Mass Measurement

Revision in Part A.3 such that
$-0.8 \leqq a \leqq -0.3$ mm (0.1)
instead of $-0.08 \leqq a \leqq -0.03$ mm (0.1).

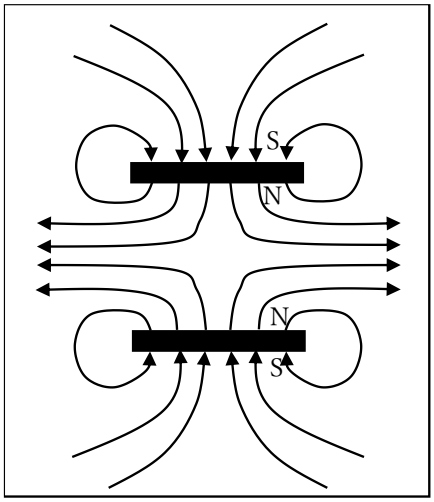
Write down the numbers 0 to 9 in

0	1	2	3	4	5	6	7	8	9
0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*

No points

Part A: Hooke's law and electromagnetic forces (2.4 points)

A.1 (0.4pt)



Magnetic field lines have arrows from N to S (0.1)
At least one end comes from a magnet (0.1)
Multiple horizontal lines near the edge of the magnet gap (0.1)
No contradictions such as asymmetry, crossing or branching (0.1)

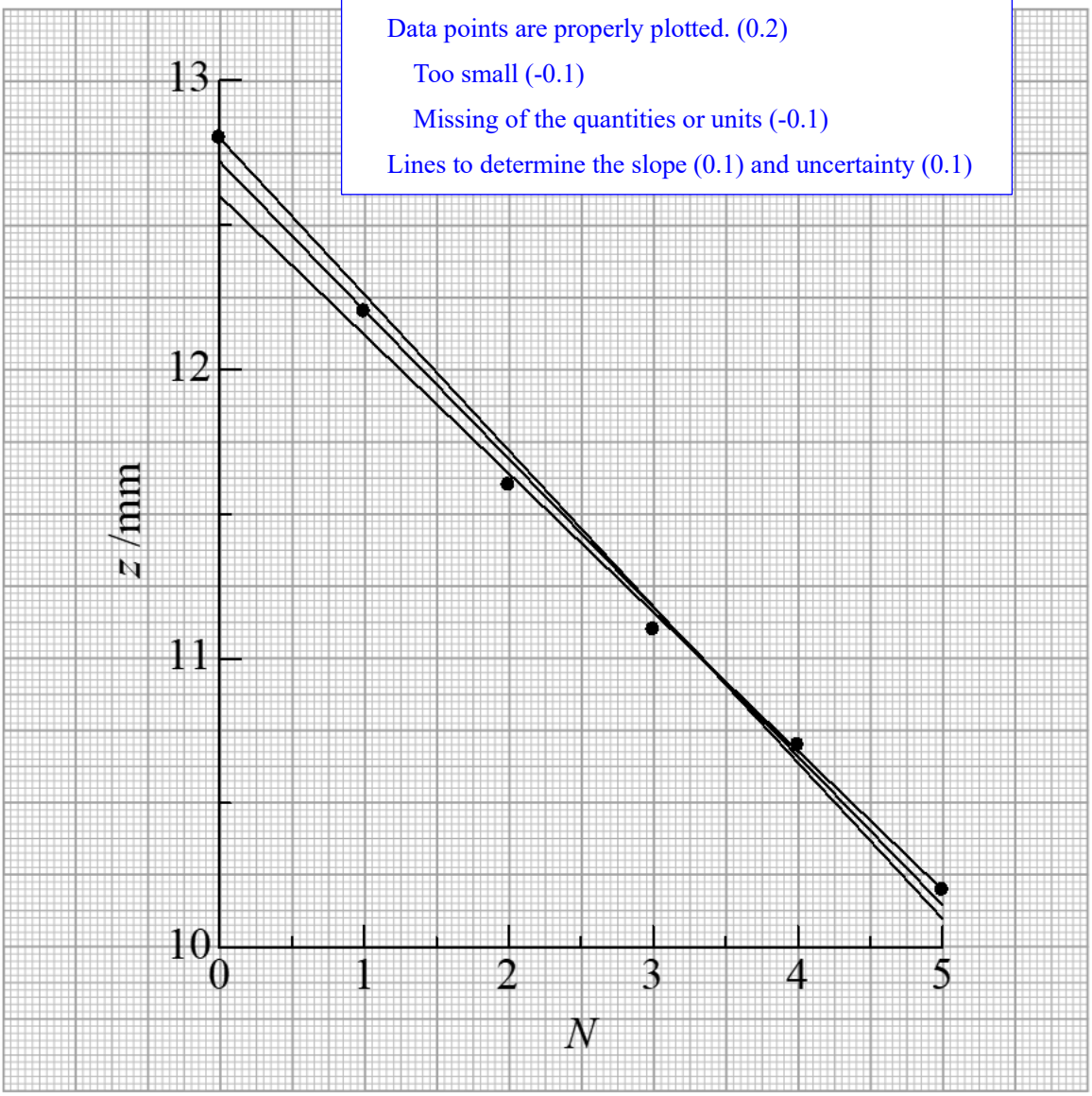
A.2 (0.6pt)

Missing measurement points (-0.1 each)

N	z /mm	I /A
0	12.8	0
1	12.2	0.103
2	11.6	0.213
3	11.1	0.323
4	10.7	0.423
5	10.2	0.524

A.3 (0.7pt)

Graph (max 0.4)
- Data points are properly plotted. (0.2)
  - Too small (-0.1)
  - Missing of the quantities or units (-0.1)
- Lines to determine the slope (0.1) and uncertainty (0.1)



$$a = \frac{\Delta z}{\Delta N} = \frac{10.15-12.70}{5} = -0.51$$

$$a_+ = \frac{10.20-12.60}{5} = -0.48$$

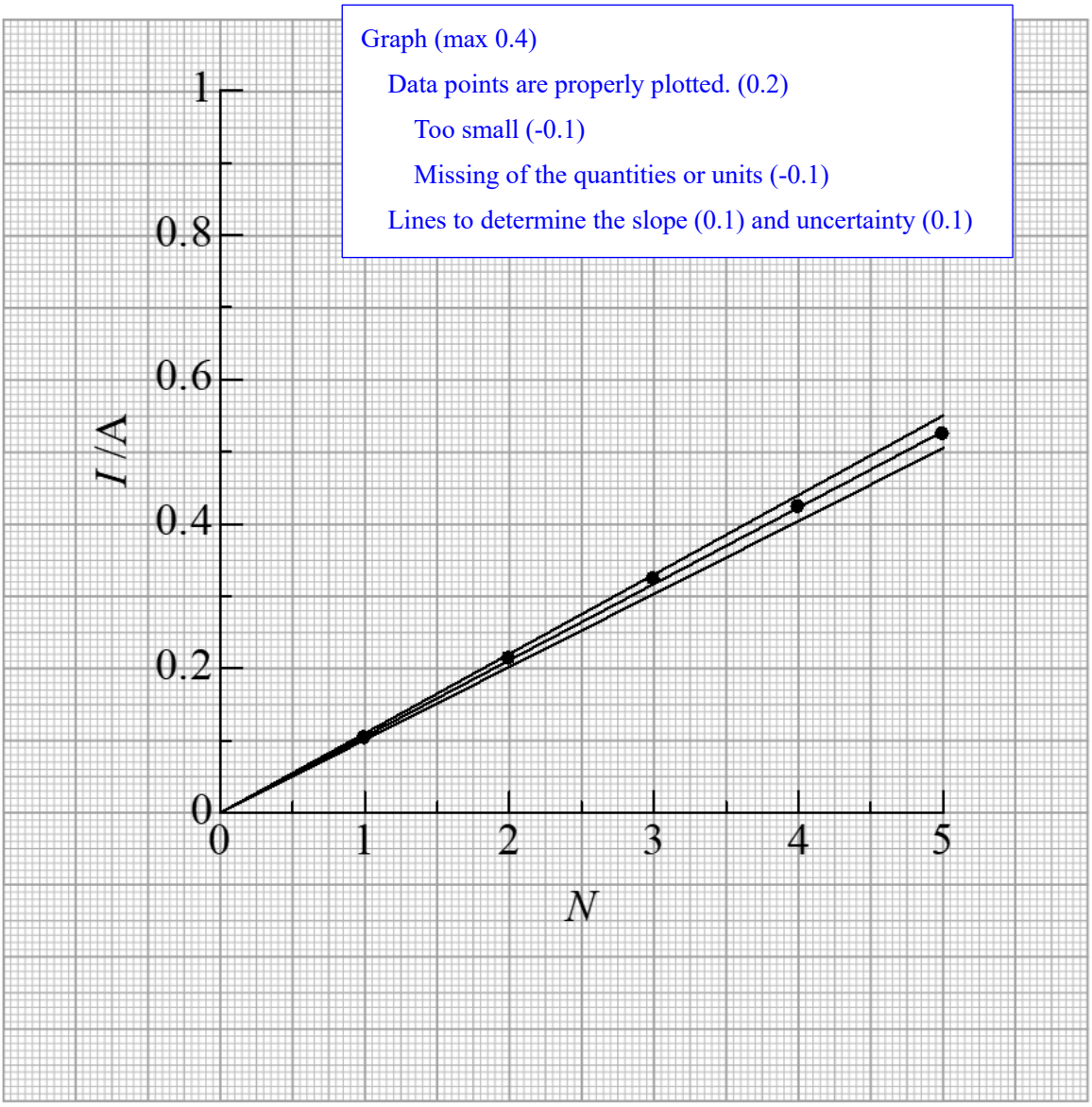
$$a_- = \frac{10.10-12.80}{5} = -0.54$$

$$\Delta a = \frac{-0.48-(-0.54)}{2} = 0.03$$

$$a = -0.51 \pm 0.03 \ \text{mm}$$

Reading of a from the graph (max 0.3)
- Reasonable value (0.1) and uncertainty (0.1)
  - Missing or incorrect units (-0.1)
- Reasonable result of a (correct reading and units required)
  - ~~$-0.08 \leqq a \leqq -0.03$ mm (0.1)~~
  - $-0.8 \leqq a \leqq -0.3$ mm (0.1) Revised

A.4 (0.7pt)



Graph (max 0.4)
- Data points are properly plotted. (0.2)
  - Too small (-0.1)
  - Missing of the quantities or units (-0.1)
- Lines to determine the slope (0.1) and uncertainty (0.1)

$$b = \frac{I}{N} = \frac{0.53}{5} = 0.106$$

$$b_+ = \frac{0.55}{5} = 0.110$$

$$b_- = \frac{0.505}{5} = 0.101$$

$$\Delta b = \frac{0.110 - 0.101}{2} = 0.005$$

$$b = 0.106 \pm 0.005 \ \text{A}$$

Reading of b from the graph (max 0.3)
- Reasonable value (0.1) and uncertainty (0.1)
  - Missing or incorrect units (-0.1)
- Reasonable result of b (correct reading and units required)
  - 0.08–0.13 A (0.1)

Part B: Induced electromotive force (3.0 points)

B.1 (0.2pt)

$V = 2\pi f ABL$

Correct equation (0.2)

B.2 (0.5pt)

$f_B =$ 15.85 Hz

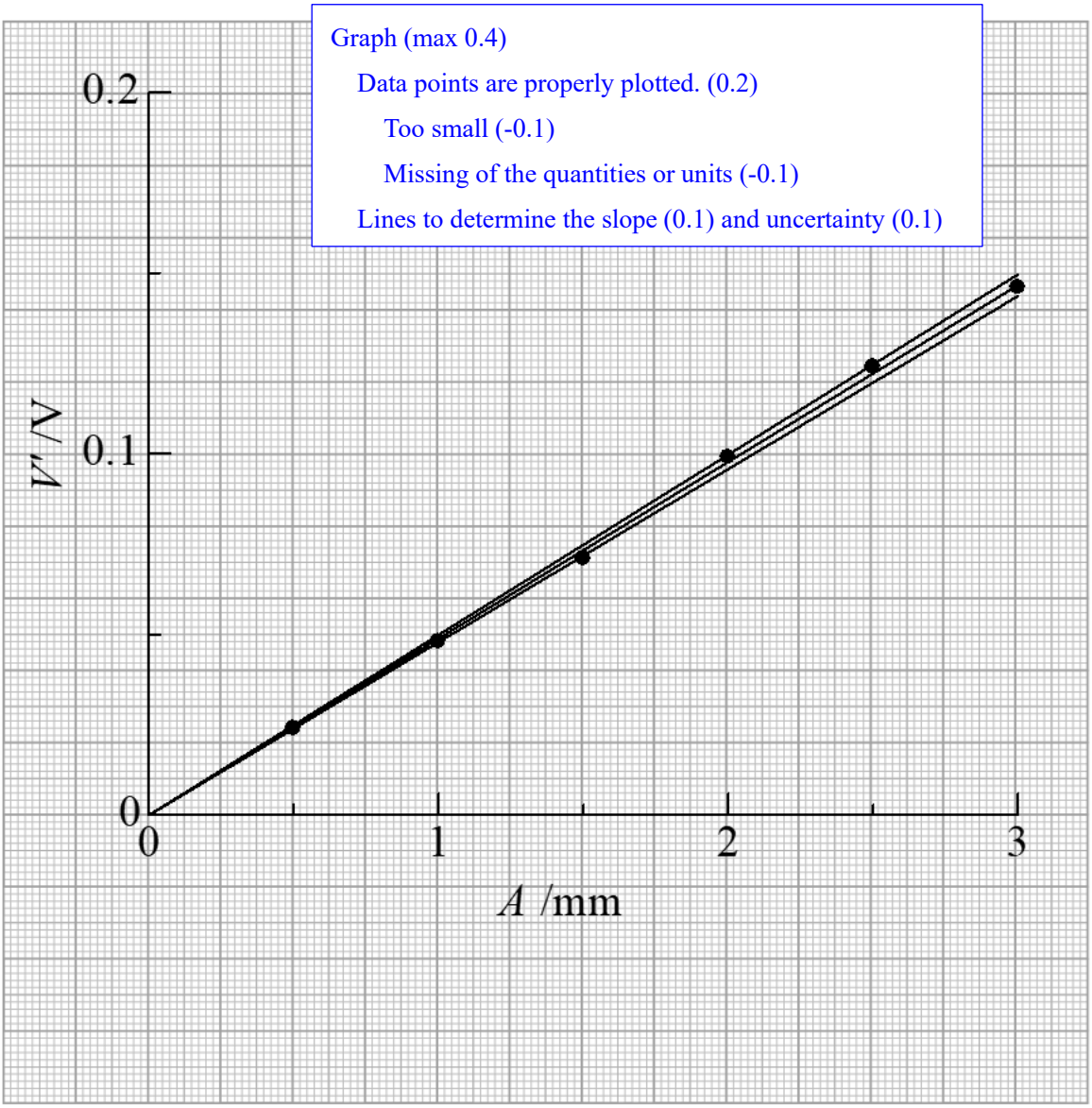
Reasonable result of f and correct units: 12–20 Hz (0.1)

A /mm	V' /V
0.5	0.024
1.0	0.048
1.5	0.071
2.0	0.099
2.5	0.124
3.0	0.146

Measurements of A and V' (max 0.4)
Data points (max 0.3)
5 or more (0.3), 3 or 4 (0.2), 1 or 2 (0.1)
The largest A is 2.5–3.0 mm. (0.1)

B.3 (0.7pt)

Graph (max 0.4)
- Data points are properly plotted. (0.2)
  - Too small (-0.1)
  - Missing of the quantities or units (-0.1)
- Lines to determine the slope (0.1) and uncertainty (0.1)



$$c = \frac{V'}{A} = \frac{0.147}{5} = 0.049 \quad \mathrm{V/mm}$$

$$c_+ = \frac{0.150}{5} = 0.050 \ , \ c_- = \frac{0.144}{5} = 0.048$$

$$\Delta c = \frac{0.050-0.048}{2} = 0.001 \quad \mathrm{V/mm}$$

$$c = 0.049 \pm 0.001 \ \mathrm{V/mm}$$

Reading of c from the graph (max 0.3)
- Reasonable value (0.1) and uncertainty (0.1)
  - Missing or incorrect units (-0.1)
- Reasonable result of c (correct reading and units required)
  - 0.03–0.08 V/mm (0.1)

B.4 (0.4pt)

$BL = \frac{V}{2\pi A f_B}$, $V' = V/\sqrt{2}$

Calculation of BL using the obtained results (max 0.2)
- Correct value and units (0.2), correct calculation formula only (0.1)

Calculation of the uncertainty (max 0.2)
- Correct value (0.2), correct calculation formula only (0.1)

$BL = \frac{\sqrt{2}V'}{2\pi A f_B} = \frac{\sqrt{2}c}{2\pi f_B} = \frac{\sqrt{2}\times 0.049}{2\pi\times 15..85} = 0.000696$ Vs/mm = 0.696 Vs/m

$\Delta(BL) = \frac{\sqrt{2}}{2\pi f_B}\Delta c = \frac{\sqrt{2}\times 0.001}{2\pi\times 15..85} = 0.000014$ Vs/mm = 0.014 Vs/m ($\Delta(BL) = \frac{\boldsymbol{BL}}{c}\Delta c$ available)

$BL = 0.696 \pm 0.014$ Vs/m

B.5 (1.2pt)

$m = \frac{mg}{BL}\cdot\frac{BL}{g} = \frac{I}{N}\cdot\frac{BL}{g} = b\frac{BL}{g} = 0.106 \times \frac{0.696}{9.80} = 0.0075$ kg = 7.5 g

$\Delta m = \sqrt{(\Delta b)^2\cdot\left(\frac{BL}{g}\right)^2 + \left(\frac{b}{g}\right)^2\cdot(\Delta(BL))^2} = 0.00039$ kg = 0.4 g

($\Delta m = \left|\frac{BL}{g}\right|\Delta b + \left|\frac{b}{g}\right|\Delta(BL)$, $\frac{\Delta m}{m} = \frac{\Delta b}{b} + \frac{\Delta(BL)}{BL}$, $\frac{\Delta m}{m} = \sqrt{\left(\frac{\Delta b}{b}\right)^2 + \left(\frac{\Delta(BL)}{BL}\right)^2}$ available)

$m = 7.5 \pm 0.4$ g

Calculation of m using the obtained results (max 0.5)
- Correct value and units (0.2), correct calculation formula only (0.1)
- Reasonable result (correct calculation and units required) (max 0.3)
  - 7.2–8.2 g (0.3), 6.7–8.7 g (0.2), 6.2–9.2 g (0.1)

Calculation of the uncertainty (max 0.2)
- Correct value (0.2), correct calculation formula only (0.1)

$k = -\frac{mg}{a} = -\frac{0.0075\times 9.80}{-0.51} = 0.144$ N/mm =144 N/m

$\Delta k = \sqrt{(\Delta a)^2\cdot\left(\frac{mg}{a^2}\right)^2 + \left(\frac{g}{a}\right)^2\cdot(\Delta m)^2} = 0.011$ N/mm = 11 N/m

($\Delta k = \left|\frac{mg}{a^2}\right|\Delta a + \left|\frac{g}{a}\right|\Delta m$, $\frac{\Delta k}{k} = \frac{\Delta a}{|a|} + \frac{\Delta m}{m}$, $\frac{\Delta k}{k} = \sqrt{\left(\frac{\Delta a}{a}\right)^2 + \left(\frac{\Delta m}{m}\right)^2}$ available)

$k = 144 \pm 11$ N/m

Calculation of k using the obtained results (max 0.3)
- Correct value and units (0.2), correct calculation formula only (0.1)
- Reasonable result (correct calculation and units required):
  - 120–180 N/m (0.1)

Calculation of the uncertainty (max 0.2)
- Correct value (0.2), correct calculation formula only (0.1)

Part C. Mass-dependent resonant frequency (2.3 points)

C.1 (0.2pt)

$$f_N = \frac{1}{2\pi}\sqrt{\frac{k\prime}{M+Nm}}$$

Correct equation (0.2)

C.2 (0.5pt)

Measurements of f (max 0.5)
Missing measurement points (-0.1 each)

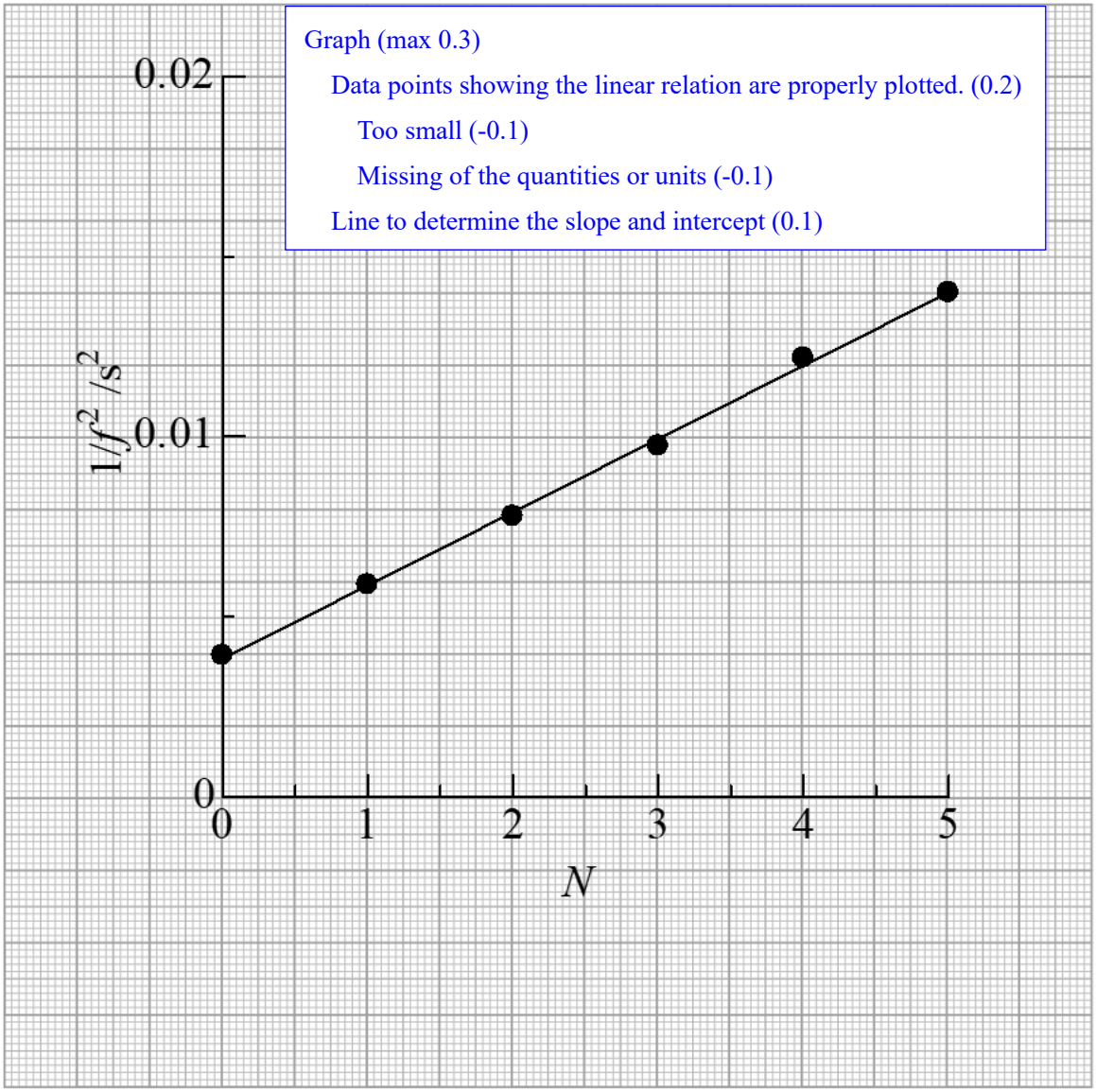
N	f /Hz	$1/f^2$ /s^2		
0	15.96	0.003926		
1	13.03	0.005390		
2	11.33	0.007790		
3	10.13	0.009745		
4	9.06	0.01218		
5	8.45	0.01401		

Calculation for linear relationship (points in C.3)

Calculation for linear relationship ($1/f^2$) in Table C.2 (max 0.3)
Missing or incorrect units (-0.1)
Missing or error of calculation (-0.1 each)

C.3 (1.0pt)

Graph (max 0.3)
Data points showing the linear relation are properly plotted. (0.2)
Too small (-0.1)
Missing of the quantities or units (-0.1)
Line to determine the slope and intercept (0.1)



Using the equation $\frac{1}{f^2} = (2\pi)^2\left(\frac{M}{k'} + \frac{m}{k'}N\right)$, $\frac{M}{k'}$ and $\frac{m}{k'}$ are obtained from the graph.

$$\frac{M}{k'} = \frac{1/f_0^2}{(2\pi)^2} = \frac{0.0039}{(2\pi)^2} = 9.88 \times 10^{-5} \quad \mathrm{s}^2$$

Reading from the graph and calculation (max 0.4)
Reasonable values of $\frac{M}{k'}$ (0.2) and $\frac{m}{k'}$ (0.2)
Missing or incorrect units (-0.1 each)

$$\frac{m}{k'} = \frac{(0.0140-0.0039)/5}{(2\pi)^2} = \frac{0.00202}{(2\pi)^2} = 5.12 \times 10^{-5} \quad \mathrm{s}^2$$

C.4 (0.6pt)

$$\frac{M}{m} = \frac{M/k'}{m/k'} = \frac{9.88}{5.12}$$

$$\frac{M}{m} = 1.93$$

Calculation of $\frac{M}{m}$ using the obtained results (max 0.4)
Correct value and units (0.1)
Reasonable result (correct calculation and units required) (max 0.3)
1.85–2.0 (0.3), 1.75–2.1 (0.2), 1.65–2.2 (0.1)

$$M = \frac{M}{m} \cdot m = 1.93 \times 0.0075 = 0.0145 \text{ kg} = 14.5 \text{ g}$$

$$M = 14.5 \text{ g}$$

Correct value and units of M using the obtained results (0.1)

$$k' = \frac{M}{\frac{M}{k'}} = \frac{0.0145}{9.88\times10^{-5}}$$

$$k' = 147 \text{ N/m}$$

Correct value and units of k' using the obtained results (0.1)

Part D. Resonance characteristics (2.3 points)

D.1 (0.4pt)

$V'_{\mathrm{AC}} = 0.157$ V

Measurement of V'_{AC} and correct units (0.1)

$F_{\mathrm{AC}} = BLI_{\mathrm{AC}} = BL \times 0.106 \times \sqrt{2}V'_{\mathrm{AC}} = 0.696 \times 0.106 \times \sqrt{2} \times 0.157 = 0.0164$ N

Calculation of F_{AC} using the obtained results (max 0.3)
Correct value and units (0.3), correct calculation formula only (0.1)

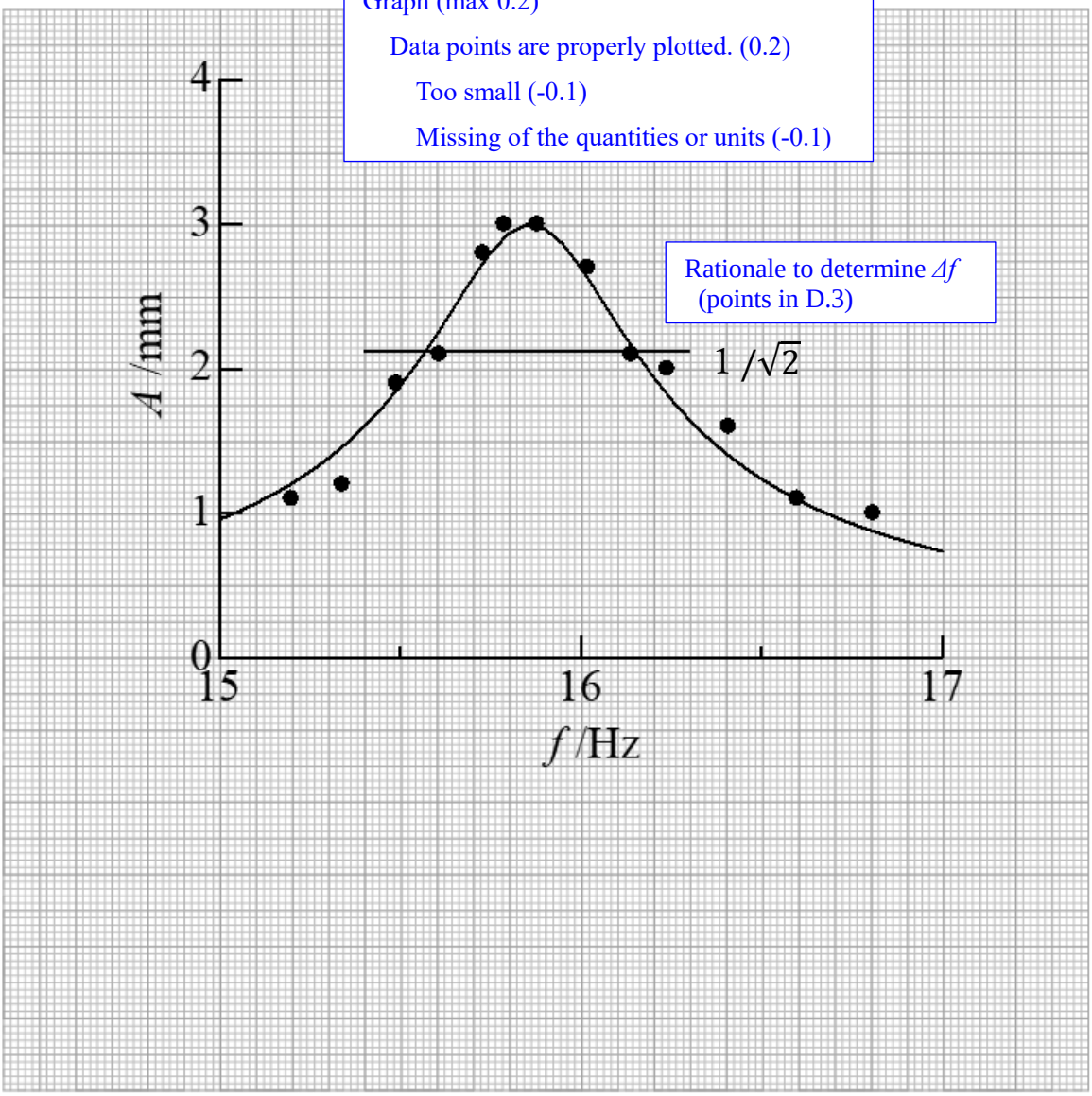
D.2 (0.9pt)

f/Hz	A/mm		
15.88	3.0		
15.79	3.0		
15.73	2.8		
15.61	2.1		
15.49	1.9		
15.34	1.2		
15.20	1.1		
16.02	2.7		
16.14	2.1		
16.24	2.0		
16.41	1.6		
16.60	1.1		
16.81	1.0		

Measurements of f and A (max 0.7)
Data points (max 0.3)
≧10 (0.3), 5–9 (0.2), 3 or 4 (0.1)
Points smaller than half maximum of A (max 0.2: 0.1 each side)
Existence of f interval smaller than 0.2 Hz (0.1)
The largest A is 2.5–3.3 mm. (0.1)

D.2 (cont.)

Graph (max 0.2)
Data points are properly plotted. (0.2)
Too small (-0.1)
Missing of the quantities or units (-0.1)



D.3 (1.0pt)

Reading from the graph D.2

$f_0 = 15.83$ Hz

$A(f_0) = 3.0$ mm

$\Delta f = \frac{16.14-15.56}{2} = 0.29$ Hz

Reading from the graph (max 0.4)
Rationale to determine Δf (0.1)
Reasonable values of f_0, $A(f_0)$, and Δf (0.1 each)

Calculation using Eq.(4)

$$M = \frac{F_{AC}}{8\pi^2 f_0 \Delta f A(f_0)} = \frac{0.0164}{8\pi^2 \times 15.83 \times 0.29 \times 0.003} = 0.0151 \text{ kg} = 15.1 \text{ g}$$

$M = 15.1$ g

Calculation of M using the obtained results (max 0.6)
Correct value and units (0.3), correct calculation formula only (0.1)
Reasonable result (correct calculation and units required) (max 0.3)
13.5–16 g (0.3), 12–17.5 g (0.2), 10.5–19 g (0.1)

Thickness Measurements Using Birefringence (10 points)

Part A. Measurement System Setup (2.3 points)

A.1 (0.3 pt)

$\lambda = 684$ nm

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

$\theta = 20.0°$

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

A.2 (0.2 pt)

$\theta = -30.0°,\ 70.0°$

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

A.3 (0.8 pt)

$\theta = -28.0°$

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

$\alpha = 40.0°$

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

○ 450 nm $\leq \lambda_{\mathrm{Peak}} \leq$ 460 nm $\rightarrow$ **0.5** pt (full marks)
440 nm $\leq \lambda_{\mathrm{Peak}} <$ 450 nm or 460 nm $< \lambda_{\mathrm{Peak}} \leq$ 470 nm $\rightarrow$ 0.3 pt
430 nm $\leq \lambda_{\mathrm{Peak}} <$ 440 nm or 470 nm $< \lambda_{\mathrm{Peak}} \leq$ 480 nm $\rightarrow$ 0.1 pt

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

A.4 (0.3 pt)

$\varphi_{\perp} = 90°$ or $270°$

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

$\varphi_{\parallel} = \varphi_{\perp} + 90°$ or $\varphi_{\perp} - 90°$

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

A.5 (0.2 pt)

$I_{\text{Offset }\perp} = 0.005$ V or 5 mV
$I_{\text{Offset }\perp} \leq 0.010$ V $\rightarrow$ **0.1** pt

$I_{\text{Offset }\parallel} = 0.010$ V or 10 mV
$I_{\text{Offset }\parallel} \leq 0.020$ V $\rightarrow$ **0.1** pt

A.6 (0.5 pt)

$I_{\perp} = 0.001$ V or 1 mV
$0.000 \text{ V} \leq I_{\perp} \leq 0.003$ V $\rightarrow$ **0.2** pt (full marks)
$0.004 \text{ V} \leq I_{\perp} \leq 0.006$ V $\rightarrow$ 0.1 pt

$I_{\parallel} = 0.160$ V or 160 mV
$I_{\parallel} \geq 0.100$ V $\rightarrow$ **0.3** pt (full marks)
$0.050 \text{ V} \leq I_{\parallel} \leq 0.099$ V $\rightarrow$ 0.2 pt
$0.030 \text{ V} \leq I_{\parallel} \leq 0.049$ V $\rightarrow$ 0.1 pt

Part B. Measurement of transmitted light intensities (4.7 points)

B.1 (2.0 pt)

○ Data available at $\lambda \leq 440$ nm $\rightarrow$ **0.1** pt

○ Data available at $\lambda \geq 660$ 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 pt
$10 \leq N \leq 14$ $\rightarrow$ 0.3 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 beween θ and λ (each) $\rightarrow -0.1$ pt

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

▶ Max deduction -2.0 pt

B.1 (2.0 pt)

θ_{Stage}/degree	θ/degree	λ/nm	$I_{\perp}$/mV	$I_{\parallel}$/mV	I_{Total}/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)

θ_{Stage}/degree	θ/degree	λ/nm	$I_{\perp}$/mV	$I_{\parallel}$/mV	I_{Total}/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)

(Continued)

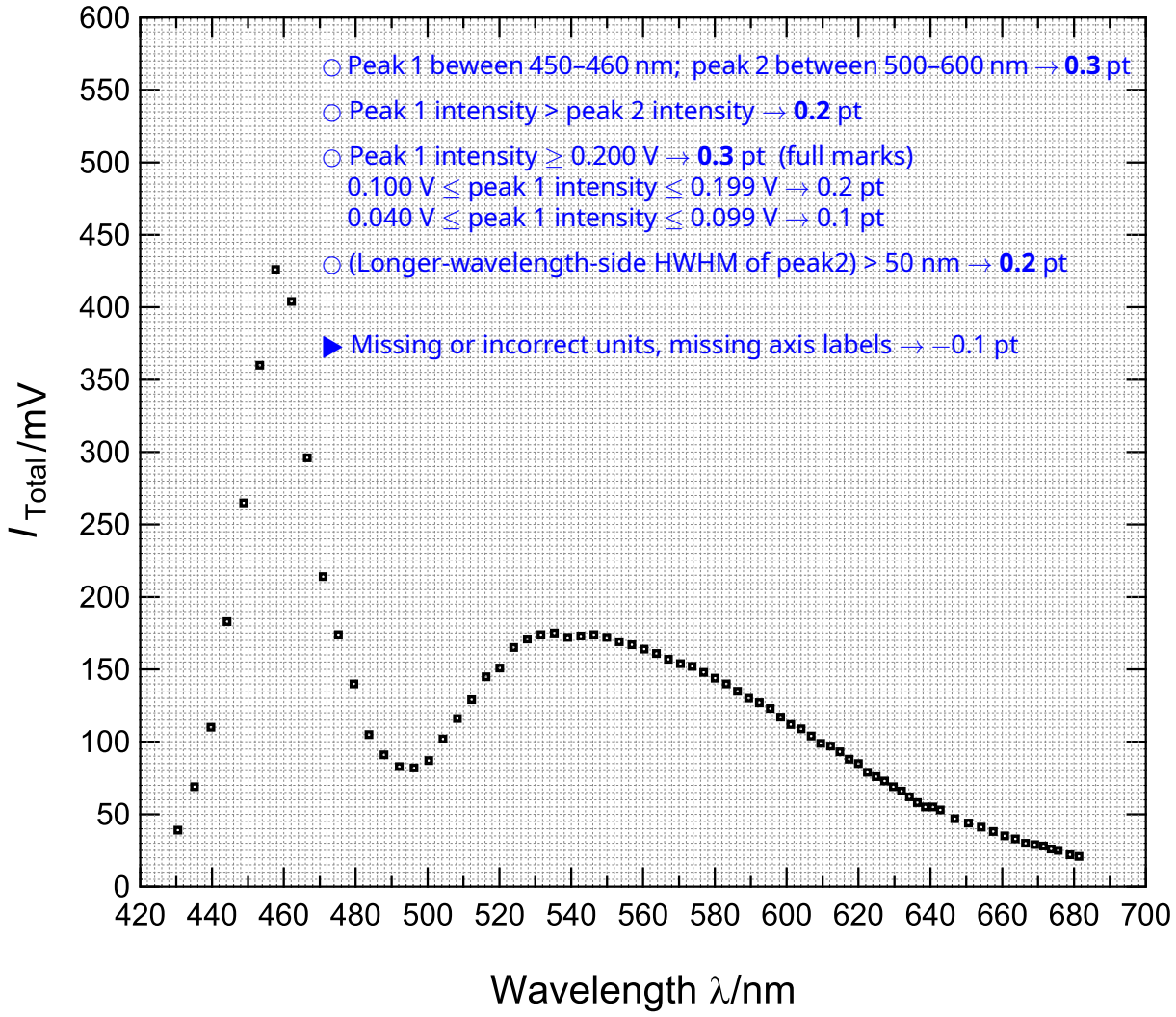
θ_{Stage}/degree	θ/degree	λ/nm	$I_{\perp}$/mV	$I_{\parallel}$/mV	I_{Total}/mV	I_{Norm}
11.5	-12	580.1	127	17	144	0.882
11	-11.5	583.2	114	26	140	0.814
10.5	-11	586.3	97	38	135	0.719
10	-10.5	589.4	80	50	130	0.615
9.5	-10	592.4	67	60	127	0.528
9	-9.5	595.4	54	69	123	0.439
8.5	-9	598.3	41	76	117	0.350
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)

θ_{Stage}/degree	θ/degree	λ/nm	$I_{\perp}$/mV	$I_{\parallel}$/mV	I_{Total}/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)

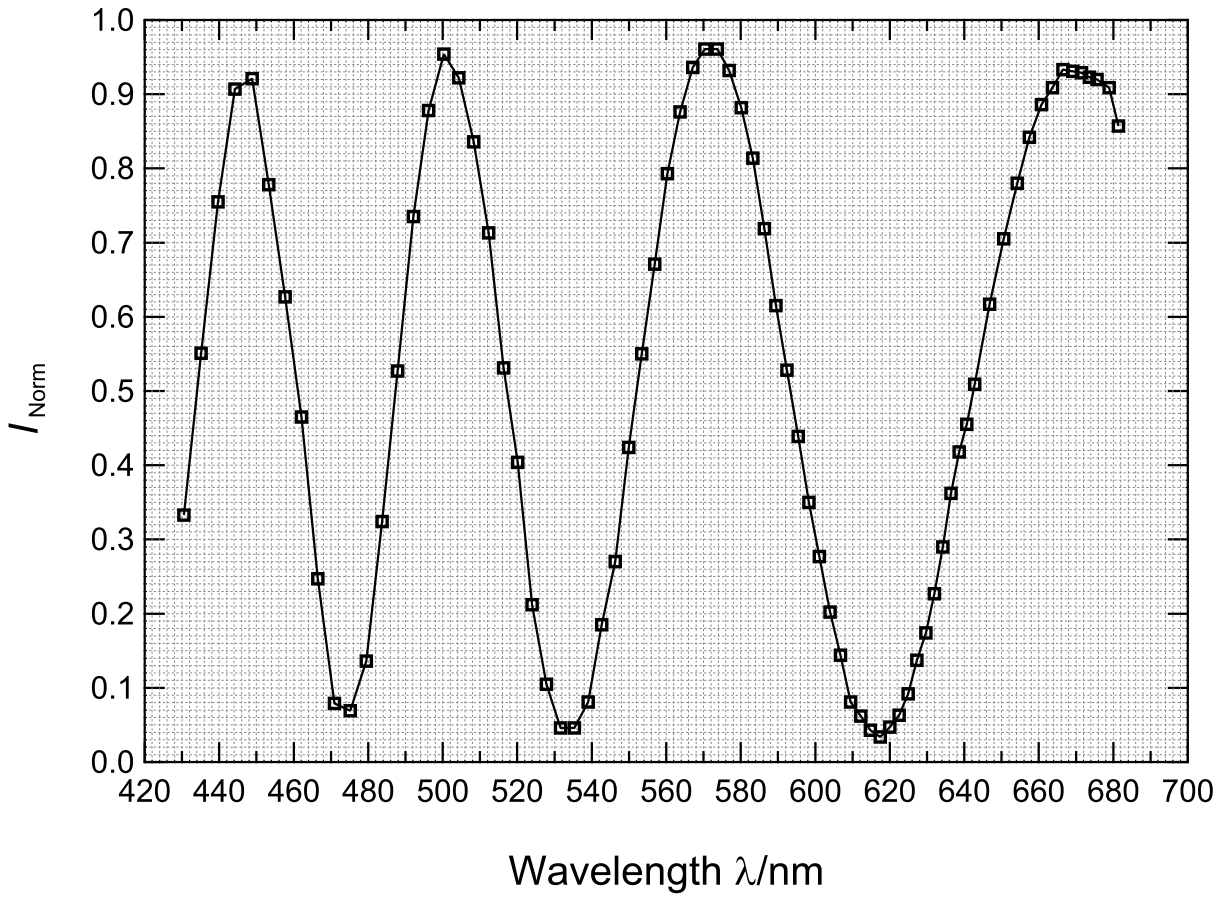


B.3 (0.2 pt)

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

$\Delta\lambda_{\mathrm{FWHM}} \leq 40$ nm → **0.2** pt

B.4 (1.5 pt)



○ Three local minima such that $I_{\mathrm{Norm}} \leq 0.3 \rightarrow$ **0.6** pt (full marks)
Two local minima such that $I_{\mathrm{Norm}} \leq 0.3 \rightarrow$ 0.3 pt

○ Local minimum height $I_{\mathrm{Norm}} \leq 0.2$ (0.1 pt each) → **0.3** pt (full marks)

○ Three or more local maxima such that $I_{\mathrm{Norm}} \geq 0.7 \rightarrow$ **0.6** pt (full marks)
Two local maxima such that $I_{\mathrm{Norm}} \geq 0.7 \rightarrow$ 0.3 pt

▶ Missing or incorrect units, missing axis labels → −0.1 pt

Part C. Analyses of Measured Results (3.0 points)

C.1 (1.5 pt)

$\lambda = 473\ \text{nm},\ 534\ \text{nm},\ 617\ \text{nm}$

$455 < \lambda < 479$ nm $\rightarrow$ **0.4** pt (full marks)
$444\ \text{nm} < \lambda \leq 455\ \text{nm}$ or $479\ \text{nm} \leq \lambda < 490\ \text{nm}$ $\rightarrow$ 0.2 pt

$513 < \lambda < 539$ nm $\rightarrow$ **0.4** pt (full marks)
$500\ \text{nm} < \lambda \leq 513\ \text{nm}$ or $539\ \text{nm} \leq \lambda < 553\ \text{nm}$ $\rightarrow$ 0.2 pt

$590 < \lambda < 620$ nm $\rightarrow$ **0.4** pt (full marks)
$575\ \text{nm} < \lambda \leq 590\ \text{nm}$ or $620\ \text{nm} \leq \lambda < 636\ \text{nm}$ $\rightarrow$ 0.2 pt

$m = 8, \quad 7, \quad 6$

Correct values of m consistent with Eq. (6) (0.1 pt each) $\rightarrow$ **0.3** pt (full marks)

C.2 (1.5 pt)

$L = 407\ \mu\text{m}$

With respect to $\Delta L \equiv L - 400\ \mu$m
$|\Delta L| < 10\ \mu$m $\rightarrow$ **1.5** pt (full marks)
$10\ \mu\text{m} \leq |\Delta L| < 20\ \mu$m $\rightarrow$ 1.2 pt
$20\ \mu\text{m} \leq |\Delta L| < 30\ \mu$m $\rightarrow$ 0.8 pt
$30\ \mu\text{m} \leq |\Delta L| < 40\ \mu$m $\rightarrow$ 0.4 pt
$40\ \mu\text{m} \leq |\Delta L| < 50\ \mu$m $\rightarrow$ 0.1 pt