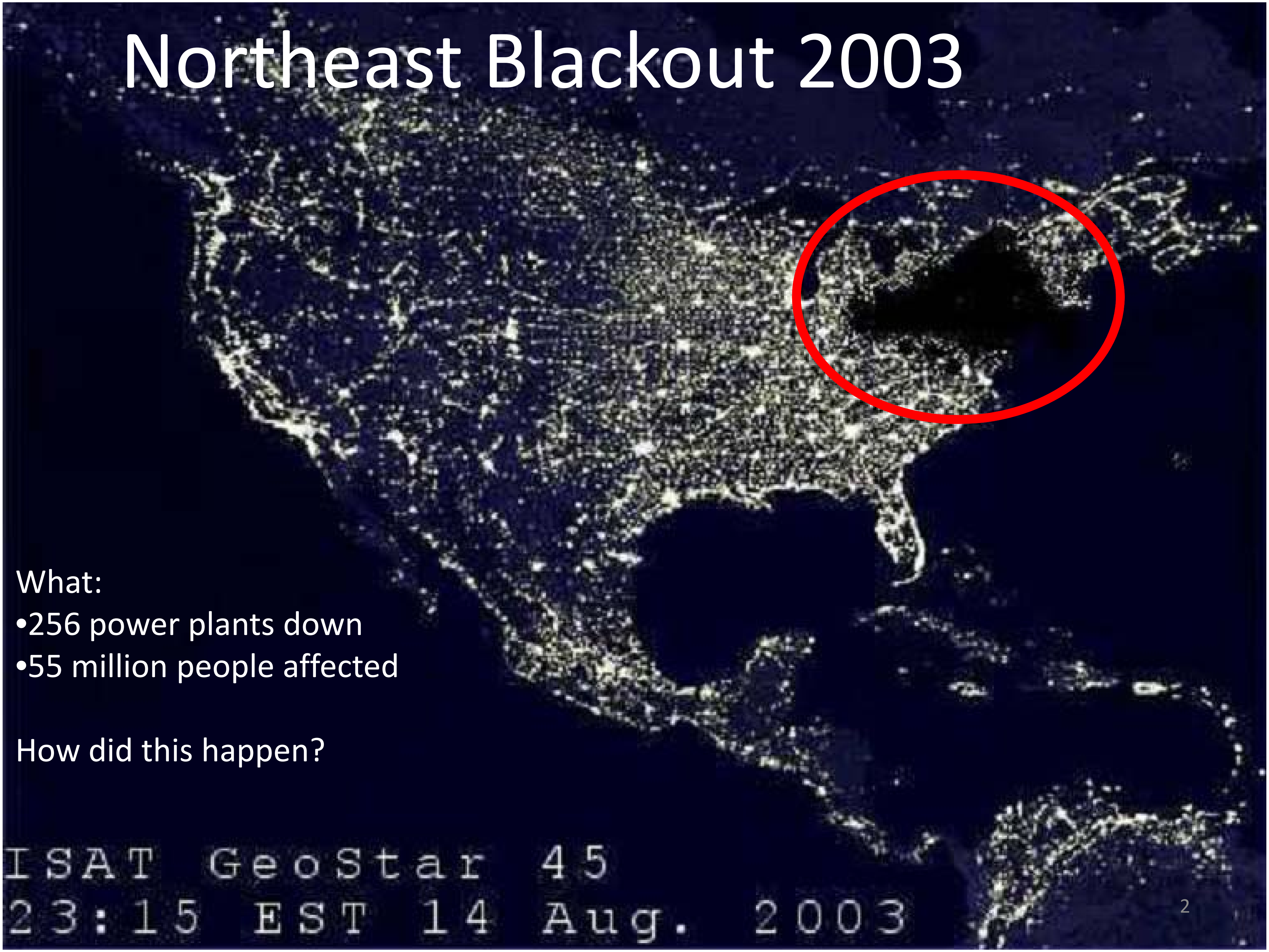
EECS 70A: Network Analysis

Lecture 1

Northeast Blackout 2003



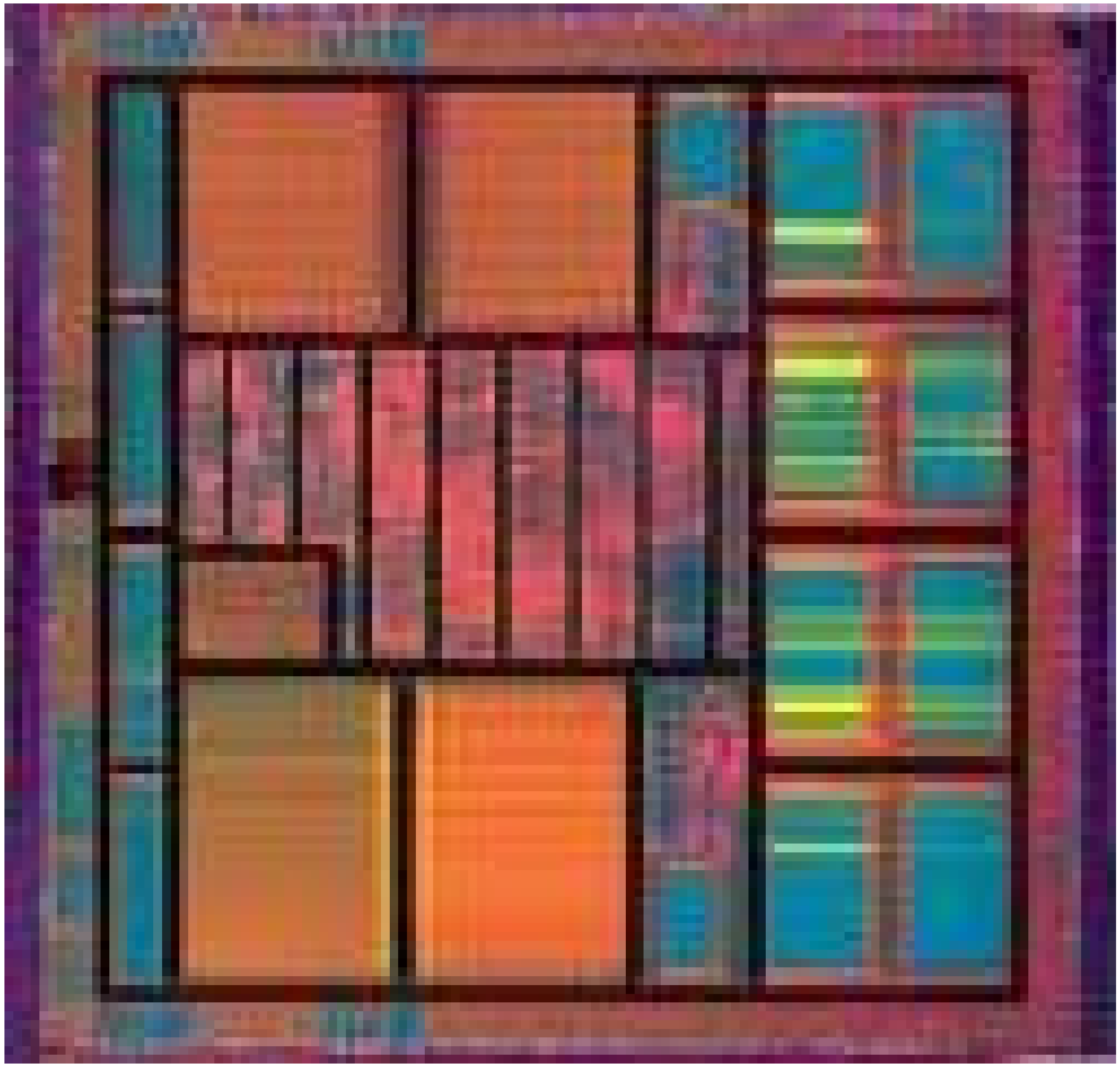
What:
- 256 power plants down
- 55 million people affected

How did this happen?

Power Networks

- How much power used?
- How do we quantify power?
- What if someone turns on one light?

Digital circuits



- How do we understand what every transistor is doing?
- There are *hundreds of millions…*

Simplifications

Leon Charles Thevenin
1857–1926

Edward Lawry Norton
1898–1983

Ultimate problem solvers: Take a complex system, break it into its component parts:

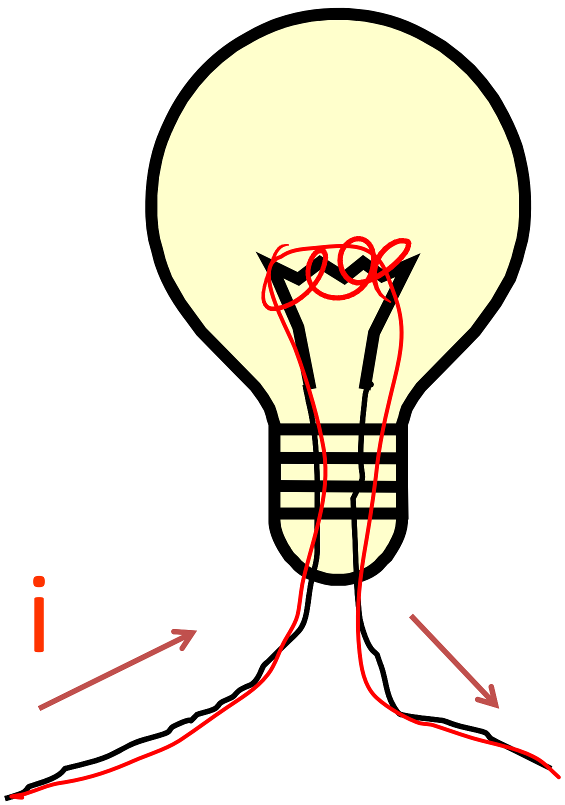
Network analysis

Current

DEMO…

Charge of an electron:

$e = -1.6 \times 10^{-19}$ Coulomb [C]



Current is flow of charge.

In a wire, charges are free electrons.

$$i = dq/dt$$

Amperes [A] = Coulombs/second [C]/[s]

Examples

1 electron per second flows past a plane.
What is the current? (instructor)

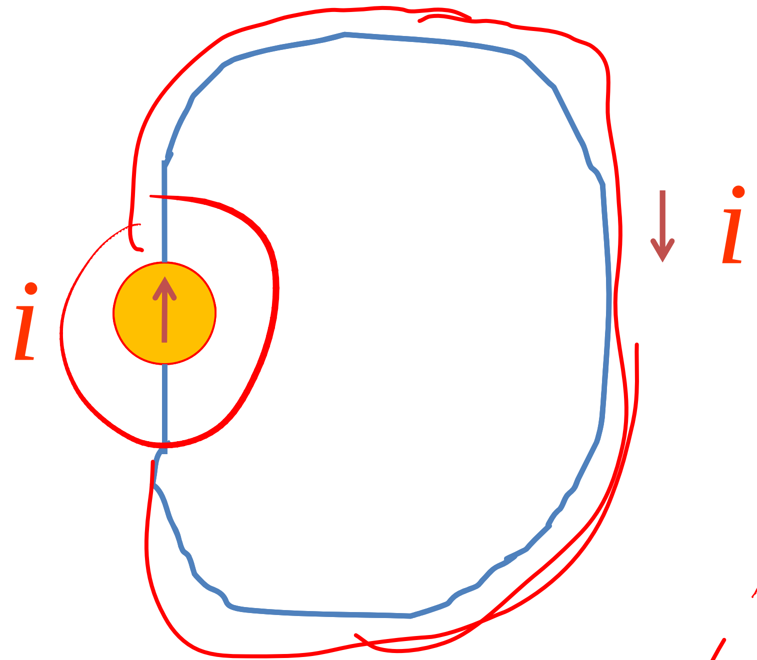
$$i = \frac{dq}{dt} = \frac{1.6\times10^{-19}\,C}{1\,sec} = 1.6\times10^{-19}\,\frac{C}{s} = 1.6\times10^{-19}\,A$$

10 A of current flows.
How many electrons per second flow past a plane? (students)

$$i = 10A = 10\,\frac{C}{s} \qquad \# = \frac{10\,C/s}{1.6\times10^{-19}\,C} = \frac{1}{1.6}\,10^{-18}\,\frac{1}{s}$$

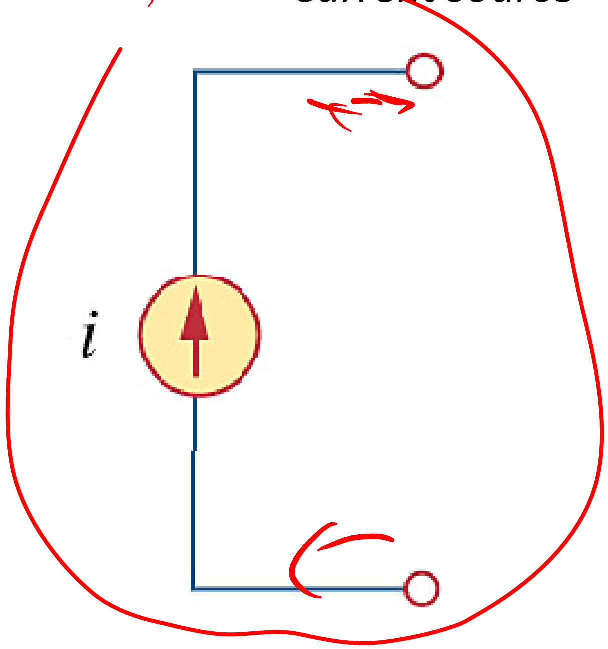
$$1.6\times10^{-19}\,C$$

Demo circuit: Current source



DEMO…

Our first circuit element:
Current source

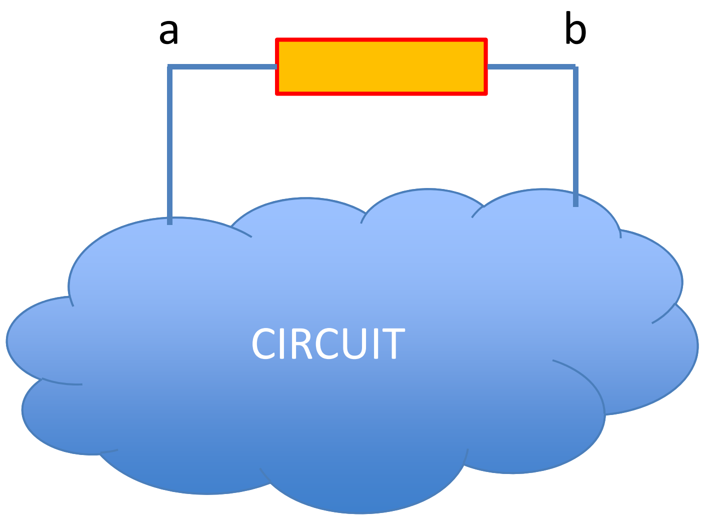


Voltage

Physically, how do we get electrons to move? Apply a force.

$$F = eE$$

$$\int_a^b E dx = V_{ab} = V_a - V_b = \Delta V$$



$V_{ab} \neq 0$ => electrons pushed a to b, causing current to flow

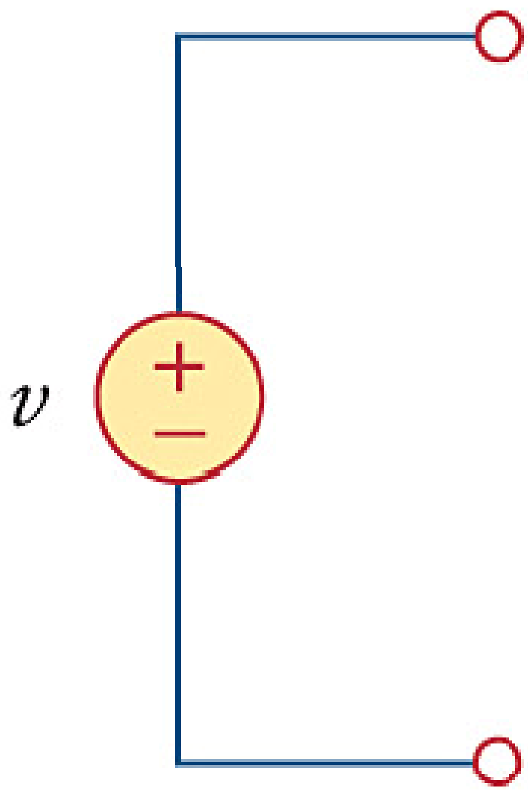
E electric field: Volts/meter [V/m]

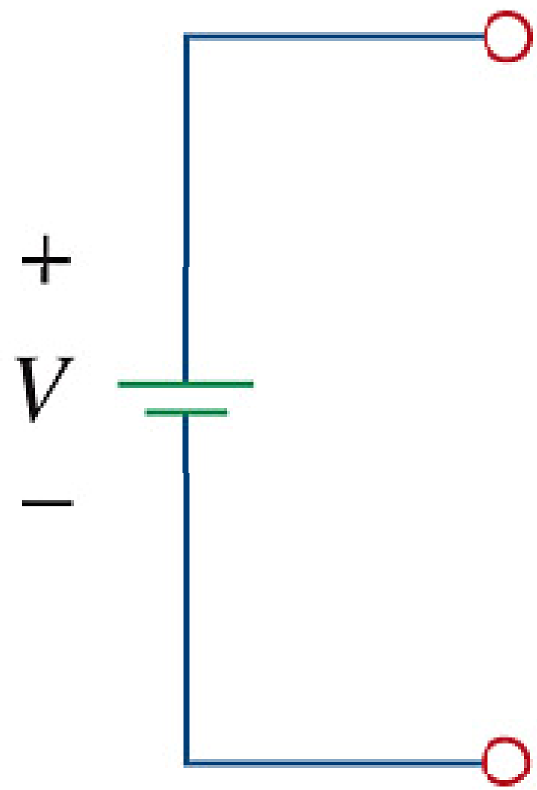
V voltage (aka potential difference): Volts [V]

Voltage source

Our next circuit element:

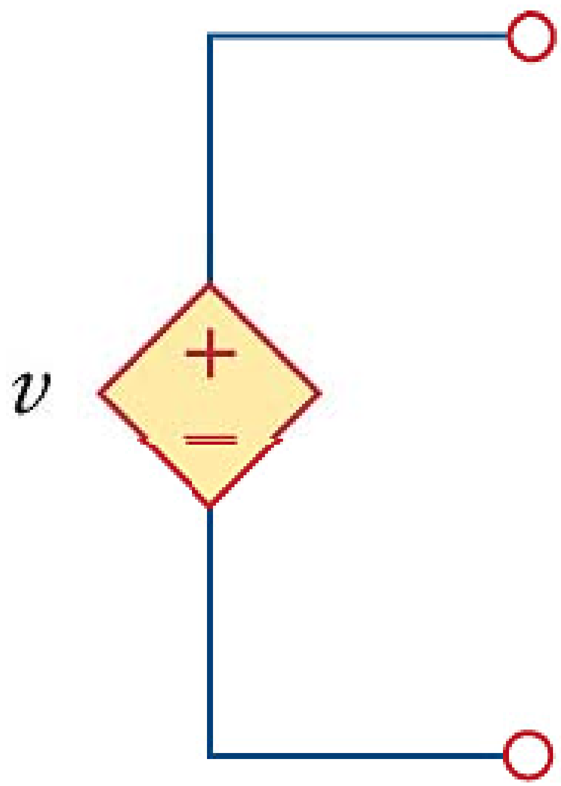
Voltage source



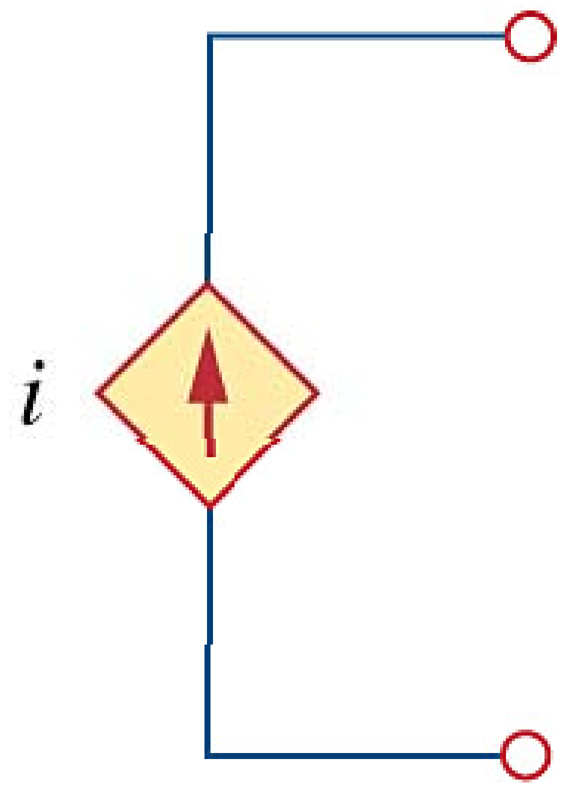


Makes V_{ab} constant, regardless of how much current flows through it.

Dependent sources



Value of voltage is determined by something somewhere else in circuit.

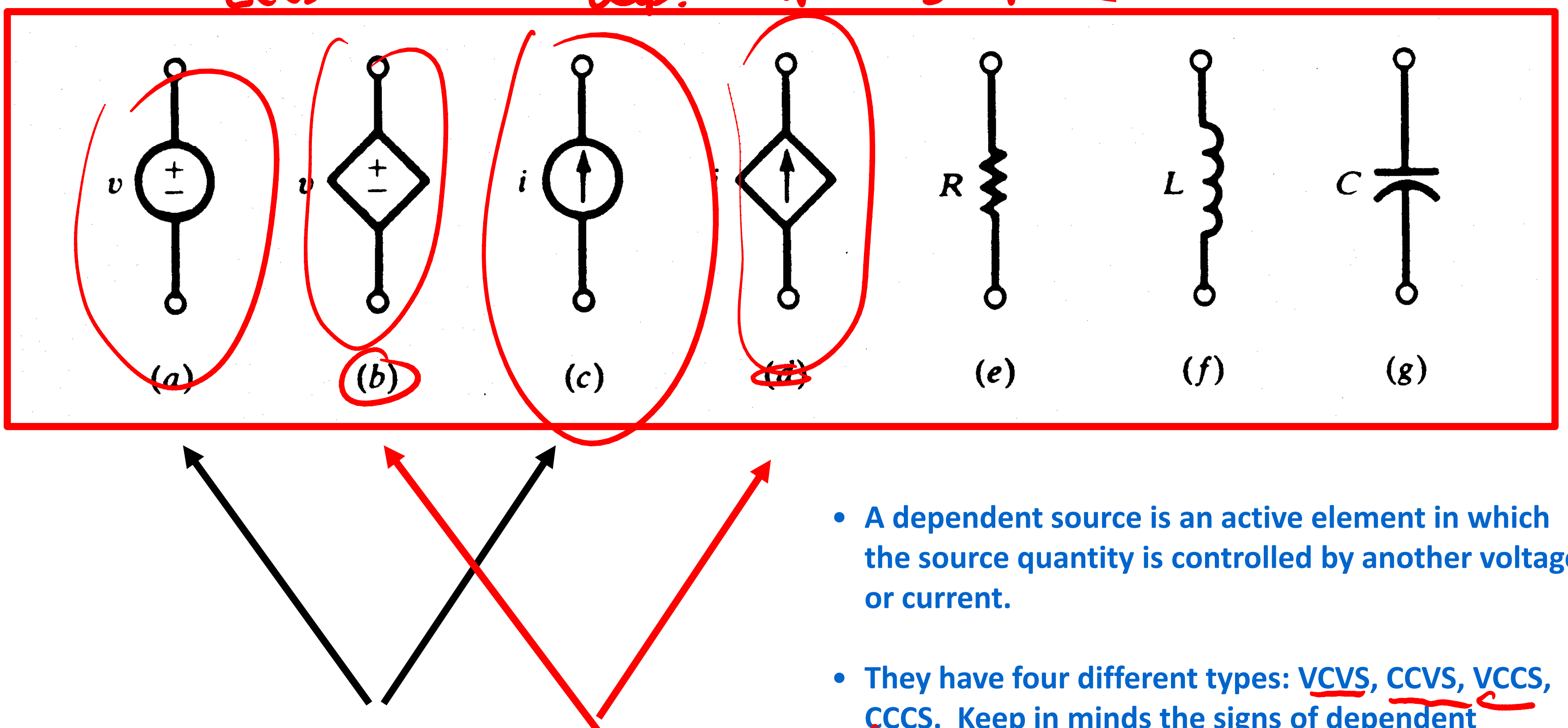


Value of current is determined by something somewhere else in circuit.

b [VCVS voltage dependent voltage source
CCVS curr. dep. volt source

Circuit elements

d [VCCS Voltage dep curr. source
CCCS curr. dep. curr source

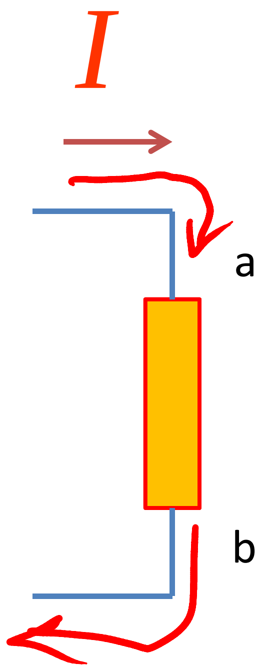


Independent sources

Dependent sources

- 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.

Power



$$I \times V_{ab} = power$$

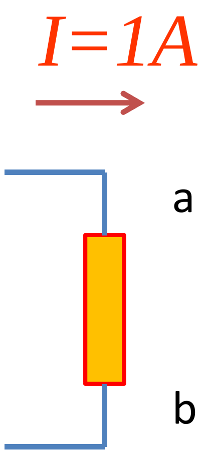
Watts [W] = Volt Amp [V-A]

Note: MKSA unit system:
Meters Kilogram Second Amp

MKSA ← C Coulomb, W watt, J Joule, V Volt

meter, kilogram, second, amp

Examples



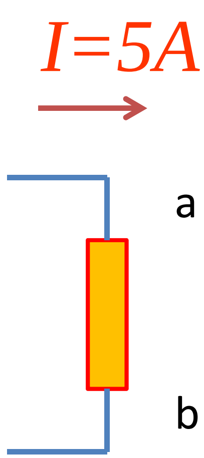
V_{ab} = 100 Volts

P = ?   (instructor)

current ↑, voltage ↗

$P = I V_{ab} = 1\,A \cdot 100\,V = 100\,A\text{-}V = 100\,W$

unit   unit



P = 10 W

V_{ab} = ?

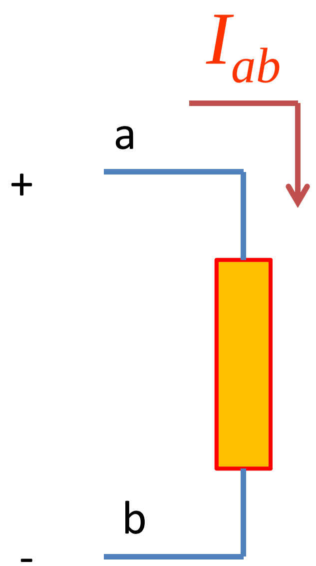
(students)

$V_{ab} = 2V$

$W = A\,V$

$P = IV \quad V = \frac{P}{I} = \frac{10W}{5A} = 2\,\frac{W}{A} = 2\,V$

Sign convention

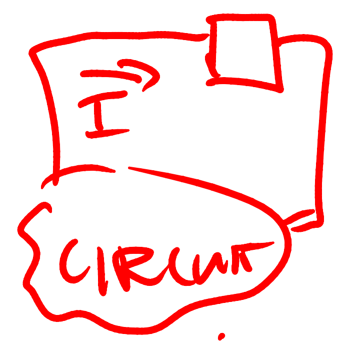


V_{ab} positive => $V_a > V_b$

I_{ab} positive => current flows from a to b

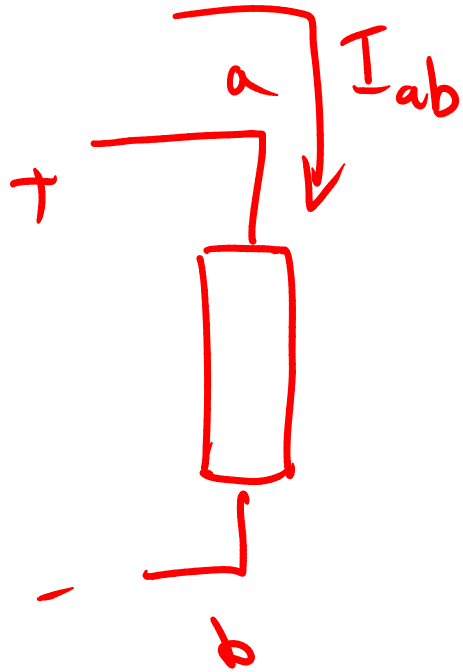
V_{ab} negative => $V_a < V_b$

I_{ab} negative => current flows from b to a



Define convention first, then solve problem.

P > 0 means power flowing into element (e.g. resistor)
P < 0 means power flowing out of element (e.g. battery)



CASE 1:

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

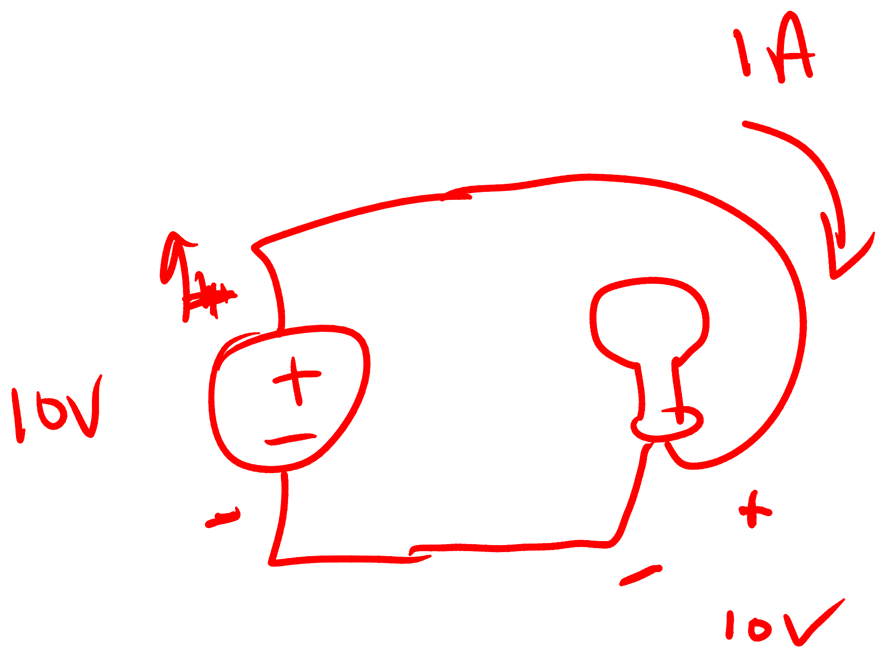
$I_{ab} > 0$, $V_{ab} > 0$ $\Rightarrow P > 0$

$\Rightarrow$ Energy Flowing <u>into</u> "element"

CASE II

$P < 0$ $\Rightarrow$ Energy flowing <u>out</u> of element

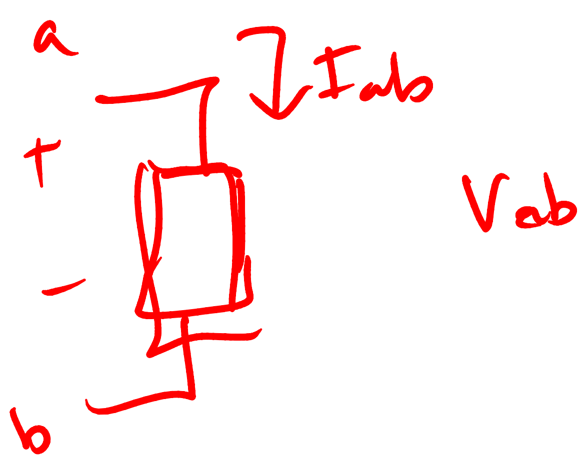
<u>Source</u>



$$P_{bulb} = 1A \times 10V = 10W > 0$$

$$P = 10V\,(-1A) = -10W$$

source



Example

V = 120 V @ socket (assume DC). → TRICK

Cost of electricity is 10 cents/kW-h

Day nothing, night 10 light bulbs on (100 W bulbs) for 1 hr.

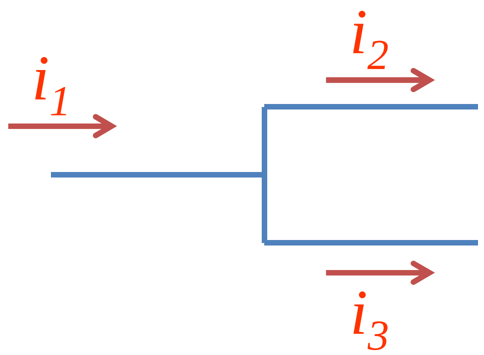
What is monthly electric bill?

(instructor)

$$P_{TOTAL} = 10 \times 100\,W = 1\,kW$$

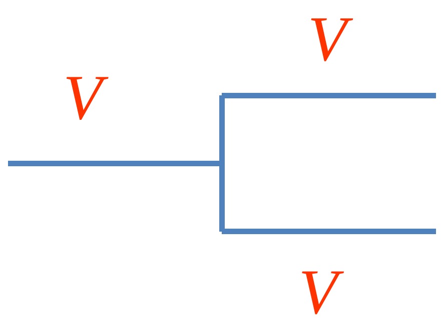
$$\$ = \frac{\$0.1}{kW\text{-}h} \cdot 1\,kW \cdot 1\,hour \cdot 30 = \$3$$

Topology



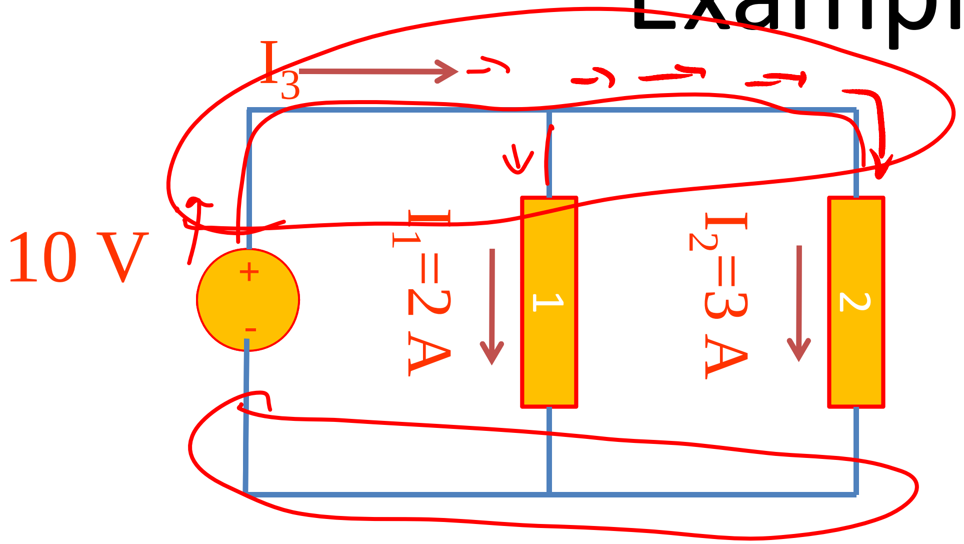
$$i_1 = i_2 + i_3$$

Like water in a river…



Voltage same everywhere….
Concept of a node

Example



I_3 = ?
$V_{element\ 1}$ = ?
$V_{element\ 2}$ = ?
Power supplied by source =?

(instructor)

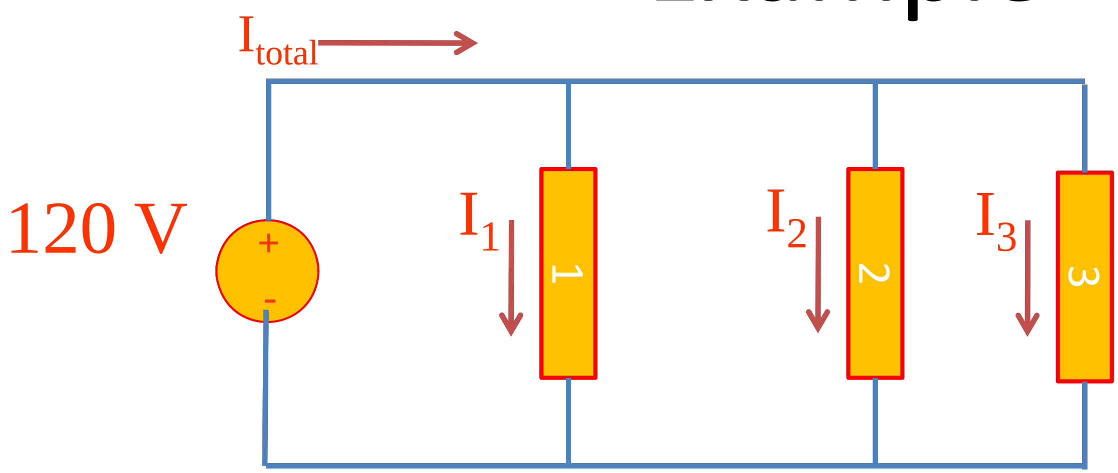
$I_3 = I_1 + I_2 = 2A + 3A = 5A$

$V_{element_1} = 10V$

$V_{element_2} = 10V$

$P = 10V(-5A) = -50W$

Example



(student)

Three light bulbs (100 W each) on 1 hour/night. 120 V @ socket.

a What is I per bulb? Hint $P_{bulb} = 100W = V_{bulb} I_{bulb} = \frac{5}{6}A$ (V_{bulb}: 120V)

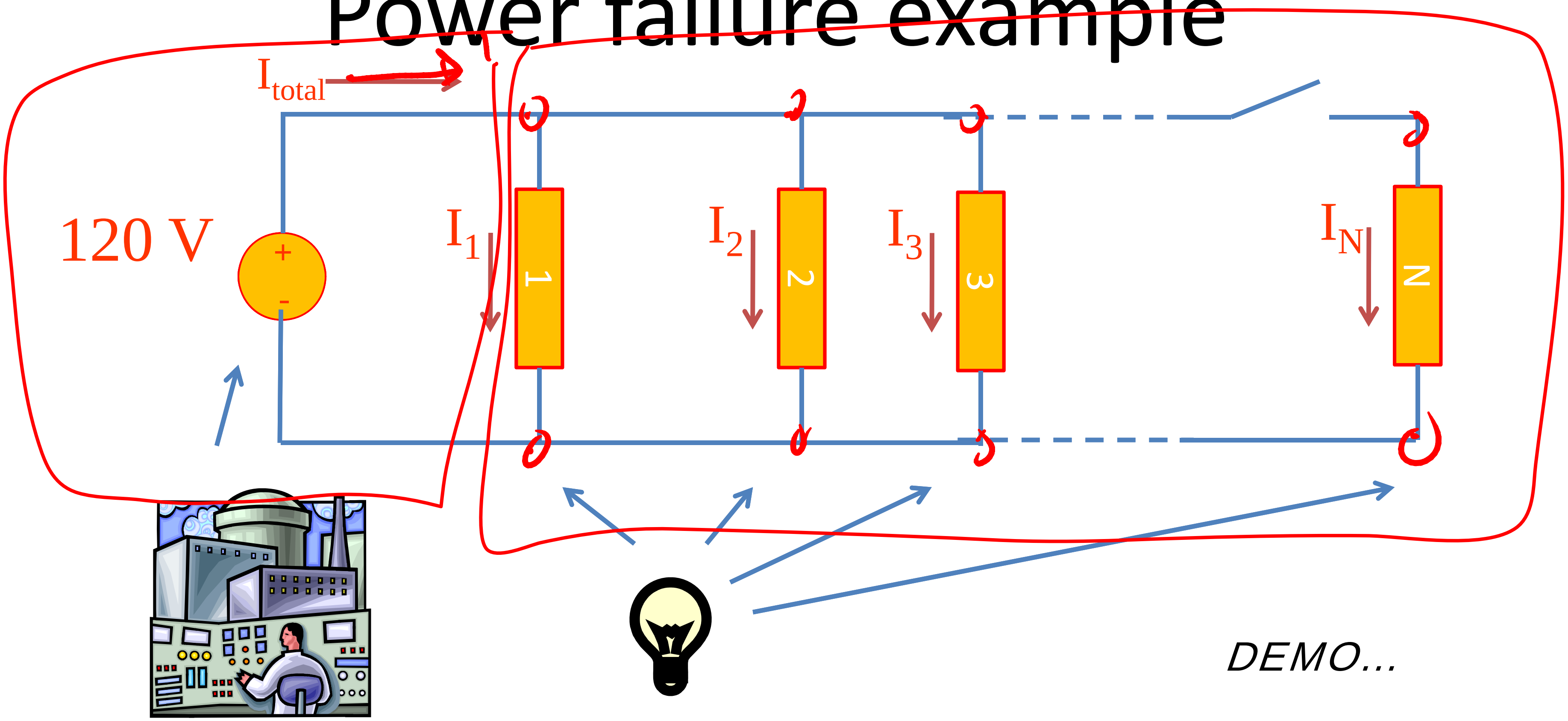
b What is I_{total} from supply? $I_{TOT} = \sum = \frac{5}{6}A + \frac{5}{6}A + \frac{5}{6}A = \frac{15}{6}A$

c ~~What is bill?~~

what is power sourced?

$120V \times \frac{15}{6}A = 300W$

Power failure example



Generator will fail of power required > 1 MW
How many light bulbs need to be turned on to damage the generator?