

Introduction to voltage, current, voltage source, conductors, insulators, resistances; Ohm's law, KVL, KCL, voltage and current divider rules;

Network sources and Analysis: Voltage sources; Voltage sources in parallel; Open and short circuits; Current sources in series and parallel; Source conversion; Branch-current analysis; Mesh analysis; Nodal analysis; Y- Δ and Δ -Y conversion.

Network Theorems: Superposition theorem; Thevenin's theorem; Norton's theorem; Maximum power transfer theorem;

Basic Passive Elements: Resistors, inductors and capacitors in series and parallel; transient response in capacitive networks; Charging and discharging phases; R-L transients; Storage cycle, Decay phase.

Fundamentals of AC and the Basic elements and Phasors: AC fundamentals; Sine wave; Frequency spectrum and phase relations; General format of sinusoidal voltage and currents; Phase & algebraic representations of sinusoids; Average & RMS (effective) values; Response of basic R,L,C elements to a sinusoidal voltage & currents; frequency response of basic elements; Impedance and phasor diagram; Average power & power factor;

Energy Bands in Solids: The nature of the Atom, Atomic energy levels, Valence and conduction bands, Conductors, Semiconductors and Insulators.

Semiconductor Diode and Rectifiers: Semiconductors' characteristics and their types, P-N

Junction Diodes and their V-I Characteristics; Zener Diode, Ideal Rectifier Concept, P-N Junction Diode as a Rectifier; Half-wave and Full-wave Rectifiers; Rectifier Filters and Ripple Factor, Voltage Regulator Using Zener Diode, Clipper, Clamper.

Transistor: PNP and NPN Junction Transistors; CB, CE and CC Configurations and their V_c - I_c Characteristics; Transistor Action; Different Types and Biasing; Bias Stabilization; Operating Point; DC and AC Load Lines;

Transistor Amplifiers: Transistor DC Amplifiers; CE, CB and CC Amplifiers, their Equivalent Circuits and Computation of Current, Voltage and Power Gains; Class A, Class B and Class C Amplifiers, class AB pushpull Amplifier, concept of feedback amplifications and oscillations. MOS devices: Introduction to JFET, MOSFET, PMOS, NMOS & CMOS: biasing & application.

Q. Define Semiconductor. How does it compare with a conductor and insulator?

A semiconductor is a type of material that has an electrical conductivity between that of a conductor and an insulator. It is characterized by its ability to conduct electricity under certain conditions but not as well as a conductor and not as poorly as an insulator.

In terms of the behavior of electrons, a conductor has a high density of free electrons that are easily movable, allowing electric current to flow through it with little resistance. This is due to the presence of a partially filled valence band and an overlapping conduction band in conductors. Examples of conductors include metals like copper and aluminum.

On the other hand, an insulator is a material that has a very low electrical conductivity. In insulators, the valence band is fully occupied, and there is a large energy gap between the valence band and the conduction band, making it difficult for electrons to move and carry an electric current. Materials like rubber and glass are good insulators. Semiconductors, such as silicon and germanium, have properties that lie between those of conductors and insulators. They have a partially filled valence band like conductors but also possess a relatively small energy gap between the valence band and the conduction band. This energy gap, also known as the band gap, is small enough that at room temperature, some electrons can acquire enough energy to move from the valence band to the conduction band, becoming mobile and allowing current to flow. However, the conductivity of semiconductors is generally lower than that of conductors.

The conductivity of a semiconductor can be increased by various means, such as doping the material with impurities to introduce extra charge carriers or by applying an electric field. This property of semiconductors makes them useful in electronic devices, such as transistors and diodes, which form the basis of modern electronics.

Q. Deferent between Semiconductor, conductor and insulator?

Parameter	Conductor	Semiconductor	Insulator
Definition	A material that allows electric current to pass through it very easily.	A material that has conductivity in between conductors and insulators.	Materials that do not allow the electric current to pass through them.
Forbidden Energy Gap	No energy gap i.e. the conduction band overlap the valance band.	Small energy gap (approx. 1 eV).	Very large energy gap (approx. 15 eV).
Conductivity	High Conductivity (of the order of 10^{-7} mho/m).	Intermediate conductivity (ranging from 10^{-7} mho/m to 10^{-13} mho/m).	Very low conductivity(of the order of 10^{-13} mho/m).
Conduction	Due to free electrons.	Due to movement of both electrons and holes (positive charge carriers).	No conduction.
Resistivity	Low (of the order of $10^{-5}\Omega/\text{m}$).	Intermediate (from $10^{-5}\Omega/\text{m}$ to $10^5 \Omega/\text{m}$).	Very high (of the order of $10^5 \Omega/\text{m}$).
Temperature Coefficient of Resistivity	Positive	Negative	Negative
Valance Electrons in Outermost Shell	Less than 4	4	More than 4
Examples	Metals like silver (best conductor), gold, copper, aluminium etc.	Silicon, Germanium, Gallium, Arsenide etc.	Air, Mica, Glass, Paper, Porcelain, Wood etc.
Application	In the manufacturing of conducting wires and cables.	In the manufacturing of solid state electronic devices like ICs, diodes, transistors etc.	Used for providing insulation electrical and electronic devices, for preventing electric shock etc

2. C. Q. If the resistance of a copper wire at freezing (0°C) is 90Ω , what is its resistance at -20°C?

I apologize for the confusion in my previous response. I made an error in calculating the resistance at -20°C. To determine the resistance at -20°C, we need to take into account the temperature coefficient of resistance for copper.

The temperature coefficient of resistance for copper is approximately 0.00393 per degree Celsius (°C). This means that the resistance of copper wire increases by 0.00393 times its initial value for every degree Celsius decrease in temperature.

To calculate the resistance at -20°C, we can use the following formula:

$$R_2 = R_1 * (1 + \alpha * (T_2 - T_1))$$

Where:

R1 = Resistance at the initial temperature (0°C)

R2 = Resistance at the final temperature (-20°C)

α = Temperature coefficient of resistance for copper (0.00393/°C)

T1 = Initial temperature (0°C)

T2 = Final temperature (-20°C)

Plugging in the values:

$$R_2 = 90\Omega * (1 + 0.00393/^{\circ}\text{C} * (-20^{\circ}\text{C} - 0^{\circ}\text{C}))$$

$$R_2 = 90\Omega * (1 + 0.00393/^{\circ}\text{C} * (-20^{\circ}\text{C}))$$

$$R_2 = 90\Omega * (1 - 0.0786)$$

$$R_2 = 90\Omega * 0.9214$$

$$R_2 \approx 82.93\Omega$$

Therefore, the resistance of the copper wire at -20°C would be approximately 82.93Ω.

2. D. Q. Calculate the resistance of 60 W bulb if a current of 500mA results from an applied voltage of 120 v.

To calculate the resistance of a 60W bulb given the current and applied voltage, you can use Ohm's law, which states that resistance (R) is equal to voltage (V) divided by current (I).

$$R = V / I$$

Given:

Current (I) = 500mA = 500 * 10⁽⁻³⁾ A

Applied voltage (V) = 120V

Using Ohm's law:

$$R = 120\text{V} / 500 * 10^{(-3)} \text{ A}$$

$$R = 120\text{V} / 0.5\text{A}$$

$$R = 240\Omega$$

Therefore, the resistance of the 60W bulb is approximately 240Ω.

4. B. Q. explain current divider rule in EEE?

Certainly! In electrical and electronic engineering (EEE), the current divider rule is a technique used to determine the distribution of current among parallel branches in a circuit. It helps us understand how current is divided between multiple paths connected in parallel.

When resistors or other components are connected in parallel, they share the same voltage across their terminals but have different currents flowing through them. The current divider rule allows us to calculate the current flowing through each branch based on their respective resistances.

The current divider rule states that the current through a specific branch is equal to the total current entering the parallel combination multiplied by the ratio of the resistance of that branch to the total resistance of all the branches. Mathematically, it can be expressed as:

$$I_{\text{branch}} = (I_{\text{total}} * R_{\text{total}}) / R_{\text{branch}}$$

Where:

- I_{branch} is the current flowing through a specific branch.
- I_{total} is the total current entering the parallel combination of branches.
- R_{total} is the sum of the resistances of all branches.
- R_{branch} is the resistance of the specific branch for which the current is being calculated.

Here's a step-by-step explanation of how to use the current divider rule:

1. Identify the parallel branches in the circuit.
2. Determine the resistance of each branch (R_1 , R_2 , R_3 , etc.).
3. Calculate the total resistance of the parallel combination (R_{total}) by taking the reciprocal of the sum of the reciprocals of individual resistances: $1/R_{\text{total}} = 1/R_1 + 1/R_2 + 1/R_3 + \dots$
4. Determine the total current entering the parallel combination (I_{total}) from the circuit or power source.
5. Apply the current divider rule formula to calculate the current flowing through each branch (I_{branch}).

It's important to note that the current divider rule assumes that the components in parallel are purely resistive and that there are no reactive elements such as inductors or capacitors present.

By using the current divider rule, engineers and technicians can analyze and design parallel circuits to ensure proper current division and understand the behavior of each branch in a circuit.

Energy Bands Description

In gaseous substances, the arrangement of molecules is spread apart and are not so close to each other. In liquids, the molecules are closer to each other. But, in solids, the molecules are closely arranged together, due to this atoms of molecules tend to move into the orbitals of neighbouring atoms. Hence, the electron orbitals overlap when atoms come together.

In solids, several bands of energy levels are formed due to the intermixing of atoms in solids. We call these set of energy levels as **energy bands**.

Formation of Energy Bands

In an isolated atom, the electrons in each orbit possess definite energy. But, in the case of solids, the energy level of the outermost orbit electrons is affected by the neighbouring atoms.

When two isolated charges are brought close to each other, the electrons in the outermost orbit experience an attractive force from the nearest or neighbouring atomic nucleus. Due to this reason, the energies of the electrons will not be at the same level, the energy levels of electrons are changed to a value which is higher or lower than that of the original energy level of the electron.

The electrons in the same orbit exhibit different energy levels. The grouping of these different energy levels is known as the energy band.

However, the energy of the inner orbit electrons is not much affected by the presence of neighbouring atoms.

Classification of Energy Bands

Valence Band

The electrons in the outermost shell are known as valence electrons. These valence electrons contain a series of energy levels and form an energy band known as the valence band. The valence band has the highest occupied energy.

Conduction Band

The valence electrons are not tightly held to the nucleus due to which a few of these valence electrons leave the outermost orbit even at room temperature and become free electrons. The free electrons conduct current in conductors and are therefore known as conduction electrons. The conduction band is one that contains conduction electrons and has the lowest occupied energy levels.

Forbidden Energy Gap

The gap between the valence band and the conduction band is referred to as the forbidden gap. As the name suggests, the forbidden gap doesn't have any energy and no electrons stay in this band. If the forbidden energy gap is greater, then the valence band electrons are tightly bound or firmly attached to the nucleus. We require some amount of external energy that is equal to the forbidden energy gap.

The figure below shows the conduction band, valence band and the forbidden energy gap.

Conductors

Gold, Aluminium, Silver, Copper, all these metals allow an electric current to flow through them.

There is no forbidden gap between the valence band and conduction band which results in the overlapping of both the bands. The number of free electrons available at room temperature is large.

Insulators

Glass and wood are examples of the insulator. These substances do not allow electricity to pass through them. They have high resistivity and very low conductivity.

The energy gap in the insulator is very high up to 7eV. The material cannot conduct because the movement of the electrons from the valence band to the conduction band is not possible.

Semiconductors

Germanium and Silicon are the most preferable material whose electrical properties lie in between [semiconductors and insulators](#). The energy band diagram of semiconductors is shown where the conduction band is empty and the valence band is completely filled but the forbidden gap between the two bands is very small that is about 1eV. For Germanium, the forbidden gap is 0.72eV and for Silicon, it is 1.1eV. Thus, semiconductor requires small conductivity.

Energy Band Theory

According to Bohr's theory, every shell of an atom contains a discrete amount of energy at different levels. Energy band theory explains the interaction of electrons between the outermost shell and the innermost shell. Based on the energy band theory, there are three different energy bands:

1. Valence band
2. Forbidden energy gap
3. Conduction band

Q1

The valence band and the conduction band overlap in _____.

The valence band and the conduction band overlap in conductors.

Q2

What is the energy that a valence electron should have to jump from the valence band to the conduction band called?
The valence electrons must have the same energy as an energy gap to jump from the valence band to conduction band.

Q3

What is the energy gap between the valence and conduction band termed as?

The energy gap between the valence and the conduction band is termed as energy gap.

Q4

The band in which the electrons move freely is known as _____.

The band in which the electrons move freely is known as the conduction band.

Q5

What is a band model?

Band theory models the behavior of electrons in solids by postulating the existence of energy bands. It successfully uses a material's band structure to explain the many physical properties of solids.

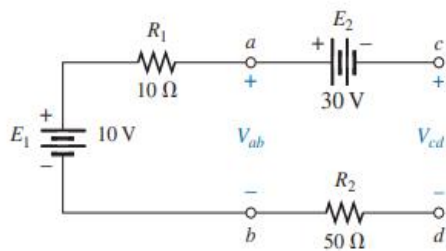


FIG. 54
Network for Example 26.

EXAMPLE 26 Determine voltages V_{ab} and V_{cd} for the network in Fig. 54.

Solution: The current through the system is zero amperes due to the open circuit, resulting in a 0 V drop across each resistor. Both resistors can therefore be replaced by short circuits, as shown in Fig. 55. Voltage V_{ab} is then directly across the 10 V battery, and

$$V_{ab} = E_1 = 10 \text{ V}$$

Voltage V_{cd} requires an application of Kirchhoff's voltage law:

$$+E_1 - E_2 - V_{cd} = 0$$

or
$$V_{cd} = E_1 - E_2 = 10 \text{ V} - 30 \text{ V} = -20 \text{ V}$$

The negative sign in the solution indicates that the actual voltage V_{cd} has the opposite polarity of that appearing in Fig. 54.

6. b. Find the branch currents of the networks in Fig-10?

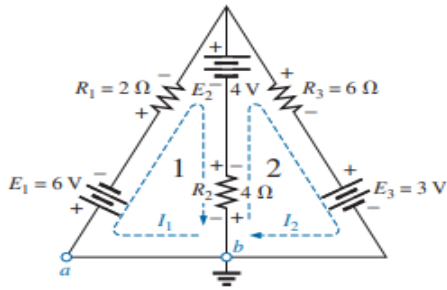


FIG. 30
Example 13.

Steps 1 and 2: These are as indicated in the circuit.

Step 3: Kirchhoff's voltage law is applied around each closed loop:

$$\text{loop 1: } -E_1 - I_1 R_1 - E_2 - V_2 = 0 \quad (\text{clockwise from point } a) \\ -6 \text{ V} - (2 \Omega) I_1 - 4 \text{ V} - (4 \Omega)(I_1 - I_2) = 0$$

$$\text{loop 2: } -V_2 + E_2 - V_3 - E_3 = 0 \quad (\text{clockwise from point } b) \\ -(4 \Omega)(I_2 - I_1) + 4 \text{ V} - (6 \Omega)(I_2) - 3 \text{ V} = 0$$

which are rewritten as

$$\left. \begin{aligned} -10 - 4I_1 - 2I_1 + 4I_2 &= 0 \\ +1 + 4I_1 + 4I_2 - 6I_2 &= 0 \end{aligned} \right\} \begin{aligned} -6I_1 + 4I_2 &= +10 \\ +4I_1 - 10I_2 &= -1 \end{aligned}$$

or, by multiplying the top equation by -1 , we obtain

$$\begin{aligned} 6I_1 - 4I_2 &= -10 \\ 4I_1 - 10I_2 &= -1 \end{aligned}$$

$$\text{Step 4: } I_1 = \frac{\begin{vmatrix} -10 & -4 \\ -1 & -10 \end{vmatrix}}{\begin{vmatrix} 6 & -4 \\ 4 & -10 \end{vmatrix}} = \frac{100 - 4}{-60 + 16} = \frac{96}{-44} = -2.18 \text{ A}$$

$$I_2 = \frac{\begin{vmatrix} 6 & -10 \\ 4 & -1 \end{vmatrix}}{-44} = \frac{-6 + 40}{-44} = \frac{34}{-44} = -0.77 \text{ A}$$

The current in the 4Ω resistor and 4 V source for loop 1 is

$$\begin{aligned} I_1 - I_2 &= -2.18 \text{ A} - (-0.77 \text{ A}) \\ &= -2.18 \text{ A} + 0.77 \text{ A} \\ &= -1.41 \text{ A} \end{aligned}$$

revealing that it is 1.41 A in a direction opposite (due to the minus sign) to I_1 in loop 1.

EXAMPLE 1 For the sinusoidal waveform in Fig. 7.

- What is the peak value?
- What is the instantaneous value at 0.3 s and 0.6 s?
- What is the peak-to-peak value of the waveform?
- What is the period of the waveform?
- How many cycles are shown?
- What is the frequency of the waveform?

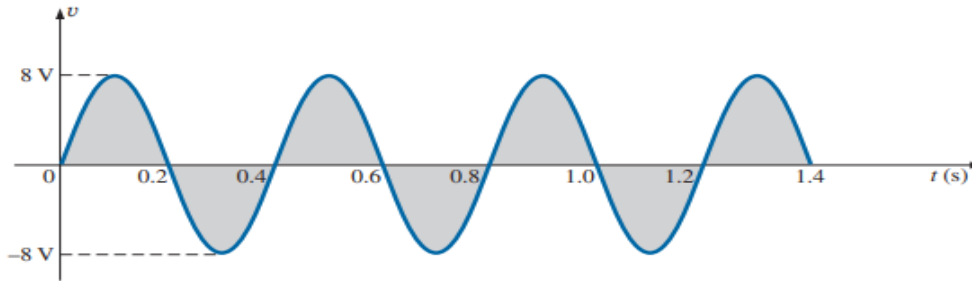


FIG. 7
Example 1.

Solutions:

- 8 V.**
- At 0.3 s, **-8 V**; at 0.6 s, **0 V**.
- 16 V.**
- 0.8 s.**
- 3.5 cycles.**
- 2.5 cps, or 2.5 Hz.**

EXAMPLE 14 Determine the average value of the waveforms in Fig. 44.

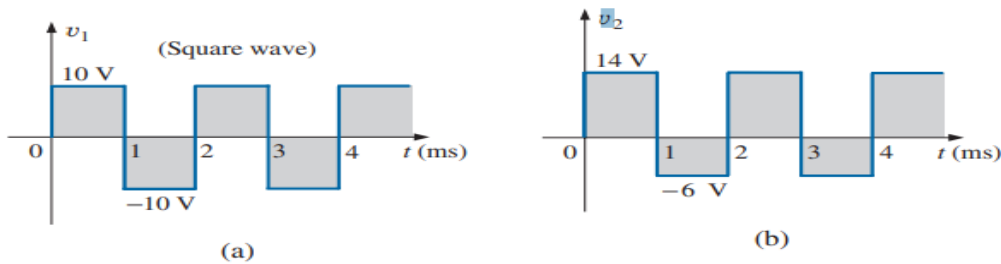


FIG. 44
Example 14.

Solutions:

- By inspection, the area above the axis equals the area below over one cycle, resulting in an average value of zero volts. Using Eq. (26) gives

$$G = \frac{(10 \text{ V})(1 \text{ ms}) - (10 \text{ V})(1 \text{ ms})}{2 \text{ ms}} = \frac{0}{2 \text{ ms}} = \mathbf{0 \text{ V}}$$

- Using Eq. (26) gives

$$G = \frac{(14 \text{ V})(1 \text{ ms}) - (6 \text{ V})(1 \text{ ms})}{2 \text{ ms}} = \frac{14 \text{ V} - 6 \text{ V}}{2} = \frac{8 \text{ V}}{2} = \mathbf{4 \text{ V}}$$

as shown in Fig. 45.

In reality, the waveform in Fig. 44(b) is simply the square wave in Fig. 44(a) with a dc shift of 4 V; that is,

$$v_2 = v_1 + 4 \text{ V}$$

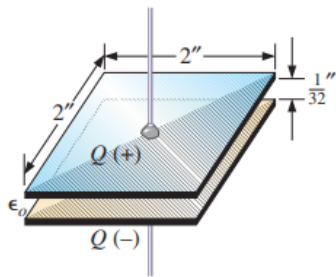


FIG. 10

Air capacitor for Example 3.

EXAMPLE 3 For the capacitor in Fig. 10:

- Find the **capacitance**.
- Find the strength of the electric field between the plates if 48 V are applied across the plates.
- Find the charge on each plate.

Solutions:

- First, the area and the distance between the plates must be converted to the SI system as required by Eq. (11):

$$d = \frac{1}{32} \text{ in.} \left(\frac{1 \text{ m}}{39.37 \text{ in.}} \right) = 0.794 \text{ mm}$$

$$\text{and } A = (2 \text{ in.})(2 \text{ in.}) \left(\frac{1 \text{ m}}{39.37 \text{ in.}} \right) \left(\frac{1 \text{ m}}{39.37 \text{ in.}} \right) = 2.581 \times 10^{-3} \text{ m}^2$$

Eq. (11):

$$C = 8.85 \times 10^{-12} \epsilon_r \frac{A}{d} = 8.85 \times 10^{-12} (1) \frac{(2.581 \times 10^{-3} \text{ m}^2)}{0.794 \text{ mm}} = \mathbf{28.8 \text{ pF}}$$

- The electric field between the plates is determined by Eq. (7):

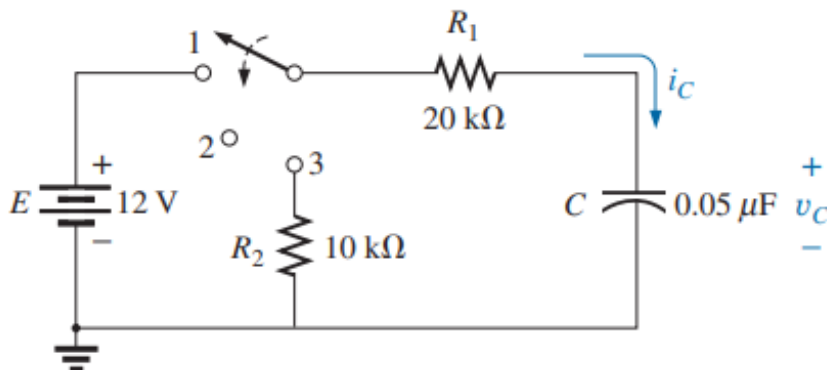
$$\mathcal{E} = \frac{V}{d} = \frac{48 \text{ V}}{0.794 \text{ mm}} = \mathbf{60.5 \text{ kV/m}}$$

- The charge on the plates is determined by Eq. (6):

$$Q = CV = (28.8 \text{ pF})(48 \text{ V}) = \mathbf{1.38 \text{ nC}}$$

EXAMPLE 8 For the circuit in Fig. 44:

- Find the **mathematical expressions** for the transient behavior of the voltage v_C and the current i_C if the capacitor was initially uncharged and the switch is thrown into position 1 at $t = 0$ s.
- Find the **mathematical expressions** for the voltage v_C and the current i_C if the switch is moved to position 2 at $t = 10$ ms. (Assume



that the leakage resistance of the capacitor is infinite ohms; that is, there is no leakage current.)

- c. Find the mathematical expressions for the voltage v_C and the current i_C if the switch is thrown into position 3 at $t = 20$ ms.
- d. Plot the waveforms obtained in parts (a)–(c) on the same time axis using the defined polarities in Fig. 44.

Solutions:

- a. *Charging phase:*

$$\begin{aligned}\tau &= R_1 C = (20 \text{ k}\Omega)(0.05 \text{ }\mu\text{F}) = 1 \text{ ms} \\ v_C &= E(1 - e^{-t/\tau}) = \mathbf{12 \text{ V}(1 - e^{-t/1 \text{ ms}})} \\ i_C &= \frac{E}{R_1} e^{-t/\tau} = \frac{12 \text{ V}}{20 \text{ k}\Omega} e^{-t/1 \text{ ms}} = \mathbf{0.6 \text{ mA} e^{-t/1 \text{ ms}}}\end{aligned}$$

- b. *Storage phase:* At 10 ms, a period of time equal to 10τ has passed, permitting the assumption that the capacitor is fully charged. Since $R_{\text{leakage}} = \infty \text{ }\Omega$, the capacitor will hold its charge indefinitely. The result is that both v_C and i_C will remain at a fixed value:

$$v_C = \mathbf{12 \text{ V}}$$

$$i_C = \mathbf{0 \text{ A}}$$

- c. *Discharge phase* (using 20 ms as the new $t = 0$ s for the equations):
The new time constant is

$$\tau' = RC = (R_1 + R_2)C = (20 \text{ k}\Omega + 10 \text{ k}\Omega)(0.05 \text{ }\mu\text{F}) = 1.5 \text{ ms}$$

$$v_C = E e^{-t/\tau'} = \mathbf{12 \text{ V} e^{-t/1.5 \text{ ms}}}$$

$$\begin{aligned}i_C &= -\frac{E}{R} e^{-t/\tau'} = -\frac{E}{R_1 + R_2} e^{-t/\tau'} \\ &= -\frac{12 \text{ V}}{20 \text{ k}\Omega + 10 \text{ k}\Omega} e^{-t/1.5 \text{ ms}} = \mathbf{-0.4 \text{ mA} e^{-t/1.5 \text{ ms}}}\end{aligned}$$