

第4届 CPHO-S 物理竞赛联考 实验笔试参考答案及评分标准

2021 年 6 月 5 日 下午 15:00-16:00

命题：李瀚奕

A	A.1	(1) $d = 31.80 \text{ mm}$ [31.78~31.82 mm: 0.5pt; others: 0pt.]
		(2) $a = 9.356 \text{ mm}$ [9.355~9.358 mm: 0.5pt; others: 0pt.]
		(3) $\theta = 213^\circ 19'$ [213°18'~213°20': 0.5pt; others: 0pt.]
		(4) $I = 89 \mu\text{A}$ [88.5,89,89.5 μA : 0.5pt; others: 0pt.]
	A.2	(1) -763.6 [-763.6: 0.5pt; others: 0pt.]
		(2) 3.44×10^{-4} [3.44×10^{-4} : 0.5pt; others: 0pt.]
		(3) 0.4632 [0.4632: 0.5pt; others: 0pt.]
		(4) $0.267(0.27)$ [0.267,0.27: 0.5pt; others: 0pt.]
		(5) 6.807×10^{-2} [6.807×10^{-2} : 0.5pt; others: 0pt.]
		(6) 1.46 [1.46: 0.5pt; others: 0pt.]

B	B.1	<p>分光计调节的基本要求：</p> <p>(1) 平行光管出射平行光；</p> <p>(2) 望远镜接收平行光；</p> <p>(3) 平行光管和望远镜的光轴与仪器转轴垂直且平行于载物平面。</p> <p>[2 = 0.5pt × 3 + 0.5pt(完全正确附加分).]</p> <p>分光计调节步骤：</p> <p>(1) 目视粗调；</p> <p>(2) 调节目镜；</p> <p>(3) <u>自准直法</u>调节<u>望远镜接收平行光</u>；</p> <p>(4) <u>各半调节法</u>调节<u>载物平台及望远镜水平</u>；</p> <p>(5) 准直调节平行光管出射平行光。</p> <p>[4 = 0.5 + 0.5 + 0.5 × 2* + 0.5 × 2 + 0.5 + 0.5(完全正确附加分).]</p> <p>*: 带下划线的文字为给分点，后同</p>

B.2	<div>实验原理:</div> <div>$n = \frac{\sin \frac{\alpha + \phi}{2}}{\sin \frac{\alpha}{2}}$</div> <div>实验步骤:</div> <div>转动载物平台使得出射光线具有最小偏向角，并记录入射光线、出射光线位置θ_0, θ_1。</div> <div>[5 = 2(图示: 光路箭头未标 - 0.2; 角位置标注每处 - 0.2) + 1(实验原理) + (1.5 + 0.5).]</div>																																					
B.3	<div>数据表 B.3 三棱镜折射率测量数据表</div> <table><tr><th>光谱</th><th>$\theta_0 / ^\circ$</th><th>$\theta_{1L} / ^\circ$</th><th>$\theta_{1R} / ^\circ$</th><th>$\phi / ^\circ$</th><th>n</th></tr><tr><td>蓝紫</td><td rowspan="6">$\theta_{0L} = 319^\circ 41'$ $\theta_{0R} = 139^\circ 40'$</td><td>266°28'</td><td>86°27'</td><td>53°13'</td><td>1.6698</td></tr><tr><td>蓝</td><td>267°1'</td><td>87°1'</td><td>52°40'</td><td>1.6646</td></tr><tr><td>绿</td><td>267°37'</td><td>87°37'</td><td>52°4'</td><td>1.6587</td></tr><tr><td>黄</td><td>268°42'</td><td>88°41'</td><td>50°59'</td><td>1.6481</td></tr><tr><td>红</td><td>269°20'</td><td>89°20'</td><td>50°20'</td><td>1.6416</td></tr><tr><td>暗红</td><td>269°34'</td><td>89°33'</td><td>50°7'</td><td>1.6395</td></tr></table> <div>$\phi = \frac{1}{2}[(\theta_{0L} - \theta_{1L}) + (\theta_{0R} - \theta_{1R})] \quad n = \frac{\sin \frac{\alpha + \phi}{2}}{\sin \frac{\alpha}{2}}, \alpha = 60^\circ \pm 1'$</div> <div>[4 = 1.5($\phi$: 单位错误 - 0.3; 计算错误** 每处 - 0.2) + 1.8(n: 计算错误每处 - 0.3) + 0.7.]</div> <div>[若在 B.3 中未给出ϕ的计算式, 但在 B.2 中给出$\phi = \theta_1 - \theta_0$: -0.4.]</div> <div>** : 计算错误包含有效数字错误, 下同</div>	光谱	$\theta_0 / ^\circ$	$\theta_{1L} / ^\circ$	$\theta_{1R} / ^\circ$	$\phi / ^\circ$	n	蓝紫	$\theta_{0L} = 319^\circ 41'$ $\theta_{0R} = 139^\circ 40'$	266°28'	86°27'	53°13'	1.6698	蓝	267°1'	87°1'	52°40'	1.6646	绿	267°37'	87°37'	52°4'	1.6587	黄	268°42'	88°41'	50°59'	1.6481	红	269°20'	89°20'	50°20'	1.6416	暗红	269°34'	89°33'	50°7'	1.6395
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B.4	<div>$n = A + \frac{B}{\lambda^2} \rightarrow X = \frac{1}{\lambda^2}, Y = n$</div> <table><tr><th>$\lambda / \mu\text{m}$</th><td>0.4471</td><td>0.4713</td><td>0.5016</td><td>0.5876</td><td>0.6678</td><td>0.7066</td></tr><tr><td>$X = \frac{1}{\lambda^2} / \mu\text{m}^{-2}$</td><td>5.002</td><td>4.502</td><td>3.836</td><td>2.896</td><td>2.242</td><td>2.003</td></tr><tr><td>$Y = n$</td><td>1.6698</td><td>1.6646</td><td>1.6587</td><td>1.6481</td><td>1.6416</td><td>1.6395</td></tr></table> <div>$\hat{B} = \frac{\overline{xy} - \bar{x}\bar{y}}{\overline{x^2} - \bar{x}^2} = \frac{\overline{\left(\frac{1}{\lambda^2}\right)n} - \left(\frac{1}{\lambda^2}\right)\bar{n}}{\overline{\left(\frac{1}{\lambda^2}\right)^2} - \left(\frac{1}{\lambda^2}\right)^2}, \hat{A} = \bar{y} - \hat{B}\bar{x}$</div> <div>$A = 1.6189, B = 0.0102 \mu\text{m}^2$</div> <div>[4 = 1(数据表: 单位错误 - 0.2, 计算错误每处 - 0.2) + 0.5 × 2(拟合公式) + 1 × 2(A, B) A: ±0.0002: 1pt; ±0.0004: 0.5pt; others: 0pt; 5Num: Full; 4Num: -0.2; others: -1; B: ±0.0005: 1pt; ±0.0010: 0.5pt; others: 0pt; 3Num: Full; 2Num: -0.2; others: -1; 单位: -0.5.]</div>	$\lambda / \mu\text{m}$	0.4471	0.4713	0.5016	0.5876	0.6678	0.7066	$X = \frac{1}{\lambda^2} / \mu\text{m}^{-2}$	5.002	4.502	3.836	2.896	2.242	2.003	$Y = n$	1.6698	1.6646	1.6587	1.6481	1.6416	1.6395																
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B.5	<div>a.垂直底边法: 掠入射法无法分清各谱线边界; 最小偏向角法需多次转动载物平台, 垂直底边法在测量过程中无需多次转动调节, 实验操作相对更加简便。</div> <div>b.最小偏向角法: 掠入射法无法分清各谱线边界; 垂直底边法需要人为调节垂直底边入射条件, 最小偏向角法利用极值进行测量, 误差相对较小。</div> <div>[3 = 1 + 1 + 1, 若选择掠入射法则 B.5 部分均不得分.]</div>																																					

数据表 C.1 PZT 陶瓷片基本参数测量数据表

$a = (45.01 \pm 0.02) \text{ mm}, b = (7.02 \pm 0.02) \text{ mm}$

游标卡尺零差 $\Delta_0 = 0.02 \text{ mm}$

数据点 i	厚度 t/mm	质量 m/g
1	1.02	2.24
2	1.02	2.23
3	1.00	2.26
4	1.00	2.25
5	1.02	2.25
6	1.02	2.25

$$t = \frac{1}{6} \sum_{i=1}^6 t_i - \Delta_0 = 0.99 \text{ mm}$$

$$\Delta_{tA} = \sqrt{\frac{(t - t_i + \Delta)^2}{6 \times 5}} = 0.005 \text{ mm}, \Delta_{tB} = \frac{e}{\sqrt{3}} = 0.011 \text{ mm}$$

$$\Delta_t = \sqrt{\Delta_{tA}^2 + \Delta_{tB}^2} = 0.02 \text{ mm}, t = (0.99 \pm 0.02) \text{ mm}$$

$$\begin{aligned} 2 = & 0.5(t: 0.99: 0.5\text{pt}; \text{others: } 0\text{pt}) + 0.5(\Delta_{tA}: 0.3 + 0.2, \text{公式允许差异}) \\ & + 0.3(\Delta_{tB}: 0.1 + 0.2, \text{公式允许有差异}) + 0.5(\Delta_t: 0.02: 0.5\text{pt}; 0.03: 0.3\text{pt}; \text{others: } 0\text{pt}) + 0.2. \end{aligned}$$

$$m = \frac{1}{6} \sum_{i=1}^6 m_i = 2.25 \text{ g}$$

$$\Delta_{mA} = \sqrt{\frac{(m - m_i)^2}{6 \times 5}} = 0.005 \text{ mm}, \Delta_{mB} = \frac{e}{\sqrt{3}} = 0.006 \text{ mm}$$

$$\Delta_m = \sqrt{\Delta_{mA}^2 + \Delta_{mB}^2} = 0.01 \text{ g}, m = (2.25 \pm 0.01) \text{ g}$$

$$\begin{aligned} 2 = & 0.5(m: 2.25: 0.5\text{pt}; \text{others: } 0\text{pt}) + 0.5(\Delta_{mA}: 0.3 + 0.2, \text{公式允许差异}) \\ & + 0.3(\Delta_{mB}: 0.1 + 0.2, \text{公式允许有差异}) + 0.5(\Delta_m: 0.01 \sim 0.02: 0.5\text{pt}; 0.03: 0.1\text{pt}; \text{others: } 0\text{pt}) + 0.2. \end{aligned}$$

$$\rho = \frac{m}{abt} = 7.19(7.2) \text{ g/cm}^3$$

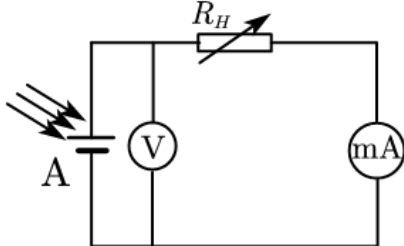
$$\frac{\Delta_\rho}{\rho} = \sqrt{\left(\frac{\Delta_a}{a}\right)^2 + \left(\frac{\Delta_b}{b}\right)^2 + \left(\frac{\Delta_t}{t}\right)^2 + \left(\frac{\Delta m}{m}\right)^2} = 0.021$$

$$\Delta_\rho = \left(\frac{\Delta_\rho}{\rho}\right) \cdot \rho = 0.16(0.2) \text{ g/cm}^3, \rho = (7.19(7.2) \pm 0.16(0.2)) \text{ g/cm}^3$$

$$\begin{aligned} 3 = & 1(\rho: 7.19, 7.2: 1\text{pt}; 7.18 \sim 7.20: 0.5\text{pt}; \text{others: } 0\text{pt}) + 1(\Delta_\rho/\rho: 0.8 + 0.2) \\ & + 0.5(\Delta_\rho: 0.2 \sim 0.3: 0.5\text{pt}; \text{others: } 0\text{pt}) + 0.5(2 \sim 3\text{Num: Full}; \text{others: } -0.5). \end{aligned}$$

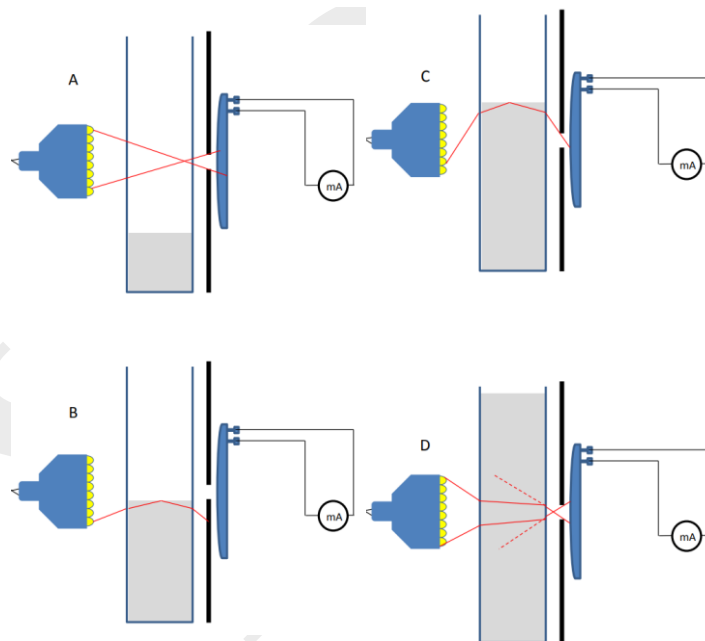
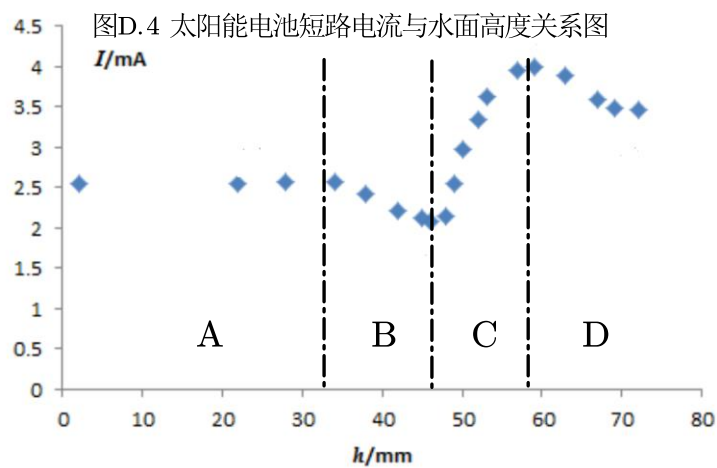
		数据表 C.2 PZT 陶瓷片电容测量数据表																								
		<table><tr><td>$T/^{\circ}\text{C}$</td><td>17.0</td><td>30.0</td><td>40.0</td><td>50.0</td><td>60.0</td><td>70.0</td><td>80.0</td></tr><tr><td>C/nF</td><td>16.80</td><td>18.25</td><td>19.77</td><td>21.08</td><td>23.07</td><td>25.60</td><td>27.80</td></tr><tr><td>$\frac{1}{C}/\mu\text{F}^{-1}$</td><td>59.52</td><td>54.79</td><td>50.58</td><td>47.44</td><td>43.35</td><td>39.06</td><td>35.97</td></tr></table>	$T/^{\circ}\text{C}$	17.0	30.0	40.0	50.0	60.0	70.0	80.0	C/nF	16.80	18.25	19.77	21.08	23.07	25.60	27.80	$\frac{1}{C}/\mu\text{F}^{-1}$	59.52	54.79	50.58	47.44	43.35	39.06	35.97
$T/^{\circ}\text{C}$	17.0	30.0	40.0	50.0	60.0	70.0	80.0																			
C/nF	16.80	18.25	19.77	21.08	23.07	25.60	27.80																			
$\frac{1}{C}/\mu\text{F}^{-1}$	59.52	54.79	50.58	47.44	43.35	39.06	35.97																			
	C.2	$C = \frac{\varepsilon_r \varepsilon_0 ab}{t}$ $\varepsilon_r = \frac{B}{2(T_c - T)}$ $\frac{1}{C} = -\frac{2t}{\varepsilon_0 ab B} T + \frac{2t}{\varepsilon_0 ab B} T_c \rightarrow X = T, Y = \frac{1}{C}$ $B = -\frac{2t}{\varepsilon_0 ab k} = 1.90 \times 10^{12} \text{ }^{\circ}\text{C}, A = -\frac{\beta}{k} = 177 \text{ }^{\circ}\text{C}$ <div>$11 = 1\left(\text{数据表: 亦可计算 } \frac{1}{\varepsilon_r}\right) + 1(C) + 1(\text{拟合公式}) + 6(\text{图示}) + 1 \times 2(A, B).$<p>A: 计算式: 0.2pt; ± 3: 0.8pt; ± 6: 0.4pt; ± 10: 0.1pt; others: 0pt; 3Num: Full; others: -0.8;</p><p>B: 计算式: 0.2pt; ± 10: 0.8pt; ± 20: 0.4pt; ± 30: 0.1pt; others: 0pt; 3Num: Full; others: -0.8;</p><p>图: 0.5×3(图名, 坐标轴及标注: 图占比不足 60% - 0.3, 标注错误每处 - 0.3)</p><p>+2(描点: 描点错误每处 - 0.4) + 1(合理直线) + 0.5(斜率标点) + 0.5×2(斜率计算).</p></div>																								
C	C.3	$Z = \left[\left(\frac{1}{i\omega C_0} \right)^{-1} + \left(\frac{1}{i\omega C_1} + i\omega L_1 \right)^{-1} \right]^{-1} = \frac{1}{i\omega} \frac{1 - \omega^2 L_1 C_1}{(C_0 + C_1) - \omega^2 L_1 C_0 C_1}$ $f_r = \frac{1}{2\pi\sqrt{L_1 C_1}}$ $f_a = \frac{1}{2\pi} \sqrt{\frac{1}{L_1 C_1} + \frac{1}{L_1 C_0}}$ <div>$4 = 2(Z: \text{未化简} \leq 1\text{pt}) + 1 + 1.$</div>																								

D	D.1	D.1.1 (b) [(b): 1.5pt; (a), (d): 0.5pt; (c): 0pt.]
	D.1	D.1.2 (b) 不同档位电流表电阻大小不同 [1.5 = 0.5 + 1.]
	D.1	D.1.3 实验未考虑背景光(即本底电流)影响, $I(r) = I - I_0$ [本底电流: 2pt; others: $\leq 1\text{pt}.$]

D	D.2.1																																																																								
	D.2	<p>[3 = 2(电路: 电流表内接: 2pt; 电流表外接: 1pt; others ≤ 1.5pt) + 1(标注: 标注错误每处 - 0.2).]</p> <p>数据表 D.2 太阳能电池输出特性测量数据表</p> <table><tr><td>I/mA</td><td>0.5</td><td>1.5</td><td>5.0</td><td>8.9</td><td>14.1</td></tr><tr><td>U/V</td><td>0.532</td><td>0.531</td><td>0.526</td><td>0.520</td><td>0.509</td></tr><tr><td>P/mW</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>R/Ω</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>I/mA</td><td>21.6</td><td>25.3</td><td>27.8</td><td>29.2</td><td>30.6</td></tr><tr><td>U/V</td><td>0.488</td><td>0.471</td><td>0.454</td><td>0.435</td><td>0.410</td></tr><tr><td>P/mW</td><td></td><td>11.91</td><td>12.62</td><td>12.70</td><td>12.54</td></tr><tr><td>R/Ω</td><td></td><td>18.6</td><td>16.3</td><td>14.7</td><td>13.4</td></tr><tr><td>I/mA</td><td>31.9</td><td>32.6</td><td>33.1</td><td>33.3</td><td>33.5</td></tr><tr><td>U/V</td><td>0.364</td><td>0.307</td><td>0.239</td><td>0.138</td><td>0.046</td></tr><tr><td>P/mW</td><td>11.61</td><td></td><td></td><td></td><td></td></tr><tr><td>R/Ω</td><td>11.4</td><td></td><td></td><td></td><td></td></tr></table>	I/mA	0.5	1.5	5.0	8.9	14.1	U/V	0.532	0.531	0.526	0.520	0.509	P/mW						R/Ω						I/mA	21.6	25.3	27.8	29.2	30.6	U/V	0.488	0.471	0.454	0.435	0.410	P/mW		11.91	12.62	12.70	12.54	R/Ω		18.6	16.3	14.7	13.4	I/mA	31.9	32.6	33.1	33.3	33.5	U/V	0.364	0.307	0.239	0.138	0.046	P/mW	11.61					R/Ω	11.4			
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D	D.2.2	<p>$P_{\max} = 12.72 \text{ mW}$ $U_{\max} = 0.533 \text{ V}, I_{\max} = 33.6 \text{ mA}$ $K.K = \frac{P_{\max}}{U_{\max} \cdot I_{\max}} = 0.710$ $R_{\text{opt}} = 14.5 \Omega$</p>																																																																							
	D.2	<p>[6 = 1 × 2(数据表: $n \geq 4$: 1pt; $n = 3$: 0.8pt; $n = 2$: 0.3pt; $n = 1$: 0.1pt) +1(P_{\max}: 12.71~12.73: 1pt; 12.70, 12.74~12.75: 0.5pt; others: 0pt) +0.3 × 2(U_{\max}, I_{\max}: 图上标记 0.1; $U_{\max} > 0.532 \text{ V}$ or $I_{\max} > 33.5 \text{ mA}$: Full; others: -0.2) +0.4(K.K: ±0.10: 0.4pt; others: 0; 3Num: Full; 2Num: -0.1; others: -0.4) +2(R_{opt}: 14.3~14.6: 2pt; 14.4, 14.1~14.2: 1pt; others: 0pt; 3Num: Full; 4Num: -0.5; others: 0).]</p>																																																																							
D	D.3.1	<p>$P_{\max 1} = 2P_{\max} = 12.72 \text{ mW}$ $R_1 = \frac{1}{2}R_{\text{opt}} = 7.2 \Omega$</p> <p>[3 = 1(Analysis) + 0.5 × 2 + 0.5 × 2.]</p>																																																																							
	D.3	<p>D.3.2 $k' = \frac{1}{2}R_2$ $(U, I) = (0.238 \text{ V}, 33.0 \text{ mA})$ $P_{\max 2} = 2UI = 15.7 \text{ mW}$</p> <p>[5 = 1(Analysis) + 1(作图) + 1(U, I) +2($P_{\max 2}$: ±0.2: 2pt; ±0.5: 1pt; ±1: 0.5pt; 3Num, 4Num: Full; others: -1).]</p>																																																																							

数据表 D.4 太阳能电池短路电流随水面高度关系数据表

h/mm	2	22	28	34	38
I/mA	2.54	2.55	2.56	2.57	2.42
h/mm	42	45	46	48	49
I/mA	2.21	2.13	2.08	2.15	2.54
h/mm	50	52	53	57	59
I/mA	2.97	3.36	3.61	3.96	3.99
h/mm	63	67	69	72	
I/mA	3.89	3.60	3.49	3.47	



[10 = 1 + 4 + 4 + 1.]

