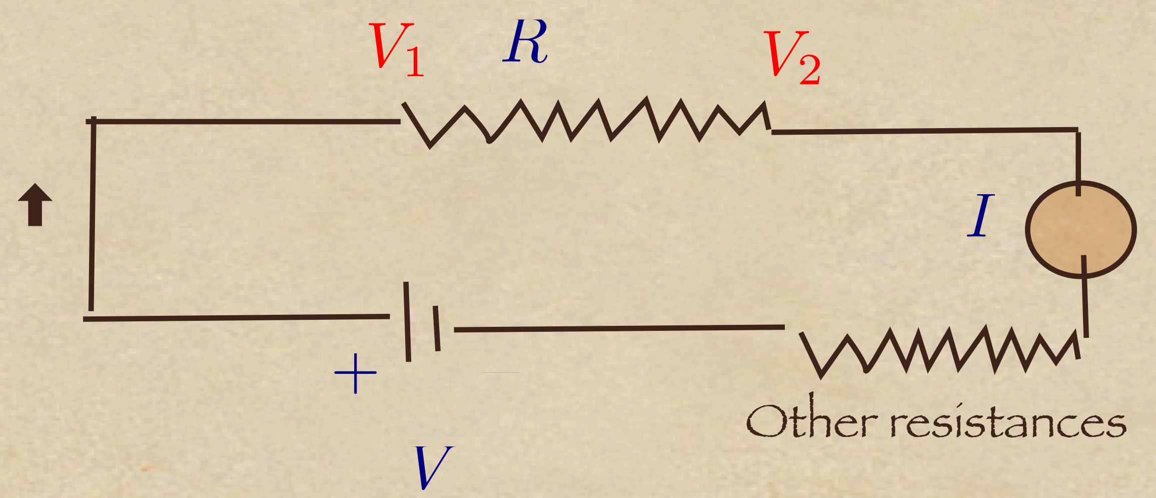
Lecture 15

May 4, 2012

Resistance and Ohm's law



$[R] = Ohms \;\rightarrow\; \Omega$

$V_1 - V_2 = I \times R$ Potential drop across R and current I are connected by Ohm's law

$P = (V_1 - V_2) \times I = I^2 \times R$ Power dissipated in (Joule) heating across R

Current, Voltage, and Power redux

$V = I \times R$ Ohm's law

$I = f(V)$ More general than Ohm's law

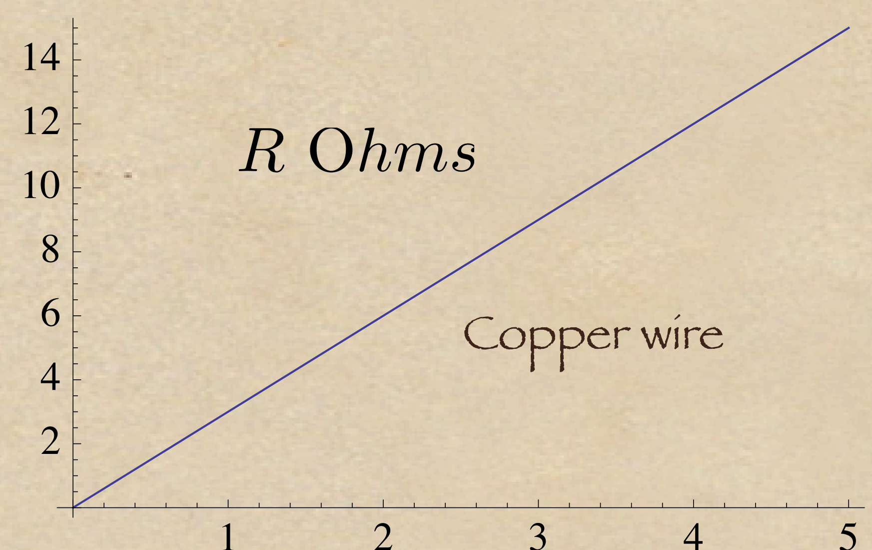
V= I x R Ohm's Law for resistances (Linear curves)

P= I^2 R for resistances

V Volts

I Amperes

$P = I\ V$ Power in Watts

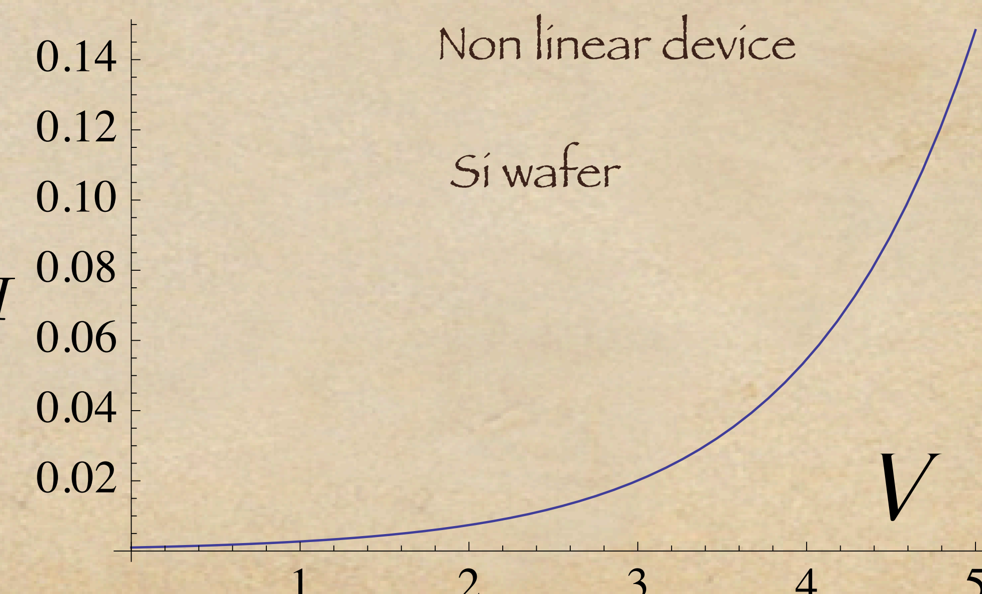


I

R Ohms

Copper wire

V



Non linear device

Si wafer

I

V

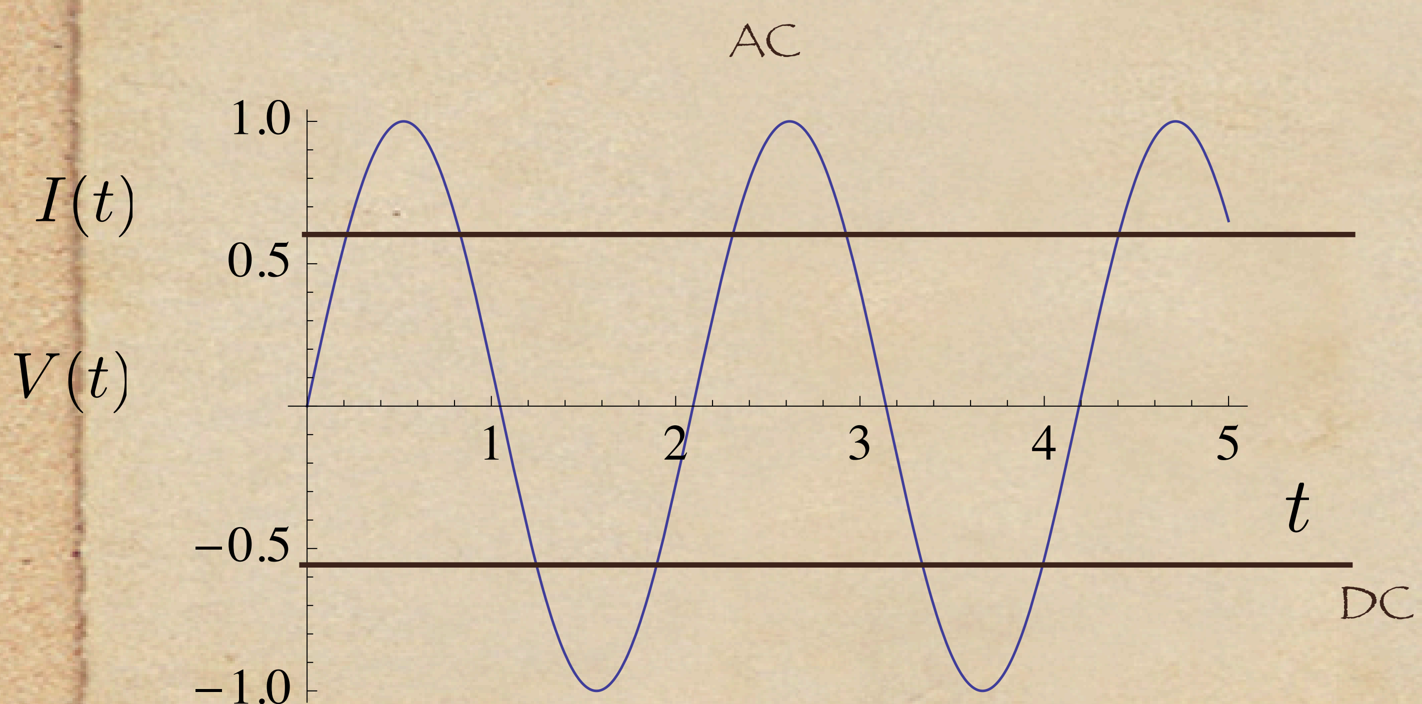
Household voltage 115 V (USA) 220 V (India) 240 V (UK)

DC = direct current

AC= alternating current

AC is much easier to generate using the idea of electromagnetic induction of Michael Faraday

Practical usage case: AC current and AC voltage, where these are time dependent



$$\sin(\omega t)$$

$$\omega = \frac{2\pi}{T}$$

Cycles per second

Household current

60 Hertz= 60 cycles per second

POWER and Energy used

$$P = I \times V \;\; Watts \qquad I \sim \; Amps, \& \; V \sim \; Volts$$

Joule Heating is covered in this equation

Example: 12 V battery drawing 10 amps current (high beam) consumes 120 Watts power

Combining Ohms law and Power equation, we can solve many problems.

$$V = I \times R \;\; (1)$$
$$P = I \times V \;\; (2)$$

P V R I

Four variables two equations
Hence given any two, the other two follow

1) Given Voltage Source

V

Connected to various resistances

R

$$I = V/R$$

$$P = V^2/R$$

II) Given Current Source

I

Connected to various resistances

R

$$V = IR$$

$$P = I^2R$$

III) Given Voltage Source

V

Connected to various appliances with given

P

$$I = P/V$$

$$R = V^2/P$$

Question:Given 1000 Watts toaster running for 5 minutes, what is the current drawn and energy used, and charges to PG&E!!!

$$V = 115\ Volts$$

$$I = 1000/115 = 8.7\ Amps$$

$$E = 1kW \times 5minutes \times 1\ hour/60minutes = .083kWH$$

$$\times .12\$\ per\ kwH$$

$$= .010\$$$

$$R = V^2/P = 13.2\ Ohms$$

Cooking range	12 kW
Heat pump	12 kW
Clothes dryer	5 kW
Oven	3.2 kW
Microwave Oven	1.5 kW
Hand Iron	1 kW
Room Airconditioner	1.6 kW
TV	.33 kW

Determining Joule heating losses

We would like to be able to calculate the losses to Joule heat in various situations.

Suppose a 1000 MW power plant sends its power out on a 800,000 V high voltage line. If the total resistance of the line is 2.2 Ω, what percentage of the electrical power will be lost due to Joule heating?

We may find the current in the transmission line, because we know that $P = IV$, so $I = P/V$:

$$I = \frac{P}{V} = \frac{1000 \text{ MW}}{800\,000 \text{ V}} = \frac{1\,000\,000\,000 \text{ W}}{800\,000 \text{ V}} = 1250 \text{ A}.$$

The power in Joule heating is found by $P_{\text{Joule heating}} = I^2R$,

$$P_{\text{Joule heating}} = I^2R = (1250 \text{ A})^2 \times 2.2\ \Omega = 3{,}437{,}500 \text{ W} = 3.44 \text{ MW}.$$

Hence $\frac{P_{\text{Joule heating}}}{P_{\text{transmitted}}} = \frac{3.44 \text{ MW}}{1000 \text{ MW}} = 0.344\%$ and so about one-third of a percent of the transmitted electric power is lost to Joule heating in this case.

Question: What is the voltage at the end of the line?
We will return to this interesting question soon!

How about a lower voltage?

Same problem but now we transmit the power on a 400 Volt line

$$I = \frac{P}{V} = \frac{10^9\ W}{400V} = 2.5 \times 10^6\ Amps$$

Joule Heating:

$$P_{Joule} = I^2 \times R = 2.2 \times 6.25 \times 10^{12} = 1.37 \times 10^{13} W$$

But !! $$P_{Generated} = 10^9 W$$

This is a big problem!

$$P_{Joule} = I^2 \times R$$

$$P_{Generated} = I \times V$$

$$P_{Joule} = P^2_{Generated} \times \frac{R}{V^2}$$

Big V is the solution.

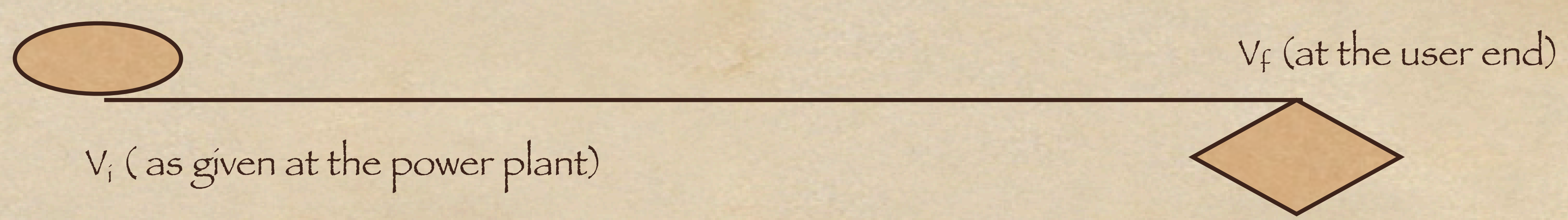
Comment: In using the above relations, we should note that the Ohm's law needs to be handled carefully:

In particular we cannot use

$$V = I \times R$$ Wrong formula

to calculate I from the given line voltage V and resistance R.

Key point is that the voltage line has a potential drop across its length:



$$V_i - V_f = I \times R$$ Correct formula