PRACTICAL WORKBOOK

PHYSICS

PH-311

FOR

THIRD YEAR APPLIED PHYSICS

Spring Semester 2024

NAME OF STUDENT: _____

CLASS ROLL NO.: _____ **SECTION:** _____

DISCIPLINE: _____

BATCH: _____

DEPARTMENT OF PHYSICS

NED UNIVERSITY OF ENGINEERING & TECHNOLOGY,

KARACHI, PAKISTAN.

<u>CERTIFICATE</u>

Certified that Mr. / Ms. _____

of Class **Third Year Applied Physics** Bearing Seat No.

_____

Department_____ has completed

the practical course **PH-311** of **Applied Physics** as prescribed by the NED

University of Engineering & Technology, Karachi for the Academic

Session_____.

_____

Lab. Teacher

PHYSICS (PH-311) PRACTICAL

NAME OF STUDENT: _____

CLASS ROLL NO.:_____

S.NO.	Description	Remarks	Signature & Date
1	Determine the energy values of the characteristic X-rays of copper and compare them with the values that were determined based on the corresponding energy-level diagram.		
2	To verify the absorption edge (Monochromatization) of the characteristic X-rays of copper by using nickel filter.		
3	To determine the lattice parameter of cubic crystalline material using XRD pattern.		
4	To determine the permittivity of free space by using parallel plate capacitor.		
5	To determine the dielectric constant of given material by using parallel plate capacitor.		
6	To determine charge carrier density of given semiconductor using Hall's effect.		
7	To study the damped harmonic motion of an oscillator and the types of damping through software/programming tool.		
8	To model an ODE based physical phenomena by using a programming language.		

EXPERIMENT # 01

OBJECT:

Determine the energy values of the characteristic X-rays of copper and compare them with the values that were determined based on the corresponding energy-level diagram.

APPARATUS:

XR 4.0 expert unit	09057-99
X-ray goniometer	09057-10
X-ray plug-in unit with a copper X-ray tube	09057-50
Counter tube, type B	09005-00
X-ray lithium fluoride crystal, mounted in a holder	09056-05
X-ray potassium bromide crystal, mounted in a holder	09056-01
measure XRm 4.0 X-ray software	14414-61
Data cable USB, plug type A/B	14608-00
X-ray diaphragm tube, 2 mm	09057-02

THEORY:

When electrons impinge on the metallic anode of the X-ray tube with a high level of kinetic energy, X-rays with a continuous energy distribution (the so-called bremsstrahlung) are produced. The spectrum of the bremsstrahlung is superimposed by additional discrete lines. If an atom of the anode material is ionised on the *K* shell following an electron impact, an electron from a higher shell can take up the free place while emitting an X-ray quantum. The energy of this X-ray quantum corresponds to the energy difference of the two shells that are involved in this process. Since this energy difference is atom-specific, the resulting radiation is also called characteristic X-radiation.

Figure 1 shows the energy-level diagram of a copper atom. Characteristic X-radiation that is produced following a transition from the L shell to the K shell is called K_α radiation, while the radiation that is produced following a transition from the

M shell to the K shell is called K_β radiation ($M_1 \rightarrow K$ and $L_1 \rightarrow K$ transitions are not allowed due to quantum-mechanical selection rules).

The characteristic X-ray lines of copper have the following energy levels (Fig. 1):

$E_{K\alpha}* = E_K - 1/2 \, (E_{L2} + E_{L3}) = 8.038$ keV

$E_{K\beta} = E_K - E_{M2.3} = 8.905$ keV

$E_{K\alpha}*$ is the energetic mean value of the $K_{\alpha 1}$ and $K_{\alpha 2}$ lines.
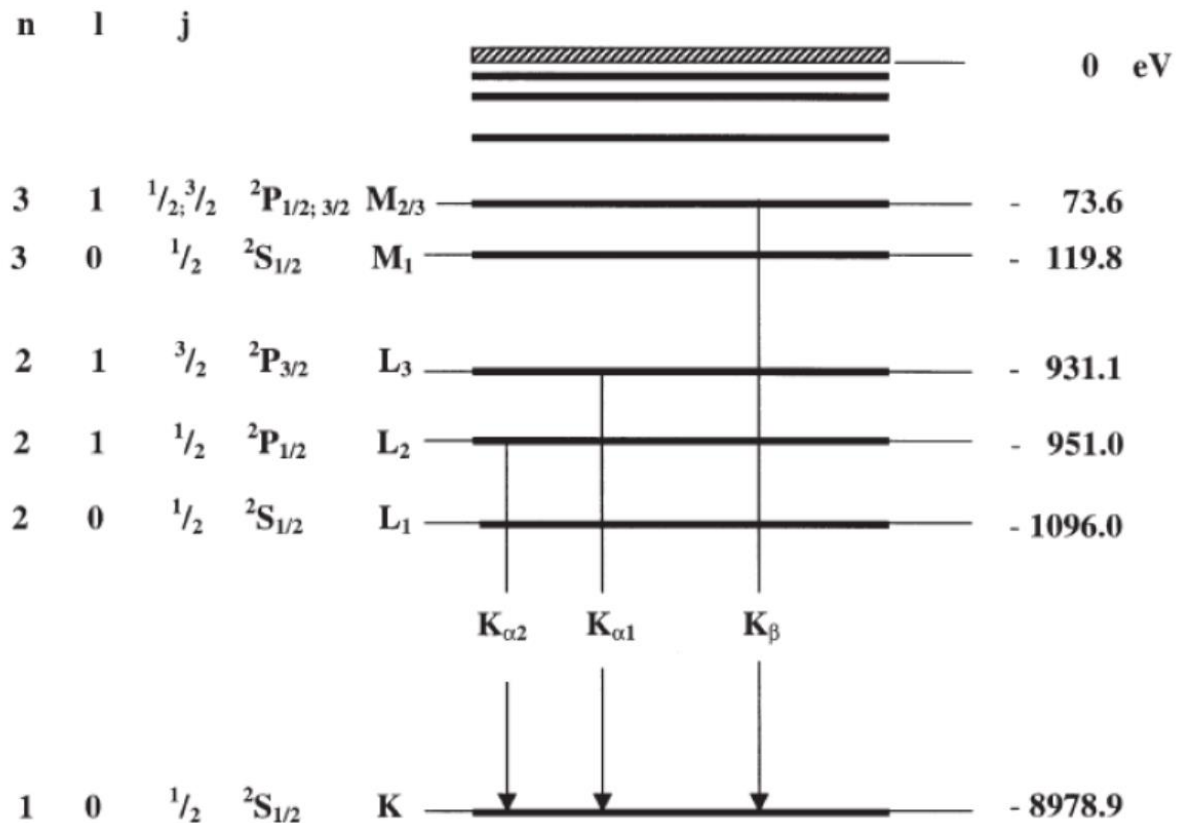

Figure 1 Energy-level diagram of copper (Z = 29)

The analysis of polychromatic X-rays is made possible through the use of a monocrystal. When X-rays of the wavelength λ impinge on the lattice planes of a monocrystal under the glancing angle θ, the rays that are reflected on the lattice planes interfere with each other in a constructive manner pro-vided that their path difference Δ corresponds to an integral multiple of the wavelength. In accordance with Figure 2, Bragg's law applies to constructive interference:

$$2dSin\theta = n\lambda \qquad (1)$$
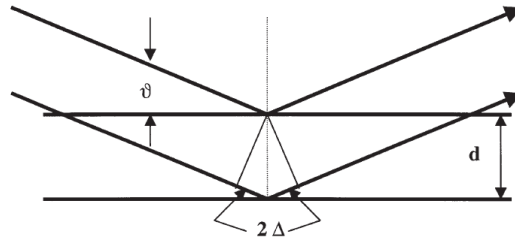
(d = interplanar spacing; n = 1, 2, 3,…)

Figure 2 Bragg scattering on a pair of lattice planes

If the interplanar spacing d is known, the wavelength λ can be determined with the aid of the glancing angle θ. The energy of the radiation then results from:

$$E = \frac{hc}{\lambda} \tag{2}$$

When combining (1) and (2), we obtain:

$$E = nhc/2dSin\theta \tag{3}$$

Planck's constant	h	$= 6.6256 \times 10^{-34}$ Js
Velocity of light	c	$= 2.9979 \times 10^{8}$ m/s
Interplanar spacing	d	$= 2.014 \times 10^{-10}$ m
LiF (200)		
Equivalent	1 eV	$= 1.6021 \times 10^{-19}$ J

PROCEDURE:

Setup:

The experimental setup is shown in Figure 3

Figure 3 XR 4.0 expert unit 09057-99

6

Connect the goniometer and the Geiger-Müller counter tube to their respective sockets in the experiment chamber (see the red markings in Fig. 4). The goniometer block with the analyzer crystal should be located at the end position on the right-hand side. Fasten the Geiger-Müller counter tube with its holder to the back stop of the guide rails. Do not forget to install the diaphragm in front of the counter tube (see Fig. 5).

Insert a diaphragm tube with a diameter of 2 mm into the beam outlet of the tube plugin unit.

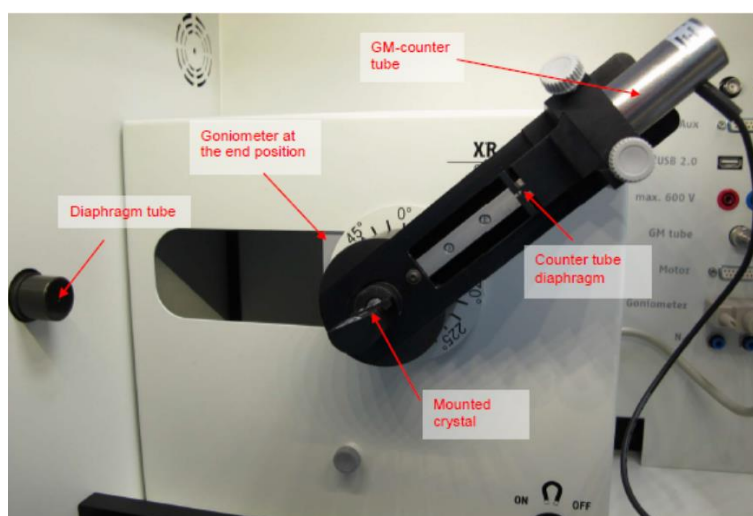Figure 4 Connectors in the experiment chamber

Figure 5 Set-up of the goniometer

Steps:

1. Connect the X-ray unit via the USB cable to the USB port of your computer (the correct port of the X-ray unit is marked in Figure 6).

2. Start the "measure" program. A virtual X-ray unit will be displayed on the screen.

3. You can control the X-ray unit by clicking the various features on and under the virtual X-ray unit. Alternatively, you can also change the parameters at the real X-ray unit. The program will automatically adopt the settings.

4. Click the experiment chamber (see the red marking in Figure 7) to change the parameters for the experiment. Select the parameters as shown in Figure 6 for the LiF crystal. If you use the KBr crystal, select a start angle of 3° and a stop angle of 75°.

5. If you click the X-ray tube (see the red marking in Figure 7), you can change the voltage and current of the X-ray tube. Select the parameters as shown in Fig. 8 and 9.

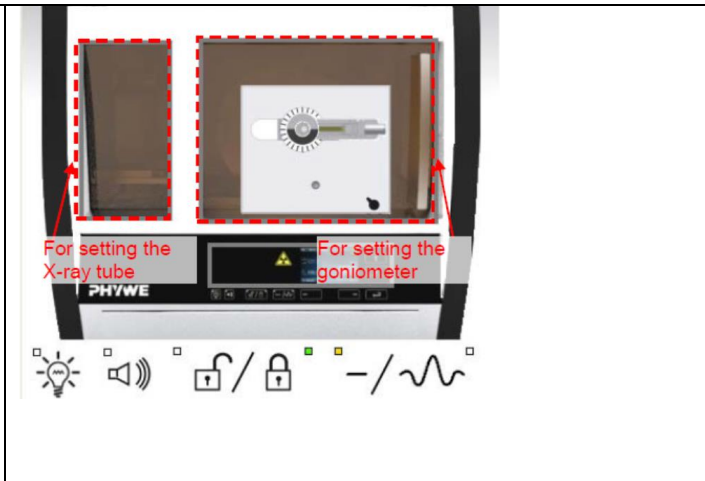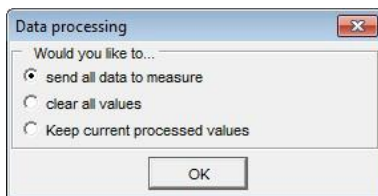|	
Figure 6 Connection of the computer	Figure 7 Part of the user interface of the software

6. Start the measurement by clicking the red circle:

7. After the measurement, the following window appears:

8. Select the first item and confirm by clicking OK. The measured values will now be transferred directly to the "measure" software.

Overview of the settings of the goniometer and X-ray unit:
-   1:2 coupling mode
-   Gate time 2 s; angle step width 0.1°
-   Scanning range 4°-55° (LiF monocrystal) and 3°-75° (KBr monocrystal)
-   Anode voltage U_A = 35 kV; anode current I_A = 1 mA
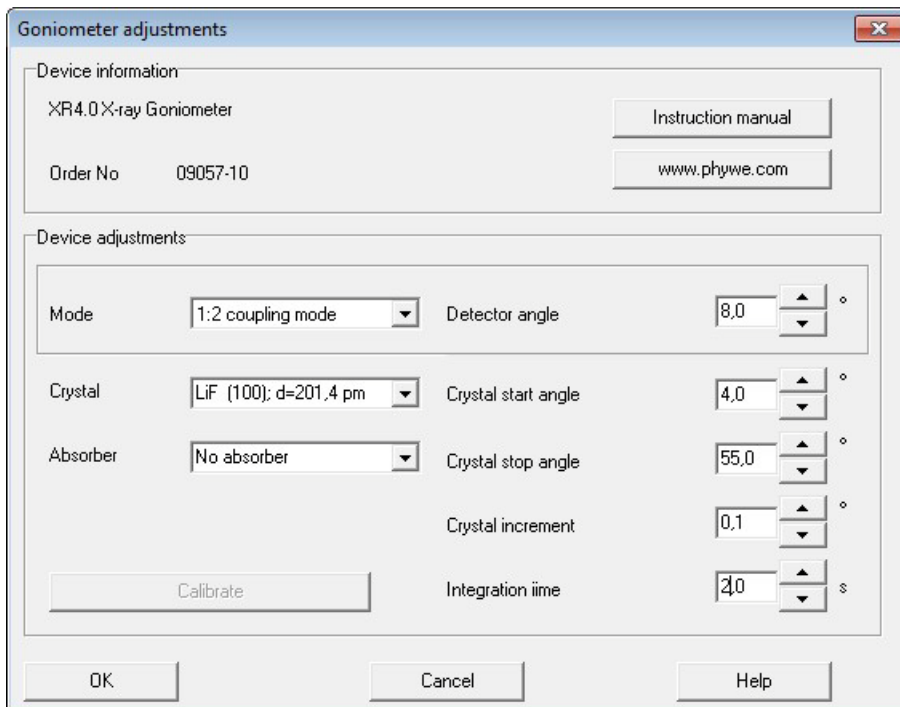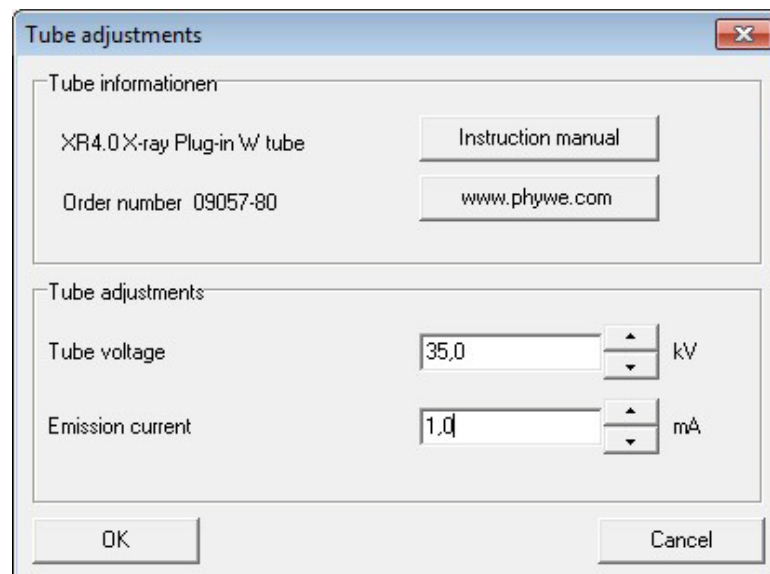
Figure 8 Settings of the goniometer (LiF crystal)

Figure 9 Voltage and current settings

OBSERVATIONS:

	θ (^{0})	Line	E_{exp} (KeV)
n=1			
n=2			

RESULTS AND DISSCUSION:

Task 1: *Analyze the intensity of the copper X-radiation as a function of the Bragg angle and with the aid of a LiF monocrystal.*

Task 2: *Determine the energy values of the characteristic X-rays of copper and compare them with the values that were determined based on the corresponding energy-level diagram.*

EXPERIMENT # 02

OBJECT:

Determine the energy values of the characteristic X-rays of copper and compare them with the values that were determined based on the corresponding energy-level diagram.

APPARATUS:

XR 4.0 expert unit	09057-99
X-ray goniometer	09057-10
X-ray plug-in unit with a copper X-ray tube	09057-50
Counter tube, type B	09005-00
X-ray lithium fluoride crystal, mounted in a holder	09056-05
X-ray potassium bromide crystal, mounted in a holder	09056-01
measure XRm 4.0 X-ray software	14414-61
Data cable USB, plug type A/B	14608-00
X-ray diaphragm tube, 2 mm	09057-02

THEORY:

The X-rays that are generated by an X-ray tube are polychromatic. Lines whose energies are not de-pendent on the anode voltage but on the anode ma-terial are superimposed on the bremsspectrum. Since some experiments (Debye-Scherrer experiments concerning crystal structures) require monochromatic X-radiation, this radiation is generated by filtration with monocrystals or with the aid of metal foils.

When X-rays of the wavelength λ impinge on the lattice planes of a monocrystal under the glancing angle θ, the rays that are reflected on the lattice planes interfere with each other in a constructive manner provided that their path difference corresponds to an integral multiple of the wavelength. This situation is explained by Bragg's law:

$$2dSin\theta = n\lambda \qquad (1)$$

(d = interplanar spacing; n = 1, 2, 3,…)

If the interplanar spacing d is known, the wavelength λ can be determined with the aid of the glancing angle θ. The energy of the radiation then results from:

$$E = \frac{hc}{\lambda} \qquad \qquad (2)$$

When combining (1) and (2), we obtain:

$$E = nhc/2dSin\theta \qquad \qquad (3)$$

Planck's constant   h $= 6.6256 \times 10^{-34}$ Js
Velocity of light   c $= 2.9979 \times 10^{8}$ m/s
Interplanar spacing   d $= 2.014 \times 10^{-10}$ m
LiF (200)
Equivalent   1 eV $= 1.6021 \times 10^{-19}$ J

PROCEDURE:

Setup:

The experimental setup is shown in Figure 1

Figure 1 XR 4.0 expert unit 09057-99

Connect the goniometer and the Geiger-Müller counter tube to their respective sockets in the experiment chamber (see the red markings in Fig. 2). The goniometer block with the analyzer crystal should be located at the end position on the right-hand side. Fasten the Geiger-Müller counter tube with its holder to the back stop of the guide rails. Do not forget to install the diaphragm in front of the counter tube (see Fig. 3).

Insert a diaphragm tube with a diameter of 2 mm into the beam outlet of the tube plugin unit.

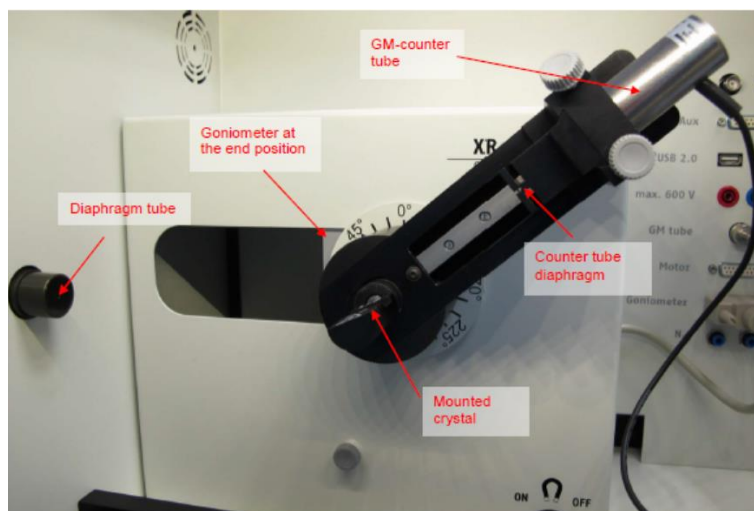Figure 2 Connectors in the experiment chamber

Figure 3 Set-up of the goniometer

Steps:

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2. Start the "measure" program. A virtual X-ray unit will be displayed on the screen.

3. You can control the X-ray unit by clicking the various features on and under the virtual X-ray unit. Alternatively, you can also change the parameters at the real X-ray unit. The program will automatically adopt the settings.

4. Click the experiment chamber (see the red marking in Figure 5) to change the parameters for the experiment. Select the parameters as shown in Figure 6 for the LiF crystal. If you use the KBr crystal, select a start angle of 3° and a stop angle of 75°.

5. If you click the X-ray tube (see the red marking in Figure 5), you can change the voltage and current of the X-ray tube. Select the parameters as shown in Fig. 6.

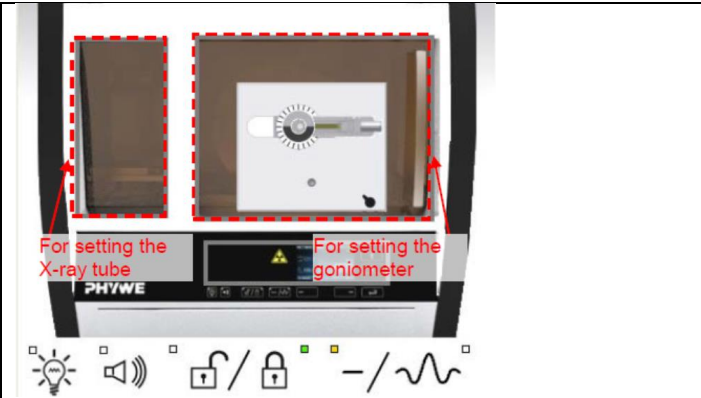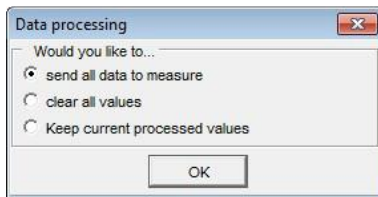|	
Figure 4 Connection of the computer	Figure 5 Part of the user interface of the software

6. Start the measurement by clicking the red circle:

7. After the measurement, the following window appears:

8. Select the first item and confirm by clicking OK. The measured values will now be transferred directly to the "measure" software.

Overview of the settings of the goniometer and X-ray unit:
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-   Gate time 2 s; angle step width 0.1°
-   Scanning range 4°-55° (LiF monocrystal) and 3°-75° (KBr monocrystal)
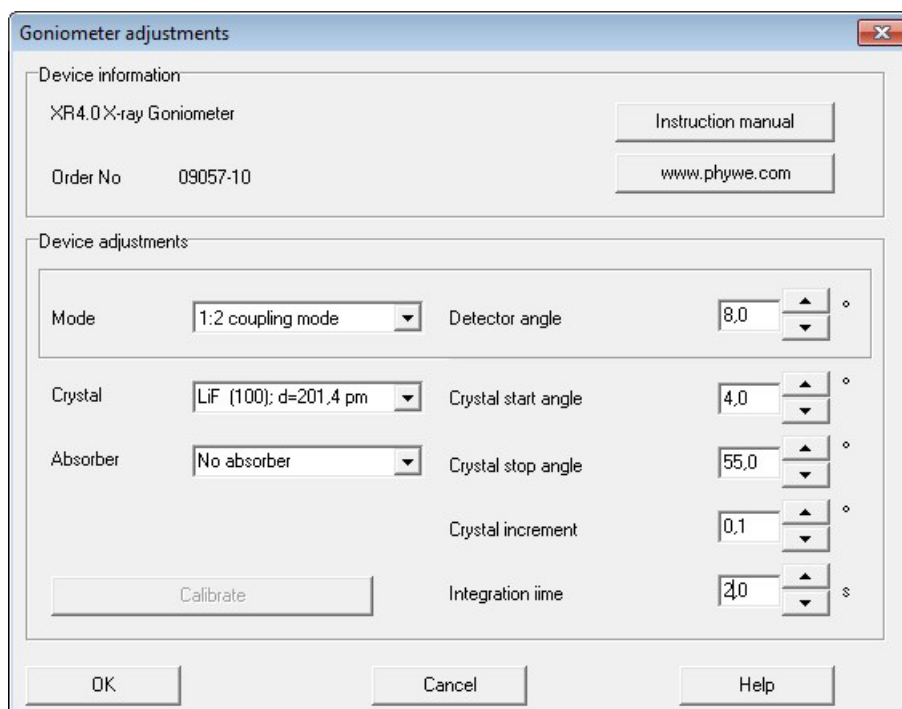-   Anode voltage U_A = 35 kV; anode current I_A = 1 mA

Figure 6 Settings of the goniometer (LiF crystal)

RESULTS AND DISSCUSION:

EXPERIMENT # 03

OBJECT:

To determine the lattice parameter of cubic crystalline material using XRD pattern.

MATERIAL:

Fine powders (-325 mesh, *<45/lm* in size) of chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), silicon (Si), and titanium nitride (TiN).

THEORY:

The size and shape of the unit cell determine the angular positions of the diffraction peaks, and the arrangement of the atoms within the unit cell determines the relative intensities of the peaks. Thus, it is possible to calculate the size and shape of the unit cell from the angular positions of the peaks and the atom positions in the unit cell (though not in any direct manner) from the intensities of the diffraction peaks.

Complete determination of an unknown crystal structure consists of three steps:

1. Calculation of the size and shape of the unit cell from the angular positions of the diffraction peaks.
2. Computation of the number of atoms per unit cell from the size and shape of the unit cell, the chemical composition of the spedmen, and its measured density.
3. Deduction of the atom positions within the unit cell from the relative intensities of the diffraction peaks

In this experimental module, we only do step 1.

Indexing the Pattern

"Indexing the pattern" involves assigning the correct Miller indices to each peak in the diffraction pattern. These peaks are also referred to as reflections, and as in Part I, we use both terms interchangeably. It is important to remember that correct indexing is done only when *all* the peaks in the diffraction pattern are accounted for and no peaks expected for the structure are missing from the diffraction pattern. A typical example of indexing diffraction patterns obtained from materials with a cubic structure is presented here. The procedure is the same for a metal, a semiconductor, or a ceramic.

The interplanar spadng *d,* the distance between adjacent planes in the set *(hkl)* of a material with a cubic structure and lattice parameter *a,* may be obtained from the equation

$$\frac{1}{d^2} = \frac{h^2 + k^2 + l^2}{a^2} \qquad (1)$$

Combining Bragg's law with Eq. (1) yields

$$\frac{1}{d^2} = \frac{h^2 + k^2 + l^2}{a^2} = \frac{4Sin^2\theta}{\lambda^2} \qquad (2)$$

Rearranging gives

$$Sin^2\theta = \left(\frac{\lambda^2}{4a^2}\right)(h^2 + k^2 + l^2) \qquad (3)$$

Realizing that $\frac{\lambda^2}{4a^2}$ is a constant for anyone pattern, we note that $Sin^2\theta$ is proportional to $h^2 + k^2 + l^2$; i.e., as θ increases, planes with higher Miller indices will diffract. Writing Eq. (3) for two different planes and dividing, we get

$$\frac{Sin^2\theta_1}{Sin^2\theta_2} = \frac{h_1^2 + k_1^2 + l_1^2}{h_2^2 + k_2^2 + l_2^2}$$

In the cubic system, the first reflection in the diffraction pattern is due to diffraction from planes with the Miller indices (100) for primitive cubic, (110) for body-centered cubic, and (III) for face-centered cubic lattices (planes with the highest planar density in each case), so $h^2 + k^2 + l^2 = 1, 2, or\ 3$ respectively. Since the ratio of $Sin^2\theta$ values scales with the ratio of $h^2 + k^2 + l^2$ values for different planes, and since *h, k,* and I are always integers, the $h^2 + k^2 + l^2$ values can be obtained by dividing the $Sin^2\theta$ values of different reflections with the minimum one (i.e., $Sin^2\theta$ of the first reflection) and multiplying the ratios thus obtained by an appropriate integer. Therefore, the $Sin^2\theta$ values calculated for all peaks in the diffraction pattern are divided by the smallest value (first reflection). These ratios, when multiplied by 2 or 3, yield integers (if they are not already integers).

Identification of the Bravais Lattice

The Bravais lattice can be identified by noting the systematic presence (or absence) of reflections in the diffraction pattern. Table 1 summarizes the selection rules (or extinction conditions as they are also known) for cubic lattices. According to these selection rules, the values $h^2 + k^2 + l^2$ for the different cubic lattices follow the sequence.

Primitive 1, 2, 3,4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 16, ...

Body-centered 2,4, 6, 8, 10, 12, 14, 16, ...

Face-centered 3,4, 8, 11, 12, 16, 19,20, 24, 27, 32, ...

CALCULATION:

The lattice parameter *a* can be calculated from

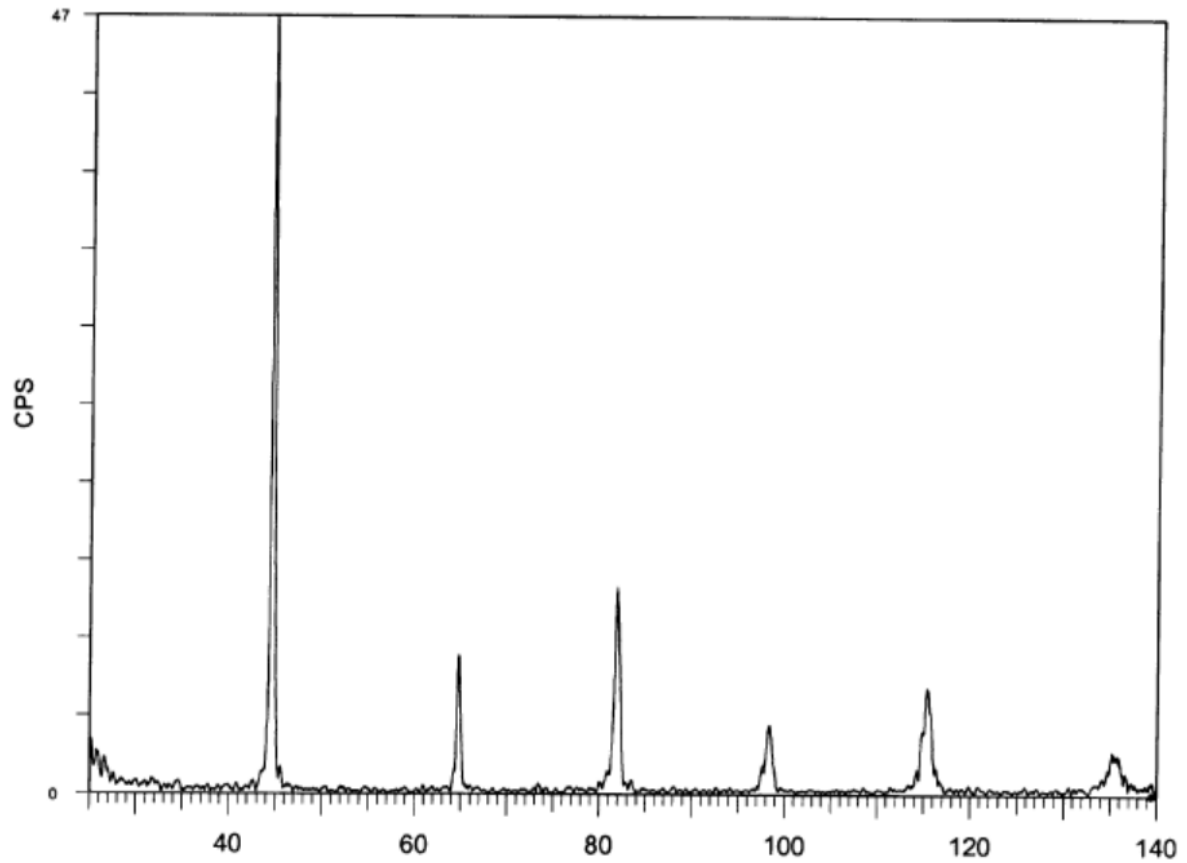$$a = \frac{\lambda}{2 Sin\theta}(h^2 + k^2 + l^2)^{1/2}$$

FIGURE1: X-RAY DIFFRACTION PATTERN FRO CHROMIUM

Material: Chromium   Radiation: CuKα $\lambda_{k\alpha 1} = 0.154056\ nm$

Peak#	2θ (°)	$Sin^2\theta$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}}$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\,2$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\,3$	$h^2 + k^2 + l^2$	hkl	a (nm)
1	44.41							
2	64.59							
3	81.77							
4	98.26							
5	115.34							
6	135.47							

Figure 2: X-ray diffraction of copper

Material: Copper   Radiation: CuKα $\lambda_{k\alpha 1} = 0.154056 \ nm$

Peak#	2θ (°)	$Sin^2\theta$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}}$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X \ 2$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X \ 3$	$h^2 + k^2 + l^2$	hkl	a (nm)
1	43.16							
2	50.30							
3	73.99							
4	89.85							
5	95.03							
6	116.92							
7	136.59							

Figure 3: X-ray diffraction pattern of iron.

Material: Iron   Radiation: CuKα $\lambda_{k\alpha 1} = 0.154056\ nm$

Peak#	2θ (°)	$Sin^2\theta$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}}$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\ 2$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\ 3$	$h^2 + k^2 + l^2$	hkl	a (nm)
1	44.73							
2	65.07							
3	82.40							
4	99.00							
5	116.45							
6	137.24							

Figure 4: X-ray diffraction of nickel.

Material: Nickel   Radiation: CuKα $\lambda_{k\alpha1} = 0.154056\ nm$

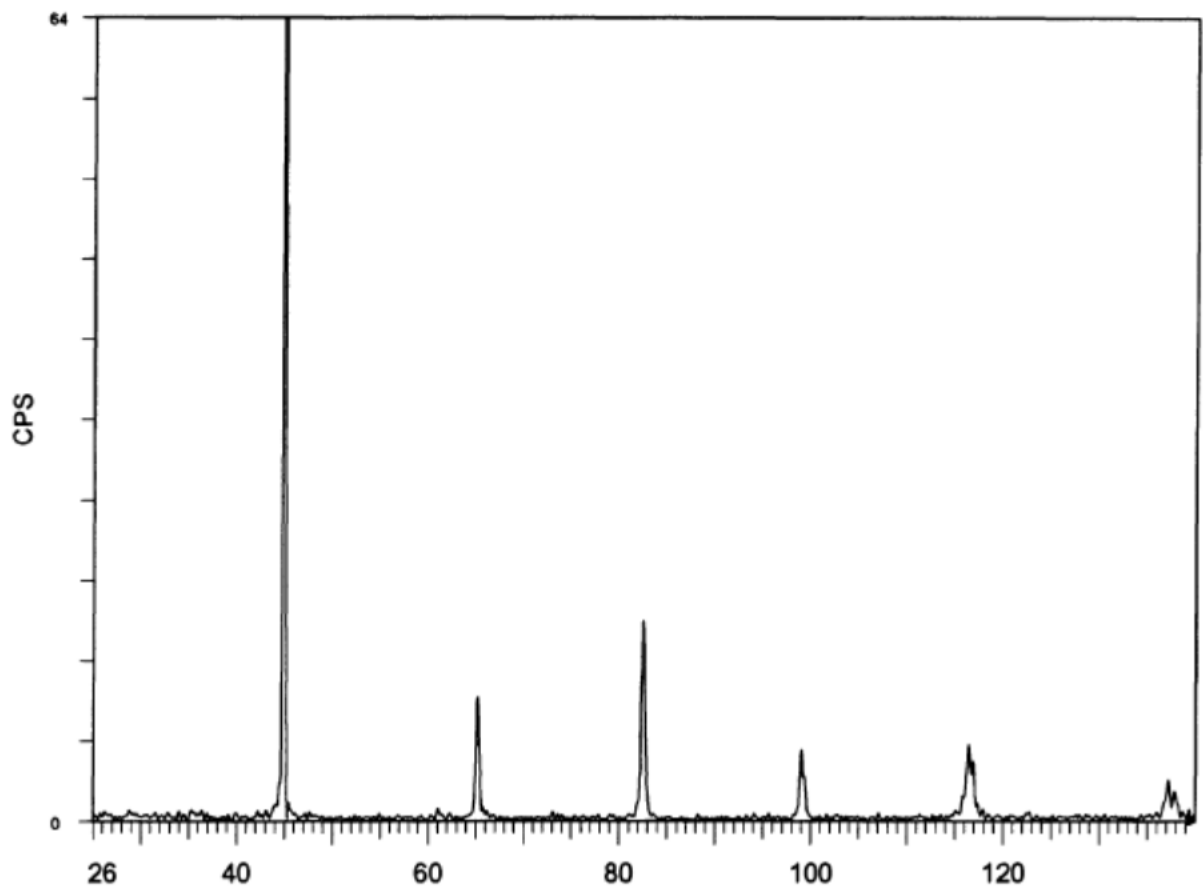| Peak#	2θ (°)	$Sin^2\theta$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}}$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\,2$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\,3$	$h^2 + k^2 + l^2$	hkl	a (nm)
1	44.53							
2	51.89							
3	76.45							
4	93.01							
5	98.51							
6	122.12							

Figure 5: X-ray diffraction pattern of Silicon

Material: Silicon   Radiation: CuKα $\lambda_{k\alpha1} = 0.154056\ nm$

Peak#	2θ (°)	$Sin^2\theta$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}}$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\ 2$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\ 3$	$h^2 + k^2 + l^2$	hkl	a (nm)
1	28.41							
2	47.35							
3	56.12							
4	69.10							
5	76.35							
6	88.04							
7	94.94							
8	106.75							
9	114.11							
10	127.56							
11	136.91							

Figure 7: X-ray diffraction of titanium nitride

Material: Titanium Nitride   Radiation: CuKα $\lambda_{k\alpha1} = 0.154056\ nm$

Peak#	2θ (°)	$Sin^2\theta$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}}$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\ 2$	$\dfrac{Sin^2\theta}{Sin^2\theta_{min}} X\ 3$	$h^2 + k^2 + l^2$	hkl	a (nm)
1	36.71							
2	42.67							
3	61.85							
4	74.12							
5	77.98							
6	93.30							
7	104.76							
8	108.61							
9	125.68							

EXPERIMENT # 04

OBJECT:

       To determine the permittivity of free space by using parallel plate capacitor.

Keywords:

       Maxwell's equations, electric constant, capacitance of a plate capacitor, real charges, free charges.

APPARATUS:

1	Plate capacitor, d 260mm
2	High-value resistor, 10 MOhm
3	PHYWE Universal measuring amplifier
4	PHYWE High voltage supply unit with digital display DC: 0... ± 10 kV, 2 mA
5	Capacitor 220nF/250V, G1
6	Voltmeter, 0.3-300 V DC, 10-300 V AC

THEORY:

       The electric constant is determined by measuring the charge of a plate capacitor to which a voltage is applied. The dielectric constant is determined in the same way, with plastic or glass filling the space between the plates.

       The charge Q of the capacitor is thus proportional to voltage U_c; the proportionality constant C is called the capacitance of the capacitor.

$$Q = CU_c = \varepsilon_o \frac{A}{d} U_c \qquad \text{------------------- (1)}$$

       The linear relation between charge Q and voltage U applied to the otherwise unchanged capacitor is represented in fig. 4.

Equation (1) further shows that the capacitance C of the capacitor is inversely proportional to the distance d between the plates:
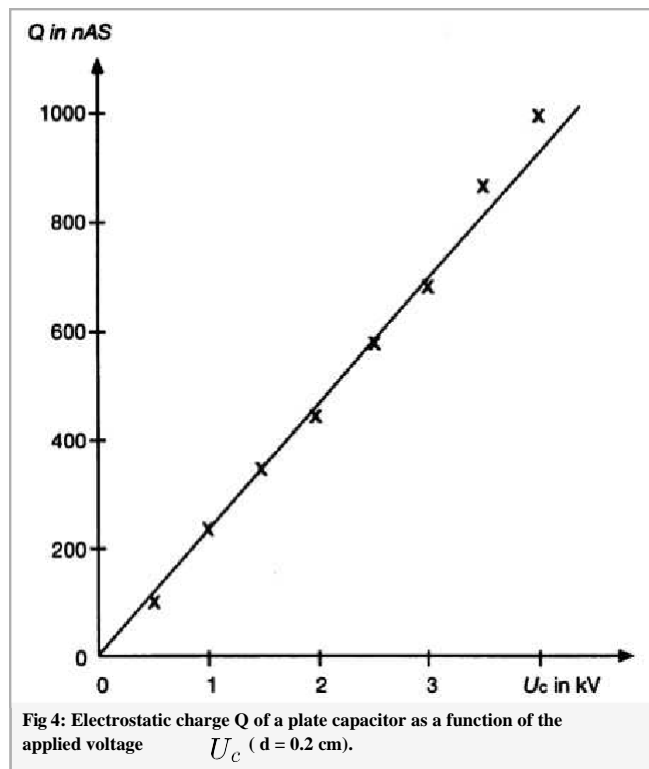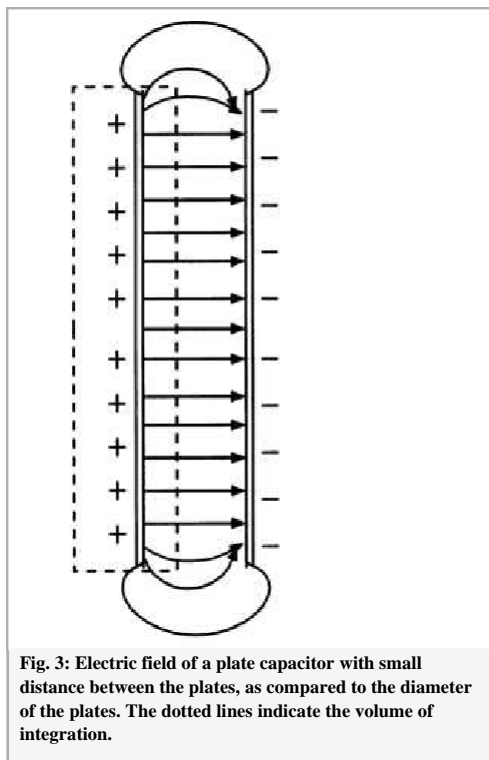
$$Q = \varepsilon . \varepsilon_o \frac{A}{d} U_c \qquad \text{----------------(2)}$$

25

For constant voltage, the inverse distance between the plates, and thus the capacitance, are a measure for the amount of charge a capacitor can take (cf. fig. 5). If inversely U, Q, A and d were measured, these measurement data allow to calculate the electric constant ε_0 :

$$\boxed{\varepsilon_o = \frac{d}{A}\frac{Q}{U_c}} \qquad \text{---------------(3)}$$

In this example of measurement, one obtains $\varepsilon_0 = 8.8 \times 10^{-12}$ As/(Vm), as compared to the exact value of $\varepsilon_0 = 8.8542 \times 10^{-12}$As/(Vm).

Equations (1), (2) and (3) are valid only approximately, due to the assumption that field lines are parallel. By too large distances.

Fig. 3: Electric field of a plate capacitor with small distance between the plates, as compared to the diameter of the plates. The dotted lines indicate the volume of integration.

Fig 4: Electrostatic charge Q of a plate capacitor as a function of the applied voltage U_c (d = 0.2 cm).

PRODEDURE:

The experimental set-up is shown in Fig. 1 and the corresponding wiring diagram in Fig. 2. The highly insulated capacitor plate is connected to the upper connector of the high voltage power supply over the 10 MΩ protective resistors. Both the middle connector of the high voltage power supply and the opposite capacitor

plate are grounded over the 220nF capacitor. Correct measurement of the initial voltage is to be assured by the corresponding adjustment of the toggle switch on the unit. The electrostatic induction charge on the plate capacitor can be measured over the voltage on the 220nF capacitor, according to equation (1).

The measurement amplifier is set to high input resistance, to amplification factor 1 and to time constant 0.

1. In a first step the plate capacitor is charged with the high voltage power supply.
2. In a second step (with the high voltage power supply disconnected!) the charge of the plate capacitor is measured.
3. the distance between the plates of the plate capacitor is varied under constant voltage, and the charge on the capacitor plates is measured. The linear relation between charge and plate capacitor voltage is then verified.
4. Plot the graph between Q and U_c and make calculation from it.

Figure 1: Measurement set-up: Dielectric constant of different materials.

OBSERVATIONS:

Area of Plate(A)= <u>0.0531m^2</u>,   d=_____,   C= <u>218nF</u>

S.No.	U_c (kV)	U(V)	Q = CV (C)	ε_o
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

CALCULATION:

$$\varepsilon_o = \frac{d}{A}\frac{Q}{U_c}$$

Calculation from the graph

RESULTS:

PRECAUTIONS:

Be sure not to be near the capacitor during measurements, as otherwise the electric field of the capacitor might be distorted.
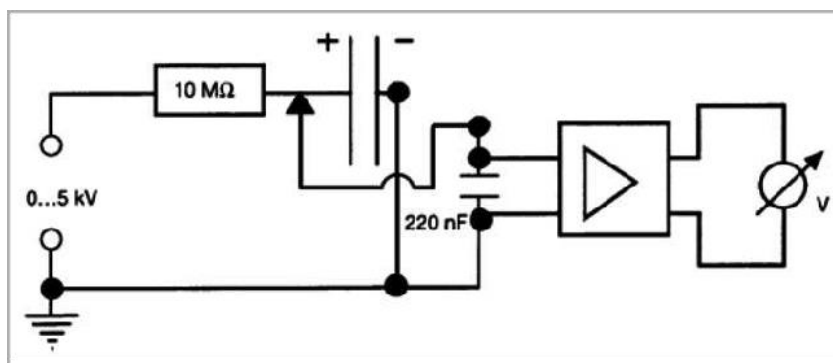
CIRCUIT DIAGRAM:

Figure 2: Wiring diagram

__Graph Paper__

EXPERIMENT # 05

OBJECT:

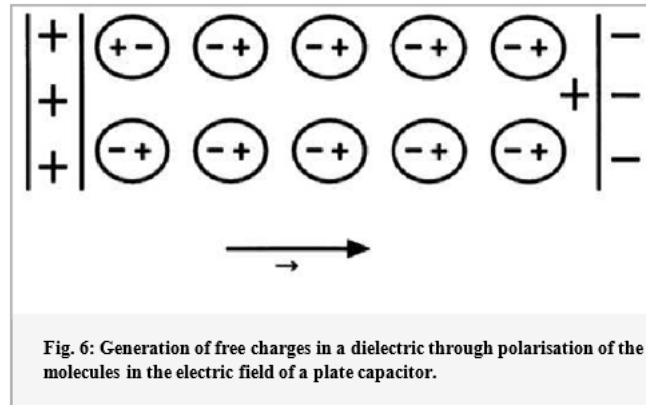To determine the dielectric constant of given material by using parallel plate capacitor.

APPARATUS:

1	Plate capacitor, d 260 mm
2	Plastic plate 283 x 283 mm
3	Glass plates
4	High-value resistor, 10 MOhm
5	PHYWE Universal measuring amplifier
6	PHYWE High voltage supply unit with digital display DC: 0... ± 10 kV, 2 mA
7	Capacitor 220nF/250V, G1
8	Voltmeter, 0.3-300 V DC, 10-300 V AC

THEORY:

The electric constant is determined by measuring the charge of a plate capacitor to which a voltage is applied. The dielectric constant is determined in the same way as we did in the previous experiment, with plastic or glass filling the space between the plates.

Things change once insulating material (dielectrics) are inserted between the plates. Dielectrics have no free moving charge carriers, as metals have, but they do have positive nuclei and negative electrons. These may be arranged along the lines of an electric field. Formerly nonpolar molecules thus behave as locally stationary dipoles. As can be seen in fig. 6, the effects of the single dipoles cancel each other macroscopically inside the dielectric. However, no partners with opposite charges are present on the surfaces; these thus have a stationary charge, called a free charge.

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Fig. 6: Generation of free charges in a dielectric through polarisation of the molecules in the electric field of a plate capacitor.

The free charges in turn weaken the electric field E of the real charges Q, which are on the capacitor plates, within the dielectric.

The weakening of the electric field E within the dielectric is expressed by the dimensionless, material specific dielectric constant ε (ε = 1 in vacuum):

$$\vec{E} = \frac{\vec{E_0}}{\varepsilon} \qquad \text{----------------(4)}$$

where $\vec{E_0}$ is the electric field generated only by the real charges Q. Thus, the opposite field generated by the free charges must be

$$\vec{E}_f = \vec{E}_0 - \vec{E} = \frac{\varepsilon-1}{\varepsilon}\vec{E}_0 \qquad \text{-------------(5)}$$

Neglecting the charges within the volume of the dielectric macroscopically, only the free surface charges ($\pm Q_f$) generate effectively the opposite field:

$$E_f = \frac{Q_f}{A\varepsilon_0} = \frac{Q_f \cdot d}{V\varepsilon_0} = \frac{p}{V\varepsilon_0} \qquad \text{-----------(6)}$$

where p is the total dipole moment of the surface charges. In the general case of an inhomogeneous dielectric, equation (6) becomes:

$$\vec{E}_f = \frac{1}{\varepsilon_0} \int \frac{d\vec{P}}{dV} = \frac{1}{\varepsilon_0}\vec{P} \qquad \text{-------------(7)}$$

Where $\vec{P}$ -total dipole moment per unit volume – is called dielectric polarization.

If additionally, a $\vec{D}$ -field (dielectric displacement) is defined:

$$\vec{D} = \varepsilon \cdot \varepsilon_0 \cdot \vec{E} \text{ ------------(8)}$$

whose field lines only begin or end in real (directly measurable) charges, the three electric magnitudes, field intensity $\vec{E}$, dielectric displacement $\vec{D}$ and dielectric polarization $\vec{P}$ are related to one another through the following equation:

$$\vec{D} = \varepsilon_0 \cdot \vec{E} + \vec{P} = \varepsilon \cdot \varepsilon_0 \cdot \vec{E} \text{ ---------(9)}$$

If the real charge Q remains on the capacitor, whilst a dielectric is inserted between the plates, according to definition, voltage U_c between the plates is reduced as compared to voltage U_{vac} in vacuum (or to a good approximation, in air) by the dielectric constant:

$$U_C = \frac{U_{vac}}{\varepsilon} \text{ --------------(10)}$$

Similarly, one obtains from the definition of capacitance in previous experiment (1):

$$C = \varepsilon \cdot C_{vac} \text{ ------------(11)}$$

The general form of equation (4) is thus:

$$Q = \varepsilon \cdot \varepsilon_0 \cdot \frac{A}{d} \cdot U_c \text{ ----------(12)}$$

In Fig. 7, charge Q on the capacitor is plotted against the applied plate voltage U_c for comparison to the situation with and without plastic plate between the capacitor plates, all other conditions remaining unchanged: thus, for the same voltage, the amount of charge of the capacitor is significantly increased by the dielectric, in this example by a factor of 2.9.

If the charges obtained with and without plastic (equations [1] and [12]) are divided by each other:

$$\frac{Q_{plastic}}{Q_{vacuum}} = \varepsilon$$

the obtained numerical value is the dielectric constant of the plastic.

For the glass plates, a value of $\varepsilon = 9.1$ is obtained similarly.

PRODEDURE:

1. The dependence of the electrostatic induction charge from voltage, with and without plastic plate (without air gap), is examined in the space between the plates, with the same distance between the plates. The ratio between the electrostatic induction charges allows to determine the dielectric constant of plastic. The dielectric constant of the glass plate is determined in the same way.

   The experimental set-up is shown in Fig. 1 and the corresponding wiring diagram in Fig. 2. The highly insulated capacitor plate is connected to the upper connector of the high voltage power supply over the 10 MΩ protective resistors. Both the middle connector of the high voltage power supply and the opposite capacitor plate are grounded over the 220nF capacitor. Correct measurement of the initial voltage is to be assured by the corresponding adjustment of the toggle switch on the unit. The electrostatic induction charge on the plate capacitor can be measured over the voltage on the 220nF capacitor, according to equation (1). The measurement amplifier is set to high input resistance, to amplification factor 1 and to time constant 0.

2. the whole procedure as explained in point 1 is to be performed twice:
   (i)   With the placement of dielectric medium between the plates.
   (ii)   Without the placement of dielectric medium between the plates but having same separation between the plates (same value of d).

3. Plot the graph between charge(Q) and voltage (U_c) for both the cases on same graph paper and make calculation from it.

OBSERVATIONS:

Area of Plate(A)= 0.0531m^2 ,   d=_____ ,   C= _218nF_

S.No.	U_c (kV)	U(V)	Q = CU (C)	U'	Q'= CU' (C)	ε_r = Q'/Q
		Without dielectric medium		With dielectric medium		
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

CALCULATION:

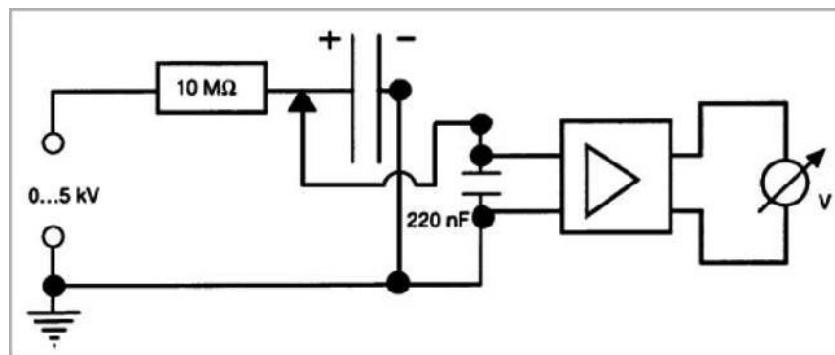$$\varepsilon_r = \frac{Q'}{Q}$$

Calculation from the graph

RESULT:

PRECAUTIONS:

Be sure not to be near the capacitor during measurements, as otherwise the electric field of the capacitor might be distorted.

CIRCUIT DIAGRAM:

PHOTOGRPAH OF THEAPPARATUS

__Graph Paper__

EXPERIMENT # 06

OBJECT:

To determine charge carrier density of given semiconductor using Hall's effect.

APPARATUS:

1	Hall effect module,	11801-00
1	Hall effect, p-Ge, carrier board	11805-01
2	Coil, 600 turns	06514-01
1	Iron core, U-shaped, laminated	06501-00
1	Pole pieces, plane, 30×30×48 mm, 2	06489-00
1	Hall probe, tangent., prot. cap	13610-02
1	Power supply 0-12 V DC/6 V, 12 V AC	13505-93
1	Tripod base -PASS-	02002-55
1	Support rod -PASS-, square, l = 250 mm	02025-55
1	Right angle clamp -PASS-	02040-55
3	Connecting cord, l = 500 mm, red	07361-01
2	Connecting cord, l = 500 mm, blue	07361-04
2	Connecting cord, l = 750 mm, black	07362-05
1	Teslameter, digital	13610-93
1	Digital multimeter	07134-00

THEORY:

If a current I flows through a conducting strip of rectangular section and if the strip is
traversed by a magnetic field at right angles to the direction of the current, a voltage – the so-called Hall voltage – is produced between two superposed points on opposite sides of the strip.

This phenomenon arises from the Lorentz force; the charge carriers giving rise to the current flowing through the sample are deflected in the magnetic field B as a function of their sign and their velocity v:

$$F = e\,(\vec{v} \times B)$$

(F = force acting on charge carriers, e = elementary charge).
Since negative and positive charge carriers in semiconductors move in opposite directions, they are deflected in the same direction.
The type of charge carrier causing the flow of current can therefore be determined from the polarity of the Hall voltage, knowing the direction of the current and that of the magnetic field.
With the directions of control current and magnetic field shown in Fig. 1, the charge carriers giving rise to the current in the sample are deflected towards the front edge of the sample. Therefore, if (in an n-doped probe) electrons are the predominant charge carriers, the front edge will become negative, and, with hole conduction in a p-doped sample, positive.

The conductivity σ_0, the charge-carrier mobility μ, and the charge-carrier concentration p are related through the Hall constant R_H:

$$R_H = \frac{U_H}{B}\frac{d}{I}$$

$$\mu = R_H\sigma_0$$

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

Where, U_H is the Hall's Voltage, d is the thickness of the sheet and B is the magnetic field strength.
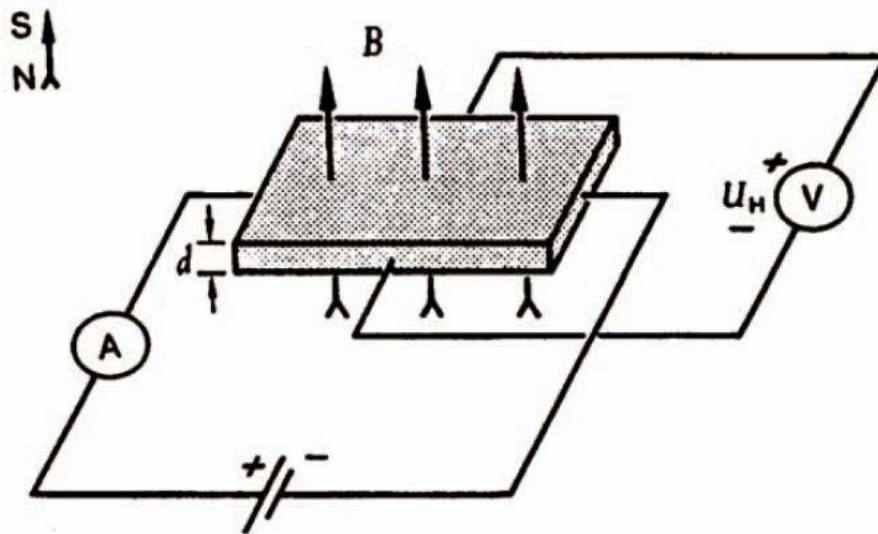

Figure 1: Hall effect in sample of rectangular section. The polarity sign of the Hall voltage shown applies when the carriers are negatively charged.

PRODEDURE:

1. Set up the experiment as shown in Fig. 2.
2. Set the current to a value of 30 mA. Connect the multimeter to the sockets of the hall voltage (U_H) on the front-side of the module. Determine the Hall voltage as a function of the magnetic induction. Start with −300 mT by changing the polarity of the coil-current and increase the magnetic induction in steps of nearly 20 mT. At zero point, you have to change the polarity. A typical measurement is shown in Fig. 3.
3. Plot a graph between U_H and B. The regression line formula for the graph is the regression line with the formula

$$U_H = U_0 + b \cdot B$$
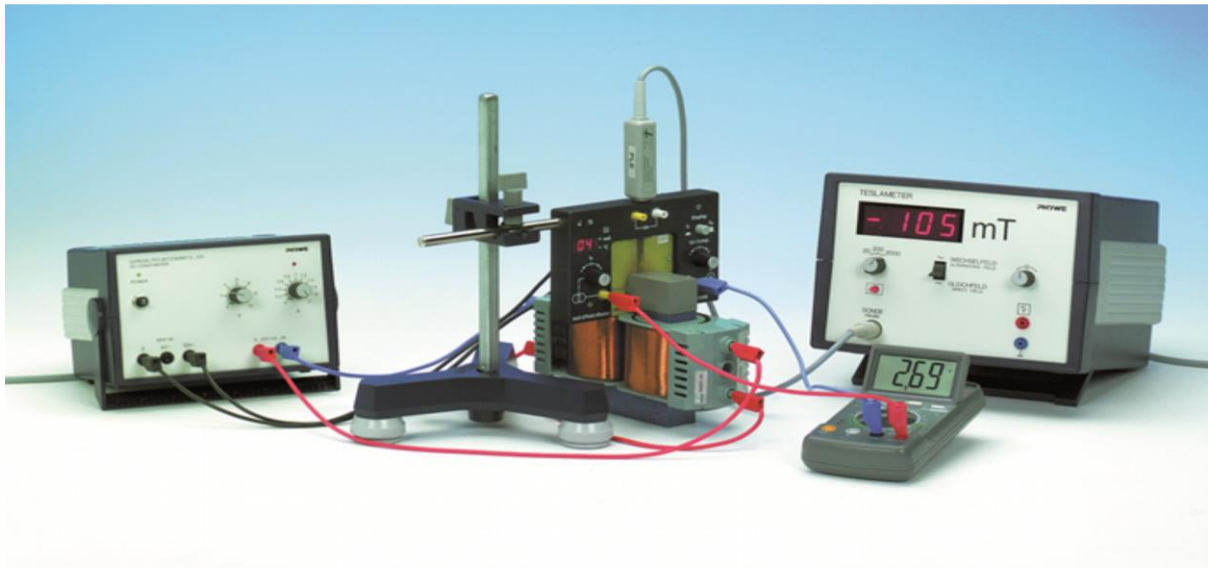
4. Find the slope of the graph to find the value of b.
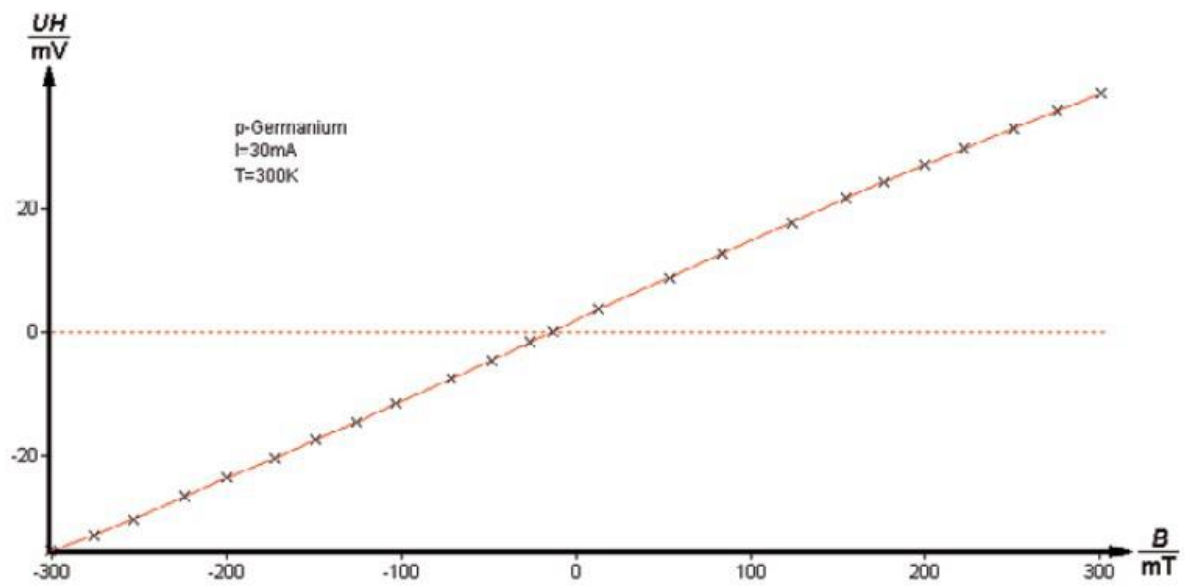
Figure 2: Experimental set-up

Figure 3: Hall voltage as a function of magnetic induction.

OBSERVATIONS:

d= _____ ,   I = _____

S. No.	B (mT)	U_H(mV)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

CALCULATION:

RESULT:

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__Graph Paper__

EXPERIMENT # 07

OBJECT:

To study the damped harmonic motion of an oscillator and the types of damping through software/programming tool.

WORKING FORMULA:

$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0$$

Characteristic root of the above equation is as follows

$$D = \frac{-b \pm \sqrt{b^2 - 4mk}}{2m}$$

Types of damping

$b^2 - 4mk > 0$, over damped

$b^2 - 4mk = 0$, critically damped

$b^2 - 4mk < 0$, underdamped

Solution for critical damping

$$x1 = Ae^{\frac{-bt}{2m}}$$

Solution for under damped

$$x2 = Be^{\frac{-bt}{2m}}\cos(\omega' t + \varphi)$$

Angular frequency

$$\omega' = \frac{\sqrt{b^2 - 4mk}}{2m}$$

Where 'A' and 'B' are the amplitudes, 'b' is the damping constant, 't' is the time, 'ф' is the phase shift, 'm' is the mass and 'k' is the spring constant.

Conclusion

EXPERIMENT # 08

OBJECT:

To model an ODE based physical phenomena by using a programming language.