The active and passive components are differentiated on various factors like nature of the source, its functions, power gain, controlling the flow of current.

Active components and their functions

Active components require a source of energy, typically in the form of a direct current, in order to perform their specific function. They are able to manipulate the flow of electricity in some way. Most active components consist of semiconductor devices, such as diodes, transistors and integrated circuits.

- **Transistor:** Mostly used for amplifying electrical signals or as switching devices
- **Diode:** Permits electricity to flow in one direction only
- **Integrated circuit (chips or microchips):** multiple complex circuits on a circuit board; used to perform all kinds of tasks; still considered a component despite consisting of many other components
- **Display devices** such as LCD, LED and CRT displays
- **Power sources** such as batteries and other sources of alternating current (AC) or direct current (DC)

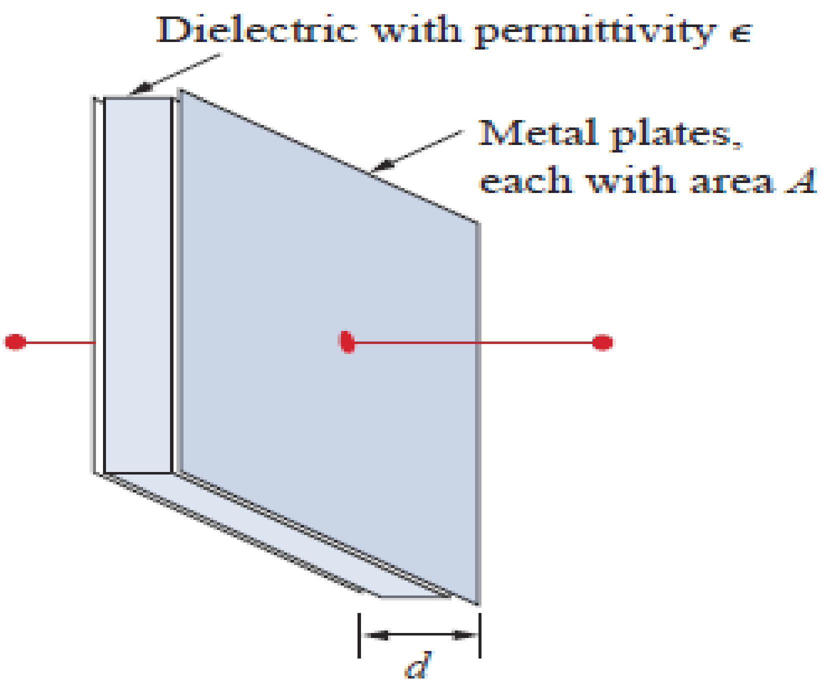
Passive components and their functions

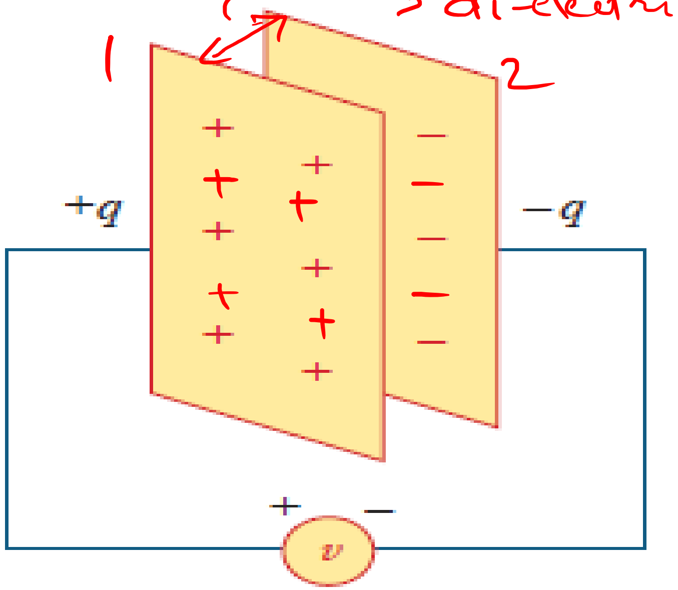
Passive components can influence the flow of electricity running through them. For example, they can resist its flow, store energy for later use, or produce inductance. However, they cannot control or amplify electricity themselves.

The most common components and their functions:

- **Resistor:** Resists the flow of electrical current in a circuit; used to lower voltage
- **Capacitor:** Stores electrical energy electrostatically in an electric field (known as 'charging'), and can release it later when needed
- **Inductor:** Stores electrical energy in a magnetic field; allows direct current (DC) to flow through it, but not alternating current (AC)
- **Transducer:** Converts an input signal from one type of energy into another type; sensors are a type of transducer that convert physical action/input into an electrical signal

Capacitors





ε_0

$\varepsilon = \varepsilon_0 \varepsilon_r$

A capacitor is a passive element designed to store energy in its electric field. Besides resistors, capacitors are the most common electrical components.

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

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

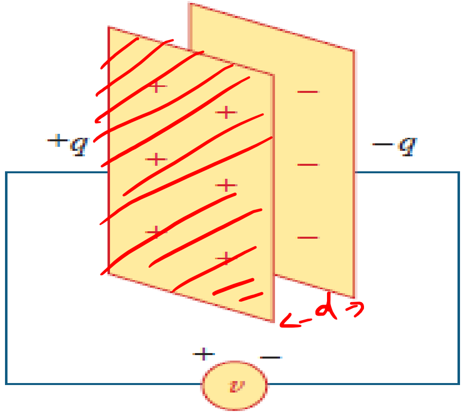
$$\boxed{q = Cv}$$

$q \propto V$

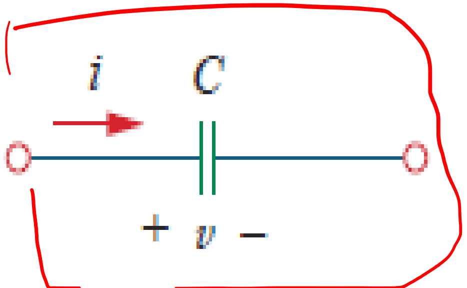
1 farad = 1 coulomb/volt.

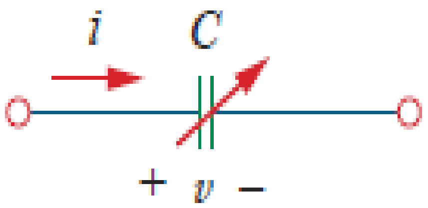
the parallel-plate capacitor : $\boxed{C = \dfrac{\epsilon A}{d}}$

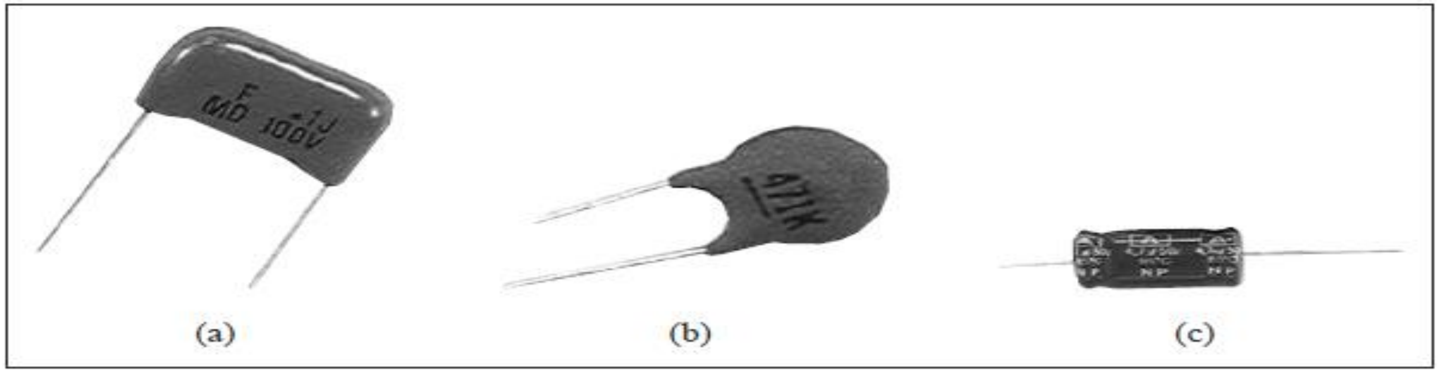
$\varepsilon = \varepsilon_0 \varepsilon_r$



1. The surface area of the plates—the larger the area, the greater the capacitance.
2. The spacing between the plates—the smaller the spacing, the greater the capacitance.
3. The permittivity of the material—the higher the permittivity, the greater the capacitance.







Fixed capacitors: (a) polyester capacitor, (b) ceramic capacitor, (c) electrolytic capacitor.
Courtesy of Tech America.

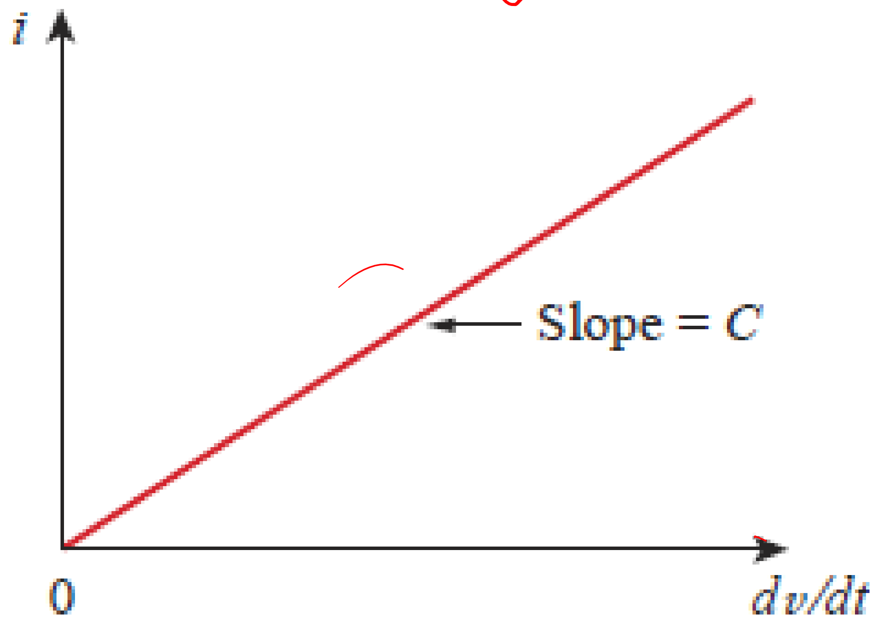
Variable capacitors: (a) trimmer capacitor,
(b) filmtrim capacitor.
Courtesy of Johanson.

To obtain the current-voltage relationship of the capacitor,

$$\boxed{q = Cv} \qquad i = \frac{dq}{dt} \qquad \boxed{i = C\frac{dv}{dt}}$$

linear:

$C = \frac{q}{v}$



For a *nonlinear capacitor*,
the plot of the current-voltage relationship is not a straight line.

The voltage-current relation of the capacitor

$$v = \frac{1}{C}\int_{-\infty}^{t} i\,dt$$

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

$i = \frac{dq}{dt}$

$dq = i\,dt$

where $v(t_0) = q(t_0)/C$ is the voltage across the capacitor at time t_0.

shows that capacitor voltage depends on the past history of the capacitor current. Hence, the capacitor has memory—a property that is often exploited.

$t_0 \longrightarrow t$

$v(t_0) = q(t_0)/c$

The instantaneous power delivered to the capacitor

$$\boxed{p = vi = Cv\frac{dv}{dt}}$$

The energy stored in the capacitor is therefore

$$w = \int_{-\infty}^{t} p\,dt = C\int_{-\infty}^{t} v\frac{dv}{dt}dt = C\int_{v(-\infty)}^{v(t)} v\,dv = \frac{1}{2}Cv^2\Big|_{v(-\infty)}^{v(t)}$$

We note that $v(-\infty) = 0$, because the capacitor was uncharged at $t = -\infty$. Thus,

VC

$$\boxed{w = \frac{1}{2}Cv^2}$$

$$\boxed{w = \frac{q^2}{2C}}$$

word *capacitor* is derived from this element's capacity to store energy in an electric field.

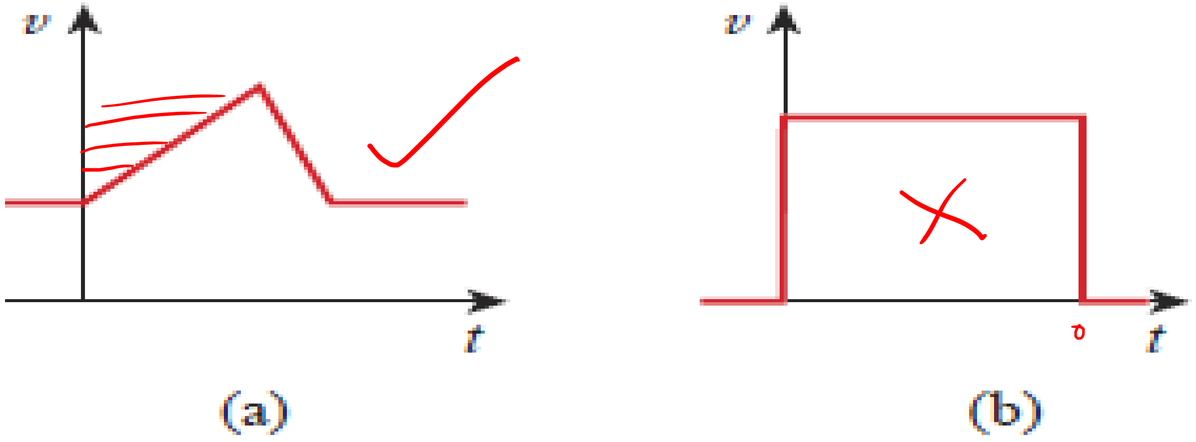
1. Note from Eq. (6.4) that when the voltage across a capacitor is not changing with time (i.e., dc voltage), the current through the capacitor is zero. Thus,

> A capacitor is an open circuit to dc.

However, if a battery (dc voltage) is connected across a capacitor, the capacitor charges.

2. The voltage on the capacitor must be continuous.

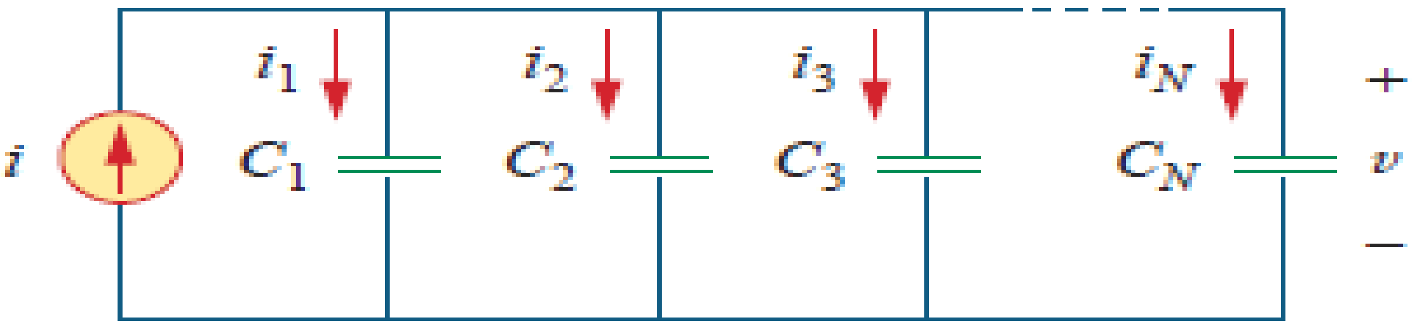
> The voltage on a capacitor cannot change abruptly.

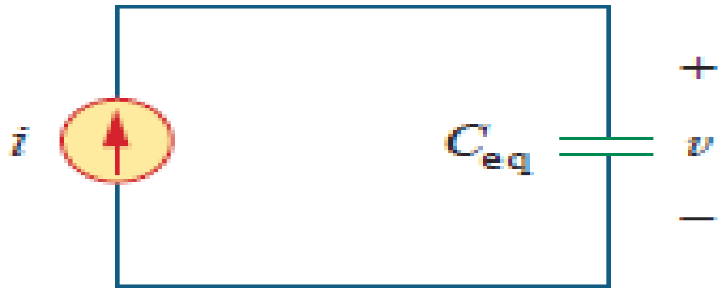


Voltage across a capacitor: (a) allowed, (b) not allowable; an abrupt change is not possible.

3. The ideal capacitor does not dissipate energy. It takes power from the circuit when storing energy in its field and returns previously stored energy when delivering power to the circuit.

Series and Parallel Capacitors





(b)

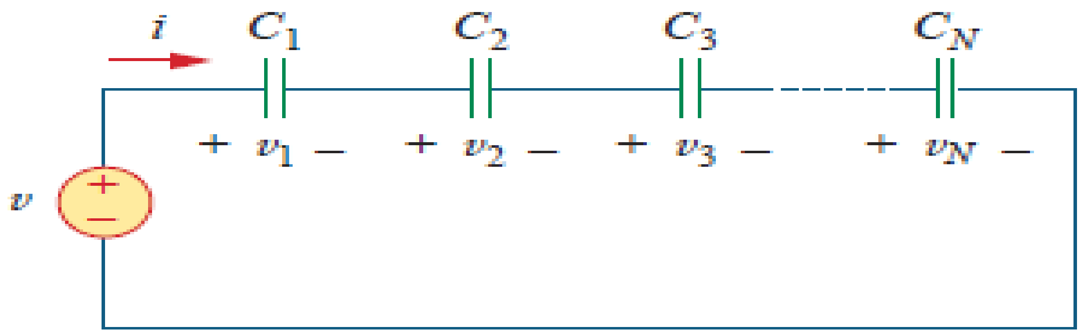
$$i = i_1 + i_2 + i_3 + \cdots + i_N$$

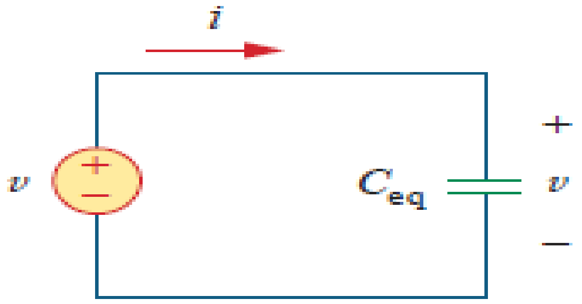
But $i_k = C_k\,dv/dt$. Hence,

$$\begin{aligned} i &= C_1\frac{dv}{dt} + C_2\frac{dv}{dt} + C_3\frac{dv}{dt} + \cdots + C_N\frac{dv}{dt} \\ &= \left(\sum_{k=1}^{N} C_k\right)\frac{dv}{dt} = C_{eq}\frac{dv}{dt} \end{aligned}$$

$$\boxed{C_{eq} = C_1 + C_2 + C_3 + \cdots + C_N}$$

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





$$v = v_1 + v_2 + v_3 + \cdots + v_N$$

But $v_k = \dfrac{1}{C_k}\displaystyle\int_{t_0}^{t} i(t)\,dt + v_k(t_0)$. Therefore,

$$v = \frac{1}{C_1}\int_{t_0}^{t} i(t)\,dt + v_1(t_0) + \frac{1}{C_2}\int_{t_0}^{t} i(t)\,dt + v_2(t_0)$$

$$+ \cdots + \frac{1}{C_N}\int_{t_0}^{t} i(t)\,dt + v_N(t_0)$$

$$= \left(\frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_N}\right)\int_{t_0}^{t} i(t)\,dt + v_1(t_0) + v_2(t_0)$$

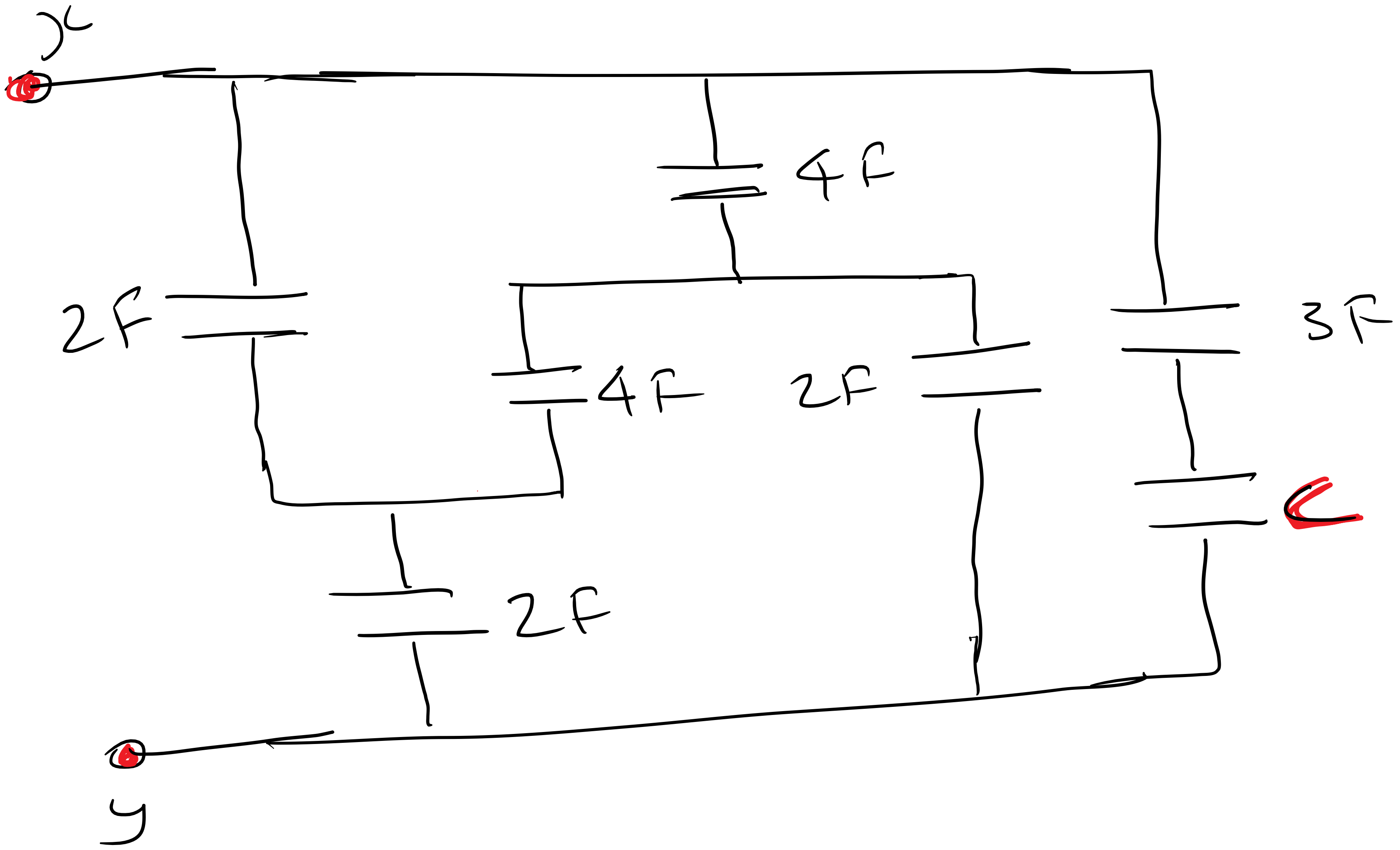
$$+ \cdots + v_N(t_0)$$

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

$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_N}}$$

The equivalent capacitance between x & y is 5 F

find C ?



A voltage source $V(t)$ is connected across a capacitor of 2F. Find the energy stored in the capacitor from $t=0$ to 10 sec

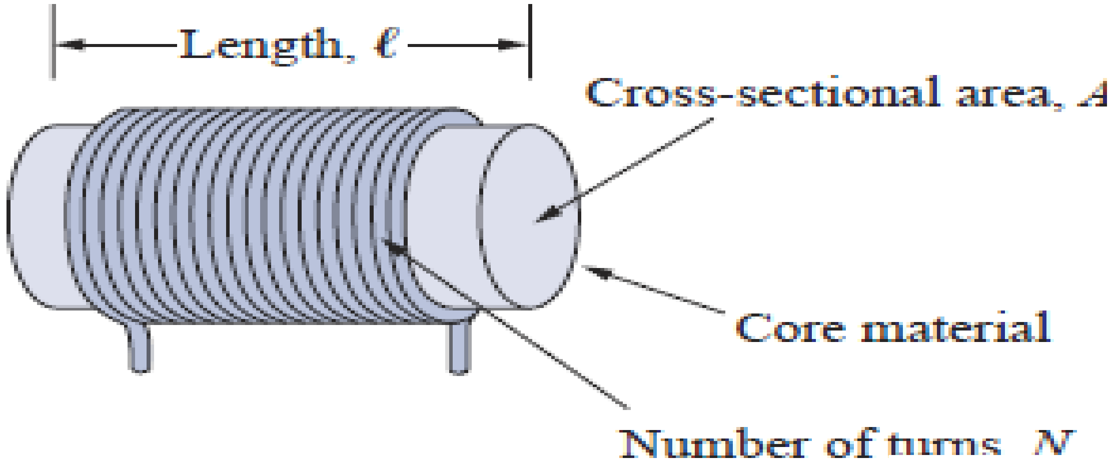
if $V(t) = t^2 e^{-2t}$

$$\text{Energy} = \int_{t_0}^{t=10\,sec} V(t)\, i(t)\, dt = \int_{t_0}^{t} V_c \frac{dv}{dt}\, dt$$

$$= C \int_{t_0}^{t} v\, dv$$

Inductors

An inductor is a passive element designed to store energy in its magnetic field. Inductors find numerous applications in electronic and power systems. They are used in power supplies, transformers, radios, TVs, radars, and electric motors.

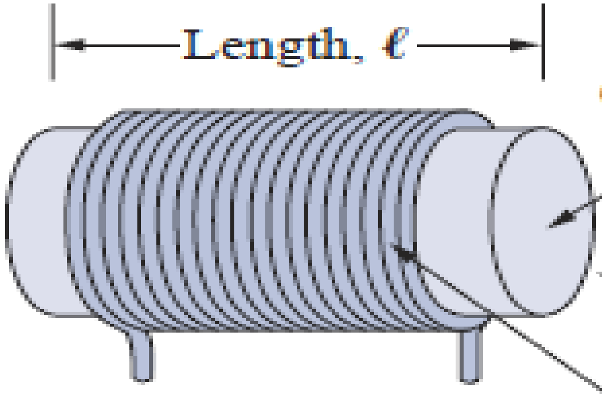


$$v = L\frac{di}{dt}$$

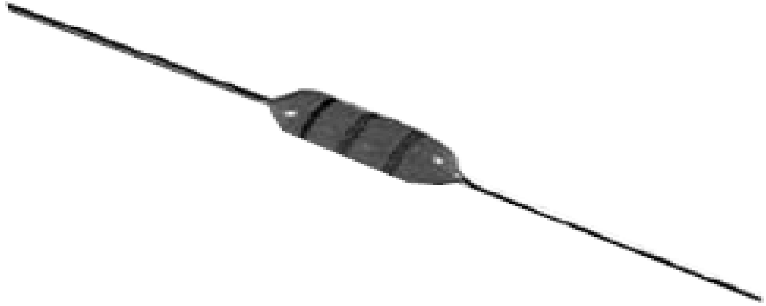
The unit of inductance is the henry (H).

An **inductor** consists of a coil of conducting wire.

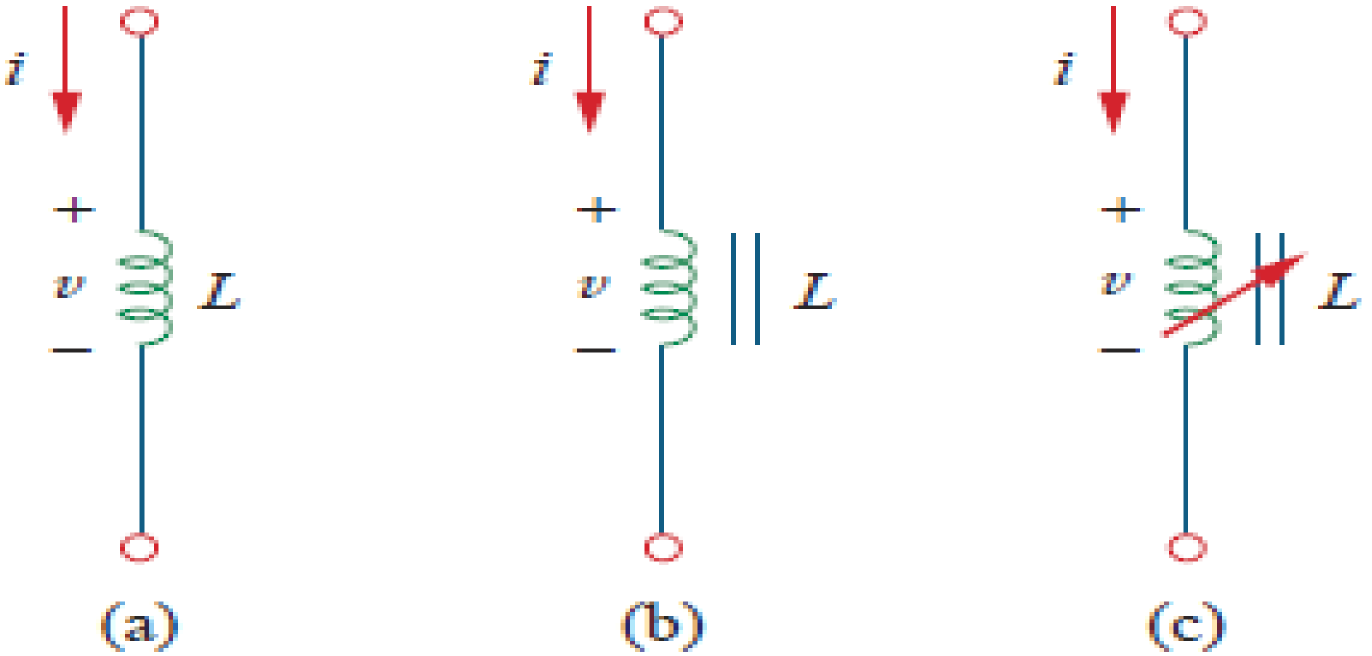
Inductance is the property whereby an inductor exhibits opposition to the change of current flowing through it, measured in henrys (H).



$$L = \frac{N^2 \mu A}{\ell}$$



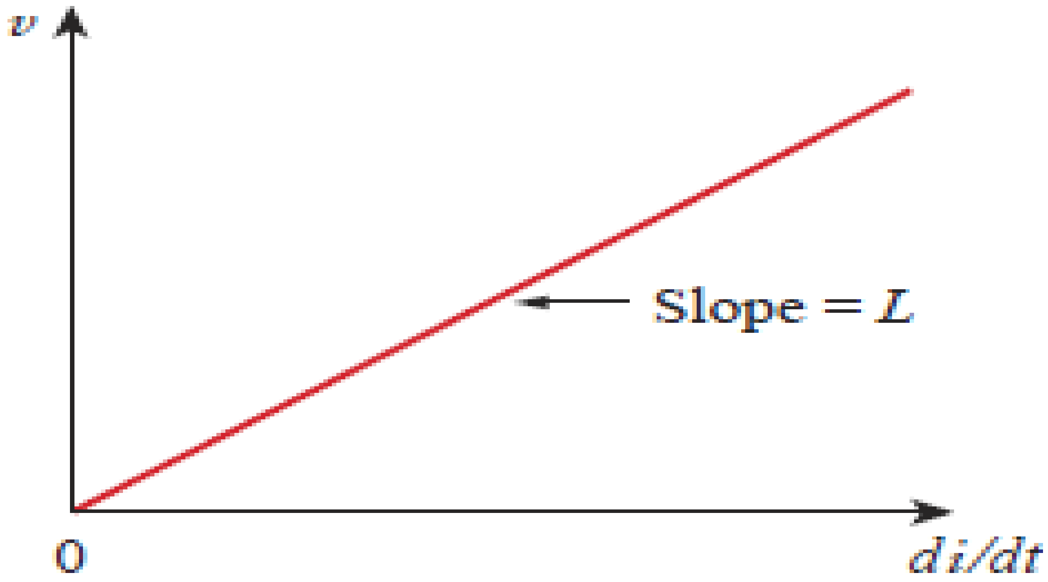
Various types of inductors: (a) solenoidal wound inductor, (b) toroidal inductor, (c) chip inductor.



Circuit symbols for inductors: (a) air-core, (b) iron-core, (c) variable iron-core.

linear inductor.

$$\boxed{v = L\frac{di}{dt}}$$



The current-voltage relationship

$$\boxed{v = L\frac{di}{dt}}$$

$$di = \frac{1}{L} v \, dt$$

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

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

where $i(t_0)$ is the total current for $-\infty < t < t_0$

The inductor is designed to store energy in its magnetic field.

$$p = vi = \left(L\frac{di}{dt}\right)i$$

The energy stored is

$$w = \int_{-\infty}^{t} p\,dt = \int_{-\infty}^{t} \left(L\frac{di}{dt}\right)i\,dt$$
$$= L\int_{-\infty}^{t} i\,di = \frac{1}{2}Li^2(t) - \frac{1}{2}Li^2(-\infty)$$

Since $i(-\infty) = 0$,

$$\boxed{w = \frac{1}{2}Li^2}$$

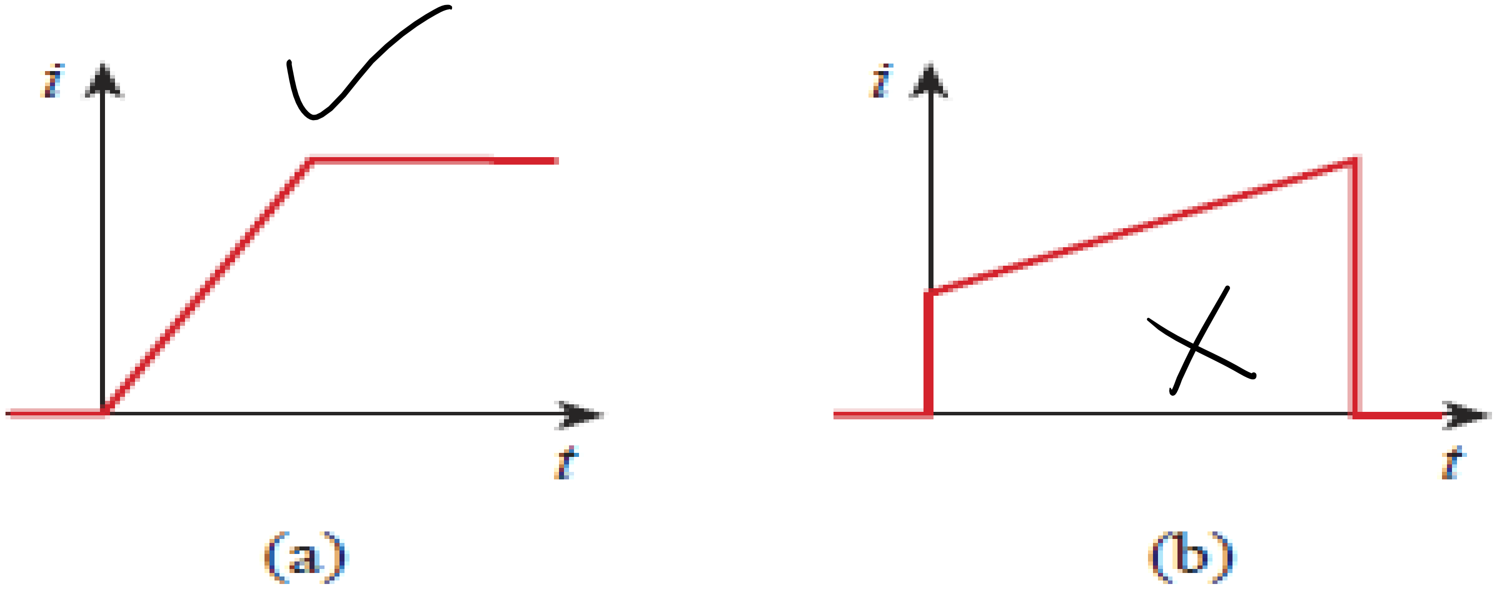
$$\boxed{v = L\frac{di}{dt}}$$

1. Note from Eq. (6.18) that the voltage across an inductor is zero when the current is constant. Thus,

> An inductor acts like a short circuit to dc.

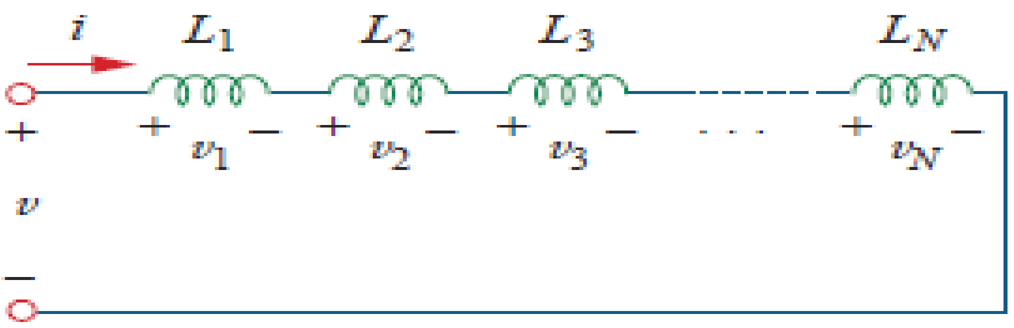
2. An important property of the inductor is its opposition to the change in current flowing through it.

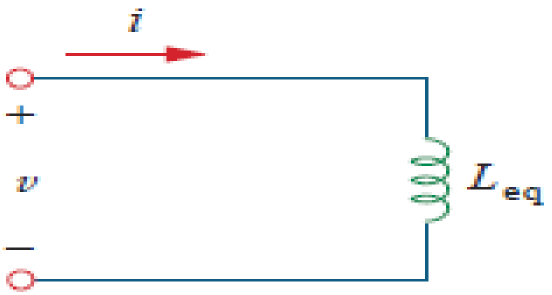
> The current through an inductor cannot change instantaneously.



Current through an inductor: (a) allowed, (b) not allowable; an abrupt change is not possible.

Series and Parallel Inductors





Applying KVL to the loop, $v = v_1 + v_2 + v_3 + \cdots + v_N$

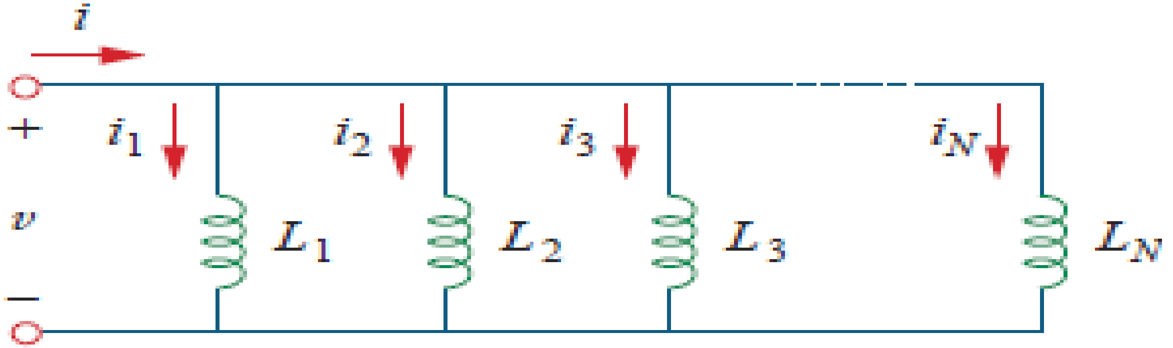
Substituting $v_k = L_k\, di/dt$ results in

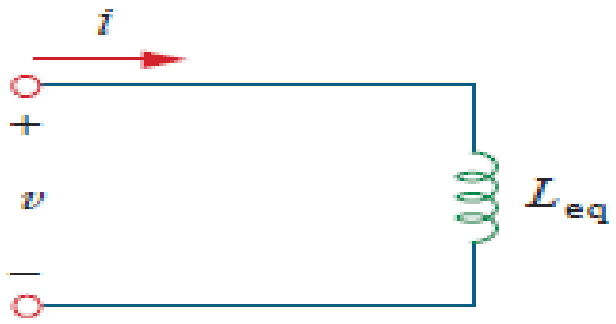
$$\begin{aligned} v &= L_1\frac{di}{dt} + L_2\frac{di}{dt} + L_3\frac{di}{dt} + \cdots + L_N\frac{di}{dt} \\ &= (L_1 + L_2 + L_3 + \cdots + L_N)\frac{di}{dt} \\ &= \left(\sum_{k=1}^{N} L_k\right)\frac{di}{dt} = L_{eq}\frac{di}{dt} \end{aligned}$$

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

$$\boxed{L_{eq} = L_1 + L_2 + L_3 + \cdots + L_N}$$

A parallel connection of N inductors,





$$i = i_1 + i_2 + i_3 + \cdots + i_N$$

But $i_k = \dfrac{1}{L_k}\displaystyle\int_{t_0}^{t} v\,dt + i_k(t_0)$; hence,

$$\boxed{v = L\frac{di}{dt}}$$

$$\begin{aligned}
i &= \frac{1}{L_1}\int_{t_0}^{t} v\,dt + i_1(t_0) + \frac{1}{L_2}\int_{t_0}^{t} v\,dt + i_2(t_0) \\
&\quad + \cdots + \frac{1}{L_N}\int_{t_0}^{t} v\,dt + i_N(t_0) \\
&= \left(\frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_N}\right)\int_{t_0}^{t} v\,dt + i_1(t_0) + i_2(t_0) \\
&\quad + \cdots + i_N(t_0) \\
&= \left(\sum_{k=1}^{N}\frac{1}{L_k}\right)\int_{t_0}^{t} v\,dt + \sum_{k=1}^{N} i_k(t_0) = \frac{1}{L_{eq}}\int_{t_0}^{t} v\,dt + i(t_0)
\end{aligned}$$

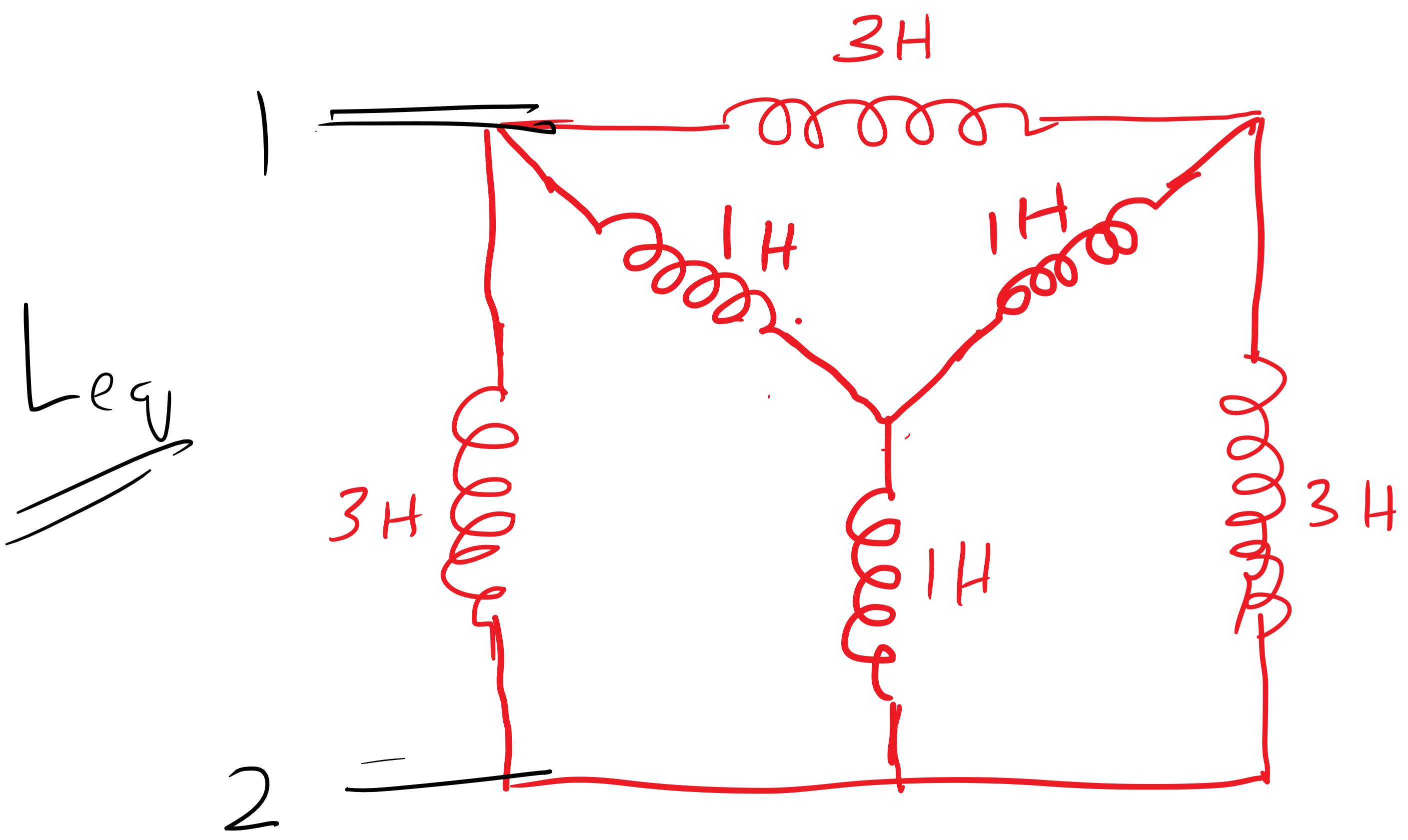
$$\boxed{\frac{1}{L_{\text{eq}}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots + \frac{1}{L_N}}$$

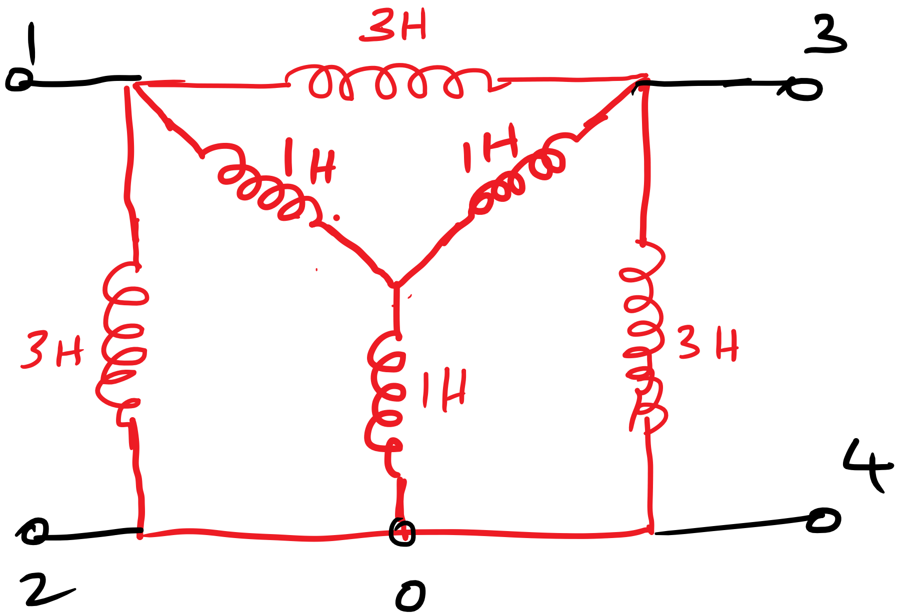
The **equivalent inductance** of parallel inductors is the reciprocal of the sum of the reciprocals of the individual inductances.

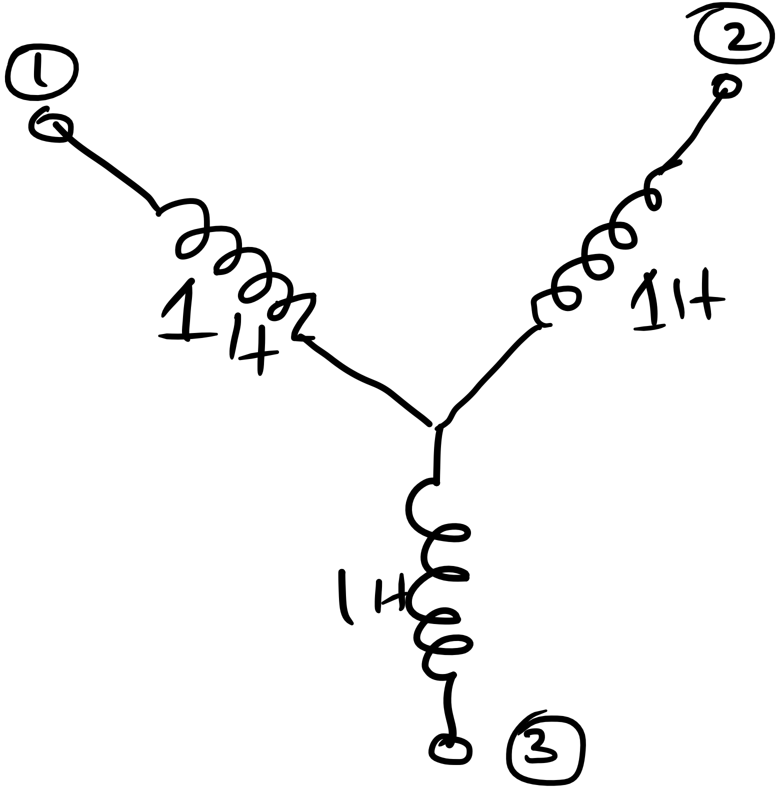
Relation	Resistor (R)	Capacitor (C)	Inductor (L)
v-i:	$v = iR$	$v = \frac{1}{C}\int_{t_0}^{t} i\,dt + v(t_0)$	$v = L\frac{di}{dt}$
i-v:	$i = v/R$	$i = C\frac{dv}{dt}$	$i = \frac{1}{L}\int_{t_0}^{t} v\,dt + i(t_0)$
p or w:	$p = i^2R = \frac{v^2}{R}$	$w = \frac{1}{2}Cv^2$	$w = \frac{1}{2}Li^2$

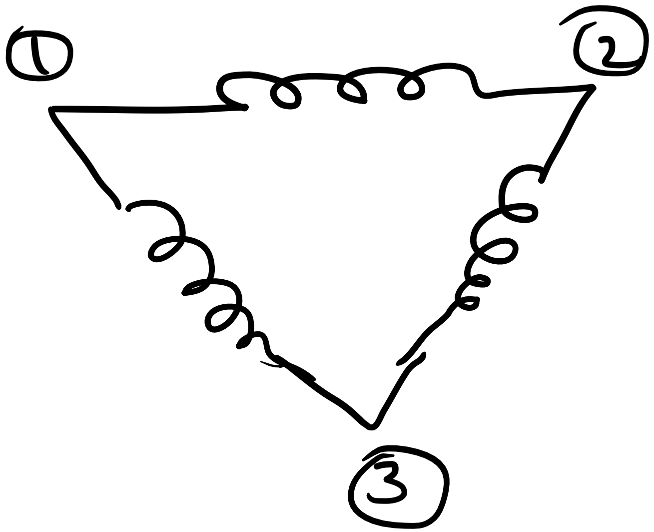
Relation	Resistor (R)	Capacitor (C)	Inductor (L)
Series:	$R_{eq} = R_1 + R_2$	$C_{eq} = \dfrac{C_1 C_2}{C_1 + C_2}$	$L_{eq} = L_1 + L_2$
Parallel:	$R_{eq} = \dfrac{R_1 R_2}{R_1 + R_2}$	$C_{eq} = C_1 + C_2$	$L_{eq} = \dfrac{L_1 L_2}{L_1 + L_2}$
At dc:	Same	Open circuit	Short circuit
Circuit variable that cannot change abruptly:	Not applicable	v	i

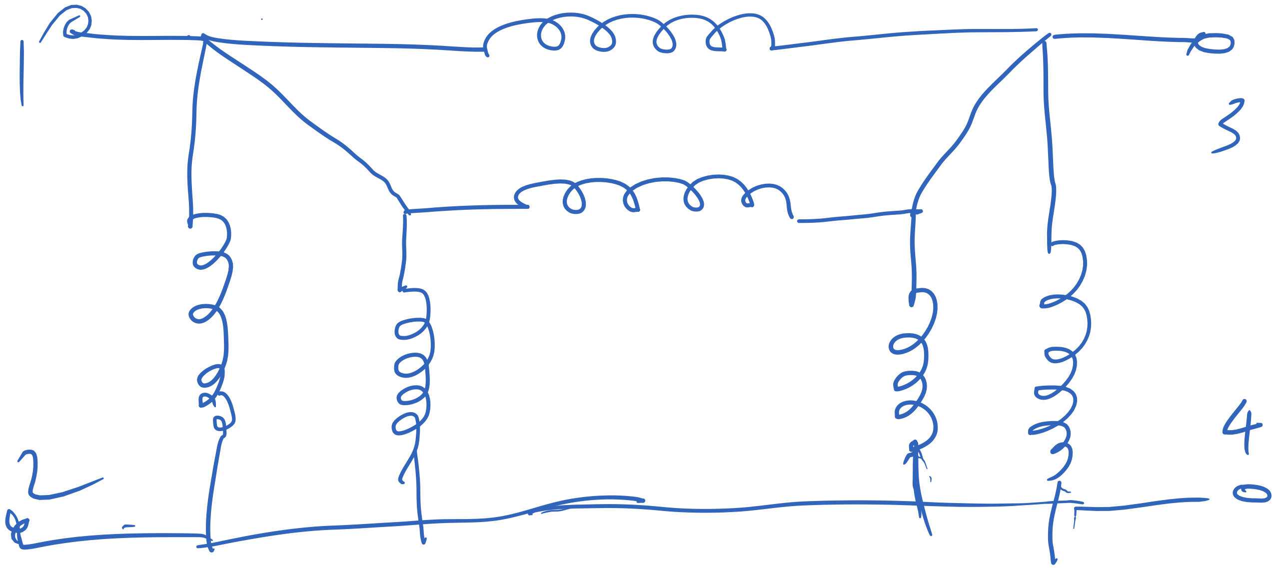
Obtain the equivalent inductance at terminal 1–2 for the circuit shown below.

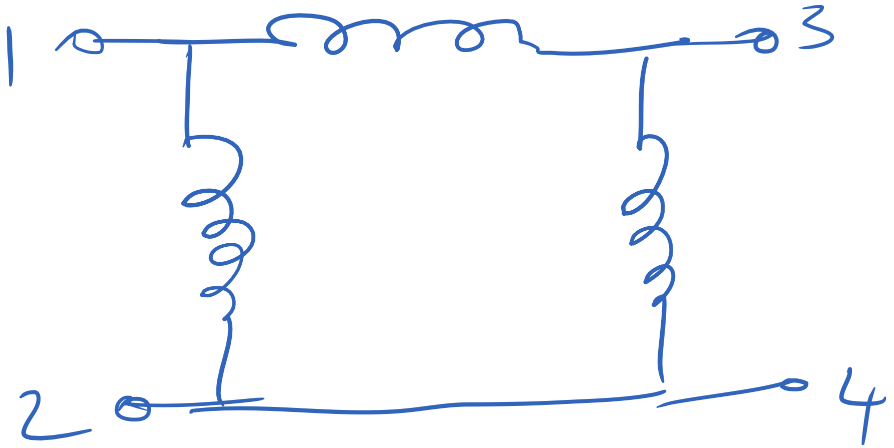



1
3H
3
1H
1H
3H
1H
3H
4
2
0


1
2
1H
1H
1H
3


1
2
3


1
3
4
2


1
3
2
4