

Thickness Measurements Using Birefringence (10 points)

Part A. Measurement System Setup (2.3 points)

A.1 (0.3 pt)

$$\lambda = 684 \text{ nm}$$

Correct value of $\lambda \rightarrow$ **0.2 pt**

$$\theta = 20.0^\circ$$

Correct value of $\theta \rightarrow$ **0.1 pt**

A.2 (0.2 pt)

$$\theta = -30.0^\circ, 70.0^\circ$$

Correct values of θ (0.1 each) \rightarrow **0.2 pt**

A.3 (0.8 pt)

$$\theta = -28.0^\circ$$

$$\lambda_{\text{Peak}} = 458 \text{ nm}$$

$$\alpha = 40.0^\circ$$

λ_{Peak} and θ fulfill Eqs. (7) and (8) \rightarrow **0.1 pt**

$450 \text{ nm} \leq \lambda_{\text{Peak}} \leq 460 \text{ nm} \rightarrow$ **0.5 pt** (full marks)

$440 \text{ nm} \leq \lambda_{\text{Peak}} < 450 \text{ nm}$ or $460 \text{ nm} < \lambda_{\text{Peak}} \leq 470 \text{ nm} \rightarrow$ **0.3 pt**

$430 \text{ nm} \leq \lambda_{\text{Peak}} < 440 \text{ nm}$ or $470 \text{ nm} < \lambda_{\text{Peak}} \leq 480 \text{ nm} \rightarrow$ **0.1 pt**

$\alpha = 40.0^\circ$ or a corrected value of α for $450 \text{ nm} \leq \lambda_{\text{Peak}} \leq 460 \text{ nm} \rightarrow$ **0.2 pt**

A.4 (0.3 pt)

$$\varphi_{\perp} = 90^\circ \text{ or } 270^\circ$$

$85^\circ \leq \varphi_{\perp} \leq 95^\circ$ or $265^\circ \leq \varphi_{\perp} \leq 275^\circ \rightarrow$ **0.2 pt**

$$\varphi_{\parallel} = \varphi_{\perp} + 90^\circ \text{ or } \varphi_{\perp} - 90^\circ$$

Correct value of $\varphi_{\parallel} \rightarrow$ **0.1 pt**

A.5 (0.2 pt)

$$I_{\text{Offset } \perp} = 0.005 \text{ V or } 5 \text{ mV}$$

$$I_{\text{Offset } \perp} \leq 0.010 \text{ V} \rightarrow \mathbf{0.1 \text{ pt}}$$

$$I_{\text{Offset } \parallel} = 0.010 \text{ V or } 10 \text{ mV}$$

$$I_{\text{Offset } \parallel} \leq 0.020 \text{ V} \rightarrow \mathbf{0.1 \text{ pt}}$$

A.6 (0.5 pt)

$$I_{\perp} = 0.001 \text{ V or } 1 \text{ mV}$$

$$0.000 \text{ V} \leq I_{\perp} \leq 0.003 \text{ V} \rightarrow \mathbf{0.2 \text{ pt (full marks)}}$$

$$0.004 \text{ V} \leq I_{\perp} \leq 0.006 \text{ V} \rightarrow 0.1 \text{ pt}$$

$$I_{\parallel} = 0.160 \text{ V or } 160 \text{ mV}$$

$$I_{\parallel} \geq 0.100 \text{ V} \rightarrow \mathbf{0.3 \text{ pt (full marks)}}$$

$$0.050 \text{ V} \leq I_{\parallel} \leq 0.099 \text{ V} \rightarrow 0.2 \text{ pt}$$

$$0.030 \text{ V} \leq I_{\parallel} \leq 0.049 \text{ V} \rightarrow 0.1 \text{ pt}$$

Part B. Measurement of transmitted light intensities (4.7 points)**B.1** (2.0 pt)

Data available at $\lambda \leq 440 \text{ nm}$ \rightarrow **0.1 pt**

Data available at $\lambda \geq 660 \text{ nm}$ \rightarrow **0.1 pt**

Number of data points $N \geq 20$ \rightarrow **0.9 pt (full marks)**

$$15 \leq N \leq 19 \rightarrow 0.6 \text{ pt}$$

$$10 \leq N \leq 14 \rightarrow 0.3 \text{ pt}$$

Data spacing 5 nm or less within $\Delta\lambda_{\text{FWHM}}$ around λ_{Peak} \rightarrow **0.3 pt**

Wavelength spacing 5 nm or less with respect to three data points around each minimum of I_{Norm} (0.2 pt each) \rightarrow **0.6 pt (full marks)**

▶ Incorrect relation between θ and λ (each) $\rightarrow -0.1 \text{ pt}$

▶ Incorrect relation between I_{\perp} , I_{\parallel} , and I_{Norm} (each) $\rightarrow -0.1 \text{ pt}$

▶ Max deduction -2.0 pt

B.1 (2.0 pt)

$\theta_{\text{Stage}}/\text{degree}$	θ/degree	λ/nm	I_{\perp}/mV	I_{\parallel}/mV	$I_{\text{Total}}/\text{mV}$	I_{Norm}
30.5	-31	430.5	13	26	39	0.333
30	-30.5	435.1	38	31	69	0.551
29.5	-30	439.7	83	27	110	0.755
29	-29.5	444.2	166	17	183	0.907
28.5	-29	448.8	244	21	265	0.921
28	-28.5	453.3	280	80	360	0.778
27.5	-28	457.7	267	159	426	0.627
27	-27.5	462.1	188	216	404	0.465
26.5	-27	466.5	73	223	296	0.247
26	-26.5	470.9	17	197	214	0.079
25.5	-26	475.2	12	162	174	0.069
25	-25.5	479.5	19	121	140	0.136
24.5	-25	483.7	34	71	105	0.324
24	-24.5	487.9	48	43	91	0.527
23.5	-24	492.1	61	22	83	0.735
23	-23.5	496.2	72	10	82	0.878
22.5	-23	500.3	83	4	87	0.954
22	-22.5	504.3	94	8	102	0.922
21.5	-22	508.3	97	19	116	0.836

B.1 (2.0 pt)

(Continued)

$\theta_{\text{Stage}}/\text{degree}$	θ/degree	λ/nm	I_{\perp}/mV	I_{\parallel}/mV	$I_{\text{Total}}/\text{mV}$	I_{Norm}
21	-21.5	512.3	92	37	129	0.713
20.5	-21	516.3	77	68	145	0.531
20	-20.5	520.1	61	90	151	0.404
19.5	-20	524.0	35	130	165	0.212
19	-19.5	527.8	18	153	171	0.105
18.5	-19	531.6	8	166	174	0.046
18	-18.5	535.3	8	167	175	0.046
17.5	-18	539.0	14	158	172	0.081
17	-17.5	542.7	32	141	173	0.185
16.5	-17	546.3	47	127	174	0.270
16	-16.5	549.9	73	99	172	0.424
15.5	-16	553.4	93	76	169	0.550
15	-15.5	556.9	112	55	167	0.671
14.5	-15	560.3	130	34	164	0.793
14	-14.5	563.7	141	20	161	0.876
13.5	-14	567.1	147	10	157	0.936
13	-13.5	570.4	148	6	154	0.961
12.5	-13	573.7	146	6	152	0.961
12	-12.5	576.9	138	10	148	0.932

B.1 (2.0 pt)

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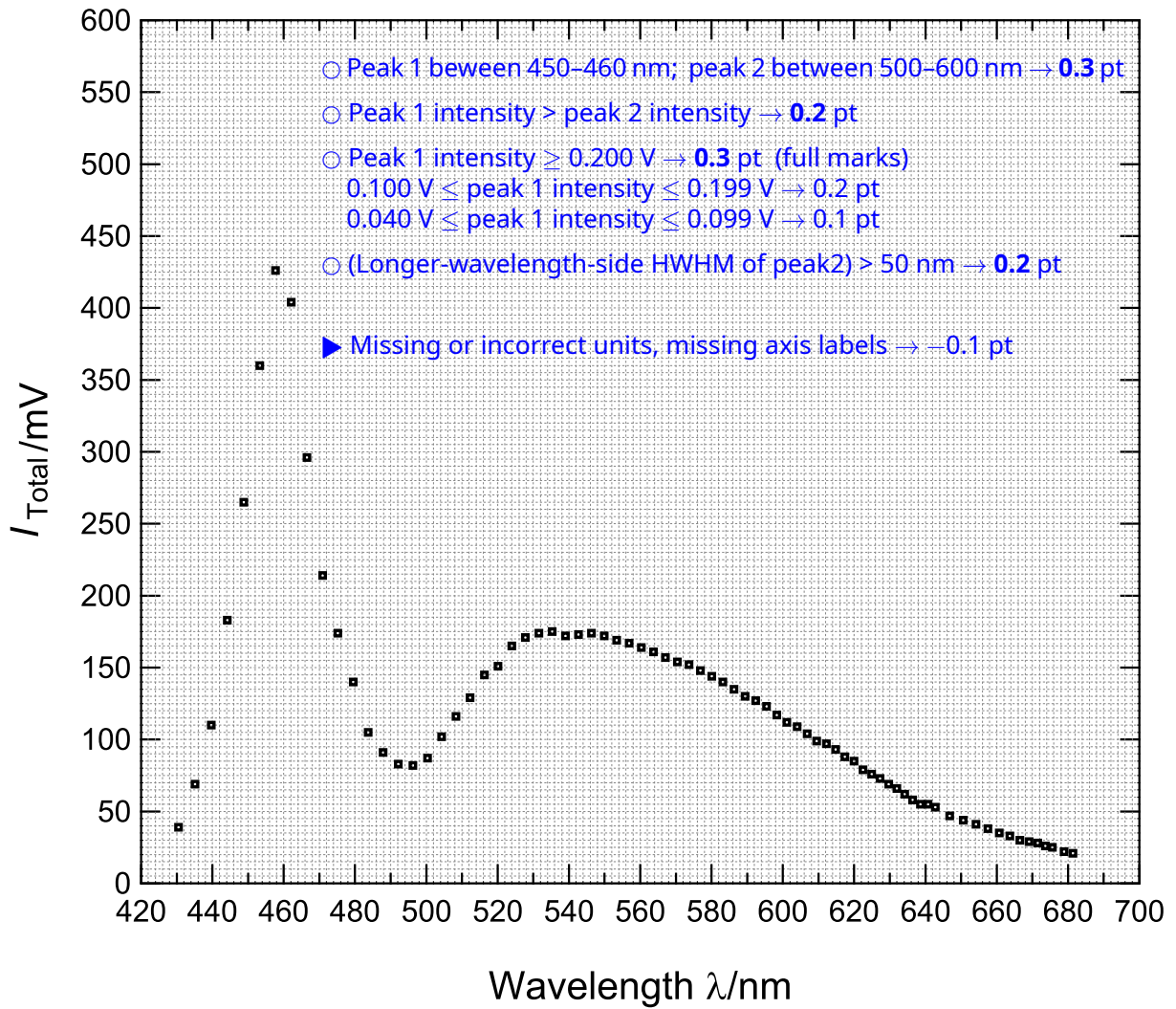
$\theta_{\text{Stage}}/\text{degree}$	θ/degree	λ/nm	I_{\perp}/mV	I_{\parallel}/mV	$I_{\text{Total}}/\text{mV}$	I_{Norm}
11.5	-12	580.1	127	17	144	0.882
11	-11.5	583.2	114	26	140	0.814
10.5	-11	586.3	97	38	135	0.719
10	-10.5	589.4	80	50	130	0.615
9.5	-10	592.4	67	60	127	0.528
9	-9.5	595.4	54	69	123	0.439
8.5	-9	598.3	41	76	117	0.350
8	-8.5	601.1	31	81	112	0.277
7.5	-8	604.0	22	87	109	0.202
7	-7.5	606.8	15	89	104	0.144
6.5	-7	609.5	8	91	99	0.081
6	-6.5	612.2	6	91	97	0.062
5.5	-6	614.8	4	89	93	0.043
5	-5.5	617.4	3	85	88	0.034
4.5	-5	620.0	4	81	85	0.047
4	-4.5	622.5	5	74	79	0.063
3.5	-4	624.9	7	69	76	0.092
3	-3.5	627.3	10	63	73	0.137
2.5	-3	629.7	12	57	69	0.174

B.1 (2.0 pt)

(Continued)

$\theta_{\text{Stage}}/\text{degree}$	θ/degree	λ/nm	I_{\perp}/mV	I_{\parallel}/mV	$I_{\text{Total}}/\text{mV}$	I_{Norm}
2	-2.5	632.0	15	51	66	0.227
1.5	-2	634.2	18	44	62	0.290
1	-1.5	636.4	21	37	58	0.362
0.5	-1	638.6	23	32	55	0.418
0	-0.5	640.7	25	30	55	0.455
-0.5	0	642.8	27	26	53	0.509
-1.5	1	646.8	29	18	47	0.617
-2.5	2	650.6	31	13	44	0.705
-3.5	3	654.2	32	9	41	0.780
-4.5	4	657.5	32	6	38	0.842
-5.5	5	660.7	31	4	35	0.886
-6.5	6	663.7	30	3	33	0.909
-7.5	7	666.5	28	2	30	0.933
-8.5	8	669.1	27	2	29	0.931
-9.5	9	671.5	26	2	28	0.929
-10.5	10	673.6	24	2	26	0.923
-11.5	11	675.6	23	2	25	0.920
-13.5	13	678.9	20	2	22	0.909
-15.5	15	681.4	18	3	21	0.857

B.2 (1.0 pt)

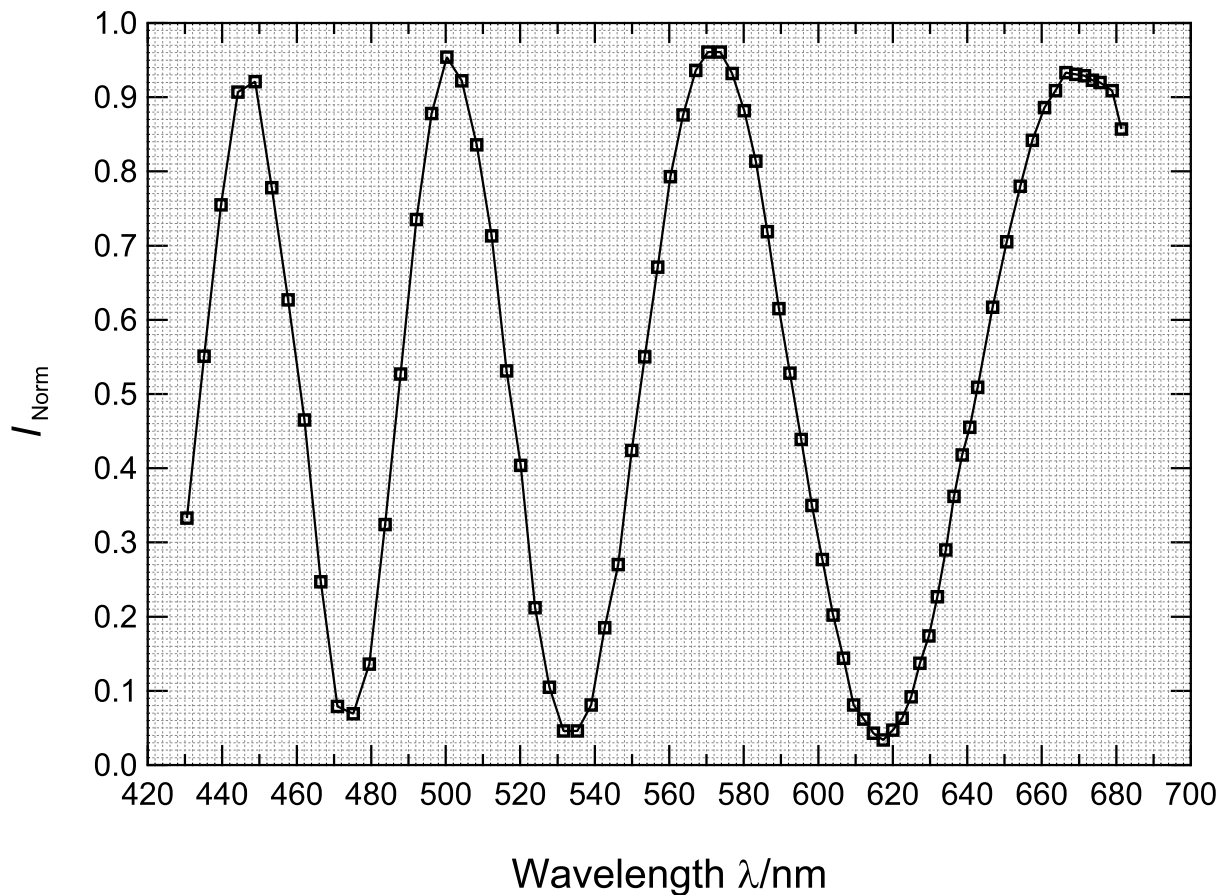


B.3 (0.2 pt)

$$\Delta\lambda_{\text{FWHM}} = 25 \text{ nm}$$

$$\Delta\lambda_{\text{FWHM}} \leq 40 \text{ nm} \rightarrow \mathbf{0.2 \text{ pt}}$$

B.4 (1.5 pt)



- Three local minima such that $I_{\text{Norm}} \leq 0.3 \rightarrow 0.6$ pt (full marks)
Two local minima such that $I_{\text{Norm}} \leq 0.3 \rightarrow 0.3$ pt
- Local minimum height $I_{\text{Norm}} \leq 0.2$ (0.1 pt each) $\rightarrow 0.3$ pt (full marks)
- Three or more local maxima such that $I_{\text{Norm}} \geq 0.7 \rightarrow 0.6$ pt (full marks)
Two local maxima such that $I_{\text{Norm}} \geq 0.7 \rightarrow 0.3$ pt
- ▶ Missing or incorrect units, missing axis labels $\rightarrow -0.1$ pt

Part C. Analyses of Measured Results (3.0 points)**C.1** (1.5 pt) $\lambda = 473 \text{ nm}, 534 \text{ nm}, 617 \text{ nm}$ $455 < \lambda < 479 \text{ nm} \rightarrow \mathbf{0.4 \text{ pt}}$ (full marks) $444 \text{ nm} < \lambda \leq 455 \text{ nm}$ or $479 \text{ nm} \leq \lambda < 490 \text{ nm} \rightarrow 0.2 \text{ pt}$ $513 < \lambda < 539 \text{ nm} \rightarrow \mathbf{0.4 \text{ pt}}$ (full marks) $500 \text{ nm} < \lambda \leq 513 \text{ nm}$ or $539 \text{ nm} \leq \lambda < 553 \text{ nm} \rightarrow 0.2 \text{ pt}$ $590 < \lambda < 620 \text{ nm} \rightarrow \mathbf{0.4 \text{ pt}}$ (full marks) $575 \text{ nm} < \lambda \leq 590 \text{ nm}$ or $620 \text{ nm} \leq \lambda < 636 \text{ nm} \rightarrow 0.2 \text{ pt}$ $m = 8, 7, 6$ Correct values of m consistent with Eq. (6) (0.1 pt each) $\rightarrow \mathbf{0.3 \text{ pt}}$ (full marks)**C.2** (1.5 pt) $L = 407 \mu\text{m}$ With respect to $\Delta L \equiv L - 400 \mu\text{m}$ $|\Delta L| < 10 \mu\text{m} \rightarrow \mathbf{1.5 \text{ pt}}$ (full marks) $10 \mu\text{m} \leq |\Delta L| < 20 \mu\text{m} \rightarrow 1.2 \text{ pt}$ $20 \mu\text{m} \leq |\Delta L| < 30 \mu\text{m} \rightarrow 0.8 \text{ pt}$ $30 \mu\text{m} \leq |\Delta L| < 40 \mu\text{m} \rightarrow 0.4 \text{ pt}$ $40 \mu\text{m} \leq |\Delta L| < 50 \mu\text{m} \rightarrow 0.1 \text{ pt}$