AP PHYSICS C: ELECTRICITY AND MAGNETISM • EXERCISE SHEET

11.8 Resistor-Capacitor (RC) Circuits

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS time constant 时间常数 • steady state 稳态 • rc circuit RC 电路 • resistance 电阻

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**

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

■ **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 kΩ resistor and a 20 μF 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** $1/(RC)$

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

3.3 A 2.0 kΩ resistor charges a 50 μF capacitor from a 10 V supply.

(a) Find the time constant. [2]

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

Solutions

2.1 $\tau = RC = (5.0 \times 10^3)(20 \times 10^{-6}) = 0.10$ 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) $\tau = RC = (2.0\times10^3)(50\times10^{-6}) = 0.10$ s. (b) $I_0 = \dfrac{V}{R} = \dfrac{10}{2.0 \times 10^3} = 5.0\times10^{-3}$ A.