Mark Scheme

Q1.

Question Number	Answer	Mark
	A is the correct answer B is not the correct answer as wavelength is a distance C is not the correct answer as d is a distance D is not the correct answer as θ is an angle	1

Q2.

Question Number	Answer	Mark
	D is the correct answer as $n\lambda = d\sin\theta$ where $n = 1$ and $d = 1/300$. $\tan\theta =$ 0.40m / 2.00m. A is not the correct answer as the wavelength is not $300\sin\theta$ B is not the correct answer as the wavelength is not $300\sin\theta$ C is not the correct answer as θ is not $\sin^{-1}$ (0.40/2.00)	(1)

Q3.

Question Number	Answer	Mark
	A is the correct answer B is not the correct answer as the distance between the diffraction grating and the screen is not represented by any letter in this equation. C is not the correct answer as this is $1/d$ D is not the correct answer as this is n	(1)

Q4.

Question Number	Answer	Mark
	C is the correct answer as the distance between the laser and diffraction grating is not required in the equation $n\lambda = d\sin\theta$ A is not the correct answer as the distance from the diffraction grating to the screen is used to calculate θ in the equation $n\lambda = d\sin\theta$ B is not the correct answer as the distance from the central maximum to the first order maximum is used to calculate θ in the equation $n\lambda = d\sin\theta$ D is not the correct answer as the distance between the slits in the diffraction grating is used to calculate d in the equation $n\lambda = d\sin\theta$	**(1)**

Q5.

Question Number	Answer	Mark
	D is the correct answer as decreasing the distance between the central maximum and the first order maximum would require sinθ to be reduced (presuming that the distance from the diffraction grating to the screen is unchanged), and $\lambda = \frac{d\sin\theta}{n}$ A is not the correct answer as this does not affect sinθ B is not the correct answer as this would increase the distance between the central maximum and first order maximum C is not the correct answer as more lines per mm would make d smaller, so as $d = \frac{n\lambda}{\sin\theta}$, which would make sinθ increas	(1)

Q6.

Question Number	Answer	Mark
	A is the correct answer as diffraction is the spreading of waves as they pass an object B is not the correct answer as interference is not the spreading of waves C is not the correct answer as reflection is not the spreading of waves D is not the correct answer as refraction is not the spreading of waves	(1)

Q7.

Question Number	Answer	Mark
	C is the correct answer (The diffraction grating is set up so that it is parallel to the screen) A is not the correct answer as θ is calculated by taking measurements of diffraction grating to screen distance and the distance between bright dots then using trigonometry B is not the correct answer as the diffraction grating should be perpendicular to the laser light beam D is not the correct answer as the distance between the bright dots is best measured using a metre rule	**(1)**

Q8.

Question Number	Answer	Mark
	D is the correct answer as, for a first order maximum, $\lambda = d \sin\theta$, where d is $\frac{1}{\text{number of lines per m}}$ and $\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$ or $\frac{(0.378)}{(2.035)}$ A is not the correct answer as the distance between adjacent slits is not 300,000m. B is not the correct answer as the distance between adjacent slits is not 300,000m. C is not the correct answer as $\sin\theta$ is not $\frac{(0.378)}{(2.000)}$	**(1)**

Q9.

Question Number	Answer	Mark
	B is the correct answer as $n\lambda = d\sin\theta$, and reducing d would increase $\sin\theta$ if n and λ remain the same. A is not the correct answer as this would result in the maxima being closer together C is not the correct answer as this would have no effect on the distance D is not the correct answer as this would result in the maxima being closer together	**(1)**

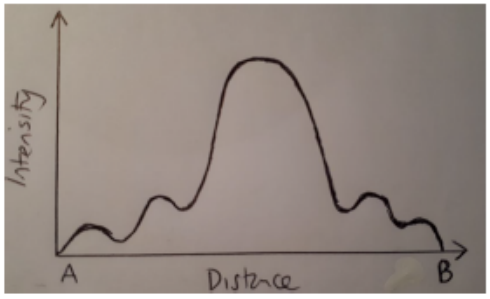
Q10.

Question Number	Answer	Mark
	B is the correct answer as λ is much smaller than the gap size A is not the correct answer as λ matches the gap size C is not the correct answer as λ is larger than the gap size D is not the correct answer as λ matches the gap size	**(1)**

Q11.

Question Number	Answer	Mark
(a)	Violet light has the shortest wavelength (in the visible spectrum) **Or** Violet light has a shorter wavelength than red light **(1)** So needs a shorter path difference to give constructive interference **Or** So $d\sin(\theta)$ for violet light takes a smaller value, and therefore θ must be smaller **(1)** **Or** $\lambda = d\sin(\theta)$ so $\sin(\theta)$ is smaller	**2**
(b)	Use of $n\lambda = d\sin(\theta)$ **(1)** $\lambda = 3.9 \times 10^{-7}$ m **(1)** <u>Example of calculation</u> $\lambda = 1.62 \times 10^{-6}\,\text{m} \times \sin(14°) = 3.919 \times 10^{-7}\,\text{m}$	**2**
	Total for question	**4**

Q12.

Question Number	Answer		Mark
a	Waves spread out (as they pass through the gap)	(1)	
	Each point on the wave(front) acts as a source of new/secondary wave(let)s	(1)	(2)
b	Maximum intensity halfway between A and B (by eye)	(1)	
	Central maximum broader than other maxima (by eye)	(1)	
	Central maximum greater than twice the height from zero intensity (by eye) of other maxima	(1)	
			(3)

Q13.

Question Number	Answer		Additional Guidance	Mark
(a)	Calculates θ (using tan)	(1)	Example of calculation	
	Use of $n\lambda = d\sin\theta$	(1)	$\tan\theta = \frac{0.78\text{ m}}{4\text{ m}}$, therefore $\theta = 11.03°$	
	Calculates number of lines per mm $= \frac{1}{d \times 1000}$	(1) (1)	$d = \frac{1 \times \lambda}{\sin\theta} = \frac{635 \times 10^{-9}\text{ m}}{\sin 11.03} = 3.32 \times 10^{-6}\text{ m}$	
	$d = 300$ lines per mm		number of lines per mm $= \frac{1}{3.32 \times 10^{-6}\text{ m} \times 1000} = 301$	4
(b)	The path difference between waves (from adjacent slits) is one wavelength	(1)	Allow whole number of wavelengths	
	So the waves are in phase	(1)		
	So constructive interference occurs	(1)		3
	Total for question			7

Q14.

Question Number	Answer	Mark
(a)	Oscillations / vibrations are perpendicular to the <u>direction</u> of energy transfer **Or** Oscillations / vibrations are perpendicular to the <u>direction</u> of wave travel (allow propagation for wave travel) (1)	1
(b)(i)	Uses appropriate trigonometry to determine θ (1) Use of $n\lambda = d\sin\theta$ to calculate d (1) Calculate $\frac{1}{d}$ (1) Number of lines per mm = 260 (1) <u>Example calculation</u> $\theta = \tan^{-1}\left(\frac{0.22\text{ m}}{1.30\text{ m}}\right) = 9.61°$ $1 \times 650 \times 10^{-9}\text{ m} = d\sin(9.61°)$ $d = \frac{650 \times 10^{-9}\text{ m}}{\sin(9.61)} = 3.89 \times 10^{-6}\text{ m}$ No. of lines per mm $= \frac{10^{-3}}{3.89 \times 10^{-6}\text{ m}} = 257$	4
(b)(ii)	The path difference (for light from different slits travelling to the screen) is one wavelength (1) (So) the waves are in phase at the screen (1) (So) constructive interference occurs (causing a maximum) (1)	3
	Total for question	**8**

Q15.

Question Number	Answer		Mark
(a)	Direct the laser away from people's eyes Stand behind the laser Avoid directing the laser at reflective surfaces	(1)	1
(b)	The distance from the central maximum to any other maximum or the distance between two maxima of the same order	(1)	
	The (perpendicular) distance between the diffraction grating and the screen	(1)	2
(c)(i)	$\theta = 9°$	(1)	
	Calculates d	(1)	
	Use of $n\lambda = d \sin\theta$	(1)	
	$\lambda = 630$ (nm)	(1)	4
	<u>Example calculation</u> $\theta = \frac{18°}{2} = 9°$ $d = \frac{10^{-3}\text{ m}}{250} = 4 \times 10^{-6}\text{ m}$ $\lambda = 4 \times 10^{-6}\text{ m} \times \sin(9°) = 626\text{ nm}$		
(c)(ii)	Use of $n\lambda = d \sin\theta$ with $\theta = 90°$	(1)	
	$n_{max} = 6$ (ecf from (c)(i))	(1)	2
	<u>Example calculation</u> $n_{max} = \frac{4 \times 10^{-6}}{630 \times 10^{-9}} = 6.3$		
	Total for question		**9**

Q16.

Question Number	Answer	Mark
a	Use of $n\lambda = d \sin\theta$ (1) $\theta_2 = 29°$ (1) (For MP1, allow calculation of $d/\lambda = 4.13$ or $\lambda/d = 0.242$) <u>Example of calculation</u> $\sin 14.0° = 0.242$ (when $n = 1$) $n = \frac{d}{\lambda} \sin\theta$, so if d and λ are the same, when $n = 2$, $\sin\theta$ is doubled so $\sin\theta_2 = 0.242 \times 2 = 0.484$ $\sin^{-1} 0.484 = 28.9°$	2
b	Suitable graph suggested (see table below) (1) Calculate/determine gradient (1) Correct method for determining λ from gradient of graph (1) (MP2 do not award without any suggestion of the graph to be plotted) (MP2 do not award if either of the axes involves λ)	3

MP1		MP3	
y-axis	**x-axis**	**gradient =**	**or λ =**
n	$d \sin\theta$	$1/\lambda$	1/gradient
$d \sin\theta$	n	λ	gradient
n	$\sin\theta$	d/λ	d/gradient
$\sin\theta$	n	λ/d	gradient × d
$\sin\theta$	n/d	λ	gradient
n/d	$\sin\theta$	$1/\lambda$	1/gradient

c	Use of tan to calculate θ_2 (allow Pythagoras to find hypotenuse and then using sin or cos) (1) Use of $n\lambda = d\sin\theta$ with $n = 2$ (1) Use number of lines per m(m) = 1 / d (1) Number of lines per mm = 149, so labelling incorrect **Or** $d = 3.33 \times 10^{-6}$ m, not 6.69×10^{-6} m, so labelling incorrect (1) <u>Example of calculation</u> Tan $\theta = 0.397$ m / 2.00 m = 0.199, $\theta = 11.2°$ $n\lambda = d\sin\theta$, so d = $n\lambda$ / sin θ = $2 \times 650 \times 10^{-9}$ m / sin (11.2°) d = 6.69×10^{-6} m number of lines per metre = 1/d = 1 / 6.69×10^{-6} m = 149,000 m^{-1} = 149 mm^{-1}	4
	Total for question	**9**

Q17.

Question Number	Answer	Mark
(a)	Each point on a wavefront is (treated as) a source of (secondary) wavelets (1) these further wave (let)s interfere / superpose (and the resulting waves predict the shape) (1)	2

* (b)	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. IC points / IC mark / Max linkage mark / Max final mark 6 / 4 / 2 / 6 5 / 3 / 2 / 5 4 / 3 / 1 / 4 3 / 2 / 1 / 3 2 / 2 / 0 / 2 1 / 1 / 0 / 1 0 / 0 / 0 / 0 The following table shows how the marks should be awarded for structure and lines of reasoning. Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout — 2 Answer is partially structured with some linkages and lines of reasoning — 1 Answer has no linkages between points and is unstructured — 0 (Number of marks awarded for structure of answer and sustained line of reasoning) **Indicative content** IC1 Waves (from each gap) interfere / superpose IC2 At position A there is no path / phase difference IC3 So, there is constructive interference (leading to large amplitude oscillations) IC4 At position B, the phase difference varies with wavelength IC5 If there is an odd number of half wavelengths path difference, there is destructive interference leading to small oscillations **Or** If the waves are in antiphase there is destructive interference leading to small oscillations IC6 And if there is a whole number of wavelengths path difference there is constructive interference leading to large oscillations **Or** If the waves are in phase there is constructive interference leading to large oscillations	6
	Total for question	**8**

Q18.

Question Number	Answer		Mark
a	Calculates θ (using tan)	(1)	
	Calculates d using $\frac{1}{\text{number of lines per m}}$	(1)	
	Use of $n\lambda = d\sin\theta$	(1)	
	$\lambda = 6.3 \times 10^{-7}$ m	(1)	4
	<u>Example of calculation</u> $\tan\theta = \frac{0.500\text{ m}}{1.690\text{ m}}$, therefore $\theta = 16.5°$ $d = \frac{1}{450{,}000} = 2.22 \times 10^{-6}$ m. $\lambda = \frac{d\sin\theta}{n} = \frac{(2.22 \times 10^{-6}\text{m})(\sin 16.5°)}{(1)} = 6.31 \times 10^{-7}$ m		
b	(Waves from the different slits meet and) superposition/interference takes place	(1)	
	(Bright dots are where) waves are in phase	(1)	
	(Superposition/interference) is constructive	(1)	3
c	White dot at O	(1)	
	Spectra seen (either side of O)	(1)	2
	Total for question		**9**

Q19.

Question Number	Answer		Mark
(a)	Light directed through one polarising filter	(1)	
	Filter is rotated until no light passes through **Or** filter is rotated and light changes intensity	(1)	2
	(Answers involving use of more than one polarising filter can only potentially score MP2)		
(b)(i)	Distance between (adjacent) slits **Or** grating spacing **Or** line spacing **Or** slit spacing **Or** $\frac{1}{lines\ per\ m}$	(1)	1
(b)(ii)	Use of $\tan\theta = \frac{\text{distance from central maximum to first order}}{\text{grating to screen distance}}$	(1)	
	Use of $n\lambda = d\sin\theta$	(1)	
	number of lines per mm = 950	(1)	3
	(MP1 – award if $\sin\theta$ calculated from Pythagoras) (Use of Young's Double Slit equation scores 0)		
	<u>Example of calculation</u> $\tan\theta = 1.61\text{m} / 2.74\text{m}$, $\theta = 30.4°$ $d = n\lambda / \sin\theta = (1)(532 \times 10^{-9}\ \text{m}) / \sin(30.4°)$ $d = 1.05 \times 10^{-6}$ m number of lines per m = $1 / 1.05 \times 10^{-6}$ m = $9.52 \times 10^{5}\ \text{m}^{-1}$. number of lines per mm = 952		
(b)(iii)	Measuring distance from from first order maxima on one side of the central maxima to the first order maxima on the other side	(1)	
	Increasing distance from diffraction grating to screen	(1)	
	It would decrease <u>percentage</u> uncertainty	(1)	3
	(MP3 is dependent upon awarding MP1 or MP2)		
	Total for Question		**9**

Q20.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	Constant phase difference / relationship **(1)**		**1**
(a)(ii)	(At a bright dot) the path difference is equal to a whole number of wavelengths **(1)** (So) these waves are in phase **(1)** So constructive superposition / interference takes place **(1)**	Accept path difference = $n\lambda$ Accept (so) the phase difference for these waves is zero	**3**
(b)(i)	Use of $n\lambda = d\sin\theta$ **(1)** $\theta = 30°$ **(1)**	<u>Example of calculation</u> $\sin\theta = \frac{532 \times 10^{-9}\ \text{m}}{1.07 \times 10^{-6}\ \text{m}}$ $\theta = 29.8°$	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(ii)	**EITHER** Use of $n\lambda = d\sin\theta$ with n = 3 **(1)** $\sin\theta = 1.49$ **(1)** maximum value of $\sin\theta = 1$ (so third order maximum not possible) **(1)** **OR** Maximum diffraction angle is 90° **(1)** At 90° the path difference (for adjacent slits) is the same as the slit separation d **(1)** $d < 3\lambda$ (so third order maximum not possible) **(1)** **OR** Use of $n\lambda = d\sin\theta$ with $\sin\theta = 1$ **(1)** n = 2.01 **(1)** maximum number of orders = 2 (so third order maximum not possible) **(1)**	Allow $\sin^{-1}(1.49)$ does not exist Allow 1.49 > 1	**3**
(c)	A white dot in the centre **(1)** Spectra either side **(1)** Violet / blue closest to the centre **(1)**	Allow red is furthest from centre	**3**
	Total for question		**12**