Exercise walk-through

Resistor-Capacitor (RC) Circuits ▪ 11.8

eXercise

You must be able to

- describe the **charging** and **discharging** of a capacitor through a resistor
- define the **time constant** 时间常数 $\tau = RC$
- use $q(t) = Q(1 - e^{-t/\tau})$ (charging) and $q(t) = Q\,e^{-t/\tau}$ (discharging)
- analyse the **initial** and **steady-state** behaviour

Method — Charging and discharging

$$q(t) = Q\left(1 - e^{-t/\tau}\right) \text{ (charging)}, \qquad q(t) = Q\,e^{-t/\tau} \text{ (discharging)}.$$

Method — Time constant

$\tau = RC$ is the characteristic time; after one τ the charge reaches about 63% (charging) or falls to 37% (discharging).

Method — Start and steady state

At $t = 0$ an uncharged capacitor acts like a **wire** (current $I_0 = V/R$); at steady state it is fully charged and carries **no** current.

Practice 2.1 ▪ 2 marks

Find the time constant of a 5.0 kΩ resistor and a 20 μF capacitor.

Solution 2.1

Method: Time constant

Worked steps

$\tau = RC = (5.0 \times 10^{3})(20 \times 10^{-6}) = 0.10$ s M1 A1.

Practice 2.2 ▪ 1 mark

State the current a long time after charging begins.

Solution 2.2

Method: Time constant

Worked steps

zero (the capacitor is fully charged) B1.

Practice 2.3 ▪ 1 mark

Write the expression for the charge on a **discharging** capacitor.

Solution 2.3

Method: Time constant

Worked steps

$q(t) = Q\,e^{-t/\tau}$ B1.

Exam-style 3.1 ▪ 1 mark

The time constant of an RC circuit is

A R/C

B RC

C $R+C$

D $1/(RC)$

Solution 3.1

Method: Time constant

A R/C

B RC ✓

C $R + C$

D $1/(RC)$

Worked steps

B.

Exam-style 3.2 ▪ 1 mark

At $t = 0$, an uncharged capacitor in an RC circuit behaves like a

A break in the circuit

B plain wire

C battery

D resistor of infinite resistance

Solution 3.2

Method: Start and steady state

A break in the circuit

B plain wire ✓

C battery

D resistor of infinite resistance

Worked steps

B.

Exam-style 3.3 ▪ 2 marks

A 2.0 kΩ resistor charges a 50 μF capacitor from a 10 V supply.
(a) Find the time constant.
(b) Find the initial current (at $t = 0$).

Solution 3.3

Worked steps

(a) $\tau = RC = (2.0 \times 10^3)(50 \times 10^{-6}) = 0.10$ s M1 A1. (b) $I_0 = \dfrac{V}{R} = \dfrac{10}{2.0 \times 10^3} = 5.0 \times 10^{-3}$ A M1 A1.