Mark schemes

Q1.

(a) Measurement of <u>at least 30</u> fringe widths
(check that candidate has not miscounted) e.g. 30 fringe widths = 40 mm or 41 mm.

Correct answer of 1.3 or 1.4 mm quoted to 2sf with unit ✓(one mark)
OR
Correct answer 1.33 – 1.37 mm to 3sf with correct unit ✓✓ (two marks).

If candidate quotes value in range 1.33 – 1.37 mm to 3sf they achieve both the 2nd and 3rd marks (A quote to 3sf is justified in terms of uncertainty if a large number of fringe widths have been measured).

For 2nd & 3rd marks allow ecf from incorrect measurement in 1st mark.

If the printing process in your centre alters the scale of this diagram, measure the values on your printed question papers and mark the scripts accordingly. Send details to the moderator.

If a candidate is visually impaired and using a modified paper that alters the scale of this diagram, measure the values on the printed question paper and mark the script accordingly.

3

(b) 1 mark for intermediate step where candidate doesn't get correct final answer. i.e. calculating % uncertainty of total measurement (i.e. % uncertainty in *w*) ✓

OR for both marks:

Uncertainty in *w* = ± 0.03 mm ✓✓

(Full 2 marks for correct answer with unit – No unit no mark unless a correct intermediate step has been completed which will have been credited for 1 mark as explained above)

Uncertainty in measurement of multiple fringes is ± 1 mm (precision of ruler used).

E.g. for length 41 mm ± 1 mm % uncertainty = 1/41 x 100 = 2.4 %

Uncertainty in w (single fringe)
= 2.4 x 1.4/100 = ±0.03 mm

Simply quoting 0.03 - ***NO marks***

No penalty for omission of ±

2

(c) (i) (Using w = 1.40 mm)

Wavelength = 5.60×10^{-7} m ✓

*Allow ecf for value of w from **(b)***
Consistent unit required for the mark. No sf penalty.

1

(ii) (Intermediate step) % uncertainty = 5.8% ✓

(From %uncty s = 3.3%, w = 2.4%, D = 0.1% % uncertainty in wavelength = 3.3 +2.4+0.1 = 5.8%).
*Allow ecf from **(b)***

1

(iii) (Using wavelength = 5.60×10^{-7} m)

Uncertainty in wavelength = $\pm 3.2 \times 10^{-8}$ (m) ✓ or ± 32 (nm) or $\pm 3.2 \times 10^{-5}$ (mm)

*Allow ecf from **(c)(i)** & **(ii)***
No sf penalty
*If the value is consistent with the wavelength quoted in **(c)(i)**, **allow the numerical answer without the unit**, otherwise a unit is required.*

1

[8]

Q2.

(a) *w* from $\frac{R2 - R1}{6} = 0.408\text{mm} = 4.08 \times 10^{-4}\text{m}$ ✓

3 sf answer ✓

2

(b) double slit formula rearranged to give $d = \frac{\lambda \times D}{w}$ $_1$✓

$d = \frac{589.3 \times 10^{-9} \times 0.395}{0.408 \times 10^{-3}} = 5.7(1) \times 10^{-4}\text{m}$ $_2$✓

allow ecf in $_2$✓ for wrong w but not for POT error

2

(c) use of $PQ = \frac{d \times (D + L)}{L} = 5.46 \times 10^{-3}\text{m}$ $_1$ ✓

allow ecf for wrong d in $_1$ ✓

number of fringes seen $= \frac{PQ}{w} = \frac{5.46}{0.41}$ $_2$ ✓

number of fringes seen = 13 (integer only)$_3$ ✓

allow 12 or 14 fringes

3

(d) close jaws using ratchet ✓

confirm that instrument reads zero ✓

2

(e) mean = 0.57(0) mm; uncertainty = 0.5 × range ✓

$$\text{percentage uncertainty} = 100 \times \frac{0.5 \times (0.574 - 0.566)}{0.570} = 0.70(2)\,\%$$ ✓

2

[11]

Q3.

(a) 180 degrees

accept ° for degrees

OR

π radians ✓

condone ^{c} or 'rad' for radian

reject 'half a cycle'

treat 'π radians in phase' as talk out

1

(b) (idea that) sets of combining waves do not have the same amplitude ✓

condone 'waves do not have same intensity' or 'same energy' or 'some energy is absorbed on reflection' or 'same power' or 'same strength' or idea that non point source or non point receiver would lead to imperfect cancellation

condone the idea that the waves may not be monochromatic

ignore 'some waves travel further' or 'waves do not perfectly cancel out'

reject 'waves may not be 180° out of phase'

1

(c) valid use of a set square or protractor against TR (to ensure perpendicular) $_1$ ✓

measure *x* at two <u>different</u> points [at each end of M] **<u>and</u>** adjust until [make sure] both <u>distances are the same</u> $_2$ ✓

OR

use of set square to align M with the perpendicular line earns $_2$ ✓

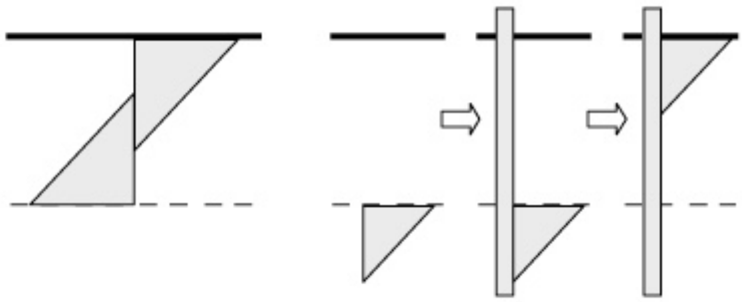
if method used does not allow <u>continuous</u> variation in *x* then award maximum 1 mark

OR

align <u>graph paper</u> with TR $_1$ ✓

align M with grid lines on graph paper $_2$ ✓

both marks can be earned for suitable sketch showing a viable procedure involving one or more recognisable set squares or protractors; the sketch may also show a *recognisable ruler, eg*



allow use of scale on set square to measure the perpendicular distances don't penalise incorrect reference to the set square, eg as 'triangular ruler', as long as the sketch shows a recognisable set square

2

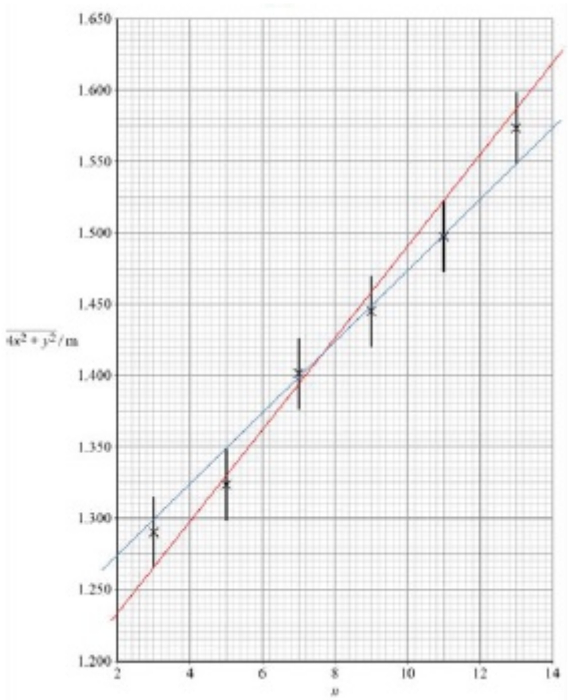
(d) G_{max} line ruled through bottom of n = 3 error bar and through top of n = 11 error bar 1✔

G_{min} line ruled through top of n = 5 error bar and through bottom of n = 13 error bar 2 ✔

G_{max} and G_{min} calculated from valid y step divided by valid x step; both n steps ≥ 6 3 ✔

allow 1 mm tolerance when judging intersection of gradient lines with error bars

ignore any unit given with G_{max} or G_{min}; penalise power of ten error in 01.5



12 ✔= 1 MAX if (either) line is thicker than half a grid square or of variable width or not continuous;

expect G_{max} = 3.2(1) × 10^{-2} and G_{min} = 2.5 (2.49) × 10^{-2}

3

(e) $\lambda(\text{from } \frac{G_{max} + G_{min}}{2})$

AND

result in range 2.8(0) to 2.9(0) × 10^{-2} (m) 1 ✓ 2 ✓

OR

award one mark for

2.7(0) to 3.0(0) × 10^{-2} (m) 12 ✓

penalise 1 mark for a power of ten error

reject 1 sf 3 × 10^{-2} (m)

if a best fit line is drawn between the G_{max} and G_{min} lines and the gradient of this is calculated award 1 mark for λ in range 2.8(0) to 3.0(0) × 10^{-2}(m)

2

(f) uncertainty in $\lambda = G_{max} - \lambda$

OR

$\lambda - G_{min}$

OR

$\left(\frac{G_{max} - G_{min}}{2}\right)$ 1 ✓

percentage uncertainty = (uncertainty/λ)×100 2 ✓

result in range 11(.0) % to 14(.0) % 3 ✓

1 ✓ can be earned by showing a valid uncertainty then dividing by λ

ecf their λ, G_{max} and G_{min} for 1 ✓ and 2 ✓

allow λ found from best fit line

accept $\left(\frac{G_{max} - \lambda}{\lambda}\right) \times 100$ or $\left(\frac{G_{max} - G_{min}}{G_{max} + G_{min}}\right) \times 100$ etc for 12 ✓

allow $\left(\frac{\Delta\lambda}{\lambda}\right)$ × 100 where $\Delta\lambda$ is any plausible uncertainty for 2 ✓

numerical answer without valid working can only earn 3 ✓

3

(g) (states) calculate the (vertical) intercept 1 ✓

OR

outlines a valid calculation method to calculate *y* 1 ✓

determine the intercept for <u>both lines</u> and calculate average value 2 ✓

OR

determine the (vertical) intercept of the line of best fit (between G_{max} and G_{min}) 2 ✓

draw the line of best fit (between G_{max} and G_{min}); perform calculation to find intercept earns 12 ✓

2

(h)

result	reduced	not affected	increased
G_{max}		✓	
G_{min}	✓		
λ	✓		
y			✓

general marker question

allow any distinguishing mark as long as only one per row

for ✓ and X in same row ignore X

for ✓ and ✓ in same row give no mark

ignore any crossed-out response

4

alternative approach: single best fit line drawn on **Figure 4**

(d) *G* calculated from *y* step divided by *x* step;

n step ≥ 6 3 ✓

MAX 1

(e) λ in range 2.8(0) to 2.9(0) × 10^{-2} ✓

MAX 1

(f) percentage uncertainty in $\lambda = \left(\frac{\Delta\lambda}{\lambda}\right) \times 100$

AND

result in range 11(.0) % to 14(.0) % ✓

MAX 1

(g) <u>calculate</u> intercept

OR

outlines a valid calculation method to find *y* ✓

MAX 1

(h) as main scheme

no ecf possible

4

alternative approach: non-crossing lines for G_{max} and G_{min} on **Figure 4**: includes lines that meet but do not cross

(d) G_{max} and G_{min} calculated from *y* step divided by *x* step; both *n* steps ≥ 6 3 ✓

MAX 1

1

[18

Q4. (a)

(b) Both plotted points to nearest mm ✓
1.43, 1.29

Best line of fit to points ✓ 1

The line should be a straight line with approximately an

equal number of points on either side of the line.

2

(c) (i) Large triangle drawn (at least 8 cm × 8 cm) ✓

Correct values read from graph ✓

Gradient value in range (0.618 to 0.652) × 10^{-6} to 2 or 3 sf ✓

Allow the 2nd mark for incorrect numerical values read ignoring incorrect power of 10.

Incorrect power of 10 is penalised in gradient value.

3

(ii) Same figure quoted for gradient but with correct unit

1

(d) (i) Straight line (through origin) ✓

(directly) proportional ✓

2

(ii) Evidence of substituting data from the table / graph into $w = mD/s + c$ (from $y = mx + c$) ✓

Computation of correct value for c (i.e. value of w when $D/s = 0$) with correct unit.

Should be approximately 0.1 × 10^{-3} m, depending on the exact lobf drawn.

2

(iii) *w*

1

(e) Any reference to **either** width of slits **OR** single slit diffraction ✓

1

[13]

Q5.

(a) D could not be measured with enough **precision**; [can only resolve to 1 sf / 2 dp (and 3 sf / 4 dp needed) / needs to measure to 0.0001 mm] ✓
example given to correctly illustrate this point, eg 0.0855 mm would be read as 0.09 mm ✓

same D would be produced for different α ✓
example given to correctly illustrate this point, eg when α = 12° / 14° / 16° ✓

there would be a large **percentage** uncertainty [**percentage** error] in D ✓
example given to correctly illustrate this point, eg when α = 8° percentage uncertainty is 47% ✓ (tolerate answers using ΔD = 0.01 mm or 0.02 mm)

α / °	D / mm spreadsheet	D / mm to 0.01 mm	% uncertainty (ΔD = 0.01 mm)
2	0.0855	0.09	11.7%
4	0.0428	0.04	23.4%
6	0.0285	0.03	35.1%
8	0.0214	0.02	46.8%
10	0.0171	0.02	58.5%
12	0.0143	0.01	70.2%
14	0.0122	0.01	81.9%
16	0.0107	0.01	93.6%

max 4

(b) argument is not sensible because (larger value of D leads to) very small values of α ✓
(hence) α cannot be measured accurately [uncertainty would be very large] ✓ **2**

(c) $\frac{0.0859 - 0.0855}{0.0859}$

2)

= 0.466% or 0.47% **only** ✓ (ie 0.5% is worth 1 max) **2**

[8]

× 100 ✓ (working must show 0.0859 in denominator, or 0 /

Q30.

(a) (i) $W = 2mg\cos\varphi \quad \therefore m = W/(2g\cos\varphi)$ ✓

The question says *<u>show that</u>*, *so the candidates must write down both steps.*

1

(ii) Well drawn straight line of best fit.✓

The line should follow the trend of the points with an even scatter of points on either side of the line.

1

(b) (i) Triangle drawn with smallest side at least 8 cm in length. ✓

Correct readings taken from the line for the triangle ✓
Gradient in the range 0.45 to 0.49 (0.445 to 0.494) quoted to 2 or 3 significant figures ✓

The size of the triangle can be identified from readings taken from the line.
The third mark is independent of the other two: error carried forward for incorrect readings (or for a poor line of best fit) which give a gradient out of range is not allowed.

3

(ii) Candidate's answer for gradient in (b)(i) correctly multiplied by g (expected answer 4.6)✓
N ✓

No s.f. penalty.
The second mark is for the unit and can be awarded if the numerical answer is incorrect.

2

(c) δx% = 0.2 and δy% = 0.5✓
$\delta(x/y)\% = \delta x\% + \delta y\% = 0.2 + 0.5 = 0.7$ ✓
Use of $\delta(x/y.)^2\% = 2 \times \delta(x/y)(\%)$ ✓

Final answer is (±) 1.4 (%) which automatically gains all three marks
Otherwise
Accept only 1 s.f. for 1st and/or 2nd marks.
The third mark is for the method, not the final answer

3

(d) (i) Systematic errors in measurements are errors which show a pattern or a bias or a trend ✓

Some acceptable alternatives

- ***A systematic error** is one which deviates by a fixed amount from the true value of a measurement*
- *An error which has the same value in all readings*
- *A difference between the true value of a quantity and the indicated value caused by a fault in the measuring device*
- *Accept a good example of systematic error.*

1

(ii) y would be larger✓
because angle θ would be smaller
or
because friction would be opposing the increasing weight of m✓

2

[13]

Q31.

(a) smooth curve of decreasing positive gradient through all 5 points ✓

shaky or fuzzy line does not gain mark

1

(b) sensible tangent drawn at *b* = 25; correct read−offs for points (± 1 mm) from triangle

Q6.

(a) smooth curve of decreasing positive gradient through all 5 points ✓

shaky or fuzzy line does not gain mark

1

(b) sensible tangent drawn at *b* = 25; correct read−offs for points (± 1 mm) from triangle

with step sizes at least 8 × 8 $_1$✓

substitution correct $_2$✓

G = 0.11(2) $_3$✓

change in d divided by change in b for $_3$; don't penalise if change in d is given in m ✓

acceptable range if d is in mm 0.109 to 0.116 for d in m adjust accordingly; accept only 0.11 for 2 sf; accept ≥ 3 sf for 3✓

3

(c) *d* in range 14.25 to 14.30 mm $_1$✓

substitution correct $_2$✓

R in range 1.34 to 1.38 m $_3$✓

accept result for R in mm; no ecf for incorrect or out of range G

3

[7]