Problem 1.

Ms. Anna Logge, founder at a local MIT startup, has developed a device to be used as an inverter. Anna is considering the choice of parameters by which her logic family will represent logic values and needs your help.

The figure on the right shows the voltage transfer curve of a proposed inverter for a new logic family (you can find spare copies below).

Several possible schemes for mapping logic values to voltages are being considered, as summarized in the incomplete table below. **Noise Immunity (last row) is defined as the smaller of the two noise margins.**

Complete the table by filling in missing entries. Choose each value to maximize the noise margins of the corresponding scheme. **If the numbers in a scheme can't be completed such that the device functions as an inverter with positive noise margins, fill the entries for that column with Xs.**

### LNI's Possible Logic Mappings:

<table>
<thead>
<tr>
<th></th>
<th>Scheme A</th>
<th>Scheme B</th>
<th>Scheme C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{OL}$</td>
<td>X</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>$V_{IH}$</td>
<td>X</td>
<td>3</td>
<td>X</td>
</tr>
<tr>
<td>$V_{OH}$</td>
<td>X</td>
<td>5</td>
<td>X</td>
</tr>
<tr>
<td>Noise Immunity</td>
<td>X</td>
<td>0.5</td>
<td>X</td>
</tr>
</tbody>
</table>

**No possible value for** $V_{IH}$ **such that** $V_{out} \geq V_{IH}$ **for all** $V_{in} < 2$.

**Invalid,** $V_{OL} > V_{IL}$ **so noise margin is negative.**
Problem 2.

Suppose we define all signaling thresholds in our digital system to be relative to the supply voltage, $V_{DD}$:

- $V_{OL} = 0.1V_{DD}$
- $V_{IL} = 0.4V_{DD}$
- $V_{IH} = 0.6V_{DD}$
- $V_{OH} = 0.9V_{DD}$

We want to connect two types of digital devices, A and B, that use different supply voltages, $V_{DD,A}$ and $V_{DD,B}$. Assume that $V_{DD,A} = 1V$.

1. In the circuit below, under what range of supply voltages $V_{DD,B}$ will the system work correctly?

```
A → B
```

Outputs of A must be valid inputs to B

$V_{OL,A} \leq V_{IL,B}$
$0.1 \leq 0.4V_{DD,B}$
$0.25 \leq V_{DD,B}$

$V_{OH,A} \geq V_{IH,B}$
$0.9 \geq 0.6V_{DD,B}$
$1.5 \geq V_{DD,B}$

$0.25 \leq V_{DD,B} \leq 1.5$

2. In the circuit below, under what range of supply voltages $V_{DD,B}$ will the system work correctly?

```
A → B → A
```

Additional constraints: outputs of B are valid inputs to A

$V_{OL,B} \leq V_{IL,A}$
$0.1V_{DD,B} \leq 0.4$
$V_{DD,B} \leq 4$ (already satisfied)

$V_{OH,B} \geq V_{IH,A}$
$0.9V_{DD,B} \geq 0.6$
$V_{DD,B} \geq 2/3$

$2/3 \leq V_{DD,B} \leq 1.5$

3. For the same circuit as in part 2, under what range of supply voltages $V_{DD,B}$ will the system have noise margins of at least 0.1V?

```
V_{OL,A} + 0.1 \leq V_{IL,B}
0.5 \leq V_{DD,B} \leq 4/3

V_{OH,A} - 0.1 \geq V_{IH,B}
```

```
V_{OL,B} + 0.1 \leq V_{IL,A}
7/4 \leq V_{DD,B} \leq 4/3

V_{OH,B} - 0.1 \geq V_{IH,A}
```

$7/4 \leq V_{DD,B} \leq 4/3$
Problem 3.

The following are voltage transfer characteristics of single-input, single-output devices to be used in a new logic family:

![Device A and Device B diagrams]

Your job is to choose a single set of signaling thresholds $V_{OL}$, $V_{IL}$, $V_{OH}$, and $V_{IH}$ to be used with both devices to give the best noise margins you can. Recall that the VTC can touch the edge of the forbidden regions but not pass through those regions. Fill in your answers below, together with the resulting noise margins. You'll get partial credit for anything that works with nonzero noise margins; for full credit, maximize the noise immunity (i.e., the smaller of the two noise margins).

$V_{OL} = 0.5$  $V_{IL} = 1.67$  $V_{IH} = 3.5$  $V_{OH} = 4.5$

Low Noise Margin = 1.57  High Noise Margin = 1
Problem 4.

The following are voltage transfer characteristics of devices to be used in a new logic family as an inverter and buffer, respectively:

![VTC Diagrams](image)

Your job is to choose a single set of signaling thresholds $V_{OL}$, $V_{IL}$, $V_{OH}$, and $V_{IH}$ to be used with both devices to give the best noise margins you can. Recall that the VTC can touch the edge of the forbidden regions but not pass through those regions. Fill in your answers below, together with the resulting noise margins. You'll get partial credit for anything that works with nonzero noise margins; for full credit, maximize each of the noise margins.

\[
V_{OL} = \_1 \quad V_{IL} = \_1.5 \quad V_{IH} = \_3 \quad V_{OH} = \_4
\]

Low Noise Margin = \_0.5 \quad High Noise Margin = \_1

*Scratch copy of the VTC diagrams:*

![Scratch VTC Diagrams](image)
Problem 5.

The voltage transfer curve for an inverter is shown to the right. The manufacturer decided to crowd-source the digital signaling specifications for their inverter and has received some suggestions for $V_{OL}$, $V_{IL}$, $V_{IH}$, and $V_{OH}$, presented below in tabular form below.

For each suggested specification, determine if the inverter would be a legitimate combinational device with non-zero positive noise margins. If it is a legitimate combinational device, give the noise immunity of the inverter (the smaller of the low and high noise margins) when operating under that specification. If the inverter wouldn’t be a legitimate combinational device, please write NOT LEGIT in the rightmost column.

**Fill in rightmost column for each suggested specification.**

<table>
<thead>
<tr>
<th>Suggestion</th>
<th>$V_{OL}$</th>
<th>$V_{IL}$</th>
<th>$V_{IH}$</th>
<th>$V_{OH}$</th>
<th>Noise immunity, or NOT LEGIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>0.00</td>
<td>0.50</td>
<td>1.50</td>
<td>2.00</td>
<td>Not legit</td>
</tr>
<tr>
<td>#2</td>
<td>0.25</td>
<td>0.75</td>
<td>1.25</td>
<td>1.75</td>
<td>Not legit</td>
</tr>
<tr>
<td>#3</td>
<td>0.50</td>
<td>0.75</td>
<td>1.25</td>
<td>1.50</td>
<td>0.25</td>
</tr>
<tr>
<td>#4</td>
<td>0.75</td>
<td>0.50</td>
<td>1.75</td>
<td>1.50</td>
<td>Not legit</td>
</tr>
</tbody>
</table>

#1: Can't produce 0 output

#2: Test — for $V_{in} \geq V_{IH}$, is $V_{out} \leq V_{OL}$? Not satisfied (1.25) (0.25)

#3: Valid

#4: Test — is $V_{OL} < V_{IL} < V_{IH} < V_{OH}$? Not satisfied