(A) Design, build and test a circuit to experimentally determine the truth table of a 7400 NAND gate

1 x 7400 (Quad 2 input Nand Gate)
1 x LED
Resistors and Switches
First, connect an LED and resistor between ground and 5V and check it lights.

Next, hard wire the 7400 NAND inputs and confirm it works.

Finally, add the switches and pull down resistors and confirm the truth table.
Ohm's Law - the most fundamental formula in electrical engineering

Georg Simon Ohm (16 March 1789 – 6 July 1854) was a German physicist and mathematician.

Ohm's Law

The law states that the direct current flowing in a conductor is directly proportional to the potential difference between its ends. It is usually formulated as $V = IR$, where $V$ is the potential difference, or voltage, $I$ is the current, and $R$ is the resistance of the conductor.
Resistors

The electrical resistance of an electrical conductor is the opposition to the passage of an electric current through that conductor.

The SI unit of electrical resistance is the ohm (Ω).

For a wide variety of materials and conditions, V and I are directly proportional to each other.

This proportionality is called Ohm's law, and materials that satisfy it are called "Ohmic" materials.

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element.
# Resistor Color Code Guide

A resistor color code is a system where colors represent specific values for resistors. The color bands on a resistor correspond to its resistance value, tolerance, and other specifications. The chart below provides a guide to decode resistor color codes:

## 4-Band-Code

<table>
<thead>
<tr>
<th>COLOR</th>
<th>1st BAND</th>
<th>2nd BAND</th>
<th>3rd BAND</th>
<th>MULTIPLIER</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1Ω</td>
<td>± 1% (F)</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10Ω</td>
<td>± 2% (G)</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100Ω</td>
<td>± 3% (D)</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1KΩ</td>
<td>± 3% (B)</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>10KΩ</td>
<td>± 0.1% (K)</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>100KΩ</td>
<td>± 0.5% (D)</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>1MΩ</td>
<td>± 0.25% (C)</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>10MΩ</td>
<td>± 0.10% (B)</td>
</tr>
<tr>
<td>Grey</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
<td>± 0.05%</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td>± 5% (J)</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td></td>
<td></td>
<td>0.01</td>
<td>± 10% (K)</td>
</tr>
</tbody>
</table>

## 5-Band-Code

- First band: Color of the resistor.
- Second band: Numeric value of the resistor.
- Third band: Multiplier of the resistor.
- Fourth band: Tolerance of the resistor.
- Fifth band: Additional tolerance code.

### Example

- Black, Brown, Purple, Gold, Silver: 1Ω ± 5% (J)
- Red, Black, Yellow, Silver, Gold: 100Ω ± 1% (E)

The chart also includes examples of 5-band codes and their corresponding values.
A short circuit is an electrical circuit that allows a current to travel along an unintended path, often where essentially no (or a very low) electrical resistance is encountered.

A common type of short circuit occurs when the positive and negative terminals of a battery are connected with a low-resistance conductor, like a wire.

With low resistance in the connection, a high current exists, causing the cell to deliver a large amount of energy in a short time.

A large current through a battery can cause the rapid buildup of heat, potentially resulting in an explosion or the release of hydrogen gas and electrolyte (an acid or a base), which can burn tissue, cause blindness or even death.

Overloaded wires can also overheat, sometimes causing damage to the wire's insulation, or a fire.
A fuse is a type of low resistance resistor that acts as a sacrificial device to provide overcurrent protection in either the load or source circuit.

Its essential component is a metal wire or strip that melts when too much current flows through it, interrupting the circuit that it connects.

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit.
When a light-emitting diode is switched on, electrons are able to recombine with holes within the device, releasing energy in the form of photons.

This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor.

In silicon or germanium diodes, the electrons and holes usually recombine by a non-radiative transition, which produces no optical emission. The materials used for the LED have energies corresponding to near-infrared, visible, or near-ultraviolet light.

An LED is often small in area (less than 1 mm x 1mm), and integrated optical components may be used to shape its radiation pattern. LED anvil can have either polarity.
Light Emitting Diode

An anode is an electrode through which electric current flows into a polarized electrical device.

The direction of electric current is, by convention, opposite to the direction of electron flow.

In other words, the electrons flow from the anode into, for example, an electrical circuit.

The word was coined in 1834 by William Whewell, who had been consulted by Michael Faraday over some new names needed to complete a paper on the recently discovered process of electrolysis.
Notice that the leads of the device are two different lengths. This is to indicate that one “leg” of the device is the anode, and the other is the cathode. On an LED device the longer leg is always the anode, and the shorter leg is the cathode. Current always flows from the anode to the cathode. In a simple circuit, the anode of the LED is connected to the positive voltage supply, and the cathode is connected to ground, or the negative voltage supply.

A good way to remember the names using the schematic symbol is that “anode” and “arrow” both start with the letter “a”. So the side of the schematic symbol connected to the “arrow” is the “anode”, making the side connected to the line the cathode.
You can often connect LEDs to give a visual indication of a 1 (LED lighted) or a 0 (LED dark). Here some LEDs are shown, together with a 470 current limiting resistor.

If you connect LED indicators to your circuit remember that an LED is not the same in both directions, and you have to get the correct end connected to the resistor. The other end of each LED is connected to ground (or just "grounded"). Here's the circuit to show the output of a NAND gate

When the output of the gate is a 1, the output voltage will be five (5) volts. Current will flow through the series combination of the resistor and the LED, so the LED will light. When the output of the gate is a 0, the output voltage will be zero (0) volts and the LED will not be lit. Thus, the LED lights up when the output is a 1, and doesn't light when the output is a 0. You can use this indication scheme to show the status for any signal. It doesn't have to be the output of a gate.
LEDs have two properties that you care about:

1. forward voltage drop - how much voltage has to go across the led to light up
2. maximum current - how much current the LED can handle.

The forward voltage drop varies depending on the chemicals/materials used inside the LED but typically, they're

<table>
<thead>
<tr>
<th>Color</th>
<th>Current</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>30mA</td>
<td>1.7V</td>
</tr>
<tr>
<td>Bright red</td>
<td>30mA</td>
<td>2.0V</td>
</tr>
<tr>
<td>Yellow</td>
<td>30mA</td>
<td>2.1V</td>
</tr>
<tr>
<td>Green</td>
<td>25mA</td>
<td>2.2V</td>
</tr>
<tr>
<td>Blue</td>
<td>30mA</td>
<td>3.3V</td>
</tr>
</tbody>
</table>

If the LED doesn't get this much voltage, it may not light up. The maximum current is exactly that, the maximum the LED can tolerate. If you give it more current than the value the datasheet says the LED can handle, the LED may destroy itself or it may become so bright the color changes (for example red becomes orange).

Even though a datasheet may say the LED supports up to - for example - 20 mA, it doesn't mean you should configure the circuit to give it 20mA. 20 mA for that LED may be super bright. You might find 10mA is easier on the eyes and bright enough for your needs.
Voltage = Current x Resistance

Voltage is the voltage you supply to the circuit, from which you take out the forward voltage of the LED.
Current is how much current you want to allow through the LED in Amperes: 1A = 1000 mA so 10 mA = 0.01A, 100mA = 0.1A etc

So if your input voltage is 5v and you want to use a LED with a forward voltage of 2.2v at a maximum of 10 mA, then your formula becomes:

5v - 2.2v = 0.01 x R

so R becomes \((5-2.2) / 0.01\) = 280 ohms.

This 280 ohms is not a standard value, so you can use 270 ohms or 300 ohms, which are easy to find. A lower resistor value means a bit more current is allowed through led, a higher value means less current is allowed.
Because resistors dissipate heat energy as the electric currents through them overcome the "friction" of their resistance, resistors are also rated in terms of how much heat energy they can dissipate without overheating and sustaining damage.

This power rating is specified in the physical unit of "watts."

You might also be interested in knowing how big a resistor you need to use. The power dissipated in a resistor by limiting the current is determined with the formula $P = I \times I \times R$

So if we go with the example above where we go with a 270 ohm resistor and 10mA goes through it, then the power will be $0.01 \times 0.01 \times 270 = 0.027$ watts, which means a 0.125w resistor (1/8w) is more than enough for this.
The two 2.2 kΩ resistors are placed in the circuit to avoid floating input conditions on the used gate. With a switch closed, the respective input will be directly connected to Vcc and therefore be "high." With a switch open, the 2.2 kΩ "pulldown" resistor provides a resistive connection to ground, ensuring a secure "low" state at the gate's input terminal. This way, the input will not be susceptible to stray static voltages.
A pull resistor works because you can basically model most logic inputs as a really big resistor if input valid. One terminal of the resistor is your input node, this is what is sampled by your logic device. The other terminal goes to ground. Sometimes called a high-impedance input and is pretty standard on most TTL devices. When you put a pull resistor on it you’re creating one of two potential circuits. With a pull-down you have a parallel resistance.

A rule of thumb is to use a resistor that is at least 10 times smaller than the value of the input pin impedance. In bipolar logic families which operate at 5V, the typical pull resistor value is 1-5 kΩ.
With a pull-up resistor you’ve got a voltage divider

The appropriate value for the pull-up resistor is limited by two factors. The first factor is power dissipation. If the resistance value is too low, a high current will flow through the pull-up resistor, heating the device and using up an unnecessary amount of power when the switch is closed. This condition is called a strong pull-up and is avoided when low power consumption is a requirement. The second factor is the pin voltage when the switch is open. If the pull-up resistance value is too high, combined with a large leakage current of the input pin, the input voltage can become insufficient when the switch is open.
A breadboard is a construction base for prototyping of electronics. Originally it was literally a bread board, a polished piece of wood used for slicing bread. In the 1970s the solderless breadboard (AKA plugboard, a terminal array board) became available and nowadays the term "breadboard" is commonly used to refer to these.