

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

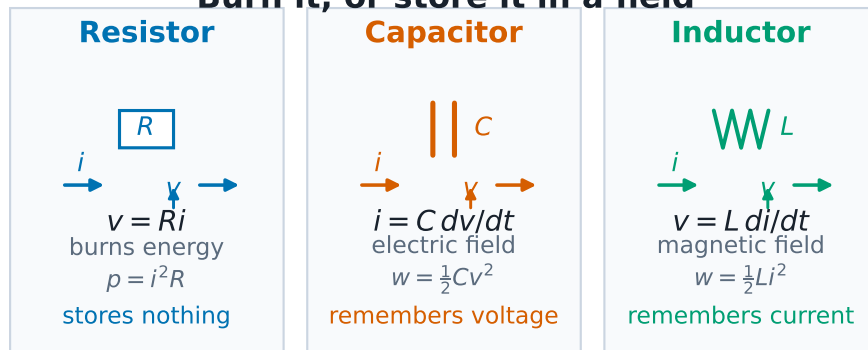
A **capacitor** stores separated charge; its **capacitance** C (farads) gives $q = Cv$ and

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

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 $0 \rightarrow 10$ 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]

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]

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

3 Exam-style questions

3.1 A 470 μF capacitor is charged to 20 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 s at roughly constant average power, estimate that power. [6]

3.2 A 12 V source feeds 100 Ω in series; node A then has a 200 Ω resistor in parallel with a large capacitor.

Using DC steady-state reasoning, find the current in the 100 Ω , 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]
