A-Level Physics

Diffraction

Mark Scheme

Time available: 61 minutes
Marks available: 48 marks

1.

(a) One wavelength✓

Accept λ

1

(b) Light from slits overlap / undergo diffraction✓

Path difference is a whole number of wavelengths

Or

Arrive at screen in phase / zero phase difference ✓

(Meet and) undergo superposition / waves superpose✓

*If no other mark awarded allow **one** mark for:*

interfere constructively / Produces reinforcement / produces constructive interference

3

(c) Pointer **A** and CD ✓

Condone:

smallest wavelength and greatest slit spacing

(Smallest) angular spread for each order (θ_{min}) is given by $\sin \theta_{(min)} = \frac{n\lambda}{d}$

OR

Greatest number of maxima is given by $n_{max} = \frac{d}{\lambda}$ ✓

***Max 1 mark for**:*

An argument that links spacing to slit width and its effect on diffraction.

2

(d) use of $n\lambda = d \sin\theta$ ✓

For example, where:

$n = 1$, $\lambda = 6.36 \times 10^{-7}$ m and $d = 1.6 \times 10^{-6}$ m ($\theta = 23°$)

or

$n = 2$, $\lambda = 6.36 \times 10^{-7}$ m and $d = 1.6 \times 10^{-6}$ m ($\theta = 53°$)

use of $\tan\theta = r / 15$

or

adds θ_2 and θ_1 and compares to 90°

or

adds θ_2 andθ_2 and compares to 90°

or

adds θ_1 and θ_1 and compares to 90°✓

Allow use of $\tan\theta = r / 15$

for any combination of θ, r and 15 where unknown has been made subject.

No, can see 4 (bright spots)✓

$\theta = 45°$ and 3 bright spots therefore yes is a maximum of max 2 marks

Allow use of $n = \frac{d}{\lambda}$ where they have reached a conclusion for 1 mark maximum.

3

[9]

2. (a) reads off $\lambda_{p\ 1}$✓

for $_1$✓ condone POT;

expect λ_p = 635 ± 2 (nm) /

635 ± 0.02 × 10^{-9} / 6.35 ± 0.02 × 10^{-7} (m)

*allow evidence of working on **Figure 1***

1

use of n × their $\lambda_p = d \sin\theta$ $_2$✓

for $_2$✓ accept subject n with no / incomplete substitution, eg

$N = \frac{\sin\theta}{n \times \lambda_p}$

OR

subject d and <u>full</u> substitution, eg

$d = \frac{5 \times \text{their } \lambda_p}{\sin 76.3}$ / 5.15 × their λ_p *5.15 × their λ_p*

OR

correct result d = 3.27 (× 10^{-6} (m));

allow ECF in λ_p including POT;

allow recognisable d / 2 sf intermediate result

3

$N = \left(= \frac{1}{d} = \frac{1}{3.27 \times 10^{-6}} \right) = 3.06 \times 10^5$ $_3$✓

for $_3$✓ accept ≥ 3 sf in range 3.05 to 3.07 × 10^5 OR

$N = \frac{0.194}{their\ \lambda p}$ *(allow ECF for λ_p out of range but*

not if due to POT)

1

(b) identifies an appropriate physical characteristic that makes the measurement of the (5^{th}) maximum more difficult ✓

take 'it' to be the 5 th maximum / peak

(centre difficult to locate because)

(5^{th}) 'maximum is wider' / 'peak less pronounced' / 'less defined' or wtte;

allow 'maximum more spread out' / 'less pronounced'

OR

maximum 'is fainter' / 'less bright' / 'intensity reduced';

reject 'not as clear'

OR

(cannot use edges to determine location of centre because)

'whole maximum (may be) not visible' / 'can't see edges'

OR

*(**L_R** produces a range of wavelengths so)*

4th and 5th / adjacent fringes may overlap

1

(c) extrapolation of linear region of the $\mathbf{L_R}$ characteristic $_1$✓

*for $_1$✓ reads off where a ruled extrapolation to the linear region of the **L_R** characteristic reaches the horizontal axis*

the line must be free from discontinuities; condone a ruled dashed line

condone tangent meeting curve at I ≥ 10 mA

V_A for $\mathbf{L_R}$ in range 1.91 to 1.93 (V) $_2$✓

for $_2$✓ > 3 sf acceptable if rounding to 3 sf

2

(d) any fully correct calculation of the Planck constant $_1$✓

for $_1$✓ allow 2 sf

use of c = 3(.00) × 10^8 AND e = 1.6(0) × 10^{-19}

AND EITHER

V_A from (c) AND λ_p in range 620 to 650 nm / ECF their λ_p from (a)

OR

V_A = 2.00 AND λ_p in range 550 to 580 nm;

calculates mean of two valid calculations of the Planck constant;

result in range 6.10 to 6.50 × 10^{-34} (J s) $_2$✓

for $_2$✓ Planck constant result rounding to correct 3 sf

(check very carefully working leading to data booklet value 6.63 × 10^{-34})

1

(e) V_F corresponding to I_F = 21 mA read from **L_R** graph in **Figure 3**;

use of V_F = 2.01 (V) leading to R = 195 (Ω) earns both marks

calculates R from $\frac{6.1 - \text{their } V_F}{21(.0 \times 10^{-3})}$ $_1$✓

*for $_1$✓ accept evidence of working on **Figure 3** condone 2 sf eg V_F = 2.0 (V)*

allow POT error for I_F

1

R = 195 (Ω) from $\frac{6.10 - 2.01}{21(.0) \times 10^{-3}} = 195$ $_2$✓ 195 $_2$✓

for $_2$✓ evidence to show use of V_F = 2.01 ± 0.01 (V) must be seen, ie allow

$\frac{6.10 - 2.00}{21(.0) \times 10^{-3}} = 195$ OR $\frac{6.10 - 2.02}{21(.0) \times 10^{-3}} = 194$

1

[10]

3. (a) MAX 2

Uncertainty in one/each <u>reading</u> is 1 mm $_1$✓

Allow the uncertainty in (reading) the position of a spot is 1 mm. $_1$✓

OR

The measurement involves making two readings / there are two uncertainties (to be considered) in this measurement $_1$✓

Owtte

Difficulty / uncertainty in locating (exact) position of (centre of) spot $_2$✓

Or

Difficulty / uncertainty in lining up the (centre of the) spot with a graduation on the ruler $_2$✓

Or

Difficulty / uncertainty in locating the position of A / B $_2$✓

Do not allow:

- *because the smallest division is 1 mm*
- *hard to see measurements to less than 1 mm (need to link to position of spot (or A or B)*
- *"because of both sides of the ruler" on its own*
- *"ruler slightly misaligned" too vague*

the uncertainties from two (readings) are added $_3$✓

insufficient includes:

- *uncertainty doubles*
- *uncertainty is twice the smallest division*
- *Random error or human error or error without further detail.*

However:

The uncertainty doubles because there are two readings scores MP1

Also:

The uncertainty doubles because there are two readings <u>with identical uncertainties</u> would score 2 marks.

Mention of range of repeated measurements ÷ 2 is not applicable in this case.

2

(b) (Adds the uncertainties =) 4 (mm) $_1$✓

Or
Use of by substitution

(percentage uncertainty=) $\frac{\text{uncertainty}}{\text{value}}$ (×100) (%) $_1$✓

(% uncertainty =) 0.74 **or** 0.7 (c.a.o) $_2$✓ (**1 or 2 significant figures only**)

1st mark

Expect to see:

(percentage uncertainty=) $\frac{4}{544}$ *(×100) (%)*

Maximum 1 mark for

Condone (in substitution):

- *2/289, 2/255, 2/272, 2/544, 4/289, 4/255, 4/272*
- *power of ten errors (POT errors)*
- *must be a recognisable uncertainty*

Maximum 1 mark for

use of

(percentage uncertainty=) $\frac{\text{uncertainty}}{\text{mean (value)}}$ *(value)(×100) (%)*

along with substitutions of

- *2/289, 2/255, 2/272, 2/544, 4/289, 4/255, 4/272, 4/544*
- *power of ten errors*

condone for 1 mark

((2/289 + 2/255) × 100 =)

1.48% or 1.5%

2nd mark

Condone working leading to 2nd mark for:

Use of (percentage uncertainty=) $\frac{2}{272}$

*Do not allow mean of two separate % uncertainties **or** incorrect formula quoted and used in workings*

2

(c) MAX 2

The <u>percentage</u> uncertainty in c is smaller <u>than for a or b</u> because c has a larger value (than a or b separately)$_1$✓

or % uncertainty in c is half the percentage uncertainty in a + b $_1$✓

or The <u>percentage</u> uncertainty in c is smaller <u>because</u> its uncertainty is smaller for the same data value $_1$✓

Insufficient:

- *c has a smaller uncertainty*
- *a + b has a larger uncertainty*
- *The uncertainty of a + b is combined*

c's (% uncertainty =) 0.37 or 0.4 $_2$✓ or *c*'s (% uncertainty =) $\frac{2}{544} \times 100$ $_2$✓

idea that *c*'s measurement involves fewer readings than the sum of a and b $_3$✓
or
idea that c requires fewer measurements than the sum of a and b $_3$✓

Accept converse

Where numbers are quoted, these must be consistent with terms used.

4 readings, 2 readings

2 measurements, 1 measurement

2

(d) (when laser is switched on) always stand behind the laser (unless taking readings) ✓

Or
if <u>in front of laser</u> (when switched on) look away from the laser (eg when taking readings) ✓

Or
if <u>in front of laser</u> (when switched on) don't look at/towards the laser (eg when taking readings) ✓

Or
don't look directly into the laser (beam) ✓

Or
direct laser towards nearest wall ✓

Or
switch off laser when not in use ✓

Or
ensure (glass) reflective surfaces are covered (prevent reflections) ✓

Or

Do not shine the laser onto a reflective surface ✓

Or

place safety notices outside the laboratory [room] ✓

Or

don't shine laser at eye level ✓

Or

mark positions with pen/pencil and measure after laser switched off ✓

Or

laboratory is normally illuminated (not darkened) ✓

Where a list of safety measures has been given:

- *Treat more than one correct as neutral*
- *Penalise incorrect safety measure in a list that may include correct safety measures.*

Do not credit weak statements:

- *Do not look at the laser*
- *Don't point the laser anywhere except at the grating*
- *Don't look directly at the laser*

Beware of references to "the light".

1

(e) $(\tan\theta = \frac{0.544}{1.280} \ = \theta =) \ 23.0(°)$ ✓

allow 2 or more significant figure answer

acceptable common answers:

23, 23.0, 23.03, 23.025, 23.0255

Where more than 3 sf quoted, the number must be correct.

alternative method

*(valid attempt to determine distance from grating to spot **E**, eg*

(distance = $(\sqrt{0.544^2+1.280^2})$ *= 1.391)*

(sin $\theta = \frac{0.544}{1.391}$ *= 0.391)*

(θ *=) 23.0(°)* ✓

allow 2 or more significant figure answer

acceptable common answers:

23, 23.0, 23.03, 23.025, 23.0255

Condone mid-calculation rounding leading to errors in 4th sf where quoted.

1

(f) use of $n\lambda = d\sin\theta$ $_1$✓

or

(if nothing else seen) d = 3.3 × 10^{-6}m $_1$✓

Use of:

Correct rearrangement where subject would be λ

or correct substitution of n, d and θ

Expect to see n = 2 , d = 3.3(3) × 10^{-6} , θ = 23(.0)

*Condone **one** error in substitution for n or d in a correctly rearranged equation where subject would be λ*

(or where answer indicates the correct working for incorrect numbers, d error leads to 5.86 × 10^4)

Condone power of ten errors in working

λ = 6.5(2) × 10^{-7} (m) $_2$✓ ecf

2 or 3 sf only

where 3 sf quoted answer must be in range 651 to 652 nm (or ecf)

Common ecf (sin θ error in 1.5):

Expect to see an answer that rounds to 7.1 × 10^{-7}m to 2 sf

2

(g) The second mark ($_2$✓) is contingent on the award of the first mark ($_1$✓).

Increase distance from grating to screen / increase y $_1$✓

(This will increase distance y (and/or c) therefore) decreasing the percentage uncertainty in y / c / fringe spacing / θ / sin θ $_2$✓

Do not accept:

- *darkened room*
- *use a (vernier) caliper*
- *use a travelling microscope*
- *Repeat*
- *Repeat and average*
- *Computer / data logger / camera*
- *Ruler with smaller divisions*
- *Make the maxima further apart (details on how this is achieved are required)*
- *Increase distance between laser and screen.*

Decreases the <u>percentage</u> uncertainty in y $_2$✓

Or

Use a higher-order spot $_1$✓

(This will increase distance from centre spot to higher-order spot therefore)
decreasing the <u>percentage</u> uncertainty in the fringe spacing/θ /sin θ $_2$✓

Condone reference to this distance as c

Or
Measure distance between A and E $_1$✓

(This increases the distance therefore) decreasing the <u>percentage</u> uncertainty in c $_2$✓

No details of determination of c are required.

2

[12]

4. (a) one of:
(spectral) analysis of light from stars
(analyse) composition of stars
chemical analysis
measuring red shift \ rotation of stars ✓

insufficient answers:
'observe spectra', 'spectroscopy', 'view absorption \ emission spectrum', 'compare spectra', 'look at light from stars'.

Allow : measuring wavelength or frequency from a <u>named source</u> of light

Allow any other legitimate application that specifies the source of light. E.g.
absorbtion \ emission spectra in stars,
'observe spectra of materials'

1

(b) (i) first order beam
first order spectrum
first order image
✓

Allow 'n = 1' , '1' , 'one', 1 st

1

(ii) the light at A will appear white (and at B there will be a spectrum)
OR greater intensity at A ✓

1

(c) (d = 1 / (lines per mm × 10^3)
= 6.757 × 10^{-7} (m) OR 6.757 × 10^{-4} (mm) ✓

(nλ = d sin θ)
= 6.757 × 10^{-7} × sin 51.0 ✓ ecf **only** for :
- incorrect power of ten in otherwise correct calculation of d
- use of d = 1480, 1.48, 14.8 (etc)
- from incorrect order in bii

= 5.25 × 10^{-7} (m) ✓ ecf **only** for :
- incorrect power of ten in otherwise correct d
- from incorrect order in bii

Some working required for full marks. Correct answer only gets 2
Power of 10 error in d gets max 2
For use of d in mm, answer =
5.25 × 10^{-4} gets max 2
n = 2 gets max 2 unless ecf from bii
use of d = 1480 yields wavelength of 1150m

3

(d) n = d (sin90) / λ OR n = 6.757 × 10^{-7} / 5.25 × 10^{-7} ✓ ecf both numbers from c

= 1.29 so <u>no more</u> beams observed ✓ or answer consistent with their working

OR

2 = d (sinθ) / λ OR sinθ = 2 × 5.25 × 10^{-7} / 6.757 × 10^{-7} ✓ ecf both numbers from c

sinθ = 1.55 (so not possible to calculate angle) so <u>no more</u> beams ✓

OR $\sin^{-1}$(2 × (their λ / their d)) ✓
(not possible to calculate) so <u>no more</u> beams ✓ ecf

Accept 1.28, 1.3
Second line gets both marks
Conclusion consistent with working

2

[8]

5. (a) Answer D ✓ (violet)

1

(b) (light from each slit) <u>superpose</u>
light from adjacent slits have a path difference of <u>one</u> wavelength
(at this angle all) the waves are in phase
constructive interference / peaks coincide / (positively) reinforce

any 3 points ✓ ✓ ✓ max 3

Ignore reference to nodes or antinodes

If general statements are made only give marks for parts related to 'Bright line' or 'First order' which appears in the question.

3

(c) (i) use of sin $\theta = \lambda / d = 5.3 \times 10^{-7} / 1.8 \times 10^{-6}$ ✓ (= 0.294)

$\theta = 17°$ ✓ (17.1°)

Answer alone scores both marks

2

(ii) (use of $n = d \sin\theta / \lambda$) $n_{max} = (d \sin 90° / \lambda) = d / \lambda =$ ✓

$= 1.8 \times 10^{-6} / 5.3 \times 10^{-7} = 3.4$ ✓

max order = 3 ✓

Showing that n=4 is not possible is not answering the question but the first mark (equation mark) can be gained this way

Max order is an independent mark from reducing a calculated value for n to the next lowest integer.

3

[9]