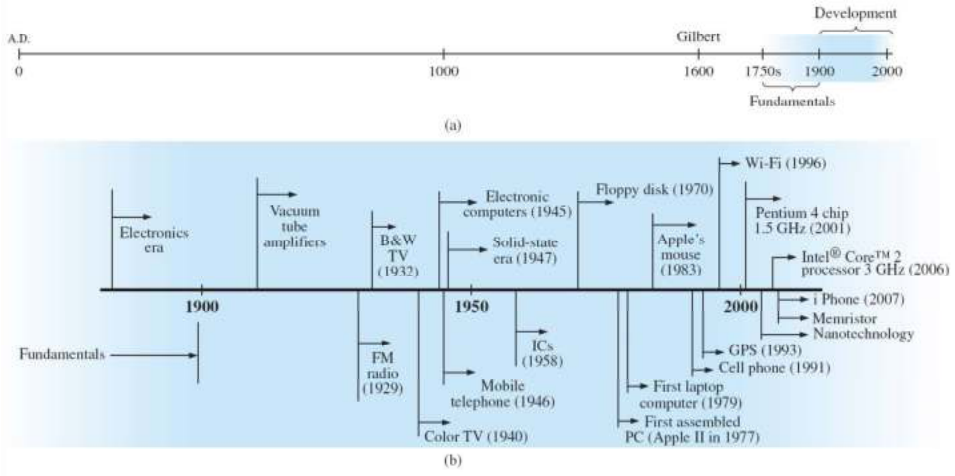
Unit 1
Basic Concepts

8022003-2
Electrical Engineering:
Concepts & Applications
Fall 2020

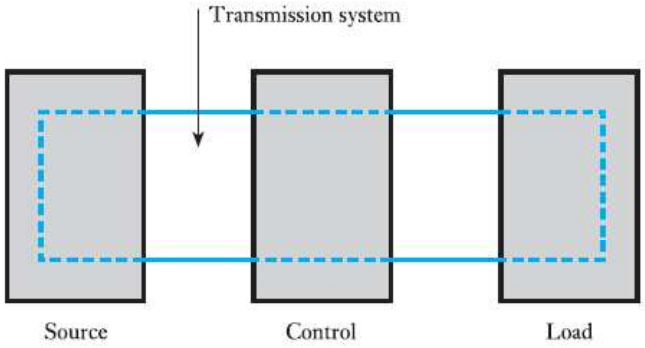
A Brief History



Time charts: (a) long-range; (b) expanded.

Parts of an electrical system

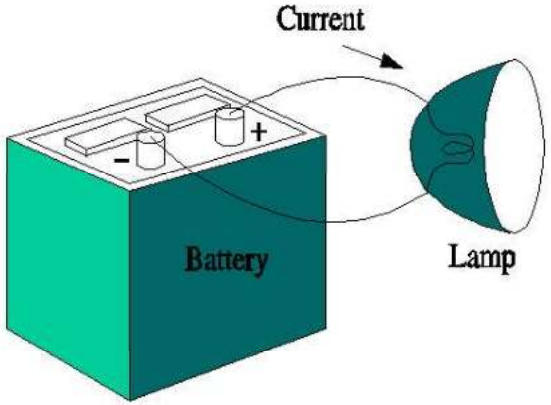
Four parts:



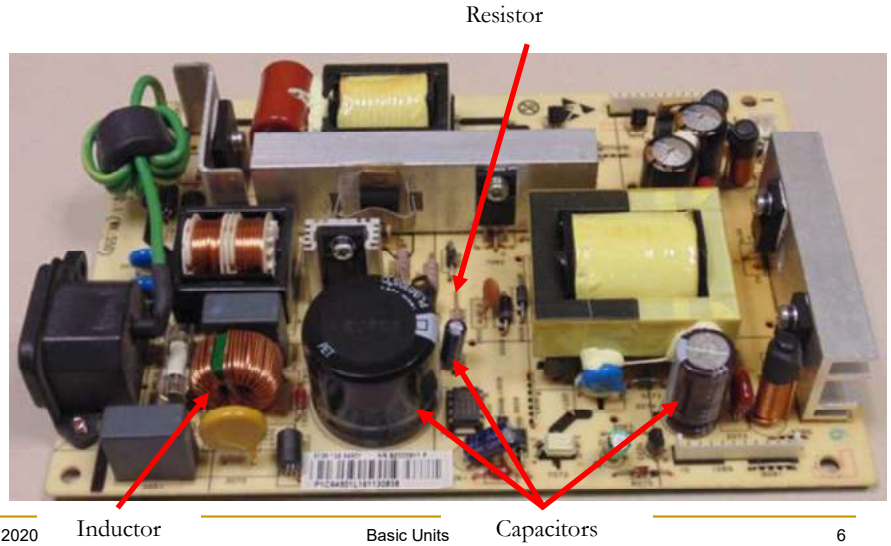
What is an Electric Circuit?

- An electric circuit is an interconnection of electrical elements.
- Five electrical elements that we'll focus on:
  - Resistors
  - Capacitors
  - Inductors
  - Voltage Sources
  - Current Sources

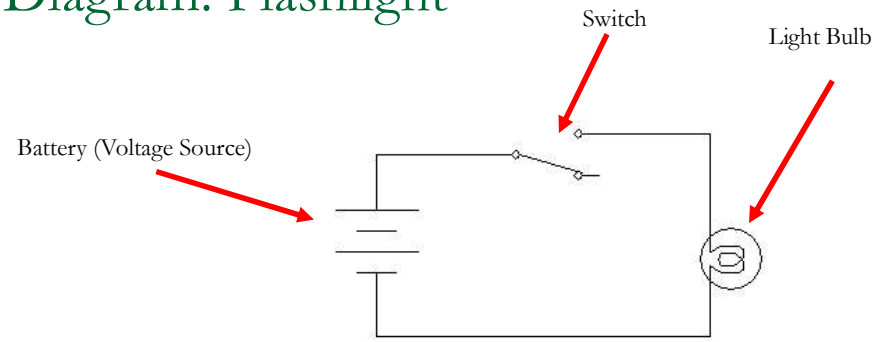
Electric Circuit



Example Circuit: A Power Supply from a Flat-Screen Television

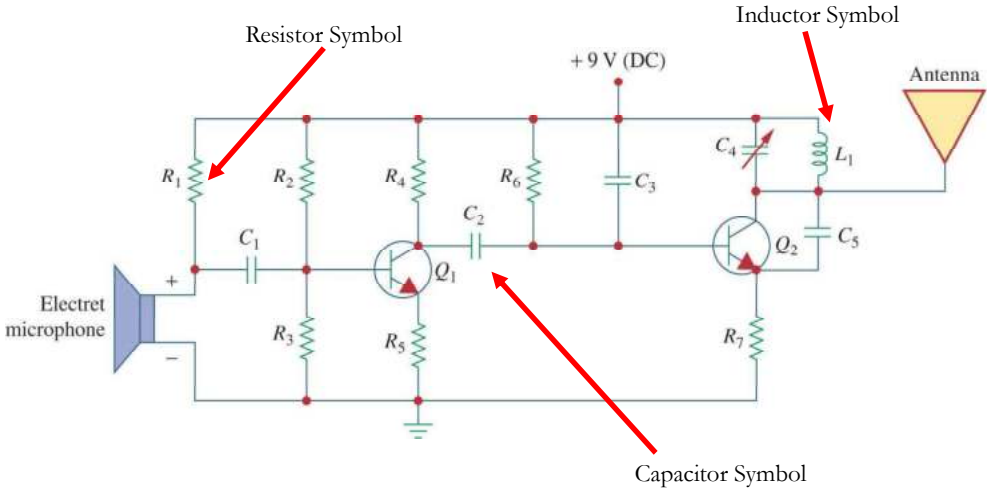


A Simpler Example Schematic Diagram: Flashlight



- When the switch is open (as drawn), no current flows, so the bulb is dark.
- When the switch is closed, current flows, and the bulb lights.

Example Schematic Diagram: A Radio Transmitter



Basic Concepts

1. Systems of Units.
2. Electric Charge.
3. Current.
4. Voltage.
5. Power and Energy.
6. Circuit Elements.

1. System of Units: SI units

- When taking measurements, we must use units to quantify values
- We use the International Systems of Units (SI for short)
- Prefixes on SI units allow for easy relationships between large and small values

Table 1: Six basic SI units

Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic Temperature	kelvin	K
Luminous intensity	candela	cd

Derived units in SI

Table 2: Derived units in SI, commonly used in electric circuits

Quantity	Unit Name (Symbol)	Formula
Frequency	hertz (Hz)	s^{-1}
Force	newton (N)	$kg \cdot m/s^2$
Energy or work	joule (J)	$N \cdot m$
Power	watt (W)	J/s
Electric charge	coulomb (C)	$A \cdot s$
Electric potential	volt (V)	J/C
Electric resistance	ohm (Ω)	V/A
Electric conductance	siemens (S)	A/V
Electric capacitance	farad (F)	C/V
Magnetic flux	weber (Wb)	$V \cdot s$
Inductance	henry (H)	Wb/A

Large and Small Numbers

- We must often deal with very large or very small numbers.
- ***Example:*** a resistor might have a resistance of 680,000 Ω and a current of 0.000145 A.
- It's not convenient to use so many zeroes when writing or discussing numbers.
- Instead we use **SI prefixes** (or **engineering prefixes**), which are abbreviations for certain powers of 10.

Table 3: The SI prefixes

Multiplication Factors	SI Prefix	SI Symbol
$1\,000\,000\,000\,000\,000\,000 = 10^{18}$	exa	E
$1\,000\,000\,000\,000\,000 = 10^{15}$	peta	P
$1\,000\,000\,000\,000 = 10^{12}$	tera	T
$1\,000\,000\,000 = 10^{9}$	giga	G
$1\,000\,000 = 10^{6}$	mega	M
$1\,000 = 10^{3}$	kilo	k
$0.001 = 10^{-3}$	milli	m
$0.000\,001 = 10^{-6}$	micro	μ
$0.000\,000\,001 = 10^{-9}$	nano	n
$0.000\,000\,000\,001 = 10^{-12}$	pico	p
$0.000\,000\,000\,000\,001 = 10^{-15}$	femto	f
$0.000\,000\,000\,000\,000\,001 = 10^{-18}$	atto	a

SI or Engineering Prefixes

- You must memorize these prefixes.
- You must also be able to convert between numbers written with engineering prefixes and numbers written in everyday (floating-point) notation.

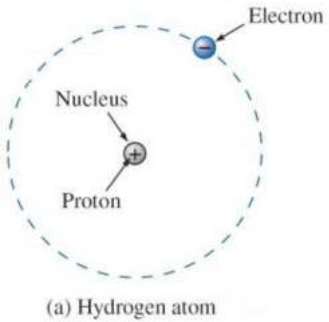
- Whenever you have a number that's **greater than 1000 or less than 1**, you should use the SI prefixes.

Example using Prefixes

- ***Example:*** a resistor might have a resistance of 680,000 Ω and a current of 0.000145 A.
- Using Prefixes
  - Instead of writing 680,000 Ω, write 680 kΩ (pronounced "680 kilo-ohms").
  - Instead of writing 0.000145 A, write 145 μA (pronounced "145 microamps").

Atoms

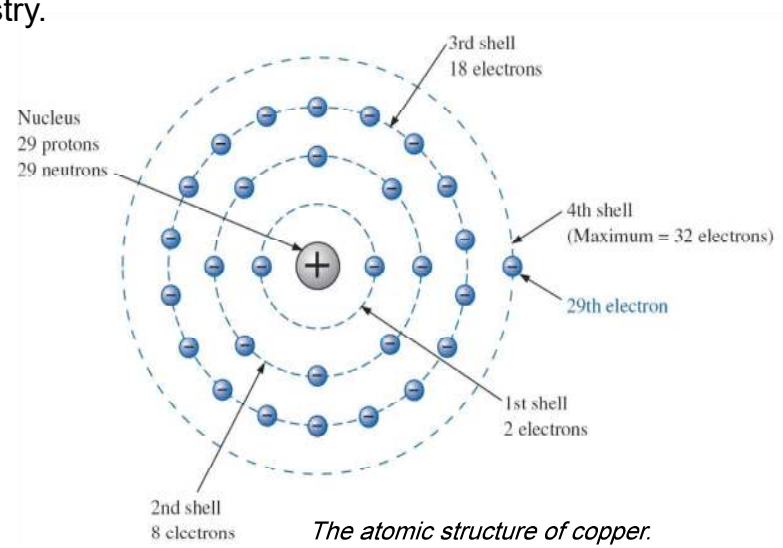
- The simplest of all atoms is the hydrogen atom, made up of two basic particles, the **proton** and the **electron.**
- The **nucleus** of the hydrogen atom is the proton, a positively charged particle.
- *The orbiting electron carries a negative charge equal in magnitude to the positive charge of the proton.*



(a) Hydrogen atom

Atoms

- **Copper** is the most commonly used metal in the electrical industry.



The atomic structure of copper.

2. Electric Charges

- **Charge** (Q or q) is an electrical property of the atomic particles of which matter consists, measured in SI unit Coulombs (C).
- **Charge of one electron = -1.602×10^{-19} C.**
  - This is called the **electronic charge *(e)***. Note it has a negative sign.
- Charge of **one proton = +1.602×10^{-19} C.**
  - Note it has a positive sign.
- **One Coulomb = 6.24×10^{18} electrons**. (Very Large)
- **Charge cannot be created or destroyed, only transferred.**

Example 1:

How much charge is represented by 4,600 electrons?

Practice 1: Calculate the amount of charge represented by six million protons.

Answer: +9.612 ×10^{-13}C.

What is Electricity?

- One might define electricity as

"The separation of positive and negative electric charge."

- When the charges are *separated* and *stationary* we call this ***static electricity***.
- The separation of charge between clouds and the earth before a lighting discharge is a static electricity.
- When the charges are *in motion* (changing with time relative to one another) we have ***variable electricity***.

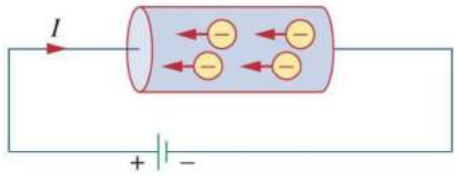
3. Current

$$i(t) = \frac{dq}{dt} \qquad i(t) = \frac{\Delta q}{\Delta t}$$

- **Current: is the rate of charge flow.**
- Current, ***i***, is measured as charge moved per unit time through an element.
- Unit is Ampere (A), is one Coulomb/second

$$I = \frac{Q}{t}$$

- Historically the moving charges were thought to be positive.
- Thus we always note the direction of the equivalent positive charges, even if the moving charges are negative.



Battery

$$q(t) = \int_0^t i(t)dt + q(0)$$

Example 2:

A conductor has a constant current of 5 A. How many electrons pass a fixed point on the conductor in one minute?

Practice 2: Determine the total charge entering a terminal between $t = 1$s and $t = 2$s, if the current passing the terminal is $i = (3t^2 - t)$ A.
Answer: $Q = 7.5$ C.

Example 3:

Find the current in a element if the charge flowing through the element is $q(t) = 3t^3 + 6t^2 + 8t - 4$.

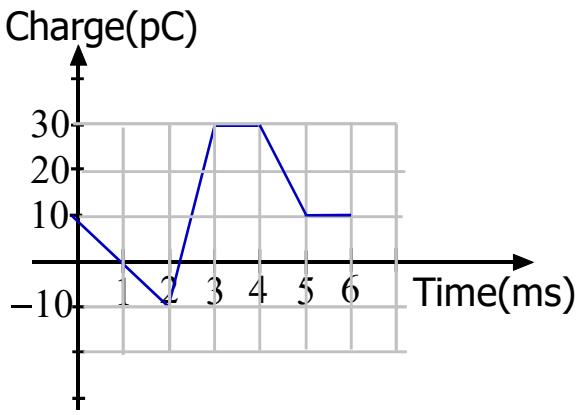
Example 4:

If the current in an electrical device is given by,

$$i(t) = 2t + 4$$

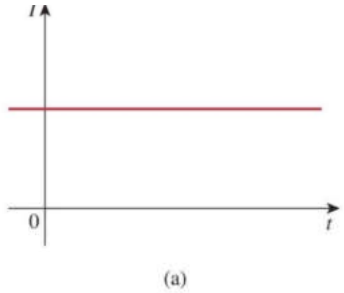
With $q(0) = 1.5$ C
Find the charge flowing through the device.

Practice 3: Determine the current.



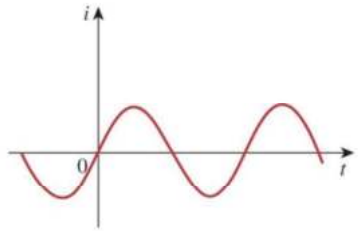
DC vs. AC

- A current that remains constant with time is a Direct Current (DC or dc)
- Constant current is represented by the capital *I*,
- A source of DC is a battery.



(a)

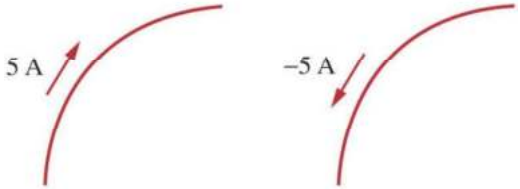
- A current that varies sinusoidally with time is an Alternating Current (AC or ac)
- Time varying current uses the lowercase, *i*.
- Mains power is an example of AC



(b)

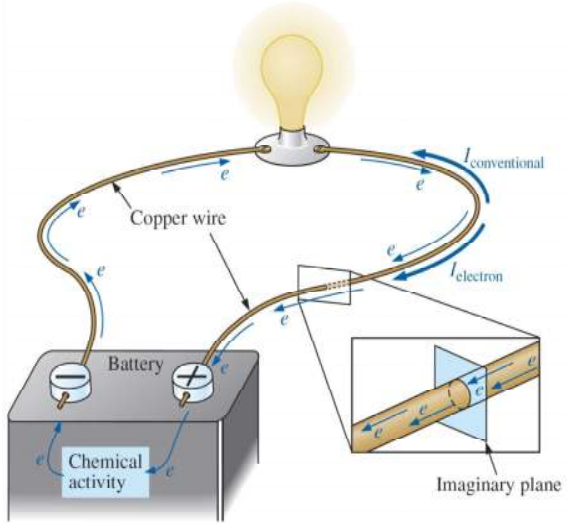
Current Direction

- The sign of the current indicates the direction in which the charge is moving with reference to the direction of interest we define.
- We need not use the direction that the charge moves in as our reference, and often have no choice in the matter.
- A positive current through a component is the same as a negative current flowing in the opposite direction.



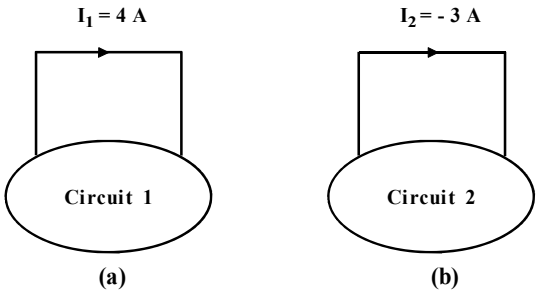
(a) (b)

Current direction



Current in Circuits

In solving for current in a circuit, we must **assume a direction**, solve for the current, then reconcile our answer.



In the diagram above, current I_1 is actually 4 A as assumed. The actual positive direction of current I_2 (equal to -3 A) in the opposite direction of the arrow for I_2.

4. Voltage

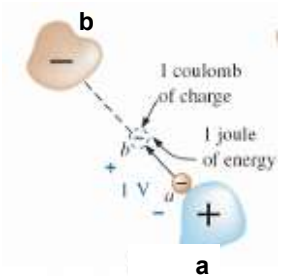
- Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).
- Mathematically, $v_{ab} = dw/dq$ (volt) $V_{ab} = W/Q$
- w is energy in joules (J) and q is charge in coulomb (C).
- Electric voltage, $v_{ab,}$ is always across the circuit element or between two points in a circuit.
  - $v_{ab} > 0$ means the potential of a is higher than potential of b.
  - $v_{ab} < 0$ means the potential of a is lower than potential of b.

Voltage

- If one coulomb of charge is located at point **b** and one joule of energy is required to move the charge to point **a**. Then we say that

  V_{ab} = 1 volt = 1 joule/coulomb

  = 1 newton·meter/coulomb

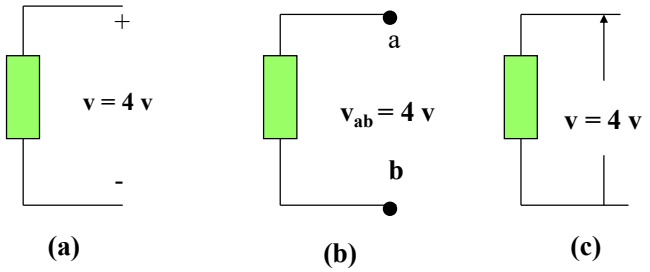


- V_{ab} = 1 volt states that the potential of point **a** (voltage at point a) is 1 volt (positive) with respect to point **b**.
- The sign associated with a voltage is also called its **polarity**.

Voltage in Circuits

- As in the case for current, we must assume a positive direction (polarity) for the voltage.

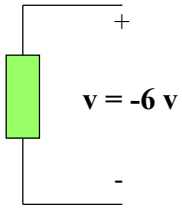
Consider the three diagrams below.



Each of the above gives the same information.

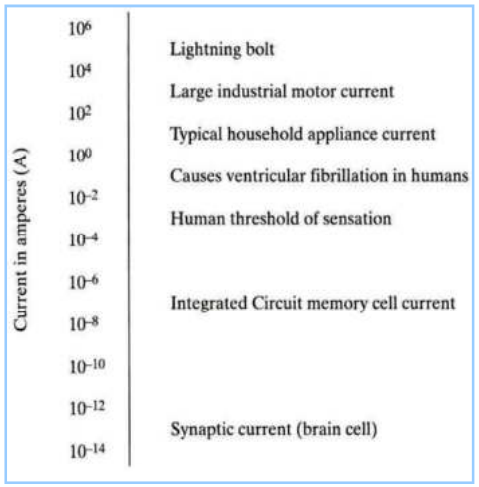
Voltage in Circuits

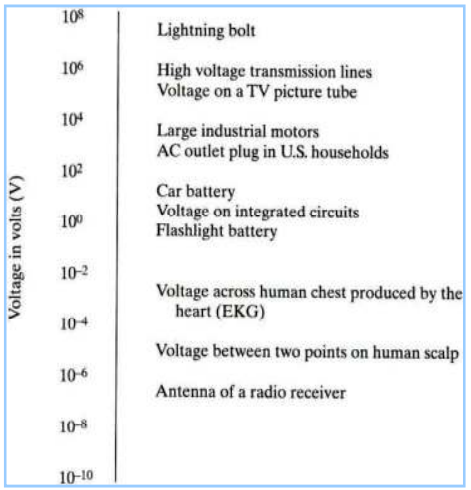
- Assume a polarity for the voltage.
- When solving the circuit for the voltage, we may find that the actual polarity is not the polarity we assumed.



The negative sign for 6 v indicates that if the red lead of a voltmeter is placed on + terminal and the black lead on the – terminal the meter will read–6v.

Current and Voltage Ranges





5. Power

- In general, *the term power is applied to provide an indication of how much work (energy conversion) can be accomplished in a specified amount of time; that is, power is a rate of doing work.*
- **It is measured in watts (W), which equals (J/s)**
- In equation form, power (*P*) is determined by:

$$P = \frac{W}{t}$$ (watts, W, or joules/second, J/s)

5. Power sign

- Power (*P*) is the rate of expending or absorbing energy.

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = vi$$

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

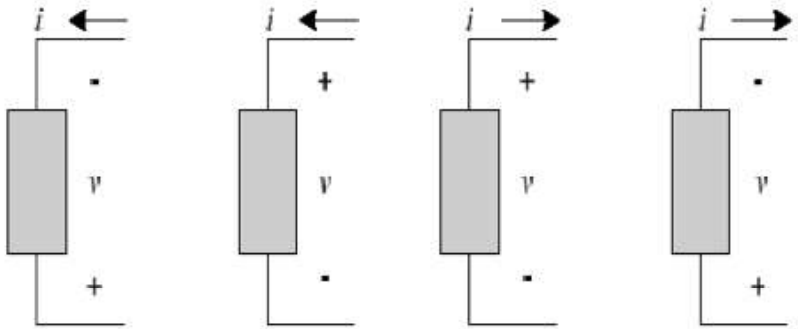
p* = +*vi
Absorbing power

Passive Sign Convention (PSC)

p* = –*vi
Supplying power

Passive Sign Convention (PSC)

- Determine whether the PSC is satisfied and write equations for the power for each diagram below.



Energy

- For power, which is the rate of doing work, to produce an energy conversion of any form, it must be *used over a period of time.*
- The **energy** (*W*) lost or gained by any system is therefore determined by:

$$W = Pt$$ (wattseconds, Ws, or joules)

$$w = \int_{t_0}^{t} p\,dt = \int_{t_0}^{t} vi\,dt$$

Energy

- The electric power utility companies measure energy in watt-hours (Wh) or kilo-watt-hours (kWh), where

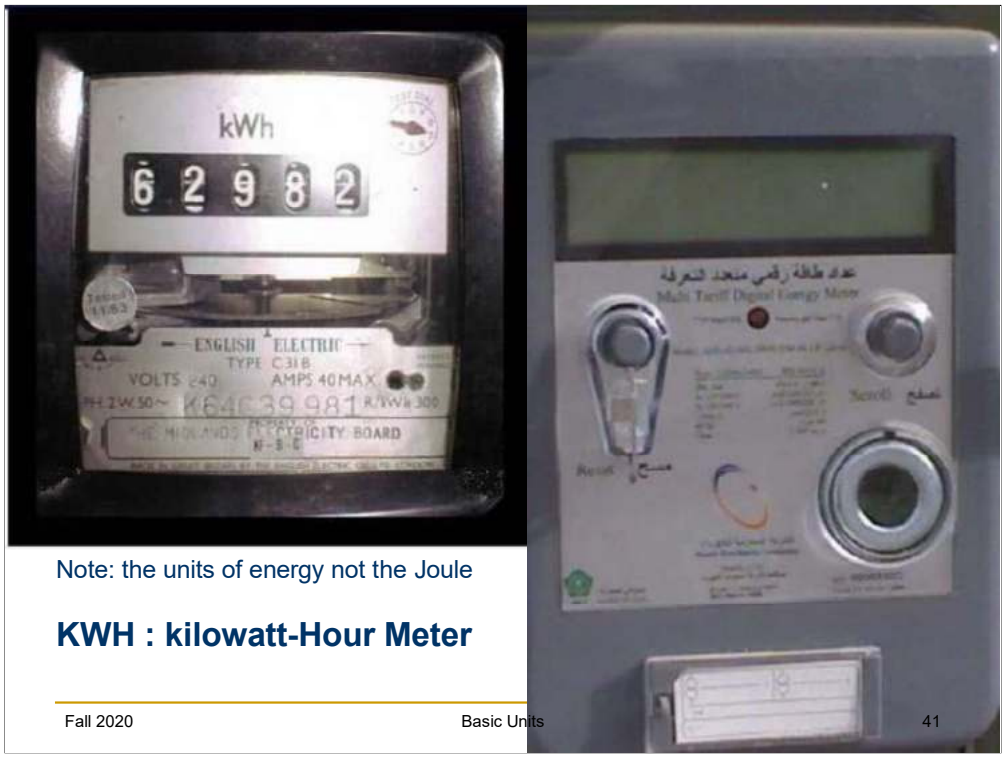
1 Wh = 3,600 J

$$\text{Energy (Wh)} = \text{power (W)} \times \text{time (h)}$$

$$\text{Energy (kWh)} = \frac{\text{power (W)} \times \text{time (h)}}{1000}$$

Energy

- Consider that *1 kWh is the energy dissipated by a 100 W bulb in 10 h.*
- The **kilo-watt-hour meter** is an instrument for measuring the energy supplied to the residential or commercial user of electricity.



Note: the units of energy not the Joule

KWH : kilowatt-Hour Meter

Appliance	Wattage Rating	Appliance	Wattage Rating
Air conditioner (room)	1400	Laptop computer: Sleep	<1 (typically 0.3 to 0.5)
Blow dryer	1300	Average use	78
Cellular phone: Standby	≅35 mW	Microwave oven	1200
Talk	≅4.3 W	Nintendo Wii	19
Clock	2	Radio	70
Clothes dryer (electric)	4300	Range (self-cleaning)	12,200
Coffee maker	900	Refrigerator (automatic defrost)	1800
Dishwasher	1200	Shaver	15
Fan:		Sun lamp	280
Portable	90	Toaster	1200
Window	200	Trash compactor	400
Heater	1500	TV:	
Heating equipment:		Plasma	340
Furnace fan	320	LCD	220
Oil-burner motor	230	VCR/DVD	25
Iron, dry or steam	1000	Washing machine	500
		Water heater	4500
		Xbox 360	187

Typical wattage ratings of some common household items.

Energy Conservation

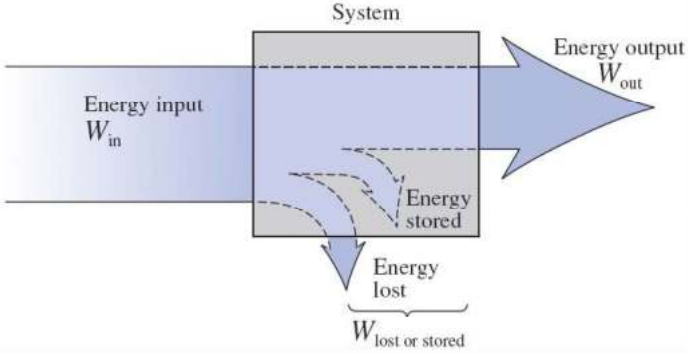
- Conservation of energy requires that
  - **Energy input = energy output + energy lost or stored by the system**

Energy Conservation

$$\sum w = 0$$

Power Conservation

$$\sum p = 0$$



Energy flow through a system.

Example 5:

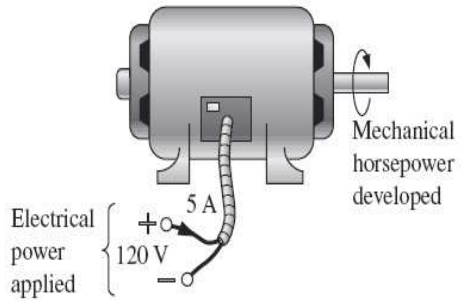
An energy source forces a constant current of 2 A for 10 s to flow through a light bulb. If 2.3 kJ is given off in the form of light and heat energy, calculate the voltage drop across the bulb.

Practice 3: To move charge q from point a to point b requires −30 J. Find the voltage drop v_{ab} if: (a) $q = 6$ C, (b) $q = -3$ C.

Answer: (a) − 5 V , (b) 10 V.

Example 6

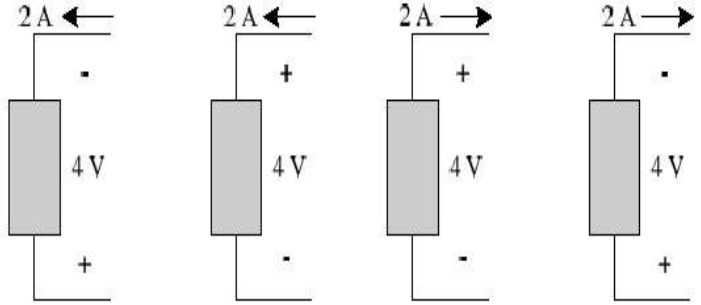
Find the power delivered to the machine.



Example 7:

Passive sign convention

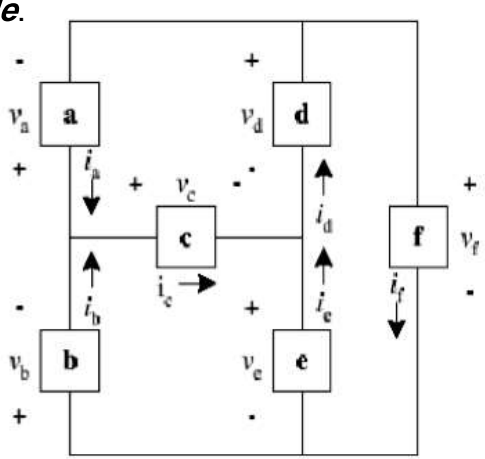
Find the power absorbed for each device



Example 8:

Verify that the voltage & current measurements satisfy the ***power conservation principle***.

	Voltage (V)	Current (A)	Power (W)
a	-18	-51	
b	-18	45	
c	2	-6	
d	20	-20	
e	16	-14	
f	36	31	



Example 9:

How much energy does a 100-W electric bulb consume in two hours?

Practice 5: A stove element draws 15 A when connected to a 240-V line. How long does it take to consume 180 kJ?
Answer: 50 s.

Energy Consumption

تعريفة استهلاك الطاقة الكهربائية

صدر قرار مجلس الوزراء الموقر بتاريخ 2017/12/12م بخصوص تطبيق تعريفة استهلاك جديدة للطاقة الكهربائية لكافة شرائح الإستهلاك والتي ستطبق ابتداءً من 2018/1/1م .

موضحه حسب الجدول التالي:

شرائح الاستهلاك (ك.و.س/ شهر) kWh/month	Halalah/kWh (هللة/ ك.و.س)					
	السكني Residential	التجاري Commercial	الزراعي والجمعيات الخيرية Agricultural and Charitable	الحكومي Governmental	المصانع Industrial	المنشآت الصحية الخاصة والمؤسسات والمعاهد والمدارس الأهلية Private Medical Centers, Schools, Institutes,
1 – 6000	18	20	16	32	18	18
أكثر من 6000	30	30	20			

Cost Calculation

For example
How much does it cost to run a 60W lamp for 20 hours?
The electricity tariff price is 20 halalah/kWh.

- First, convert power unit from (W) into (kW) by dividing by1000
- Then, multiply the power (kW) by time (hours) to get energy (kWh)
- Finally, multiply the energy (kWh) by tariff price (halalah/kWh).

Example 10:

A 100 W computer being used 6 hours per day for 22 days per one month. Calculate the monthly bill in Saudi Riyal if the cost of energy is 18 Halalah/kWh.

Example 11:

Calculate the total energy used for 30 days in (kWh) and the total monthly bill in a ***commercial*** office using the following devices:

Device	Power (W)	Operation (hours/day)
Air Condition	3500	12
PC	500	10
Printer	1500	5
Copy machine	1200	4
Coffee Machine	2000	6
Refrigerator	400	20
Water Heater	2500	7

Electricity cost for commercial consumer:

kWh/month	Halalah/kWh
1 – 6000	20
More than 6000	30

Device	Power (W)	Operation (hours/day)
Air Condition	3500	12
PC	500	10
Printer	1500	5
Copy machine	1200	4
Coffee Machine	2000	6
Refrigerator	400	20
Water Heater	2500	7

6. Circuit Elements

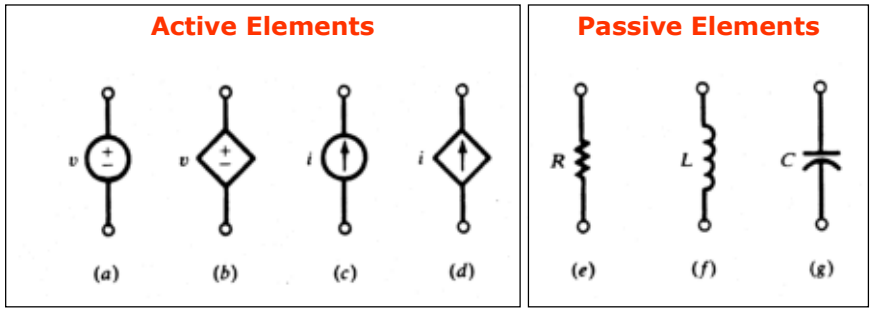
We classify circuit elements as passive and active.

Passive elements cannot generate energy. Common examples of passive elements are resistors, capacitors and inductors. We will see later than capacitors and inductors can store energy but cannot generate energy.

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

For the present time we will be concerned only with sources. The types of sources we consider are independent and dependent.

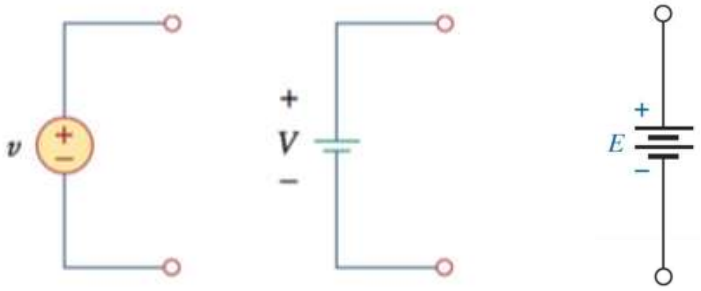
6. Circuit Elements



- **A dependent source is an active element in which the source quantity is controlled by another voltage or current.**
- **They have four different types: VCVS, CCVS, VCCS, CCCS. Keep in minds the signs of dependent sources.**

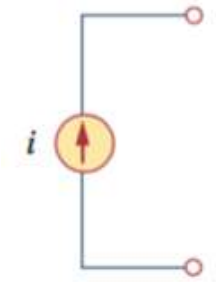
Ideal Independent Voltage Source

- An deal independent source is an active element that provides a specified voltage that is completely independent of other circuit elements.
- The ideal voltage source can supply any amount of current. Furthermore, the ideal independent voltage source can supply any amount of power. ***But it is not practical.***



Ideal Independent Current Source

- An deal independent source is an active element that provides a specified current that is completely independent of other circuit elements.
- If the current source is truly ideal, it can provided any value of voltage and any amount of power. ***But it is not practical.***



Voltage Sources

- In general, dc voltage sources can be divided into 3 basic types:
  1. Batteries (chemical action or solar energy),
  2. Generators (electromechanical), and
  3. Power supplies (rectification).

Batteries:

- **Primary Cells (Non-rechargeable)**
- **Secondary Cells (Rechargeable)**
  - *Lead-Acid*
  - *Nickel–Metal Hydride (NiMH)*
  - *Lithium-ion (Li-ion)*

Voltage Sources: Batteries

Alkaline primary cell (non-rechargeable batteries):
(a) Cutaway of cylindrical Energizer® cell;
(b) (b) various types of Eveready Energizer® primary cells.

Voltage Sources: Batteries

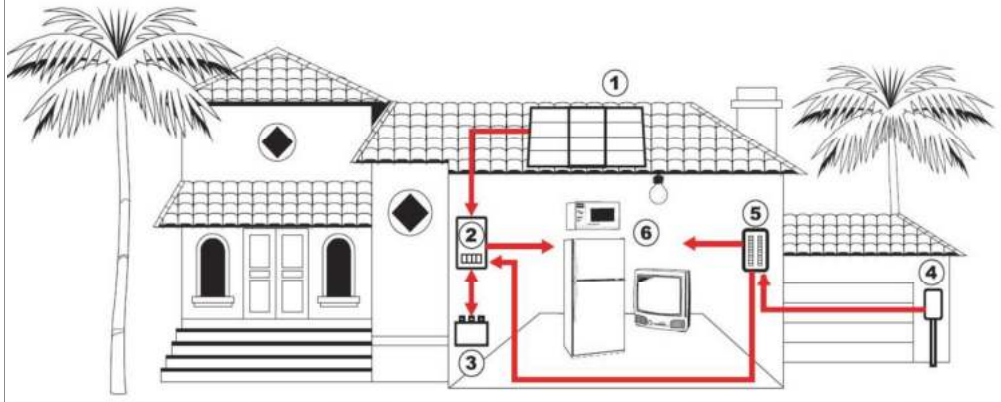
Nickel–metal hydride (NiMH) rechargeable batteries.

Voltage Sources: Batteries

Lithium primary batteries.

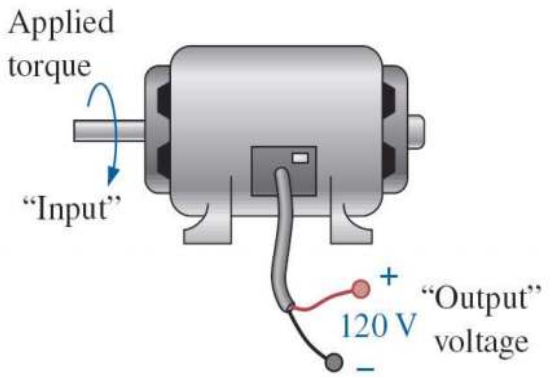
Dell laptop lithium-ion battery: 11.1 V, 4400 mAh.

Voltage Sources: Solar Cell



Solar System: panels on roof.

Voltage Sources: Generators



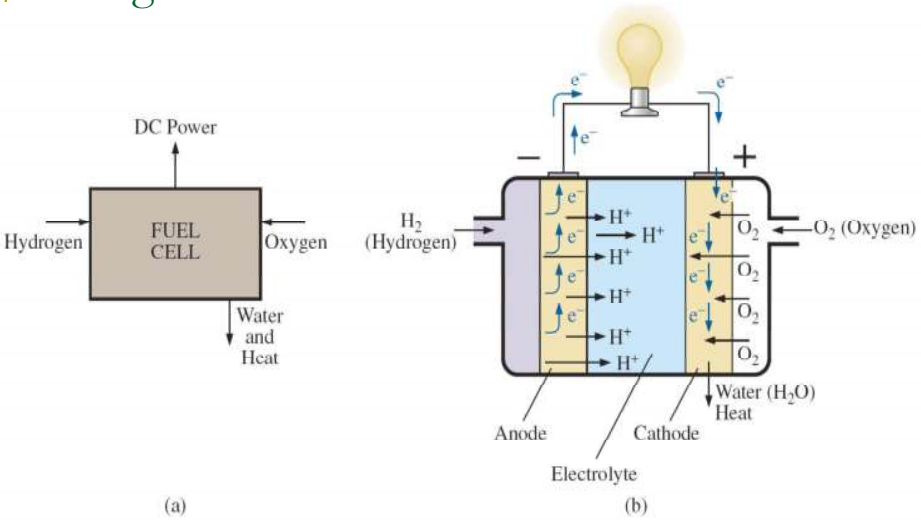
dc generator.

Voltage Sources: Power Supplies

- The dc power supply
- (used in most labs) uses **rectification** & ***filtering*** processes to obtain a steady dc voltage.

A 0 V to 60 V, 0 to 1.5 A digital display dc power supply

Voltage Sources: Fuel Cells



Fuel cell (a) components; (b) basic construction.