VINNITSA NATIONAL AGRARIAN UNIVERSITY

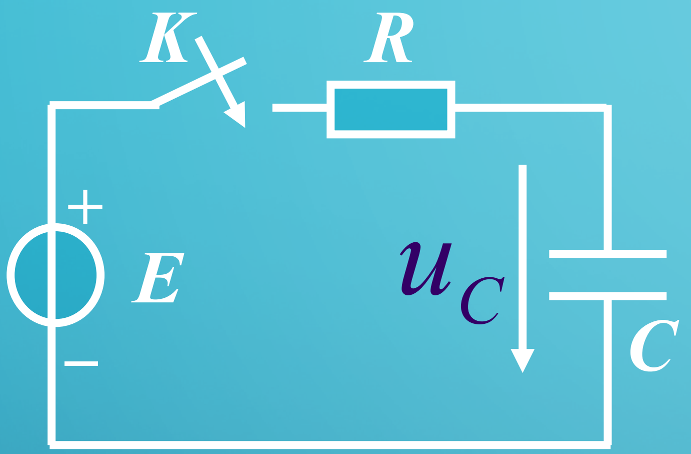
Department of General Engineering Sciences and Labour Safety

TRANSIENTS IN ELECTRICAL CIRCUITS

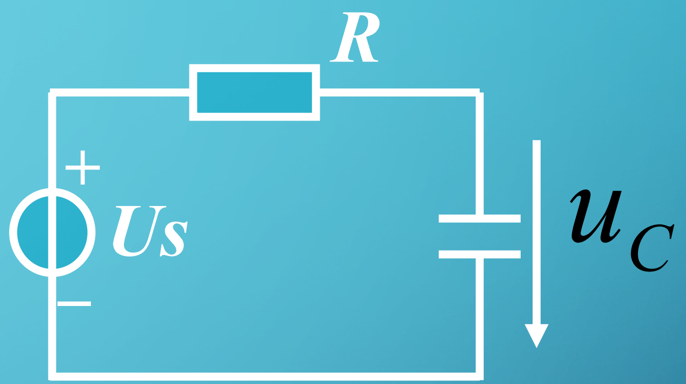
by Associate Professor V. Hraniak

Introduction

Conception of steady state and transient state



Switch *K is closed*

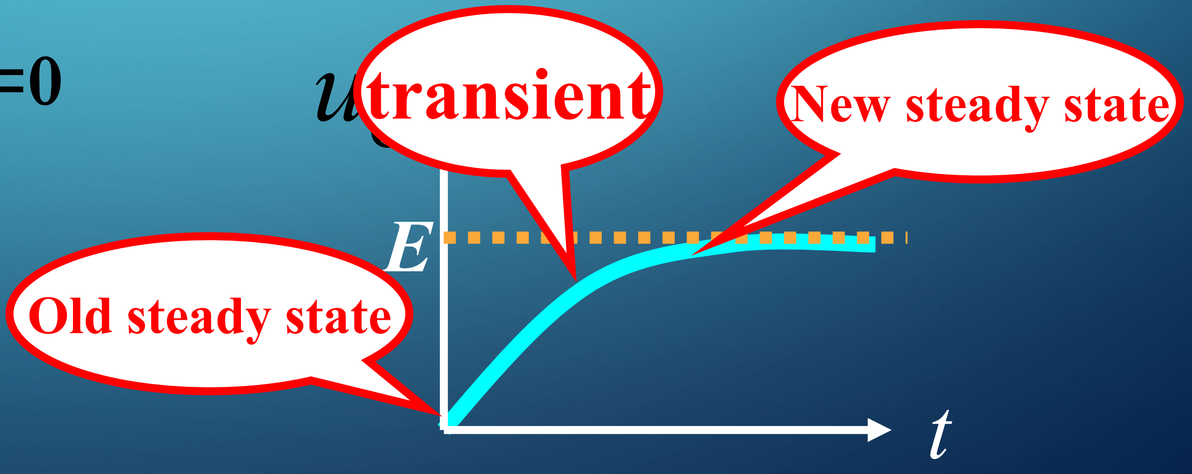


New steady state

When t=∞, $u_c(\infty)=U_s$

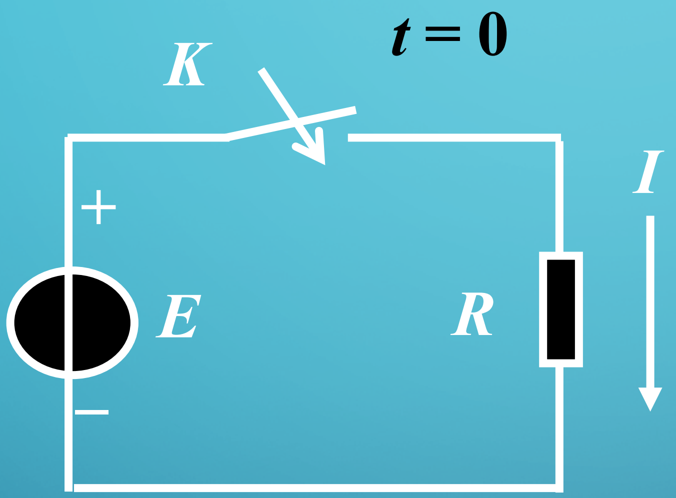
Old steady state

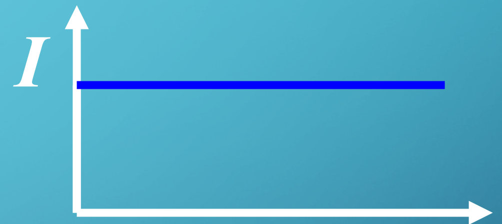
When t=0， $u_c(0)=0$



Why the transient response happens?

Resistance circuit





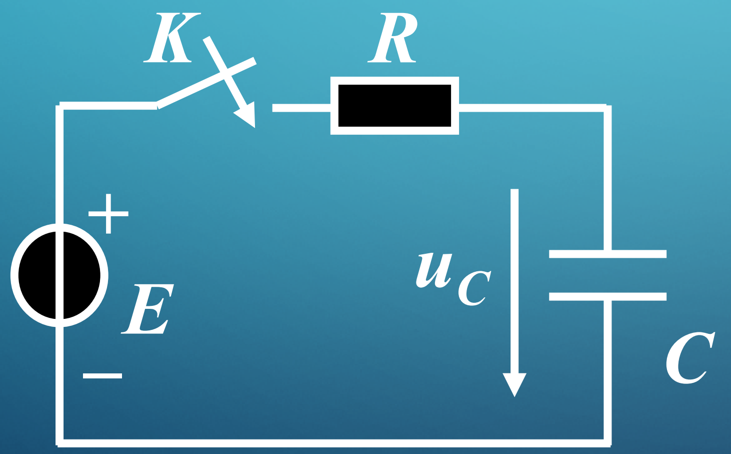
No transient

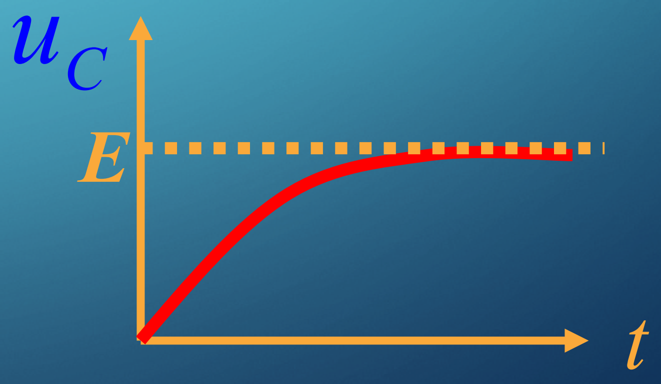
Resistor is a energy-consumption element, current is proportional to voltage, no transient response will happen even if changing source

Energy can not change instantly because of accumulating or decaying period.

Electric field energy $\left(W_C = \frac{1}{2} C u_C^{\,2}\right)$

W_C **Charging or discharging** ⇨ u_C **Change gradually**

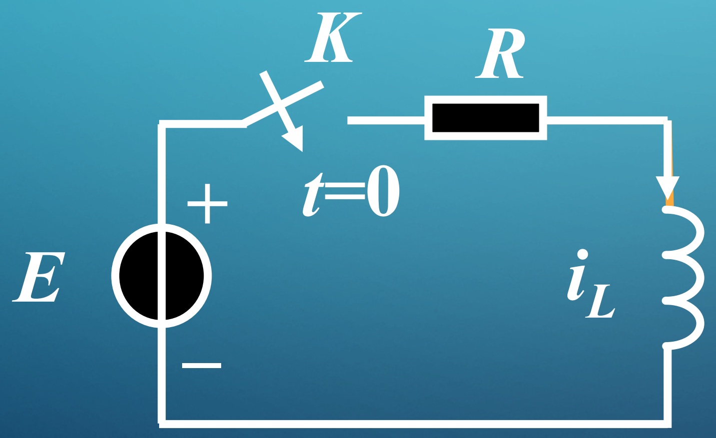


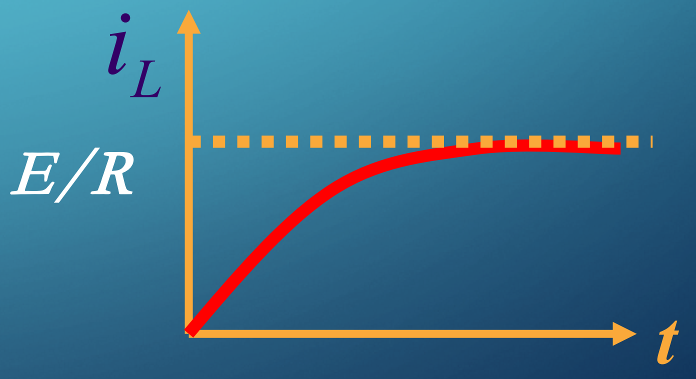


Energy can not change instantly because of accumulating or decaying period.

Magnetic field energy $\left(W_L = \frac{1}{2} L i_L^{\ 2}\right)$

W_L $\Longrightarrow$ i_L **Change gradually**





Transients

The time-varying currents and voltages resulting from the sudden application of sources, usually due to switching.

By writing circuit equations, we obtain integrodifferential equations.

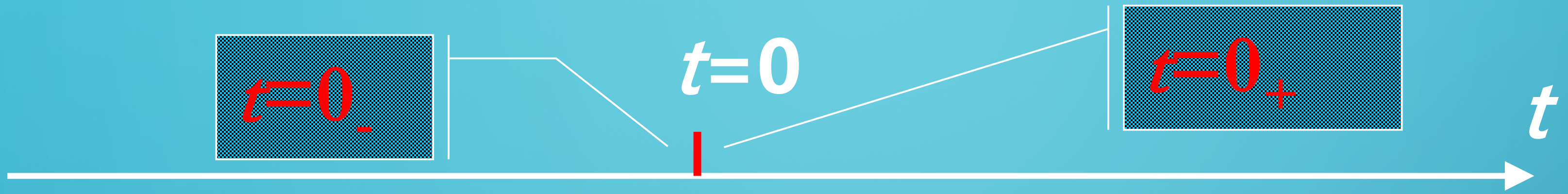
The causes of transients:

1. Energy storage elements
   -inductors and capacitors

   u_C, i_L change gradually;

2. Changing circuit, such as switching source.

INITIAL STATE AND STEADY STATE



Assume changing circuit when t=0, then t=0– is end point of old steady state; t=0+ is the start point of transient state.

$$\begin{cases} W_L(0_-) = W_L(0_+) \\ W_C(0_-) = W_C(0_+) \end{cases}$$

The law of changing circuit

$$\begin{cases} i_L(0-) = i_L(0+) \\ u_C(0-) = u_C(0+) \end{cases}$$

From t=0_ to t=0+, i_L、 u_C change continuously.

DC STEADY STATE RESPONSE

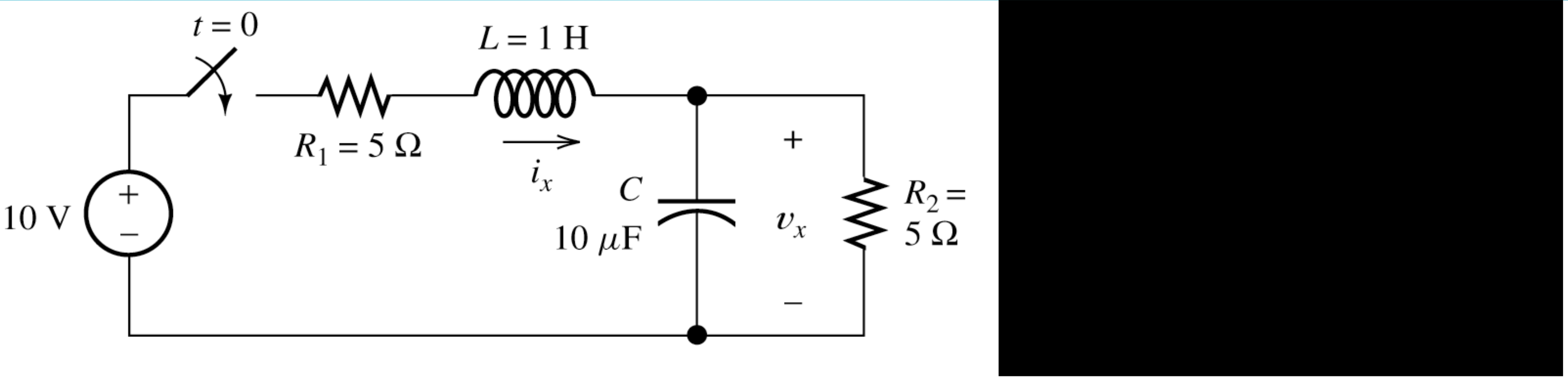
The steps in determining the forced response or steady state response for *RLC* circuits with DC sources are:

1. Replace capacitances with open circuits.

2. Replace inductances with short circuits.

3. Solve the remaining circuit.

Example Find steady-state values of v_x and i_x in this circuit for t>>0.



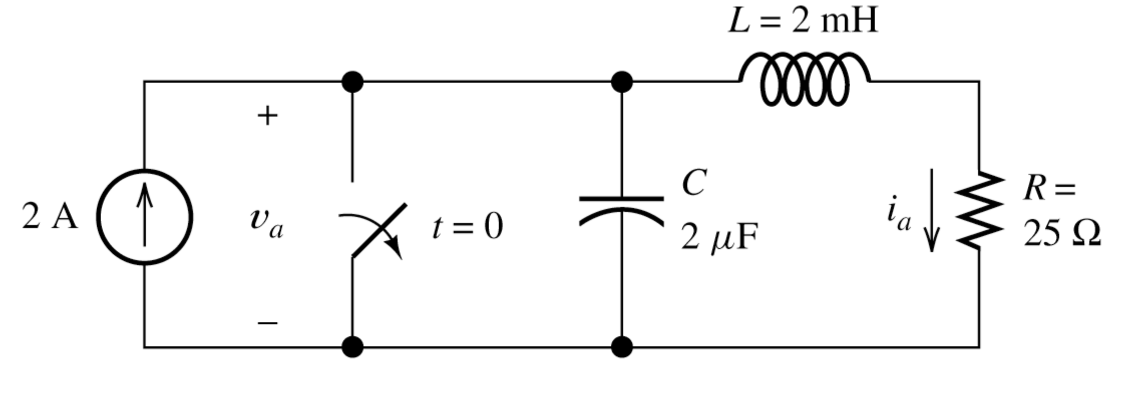
(a) Original circuit

(b) Equivalent circuit for steady state

Figure 4.5 The circuit and its dc steady-state equivalent for Example 4.1.

Answer: v_x =5V, i_x = 1A t>>0

Exercise 4.3 Find steady-state values of labeled currents and voltages for t>>0.



Answer: v_a =50V, i_a = 2A

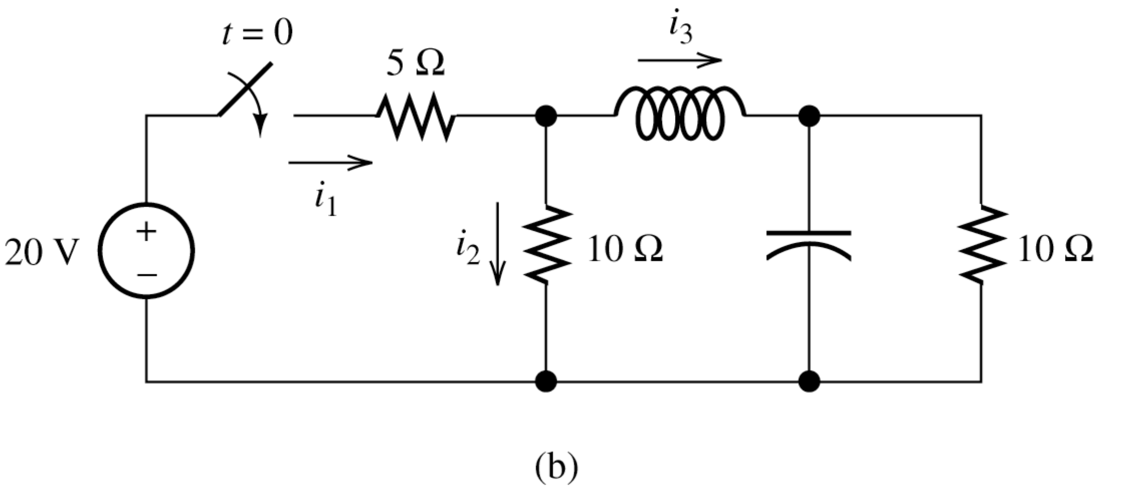
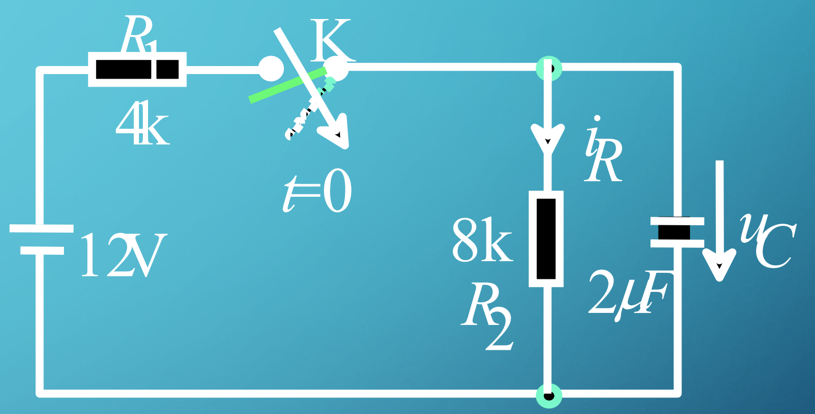


Figure 4.6 Circuits for Exercise 4.3.

i_1 = 2A, i_2=1A, i_3=1A

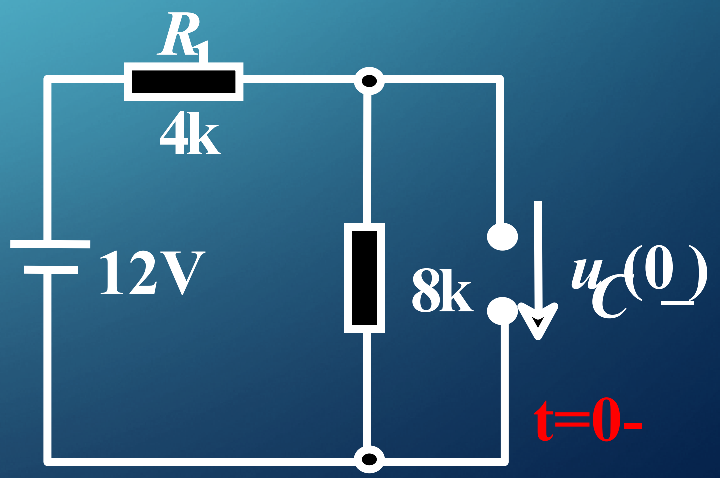
HOW TO GET INITIAL VALUE

Exercise 1: Assuming old circuit is in DC steady state before switch K is closed. How to get $u_C(0+), i_R(0+)$?



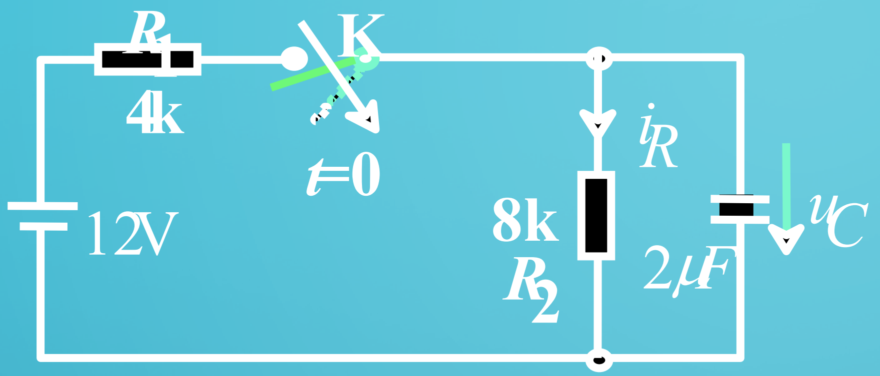
Solution:

When t=0-, capacitor is considered as open circuit, we get equivalent circuit.



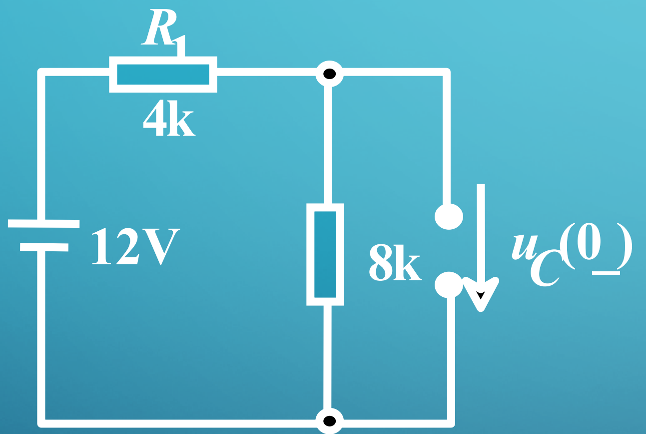
$$u_C(0\_) = \frac{8}{4+8} \times 12 = 8\,\text{V}$$

How to get initial value

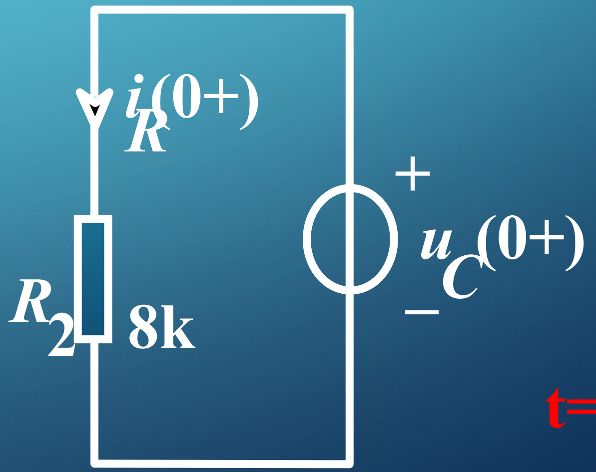


$$u_C(0_-) = \frac{8}{4+8} \times 12 = 8\,\mathrm{V}$$

$$\mathbf{u}_C(0_+) = \mathbf{u}_C(0_-) = 8\mathbf{V}$$



substituting voltage source for $u_C(0_+)$



$t=0_+$

$$i_R(0+) = \frac{u_C(0+)}{R_2} = \frac{8}{8} = 1\,\mathrm{mA}$$

How to get initial value

Exercise 2: Given by R1=4Ω, R2=6Ω, R3=3Ω, C=0.1μF, L=1mH, US=36V, switch S is closed for a long time. Open the switch S when t=0, how to get the initial values of all elements?