General Physics:
Lab Report

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Problem 1

1. 计算公式

1.算术平均值

$$\bar{N} = \frac{\sum_{i=1}^{n} N_i}{n}$$

2.测量值的标准偏差

$$\sigma_N = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n-1}}$$

3.平均值的标准偏差

$$\sigma_{\bar{N}} = \frac{\sigma_N}{\sqrt{n}} = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n(n-1)}}$$

4.粗差的剔除　拉依达准则

$$|\Delta N_i| < 3\sigma_N$$

5.不确定度

$$U = \sqrt{\Delta_A^2 + \Delta_B^2}$$

Step1：计算根据测得的小球直径计算出体积，进而利用$\rho = \frac{M}{V}$求出小球密度

1号小球

小球质量：$3.19g$
小球体积: [0.604, 0.605, 0.605, 0.605, 0.605, 0.605]
小球密度: [5.279, 5.276, 5.273, 5.275, 5.276, 5.273]

$$\bar{N} = \frac{1}{6}(5.279 + 5.276 + 5.273 + 5.275 + 5.276 + 5.273) = 5.275$$

$$\sigma_N = 0.0023 \quad \sigma_{\bar{N}} = 0.00092 \quad U = \frac{t_0.95}{\sqrt{n}}\sigma_N = 0.0024$$

利用定义求得1号小球的密度的平均测量值为

$$\rho_1 = (\rho \pm U) = (5.275 \pm 0.0024)\,\mathrm{g/cm^3}$$

2号小球

小球质量：$1.05g$
小球体积: [0.261, 0.261, 0.261, 0.261, 0.261, 0.26]
小球密度: [4.024, 4.03, 4.027, 4.029, 4.027, 4.032]

$$\bar{N} = \frac{1}{6}(4.024 + 4.03 + 4.027 + 4.029 + 4.027 + 4.032) = 4.028$$

$$\sigma_N = 0.0027 \quad \sigma_{\bar{N}} = 0.0011 \quad U = \frac{t_0.95}{\sqrt{n}}\sigma_N = 0.0029$$

利用定义求得2号小球的密度的平均测量值为

$$\rho_2 = (\rho \pm U) = (4.028 \pm 0.0029)g/cm^3$$

3号小球

小球质量：$0.88g$
小球体积: [0.261, 0.262, 0.261, 0.261, 0.261, 0.261]
小球密度: [3.369, 3.364, 3.368, 3.369, 3.37, 3.369]

$$\bar{N} = \frac{1}{6}(3.369 + 3.364 + 3.368 + 3.369 + 3.37 + 3.369) = 3.368$$

$$\sigma_N = 0.0021 \quad \sigma_{\bar{N}} = 0.00087 \quad U = \frac{t_0.95}{\sqrt{n}}\sigma_N = 0.0022$$

利用定义求得3号小球的密度的平均测量值为

$$\rho_3 = (\rho \pm U) = (3.368 \pm 0.0022)g/cm^3$$

Step2：利用流体静力称衡法得出的小球的密度

1号小球

六组数据密度的测量值分别为 [7.25, 4.833, 5.596, 5.907, 5.596, 5.23]

$$\bar{N} = \frac{1}{6}(7.25 + 4.833 + 5.596 + 5.907 + 5.596 + 5.23) = 5.735$$

$$\sigma_N = 0.828 \quad \sigma_{\bar{N}} = 0.338 \quad U = \frac{t_0.95}{\sqrt{n}}\sigma_N = 0.870$$

求得1号小球的密度的平均测量值为

$$\rho_1 = (\rho \pm U) = (5.735 \pm 0.870)g/cm^3$$

2号小球

六组数据密度的测量值分别为 [4.038, 4.2, 4.2, 3.889, 4.038, 4.038]

$$\bar{N} = \frac{1}{6}(4.038 + 4.2 + 4.2 + 3.889 + 4.038 + 4.038) = 4.067$$

$$\sigma_N = 0.118 \quad \sigma_{\bar{N}} = 0.048 \quad U = \frac{t_0.95}{\sqrt{n}}\sigma_N = 0.124$$

求得2号小球的密度的平均测量值为

$$\rho_1 = (\rho \pm U) = (4.067 \pm 0.124)g/cm^3$$

3号小球

六组数据密度的测量值分别为 [3.52, 3.52, 3.385, 3.385, 3.52, 3.385]

$$\bar{N} = \frac{1}{6}(3.52 + 3.52 + 3.385 + 3.385 + 3.52 + 3.385) = 3.453$$

$$\sigma_N = 0.074 \quad \sigma_{\bar{N}} = 0.030 \quad U = \frac{t_0.95}{\sqrt{n}}\sigma_N = 0.078$$

求得3号小球的密度的平均测量值为

$$\rho_1 = (\rho \pm U) = (3.453 \pm 0.078)g/cm^3$$

$$\frac{2^{h+1} - 1}{2^h} = 2 \times \frac{2^h}{2^h} - \frac{1}{2^h} = 2 - 0 = 2$$

Problem 2

1. 计算公式

1.算术平均值

$$\bar{N} = \frac{\sum_{i=1}^{n} N_i}{n}$$

2.测量值的标准偏差

$$\sigma_N = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n-1}}$$

3.平均值的标准偏差

$$\sigma_{\bar{N}} = \frac{\sigma_N}{\sqrt{n}} = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n(n-1)}}$$

4.粗差的剔除　拉依达准则

$$|\Delta N_i| < 3\sigma_N$$

5.不确定度

$$U = \sqrt{\Delta_A^2 + \Delta_B^2}$$

Part1：用新型焦利秤测定弹簧的劲度系数K

①通过添加砝码作出的F-Δy图像如下

斜率

$$K = 0.1823 g/mm$$

结合g=9.794N/kg测得的弹簧的劲度系数为

$$K = 1.785 N/m$$

②通过减少砝码作出的F-Δy图像如下

斜率

$$K = 0.1796 g/mm$$

结合g=9.794N/kg测得的弹簧的劲度系数为

$$K = 1.759 N/m$$

Part2：测量弹簧简谐振动周期，计算得出弹簧的劲度系数K

铁砝码质量：[21.50,21.48,21.48,21.47,21.46]

$$\bar{N} = \frac{1}{5}(21.50 + 21.48 + 21.48 + 21.47 + 21.46) = 21.48$$

$$\sigma_N = 0.0148 \quad \sigma_{\bar{N}} = 0.066 \quad U = \frac{t_0.95}{\sqrt{n}}\sigma_N = 0.02$$

求得铁砝码质量的平均测量值为

$$M = (M \pm U) = (21.48 \pm 0.02)g$$

弹簧质量：[13.60,13.58,13.54,13.54,13.56]

$$\bar{N} = \frac{1}{5}(13.60 + 13.58 + 13.54 + 13.54 + 13.56) = 13.56$$

$$\sigma_N = 0.0260 \quad \sigma_{\bar{N}} = 0.012 \quad U = \frac{t_0.95}{\sqrt{n}}\sigma_N = 0.03$$

求得弹簧质量的平均测量值为

$$M_0 = (M_0 \pm U) = (13.56 \pm 0.03)g$$

10T：[7.592,7.586,7.602,7.594,7.500,7.590,7.590,7.586,7.592,7.593]
T：[0.7592,0.7586,0.7602,0.7594,0.750,0.759,0.759,0.7586,0.7592,0.7593]

$$\bar{N} = \frac{1}{10}(0.7592 + 0.7586 + 0.7602 + 0.7594 + 0.750 + 0.759 + 0.759 + 0.7586 + 0.7592 + 0.7593)$$
$$= 0.758$$

$$\sigma_N = 0.0029 \quad \sigma_{\bar{N}} = 0.00092 \quad U = \frac{t_0.95}{\sqrt{n}}\sigma_N = 0.010$$

求得T的平均测量值为

$$T = (T \pm U) = (0.758 \pm 0.010)s$$

结合公式

$$T = 2\pi\sqrt{\frac{M + PM_0}{K}}$$

可得

$$K = \frac{(4\pi^2)(M + PM_0)}{T^2}$$

将

$$p = \frac{1}{3}$$

带入并进行单位转换可得

$$K = 1.786N/m$$

Problem 3

1. 计算公式

1.算术平均值

$$\bar{N} = \frac{\sum_{i=1}^{n} N_i}{n}$$

2.测量值的标准偏差

$$\sigma_N = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n-1}}$$

3.平均值的标准偏差

$$\sigma_{\bar{N}} = \frac{\sigma_N}{\sqrt{n}} = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n(n-1)}}$$

4.粗差的剔除　拉依达准则

$$|\Delta N_i| < 3\sigma_N$$

5.不确定度

$$U = \sqrt{\Delta_A^2 + \Delta_B^2}$$

Part1：小球直径d

小球直径：[1.030,1.033,1.029,1.032,1.030]　单位：mm

$$\bar{N} = \frac{1}{5}(1.030 + 1.033 + 1.029 + 1.032 + 1.030) = 1.031$$

$\sigma_N = 0.0016$　$\sigma_{\bar{N}} = 0.00073$　$\Delta A = 0.0019$　$\Delta B = 0.0095$　$U = \sqrt{\Delta A^2 + \Delta B^2} = 0.010$

求得小球直径的平均测量值为

$$d = (d \pm U) = (1.031 \pm 0.010)mm$$

Part2：v0的测定

19°C　t:[29.15,29.12,29.12,29.26,29.02]

$$\bar{N} = \frac{1}{5}(29.15 + 29.12 + 29.12 + 29.26 + 29.02) = 29.13$$

$\sigma_N = 0.086$　$\sigma_{\bar{N}} = 0.038$　$\Delta A = 0.0987$　$\Delta B = 0.0095$　$U = \sqrt{\Delta A^2 + \Delta B^2} = 0.10$

求得时间的平均测量值为

$$t = (t \pm U) = (29.13 \pm 0.10)s$$

速度

$$v_0 = \frac{L}{\bar{t}} = \frac{0.1}{29.13} = 3.43 \times 10^{-3} m/s$$

Problem 3 continued on next page...

粘度η

$$\eta = \frac{(\rho - \rho_0)gd^2}{18v_0(1 + 2.4\frac{d}{D})} = 1.026Pa \cdot s$$

修正粘度η_1

$$\eta_1 = \eta - \frac{3}{16}v_0 d\rho_0 = 1.025Pa \cdot s$$

21°C t:[25.44,25.19,25.21,25.67,25.28]

$$\bar{N} = \frac{1}{5}(25.44 + 25.19 + 25.2 + 25.67 + 25.28) = 25.36$$

$\sigma_N = 0.200$ $\sigma_{\bar{N}} = 0.089$ $\Delta A = 0.23$ $\Delta B = 0.01$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.23$

求得时间的平均测量值为

$$t = (t \pm U) = (25.36 \pm 0.23)s$$

速度

$$v_0 = \frac{L}{\bar{t}} = \frac{0.1}{25.36} = 3.94 \times 10^{-3} m/s$$

粘度η

$$\eta = \frac{(\rho - \rho_0)gd^2}{18v_0(1 + 2.4\frac{d}{D})} = 0.893Pa \cdot s$$

修正粘度η_1

$$\eta_1 = \eta - \frac{3}{16}v_0 d\rho_0 = 0.892Pa \cdot s$$

23°C t:[22.70,22.55,22.17,22.01,21.95]

$$\bar{N} = \frac{1}{5}(22.70 + 22.55 + 22.17 + 22.01 + 21.95) = 22.28$$

$\sigma_N = 0.332$ $\sigma_{\bar{N}} = 0.149$ $\Delta A = 0.38$ $\Delta B = 0.01$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.38$

求得时间的平均测量值为

$$t = (t \pm U) = (22.28 \pm 0.38)s$$

速度

$$v_0 = \frac{L}{\bar{t}} = \frac{0.1}{22.28} = 4.49 \times 10^{-3} m/s$$

粘度η

$$\eta = \frac{(\rho - \rho_0)gd^2}{18v_0(1 + 2.4\frac{d}{D})} = 0.783Pa \cdot s$$

修正粘度η_1

$$\eta_1 = \eta - \frac{3}{16}v_0 d\rho_0 = 0.782Pa \cdot s$$

Problem 3 continued on next page...

25°C t:[20.09,19.55,19.18,18.93,18.87]

$$\bar{N} = \frac{1}{5}(20.09 + 19.55 + 19.18 + 18.93 + 18.87) = 19.32$$

$\sigma_N = 0.505$ $\sigma_{\bar{N}} = 0.226$ $\Delta A = 0.58$ $\Delta B = 0.01$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.58$

求得时间的平均测量值为

$$t = (t \pm U) = (19.32 \pm 0.58)s$$

速度

$$v_0 = \frac{L}{\bar{t}} = \frac{0.1}{19.32} = 5.12 \times 10^{-3} m/s$$

粘度η

$$\eta = \frac{(\rho - \rho_0)gd^2}{18v_0(1 + 2.4\frac{d}{D})} = 0.687 Pa \cdot s$$

修正粘度η_1

$$\eta_1 = \eta - \frac{3}{16}v_0 d\rho_0 = 0.686 Pa \cdot s$$

27°C t:[17.08,16.66,17.05,16.60,16.33]

$$\bar{N} = \frac{1}{5}(17.08 + 16.66 + 17.05 + 16.60 + 16.33) = 16.74$$

$\sigma_N = 0.318$ $\sigma_{\bar{N}} = 0.142$ $\Delta A = 0.36$ $\Delta B = 0.01$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.36$

求得时间的平均测量值为

$$t = (t \pm U) = (16.74 \pm 0.36)s$$

速度

$$v_0 = \frac{L}{\bar{t}} = \frac{0.1}{16.74} = 5.97 \times 10^{-3} m/s$$

粘度η

$$\eta = \frac{(\rho - \rho_0)gd^2}{18v_0(1 + 2.4\frac{d}{D})} = 0.589 Pa \cdot s$$

修正粘度η_1

$$\eta_1 = \eta - \frac{3}{16}v_0 d\rho_0 = 0.588 Pa \cdot s$$

29°C t:[15.03,14.96,14.44,14.09,14.08]

$$\bar{N} = \frac{1}{5}(15.03 + 14.96 + 14.44 + 14.09 + 14.08) = 14.52$$

$\sigma_N = 0.458 \quad \sigma_{\bar{N}} = 0.205 \quad \Delta A = 0.52 \quad \Delta B = 0.01 \quad U = \sqrt{\Delta A^2 + \Delta B^2} = 0.52$

求得时间的平均测量值为

$$t = (t \pm U) = (14.52 \pm 0.52)s$$

速度

$$v_0 = \frac{L}{\bar{t}} = \frac{0.1}{14.52} = 6.88 \times 10^{-3} m/s$$

粘度η

$$\eta = \frac{(\rho - \rho_0)gd^2}{18v_0(1 + 2.4\frac{d}{D})} = 0.511 Pa \cdot s$$

修正粘度η_1

$$\eta_1 = \eta - \frac{3}{16} v_0 d\rho_0 = 0.510 Pa \cdot s$$

Part3：图像拟合

η-T表格，图像如下

分析可知蓖麻油粘度随温度的升高而降低，且近似成指数关系(拟合方程已在图中标出)

Problem 4

1. 计算公式

1.算术平均值

$$\bar{N} = \frac{\sum_{i=1}^{n} N_i}{n}$$

2.测量值的标准偏差

$$\sigma_N = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n-1}}$$

3.平均值的标准偏差

$$\sigma_{\bar{N}} = \frac{\sigma_N}{\sqrt{n}} = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n(n-1)}}$$

4.粗差的剔除　拉依达准则

$$|\Delta N_i| < 3\sigma_N$$

5.不确定度

$$U = \sqrt{\Delta_A^2 + \Delta_B^2}$$

Part1：圆环外径D1与D2的测定

D_1：[35.04,35.06,35.06,35.02,35.04]　单位：$\times 10^{-3}m$

$$\bar{N} = \frac{1}{5}(35.04 + 35.06 + 35.06 + 35.02 + 35.04) = 35.04$$

$\sigma_N = 0.017$　$\sigma_{\bar{N}} = 0.007$　$\Delta A = 0.019$　$\Delta B = 0.0095$　$U = \sqrt{\Delta A^2 + \Delta B^2} = 0.02$

求得圆环外径D_1的平均测量值为

$$D_1 = (D_1 \pm U) = (35.04 \pm 0.02) \times 10^{-3}m$$

D_2：[33.02,33.02,33.00,33.02,33.00]　单位：$\times 10^{-3}m$

$$\bar{N} = \frac{1}{5}(33.02 + 33.02 + 33.00 + 33.02 + 33.00) = 33.01$$

$\sigma_N = 0.011$　$\sigma_{\bar{N}} = 0.005$　$\Delta A = 0.013$　$\Delta B = 0.0095$　$U = \sqrt{\Delta A^2 + \Delta B^2} = 0.02$

求得圆环内径D_2的平均测量值为

$$D_2 = (D_2 \pm U) = (33.01 \pm 0.02) \times 10^{-3}m$$

Part2：图像拟合 U=Bf

U-f拟合直线，图像如下

Part3：求解水的表面张力系数

Δ U Δ U:[39.8,39.5,40.6,38.2,40.7,41.0] 单位：$\times 10^{-3}V$

$$\bar{N} = \frac{1}{6}(39.8 + 39.5 + 40.6 + 38.2 + 40.7 + 41.0) = 40.0$$

$\sigma_N = 1.036$ $\sigma_{\bar{N}} = 0.423$ $\Delta A = 1.088$ $\Delta B = 0.0095$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 1.1$

求得 Δ U的平均测量值为

$$\Delta U = (\Delta U \pm U) = (40.0 \pm 1.1) \times 10^{-3}V$$

表面张力

$$f = (U_1 - U_2)/B = \frac{\Delta U}{B} = 13.3 \times 10^{-3}N$$

表面张力系数α

$$\alpha = \frac{f}{\pi(D_1 + D_2)} = 0.062N/m$$

Problem 5

1. 计算公式

1.算术平均值

$$\bar{N} = \frac{\sum_{i=1}^{n} N_i}{n}$$

2.测量值的标准偏差

$$\sigma_N = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n-1}}$$

3.平均值的标准偏差

$$\sigma_{\bar{N}} = \frac{\sigma_N}{\sqrt{n}} = \sqrt{\frac{\sum_{i=1}^{n}(N_i - \bar{N})^2}{n(n-1)}}$$

4.粗差的剔除　拉依达准则

$$|\Delta N_i| < 3\sigma_N$$

5.不确定度

$$U = \sqrt{\Delta_A^2 + \Delta_B^2}$$

Part1：已知量的测量

砝码质量　m：[39.2,39.2,39.2,39.1,39.2,39.2]　单位：$\times 10^{-3}kg$

$$\bar{N} = \frac{1}{6}(39.2 + 39.2 + 39.2 + 39.1 + 39.2 + 39.2) = 39.2$$

$\sigma_N = 0.04$　$\sigma_{\bar{N}} = 0.017$　$\Delta A = 0.043$　$\Delta B = 0.0095$　$U = \sqrt{\Delta A^2 + \Delta B^2} = 0.044$

求得砝码质量m的平均测量值为

$$m = (m \pm U) = (39.2 \pm 0.0) \times 10^{-3}kg$$

圆环样品质量　$M_{环}$：[426.5,426.5,426.5,426.5,426.5,426.5]　单位：$\times 10^{-3}kg$

$$\bar{N} = \frac{1}{6}(426.5 + 426.5 + 426.5 + 426.5 + 426.5 + 426.5) = 462.5$$

$\sigma_N = 0.0$　$\sigma_{\bar{N}} = 0.0$　$\Delta A = 0.0$　$\Delta B = 0.0095$　$U = \sqrt{\Delta A^2 + \Delta B^2} = 0.0095$

求得圆环样品质量$M_{环}$的平均测量值为

$$M_{环} = (M_{环} \pm U) = (462.5 \pm 0.0) \times 10^{-3}kg$$

圆环外径　$D_{外}$：[239.42,239.40,239.42,239.40,239.42,239.40]　单位：$\times 10^{-3}m$

$$\bar{N} = \frac{1}{6}(239.42 + 239.40 + 239.42 + 239.40 + 239.42 + 239.40) = 239.41$$

$\sigma_N = 0.011 \quad \sigma_{\bar{N}} = 0.004 \quad \Delta A = 0.011 \quad \Delta B = 0.0095 \quad U = \sqrt{\Delta A^2 + \Delta B^2} = 0.01$

求得圆环外径$D_{外}$的平均测量值为

$$D_{外} = (D_{外} \pm U) = (239.41 \pm 0.01) \times 10^{-3} m$$

圆环内径 $D_{内}$：[210.40,210.38,210.38,210.40,210.38,210.38] 单位：$\times 10^{-3} m$

$$\bar{N} = \frac{1}{6}(210.40 + 210.38 + 210.38 + 210.40 + 210.38 + 210.38) = 210.39$$

$\sigma_N = 0.010 \quad \sigma_{\bar{N}} = 0.004 \quad \Delta A = 0.011 \quad \Delta B = 0.0095 \quad U = \sqrt{\Delta A^2 + \Delta B^2} = 0.01$

求得圆环内径$D_{外}$的平均测量值为

$$D_{内} = (D_{内} \pm U) = (210.39 \pm 0.01) \times 10^{-3} m$$

圆柱1质量 $M_{柱1}$：[165.4,165.4,165.4,165.4,165.4,165.4] 单位：$\times 10^{-3} kg$

$$\bar{N} = \frac{1}{6}(165.4 + 165.4 + 165.4 + 165.4 + 165.4 + 165.4) = 165.4$$

$\sigma_N = 0.0 \quad \sigma_{\bar{N}} = 0.0 \quad \Delta A = 0.0 \quad \Delta B = 0.0095 \quad U = \sqrt{\Delta A^2 + \Delta B^2} = 0.0$

求得圆柱1质量$M_{柱1}$的平均测量值为

$$M_{柱1} = (M_{柱1} \pm U) = (165.4 \pm 0.0) \times 10^{-3} kg$$

圆柱2质量 $M_{柱2}$：[164.8,164.7,164.7,164.7,164.8,164.8] 单位：$\times 10^{-3} kg$

$$\bar{N} = \frac{1}{6}(164.8 + 164.7 + 164.7 + 164.7 + 164.8 + 164.8) = 164.8$$

$\sigma_N = 0.055 \quad \sigma_{\bar{N}} = 0.022 \quad \Delta A = 0.057 \quad \Delta B = 0.0095 \quad U = \sqrt{\Delta A^2 + \Delta B^2} = 0.01$

求得圆柱2质量$M_{柱2}$的平均测量值为

$$M_{柱2} = (M_{柱2} \pm U) = (164.8 \pm 0.1) \times 10^{-3} kg$$

圆柱1直径 $D_{柱1}$：[30.02,30.02,30.00,30.02,30.00,30.00] 单位：$\times 10^{-3} m$

$$\bar{N} = \frac{1}{6}(30.02 + 30.02 + 30.00 + 30.02 + 30.00 + 30.00) = 30.01$$

$\sigma_N = 0.010 \quad \sigma_{\bar{N}} = 0.004 \quad \Delta A = 0.011 \quad \Delta B = 0.0095 \quad U = \sqrt{\Delta A^2 + \Delta B^2} = 0.01$

求得圆柱1直径$D_{柱1}$的平均测量值为

$$D_{柱1} = (D_{柱1} \pm U) = (30.01 \pm 0.01) \times 10^{-3} m$$

Problem 5 continued on next page...

圆柱2直径 $D_{柱2}$：[30.00,30.00,29.98,30.00,29.98,30.00] 单位：$\times 10^{-3}m$

$$\bar{N} = \frac{1}{6}(30.00 + 30.00 + 29.98 + 30.00 + 29.98 + 30.00) = 29.99$$

$\sigma_N = 0.010$ $\sigma_{\bar{N}} = 0.004$ $\Delta A = 0.011$ $\Delta B = 0.0095$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.01$

求得圆柱2径$D_{柱2}$的平均测量值为

$$D_{柱2} = (D_{柱2} \pm U) = (29.99 \pm 0.01) \times 10^{-3}m$$

Part2：β 的测量

角加速度 β_1：[-0.0529, -0.0694, -0.0597, -0.0657, -0.0604, -0.0632, -0.0589, -0.0611, -0.0581] 单位：rad/s^2

$$\bar{N} = \frac{1}{9}(-0.0529+-0.0694+-0.0597+-0.0657+-0.0604+-0.0632+-0.0589+-0.0611+-0.0581) = -$$

$\sigma_N = 0.0047$ $\sigma_{\bar{N}} = 0.0016$ $\Delta A = 0.004$ $\Delta B = 0.0095$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.0103$

求得角加速度β_1的平均测量值为

$$\beta_1 = (\beta \pm U) = (-0.0610 \pm 0.0103)rad/s^2$$

角加速度 β_2：[1.6854, 1.6628, 1.6745, 1.6565, 1.6635, 1.6448, 1.6544, 1.4753, 1.2807] 单位：rad/s^2

$$\bar{N} = \frac{1}{9}(1.6854+1.6628+1.6745+1.6565+1.6635+1.6448+1.6544+1.4753+1.2807) = 1.5998$$

$\sigma_N = 0.1353$ $\sigma_{\bar{N}} = 0.0451$ $\Delta A = 0.1159$ $\Delta B = 0.0095$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.1163$

求得角加速度β_2的平均测量值为

$$\beta_2 = (\beta \pm U) = (1.5998 \pm 0.1163)rad/s^2$$

角加速度 β_3：[-0.0503, -0.0330, -0.0405, -0.0335, -0.0378, -0.0337, -0.0364, -0.0336, -0.0357] 单位：rad/s^2

$$\bar{N} = \frac{1}{9}(-0.0503+-0.0330+-0.0405+-0.0335+-0.0378+-0.0337+-0.0364+-0.0336+-0.0357) = -$$

$\sigma_N = 0.0055$ $\sigma_{\bar{N}} = 0.0018$ $\Delta A = 0.005$ $\Delta B = 0.0095$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.0106$

求得角加速度β_3的平均测量值为

$$\beta_3 = (\beta \pm U) = (-0.0372 \pm 0.0106) rad/s^2$$

角加速度 β_4：[0.9013, 0.8893, 0.8956, 0.8853, 0.8920, 0.8816, 0.8844, 0.7790, 0.6756]
单位：rad/s^2

$$\bar{N} = \frac{1}{9}(0.9013+0.8893+0.8956+0.8853+0.8920+0.8816+0.8844+0.7790+0.6756) = 0.8538$$

$\sigma_N = 0.0765$ $\sigma_{\bar{N}} = 0.0255$ $\Delta A = 0.066$ $\Delta B = 0.0095$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.0662$

求得角加速度β_4的平均测量值为

$$\beta_4 = (\beta \pm U) = (0.8538 \pm 0.0103) rad/s^2$$

角加速度 β_5：[-0.0312, -0.0369, -0.0325, -0.0345, -0.0322, -0.0344, -0.0336, -0.0340, -0.0324] 单位：rad/s^2

$$\bar{N} = \frac{1}{9}(-0.0312+-0.0369+-0.0325+-0.0345+-0.0322+-0.0344+-0.0336+-0.0340+-0.0324) = -$$

$\sigma_N = 0.0017$ $\sigma_{\bar{N}} = 0.0006$ $\Delta A = 0.014$ $\Delta B = 0.0095$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.0096$

求得角加速度β_5的平均测量值为

$$\beta_5 = (\beta \pm U) = (-0.0335 \pm 0.0096) rad/s^2$$

角加速度 β_6：[1.0379, 1.0482, 1.0332, 1.0420, 1.0301, 1.0379, 1.0275, 1.0275, 0.9108]
单位：rad/s^2

$$\bar{N} = \frac{1}{9}(1.0379+1.0482+1.0332+1.0420+1.0301+1.0379+1.0275+1.0275+0.9108) = 1.0217$$

$\sigma_N = 0.0042$ $\sigma_{\bar{N}} = 0.0140$ $\Delta A = 0.0361$ $\Delta B = 0.0095$ $U = \sqrt{\Delta A^2 + \Delta B^2} = 0.0373$

求得角加速度β_6的平均测量值为

$$\beta_6 = (\beta \pm U) = (1.0217 \pm 0.0373) rad/s^2$$

Part3：测量并计算放上圆环后的转动惯量并于理论值比较

放上圆环后的转动惯量的实验值，由计算公式

$$J_1 = \frac{Rm(g - R\beta_2)}{\beta_2 - \beta_1}$$

$$J_2 = \frac{Rm(g - R\beta_4)}{\beta_4 - \beta_3}$$
$$J_3 = J_2 - J_1$$

可得

$$J_1 = 0.0069 \quad J_2 = 0.0129 \quad J_3 = 0.0060$$

放上圆环后的理论计算值，由公式

$$J = \frac{m}{2}(R_{外}^2 + R_{内}^2)$$

可得

$$J = 0.0054$$

相对误差

$$E = \frac{J_3 - J}{J} \times 100\% = 10\%$$

Part4：验证平行轴定理

两圆柱体的转动惯量在与中心距离为d的实验值，由计算公式

$$J_1 = \frac{Rm(g - R\beta_2)}{\beta_2 - \beta_1}$$
$$J_2 = \frac{Rm(g - R\beta_6)}{\beta_6 - \beta_5}$$
$$J_3 = J_2 - J_1$$

可得

$$J_1 = 0.0069 \quad J_2 = 0.0109 \quad J_3 = 0.0040$$

依据平行轴定理得出转动惯量的理论计算值，由公式

$$J_0 = \frac{m_1}{2}R_1^2 + \frac{m_2}{2}R_2^2 = \frac{1}{2} \times 0.1654 \times (0.0150)^2 + \frac{1}{2} \times 0.1648 \times (0.0150)^2 = 3.7147 \times 10^{-5}$$

$$(m_1 + m_2)d^2 = (0.1654 + 0.1648) \times 0.1125 = 0.0042$$

即

$$J = J_0 + md^2 = 0.0042$$

相对误差

$$E = \frac{J_3 - J}{J} \times 100\% = 4.8\%$$

Part5：思考与讨论

1.游标卡尺的一对内外测量爪之间均有缝隙，测量圆柱半径时注意减去相应距离
2.使用电子天平称重时应注意仪器的精度范围，从而确保实验数据的准确性
3.选择的悬挂砝码的细线应足够长以确保能收集到足够多的数据
4.实验过程应确保仪器水平放置，以减小重力等其它无关因素对实验的影响

Problem 6

1.