

Exercise walk-through

11.8

Resistor-Capacitor (RC) Circuits

AP Physics C: Electricity and Magnetism

What a circuit is, and what Ohm's law claims

a circuit	closed loops of wires, batteries, resistors, bulbs, capacitors, inductors, switches and meters – charge flows only around a closed loop
steady state	current the same everywhere along one branch; nothing accumulates
Ohm's law	$I = \frac{\Delta V}{R}$ for an ohmic element – one whose R does not change with I
resistance	$R = \frac{\rho \ell}{A}$: material through ρ , and geometry through ℓ and A
ideal battery	maintains a fixed emf with zero internal resistance; a real one has r in series

Current is a **scalar** with a chosen direction, not a vector. Conventional current runs the way **positive** charge would move.

RC circuits

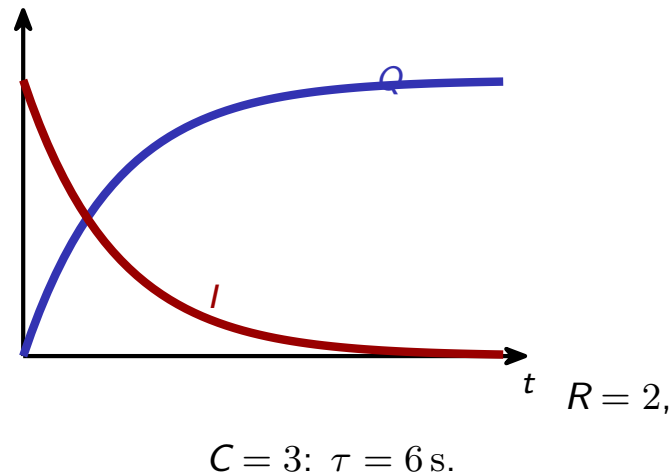
A capacitor charges through a resistor with
time constant $\tau = RC$:

Charging

$$Q(t) = C\varepsilon \left(1 - e^{-t/\tau}\right)$$

$$I(t) = \frac{\varepsilon}{R} e^{-t/\tau}$$

Empty capacitor = a wire at first; full = blocks
steady current.



Exam tips

- Relate current to charge flow $I = \frac{dQ}{dt}$ and use $J = \sigma E$, $R = \frac{\rho L}{A}$ for resistance.
- Apply **Kirchhoff's laws** (junction: charge; loop: energy) with consistent sign conventions.
- Analyse **RC circuits** with calculus: charging/discharging give exponentials with time constant $\tau = RC$.
- Combine resistors (series add, parallel reciprocal) and track power $P = IV = I^2 R$.
- At $t = 0$ a capacitor acts like a wire; after a long time ($t \rightarrow \infty$) it acts like an open branch.

Exercises 2.1-2.3

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]

Exercises 2.1·2.3

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

2.1

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

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

2.2

- zero (the capacitor is fully charged)
-

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

2.3

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

Exercises 3.1-3.2

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

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3.2 B

- plain wire.

Exercise 3.3 (a)

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]

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(a)

- $\tau = RC = (2.0 \times 10^3)(50 \times 10^{-6}) = 0.10 \text{ s}$

Exercise 3.3 (b)

3.3 A $2.0 \text{ k}\Omega$ resistor charges a $50 \text{ }\mu\text{F}$ capacitor from a 10 V supply.

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

[2]

Exercise 3.3 (b)

3.3 A $2.0 \text{ k}\Omega$ resistor charges a $50 \text{ }\mu\text{F}$ capacitor from a 10 V supply.

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

[2]

(b)

- $$I_0 = \frac{V}{R} = \frac{10}{2.0 \times 10^3} = 5.0 \times 10^{-3} \text{ A}$$