Higher Waves

Past Paper Answers

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Higher Waves Answers

Interference and Diffraction Gratings

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|  |  |  |
| --- | --- | --- |
| 16a) | mλ = dsinθ 1 x 633 x 10-9 = d x sin(18.5) d = 1.99… x 10-6 (m)  1 metre/d = number of lines per metre number of lines per metre = 501000 | (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 meet 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) | mλ = dsinθ 2 x 4.73 x 10-7 = 2 x 10-6 x sinθ θ = 28.2o | (1) (1) (1) |
| 18a) | path difference = (m + ½)λ 2.14 - 1.8 = (0 + ½) x λ λ = 0.68 m | (1) (1) (1) |
| 18b) | The amplitude of the sound increases/the sound is louder as destructive 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) | mλ = dsinθ 2 x λ= 5 x 10-6 x sin(11) λ = 4.77 x 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 meet out of phase (a minimum occurs). *or* When crests meet troughs. | (1) |
| 20aii) | path difference = mλ path difference = 3 x 28  path difference = 84  S2 to P = 620 + 84 S2 to P = 704 mm | (1) (1)  (1) |
| 20b) | mλ = dsinθ m x 420 x 10-9 = 3.27 x 10-6 x sin(40) m = 5 (so 5th order maximum above the dotted line)  5 above + 5 below + central order maximum = 11 | (1) (1) (1)  (1) |
| 21a) | mλ = dsinθ 3 x 589 x 10-9 = 5 x 10-6 x sinθ θ = 20.7o | (1) (1) (1) |
| 21bi) | path difference = mλ 500 - 425 = m x 30 m = 2.5 (so 2 + ½)  Destructive interference  *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 meet in phase. *or* ... when waves meet peak to peak. *or* ... when waves meet 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 meet in phase. *or* ... when waves meet peak to peak. *or* ... when waves meet trough to trough. | (1) |
| 23bi) | *Pick a point on the line of best fit, e.g. sin θ = 0.30 so 1/d = 0.62 x 10 6*  1/d = 0.62 x 106 d = 1/(0.62 x 106)  mλ = dsinθ 1 x λ = 1/(0.62 x 106) 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 = 13.9o *or* 1/d = 1/(2 x 10-6) 1/d = 500000 1/d = 0.5 x 106 on the line of best fit for this graph this gives sinθ as 0.24 sinθ = 0.24 (from graph) θ = 13.9o | (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 meet in phase. *or* ... when waves meet peak to peak. *or* ... when waves meet trough to trough. | (1) |
| 24aii) | mλ = dsinθ 3 x 630 x 10-9 = (1 x 10-3)/250 x sinθ θ = 28.2o  *250 lines per millimetre means the grating spacing will be 1 mm divided by 250 lines, so 1 x 10 -3/250.* | (1) (1) (1) |
| 24aiii) | If the grating spacing decreases (1 x 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* crossed 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) | mλ = dsinθ 1 x λ= 3.3 x 10-6 x sin(8.9) λ = 5.11 x 10-7 m (so 511 x 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) |

Irradiance

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

7. A 8. A 9. D

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| --- | --- | --- |
| 10a) | A = **π**r2 A = **π** x (5 x 10-4)2 A = 7.85... x 10-7  I = P/A 1020 = P/7.85... x 10-7 P = 8.01 x 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 m2. | (1) |
| 11b) | I = k/d2  675 = k/0.22 302 = k/0.32  k = 27 k = 27  170 = k/0.42 108 = k/0.52  k = 27 k = 27  I x d2 = 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 x 10-3/8x10-5 I = 25 W m-2 | (1)  (1) (1) (1) |
| 12b) | I = k/d2  675 = k/0.22 302 = k/0.32  k = 27 k = 27  170 = k/0.42 **P.T.O** k = 27  I x d2 = 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 x3    (1) statement |
| 13a) | It has a high irradiance as the area/radius of the beam is small. | (1) |
| 13b) | E = hf E = 6.63 x 10-34 x 4.74 x 1014 E = 3.14 x 10-19 J | (1) (1) (1) |
| 13c) | v = fλ 3 x 108 = 4.74 x 1014 x λ λ = 6.32... x 10-7 m  mλ = dsinθ 2 x 6.32... x 10-7 = d x sin(30) d = 2.53 x 10-6 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/d2 I = k/d2  4 = k/1.62 I = 10.24/0.42  k = 10.24 I = 64 W m-2  *Using I1d12 = I2d22 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/d2  242 = k/0.12 106 = k/0.152  k = 2.4 k = 2.4  60 = k/0.22 39 = k/0.252 **P.T.O** k = 2.4 k = 2.4  I x d2 = 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) equation  (1) ans x4    (1) statement |
| 15bi) | Light from the laser won't diverge/spread out. | (1) |
| 15bii) | v = fλ 3 x 108 = f x 633 x 10-9 f = 4.73... x 1014 Hz  E = hf E = 6.63 x 10-34 x 4.73... x 1014 E = 3.14 x 10-19 J | (1) both eq. (1), (1) sub. (1) final ans. |
| 15biii) | P = E/t 1 x 10-4 = E/5 E = 5 x 10-4 J  No. of photons = Total energy/energy of one photon No. of photons = 5 x 10-4/3.14 x 10-19 No. of photons = 1.59 x 1015 (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 m2. | (1) |
| 16b) | I = k/d2  134 = k/0.22 60.5 = k/0.32  k = 5.4 k = 5.4  33.6 = k/0.42 21.8 = k/0.52  k = 5.4 k = 5.5  I x d2 = 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/d2  I = 5.4/0.62  I = 15 W m-2  *Using I1d12 = I2d22 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

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| 11a) | 6 | (1) |
| 11b) | Q3 to Q2  *Q3 - Q2 is incorrect. Must use "to" or "→" i.e. Q3 to Q2 or Q3 → Q2* | (1) |
| 11c) | (Shortest wavelength means highest frequency so highest energy/energy transition so P2 to P0.)  E2 - E1 = hf -2.4 x 10-19 - (-21.8 x 10-19) = 6.63 X 10-34 x f f = 2.92... x 1015 Hz  v = fλ 3 x 108 = 2.92... x 1015 x λ λ = 1.03 x 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) | E0 to E3 (*the other way around is incorrect) or* E0 →E3 | (1) |
| 12b) | E2 - E1 = hf -1.36 x 10-19 - (-5.42 x 10-19) = 6.63 X 10-34 x f f = 6.12 x 1014 Hz | (1) (1) (1) |
| 13a) | Any two correct answers:  - A positively charged nucleus. - 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. | (2) |
| 13b) | E2 - E1 = hf -1.36 x 10-19 - (-5.45 x 10-19) = 6.63 X 10-34 x f f = 6.17 x 1014 Hz | (1) (1) (1) |
| 13c) | z = (λo - λr)/λr z = (661 - 656)/656 z = 7.62... x 10-3  z = v/c 7.62... x 10-3 = v/3 x 108 v = 2.29 x 106 m s-1 | (1) (1)  (1) (1) (1) |
| 14ai) | E3 to E0 as the shortest wavelength will have the highest frequency, therefore the highest energy/energy level transition. | (1)  (1) |
| 14aii) | E2 - E1 = hf -5.2 x 10-19 - (-9 x 10-19) = 6.63 X 10-34 x f f = 5.73 x 1014 Hz | (1) (1) (1) |
| 14b) | In the air v = fλ 3 x 108 = 4.6 x 1014 x λ λ = 6.52... x 10-7  In the glass λ1/ λ2 = sinθ1/sinθ2 6.52... x 10-7/λ2­ = sin(53)/sin(30) λ2­ = 4.08 x 10-7 m | (1) both eq.(1), (1) sub. (1) final ans. |
| 15a) | v = fλ 3 x 108 = f x 656.28 x 10-9 f = 4.57... x 1014 Hz  E2 - E1 = hf E2 - E1 = 6.63 X 10-34 x 4.57... x 1014 E2 - E1 = 3.03 x 10-19 J  E3 to E2 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 = (λo - λr)/λr z = (656.41 - 656.28)/656.28 z = 1.98... x 10-4  z = v/c 1.98... x 10-4 = v/3 x 108 v = 5.94 x 104 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 towards the red as the galaxies are moving away. | (1) (1) |
| 16bii) | z = (λo - λr)/λr z = (450 x 10-9 - 410 x 10-9)/410 x 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 x 108 v = 2.94 x 107 m s-1  v = H­0­d 2.94 x 107 = 2.3 x 10-18 x d d = 1.3 x 1025 m | (1) (1)  (1) (1) (1) |
| 17ai) | E2 - E1 = hf -2.976 x 10-18 - (-3.29 x 10-18) = 6.63 X 10-34 x f f = 4.73... x 1014 Hz  v = fλ 3 x 108 = 4.73... x 1014 x λ λ = 6.33 x 10-7 m | (1) both eq. (1), (1) sub. (1) final ans. |
| 17aii) | A = **π**r2 A = **π** x (4 x 10-4)2  I = P/A 9950 = P/(**π** x (4 x 10-4)2) P = 5 x 10-3 W | (1)  (1) (1) (1) |
| 17b) | Measure values of irradiance for different distances Plot a graph of I against 1/d2 Graph of I against 1/d2 is a straight line through the origin **P.T.O**  *or* Measure values of irradiance for different distances Determine I x d2  Values of I x d2 are constant (verifying the inverse square law of light) | (1) (1) (1)  *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) | mλ = dsinθ 2 x 486 x 10-9 = 2.16 x 10-6 x sinθ θ = 26.7o | (1) (1) (1) |
| 23bi) | n = sinθ­1­/sinθ­2 n = sin47/sin27 n = 1.61  *“Show” question means you’ve already been given the answer – no mark for this part.* | (1) (1) |
| 23bii) | n = 1/sinθ­c 1.61 = 1/sinθ­c θ­c = 38o  As 63o > 38o 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 = sinθ­1­/sinθ­2 n = sin20/sin13 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 90o. | (1) |
| 24c) | n = 1/sinθ­c 1.52 = 1/sinθ­c θ­c = 41o | (1) (1) (1) |
| 24d) | *Total Internal Reflection  47o  Refraction away from the normal on exit  13o + 20o* | (1) (1) (1) (1) |
| 25ai) | n = sinθ1/sinθ2 n = sin(82)/sin(45) n = 1.4 | (1) (1) (1) |
| 25aii) | The angle of refraction will be greater than 82o as if the refractive index n is greater and sinθ2 (sin45) is constant then sinθ1 must be greater (n = sinθ1/sinθ2) so θ1 is greater.  *Could prove through a calculation but would need to be backed up with a statement and explanation.* | (1)  (1) |
| 25b) | n = 1/sinθ­c 1.44 = 1/sinθ­c θ­c = 44o  As 45o > 44o 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 = sinθ1/sinθ2 n = sin(47)/sin(29) n = 1.51 | (1) (1) (1) |
| 26aii) | n = 1/sinθ­c 1.51 = 1/sinθ­c θ­c = 41o | (1) (1) (1) |
| 26aiii) | *Refraction out of the prism  31o 51o 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) | mλ = dsinθ 2 x 650 x 10-9 = (1 x 10-3)/300 x sinθ θ = 23o  *300 lines per millimetre means the grating spacing will be 1 mm divided by 300 lines, so 1 x 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 = sinθ1/sinθ2 1.5 = sin(50)/sinθ2 θ2 = 31o | (1) (1) (1) |
| 27b) | n = λ­1­/λ­2 1.5 = λ­1­/420 x 10-9 λ­1 = 6.3 x 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 = sinθ1/sinθ2 1.61 = sin(28)/sinθ2 θ2 = 17o | (1) (1) (1) |
| 28aii) | In the air v = fλ 3 x 108 = 4.8 x 1014 x λ λ = 6.25 x 10-7  In the glass n = λ1/ λ2  1.61 = 6.25 x 10-7/λ2­ λ2­ = 3.88 x 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 = sinθ1/sinθ2 n = sin(60)/sin(41) n = 1.32 | (1) (1) (1) |
| 29c) | n = 1/sinθ­c 1.32 = 1/sinθ­c θ­c = 49o | (1) (1) (1) |
| 29d) | Less than as shorter wavelengths refract more/have a larger refractive index. | (1) (1) |
| 30ai) | n = sinθ1/sinθ2 1.66 = sin(40)/sinθ2 θ2­ = 23o | (1)  (1) (1) |
| 30aiiA) | n = 1/sinθ­c 1.66 = 1/sinθ­c θ­c = 37o | (1) (1) (1) |
| 30aiiB) | 74o  *If you put a normal on the surface where angle X is then the angle of incidence would be the critical angle, 37o, so angle X is 37o + the angle of reflection, which is also 37o.* | (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 = sinθ1/sinθ2 1.33 = sinθ1/sin(36) θ1­ = 51o | (1)  (1) (1) |
| 31bi) | The angle of refraction equals 90o­. | (1) |
| 31bii) | n = 1/sinθ­c 1.33 = 1/sinθ­c θ­c = 49o | (1) (1) (1) |
| 31c) | *Totally internally reflected ray* | (1) |
| 32a) | n = sinθ1/sinθ2 1.49 = sinθ1/sin(19) θ1­ = 29o | (1) (1) (1) |
| 32b) | n = 1/sinθ­c 1.49 = 1/sinθ­c θ­c = 42o | (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 = sinθ1/sinθ2 1.615 = sinθ1/sin(38) θ1­ = 84o  *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 = v1/v2).* | (1) (1) |
| 34ai) | Different frequencies/colours are refracted through different angles. *or* The refractive index is different for different frequencies/colours. | (1) |
| 34aii) | n = v1/v2 1.54 = 3 x 108/v2 v2­ = 1.95 x 108 m s-1 | (1) (1) (1) |
| 34bi) | v = fλ 3 x 108 = 4.57 x 1014 x λ λ = 6.56... x 10-7 m  mλ = dsinθ 2 x 6.56... x 10-7  = d x sin(19) d = 4.03 x 10-6 m | (1) both eq. (1), (1) sub. (1) final ans. |
| 34bii) | Blue light has a smaller wavelength than red light. As mλ = dsinθ, (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 = sinθ1/sinθ2 n = sin(36)/sin(18) n = 1.9 | (1) (1) (1) |
| 35c) | n = 1/sinθ­c 1.9 = 1/sinθ­c θ­c = 32o | (1) (1) (1) |
| 36a) | n = sinθ1/sinθ2 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 90o. | (1) |
| 36bii) | n = 1/sinθ­c 1.89 = 1/sinθ­c θ­c = 32o | (1) (1) (1) |
| 36biii) | *Total Internal Reflection  38o  Refraction away from the normal on exit  22o + 45o* | (1) (1) (1) (1) |
| 37a) | n = sinθ1/sinθ2 2.42 = sin(49)/sinθ2 θ2­ = 18o | (1) (1) (1) |
| 37b) | n = 1/sinθ­c 2.42 = 1/sinθ­c θ­c = 24o | (1) (1) (1) |
| 37c) | More as the critical angle for moissanite will be smaller (due to greater refractive index) meaning more light will be totally internally reflected. | (1) (1)  (1) |