SCHOOL OF PHYSICS
UNIVERSITI SAINS MALAYSIA

ZCT191/192 PHYSICS PRACTICAL I/II
1OS1 INTERFERENCE

Lab Manual

OBJECTIVES

1. *To determine the position of the first intensity minimum due to a single slit and to calculate the width of the slit;*
2. *To determine the intensity distribution of the diffraction patterns of a threefold, fourfold and fivefold slit, where the slits have all the same widths and the same distances among each other;*
3. *To assess the intensity relations of the central peaks; and*
4. *To determine the transmission grids with different lattice constants, the position of the peaks of several orders of diffraction, and to calculate the wavelength of the laser light.*

THEORY

If monochromatic light of wavelength λ impinges on a system of parallel and equidistant slits, the following will be true for the light intensity I of beams deflected by an angle φ:

$$I(\varphi) \propto b^2 \cdot \frac{\sin^2\left(\frac{\pi}{\lambda} b \sin\varphi\right)}{\left(\frac{\pi}{\lambda} b \sin\varphi\right)^2} \cdot \frac{\sin^2\left(\frac{p\pi}{\lambda} g \sin\varphi\right)}{\sin^2\left(\frac{\pi}{\lambda} g \sin\varphi\right)}, \tag{1}$$

where b is the width of the slit, g is the distance between slits and p is the number of slits. According to Fraunhofer, the minima and the peaks of a single slit are called 1st class interferences, whereas the interaction of several yields 2nd class interferences.

Observing only a single slit (1st factor), this yields a minimum intensity when the numerator becomes zero. In this case, the following is valid:

$$\sin\varphi_k = \frac{k \cdot \lambda}{b}, \qquad (k = 1,2,3,\ldots). \tag{2}$$

The angular position of the 1st class peaks is given approximately through:

$$\sin\varphi_{k^*} = \frac{2k^* + 1}{2} \cdot \frac{\lambda}{b}, \qquad (k^* = 1,2,3,\ldots). \tag{3}$$

If several slits act together, the minima of the single slits always remain. Supplementary 2nd class minima appear when the 2nd factor also becomes zero.

For a double slit ($p = 2$), the zero points can be easily calculated by simple transformation of the 2nd factor. Equation (1) then yields

$$4\cos^2\left(\frac{\pi}{\lambda} \cdot g \sin\varphi\right) = \pm 1. \tag{4}$$

This expression becomes zero for

$$\sin\varphi_h = \frac{2h + 1}{2} \cdot \frac{\lambda}{g}, \qquad (h = 0,1,2,3,\ldots). \tag{5}$$

The following is valid for the intensity I for the main 2nd class peaks:

$$I \propto p^2. \tag{6}$$

The main 2nd class peaks thus become more prominent as the number of slits increases. There are still $p - 2$ secondary 2nd class peaks between the main peaks.

When light is diffracted through transmission grids with lattice constants g, the diffraction angle φ of the main peaks fulfils the following relation:

$$\sin\varphi_k = \frac{k\lambda}{g}, \qquad (k = 0,1,2,3,\ldots). \tag{7}$$

PROCEDURES

1. The experiment's equipment is set-up as shown in the lab manual. With the assistance of the $f = 20$ mm and $f = 100$ mm lenses, a widened and parallel laser beam is generated, which must impinge centrally on the photocell with the slit aperture, the photocell being situated approximately at the centre of its shifting range.
2. Set the diffracting objects in the object holder. It must be ensured that the diffraction objects which are to be investigated are set vertically in the object holder, and uniformly illuminated.
3. In order to avoid undesirable intensity fluctuations, the laser and the measuring amplifier should be warmed up for about 15 minutes before measurements are made. Connect the photocell to the $10^4\ \Omega$ input of the measuring amplifier (amplification factor $10^3 - 10^5$). The zero-point measurement of the amplifier must be checked while the photocell is covered, or when the amplification factor is changed, and corrected when necessary.
4. Place the diaphragm with single slits (08522.00) at the object holder. Measure the diffraction intensity I as a function of position x by moving the photocell.
    - Read the measurements and record the values in **Table 1**.
    - Plot a graph of diffraction intensity as a function of the position x for $b = 0.1$ mm, $b = 0.2$ mm and $b = 0.4$ mm.
    - Determine the angle φ between the central peak and the secondary peaks. Consider $\sin\varphi \approx \tan\varphi$.
5. Change the diaphragm to a multiple slit (08526.00) at the object holder. Measure the diffraction intensity I as a function of position x by moving the photocell.
    - Read the measurements and record the values in **Table 2**.
    - Plot a graph of diffraction intensity I as a function of position x for $n = 2, 3, 4$ and 5.
6. Put the diffraction grating on the object holder. Determine the distance of the diffraction peaks up to the 3rd order of diffraction ($k = 3$) for diffraction gratings with 4, 8, 10 and 50 lines/mm. For the 50 lines/mm transmission grid, the secondary peaks are outside the shifting range of the photocell, in this case mark the positions of the diffraction reflexes on a sheet of paper and measure their distances with a ruler.
    - Read the measurements and record the values in **Table 3**.
    - Plot a graph of lattice constant g as a function of reciprocal distance of diffraction peaks up to 3rd order.
    - Based on Equation (7), calculate the wavelength of the laser used.

ACKNOWLEDGEMENT

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DATA AND GRAPHS

Table 1

$b = 0.1$ mm

Position, x/mm	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Diffraction Intensity, *I*							

Position, x/mm	−0.1	−0.2	−0.3	−0.4	−0.5	−0.6	−0.7
Diffraction Intensity, *I*							

$b = 0.2$ mm

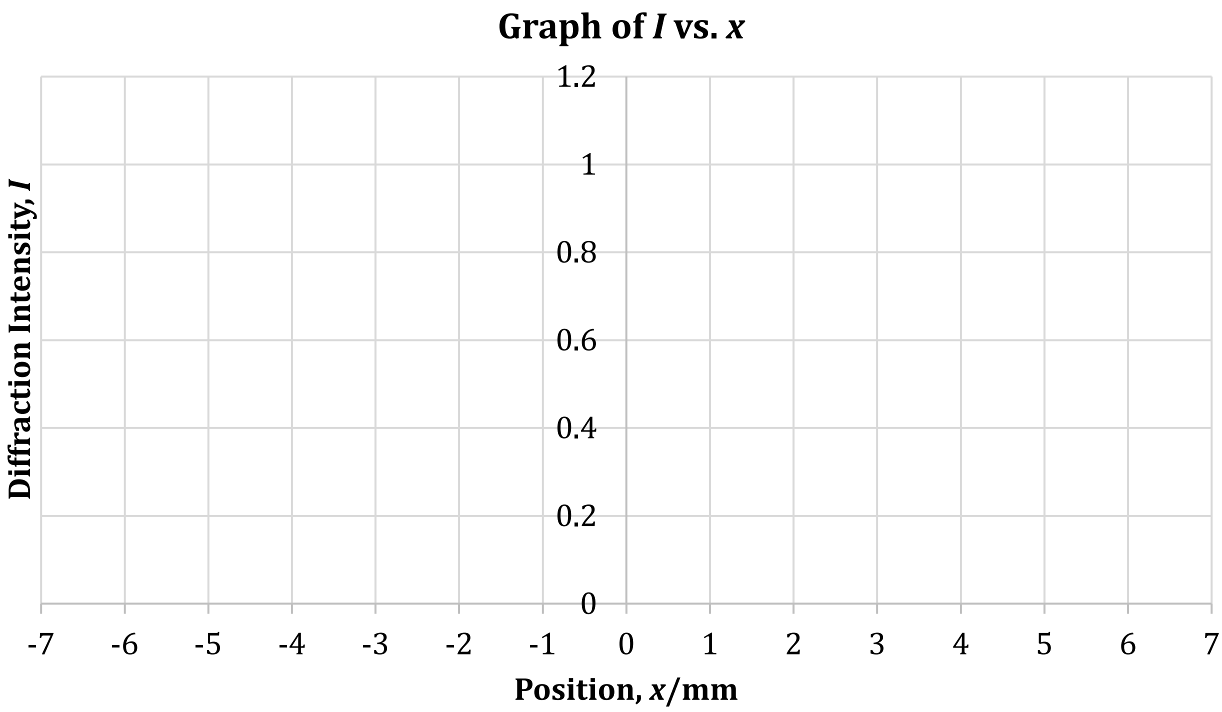
Position, x/mm	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Diffraction Intensity, *I*							

Position, x/mm	−0.1	−0.2	−0.3	−0.4	−0.5	−0.6	−0.7
Diffraction Intensity, *I*							

$b = 0.4$ mm

Position, x/mm	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Diffraction Intensity, *I*							

Position, x/mm	−0.1	−0.2	−0.3	−0.4	−0.5	−0.6	−0.7
Diffraction Intensity, *I*							



Description:
$b = 0.4$ mm; $b = 0.2$ mm; $b = 0.1$ mm

Table 2

$b_1 = 0.1$ mm, g $= 0.25$ mm, $n = 2$

Position, x/mm	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Diffraction Intensity, I							

Position, x/mm	−0.1	−0.2	−0.3	−0.4	−0.5	−0.6	−0.7
Diffraction Intensity, I							

$b_1 = 0.1$ mm, g $= 0.25$ mm, $n = 3$

Position, x/mm	−0.1	−0.2	−0.3	−0.4	−0.5	−0.6	−0.7
Diffraction Intensity, I							

Position, x/mm	−0.1	−0.2	−0.3	−0.4	−0.5	−0.6	−0.7
Diffraction Intensity, I							

$b_1 = 0.1$ mm, g $= 0.25$ mm, $n = 4$

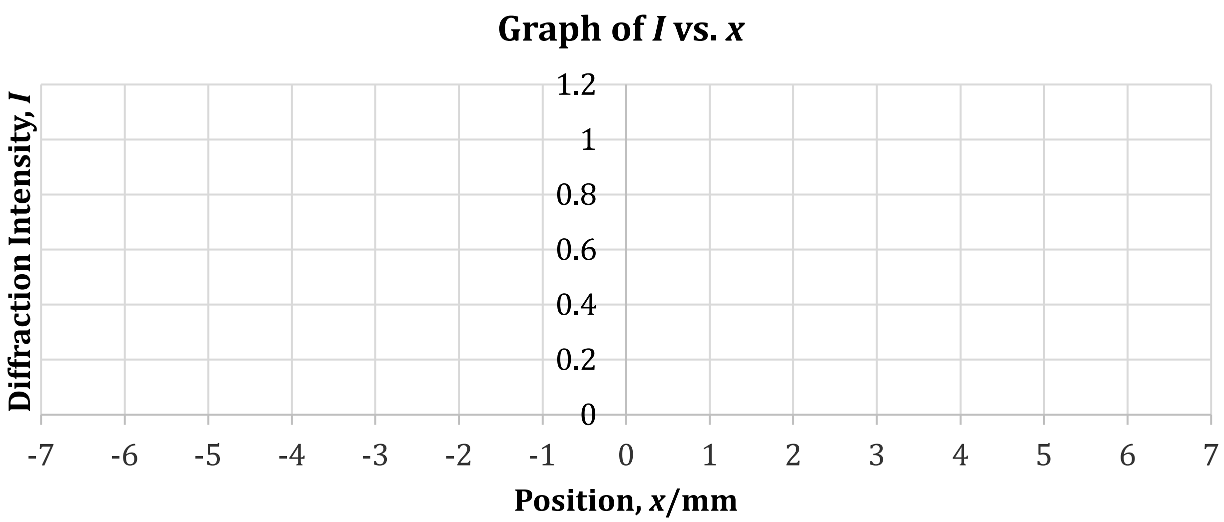
Position, x/mm	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Diffraction Intensity, I							

Position, x/mm	−0.1	−0.2	−0.3	−0.4	−0.5	−0.6	−0.7
Diffraction Intensity, I							

$b_1 = 0.1$ mm, g $= 0.25$ mm, $n = 5$

Position, x/mm	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Diffraction Intensity, I							

Position, x/mm	−0.1	−0.2	−0.3	−0.4	−0.5	−0.6	−0.7
Diffraction Intensity, I							



Description:
$n = 2; n = 3; n = 4; n = 5$

Table 3

$\boldsymbol{k = 1}$

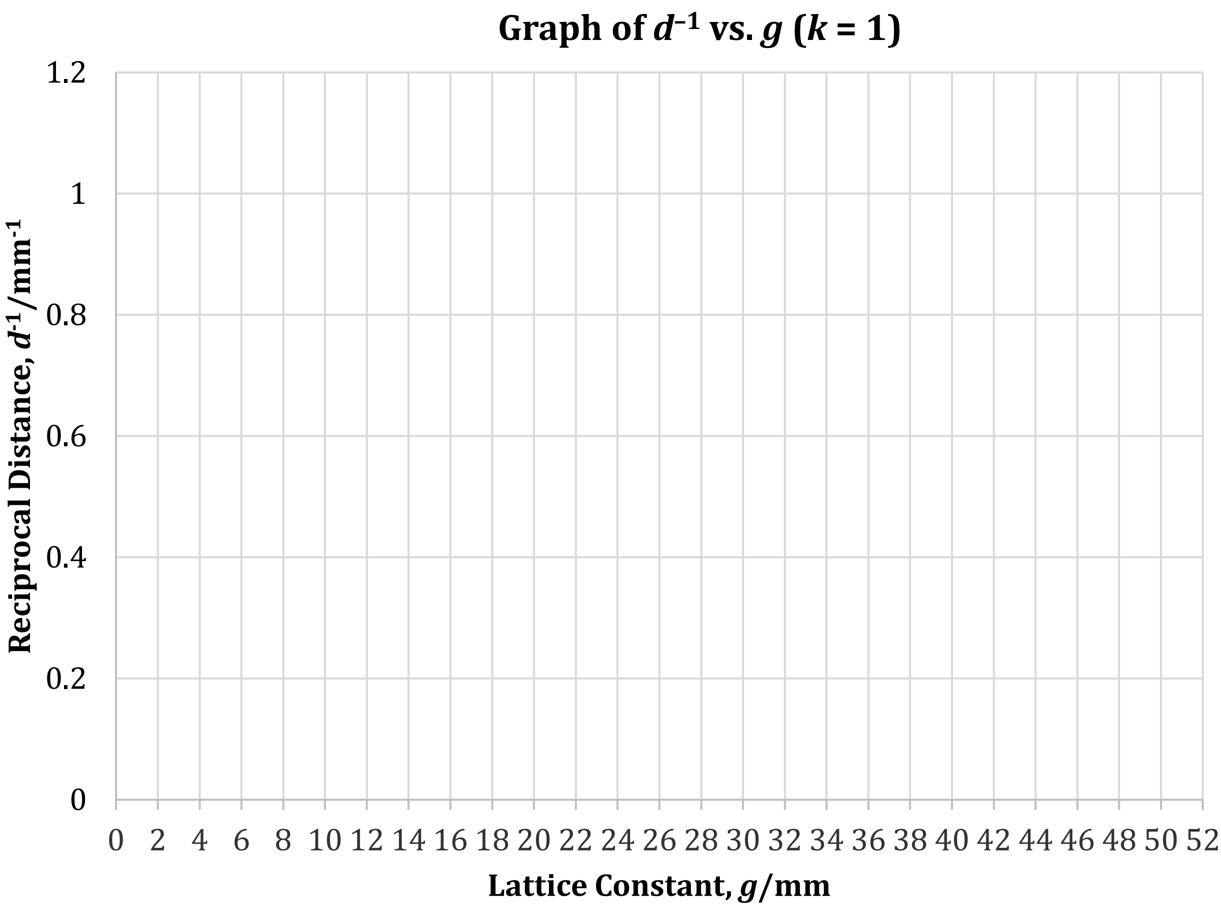
Lattice Constant, g/mm	1/4	1/8	1/10	1/50
Reciprocal Distance, d^{-1}/mm^{-1}				

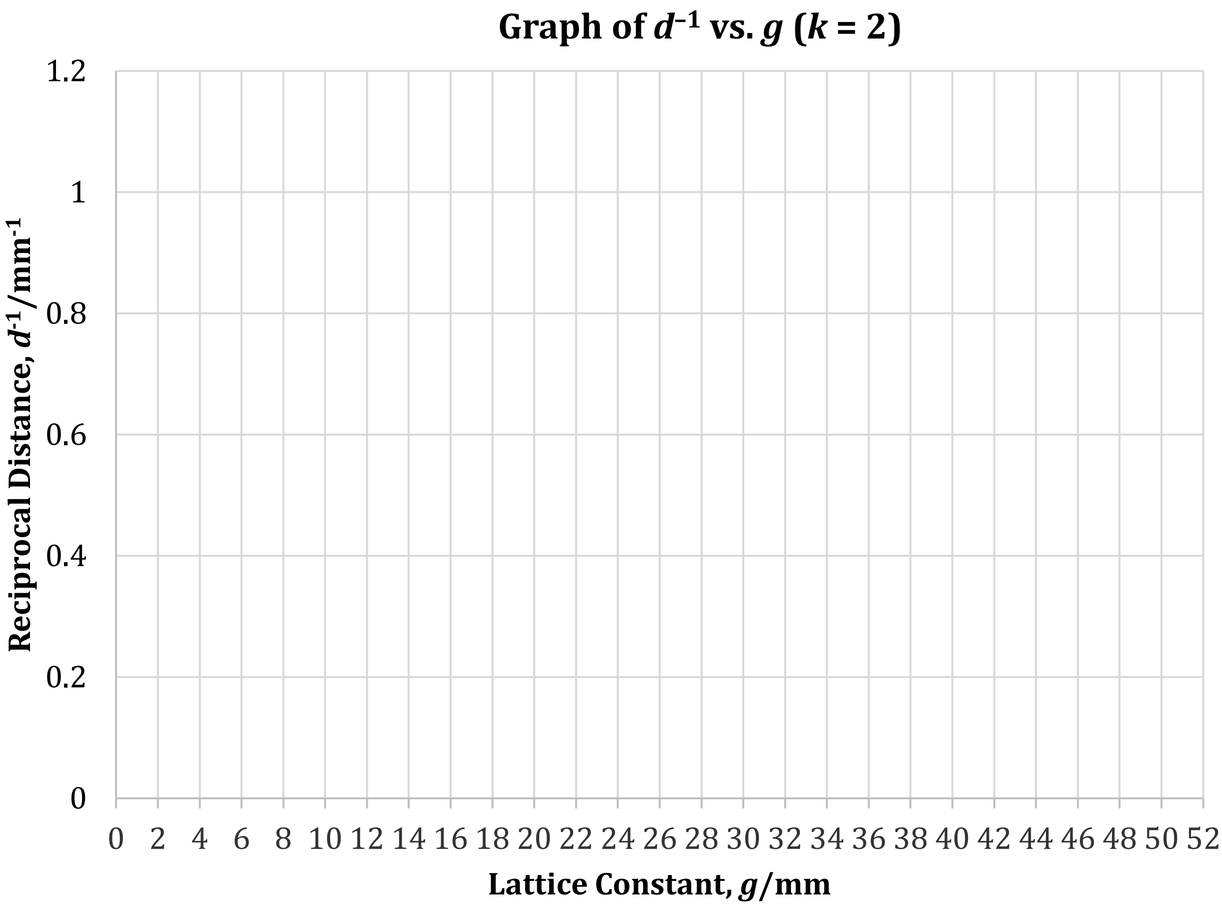
$\boldsymbol{k = 2}$

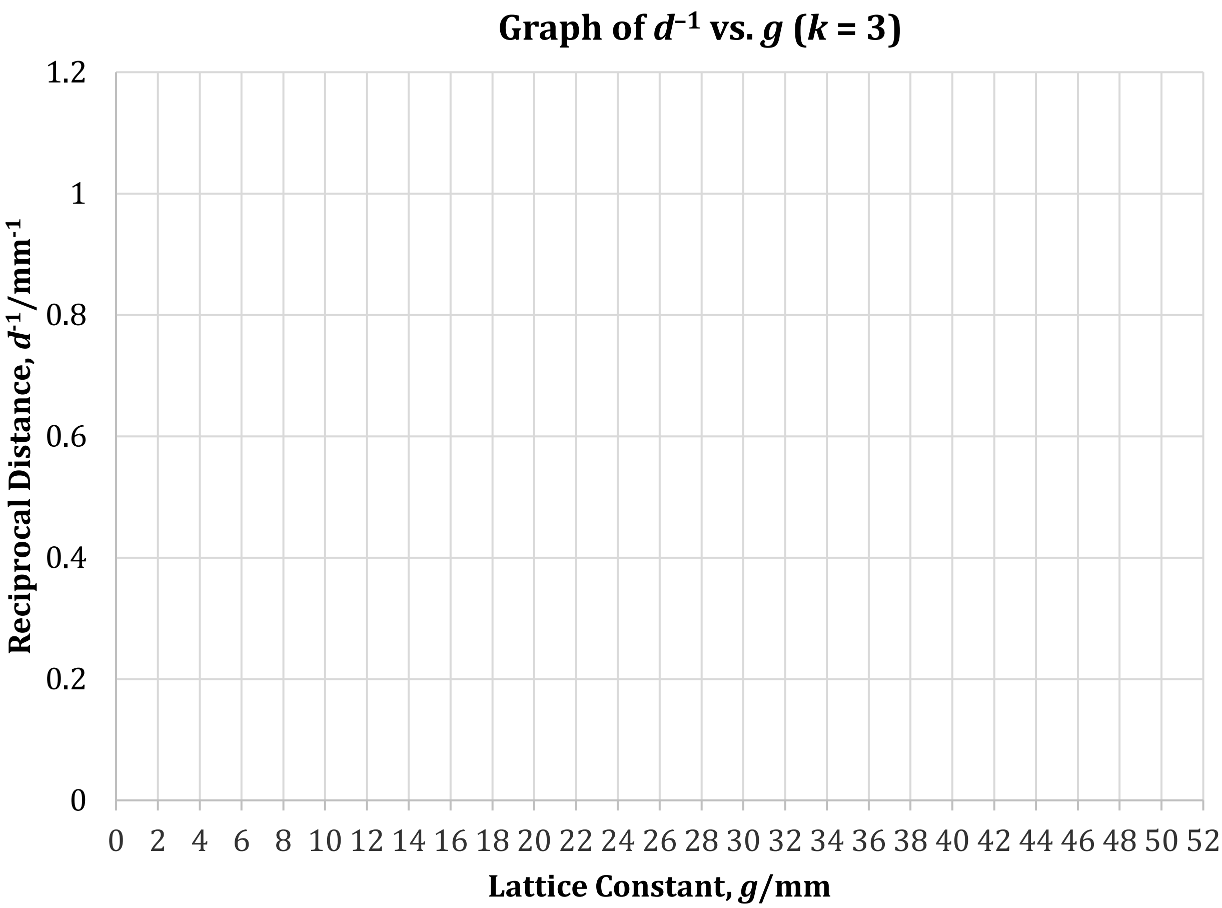
Lattice Constant, g/mm	1/4	1/8	1/10	1/50
Reciprocal Distance, d^{-1}/mm^{-1}				

$\boldsymbol{k = 3}$

Lattice Constant, g/mm	1/4	1/8	1/10	1/50
Reciprocal Distance, d^{-1}/mm^{-1}	–			




Graph of d^{-1} vs. g (k = 2)
1.2
1
0.8
0.6
0.4
0.2
0
Reciprocal Distance, d^{-1}/mm^{-1}
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
Lattice Constant, g/mm


Graph of d^{-1} vs. g (k = 3)
1.2
1
0.8
0.6
0.4
0.2
0
Reciprocal Distance, d^{-1}/mm^{-1}
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
Lattice Constant, g/mm

CALCULATIONS AND ANALYSIS

DISCUSSION

CONCLUSION

REFERENCES