

Name: _____

USC ID#: _____

I hereby affirm that all the answers below are my own. I have neither searched online nor taken assistance from any external entity.

Student Signature Above

EE105 – Fall 2025 Practice Midterm

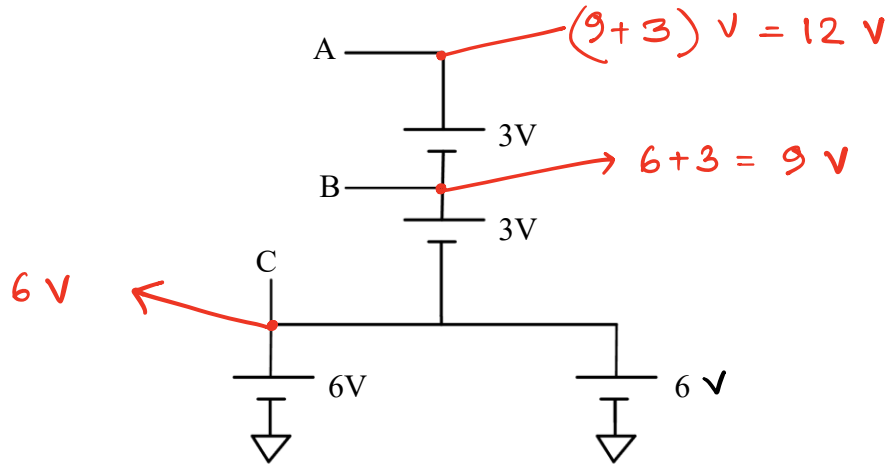
Time Limit: 2 hours

Total number of pages is 6 (including this page). Put your name on every page where noted

Section A (25 points)

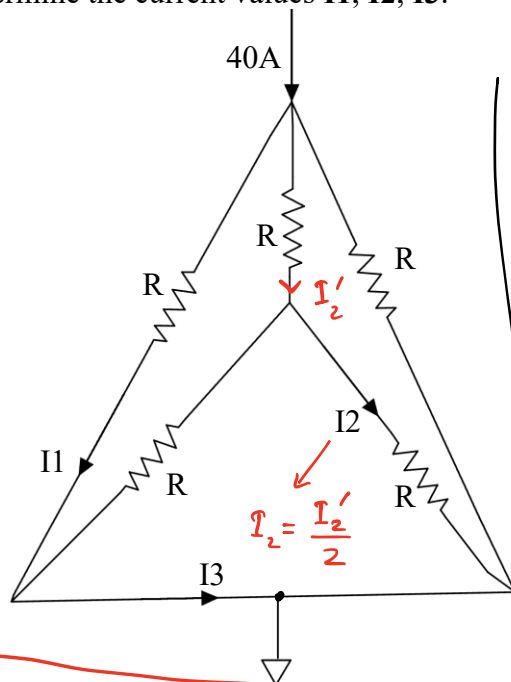
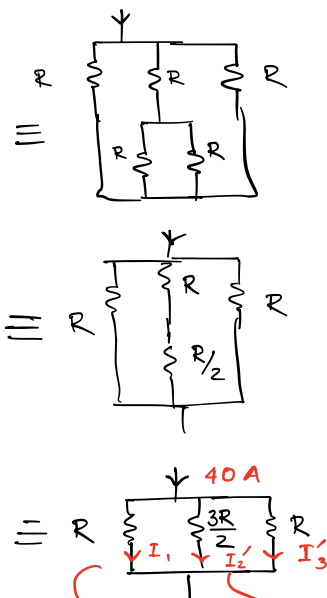
Question 1 (4 points)

Given the circuit diagram with nodes A, B, and C, each connected to either 3V or 6V sources as shown. Determine the voltages V_A , V_B , and V_C at the respective nodes with respect to the ground.



Question 2 (6 points)

Given the circuit below, determine the current values I_1 , I_2 , I_3 .



$$I_2 = \frac{I_2'}{2} = 5A$$

$$I_3 = I_1 + I_2 = 20A$$

Method 1:

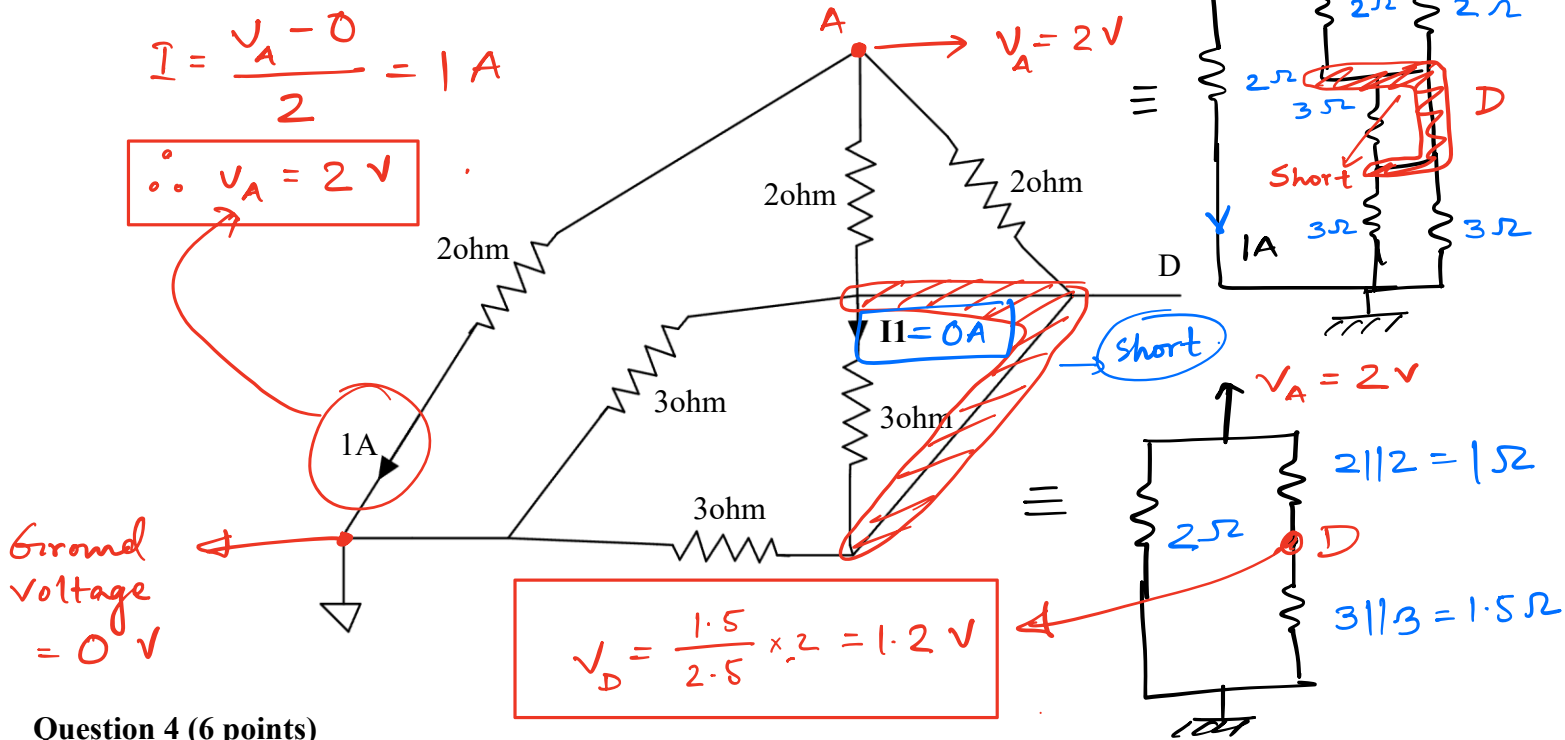
Curr. Div. Rule $I_1 = \frac{\frac{1}{R}}{\frac{1}{R} + \frac{1}{R} + \frac{2}{3R}} 40A$

$$= \frac{40}{(2 + \frac{2}{3})} = 15A = I_3' \text{ (Same Resistance)}$$

$I_2' = 40A - 2 \times 15A = 10A$

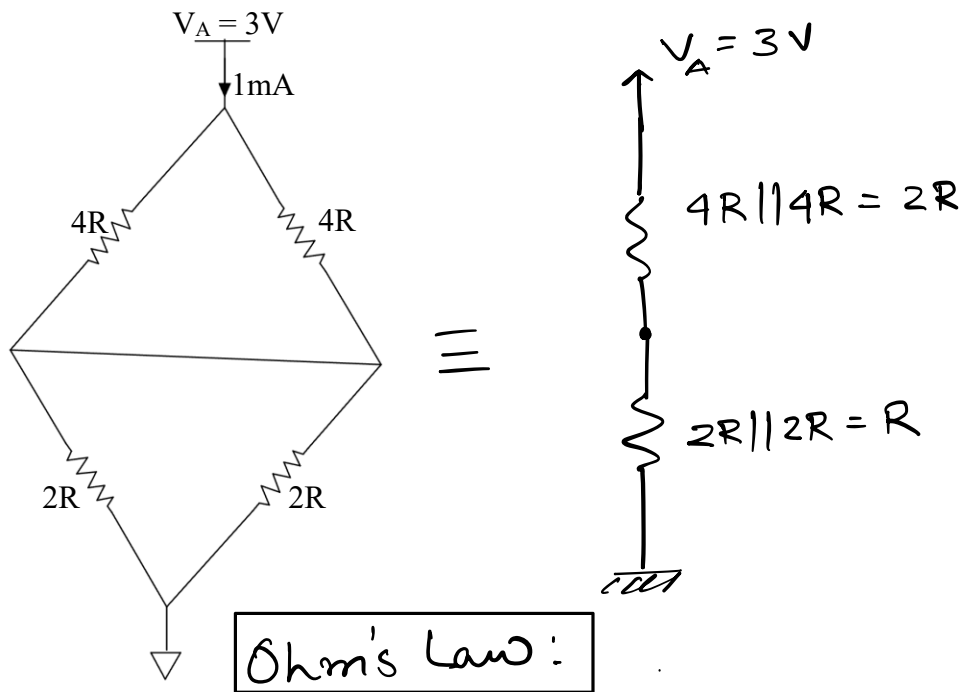
Question 3 (6 points)

Given the circuit with six resistors as shown. Find voltage at node D (V_D) and current I_1 .



Question 4 (6 points)

The voltage at node A with respect ground is 3V and total current going through the circuit is 1mA. Determine resistance value R.



Ohm's Law:

$$\therefore \frac{V_A - 0}{2R + R} = \frac{3}{3R} = 1mA$$

$$\Rightarrow R = 1k\Omega$$

Question 5 (6 points)

Complete the following python function.

```
import numpy as np

def create_and_print_evens(num_elements, lower_limit, upper_limit):
    """
    Creates a random integer array and then prints its even numbers.

    Args:
        num_elements: The number of integers to create in the array.
        lower_limit: The lowest possible value for the random integers (inclusive).
        upper_limit: The highest possible value for the random integers (inclusive).
    """
    # Step 1: Create a NumPy array with 'num_elements' random integers
    # that are between 'lower_limit' and 'upper_limit'.
    # YOUR CODE HERE
```

```
    A = np.random.randint(lower_limit, upper_limit, size=(num_elements))
```

```
    # Step 2: Now, loop through the random array you just created.
    # If a number is even, print it.
    # YOUR CODE HERE
```

```
    for i in A:
        if i%2 == 0:
            print(i)
```

Question 6 (6 points)

Given the three python lists:

```
a = [1, 2, 3]
b = [-1, 1, 2]
c = a + b
```

determine the following values:

```
c =
a[-2:1] =
a[3] =
```

```
c = [1,2,3,-1,1,2]
```

```
a[-2:1] = []
```

```
a[3] will give index error
```

Question 7 (6 points)

Look at the following code has been uploaded to an Arduino.

```
void setup() {
  pinMode(LED_BUILTIN, OUTPUT);
}

void loop() {
  digitalWrite(LED_BUILTIN, HIGH);
  delay(2000);
  digitalWrite(LED_BUILTIN, LOW);
  delay(2000);
}
```

$td = 2000 = 2 \text{ s}$

- How many times does the *void setup()* function run? **Once**
- In each cycle, how long does the LED stay ON? **2 seconds**
- Explain relationship between delay time and frequency of LED blinking. **$f = 1/(2*td)$**
- How should you modify the code if the LED blinking frequency needs to be 2Hz?

$$td = 0.5 * (1/2 \text{ s}) = 0.25 \text{ s} = 250$$

Question 8 (8 points)

A microcontroller uses a 12-bit ADC with a 5V reference voltage. The ADC outputs digital values in the range 0–4095 (since it is 12-bit).

- What is the range of the raw ADC output?
- Derive the formula for converting the raw ADC output into the corresponding analog voltage.
- Calculate the ADC conversion factor (the multiplier needed to convert the raw ADC value to voltage).
- If the ADC reading is 2175, compute the actual voltage.

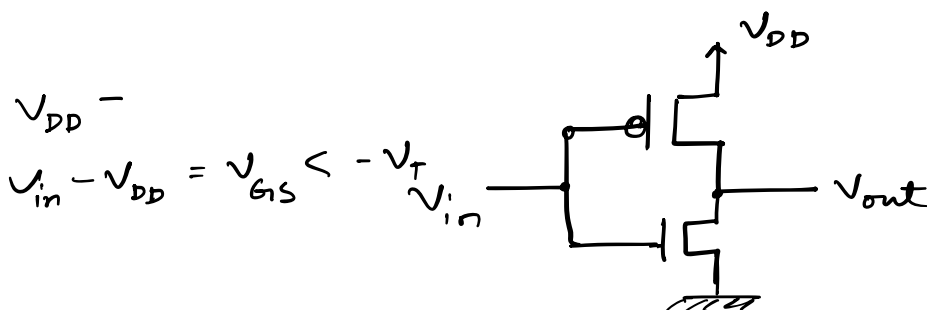
a) **Range = $1/4095 * 5 = 0.00122$** c) **$5.0/4095.0 = 1/819$**

b) **$adc_out * 5.0 / 4095.0$** d) **$2175 * 5.0/4095.0 = 2.656 \text{ V}$**

Question 9 (6 points)

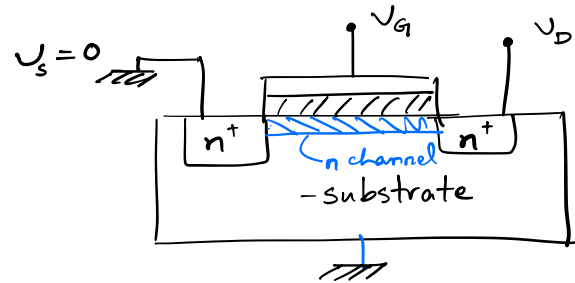
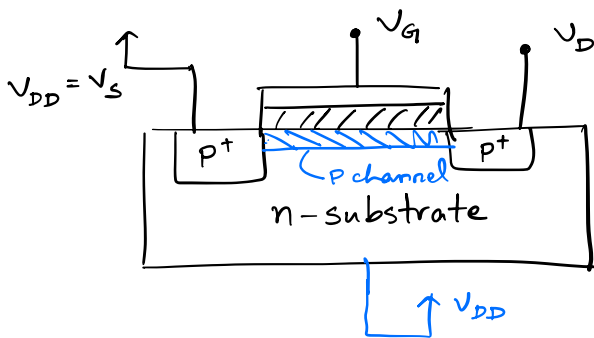
Draw the CMOS inverter and explain it's operation to fill up the following table

V _{in}	V _{out}
V _{DD}	0
0	V _{DD}



Question 10 (8 points)

Draw the cross section of p-channel and n-channel MOSFETs. Label each layer and terminal. What gate bias will be needed to turn on the p-channel and n-channel MOSFETs?



$$V_{GS} < -V_t$$

Channel forms

$$V_{GS} > V_t$$

Question 11 (8 points)

$$I = \frac{k V_{DSAT}^2}{2}$$

Consider an n-channel MOSFET with the following parameters:

- Mobility-oxide product: $\mu C_{ox} = 200 \mu A/V^2$

- Width/Length ratio: $W/L = 10$

- Threshold voltage: $V_T = 1.0 V$

$$k = \mu C_{ox} \left(\frac{W}{L} \right) = 0.2 \times 10 \text{ mA/V}^2 = 2 \text{ mA/V}^2$$

a) For $V_{GS} = 2.5 V$ and $V_{DS} = 1.0 V$:

- Determine whether the MOSFET operates in the linear or saturation region.
- Calculate the drain current I_D .

b) For $V_{GS} = 4.0 V$ and $V_{DS} = 5.0 V$:

- Check the region of operation.
- Calculate I_D .

c) Compare the results from (1) and (2) and briefly explain why I_D changes with operating region.

a) $V_{GS} = 2.5 V > V_T$; $V_{DS} = 1 V < 1.5 V$

$V_{OV} = V_{GS} - V_T = 1.5 V$

Triode Region / Linear region.

ii) $I_D = k \left[V_{DS} (V_{GS} - V_T) - \frac{V_{DS}^2}{2} \right]$

$= 0.2 \left[1.5 - \frac{1}{2} \right] \text{ mA} = 0.2 \text{ mA}$

(b)

$$V_{GS} = 4V > V_T$$

$$V_{GS} - V_T = 4 - 1 = 3V$$

$$V_{DS} = 5V > V_{GS} - V_T = 3V$$

(i) Saturation

(ii)

$$I_D = \frac{k}{2} V_{DSAT}^2 = \frac{0.2}{2} \times 3^2 \text{ mA} = 0.3 \text{ mA}$$

(c)

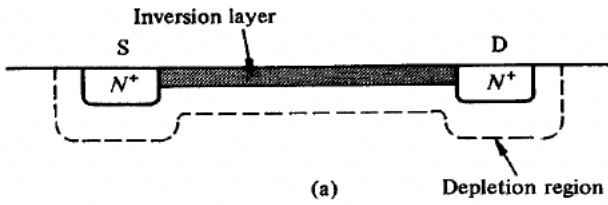
In linear region, the n-channel between drain and source is formed and not yet pinched off. So, for low enough V_{DS} ($V_{DS} \ll V_{GS} - V_{th}$), the channel acts like a linear resistor and allows current flow roughly proportional to the drain to source voltage.

Close to the saturation voltage ($V_{DS} \rightarrow V_{GS} - V_{th}$), the channel approaches pinch off and the rate of current increase with voltage decreases ($-V_{DS}^2/2$ term begins to dominate).

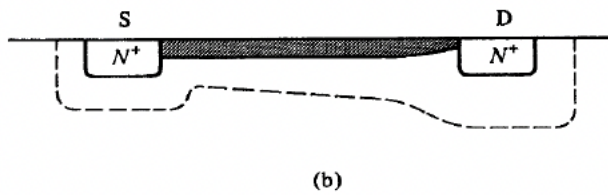
At higher V_{DS} ($V_{DS} \geq V_{GS} - V_{th}$) the channel begins to be pinched off and does not allow an increase in the current flow once the channel has been pinched off.

Question 12 (8 points)

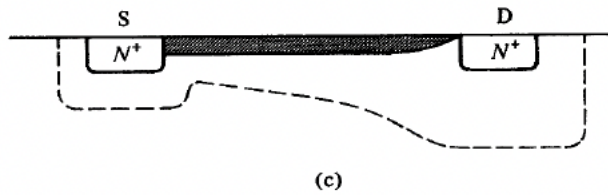
Briefly explain what happens at each stage of the following figure. Discuss V_G , V_T relationship, V_{DS} , and I_D values for each of the four stages. Define pinch-off and show how $V_{DS,sat}$ is related to V_{GS} and V_T .



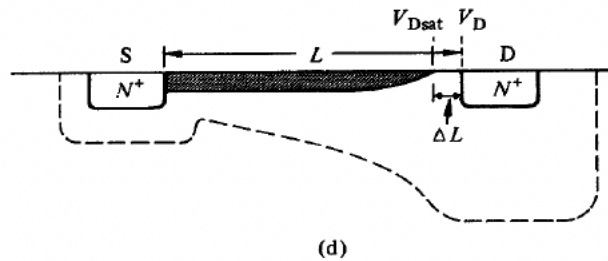
$V_G > V_T$; $V_{DS} \approx 0$
 I_D increases with V_{DS}



$V_G > V_T$; V_{DS} small, > 0
 I_D increases with V_{DS} , but rate of increase decreases.



$V_G > V_T$; $V_{DS} \approx \text{pinch-off}$
 I_D reaches a saturation value, $I_{D,sat}$
 The V_{DS} value is called $V_{DS,sat}$



$V_G > V_T$; $V_{DS} > V_{DS,sat}$
 I_D does not increase further, saturation region.