Higher Waves

Past Paper Answers

Contents

Higher Waves Answers

Interference and Diffraction Gratings

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13. E	14. B	15. C			

16a)	$m\lambda = d\sin\theta$ $1 \times 633 \times 10^{-9} = d \times \sin(18.5)$ $d = 1.99\ldots \times 10^{-6}$ (m) 1 metre/d = number of lines per metre number of lines per metre = <u>501000</u>	(1) (1) (1) (1)
16b)	If the bright spots are closer together then the angle θ is smaller. Assuming m and d constant, the wavelength must therefore be smaller. *Could prove through a calculation to justify your statement about the wavelength being smaller.*	(1) (1)
17a)	A minimum is produced when waves <u>meet</u> out of phase. *or* When the trough of a wave meets the crest of another wave.	(1)
17b)	Blue light has a smaller wavelength than red light. Assuming m and d are constant, the angle θ will be smaller (so the maxima are closer together). *Could prove through a calculation but must be backed up by an explanation/statement.*	(1) (1)
17c)	$m\lambda = d\sin\theta$ $2 \times 4.73 \times 10^{-7} = 2 \times 10^{-6} \times \sin\theta$ $\theta = 28.2^{o}$	(1) (1) (1)
18a)	path difference = $(m + \frac{1}{2})\lambda$ $2.14 - 1.8 = (0 + \frac{1}{2}) \times \lambda$ $\lambda = 0.68$ m	(1) (1) (1)
18b)	The amplitude of the sound increases/the sound is louder as <u>destructive</u> interference is no longer occurring.	(1) (1)

19a)	That light is a wave. *or* That light travels as a wave. *or* That energy in light is carried as a wave.	(1)
19bi)	$m\lambda = d\sin\theta$ $2 \times \lambda = 5 \times 10^{-6} \times \sin(11)$ $\lambda = 4.77 \times 10^{-7}$ m	(1) (1) (1)
19bii)	The spacing will increase as the wavelength increases (when the refractive index decreases). *Could prove through a calculation but must be backed up by an explanation/statement.*	(1) (1)
20ai)	When two waves <u>meet</u> out of phase (a minimum occurs). *or* When crests <u>meet</u> troughs.	(1)
20aii)	path difference = $m\lambda$ path difference = 3 x 28 path difference = 84 S_2 to P = 620 + 84 S_2 to P = 704 mm	(1) (1) (1)
20b)	$m\lambda = d\sin\theta$ $m \times 420 \times 10^{-9} = 3.27 \times 10^{-6} \times \sin(40)$ m = 5 (so 5th order maximum above the dotted line) 5 above + 5 below + central order maximum = <u>11</u>	(1) (1) (1) (1)
21a)	$m\lambda = d\sin\theta$ $3 \times 589 \times 10^{-9} = 5 \times 10^{-6} \times \sin\theta$ $\theta = 20.7^{\circ}$	(1) (1) (1)
21bi)	path difference = $m\lambda$ 500 - 425 = m x 30 m = 2.5 (so 2 + ½) <u>Destructive interference</u> *No attempt to justify by calculation means 0 marks, even if you said destructive interference* *"**must** justify your answer by calculation".*	 (1) (1)
21bii)	The strength of the signal increases as (destructive) interference is no longer occurring. *No attempt to explain means 0 marks, even if you said it increases.* *"**must** explain your answer".*	(1) (1)

22a)	Coherent waves have a constant phase relationship (and have the same frequency, wavelength and speed).	(1)
22b)	A maximum is produced when two waves <u>meet</u> in phase. *or* ... when waves <u>meet</u> peak to peak. *or* ... when waves <u>meet</u> trough to trough.	(1)
22c)	path difference = mλ 282 - 204 = 2 x λ λ = 39 mm	(1) (1) (1)
22d)	The path difference stays the same as the wavelength is still the same. *Could prove through a calculation but must be backed up by an explanation/statement.*	(1) (1)
23a)	A maximum is formed when two waves <u>meet</u> in phase. *or* ... when waves <u>meet</u> peak to peak. *or* ... when waves <u>meet</u> trough to trough.	(1)
23bi)	*Pick a point <u>on</u> the line of best fit, e.g. sin θ = 0.30 so 1/d = 0.62 x 10^6* 1/d = 0.62 x 10^6 d = 1/(0.62 x 10^6) mλ = dsinθ 1 x λ = 1/(0.62 x 10^6) x 0.30 λ = 4.8 x 10^{-7} m	 (1) (1) (1)
23bii)	mλ = dsinθ 1 x 4.8 x 10^{-7} = 2 x 10^{-6} x sinθ θ = 13.9^o *or* 1/d = 1/(2 x 10^{-6}) 1/d = 500000 1/d = 0.5 x 10^6 on the line of best fit for this graph this gives sinθ as 0.24 sinθ = 0.24 (from graph) θ = 13.9^o	(1) (1) (1) *or* (1) (1) (1)
23c)	Any two correct answers from: - Repeat measurements - Use additional gratings - Move screen further away - Use second order maxima to determine θ - Measure angle from first order to first order	(2)

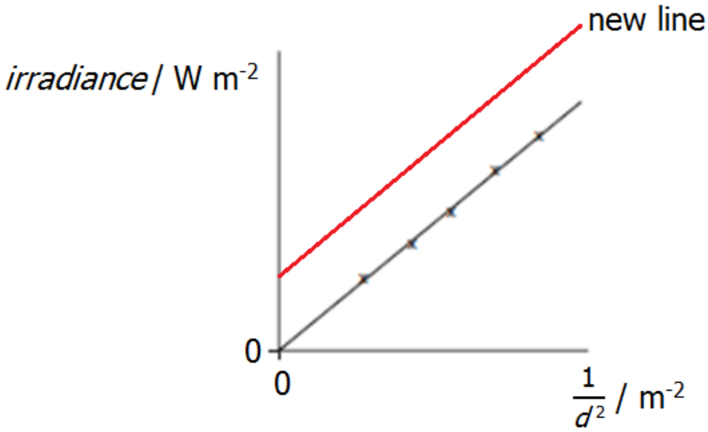
24ai)	Bright spots are produces when waves <u>meet</u> in phase. *or* ... when waves <u>meet</u> peak to peak. *or* ... when waves <u>meet</u> trough to trough.	(1)
24aii)	$m\lambda = d\sin\theta$ $3 \times 630 \times 10^{-9} = (1 \times 10^{-3})/250 \times \sin\theta$ $\theta = 28.2^{o}$ *250 lines per millimetre means the grating spacing will be 1 mm divided by 250 lines, so $1 \times 10^{-3}/250$.*	(1) (1) (1)
24aiii)	If the grating spacing decreases ($1 \times 10^{-3}/600$) then the angle θ will increase. *Could prove through a calculation to justify your statement about the angle θ increasing.*	(1) (1)
24b)	The note has vertical and horizontal lines *or* <u>crossed</u> lines/grating/grid *or* mesh	(1)
25a)	Blue light has the shortest wavelength so the angle θ will be the smallest. *Could prove through a calculation but would need to state which colour of light at the end. You'd also need to use appropriate wavelengths (i.e. found on your data sheet).*	(1) (1) (1)
25bi)	$m\lambda = d\sin\theta$ $1 \times \lambda = 3.3 \times 10^{-6} \times \sin(8.9)$ $\lambda = 5.11 \times 10^{-7}$ m (so 511×10^{-9} or 511 nm)	(1) (1) (1)
25bii)	Green (use data sheet)	(1)
25biii)	(If d is greater then) angle θ will be smaller. Smaller angles are more difficult to measure accurately.	(1) (1)

<u>Irradiance</u>

1. B 2. B 3. D 4. D 5. A 6. C

7. A 8. A 9. D

10a)	$A = \pi r^2$ $A = \pi \times (5 \times 10^{-4})^2$ $A = 7.85... \times 10^{-7}$ $I = P/A$ $1020 = P/7.85... \times 10^{-7}$ $P = 8.01 \times 10^{-4}$ W	 (1) (1) (1) (1)
10b)	The radius will be the same size as light from the laser beam won't diverge/spread out. *No attempt to justify means 0 marks, even if you said it stays the same.* *"**must** justify your answer".*	(1) (1)
11a)	Irradiance is the power per unit area. *or* Irradiance is the power per m^2.	(1)
11b)	$I = k/d^2$ $675 = k/0.2^2$ $302 = k/0.3^2$ k = 27 k = 27 $170 = k/0.4^2$ $108 = k/0.5^2$ k = 27 k = 27 $I \times d^2$ = constant *Must use **all** the data to get all three marks.* *Could also plot a graph of I vs $1/d^2$ with the line of best fit passing through the origin:1 mark for accurate points, 1 mark for axis titles (units not needed), 1 mark for statement.*	(1) equation (1) ans x4 (1) statement
11c)	To reduce/prevent reflections from the bench. *or* To absorb light.	(1)
11d)	The same reading as light from the laser beam won't diverge/spread out.	(1) (1)
12a)	(20 mV means 1 mW so) 40 mV means 2 mW $I = P/A$ $I = 2 \times 10^{-3}/8\times10^{-5}$ $I = 25$ W m^{-2}	 (1) (1) (1) (1)
12b)	$I = k/d^2$ $675 = k/0.2^2$ $302 = k/0.3^2$ k = 27 k = 27 $170 = k/0.4^2$ **P.T.O**	(1) equation (1) ans x3

	$k = 27$ $I \times d^2 = \text{constant}$ *Must use* ***all*** *the data to get all three marks.* *Could also plot a graph of I vs $1/d^2$ with the line of best fit passing through the origin:1 mark for accurate points, 1 mark for axis titles (units not needed), 1 mark for statement.*	(1) statement
13a)	It has a high irradiance as the area/radius of the beam is small.	(1)
13b)	$E = hf$ $E = 6.63 \times 10^{-34} \times 4.74 \times 10^{14}$ $E = 3.14 \times 10^{-19}$ J	(1) (1) (1)
13c)	$v = f\lambda$ $3 \times 10^{8} = 4.74 \times 10^{14} \times \lambda$ $\lambda = 6.32... \times 10^{-7}$ m $m\lambda = d\sin\theta$ $2 \times 6.32... \times 10^{-7} = d \times \sin(30)$ $d = \underline{2.53 \times 10^{-6}\text{ m}}$	(1) both eq. (1), (1) sub. (1) final ans.
14a)	As the graph shows a straight line through the origin	(1)
14b)	$I = k/d^2$ $4 = k/1.6^2$ $k = 10.24$ $I = k/d^2$ $I = 10.24/0.4^2$ $I = 64$ W m^{-2} *Using $I_1d_1^2 = I_2d_2^2$ is also an acceptable method of finding the answer.*	(1) equation (1) all sub. (1) final ans.
14c)	 *straight line which is parallel to the other one, but higher than it (doesn't pass through the origin)*	(1)
15a)	$I = k/d^2$ $242 = k/0.1^2$ $k = 2.4$ $106 = k/0.15^2$ $k = 2.4$ $60 = k/0.2^2$ $39 = k/0.25^2$ **P.T.O**	(1) equation (1) ans x4

	k = 2.4 k = 2.4 I x d^2 = constant, so it behaves like a point source. *Must use **all** the data to get all three marks.* *Could also plot a graph of I vs $1/d^2$ with the line of best fit passing through the origin:1 mark for accurate points, 1 mark for axis titles (units not needed), 1 mark for statement.*	 (1) statement
15bi)	Light from the laser won't diverge/spread out.	(1)
15bii)	$v = f\lambda$ $3 \times 10^8 = f \times 633 \times 10^{-9}$ $f = 4.73... \times 10^{14}$ Hz $E = hf$ $E = 6.63 \times 10^{-34} \times 4.73... \times 10^{14}$ E = <u>3.14×10^{-19} J</u>	(1) both eq. (1), (1) sub. (1) final ans.
15biii)	$P = E/t$ $1 \times 10^{-4} = E/5$ $E = 5 \times 10^{-4}$ J No. of photons = Total energy/energy of one photon No. of photons = $5 \times 10^{-4}/3.14 \times 10^{-19}$ No. of photons = 1.59×10^{15} (photons)	 (1) (1) (1) (1)
15biv)	Coherent waves have a constant phase relationship (and have the same frequency, wavelength and speed).	(1)
16a)	Irradiance is the power per unit area. *or* Irradiance is the power per m^2.	(1)
16b)	$I = k/d^2$ $134 = k/0.2^2$ $60.5 = k/0.3^2$ k = 5.4 k = 5.4 $33.6 = k/0.4^2$ $21.8 = k/0.5^2$ k = 5.4 k = 5.5 I x d^2 = constant *Must use **all** the data to get all three marks.* *Could also plot a graph of I vs $1/d^2$ with the line of best fit passing through the origin:1 mark for accurate points, 1 mark for axis titles (units not needed), 1 mark for statement.*	(1) equation (1) ans x4 (1) statement

16c)	$I = k/d^2$ $I = 5.4/0.6^2$ $I = 15\ W\ m^{-2}$ *Using $I_1d_1^2 = I_2d_2^2$ is also an acceptable method of finding the answer (which should be the same as or very similar to $15\ W\ m^{-2}$)*	(1) (1) (1)
16d)	Use a smaller lamp as this will act more like a point source. *or* Put a black cloth on the table/bench as this will reduce reflections/absorb light.	(1) (1) *or* (1) (1)

Line Spectra

1. C 2. E 3. D 4. C 5. E 6. B

7. B 8. A 9. D 10. A

11a)	6	(1)
11b)	Q_3 to Q_2 *Q_3 - Q_2 is incorrect. Must use "to" or "→" i.e. Q_3 to Q_2 or $Q_3 \rightarrow Q_2$*	(1)
11c)	(Shortest wavelength means highest frequency so highest energy/energy transition so P_2 to P_0.) $E_2 - E_1 = hf$ $-2.4 \times 10^{-19} - (-21.8 \times 10^{-19}) = 6.63 \times 10^{-34} \times f$ $f = 2.92... \times 10^{15}$ Hz $v = f\lambda$ $3 \times 10^8 = 2.92... \times 10^{15} \times \lambda$ $\lambda = \underline{1.03 \times 10^{-7}\ m}$	 (1) both eq. (1), (1) sub. (1) final ans.
11d)	Energy gap is the same size so frequency/wavelength is the same.	(1)
12a)	E_0 to E_3 (*the other way around is incorrect)* *or* $E_0 \rightarrow E_3$	(1)
12b)	$E_2 - E_1 = hf$ $-1.36 \times 10^{-19} - (-5.42 \times 10^{-19}) = 6.63 \times 10^{-34} \times f$ $f = 6.12 \times 10^{14}$ Hz	(1) (1) (1)
13a)	Any two correct answers: - A positively charged nucleus.	(2)

	- Electrons are in (discrete) energy levels/shells. - When an electron moves from one stat to another, the energy lost or gained is done so only in very specific amounts of energy. - Each line in a spectrum is produced when an electron moves from one energy level/orbit/shell to another.	
13b)	$E_2 - E_1 = hf$ $-1.36 \times 10^{-19} - (-5.45 \times 10^{-19}) = 6.63 \text{ X } 10^{-34} \times f$ $f = 6.17 \times 10^{14}$ Hz	(1) (1) (1)
13c)	$z = (\lambda_o - \lambda_r)/\lambda_r$ $z = (661 - 656)/656$ $z = 7.62... \times 10^{-3}$ $z = v/c$ $7.62... \times 10^{-3} = v/3 \times 10^8$ $v = 2.29 \times 10^6$ m s^{-1}	(1) (1) (1) (1) (1)
14ai)	E_3 to E_0 as the shortest wavelength will have the highest frequency, therefore the highest energy/energy level transition.	(1) (1)
14aii)	$E_2 - E_1 = hf$ $-5.2 \times 10^{-19} - (-9 \times 10^{-19}) = 6.63 \text{ X } 10^{-34} \times f$ $f = 5.73 \times 10^{14}$ Hz	(1) (1) (1)
14b)	In the air $v = f\lambda$ $3 \times 10^8 = 4.6 \times 10^{14} \times \lambda$ $\lambda = 6.52... \times 10^{-7}$ In the glass $\lambda_1 / \lambda_2 = \sin\theta_1 / \sin\theta_2$ $6.52... \times 10^{-7}/\lambda_2 = \sin(53)/\sin(30)$ $\lambda_2 =$ 4.08×10^{-7} m	(1) both eq. (1), (1) sub. (1) final ans.
15a)	$v = f\lambda$ $3 \times 10^8 = f \times 656.28 \times 10^{-9}$ $f = 4.57... \times 10^{14}$ Hz $E_2 - E_1 = hf$ $E_2 - E_1 = 6.63 \text{ X } 10^{-34} \times 4.57... \times 10^{14}$ $E_2 - E_1 = 3.03 \times 10^{-19}$ J E_3 to E_2 produces the hydrogen alpha line.	 (1) "f" value (1) equation (1) sub. (1) statement
15bi)	(Period of time for one wave cycle e.g. peak to peak) 12 days	 (1)

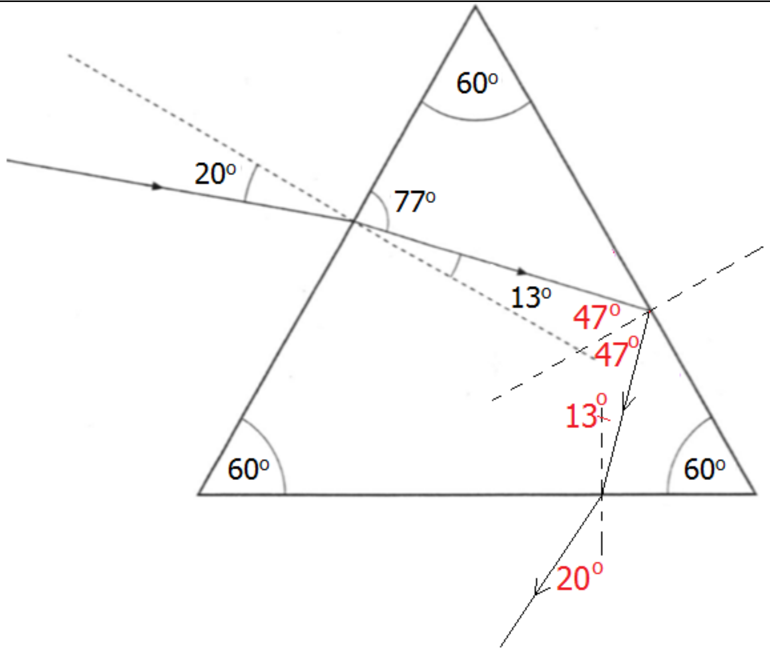
15bii)	$z = (\lambda_o - \lambda_r)/\lambda_r$ $z = (656.41 - 656.28)/656.28$ $z = 1.98... \times 10^{-4}$ $z = v/c$ $1.98... \times 10^{-4} = v/3 \times 10^8$ $v = 5.94 \times 10^4$ m s^{-1}	(1) (1) (1) (1) (1)
15biii)	The blueshift is less than the redshift so the approach velocity is smaller. *Could prove by calculation but needs to be backed up with a statement about the approach velocity being smaller.*	(1) (1)
16a)	Photons of particular energy/frequency are absorbed in the Sun's atmosphere/outer layers	(1) (1)
16bi)	Light is redshifted/shifted <u>towards</u> the red as the galaxies are moving away.	(1) (1)
16bii)	$z = (\lambda_o - \lambda_r)/\lambda_r$ $z = (450 \times 10^{-9} - 410 \times 10^{-9})/410 \times 10^{-9}$ $z = 0.098$ *"Show" question means you've already been given the answer – no mark for this part.*	(1) (1)
16biii)	$z = v/c$ $0.098 = v/3 \times 10^8$ $v = 2.94 \times 10^7$ m s^{-1} $v = H_0 d$ $2.94 \times 10^7 = 2.3 \times 10^{-18} \times d$ $d = 1.3 \times 10^{25}$ m	(1) (1) (1) (1) (1)
17ai)	$E_2 - E_1 = hf$ $-2.976 \times 10^{-18} - (-3.29 \times 10^{-18}) = 6.63 \text{ X } 10^{-34} \times f$ $f = 4.73... \times 10^{14}$ Hz $v = f\lambda$ $3 \times 10^8 = 4.73... \times 10^{14} \times \lambda$ $\lambda = \underline{6.33 \times 10^{-7} \text{ m}}$	(1) both eq. (1), (1) sub. (1) final ans.
17aii)	$A = \pi r^2$ $A = \pi \times (4 \times 10^{-4})^2$ $I = P/A$ $9950 = P/(\pi \times (4 \times 10^{-4})^2)$ $P = 5 \times 10^{-3}$ W	 (1) (1) (1) (1)
17b)	Measure values of irradiance for different distances Plot a graph of I against $1/d^2$ Graph of I against $1/d^2$ is a straight line <u>through the origin</u> **P.T.O**	(1) (1) (1)

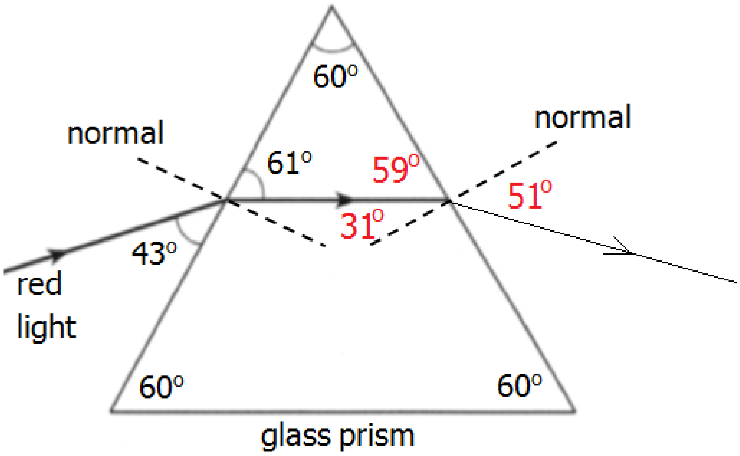
	or Measure values of irradiance for different distances Determine I x d^2 Values of I x d^2 are constant (verifying the inverse square law of light)	*or* (1) (1) (1)

Refraction

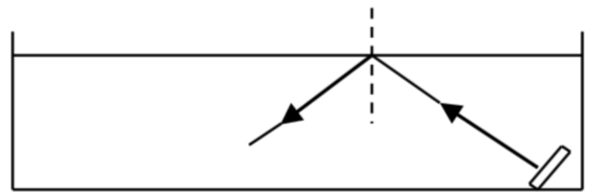
1. C	2. C	3. C	4. D	5. A	6. A
7. B	8. A	9. D	10. C	11. E	12. B
13. E	14. D	15. B	16. B	17. A	18. E
19. D	20. E	21. D	22. C		

23a)	$m\lambda = d\sin\theta$ $2 \times 486 \times 10^{-9} = 2.16 \times 10^{-6} \times \sin\theta$ $\theta = 26.7^{o}$	(1) (1) (1)
23bi)	$n = \sin\theta_1/\sin\theta_2$ $n = \sin 47/\sin 27$ $n = 1.61$ *"Show" question means you've already been given the answer – no mark for this part.*	(1) (1)
23bii)	$n = 1/\sin\theta_c$ $1.61 = 1/\sin\theta_c$ $\theta_c = 38^{o}$ As $63^{o} > 38^{o}$ then the ray will totally internally reflect at point **X**. *No attempt to justify by calculation means 0 marks, even if you said it the ray will totally internally reflect.* *"**must** justify your answer by calculation".*	 (1) (1)
24a)	$n = \sin\theta_1/\sin\theta_2$ $n = \sin 20/\sin 13$ $n = 1.52$ *"Show" question means you've already been given the answer – no mark for this part.*	(1) (1)
24b)	When the angle of incidence is equal to the critical angle, the angle of refraction is equal to 90^{o}.	(1)
24c)	$n = 1/\sin\theta_c$ $1.52 = 1/\sin\theta_c$ $\theta_c = 41^{o}$	(1) (1) (1)

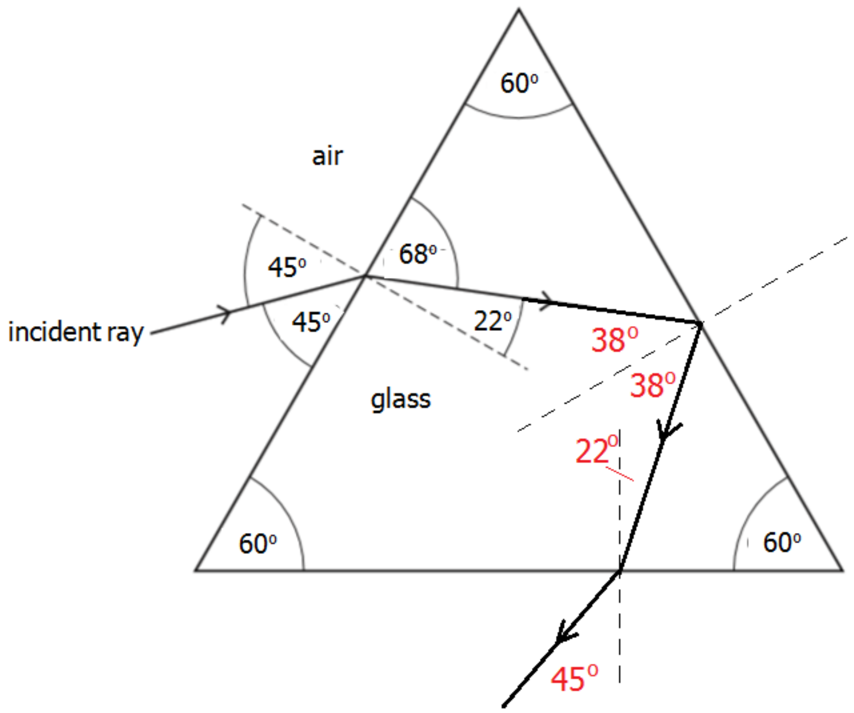
24d)	 *Total Internal Reflection* *47°* *Refraction away from the normal on exit* *13° + 20°*	 (1) (1) (1) (1)
25ai)	$n = \sin\theta_1/\sin\theta_2$ n = sin(82)/sin(45) n = 1.4	(1) (1) (1)
25aii)	The angle of refraction will be greater than 82° as if the refractive index n is greater and $\sin\theta_2$ (sin45) is constant then $\sin\theta_1$ must be greater ($n = \sin\theta_1/\sin\theta_2$) so θ_1 is greater. *Could prove through a calculation but would need to be backed up with a statement and explanation.*	(1) (1)
25b)	$n = 1/\sin\theta_c$ $1.44 = 1/\sin\theta_c$ $\theta_c = 44°$ As 45° > 44° then the ray will totally internally reflect at the surface. *No attempt to justify by calculation means 0 marks, even if you said it the ray will totally internally reflect.* *"**must** justify your answer by calculation".*	 (1) (1)
26ai)	$n = \sin\theta_1/\sin\theta_2$ n = sin(47)/sin(29) n = 1.51	(1) (1) (1)

26aii)	$n = 1/\sin\theta_c$ $1.51 = 1/\sin\theta_c$ $\theta_c = 41^o$	(1) (1) (1)
26aiii)	 *Refraction out of the prism* *31°* *51°* *Arrow on ray*	 (1) (1) (1) (1)
26bi)	A bright fringe/maximum is produced when two waves meet in phase. *or* ... when two waves meet peak to peak. *or* .... when two waves meet trough to trough.	(1)
26bii)	$m\lambda = d\sin\theta$ $2 \times 650 \times 10^{-9} = (1 \times 10^{-3})/300 \times \sin\theta$ $\theta = 23^o$ *300 lines per millimetre means the grating spacing will be 1 mm divided by 300 lines, so* $1 \times 10^{-3}/300$.	(1) (1) (1)
26biii)	The angle θ will decrease/the bright fringes will be closer together as the wavelength is now smaller (blue light has a smaller wavelength than red). *Could prove through a calculation to justify your statement about the angle* θ *being smaller.*	(1) (1)
27a)	$n = \sin\theta_1/\sin\theta_2$ $1.5 = \sin(50)/\sin\theta_2$ $\theta_2 = 31^o$	(1) (1) (1)
27b)	$n = \lambda_1/\lambda_2$ $1.5 = \lambda_1/420 \times 10^{-9}$ $\lambda_1 = 6.3 \times 10^{-7}$ m (or 630 nm)	(1) (1) (1)

27c)	The angle of refraction θ inside the glass will be lesser as blue light is refracted by a prism more than red light. *or* as the refractive index of blue light is more than that of red light.	(1) (1) *or* (1)
28ai)	$n = \sin\theta_1/\sin\theta_2$ $1.61 = \sin(28)/\sin\theta_2$ $\theta_2 = 17^o$	(1) (1) (1)
28aii)	<u>In the air</u> $v = f\lambda$ $3 \times 10^8 = 4.8 \times 10^{14} \times \lambda$ $\lambda = 6.25 \times 10^{-7}$ <u>In the glass</u> $n = \lambda_1/\lambda_2$ $1.61 = 6.25 \times 10^{-7}/\lambda_2$ $\lambda_2 = \underline{3.88 \times 10^{-7}\ m}$	(1) both eq. (1), (1) sub. (1) final ans.
28b)	X as blue light is refracted more (by glass compared to red light).	(1) (1)
29a)	It remains unchanged/constant.	(1)
29b)	$n = \sin\theta_1/\sin\theta_2$ $n = \sin(60)/\sin(41)$ $n = 1.32$	(1) (1) (1)
29c)	$n = 1/\sin\theta_c$ $1.32 = 1/\sin\theta_c$ $\theta_c = 49^o$	(1) (1) (1)
29d)	Less than as shorter wavelengths refract more/have a larger refractive index.	(1) (1)
30ai)	$n = \sin\theta_1/\sin\theta_2$ $1.66 = \sin(40)/\sin\theta_2$ $\theta_2 = 23^o$	(1) (1) (1)
30aiiA)	$n = 1/\sin\theta_c$ $1.66 = 1/\sin\theta_c$ $\theta_c = 37^o$	(1) (1) (1)
30aiiB)	74^o *If you put a normal on the surface where angle X is then the angle of incidence would be the critical angle, 37°, so angle X is 37° + the angle of reflection, which is also 37°.*	(1)
30b)	No, it won't refract (it will totally internally reflect) as blue light has a higher refractive index than red light so the critical angle will be smaller.	(1) (1)

31a)	$n = \sin\theta_1/\sin\theta_2$ $1.33 = \sin\theta_1/\sin(36)$ $\theta_1 = 51^o$	(1) (1) (1)
31bi)	The angle of refraction equals 90^o.	(1)
31bii)	$n = 1/\sin\theta_c$ $1.33 = 1/\sin\theta_c$ $\theta_c = 49^o$	(1) (1) (1)
31c)	 *Totally internally reflected ray*	(1)
32a)	$n = \sin\theta_1/\sin\theta_2$ $1.49 = \sin\theta_1/\sin(19)$ $\theta_1 = 29^o$	(1) (1) (1)
32b)	$n = 1/\sin\theta_c$ $1.49 = 1/\sin\theta_c$ $\theta_c = 42^o$	(1) (1) (1)
32c)	Different frequencies/colours are refracted through different angles. *or* The refractive index is different for different frequencies/colours.	(1)
33a)	$n = \sin\theta_1/\sin\theta_2$ $1.615 = \sin\theta_1/\sin(38)$ $\theta_1 = 84^o$ *Find the refractive index from the graph when the wavelength is 660 nm.*	(1) (1) (1)
33b)	The speed in the prism will be less as shorter wavelength light will have a higher refractive index. *Could prove through a calculation to justify your statement about the speed being less ($n = v_1/v_2$).*	(1) (1)
34ai)	Different frequencies/colours are refracted through different angles. *or* The refractive index is different for different frequencies/colours.	(1)
34aii)	$n = v_1/v_2$ $1.54 = 3 \times 10^8/v_2$ $v_2 = 1.95 \times 10^8$ m s^{-1}	(1) (1) (1)

34bi)	$v = f\lambda$ $3 \times 10^8 = 4.57 \times 10^{14} \times \lambda$ $\lambda = 6.56... \times 10^{-7}$ m $m\lambda = d\sin\theta$ $2 \times 6.56... \times 10^{-7} = d \times \sin(19)$ $d = 4.03 \times 10^{-6}$ m	(1) both eq. (1), (1) sub. (1) final ans.
34bii)	Blue light has a smaller wavelength than red light. As $m\lambda = d\sin\theta$, (and m and d are constant) this means the angle between the 2nd order maximum and the central maximum will be smaller.	(1) (1)
35a)	The ratio of the speed of light in a vacuum to the speed of light in a medium.	(1)
35b)	$n = \sin\theta_1/\sin\theta_2$ $n = \sin(36)/\sin(18)$ $n = 1.9$	(1) (1) (1)
35c)	$n = 1/\sin\theta_c$ $1.9 = 1/\sin\theta_c$ $\theta_c = 32^o$	(1) (1) (1)
36a)	$n = \sin\theta_1/\sin\theta_2$ $n = \sin(45)/\sin(22)$ $n = 1.89$ *"Show" question means you've already been given the answer – no mark for this part.*	(1) (1)
36bi)	When the angle of incidence is equal to the critical angle, the angle of refraction is equal to 90^o.	(1)
36bii)	$n = 1/\sin\theta_c$ $1.89 = 1/\sin\theta_c$ $\theta_c = 32^o$	(1) (1) (1)

<table>
<tr><td>36biii)</td><td>

Total Internal Reflection
38°
Refraction <u>away</u> from the normal on exit
22° + 45°</td><td>(1)
(1)
(1)
(1)</td></tr>
<tr><td>37a)</td><td>$n = \sin\theta_1/\sin\theta_2$
$2.42 = \sin(49)/\sin\theta_2$
$\theta_2 = 18°$</td><td>(1)
(1)
(1)</td></tr>
<tr><td>37b)</td><td>$n = 1/\sin\theta_c$
$2.42 = 1/\sin\theta_c$
$\theta_c = 24°$</td><td>(1)
(1)
(1)</td></tr>
<tr><td>37c)</td><td>More
as the critical angle for moissanite will be smaller (due to greater refractive index)
meaning more light will be totally internally reflected.</td><td>(1)
(1)

(1)</td></tr>
</table>