

Mark Scheme

Q1.

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)

Q2.

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)

Q3.

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)

Q4.

Question Number	Answer	Mark
	D is the correct answer as $n\lambda = d\sin\theta$ where $n = 1$ and $d = 1/300$. $\tan\theta = 0.40\text{m} / 2.00\text{m}$. 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)

Q5.

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

Q6.

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> $\theta = \tan^{-1} \left(\frac{0.22 \text{ m}}{1.30 \text{ m}} \right) = 9.61^\circ$ $1 \times 650 \times 10^{-9} \text{ m} = d \sin(9.61^\circ)$ $d = \frac{650 \times 10^{-9} \text{ m}}{\sin(9.61)} = 3.89 \times 10^{-6} \text{ m}$ 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

Q7.

Question Number	Answer	Mark																																
a	Use of $n\lambda = d \sin \theta$ (1) $\theta_2 = 29^\circ$ (1) (For MP1, allow calculation of $d/\lambda = 4.13$ or $\lambda/d = 0.242$) <u>Example of calculation</u> $\sin 14.0^\circ = 0.242$ (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 $\sin \theta_2 = 0.242 \times 2 = 0.484$ $\sin^{-1} 0.484 = 28.9^\circ$	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) <table border="1"> <thead> <tr> <th colspan="2">MP1</th> <th colspan="2">MP3</th> </tr> <tr> <th>y-axis</th> <th>x-axis</th> <th>gradient =</th> <th>or λ =</th> </tr> </thead> <tbody> <tr> <td>n</td> <td>$d \sin \theta$</td> <td>$1/\lambda$</td> <td>$1/\text{gradient}$</td> </tr> <tr> <td>$d \sin \theta$</td> <td>n</td> <td>λ</td> <td>gradient</td> </tr> <tr> <td>n</td> <td>$\sin \theta$</td> <td>d/λ</td> <td>$d/\text{gradient}$</td> </tr> <tr> <td>$\sin \theta$</td> <td>n</td> <td>λ/d</td> <td>gradient $\times d$</td> </tr> <tr> <td>$\sin \theta$</td> <td>n/d</td> <td>λ</td> <td>gradient</td> </tr> <tr> <td>n/d</td> <td>$\sin \theta$</td> <td>$1/\lambda$</td> <td>$1/\text{gradient}$</td> </tr> </tbody> </table>	MP1		MP3		y-axis	x-axis	gradient =	or λ =	n	$d \sin \theta$	$1/\lambda$	$1/\text{gradient}$	$d \sin \theta$	n	λ	gradient	n	$\sin \theta$	d/λ	$d/\text{gradient}$	$\sin \theta$	n	λ/d	gradient $\times d$	$\sin \theta$	n/d	λ	gradient	n/d	$\sin \theta$	$1/\lambda$	$1/\text{gradient}$	3
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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> $\tan \theta = 0.397 \text{ m} / 2.00 \text{ m} = 0.199$, $\theta = 11.2^\circ$ $n\lambda = d \sin \theta$, so $d = n\lambda / \sin \theta = 2 \times 650 \times 10^{-9} \text{ m} / \sin (11.2^\circ)$ $d = 6.69 \times 10^{-6} \text{ m}$ number of lines per metre = $1/d = 1 / 6.69 \times 10^{-6} \text{ m} = 149,000 \text{ m}^{-1}$ = 149 mm^{-1}	4
Total for question		9

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

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)	$\theta = 9^\circ$ (1) Calculates d (1) Use of $n\lambda = d \sin \theta$ (1) $\lambda = 630 \text{ (nm)}$ (1) <u>Example calculation</u> $\theta = \frac{18^\circ}{2} = 9^\circ$ $d = \frac{10^{-3} \text{ m}}{250} = 4 \times 10^{-6} \text{ m}$ $\lambda = 4 \times 10^{-6} \text{ m} \times \sin(9^\circ) = 626 \text{ nm}$	4
(c)(ii)	Use of $n\lambda = d \sin \theta$ with $\theta = 90^\circ$ (1) $n_{\max} = 6$ (ecf from (c)(i)) (1) <u>Example calculation</u> $n_{\max} = \frac{4 \times 10^{-6}}{630 \times 10^{-9}} = 6.3$	2
Total for question		9

Q10.

Question Number	Answer	Mark
a	(Sodium) electrons/atoms gain/absorb energy (1) And electrons move to higher energy levels (1) (Sodium) electrons drop to lower energy levels, releasing <u>photons</u> (1) (For MP2 & MP3, allow excited and de-excited) (For MP2 & MP3, do not allow “atoms” for “electrons”) (For “levels” accept shells, orbitals, states)	3
b	Use of $c = f\lambda$ and Use of $E = hf$ (1) Converts J to eV (1) Energy = 2.11 eV (1) <u>Example of calculation</u> $f = (3.00 \times 10^8 \text{ m s}^{-1}) / (589 \times 10^{-9} \text{ m}) = 5.09 \times 10^{14} \text{ Hz}$ $E = (6.63 \times 10^{-34} \text{ Js}) \times (5.09 \times 10^{14} \text{ Hz}) = 3.38 \times 10^{-19} \text{ J}$ $E (\text{in eV}) = (3.38 \times 10^{-19} \text{ J}) / (1.60 \times 10^{-19} \text{ J eV}^{-1}) = 2.11 \text{ eV}$	3
c	Uses $\tan \theta = s / D$ (1) Use of $n\lambda = d \sin \theta$ with $n = 1$ (1) Grating has 301 lines / mm, so the label is correct. (1) OR Uses $\sin \theta = \frac{s}{\sqrt{s^2 + D^2}}$ (1) Use of $n\lambda = d \sin \theta$ with $n = 1$ (1) Grating has 301 lines / mm, so the label is correct. (1) (Use of double slit or single slit equations does not gain any credit) (Allow reverse calculation to show that 300 lines per mm leads to a value of λ that is close to the given value or that 300 lines per mm leads to a value of d or θ that is close to a value calculated). <u>Example of calculation</u> $\tan \theta = 0.234 \text{ m} / 1.30 \text{ m} = 0.18$ $\theta = 10.2^\circ$ $n\lambda = d \sin \theta$, so $d = 589 \times 10^{-9} \text{ m} / \sin 10.2^\circ = 3.33 \times 10^{-6} \text{ m}$ lines per mm = $1 / 3.33 \times 10^{-3} \text{ m} = 301$.	3
Total for question		9