(a) Capacitor initially uncharged

No current.
Then close switch.

(b) Charging the capacitor

When the switch is closed, the charge on the capacitor increases over time while the current decreases.

Apply Kirchhoff’s Loop Rule.

Across resistor potential change $IR$

Across battery potential change $\varepsilon$

Across capacitor potential change $\frac{Q}{C}$
The charge on the capacitor increases exponentially with time.

\[ Q = C \varepsilon \left( 1 - e^{-\frac{t}{RC}} \right) \]

(b) Graph of capacitor charge versus time for a charging capacitor

The charge on the capacitor increases exponentially with time toward the final value \( Q_f \).
\[ Q_f = C \varepsilon \]

Charge on capacitor:

\[ Q = Q_f \left(1 - e^{-\frac{t}{RC}}\right) \]

\[ i = \frac{\varepsilon}{R} e^{-\frac{t}{RC}} \]

And \( \frac{\varepsilon}{R} = i_0 \)

\[ i = i_0 e^{-\frac{t}{RC}} \]

Define \( \tau = RC = \text{Circuit Time Constant} \)
\[ i = i_0 e^{-t/\tau} \]

Current starts \( i = i_0 \) and decreases

(a) Graph of current versus time for a charging capacitor

The current decreases exponentially with time as the capacitor charges.
After long time capacitor has charge \( Q_0 \).

Connect points \( a \) and \( c \).
Now capacitor discharges through the resistor and:

\[ IR = V_c = \frac{Q}{C} \]

\[ Q = Q_0 e^{-\frac{t}{RC}} \]

\[ I = I_0 e^{-\frac{t}{RC}} \]