

11.8 Resistor-Capacitor (RC) Circuits

Name: _____ Class: _____ Date: _____

Total: 10 marks

Objective

Build the skills to answer exam questions on **resistor-capacitor (RC) circuits**.

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

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ Charging and discharging

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

■ Time constant

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

■ 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.

2 Practice

2.1 Find the time constant of a $5.0 \text{ k}\Omega$ resistor and a $20 \text{ }\mu\text{F}$ capacitor. [2]

2.2 State the current a long time after charging begins. [1]

2.3 Write the expression for the charge on a **discharging** capacitor. [1]

3 Exam-style questions

3.1 The time constant of an RC circuit is [1]

- **A** R/C
 - **B** RC
 - **C** $R + C$
 - **D** $1/(RC)$
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3.2 At $t = 0$, an uncharged capacitor in an RC circuit behaves like a [1]

- **A** break in the circuit
 - **B** plain wire
 - **C** battery
 - **D** resistor of infinite resistance
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3.3 A $2.0\text{ k}\Omega$ resistor charges a $50\text{ }\mu\text{F}$ capacitor from a 10 V supply.

(a) Find the time constant. [2]

(b) Find the initial current (at $t = 0$). [2]

4 Go further

- work through the **11.8 Resistor-Capacitor (RC) Circuits** lesson on the **Learn** page;
- read the **Electric Circuits** section of the AP Physics C: E&M handout on the **Know** page.

Solutions

2.1 $\tau = RC = (5.0 \times 10^3)(20 \times 10^{-6}) = 0.10 \text{ s}.$

2.2 zero (the capacitor is fully charged).

2.3 $q(t) = Q e^{-t/\tau}.$

3.1 B.

3.2 B.

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