Past-paper walk-through

Interference ▪ 8.3

eXercise

Questions in this set

- 9702/11 N25 Q28 ▪ 1 mark
- 9702/12 N25 Q31 ▪ 1 mark
- 9702/14 N25 Q31 ▪ 1 mark
- 9702/22 N25 Q4 ▪ 8 marks
- 9702/12 J25 Q31 ▪ 1 mark
- 9702/13 J25 Q28 ▪ 1 mark
- 9702/14 J25 Q27 ▪ 1 mark
- 9702/21 J25 Q4 ▪ 8 marks
- 9702/12 M25 Q27 ▪ 1 mark
- 9702/21 N24 Q6 ▪ 9 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 28

9702/11 N25 ▪ Q28 ▪ 1 mark

A student carries out a double-slit experiment using a laser emitting red light of wavelength of 680 nm. The light is incident normally on a double slit.

The diagram shows part of the pattern of bright fringes visible on a screen at a distance of 2.4 m from the slits. The distance across five bright fringes is measured as 34 mm.

What is the slit separation? **[1]**

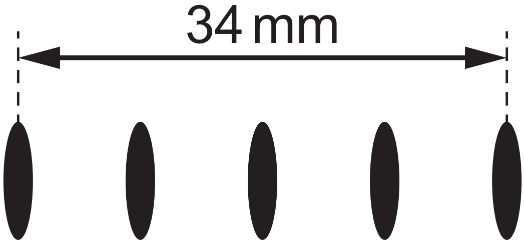
A 8.5×10^{-3} m

B 2.4×10^{-4} m

C 1.9×10^{-4} m

D 4.8×10^{-5} m

Question 28



Solution 28

A 8.5×10^{-3} m

B 2.4×10^{-4} m

C 1.9×10^{-4} m ✓

D 4.8×10^{-5} m

Why

- Five bright fringes enclose *four* fringe separations, so $x = 34/4 = 8.5$ mm.
- Rearranging $x = \lambda D/a$ gives $a = \lambda D/x$.
- $a = (680 \times 10^{-9})(2.4)/(8.5 \times 10^{-3}) = 1.9 \times 10^{-4}$ m; dividing by five instead gives B.

Question 31

9702/12 N25 ▪ Q31 ▪ 1 mark

A student connects two loudspeakers to a signal generator.

As the student walks from P to Q, he notices that the loudness of the sound rises and falls repeatedly.

What causes the loudness of the sound to vary? **[1]**

A diffraction of the sound waves

B Doppler shift of the sound waves

C interference of the sound waves

D reflection of the sound waves

Solution 31

A diffraction of the sound waves

B Doppler shift of the sound waves

C interference of the sound waves ✓

D reflection of the sound waves

Why

- Two loudspeakers driven by one signal generator are coherent sources.
- Their waves superpose, reinforcing at some points and cancelling at others.
- Walking through that fixed pattern is what makes the loudness rise and fall.

Question 31

9702/14 N25 ▪ Q31 ▪ 1 mark

Two light sources are used to produce an interference pattern.

Interference fringes appear when the two sources emit waves that are coherent.

What is meant by coherent waves? **[1]**

A The two waves are emitted with the same frequency.

B The two waves are emitted with constant phase difference.

C The two waves are emitted with the same intensity.

D The two waves are emitted with zero phase difference.

Solution 31

A The two waves are emitted with the same frequency.

B The two waves are emitted with constant phase difference. ✓

C The two waves are emitted with the same intensity.

D The two waves are emitted with zero phase difference.

Why

- Coherent means the phase difference between the two waves stays constant in time.
- It need not be zero – a steady 180° is just as coherent, so D is too strict.
- Equal frequency is necessary but not sufficient, and equal intensity is not required at all.

Question 4

9702/22 N25 ▪ Q4 ▪ 8 marks

A laser emits visible light of a single frequency in a vacuum. The light is incident normally on a double slit and then forms a pattern of bright and dark fringes on a screen, as shown in Fig. 4.1.

The separation of the slits is 1.0×10^{-3} m. The distance from the slits to the screen is 4.8 m. The distance between the centres of adjacent dark fringes on the screen is 3.3 mm.

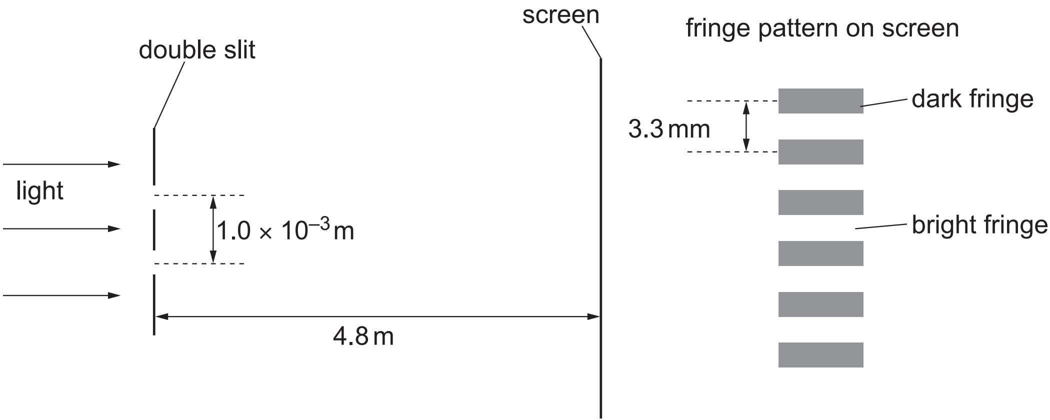
(a) Explain how the pattern of bright and dark fringes is formed. **[3]**

(b) Calculate the frequency of the light emitted by the laser. **[4]**

(c) The double slit is removed. A second laser is placed beside the first laser. The second laser produces visible light of a different frequency from that of the first laser. The beams of light from the two lasers overlap on the screen.

Explain why a steady pattern of bright and dark fringes is **not** formed on the screen.**[1]**

Question 4


screen
double slit
fringe pattern on screen
dark fringe
3.3 mm
light
bright fringe
1.0 × 10⁻³ m
4.8 m

Solution 4

(a)

Mark scheme

- light diffracts / spreads (at slit(s)) **B1**
- light (from each slit) superposes / interferes (at screen) **B1**
- when phase difference is 0 / path difference is $n\lambda$ (where n is an integer) a bright fringe is formed or when phase difference is 180(°) / path difference is $(n + 1)\lambda$ / 2 (where n is an integer) a dark fringe is formed **B1**

Solution 4

(b) Worked steps

Two steps: the fringes give you the wavelength, the wave equation turns it into a frequency.

- Double-slit formula: $\lambda = \dfrac{ax}{D}$
- $\lambda = \dfrac{1.0 \times 10^{-3} \times 3.3 \times 10^{-3}}{4.8} = 6.9 \times 10^{-7}$ m
- Sanity check: about 690 nm, which is red light — reasonable for a visible laser.
- $c = f\lambda$, so $f = \dfrac{c}{\lambda} = \dfrac{3.0 \times 10^{8}}{6.875 \times 10^{-7}}$
- $f = 4.4 \times 10^{14}$ Hz

Solution 4

Mark scheme

- $\lambda = \mathrm{ax} / \mathrm{D}$ **C1**
- $\lambda = 1.0 \times 10–3 \times 3.3 \times 10–3 / 4.8$
- $(= 6.875 \times 10–7\ \mathrm{m})$ **C1**
- $\mathrm{f} = \mathrm{v} / \lambda$ **C1**
- $= 3.0 \times 108 / 6.875 \times 10–7$
- $= 4.4 \times 1014\ \mathrm{Hz}$ **A1**

Solution 4

(c)

Mark scheme

- the light / beams (have different frequencies so) are not coherent / do not have constant phase difference **B1**

Question 31

9702/12 J25 ▪ Q31 ▪ 1 mark

Light of a single wavelength is incident normally on a double slit. Interference fringes are observed on a screen.

The distance from the double slit to the screen is 0.60 m and the fringe separation is 1.8 mm.

The distance from the double slit to the screen increases by 0.90 m.

What is the new fringe separation? **[1]**

A 1.2 mm

B 2.7 mm

C 4.5 mm

D 5.4 mm

Solution 31

A 1.2 mm

B 2.7 mm

C 4.5 mm ✓

D 5.4 mm

Why

- Fringe separation is $x = \lambda D/a$, so it is proportional to the slit-to-screen distance.
- That distance rises from 0.60 m to $0.60 + 0.90 = 1.50$ m, a factor of 2.5.
- $x = 1.8 \times 2.5 = 4.5$ mm; B uses only the extra 0.90 m.

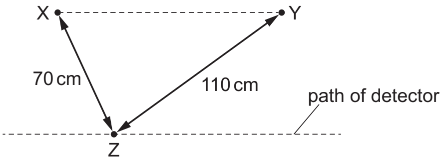
Question 28

9702/13 J25 ▪ Q28 ▪ 1 mark

28 Electromagnetic waves of equal wavelengths are emitted from two sources, X and Y. The waves are emitted from X and Y with a phase difference of 180°.

A detector moves along a path that is parallel to the line XY and detects a pattern of intensity maxima and minima.

The diagram shows the arrangement of the sources and the path of the detector.



An intensity maximum is detected at point Z. Length XZ is 70 cm and length YZ is 110 cm.

Question 28

What is a possible wavelength of the waves?

A 10 cm　　**B** 16 cm　　**C** 20 cm　　**D** 40 cm

Solution 28

Answer: **B**

Why

- The path difference is $110 - 70 = 40$ cm.
- The sources are in *antiphase*, so a maximum needs an odd number of half-wavelengths: $40 = (n + \frac{1}{2})\lambda$.
- That gives $\lambda = 80/(2n + 1)$ – 80, 26.7, 16, ... cm – and only 16 cm is offered.

Question 27

9702/14 J25 ▪ Q27 ▪ 1 mark

27 Red light of a single wavelength from a laser is incident on a double slit.

A pattern of interference fringes is observed on a flat screen that is placed parallel to the double slit.

Which change increases the separation of the interference fringes on the screen?

A Decrease the distance from the double slit to the screen.

B Decrease the separation of the slits.

C Replace the red light with blue light.

D Replace the red light with green light.

Solution 27

Answer: **B**

Why

- Fringe separation is $x = \lambda D/a$.
- Reducing the slit separation a makes x larger.
- A reduces D and C shortens the wavelength – both push the fringes closer together.

Question 4

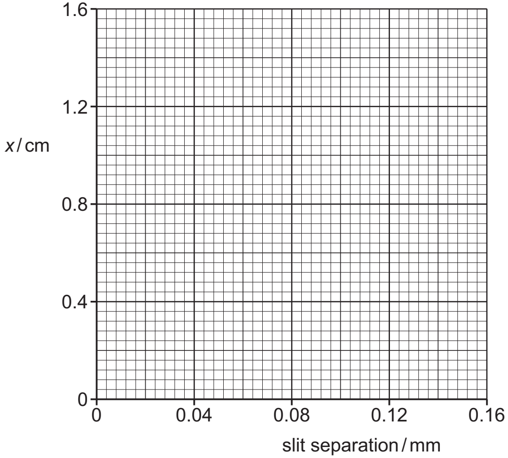
9702/21 J25 ▪ Q4 ▪ 8 marks

(a) State the principle of superposition. **[2]**

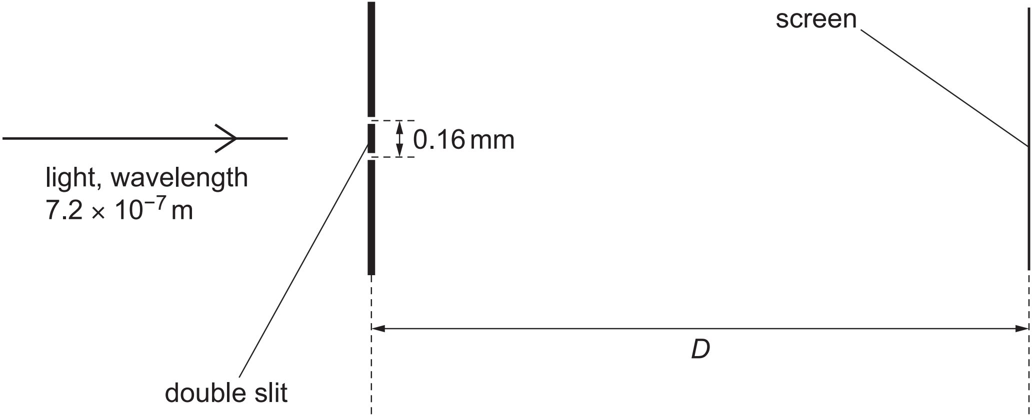
(b)(i) The distance between the centres of the first and ninth dark fringes is 3.2 cm.
Calculate *D*. **[3]**

(b)(ii) The slit separation is now gradually decreased from 0.16 mm to 0.04 mm. The distance between the centres of adjacent dark fringes is *x*.
On Fig. 4.3, sketch the variation of *x* with slit separation. **[3]**

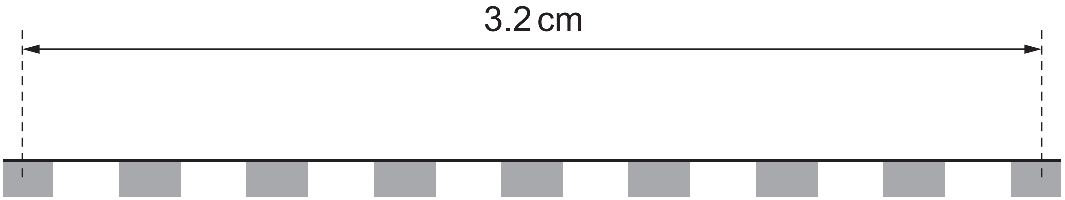
Question 4



Question 4



Question 4



Solution 4

(a)

Mark scheme

- (when two or more) waves meet / overlap (at a point) **B1**
- (resultant) displacement is sum of the individual displacements **B1**

Solution 4

(b)(i) Worked steps

The trap is the fringe count: from the **first** to the **ninth** fringe there are eight gaps, not nine.

- Fringe spacing $x = \dfrac{3.2 \times 10^{-2}}{8} = 4.0 \times 10^{-3}$ m
- Rearrange $\lambda = \dfrac{ax}{D}$ to give $D = \dfrac{ax}{\lambda}$.
- $D = \dfrac{0.16 \times 10^{-3} \times 4.0 \times 10^{-3}}{7.2 \times 10^{-7}}$
- $D = 0.89$ m

Solution 4

Mark scheme

- Fringe width, $x = 3.2 \times 10{-}2 \,/\, 8$
- $= 4.0 \times 10{-}3$ (m) **C1**
- $D = ax \,/\, \lambda$
- $= (4.0 \times 10{-}3 \times 0.16 \times 10{-}3) \,/\, 7.2 \times 10{-}7$ **C1**
- $= 0.89$ m **A1**

Solution 4

(b)(ii) Worked steps

$x = \dfrac{\lambda D}{a}$, so with λ and D fixed, x is **inversely proportional** to a: halve the slit separation and the fringes spread twice as far apart.

- Work out two or three points to guide the curve: at $a = 0.16$ mm, $x = 0.4$ mm; at 0.08 mm, $x = 0.8$ mm; at 0.04 mm, $x = 1.6$ mm.
- Draw a smooth curve through them: always falling, and getting less steep as a increases.
- It must not be a straight line — that is the mark this question is really testing.

Solution 4

Mark scheme

- Curved line with a negative gradient of decreasing magnitude throughout, from slit separation 0.04 mm to 0.16 mm **B1**
- Line of negative gradient ending at (0.16, 0.4), from slit separation 0.04 mm **B1**
- Line of negative gradient passing through (0.08, 0.8) and (0.04, 1.6) **B1**

Question 27

9702/12 M25 ▪ Q27 ▪ 1 mark

27 Light waves are emitted from two sources.

What is a necessary condition for observable interference fringes to be produced?

A The waves must be polarised.

B The waves must **not** be polarised.

C The waves must be coherent.

D The waves must have equal amplitudes.

Solution 27

Answer: **C**

Why

- Observable fringes need a constant phase relationship between the two sets of waves – coherence.
- Without it the pattern shifts about too quickly to be seen.
- Equal amplitudes only sharpen the contrast, and polarisation is not the issue here.

Question 6

9702/21 N24 ▪ Q6 ▪ 9 marks

6 Two coherent sources X and Y of microwaves of frequency 2.5 $\times$ 1010 Hz are a distance of 0.18 m apart in a vacuum, as shown in Fig. 6.1. P Q 2.3 m 0.18 m A O X Y Fig. 6.1 (not to scale)

There is a phase difference of 90° between the waves emitted at the two sources.

A microwave detector moves along the line PQ, which is parallel to the line joining the two sources and 2.3 m away from it.

Point O is on the line PQ at a position that is equidistant from the two sources.

Point A is the position on line PQ where the intensity of the microwaves is the greatest.

(a) (i) Explain why the position of greatest intensity is not at point O [2]

(ii) On Fig. 6.1, draw a cross ($\times$) to show the position of the point on line PQ where the intensity minimum that is the closest to point O occurs. Label this point B. [2] , ,

(b) (i) Show that the wavelength of the microwaves is 0.012 m.

Question 6

[2]

(ii) For point A on line PQ, determine the difference in the distances Δx travelled by the microwaves from X and the microwaves from Y.

$\Delta x =$ m [1]

(iii) Use the formula for the double-slit interference of light to calculate the distance between adjacent intensity maxima on line PQ.

distance = m [2]

, ,

(a)(i) Explain why the intensity detected at point O is not a maximum. **[2]**

(a)(ii) On Fig. 6.1, mark with the letter B another point on PQ at which the intensity is the same as that at point A. **[2]**

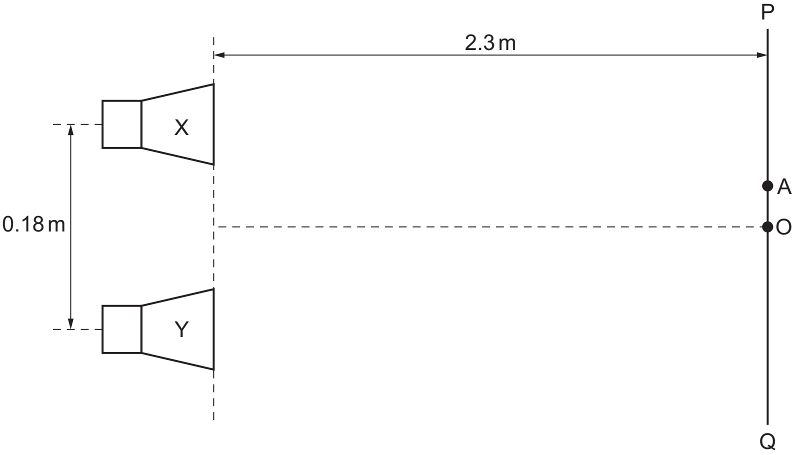
(b)(i) Calculate the wavelength of the microwaves. **[2]**

Question 6

(b)(ii) Determine the path difference, in terms of the wavelength, between the waves arriving at a point where the intensity is a maximum. **[1]**

(b)(iii) Determine the distance along PQ between adjacent points of maximum intensity. **[2]**

Question 6



Solution 6

(a)(i)

Worked steps

- A maximum needs the two waves to arrive **in phase**.
- O is the same distance from X as from Y, so the path difference there is zero — the waves arrive with the phase difference they were emitted with.
- That is 90°, not zero, so they do not fully reinforce and O is not a maximum.

Mark scheme

- for maximum intensity, waves must be in phase (at detection)
- (phase difference at source means) waves are not in phase / have a 90° phase difference at O

Solution 6

(a)(ii)

Worked steps

The pattern is symmetrical about O, so every point has a partner on the other side.

- Mark B on PQ on the **opposite side of O from A**, the same distance from O.
- Say so on the diagram: $OB = OA$.

Mark scheme

- point B labelled on the line PQ below O
- distance OB = distance OA

Solution 6

(b)(i) Worked steps

- $v = f\lambda$, and microwaves travel at the speed of light in a vacuum.
- $\lambda = \dfrac{c}{f} = \dfrac{3.00 \times 10^8}{2.5 \times 10^{10}}$
- $\lambda = 0.012$ m (12 mm)

Solution 6

Mark scheme

- $v = f\lambda$
- $\lambda = (3.00 \times 108) / (2.5 \times 1010) = 0.012\,\mathrm{m}$

Solution 6

(b)(ii) Worked steps

The path difference must undo the 90° head start built into the sources.

- 90° is a quarter of a cycle, and one whole cycle is one wavelength.
- So the waves arrive in phase where the path difference is $\dfrac{\lambda}{4} = \dfrac{0.012}{4} = 0.003$ m (3 mm).

Solution 6

Mark scheme

- $\Delta x = 0.012 / 4$
- $= 0.0030\,\mathrm{m}$

Solution 6

(b)(iii) Worked steps

This is the double-slit formula with the sources acting as the two slits.

- $x = \dfrac{\lambda D}{a}$, with $\lambda = 0.012$ m, $D = 2.3$ m and $a = 0.18$ m.
- $x = \dfrac{0.012 \times 2.3}{0.18}$
- $x = 0.15$ m

Solution 6

The spacing is large enough to walk between, which is why microwaves are used to show interference in a classroom.

Mark scheme

- $\lambda = ax \,/\, D$
- distance $= \lambda D \,/\, a = 0.012 \times 2.3 \,/\, 0.18$
- $= 0.15$ m
- 9702/21
- October/November 2024