EE2003
Circuit Theory

Chapter 6
Capacitors and Inductors

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Chapter 6

6.1 Capacitors

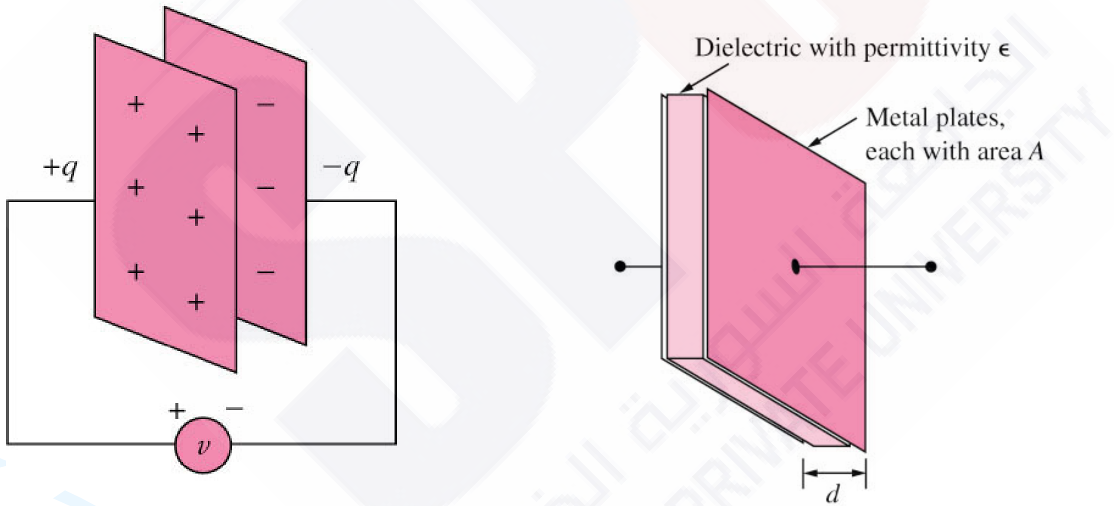
6.2 Series and Parallel Capacitors

6.3 Inductors

6.4 Series and Parallel Inductors

6.1 Capacitors (1)

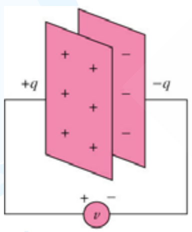
- A capacitor is a passive element designed to **store energy** in its **electric field.**



- A **capacitor** consists of two conducting plates separated by an insulator (or dielectric).

6.1 Capacitors (2)

- **Capacitance** C is the ratio of the charge q on one plate of a capacitor to the voltage difference v between the two plates, measured in farads (F).

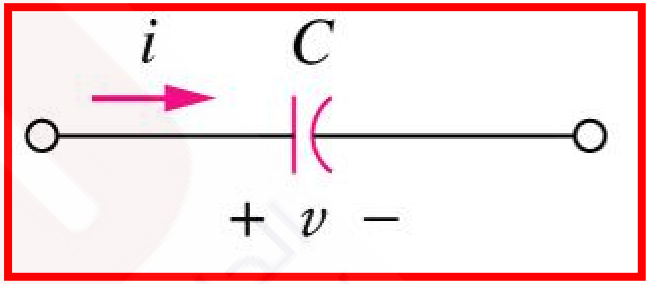


$$q = C\,v$$ and $$C = \frac{\varepsilon\, A}{d}$$

- Where ε is the permittivity of the dielectric material between the plates, A is the surface area of each plate, d is the distance between the plates.
- Unit: F, pF (10^{-12}), nF (10^{-9}), and **μF (10^{-6})**

6.1 Capacitors (3)

- If ***i*** is flowing into the +ve terminal of C
  - Charging => ***i*** is +ve
  - Discharging => ***i*** is –ve



- The current-voltage relationship of capacitor according to above convention is

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

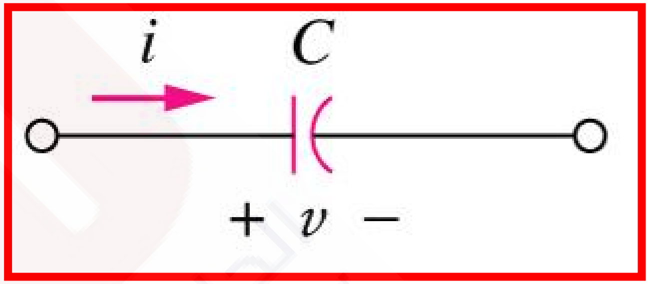
and

$$\boxed{v = \frac{1}{C}\int_{t_0}^{t} i\,dt + v(t_0)}$$

6.1 Capacitors (4)

- The energy, ***w***, stored in the capacitor is

$$\boxed{w = \frac{1}{2} C v^2}$$



- A capacitor is
  - an **open circuit** to dc (dv/dt = 0).
  - its voltage **cannot change abruptly**.

6.1 Capacitors (5)

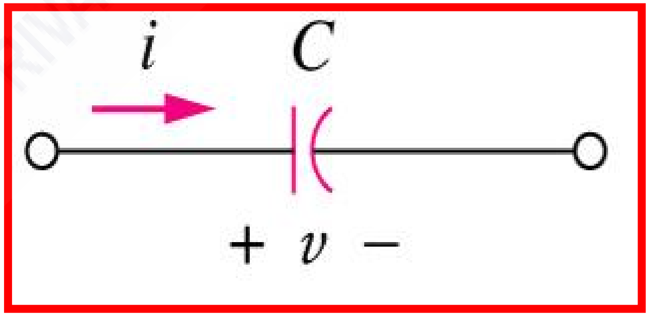
Example 1

The current through a 100-μF capacitor is

$$i(t) = 50 \sin(120\,\pi t) \text{ mA.}$$

Calculate the voltage across it at t =1 ms and t = 5 ms.

Take $v(0)$ =0.



Answer:

v(1ms) = 93.14mV

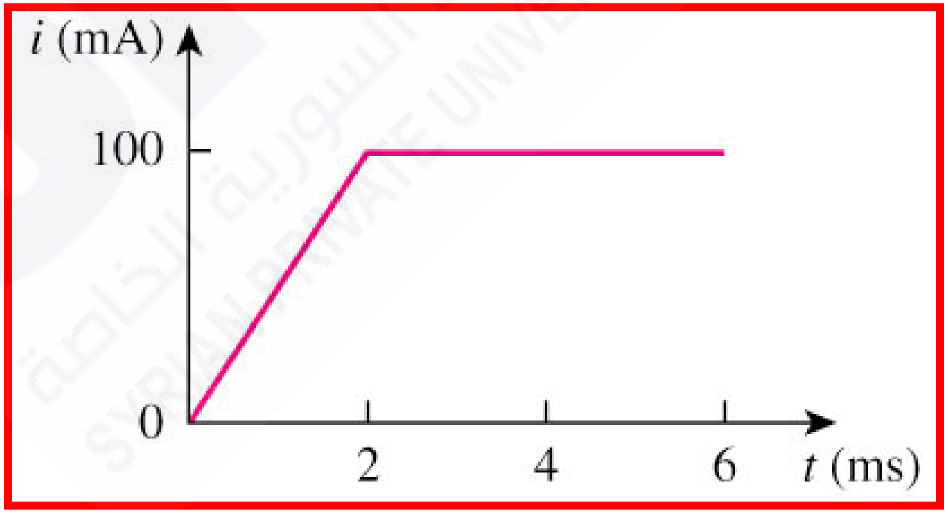
v(5ms) = 1.7361V

6.1 Capacitors (6)

Example 2

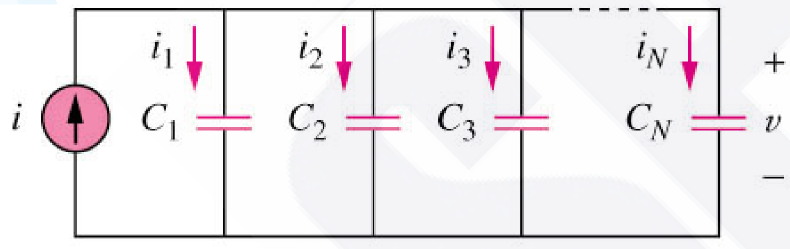
An initially uncharged 1-mF capacitor has the current shown below across it.

Calculate the voltage across it at t = 2 ms and t = 5 ms.



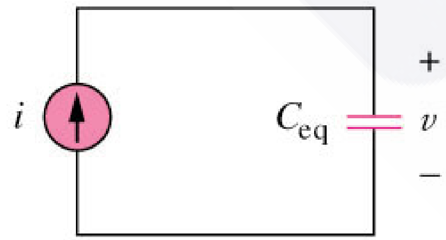
6.2 Series and Parallel Capacitors (1)

- The equivalent capacitance of *N* **parallel-connected** capacitors is the sum of the individual capacitances.



(a)

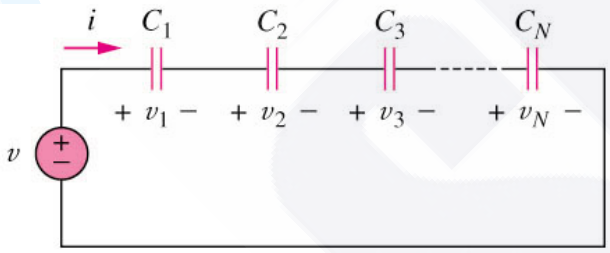
$$C_{eq} = C_1 + C_2 + \ldots + C_N$$



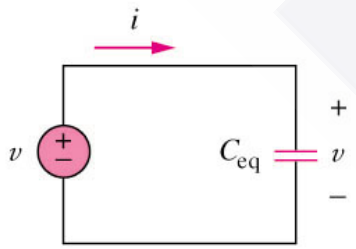
(b)

6.2 Series and Parallel Capacitors (2)

- The equivalent capacitance of *N* **series-connected** capacitors is the reciprocal of the sum of the reciprocals of the individual capacitances.



(a)



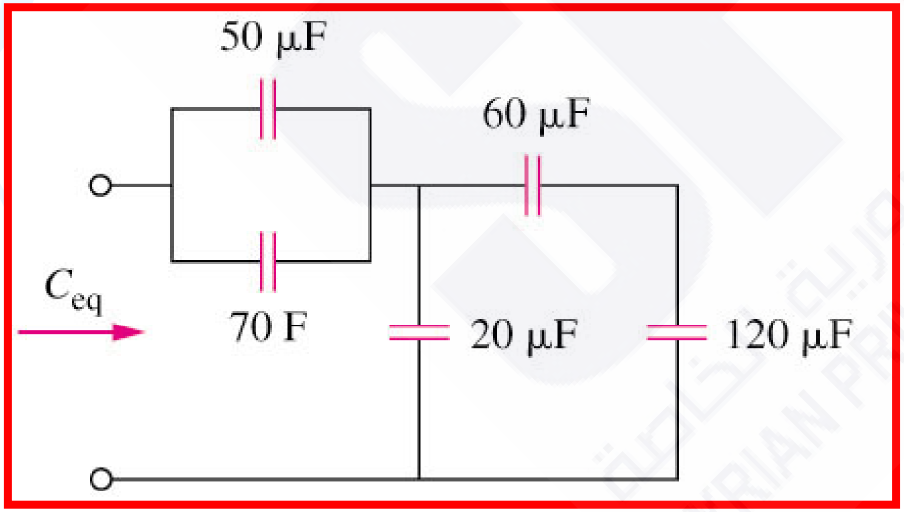
(b)

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_N}$$

6.2 Series and Parallel Capacitors (3)

Example 3

Find the equivalent capacitance seen at the terminals of the circuit in the circuit shown below:



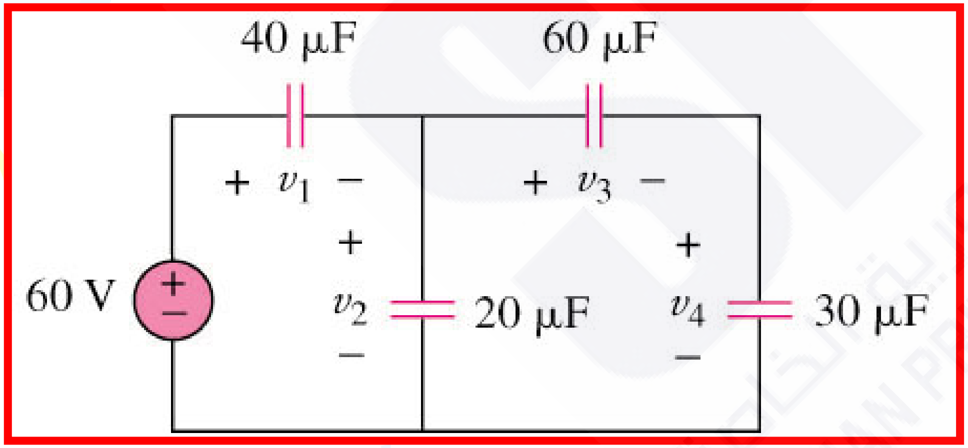
Answer:

C_{eq} = 40μF

6.2 Series and Parallel Capacitors (4)

Example 4

Find the voltage across each of the capacitors in the circuit shown below:



Answer:

v_1 = 30V

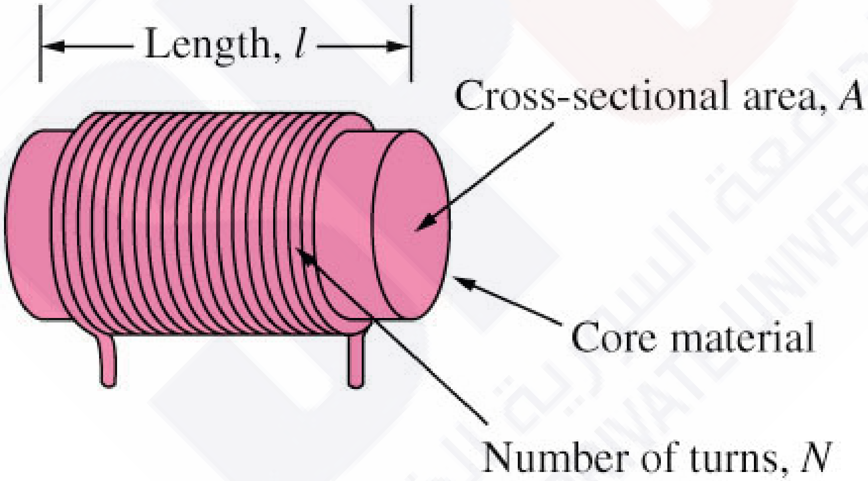
v_2 = 30V

v_3 = 10V

v_4 = 20V

6.3 Inductors (1)

- An inductor is a passive element designed to store energy in its magnetic field.



- An inductor consists of a coil of conducting wire.

6.3 Inductors (2)

- Inductance is the property whereby an inductor exhibits opposition to the change of current flowing through it, measured in henrys (H).

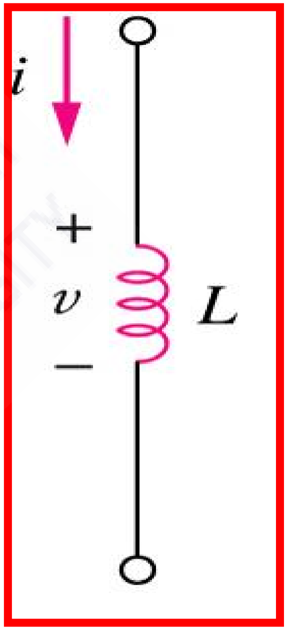
$$v = L\frac{di}{dt} \quad \text{and} \quad L = \frac{N^2 \mu A}{l}$$

- The unit of inductors is Henry (H), mH (10^{-3}) and μH (10^{-6}).

6.3 Inductors (3)

- The current-voltage relationship of an inductor:

$$i = \frac{1}{L}\int_{t_0}^{t} v(t)\,dt + i(t_0)$$



- The power stored by an inductor:

$$w = \frac{1}{2} L i^2$$

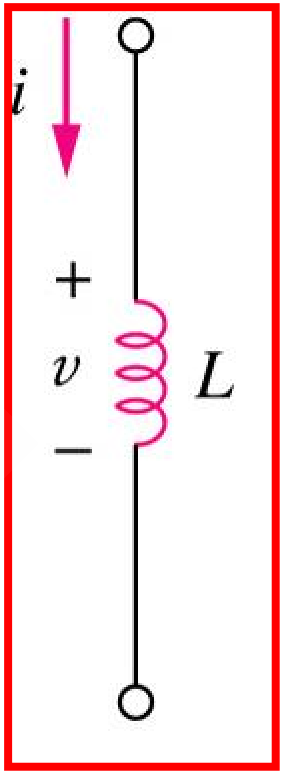
- An inductor acts like a short circuit to dc (di/dt = 0) and its current cannot change abruptly.

6.3 Inductors (4)

Example 5

The terminal voltage of a 2-H inductor is

$$v = 10(1-t)\ \text{V}$$



Find the current flowing through it at $t = 4$ s and the energy stored in it within $0 < t < 4$ s.

Assume $i(0) = 2$ A.

Answer:

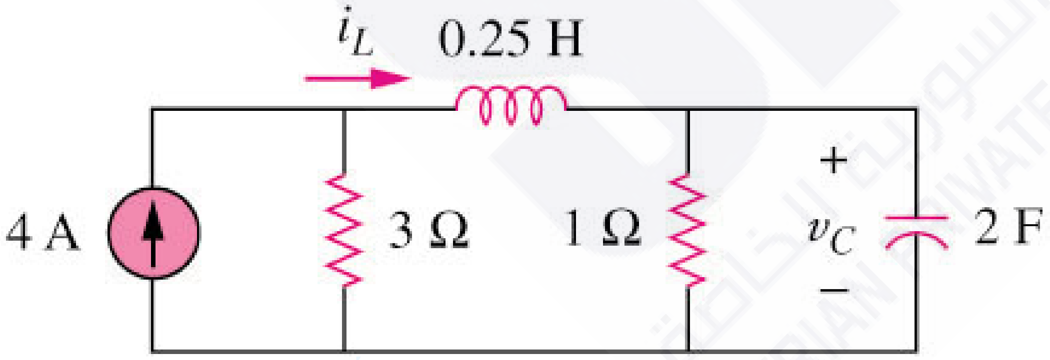
$i(4s) = -18V$

$w(4s) = 320J$

6.3 Inductors (5)

Example 6

Determine v_c, i_L, and the energy stored in the capacitor and inductor in the circuit of circuit shown below under dc conditions.



Answer:

$i_L = 3A$

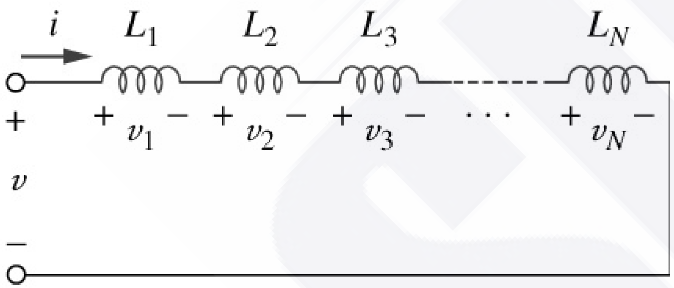
$v_C = 3V$

$w_L = 1.125J$

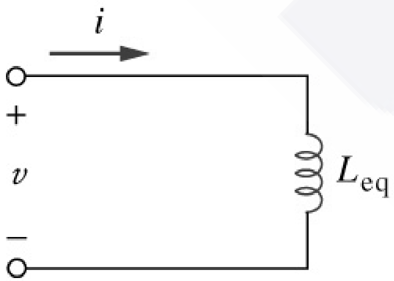
$w_C = 9J$

6.4 Series and Parallel Inductors (1)

- The equivalent inductance of **series-connected** inductors is the sum of the individual inductances.



(a)

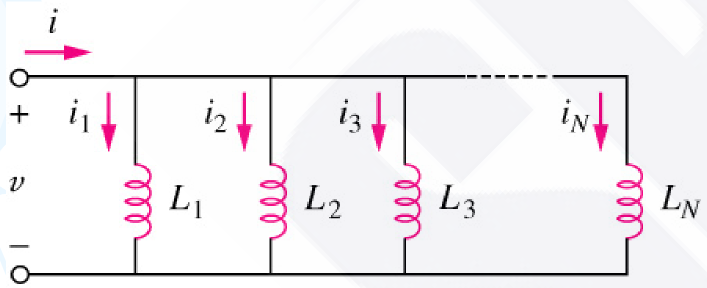


(b)

$$L_{eq} = L_1 + L_2 + \ldots + L_N$$

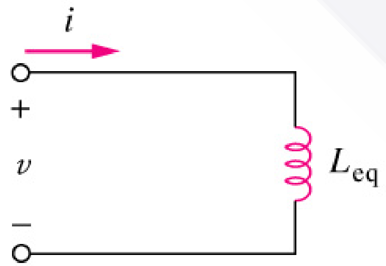
6.4 Series and Parallel Inductors (2)

- The equivalent capacitance of **parallel** inductors is the reciprocal of the sum of the reciprocals of the individual inductances.



(a)

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots + \frac{1}{L_N}$$

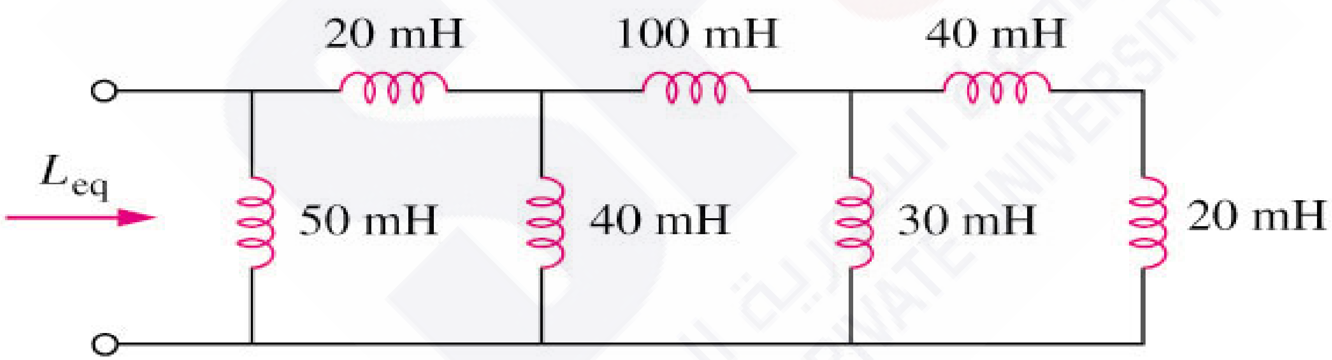


(b)

6.4 Series and Parallel Capacitors (3)

Example 7

Calculate the equivalent inductance for the inductive ladder network in the circuit shown below:

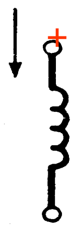
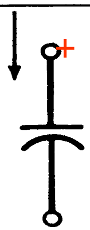


Answer:

L_{eq} = 25mH

6.4 Series and Parallel Capacitors (4)

- Current and voltage relationship for R, L, C

Circuit element	Units	Voltage	Current	Power
 Resistance	ohms (Ω)	$v = Ri$ (Ohm's law)	$i = \frac{v}{R}$	$p = vi = i^2R$
 Inductance	henries (H)	$v = L\frac{di}{dt}$	$i = \frac{1}{L}\int v\,dt + k_1$	$p = vi = Li\frac{di}{dt}$
 Capacitance	farads (F)	$v = \frac{1}{C}\int i\,dt + k_2$	$i = C\frac{dv}{dt}$	$p = vi = Cv\frac{dv}{dt}$