AQA AS Interference, Diffraction and Diffraction Gratings solutions

Matching solutions and teaching prompts for the class review

Specification points covered

• 3.3.2.1(a) Path difference and coherence. • 3.3.2.1(b) Laser interference and diffraction. • 3.3.2.1(c) Young double slit and coherent sources. • 3.3.2.1(d) Use $w = \lambda D/s$. • 3.3.2.1(e) White-light interference pattern. • 3.3.2.1(f) Laser safety. • 3.3.2.1(g) Laser operation is not required. • 3.3.2.1(h) Sound and electromagnetic interference.	• 3.3.2.1(i) Changing understanding of electromagnetic waves. • 3.3.2.2(a) Single-slit patterns in monochromatic and white light. • 3.3.2.2(b) Central maximum, wavelength and slit width. • 3.3.2.2(c) Intensity–angle graph is not required. • 3.3.2.2(d) Plane transmission grating at normal incidence. • 3.3.2.2(e) Derive and use $d \sin \theta = n\lambda$. • 3.3.2.2(f) Applications of diffraction gratings. • 3.3.2.2(g) Spectrometer use is not tested.

Teaching focus

Insist on precise particle, wave and energy language as well as correct calculations.
Use each common-error prompt to correct the pupil's model or reasoning, not only the final answer.

1. Establishing coherence

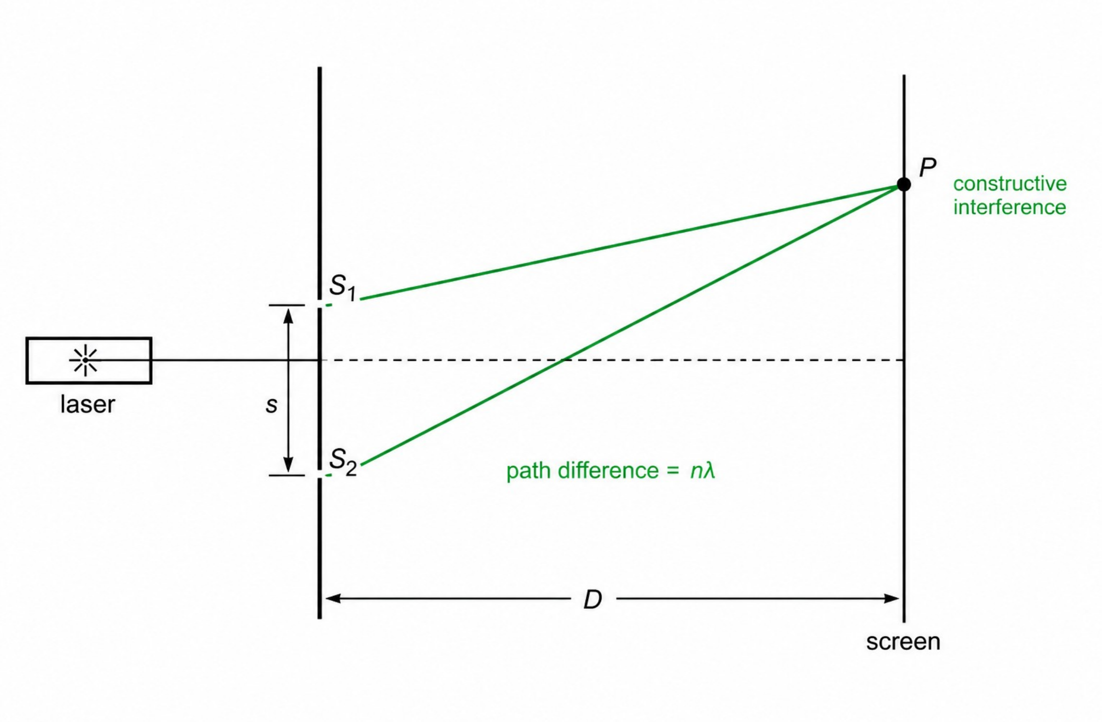
1. The robot uses one laser and a double slit to align its camera. Define coherent sources and path difference. [2 marks]

Answer / mark points: Coherent sources have a constant phase difference and the same frequency. Path difference is the difference between the distances travelled by two waves from their sources to the same point.

Teacher prompt / common error: Coherence requires a constant phase difference, not merely equal amplitudes.

2. Double-slit geometry

2. The diagram shows light from slits S_1 and S_2 reaching P. Explain the condition for P to be at the centre of a bright fringe and state the path-difference condition for any bright fringe. [2 marks]



Answer / mark points: At the central bright fringe $S_1P = S_2P$, so path difference is zero and the waves arrive in phase. Any bright fringe occurs when path difference = $n\lambda$, where n is an integer.
Teacher prompt / common error: A bright fringe needs an integer-wavelength path difference; the centre has n = 0.

3. The laser wavelength is 532 nm, the slit separation is 0.300 mm and the screen is 2.40 m away. Calculate the fringe spacing. [2 marks]

Answer / mark points: $w = \lambda D/s = (532 \times 10^{-9} \times 2.40)/(0.300 \times 10^{-3}) = 4.26 \times 10^{-3}$ m = 4.26 mm.
Teacher prompt / common error: Convert nanometres and millimetres into metres before using the formula.

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3. Reading and changing fringes

4. To reduce percentage uncertainty, a technician measures across 11 consecutive bright fringes and obtains 42.6 mm from the first to the eleventh centre. Calculate the wavelength indicated by this measurement. [3 marks]

Answer / mark points: From the first to the eleventh bright centre there are 10 spacings, so w = 42.6/10 = 4.26 mm. $\lambda = ws/D = (4.26 \times 10^{-3} \times 0.300 \times 10^{-3})/2.40 = 5.33 \times 10^{-7}$ m, about 533 nm.	
Teacher prompt / common error: Eleven fringe centres contain ten spacings. This is the intended uncertainty-reduction idea.	

5. Predict the separate effect on fringe spacing of (a) doubling screen distance, (b) halving slit separation and (c) replacing the laser with a shorter-wavelength laser. [3 marks]

Answer / mark points: From $w = \lambda D/s$: (a) doubling D doubles w; (b) halving s doubles w; (c) reducing λ reduces w in the same ratio.	
Teacher prompt / common error: Change one variable at a time using $w = \lambda D/s$.	

6. At a nominal dark fringe the waves arrive in antiphase, but the intensities from the two slits are unequal. Explain why the intensity does not fall to zero. [2 marks]

Answer / mark points: Antiphase waves cancel only if their amplitudes are equal. With unequal amplitudes, cancellation is incomplete, leaving a non-zero resultant amplitude and intensity.	
Teacher prompt / common error: Destructive interference gives zero only for equal amplitudes.	

7. The laser is replaced by white light. Describe the central fringe and the coloured fringes observed away from the centre. [3 marks]

Answer / mark points: The central fringe is white because all wavelengths have zero path difference there. Away from the centre the colours separate because fringe spacing increases with wavelength; violet is nearer the centre and red is farther out. The coloured fringes eventually overlap and become indistinct.	
Teacher prompt / common error: White at the centre follows from zero path difference for every wavelength.	

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4. Diffraction in other settings

8. State two precautions that reduce risk when aligning the laser and screen. [2 marks]

Answer / mark points: Any two: keep the beam below or above eye level; never look into the beam or a specular reflection; use a low-power laser; terminate the beam on a screen; remove reflective jewellery and objects; switch off while adjusting.

Teacher prompt / common error: Safety statements must describe an action, not only say ‘be careful’.

9. Two loudspeakers emit coherent 400 Hz sound. At the robot's microphone their path difference is 0.425 m. The sound speed is 340 m s^{-1}. Determine whether the interference is constructive or destructive and justify your answer. [3 marks]

Answer / mark points: $\lambda = v/f = 340/400 = 0.850$ m. The path difference 0.425 m = $\lambda/2$, so the waves arrive in antiphase and produce destructive interference.

Teacher prompt / common error: Compare path difference with $\lambda/2$, not with the frequency directly.

10. A single adjustable slit is placed in front of the laser. Describe the monochromatic diffraction pattern and explain how narrowing the slit changes it. Then state one difference for white light. [3 marks]

Answer / mark points: A monochromatic single-slit pattern has a wide, bright central maximum with narrower, dimmer side maxima separated by minima. Narrowing the slit increases the angular or linear width of the pattern. With white light the centre is white and side maxima are coloured because different wavelengths diffract by different amounts.

Teacher prompt / common error: Narrower slit means greater diffraction and a wider central maximum.

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5. Diffraction grating

11. A grating has 600 lines per millimetre. Calculate the grating spacing and the first-order angle for 532 nm light at normal incidence. **[3 marks]**

Answer / mark points: $d = 1/(600 \times 10^3) = 1.67 \times 10^{-6}$ m. For $n = 1$, $\sin\theta = \lambda/d = (532 \times 10^{-9})/(1.67 \times 10^{-6}) = 0.319$, so $\theta = 18.6°$.

Teacher prompt / common error: Lines per millimetre must become lines per metre before taking the reciprocal.

12. Calculate the highest possible order for the grating in Question 11 and explain one advantage of a diffraction grating over a double slit for measuring wavelength. **[3 marks]**

Answer / mark points: $n \le d/\lambda = (1.67 \times 10^{-6})/(532 \times 10^{-9}) = 3.13$, so the highest possible order is 3. A grating produces sharp, well-separated principal maxima, allowing angle and wavelength to be measured more precisely.

Teacher prompt / common error: An order is possible only when $\sin\theta \le 1$; take the greatest whole number.

13. Design a grating experiment to measure an unknown laser wavelength. Include apparatus and alignment, measurements, use of several orders or repeats, calculation, uncertainty reduction and safety. **[6 marks]**

Answer / mark points: A high-level method: mount the laser, grating and screen so the beam is normal to the grating; know the line density and calculate d; mark the central maximum and matching +n and -n maxima; measure screen distance and symmetric displacements or use a protractor to obtain θ; calculate $\lambda = d\sin\theta/n$; use several orders and repeat on both sides, then average; use a large distance or multiple orders and avoid parallax to reduce percentage uncertainty; keep the beam away from eyes and terminate it on the screen. Award any six distinct points including a valid calculation route.

Teacher prompt / common error: Normal incidence, symmetric orders, repeats and a clear route from measurements to wavelength are essential.

Language and method check

Award independent, creditworthy physics steps; do not award extra marks for repeated statements.
Accept equivalent methods when the physical reasoning, units and final precision remain consistent.

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