EXPERIMENT -6

AIM:

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

1. The relation between Q and Voltage V accross a parrallel plate capacitor is observed
2. Electric constant (εo) is calculated using the relation found between Q and V
3. The dependance of charge deposited on a capacitor on the distance between the plates is observed
4. Relation between Q and V for capacitor is dielectrics in between its plates is measured. This is used to calculate ε values for plastic and glass respectively.

EQUIPMENT USED:

- High Power Voltage supply (0-10kV)
- Parallel plate capacitor setup
- 10 MΩ resistor
- Multimeter
- 220nF Capacitor
- connecting wires
- dielectric sheets of plastic and glass (thickness 1cm)

THEORY:

General Procedure:

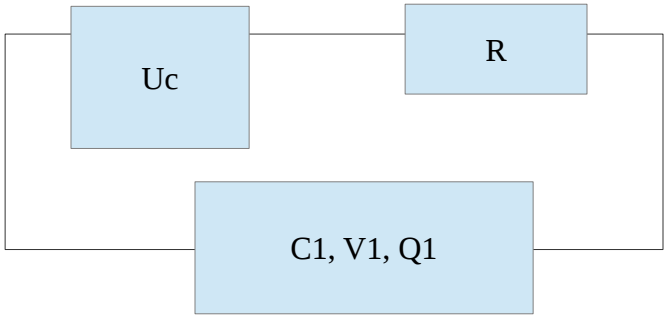
Convention used:

Uc	Source Voltage in kV
C1	Parallel Plate capacitor of unknown capacitance
Q1	Charge on C1
V1	Potential accross C1
C2	220 nF Capacitor
Q2	Charge accross C2
V2	Potential accross C2

Note:

- Uc is varied on the source voltage
- V2 is measured using potentiometer

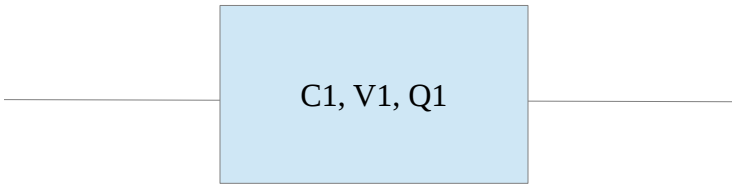
At t=0 =>potential Accross C1 is V1, Charge on it is Q1, the source voltage being Uc



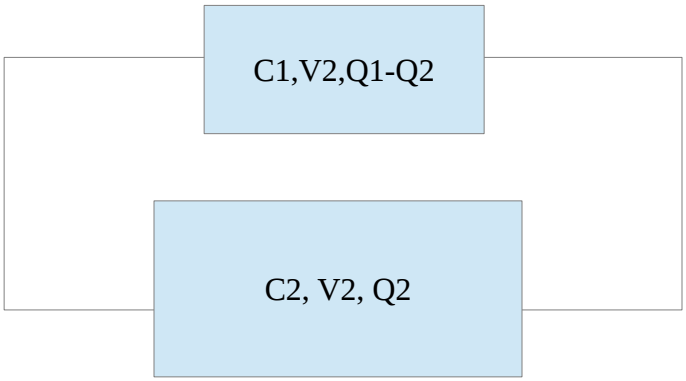
Uc=I*R+Q1/C1

After the capacitor is charged(steady state), it behaves like open circuit, hence I=0 => Uc=Q1/C1=V1

At t=T, The capacitor is disconnected.



The capacitor is connected instantaneously to 220nF Capacitor (C2)



We know, accross a capacitor => Q= CV
Hence,

from C1 => Q1-Q2=C1*V2

from C2 => Q2=C2*V2

This gives, Q1-C2*V2=C1*V2

=>V2(C1+C2)=Q1

V2(C1+C2)=C1V1

=>V1=V2(C1+C2)/C1

Let us **assume:** C1<<C2 => C1+C2 is almost equal to C2 [see note]

V1=V2*C2/C1

=> Uc=V2*C2/C1, Hence a V2 is directly proportional to Uc.

Also since, C1<<C2 => V2<<V1

Hence it is reasonable that V1 values are in kV (being equal to Uc) while our observed values(V2) were small (in Volts).

The reason why a high capacitance was used for C2 as compared to C1, was to get rasonably low values of V2, enabling higher precision of observation through the voltmeter(multimeter).

Note: Our assumption of C1<<C2 was based on our calculation of C1 using the formlua
C= εoA/d
where εo=8.85x10E-12 F/m

A=0.0531 m^2

d=0.2cm

The value of C1 comes to 0.0469 nF which is much less than 220nF

Dependence of C on d(distance between plates)

Since C = εoA/d
The relation between C and 1/d should be linear.
The electric constant (εo) is defined as the capacitance of a capacitor of unit area and unit distance between the plates, when the dielectric between them is air.

We know, C= εoA/d

=>εo=C*d/A

Units of εo: F/m

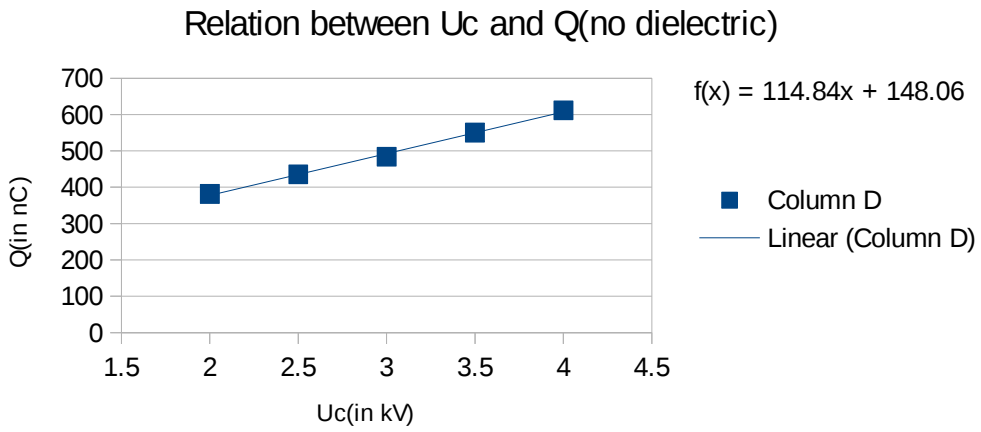
A is taken as (given)= 0.0531 m^2

OBSERVATION AND CALCULATIONS:

The four tasks yielded results depicted by the following graphs:

Task 1: Determination of the relation between charge on capacitor (Q) and source voltage (Uc)

Dieledctric: Air		D: 0.2cm	C1(nF): 220
Sr. No	Uc(kV)	V2	Q(nC)
1	2	1.735	381.7
2	2.5	1.98	435.6
3	3	2.2	484
4	3.5	2.5	550
5	4	2.78	611.6



The linear nature of the graph reflects direct proportionality between the potential accross the capacitor and the charge on it.
Possible causes for diviation: A non zero Y intercept is observed, But it is quite small (148 nC) and within the limits of experimental error. There residual charge on the plates even at zero source potential could be due charge retention on the plates or deviation in observed values due to environmental causes.

Task 2:

From 1, the slope=114.84. This is equal to the capacitance of the capacitor in air.

We know, C= εoA/d

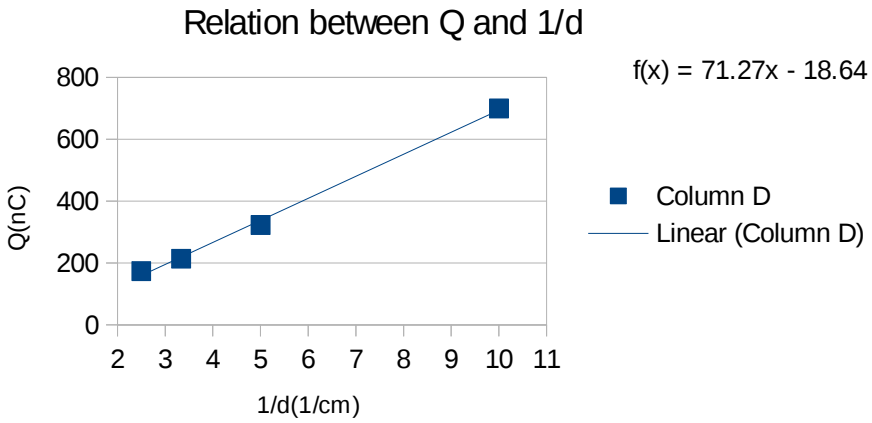
E0=C*d/A=(Q*d/Uc*A)

Dieledctric: Air		D: 0.2cm	C1(nF): 220	
Sr. No	Uc(kV)	V2	Q(nC)	E0
1	2	1.735	381.7	7.19
2	2.5	1.98	435.6	6.56
3	3	2.2	484	6.08
4	3.5	2.5	550	5.92
			Average:	6.44

Hence we calculate εo=6.44 E-9 F/m

Task 3: Determination of the relation between charge on capacitor (Q) and 1/d (where d is the separation between plates)

d(cm)	1/d(cm inv)	V2	Q2(=C2V2)
0.4	2.5	0.791	174.02
0.3	3.3333333333	0.972	213.84
0.2	5	1.467	322.74
0.1	10	3.18	699.6



It is obseved that the charge on the capacitor increases with increase in 1/d, i.e decrease in d, the distance between the plates. The potential accross the plates is kept constant

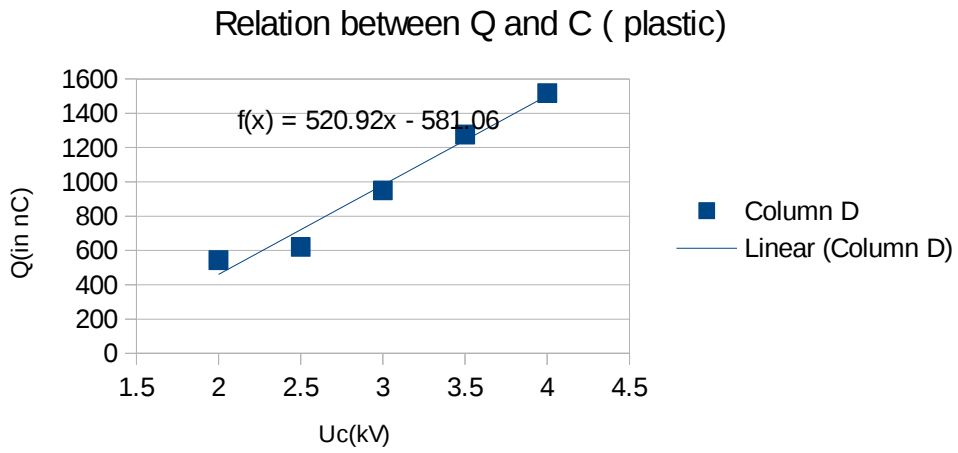
Task 4: Determination of the relation between charge(Q) and source voltage(Uc) with

i. Plastic as dielectric

Observation table:

dielectric: Plastic d: 1cm C1(nF): 220

Sr. No	Uc(kV)	V2	Q2(=C2V2)
1	2	2.47	543.4
2	2.5	2.821	620.62
3	3	4.32	950.4
4	3.5	5.8	1276
5	4	6.9	1518



Determination of E value is done using the relation C=Eo.E.A/d
The following are the calculations:

dielectric: Plastic d: 1cm C1(nF): 220

Uc(kV)	V2	Q2(=C2V2)	E.Eo
2	2.47	543.4	10.23
2.5	2.821	620.62	9.35
3	4.32	950.4	11.93
3.5	5.8	1276	13.73
4	6.9	1518	14.29
		Average:	11.91

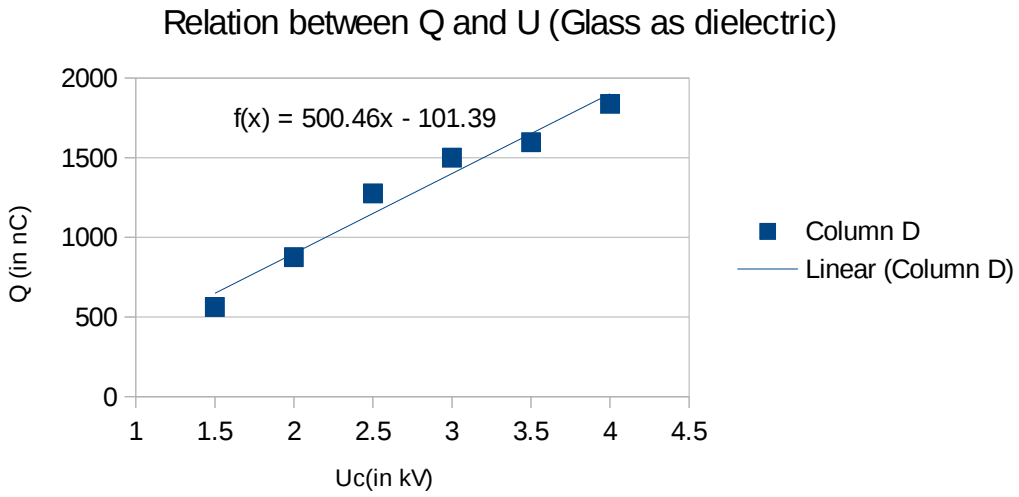
E.Eo=11.91 nF/m
Eo from Task 1=> 6.44
So, E=11.91/6.44
E=1.85

Determination of the relation between charge (Q) and source voltage (Uc) with glasss as dielectric.

Observations:

dieledctric: Glass d: 1cm C1(nF): 220

Sr. No	Uc(kV)	V2	Q2(=C2V2)
1	1.5	2.56	563.2
2	2	3.98	875.6
3	2.5	5.8	1276
4	3	6.819	1500.18
5	3.5	7.26	1597.2
6	4	8.35	1837



Calculation of E value for glass is done as follows:

E=C*d/A=(Q*d/Uc*A)

dielectric: Glass d: 1cm C1(nF): 220

Uc(kV)	V2	Q2(=C2V2)	E.Eo
2.5	5.8	1276	19.22
3	6.819	1500.18	18.83
3.5	7.26	1597.2	17.19
4	8.35	1837	17.30
		Average:	18.136090934

E.Eo=18.13 nF/m

Eo from Task 1=> 6.44

So, E=18.13/6.44

E=2.846

INFERENCE:

- When the voltage of the source was increased, while keeping the separation between the plates(d) constant, the charge on the capacitor increased. The plot for Q vs Uc revealed a linear relation. This implies, Q=k*Uc, where k depends only on the properties of the capacitor. Capacitance does not depend on the source voltage.

- The electric constant was calculated from the slope (which is the capacitance of the capacitor). Eo is given by slope*d/A. This was found to be 6.44 E-9 F/m

- The distance between the plates was changed while keeping the voltage fixed, thus changing the capcitance. With increasing d, charge Q on the capacitor decreased, when Q was plotted against 1/d it gave a linear graph. Implying Q is directly proportional to 1/d, at constanct voltage. That is, Capacitance in inversely porportional to d.

- When using dielectrics such as plastic and glass instead of air between the plates the capacitance changed (by a factor called the dielectric constant twhich is independent of the source voltage or the distance between the plates). Since charge on the capacitor is proportional to the capacitance the charge was more with the dielectric for a given value of voltage than it would have been with air in between. Different dielectrics have a different capacitance for the same distance d and area A. The dielectric contance of plastic was found to be _____and glass was found to be .

POSSIBLE CAUSES OF ERROR:

- Residual charge: Inherent error in our method due to the assuption that the capacitor is completely discharged (which is not true as shown in the theory) but only a viable assumption is that the capacitance is much lesser than 220nF
- Systematic error: In the power source, multimeter and the scale to measure ‘d’
- Error in measurement: The first reading observed on the voltmeter is to be measured, which could be wrong due to human error in instantaneous measurent, leading to the second reading to be measured which is considerably lower due to exponential
- Charge dissipation : There is always a certain time gap betwee removing of the pins from the capacitor and discharging it, or to measuring it, which could lead to loss in charge.

- Leakage current : Through the table or accidental contact of pins

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