stationary wave with nodes and antinodes is formed.

[3]

ii. The student measures the amplitude of the stationary wave at a range of distances from the reflecting sheet **A**. Their results are shown below.



The amplitudes at the nodes are observed to be:

- not exactly equal to zero
- closer to zero at distances closer to the reflecting sheet.

Explain these observations.

[3]

iii. The student measures the distance between two adjacent nodes as 0.84 m.

The frequency of the sound wave is 200 Hz.

Use these measurements to calculate a value for the speed of sound waves in air.

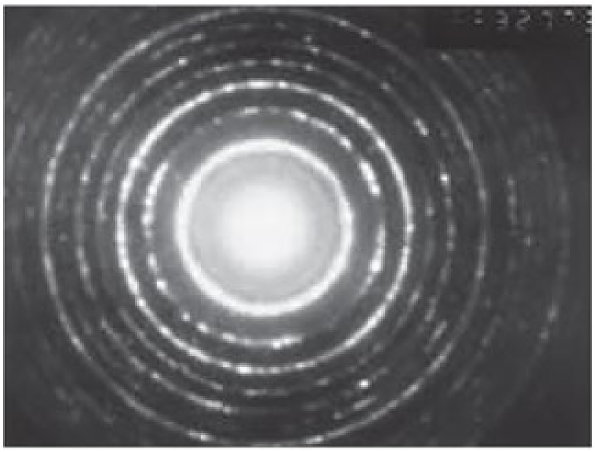
speed of sound waves = ... m s $^{-1}$ **[2]**

iv. The student wants to reduce the uncertainty in their calculated value for the speed of sound waves in air.

Suggest a suitable improvement to the student's method.

[1]

8. The picture shows an electron diffraction pattern produced by graphite in a cathode-ray tube.



Explain why light and dark circles as shown in the picture are produced, stating what this evidence provides about electron behaviour.

[3]

9(a). Fig.1 shows the pattern obtained in a Young double-slit experiment. The pattern is **not** to scale. Three regions of the pattern are labelled **A**, **B** and **D**. The central maximum is labelled **C**.

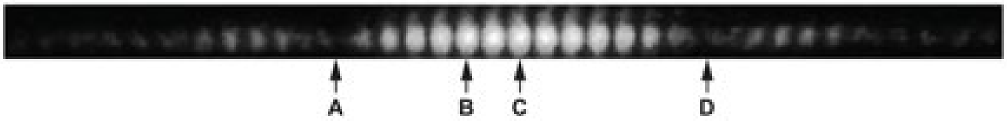


Fig. 1

Red light of wavelength 640 nm was used in the experiment. The distance between the centres of the two slits was 1.00×10^{-5} m. The distance from the double-slit to the screen was 4.0 m.

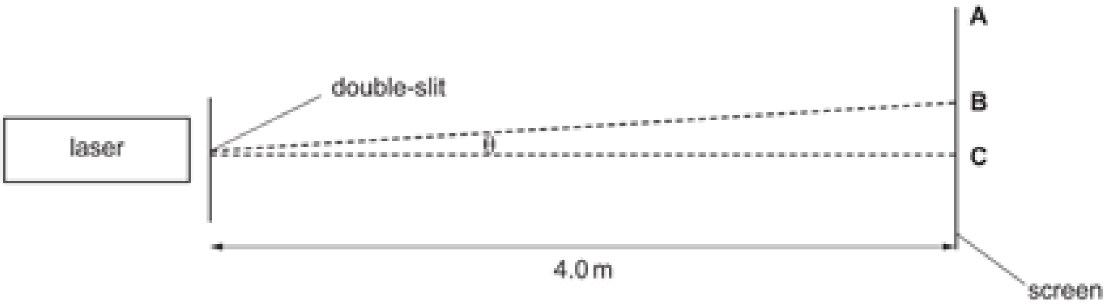


Fig. 2

Explain how the part of the pattern labelled **B** is formed.

--- **[2]**

(b). Calculate the angle θ from the central maximum **C** to the maximum labelled **B** as shown in **Fig. 2**.

θ = ... ° **[3]**

(c). Name the physical processes that cause the features labelled **A**, **D** and **B**, **C** in **Fig. 1**.

A and **D** ---

B and **C** ---

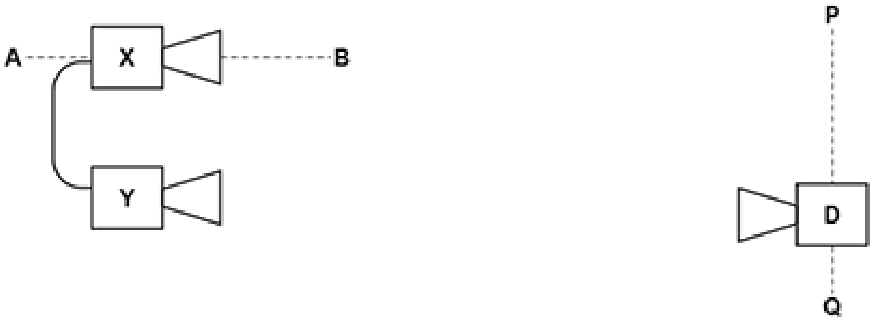
[2]

(d). The Young double-slit experiment uses **coherent** waves. State what **coherent** means.

--**[1]**

10. A student experiments with microwaves emitted from a transmitter. The frequency *f* of the microwaves from the transmitter can be adjusted.

The student connects two microwave transmitters **X** and **Y**, and places them in front of a microwave detector **D**, as shown in the diagram below.



The transmitters **X** and **Y** produce **coherent** vertically polarised microwaves with the same frequency *f*.

The detector **D** is sensitive to vertically polarised microwaves only.

When the detector **D** is moved along the line **PQ**, a pattern of maximum and minimum intensity is observed. Adjacent maxima are separated by a distance *x*.

i. *Explain:

- why this pattern of intensity occurs
- the expected relationship between the frequency *f* and the distance *x*
- how to verify this relationship experimentally.

[6]

ii. Transmitter **X** is rotated about the line **AB** and the experiment is repeated at different orientations until it has been rotated by 180°.

Describe and explain the observed patterns of maximum and minimum intensity.

[3]

11.

A beam of coherent light of wavelength λ is incident normally at two parallel slits (double-slit).
A series of bright and dark fringes are formed on a distant screen placed parallel to the line joining the slits.
The location of some of these fringes is shown in **Fig. 16. 1**.

Fig. 16.1 (not to scale)

The bright fringes are seen at points **M**, **O** and **Q**. The dark fringes are seen at points **N** and **P**.

State the phase difference ϕ in degrees, and the path difference d in terms of wavelength λ, for the waves from the two slits meeting at point **P**.

ϕ = ... ° **[1]**
d = ... λ **[1]**

12. A student is carrying out the Young double-slit experiment using visible light. The distance between the slits and the screen is kept constant.
The wavelength of light is λ and the separation of the slits is *a*.

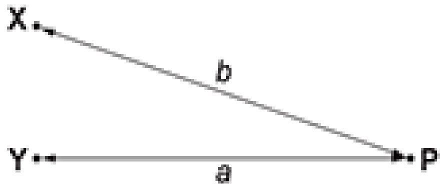
The following results are collected by the student.

	λ/nm	*a* / mm
A	450	0.20
B	510	0.15
C	550	0.25
D	610	0.30

Which combination of λ and *a* will give the **largest** separation between the adjacent bright fringes?

Your answer ☐ **[1]**

13. Two coherent waves are emitted from the sources **X** and **Y**.



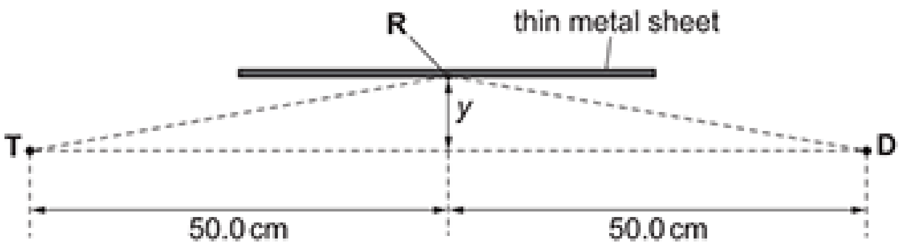
The diagram is not to scale.
The waves at **X** and **Y** are in phase.
The waves have wavelength 4.0 cm.
The phase difference of the two waves meeting at point **P** is 270°.

Which row gives possible distances for *a* and *b*?

	a / cm	***b*** / cm
A	20.0	26.0
B	20.0	22.0
C	15.0	18.0
D	10.0	14.0

Your answer ☐ **[1]**

14. *In an experiment to investigate microwaves, a microwave detector **D** is placed 100.0 cm from a microwave transmitter **T**.



A thin metal sheet is placed parallel to the line joining **T** and **D**. Point **R** is at the bottom of the metal sheet. The perpendicular distance between this line and point **R** is *y*.
The diagram shows the path of microwaves travelling directly from **T** to **D** and the path of microwaves from **T** reflected from **R** to **D**. There is a 180° phase change when microwaves are reflected at **R**.

The metal sheet is moved away from the line joining **T** and **D** so that *y* increases. The metal sheet remains parallel to the line from **T** and **D**. A series of maximum and minimum intensities are observed.

The table shows the values of *y* for successive maximum and minimum intensities.

Intensity	***y* / cm**
maximum	8.4
minimum	11.9
maximum	14.6
minimum	17.0

Explain the presence of the regions of maximum and minimum intensities **and** determine the wavelength of the microwaves.

[6]

END OF QUESTION PAPER