# Fundamentals of Physics II

Faculty of Physics-Kharazmi University

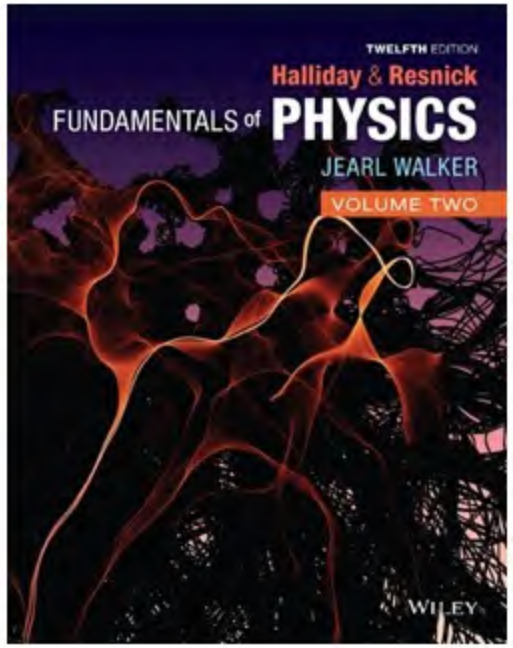
Dr. Faramarz Kanjouri

Spring 2025

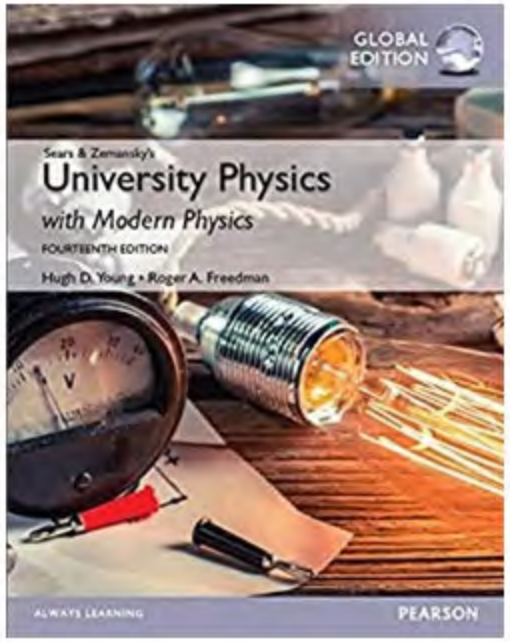
اگر همواره مانند گذشته بیندیشید، همیشه همان
چیزهایی را به‌دست می‌آورید که تاکنون کسب کرده‌اید

If you always think the way you've always thought, you'll always get what you've always got.

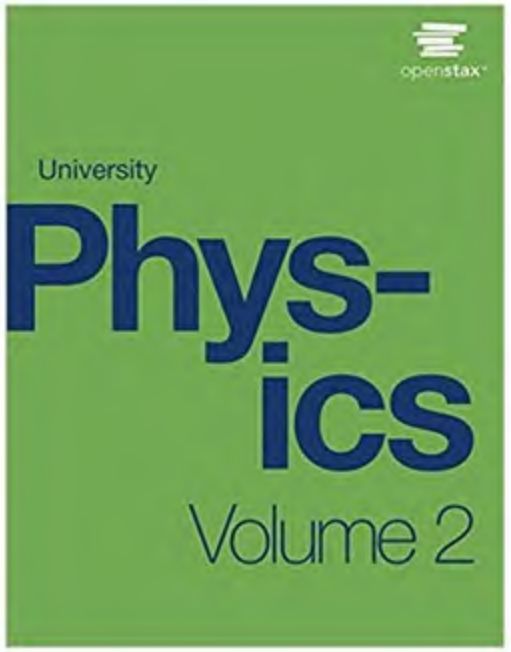
Fundamentals of Physics (12th Ed.)
Halliday, David; Resnick, Robert; Walker, Jearl



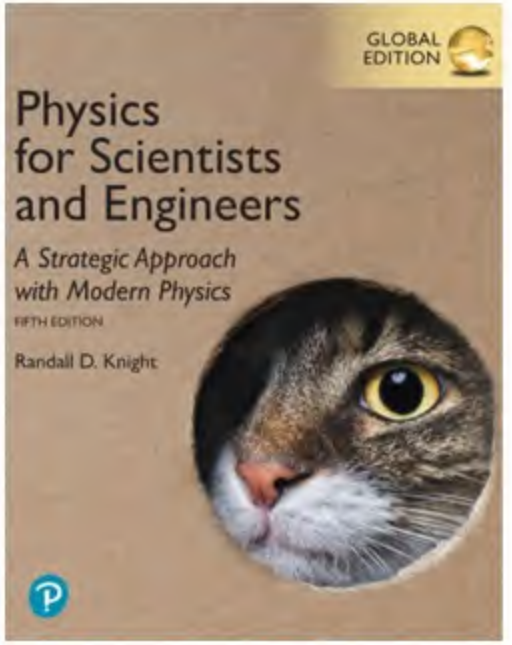

University Physics with Modern Physics (14th Global Ed.)
Hugh D. Young, Roger A. Freedman




University Physics Volume 2
Samuel J. Ling, Jeff Sanny, William Moebs



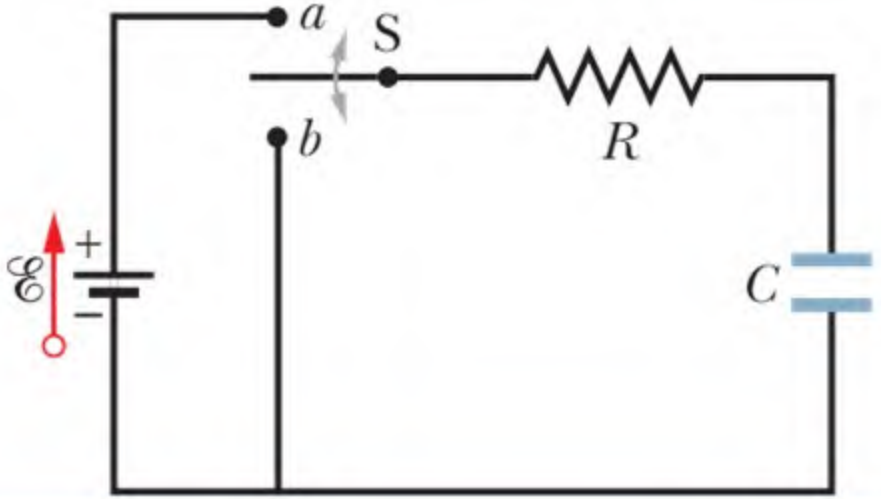

PHYSICS For Scientists and Engineers, 5e, (2023)
Randall D. Knight



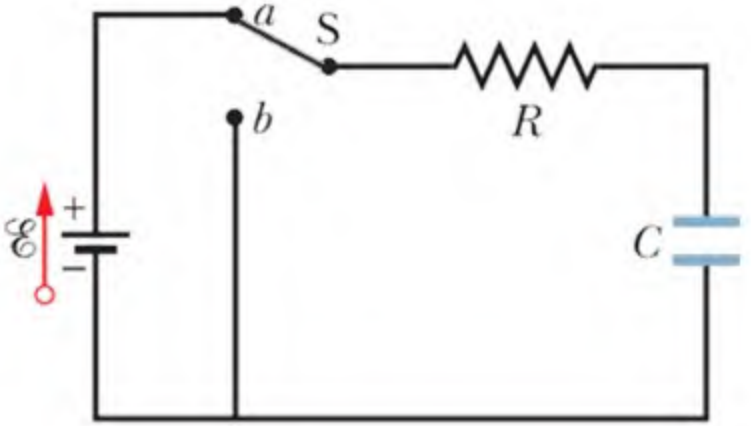
# درس بیست و هفتم

# مدارهای RC

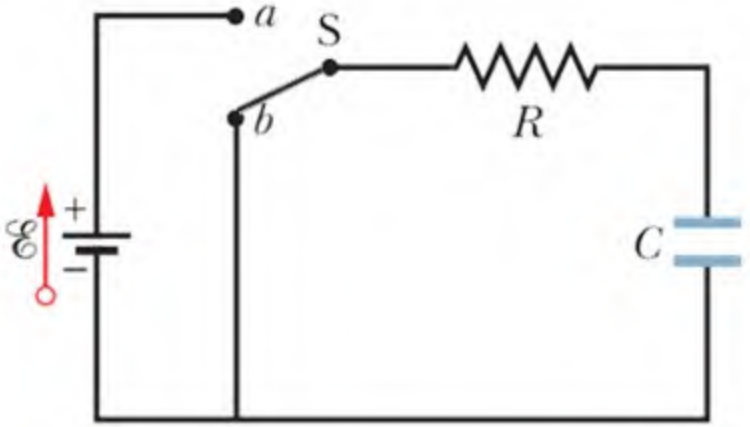
# RC Circuits

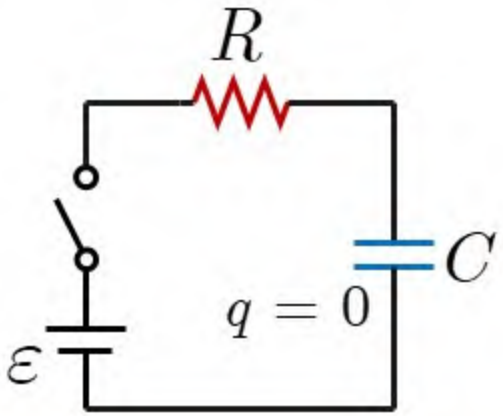


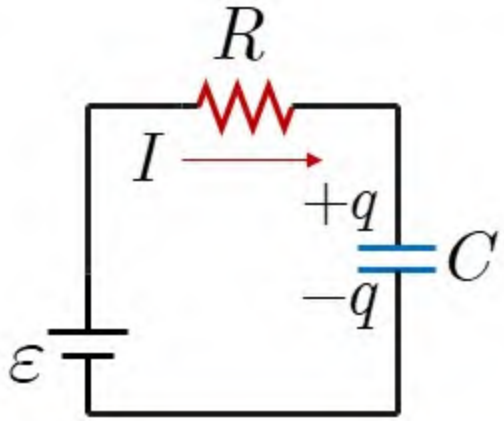

شارژ خازن: کلید را به $a$ وصل می‌کنیم




دشارژ خازن: بعداز پر شدنِ خازن، کلید را به $b$ وصل می‌کنیم






$$\varepsilon - IR - \frac{q}{C} = 0$$

$$\varepsilon - \frac{dq}{dt}R - \frac{q}{C} = 0$$

$$\frac{dq}{dt} = -\frac{1}{RC}\left(q - C\varepsilon\right)$$

$$\int_0^q \frac{dq'}{\left(q' - C\varepsilon\right)} = -\frac{1}{RC}\int_0^t dt'$$

$$\int_0^q \frac{dq'}{\left(q' - C\mathscr{E}\right)} = -\frac{1}{RC}\int_0^t dt'$$

$$\ln\left(\frac{q - C\mathscr{E}}{-C\mathscr{E}}\right) = -\frac{t}{RC}$$

$$q(t) = C\mathscr{E}\left(1 - e^{-t/RC}\right) = q_0\left(1 - e^{-t/\tau}\right)$$

$$I(t) = \frac{dq}{dt} = \frac{\mathscr{E}}{R}e^{-t/RC} = I_0 e^{-t/\tau}$$

$$\tau = RC$$

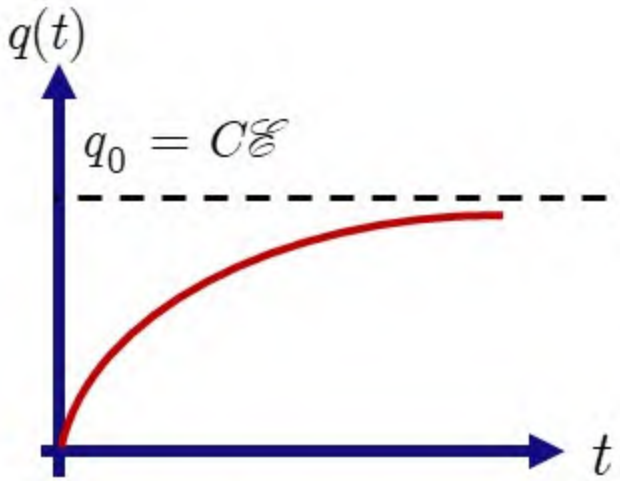
$$[\tau] = \left[\frac{\mathrm{V}}{\mathrm{A}}\right]\left[\frac{\mathrm{C}}{\mathrm{V}}\right] = [\mathrm{s}]$$

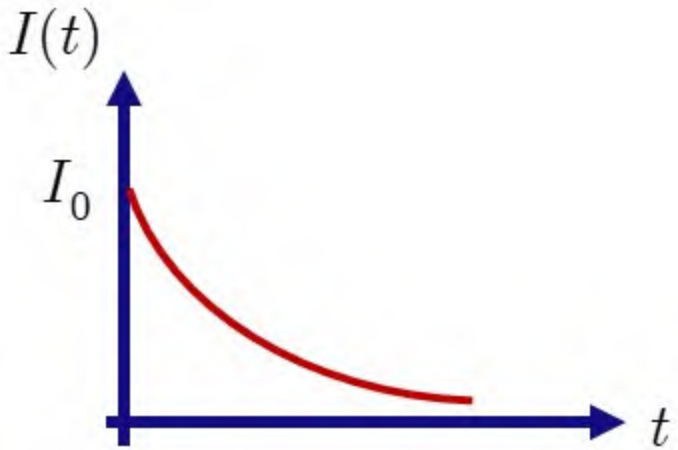
$RC$ دیمانسیون زمان دارد و ثابت زمانی نامیده می‌شود.

| | |
|---|---|
| 10% | $0.105\tau$ |
| 25% | $0.288\tau$ |
| 50% | $0.693\tau$ |
| 90% | $2.30\tau$ |
| 99% | $4.60\tau$ |
| 99.99% | $9.21\tau$ |

$$t = \tau \quad \Rightarrow \quad q = \left(1 - \frac{1}{e}\right) q_0 = 0.632 q_0$$

$$t = \tau \quad \Rightarrow \quad I = \frac{1}{e} I_0 = 0.368 I_0$$



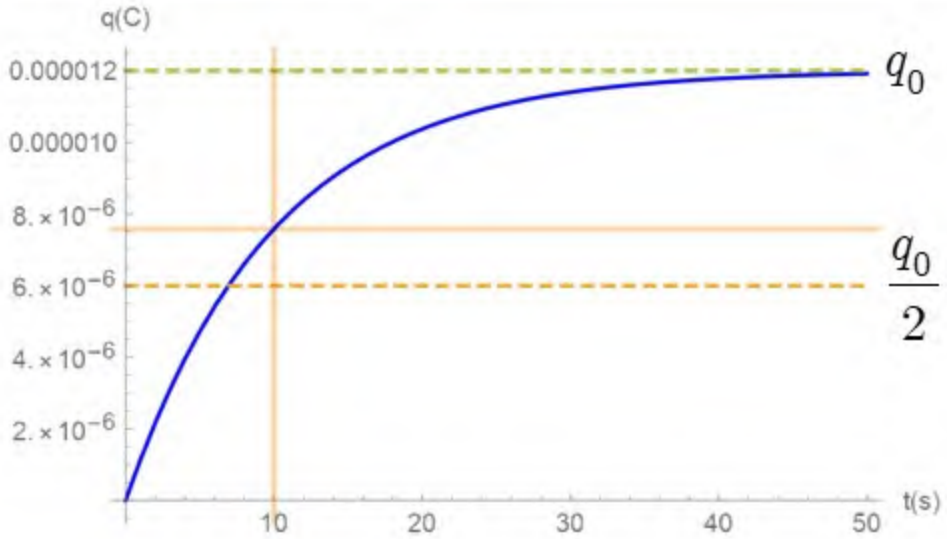



## برنامه متمتیکا برای رسم نمودار شارژ خازن

```
c = 10^-6; (*Farad*)
emf = 12.; (*Volt*)
r = 10. × 10^6; (*Ohm*)
tau = r * c;
q0 = c * emf;
q[t_] := q0 * (1 - Exp[-t/tau]);
Print[" time constant =    ", tau "s"]

Print[" q0 =    ", q0 "C"]

Plot[{q[t], q0/2, q0}, {t, 0, 50}, PlotStyle → {Blue, Dashed, Dashed},
 GridLines -> {{{10, {Orange, Thick}}}, {{q[10], {Orange, Thick}}}}, AxesLabel → {"t(s)", "q(C)"}]
```




```
time constant =    10. s
```

```
q0 =    0.000012 C
```

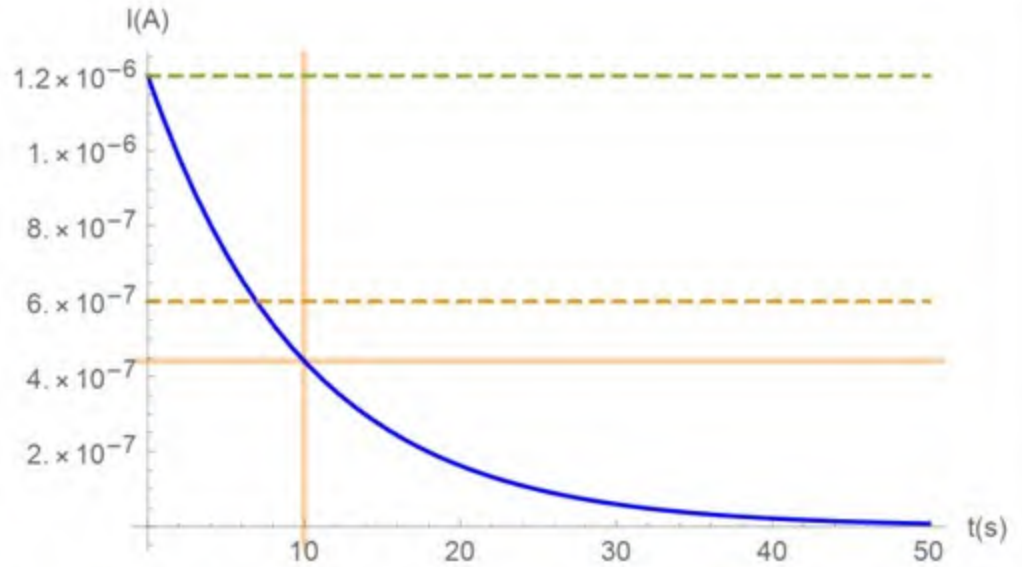
$$q(t) = 1.2 \times 10^{-5}\left(1 - c^{-t/10}\right)$$

# برنامه متمتیکا برای رسم نمودار شارژ خازن

```
c = 10^-6; (*Farad*)
emf = 12.; (*Volt*)
r = 10. × 10^6; (*Ohm*)
tau = r * c;
i0 = emf / r;
i[t_] := i0 * Exp[-t / tau];
Print[" time constant =    ", tau "s"]

Print[" i0 =    ", i0 "A"]

Plot[{i[t], i0/2, i0}, {t, 0, 50}, PlotStyle → {Blue, Dashed, Dashed},
 GridLines -> {{{10, {Orange, Thick}}}, {{i[10], {Orange, Thick}}}}, AxesLabel → {"t(s)", "I(A)"}]
```




```
time constant =    10. s
```

```
i0 =    1.2 × 10^-6 A
```

$$P_b(t) = I(t)\varepsilon = \frac{\varepsilon^2}{R} e^{-t/RC}$$ **توان باتری در هر لحظه**

$$W_b(t) = \int_0^t [P_b dt'] = \frac{\varepsilon^2}{R} \int_0^t dt' e^{-t'/RC} = C\varepsilon^2 \left(1 - e^{-t/RC}\right)$$

$$W_b(\infty) = C\varepsilon^2$$ **کل کار باتری در شارژ کامل**

$$U_C(t) = \frac{q^2(t)}{2C} = \frac{1}{2} C\varepsilon^2 \left(1\text{-}e^{-t/RC}\right)^2$$ **انرژی خازن در هر لحظه**

$$U_C(\infty) = \frac{1}{2} C\varepsilon^2$$ **انرژی خازن در شارژ کامل**

توان مصرفی در مقاومت ( گرمای ژول)

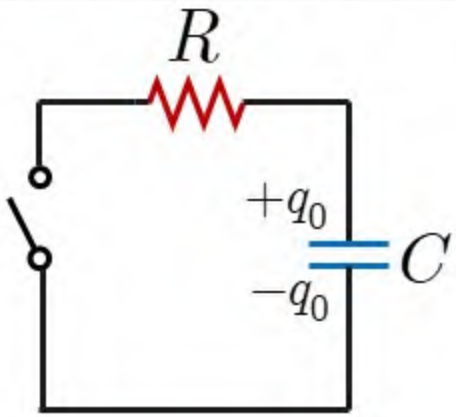
$$P_R(t) = RI^2(t) = \frac{\varepsilon^2}{R} e^{-2t/RC}$$

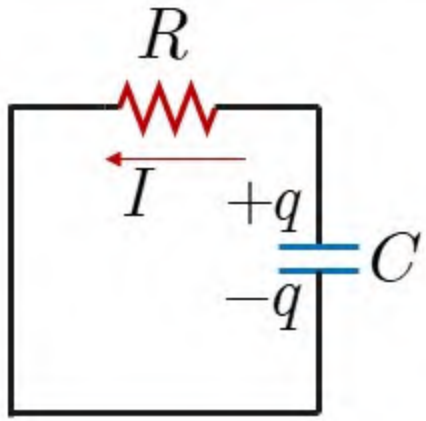
$$U_R(t) = \int_0^t RI^2 dt' = \frac{\mathscr{E}^2}{R} \int_0^t dt' e^{-2t'/RC}$$

$$U_R(t) = \frac{1}{2} C\varepsilon^2 \left(1 - e^{-2t/RC}\right)$$

گرمای اتلافی در مقاومت در شارژ کامل

$$U_R(\infty) = \frac{1}{2} C\varepsilon^2$$




$$-IR + \frac{q}{C} = 0$$

$$I = -\frac{dq}{dt}$$

$$-\frac{dq}{dt}R = \frac{q}{C} \qquad \frac{dq}{q} = -\frac{dt}{RC}$$

$$\int_{q_0}^{q} \frac{dq'}{q'} = -\frac{1}{RC}\int_0^t dt'$$

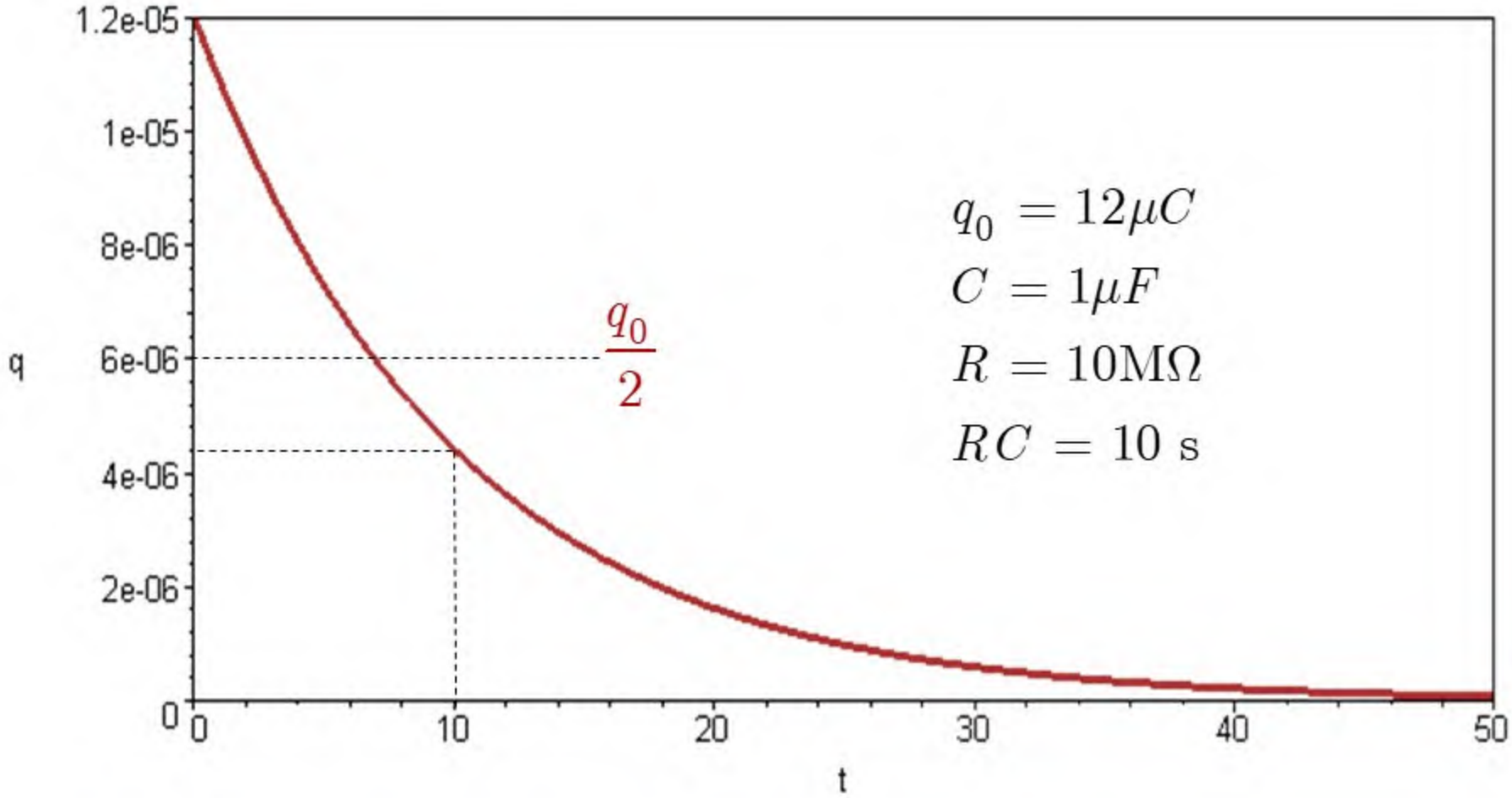
$$q(t) = q_0 e^{-t/\tau}$$

$$I(t) = -\frac{dq}{dt} = \frac{q_0}{RC} e^{-t/\tau}$$

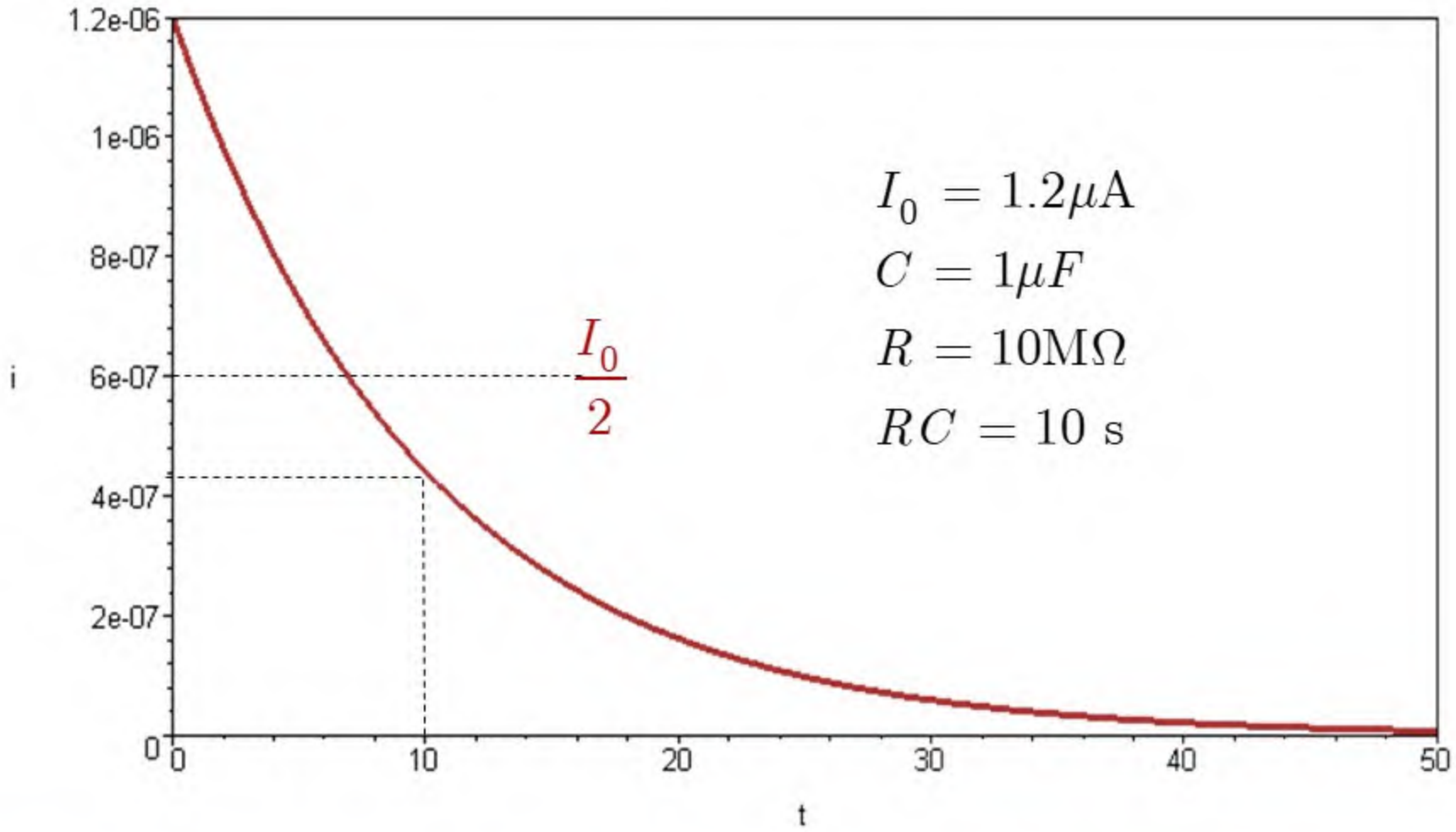
$$q(t) = q_0 e^{-t/\tau}$$
$$I(t) = I_0 e^{-t/\tau}$$

$$\tau = RC$$
$$I_0 = \frac{q_0}{RC}$$

$$q(t) = 1.2 \times 10^{-5} e^{-t/10}$$



$$I(t) = 1.2 \times 10^{-6} e^{-t/10}$$



# شاد و مهربان باشید