Video Material Week 07

Inductors Worked example

1. Introduction

An inductor is another circuit element that gives rise to time-dependent voltages and currents in an electric circuit. We can apply the same shorthand approach to analyse circuits containing inductors as we did for capacitors. Consequently, there is some element of revision in this video material.

Before we get started, it may be useful to keep the following idea in mind. Capacitors and inductors are devices that are able to store electrical energy. In the case of the capacitor, energy is stored in the electric field that develops across a capacitor when a battery is connected. In the case of the inductor, energy is stored in a magnetic field. Under certain circumstances, this enables capacitors and inductors to behave a bit like batteries or current sources, albeit rather limited ones.

2. Worked problem

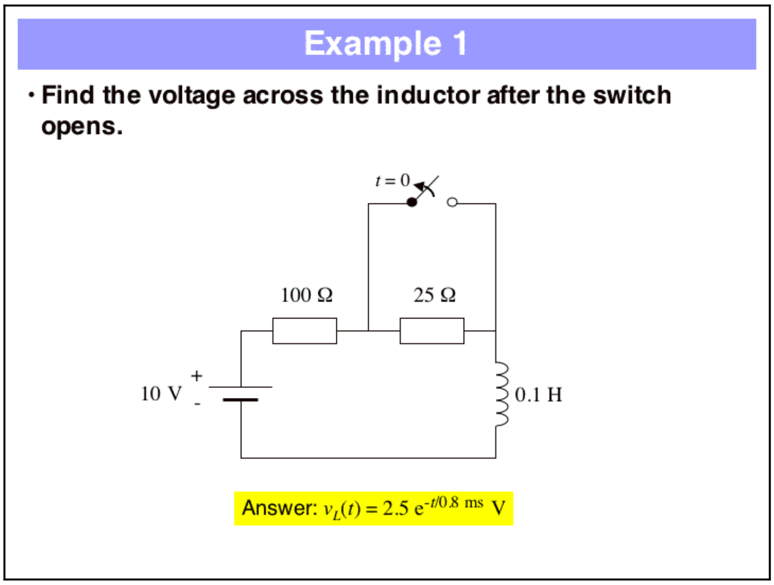

Figure 1.1: Worked example.

In this problem, a switch, that was initially closed, opens at time t = 0. Notice that when the switch is closed it shorts-out the 25 Ω resistor. What is more, a steady current must already flow through the inductor, assuming that the switch has been closed for a long time before it is opened. If this is the case, the inductor looks like a short-circuit to the battery before the switch opens. The initial current in the inductor is then simply given by i_L=V/R=10/100=0.1 A.

When the switch opens, the inductor tries to maintain the current flowing through it.

Therefore, we know that just after the switch opens 0.1 A still flows through the inductor, since the current in the inductor cannot change instantaneously. The situation is shown in the circuit below.

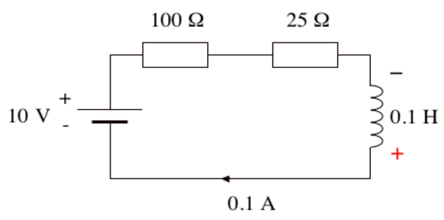

Figure 1.2: Example 1 - Solution.
The situation just after the switch opens.

By opening the switch we have effectively added resistance to the circuit, so the tendency will be for the current to drop. The inductor will oppose this change by momentarily acting like a battery in an attempt to maintain the current at its initial value. This tells us how to assign the polarity of the induced voltage. We can determine the initial voltage across the inductor in this circuit using Kirchhoff's voltage law. Going clockwise around the loop, starting at the bottom left-hand corner, and counting up the potential rises and drops we find

$$10-0.1\,x\,100-0.1\,x\,25+v_L=0$$

This gives the initial voltage across the inductor to be 2.5 V. As the current reaches its new steady-state value, the voltage across the inductor will fall exponentially to zero. This will be its final value. The time constant is given in the usual way by $\tau=L/R=0.1/(100+25)=8\times10^{-4}$s or 0.8ms. Putting these values into the general solution for RL (or RC) circuits we obtain the answer given Figure 1.1.

3. Try it for yourself

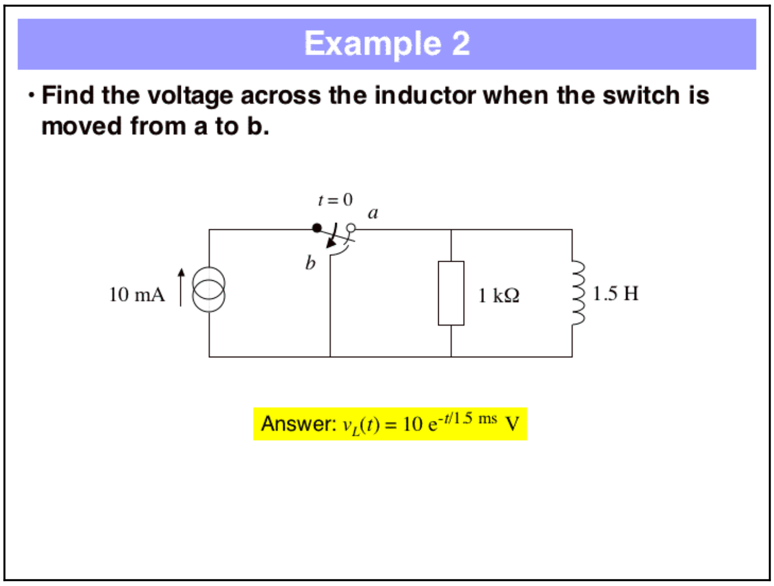

Figure 1.3: Example 2.

Here is a similar example for you to try. At time t = 0 the switch is moved from a to b. Notice that this switch looks a bit unusual. It is known as a make-before-break switch. You have to be careful when disconnecting current sources (and energised inductors) from a circuit. The reason is that both devices try to maintain a constant current. You cannot therefore just let them go open-circuit. This switch allows the current source to be shorted before breaking contact with the rest of the circuit.

To solve this problem you must determine the initial current in the inductor. You may assume that the switch has been at position a a long time before the switch is moved to position b.