Lecture - 1

Introduction

Rules of e

$$ln(e^x) = x$$

$$\ln(ab) = \ln(a) + \ln(b)$$

$$\cancel{\frac{\ln(a)}{\ln(b)}} = \ln(a) - \ln(b)$$

$\ln\left(\frac{a}{b}\right)$

Derivation

$f(x)$	$f'(x)$
x.v	x'.v + v'.x
e^x	e^x
$e^{f(x)}$	$f'(x)\ e^{f(x)}$
$\ln(x)$	$\frac{1}{x}$
sin(x)	cos(x)
cos(x)	- sin(x)
sin(u(x))	u'(x) cos(u(x))
cos(u(x))	- u'(x) sin(u(x))

Integration

$f(x)$	$\int f(x)$
$\frac{1}{x}$	$ln(x)$
sin(x)	-cos(x)
cos(ax)	$\frac{sin(ax)}{a}$
e^x	e^x
e^{ax}	$\frac{e^{ax}}{a}$
$\frac{1}{a+bx}$	$\frac{1}{b}\ln(a+bx)$

The International System of Units (SI)

Quantity	Basic Unit	Symbol
الطول Length	meter	m
الكتلة Mass	kilogram	kg
الزمن Time	second	s
التيار الكهربائي Electric current	ampere	A
درجة الحرارة Thermodynamic Temperature	kelvin	K
شدة الإضاءة Luminous intensity	candela	cd

وحدات مشتقة

Derived Units in SI (1)

Quantity	Unit name (Symbol)	Formula (units)	Formula
تردد Frequency = $\frac{1}{زمن}$	Hertz (Hz) $= \frac{1}{s}$	s^{-1}	$f = 1/t$
القوة Force الكتله x التسارع	newton (N)	$Kg.m/s^2$	$F = m . a$
الطاقة / الشغل Energy or work الشغل = القوة x المسافة	joules (J) جول	N . m $kg\,m^2/s^2$	$W = F . s$
القدرة Power القدرة = الشغل ÷ الزمن	واط watt (W)	J/s $kg\,m^2/s^3$	$P = W/\Delta t$
الشحنة الكهربائية Electric charge الشحنة = التيار x الزمن	Coulomb (C) كولوم	A . s أمبير . ثانية	$Q = I . t$
Electric potential الجهد الكهربائي	volt (V) فولت	J/C جول / كولوم	$V= W/Q$ الشغل ÷ الشحنة
Electric resistance المقاومة الكهربائية	ohm (Ω) أوم	V/A فولت / أمبير	$R = V/I$ المقاومة = $\frac{الجهد}{التيار}$

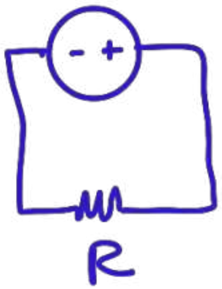
Derived Units in SI (2)

Quantity	Unit name (Symbol)	Formula (umits)	Formula
الموصلية الكهربائية Electric conductance G	siemens (S)	A/V أمبير/فولت	G = I/V = التيار ÷ الجهد
Electric capacitance السعة الكهربائية	فاراد farad (F)	C/V كولوم/فولت	C = Q/V = الشحنة ÷ الجهد
B Magnitic flux التدفق المغناطيسي	ويبر weber (Wb)	~~V . s~~ $T \cdot m^2$	B = V . s
Inductance الحث	Henry (H) هنري	Wb/A ويبر/أمبير	L = B/I

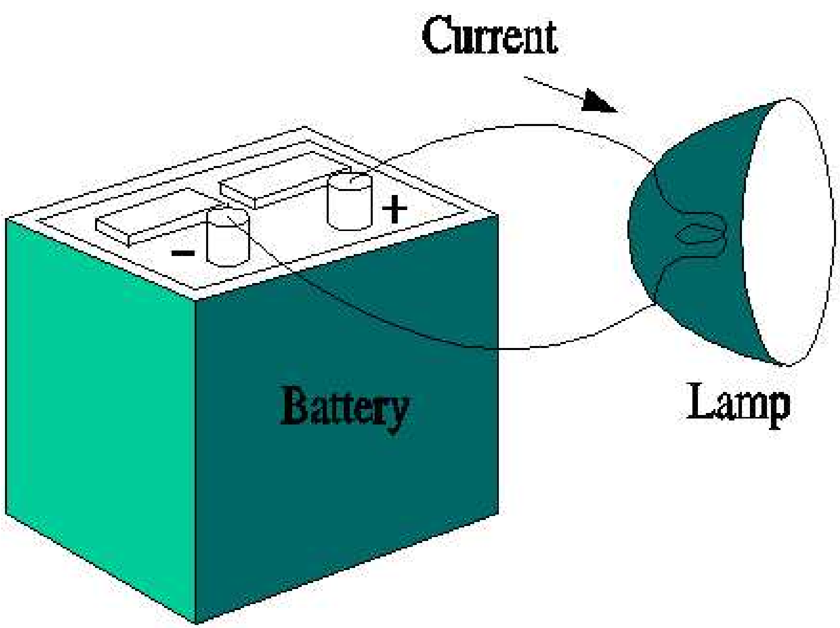
Standardized Prefixes to Signify Power of 10

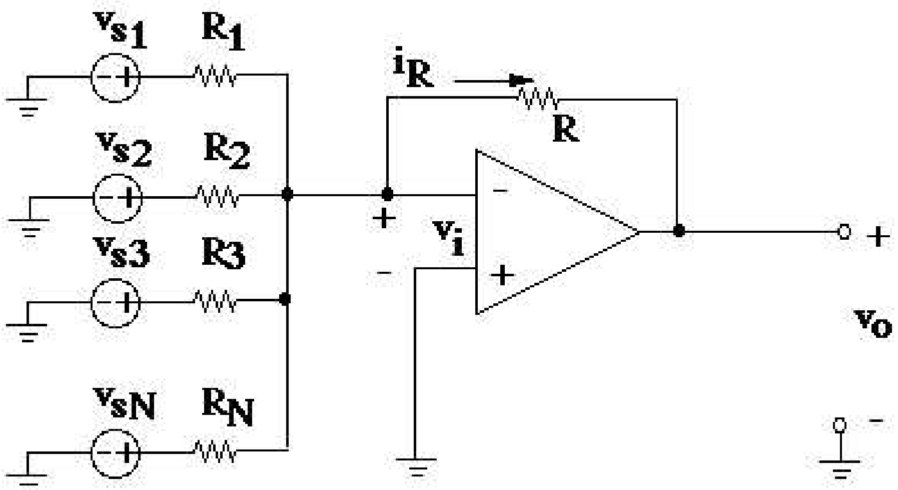
Prefix	**Symbol**	**Power**
atto	a	10^{-18}
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
Deci	d	10^{-1}
deka	da	10
hecto	h	10^{2}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}

Electric Circuit



- An electric circuit is an interconnection of electrical elements.





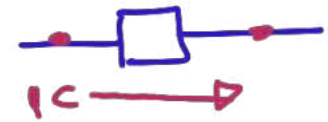
الجهد الكهربائي

Voltage

v (volt) V

الجهد حجم الطاقة المكتسبة أو المفقودة عندما يمر كولوم واحد في العنصر

- The voltage across a circuit element is the energy absorbed or produced as a unit charge moves through the element.
- Analogous to pressure in a hydraulic system.



- Sometimes called potential difference which is a measure of potential between two points.

الجهد يدفع الشحنات باتجاه واحد

- Voltage pushes charge in one direction.
- We use polarity (+ and – on batteries) to indicate which direction the charge is being pushed

اتجاه القضيب على البطارية يدل على اتجاه حركة الشحنات

$$\boxed{v = \frac{d\omega}{dq}}$$

where

υ= voltage in volts (V)

w= energy in joules (J)

q= charge in coulombs (C)

التيار الكهربائي Current i (Amperes) A

- Electric current is the flow of charge. It is measured in amperes (A). كمية الشحنة التي تتدفق خلال مدة زمن

امبير = $\frac{\text{كولوم}}{\text{ثانية}}$

- $\boxed{1\text{ A} = 1\text{ C/s.}}$
- تيار ثابت **Direct current (DC):** current remains constant.
- متردد **Alternating current (AC)**: current varies sinusoidally with time.
- The charge transferred between time t_0 and t is $\boxed{q = \int_{t_o}^{t} i\,dt}$

$$\frac{\text{شحنة}}{\text{زمن}} = i = \frac{dq}{dt}$$

where

i= current in amperes (A)

q= charge in coulombs (C)

t= time in seconds(s)

$$q = \int_0^t 5\,dt = 5\int_0^t dt$$

$$5t\Big]_0^t = \boxed{5t}\ C$$

Example 1

- No charge exists at the upper terminal of the element in the figure for t<0. At t=0, a 5A current begins to follow into the upper terminal.

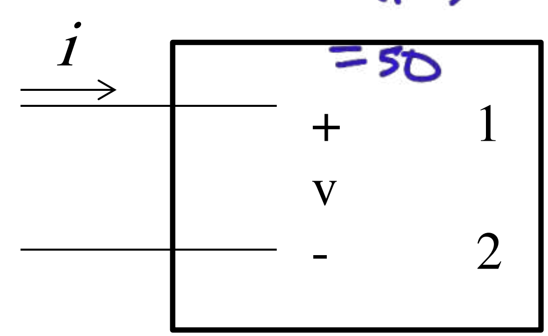
a) Derive the expression for the charge accumulating at the upper terminal of the element for t>0.

b) If the current is stopped after 10 seconds, how much charge has accumulated at the upper terminal?

$$q = \int_0^{10} 5\,dt = 5t\Big]_0^{10} = 5(10) = 50$$

----

a) Given



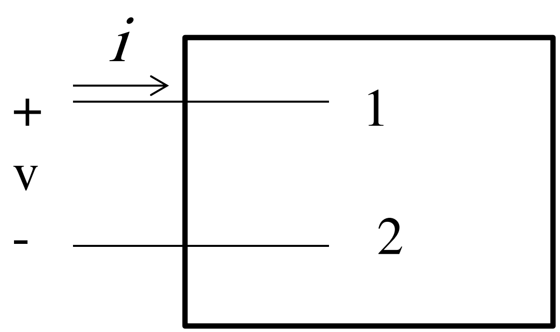
$$q(t) = \int_0^t i(t)dt$$

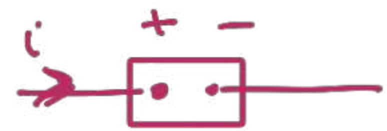
$$q(t) = \int_0^t 5\,dt = [5t] = 5t\ C$$

a) $q\,(10) = 5(10) = 50$ C

The ideal basic element

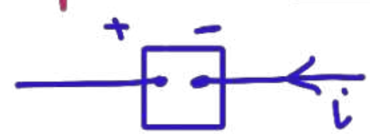
- An ideal basic element has three attributes:
  - it has only two terminals, which are points of connection to other circuit components.
  - it is described mathematically in terms of current and/or voltage.
  - it cannot be subdivided into other elements.





يستهلك طاقة

PSC ⇒ $\boxed{+}$



PSC = $\boxed{-}$ ينتج طاقة

PSC

قاعدة الإشارة السلبية

Passive sign convention

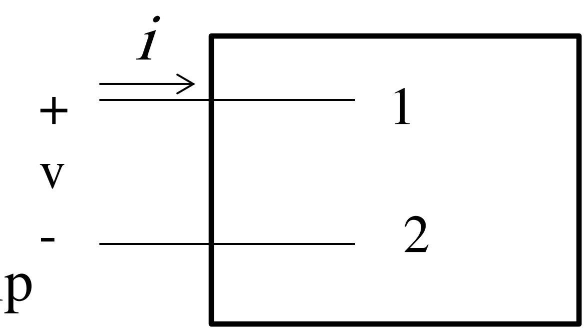
PSC is satisfied ← اذا دخل التيار من الطرف الموجب تعتبر العلاقة بين V و i موجبه

- **Passive Sign Convention (PSC):** Whenever the reference direction for the current in an element is in the direction of the reference voltage drop across the element, use a positive sign in any expression that relates the voltage to the current. Otherwise, use a negative sign. **(current enters the positive terminal of an element).**
- Most two-terminal circuit elements (e.g. batteries, light bulbs, resistors, switches) are characterised by a single equation that relates voltage to current:

$V = \pm f(i)$

$i = \pm g(V)$

$v=\pm f(\mathrm{i})$ or $\mathrm{i}=\pm g(\mathrm{v})$



PSC is satisfied

- The PSC determines the sign of the relationship
  - If PSC is satisfied: $v= f(\mathrm{i})$ or $\mathrm{i} = g(\mathrm{v})$
  - If PSC is not satisfied: $v= -f(\mathrm{i})$ or $\mathrm{i} = - g(\mathrm{v})$

power= J/s = watt

القدره Power

$\boxed{\text{Power} = \pm Vi}$

القدره = الجهد x التيار

- **Power**: time rate of expending or absorbing energy, denoted by *p*.

  المعدل الزمني لاستهلاك او انتاج الطاقة

- Circuit elements that absorb power have a positive value of *p*.
- Circuit elements that produce power have a negative value of *p*.

$$\frac{\text{الطاقه}}{\text{الزمن}} = p = \frac{dw}{dt} \quad ; \quad p = \pm vi$$

+ يستهلك

− ينتج

where:

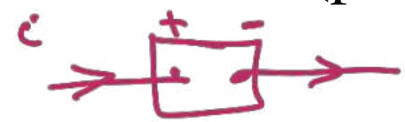
p= power in watts (W=J/s)

w= energy in joules (J)

t= time in seconds (s)

Algebraic sign of power

- If we use the passive sign convention, ($p=vi$) is correct if the reference direction for the current is in the direction of the reference voltage drop across the terminals. Otherwise, ($p=vi$) must be written with a minus sign.



- The algebraic sign of power is based on charge movement through voltage drops and rises. As positive charges move through a drop in voltage, they lose energy, and as they move through a rise in voltage, they gain energy.

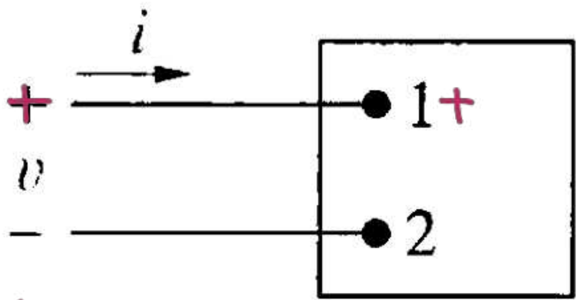
عندما نتحرك الشحنات باتجاه انخفاض الجهد (فقدان للطاقة)
باتجاه ارتفاع الجهد (نقصان للطاقة)

- If the power is negative (that is, if $p < 0$), power is being delivered to the circuit inside the box. If the power is positive (that is, if $p > 0$), power is being extracted from the circuit inside the box.

$P = -iV$ ينتج طاقة

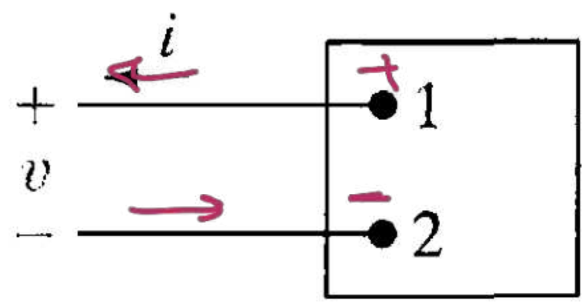
$P = iV$ يستهلك طاقة

Algebraic sign of power



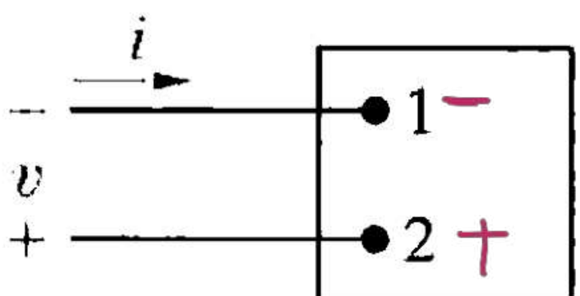
(a) $p = vi$

يستهلك



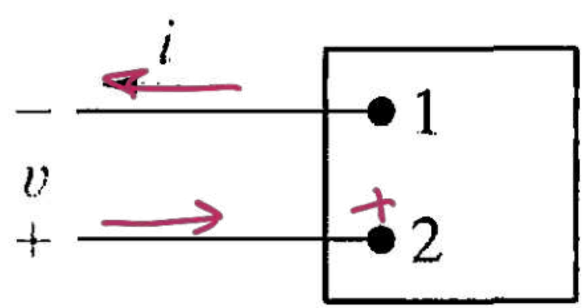
(b) $p = -vi$

ينتج طاقة



(c) $p = -vi$

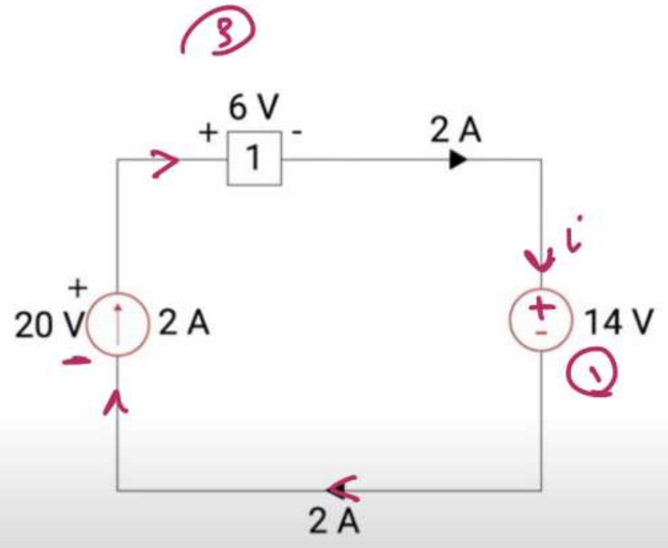
ينتج طاقة



(d) $p = vi$

يستهلك طاقة

Find the power that is absorbed or supplied by the circuit elements.



يستهلك طاقة

$$P_1 = +iV = 2(14) = 28W$$

$$P_2 = -iV = -2(20) = -40W$$

ينتج طاقة

$$P_3 = +iV = 2(6) = 12$$

الطاقة محفوظة ⇐

$$28 - 40 + 12 = 0$$

$$\text{القدرة} = \frac{\text{الشغل (الطاقة)}}{\text{الزمن}}$$

$$P = \frac{dw}{dt}$$

$$\int dw = \int P\,dt$$

$$W = \int_{t_0}^{t} P\,dt = \int_{t_0}^{t} (vi)\,dt$$

Energy

القدرة الكلية في الدارة = صفر

- **Law of Conservation of Energy**: the net power absorbed by a circuit is equal to 0.
- in other words, the total energy produced in a circuit is equal to the total energy absorbed.
- **Energy**: capacity to do work. measured in joules (J)

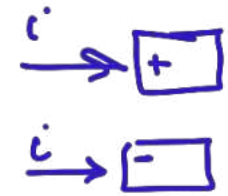
$$w = \int_{to}^{t} p\,dt = \int_{to}^{t} (\pm vi)\,dt$$

- If current and voltage are constant (DC),

جهد ثابت
وتيار ثابت
P ثابت

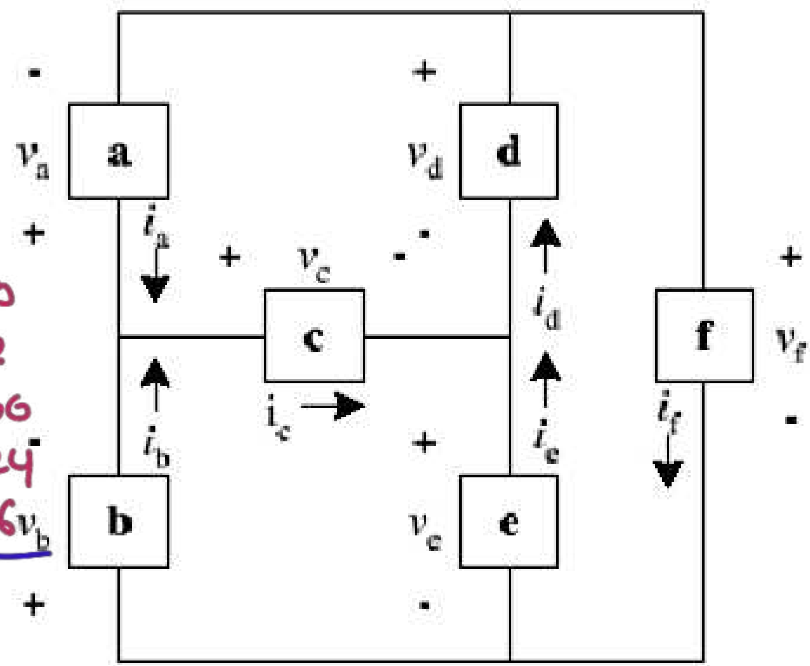
$$w = \int_{to}^{t} p\,dt = p(t - to)$$

Example 2



- Find the total power developed in the circuit. $P = \pm iV$

	Voltage (V)	Current (A)	Power (W)	
a	-18	-51	− +918	−918
b	-18	45	+ −810	−810
c	2	-6	+ −12	−12
d	20	-20	− −400	+400
e	16	-14	− −224	+224
f	36	31	+ +1116	+1116



P_{total} = zero

Example 3

- The voltage and the current at the terminals of the circuit element in the figure are $\boxed{\text{zero for } t<0}$. For $t \geq 0$ they are:

$$v = 10e^{-5000t},\ kV$$

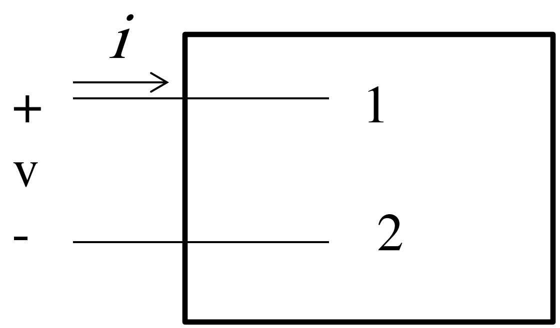
$$i = 20e^{-5000t},\ A$$

P P

a) Calculate the power supplied to the element at 1 ms.

b) Calculate the total energy (in joules) delivered to the circuit element.

ω



Example 3

$$V = 10e^{-5000t}\ kV = 10000\, e^{-5000t}$$

$$i = 20e^{-5000t}$$

a) $P = iV = \boxed{200000\, e^{-10000t}}$

at $t = 1ms = 0.001s$ $\quad P = 200\,000\, e^{-10000 \times 0.001}$

$$P = 200\,000\, e^{-10} = 9.08 \text{ watt}$$

b) $W = \int P\,dt = 200000 \int_0^{\infty} e^{-10000t}\,dt$

$$W = 20\cancel{0000}\, \frac{e^{-10000t}}{-1\cancel{0000}}\Bigg]_0^{\infty} = -20 e^{-10000t}\Big]_0^{\infty}$$

$$= -20\left[\underbrace{e^{-10000(\infty)}}_{zero} - \underbrace{e^{-10000(0)}}_{1}\right] = 20 J$$

Example 3

a) Since the current entering the + terminal of the voltage drop defined for the element, we use a "+" sign in the power equation.

$p = vi = (10{,}000e^{-5000t})\,(20e^{-5000t}) = 200{,}000e^{-10000t}$ W.

$p(0.001) = 200{,}000e^{-10000(0.001)} = 200{,}000e^{-10} = 0.908$ W

9.08

b) since $w = \int_0^t p\,dt$, to find the total power:

$$w = \int_0^\infty p\,dt = \int_0^\infty 200{,}000e^{-10{,}000t}\,dt = \left[\frac{200{,}000e^{-10{,}000t}}{-10{,}000}\right]_0^\infty$$

$$w = -20e^{-\infty} - \left(-20e^{-0}\right) = 0 + 20 = 20J$$

Circuit elements

عناصر سلبيه

- **Passive elements** cannot generate energy. Common examples of passive elements are resistors, capacitors and inductors. Capacitors and inductors can store energy but cannot generate energy.

عناصر نشطه

- **Active elements** can generate energy. Common examples of active elements are power supplies, batteries, operational amplifiers.

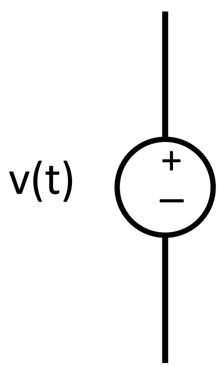
مصدر الجهد

Ideal independent voltage source

- If the voltage across an ideal voltage source can be specified independently of any other variable in a circuit, it is called an ***independent*** voltage source.

  مستقل

- The ideal voltage source can supply unlimited amount of current and power.



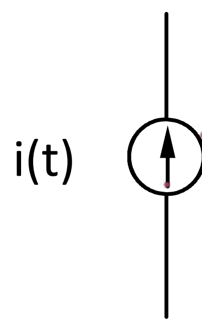
تيار كهربائي

Ideal independent current source

- If the current through an ideal current source can be specified independently of any other variable in a circuit, it is called an ***independent*** current source.

مستقل

- The ideal current source can supply unlimited amount of voltage and power.



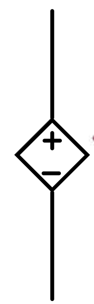
اكيد
ثابت
10A

غير مستقل

Ideal dependent voltage source

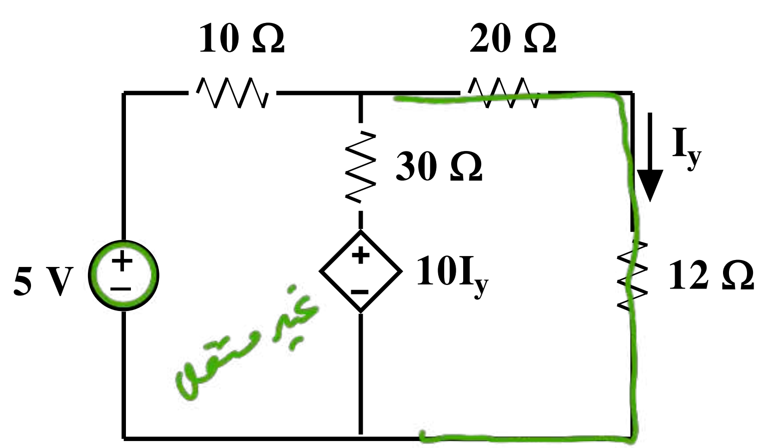
- If the voltage across an ideal voltage source is determined by some other voltage or current in a circuit, it is called a **dependent** or **controlled voltage source**.

مصدر جهد v
غير مستقل



$v = 3I_x$

$v = 2V_x$



مستقل

غير مستقل

مصدر تيار غير مستقل

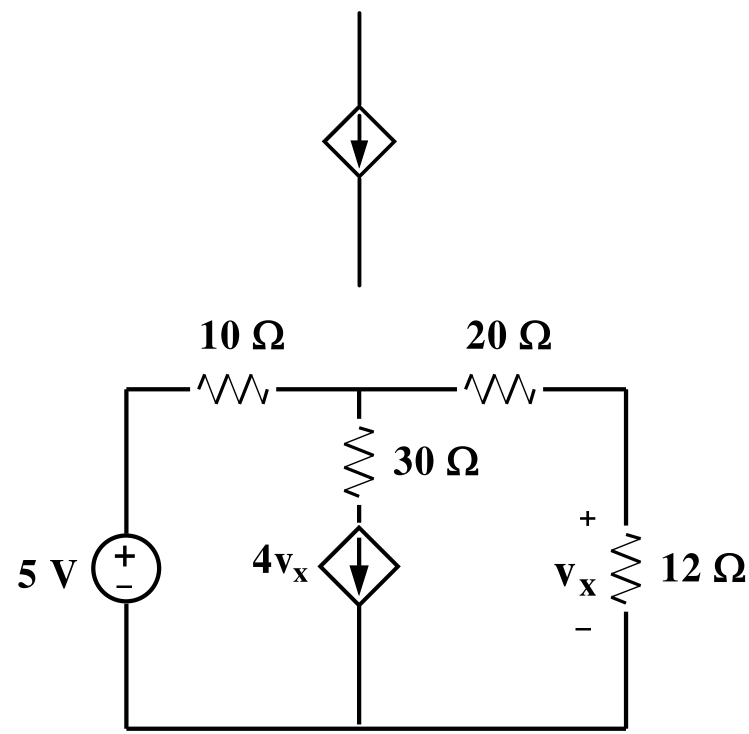
Ideal dependent current source

- If the current through an ideal current source is determined by some other voltage or current in a circuit, it is called a **dependent** or **controlled current source**.

10 A

$I = 3V_x$

$I = 5I_x$



Circuit symbols

(a) an ideal dependent voltage-controlled voltage source,

VCVS

(b) an ideal dependent current-controlled voltage source,

CCVC

(c) an ideal dependent voltage-controlled current source,

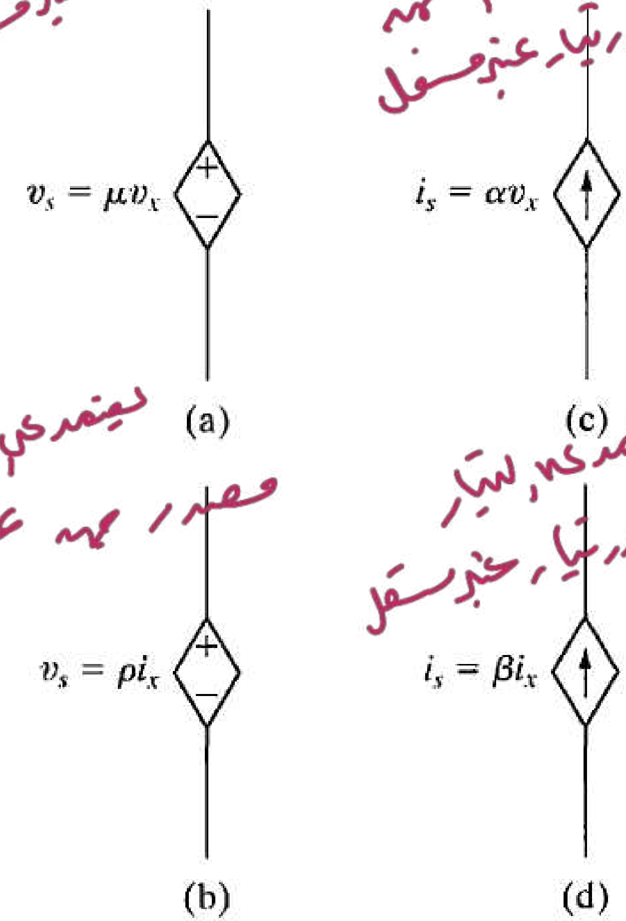
VCCS

(d) an ideal dependent current-controlled current source.

CCCS

يعتمد على الجهد
مصدر جهد غير مستقل

يعتمد على جهد
مصدر تيار غير مستقل

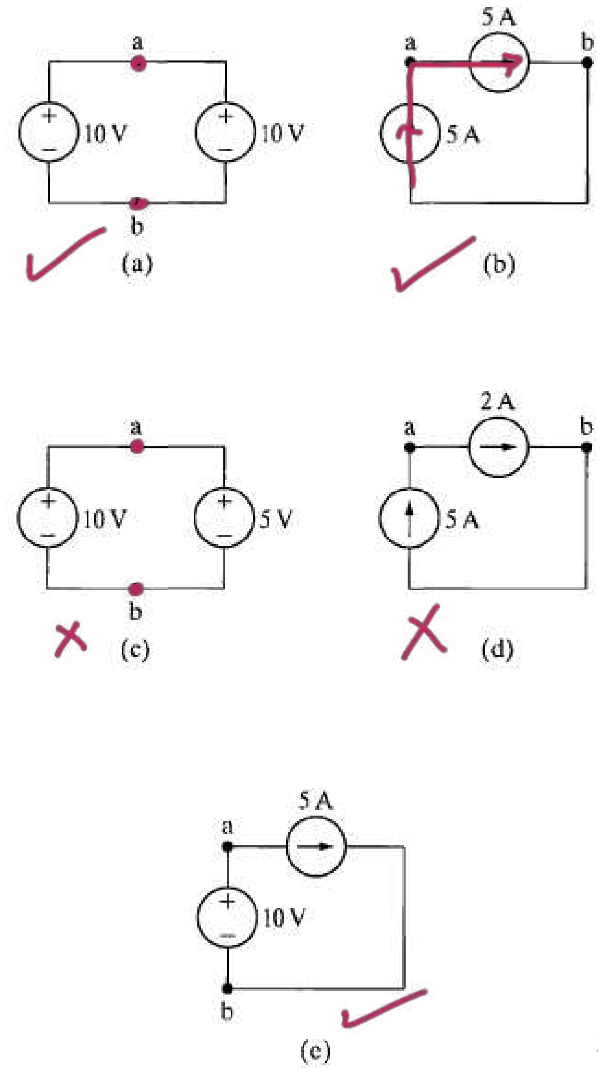


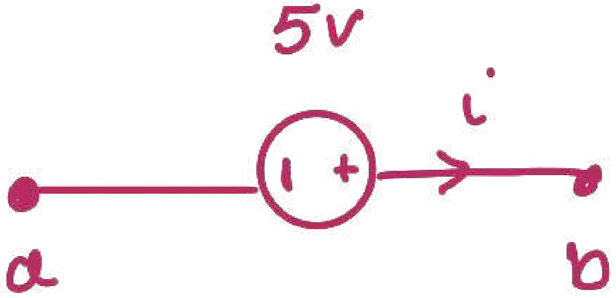
يعتمد على التيار
مصدر جهد غير مستقل

يعتمد على التيار
مصدر تيار غير مستقل

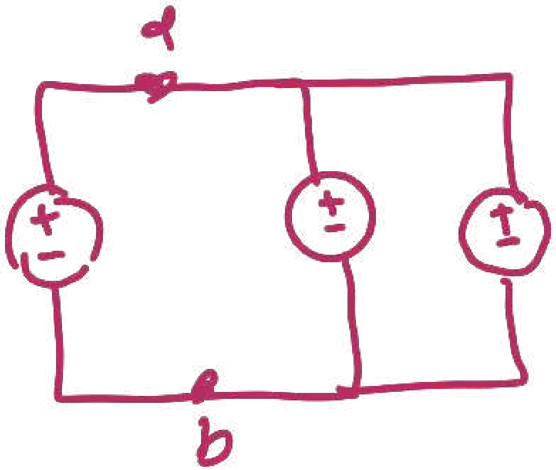
Example 4

- Using the definitions of the ideal independent voltage and current sources, state which interconnections in the figure are permissible and which violate the constraints imposed by the ideal sources.

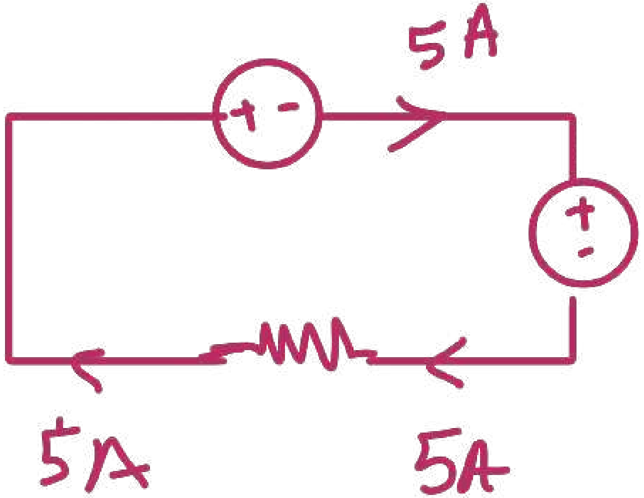




$V_{ab} = 5V$



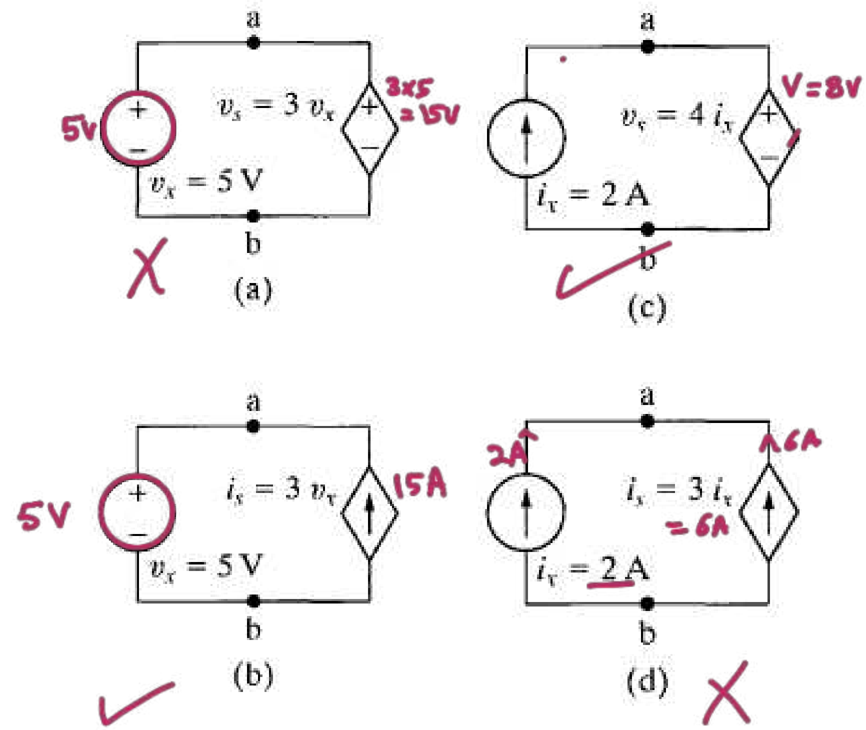
التوازي :- جميع العناصر لها نفس
الجهد



توالي
نفس التيار في
جميع العناصر.

Example 5

- Using the definitions of the ideal independent and dependent sources, state which interconnections in the figure are valid and which violate the constraints imposed by the ideal sources.



Example 6

- For the circuit shown,

a) What value of **a** is required for the interconnection to be valid?

b) For the value of **a** calculated in part (a), find the power associated with the 25 V source.

$V_x = -25$

$aV_x = a(-25)$

$15 = -a(-25)$

(a) $v_x = -25V$

$av_x = -15$

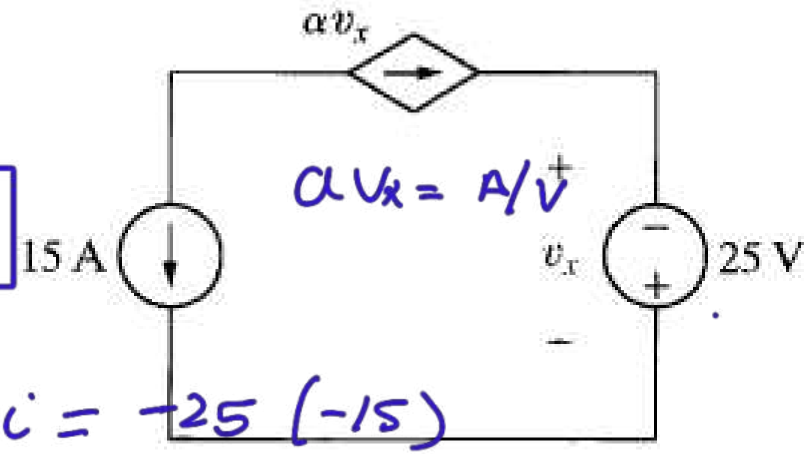
$a(-25) = -15$

$a = -15/-25$

$a = 0.6$ A/V;

$a = \frac{15}{25}$

$\boxed{a = 0.6 \text{ A/V}}$



$aV_x = A/V$

(b) p = v*i

p = - (25)*(-15)   (PSC)

p = 375 W (375 W absorbed).

$P = Vi = -25(-15)$

$P = 375$

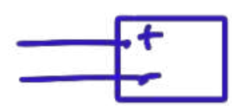
Summary

- The international System of Units (SI) enables engineers to communicate in a meaningful way about quantitative results.

- Circuit analysis is based on the variables of voltage and current.

- **Voltage** is the energy per unit charge created by charge separation and has the SI unit of volt.

- **Current** is the rate of charge flow and has the SI unit of ampere.



- The **ideal basic circuit element** is a two-terminal component that cannot be subdivided; it can be described mathematically in terms of its terminal voltage and current.

Summary

PSC

- The **passive sign convention** uses a positive sign in the expression that relates the voltage and current at the terminals of an element when the reference direction for the current through the element is in the direction of the reference voltage drop across the element.

P=IV

- **Power** is energy per unit of time and is equal to the product of the terminal voltage and current; it has the SI unit of watt.

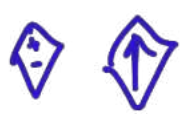
- The algebraic sign of power is interpreted as follows:
  - If *p* < *0*, power is being delivered to the circuit or circuit component.
  - If *p* > *0*, power is being extracted from the circuit or circuit component.

Summary

- An **ideal voltage source** maintains a prescribed voltage regardless of the current in the device.

- An **ideal current source** maintains a prescribed current regardless of the voltage across the device.

- **Independent** voltage and current sources are not influenced by any other current or voltage in the circuit.



- **Dependent** voltage and current sources are determined by some other current or voltage in the circuit.

Drill MCQ questions

Select an option that makes the statement TRUE

- If $p < 0$:

A. power is being extracted from the circuit.
B. power has positive sign.
C. power is being delivered to the circuit.
D. none of the above.

- The ideal basic circuit element:

A. one terminal component.
B. can be subdivided.
C. can be described in terms of voltage and current.
D. none of the above.

1. The voltage and the current at the terminals of the circuit element in the figure are zero for t<0. For t≥0 they are:

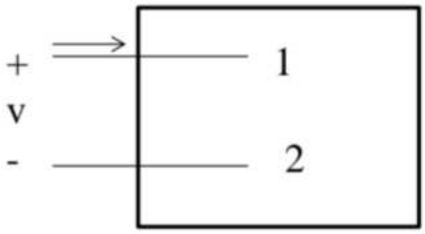
$$v = 50e^{-1600t} - 50e^{-400t}\ V$$

$$i = 5e^{-1600t} - 5e^{-400t}\ mA$$

a) find the power at t=625 µs. $\times 10^{-6}$

b) How much energy is delivered to the circuit element between 0 and 625 µs.

c) find the total energy delivered to the element.



$$V = 50e^{-1600t} - 50e^{-400t}$$

$$i = 5e^{-1600t} - 5e^{-400t}$$

$$P = (50e^{-1600t} - 50e^{-400t}) \cdot (5e^{-1600t} - 5e^{-400t}) \times 10^{-3}$$

$$250e^{-3200t} - 250e^{-2000t} - 250e^{-2000t} + 250e^{-800t}$$

$$\boxed{P = [250e^{-3200t} - 500e^{-2000t} + 250e^{-800t}] \times 10^{-3}}$$

at $t = 625 \times 10^{-6}$

$$P = [250e^{-3200(625\times10^{-6})} - 500e^{-200(625\times10^{-6})} + 250e^{-800(625\times10^{-6})}] \times 10^{-3}$$

$$P = 0.0422 \text{ watt}$$

b)

$$E = \int_0^{625\times10^{-6}} p$$

$$E = 250\times10^{-3}\int_0^{625\times10^{-6}} e^{-3200t} - 2e^{-2000t} + e^{-800t} \, dt$$

$$E = 250\times10^{-3}\left[\frac{e^{-3200t}}{-3200} - \frac{2e^{-2000t}}{-2000} + \frac{e^{-800t}}{-800}\right]_0^{625\times10^{-6}}$$

$$E = 250\times10^{-3}\left(\left[\frac{-e^{-3200(625\times10^{-6})}}{3200} + \frac{2e^{-2000(625\times10^{-6})}}{2000} - \frac{e^{-800(625\times10^{-6})}}{800}\right] - \left[\frac{-1}{3200} + \frac{1}{1000} - \frac{1}{800}\right]\right)$$

$$E = 1.21\times10^{-5} \, J$$

c)

$$E = \int_0^{\infty} p$$

$$E = 250\times10^{-3}\int_0^{\infty} e^{-3200t} - 2e^{-2000t} + e^{-800t} \, dt$$

$$E = 250\times10^{-3}\left[\frac{e^{-3200t}}{-3200} - \frac{2e^{-2000t}}{-2000} + \frac{e^{-800t}}{-800}\right]_0^{\infty}$$

$$E = 250\times10^{-3}\left(\left[0\right] - \left[\frac{-1}{3200} + \frac{1}{1000} - \frac{1}{800}\right]\right)$$

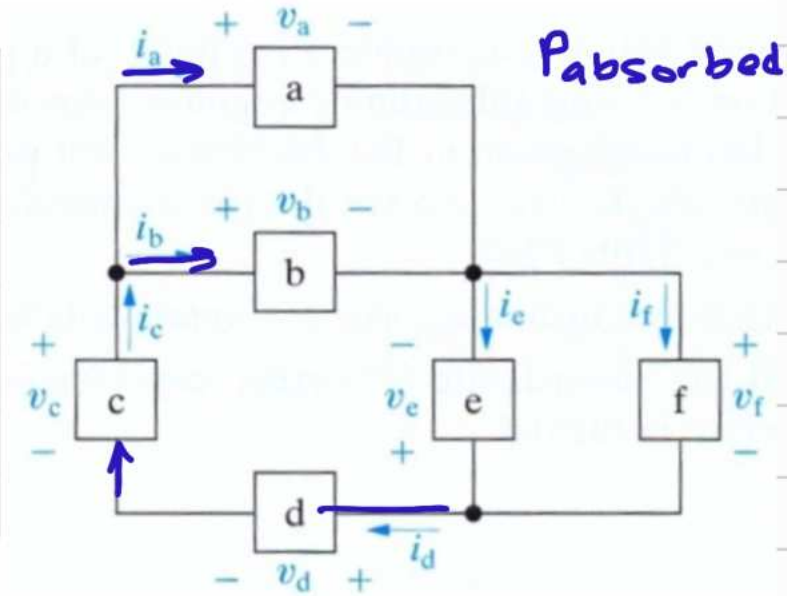
$$E = 1.4 \times 10^{-4}\ J$$

2. Find the total power developed in the circuit

$P_{developed} = 770$

$P_{absorbed} = 770$

Element	Voltage (kV)	Current (mA)
a	150	0.6
b	150	-1.4
c	100	-0.8
d	250	-0.8
e	300	-2.0
f	-300	1.2



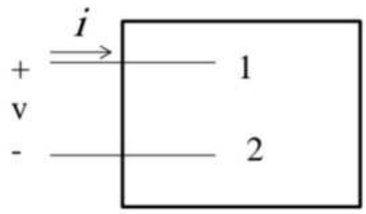
Element	
a	$P = iV = 150\times0.6 = 90\,W$
b	$P = iV = 150\times-1.4 = -210\,W$
c	$P = -iV = -100\times-0.8 = 80\,W$
d	$P = iV = 250\times-0.8 = -200\,W$
e	$P = -iV = -300\times-2 = +600$
f	$P = iV = -300\times1.2 = -360$

3. The current entering the upper terminal of the figure:

$$i = 20\cos(5000t),\ \text{A. for } t>0$$

a) Derive the expression for the charge accumulating at the upper terminal of the element for t>0.

b) If the current is stopped after 0.2 seconds, how much charge has accumulated at the upper terminal?



a)

$$q(t) = \int_0^t i(t)\,dt$$

$$q(t) = \int_0^t 20\cos 5000t\ dt$$

$$= 20\ \frac{\sin 5000t}{5000}\Bigg]_0^t = 0.004\sin 5000t$$

$$\boxed{q(t) = 0.004\sin 5000t}$$

b)

at $t = 0.2$

$$q = 0.004\sin 5000\times 0.2$$

$$q = 0.004\sin 1000 = 3.31\times 10^{-3}\,C$$