R.V. COLLEGE OF ENGINEERING®

OBSERVATION / DATA SHEET

Date 15|5|25 Name Avishkar More

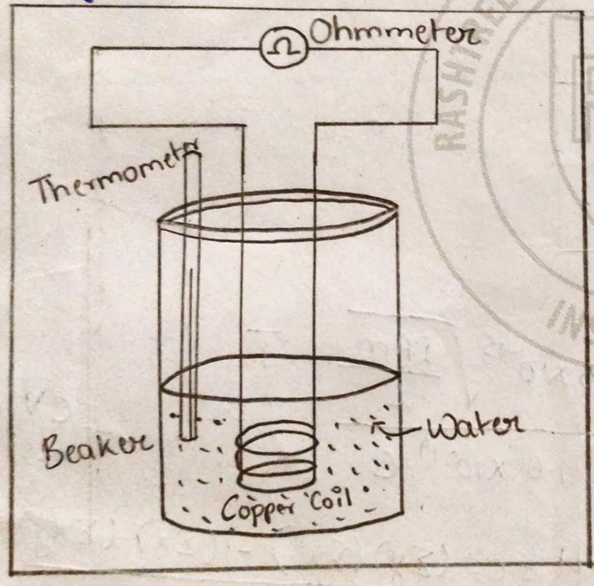
Dept./Lab Physics LAB B1 Class CY B1 Expt./No. 7

Title Fermi Energy of Copper

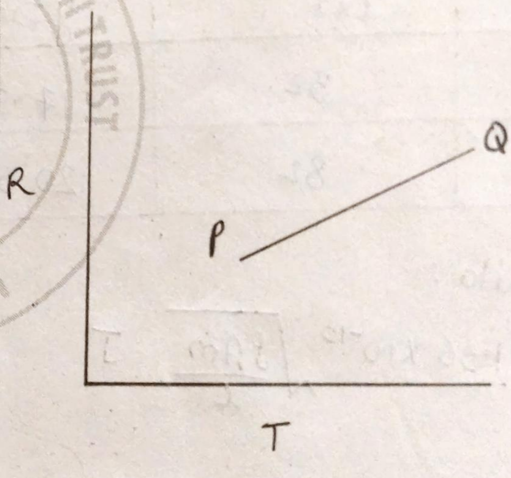
Aim: To determine the Fermi energy of copper

Apparatus: Multi meter, Beaker, Thermometer and Copper wire.

Diagram:



Graph:



Particulars	Max Marks	Marks Obtained	Faculty Signature
Data Sheet + Experimental setup + Viva Voce	10	3+6	Rg
Conduction of Experiment	10	9	
Substitution + Calculation + Accuracy	10	10	Rg
Total Marks	30	28	

Rg

Signature of Teacher Incharge

Sl. No.	Temp (°C) (x)	R (Ω) (y)	x^2	xy
Room Temp	29.7	17.~~83~~ 5	882.09	519.75
1	85	20.7	7225	1759.5
2	80	20.4	6400	1632
3	75	20.1	5625	1507.5
4	70	19.7	4900	1379
5	65	19.4	4225	1261
6	60	19.1	3600	1146
Sums	$\Sigma x = 681.7$	$\Sigma y = 227.5$	$\Sigma x^2 = 43,232.09$	$\Sigma xy = 13,304.25$

Point	Temperature (x)	Resistance (y) $y = mx + c$
P	32	17.39 ≈ 17.4
Q	82	20.56 ≈ 20.6

Formula:

$$E_F = 1.36 \times 10^{-15} \sqrt{\frac{\rho A m}{l}} \text{ J}$$

$$E_F = \frac{1.36 \times 10^{-15} \sqrt{\frac{\rho A m}{l}} \text{ J}}{1.6 \times 10^{-19} \text{ C}}$$

$$\text{Slope} = m = \frac{n\Sigma xy - (\Sigma x)(\Sigma y)}{n\Sigma x^2 - (\Sigma x)^2}$$

$$\text{Intercept} = c = \frac{(\Sigma y)(\Sigma x^2) - (\Sigma x)(\Sigma}{n(\Sigma x^2) - (\Sigma x)^2}$$

Explain the terms

A: Araa of coil $= \pi R^2$ — Diameter

m: Slope of graph — Radius (R) =

ρ: Density $= 8960$ Kg/m^3

l: length of coil $= 15$ m

E_F: Fermi Energy of copper coil

R.V. COLLEGE OF ENGINEERING ®

OBSERVATION / DATA SHEET

Date 15/5/25 Name Avishkar More

Dept./Lab Physics Lab B1 Class CY B1 Expt./No. ~~8~~ 7

Title Fermi Energy of Copper

Table: (continuation)

	(t) Temp (x)	R (Ω)	x^2	xy
7	55	18.7	3025	1028.5
8	50	18.4	2500	920
9	45	18.2	2025	819
10	40	17.9	1600	716
11	35	17.6	1225	616

Calculations:

$$m = \frac{12(13304.25) - (689.7)(227.5)}{12(43232.09) - \cancel{(43232.09)^2}\,(689.7)^2} = 0.0406$$

$$c = \frac{(227.5)(43232.09) - (689.7)(13304.25)}{12.(43232.09) - (689.7)^2} = 15.2987$$

$$E_F = 1.36\times10^{-15}\sqrt{\frac{8960\times\pi\times(10^{-4})^2\times0.0406}{15}} = 11.8709\times10^{-19}\ J$$

$$\frac{11.8709\times10^{-19}}{1.6\times10^{-19}} = 7.41\ eV$$

$\therefore E_F = 7.41\ eV$

22/5

Signature of Teacher Incharge

$y = mx + c$

$Q(82, 20.6)$

$y = (0.0406)x + 15.2987$

$x = 32$ $y = 17.39 \approx 17.4$

$x = 82$ $y = \cancel{19.82}$ ~~19~~

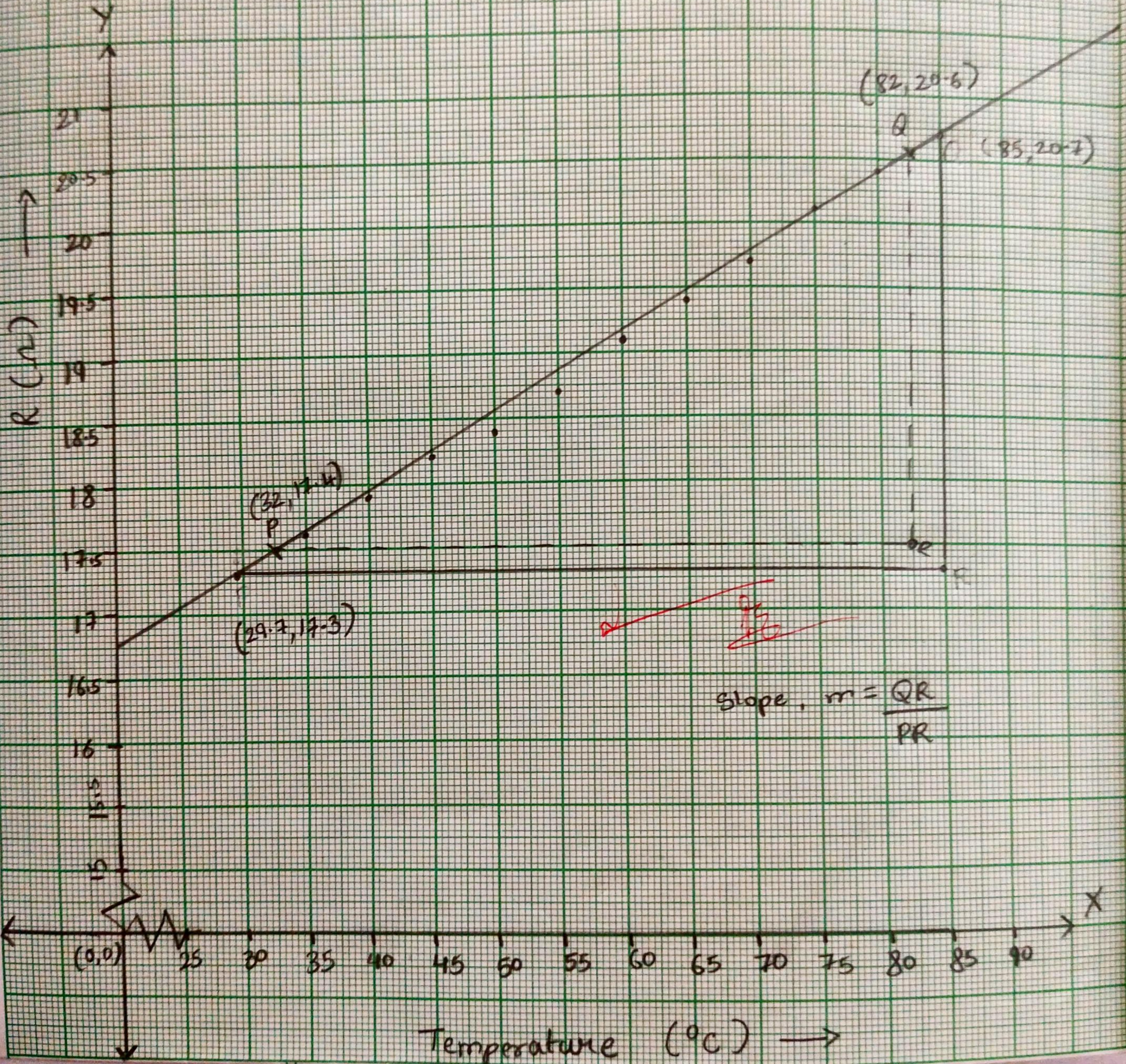
20

$y = 20.53 \approx 20.6$

Avishkar More (Y0

Scale: Y axis : 1 unit = 0.5 Ω

X axis : 1 unit = 5 °C

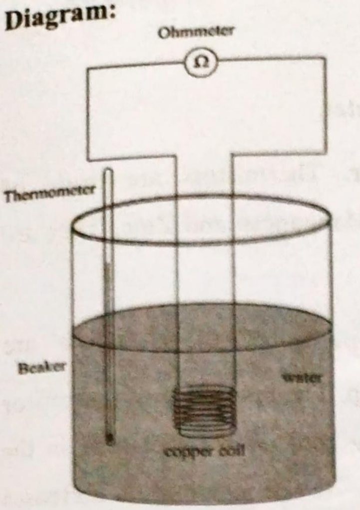


y R↑ in cond.

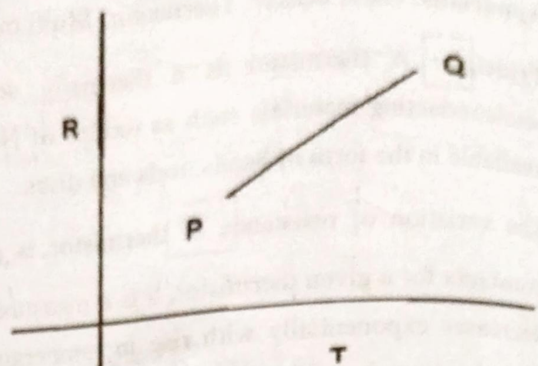
FERMI ENERGY OF COPPER

OBSERVATIONS:

Diagram:



Graph:



Formula:

$$E_F = 1.36\times10^{-15}\sqrt{\frac{\rho A m}{l}}\ \text{J} \qquad E_F = \frac{1.36\times10^{-15}\sqrt{\frac{\rho A m}{l}}\ \text{J}}{1.6\times10^{-19}\,C} = \underline{7.41}\ eV$$

$$\text{Slope} = m = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{n\sum x^2 - \left(\sum x\right)^2} \qquad \text{Intercept} = c = \frac{\left(\sum y\right)\left(\sum x^2\right) - \left(\sum x\right)\left(\sum xy\right)}{n\sum x^2 - \left(\sum x\right)^2}$$

Tabular Column:

Sl. No	Temp (^{0}C) (x)	R (Ω) (y)	x^2	xy
Room Temp	29.7	17.3	882.09	519.75
1.	85	20.7	7225	1759.5
2.	80	20.4	6400	1632
3.	75	20.1	5625	1507.5
4.	70	19.7	4900	1379
5.	65	19.4	4225	1261
6.	60	19.1	3600	1146
Sums	Σx = 689.7	Σy = 227.5	Σx^2 = 43,232.09	Σxy = 13,304.25
7.	55	18.7	3025	1028.5

Point	Temperature (x)	Resistance (y) y = mx + c
P	32	17.34
Q	82	20.6

Result: The Fermi energy of copper is E_F = 11.8709 $\times10^{-19}$ J, 7.41 eV

$$m = \frac{12(13304.25) - (689.7)(227.5)}{12(43232.09) - (689.7)^2} = 0.0406$$

$$C = \frac{(227.5)(43232.09) - (689.7)(13304)}{12.(43232.09) - (689.7)^2}$$

$$C = 15.2987$$

FERMI ENERGY OF COPPER

Experiment No: 7 **Date:** 15/5/25

Aim: To determine the Fermi energy of copper

Apparatus: Multi meter, Beaker, Thermometer and copper wire.

Theory: In a conductor, the electrons fill the available energy states starting from the lowest energy level. The highest occupied energy level at zero kelvin is called fermi level and its energy is called fermi energy and it is denoted by Ef. Therefore, at Zero kelvin, all the levels with an energy E less than a certain value E_f will be filled with electrons, whereas the levels with E greater than E_F will remain vacant. At temperature greater than zero Kelvin, Fermi energy is the average kinetic energy of the electrons participating in electrical conductivity. By measuring the resistance of the copper wire at different temperatures Fermi energy is calculated by the following formula.

$$E_F = 1.36\times10^{-15}\sqrt{\frac{\rho A m}{l}}\ \mathrm{J}$$

Where E_F is the Fermi energy, T is the reference temperature (K),
A is area of cross section of the given copper wire (m^2)
l is the length of the copper wire (m)
Charge of the electron, e = 1.602×10^{-19} C.
ρ is the density of copper =8960 Kg/m^3
m is the slope of the straight line obtained by plotting resistance of the metal against absolute temperature of the metal.

Procedure:

- Connect the copper coil to the digital multi meter.
- Set the multi meter to 200 Ω mode.
- Immerse the copper coil and the thermometer in a beaker containing cold water, note down the resistance in multi meter and the temperature in thermometer. Enter the readings in the tabular column.
- Immerse the copper coil in a beaker containing hot water at about 90°C.
- Note down the resistance in multi meter for every decrement of 5°C to about 50°C and enter the corresponding resistance and temperature in the tabular column.
- Calculate the slope m and the intercept c using the relevant formulae.
- Plot a graph of resistance along y-axis and temperature along x-axis. (mark only data points and don't join the points)
- Calculate the resistance value (y) of the conductor for any two temperatures (x) using the formula y=mx+c. Enter the values in the tabular column. Let the points be P and Q.
- Mark the points P and Q in the same graph with other data point, draw the line PQ. (This is the best fit line for the data)
- Calculate the Fermi energy of the material by using the calculated slope m in the relevant formula.

$y = mx + c$ $\Rightarrow y = (0.0406)x + 15.2987$

28/30

Result: The Fermi energy of copper is E_F = 11.8709×10^{-19} J, 7.41 eV.

$x = 32$ $y = 17.39 \approx 17.\blacksquare4$

$x = 64$ $y = 20.53 \approx 20.6$

R.Y. 29/05/25

R.V. COLLEGE OF ENGINEERING®

OBSERVATION / DATA SHEET

Date 29/5/25 Name Avishkar More

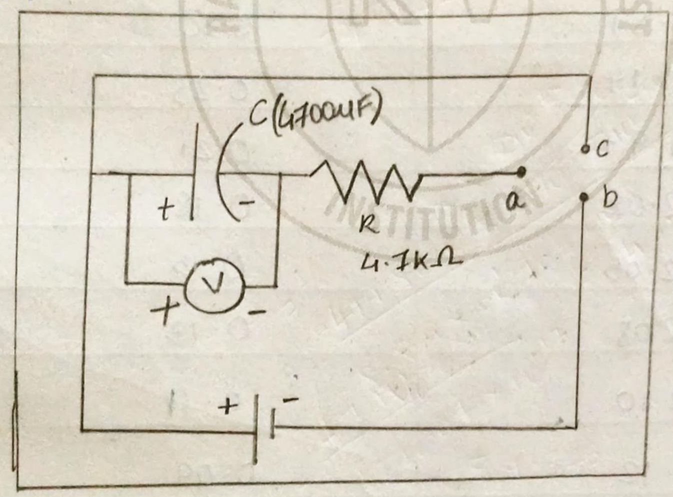
Dept./Lab Physics Lab B1 Class cy B1 Expt./No. 8

Title Dielectric Constant

Aim: To determine the capacity of a parallel plate capacitor and hence to calculate the dielectric constant of the dielectric medium in it.

Apparatus: Battery of ten volts, electrolytic capacitor, digital multimeter, two way key and stop clock.

Circuit Diagram:



Particulars	Max Marks	Marks Obtained	Faculty Signature
Data Sheet + Experimental setup + Viva Voce	10	4+6	Rg
Conduction of Experiment	10	9	
Substitution + Calculation + Accuracy	10	9	
Total Marks	30	28	5/6

29/5

Signature of Teacher Incharge

Table:

Time in seconds (s)	Voltage during charging (V)	Voltage during discharging (V)
0	0	2.19
30	0.37	1.80
60	0.67	1.50
90	0.92	1.25
120	1.13	1.04
150	1.30	0.87
180	1.45	0.73
210	1.57	0.61
240	1.68	0.51
270	1.76	0.43
300	1.84	0.36
330	1.89	0.30
360	1.94	0.25
390	1.99	0.21
420	2.02	0.18
450	2.05	0.15
480	2.08	0.13
510	2.10	0.11
540	2.12	0.09
570	2.13	0.08
600	2.15	0.06
630	2.16	0.05
660	2.17	0.05
690	2.17	0.04
720	2.18	0.03
750	2.19	0.02
780	2.19	0.02
810	2.19	0.02

R.V. COLLEGE OF ENGINEERING®

OBSERVATION / DATA SHEET

Date 29/5/25 Name Avishkar More

Dept./Lab Physics LAB B1 Class CY B1 Expt./No. ~~10~~ 8

Title Dielectric Constant

Formula: The capacitance and dielectric constant of the given capacitor are calculated by using the formulae given below:

1. $C = \tau/R$ (F)

2. $\varepsilon_r = \frac{Cd}{\varepsilon_0 A}$

where : τ : Time constant

R : Resistance (Ω) = 47 KΩ

A : Area of each plate (m^2)

d : thickness of the dielectric (m)

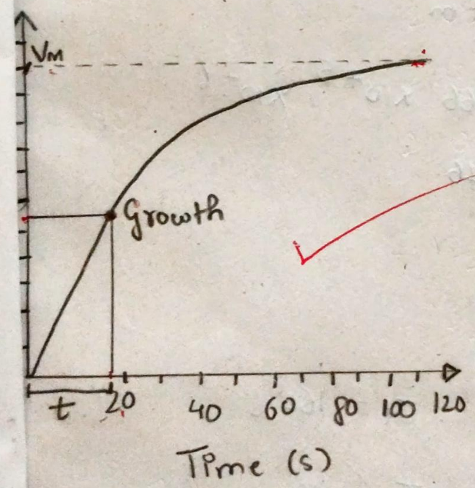
ε_r : Relative permittivity or the dielectric constant of the dielectric

ε_0 : Absolute permittivity of free space $= 8.854 \times 10^{-12}$ F/m

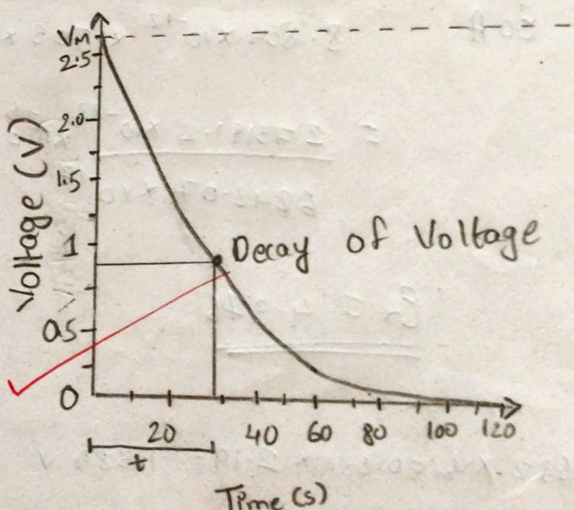
C : Capacitance of capacitor (F)

Model Graph:

I. Charging Curve



II. Discharging Curve



Signature of Teacher Incharge

Charging time constant, $\tau_1 = 162$ sec Discharging

Average time constant : $\tau = \frac{\tau_1 + \tau_2}{2} = \frac{321}{2} = 160.5$ R≈47kΩ 247

Capacitance of capacitor : $C = \frac{\tau}{R} = \frac{160.5}{47{,}000} = 0.0034148\ F = 3414.89\ \mu F$

R: Resistance C: Capacitance of capacitor in the circuit

• Dielectric constant is determined by using the formula, $\varepsilon_r = \frac{Cd}{\varepsilon_0 A}$

where : τ = time constant ε_r = dielectric constant of the dielectric

ε_0 = Absolute permittivity of free space

$= 8.854 \times 10^{-12}$ F/m $l = 47$ cm $= 47 \times 10^{-2}$

C: Capacitance of capacitor $b = 1.5$ cm $= 1.5 \times 10^{-2}$

Thickness of dielectric medium, d (m) $= 80\ \mu m = 80 \times 10^{-6}$ m

Area of each plate, $A = l \times b$ (m^2) $= 0.00705\ m^2 = 70.5 \times 10^{-4}$

Calculations:

$$\varepsilon_r = \frac{Cd}{\varepsilon_0 A} = \frac{3414.89 \times 10^{-6} \times 80 \times 10^{-6} \cancel{\times 705 \times 10^{-5}}\ Fm}{8.854 \times 10^{-12} \times 705 \times 10^{-5}\ Fm} \times 10^{-6}$$

$$= \frac{273191.2 \times 10^{-12} \times 10^{-6}}{6242.07 \times 10^{-17}} = 43.766 \times 10^{+5} \times 10^{-6}$$

$$= 4.376$$

$\underline{\varepsilon_r = 4.376}$

$V_1 = 0.632 \times V_m = 0.632 \times 2.19 = 1.384$ V $\tau_1 = 162$ s

$V_2 = 0.368 \times V_m = 0.368 \times 2.19 = 0.805$ V $\tau_2 = 159$ s

Result: Capacity of parallel plate capacitor, $C = 3414.89\ \mu F$

Dielectric constant of the given dielectric material, $\varepsilon_r = 4.376$

Avishkar More 007
Physics
Batch. No.... B1

Date: 29 05 2025

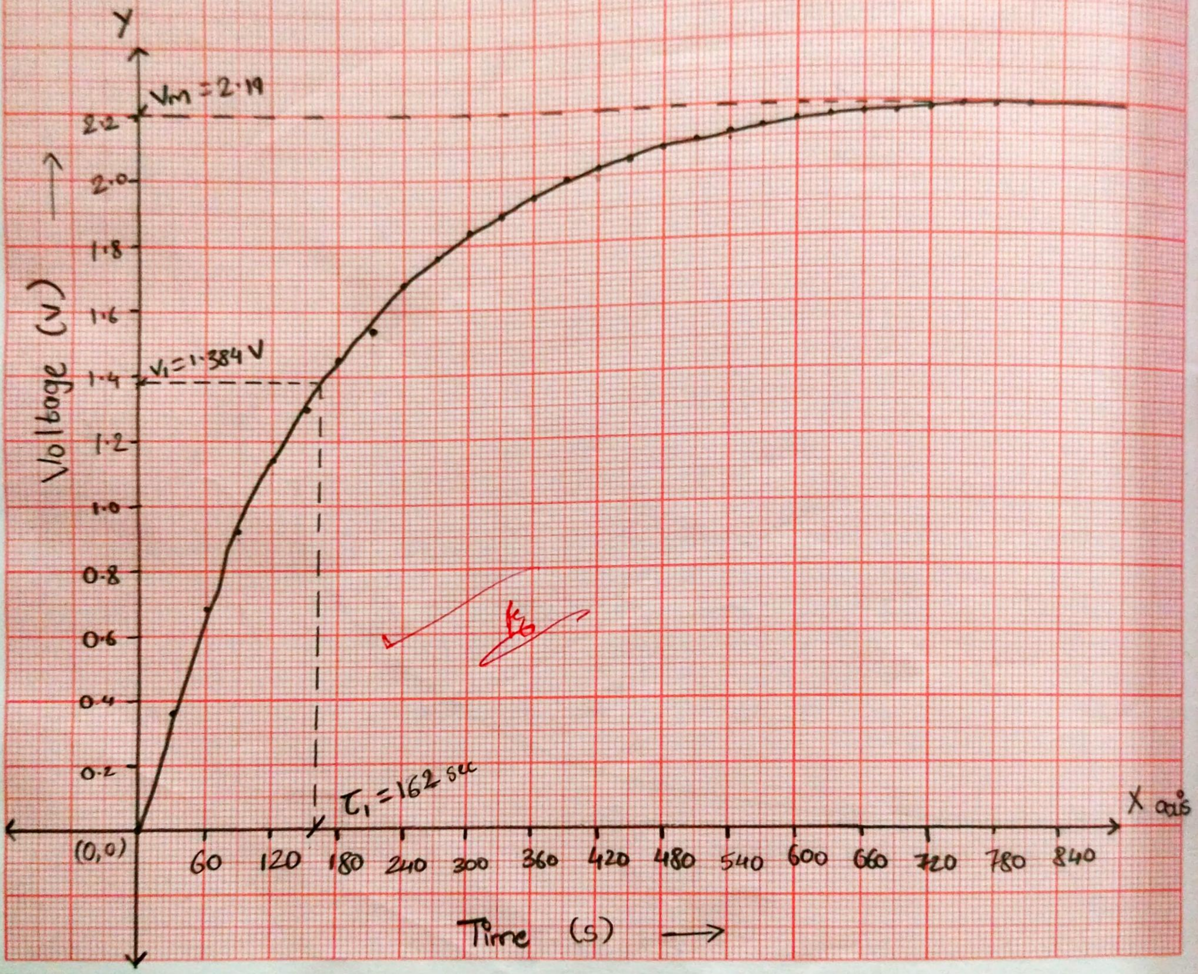
Voltage vs Time Graph

Scale: Y axis: 1 unit = 0.2 V

X axis: 1 unit = 60 sec

(a) Charging

$0.632 V_m = 1.384\ V = V_1$



Physics

Batch. No. B1

Date: 29 05 2025

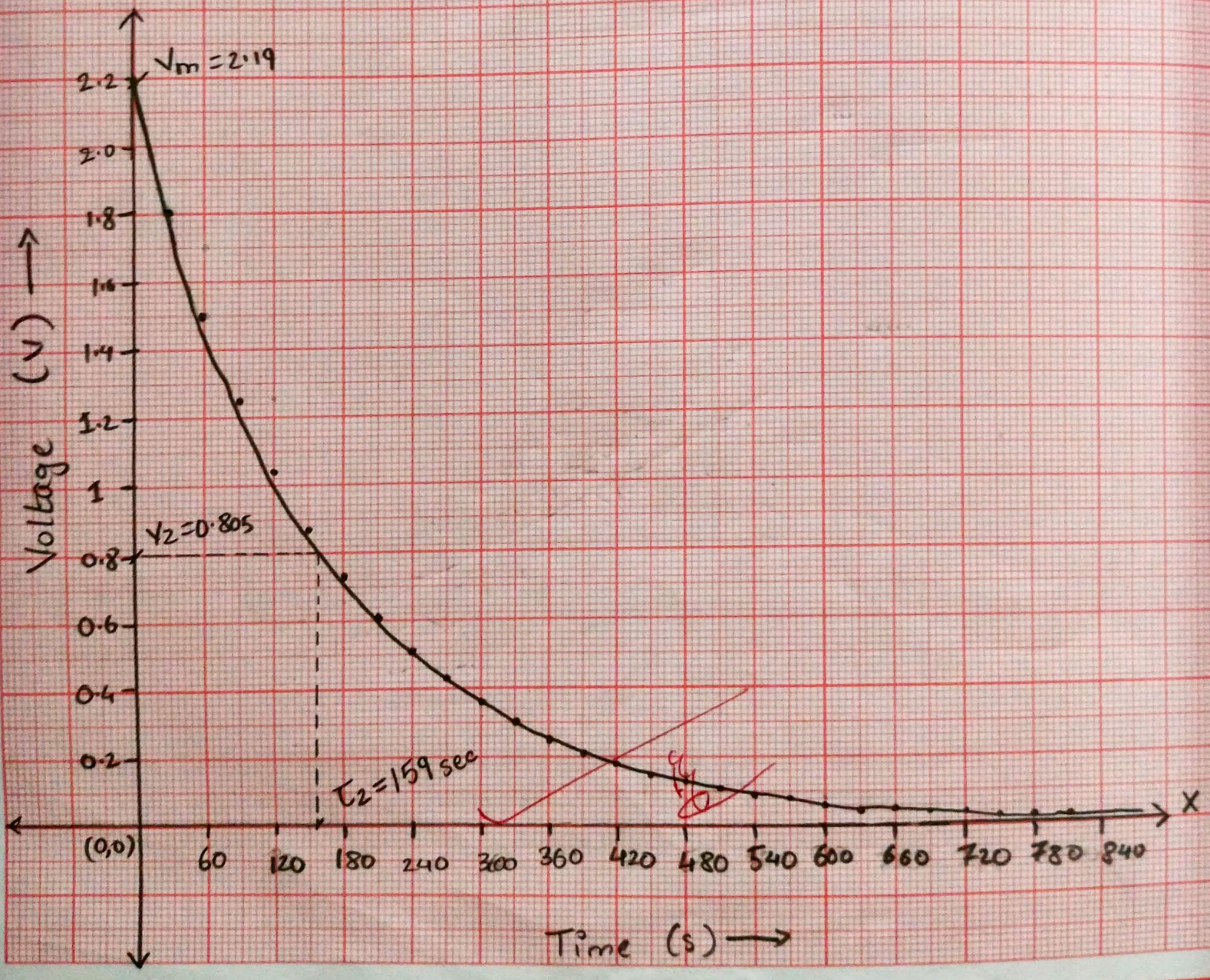
Voltage vs Time Graph

Scale: Y axis: 1 unit = 0.2 V

X axis: 1 unit = 60 sec

(b) Discharging

$0.368 \times V_m = 0.805\ V = V_2$

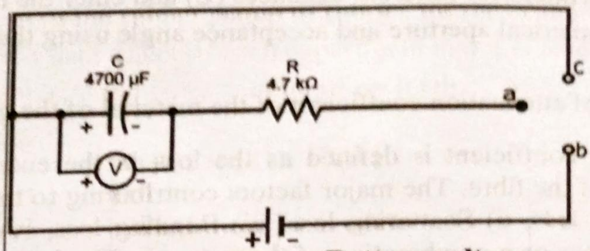


BHASKAR'S

DIELECTRIC CONSTANT

OBSERVATIONS

Circuit diagram:



R = <u>47</u> KΩ **Battery voltage=____________Volt**

Time in seconds (s)	Voltage during charging (V)	Voltage during discharging (V)
0	0	2.19
30	0.37	1.80
60	0.67	1.50
90	0.92	1.25
120	1.13	1.04
150	1.30	0.87
180	1.45	0.73, 0.61
240 =210	1.57	0.51
270	1.68	0.43
300	1.76	0.36
330	1.84	0.30
360	1.89	0.25
390	1.94	0.21
420	1.99 2.02	0.18
450	2.05	0.15
480	2.08	0.13
510	2.10	0.11
540	2.12	0.09
570	2.13	0.08
600	2.15	0.06
630	2.16	0.05
⋮	⋮	⋮
810	2.19	0.02

FORMULA:

The capacitance and dielectric constant of the given capacitor are calculated by using the formulae given below:

1. $C = \tau / R$ (F) 2. $\varepsilon_r = \dfrac{Cd}{\varepsilon_o A}$

where τ : time constant; ε_r : relative permittivity or the dielectric constant of the dielectric. ε_o : Absolute permittivity of free space = 8.854×10^{-12} F/m; C: capacitance of the capacitor (F); R: resistance (Ω); A: area of each plate (m^2); d: thickness of the dielectric (m).

$\tau_1 = 162$ $\tau_2 = 159$ $\tau_{avg} = \dfrac{\tau_1 + \tau_c}{2} = 160.5$ s

DIELECTRIC CONSTANT

Experiment No: 8 Date: 27/5/25

Aim: To determine the capacity of a parallel plate capacitor and hence to calculate the dielectric constant of the dielectric medium in it.

Apparatus: Battery of ten volts, electrolytic capacitor, digital multi meter, two way key and stop clock.

Principle: When a capacitor and a resistor are in series with a dc source, the capacitor gets charged and at any instant the voltage of the capacitor is $V = V_0(1 - e^{-t/RC})$ where V_0 is the maximum voltage. τ is called the time constant of the circuit, it is the time taken for the voltage to reach 63% of V_0. Similarly, while discharging the voltage across the capacitor is given by $V = V_0(e^{-t/RC})$. The time constant is the time taken for voltage to decrease to 37% of the maximum value i.e., V_0. The time constant $\tau = RC$

Theory:
A dielectric is a material which has poor electric conductivity but inherits an ability to store an electric charge (due to polarization). Dielectric constant also called relative permittivity is equal to ratio of the capacitance of a capacitor filled with the dielectric material to its capacitance without the dielectric material.

The capacitance of a capacitor is $C = \frac{Q}{V}$

The electric flux through a closed surface area in vacuum is given by Gauss's law

$\Phi = \oiint_S \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$, Where $\vec{E}$ is electric field intensity, Q is the charge enclosed by closed surface A, ϵ_0 is the permittivity constant in free space and S is a closed surface area.

$E = \frac{\Phi}{A} = \frac{Q}{\epsilon_0 A}$ --- (1)

The capacitance of a capacitor is $C = \frac{Q}{V} = \frac{Q}{Ed}$ --- (2); Substituting *1* in *2*

Then $C = \frac{\epsilon_0 A}{d}$ --- (3)

If the space between capacitor plates is filled fully with dielectric medium having dielectric constant ϵ_r. Then, the Capacitance is $C' = \frac{\epsilon_0 \epsilon_r A}{d}$ --- (4)

Then the dielectric constant is $\epsilon_r = \frac{C'}{C}$

Thus, the dielectric constant is defined as the ratio of the capacitance of the capacitor with a dielectric medium to the capacitance of the same capacitor with air or vacuum as dielectric.

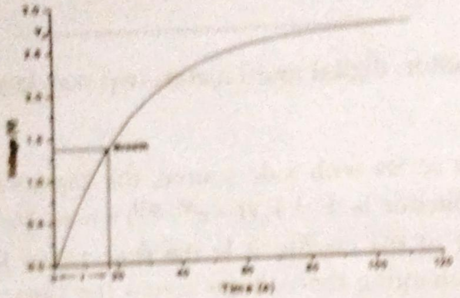
$d = 80\,\mu m = 80 \times 10^{-6}\,m$ $A = l \times b$

$l = 47\,cm = 47 \times 10^{-2}\,m$ $= 70.5 \times 10^{-4}\,m^2$

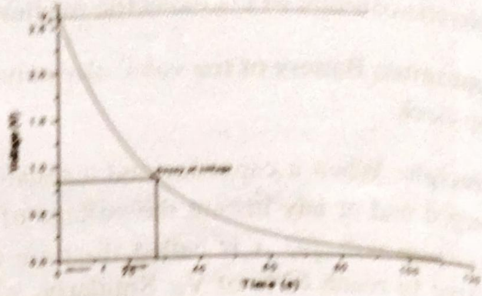
$b = 1.5\,cm = 1.5 \times 10^{-2}\,m$

Model Graph:

(I) Charging Curve



(II) Discharging Curve:



Charging time constant $\tau_1 =$ 162 s Discharging time constant $\tau_2 =$ 159 s

Average time constant $\tau = \frac{\tau_1 + \tau_2}{2} =$ 160.5 s Capacitance of the capacitor $C = \frac{\tau}{R}$ = 3414 μF

Where R is the resistance and C is the capacitance of the capacitor in the circuit.

Dielectric constant is determined by using the formula, $\varepsilon_r = \frac{Cd}{\varepsilon_o A}$

where τ : time constant, ε_r : dielectric constant of the dielectric.

ε_o : Absolute permittivity of free space = 8.854×10^{-12} F/m.

C: capacitance of the capacitor (F).

$C = \frac{160.5}{47,000} = 3414.\ldots$

Thickness of dielectric medium, d (m)	80×10^{-6} m
Area of each plate A=lxb (m²)	70.5×10^{-4} m²

Calculations:

$$\varepsilon_r = \frac{Cd}{\varepsilon_o A}$$

$$\varepsilon_r = \frac{Cd}{\varepsilon_o A} = \frac{3414.89 \times 10^{-6} \times 80 \times 10^{-6} \times 10^{-6}}{8.854 \times 10^{-12} \times 70.5 \times 10^{-4}}$$

$$\varepsilon_r = 4.376$$

Note:

1.Don't connect a wire between *b* and *c*

2.Multiply the result by 10^{-6}. This correction is needed because the dielectric in the given electrolytic capacitor is not a homogenous medium and it is a paper with alumina deposition by electrolysis.

3. Compare the calculated value of the capacity of the capacitor with the standard capacitors given and note down values of l, b and d.

Result:

1. Capacity of parallel plate capacitor C = 3414.89 μF
2. Dielectric constant of the given dielectric material ε_r = 4.376

Procedure:

(1) Charging:

1. Make the circuit connections as shown in the figure and set the battery voltage to a small value (0 to 10V)

2. Set a stop watch to zero, simultaneously start the stop clock and close the key K is along a b, the voltage across the capacitor increases slowly.

3. For every thirty seconds, the reading of the voltmeter across the capacitor is recorded in tabular column till it reaches maximum (note down the constant voltages for at least three consecutive time intervals).

4. Plot a graph of voltage versus time. Corresponding to 63.2% V_m , note down the time on x-axis and that is the time constant (τ_1) for the charging. ($\tau = R \times C$)

(II) Discharging

1. Open the key across a and b

2. Set a stop watch to zero, simultaneously start the stop watch and close the key K is along a c, the voltage across the capacitor decreases very fast.

3. For every thirty seconds, the reading of the voltmeter across the capacitor is recorded in tabular column till it reaches minimum (i.e the voltage remains constant with time).

4. Plot a graph of voltage versus time. Corresponding to 36.8% Vm , note down the time on x-axis and that is the time constant (τ_2) for the discharging.

Dimensions of the capacitors:

C = 3300 μF	C = 4700 μF
R = 47 kΩ	R = 47 kΩ
L = 47 cm	L = 55 cm
B = 1.5 cm	B = 2.5 cm
d = 80 μm	d = 80 μm

RESULT:

1. Capacity of parallel plate capacitor C = 3414.89 μF

2. Dielectric constant of the given dielectric material ε_r = 4.376

28/30

14

5/6