Pages 112–114 Exam practice questions

1 Answer B

2 Answer A

3 Answer D

4 Answer C

5 Answer A

6 Answer B

7 Answer B

8 Answer C

9 a) Spacing, $d = 1 \times 10^{-3}/500 = 2 \times 10^{-6}$ m

b) $\sin\theta = n\lambda/d$ so $\theta = \sin^{-1}(3 \times 633 \times 10^{-9})/2 \times 10^{-6} = 71.7^{\circ}$

c) No as $(4 \times 633 \times 10^{-9})/2 \times 10^{-6}$ is greater than 1. Sine has a maximum value of 1.

10 a) Separation, $x_n = n\lambda D/a = 10 \times 557 \times 10^{-9} \times 3 / 0.3 \times 10^{-3} = 0.557$ m

b) The student could increase the separation of the screen and slits (but this reduces the intensity), increase the wavelength using a different source of light or decrease the separation of the slits.

11 a) Wavelength of light similar to the spacing between eyelashes; light must contain more than one colour for a spectrum to be seen.

b) When the spacing is taken as 0.1 mm, $\sin\theta = n\lambda/d$, so $\sin\theta_4 = 4 \times 400 \times 10^{-9}/0.1 \times 10^{-3}$ at a minimum, up to a maximum of $\sin\theta_4 = 4 \times 700 \times 10^{-9}/0.1 \times 10^{-3}$. The range of angles that the first order spectrum will be see is $\theta_1 = 0.92^{\circ}$–1.6°

c) These angles are so small, so it is unlikely that the spectrum can be viewed close up (i.e. resolution is insufficient); the coloured fringes are so close that the spectrum is likely to overlap and so the spectrum will not be visible (colours blending into each other).

12 a) A stationary wave is a wave formed from the superposition of two waves travelling in opposite directions in a bounded space with nodes and antinodes in fixed positions.

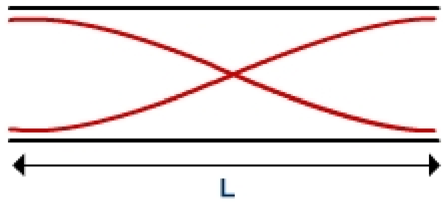
b) i) $\lambda = c/f = 3 \times 10^{8}\ \text{ms}^{-1}/\ 2.4 \times 10^{9}\ \text{m} = 0.125$ m

ii) Distance between antinodes = $\lambda/2 = 0.0625$ m

c) The cheese melts at the antinodes where the microwaves have maximum amplitude, and in between, at nodes, the cheese is unmelted; frequency = $c/\lambda = 2c/d$ where d is the distance between antinodes.

© Nick England, Jeremy Pollard, Nicky Thomas & Carol Davenport 2015

13



The node is in the centre of the pipe; antinodes are at each end of the pipe.

Nodes form where there is destructive superposition and the waves travelling in opposite directions cancel out.

Antinodes form where there is constructive superposition and the amplitudes of waves travelling in opposite directions reinforce.

Conditions needed are two waves travelling in opposite direction with equal speed, amplitude and frequency; the open pipe must be $\lambda/2$ long.

14 a) e.g. evidence that light waves can interfere with each other and therefore evidence for the wave nature of light.

b) Coherent waves have a fixed phase difference frequency and amplitude; fringe pattern is due to constructive (path difference of $n\ \lambda$] and destructive interference (path difference of $(n + 1/2)\ \lambda$).

c) The equation for Young's slits is $ws/D = \lambda$

so $s/D = \lambda/w = 460 \times 10^{-9}$ m$/1.8 \times 10^{-3}$ m $= 2.6 \times 10^{-4}$.

15 a) The light has a single frequency (do not accept a single colour).

b) The fringes either side of the central peak are further apart; the graph remains symmetrical; the central maximum is wider than the subsidiary fringes.

c) The risk from lasers is damage to cells in the eye as laser light is very intense. Reduce this by one of the following: do not shine lasers directly at people or direct the reflections into their eyes; use warning signs or laser goggles; stand behind the laser.

d) The central maximum is white; fringes either side are separated into a spectrum with red furthest from the centre; fringe spacing for each individual colour is less than the fringe spacing for the central white fringe.

16 a) For first-order maxima, the path difference from adjacent slits, a distance d apart, is λ for light travelling at angle θ_1. Sin θ_1 is opposite/hypotenuse and the hypotenuse is the slit spacing and the opposite side is the path difference.

Substituting, the condition for constructive interference is $\sin \theta_1 = \lambda/d$

For second-order fringes, the path difference is 2λ and light travels at angle θ_2 to the direction of incident light. The equation becomes: $\sin \theta_2 = 2\lambda/d$. This means that $\sin \theta_n = n\lambda/d$, where n is a whole number,

© Nick England, Jeremy Pollard, Nicky Thomas & Carol Davenport 2015

b) sin $\theta_n = n\lambda/d$ where n is a whole number. As λ increases, sin θ increases so the maxima either side of the central maxima move further apart. Higher order maxima are not seen if $n\lambda/d$ is more than 1 (sin θ_n cannot be more than 1) so fewer sets of maxima will be seen.

c) $d \sin\theta_n/n = \lambda = 1 \times 10^{-6}$ m × (sin 70)/3 = 3.1×10^{-7} m

17 d sin42 = $n\lambda = 1.338 \times 10^{-6}$ m

If $n = 2$, $\lambda = 669$ nm

If $n = 3$, $\lambda = 446$ nm

the red light is 2nd order, the blue light is 3rd order.

18 a) Slit spacing = 1×10^{-3} m/300 = 3.3×10^{-6} m

a) $\sin\theta/n = \lambda/d = 7 \times 10^{-7}/3.3 \times 10^{-6} = 0.21$

$\sin\theta = 0.21 \times n$, and cannot be more than 1.

n can be 0,1,2,3,4

$\theta = 0°$ (1st order); 12° (1st order); 25° (2nd order); 39° (3rd order); 57° (4th order)

Pages 114–115 Stretch and challenge questions

19 All methods result in a fringe pattern. Dark fringes are due to destructive interference (path difference $(n + 1/2)\lambda$), and bright fringes due to constructive interference from the light sources (path difference $n\lambda$).

The number of slits in the experiments varies: diffraction can be seen through one slit, or through a grating with hundreds of slits, and Young's experiment uses 2 slits to see interference. The narrowest slits are in the diffraction grating.

The resolution (sharpness) of fringes is greatest with the diffraction grating so it is used to separate out spectral colours of light.

Increasing the number of slits increases the number of fringes visible. Increasing the width of the single slit increases the width of the central maxima. Different maxima are seen for different orders for diffraction $\sin\theta = n\lambda/d$; for Young's double slits the angle is so small that the small angle approximation is used: $a x_n/D = n\lambda$

In Young's experiment, the fringes are equal in intensity; with a single slit, there is a brighter central maxima; with many slits there are fewer fringes more widely spaced.

20 The red light diffracts more than violet light so:

for red light, $\sin\theta_1 = \lambda/d = 700 \times 10^{-9}/d$

for violet light, $\sin\theta_2 = 2\lambda/d = 400 \times 10^{-9} \times 2/d = 800 \times 10^{-9}/d$

1st and 2nd orders do not overlap as the second order angle for violet light is greater than the first order angle for red light.

$\sin\theta_2 = \lambda/d = 1400 \times 10^{-9}/d$; $\sin\theta_3 = 2\lambda/d = 400 \times 10^{-9} \times 3/d = 1200 \times 10^{-9}/d$

© Nick England, Jeremy Pollard, Nicky Thomas & Carol Davenport 2015

2nd and 3rd orders do overlap as the third order angle for violet light is less than the second order angle for red light

21 a) Path difference = AR – BR

b) There is an intensity maximum when the waves are in phase. Since there is a phase difference on reflection, the path difference must be (n +1/2) λ for the waves to be in phase if they are initially in phase.

AR = 100/(sin θ); BR/AR = θ and BR = AR cos 2θ

So:

AR – BR = 100/(sin θ) [1 – cos 2θ] = {100/(sin θ)} × [2sin^2 θ] = 200 sin θ

c) As the Sun sets the angles of the incident rays changes so the angle θ changes. The path difference continuously changes from whole wavelengths (minimum) through to half wavelengths (maximum).

a) Sinθ changes most rapidly for small values of θ so these changes will be most rapid when the Sun is low.

22 The answer is in the question. If the path difference between the first and second slit is 0.01λ, the path difference between the first and fifty-first slit is λ/2. So, the light from each slit is cancelled by the light from a slit 50 below it. Thus the maxima are very sharp because the path difference between each slit must be very close to λ, 2λ etc.

23 a) The ray reflecting from the top face of the lower slide.

b) The waves have a path difference of (n + ½) λ where n is a whole number.

c) Path difference for destructive interference = (n + ½) λ = 2d + λ/2 (allowing for the phase change on reflection) so $n\lambda$ = 2d.

d) The wavelength in the liquid is smaller than the wavelength in air, so the fringe spacing gets closer.

The wavelength increases, so the fringe spacing increases.

© Nick England, Jeremy Pollard, Nicky Thomas & Carol Davenport 2015