Mark schemes

1 A

[1]

2 C

[1]

3 A

[1]

4 B

[1]

5 sin*θ* = *nλ*/*d* in this form/correct calculations of *d*/*d* = 1/300

C1

substitutes correctly – condone powers of 10

C1

18.9

C1

2 or 3 sf only

A1

[4]

6 (a) 1.06×10^{-6} m

B1

1

(b) use of $n\lambda = d\sin\theta$ with $n = 2$ and d = ans to (a)

C1

$\lambda = 1.06 \times 10^{-6} \times \sin 55°/2$

C1

4.34×10^{-7} m

A1

3

[4]

7 (a) (i) $= 590 \times 10^{-9}$m **(1)**

(using $d \sin \theta = n\lambda$ gives)

$\sin\theta = \frac{n\lambda}{d}$ or $= \frac{2 \times 590 \times (10^{-9})}{1.67 \times 10^{-6}}$ **(1)** = **0.707** or

7.07×10^8 if nm used **(1)**

$\theta = 45.0°$ **(1)** (accept 45°)

(ii) ($\sin\theta \le 1$) gives $\frac{n\lambda}{d} \le 1$ or $n \le \frac{d}{\lambda}$ or $= \frac{1.67 \times 10^{-6}}{590 \times 10^{-9}}$ **(1)** = 2.83 **(1)**

so 3rd order or higher order is not possible **(1)**

alternative solution:
(substituting) ***n* = 3** (into $d \sin \theta = n\lambda$ gives) **(1)**

$\sin\theta \left(= \frac{n\lambda}{d} = \frac{3 \times 590 \times 10^{-9}}{1.67 \times 10^{-6}}\right) = 1.06$ **(1)**

gives 'error'/which is not possible **(1)**

7

(b) (using $d \sin \theta = n\lambda$ gives)

$2\lambda = 1.67 \times 10^{-6} \times \sin 42.1$ **(1)**

$\lambda (= 0.5 \times 1.67 \times 10^{-6} \times \sin 42.1) = 5.6(0) \times 10^{-7}$ m (or 560 nm) **(1)**

2

[9]

8 (i) use of (26 ± 2) mm for 2θ **or** (13 ± 1) mm for θ

M1

range 2.60 → 3.02

A1

(ii) $n\lambda = d \sin \theta$ seen

M1

substitution with correct powers
$1.20 \times 10^{-5} \rightarrow 1.40 \times 10^{-5}$

A1

$1/d$ or number of lines m^{-1} calculated
71400 → 833300 needs unit

B1

conversion to number of lines mm^{-1}
71(.4) → 83(.3) needs unit

B1

[6]

9 (a) $d \sin \theta = n \lambda$ or $d \sin 12 = 6.3 \times 10^{-7}$

C1

3.0×10^{-6} m

A1

2

(b) $n \sin 90 = (\leq)\ 3.0 \times 10^{-6} / 6.3 \times 10^{-7}$ or $n = 4.8$

Allow for approach using different n values even if unsuccessful

C1

number of orders visible = 4

A1

Total maxima = twice their maximum order + 1

B1

3

[5]

10 (a) Separation = 1/630000

B1

1

(b) (i) quote $n\lambda = d \sin\theta$

C1

$\lambda = 1.59 \times 10^{-6} \times \sin(25.4)$

C1

$= 6.8 \times 10^{-7}$ m or 6.8×10^{-4} mm

A1

3

(ii) Central maximum/zeroth order mentioned

B1

Central maximum is white

B1

Describe/draw 1st/2nd orders colours in correct order

B1

Third order overlap
symmetry of pattern
dispersion change
fainter away from centre

B1

max 4

[8]

11

(a) (i) 0, 2π or 4π [or 0, 360° or 720°] **(1)**

(ii) 4λ **(1)**

(iii) $\sin\theta = \frac{CE}{AC}$ **(1)**

[or $\sin\theta = \frac{BD}{AB}$]

CE = 4λ and AC = $2d$ **(1)** (hence result)

[or BD = 2λ and AB = d]

max 3

(b) (limiting case is when θ = 90° or $\sin\theta$ = 1)

$$n\left(=\frac{d\sin\theta}{\lambda}\right) = \frac{2.22\times10^{-6}(\times1)}{486\times10^{-9}}$$ **(1)** (= 4.6)

highest order is 4th **(1)**

2

[5]

12

(a) Answer D ✓ (violet)

1

(b) (light from each slit) <u>superpose</u>
light from adjacent slits have a path difference of <u>one</u> wavelength
(at this angle all) the waves are in phase
constructive interference / peaks coincide / (positively) reinforce

any 3 points ✓ ✓ ✓ max 3

Ignore reference to nodes or antinodes

If general statements are made only give marks for parts related to 'Bright line' or 'First order' which appears in the question.

3

(c) (i) use of $\sin\theta = \lambda / d = 5.3\times10^{-7} / 1.8\times10^{-6}$ ✓ (= 0.294)
θ = 17° ✓ (17.1°)

Answer alone scores both marks

2

(ii) (use of $n = d \sin \theta / \lambda$) $n_{max} = (d \sin 90° / \lambda) = d / \lambda$ = ✓

= $1.8 \times 10^{-6} / 5.3 \times 10^{-7} = 3.4$ ✓

max order = 3 ✓

Showing that n=4 is not possible is not answering the question but the first mark (equation mark) can be gained this way

Max order is an independent mark from reducing a calculated value for n to the next lowest integer.

3

[9]

13 (a) one of:

(spectral) analysis of light from stars

(analyse) composition of stars

chemical analysis

measuring red shift \ rotation of stars ✓

insufficient answers:

'observe spectra', 'spectroscopy', 'view absorption \ emission spectrum', 'compare spectra', 'look at light from stars'.

Allow : measuring wavelength or frequency from a <u>named source</u> of light

Allow any other legitimate application that specifies the source of light. E.g.
absorbtion \ emission spectra in stars,
'observe spectra of materials'

1

(b) (i) first order beam
first order spectrum
first order image
✓

Allow 'n = 1', '1', 'one', 1st

1

(ii) the light at A will appear white (and at B there will be a spectrum)
OR greater intensity at A ✓

1

(c) (d = 1 / (lines per mm × 10^3)
= 6.757 × 10^{-7} (m) OR 6.757 × 10^{-4} (mm) ✓

($n\lambda = d \sin\theta$)
= 6.757 × 10^{-7} × sin 51.0 ✓ ecf **only** for :

- incorrect power of ten in otherwise correct calculation of d
- use of d = 1480, 1.48, 14.8 (etc)
- from incorrect order in bii

= 5.25 × 10^{-7} (m) ✓ ecf **only** for :

- incorrect power of ten in otherwise correct d
- from incorrect order in bii

Some working required for full marks. Correct answer only gets 2
Power of 10 error in d gets max 2
For use of d in mm, answer =
5.25 × 10^{-4} gets max 2
n = 2 gets max 2 unless ecf from bii
use of d = 1480 yields wavelength of 1150m

3

(d) n = d (sin90) / λ OR n = 6.757 × 10^{-7} / 5.25 × 10^{-7} ✓ ecf both numbers from c

= 1.29 so <u>no more</u> beams observed ✓ or answer consistent with their working

OR

2 = d (sinθ) / λ OR sinθ = 2 × 5.25 × 10^{-7} / 6.757 × 10^{-7} ✓ ecf both numbers from c

sinθ = 1.55 (so not possible to calculate angle) so <u>no more</u> beams ✓

OR $\sin^{-1}$(2 × (their λ / their d)) ✓
(not possible to calculate) so <u>no more</u> beams ✓ ecf

Accept 1.28, 1.3
Second line gets both marks
Conclusion consistent with working

2

[8]

14 (a) 2.9% ✓

Allow 3%

1

(b) $\frac{1}{3.5 \times 10^3}$ seen ✓

1

0.29 mm or 2.9 x 10^{-4} m✓ must see 2 sf **only**

1

(c) ± 0.01 mm ✓

1

(d) Clear indication that at least 10 spaces have been measured to give a spacing = 5.24 mm✓

spacing from at least 10 spaces
Allow answer within range ±0.05

1

(e) Substitution in $d\ sin\theta = n\lambda$✓

The 25 spaces could appear here as n with sin θ as 0.135 / 2.5

1

d = 0.300 x 10^{-3} m so
number of lines = 3.34 x10^3✓

Condone error in powers of 10 in substitution
Allow ecf from 1-4 value of spacing

1

(f) Calculates % difference (4.6%) ✓

1

and makes judgement concerning agreement ✓

Allow ecf from 1-5 value

1

(g) care not to look directly into the laser beam✓
OR
care to avoid possibility of reflected laser beam ✓
OR
warning signs that laser is in use outside the laboratory✓
ANY ONE

1
[10]

15 (a) filament lamp / sun etc.

B1
(1)

(b) (i) $d = 1.0 \times 10^{-4}$ m

C1

use of $\lambda = d\sin\theta$ or substituted values

C1

$\theta_1 = 0.286° / 0.29°$

A1
(3)

(ii) $\Delta\theta = 0.115°$ (c.a.o.)

B1
(1)

(iii) width = 4.0×10^{-3} m or 3.9×10^{-3} m (e.c.f. for 2 × sin (b(ii)) or 2 × tan (b(ii)); allow 1 s.f.)

B1
(1)

(c) lower intensity

because energy spreads **C1**

use or statement of inverse square law **C1**

ratio 0.16 or falls by factor of 6.25 c.a.o. **C1**

A1

(4)

[10]

16 (a) (i) vertical or parallel **(1)**
equally spaced **(1)**
black and yellow [or dark and light] bands **(1)**

(ii) $w\left(=\frac{\lambda D}{s}\right)=\frac{5.86\times10^{-7}\times1.8}{0.36\times10^{-3}}$ **(1)**

$= 2.9 \times 10^{-3}$ m **(1)**

$\tan\theta = \frac{2\times2.9\times10^{-3}}{1.8}$ **(1)** gives $\theta = 0.18°$ **(1)**

(iii) narrower slits give more diffraction **(1)**
more overlap (so more fringes) **(1)**
fringes same width **(1)**

(max 8)

(b) (i) $d = \frac{1}{400\times10^{3}}$ **(1)**

$\frac{1}{400\times10^{3}} \times \sin\theta = 5.86 \times 10^{-7}$ **(1)**

$\theta = 13.6°$ **(1)**

(ii) $\theta = 90°$ and correctly used **(1)**

$n = \frac{1}{400\times10^{3}\times5.86\times10^{-7}} = 4.3 \therefore$ 4th order **(1)**

(5)

(c) brighter images **(1)**
large angles **(1)**
sharper (or narrower) lines **(1)**

(max 2)

[15]

17

(a) λ correct **(1)**

d correct **(1)** arrow or line needed, both ends extending beyond central black line

2

(b) angle θ gets smaller **(1)**

because path difference gets smaller/***d* constant**, (λ smaller) so sin θ smaller **(1)**

max 1 for correct explanation for λ increasing

2

(c) boxes 1,5,6 **(1)(1)**

two correct 1 mark

4 ticks max 1

5 or 6 ticks gets 0

2

(d) (i) 3.3×10^{-6} m **(1)** ($1/300 = 3.33 \times 10^{-3}$ **mm**, 3300 **nm**) DNA 1 sf here DNA 1/300 000 as answer

accept 3 1/3 × 10^{-6}, 3.33 × 10^{-6} recurring, etc

1

(ii) $(\sin\theta =)\ \dfrac{540 \text{ to } 560 \times (10^{-9})}{((d)(i))}$ **(1)**

correct wavelength used and seen (**545 to 548 × 10^{-9}**)

and 9.4 to 9.6 (°) **(1)** ecf (d) (i), for correct wavelength only (545 to 548 × 10^{-9})

2

[9]

Examiner reports

5 Many candidates answered this question well. The most common error was to use the value for the number of lines per mm as the grating spacing. Otherwise, a few candidates had their calculators set in radians rather than degrees. Significant figures were coped with well.

6 Large numbers of candidates scored well on this part, apart from the inevitable difficulties with powers of ten, but let themselves down by omitting the unit or by writing mm for m (or vice-versa). Even more able candidates need to pay attention to checking these matters. Examiners were looking not just for a final answer but for a clear exposition of the calculation in this part. Again, as in an earlier question, it is apparent that some can recognise the equation to use but not which quantity to substitute for the various symbols.

7 There were common mistakes to part (a) (i), such as failing to put n = 2. Some candidates thought n was the refractive index and for this reason put n = 1. A significant number did not convert from nm to m. Part (a) (ii) was done very well by the majority of candidates, either by substituting in 90° or n = 3. Most were successful in finding the wavelength to part (b).

8

(i) Few candidates used both first order images to calculate *26* and hence *6.* Many went straight into either the diffraction grating equation or single slit equation and used incorrect values for the variables.

(ii) Having used the diffraction grating equation in (i) many candidates made incorrect use of the double slit equation here or else used the diffraction grating equation again but calculated n as number of lines per mm. Only a limited number were able to progress all the way through this calculation.

9

(a) Some incorrectly quoted and used $\sin\theta = \lambda/b$ but most used the appropriate formula. Forgetting a unit cost some the second mark.

(b) Relatively few gained all three marks here. Those who were on the right track obtained 4.8 and rounded down to 4 orders but then forgot about the symmetry of the pattern and the central maximum. There was a significant proportion who simply divided 180° by 12°.

10 This question examined topics in diffraction-grating theory.

(a) Many could show successfully how the grating spacing was calculated.

(b) (i) Again many could carry out the simple calculation accurately. Common errors were to treat n in the equation $n\lambda = \sin\theta$ not as '1' but as 6.30×10^5 lines per metre, and to carry through the calculation in millimetres, but express the answer in metres.

(ii) Judging by the poor quality of many answer, few candidates have ever seen a diffraction grating pattern during their course of study. There were a number of possible scoring points available featuring the appearance of the central maximum, the order of colours (which could be deduced from the question), the overlap of orders, and so on. Only a few candidates scored more than one or two marks.

11 Knowledge of the derivation of $d \sin\theta = n\lambda$ for the diffraction grating is required by section 13.1.7 of the Specification. Fundamental to this derivation, is familiarity with the concepts of phase and path difference. Part (a) proved to be an effective test of candidates' understanding in these areas, and the question seemed to strike many candidates with apprehension: blank spaces were fairly common and ridiculous answers very frequent. Phase difference was particularly badly known, with many answers to part (i) expressed in terms of λ A correct answer of 4λ in part (ii) became almost a prerequisite for a successful approach to part (iii). Clearly $2\lambda = d \sin\theta$ can be shown by inserting $n = 2$ into the standard formula, but this was not the target of part (iii) and no marks could be awarded for such a trivial response.

Several recent questions about the diffraction grating in the Unit 4 Section A papers have covered areas similar in content to part (b), and candidates answers to this part were usually much more satisfactory than those in part (a). There was some confusion between the number of lines per metre (4.5×10^5) and the grating spacing (2.2×10^{-6} m). A small number of candidates took the numbers from their calculations too literally, quoting their final answers for the order as 4.57, whilst others failed to comprehend that this meant that the highest order would be the fourth rather than the fifth.

12

(a) Although the correct answer (violet) was the most common response all the alternatives were given in significant numbers.

(b) On the whole the answers were set out well. A majority of students discussed constructive interference as well as superposition. Inevitably some wrote 'superposition as 'superimposition'. It was also common to see an 'in-phase' statement but only a minority made all three statements. The idea that the path difference between light coming from adjacent slits was one wavelength was not seen often. The path difference was normally given as n times the wavelength. Students also failed to gain marks by describing the whole pattern of light and dark fringes in which it was not clear what part of the pattern a reference to 'constructive interference' belonged.

(c) (i) This calculation was performed well and the usual tail of students who have difficulty in using a calculator was not seen.

(ii) Most students performed this calculation as shown in the mark scheme. Other students who chose to show the diffraction angle of each order including the fourth order, which is not possible, could score full marks. However many of those students did not show enough work to justify their answer. For example, showing only that the fourth order is not possible does not exclude the answer 'second order'.

13

(a) There were some rather vague answers here such as ‘ *To calculate the wavelength of a light* or ‘ *to look at the light from stars*’. There needed to be a little more than this to get the mark, i.e. a specific example such as ‘analyse the elements present in the atmosphere of a star’ or explain that the composition of a material or gas can be determined.

(b) The candidates who knew this often lacked detail in their answer, e.g. ‘it would be dimmer’. Some thought there would only be one colour at **B** rather than a spectrum.

Quite a few thought that the wavelength at **B** would be different from **A** due to the increased angle.

Some candidates thought that the light at **B** would be composed of different wavelengths and the white light at **A** would be a single wavelength.

(c) This was a fairly standard exam question but surprisingly there were few correct answers. Students seemed to be poorly prepared for this question and confusion reigned regarding the meaning of the terms in the grating equation. Use of the *lines per mm* as the line spacing ($d = 1480$) was very common.

There was also confusion between line spacing, d, and order, n. Some used 1480 for d and for n.

Candidates often used 1 / 1480 and then failed to convert this into metres.

(d) There were a surprising number of candidates who did not attempt this question.
Even if they felt they had the wrong numbers for wavelength and line spacing in part (c), candidates simply needed to divide their d by their λ, and if greater than 1, conclude that no further orders are possible.

There was also some confusion over the method required, e.g. some used the angle given in part (c), (51°), and calculated a new wavelength that would give a second order at that angle.

15

(a) Many candidates incorrectly gave *laser* or *sodium vapour lamp* as a source producing a continuous spectrum.

(b) (i) Many candidates correctly calculated the first angle.

(ii) Many simply doubled the answer to part (i) to calculate the angular dispersion. Use of the sine or tangent was relatively uncommon and even with error carried forward few candidates gained the mark for the width of the first order spectrum.

(c) Most candidates recognised that the intensity would fall because the energy was being spread out over a larger area, many candidates recognised that this was an inverse square relationship but only the strongest calculated the correct factor.

16

Descriptions of the fringes in part (a)(i) were generally poor. In spite of the emphasis on the word **vertical**, hardly any candidates referred to the vertical lines which result. Furthermore, simple references to dark and bright equally-spaced bands were very rare. Confusion with the single diffraction pattern was common and some candidates contradicted themselves by referring to equally- spaced fringes at the same time as showing a diagram of the single slit pattern. Some of the descriptions made it difficult to believe that the writer had ever seen double slit interference fringes.

The large majority of candidates correctly calculated the fringe separation but failed to determine the angle. The word ‘angle’ frequently triggered the diffraction grating equation and, for those candidates who did attempt a simple geometrical calculation, many calculated the angle only to the first bright fringe and not the second. Such candidates penalised themselves by failing to read the question carefully. Several candidates who had calculated d correctly were quite prepared to offer a maximum order of thousands as their answer to part (b)(ii).

Answers to part (a)(iii) showed a general weak understanding of the relative parts played by interference and diffraction in this part of the question. One group of candidates failed to score any marks because they confused variation of slit width with slit separation and gave their answer in terms of the latter. For those candidates who did consider the narrowing of each slit, many scored only a single mark for recognising that the light at each slit will be diffracted through a larger angle. Although answers were often given in rather vague terms such as “more diffraction”. To gain full credit, it was necessary to refer to the greater area of overlap of the diffracted beams and to recognise that more fringes are seen in this increased area because the fringe width is unchanged. Hardly any candidates made the last of these two points.

Calculations in parts (b)(i) and (b)(ii) were done well and many candidates scored full marks. Common errors in part (b)(i) included incorrect conversion of units from 400 lines per millimetre, poor arithmetic and the often seen confusion between the grating constant, d, and the number of rulings per unit length, N.

Good answers to part (c) were rare and the two systems were not often compared from a position of secure knowledge. Very few candidates were able to state that the grating is designed to produce fewer lines which are brighter and more widely spaced. Indeed, many candidates stated that the grating produced more fringes. Most answers concentrated on the accuracy of the readings rather than on how the readings were to be obtained. Answers were, in general, very vague.

17 Many candidates did not seem at all familiar with the use of this diagram in the derivation of the grating equation in part (a) and the placing of the labels was often completely random. A large number did not attempt to label the diagram and half of all candidates did not score any marks.

Many who scored one mark had labelled the wavelength correctly but did not accurately indicate the 'line spacing' with a suitable arrow or line.

Most candidates gained the first mark in part (b) for realising that sin θ decreased so θ would decrease. Many candidates failed to gain the second mark by not stating that d remained constant. Very few candidates attempted to explain in terms of path difference.

The majority of candidates had no problem matching up the spectral lines in part (c).

In part (d) (i), about half of all candidates were unable to convert lines per mm to line spacing and there was considerable confusion with powers of ten. Many candidates did not convert to metres and many also rounded to one significant figure.

In part (d) (ii) it was expected that the candidate would read an accurate value off the scale.

However, many chose a value to the nearest 10 nm, typically 550 nm. In this situation, it is always best to interpolate when reading off the scale. The uncertainty in this reading can then be expressed by giving the final answer to two significant figures. Line P is somewhere between 545 and 548 nm.