Answers to Coursebook questions – Chapter G3

1 $d\sin\theta = n\times 680$ and $d\sin\theta = (n+1)\times 510$.
Thus, $n\times 680 = (n+1)\times 510 \Rightarrow 680n = 510n + 510 \Rightarrow n = 3$.

2 The waves arriving at the observer from the two speakers interfere due to the path difference between them. At point P there must be destructive interference.
At P we must have $d\sin\theta = (0+\frac{1}{2})\lambda$. The angle obeys $\tan\theta = \frac{2}{12} \Rightarrow \theta = 9.46^\circ$.
Hence, $1.0\times\sin 9.46^\circ = (0+\frac{1}{2})\lambda \Rightarrow \lambda = 0.329 \approx 0.33\text{ m}$.

Note: Using the small-angle approximation would give $\sin\theta \approx \tan\theta = \frac{2}{12}$
and so $1.0\times\frac{2}{12} = (0+\frac{1}{2})\lambda \Rightarrow \lambda = 0.333\text{ m}$ in agreement with the above.

3 The separation is given by the booklet formula $s = \frac{\lambda D}{d} = \frac{680\times10^{-9}\times1.50}{0.12\times10^{-3}} = 8.5\text{ mm}$.

4 The two flashlights are not coherent. This means that the phase difference between them keeps changing with time (very fast, on a timescale of nanoseconds). Thus, whatever interference pattern is produced at any moment in time, a different pattern will be produced a nanosecond later. Therefore all we can observe is an average of the rapidly changing patterns on the screen, i.e. no interference at all.

5 Assuming that the film does not introduce any additional phase differences, then at the points where we had constructive interference we will still have constructive interference but the brightness of the maximum will be reduced.
At the points we used to have destructive interference, the two waves will no longer cancel out completely since the two amplitudes will not be equal. Thus instead of a dark fringe we will have some light.

6 Interference of sound is the reason for the observations. The intensity will never be exactly zero anywhere since

i there is sound reflected from walls, the floor etc.

ii the sources of sound are not point sources

iii the sound emitted does not have just one wavelength but a small range of wavelengths.

7 We use $s = \dfrac{\lambda D}{d}$.

a The spot separation will increase.

b The spot separation will increase.

c The separation will increase but the brightness of the spots will decrease.

d There will be no effect on the separation but the brightness of the spots will decrease.

8 **a** The distance is given by $s = \dfrac{5\lambda D}{d} = \dfrac{5\times 644\times 10^{-9}\times 1.2}{1.0\times 10^{-3}} = 3.864 \approx 3.86\ \text{mm}$.

b In water the wavelength of light would be $\dfrac{644\times 10^{-9}}{1.33} = 484\times 10^{-9}\ \text{m}$

and so the separation in **a** would decrease accordingly to $\dfrac{3.864}{1.33} = 2.91\ \text{mm}$.

9 We have destructive interference at point B.

The wavelength is $\lambda = \dfrac{c}{f} = \dfrac{3.0\times 10^{8}}{95.0\times 10^{6}} = 3.158\ \text{m}$.

The distance AB is $s = \dfrac{1}{2}\dfrac{\lambda D}{d} = \dfrac{1}{2}\dfrac{3.158\times 2.0\times 10^{3}}{30} = 105\ \text{m}$.

10 **a** The intensity alternates with a frequency of 0.560 Hz, i.e. every $\dfrac{1}{0.560} = 1.7857\ \text{s}$.

In this time the satellite travels a distance of $7.50\times 1.7857 = 13.39 \approx 13.4\ \text{km}$.

b Using

$$s = \frac{\lambda D}{d} \Rightarrow 13.39\times 10^{3} = \frac{1.50\times D}{80} \Rightarrow D = 714.13\times 10^{3}\ \text{m} \approx 714\ \text{km}$$

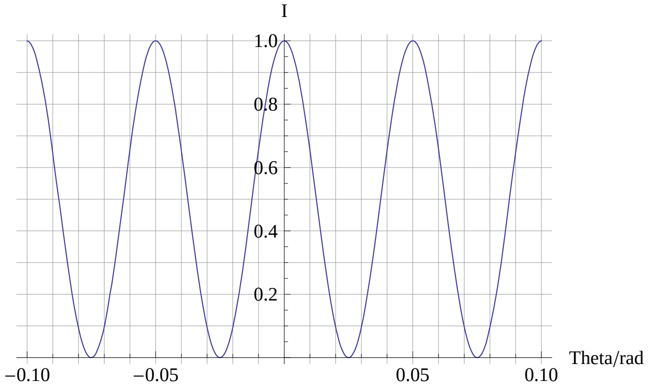
11 We must have $d \sin 20^{\circ} = 1\times\lambda$ and so $d = \dfrac{\lambda}{\sin 20^{\circ}} = 2.92\times\lambda$.

12 The separation of the maxima will increase as in the graph provided in the answers on page 814 in *Physics for the IB Diploma*.

13 It must be that at the position of the third maximum on either side we now get a diffraction minimum from diffraction within a slit.
The angular position of the third interference maximum is given by $d\sin\theta = 3\lambda$.
At the same angle we must have the first diffraction minimum given by $b\sin\theta = \lambda$ and so $\dfrac{3\lambda}{d} = \dfrac{\lambda}{b}$, giving a slit width $b = \dfrac{d}{3}$.

14 **a** Coherent light means light where the phase difference between any two points on the same cross-section of the beam is constant. Monochromatic light means light of the same wavelength.

b



c The effect of slit width is not on the syllabus, and this part of the question should be ignored.

15 **a**

$$\frac{1}{350}\sin 8.34^\circ = 1\times\lambda_1 \Rightarrow \lambda_1 = 4.14\times10^{-4}\text{ mm} = 414\text{ nm}$$ and

$$\frac{1}{350}\sin 8.56^\circ = 1\times\lambda_2 \Rightarrow \lambda_2 = 4.25\times10^{-4}\text{ mm} = 425\text{ nm}$$.

b

$$\frac{1}{350}\sin\theta_1 = 2\times4.14\times10^{-4} \Rightarrow \theta_1 = 16.84598^\circ$$ and

$$\frac{1}{350}\sin\theta_2 = 2\times4.25\times10^{-4} \Rightarrow \theta_1 = 17.30751^\circ$$ so that

$$\theta_2 - \theta_1 = 17.30751^\circ - 16.84598^\circ = 0.462^\circ .$$

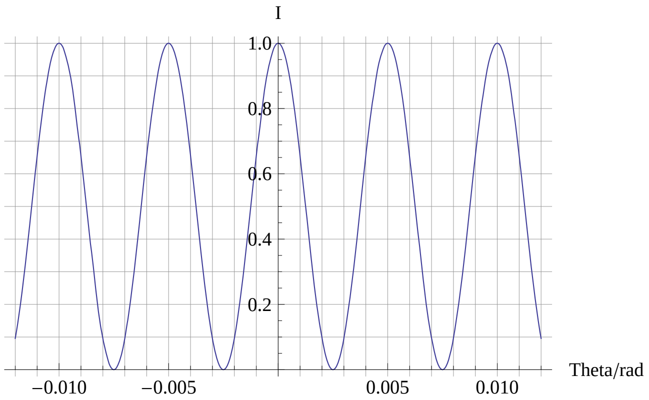
16 **a** Use $d\sin\theta = n\lambda$ with $d = \frac{1}{400}$ mm and $\lambda = 600.0$ nm to get

n	θ
0	0.0°
1	13.89°
2	28.69°
3	46.05°
4	73.74°

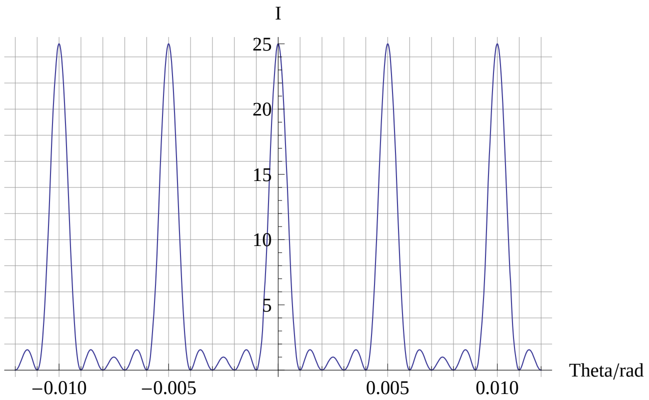
b $n = 4$

17 The central maximum appears white as it is composed of all visible wavelengths. The higher-order maxima are coloured. For example, the first-order maximum for $\lambda = 400.0\ \text{nm}$ occurs at 9.21° and that for a wavelength of $\lambda = 700.0\ \text{nm}$ at 16.26°.

18 **a**



b



Notice the generic features of increasing the number of slits. First, the appearance of secondary maxima (3 in the case of 5 slits) and the fact that the positions of the maxima are the same as for the 2 slit case. Note also how narrow the maxima have become compared to the 2 slit case. Notice finally, that the maximum intensity is much larger than for the 2 slit case.