

ENG2200

Electric Circuits

Chapter 5

Inductance, Capacitance and Mutual Inductance

Objectives

- Understand how an inductor or a capacitor behaves in the presence of a constant current or constant voltage
- Know and being able to use the equations of current, voltage power and energy in an inductor and capacitor
- Be able to combine inductors (capacitors) with an initial condition in series and parallel to form a single equivalent conductor (capacitor).
- Understand the basic concept of mutual inductance and being able to write mesh-current equations for a circuit containing magnetically coupled coils using the dot convention correctly.

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

L in henrys
 i in amperes
 t in seconds

The current (i) can not change suddenly

(a)

(b)

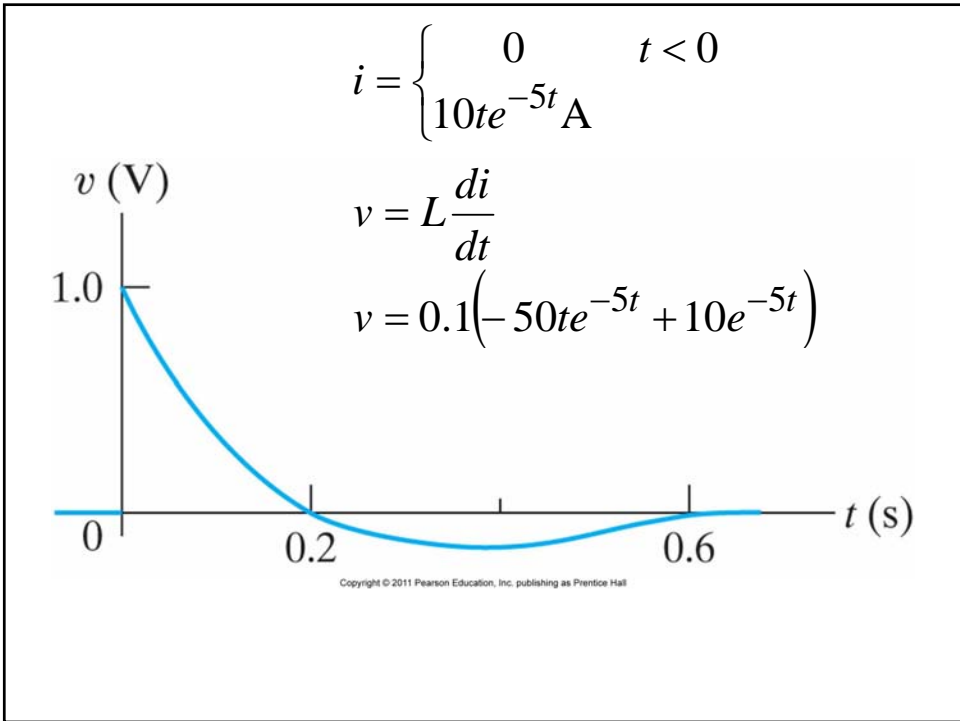
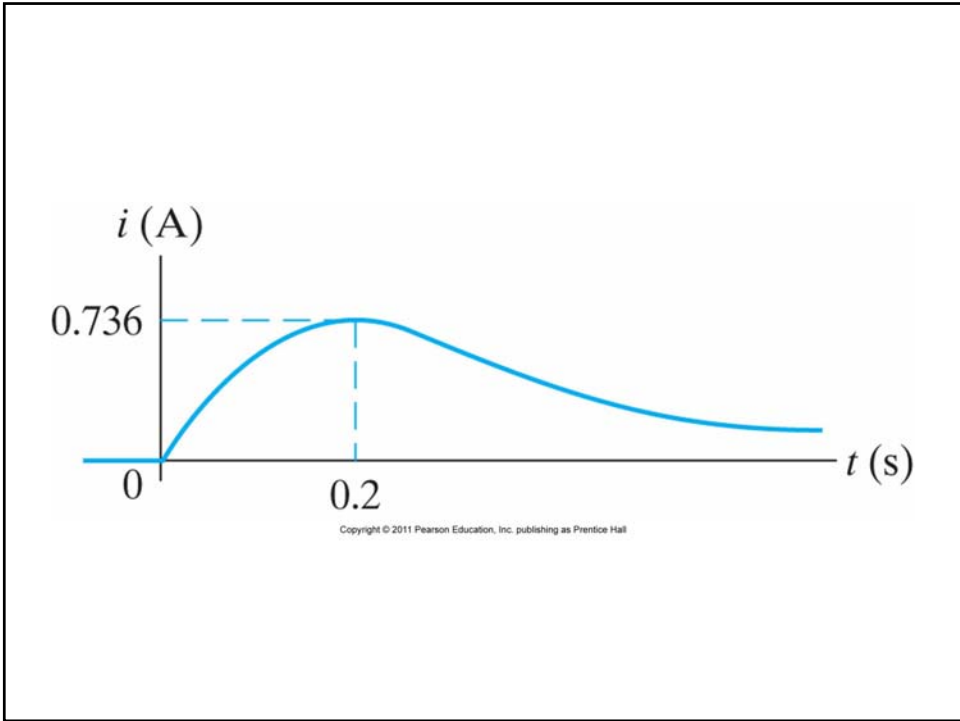
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100 mH

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$i = 0, \quad t < 0$

$i = 10te^{-5t} \text{ A}, \quad t > 0$



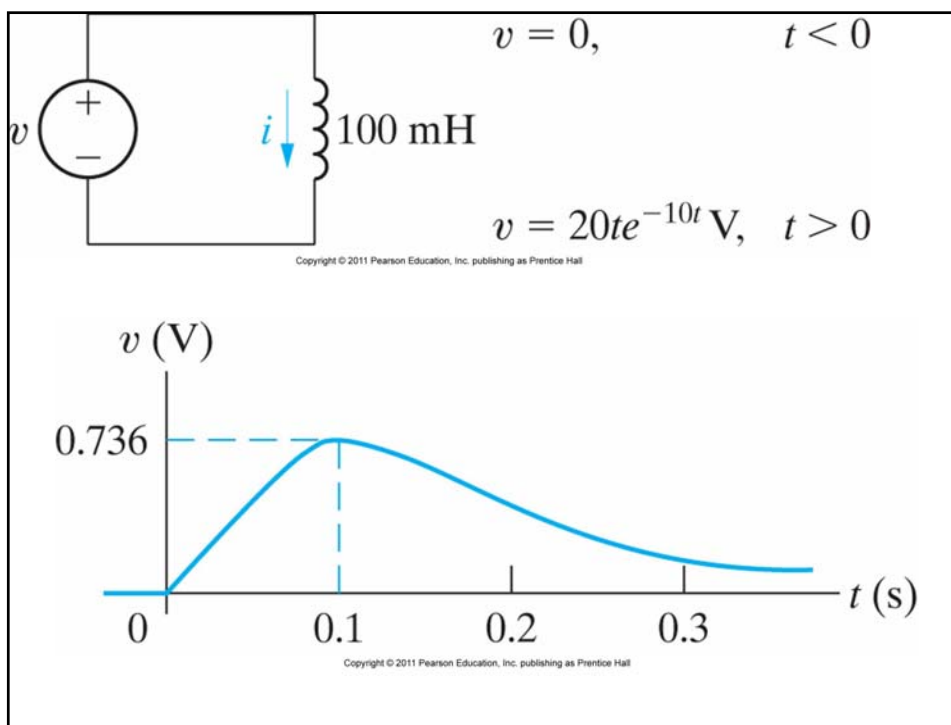
Inductor

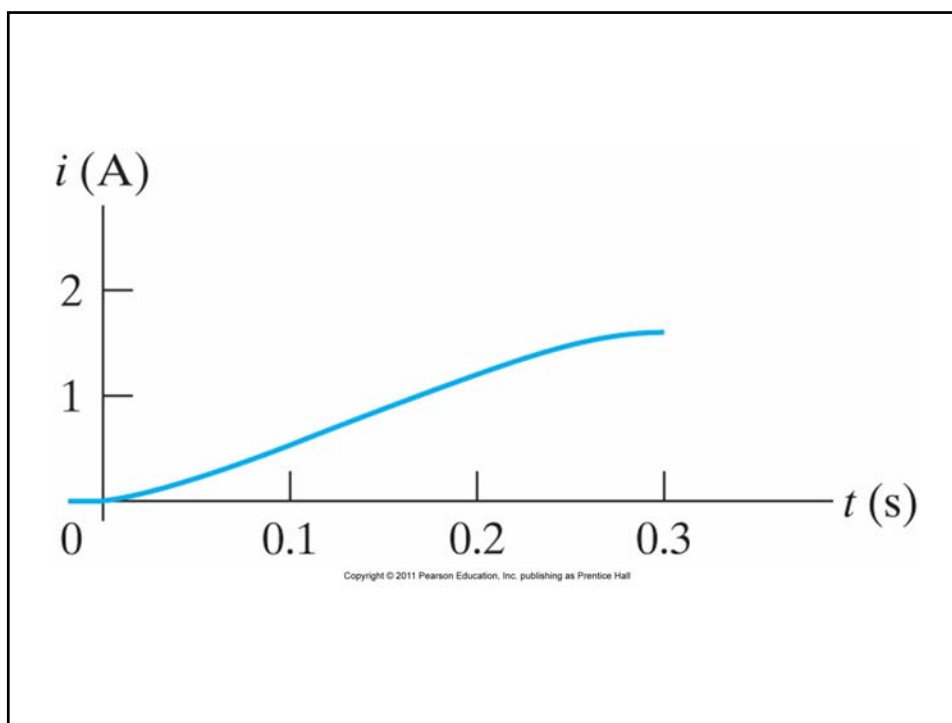
$$v = L \frac{di}{dt}$$

$$v dt = L di$$

$$L \int_{i(t_0)}^{i(t)} dx = \int_0^t v dt$$

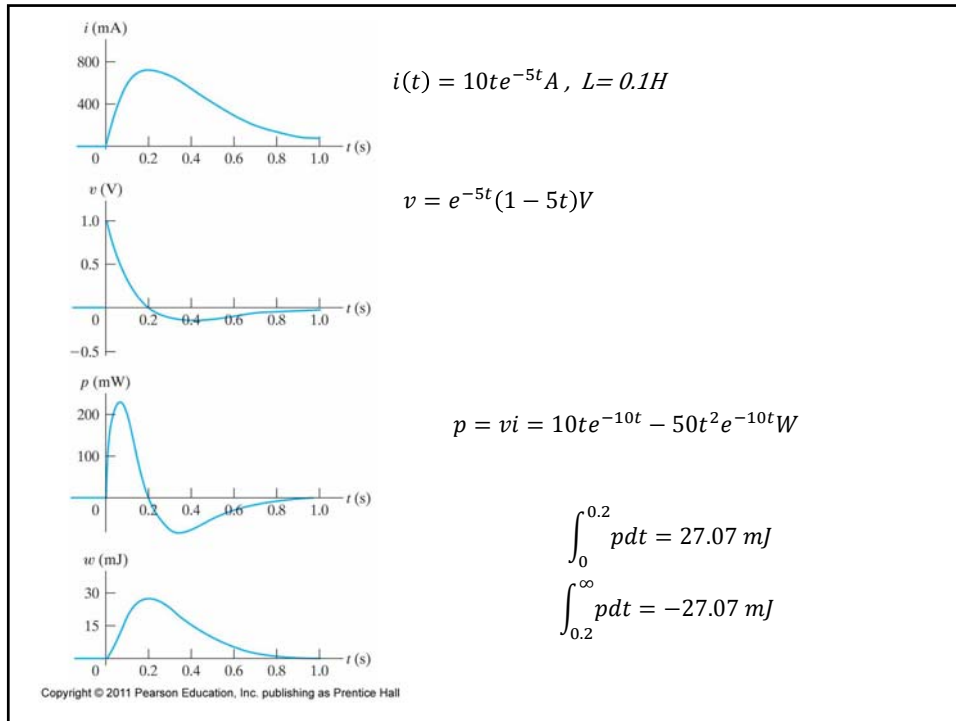
$$i(t) = \frac{1}{L} \int_0^t v d\tau + i(t_0)$$





Power and Energy

- Power in an inductor can be expressed as $p=vi$
- $p = Li \frac{di}{dt}$
- $p = v \left[\frac{1}{L} \int_{t_0}^t v d\tau + i(t_0) \right]$
- $p = \frac{dw}{dt} = Li \frac{di}{dt} \rightarrow dw = Ldi$
- $\int_0^w dx = L \int_0^i y dy$
- $w = \frac{1}{2} Li^2$



Capacitors

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

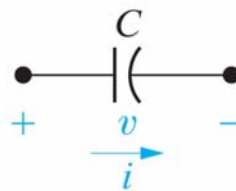
$$v(t) = \frac{1}{C} \int_{t_0}^t i d\tau + v(t_0)$$

$$p = i \left[\frac{1}{C} \int_{t_0}^t i d\tau + v(t_0) \right]$$

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



(a)



(b)

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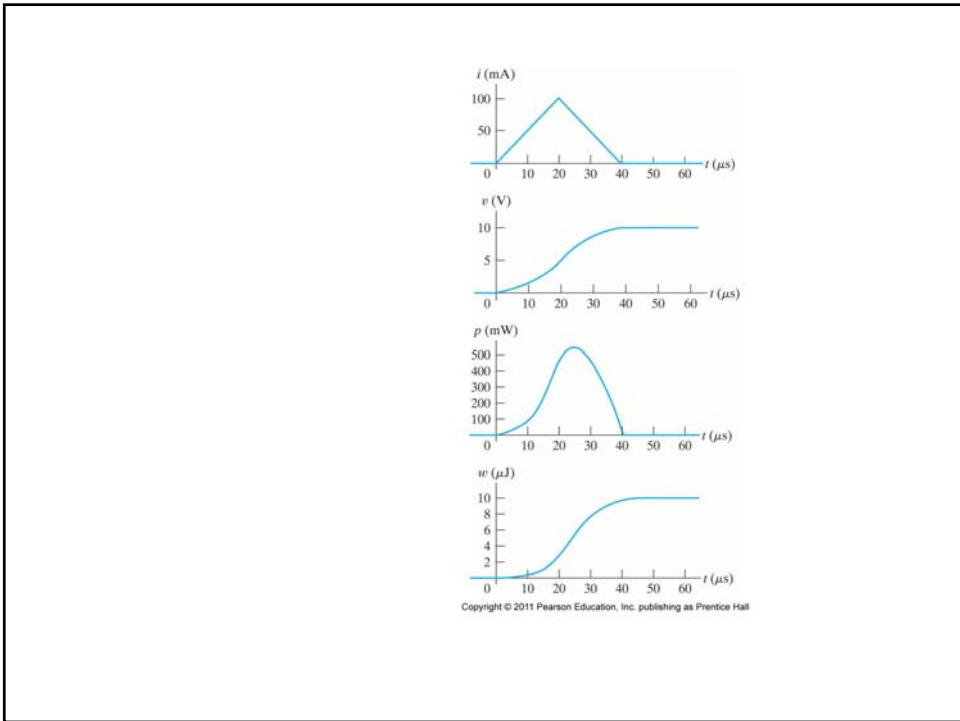
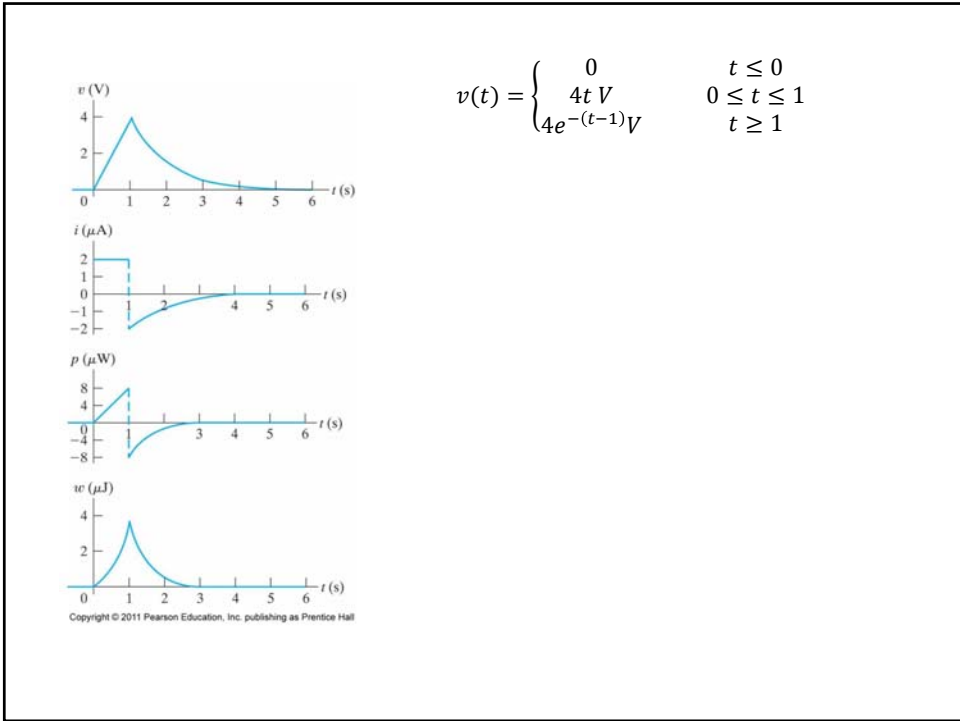
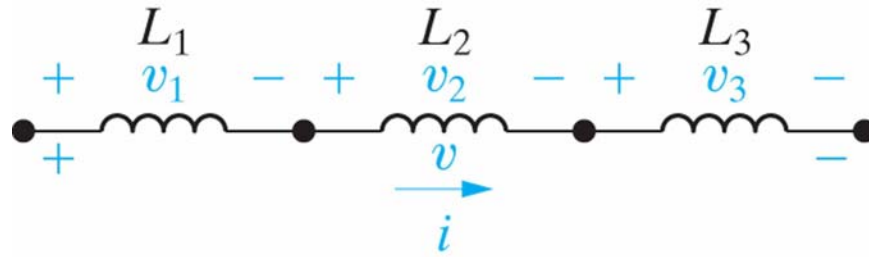
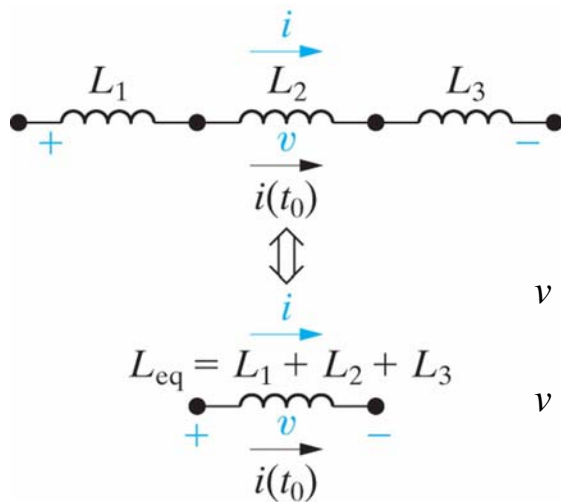


Figure 6.13 Inductors in series.



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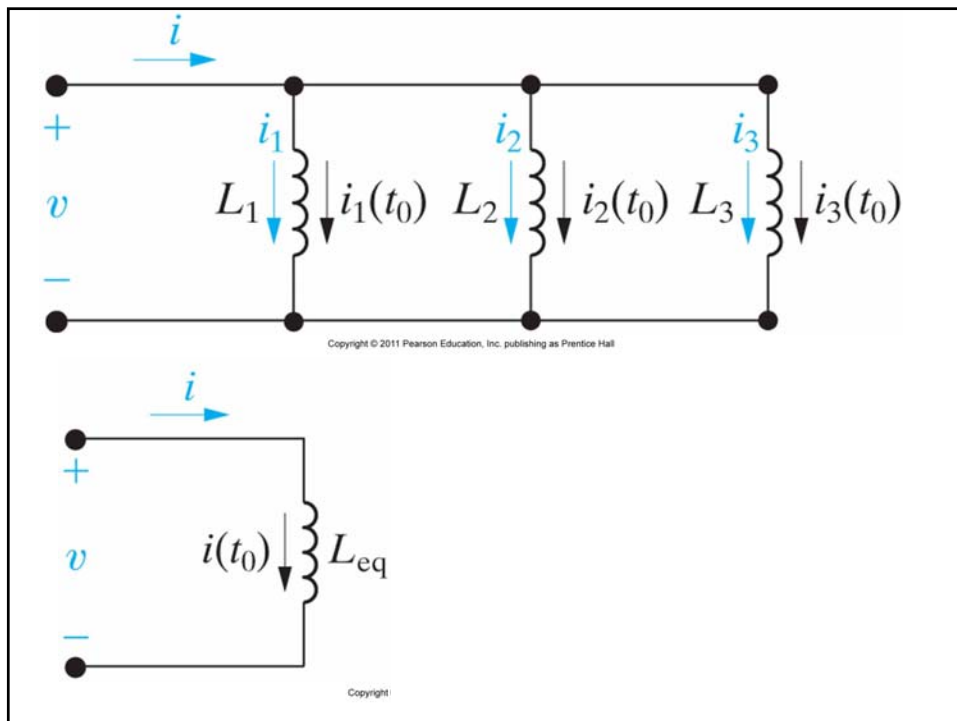
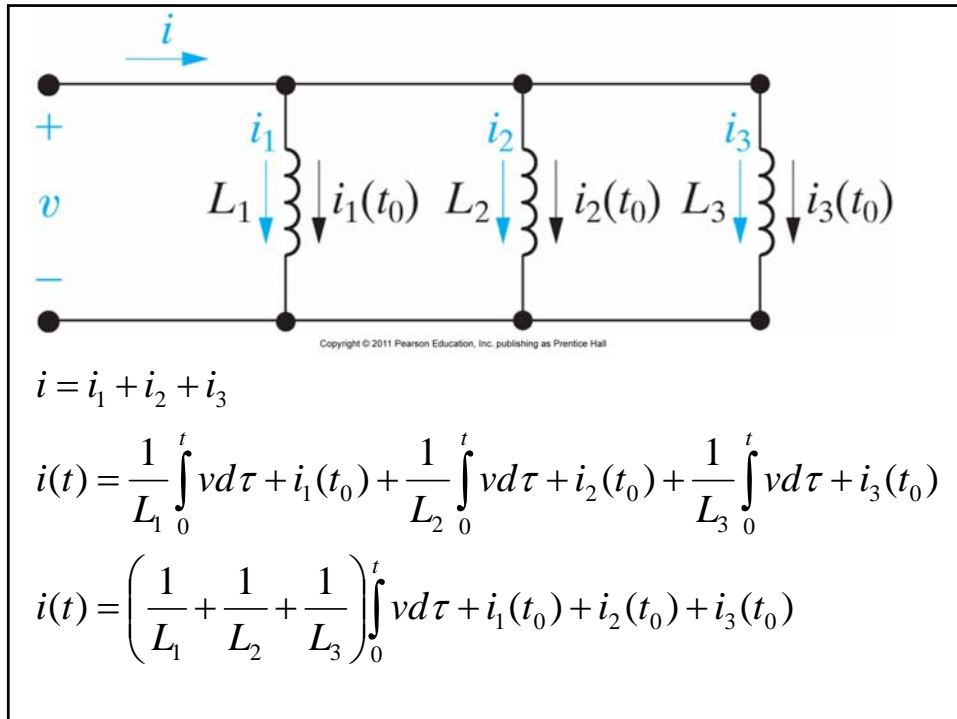


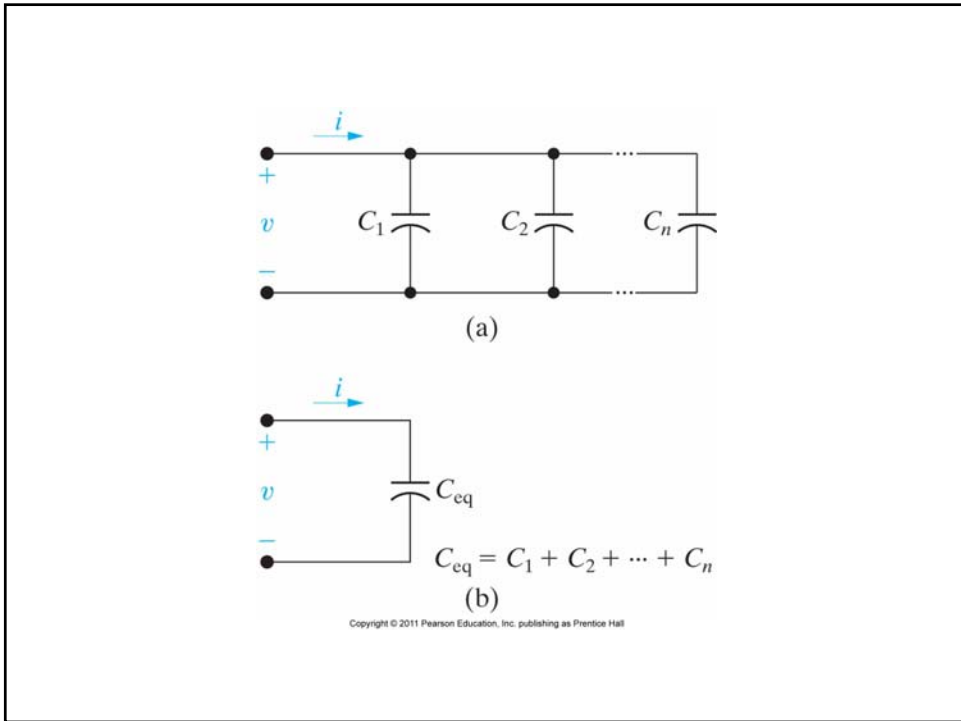
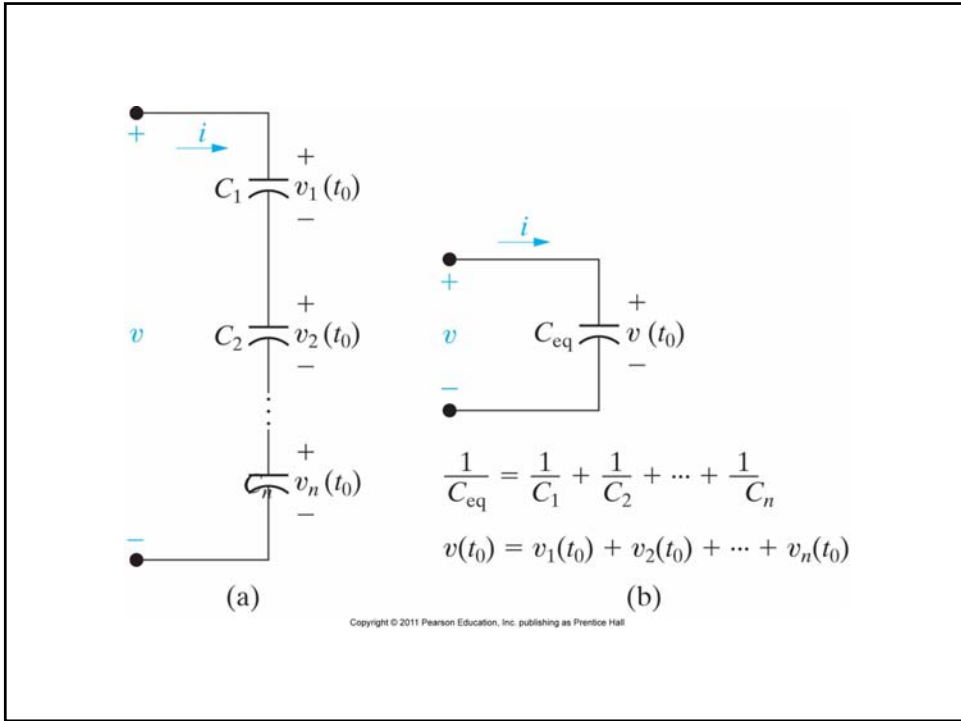
$$v = L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + L_3 \frac{di}{dt}$$

$$v = (L_1 + L_2 + L_3) \frac{di}{dt}$$

$$L_{eq} = L_1 + L_2 + L_3$$

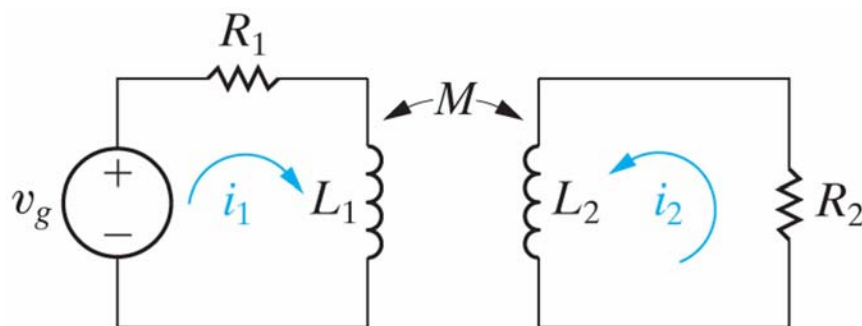
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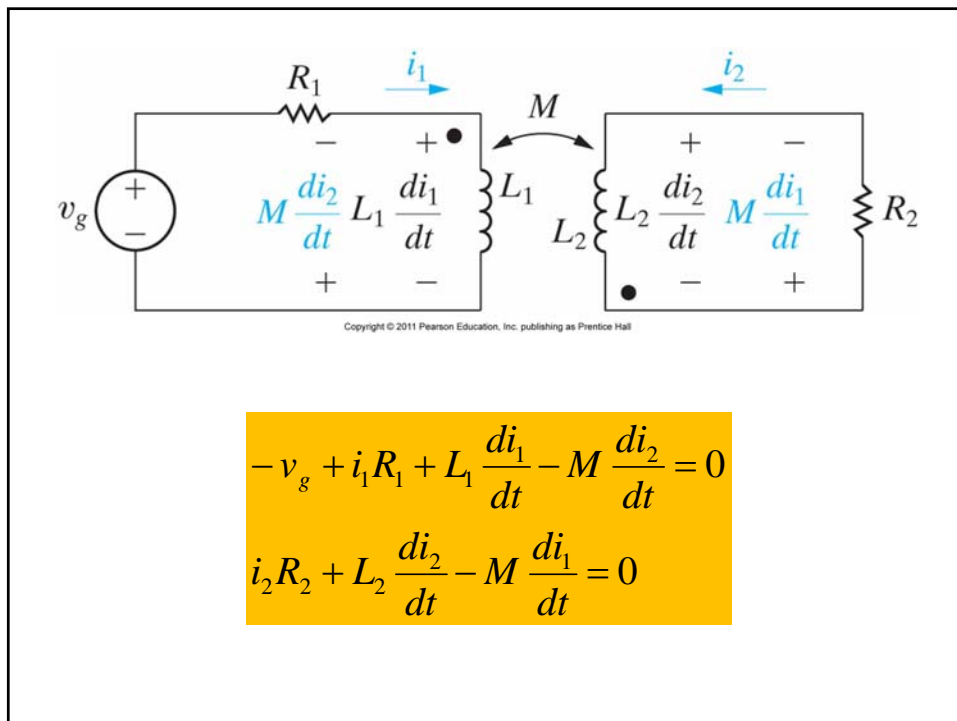
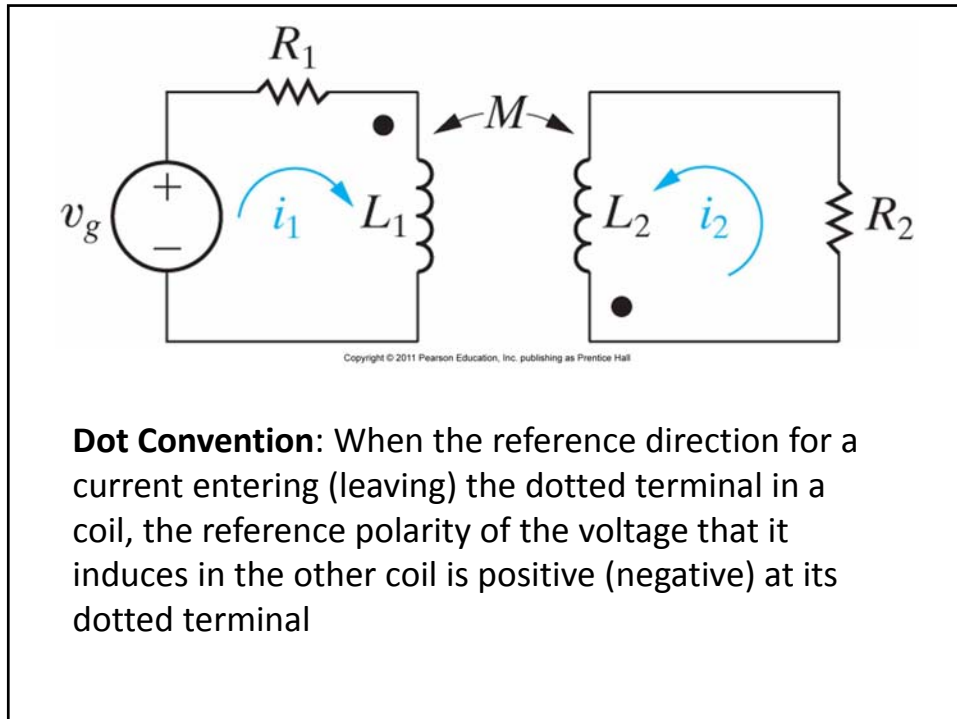


Mutual Inductance

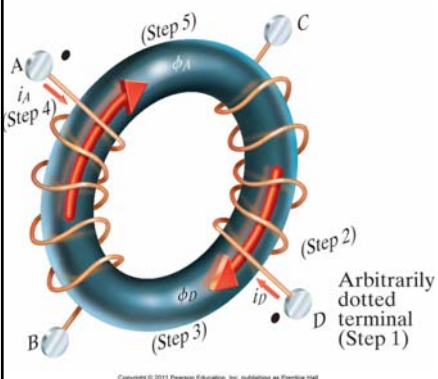
- So far, we are studying a single circuit element, where the change in the current affects the voltage across that element (and vice versa).
- Now, we consider two circuits linked by a magnetic field, such that changes in the current in the first circuit affect the voltage in the second circuit.



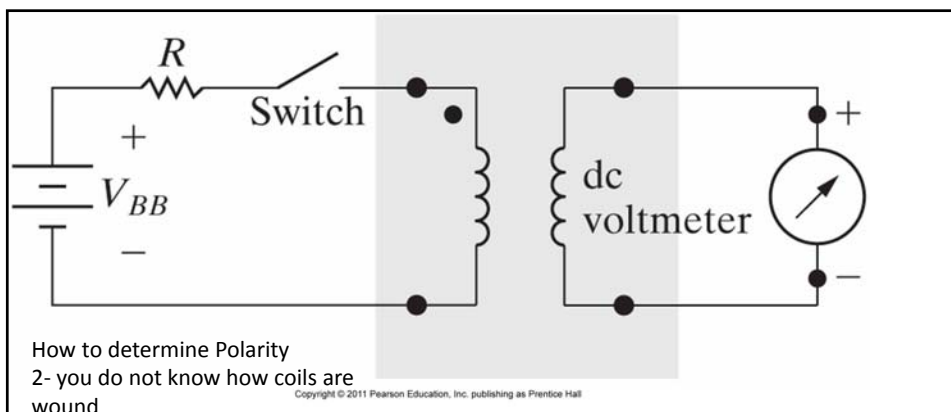
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How to determine Polarity
1- you know how coils are wound



1. Arbitrarily mark one terminal of one coil (D)
2. Assign a current into that terminal (i_D)
3. Use the right-hand rule to determine the direction of the magnetic flux inside the coils
4. Arbitrarily pick one terminal (A) of the other coil and assign a current into it (i_A)
5. Use the right-hand rule to determine the direction of the magnetic flux from this current inside the coils
6. Compare the two fluxes directions: If the direction is the same place a dot at the referenced terminal (A) if they are opposite select the opposite terminal (B).



How to determine Polarity
2- you do not know how coils are wound

When the switch is closed...

- The second polarity mark goes on the terminal connected to the **positive terminal** of the voltmeter if the voltmeter momentarily deflects **upscale**
- The second polarity mark goes on the terminal connected to the **negative terminal** of the voltmeter if the voltmeter momentarily deflects **downscale**

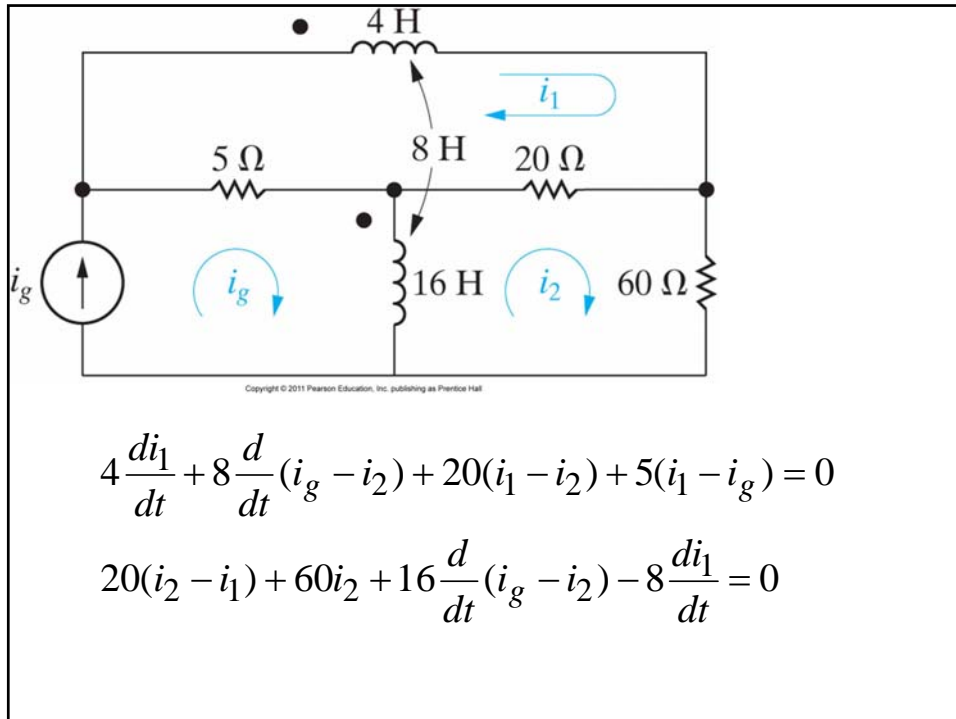


Figure 6.27 Representation of a magnetic field linking an N -turn coil.

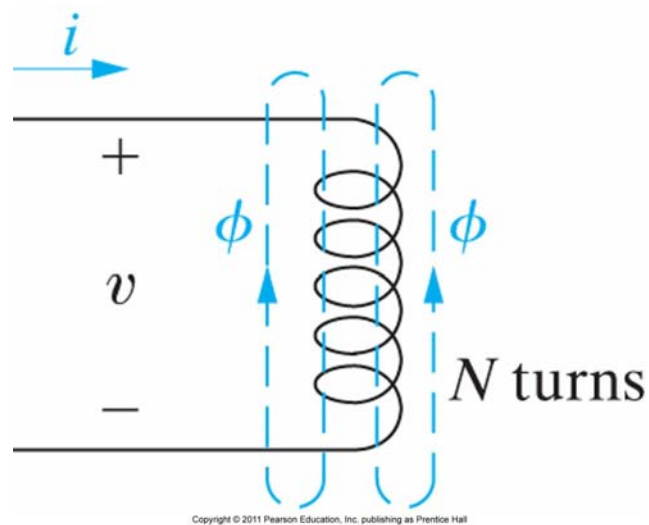


Figure 6.28 Two magnetically coupled coils.

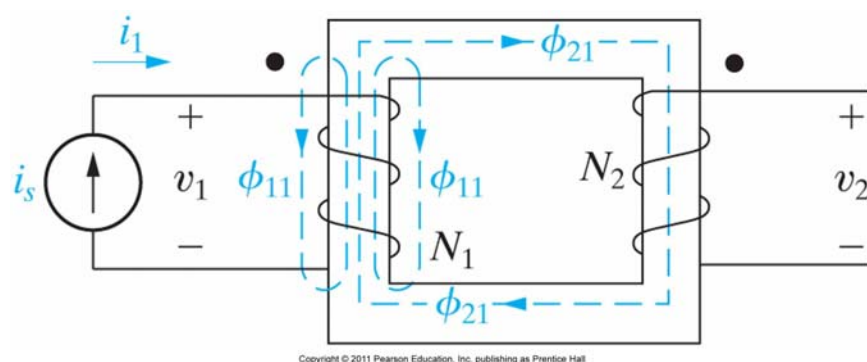


Figure 6.29 The magnetically coupled coils of Fig. 6.28, with coil 2 excited and coil 1 open.

