ELEC 22541

Experiment No: E06

CHARGE AMPLIFIER

Student No: PE/2021/004

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Experiment No - E06

Experiment Name - Charge Amplifier

APPARATUS

- 741 op amp
- $10 \times 10^{6}\ \Omega$ resistor
- Capacitor
  - 10×10^{-6} F
  - 1×10^{-6} F
  - 1×10^{-6} F variable resistor
- Connecting wires
- 5V power supply
- ± 15 V power supply
- Voltmeter
- Stop watch

THEORY AND DIAGRAMS

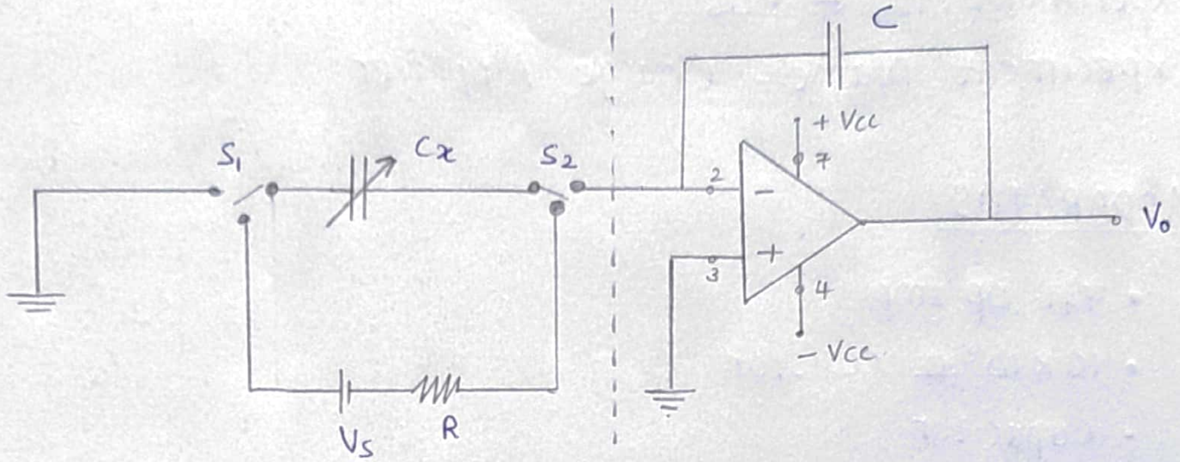
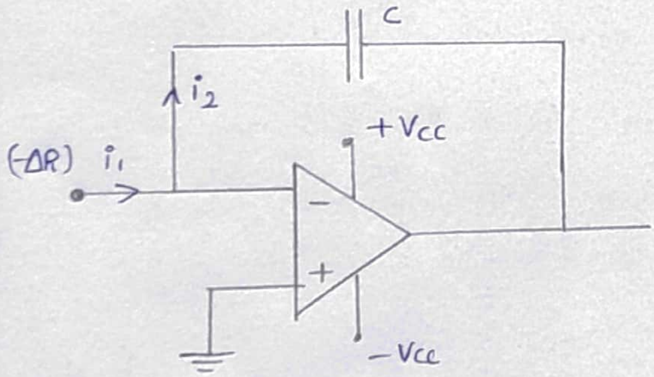


Figure 01



$V_p = 0V$ and $i_1 = i_2$

$$I_1 = \frac{-\Delta Q}{\Delta t}$$

$$I_2 = \frac{C\,\Delta V}{\Delta t}$$

$$I_1 = I_2 \Rightarrow \frac{-\Delta R}{\Delta t} = C\left(\frac{\Delta V}{\Delta t}\right)$$

$$\frac{-\Delta R}{\Delta t} = \frac{C(0 - V_o)}{\Delta t}$$

$$\Rightarrow \Delta Q = C \cdot V_o$$

$$V_o = \frac{1}{C}(\Delta Q)$$

* Part 1

$$\underset{y}{V_o} = \underset{m}{\frac{1}{C}}\ \underset{x}{(\Delta Q)}$$

for capacitor charging cycle

$$V_t = V_s(1 - e^{-t/RC})$$

then,

$C_x = 1 \times 10^{-6} F$

$R = 10 \times 10^{6} \Omega$

$RC = 10\ s$

To find $(\Delta\theta)$ value

I] $V_t \rightarrow V_t = V_s(1 - e^{-t/RC})$

II] $\Delta\theta \rightarrow \Delta\theta = C_x V_t$

$$\therefore \Delta\theta = C_x V_s (1 - e^{-t/RC})$$

when $C_x = 1 \times 10^{-6} F$ and $V_s = 5V$

$$\Delta\theta = 5 \times 10^{-6} [1 - e^{-t/10}]$$

finally we can plot the graph of V_o Vs $\Delta\theta$

$$V_o = 1/C \, \Delta\theta$$

$$m = 1/C.$$

* Part II

$V_o = \frac{1}{C}(\Delta\theta)$ — (A)

$\Delta\theta = C_x V_t$, for this case $V_s = V_t = 5V$

$$\therefore R_C = 0.95 < 10S$$

$$\Delta\theta = 5C_x \text{ — (B)}$$

from (A) and (B)

$$V_o = \frac{1}{C}[5C_x]$$

$$= \frac{5}{C} C_x$$

$$\underset{y}{V_o} = \underset{m}{\left(\frac{5}{C}\right)} \underset{x}{C_x}$$

$$m = 5/C.$$

PROCEDURE

① The circuit was connected as shown in figure 01 using 741 op-amp. The capacitor C_x was adjusted to 1×10^{-6} F

② Switches S_1 and S_2 were set to the position 1 and the capacitor was charged for 10 seconds.

③ Switches S_1 and S_2 were set to the position 2 and output voltage was obtained when it reaches to its maximum value.

④ Step (2) and (3) were repeated for other charging time given in the sample data sheet and results were tabulated.

⑤ The capacitor C was replaced from the 1×10^{-6} F capacitor and C_x was adjusted to 0.1×10^{-6} F

⑥ Steps (2) and (3) were repeated

⑦ Step 6 was repeated for other C_x values given in the sample data sheet and your results were tabulated.

⑧

OBSERVATIONS

Date : 02/12/2024
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Experiment No: E06

Part I

Charging Time, t (s)	Output voltage (V_0) V
10	1.561
20	1.671
30	1.702
40	1.707
50	1.712
60	1.718
70	1.723
80	1.727
90	1.732

Part II

Capacitance, Cx ($\times 10^{-6}$ F)	Output Voltage (V_0) (V)
0.1	0.021
0.2	0.035
0.3	0.105
0.4	0.165
0.5	0.170
0.6	0.179
0.7	0.186
0.8	0.194
0.9	0.200

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CALCULATIONS

~~Part~~ part I

t(s)	$\Delta\theta$	V_o (V)
10	3.1606	1.561 (neglected)
20	4.3233	1.671
30	4.7511	1.702
40	4.9084	1.707
50	4.9663	1.712
60	4.9876	1.718
70	4.9954	1.723
80	4.9983	1.727 (neglected)
90	4.9994	1.732 (neglected)

$C_x = 1 \times 10^{-6}\, F$

$V_s = 5\, V$

Gravity point of the graph $G(\bar{x}, \bar{y})$

$$\bar{y} = \frac{1.671 + 1.702 + 1.707 + 1.712 + 1.718 + 1.723}{6}$$

$$= 1.706\ V$$

$$\bar{x} = \frac{4.32 + 4.75 + 4.91 + 4.97 + 4.99 + 5.00}{6}$$

$$= 4.82 \times 10^{-6}\, C$$

$(4.82 \times 10^{-6} C,\ 1.706\ V)$

$$\text{Gradient of the graph} = \frac{(1.715 - 1.680)\ V}{(4.95 - 4.45) \times 10^{-6}\ C}$$

$$= 0.07 \times 10^{6}\ VC^{-1}$$

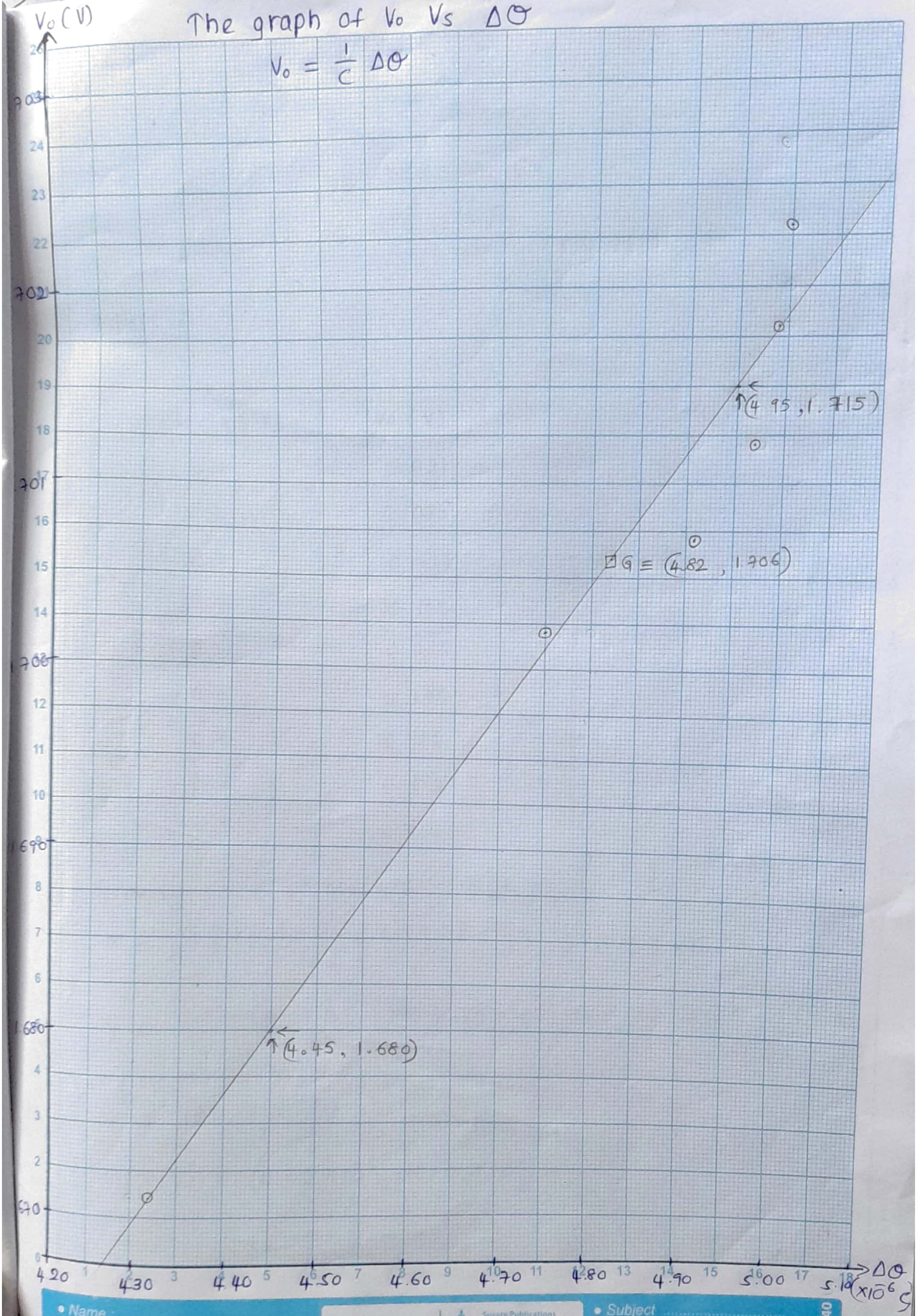
$$m = 1/c$$

$$c = 1/m$$

$$C = \frac{1}{0.07 \times 10^{6}\ VC^{-1}}$$

$$= 14.286 \times 10^{-6}\ CV^{-1}$$

$$= 14.286 \times 10^{-6}\ F$$



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$$C = \frac{1}{0.07 \times 10^{+6}\ V C^{-1}}$$

$$= 14.286 \times 10^{-6}\ C V^{-1}$$

$$= 14.286 \times 10^{-6}\ F$$

*** Part II**

C_x ($\times 10^{-6} F$)	V_o (V)
0.1	0.021 (neglected)
0.2	0.035 (neglected)
0.3	0.105 (neglected)
0.4	0.165
0.5	0.170
0.6	0.179
0.7	0.186
0.8	0.194
0.9	0.200

Gravity point of the graph $G(\bar{x}, \bar{y})$

$$\bar{x} = \frac{0.4+0.5+0.6+0.7+0.8+0.9}{6} = 0.65 \times 10^{-6} F$$

$$\bar{y} = \frac{(\cancel{0.021+0.02}\ 165+170+179+186+194+200) \times 10^{-3}}{6}\ V$$

$$= 182.3 \times 10^{-3} V$$

$$G(\bar{x}, \bar{y}) = (0.65 \times 10^{-6},\ 182.3 \times 10^{-3}).$$

Gradient of the graph(m) = $\dfrac{(195 - 162) \times 10^{-3}\ V}{(0.81 - 0.40) \times 10^{-6}\ F}$

$(m) = 80.49 \times 10^{3}\ VF^{-1}$

$m = \dfrac{5}{C}$

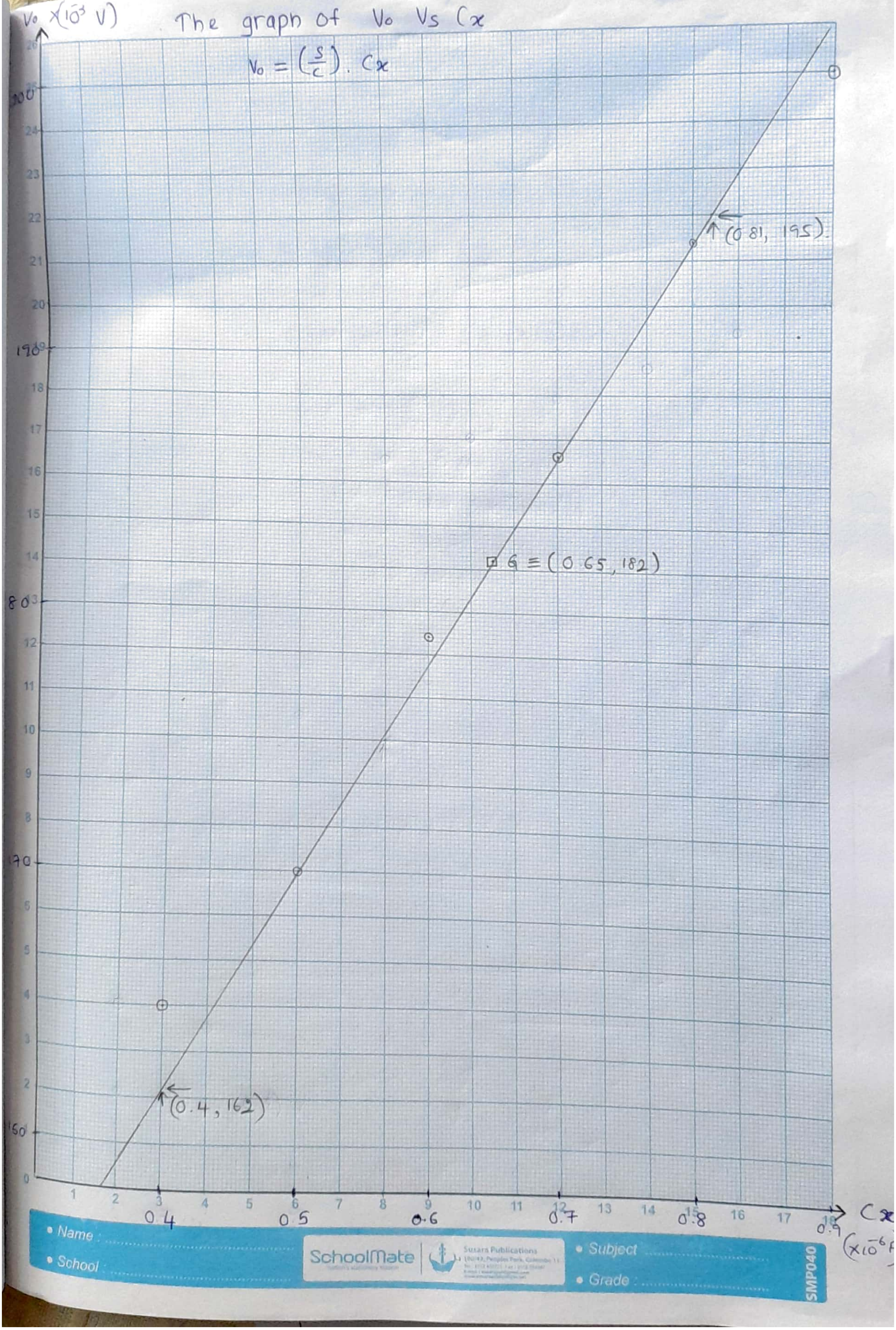
$C = \dfrac{5}{m}$

$= \dfrac{5\ V}{80.49 \times 10^{3}\ VF^{-1}}$

$\cancel{= 62.12 \times 10^{-6}\ F}$

$= 0.062119 \times 10^{-3}\ F$

$C = 62.12 \times 10^{-6}\ F$



$V_o \times (10^{-3}\ V)$
The graph of V_o Vs C_x
$V_o = \left(\frac{s}{c}\right) . C_x$
(0.81, 195)
G = (0.65, 182)
(0.4, 162)
C_x
$(\times 10^{-6} F)$
0.4
0.5
0.6
0.7
0.8
0.9
200
190
180
170
160
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CONCLUSION

	Experimental Value	Theoritical Value
Part I	$C = 14.286 \times 10^{-6}\,F$	$C = 10 \times 10^{-6}\,F$
Part II	$C = 62.12 \times 10^{-6}\,F$	$C = 1 \times 10^{-6}\,F$

DISCUSSION

The charge amplifier experiment demonstrates the operation of a charge-to-voltage converter and capacitance-to-voltage converter. By charging and discharging a capacitor using the specified circuit, the relationship between charge, capacitance and output voltage is explored. The use of the 741 operational amplifier ensures accurate signal processing, but careful adjustment of the components, such as the variable capacitor and resistors, is critical for precise measurements. This experimental setup effectively illustrates the working principle of capacitive sensors, converting changes in capacitance into measurable output voltages.

Several challengers were encountered during the experiment. One significant issue was maintaining ~~the~~ the stability of the output voltage during the measurement process, as fluctuations could arise due to norce or inproper grounding. This could be mitigated by ensuring a clean power supply, proper shielding and consistent connection of the circuit components. Another challenge involved the precise adjustment of the variable capacitor, as even slight deviations could lead to errors in the measurements. To address this careful calibrations and the use of precise measurements instruments were essential. Additionaly accurately timing the charging and discharging processes required a reliable stopwatch and adherence to the procedure to minimize human error.

Charge amplifiers find numerous applications in modern technology. They are extensively used in capacitive sensors to measure variables such as pressure, acceleration and proximity. The principle learned from this experiment provide fundational knowledge for designing and implementing such advance systems.