CAMBRIDGE INTERNATIONAL AS & A LEVEL • PHYSICS 9702

Topical Questions

Units 7 & 8: Progressive Waves and Superposition

Past Papers 2021 – 2025

MARK SCHEME 46 Questions

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Question 1 — Mark Scheme

Question	Answer	Mark
4(a)	(two or more) waves meet (at a point)	**B1**
	(resultant) displacement is the sum of the individual displacements	**B1**
4(b)(i)	it is a (wave) reflector / it reflects (the wave)	**B1**
4(b)(ii)	$v = f\lambda$ or $c = f\lambda$	**C1**
	$f = 3.0 \times 10^8 / 0.040$ $= 7.5 \times 10^9$ (Hz) $= 7.5 \times 10^9 / 10^9$ (GHz)	**C1**
	= 7.5 GHz	**A1**
4(b)(iii)	1 distance = 0.020 m	**A1**
	2 number = 5	**A1**

Question 2 — Mark Scheme

Question	Answer	Mark
5(a)	$f_o = f_s\, v / (v + v_s)$ $f_o = 951 \times 330 / (330 + 12)$	C1
	= 918 Hz	A1
5(b)	$t = d / 12$ $= (\pi \times 2.4) / 12$	C1
	= 0.63 s	A1

Question 3 — Mark Scheme

Question	Answer	Marks
4(a)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts	**B1**
4(b)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	**C1**
	$T = 460 \times 10^{-9} / 3.00 \times 10^{8}$	**C1**
	$= 1.5 \times 10^{-15}$ s	**A1**
4(c)	waves pass through/enter the slit(s)	**B1**
	waves spread (into geometric shadow)	**B1**
4(d)(i)	$n\lambda = d \sin\theta$	**C1**
	$G = \sin\theta / \lambda$ $d = 4 / G$	**A1**
4(d)(ii)	straight line from 400 nm to 700 nm that is always below printed line	**M1**
	straight line has smaller gradient than printed line and is 5 small squares high at wavelength of 700 nm	**A1**

Question 4 — Mark Scheme

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Question	Answer	Marks
4(a)	time for one oscillation/vibration/cycle **or** time between adjacent wavefronts (passing the same point) **or** shortest time between two wavefronts (passing the same point)	**B1**
4(b)	(when two or more) waves meet/overlap (at a point)	**B1**
	(resultant) displacement is sum of the individual displacements	**B1**
4(c)(i)	microwave(s)	**B1**
4(c)(ii)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1/T$	**C1**
	$T = 0.040 / 3.00 \times 10^8$	**C1**
	$= 1.33 \times 10^{-10}$ (s) $= 1.33 \times 10^{-10} / 10^{-12}$ (ps) = 130 ps	**A1**
4(c)(iii)	$(1.380 - 1.240) / 0.040 = 3.5$ **or** $1.380 / 0.040 - 1.240 / 0.040 = 3.5$	**A1**
4(c)(iv)	phase difference = 1260° **or** 180°	**A1**
4(c)(v)	(always) zero	**A1**
4(c)(vi)	increase in distance between (adjacent intensity) maxima/minima	**A1**

Question 5 — Mark Scheme

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Question	Answer	Marks
4(a)	(when two or more) waves meet/overlap (at a point)	B1
	(resultant) displacement is sum of the individual displacements	B1
4(b)	intensity $\propto$ amplitude^2	C1
	maximum intensity = $9I$	A1
4(c)(i)	$x = \lambda D / a$	C1
	$= (550 \times 10^{-9} \times 1.2) / (0.35 \times 10^{-3})$	C1
	$= 1.9 \times 10^{-3}$ m	A1
4(c)(ii)	red light has longer wavelength (than 550 nm) so distance (between fringes) increases	B1

Question 6 — Mark Scheme

Question	Answer	Marks
4(a)	oscillations (of particles) are parallel to (the direction of) energy transfer	**B1**
4(b)(i)	(frequency varies as) vehicle moves relative to (stationary) observer	**C1**
	(vehicle) moving towards (observer) gives higher (observed) frequency (than 1.2 kHz) and (vehicle) moving away (from observer) gives lower (observed) frequency (than 1.2 kHz)	**A1**
4(b)(ii)	Doppler effect	**B1**
4(b)(iii)	position of vehicle labelled 'X' at top (12 o'clock) position on track	**B1**
4(b)(iv)	position of vehicle labelled 'Y' at right-hand edge (3 o'clock) position on track	**B1**
4(c)	maximum frequency = 1.40 (kHz) **or** 1.40×10^3 (Hz)	**C1**
	$1.40 = (1.2 \times 320) / (320 - v)$	**C1**
	$v = 46\ \text{m s}^{-1}$	**A1**
	or	
	minimum frequency = 1.05 (kHz) **or** 1.05×10^3 (Hz)	**(C1)**
	$1.05 = (1.2 \times 320) / (320 + v)$	**(C1)**
	$v = 46\ \text{m s}^{-1}$	**(A1)**

Question 7 — Mark Scheme

Question	Answer	Marks
5(a)	a (much) louder sound can be heard	**B1**
5(b)	$v = f\lambda$	**C1**
	λ = 340 / 530 (= 0.64 m)	**C1**
	height = 0.64 / 4 = 0.16 m	**A1**
5(c)	distance = 0.64 / 2 **or** 0.16×2 **or** $(¾ \times 0.64 - ¼ \times 0.64)$ = 0.32 m	**A1**

Question 8 — Mark Scheme

Question	Answer	Marks
4(a)(i)	decrease(s)	**B1**
4(a)(ii)	increase(s)	**B1**
4(b)	$f_o = f_s\, v / (v + v_s)$ $= 925 \times 338 / (338 + 12)$	**C1**
	$= 893$ Hz	**A1**
4(c)	distance $= (½ \times 2 \times 12) + (2 \times 12)$ $(= 36$ m$)$	**C1**
	time taken $= 36 / 338$ $= 0.11$ s	**A1**

Question 9 — Mark Scheme

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Question	Answer	Marks
5(a)	maximum displacement (of a point/particle on string/wave)	**B1**
5(b)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1/T$	**C1**
	$T = 690 \times 10^{-9} / 3.00 \times 10^{8}$	**C1**
	$= 2.3 \times 10^{-15}$ s	**A1**
5(c)(i)	$\lambda = ax / D$	**C1**
	$G = x / D$ (so) $a = \lambda / G$	**A1**
5(c)(ii)	straight line from origin always below printed line	**M1**
	line is half the height of printed line at maximum D	**A1**

Question 10 — Mark Scheme

Question	Answer	Marks
5(a)(i)	(two) waves travelling (at same speed) in opposite directions overlap	B1
	waves (of the same type) have same frequency/wavelength	B1
5(a)(ii)	phase difference = 0	A1

Question	Answer	Marks
5(b)(i)	$f_O = f_S\, v / v - v_S$ $543 = f \times 334 / (334 - 13)$	C1
	$f = 522$ Hz	A1
5(b)(ii)	(the speed is) decreasing	B1
5(c)(i)	$I \propto A^2$	B1
	$I_T / I_0 = \cos^2 20°$ or $A_T / A_0 = \cos 20°$	C1
	ratio = 0.94	A1
5(c)(ii)	angle = 140°	A1

Question 11 — Mark Scheme

Question	Answer	Marks
5(a)	wave(s) (travel along string and) reflect at fixed point / A / B / end	**B1**
	incident and reflected waves superpose / interfere **or** two waves travelling / with speed in opposite directions superpose / interfere	**B1**
5(b)	line has an approximate sinusoidal shape with maximum downward displacement at P and zero displacement at each node	**B1**
5(c)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	**C1**
	$\lambda = 35 \times 0.040$ **or** $35 / 25$ $(= 1.4\ \text{m})$	**C1**
	distance $= 1.4 \times 2.5$ $= 3.5\ \text{m}$	**A1**
5(d)	(number of periods / cycles) $(= t / T) = 0.060 / 0.040$ $(= 1.5)$	**C1**
	amplitude $= 72 / 6$ $= 12\ \text{mm}$	**A1**

Question 12 — Mark Scheme

Question	Answer	Marks
5(a)	constant phase difference (between the waves)	**B1**
5(b)(i)	path difference = 1.5 × 660 = 990 nm	**A1**
5(b)(ii)	phase difference = 360° × 1.5 = 540°	**A1**
5(c)	$\lambda = ax / D$	**C1**
	$x = (660 \times 10^{-9} \times 1.8) / 0.44 \times 10^{-3}$	**C1**
	$= 2.7 \times 10^{-3}$ m	**A1**
5(d)	bright fringes are brighter	**B1**
	no change to dark fringes	**B1**
	no change to (fringe) separation / (fringe) spacing	**B1**
5(e)	(blue light has) shorter wavelength	**M1**
	(so) decrease (slit) separation	**A1**

Question 13 — Mark Scheme

Question	Answer	Marks
5(a)(i)	power = intensity × area	C1
	= $1.3 \times 10^3 \times (\pi \times 0.055^2)$ = 12 W	A1
5(a)(ii)	intensity = power / area = $12 / (\pi \times 0.0015^2)$ = 1.7×10^6 W m^{-2}	A1
5(b)(i)	(λ =) v / f **or** c / f	C1
	(λ =) $3.0 \times 10^8 / 3.7 \times 10^{15} = 8.1 \times 10^{-8}$ (m)	A1
5(b)(ii)	ultraviolet	A1

Question	Answer	Marks
5(b)(iii)	$d \sin\theta = n\lambda$ **or** $(1/N) \times \sin\theta = n\lambda$	**C1**
	$d = 1/2400 \times 10^3$ (m) $= 4.2 \times 10^{-7}$ (m) **or** $N = 2400 \times 10^3$ (m^{-1})	**C1**
	$n = 4.2 \times 10^{-7} \times \sin 90° / 8.1 \times 10^{-8}$ **or** $\sin 90° / 2400 \times 10^3 \times 8.1 \times 10^{-8}$ $n = 5.2$ or 5.1 **or** when $n = 5$, $\theta = 76.4°$ and when $n = 6$, $\sin\theta > 1$ (so) $n = 5$	**B1**
	number of maxima = $(2 \times 5) + 1$ $= 11$	**A1**
5(b)(iv)	the wavelength has increased	**M1**
	(so) number of maxima decreases	**A1**

Question 14 — Mark Scheme

Question	Answer	Marks
4(a)(i)	oscillations are in a single direction, which is perpendicular to the direction of propagation (of the wave) **or** oscillations are in a single plane, which contains the direction of propagation (of the wave)	**B1**
4(a)(ii)	light waves are transverse **and** sound waves are longitudinal	**B1**
4(b)	$I = I_0 \cos^2\theta$	**C1**
	$\cos^2\theta = 1/4$ so $\cos\theta = 1/2$ $\theta = 60°$ or $120°$ or $240°$ or $300°$	**C1**
	angle of rotation = $(120° - 90°)$ or $(240° - 90°)$ or $(300° - 90°)$ $= 30°$ or $150°$ or $210°$ or $330°$	**A1**
4(c)(i)	the waves have different amplitudes	**B1**
	cannot have resultant displacement that is always zero **or** cannot have (complete) destructive interference (at nodes) **or** (at nodes resultant) amplitude is the difference of the amplitudes	**B1**
4(c)(ii)	$I \propto A^2$	**C1**
	$A^2 / A_0^2 = (I_0/4)/I_0$ $A = 0.5\,A_0$	**C1**
	maximum amplitude = $A_0 + 0.5\,A_0$ $= 1.5\,A_0$	**A1**

Question 15 — Mark Scheme

Question	Answer	Marks
4(a)(i)	circles drawn around any two particles with seven (uncircled) particles in between	**A1**
4(a)(ii)	curve has an initial negative displacement and initial amplitude same as original curve	**B1**
	curve has same amplitude as original curve throughout	**B1**
	curve has same wavelength as original curve throughout, with constant (non-zero) phase difference	**B1**
4(a)(iii)	(to the) right / rightwards	**A1**
4(b)	$\lambda = 2 \times 0.19$ $= 0.38$ m	**C1**
	$v = f\lambda$	**C1**
	$v = (16 \times 10^3) \times 0.38$ $v = 6100$ m s^{-1}	**A1**
4(c)	$I \propto A^2$	**C1**
	$I = (1/2)^2 I_0$ intensity = 0.25 I_0	**A1**
4(d)(i)	same frequency / wavelength / period	**B1**
4(d)(ii)	• a stationary wave has nodes/antinodes (and a progressive wave does not) • a stationary wave does not transfer/propagate energy (and a progressive wave does transfer/propagate energy) • different points on a stationary wave have different amplitudes (and all points on a progressive wave have the same/constant amplitude) • stationary wave has adjacent particles that are in phase (and adjacent particles on progressive wave are out of phase) *Any two points, 1 mark each. Allow the reverse statement for each marking point.*	**B2**

Question 16 — Mark Scheme

Question	Answer	Marks
4(a)(i)	oscillations are in a single direction, which is perpendicular to the direction of propagation (of the wave) **or** oscillations are in a single plane, which contains the direction of propagation (of the wave)	**B1**
4(a)(ii)	light waves are transverse **and** sound waves are longitudinal	**B1**
4(b)	$I = I_0 \cos^2\theta$	**C1**
	$\cos^2\theta = 1/4$ so $\cos\theta = 1/2$ $\theta = 60°$ or $120°$ or $240°$ or $300°$	**C1**
	angle of rotation = $(120° - 90°)$ or $(240° - 90°)$ or $(300° - 90°)$ $= 30°$ or $150°$ or $210°$ or $330°$	**A1**
4(c)(i)	the waves have different amplitudes	**B1**
	cannot have resultant displacement that is always zero **or** cannot have (complete) destructive interference (at nodes) **or** (at nodes resultant) amplitude is the difference of the amplitudes	**B1**
4(c)(ii)	$I \propto A^2$	**C1**
	$A^2 / A_0^2 = (I_0/4)/I_0$ $A = 0.5\,A_0$	**C1**
	maximum amplitude = $A_0 + 0.5\,A_0$ $= 1.5\,A_0$	**A1**

Question 17 — Mark Scheme

Question	Answer	Marks
5(a)	(they travel in) opposite directions	**B1**
5(b)(i)	straight line from A to B, labelled P	**B1**
	line that is 'mirror image' of given line, labelled Q	**B1**
5(b)(ii)	$\lambda = 0.80 / 2$ $(= 0.40\ \text{m})$	**C1**
	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	**C1**
	$v = 0.40 / 0.016$ **or** 62.5×0.40 $= 25\ \text{m s}^{-1}$	**A1**
5(c)(i)	$I_1 / I_0 = \cos^2 30°$	**C1**
	$= 0.75$	**A1**
5(c)(ii)	$I_2 / I_1 = \cos^2 60°$ $I_2 / I_0 = \cos^2 30° \times \cos^2 60°$ **or** $0.75 \times \cos^2 60°$	**C1**
	$= 0.19$	**A1**

Question 18 — Mark Scheme

Question	Answer	Marks
4(a)(i)	circles drawn around any two particles with seven (uncircled) particles in between	**A1**
4(a)(ii)	curve has an initial negative displacement and initial amplitude same as original curve	**B1**
	curve has same amplitude as original curve throughout	**B1**
	curve has same wavelength as original curve throughout, with constant (non-zero) phase difference	**B1**
4(a)(iii)	(to the) right / rightwards	**A1**
4(b)	$\lambda = 2 \times 0.19$ $= 0.38$ m	**C1**
	$v = f\lambda$	**C1**
	$v = (16 \times 10^3) \times 0.38$ $v = 6100$ m s^{-1}	**A1**
4(c)	$I \propto A^2$	**C1**
	$I = (1/2)^2 I_0$ intensity = 0.25 I_0	**A1**
4(d)(i)	same frequency / wavelength / period	**B1**
4(d)(ii)	• a stationary wave has nodes/antinodes (and a progressive wave does not) • a stationary wave does not transfer/propagate energy (and a progressive wave does transfer/propagate energy) • different points on a stationary wave have different amplitudes (and all points on a progressive wave have the same/constant amplitude) • stationary wave has adjacent particles that are in phase (and adjacent particles on progressive wave are out of phase) *Any two points, 1 mark each. Allow the reverse statement for each marking point.*	**B2**

Question 19 — Mark Scheme

Question	Answer	Marks
5(a)(i)	period or $T = 1 / 5000$ ($= 2 \times 10^{-4}$ s)	C1
	time-base setting = $1.5 \times 2 \times 10^{-4} / 6.0$ **or** $2 \times 10^{-4} / 4.0$ $= 5 \times 10^{-5}$ s cm^{-1}	A1
5(a)(ii)	new trace drawn with same period as original trace	B1
	new trace drawn with amplitude greater than 1.0 cm	M1
	new trace drawn with amplitude of 1.7 cm	A1
5(b)(i)	path difference (from slits to P) is zero **or** phase difference (between waves at P) is zero (so constructive interference)	B1
5(b)(ii)	$\lambda = ax / D$	C1
	$D = (3.6 \times 10^{-4} \times 4.0 \times 10^{-3}) / 630 \times 10^{-9}$	C1
	$= 2.3$ m	A1
5(c)	upward sloping straight line starting from a non-zero value of x at $\lambda = 400$ nm	B1

Question 20 — Mark Scheme

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Question	Answer	Marks
5(a)(i)	infrared	B1
5(a)(ii)	$v = f\lambda$ **or** $c = f\lambda$	C1
	$f = 3.0 \times 10^8 / 8.4 \times 10^{-6}$ $= 3.6 \times 10^{13}$ (Hz) = 36 THz	A1
5(b)(i)	constant phase difference (between the waves) (with time)	B1
5(b)(ii)	$\lambda = ax / D$	C1
	$x = 22 / 8$ **or** 2.75 (mm) **or** $22 \times 10^{-3} / 8$ **or** 2.75×10^{-3} (m)	C1
	$a = (6.2 \times 10^{-7} \times 2.8) / (22 \times 10^{-3} / 8)$ $= 6.3 \times 10^{-4}$ m	A1
5(c)(i)	difference in distances $= 6.2 \times 10^{-7} / 2$ $= 3.1 \times 10^{-7}$ m	A1
5(c)(ii)	phase difference = 360°	A1

Question 21 — Mark Scheme

Question	Answer	Marks
5(a)(i)	(they are) perpendicular	**B1**
5(a)(ii)	(they are) parallel	**B1**
5(b)(i)	$\lambda = v / f$	**C1**
	= 340 / 1700 = 0.20 m	**A1**
5(b)(ii)	$L = \frac{3}{4} \times \lambda = \frac{3}{4} \times 0.20$ = 0.15 m	**A1**
5(b)(iii)	$\lambda = 4 \times 0.15$ **or** 0.20×3 = 0.60 m	**A1**
5(c)(i)	(I =) $8.5 \times \cos^2 35° = 5.7$ (W m^{-2})	**A1**
5(c)(ii)	$5.2 = 5.7 \cos^2 \theta$ (θ = 17°)	**C1**
	α = 35° + 17° = 52°	**A1**

Question 22 — Mark Scheme

Question	Answer	Marks
4(a)	the number of wavefronts/crests/troughs passing a fixed point per unit time **or** the number of oscillations per unit time (of source / point on wave / particle of medium)	**B1**
4(b)(i)	$T = 4 \times 0.50 \times 10^{-3}$ $(= 2.0 \times 10^{-3}\ \text{s})$	**C1**
	$f = 1 / 2.0 \times 10^{-3}$ $= 500\ \text{Hz}$	**A1**
4(b)(ii)	amplitude $= 2.8 \times 0.20$ $= 0.56\ \text{V}$	**A1**
4(c)	period same as original trace	**B1**
	sinusoidal wave of constant amplitude less than 2.8 cm throughout	**M1**
	amplitude 1.4 cm	**A1**

Question	Answer	Marks
4(d)(i)	when (two or more) waves meet (at a point)	**B1**
	(resultant) displacement is the sum of the individual displacements	**B1**
4(d)(ii)	node-to-node separation is $\lambda / 2$ **or** microphone moves through 3 node-to-node separations **or** $d = 1.5\lambda$	**C1**
	$\lambda = 1.05 / 1.5$ $= 0.70$ m	**A1**
4(d)(iii)	$v = f \times \lambda$	**C1**
	$= 500 \times 0.70$ $= 350$ m s^{-1}	**A1**

Question 23 — Mark Scheme

Question	Answer	Mark
4(a)	(when two or more) waves meet / overlap (at a point)	B1
	(resultant) displacement is the sum of the individual displacements	B1
4(b)	$\lambda = ax / D$	C1
	$\lambda = [(0.65 \times 10^{-3}) \times (1.7 \times 10^{-3})] / 1.9$	C1
	$\lambda = 5.8 \times 10^{-7}$ m	A1
4(c)(i)	waves are out of phase by a quarter of a cycle / period **or** when one wave has maximum/minimum displacement, the other wave has zero displacement	B1
4(c)(ii)	(statement 2 is) not correct (because) waves do not have phase difference of 180° / not in antiphase **or** one wave has some displacement when other has no displacement **or** the displacements of the waves are not always equal and opposite	B1
4(d)	more diffraction (of light/waves by slits) **or** light/waves are more spread (by slits) **or** light/waves (from slits) have less intensity	B1
	more (bright/dark) fringes **or** bright fringes are less bright / are dimmer / have lower intensity **or** no change to fringe spacing/separation/width	B1

Question 24 — Mark Scheme

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Question	Answer	Mark
5(a)	sketch: approximately horizontal line above horizontal dashed line from $t = 0$ to $t = t_1$ **and** approximately horizontal line below horizontal dashed line from $t = t_1$ to $t = t_2$	**A1**
5(b)	$I = P / A$	**C1**
	$A = \pi \times 0.028^2$ **or** $\pi \times 2.8^2$ ($= 2.46 \times 10^{-3}$ **or** 24.6)	**C1**
	$P = 4.7 \times 10^{-3} \times 2.46 \times 10^{-3}$ $= 1.2 \times 10^{-5}$ W	**A1**

Question 25 — Mark Scheme

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Question	Answer	Marks
5(a)(i)	light intensity has maximum value at 0°, 180°, 360° and zero intensity at 90°, 270°	**M1**
	'sinusoidally-shaped' curve	**A1**
5(a)(ii)	$4.2 = 7.6 \cos^2\theta$	**C1**
	$\theta = 42°$	**A1**
5(b)	wave passes (through) an aperture **or** wave passes (by / through / around) an edge	**B1**
	wave spreads (into geometrical shadow)	**B1**
5(c)(i)	$n\lambda = d \sin\theta$	**C1**
	$d = (3 \times 4.3 \times 10^{-7}) / \sin 68°$ $= 1.4 \times 10^{-6}$ m	**A1**
5(c)(ii)	$1.4 \times 10^{-6} \times \sin 68° = 2 \times \lambda$ **or** $3 \times 4.3 \times 10^{-7} = 2 \times \lambda$	**C1**
	$\lambda = 6.5 \times 10^{-7}$ m	**A1**

Question 26 — Mark Scheme

Question	Answer	Marks
5(a)(i)	cross labelled Y drawn: at any position where wavefronts cross **or** centrally in a 'diamond' shape formed between any adjacent wavefronts from A and B	**B1**
5(a)(ii)	cross labelled Z drawn on a wavefront from one source at a point midway between adjacent wavefronts from the other source	**B1**
5(b)(i)	$\lambda = ax / D$	**C1**
	$a = (2.9 \times 10^{-5} \times 140) / (1.2 \times 10^{-2})$	**C1**
	$= 0.34$ m	**A1**
5(b)(ii)	infrared	**A1**

Question 27 — Mark Scheme

Question	Answer	Marks
6(a)	$291 = 251 \times 340 / (340 - v_{(s)})$	C1
	$v_s = 47\ m\ s^{-1}$	A1
6(b)(i)	$I \propto A^2$	B1
6(b)(ii)	sketch: line starts at (1.0, 1.0)	B1
	approximately straight line drawn with negative gradient and line ends at (4.0, 0.25)	B1

Question 28 — Mark Scheme

Question	Answer	Marks
5(a)	vibrations / oscillations (of the particles / wave) are perpendicular to the direction (of the propagation of energy)	B1
5(b)	infrared	B1
5(c)	$T = 6 \times 5.0 \times 10^{-15}$ $T = 3.0 \times 10^{-14}$	C1
	$\lambda = c\,T$ **or** $\lambda = c / f$ **and** $f = 1 / T$	C1
	$\lambda = 3.0 \times 10^8 \times 3.0 \times 10^{-14}$ **or** $\lambda = 3.0 \times 10^8 / 3.33 \times 10^{13}$ $= 9.0 \times 10^{-6}$ m	A1

Question 29 — Mark Scheme

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Question	Answer	Marks
6(a)(i)	Any three from: • Light diffracts at the (two) slits. • Light (from each slit) meets / superposes (at the screen). • When the phase difference is 0 (degrees) a bright fringe / (intensity) maximum is formed. • When the phase difference is 180 (degrees) a dark fringe / (intensity) minimum is formed.	**B3**
6(a)(ii)	$\lambda = ax / D$	**C1**
	$\lambda = 1.2 \times 10^{-3} \times (10.2 \times 10^{-3} / 6) / 3.1$	**C1**
	$\lambda = 6.6 \times 10^{-7}$ m	**A1**
6(a)(iii)	(new fringe separation will be) smaller	**B1**
6(b)(i)	A cross at the intersection of the string and the mean position line.	**B1**
6(b)(ii)	0	**A1**
6(b)(iii)	180°	**A1**

Question 30 — Mark Scheme

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Question	Answer	Marks
5(a)	wave(s) (travel along string and) reflect at fixed point / wall / Q / end / vibration generator / P	**B1**
	incident and reflected waves superpose	**B1**
5(b)	0.80 m	**A1**
5(c)	same wavelength as original throughout **and** passing through intersection of solid and dashed lines	**B1**
	reflected in dashed line **and** of same amplitude	**B1**
5(d)	180°	**A1**
5(e)	$v = f\lambda$ **and** $f = 1 / T$ **or** $v = \lambda / T$	**C1**
	$v = 6.25 \times 0.80$ **or** $0.80 / 0.16$ $= 5.0\ \text{m s}^{-1}$	**A1**

Question 31 — Mark Scheme

Question	Answer	Marks
6(a)	$n\lambda = d\sin\theta$	**C1**
	$n = (3.8\times10^{-6}\times\sin 90°)/(520\times10^{-9})$ $(= 7.3)$	**C1**
	number of bright fringes formed = 15 (given as an integer)	**A1**
6(b)(i)	(frequency of red light is) less (than frequency of original light)	**B1**
6(b)(ii)	(red light has) longer wavelength	**M1**
	(so) number (of bright fringes formed) is less / fewer (bright fringes are formed)	**A1**

Question 32 — Mark Scheme

Question	Answer	Marks
4(a)	270°	**A1**
4(b)	arrow pointing vertically downwards at T	**A1**
4(c)	$v = f\lambda$ **or** $v = \lambda / T$ **and** $f = 1 / T$	**C1**
	wavelength $= 0.62 \times 10^{-2} \times (4 / 3)$ $(= 0.83 \times 10^{-2}$ m)	**C1**
	$f = 0.27 / (0.83 \times 10^{-2})$ $= 33$ Hz	**A1**
4(d)	resultant displacement is the sum of the displacements of the waves (from S_1 and S_2) **or** waves (from S_1 and S_2) superpose (at P)	**B1**
	Any one point from: • (at P) the waves (from the two sources) (always) destructively interfere • (at P) the waves have a path difference that is (always) an odd number of half-wavelengths / their path difference is one and a half wavelengths • (at P) the waves have a phase difference that is (always) 180° / they are in antiphase / crest of one wave meets trough of other wave	**B1**
	amplitude (of the resultant wave) is zero (at all times)	**B1**

Question 33 — Mark Scheme

Question	Answer	Marks
6(a)(i)	for maximum intensity, waves must be in phase (at detection)	**B1**
	(phase difference at source means) waves are not in phase / have a 90° phase difference at O	**B1**
6(a)(ii)	point B labelled on the line PQ below O	**M1**
	distance OB = distance OA	**A1**
6(b)(i)	$v = f\lambda$	**C1**
	$\lambda = (3.00 \times 10^8) / (2.5 \times 10^{10}) = 0.012$ m	**A1**
6(b)(ii)	$\Delta x = 0.012 / 4$ $= 0.0030$ m	**A1**
6(b)(iii)	$\lambda = ax / D$	**C1**
	distance $= \lambda D / a = 0.012 \times 2.3 / 0.18$ $= 0.15$ m	**A1**

Question 34 — Mark Scheme

Question	Answer	Marks
4(a)	longitudinal waves have oscillations parallel to the (direction of) transfer of energy	B1
	transverse waves have oscillations perpendicular to the (direction of) transfer of energy	B1
4(b)(i)	A marked at the open end of the pipe	B1
4(b)(ii)	$f = v / \lambda$	C1
	$\lambda = 4 \times 4.5 \times 10^{-2}$	C1
	$f = 340 / (4 \times 4.5 \times 10^{-2})$ $= 1900$ Hz	A1
4(b)(iii)	the node–antinode distance is longer **or** the wavelength (of the wave) is longer	M1
	(the speed of sound is constant so) the frequency (of the wave) is lower	A1

Question 35 — Mark Scheme

Question	Answer	Marks
5(a)(i)	cross labelled N marked at the intersection of the solid and dashed lines or at X or Y **and** cross labelled A marked at a peak or a trough	**B1**
5(a)(ii)	(XY is 1.5 wavelengths, so) wavelength = 0.48 × (2 / 3) = 0.32 m **or** (wavelength is twice node–node distance so) $\lambda / 2 = 0.48 / 3 = 0.16$ m and wavelength = 0.16 × 2 = 0.32 m	**B1**
5(a)(iii)	$v = f\lambda$	**C1**
	frequency = 1400 / 0.32 = 4400 Hz	**A1**
5(b)(i)	$f_o = f_s v / (v - v_s)$ $f_o = (780 \times 320) / (320 - 39)$	**C1**
	maximum frequency = 890 Hz	**A1**
5(b)(ii)	line showing *f* varying both above and below a mean frequency and returning to the original start value of *f*	**B1**
	a single cycle of a smoothly oscillating curve of correct phase (starting at mean position, falling to a trough, then rising to a peak, ending at mean position)	**B1**

Question 36 — Mark Scheme

Question	Answer	Marks
4(a)	(micro)wave (from the transmitter) reflects (at metal/sheet)	B1
	The incident and reflected waves superpose	B1
	(resultant) amplitude is maximum at an antinode	B1
	(resultant) amplitude is minimum/zero at a node	B1
4(b)(i)	$\lambda = c / f$ $= 3 \times 10^8 / 6.3 \times 10^9$	C1
	$= 0.048$ m	A1
4(b)(ii)	distance PQ = $\frac{1}{4}\lambda$ $= 0.048 / 4$ $= 0.012$ m	A1

Question	Answer	Marks
4(b)(iii)	(Distance QR is the) same (as PQ) and one of: • Distance (between maxima / minima) does not depend on intensity • distance depends only on wavelength • wavelength is unchanged / constant	B1

Question 37 — Mark Scheme

Question	Answer	Marks
5(a)	$T = 5.8 \times 5.0 \times 10^{-4}$ $= 2.9 \times 10^{-3}$	C1
	$\lambda = vT$ or $v = f\lambda$ and $f = 1 / T$	C1
	$\lambda = 330 \times 2.9 \times 10^{-3}$ or $\lambda = 330 / 345$ $= 0.96$ m	A1
5(b)	(loudspeaker) moves away (from the microphone)	B1
	at an increasing speed / whilst accelerating	B1

Question 38 — Mark Scheme

Question	Answer	Marks
4(a)	(when two or more) waves meet / overlap (at a point)	B1
	(resultant) displacement is sum of the individual displacements	B1
4(b)(i)	Fringe width, $x = 3.2 \times 10^{-2} / 8$ $= 4.0 \times 10^{-3}$ (m)	C1
	$D = ax / \lambda$ $= (4.0 \times 10^{-3} \times 0.16 \times 10^{-3}) / 7.2 \times 10^{-7}$	C1
	= 0.89 m	A1

Question	Answer	Marks
4(b)(ii)	Curved line with a negative gradient of decreasing magnitude throughout, from slit separation 0.04 mm to 0.16 mm	B1
	Line of negative gradient ending at (0.16, 0.4), from slit separation 0.04 mm	B1
	Line of negative gradient passing through (0.08, 0.8) and (0.04, 1.6)	B1

Question 39 — Mark Scheme

Question	Answer	Marks
5(a)	wavelength: • wavelength = distance between successive / adjacent in phase points / wavefronts / crests / troughs • $\lambda = d$ / (number of) oscillations frequency: • frequency = (number of) oscillations / cycles crests / troughs / wavefronts (passing a point) per unit time • f = (number of) oscillations / t One correct point from **either** list	**B1**
	One correct point from **both** lists **and** speed = distance / time **and** one of: • wavelength × frequency (= distance per unit time) = speed • [(number of) oscillations / t] × [d / (number of) oscillations] = $f\lambda$ • v (= d / t) = λ / (1/f) = $f\lambda$ or v (= d / t) = λ / T = $f\lambda$	**B1**
5(b)(i)	$T = 4 \times 10^{-3}$ $f = 1 / T = 1 / 0.004$	**C1**
	f = 250 Hz	**A1**

Question	Answer	Marks
5(b)(ii)	$f_o = f_s\, v / (v - v_s)$ $250 = 236 \times v / (v - 20)$ $v = (250 \times 20) / (250 - 236)$	**C1**
	$= 360\ \text{m s}^{-1}$	**A1**

Question 40 — Mark Scheme

Question	Answer	Marks
3(a)	10.0 cm	**A1**
3(b)(i)	$v = f\lambda$ $= 16 \times 0.40$	**C1**
	$= 6.4\ \text{m s}^{-1}$	**A1**
3(b)(ii)	(X and Y have a) constant phase difference (of 180°) so (they are) coherent	**B1**
3(c)	A single wave of amplitude 10.0 cm	**B1**
	A single negative sine wave of wavelength 0.40 m	**B1**
3(d)	$I \propto A^2$ $\frac{I_X}{I_Y} = 10^2 / 20^2$	**C1**
	ratio = 0.25	**A1**

Question 41 — Mark Scheme

Question	Answer	Marks
5(a)	sound waves are longitudinal / not transverse (and only transverse waves can be polarised)	**B1**
5(b)(i)	A periodic curve of at least one period with minimum 0 and maximum I_0	**B1**
	Smooth continuous $\sin^2\alpha$ curve	**B1**
	Peaks at 90° and 270° **and** troughs at 0, 180° and 360°	**B1**
5(b)(ii)	$I \propto A^2$	**C1**
	$I = I_0 \cos^2 \theta$	**C1**
	At $\alpha = 20°$ the angle between the planes of polarisation of light and filter is 70° (or 110°) $I = I_0 \cos^2 70$ **or** $I = I_0 \cos^2 110$ ($I = 0.12\ I_0$)	**C1**
	amplitude = $0.34\ A_0$	**A1**

Question 42 — Mark Scheme

Question	Answer	Marks
6(a)	wave passes (through) an aperture and spreads **or** wave passes (by / through / around) an edge and spreads	B1
6(b)(i)	$v = f\lambda$	**C1**
	$f = 3.00 \times 10^8 / 720 \times 10^{-9}$ $= 4.2 \times 10^{14}$ Hz	**A1**
6(b)(ii)	$d = n\lambda / \sin\theta$	**C1**
	$d = (2 \times 720 \times 10^{-9}) / \sin 26$	**C1**
	$(= 3.3 \times 10^{-6}$ m) number of lines per m $= 1 / (3.3 \times 10^{-6})$ $= 3.0 \times 10^5$ m^{-1}	**A1**
6(b)(iii)	$\lambda \times 3 = 720 \times 2$ **or** $\frac{1}{3.0 \times 10^5} \sin 26 = 3\lambda$	**C1**
	$\lambda = 480$ nm	**A1**

Question 43 — Mark Scheme

Question	Answer	Marks
4(a)(i)	(a wave that) transfers / propagates energy	**B1**
4(a)(ii)	distance = $n\lambda$	**B1**
	time $t = n / f$	**B1**
4(a)(iii)	(v = distance / time) $(v) = n\lambda / (n / f)$ so $(v) = f\lambda$	**B1**
4(b)(i)	$f = 3 \times 10^8 / 4 \times 10^{-2}$ $= 7.5 \times 10^9$ (Hz) $= 7.5 \times 10^9 / 10^9$ (GHz)	**C1**
	= 7.5 GHz	**A1**
4(b)(ii)	(difference in path lengths, XQ – YQ) $= \left[72^2 + 30^2\right]^{\frac{1}{2}} - 72 = 6$ (cm)	**A1**
	Or calculate angle Q using tan and then cos to obtain XQ of 78 $\tan\theta = 30 / 72$ so $\theta = 22.6$ XQ = 72 / cos 22.6 = 78 (cm) path difference 78 – 72 = 6 (cm)	**(A1)**
	Or calculate angle X using tan and then cos to obtain XQ of 78 $\tan\theta = 72 / 30$ so $\theta = 67.4$ XQ = 72 / sin 67.4 = 78 (cm) path difference 78 – 72 = 6 (cm)	**(A1)**
4(b)(iii)	path difference (= 6 cm / 4 cm) λ = 1.5λ	**M1**
	(so) phase difference (at Q) = 540° **or** 180°	**M1**
	(so) intensity is minimum	**A1**

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Question	Answer	Marks
4(b)(iv)	amplitude changes from maximum (at P) to minimum (at Q)	**C1**
	amplitude changes from maximum (at P) to minimum to maximum to minimum (at Q)	**A1**

Question 44 — Mark Scheme

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Question	Answer	Marks
4(a)	wave passing through gap / aperture	**B1**
	(wave) spreads (out)	**B1**
4(b)(i)	$n\lambda = d \sin\theta$	**C1**
	$\theta = \sin^{-1}[(540 \times 10^{-9}) / (5.0 \times 10^{-6})] = 6.2°$	**A1**
4(b)(ii)	$\theta = 12°$	**A1**
4(b)(iii)	peaks / maxima shown at $\theta = 0$, ±6° and ±12°	**B1**
	peaks / maxima and zero intensity in between	**B1**
	central peak / maxima at intensity I_0 and the other peaks all equal to or less than I_0	**B1**
4(c)	peaks / maxima all at the same angles (as before)	**B1**
	intensity (of all peaks / maxima) halved	**B1**

Question 45 — Mark Scheme

Question	Answer	Marks
4(a)	light diffracts / spreads (at slit(s))	**B1**
	light (from each slit) superposes / interferes (at screen)	**B1**
	when phase difference is 0 / path difference is $n\lambda$ (where n is an integer) a bright fringe is formed **or** when phase difference is 180(°) / path difference is $(n + 1)\lambda / 2$ (where n is an integer) a dark fringe is formed	**B1**
4(b)	$\lambda = ax / D$	**C1**
	$\lambda = 1.0 \times 10^{-3} \times 3.3 \times 10^{-3} / 4.8$ $(= 6.875 \times 10^{-7}$ m)	**C1**
	$f = v / \lambda$	**C1**
	$= 3.0 \times 10^{8} / 6.875 \times 10^{-7}$ $= 4.4 \times 10^{14}$ Hz	**A1**
4(c)	the light / beams (have different frequencies so) are not coherent / do not have constant phase difference	**B1**

Question 46 — Mark Scheme

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Question	Answer	Marks
4(a)	when two (or more) waves meet	M1
	(resultant) displacement equals the sum of the displacements of the (two separate) waves	A1
4(b)(i)	the incident and reflected waves superpose	B1
	(the waves superpose so that the resultant) amplitude is maximum at an antinode	B1
	(the waves superpose so that the resultant) amplitude is minimum / zero at a node	B1
4(b)(ii)	$c = f\lambda$	C1
	$f = (3.00 \times 10^8) / 0.026$ $= 1.2 \times 10^{10}$ Hz	A1
4(b)(iii)	microwave	B1
4(b)(iv)	distance = 0.026 / 4 $= 6.5 \times 10^{-3}$ m	A1

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