SCHOOL OF PHYSICS
UNIVERSITI SAINS MALAYSIA

ZCT191/192 PHYSICS PRACTICAL I/II

1OS3 GEOMETRICAL OPTICS

Experiment Instructions and Guidelines

In this document, you will find the full instructions, guidelines and tips to conduct the experiment **1OS3 Geometrical Optics**.

INSTRUCTIONS

Before you enter the First Year Lab, please download all the documents listed for this experiment on eLearn, and skim through the **1OS3 Lab Manual** (especially on the **Theory** and **Equipment** sections) to better prepare yourself for the experiment.

First Session

1. Record your attendance (see QR code / lab officer).
2. Listen to a short briefing by Dr. John. If he does not appear after 10 minutes, please go ahead with the experiment, following the procedures given in the manual.
3. Collect your experimental data. You can record them manually on a printed lab manual / notebook, or type them directly into the **1OS3 Student Worksheet** (Microsoft Excel file).
4. Analyse and process your data by completing the **1OS3 Student Worksheet**, using the instructions from the **Analysis** section in the lab manual as a guide. You can refer to the **Microsoft Excel Guidelines** section below if you need help on the worksheet.
5. Prepare for the viva. Discuss with your partner, read the manual or search for online resources to better understand the underlying theory of this experiment.

Second Session

1. Record your attendance (see QR code / lab officer).
2. Attend the viva with your partner, it will be conducted group by group. You will be asked 3 questions on the theory, methodology, equipment and application of the experiment.

3. Complete your lab report. You can post questions at the **1OS3 Forum (Q&A)** on eLearn if you have any queries about the experiment, during or after the lab session.
4. Submit your lab report to **1OS3 Lab Report Submission** on eLearn before your group's specified deadline.

LAB REPORT GUIDELINES

Your lab report has to be **typed** instead of handwritten. Remember to insert relevant figures, summary tables, graphs and diagrams in your report. The **1OS3 Graph Paper** given on eLearn is for you to sketch the scaled diagram for **Part B**, you can paste it in Microsoft Word and sketch it digitally. For further tips on how to write a good lab report, refer to the **Lab Reports and Data Analysis** section on my USM profile page, under the tab **For Students**.

Before submission, please combine your lab report, worksheet and graph into **one single PDF file**. You can use Soda PDF Online to merge them.

MICROSOFT EXCEL GUIDELINES

Excel Formulae

Please make use of **Microsoft Excel formulae** to generate results in the blanks given in the **1OS3 Student Worksheet**. Here are some examples of formulae you may use:

- **Reference**: type **`=B12`** to always show what is shown in cell B12.
- **Add/Subtract**: type **`=B1+B2`** or **`B1-B2`** to add/subtract the cells B1 and B2.
- **Multiply**: type **`=J53*I53`** to multiply the cells J53 × I53.
- **Divide**: type **`=1/B11`** to get $\frac{1}{\mathrm{B11}}$.
- **Exponents**: type **`=1.0E-34`** to get 1.0×10^{-34}.
- **Power**: type **`=2.5^2`** to get 2.5^2.
- **Average**: type **`=AVERAGE(D25:D26)`** to get an average value for cells D25 to D26.
- **Square Root:** type **`=SQRT(D31^2+D23^2)`** to get $\sqrt{\mathrm{D31}^2 + \mathrm{D23}^2}$.
- **Absolute:** type **`=ABS(-4.5)`** to get $|-4.5|$.
- **Std. Dev.:** type **`=STDEV.S(D1,D4)`** to get the standard deviation of cells D1 and D4.

By default, copying a cell with a formula and pasting it into another cell will cause the formula to change by the row or column moved. E.g. the formula **`=B1+B2`** in A1, will turn into

- **`=C1+C2`** when pasted into B1 (moved to the right by one column), and
- **`=B2+B3`** when pasted into A2 (moved downwards by one row).

If you would like to keep reference to the same cell and not move colums / rows when pasting, you can put the **$** symbol in front of it, e.g. **$B1** to fix to column B, **B$1** to fix to row 1, or **B1** to fix to the cell B1. A quick keyboard shortcut to do this is to press **F4** when highlighting the cell. You can also keep reference to a cell in a different sheet by adding **[sheetname]!** in front of the cell, e.g. **=Data!B1** will make reference to the cell B1 in the sheet named **Data**.

The LINEST Function

The **LINEST()** function is used to produce some parameters for a best-fit linear regression line, these include the

- The **gradient** (m);
- The ***y*-intecept** (c);
- The **standard error of the gradient** (σ_m);
- The **standard error of the *y*-intercept** (σ_c);
- The **coefficient of determination** (r^2); and
- The **standard error of the *y*-estimate** (σ_y).

Please make use of these statistics in your report when analysing your results. The following is a step-by-step tutorial on how to use the **LINEST()** function:

1. Highlight the 6 empty cells in the box where the **LINEST()** header is found, then type **=LINEST([known_ys],[known_xs],TRUE,TRUE)**.
2. Replace **[known_xs]** and **[known_ys]** with your x and y values, e.g. **E12:E23** are the values of $1/o$ for **Table 1**. You can highlight and drag across the cells to input them too.
3. After you're done typing, press **Ctrl+Shift+Enter**.
4. In the future, if you want to force the line to pass through the origin (0,0), you can replace the first **TRUE** with **FALSE**.
5. Use the **Increase Decimal** and **Decrease Decimal** buttons to select the appropriate decimal places you want your data to show.

With the data generated for you, you can easily present your results with their respective errors, e.g. $m \pm \sigma_m = -0.953 \pm 0.004$ or $c \pm \sigma_c = 0.0977 \pm 0.0002$ (remember to use the correct units and number of significant figures). To obtain the **correlation coefficient** (r), simply take the square root of the coefficient of determination (r^2).

Plotting Graphs

In the **Part A** tab at the bottom of your worksheet, an example graph will be generated once you fill up **Table 1**. It is best that you work your graph from there, but either ways, here's how you can plot a scatter graph with a **best-fit line** and **error bars**:

1. Highlight the values of x and y you want to plot, click **Insert > Insert Scatter (X, Y) or Bubble Chart > Scatter**.
2. Right click on the chart, select **Move Chart > New Sheet**, give the chart a name, and it will appear in a different tab.

3. If your x and y-axes are reversed, you can right-click on one of the data points, click **Select Data…**, highlight your data series, and click **Edit** to manually select the range of your x and y values.
4. To plot a best-fit line across the data, right-click one of the data points, and select **Add Trendline**. A panel will appear on the right, and you can edit the colour / weight / type of trendline used.
5. To add error bars, click on a data point, then from the **Chart Design** menu, click **Add Chart Element > Error Bars > Standard Error**. Click on the horizontal error bars and press **delete**, as we only want vertical error bars.
6. We're not done yet: we actually want the error bars to be the height of σ_y. Right-click on one of the error bars, and click **Format Error Bars**, a panel on the right should appear. In the section **Error Amount**, select **Fixed value**, and key in the value of σ_y you have obtained from your **`LINEST()`** function. Your error bars may be too small to be seen if your fit is extremely good.

Last updated: 16 October 2022 (JSYH)