Higher Waves

Past Paper Answers

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Higher Waves Answers

Interference and Diffraction Gratings

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| 16a) | mλ = dsinθ1 x 633 x 10-9 = d x sin(18.5)d = 1.99… x 10-6 (m)1 metre/d = number of lines per metrenumber 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 = dsinθ2 x 4.73 x 10-7 = 2 x 10-6 x sinθθ = 28.2o | (1)(1)(1) |
| 18a) | path difference = (m + ½)λ2.14 - 1.8 = (0 + ½) x λλ = 0.68 m | (1)(1)(1) |
| 18b) | The amplitude of the sound increases/the sound is louderas 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 = dsinθ2 x λ= 5 x 10-6 x sin(11)λ = 4.77 x 10-7 m | (1)(1)(1) |
| 19bii) | The spacing will increaseas 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 = mλpath difference = 3 x 28 path difference = 84 S2 to P = 620 + 84S2 to P = 704 mm  | (1)(1)(1) |
| 20b) | mλ = dsinθm 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 = dsinθ3 x 589 x 10-9 = 5 x 10-6 x sinθθ = 20.7o | (1)(1)(1) |
| 21bi) | path difference = mλ500 - 425 = m x 30m = 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 increasesas (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 = mλ282 - 204 = 2 x λλ = 39 mm  | (1)(1)(1) |
| 22d) | The path difference stays the sameas 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 106d = 1/(0.62 x 106)mλ = dsinθ1 x λ = 1/(0.62 x 106) x 0.30λ = 4.8 x 10-7 m | (1)(1)(1) |
| 23bii) | mλ = dsinθ1 x 4.8 x 10-7 = 2 x 10-6 x sinθθ = 13.9o*or*1/d = 1/(2 x 10-6)1/d = 5000001/d = 0.5 x 106on the line of best fit for this graph this gives sinθ as 0.24sinθ = 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 = dsinθ3 x 630 x 10-9 = (1 x 10-3)/250 x sinθθ = 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 wavelengthso 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 = dsinθ1 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**r2A = **π** x (5 x 10-4)2A = 7.85... x 10-7I = P/A1020 = P/7.85... x 10-7P = 8.01 x 10-4 W | (1)(1)(1)(1) |
| 10b) | The radius will be the same sizeas 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 readingas light from the laser beam won't diverge/spread out. | (1)(1) |
| 12a) | (20 mV means 1 mW so)40 mV means 2 mWI = P/AI = 2 x 10-3/8x10-5I = 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 = hfE = 6.63 x 10-34 x 4.74 x 1014E = 3.14 x 10-19 J | (1)(1)(1) |
| 13c) | v = fλ3 x 108 = 4.74 x 1014 x λλ = 6.32... x 10-7 mmλ = dsinθ2 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 = 2.4I 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 = fλ3 x 108 = f x 633 x 10-9f = 4.73... x 1014 HzE = hfE = 6.63 x 10-34 x 4.73... x 1014E = 3.14 x 10-19 J | (1) both eq.(1), (1) sub.(1) final ans. |
| 15biii) | P = E/t1 x 10-4 = E/5E = 5 x 10-4 JNo. of photons = Total energy/energy of one photonNo. of photons = 5 x 10-4/3.14 x 10-19No. 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 = 5.5I 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 lampas this will act more like a point source.*or*Put a black cloth on the table/benchas 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) | 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 ff = 2.92... x 1015 Hzv = fλ3 x 108 = 2.92... x 1015 x λλ = 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 ff = 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 ff = 6.17 x 1014 Hz | (1)(1)(1) |
| 13c) | z = (λo - λr)/λrz = (661 - 656)/656z = 7.62... x 10-3z = v/c7.62... x 10-3 = v/3 x 108v = 2.29 x 106 m s-1 | (1)(1)(1)(1)(1) |
| 14ai) | E3 to E0as 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 ff = 5.73 x 1014 Hz | (1)(1)(1) |
| 14b) | In the airv = fλ3 x 108 = 4.6 x 1014 x λλ = 6.52... x 10-7In the glassλ1/ λ2 = sinθ1/sinθ26.52... 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 = fλ3 x 108 = f x 656.28 x 10-9f = 4.57... x 1014 HzE2 - E1 = hfE2 - E1 = 6.63 X 10-34 x 4.57... x 1014E2 - E1 = 3.03 x 10-19 JE3 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)/λrz = (656.41 - 656.28)/656.28z = 1.98... x 10-4z = v/c1.98... x 10-4 = v/3 x 108v = 5.94 x 104 m s-1 | (1)(1)(1)(1)(1) |
| 15biii) | The blueshift is less than the redshiftso 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 absorbedin the Sun's atmosphere/outer layers | (1)(1) |
| 16bi) | Light is redshifted/shifted towards the redas the galaxies are moving away. | (1)(1) |
| 16bii) | z = (λo - λr)/λrz = (450 x 10-9 - 410 x 10-9)/410 x 10-9z = 0.098*“Show” question means you’ve already been given the answer – no mark for this part.* | (1)(1) |
| 16biii) | z = v/c0.098 = v/3 x 108v = 2.94 x 107 m s-1v = H­0­d2.94 x 107 = 2.3 x 10-18 x dd = 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 ff = 4.73... x 1014 Hzv = fλ3 x 108 = 4.73... x 1014 x λλ = 6.33 x 10-7 m | (1) both eq.(1), (1) sub.(1) final ans. |
| 17aii) | A = **π**r2A = **π** x (4 x 10-4)2I = P/A9950 = 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 distancesPlot a graph of I against 1/d2Graph of I against 1/d2 is a straight line through the origin **P.T.O***or*Measure values of irradiance for different distancesDetermine I x d2Values 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

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| 23a) | mλ = dsinθ2 x 486 x 10-9 = 2.16 x 10-6 x sinθθ = 26.7o | (1)(1)(1) |
| 23bi) | n = sinθ­1­/sinθ­2n = sin47/sin27n = 1.61*“Show” question means you’ve already been given the answer – no mark for this part.* | (1)(1) |
| 23bii) | n = 1/sinθ­c1.61 = 1/sinθ­cθ­c = 38oAs 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/sinθ­2n = sin20/sin13n = 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/sinθ­c1.52 = 1/sinθ­cθ­c = 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/sinθ2n = sin(82)/sin(45)n = 1.4 | (1)(1)(1) |
| 25aii) | The angle of refraction will be greater than 82oas 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/sinθ­c1.44 = 1/sinθ­cθ­c = 44oAs 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/sinθ2n = sin(47)/sin(29)n = 1.51 | (1)(1)(1) |
| 26aii) | n = 1/sinθ­c1.51 = 1/sinθ­cθ­c = 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 = dsinθ2 x 650 x 10-9 = (1 x 10-3)/300 x sinθθ = 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 togetheras 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/sinθ21.5 = sin(50)/sinθ2θ2 = 31o | (1)(1)(1) |
| 27b) | n = λ­1­/λ­21.5 = λ­1­/420 x 10-9λ­1 = 6.3 x 10-7 m (or 630 nm)­ | (1)(1)(1) |
| 27c) | The angle of refraction θ inside the glass will be lesseras 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/sinθ21.61 = sin(28)/sinθ2θ2 = 17o | (1)(1)(1) |
| 28aii) | In the airv = fλ3 x 108 = 4.8 x 1014 x λλ = 6.25 x 10-7In the glassn = λ1/ λ2 1.61 = 6.25 x 10-7/λ2­λ2­ = 3.88 x 10-7 m  | (1) both eq.(1), (1) sub.(1) final ans. |
| 28b) | Xas blue light is refracted more (by glass compared to red light). | (1)(1) |
| 29a) | It remains unchanged/constant. | (1) |
| 29b) | n = sinθ1/sinθ2n = sin(60)/sin(41)n = 1.32 | (1)(1)(1) |
| 29c) | n = 1/sinθ­c1.32 = 1/sinθ­cθ­c = 49o | (1)(1)(1) |
| 29d) | Less thanas shorter wavelengths refract more/have a larger refractive index. | (1)(1) |
| 30ai) | n = sinθ1/sinθ21.66 = sin(40)/sinθ2θ2­ = 23o | (1) (1)(1) |
| 30aiiA) | n = 1/sinθ­c1.66 = 1/sinθ­cθ­c = 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/sinθ21.33 = sinθ1/sin(36)θ1­ = 51o | (1) (1)(1) |
| 31bi) | The angle of refraction equals 90o­. | (1) |
| 31bii) | n = 1/sinθ­c1.33 = 1/sinθ­cθ­c = 49o | (1)(1)(1) |
| 31c) |  *Totally internally reflected ray* | (1) |
| 32a) | n = sinθ1/sinθ21.49 = sinθ1/sin(19)θ1­ = 29o | (1)(1)(1) |
| 32b) | n = 1/sinθ­c1.49 = 1/sinθ­cθ­c = 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/sinθ21.615 = 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 lessas 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/v21.54 = 3 x 108/v2v2­ = 1.95 x 108 m s-1 | (1)(1)(1) |
| 34bi) | v = fλ3 x 108 = 4.57 x 1014 x λλ = 6.56... x 10-7 mmλ = dsinθ2 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/sinθ2n = sin(36)/sin(18)n = 1.9 | (1)(1)(1) |
| 35c) | n = 1/sinθ­c1.9 = 1/sinθ­cθ­c = 32o | (1)(1)(1) |
| 36a) | n = sinθ1/sinθ2n = 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/sinθ­c1.89 = 1/sinθ­cθ­c = 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/sinθ22.42 = sin(49)/sinθ2θ2­ = 18o | (1)(1)(1) |
| 37b) | n = 1/sinθ­c2.42 = 1/sinθ­cθ­c = 24o | (1)(1)(1) |
| 37c) | Moreas the critical angle for moissanite will be smaller (due to greater refractive index)meaning more light will be totally internally reflected. | (1)(1)(1) |