BASIC CONCEPTS

- System of Units: The SI standard system; prefixes
- Basic Quantities: Charge, current, voltage, power and energy
- Circuit Elements

SI DERIVED BASIC ELECTRICAL UNITS

power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
electric charge, quantity of electricity	coulomb	C	-	$s \cdot A$
electric potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
magnetic flux	weber	Wb	V·s	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
inductance	henry	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$

ONE AMPERE OF CURRENT CARRIES ONE COULOMB OF CHARGE EVERY SECOND.

$$A = C \times s$$

$$1 \ \text{COULOMB} = 6.28 \times 10^{18} \ (e)$$

(e) IS THE CHARGE OF ONE ELECTRON

VOLT IS A MEASURE OF ENERGY PER CHARGE.
TWO POINTS HAVE A VOLTAGE DIFFERENCE OF ONE VOLT IF ONE COULOMB OF CHARGE GAINS ONE JOULE OF ENERGY WHEN IT IS MOVED FROM ONE POINT TO THE OTHER.

$$V = \frac{J}{C}$$

OHM IS A MEASURE OF THE RESISTANCE TO THE FLOW OF CHARGE.
THERE IS ONE OHM OF RESISTENCE IF IT IS REQUIRED ONE VOLT OF ELECTROMOTIVE FORCE TO DRIVE THROUGH ONE AMPERE OF CURRENT

$$\Omega = \frac{V}{A}$$

IT IS REQUIRED ONE WATT OF POWER TO DRIVE ONE AMPER OF CURRENT AGAINST AN ELECTROMOTIVE DIFFERENCE OF ONE VOLTS

$$W = V \times A$$

CURRENT AND VOLTAGE RANGES

Current in amperes (A)

Current in amperes (A)	
10^{6}	
	Lightning bolt
10^{4}	
	Large industrial motor current
10^{2}	
	Typical household appliance current
10^{0}	
	Causes ventricular fibrillation in humans
10^{-2}	
	Human threshold of sensation
10^{-4}	
10^{-6}	
	Integrated Circuit memory cell current
10^{-8}	
10^{-10}	
10^{-12}	
	Synaptic current (brain cell)
10^{-14}	

Voltage in volts (V)

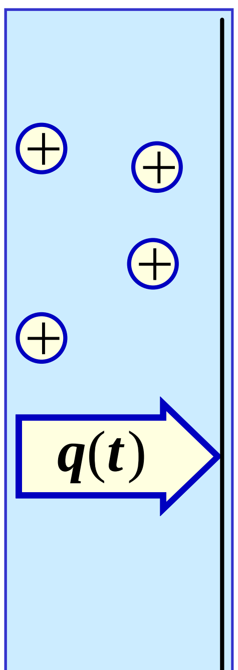
Voltage in volts (V)	
10^{8}	Lightning bolt
10^{6}	High voltage transmission lines Voltage on a TV picture tube
10^{4}	Large industrial motors AC outlet plug in U.S. households
10^{2}	Car battery Voltage on integrated circuits Flashlight battery
10^{0}	
10^{-2}	Voltage across human chest produced by the heart (EKG)
10^{-4}	Voltage between two points on human scalp
10^{-6}	Antenna of a radio receiver
10^{-8}	
10^{-10}	

Strictly speaking current is a basic quantity and charge is derived. However, physically the electric current is created by a movement of charged particles.

An electric circuit is essentially a pipeline that facilitates the transfer of charge from one point to another. The time rate of change of charge constitutes an electric *current*. Mathematically, the relationship is expressed as

$$i(t) = \frac{dq(t)}{dt} \quad \text{or} \quad q(t) = \int_{-\infty}^{t} i(x)\,dx$$

Although we know that current flow in metallic conductors results from electron motion, the conventional current flow, which is universally adopted, represents the movement of positive charges.



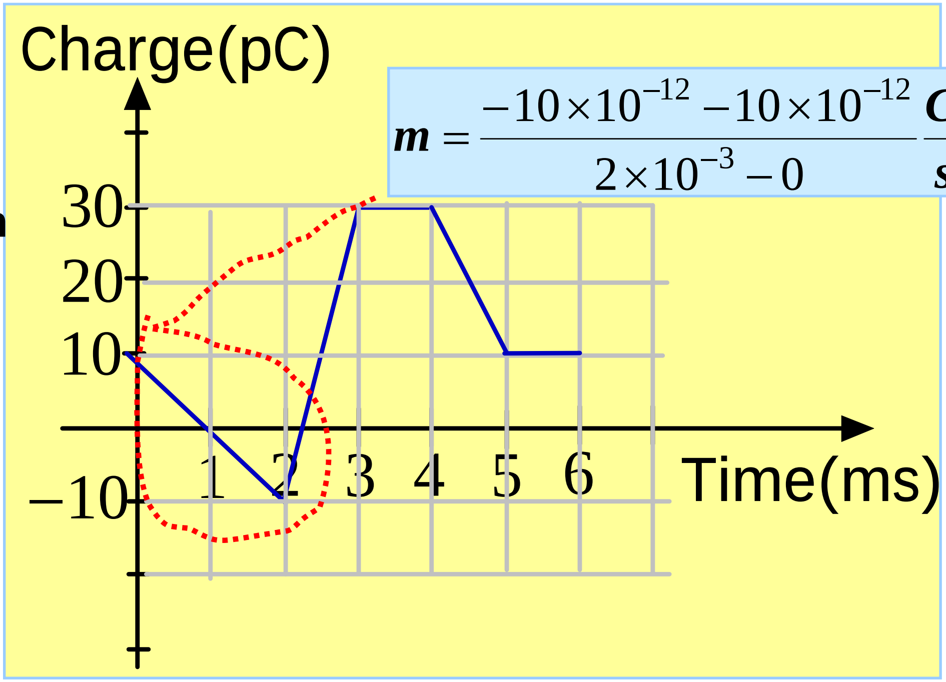
What is the meaning of a negative value for *q(t)*?

<u>PROBLEM SOLVING TIP</u>
IF THE CHARGE IS GIVEN DETERMINE THE CURRENT BY DIFFERENTIATION
IF THE CURRENT IS KNOWN DETERMINE THE CHARGE BY INTEGRATION

A PHYSICAL ANALOGY THAT HELPS VISUALIZE ELECTRIC CURRENTS IS THAT OF WATER FLOW.
CHARGES ARE VISUALIZED AS WATER PARTICLES

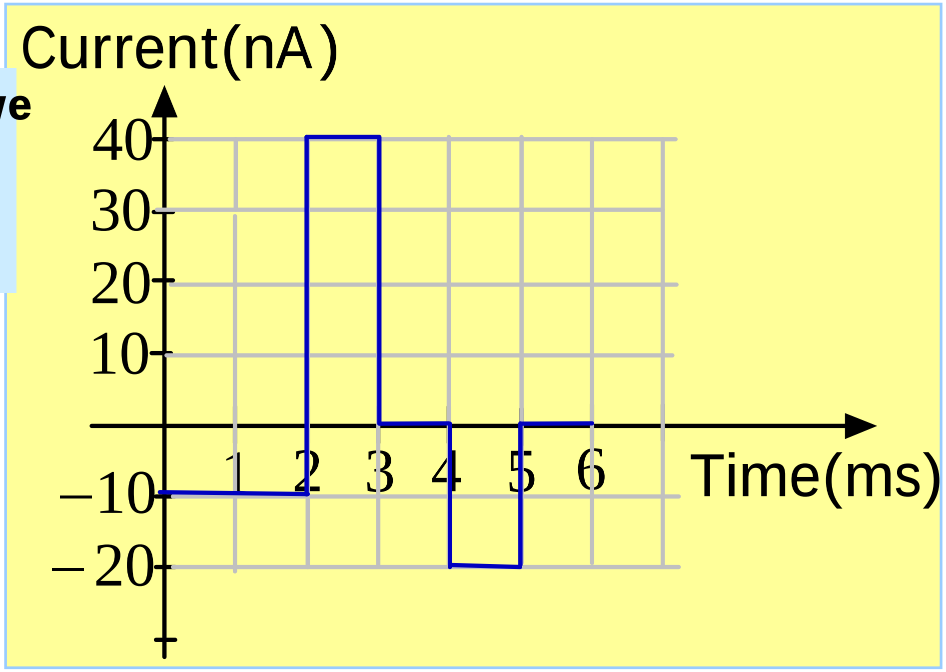
DETERMINE THE CURRENT

Here we are given the charge flow as function of time.



$$m = \frac{-10\times10^{-12} - 10\times10^{-12}}{2\times10^{-3} - 0}\frac{C}{s} = -10\times10^{-9}(C/s)$$

To determine current we must take derivatives.
<u>PAY ATTENTION TO UNITS</u>

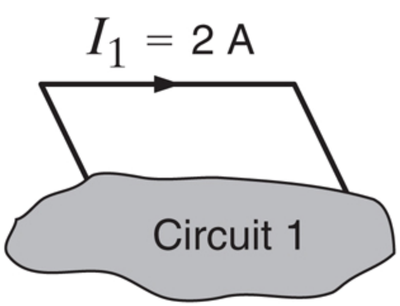


CONVENTION FOR CURRENTS

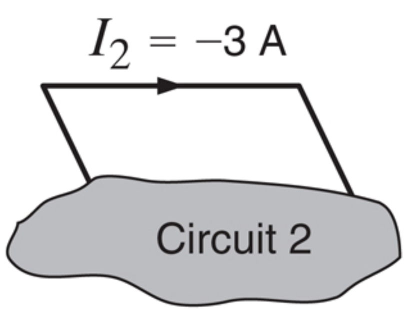
IT IS ABSOLUTELY NECESSARY TO INDICATE THE DIRECTION OF MOVEMENT OF CHARGED PARTICLES.

THE UNIVERSALLY ACCEPTED CONVENTION IN ELECTRICAL ENGINEERING IS THAT CURRENT IS FLOW OF POSITIVE CHARGES.
AND WE INDICATE THE DIRECTION OF FLOW FOR POSITIVE CHARGES

- THE REFERENCE DIRECTION -



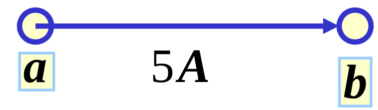
A POSITIVE VALUE FOR THE CURRENT INDICATES FLOW IN THE DIRECTION OF THE ARROW (THE REFERENCE DIRECTION)



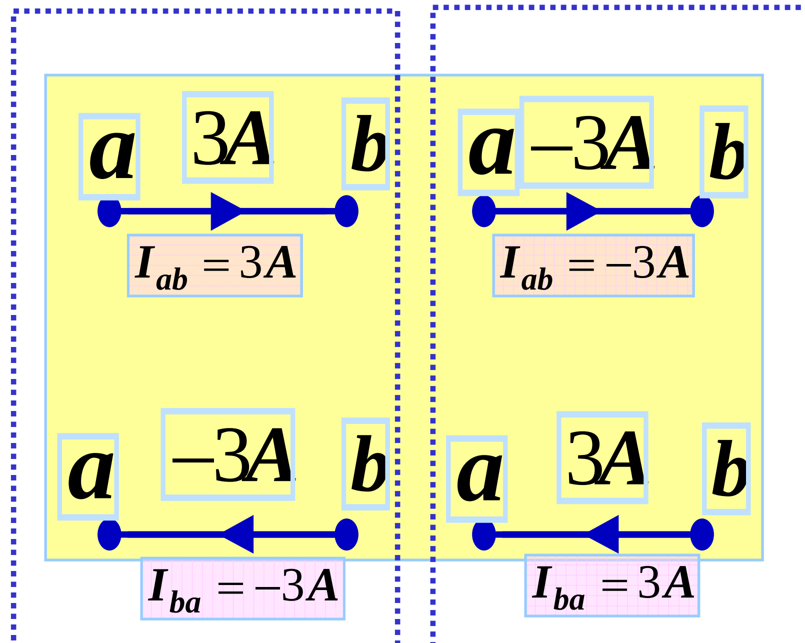
A NEGATIVE VALUE FOR THE CURRENT INDICATES FLOW IN THE OPPOSITE DIRECTION THAN THE REFERENCE DIRECTION

THE DOUBLE INDEX NOTATION

IF THE INITIAL AND TERMINAL NODE ARE LABELED ONE CAN INDICATE THEM AS SUBINDICES FOR THE CURRENT NAME



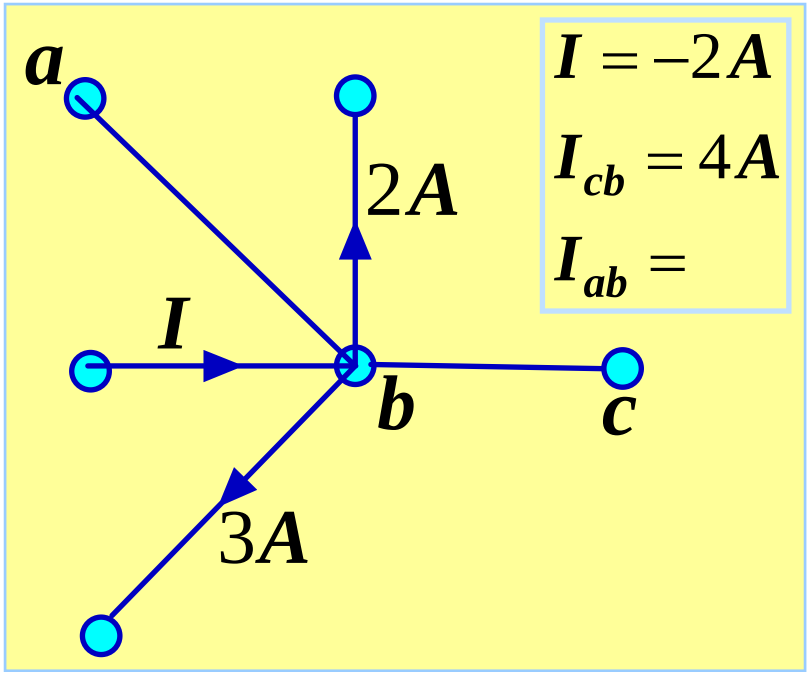
$$I_{ab} = 5A$$



POSITIVE CHARGES FLOW LEFT - RIGHT

POSITIVE CHARGES FLOW RIGHT - LEFT

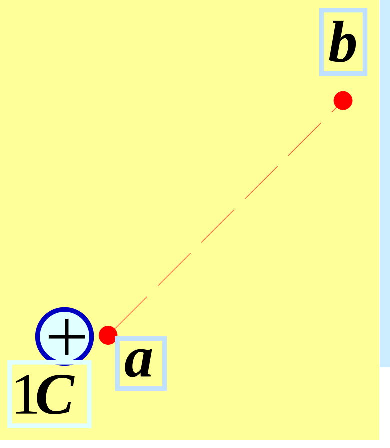
$$I_{ab} = -I_{ba}$$



This example illustrates the various ways in which the current notation can be used

CONVENTIONS FOR VOLTAGES

ONE DEFINITION FOR VOLT
TWO POINTS HAVE A VOLTAGE DIFFERENTIAL OF ONE VOLT IF ONE COULOMB OF CHARGE GAINS (OR LOSES) ONE JOULE OF ENERGY WHEN IT MOVES FROM ONE POINT TO THE OTHER



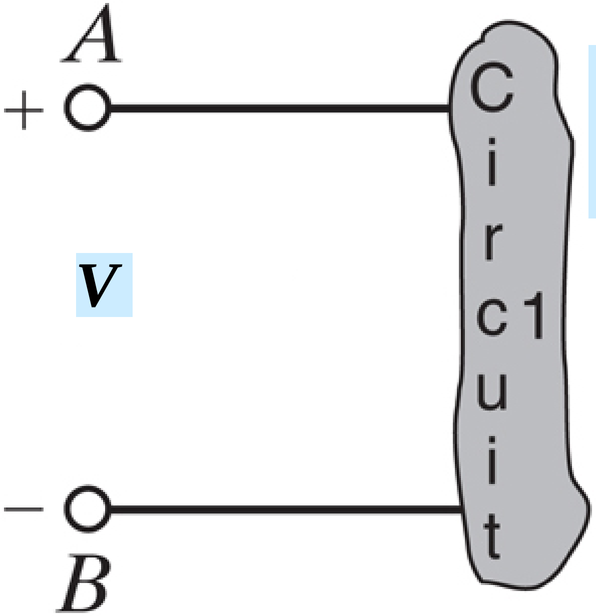
IF THE CHARGE GAINS ENERGY MOVING FROM a TO b THEN b HAS HIGHER VOLTAGE THAN a.
IF IT LOSES ENERGY THEN b HAS LOWER VOLTAGE THAN a

DIMENSIONALLY VOLT IS A DERIVED UNIT

$$\text{VOLT} = \frac{\text{JOULE}}{\text{COULOMB}} = \frac{N \bullet m}{A \bullet s}$$

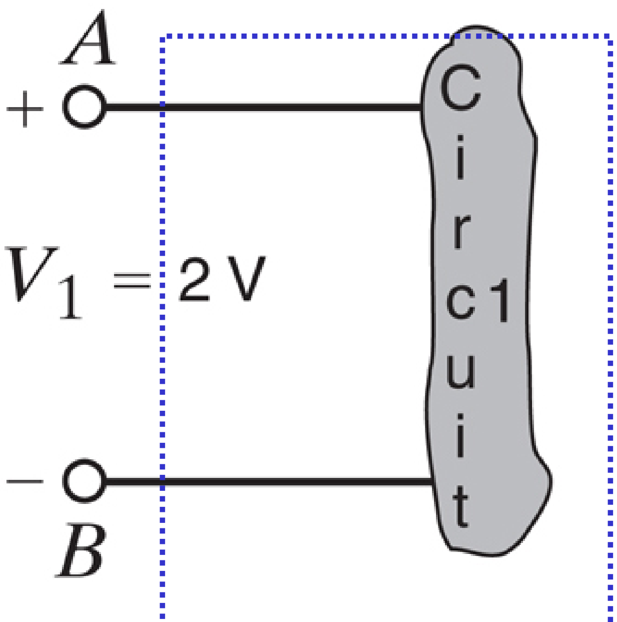
VOLTAGE IS ALWAYS MEASURED IN A RELATIVE FORM AS THE VOLTAGE DIFFERENCE BETWEEN TWO POINTS

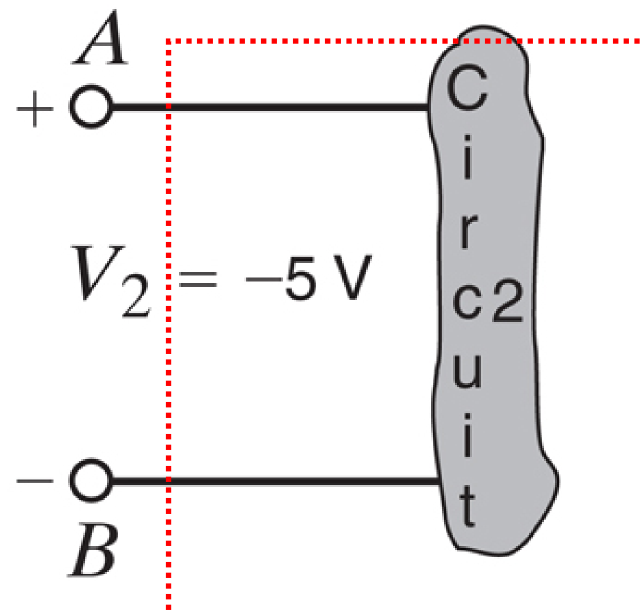
IT IS ESSENTIAL THAT OUR NOTATION ALLOWS US TO DETERMINE WHICH POINT HAS THE HIGHER VOLTAGE



THE + AND - SIGNS DEFINE THE REFERENCE POLARITY

IF THE NUMBER V IS POSITIVE POINT A HAS V VOLTS MORE THAN POINT B.
IF THE NUMBER V IS NEGATIVE POINT A HAS |V| LESS THAN POINT B



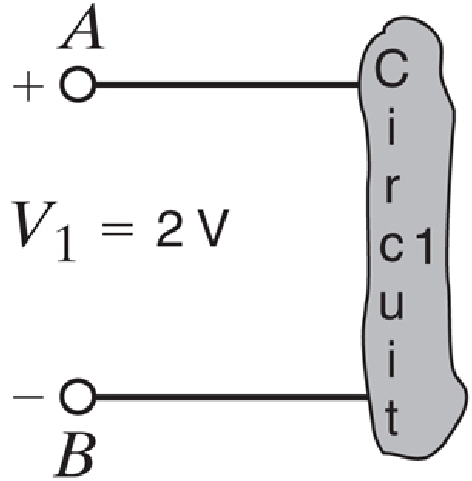


POINT A HAS 2V MORE THAN POINT B

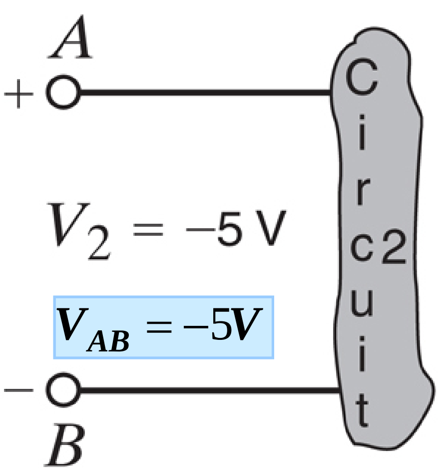
POINT A HAS 5V LESS THAN POINT B

THE TWO-INDEX NOTATION FOR VOLTAGES

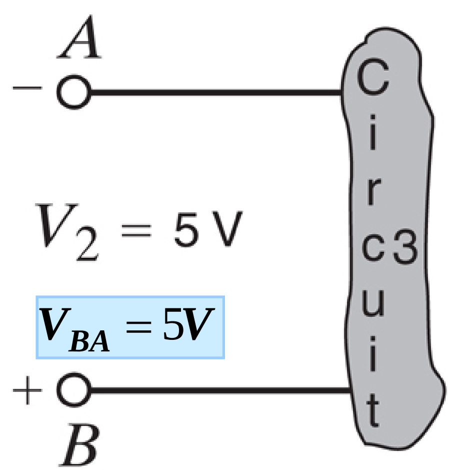
INSTEAD OF SHOWING THE REFERENCE POLARITY WE AGREE THAT THE FIRST SUBINDEX DENOTES THE POINT WITH POSITIVE REFERENCE POLARITY



$V_{AB} = 2V$



$V_{AB} = -5V$



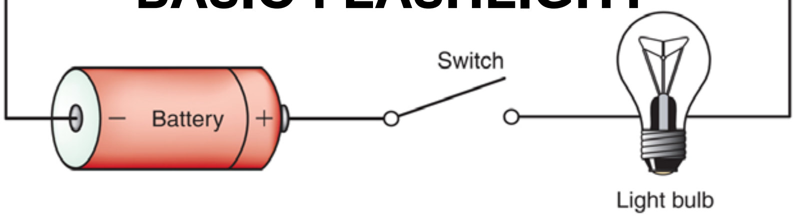
$V_{BA} = 5V$

$V_{AB} = -V_{BA}$

ENERGY

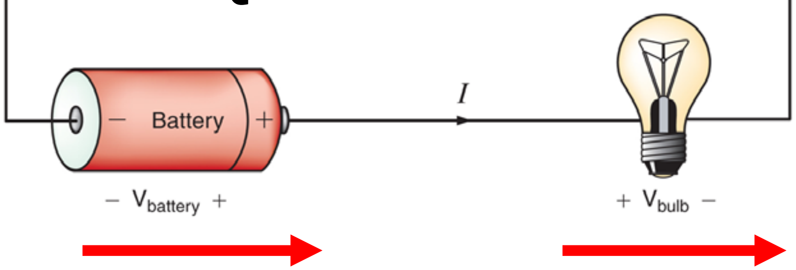
VOLTAGE IS A MEASURE OF ENERGY PER UNIT CHARGE…
CHARGES MOVING BETWEEN POINTS WITH DIFFERENT VOLTAGE ABSORB OR RELEASE ENERGY – THEY MAY TRANSFER ENERGY FROM ONE POINT TO ANOTHER

BASIC FLASHLIGHT



Converts energy stored in battery to thermal energy in lamp filament which turns incandescent and glows

EQUIVALENT CIRCUIT



The battery supplies energy to charges. Lamp absorbs energy from charges. The net effect is an energy transfer

Charges gain energy here

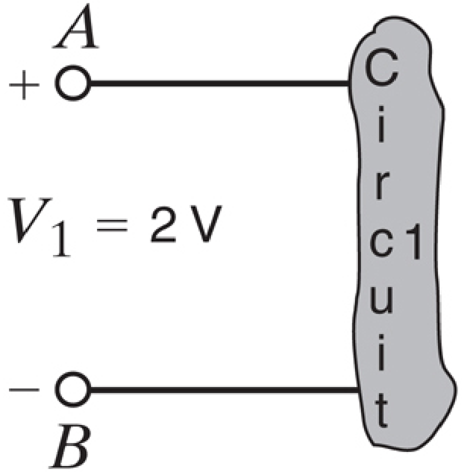
Charges supply Energy here

ENERGY

VOLTAGE IS A MEASURE OF ENERGY PER UNIT CHARGE...
CHARGES MOVING BETWEEN POINTS WITH DIFFERENT VOLTAGE ABSORB OR RELEASE ENERGY

WHAT ENERGY IS REQUIRED TO MOVE 120[C] FROM POINT B TO POINT A IN THE CIRCUIT?

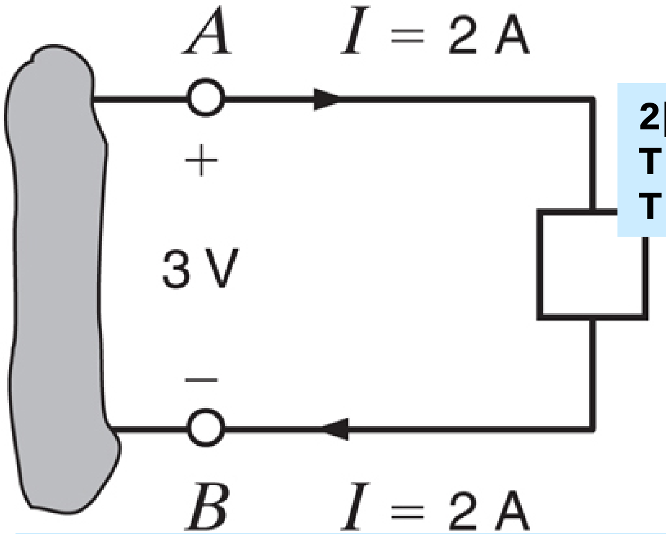
THE CHARGES MOVE TO A POINT WITH HIGHER VOLTAGE - THEY GAINED (OR ABSORBED) ENERGY
THE CIRCUIT SUPPLIED ENERGY TO THE CHARGES



$$V_{AB} = 2V$$

$$V = \frac{W}{Q} \Rightarrow W = VQ = 240J$$

ENERGY AND POWER



2[C/s] PASS THROUGH THE ELEMENT

EACH COULOMB OF CHARGE LOSES 3[J] OR SUPPLIES 3[J] OF ENERGY TO THE ELEMENT

THE ELEMENT RECEIVES ENERGY AT A RATE OF 6[J/s]

THE ELECTRIC POWER RECEIVED BY THE ELEMENT IS 6[W]

IN GENERAL

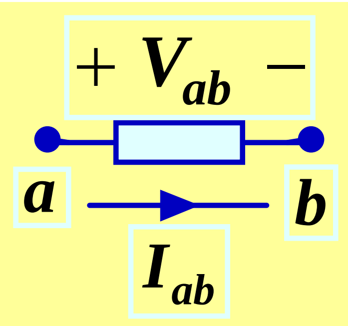
$$P = VI$$

$$w(t_2, t_1) = \int_{t_1}^{t_2} p(x)dx$$

HOW DO WE RECOGNIZE IF AN ELEMENT SUPPLIES OR RECEIVES POWER?

PASSIVE SIGN CONVENTION

POWER RECEIVED IS POSITIVE WHILE POWER SUPPLIED IS CONSIDERED NEGATIVE

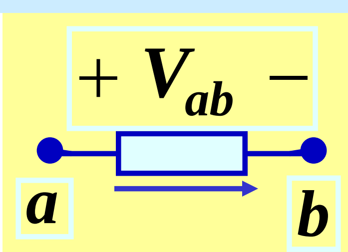


$$P = V_{ab} I_{ab}$$

IF VOLTAGE AND CURRENT ARE BOTH POSITIVE THE CHARGES MOVE FROM HIGH TO LOW VOLTAGE AND THE COMPONENT RECEIVES ENERGY - -IT IS A PASSIVE ELEMENT

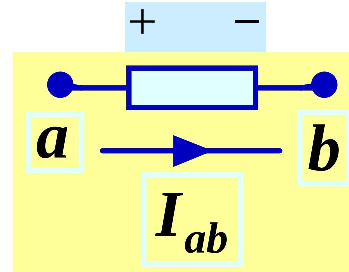
A CONSEQUENCE OF THIS CONVENTION IS THAT THE REFERENCE DIRECTIONS FOR CURRENT AND VOLTAGE ARE NOT INDEPENDENT - - IF WE ASSUME PASSIVE ELEMENTS

GIVEN THE REFERENCE POLARITY



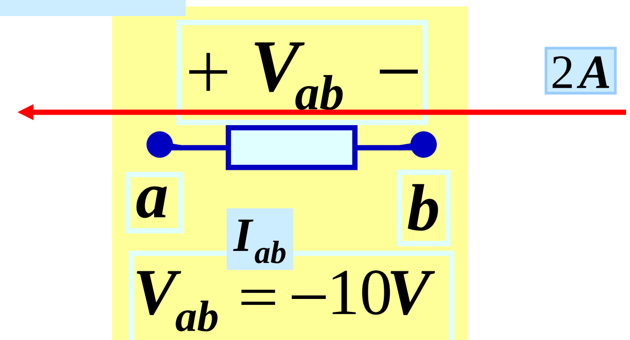
REFERENCE DIRECTION FOR CURRENT

THIS IS THE REFERENCE FOR POLARITY



IF THE REFERENCE DIRECTION FOR CURRENT IS GIVEN

EXAMPLE



THE ELEMENT RECEIVES 20W OF POWER. WHAT IS THE CURRENT?

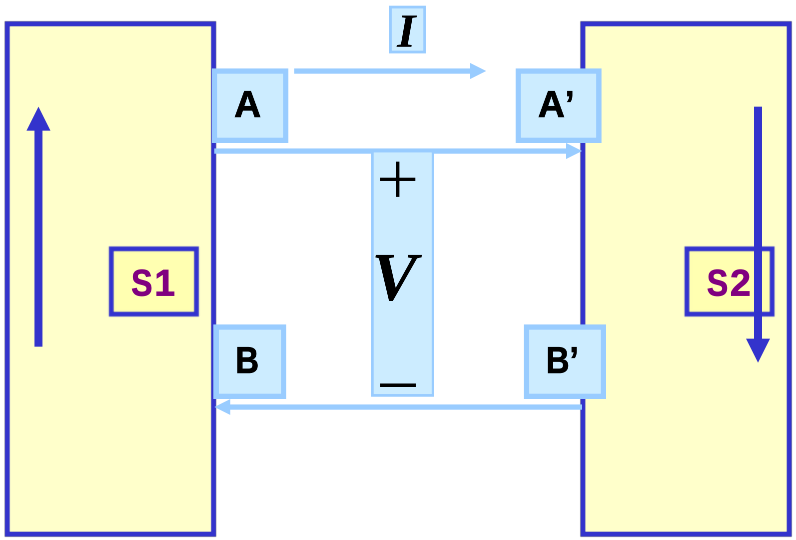
SELECT REFERENCE DIRECTION BASED ON PASSIVE SIGN CONVENTION

$$20[W] = V_{ab} I_{ab} = (-10V) I_{ab}$$

$$I_{ab} = -2[A]$$

UNDERSTANDING PASSIVE SIGN CONVENTION

We must examine the voltage across the component and the current through it



$$P_{S1} = V_{AB} I_{AB}$$
$$P_{S2} = V_{A'B'} I_{A'B'}$$

Voltage(V)	Current A - A'	S1	S2
positive	positive	supplies	receives
positive	negative	receives	supplies
negative	positive	receives	supplies
negative	negative	supplies	receives

ON S_1

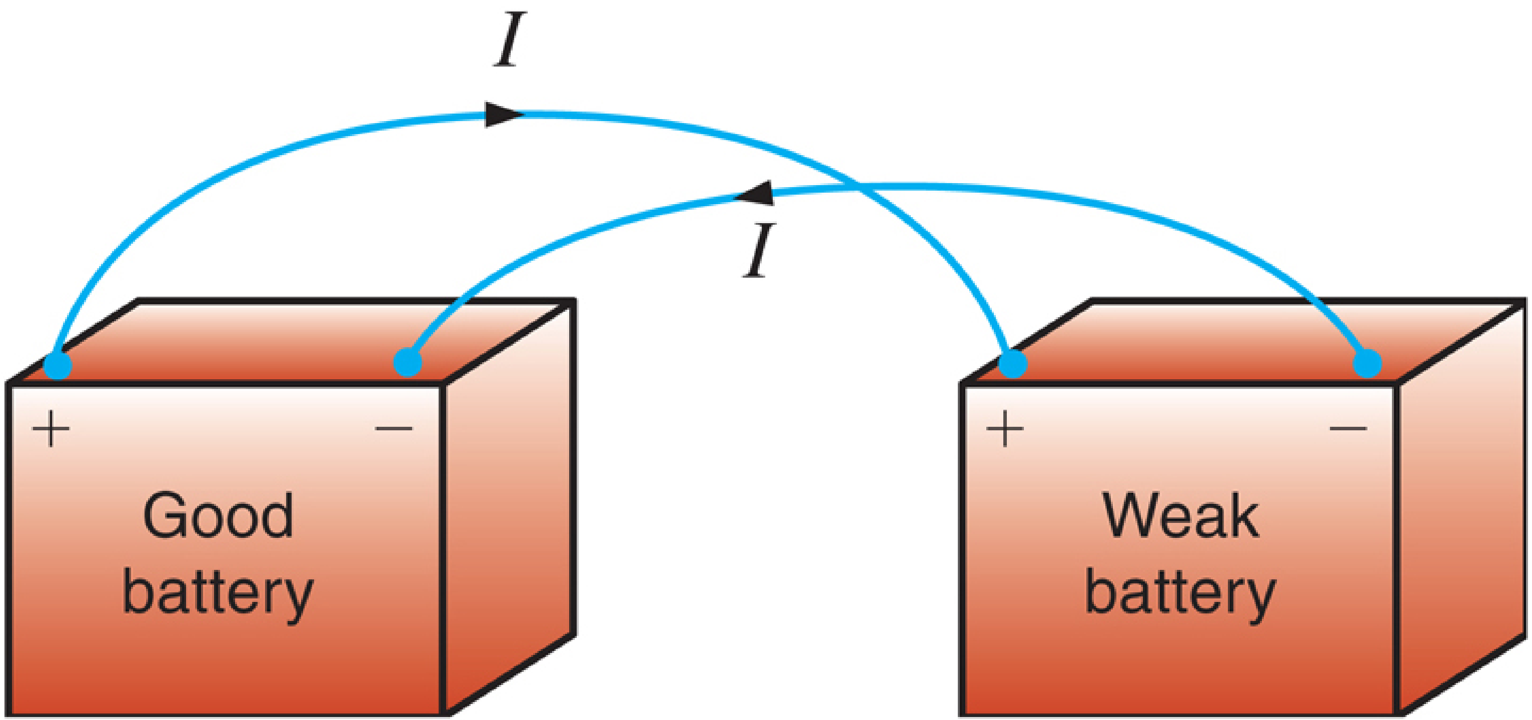
$V_{AB} > 0, I_{AB} < 0$

ON S_2

$V_{A'B'} > 0, I_{A'B'} > 0$

ON S2

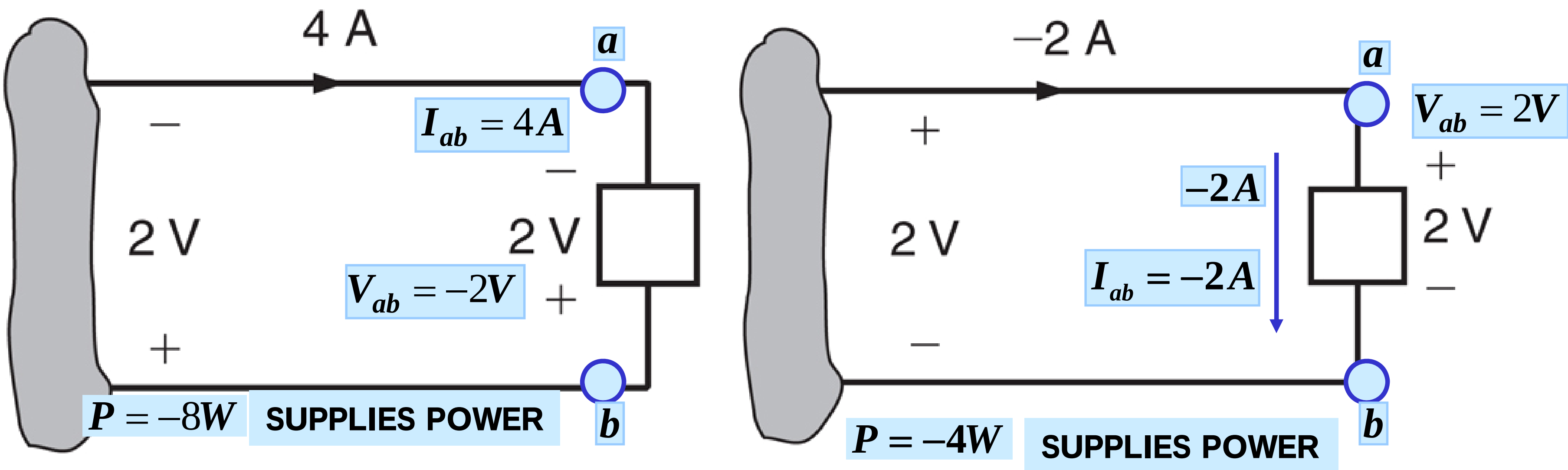
$V_{A'B'} < 0, I_{A'B'} > 0$



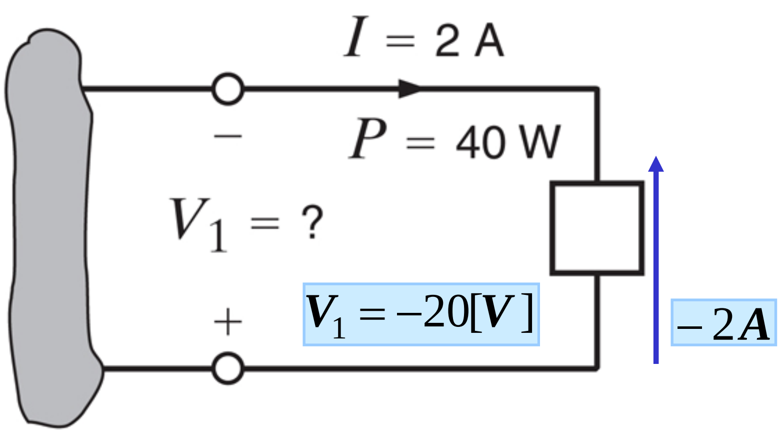
CHARGES RECEIVE ENERGY.
THIS BATTERY SUPPLIES ENERGY

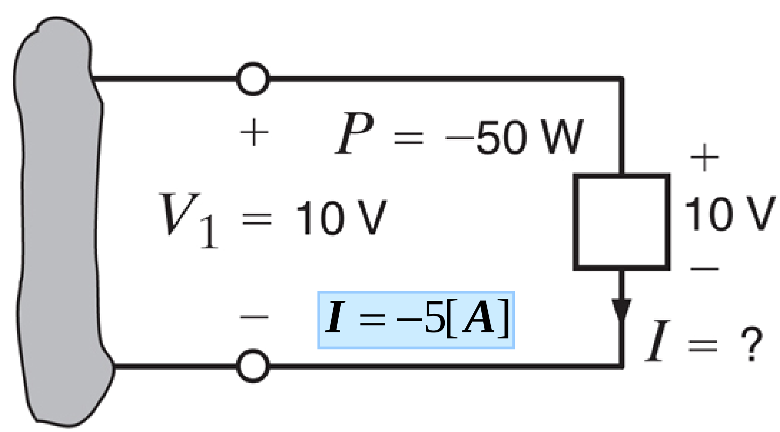
CHARGES LOSE ENERGY.
THIS BATTERY RECEIVES THE ENERGY

DETERMINE WHETHER THE ELEMENTS ARE SUPPLYING OR RECEIVING POWER AND HOW MUCH



WHEN IN DOUBT LABEL THE TERMINALS OF THE COMPONENT





$40[W] = V_1 \times (-2A)$

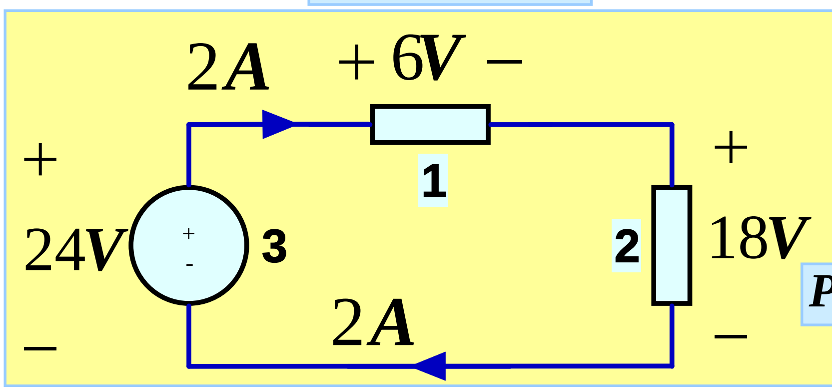
SELECT HERE THE CURRENT REFERENCE DIRECTION BASED ON VOLTAGE REFERENCE POLARITY

$-50[W] = (10[V]) \times I$

WHICH TERMINAL HAS HIGHER VOLTAGE AND WHICH IS THE CURRENT FLOW DIRECTION

COMPUTE POWER ABDORBED OR SUPPLIED BY EACH ELEMENT

$P_1 = (6V)(2A)$



$P_2 = (18V)(2A)$

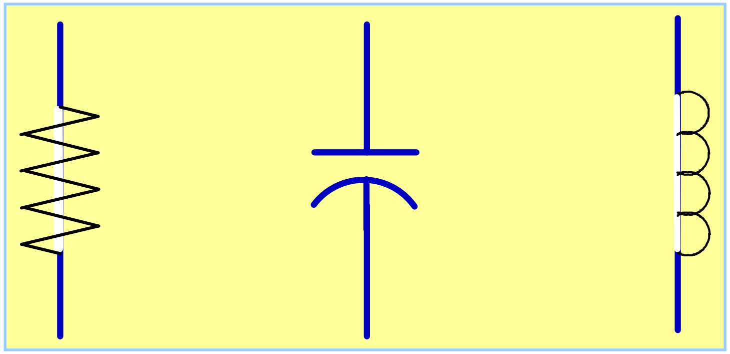
$P_3 = (24V)(-2A) = (-24V)(2A)$

P1 = 12W
P2 = 36W
P3 = -48W

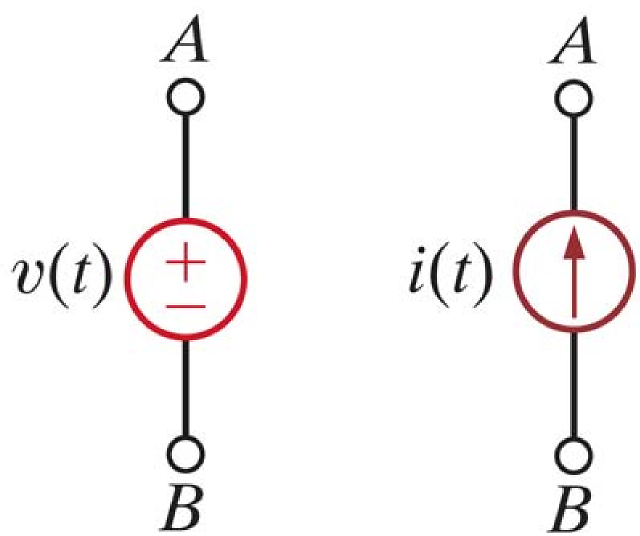
IMPORTANT: NOTICE THE POWER BALANCE IN THE CIRCUIT

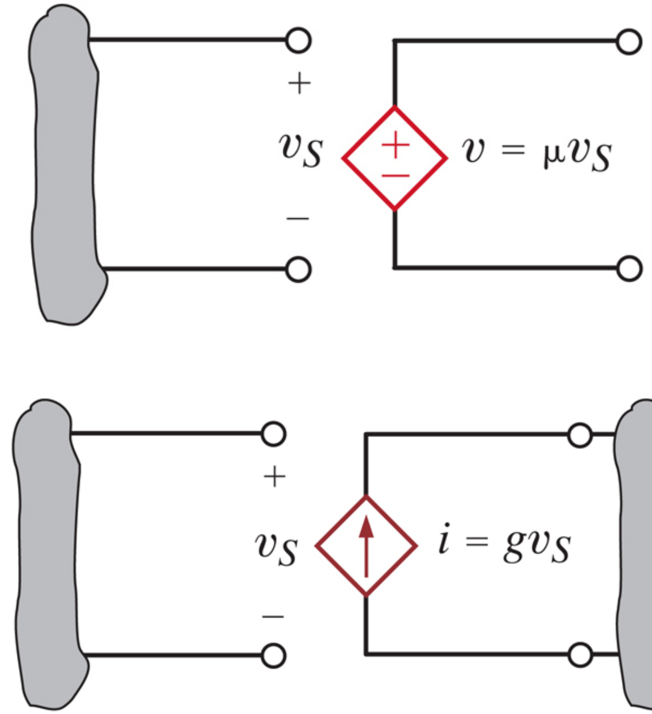
CIRCUIT ELEMENTS

PASSIVE ELEMENTS

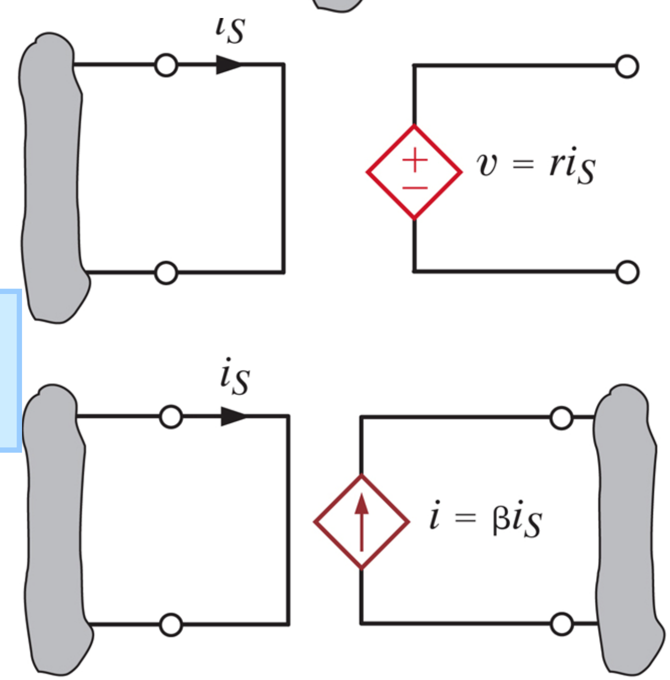


INDEPENDENT SOURCES





VOLTAGE DEPENDENT SOURCES



CURRENT DEPENDENT SOURCES