SNS COLLEGE OF TECHNOLOGY

(AN AUTONOMOUS INSTITUTION)

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Department of Biomedical Engineering

Course Name: 23BMT201 & Circuit Analysis

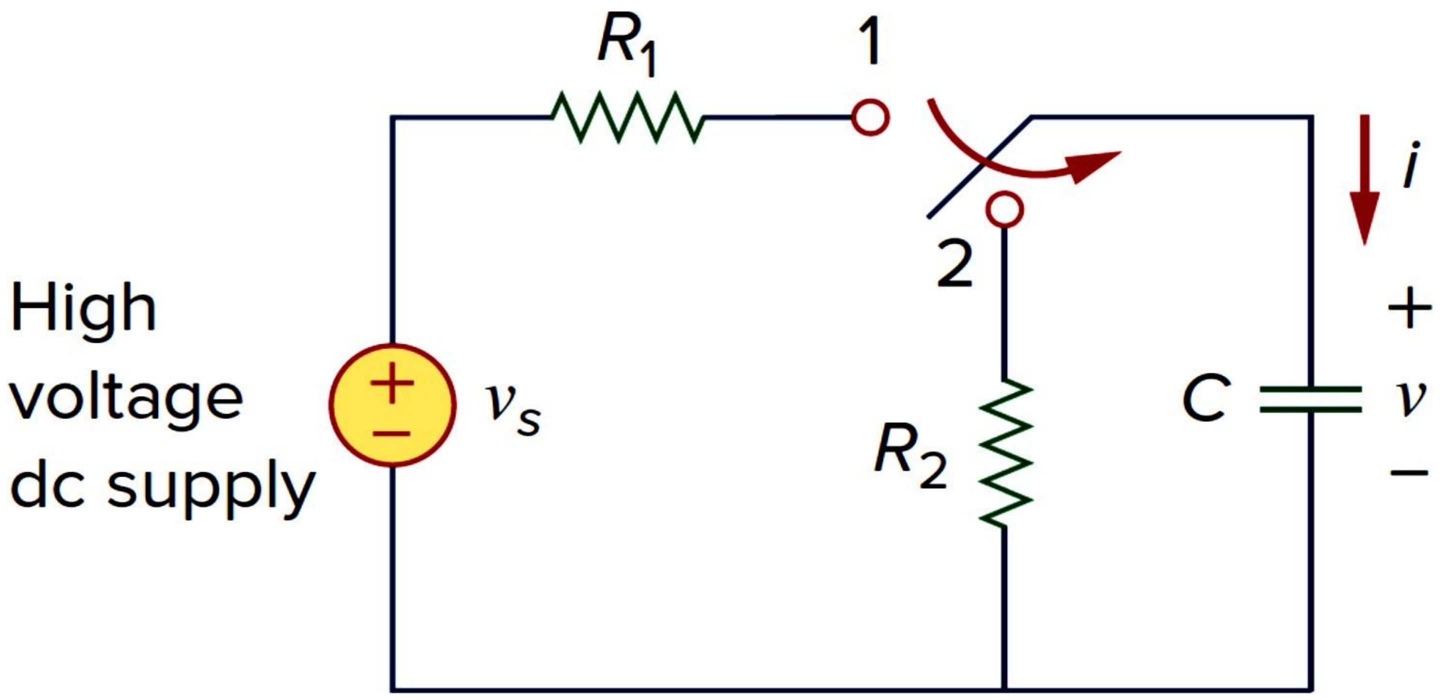
I Year : II Semester

Unit IV –TRANSIENT RESPONSE FOR DC AND AC CIRCUITS

Topic : Basic RL and RC Circuits

Real Life Applications – Photo Flash

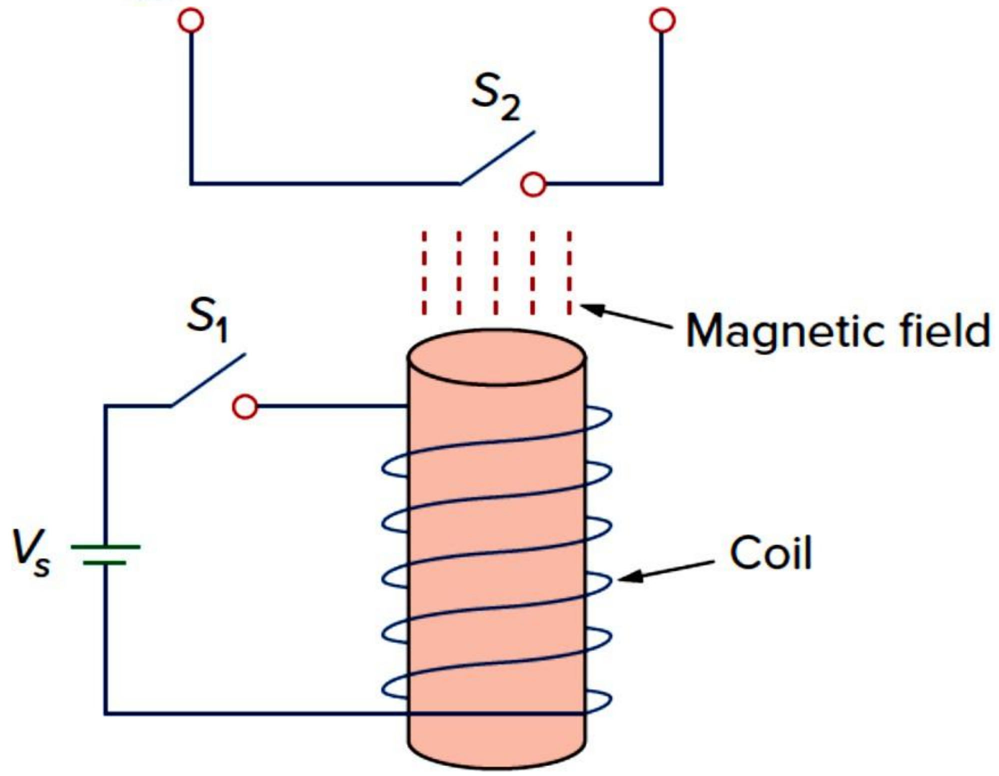
Digital Camera Flash Light utilizes a RC circuit to create a short duration high current pulse to energize the flash light.

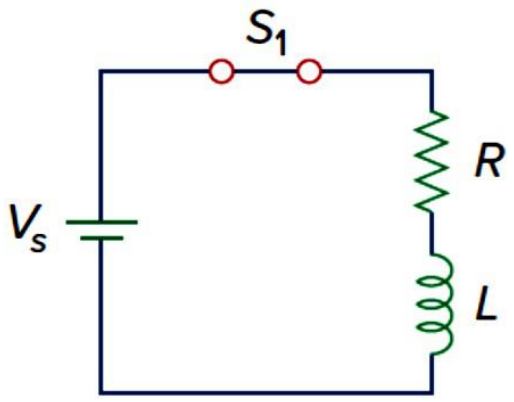


Circuit for a flash unit providing slow charge in position 1 and fast discharge in position 2 ($R_1 >> R_2$).

Real Life Applications – Relay Circuits

Relay coil is nothing but an RL circuit used to control the switching of another circuit

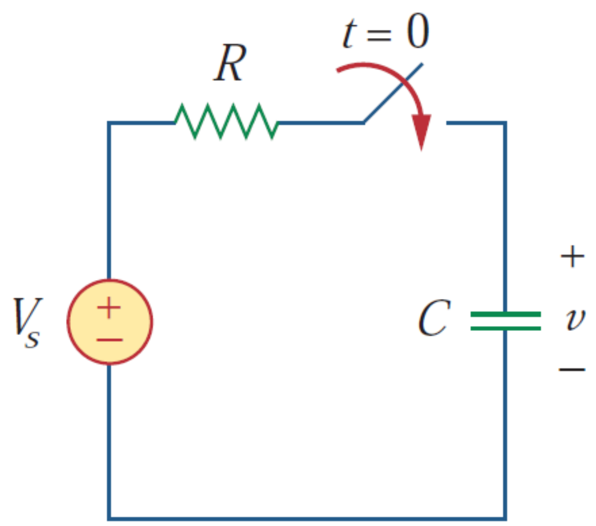


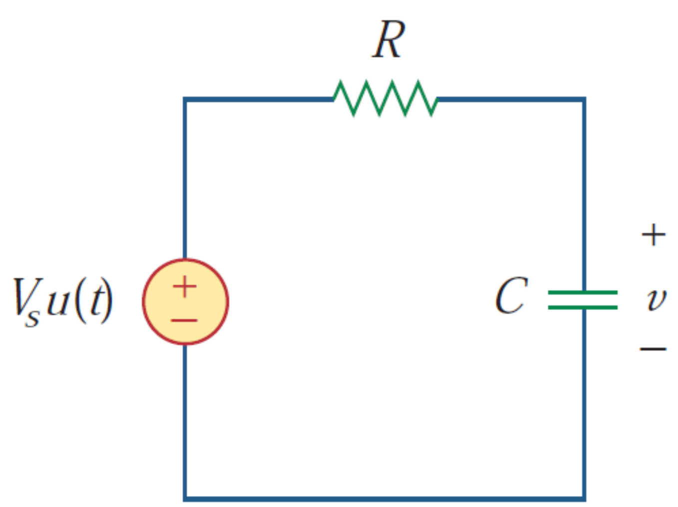


Step Response of an RC Circuit

When a DC source is suddenly turned on, the source voltage or current can be modelled as a step function

The step response of a circuit is its behavior when the excitation is the step function, which may be a voltage or a current source





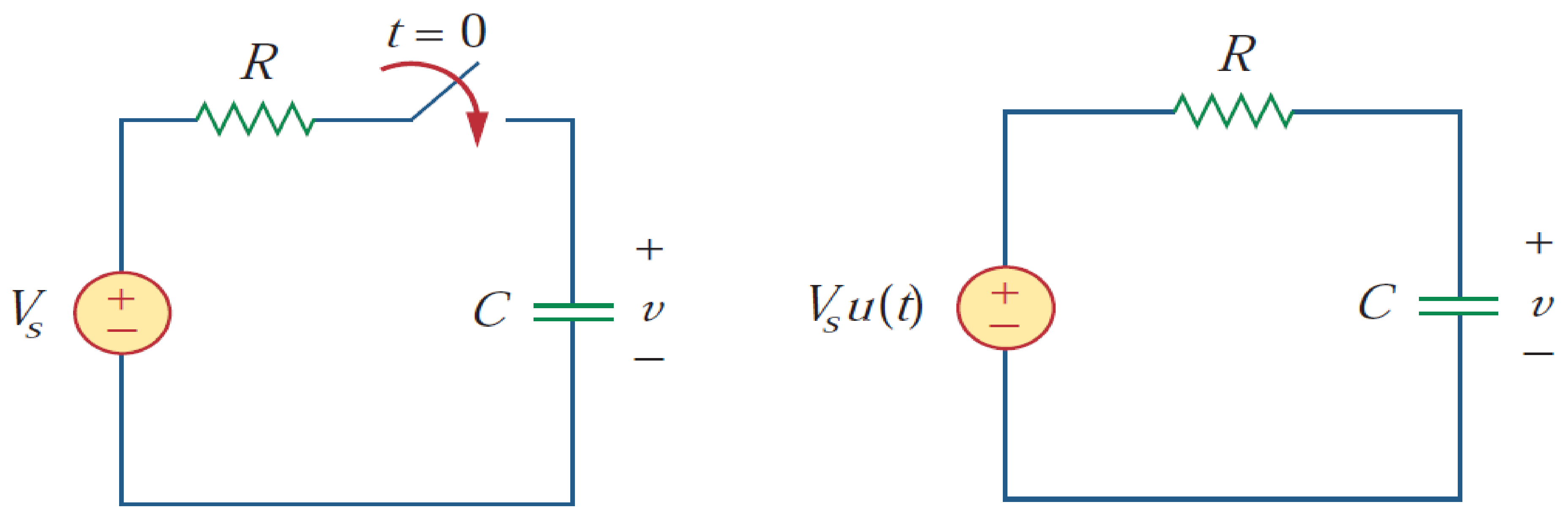
u(t): Unit-step function
= 0 for t < 0
= 1 for t > 0

Step Response of an RC Circuit

Analysis:

- Consider the RC circuit in Fig. (a) which can be replaced by the circuit in Fig. (b) for $t > 0$, where V_s is a constant dc voltage source.
- Select the capacitor voltage v as the circuit response to be determined.
- Assume an initial voltage V_0 on the capacitor.

Since, capacitor voltage cannot change instantaneously, $v(0^{\square}) \square v(0^{\square}) \square V$



Step Response of an RC Circuit

On applying KCL,

$$C\frac{dv}{dt}+\frac{v-V_s u(t)}{R}=0$$

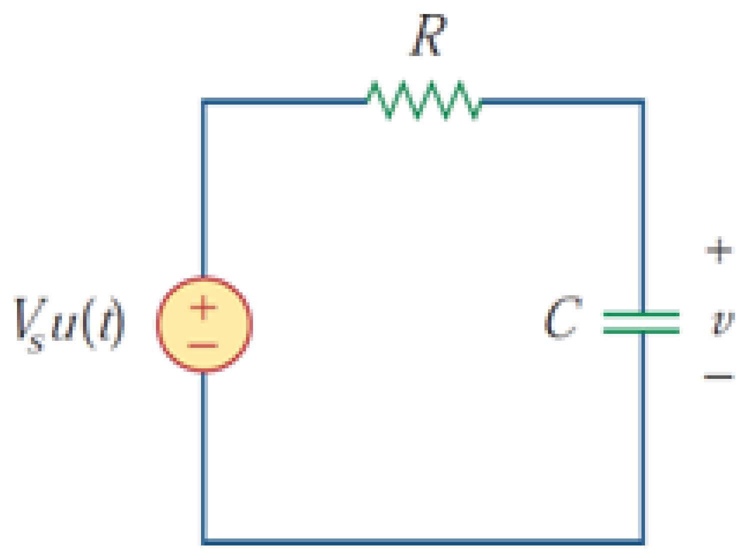
$$\frac{dv}{dt}+\frac{v}{RC}=\frac{V_s u(t)}{RC}$$

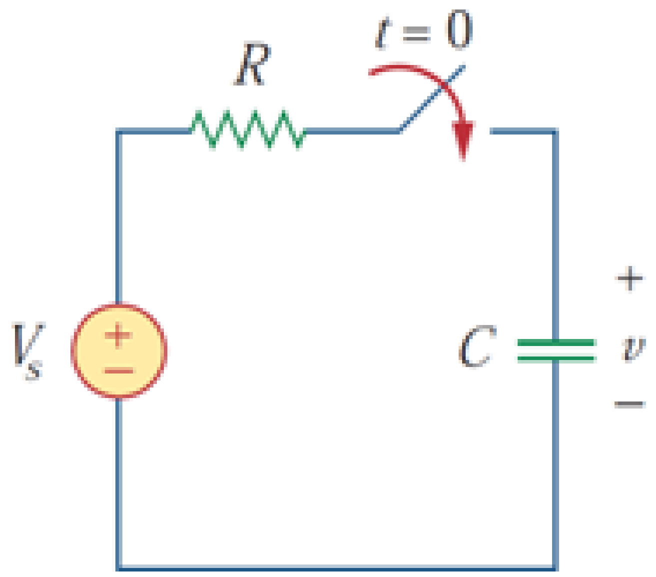
where, v is the voltage across the capacitor. For $t>0$,

$$\frac{dv}{dt}+\frac{v}{RC}=\frac{V_s}{RC}$$

$$\frac{dv}{dt}=-\frac{v-V_s}{RC}$$

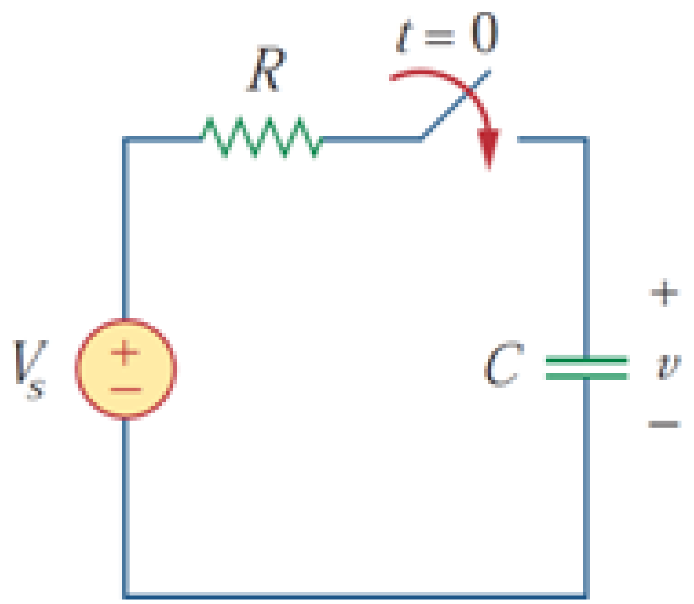
$$\frac{dv}{v-V_s}=-\frac{dt}{RC}$$





Step Response of an RC Circuit

On integration, $\ln(v - V_s)\Big|_{V_0}^{v(t)} = -\frac{t}{RC}\Big|_0^t$



$$\ln(v(t) - V_s) - \ln(V_0 - V_s) = -\frac{t}{RC} + 0; \quad \ln\frac{v - V_s}{V_0 - V_s} = -\frac{t}{RC}$$

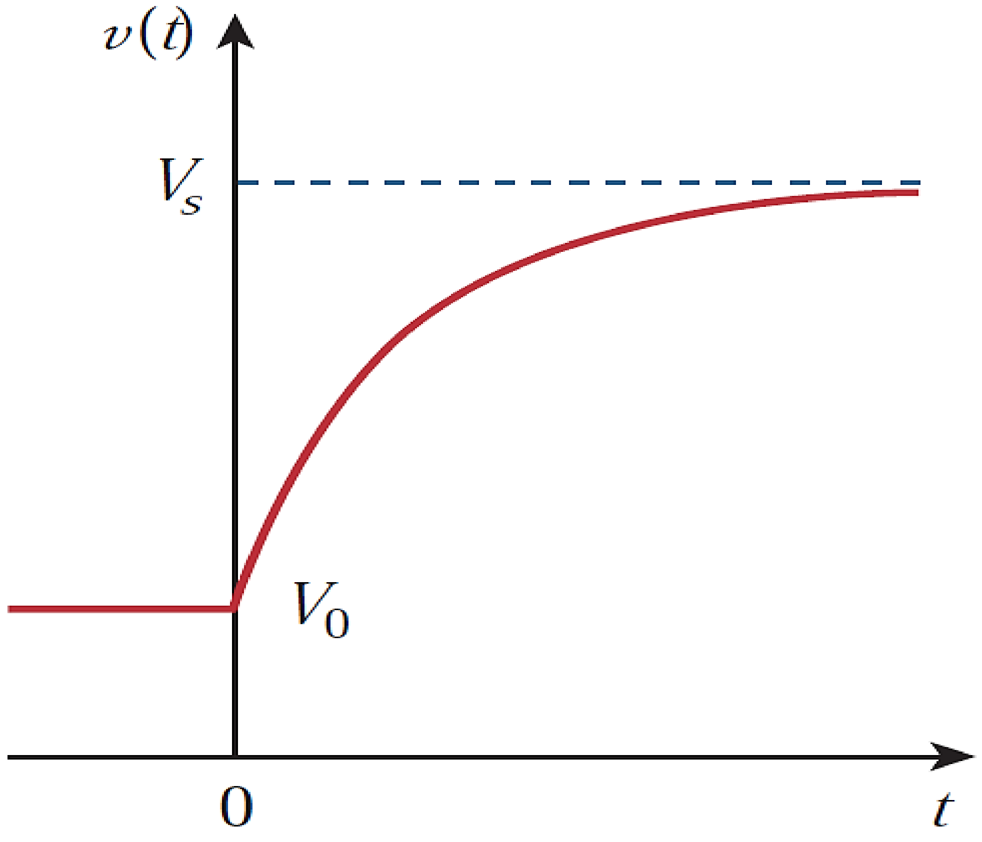
Taking exponential on both sides

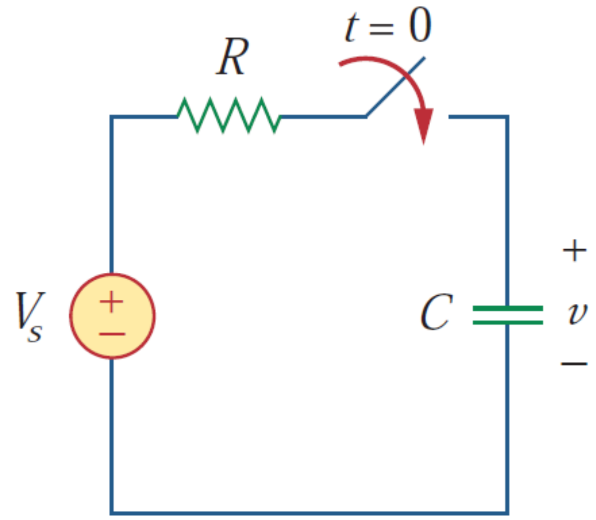
$$\frac{v - V_s}{V_0 - V_s} = e^{-\frac{t}{\tau}}, \tau = RC; \quad v(t) = V_s + (V_0 - V_s)e^{-\frac{t}{\tau}}, t > 0$$

$$\boxed{v(t) = \begin{cases} V_0 & t < 0 \\ V_s + (V_0 - V_s)e^{-\frac{t}{\tau}} & t > 0 \end{cases}}$$

Step Response of an RC Circuit

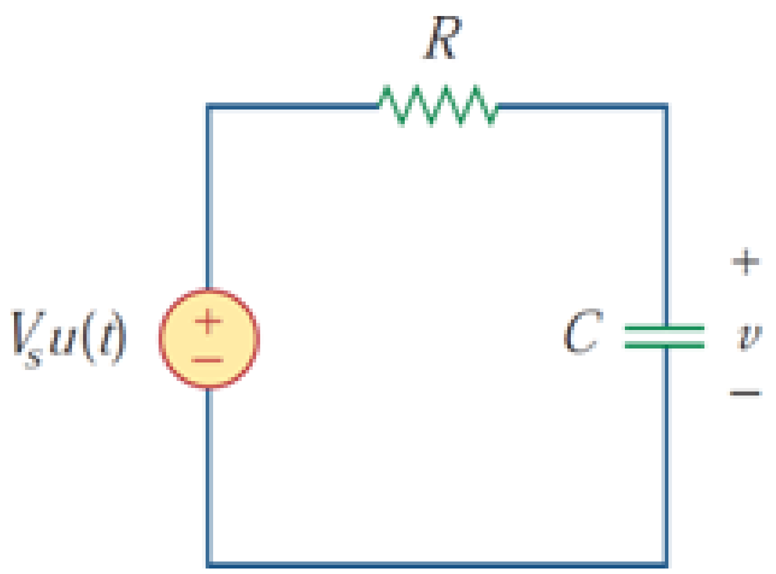
The complete response (or total response) of the RC circuit to a sudden application of a dc voltage source, assuming the capacitor is initially charged to V_0 is shown below.





Step Response of an RC Circuit

If the capacitor is uncharged initially i.e. $V_0 = 0$



$$v(t) = \begin{cases} 0 & t < 0 \\ V_s(1 - e^{-\frac{t}{\tau}}) & t > 0 \end{cases}$$

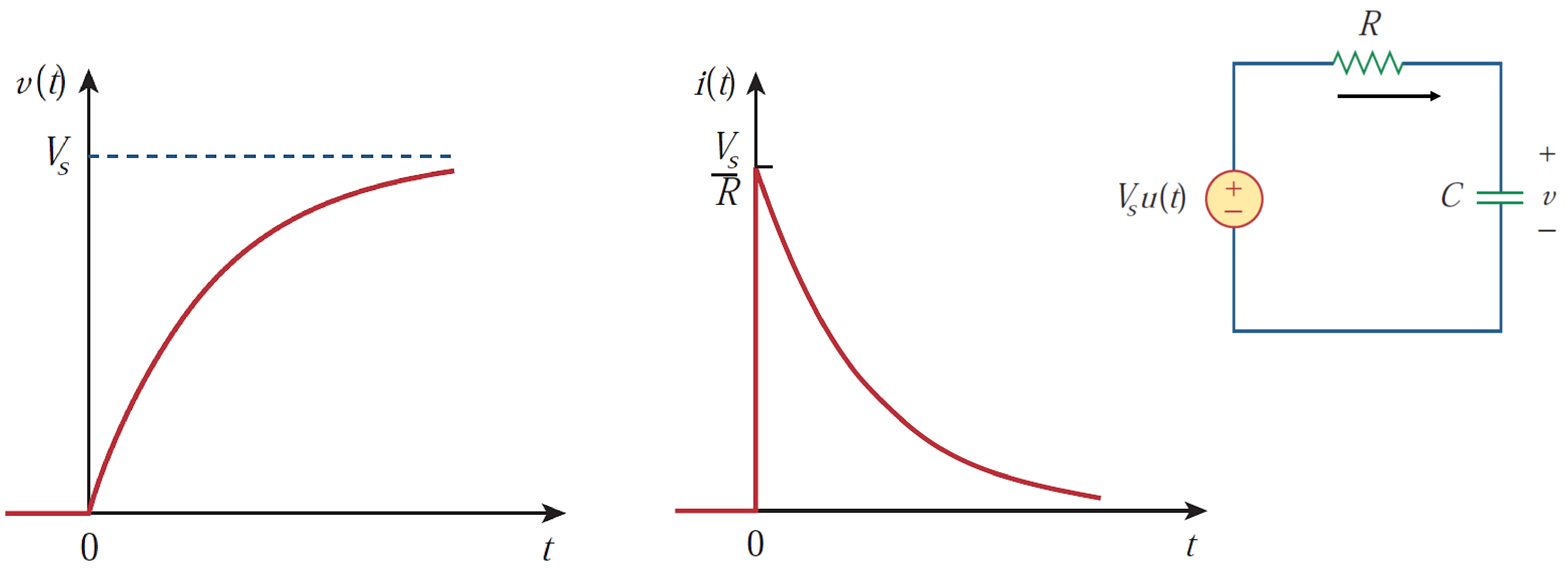
$$\boxed{v(t) = V_s(1 - e^{-\frac{t}{\tau}})u(t)}$$

This is the complete step response of the RC circuit when the capacitor is initially uncharged. The current through the capacitor is obtained as,

$$i(t) = C\frac{dv}{dt} = \frac{C}{\tau}V_s e^{-\frac{t}{\tau}}; \;\; \tau = RC; \;\; t > 0$$

$$\boxed{i(t) = \frac{V_s}{R}e^{-\frac{t}{\tau}}u(t)}$$

Step Response of an RC Circuit



(a) (b)

Step response of an RC circuit with initially uncharged capacitor