

# 1.6 Capacitors, inductors and energy

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 22 marks

**KEY WORDS** capacitor • capacitance • inductor • inductance  
• energy

## Objective

Relate capacitor and inductor behaviour to their defining laws, combine them correctly, compute stored energy, and explain why their stored quantities cannot jump.

## 1 Key knowledge and worked examples

### ■ Two storage elements, two mirror-image laws

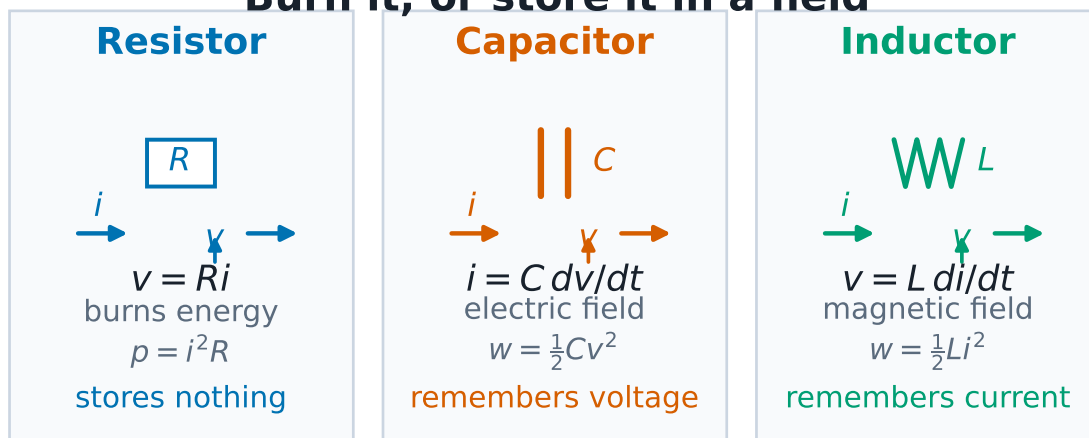
A **capacitor** stores separated charge; its **capacitance**  $C$  (farads) gives  $q = Cv$  and

$$i = C \frac{dv}{dt}$$

An **inductor** stores energy in a magnetic field; its **inductance**  $L$  (henrys) gives  $v = L \frac{di}{dt}$ . Steady DC makes the capacitor an open circuit and the inductor a short circuit – that single rule solves most steady-state problems.

Stored energy depends only on the present state:  $w_C = \frac{1}{2}Cv^2$ ,  $w_L = \frac{1}{2}Li^2$ .

### Burn it, or store it in a field



■ **Worked example: combinations are mirror images**

Capacitances in **parallel** add (areas add):  $47\mu F + 47\mu F = 94\mu F$ . In **series** the reciprocal rule applies:  $47/2 = 23.5 \mu F$ . Inductances behave the opposite way: series adds, parallel divides – the exact mirror of resistors.

A  $100 \mu F$  capacitor charged to 12 V holds  $w = \frac{1}{2} \times 100 \times 10^{-6} \times 144 = 7.2 mJ$  – enough to reset electronics, which is why large capacitors get discharged before you touch them.

■ **Worked example: rates, and the continuity argument**

With  $C = 220\mu F$  and the voltage ramping  $0 \rightarrow 10 \text{ V}$  in 50 ms:  $i = Cdv/dt = 220 \times 10^{-6} \times 200 = 44 mA$  while the ramp lasts.

An inductor  $L = 20 mH$  carrying 3 A holds  $w = \frac{1}{2} \times 0.02 \times 9 = 90 mJ$ . If its current is forced to change at 200 A/s, the terminal voltage is  $v = Ldi/dt = 4V$ . And because  $w_L$  cannot jump, **inductor current is continuous** – forcing it to zero instantly demands an enormous  $di/dt$ , and the resulting voltage arcs across the opening contact. Ignition coils work on exactly this principle.

## 2 Practice

**2.1** Two  $47 \mu F$  capacitors: (a) in parallel, (b) in series. Give both equivalent capacitances, then state which connection stores more total energy at 10 V. [4]

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**2.2** A 20 mH inductor carries 3 A. Compute the stored energy. Then, if the current falls at 200 A/s, give the inductor's terminal voltage and its polarity relative to the current direction. [4]

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**2.3** A  $220\ \mu\text{F}$  capacitor's voltage ramps from  $0\ \text{V}$  to  $10\ \text{V}$  in  $50\ \text{ms}$  and then holds steady. Give the current during the ramp and after it, with one sentence explaining the after value. [3]

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### 3 Exam-style questions

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**3.1** A  $470\ \mu\text{F}$  capacitor is charged to  $20\ \text{V}$  and then discharged through a resistor.

Compute the stored energy. Explain, in terms of the defining law  $i = C\ dv/dt$ , why the capacitor voltage cannot jump to zero in zero time, and state where the energy goes. If the discharge takes  $2\ \text{s}$  at roughly constant average power, estimate that power. [6]

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**3.2** A  $12\ \text{V}$  source feeds  $100\ \Omega$  in series; node A then has a  $200\ \Omega$  resistor in parallel with a large capacitor.

Using DC steady-state reasoning, find the current in the  $100\ \Omega$ , the voltage across the capacitor, and the energy it stores (take  $C = 100\ \mu\text{F}$ ). Then state, with a reason, what the capacitor's current is at steady state. [5]

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