Exam #2 → Thursday, October 17

Concepts Chapter #5:

1) Superposition
2) The venin's & Norton's Theorem
3) Source Transformation
4) Maximum Power Transfer

Concepts Chapter #6:

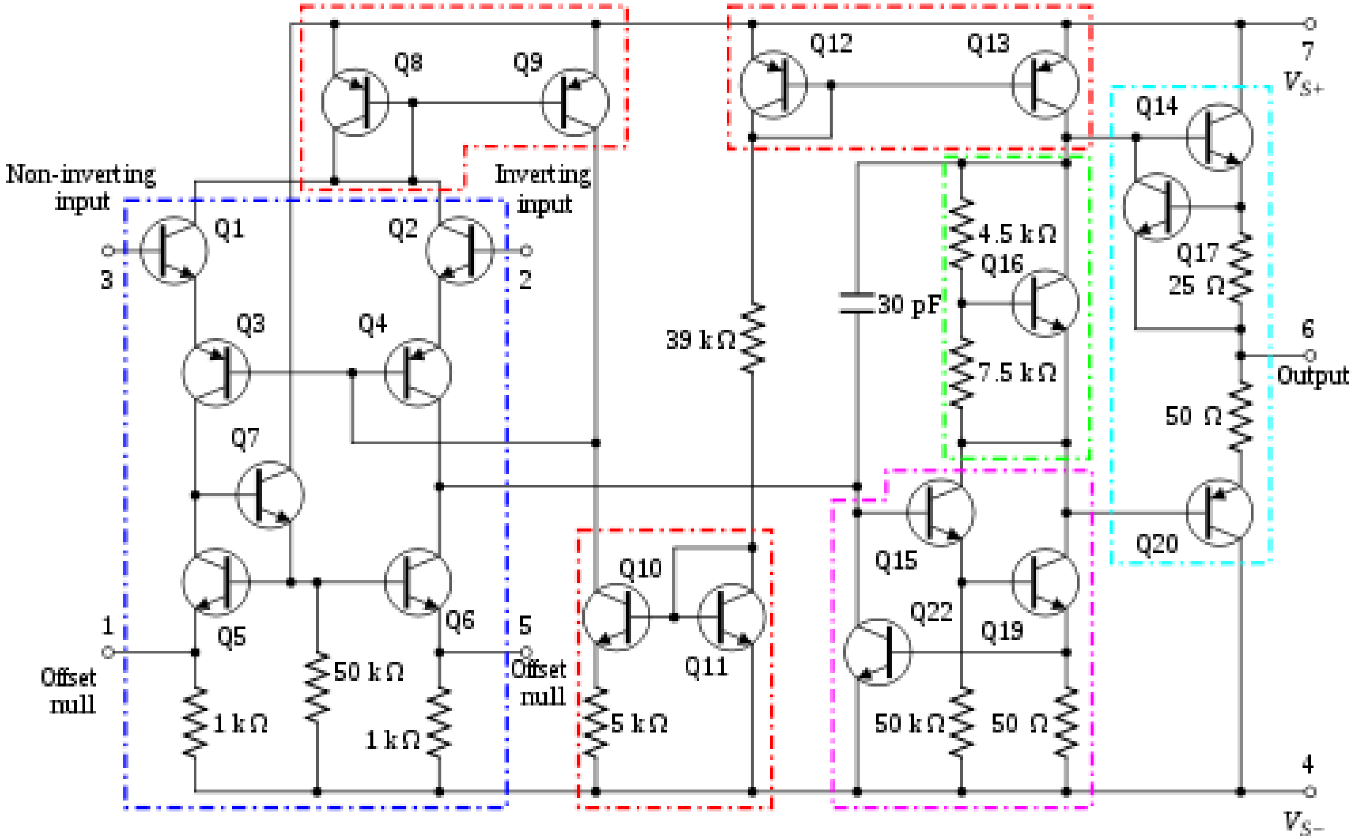
1) Capacitors
2) Inductors

Concepts Chapter #4:

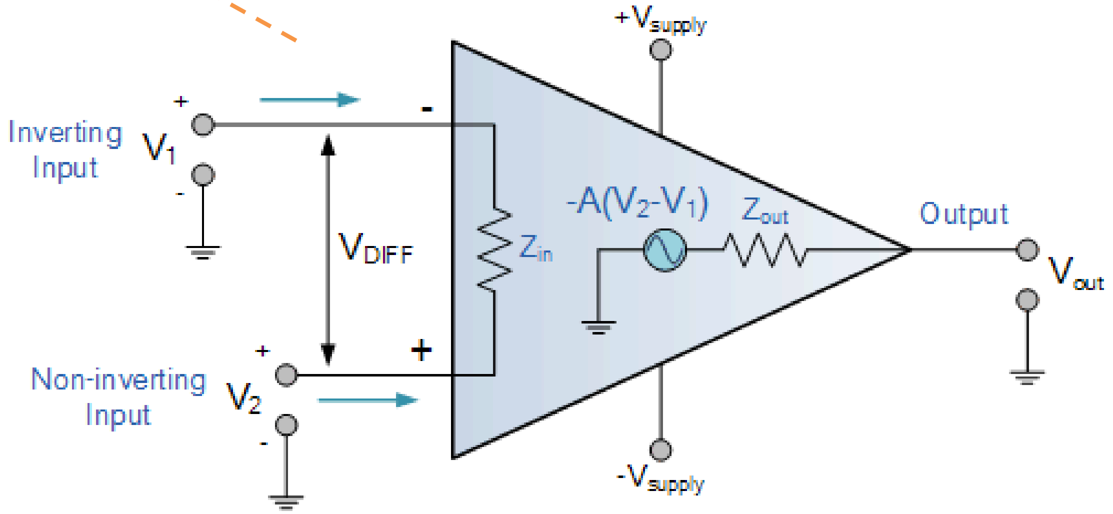
1) Op-Amps – Model
2) Op-Amps - Analysis

Last Lecture → Operational Amplifier

- **Internal Circuit Diagram**



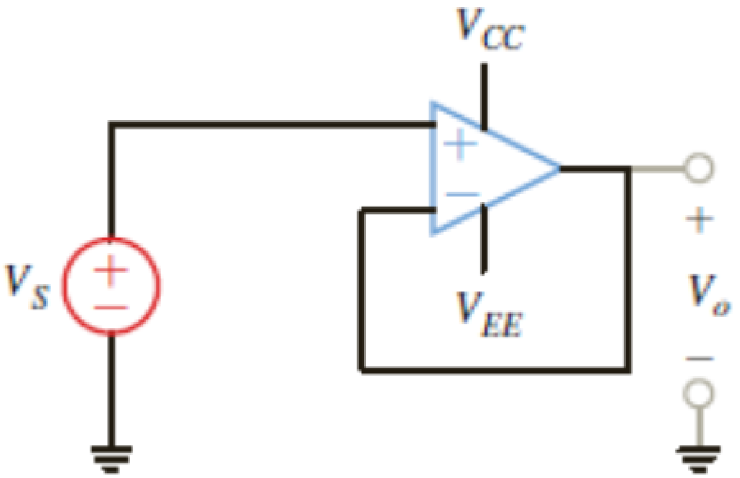
- **Symbol / Equivalent Circuit**

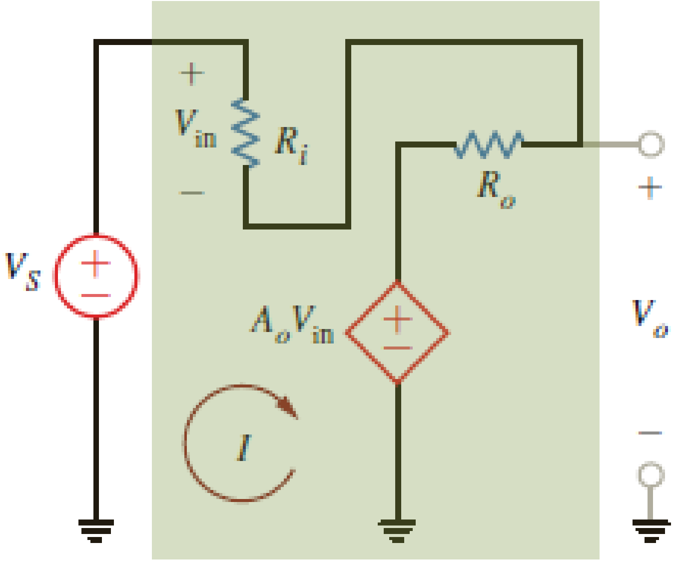


$$V_0 = A_0(IN_+ - IN_-)$$

Last Lecture → Non-Ideal Analysis

Using the op-amp model find the expression for the transfer function V_o/V_s.





Op-Amp Ideal Behavior

- $R_i = \infty$
- $A_0 = \infty$
- $R_o = 0$

$$i_{R_i} = \frac{V_{in}}{R_i} = 0$$

$$\therefore i_+ = i_- = 0$$

$$\frac{V_0}{V_s} = \frac{1}{1 + \cfrac{1}{A_0 + \cfrac{R_0}{R_i}}} \approx \frac{1}{1 + \cfrac{1}{A_0}} \approx 1$$

$R_i=\infty$, $R_0=0$ $\qquad$ $A_0=\infty$

$$V_0 = A_0(V_+ - V_-)$$

$$(V_+ - V_-) = \frac{V_0}{A_0} = 0 \qquad \therefore V_+ = V_-$$

Last Lecture → Ideal Analysis

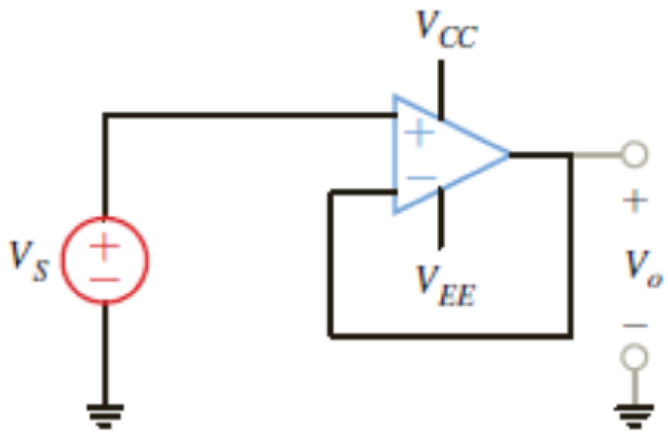
- **Stablish ideal op-amp conditions on the circuit schematic**
- **Write nodal equations at the op-amp input terminals**
- **Solve for the input/output relationship**

MODEL ASSUMPTION	TERMINAL RESULT
$A_o \to \infty$ $R_i \to \infty$	input voltage → 0 V input current → 0 A

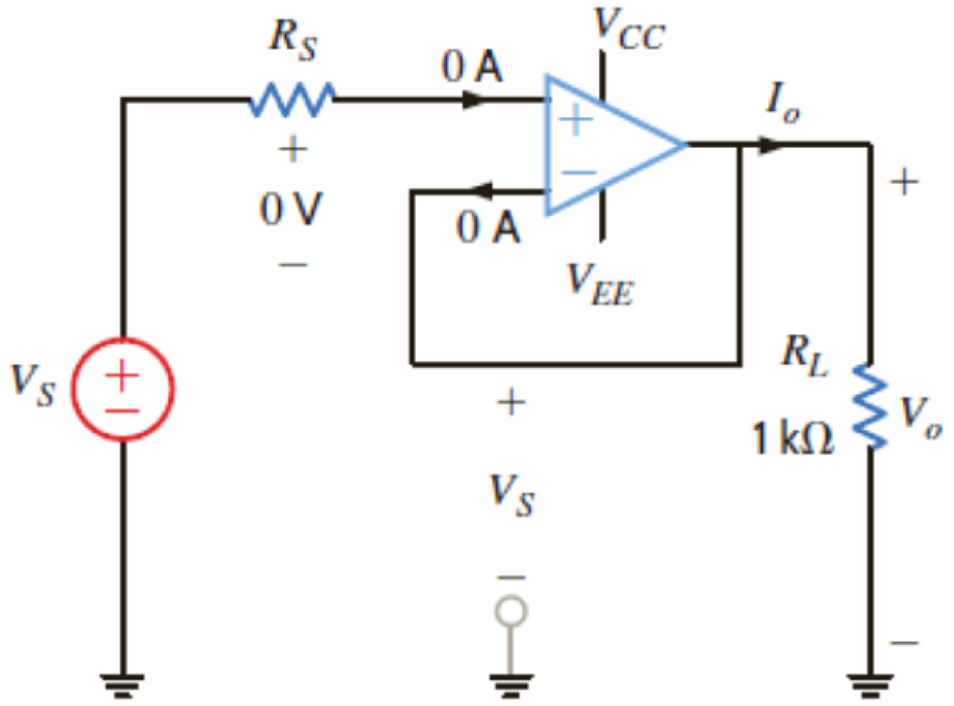
$V_+ = V_-$

$i_+ = i_- = 0$

Unity Gain Buffer - Revisited

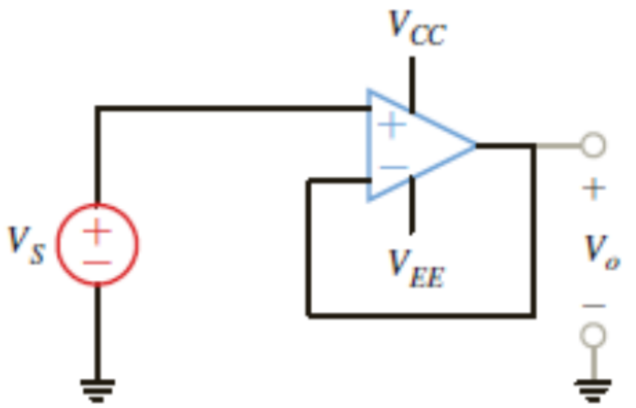


$$\therefore V_0 = V_s$$



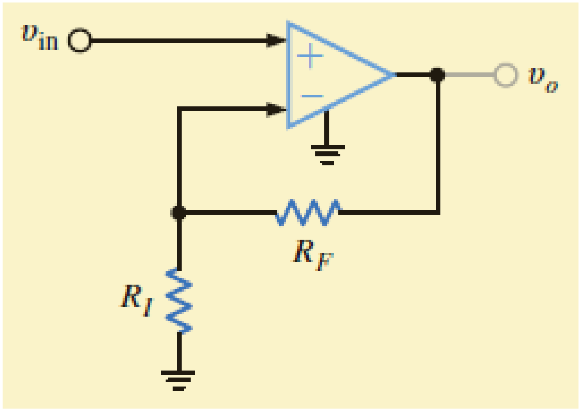
Last Lecture → Basic Circuits

- **Unity – Gain Amp.**



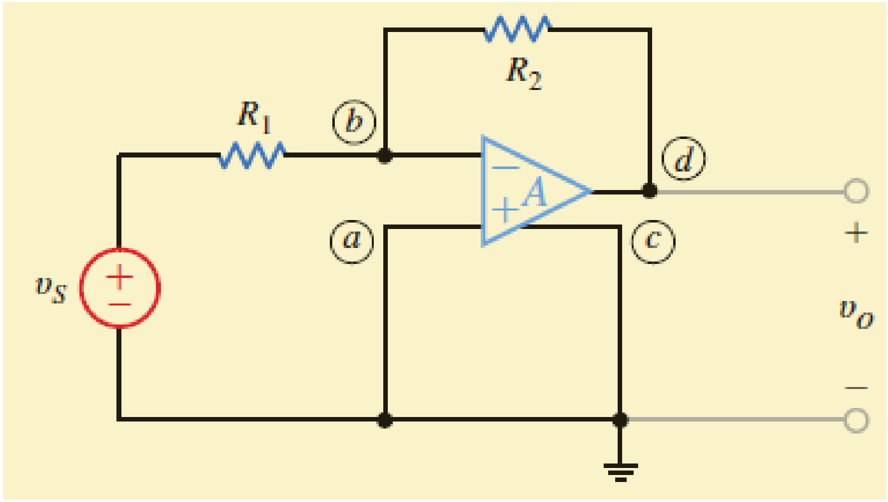
$$\frac{V_0}{V_s} \approx 1$$

- **Non-Inverting Amp.**



$$\frac{V_0}{V_s} \approx 1 + \frac{R_F}{R_I}$$

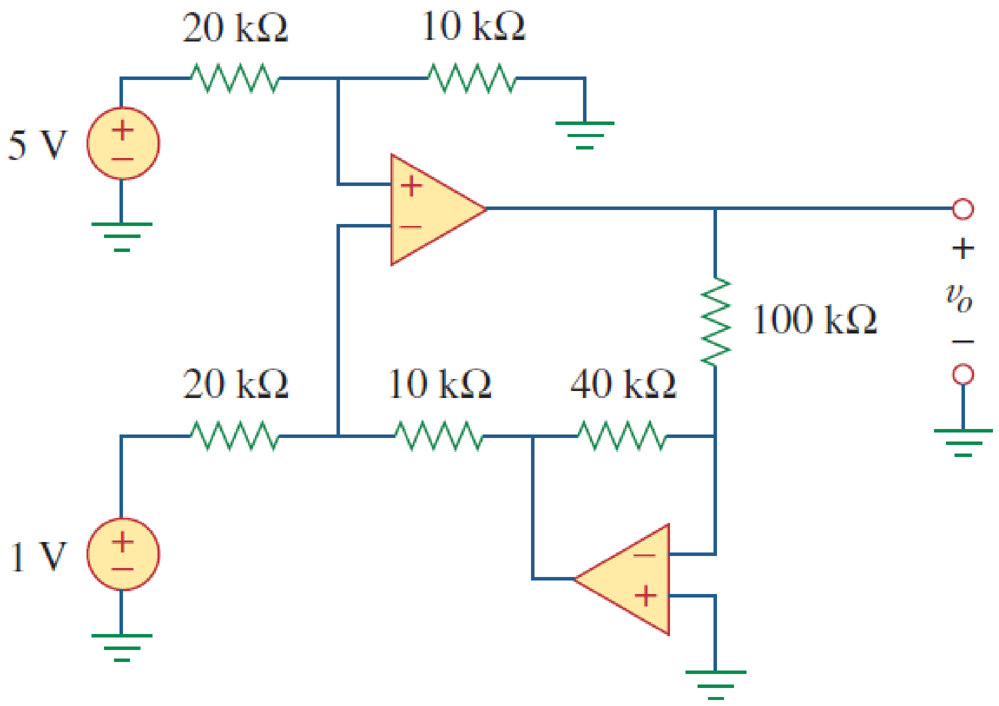
- **Inverting Amp**



$$\frac{V_0}{V_s} \approx -\frac{R_2}{R_1}$$

Problem

Determine v_0 in the circuit provided.



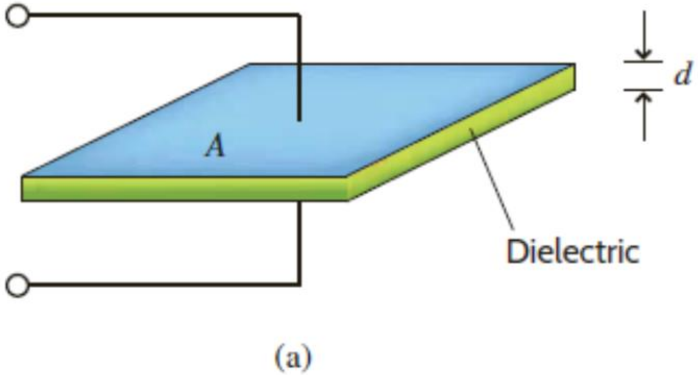
Capacitance and Inductance → Chapter #5

- **Inductor / Capacitor Model → voltages, currents, powers, stored energy**
- **Concept of Continuity → inductor: current, capacitor: voltage**
- **Circuit Analysis with DC Sources**
- **Equivalent Inductance /Capacitance → series & parallel**

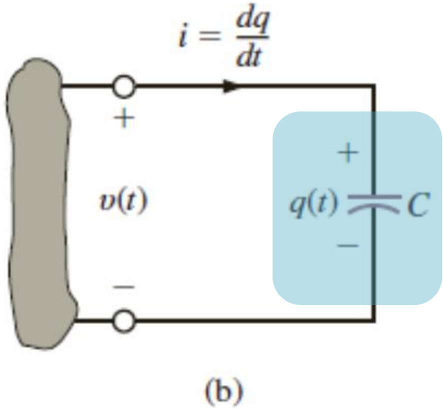
Capacitor

Typical Capacitors

… a circuit element that consists of two conducting surfaces separated by dielectric material



Simplified Capacitor



Symbol

Capacitance (C) → $C = \frac{\varepsilon_0 A}{d}$ ← permittivity of free space

⇓

Unit → farads (F) = coulombs per volts

$$q = C \cdot v \qquad i = C \cdot \frac{dv}{dt}$$

$$v(t) = v(t_0) + \frac{1}{C} \cdot \int_{t_0}^{t} i(x)dx$$

$$p(t) = C \cdot v(t)\frac{dv(t)}{dt}$$

$$w_c(t) = \frac{1}{2} C \cdot v(t)^2$$

Example 6.1

If the charge accumulated on two parallel conductors charge to 12V is 600 pC, what is the capacitance of the parallel conductors?

$$v = 12V \qquad q = 600\,pC$$

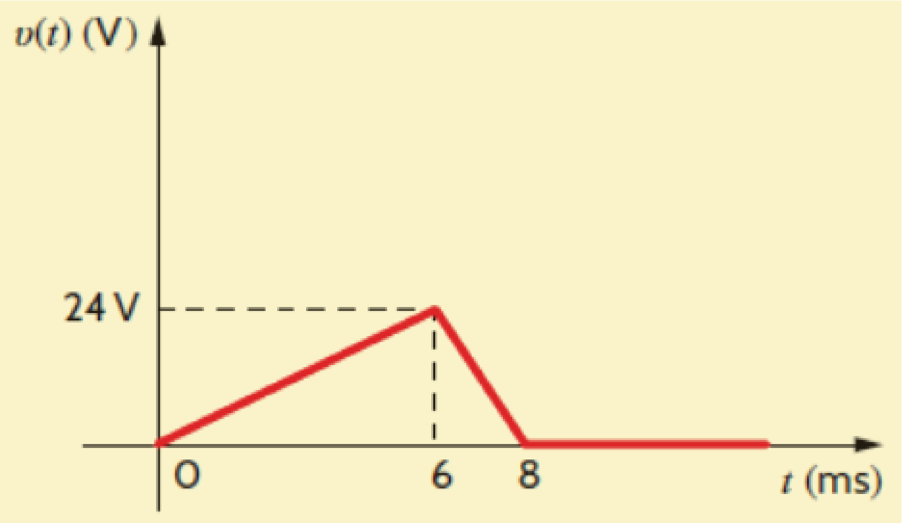
$$q = C \cdot v$$

$$\hookrightarrow \quad C = \frac{q}{v} = \frac{600p}{12} = 50pF$$

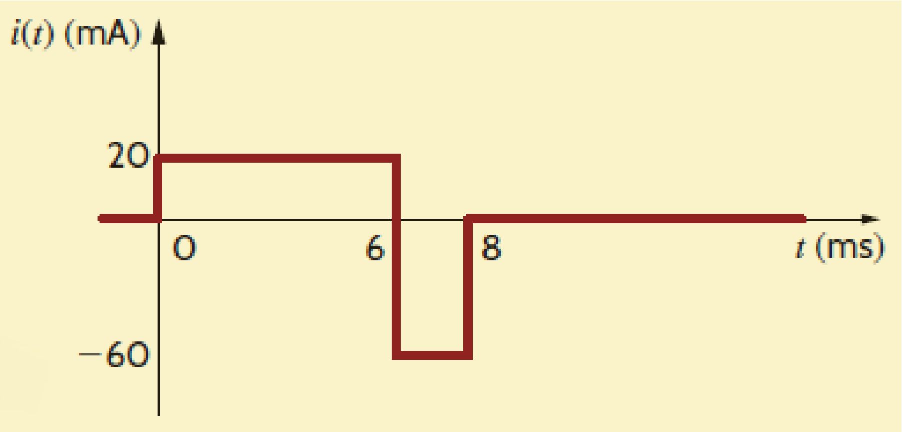
Example 6.2

If voltage across a 5-μF capacitor has the waveform shown below, determine the current waveform?

$$v(t) = \begin{cases} 4k \cdot t & \rightarrow t = [0:6] \\ 24 - 12k \cdot (t - 6m) & \rightarrow t = [6:8] \\ 0 & \rightarrow t = [8:\infty] \end{cases}$$

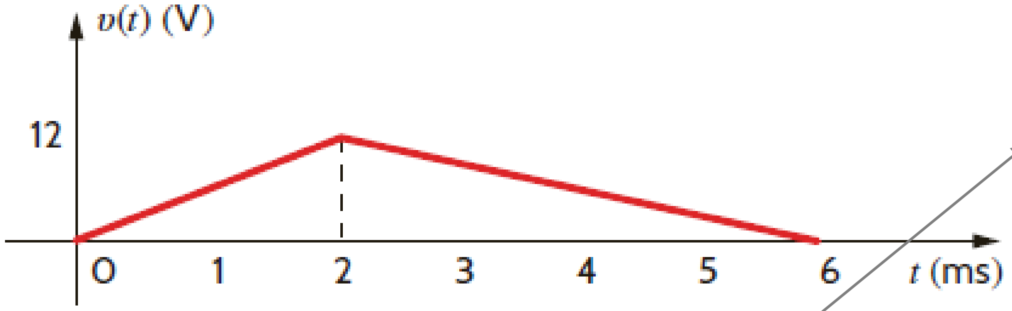


$$i = C \cdot \frac{dv}{dt} = ?$$



Learning Assessment E6.2-E6.3

The voltage across a 2-uF capacitor is provided below. Determine the waveforms for the current, power, and energy and compute the energy stored in the electric field of the capacitor at t=2ms.



$$p(t) = C \cdot v(t)\frac{dv(t)}{dt} =$$

$$v(t) =$$

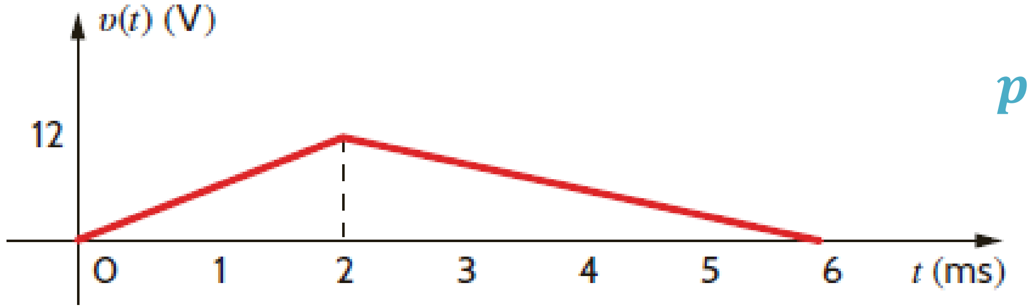
$$w_c(t) = \frac{1}{2} C \cdot v(t)^2 =$$

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

$$w_c(t = 2m) =$$

Learning Assessment E6.2-E6.3

The voltage across a 2-uF capacitor is provided below. Determine the waveforms for the current, power, and energy and compute the energy stored in the electric field of the capacitor at t=2ms.



$$p(t) = C \cdot v(t)\frac{dv(t)}{dt} = \; 72 \cdot t \;\; W \;\; \rightarrow t = [0{:}\,2]$$

$$-72 + 18 \cdot (t - 2m) \;\; W \;\; \rightarrow t = [2{:}\,6]$$

$$v(t) = \;\; 6k \cdot t \;\; \rightarrow t = [0{:}\,2]$$

$$12 - 3k \cdot (t - 2m) \;\; \rightarrow t = [2{:}\,6]$$

$$i = C \cdot \frac{dv}{dt} = \;\; 12 \; mA \;\; \rightarrow t = [0{:}\,2]$$

$$-6 \; mA \;\; \rightarrow t = [2{:}\,6]$$

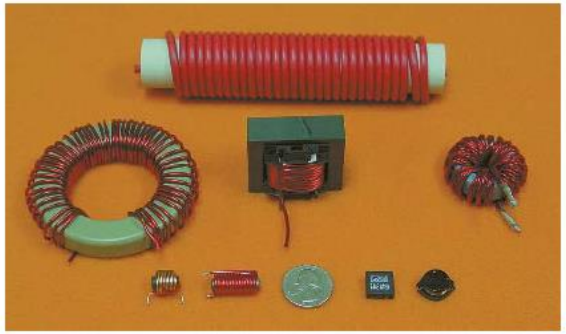
$$w_c(t) = \frac{1}{2}C \cdot v(t)^2 = \;\; 36 \cdot t^2 \;\; J \rightarrow t = [0{:}\,2]$$

$$[17 - 3k \cdot t]^2 \;\; uJ \;\; \rightarrow t = [2{:}\,6]$$

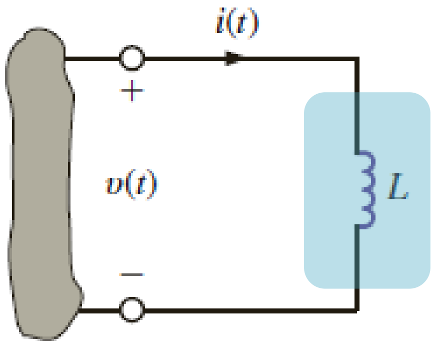
$$w_c(t = 2m) = \; 144 \; uJ$$

Inductor

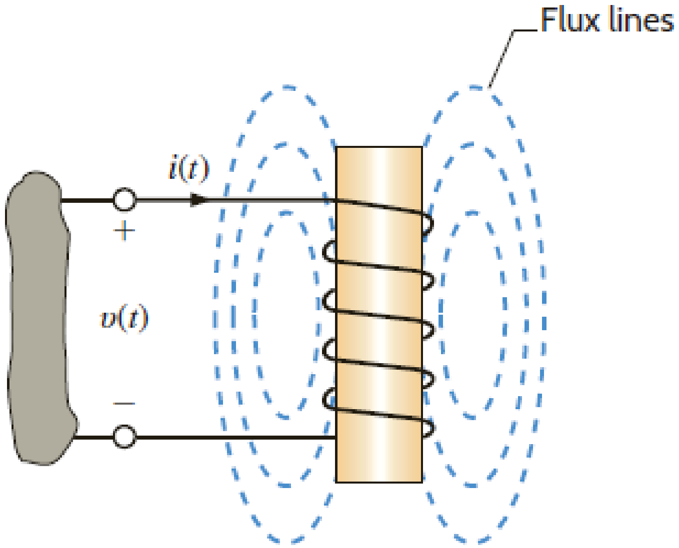
Typical Inductors



… a circuit element that consists of a conducting wire usually in the form of a coil.



Symbol



Simplified Inductor

Inductance (L)

↓

Unit → Henry (H) = 1 volt-second per ampere

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

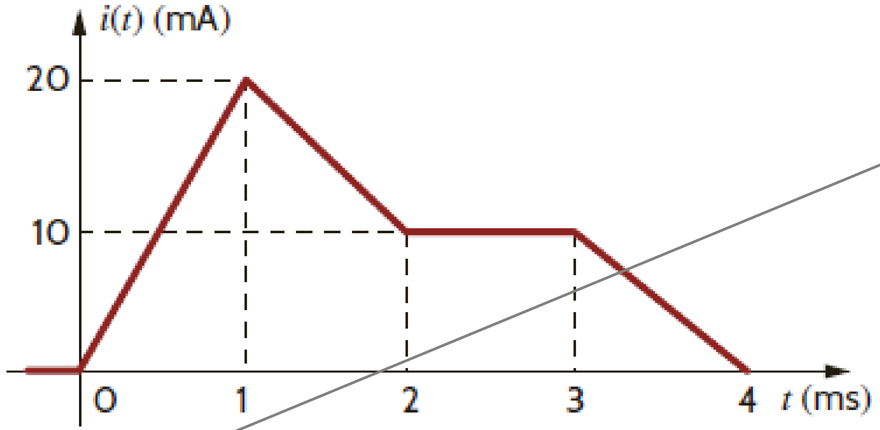
$$i(t) = i(t_0) + \frac{1}{L} \cdot \int_{t_0}^{t} v(x)dx$$

$$p(t) = L \cdot i(t)\frac{di(t)}{dt}$$

$$w_L(t) = \frac{1}{2} L \cdot i(t)^2$$

Learning Assessment E6.6-E6.7

The current across a 5-mH inductor is provided below. Determine the waveforms for the voltage, power, and energy and compute the energy stored in the magnetic field of the inductor at t=1.5ms.



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

$$p(t) = L \cdot i(t)\frac{di(t)}{dt} =$$

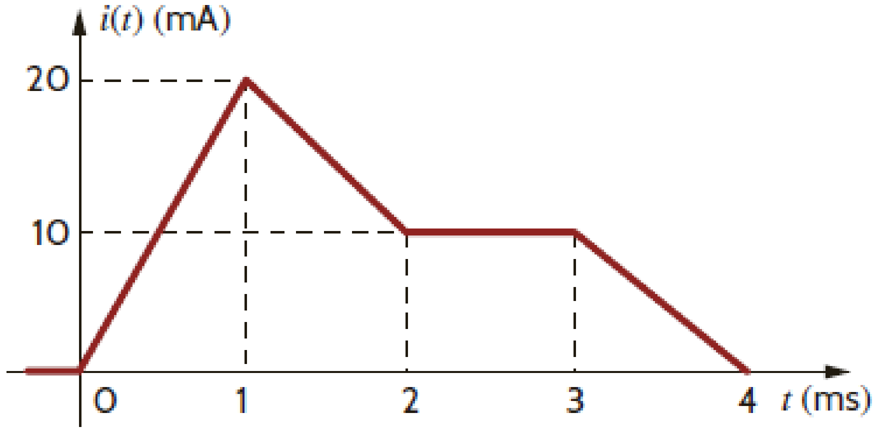
$$w_L(t) = \frac{1}{2} L \cdot i(t)^2 =$$

$$w_L(t = 1.5m) =$$

$$i(t) =$$

Learning Assessment E6.6-E6.7

The current across a 5-mH inductor is provided below. Determine the waveforms for the voltage, power, and energy and compute the energy stored in the magnetic field of the inductor at t=1.5ms.



$$i(t) = \begin{cases} 20 \cdot t \ A & \rightarrow t = [0:1] \\ 20m - 10 \cdot (t - 1m) \ A & \rightarrow t = [1:2] \\ 10 \ mA & \rightarrow t = [2:3] \\ 10m - 10 \cdot (t - 3m) \ A & \rightarrow t = [3:4] \end{cases}$$

$$v = L \cdot \frac{di}{dt} = \begin{cases} 100 \ mV & \rightarrow t = [0:1] \\ -50 \ mV & \rightarrow t = [1:2] \\ 0 & \rightarrow t = [2:3] \\ -50 \ mV & \rightarrow t = [3:4] \end{cases}$$

$$p(t) = L \cdot i(t) \frac{di(t)}{dt} = \begin{cases} 2 \cdot t \ W & \rightarrow t = [0:1] \\ -1m + 0.5 \cdot (t - 1m) \ W & \rightarrow t = [1:2] \\ 0 & \rightarrow t = [2:3] \\ -0.5m + 0.5 \cdot (t - 3m) \ W & \rightarrow t = [3:4] \end{cases}$$

$$w_L(t) = \frac{1}{2} L \cdot i(t)^2 = \begin{cases} t^2 \ J & \rightarrow t = [0:1] \\ 2.5 \cdot [30m - 10 \cdot t]^2 \ mJ & \rightarrow t = [1:2] \\ 250 \ nJ & \rightarrow t = [2:3] \\ 2.5 \cdot [40m - 10 \cdot t]^2 \ mJ & \rightarrow t = [3:4] \end{cases}$$

$$w_L(t = 1.5m) = 562 \ nJ$$