Level 3 Physics: Demonstrate understanding of Waves – Waves Behaviour - Answers

In 2013, **AS 91523** replaced **AS 90520.**

The Mess that is NCEA Assessment Schedules….

In AS 90520 there was an Evidence column with the correct answer and Achieved, Merit and Excellence columns explaining the required level of performance to get that grade. Each part of the question (row in the Assessment Schedule) contributed a single grade in either Criteria 1 (Explain stuff) or Criteria 2 (Solve stuff). From 2003 to 2008, the NCEA shaded columns that were not relevant to that question.

In 91523, from **2013 onwards**, each part of a question contributes to the overall Grade Score Marking of the question and there are no longer separate criteria. There is no shading anymore. There is no spoon. At least their equation editor has stopped displaying random characters over the units.

Question	Evidence	Achievement	Merit	Excellence
2019(3) (a)	$n\lambda = d\sin\vartheta \quad \lambda\uparrow, \quad \vartheta\downarrow$ When *d* is constant as wavelength increases (the path difference increases) and so the angle (to successive maxima) increases OR $n\lambda = \frac{dx}{l}$ When *d* and *l* are constant as wavelength increases the distance between maxima increases.	Correct answer. DO NOT ACCEPT longer wavelengths of light diffract by larger angles.		

(b)(i) (ii)	$d = \frac{1\text{ m}}{400\,000} = 2.5\times10^{-6}$ $n\lambda = d\sin\theta$ $2\lambda = (2.5\times10^{-6})\sin 20.7°$ $\lambda = 4.4184\times10^{-7}$ m $\lambda = 442$ m (if in rad $\lambda = 1.2 \times 10^{-6}\ m$)	One point. Watch $\frac{\sin\theta}{2} \neq \sin\left(\frac{\theta}{2}\right)$ so $\lambda = (2.5\times10^{-6})\sin\left(\frac{20.7}{2}\right)$ Will give an incorrect answer of 449 nm.	Both points. Accept incorrect x10^x provided substitution correct.	
(c)	(Light diffracts through the grating and acts as a point source) (not req). Constructive/destructive interference explained (linked) (when the light sources are [in phase] a [bright region] is produced). Answer includes path difference (when the path difference is a whole number *all* of the light constructively interferes to produce a bright, narrow, well defined maxima). nb a grating produces multiple waves	One point. Path difference $n\lambda$ p.d.	Both points.	

(d)	Calculation $n\lambda = d\sin\theta$ $n(5.32\times10^{-7}) = (2.5\times10^{-6})\sin 28.6°$ $n = \frac{(2.5\times10^{-6})\sin 28.6°}{(5.32\times10^{-7})}$ $n = 2.249$ - Therefore, it will be dark **because**: • (where) n is not a whole number (it lies a quarter of the way between the 2nd and the 3rd maxima) • (looking for students to recognise this is a grating, not just 2-point source (i.e. node not just at n=2.5)) • (Why) It will **not** be an antinode (as the maxima are narrow/well defined with a diffraction grating) / OR • At this point the overall effect is destructive interference. Note large angle sin*Θ* does not equal tan*Θ*.	One bullet point.	Two bullet points.	Full answer.
2018(1) (a)	$d \sin\Theta = n\lambda$ 1.68×10^{-6} m x sin16.8 = $n\lambda$ λ = 486 nm	Correct formula and substitution and answer.		

(b)	*d* sinϴ = *nλ* Wavelength and sin of angle are directly proportional. Since the angle is increasing, the wavelength of the next visible line will be larger, thus it must be the 656 nm line.	Correctly identifies it is the 656 nm line. OR links increasing angle with increasing wavelength.	Correctly identifies it is the 656 nm line. AND Correctly links increasing angle with increasing wavelength.	
(c)	Recognises that maximum order must be less than 90° and performs calculation. $d\sin\theta = n\lambda$ for $\sin\theta = 1$ $n = \frac{d}{\lambda} = \frac{1.68\times10^{-6}\text{ m}}{656\times10^{-9}\text{ m}} = 2.56$ Therefore, highest order is *n* = 2.	Recognises the angle will be less than 90°. This includes: *answers of 2.56 unrounded,* *Calculates 2 but then states that 3,4,5 orders are visible.*	Calculates the maximum order and correctly rounds to 2 (no decimal). OR Calculates angle to first and second order maxima and shows that for the third order sin ϴ has to be greater than 1 / angle can't be calculated.	
(d)	• **Maxima will be wider**, fewer sources are combining in superposition, so less perfect cancellation occurring in between maxima. • **Dimmer maxima**, only two sources of light so less energy combining at maxima. • Maxima will be located at the **same angles** as before, path differences will still be wavelength integers in the same locations since slit spacing has not changed.	Two correct descriptions. OR One correct explanation for a description.	Two correct descriptions including one explanation from: 1. Maxima at same angles because wavelengths, slit separation have not changed. 2. Dimmer maxima because fewer slits / sources allow less light / less energy through. 3. Wider maxima because less destructive interference between maxima.	Three correct descriptions AND Comprehensive explanation for wider maxima showing understanding that brightness of fringe diminishes gradually as the phase / path difference changes gradually. OR Comprehensive explanation for dimmer maxima linking fewer sources to less waves combining constructively at maxima.

2017(3) (a)	$n\lambda = d\sin\theta$ $n=1,\quad \lambda = 2\times10^{-6}\sin15.4°$ $\lambda = 5.31\times10^{-7}\text{ m}$	Correct formula and substitution and answer. Note: Don't need to substitute in n = 1. *(Note from nb2s editor – this was incorrectly left in the Excellence column)*		
(b)	The light passes through the narrow slits and diffracts. The diffracted waves overlap and interfere. The path difference for light reaching the first antinode is one wavelength so the light waves arrive in phase and add constructively (causing a bright spot).	The path difference is n wavelengths so the interference is constructive / antinode. OR The waves arrive in phase to produce constructive interference/antinode. Note: Crest + crest / trough + trough OK for achieved only. *(Note from nb2s editor – this was incorrectly left in the Excellence column)*	Concepts of **path difference of 1 wavelength**, **phase** and **constructive interference** explained and clearly linked.	
(c)	Diagram shows pattern with antinodes further apart, and central antinode in same place. Red light has a lower frequency than green, so it has a longer wavelength. $\sin\theta = \frac{n\lambda}{d}$ so a longer wavelength means the angle between the antinodes is bigger, so the antinodes are further apart.	Antinodes get further apart (stated or in diagram). AND Red light has a longer wavelength.	Antinodes get further apart (stated or in diagram). AND Explanation using either equation. (NOT λ is proportional to ϑ). OR correctly uses path difference creating constructive interference explanation.	

(d)	The maximum angle that the spectrum can be formed is 90°. The light which has its antinode at the biggest angle is red because it has the longest wavelength. So we calculate the slit separation that gives an angle of 90° for the red light. $\lambda_{red} = \frac{v}{f} = \frac{3.00\times10^8}{4.30\times10^{14}} = 6.98\times10^{-7}\text{m}$ $\sin\theta = \frac{n\lambda}{d}$ and $n = 3$ $d = \frac{n\lambda}{\sin\theta} = 3\times6.98\times10^{-7}$ $d = 2.09\times10^{-6}$ m	Uses 90 degrees. OR Red has a longer wavelength. (replacement for 3c only) OR Correct wavelength for red light.	Correct answer. OR Both correct explanations.	Correct working and answer. AND Explanations of use of red wavelength. AND 90-degree angle (or maximum path difference = 3 wavelength).
2016(3) (a)	$n\lambda = \frac{dx}{l}$ $\lambda = \frac{1.28\times10^{-4}\times0.0100}{2.10}$ $\lambda = 6.10\times10^{-7}$ m	Correct formula and substitution.		
(b)	500 lines mm^{-1} = 5×10^5 l m^{-1} $d = \frac{1}{5\times10^5} = 2\times10^{-6}$ m $\sin\theta = \frac{n\lambda}{d} = \frac{6.10\times10^{-7}}{2\times10^{-6}} = 0.305$ $\theta = 17.5°$	Correct calculation of *d.* OR Correct use of equation with incorrect *d*.	Correct formula, substitution, answer and units.	

(c)	$\sin\theta = \frac{n\lambda}{d}$ So if wavelength decreases and *d* is constant, sin*Θ* will decrease (so *Θ* will decrease) so antinodes / bright spots get closer. OR $n\lambda = \frac{dx}{l}$, so if *Θ* decreases, *x* will decrease, meaning the antinodes will get closer. OR If the wavelength decreases, then the path difference to the antinodes will decrease. This will cause the angle between the antinodes to decrease, and the bright spots to get closer together.	Antinodes get closer. OR Describes relationship between λ and θ or *x*.	Antinodes get closer AND one of: • Explanation using either equation. • Correctly uses path difference creating constructive interference explanation.	

(d)	White light contains all the wavelengths of visible light. All the wavelengths diffract as they pass through the diffraction grating and spread out through 180º. Each slit acts as a point source of all the wavelengths of light in the visible spectrum. Waves from each slit interfere with waves of the same wavelength from other slits. Interference is predominantly destructive due to the many closely spaced sources. In the dark region all visible wavelengths are experiencing destructive interfere. Only wavelengths invisible to the eye constructively interfere. No light is seen. Individual colours are seen where constructive interference is occurring for that colour but destructive interference is occurring for all other colours. The red antinode is at a larger angle than the violet, because the red light has a longer wavelength. As shown by $\sin\theta = \frac{n\lambda}{d}$ or $n\lambda = \frac{dx}{l}$. The centre of the pattern is white because there is a central antinode for all colours. Here each wavelength of light constructively interferes with other sources of the same wavelength. The resulting white light is a composite maximum of all the colours.	White seen is central antinode. OR different colours have 1st antinode at different angle. OR different colours have different wavelengths. OR dark regions are nodes (attributed to destructive interference).	Correct explanation for: White in **centre / middle** caused by **antinode / maxima constructive interference /** of **all colours / frequencies.** AND one of: • Colours with larger wavelengths have **1st antinode** at larger angles / larger *x*. • Dark regions due to destructive interference of all (visible) wavelengths. • Dark regions due to constructive interference of wavelengths not visible.	Comprehensive explanation of white central antinode AND coloured spectra AND dark regions due to destructive interference of all visible wavelengths
2015(2) (a)	$d \sin\theta = n\lambda$ $d = \frac{1 \times 532 \times 10^{-9}}{\sin 26°} = 1.21 \times 10^{-6}$ m	1.21×10^{-6} m		

(b)	Middle section / more lines per metre: less fringes / more space between fringes. Edges / less lines per metre: more fringes / less space between fringes.	Fewer/further apart fringes in the middle / more/closer fringes at the edges. *Answers must attribute fringes to interference, not diffraction.*		
(c)	$d = \frac{1}{600000} = 1.67 \times 10^{-6}$ $n\lambda = d \sin\theta$ $\sin\theta = \frac{2 \times 532 \times 10^{-9}}{1.67 \times 10^{-6}}$ $\theta = 39.6°$	$d = 1.67 \times 10^{-6}$ OR Correct answer using n =1 (18.6º) *OR* Correct answer in radians (0.69)	$\theta = 39.6°$	

(d)	$n\lambda = d\sin\theta$ $n = \frac{d\sin\theta}{\lambda}$ maximum possible value occurs when $\theta = 90°$, so For blue: $n = \frac{d}{\lambda} = \frac{1.67\times10^{-6}}{460\times10^{-9}} = 3.63$ so maximum $n = 3$ For red: $n = \frac{d}{\lambda} = \frac{1.67\times10^{-6}}{690\times10^{-9}} = 2.42$ so maximum $n = 2$ $n_B\lambda_B = d\sin\theta$ $n_R\lambda_R = d\sin\theta$ so $n_B\lambda_B = n_R\lambda_R$ $\frac{n_B}{n_R} = \frac{\lambda_R}{\lambda_B}$ $\frac{n_B}{n_R} = \frac{690\times10^{-9}}{460\times10^{-9}}$ $\frac{n_B}{n_R} = \frac{3}{2}$ so 3rd blue fringe matches 2nd red fringe.	Correct use of θ ≤ 90º OR Maximum diffracted angle of 90º Zero order maximum of red and blue occurs at 0 degrees. Magenta / purple in the centre.	Correct calculation for the number of maxima for blue is 3rd order/ 3 fringes each side and red fringes is 2nd order/2 fringes each side of central maximum. OR 3rd order blue fringe coincides with 2nd order red fringe with correct working or correct angle (55.9º). OR 0 order blue fringe coincides with 0 order red fringe with correct working.	Correct calculation for number of maxima: 3 blue and 2 red fringes each side. AND Correct calculation or angle showing that 3rd blue fringe matches 2nd red fringe. AND Maximum possible path difference occurs at 90° and equals the distance between the slits (*d*) OR maximum value of sin ϑ = 1 OR maximum angle of diffraction stated as being 90°.
2014(2) (a)	$n\lambda = d\sin\theta, n = 1, \theta = \tan^{-1}\left(\frac{7.40}{35.0}\right)$ $d = \frac{0.600}{0.207} = 2.90$ m or $n\lambda = \frac{dx}{L}, d = 2.838$ m	2.84 m $d \sin \vartheta = n \lambda$ used with any angle	2.90 m	

(b)	There are positions along AB where the waves from each slit **arrive in phase** with each other. This occurs when the path taken by two waves differs in length by a whole number of wavelengths. Between each position of constructive interference, there are positions where the waves arrive with opposite phase. This occurs when the path taken by two waves differs in length by an odd number of half wavelengths.	If the path difference is a whole number (of wavelengths), the interference is constructive. If the waves to arrive in phase, there will be constructive interference, and if they arrive in opposite phase, there will be destructive interference.	Explanation links phase difference to path difference and resulting interference for both loud / quiet positions. (i.e. n λ = *PD* for constructive and (n – ½) λ=PD for destructive).	
(c)	As *x* is inversely proportional to *d*, the positions of constructive interference (loud places) will be further apart, and there will be fewer of them.	Fewer loud positions. Loud positions further apart.	Reduction in speaker separation causes increase in distance between positions of constructive interference explained with reference to relevant formulae.	
(d)	• The positions of constructive interference would be different for different wavelengths, so different notes would be heard at different positions. • At the central position, all frequencies experience constructive interference, so a composite note would be heard. • Because the positions of constructive interference depend on sinθ, the lower frequency (longest wavelength) sounds would be heard further apart.	All sounds equally loud in the centre. Different frequencies become loud as you walk along the line. Each frequency has different distances between nodal and antinodal lines. More places where there are loud points / constructive interference.	Each frequency heard at **several** positions. **Comparison** made between single pitch / frequency heard in (b) and each frequency heard in different locations. First order of constructive interference has highest to lowest frequency from the centre moving out.	Explains that several interference patterns cause loud sounds of different frequencies to be heard in different positions. Explains that the positions of constructive interference will be more widely spaced for lower frequencies / longer wavelengths.
2013(3) (a)	Images of the lights appear on either side	Images of the lights appear on either side / bright and dark / interference pattern.		

(b)	$n\lambda = d\sin\theta$ $1 \times 589 \times 10^{-9} = d\sin 1.04$ $d = 3.25 \times 10^{-5}$ m $= 32.5\ \mu m$	Correct substitution.	Correct working and answer.	
(c)	Constructive interference occurs much less frequently because of the many sources so the bright fringes are much narrower / more defined The bright fringes are brighter because they are formed from constructive interference of light from many extra sources	Bright fringes are narrower / more defined OR dark fringes are wider. Fringes are brighter.	Constructive interference occurs much less frequently because of the many sources so the bright fringes are much narrower / more defined. The bright fringes are brighter because they are formed from constructive interference of light from many extra sources.	Both the narrowness and the brightness of the fringes are correctly explained.
(d)	The white light contains all the colours of visible light. All frequencies diffract as they pass through the diffraction grating and spread out through 180°. The frequencies with the shortest wavelengths are violet and the longest wavelengths are red. The longer the wavelength, the larger the angle will be to the first order maximum, so the further the colour will be seen from the centre	The diffraction grating causes separation of the white light into a spectrum of colours. White in the middle. Violet closest to centre / red furthest out.	Correctly linking the position of colours in spectrum to frequency or wavelength.	Increasing wavelength linked to increase in angle at which the first order maximum occurs to explain the order of the colours from violet through to red.
2012(3) (a)	The light has spread out because it diffracted as it went through a gap in the fabric. Because the gap is square, the light spreads vertically and horizontally, that being where the edges are (like two slits).	Diffraction. OR The "fabric acts like a diffraction grating".	Diffraction linked to edges / slits producing diffraction in 2 perpendicular directions.	

(b)	The stripes are due to interference between waves / light diffracting from gaps between different threads **/** other point sources.	Interference.	Complete answer.	
(c)	$n\lambda = \frac{dx}{L} \quad n = 1$ $d = \frac{n\lambda L}{x} = \frac{6.50 \times 10^{-7} \times 0.40}{1.0 \times 10^{-3}} = 2.6 \times 10^{-4}$ m	Correct answer.		
(d)	*d* will increase by $\frac{16.3}{16.0} = 1.01875$ since $x = \frac{n\lambda L}{d} \propto \frac{1}{d}$ *x* will decrease $x = \frac{1.0 \times 10^{-3}}{1.01875} = 0.98 \times 10^{-3}$ m	Identifies decrease in *x* or calculates new *d*. *d* = 2.65 × 10^{-4} m	Identifies decrease in *x* and calculates new *d*. $d = 2.6 \times 10^{-4} \times \frac{16.3}{16}$ m $= 2.65 \times 10^{-4}$ m	Complete answer.
2011(2) (a)(i)	A spectrum is produced because the amount of bending as the light goes through the grating depends on the wavelength of the light ($n\lambda = d\sin\theta$).	Correct statement of why a spectrum is produced. **Different wavelengths**/frequencies /colour bend/**diffract** at **different angles**		
(ii)	Because red light has the longest wavelength, it is bent away from the straight-through direction the most, so each spectrum will have its red side furthest from the centre.	Correct idea that **red end** of the spectrum is **furthest out** from the central position. OR The **longest wavelength is** furthest out.	Correct explanation that **red has longest wavelength**. AND **Longer (not long) wavelength diffracts more.**	

(b)	$n\lambda = d\sin\theta$ and so, for a particular wavelength, *d* is directly related to θ. This means that, as *d* gets smaller, each order spectrum is bent more and so there will be fewer spectra produced.	Smaller *d* linked to spectra being more **spread out.** OR Smaller *d* is linked to **fewer n** without the evidence of the equation.	Achievement, plus **fewer spectra** produced. OR Relates that **n is directly proportional** to d because $n\lambda = d\sin\theta$ / λ is constant.	
(c)	$n\lambda = d\sin\theta$, $n = 1$, $\lambda = \frac{c}{f} = 7.05 \times 10^{-7}$ m $\Rightarrow \sin\theta = 1 \times \frac{3.00\times10^{8}}{4.25\times10^{14}} \times \frac{1}{6.6\times10^{-7}}$ $\Rightarrow \sin\theta = 1.070$ This angle does not exist (so light of this frequency does not form a spectrum). OR Sinθ is substituted as 1 and then n is calculated to have a value of 0.935, and since this is not a whole number so no spectra will be seen.	Correct λ **7.05 × 10^{-7} m** Correct answer. Do not accept mathematical error.	Correct **sinθ = 1.070**	
(d)(i)	The waves having wavelengths **greater** than 5.2×10^{-7} **cannot be diffracted** through an angle **less than 90°,** so these wavelengths cannot contribute to the flash / spectrum.	**Some idea** of why only part of a full spectrum is produced.	**Clear idea** of why only part of a full spectrum is produced. Do not accept, light is reflected back.	Correct explanation and correct answer.
(ii)	$n\lambda = d\sin\theta$, $n = 1$, $\sin 90 = 1$ $\Rightarrow d = \lambda = 5.2 \times 10^{-7}$ m $= 5.2 \times 10^{-4}$ mm $N = \frac{1}{5.2\times10^{-4}} = 1923$ = **1 900 lines mm^{-1}**	**Correct answer** without the evidence. OR Value of **N is given in metres.**	Correct answer **1 900 lines per mm** with the **evidence**, evidence that: $d = \lambda = 5.2 \times 10^{-7}$ m, because sin 90 = 1 evidence can come from any part of the question.	

2010(3) (a)	If waves are in phase, the signal is strong / intense because peaks reinforce peaks and troughs reinforce troughs. If they are out of phase then the signals cancel (if they have the same amplitude and are completely out of phase they will cancel completely).	In phase – strong, out of phase – weak with no reasons. OR Explains either one but does not describe the other.	Correct answer with reasoning, linking phrase to constructive / destructive interference and intensity.	
(b)	1.95×10^{-7} is exactly λ/4. A wave which reflects off a pit will travel an extra λ/2, compared with a wave which reflects off the surface. Thus if the beam hits both the surface and a pit, then the waves will be out of phase and produce a weak signal. Normally the reflections are in phase and produce a strong signal. As the disk rotates, it moves over pits and as it travels over an edge, there will be a dip in the intensity.	Recognition that 1.95×10^{-7} is exactly λ/4. OR Recognition that the waves will reflect in and out of phase producing strong and weak signal as the disk rotates.	Links the pit depth to path difference for destructive interference and the production of a weak beam but does not completely answer.	Complete answer contrasts signal at pit edge to flat surface.
(c)	$n\lambda = d\sin\theta$ $\sin\theta = \frac{n\lambda}{d} = \frac{436 \times 10^{-9}}{1.6 \times 10^{-6}} = 0.2725$ $\theta = 15.8°$	Correct method (this is a show question). OR Substitutes 15.18° to show the wavelength is 4.36 m.		

(d)	$\frac{\tan\theta}{\tan 15.8°} = \frac{366}{285}$ $\theta = 19.97°$ $\lambda = d\sin\theta = 1.6\times10^{-6}\sin 19.97°$ $\lambda = 5.478\times10^{-7}$ m	Uses $\lambda = d\sin\theta$ with wrong θ.	Correct θ. *OR* Uses $n\lambda = d\frac{x}{L}$ twice to give $\lambda_{gr} = 5.60\times10^{-7}$ m	Correct answer.
2009(3) (a)	Loudspeakers make sound waves at same frequency in phase (i.e. coherent). Waves produce an interference pattern due to waves arriving at some points in phase (producing maxima / antinodes / causing constructive interference) and in some places out of phase (producing minima / nodes / causing destructive interference). For complete cancellation, waves must be of equal intensity and out of phase. The students hear loud and quiet because as they walk along they pass through maxima (loud) and minima (quiet) of the pattern. Not effective indoors because echoes (multiple reflections) will fill in the minima with other sounds of the same frequency, which will not cancel.	Interference of the sound waves causes maxima and minima where constructive / destructive superposition is occurring / it is an interference pattern because the two sources of waves are coherent/ Answer identifies reflected sound waves reducing the contrast between max and min points/ clarity of interference pattern	Achieved plus: Answer that explains the reason for the pattern in terms of path difference or phase difference.	Complete answer covering: What students hear related to interference pattern with fixed nodal lines explained in terms of phase / path difference. Correct explanation of need for lack of reflected waves for a good demonstration.

(b)(i)	$v = f\lambda$ $\lambda = \frac{v}{f} = \frac{340}{1300} = 0.261\text{ m}$	No mark for this question – bracket with (b)(ii)		
(ii)	Angular separation of maxima given when n = 1 $\sin\theta = \frac{n\lambda}{d} = \frac{0.261}{2\times 0.52} = 0.251$ $\theta = 14.5^\circ$ $(= 0.254\text{ radians})$	$\sin\theta = \frac{n\lambda}{d}$ $= \frac{0.261}{0.52} = 0.502$ $\theta = 30.1^\circ$ $(= 0.527\text{ radians})$ OR use correct formula and recognise that n = 0.5.	Correct answer Allow $\sin\theta = \frac{n\lambda}{d}$ $= \frac{0.261}{0.52} = 0.502$ $\theta_{max} = 30.1^\circ$ Angle between minima is half this. $\theta_{min} = 15.05^\circ$ $(= 0.262\text{ radians})$	
2008(3) (a)	$x = \frac{0.0102}{8}$ = 1.275 × 10^{-3} m = 1.28 × 10^{-3} m	Answer rounded to 3 sf and correct units given in 1(a), 1(b) and 3(a) or (b).	Correct answer.	
(b)	$\lambda = \frac{dx}{L}$ $\Rightarrow 6.3\times 10^{-7} = \frac{d\times 1.275\times 10^{-3}}{2.14}$ $\Rightarrow \text{d} = 1.0574\times 10^{-3}$ $= 1.06\times 10^{-3}\text{ m}$	Correct answer consequential with rounded or unrounded answer to (a).		

(c)	$d = \frac{L\lambda}{x}$ (*x* is inversely proportional to *d*), so smaller *x* means larger *d*, the threads are more widely spaced.	Threads are more widely spaced.	Wider thread spacing linked to narrower fringe spacing / lesser diffraction angle	
(d)	The new threads don't change the spacing, so the spacing of the fringes in the pattern will be the same. The narrower gaps will mean less light gets through, so they will be dimmer. The narrow gaps will increase diffraction so more fringes will be visible.	Overall decrease in brightness because of narrower gaps described / one change or similarity in the pattern of fringes described.	One change or similarity in the pattern of fringes described and explained.	One change or similarity in the pattern of fringes described and explained plus either the other change or similarity in the pattern of fringes described or the overall brightness described in terms of narrower gaps.
(e)	$\lambda = \frac{dx}{L}$, $\frac{d}{L}$ constant so $\frac{\lambda}{x}$ must also be constant $\Rightarrow \frac{\lambda_R}{8x_R} = \frac{\lambda_G}{8x_G}$ $\Rightarrow \lambda_G = \frac{\lambda_R \times 8x_G}{8x_R}$ $= \frac{6.70 \times 10^{-7} \times 3.2}{4}$ $= 5.36 \times 10^{-7}$ m	Recognition that *d* and *L* are not significant	Answer correct except for incorrect handling of units.	Correct answer
2007(3) (a)	violet / blue	Correct answer		
(b)	This is a **SHOW** question $n\lambda = d \sin\theta$ n = 1, $\theta = 49.8°$, $\lambda = 5.65 \times 10^{-7}$ m $d = \frac{5.65 \times 10^{-7}}{\sin 49.8}$ = 7.39726×10^{-7} = 7.40×10^{-7} m If rounding is incorrect or s.f. is incorrect then it is only A2 and no unit grade.	Correct working Answer given to 3 s.f., and THREE answers given with a correct unit (cannot include 3b).		

(c)	Violet light from DVD would be produced when sin θ = $\frac{438 \times 10^{-9}}{7.3973 \times 10^{-7}}$ $\Rightarrow \theta$ = 36.31° So angle from CD must be 36.31 – 20.4 = 15.91° CD track spacing is d = $\frac{438 \times 10^{-9}}{\sin 15.91}$ = 1.5978 × 10^{-6} = **1.60 × 10^{-6} m**	Correct answer to DVD's $\theta = 36.31°$ **Or** Correct track spacing of CD.	Correct answer consistent with incorrectly calculated angle **Or** Achieved plus correct value of CD's angle (= 15.91°).	Correct answer
(d)	Because the tracks are further apart, when light is shone onto a CD constructive interference for any particular colour occurs at smaller angles. This means that the spectra for a CD are narrower and closer together. Since the maximum possible angle at which interference can occur is 90°, with a CD more spectra will fit in than with a DVD.	Idea of smaller angle for constructive interference /diffraction/spectra.	Larger spacing linked to smaller angle for constructive interference/diffraction/spectra.	Complete answer links wavelengths to slit spacing and angle for constructive interference/diffraction/spectra. **AND** must mention that maximum interference that can occur is at 90°
2006(3) (a)	**This is a SHOW question** $n\lambda = d \sin \theta$, n = 1 $\Rightarrow d = \frac{\lambda}{\sin\theta} = \frac{532 \times 10^{-9}}{\sin 6.00}$ = 5.089523 × 10^{-6} = 5.09 × 10^{-6} m	Correct method.		

(b)	At 1m height, horizontal distance from centre is 0.34 m. tan $\theta = \frac{0.34}{1.00} \Rightarrow \theta = 18.77803°$ $n\lambda = d\sin\theta \Rightarrow n = \frac{d\sin\theta}{\lambda}$ $= \frac{5.09\times10^{-6}\times\sin 18.77803}{532\times10^{-9}} = 3.079$ *n* is an integer and not > 3.1, so *n* = 3. Therefore, there can be three strings each side plus the central, which gives a total of 7 strings. **OR** $n\lambda = \frac{dx}{L}$ $n\times532\times10^{-9} = 5.09\times10^{-6}\times0.34$ $n = 3.2530$ $n = 3$ **OR** In Q3a the angle 6° is given so 18.6/6 = 3 each side etc	Correct idea of the **concept** of order number i.e. shows some rounding **down** to an integer. **OR** tan value (0.34) correct **OR** angle correct (18.778°) **OR** calculation correct consistent with incorrect angle θ **OR** correct substitution into $n\lambda = \frac{dx}{L}$ **OR** 2n + 1	Correct value for n (3.079 or 3 or 3.2530) If (consistent) calculation correct from incorrect θ they must do 2n+1 for merit	Correct answer. 2*n*+1 gives 7 If *n* = 3.25 2*n* = 6.5 So Number of lines =7 (max is *M*2)

(c)	The laser beam diffracts through each slit in the grating. The diffracted waves from one slit interfere with the diffracted waves from all other slits. There are well-defined "lines" along which the waves from each of the slits arrive approximately in phase so constructive interference occurs. The lines of constructive interference are narrow because, at all positions that are not close to them, the waves from the different slits arrive with a sufficiently wide range of different phases that the result is close to destructive interference. **OR** With two sources there is one nodal point between antinodal points. With three sources there are two nodal points between antinodal points. With four sources there are three nodal points between antinodal points. With five sources there are four nodal points. Etc. As the number of slits increases then there are more and more nodal points (in the same space between antinodal lines - assuming distance between slits is unchanged). Therefore, the antinodal lines must be narrower.	Recognition that: multiple slits produce narrow bands of constructive interference. **OR** With two slits the path difference for first nodal point is $1/2\lambda$ With three slits the path difference for first nodal points are $1/3\ \lambda$, $2/3\ \lambda$ With four slits the path difference for first nodal point are $1/4\ \lambda$, $2/4\ \lambda$, $3/4\ \lambda$ With n slits the path difference for first nodal point is $1/n\ \lambda$, $2/n\ \lambda$, $3/4\ \lambda$ …. (The following is about the n = 0 and n = 1 antinodal lines but is also true for other pairs of antinodal lines). As n increases the distance from the centre line (n=0 antinodal point) to the first nodal point decreases Therefore, the antinodal lines must be narrower.	Idea that bright lines are formed by multiple constructive interference **AND** that, at all other positions, the waves interfere destructively (or partially destructively). Mentions multiple destructive interference between (primary) peaks. **OR** Or mentions idea of path difference for cancellation reducing as number of slits increases.	The relevant roles of diffraction and interference are clearly explained. Must say why falloff from antinodes is sharp. E.g. more and more nodal points between anitinodal points (which must be the same distance apart) means the antinodal lines must be narrower. **OR** Thus, as number of slits increases the distance from the centre line to the first nodal point decreases. (see evidence) Therefore, the antinodal lines must be narrower.
2005(2) (a)	The first line will be violet. λ for violet is less than λ for red, hence violet will have a smaller diffraction angle.	Idea that $\lambda_V < \lambda_R$ or $f_V > f_R$ the key concept.	Correct colour and reason.	

(b)	Spacing $d = \frac{1}{N} = \frac{1}{6100}$ $= 1.63934 \times 10^{-4}$ cm $= 1.63934 \times 10^{-6}$ m	Correct working.		
(c)	$d\sin\theta = n\lambda \Rightarrow \sin\theta = \frac{1 \times 4.86 \times 10^{-7}}{1.63934 \times 10^{-6}}$ $= 0.296461$ $\Rightarrow \theta = 17.24 = 17°$ (0.3 rad)	Correct answer.		
(d)	$d\sin\theta = n\lambda$ $\Rightarrow \lambda_{red} = 1.63934 \times 10^{-6} \times \sin 23.5°$ $= 6.53685 \times 10^{-7}$ $2\lambda_{red} = 3\lambda_{purple}$ $\lambda_{purple} = \frac{2 \times 6.53685 \times 10^{-7}}{3}$ $= 4.35790 \times 10^{-7} = 4.4 \times 10^{-7}$ m	Correct λ red		Correct answer.
(e)	Decreasing N will increase d. If d increases, the angle of diffraction for each λ must decrease. This means that each spectrum will be closer to the straight-through position and higher order spectra will be seen, e.g. there will be more than three spectra. Decreasing N and increasing d means that less waves add completely in phase or completely out of phase. Partial reinforcement or cancellation means wider, less well-defined lines.	An observed difference is stated e.g. each line will be thicker / lines will not be as sharp / angle of diffraction decreases etc.	An increase in d is linked to EITHER the decreased angle OR the increase in number of spectra seen OR less well defined lines.	2 differences are clearly explained.