(### insert plot of RC response here ###)

Figure ###: Voltage output for the RC circuit as a function of time

2.3 Inductor

An inductor is a device that stores energy in the form of current. The most common form of inductors is a wire wound into a coil. The magnetic field generated by the wire creates a counter-acting electric field which impedes changes to the current. This effect is known as Lenz's law and is stated mathematically as

$$V_L = -L\frac{dI}{dt}.$$

The unit of inductance is a Henry (H) and common inductors range from nanohenries (nH) to microhenries (μH).

In the hydrodynamic analogy of electronic circuits, an inductor can be thought of as a fluid channel pushing a flywheel as shown in *Figure 2.6*. When the fluid velocity (current) in the channel changes, the inertia of the flywheel tends to resist that change and maintain its original angular momentum. A large inductor corresponds to a flywheel with a large inertia, which will have a larger influence on the flow in the channel. Correspondingly a small inductor corresponds to a flywheel with a small inertia, which will have a lesser effect on the current.

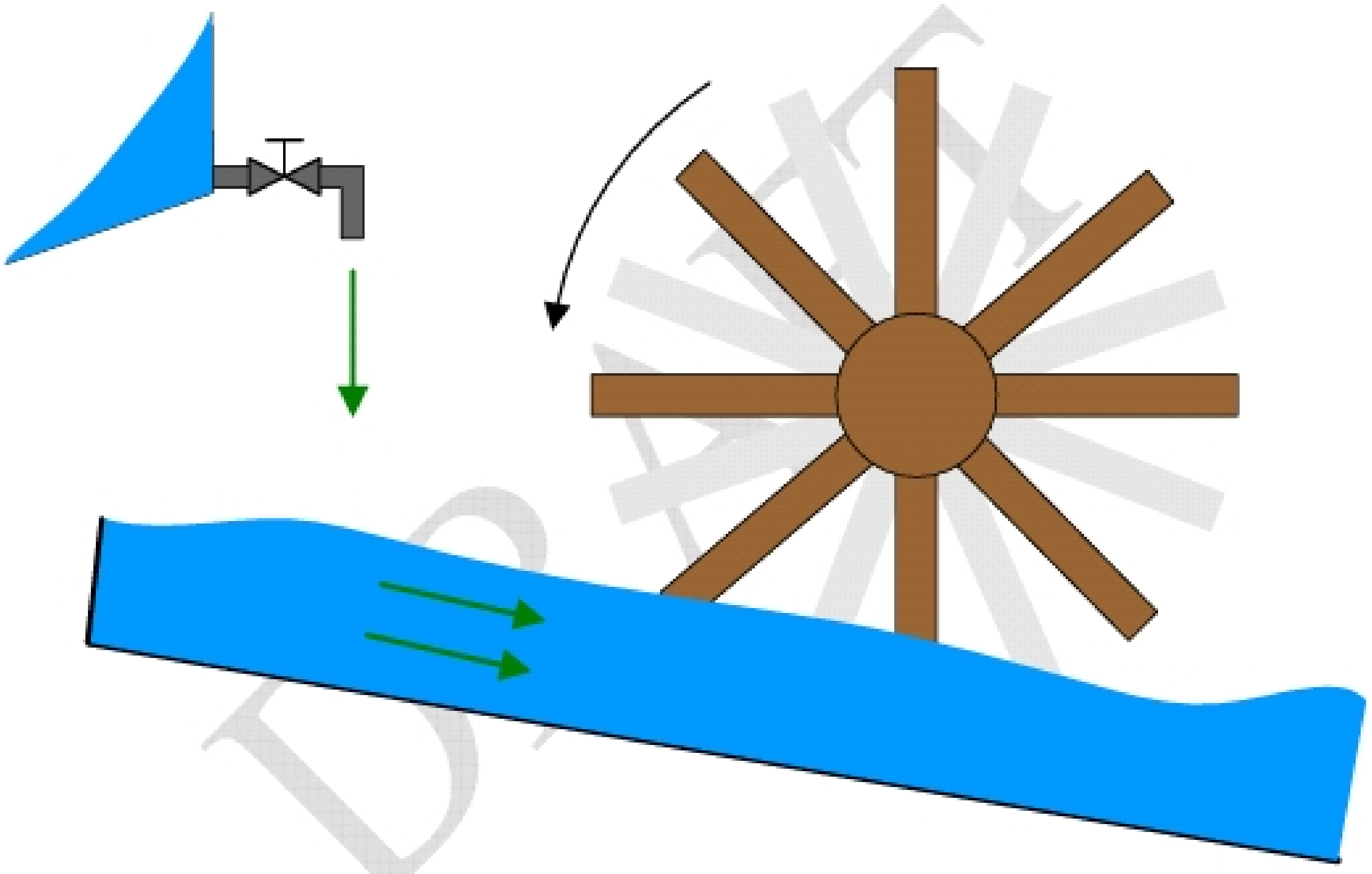

Figure 2.6: Hydrodynamic analogy of an inductor is a flywheel

An example of the time domain analysis of an inductor circuit is shown in *Figure 2.7* where the inductor is connected in series with a resistor, a switch, and an ideal voltage source. Initially, the current through the inductor is zero and the switch goes from closed to open at $t = 0$. Similar to the capacitor-resistor circuit, the time-domain behavior of this circuit can be determined by solving the first order differential equation ###. The resulting voltage across the inductor is an exponential function of time as shown in Figure ###.

6 Diodes

6.1 Diode Basics

A Diode is an electronic equivalent of a one-way valve; it allows current to flow in only one direction. There are two terminals on a diode, which are known as the anode and cathode. Current is only allowed to flow from anode to cathode. The symbol and drawing for the diode are shown in *Figure 6.1* and *Figure 6.2*. The dark band of the diode drawing indicates the cathode mark on the diode symbol. The direction of current flow is indicated by the direction of the triangle. An easy trick for remembering the direction of current flow is to remember that of the current flowing *alphabetically*, from the *anode* to the *cathode*.

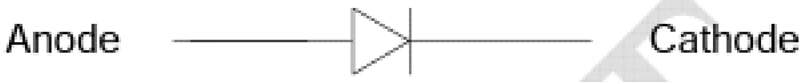

Figure 6.1: Circuit symbol for a diode

Figure 6.2: 3D model of a diode, the dark band indicate cathode (Courtesy of Vishay Semiconductors)

The unidirectional conduction through a diode is explained by semiconductor physics. A diode is a junction between N-type and P-type semiconductors, typically fabricated in thin layers as shown in *Figure 6.3*. Both N-type and P-type materials are electrically neutral, but have different mechanisms of conduction. In N-type material, negatively charged electrons are mobile and are the majority current carriers. In P-type material, positively charged holes are mobile are the majority current carriers. Holes are actually temporary positive charges created by the lack of an electron; the details of this interpretation can be found in textbooks on semiconductor physics [Ref: Sedra and Smith].

Near the junction interface, electrons from the N-type region diffuse into the P-type region while holes from the P-type region diffuse into the N-type region. The diffused electrons and holes remain in a thin boundary layer around the junction known as the depletion layer shown in *Figure 6.3*. The excess of positive and negative charges create a strong electric field at the junction which acts as a potential barrier that prevent electrons from entering the P-type region and holes from entering the N-type region.

When a negative electric field is applied from anode to cathode, the depletion region enlarges and it becomes even more difficult to conduct current across the junction. This is the reverse-conducting state. When a positive electric field is applied from anode to cathode, the depletion region narrows and allows current to conduct from the anode to the cathode. This is the forward-conducting state.

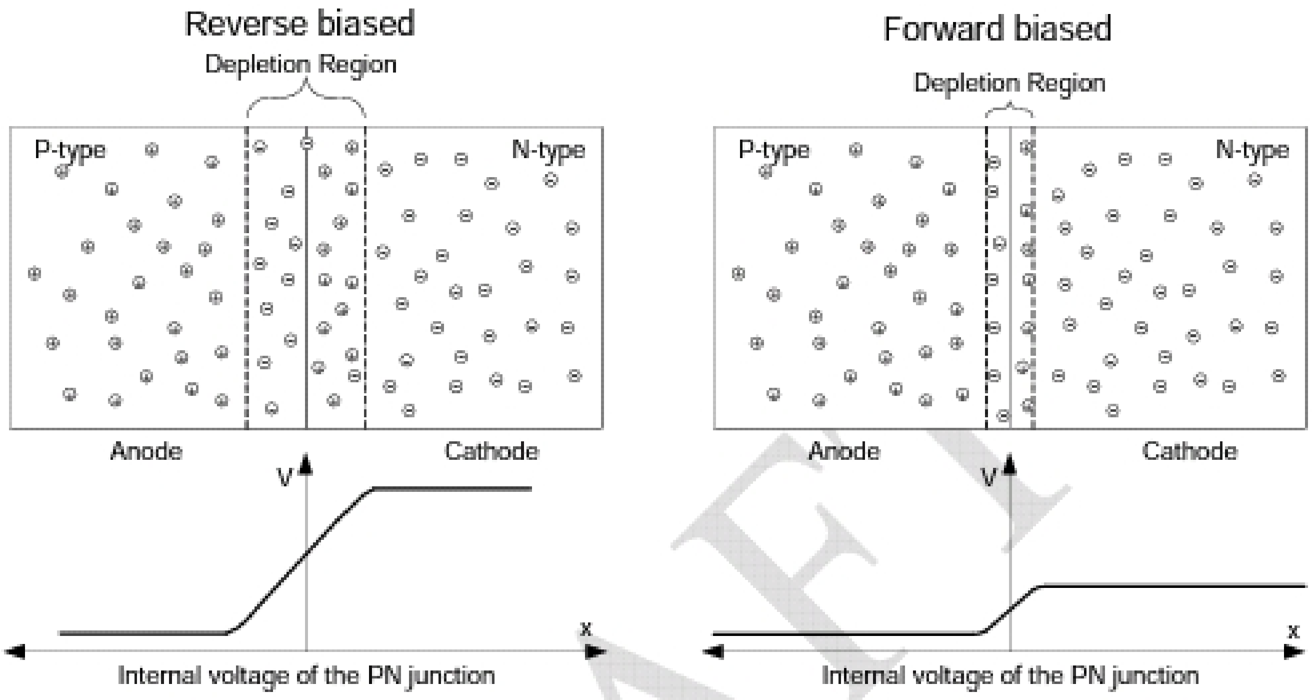

Figure 6.3: PN Junction in a diode showing the depletion region

The current-voltage relationship for a diode is shown in *Figure 6.4*. The current is an exponential function of voltage such that

$$I(V) = I_o\left(e^{\frac{V}{V_t}} - 1\right), \text{ and}$$

$$V_t = \frac{kT}{}$$