ASSIGNMENT 1

BASIC OHMMETRE AND CAPACITANCE MEASURMENT

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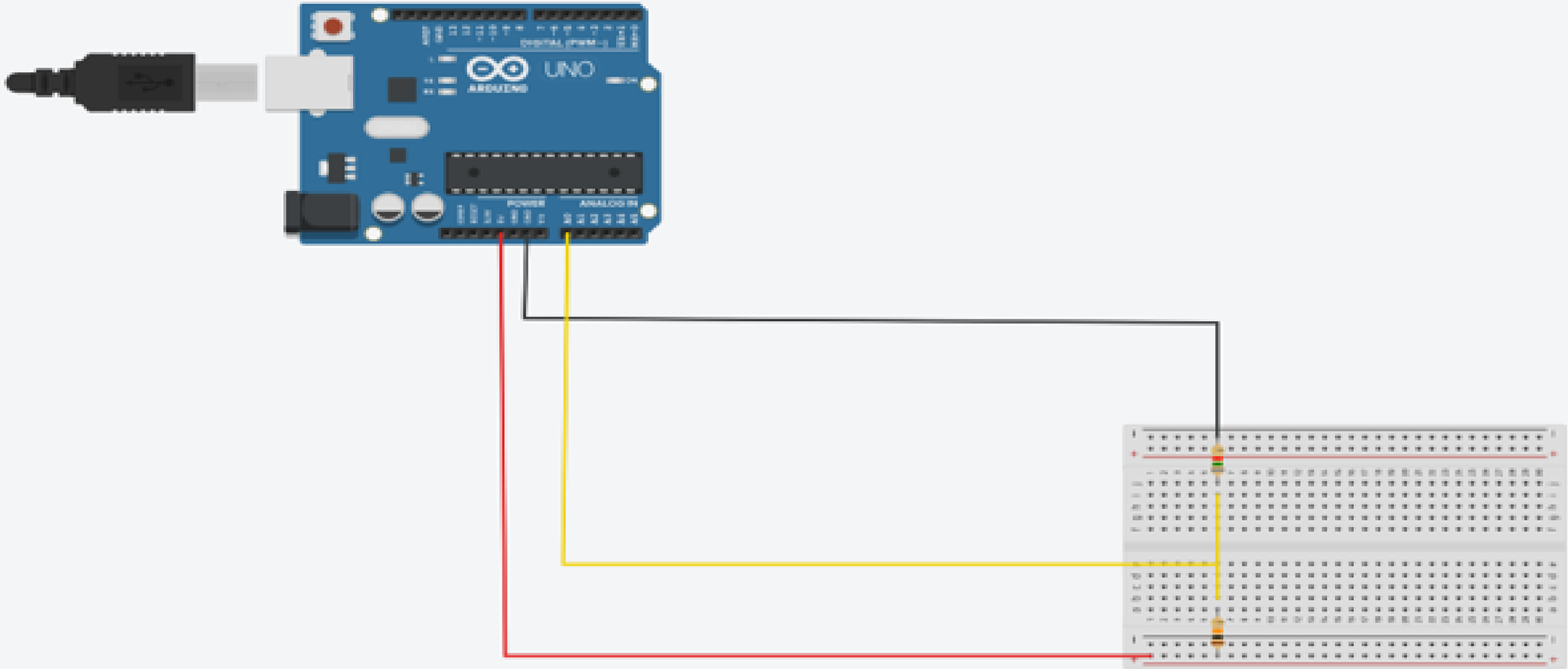
OBJECTIVE

. In this assignment we are designing a simulated measurement module that performs a basic resistance and capacitance measurement on Tinkercad using Arduino Uno.

. Understanding theoretical values and comparing them with tinker cad results to achieve a conclusion of error and noises sources present in the circuit

. The whole concept of simple ohmmeter and capacitance measurement is basic circuit laws including voltage divider analysis and calculating time upto when voltage across capacitor reaches a threshold.

TASK A -VOLTAGE DIVIDER ANALYSIS FOR ESTIMATING VOLTAGE



PAIR(10Kohm-10kohm)

1 (Arduino Uno R3)

```
const int analogpin=A0;  // v_mid is conncected to A0
const float v_ref=5.0;    // reference volatge of Arduino
const float R2 =10000.0;
const float R1=10000.0;
const float V_in =5.0;
  void setup(){
  Serial.begin(9600);   // opens serial monitor
}

void loop(){
     int ADCvalue=analogRead(analogpin); // reads the ADC reading
  // conversion of ADC reading to voltage in volt
  // consider 10bit ADC (0V-0,5V-1023)
   float V_out=((float)ADCvalue/1023)*v_ref ;  // Tinkercad outpu
   float V_theroitical= V_in*(R2/(R1+R2)); // theoritical output

  // Print results
    Serial.print("V_out:");
    Serial.println(V_out);
    Serial.print("V_theroitical:");
    Serial.println(V_theroitical);
    Serial.println();
      delay(500);  // stops program for 500ms
```

Serial Monitor

```
V_out:2.50
V_theroitical:2.50
```

PAIR(4.7Kohm-10kohm)

1 (Arduino Uno R3)

```
const int analogpin=A0;  // v_mid is conncected to A0
const float v_ref=5.0;    // reference volatge of Arduino
const float R2 =4700.0;
const float R1=10000.0;
const float V_in =5.0;
  void setup(){
  Serial.begin(9600);   // opens serial monitor
}

void loop(){
     int ADCvalue=analogRead(analogpin); // reads the ADC reading
  // conversion of ADC reading to voltage in volt
  // consider 10bit ADC (0V-0,5V-1023)
   float V_out=((float)ADCvalue/1023)*v_ref ;  // Tinkercad outpu
   float V_theroitical= V_in*(R2/(R1+R2)); // theoritical output

  // Print results
    Serial.print("V_out:");
    Serial.println(V_out);
    Serial.print("V_theroitical:");
    Serial.println(V_theroitical);
    Serial.println();
      delay(500);  // stops program for 500ms
```

Serial Monitor

```
V_out:1.60
V_theroitical:1.60
```

PAIR(1Kohm-15kohm)

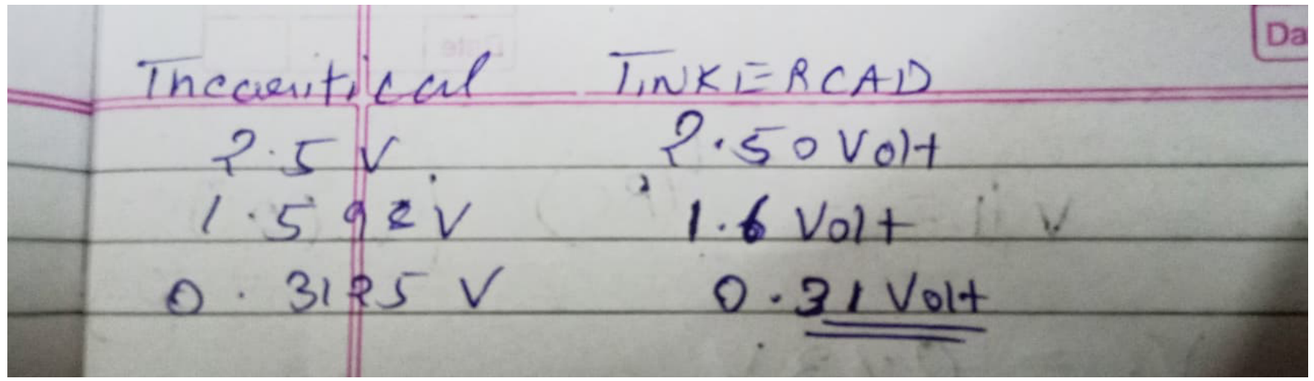
```
const int analogpin=A0;  // v_mid is conncected to A0
const float v_ref=5.0;    // reference volatge of Arduino
const float R2 =1000.0;
const float R1=15000.0;
const float V_in =5.0;
  void setup(){
  Serial.begin(9600);   // opens serial monitor
}

void loop(){
     int ADCvalue=analogRead(analogpin); // reads the ADC reading
  // conversion of ADC reading to voltage in volt
  // consider 10bit ADC (0V-0,5V-1023)
   float V_out=((float)ADCvalue/1023)*v_ref ;  // Tinkercad outpu
   float V_theroitical= V_in*(R2/(R1+R2)); // theoritical output

  // Print results
    Serial.print("V_out:");
    Serial.println(V_out);
    Serial.print("V_theroitical:");
    Serial.println(V_theroitical);
    Serial.println();
      delay(500);  // stops program for 500ms
```

Serial Monitor

```
V_out:0.31
V_theroitical:0.31
```

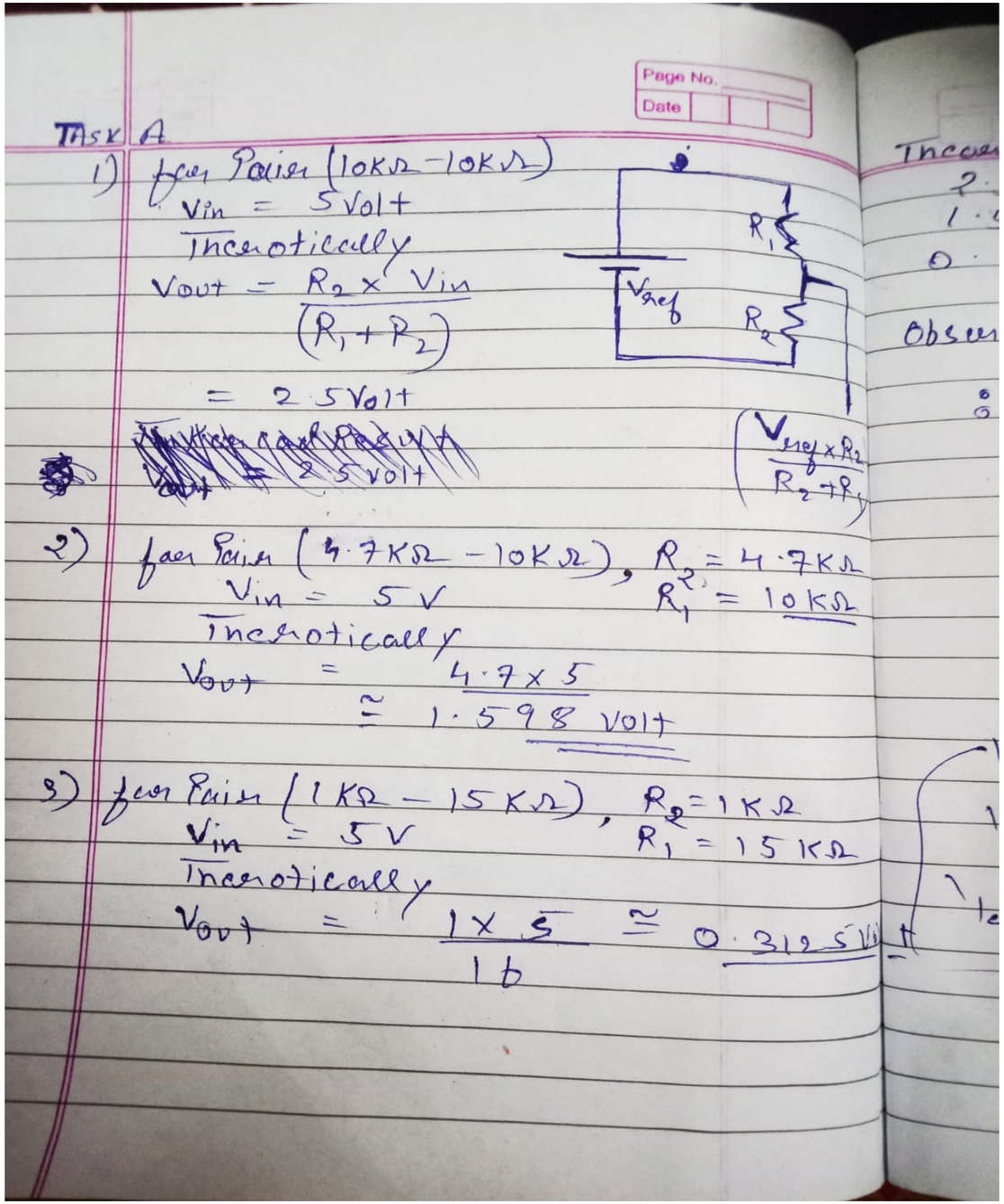


Theoritical	TINKERCAD
2.5 V	2.50 Volt
1.592 V	1.6 Volt
0.3125 V	0.31 Volt

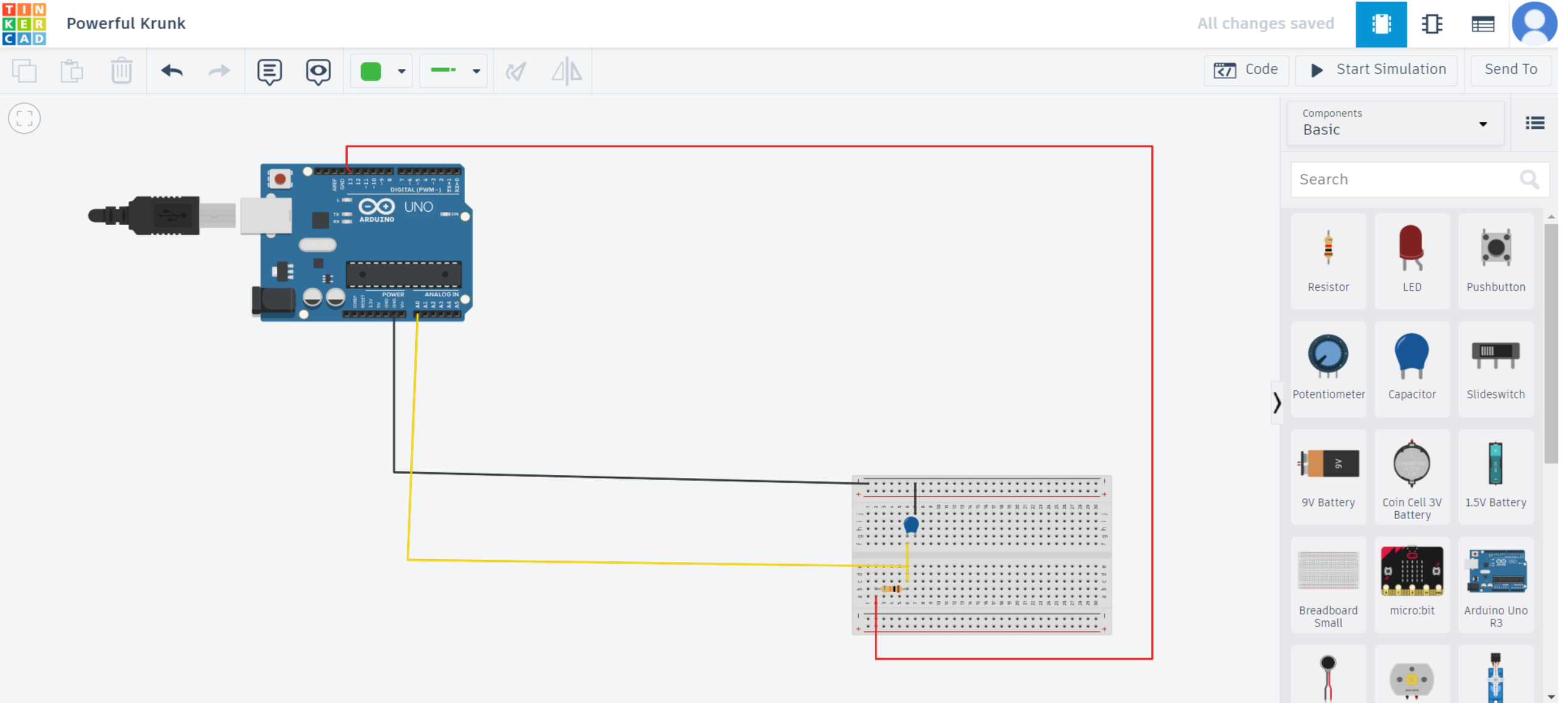
. analogRead() convert and read ADC reading that lies between 0-1023 depending on voltage across R2.

. Even for a fixed DC constant voltage , ADC reading may vary between two or more values because of ADC quantization error

. However we are getting approx same values of voltages from serial monitor as expected as tinkercad treat resistances as ideal and deals with
stable ADC readings .



TASK B – CAPACITANCE MEASUREMENT FROM RC TIME CONSTANT



For Capacitance =1uf

```
      i=analogRead(analogpin);
    }
  long end=micros();
  float t_calculated=(end-start); // in  microseconds

    // using formula C=tau/R
```

Serial Monitor

```
C_uf:0.99uFmeasured time:9904.00us
C_uf:0.99uFmeasured time:9904.00us
C_uf:0.99uFmeasured time:9904.00us
C_uf:0.99uFmeasured time:9916.00us
C_uf:0.99uFmeasured time:9908.00us
C_uf:0.99uFmeasured time:9912.00us
C_uf:0.99uFmeasured time:9900.00us
```

Send Clear

For Capacitance=2.5uf

```
// consider 10bit ADC
// ADC_threshold=((v_ref*v_fraction)/(v_ref))*1023
  int ADC_threshold= int(v_fraction*1023.0);
```

Serial Monitor

```
C_uf:2.13uFmeasured time:21280.00us
C_uf:2.13uFmeasured time:21276.00us
C_uf:2.13uFmeasured time:21272.00us
C_uf:2.13uFmeasured time:21272.00us
C_uf:2.13uFmeasured time:21276.00us
C_uf:2.13uFmeasured time:21280.00us
C_uf:2.13uFmeasured time:21280.00us
```

Send Clear

measured capacitance (Tinkercad Result)	expected capacitance (uF)	measured time (TINKER CAD)	expected time (t = R x expected capacitance)
0.99 uF	1 uF	9916 (us)	10000 us
2.13 uF	2.5 uF	21280 (us)	25000 (us)

Arduino Uno

sketch_dec13a.ino

```cpp
// C++ code
//
const int digitalpin=13; // pin use to charge or discharge a capacitor
  const int analogpin=A0; // output of circuit fed into A0
  const long R=10000;// R=100Kohm for capacitance above 1uf to ensure
 // that estimated time is not too small
  const float v_ref=5.0;
  const float v_fraction=0.63;

  void setup(){
  Serial.begin(115200);//display monitor
}
void loop(){
  pinMode(digitalpin,OUTPUT);//setting D13 as output for circuit
    // setting D13 LOW(0) to ensure that capacitor is intially discharged
  digitalWrite(digitalpin,LOW);// making v_out=0
  delay(50);

 // converting v_threshold to ADC value
 // consider 10bit ADC
 // ADC_threshold=((v_ref*v_fraction)/(v_ref))*1023
   int ADC_threshold= int(v_fraction*1023.0);

  // charging capacitor with digitalpin as a power source
  digitalWrite(digitalpin,HIGH);
  // starting timer
  long start=micros();
  int i=0;
    while(i<ADC_threshold){
      i=analogRead(analogpin);
    }
  long end=micros();
  float t_calculated=(end-start); // in  microseconds

    // using formula C=tau/R
    float C=t_calculated/R;
  // converting into uf
  float C_uf=C;
  Serial.print("C_uf:");
  Serial.print(C_uf);
  Serial.print("uF");

  Serial.print("measured time:");
  Serial.print(t_calculated);
  Serial.print("us");
  Serial.println();

    delay(500);
}
```

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Date

TASK B

1) $V_c = V(1 - e^{-t/(RC)})$ $(V_c(0) = 0)$

at $V_c = 0.63V$

$0.63 = 1 - e^{-t/RC}$

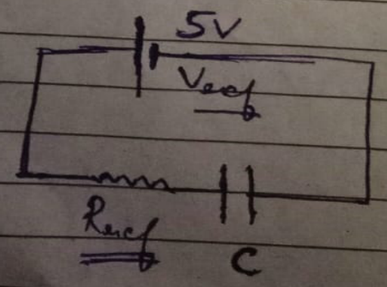
$t/RC = -\ln(1 - 0.63)$

$= t = -RC \ln(0.37)$

$= t \simeq RC$

∴ we use 63% to directly calculate C using formula $t = RC$

→ Keeping R = 100 KΩ



Some Potential sources

1) ADC Quantization error :

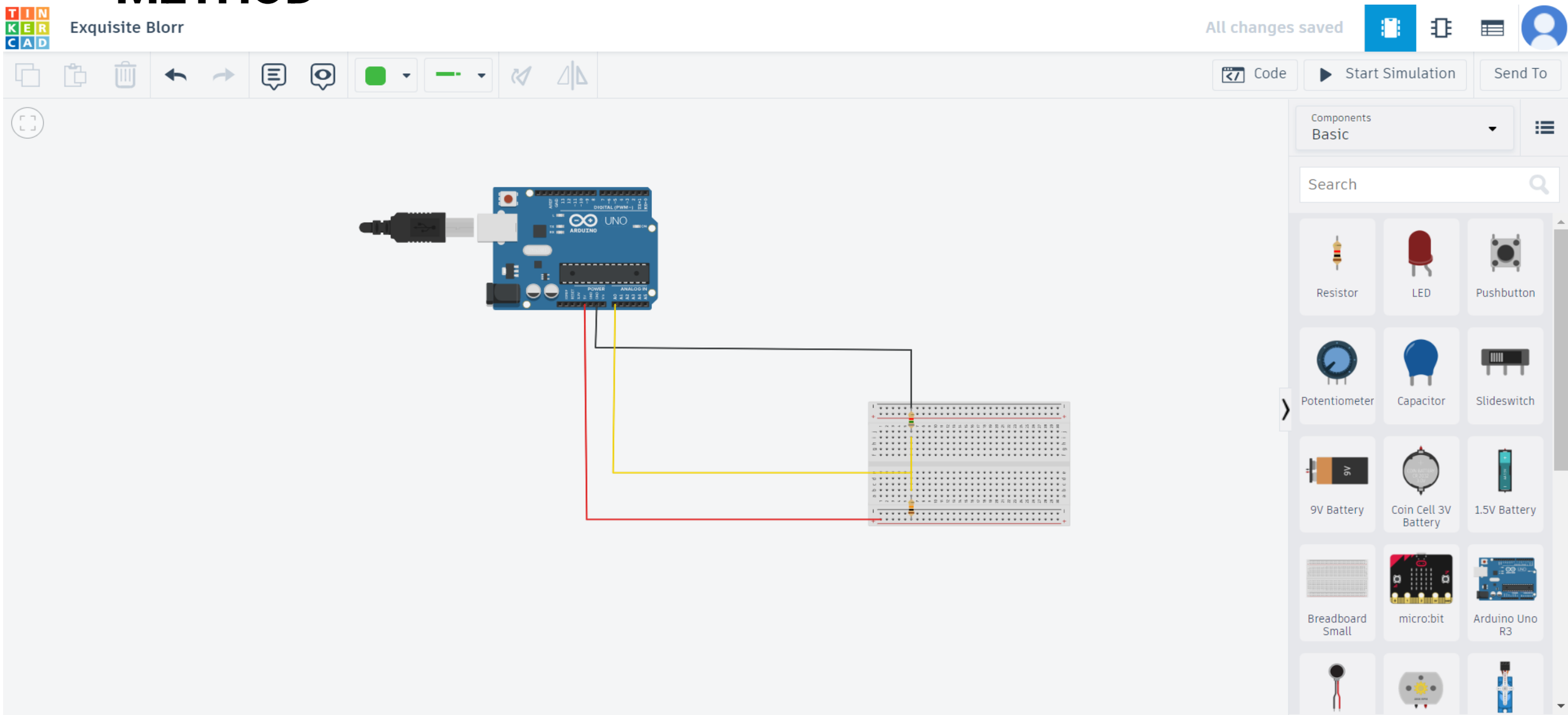
for ADC with 0-0V and 1023-5V , difference between two consecutive digital numbers =(5/1023)*1000=4.88mv so voltage change less than 4.88 cannot be detected and give previous ADC reading due to which threshold voltage may be detected slowly or early which can give error in time implies error in capacitance

2) Resistance tolerance values:

Here we used R=100kohm which is basically included with tolerance values (R+-x%) which may give error in capacitance

3) Capacitance takes some time to discharge. If it is initially not discharged completely then time taken to reach threshold voltage may be different from expected one and due to which we can get error in capacitance.

TASK C –BASIC OHMETRE USING VOLTAGE DIVIDOR METHOD



For Resistance=2.2Kohm

```
const int analogpin=A0 ;
  const float v_ref=5.0;
  const float v_in=5.0;
  const float R_ref=10000.0;

  void setup(){
  Serial.begin(9600);
}
void loop(){
  int ADCvalue=analogRead(analogpin); // ADC reading of V_mid

  // conversion of ADCvalue into Voltage
  // consider 10bit ADC
  float v_out=((float)ADCvalue*v_ref)/1023.0;// tinkercad result
    // using formula
    float R_unknown= R_ref * (v_out / (v_ref - v_out));

  Serial.print("Unknown resistance: ");
  Serial.print(R_unknown);
  Serial.println(" ohms");
  Serial.print("V_out:");
  Serial.print(v_out);
  Serial.print("volt");
Serial.println();
```

Serial Monitor

```
V_out:0.90volt
Unknown resistance: 2193.09 ohms
V_out:0.90volt
Unknown resistance: 2193.09 ohms
V_out:0.90volt
Unknown resistance: 2193.09 ohms
V_out:0.90volt
```

For Resistance=1.2Kohm

```
const int analogpin=A0 ;
  const float v_ref=5.0;
  const float v_in=5.0;
  const float R_ref=10000.0;

  void setup(){
  Serial.begin(9600);
}
void loop(){
  int ADCvalue=analogRead(analogpin); // ADC reading of V_mid

  // conversion of ADCvalue into Voltage
  // consider 10bit ADC
  float v_out=((float)ADCvalue*v_ref)/1023.0;// tinkercad result
    // using formula
    float R_unknown= R_ref * (v_out / (v_ref - v_out));

  Serial.print("Unknown resistance: ");
  Serial.print(R_unknown);
  Serial.println(" ohms");
  Serial.print("V_out:");
  Serial.print(v_out);
  Serial.print("volt");
Serial.println();
```

Serial Monitor

```
Unknown resistance: 1204.82 ohms
V_out:0.54volt
Unknown resistance: 1204.82 ohms
V_out:0.54volt
Unknown resistance: 1204.82 ohms
V_out:0.54volt
```

For Resistance=8.5Kohm

```
const int analogpin=A0 ;
  const float v_ref=5.0;
  const float v_in=5.0;
  const float R_ref=10000.0;

  void setup(){
  Serial.begin(9600);
}
void loop(){
  int ADCvalue=analogRead(analogpin); // ADC reading of V_mid

  // conversion of ADCvalue into Voltage
  // consider 10bit ADC
  float v_out=((float)ADCvalue*v_ref)/1023.0;// tinkercad result
    // using formula
    float R_unknown= R_ref * (v_out / (v_ref - v_out));

  Serial.print("Unknown resistance: ");
  Serial.print(R_unknown);
  Serial.println(" ohms");
  Serial.print("V_out:");
  Serial.print(v_out);
  Serial.print("volt");
Serial.println();
```

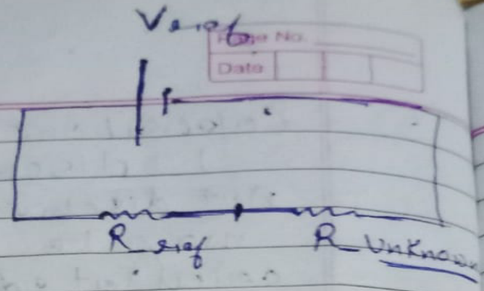
Serial Monitor

```
V_out:2.30volt
Unknown resistance: 8499.10 ohms
V_out:2.30volt
Unknown resistance: 8499.10 ohms
V_out:2.30volt
```

R expected (KΩ)	R measured (KΩ)	V out (theoritical)	V out (TINKERCAD)
2.20	2.19309	0.901 V	0.90 V
1.20	1.20482	0.535 V	0.54 V
8.50	8.49910	2.297 V	2.30 V

Theoretical Calculations

Task - 3



→ Using Circuit Laws.

$$V_{out} = \frac{V_{ref} \times R_u}{(R_{ref} + R_u)}$$

⇒ $V_{out} R_{ref} + V_{out} R_u = V_{ref} R_u$

$$\boxed{R_{unknown} = \frac{V_{out} \times R_{ref}}{V_{ref} - V_{out}}}$$

→ for $R_{ref} = 10K\Omega$, $V_{ref} = 5V$

→ 1st $R_{unknown} = 2.20K\Omega$

V_{out} (theoritical) $= \frac{5 \times 2.20}{(2.2 + 10)} \simeq 0.901$ ~~Volt~~

→ 2nd $R_{unknown} = 1.2K\Omega$

V_{out} (theoritical) $= \frac{5 \times 1.2}{(1.2 + 10)} \simeq 0.535$ Volt

→ 3rd $R_{unknown} = 8.5K\Omega$

V_{out} (theoritical)

$$= \frac{5 \times 8.5}{(8.5 + 10)} = 2.297 \text{ Volt}$$

. Suppose for unknown resistor=8.5Kohm
. We find output voltage 2.297volt theoretically

. Now consider 10 bit ADC (0-0Volt, 1023-5volt),

. We know Each step has a size of (5/1023)*1000=4.88mv

. So the maximum ADC error = +- ½(4.88mv)

. Let convert output voltage to ADC value that is

. 2.297=n(4.88/1000) which gives n approx 478.54

.So maximum Voltage ADC can read = 2.297+(1/2)*(4.88/1000)=2.29944volt

.Similarly minimum voltage ADC can read=2.297-(1/2)*(4.88/1000)=2.29454volt

.So output voltage vary from 2.29454 to 2.29944 due to which ADC reading varies as 478,479,478..

.This is called ADC quantization error.