MS1-1

Optical Measurements – Marking Scheme

Part A: The refractive index of a disk

A.1	drawing diagram:	
	The ruler, beam, disk, and α appear in the diagram (1 missing item: 0.1 pts; more than 1 missing items: 0 pts)	0.2 pts
	the incoming beam parallel to the diameter through $0°$ (can be identified by the position of α)	0.1 pts
	ruler is tilted with respect to the beam	0.1 pts
	at least 10 measurement points (for 8-9 points: 0.2 pts; for 6-7 points: 0.1 pts; less: 0 pts) (without Δs: 10 points: 0.2 pts; 8-9 points: 0.1 pts; less: 0 pts)	0.3 pts
	full 15-75 degrees region (25-65 degrees region: 0.1 pts)	0.2 pts
	varying $\Delta\delta$ according to the spot size on the screen	0.1 pts
A.2	calculated β from δ and α for all rows in the table	0.1 pts
	calculated $\sin\alpha$ and $\sin\beta$ for all rows in the table	0.1 pts
	at least 8 measured points appear in the graph	0.1 pts
	the data covers at least 75% of each coordinate length	0.1 pts
	there are labels in each axis	0.1 pts
	plotted regression line and calculate slope	0.1 pts
	value of n: $1.50 \le n \le 1.53$ if $1.48 \le n < 1.50$ or $1.53 < n \le 1.55$: 0.1 pts	0.3 pts
	value of $0.005 \le \Delta n \le 0.03$, if $1.45 \le n \le 1.58$; otherwise: 0 pts	0.1 pts
A.3	The graph includes a minimum angle of δ	0.1 pts
	labels in each axis and error bars of $\Delta\delta$ appear	0.1 pts
	value of $\delta_{\min}$: $336° \le \delta_{\min} \le 338°$	0.2 pts

	$335° \le \delta_{min} < 336°$ or $338° < \delta_{min} \le 339°$: 0.1 pts	
	value of $\alpha(\delta_{min})$ $\quad 49° \le \alpha(\delta_{min}) \le 51°$	0.1 pts
A.4	Stated that $\frac{d\delta}{d\alpha} = 0$	0.1 pts
	found that $\frac{d\beta}{d\alpha} = \frac{1}{N-1}$ ($N = 3$: full points)	0.1 pts
	Snell's Law $\cos\alpha = \frac{n\cos\beta}{N-1}$ or eq. ($N = 3$: full points)	0.2 pts
	get $\frac{1}{n^2} = \sin^2\beta + \frac{\cos^2\beta}{(N-1)^2}$ or eq. with α ($N = 3$: full points)	0.3 pts
A.5	figure includes ray path and measured angles	0.1 pts
	measurement of $\phi_j = \alpha + j\gamma$ for $j = 0,1,2,3$ only for $j = 0,3$: 0.2 pts only for $j = 0,1,2$: 0.2 pts only for $j = 0,2$: 0.1 pts	0.3 pts
	plotted a graph of ϕ_j vs. j	0.1 pts
	found value for β (or γ)	0.1 pts
	value of n: $\quad 1.510 \le n \le 1.520$ $1.505 \le n < 1.510$ or $1.520 < n \le 1.525$: 0.1 pts	0.2 pts
A.6	for $N = 4$:	
	measurement of $\phi_j = \alpha + j\gamma$ for $j = 0,1,2,...,6$ (7 values) only for $j = 0$ and $j = 5$ or 6: 0.2 pts only for $j = 0$ and $j = 3$: 0.1 pts	0.3 pts
	plotted graph of ϕ_j vs. j	0.1 pts
	found value for β (or γ)	0.1 pts
	value of n: $\quad 1.510 \le n \le 1.520$	0.2 pts

	$1.505 \le n < 1.510$ or $1.520 < n \le 1.525$: 0.1 pts	
	For $N = 5$:	
	measurement of $\phi_j = \alpha + j\gamma$ for $j = 0,1,2,...,6$ (7 values)	0.3 pts
	measurement of $\phi_j = \alpha + j\gamma$ for $j = 0$ and $j = 5$ or 6	0.2 pts
	measurement of $\phi_j = \alpha + j\gamma$ for $j = 0$ and $j = 4$	0.1 pts
	plotted graph of ϕ_j vs. j	0.1 pts
	found value for β (or γ)	0.1 pts
	value of n: $1.510 \le n \le 1.520$ $1.505 \le n < 1.510$ or $1.520 < n \le 1.525$: 0.1 pts	0.2 pts
	value of $\langle n \rangle$: $1.512 \le \langle n \rangle \le 1.518$	0.1 pts

Part B: The parameters of a diffraction grating

In part B, the final results of each student should be rescaled relative to the reference of $\lambda/d = 0.400$, according to the table supplied separately, using the ID of the grating recorded by the student in his/her answer sheet.

B.1	Plotted a diagram with all of the requested items	0.1 pts
	Distance of the diffraction grating from the screen > 45 cm	0.1 pts
	for $m = 1$ value of λ / d: $0.395 \le \lambda / d \le 0.405$ if $0.39 \le \lambda / d < 0.395$ or $0.405 \le \lambda / d < 0.41$: 0.1 pts	0.2 pts
	for $m = 2$ value of λ / d: $0.395 \le \lambda / d \le 0.405$ if λ / d: $0.39 \le \lambda / d < 0.395$ or $0.405 \le \lambda / d < 0.41$: 0.1 pts	0.3 pts
B.2	First method – using extremum:	
	plotted the diagram with all requested items	0.1 pts
	the ray is definitely not perpendicular to the grating	0.1 pts
	the grating angle changes between $m = 3$ and $m = 4$ or $m = 4$ maximum is backwards	0.1 pts
	showed that the minimal angle is at $\alpha = \theta / 2$	0.5 pts

	for extremum calculation with error: 0.4 pts	
	value of $\theta_{3\min}$: $73.0° \le \theta_{3\min} \le 74.5°$ or $36.5° \le \alpha_{3\min} \le 37.25°$ if $72.0° \le \theta_{3\min} \le 75.5°$ or $36.0° \le \alpha_{3\min} \le 37.75°$: 0.1 pts (around θ_{min} satisfying $2\sin\frac{\theta_{min}}{2} = m\frac{\lambda}{d}$ for the grating ID; $\theta_{3min} = 73.74° + 214.86° \times \Delta; \Delta = \lambda/d\ - 0.4$)	0.3 pts
	for $m = 3$ value of λ/d : $0.395 \le \lambda/d \le 0.405$ if λ/d : $0.39 \le \lambda/d < 0.395$ or $0.405 \le \lambda/d < 0.41$: 0.1 pts	0.2 pts
	value of $\theta_{4\min}$: $105.5° \le \theta_{4\min} \le 107.0°$ or $52.25° \le \alpha_{4\min} \le 53.5°$ if $104.0° \le \theta_{4\min} \le 108.5°$ or $52.0° \le \alpha_{4\min} \le 54.25°$: 0.1 pts (around θ_{4min} satisfying $2\sin\frac{\theta_{min}}{2} = m\frac{\lambda}{d}$ for the grating ID; $\theta_{4min} = 106.26° + 381.97° \times \Delta; \Delta = \lambda/d\ - 0.4$)	0.3 pts
	for $m = 4$ value of λ/d : $0.395 \le \lambda/d \le 0.405$ if λ/d : $0.39 \le \lambda/d < 0.395$ or $0.405 \le \lambda/d < 0.41$: 0.1 pts	0.2 pts
	Alternative method – measuring α directly:	
	plotted the diagram with all requested items	0.1 pts
	measuring α	0.3 pts
	for $m = 3$ value of λ/d : $0.395 \le \lambda/d \le 0.405$ if λ/d : $0.39 \le \lambda/d < 0.395$ or $0.405 \le \lambda/d < 0.41$: 0.3 pts	0.7 pts
	for $m = 4$ value of λ/d : $0.395 \le \lambda/d \le 0.405$ if λ/d : $0.39 \le \lambda/d < 0.395$ or $0.405 \le \lambda/d < 0.41$: 0.3 pts	0.7 pts

Part C: The refractive index of a triangular prism

C.1	understood that $\delta_{\min} = \delta_{\text{sym}}$, or independently obtained $49.5° \le \delta_{\text{sym}} \le 51.5°$ in C.2	0.4 pts
C.2	measured $\delta_{\min}$ for at least one prism angle: $49.5° \le \delta_{\min} \le 51.5°$	0.3 pts
	measured $\delta_{\min}$ for two more prism angles: $49.5° \le \delta_{\min} \le 51.5°$	0.3 pts
	distance between prism and screen larger than 120 cm	0.1 pts

	finding $\langle \delta_{\min} \rangle$: $50.30° \le \langle \delta_{\min} \rangle \le 50.70°$	0.3 pts
	making correct calculation of $\Delta\langle \delta_{\min} \rangle$, $\Delta\langle \delta_{\min} \rangle \le 0.1°$	0.1 pts
	finding n: $1.641 \le n \le 1.644$ $1.640 \le n < 1.641$ or $1.644 < n \le 1.645$: 0.3 pts $1.639 \le n < 1.640$ or $1.645 < n \le 1.646$: 0.2 pts $1.637 \le n < 1.639$ or $1.646 < n \le 1.648$: 0.1 pts	0.4 pts
	finding Δn using correct $\Delta\delta_{\min}$, $\Delta n \le 0.001$	0.1 pts