# Mark schemes

**1.** (a) One wavelength✓

*Accept $\lambda$*

**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 ($\theta_{min}$) 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 $\theta_2$ and $\theta_1$ and compares to 90°

or

adds $\theta_2$ and$\theta_2$ and compares to 90°

or

adds $\theta_1$ and $\theta_1$ and compares to 90°✓

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

*for any combination of $\theta$, $r$ 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) Spreading of pulse / parts of a pulse take different times to travel through the fibre / pulse broadening✓

*Do not credit material dispersion.*

*owtte*

Due to different paths through the optical fibre / due to entering the optical fibre at different angles ✓

*Accept a diagram showing different paths.*

2

(b) speed $\left(= \frac{distance}{time}\right) = \frac{10 \times 10^3}{5.225 \times 10^{-5}}$ ✓ $(= 1.91 \times 10^8)$

1

(c) Reads off Sin $\theta_R$ = 0.3391

or

use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$✓

Use of $n = \frac{c}{c_s}$ seen✓

*With their Sin $\theta_R$*

*(Refractive index of core = 1.47)*

*Allow use of their refractive index where $cs$ is the subject of the formula*

$cs = 2.03 \times 10^8$ ✓

Alternative:

Reads off Sin $\theta_R$ = 0.3391

or

$\theta = 19.8°$ ✓

$c_s \cos 19.8 = 1.9 \times 10^8$ ✓

$c_s = 2.03 \times 10^8$ ✓

*Allow finding $\theta_R$ for their read off*

*Allow use of their $\theta_R$*

**3**

(d) The refractive index of core for blue light is greater than the refractive index for red / The refractive index of core for red light is less than the refractive index for blue✓

*Max 1 mark for stating that the refractive indices are different because their speeds are different*

*MP1 can come from graph or prior knowledge*

The speed of the blue light is less than the speed of the red light and travel the same distance / The speed of the red light is greater than the speed of the blue light and travel the same distance✓

**2**

(e) the blue now travels a shorter distance than the red light (compared to (d))✓

**or**

the red light now travels a greater distance than the blue light (compared to (d))✓

**or**

the difference between the blue's velocity parallel to the central axis and the red's velocity (parallel to the central axis) has decreased (compared to (d)). ✓

*Allow: now travel different distances whereas previously travelled the same distance.*

**or**

the difference between the horizontal velocity of the red light and the horizontal velocity of the blue light has decreased (compared to (d)).✓

**1**

**[9]**

**3.** D

*70°*

**[1]**

**4.** C

*using monochromatic light of higher frequency*

**[1]**

**5.** (a) Speed = $3.0 \times 10^8/1.47$
= $2.0(4) \times 10^8$ m s$^{-1}$ ✓

*Do not accept 1 sf answer*

**1**

(b) Critical angle calculation ✓
$\sin C = n_{clad}/n_{core}$ = 1.41/1.47 = 0.96
critical angle = 73.6$^o$
Angle of refraction calculation✓
$r = 90 - C = 16.4^o$

*Do not give MP2 if calculated answer is given as A*

Angle of incidence calculation ✓ $\sin(i) = 1.47 \sin(r)$
$i = 24.5^o$

*Allow 2 sf answer; allow 24.6$^o$*

**3**

(c) Correct path of light drawn showing partial reflection and transmission of ray when it encounters the boundary ✓

Angle of incidence on core–cladding boundary decreases✓
And will now be less than critical angle ✓
(Some light will escape/be refracted into cladding
Some light will continue)

*If the diagram is not annotated and no other mark is given, 1 mark can be given for correct description of partial reflection.*

3

**[7]**

**6.** C

*433 nm*

**[1]**

**7.** (a) reads off $\lambda_p$ $_1$✓

*for $_1$✓ condone POT;*

*expect $\lambda_p$ = 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 full substitution, eg*

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

*OR*

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

*allow ECF in $\lambda_p$ 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*

$N = \dfrac{0.194}{\text{their } \lambda p}$ *(allow ECF for $\lambda_p$ 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)*

*$4^{th}$ and $5^{th}$ / adjacent fringes may overlap*

**1**

(c) extrapolation of linear region of the **$L_R$** 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 $I \geq 10$ mA*

$V_A$ for **$L_R$** 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 $c = 3(.00) \times 10^{8}$ AND $e = 1.6(0) \times 10^{-19}$*

*AND EITHER*

*$V_A$ from (c) AND $\lambda_p$ in range 620 to 650 nm / ECF their $\lambda_p$ from (a)*

*OR*

*$V_A = 2.00$ AND $\lambda_p$ 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 $\mathbf{L_R}$ 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*

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

1

**[10]**

**8.** B

**[1]**

**9.** (a) Max one from: ✓

internal ray is a <u>radius</u> (of the block)

**OR**

internal ray travels along a <u>normal</u>

**OR**

ray meets (glass-air) boundary at 90°

**OR**

angle of incidence is zero

(so angle of emergence/refraction is zero)

1

(b) Straight line ruled from centre of protractor through **ABC** ✓

*for $_1$✓ line must be reasonable and must pass through intersection of the cross-wires and must not pass above the centre of **A** or below the centre of **B***

Takes a pair of readings: 24 or 66; and angle consistent with their line ✓

*Must be between 0° and 90°*

Use of Snell's Law with their angles ✓

1.48 or 1.52 ✓

*Must be a positive value to 3 sf.*

4

(c) 1.47 or 1.471 ✓

*Reject 1.5 or >4 sf; ignore any unit written*

1

(d) 0.08 (mm) ✓

*Only acceptable answer*

1

(e) Calculates one percentage uncertainty

*For* $_1$✓ *allow ecf from* ***(d)****; expected answers are*

*% uncertainty in* $(R_2 - R_0)$ =

$$100 \times \frac{0.08}{14.28} = 0.56(0)\%$$

*% uncertainty in* $(R_2 - R_1)$ =

$$100 \times \frac{0.08}{9.71} = 0.82(4)\%$$

**OR**

Calculates max or min value ✓

$$n_{min} = \frac{14.28 - 0.08}{9.71 + 0.08} = 1.45(0);$$

$$n_{max} = \frac{14.28 + 0.08}{9.71 - 0.08} = 1.49(1);$$

Adds their percentage uncertainties
**OR**

attempt to use percentage $n = \frac{0.5(\text{max} - \text{min})}{1.47} \times 100$ ✓

*Ecf for* $_2$✓ *from wrong percentage uncertainties or wrong max or min values*

1.4(%) ✓

*Condone 3 or 4 sf*

3

**[10]**

**10.** **A**

**[1]**

**11.** (a) Attempt to resolve **A** or **B** eg 430 × cos35° or $T_B$ × cos12° ✓

360 (N) ✓

*If no other mark given, allow 430 × sin35° =* $T_B$ *× sin12° to give 1190 N for 1 mark.*

2

(b) Substitution of *F* and *A* into Young modulus or stress equation ✓

$4.4 \times 10^{-2}$ (m) ✓

*Condone POT error for Young modulus*

2

(c) Angle of **A** decreases or angle of **B** increases ✓

*Accept references to 35º or 12º*

Any correct application of trig or geometry to the situation

(eg $T_B/T_A = \cos\theta_A/\cos\theta_B$ so as $\theta_A$ decreases, $\cos\theta_A$ increases, $\cos\theta_B$ decreases, so $T_B/T_A$ increases)

**OR**

eventually $\theta_B$ will equal 35º, $\theta_A$ = 12º so forces will be reversed (as system is symmetrical)

**OR**

sum of vertical components remains unchanged and vertical component of tension becomes less as angle **A** decreases ✓

*Allow idea that more of the weight is supported by **B***

$T_A$ decreases, following some relevant discussion ✓

3

(d) Greater rate occurs when pulses are shorter (in time)/less modal dispersion ✓

*Allow reverse arguments*

Smaller diameter (leads to less modal dispersion) means smaller range of path lengths ✓

*Accept idea of fewer reflections*

**X** is more suitable because narrower core leads to lower modal dispersion or reduced pulse broadening ✓

3

**[10]**

**12.** **C**

**[1]**

**13.** (a) Understanding that for coherence sources must have same frequency/wavelength AND constant phase difference. ✓

And that this achieved by both speakers being connected to same signal (generator). ✓

2

(b) The sound waves from the two speakers superpose (at a point) ✓

*Do **not** accept 'interfere' or 'superimpose' for 'superpose'*

*Accept for MP1 waves adding together/combine at a point (e.g. point A) for 'superpose'.*

*Do not accept diagram.*

At A (and B) the two waves are in phase/ have zero phase difference (and a maximum is produced) ✓

Moving away from A introduces a path difference/phase difference/waves are out of phase (and amplitude decreases) ✓

(Moving on towards B the waves move back in phase)

*Award MP3 for formation of minimum/destructive interference due to (odd number of) half wavelength path difference/π/ 180$^o$ phase difference/ antiphase.*

**3**

(c) Clear evidence of use of Pythagoras ✓

Correct calculation of either length PB or QB ✓

PB = $(2.25^2 + (0.95 - 0.3/2)^2)^{1/2} = 2.39$ m

QB = $(2.25^2 + (0.95 + 0.3/2)^2)^{1/2} = 2.50$ m

(Path difference =) QB – PB either numerically or algebraically ✓

(= 0.11 (0.12) m)

*If ws/D used to give 0.13 (m) reward with 1 mark*

**3**

(d) (Path difference = one wavelength)

Use of speed = frequency × wavelength to give

Speed = 2960 × 0.12 = 360 m $s^{-1}$ ✓

*Working or equation must be seen.*

*Condone use of 0.10 m or 0.11 m or 0.127m or 0.13 m*

*0.10 gives 300 (296) m $s^{-1}$*

*0.11 gives 330 (325.6) m $s^{-1}$*

*0.127 gives 376 m $s^{-1}$*

*0.13 gives 380 (385) m $s^{-1}$*

**1**

(e) Wavelength (gradually) increases. ✓

So that path difference at C gets closer to one wavelength ✓

*Alternative for MP2:*

*Separation of maxima (along line AB) increases* ✓

(Amplitude of) sound will get larger/louder as waves move in phase (then smaller/quieter). ✓

*Alternatives for MP3:*

*Maximum moves (from B) towards C so amplitude of sound gets larger/louder (then quieter).*

*OR*

*Maximum moves further along path/beyond C so amplitude of sound gets quieter* ✓

3

**[12]**

**14.** **D**

**[1]**

**15.** **B**

**[1]**

**16.** (a) Max 2 from: ✓ ✓

(Because) the refractive index of water is greater than air

(and) the angle of incidence is greater than the critical angle

<u>total internal reflection</u> (of laser beam) occurs

*Allow optical density for refractive index.*

*Allow answer given as a diagram.*

2

(b) Use of $n = \frac{c}{c_s}$ eg $c_s = \frac{3.00\times10^8}{1.33}$ ✓

$2.26 \times 10^8$ (m s$^{-1}$) ✓

3 sf answer from some relevant working ✓

3

(c) 49 (°) ✓

*Do not allow 1 sf answer.*

1

(d) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question**

| Mark | Criteria |
|---|---|
| 6 | Both functions and dispersion problems discussed. No significant error or inconsistency. |
| 5 | Both functions and dispersion problems discussed. There may be some significant error or inconsistency. |
| 4 | Functions or dispersion problems described. No significant error or inconsistency. |
| 3 | Functions or dispersion problems described. There may be some significant error or inconsistency. |
| 2 | Both X and Y named and a function of one given; or A function of X and Y given, but only one named |
| 1 | X and Y identified by name or function |
| 0 | No relevant analysis |

Level 2 max if dispersion modes confused in descriptions.

*The following statements are likely to be present.*

***Names***

***X** is Core*

***Y** is Cladding*

***Functions***

***X**:*

*Propagates/Guides the wave/light*

*By TIR*

*(with) low attenuation/absorption*

*Refractive index of core > cladding*

***Y**:*

*Protects core from damage*

*Prevents cross talk between touching fibres*

*Provides 'clean' boundary for TIR*

***Dispersion problems***

***Both**: Cause pulse broadening/limited bandwidth*

***Material**: different wavelengths have different speeds due to different refractive indices within the core – use monochromatic beam*

***Modal**: different paths have different lengths so effective time along fibre differs – use single-mode fibre (narrow core/small Δn between core and cladding)*

(e) Max 2 from: ✓ ✓

*Allow responses shown on diagram.*

Light may encounter impurities at different positions/angles

Light may encounter different number of impurities

*Allow "different impurities".*

Light may encounter different sizes of impurities

Angle of incidence may become less than critical angle

*Don't accept "critical angle changes"*

Bending may cause cracks in the core/cladding

Light may be refracted (more/differently)

**2**

(f) Transverse – displacement/oscillations/vibrations at right angles/(perpendicular) to direction of energy transfer ✓

*Condone "direction of wave" once.*

*1 mark for correct reference to difference in polarisation.*

Longitudinal – displacement/oscillations/vibrations along/(parallel to) direction of energy transfer ✓

*Treat references to P and S wave as neutral.*

**2**

**[16]**

**17.** **A**

**[1]**

**18.** **A**

**[1]**

**19.** (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 )*

*($\theta$ =) 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 $\lambda$*

*or correct substitution of n, d and $\theta$*

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

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

*(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*

$\lambda$ = 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 $\theta$ 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 / $\theta$ / sin $\theta$ $_2$✓

*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 percentage uncertainty in the fringe spacing/$\theta$ /sin $\theta$ $_2$✓

*Condone reference to this distance as $c$*

Or

Measure distance between A and E $_1$✓

(This increases the distance therefore) decreasing the percentage uncertainty in c $_2$✓

*No details of determination of c are required.*

2

**[12]**

**20.** **C**

**[1]**

**21.** (a) Ray enters (prism) along normal ✓

*Allow normal explained eg at right angles to surface*

*Accept "angle of incidence is 0".*

1

(b) Treat each point independently.

Prism material/it has/they have same refractive index / optical density as windscreen ✓

*Condone 'it has' or 'they have' or just 'same'*

*Allow "no change of speed between prism and windscreen"*

*Allow "made from same material"*

*Do not allow "same refractive index between them"*

*Treat "monochromatic" as neutral*

Prism fitted to windscreen without gaps ✓

*Allow "contact between prism and windscreen is clean" etc. Allow "touching the windscreen"*

*Condone suggestion that any bonding material has same refractive index (as prism and windscreen).*

*Do not accept 'no boundary'*

2

(c) $C = \arcsin(1/1.52) = \arcsin(0.66) = 41(.1)°$ ✓

*The first mark is for the calculation.*

45° > critical angle / 41.1° resulting in <u>total internal reflection / tir</u> (at each boundary) ✓

*The second is for the discussion but is contingent on obtaining a value for C.*

*Ecf for any C < 45°*

*Accept clear reference to angle at point A in place of 45° statement.*

*Do not allow "angle of incidence> critical angle" on its own.*

**2**

(d) Calculation of critical angle at glass–water boundary (61.0°)

OR

Calculation of possible *n* from glass to water (0.707) or absolute n for glass (1.88)

OR

Calculation of angle of refraction in water (53.9°) ✓

So total internal reflection no longer takes place
**OR**
some light escapes/refracts (into water) / less light reflects ✓

(Less light stays within windscreen so less light detected at sensor)

*Do not allow suggestion that TIR occurs at critical angle/when angle of incidence=critical angle.*

*Do not allow "ray/all the light escapes/refracts" or "no light reflects" or "less TIR".*

*Do not condone "total internal refraction/diffraction"*

**2**

(e) Statement of effect of change in n on the path direction ✓

*Eg for MP1*

- *Light may change direction inside windscreen*
- *Light may change direction at a windscreen boundary*

(Sensible reference to the variation of a few per cent) leads to the idea that change is unlikely to be significant ✓

*Eg for MP2*

- *Variation too small to deviate significantly within windscreen – internal effect*
- *Variation too small to affect tir at A without droplet – boundary effect*
- *Variation too small to significantly affect transmission at A with droplet – boundary effect*

*Allow discussions that may cause a difference, eg there is a summative effect from multiple reflections etc*

**MAX 2**

(f) **More sensitive because…**

more likely to encounter/detect water drop OR will encounter more water drops ✓
bigger decrease in light intensity, so more sensitive to rain ✓

**Less sensitive because…**

more likely to encounter imperfections in glass/on surface of glass /dirt on surface of glass ✓
any curvature effects will be greater so may not hit detector ✓
light intensity reduced without presence of water / greater absorption in windscreen due to greater path length ✓

*Allow any 2 comments taken from list.*

*There must be a sense of whether the comment relates to an improvement or decrease in sensitivity.*

*Treat as list; mark 1 and 2 independently.*

*Allow idea of larger area*

*Do not allow a response that discusses travel time of ray.*

**MAX 2**

**[11]**

**22.** **D**

**[1]**

**23.** (a) Central maximum with lower intensity maxima (either side) ✓

*MP1 is for comparison of intensity. Condone references to brightness/dimness.*

Central maximum is twice as wide/wider than other maxima ✓

*MP2 is for comparison of width*

*Award credit for a drawn answer eg on Fig 1.*

*Suggestion that pattern due to white light = max 1*

*Reference to Young's slit or equation = max 1*

*If only a single maximum is referred to MP2=0 but MP1 can score for description of intensity variation.*

**2**

(b) Wider (central) maxima (maximum) ✓

*'The pattern is wider/more spread out' gets 1 mark if no other marks given.*

*Not "larger pattern".*

(Subsequent) maxima further apart ✓

*Condone "larger" distances between maxima.*

*Condone 'maxima more spaced out'*

*Reference to Young's slit or equation = max 1*

*Ignore comments related to change in wavelength*

**2**

(c) $d = 1 \times 10^{-3}/500$ ($= 2 \times 10^{-6}$) ✓

*Allow POT error for d for MP1*

($\sin\theta = n\lambda/d = 6.5 \times 10^{-7} / 2 \times 10^{-6} = 0.33$)

$\theta = 19°$ ✓

*May be seen in diffraction grating equation.*

*Allow max 1 for use of grating constant rather than d to give $7.45 \times 10^{-11}$° if no other credit available.*

**2**

(d) Any two from: ✓ ✓

(Range of wavelengths results in):

Central maximum unchanged in width

Broader maxima/range of angles for each maximum/order

Gradually getting broader/more spread out for greater order maxima

Part of third order maximum suppressed at long wavelengths (for θ > 90°)

*Give credit for answer shown in diagram*

*Evidence for these marks may be seen in calculations*

*Treat intensity variation as neutral.*

**2**

**[8]**

**24.** (a) TWO FROM:

central white fringe ✓

(fringes either side) showing range of colours/spectrum ✓

with red furthest and blue/violet closest to centre ✓

*Allow rainbow for spectrum*

*Reject different colour fringes*

*If colours mentioned for last mark must be in right order i.e. red last*

**1**
**1**
**(MAX 2)**

(b) FOUR FROM:

central fringe is a mixture of red and green light/two wavelengths ✓

EITHER (1 marks)

(separate) red and green fringes are seen (on either side) ✓

OR (for 2 marks)

spacing of green fringes is less than spacing of red fringe / green fringes closer to middle than red ✓ ✓

OR (for 3 marks)

spacing of red fringes is 20% (or 1.2 times)greater than green fringes ✓ ✓ ✓

$6^{th}$ green fringe overlaps with $5^{th}$ red fringe ✓

*Allow orange/yellow for central fringe*

*If w used must be identified as fringe spacing for third alternative*

**1**
**1**
**1**
**1**
**(MAX 4)**

(c) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.**

| Mark | Criteria | QoWC |
|---|---|---|
| 6 | Explains how (%) uncertainties combine to determine uncertainty in wavelength OR identify % uncertainty *s* as being the largest | The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear.<br>The text is legible. |
| 5 | Explain how wavelength is determined using $\lambda = \frac{ws}{D}$ | |
| 4 | Explains how second change affects fringe spacing<br>AND<br>Comments on how change in fringe spacing affects (%)uncertainty / change in *s* OR *D* affects (%)uncertainty | The student presents relevant information and in a way which assists communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning. |
| 3 | Explains how second change affects fringe spacing<br>OR<br>Comments on how change in fringe spacing affects (%)uncertainty / change in *s* OR *D* affects (%)uncertainty | |
| 2 | States how one of the changes affects fringe separation (decrease *s* increases fringe separation / decrease *D* decrease fringe separation | The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive. |
| 1 | States that one of the changes alters fringe separation | |
| 0 | No correct change identified | The student's presentation, spelling and grammar seriously obstruct understanding. |

*The following statements may be present for decreasing slit separation s:*

*Fringe separation increases*
*Uncertainty in measuring fringe separation will decrease*
*and as this is needed to measure wavelength, uncertainty in wavelength measurement will decrease*

*The following statements may be present for smaller D:*

*Uncertainty in measuring D would increase*
*Fringe separation would also decrease*
*so uncertainty in measuring fringe separation would increase*
*Both are required to find wavelength so uncertainty in finding wavelength would increase*

*FOR Middle Band* ***one*** *of these considered:*

*Decrease s*
*Larger fringe separation so smaller (%) uncertainty (in w)*
*Smaller s so higher (%) uncertainty in s*
*Decrease D*
*Smaller fringe separation so larger (%) uncertainty (in w)*
*Smaller D so higher (%) uncertainty in D*

*If explain reverse change correctly (s increase D increase) no penalty*

6

**[12]**

**25.** **D**

**[1]**

**26.** **A**

**[1]**

**27.** (a) Use of $n_A = \frac{c}{c_A}$ to make $c_A$ the subject of the equation

*Condone truncation without appropriate rounding mid-calculation*

**OR**

speed in glass **A** = 2.05(2) × $10^8$ $ms^{-1}$ $_1$✓

Speed in glass **B** = 1.985(3) × $10^8$

*Condone use of c = 3 × $10^8$*

*But must see answer to 4 sf answer*

**OR**

their speed in glass **A** × 0.96748 (or equivalent) $_2$✓

*Values obtained using c = 3×$10^8$:*

- *speed in glass A = 2.05(3)× $10^8$ $ms^{-1}$*
- *speed in glass B = 1.98(7) × $10^8$*
- *n = 1.510*

**OR**

Alternative 1st and 2nd marks

Use of $n_A/n_B = c_B/c_A$ by substitution for $n_A$ $_1$✓

Use of $n_A/n_B = c_B/c_A$ by substitution for $n_A$ and $c_B = c_A \times 0.96748$ $_2$✓

**OR**

$n_B$ = 1.461 / 0.96748 $_1$✓$_2$✓

*Watch for maths errors:*

*Dividing by 1.03252 ≠ multiplying by 0.96748*

*Multiplying by 1.03252 ≠ dividing by 0.96748*

1.510 cao to 4 sf only $_3$✓

*Correct answer to 4 sf obtains all 3 marks*

*Penalise any unit on final answer*

**3**

(b) **Relationship:**

Increase in tension (or stress) in cable produces increase in strain resulting in increase in $\lambda_R$

**OR**

Decrease in tension (or stress) causes decrease in strain resulting in decrease in $\lambda_R$ $_1$✓

**Variation due to motion:**

As the lift accelerates downwards, (the tension is less than the weight in the cable, a decrease in tension results) in $\lambda_R$ decreasing $_2$✓

At constant velocity (the tension again equals the weight and) $\lambda_R$ returns to the initial, at rest value $_3$✓

*Allow a correct comment on the directional relationship between tension, strain and $\lambda_R$ independent of the motion of the lift for first mark*

3

(c) **P** because it will produce a larger increase in $\lambda_R$ for the (same) <u>increase</u> in strain

**OR**

**P** because it has a larger gradient (must be a sense of larger increase in $\lambda_R$ for the (same) <u>increase</u> in strain) ✓

Hence <u>smaller accelerations</u> (which produce small changes in strain) can produce <u>measurable changes in $\lambda_R$</u>

**OR**

Hence gauge **P** will have a higher resolution ✓

*Selecting Q gains zero marks*

*Linking steeper gradient to being able to withstand a larger force negates this mark*

*Allow more accurate measurement of <u>acceleration</u>*

*Allow more readings of <u>acceleration</u> can be taken (over the range)*

*More sensitive treat as neutral*

2

**[8]**

**28.** C **[1]**

**29.** C **[1]**

**30.** D **[1]**

**31.** B **[1]**

**32.** **C**

**[1]**

**33.** (a) $i = \sin^{-1}(1/1.6) = 39°$ ✓

1

(b) sin 58 = n/1.6 ✓

$n$ = 1.4 (1.36) ✓

1
1

(c) blue light undergoes TIR ✓

red light refracted ✓

reason i.e. critical angle for red light is more OR critical angle for blue light is less ✓

*Allow correct description of refraction. Ignore statements about towards/away from normal*

OR

if refractive indices change by same factor ✓

critical angle stays constant ✓

so path followed by red and blue light is the same ✓

OR

don't know if refractive indices change by same factor ✓

so can't predict the effect on critical angle ✓

so can't predict paths of red and blue light ✓

*For second two alternatives third mark (i.e. about paths of red and blue) dependent on first mark (i.e. factor of refractive index change)*

1
1
1

**[6]**

**34.** **A**

**[1]**