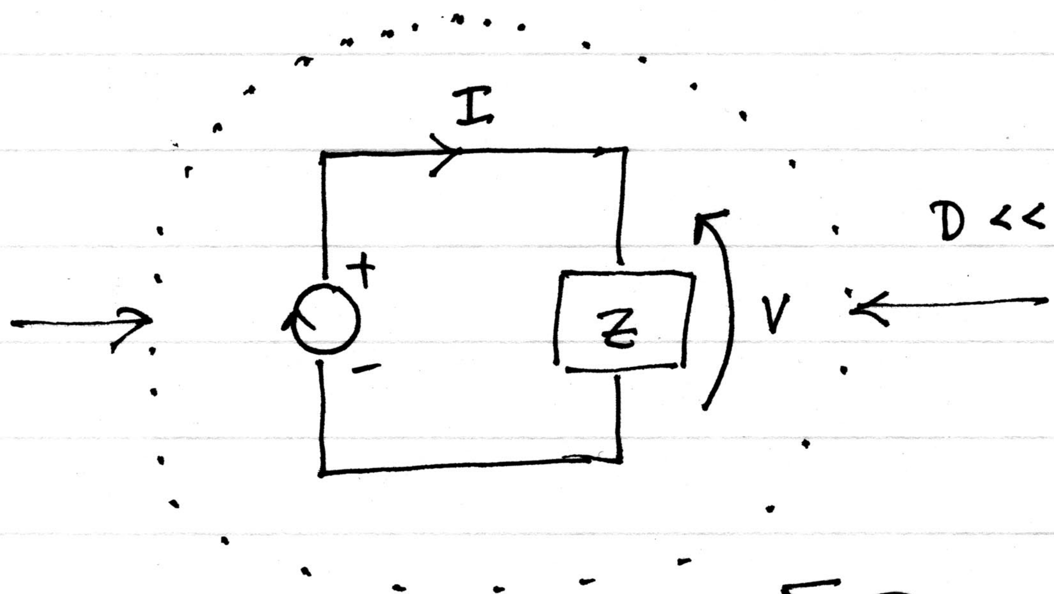
ORDINARY CIRCUIT



$$\sum I_i = 0$$

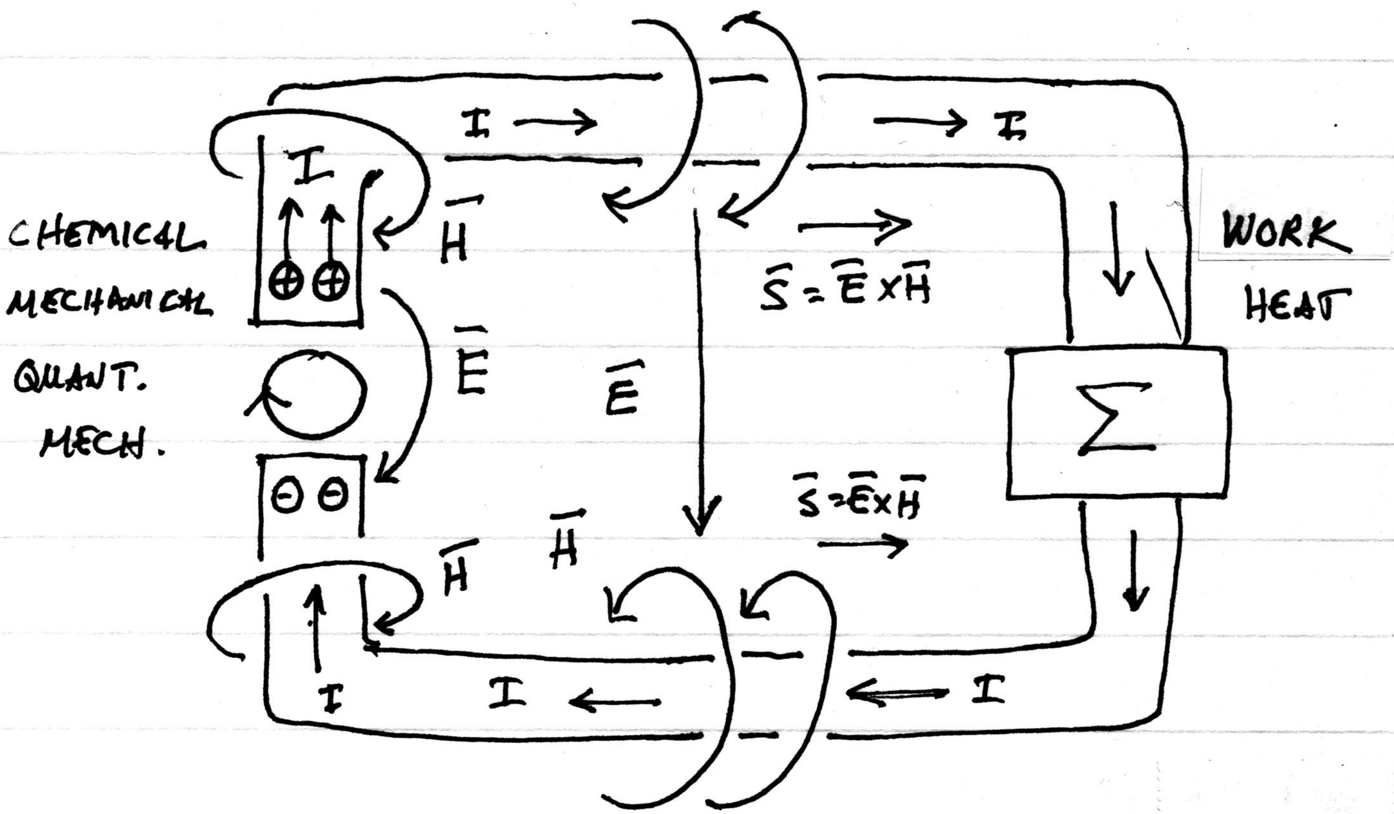
KIRCHHOFF

SUFFICIENT

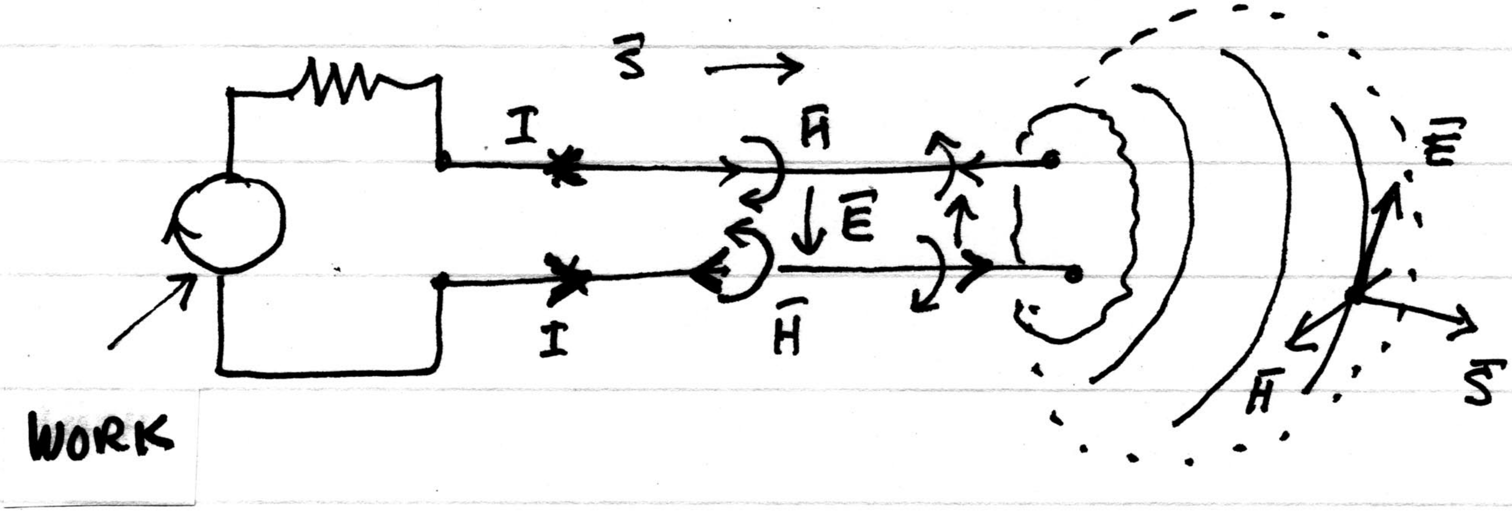
$$\sum V_j = 0$$

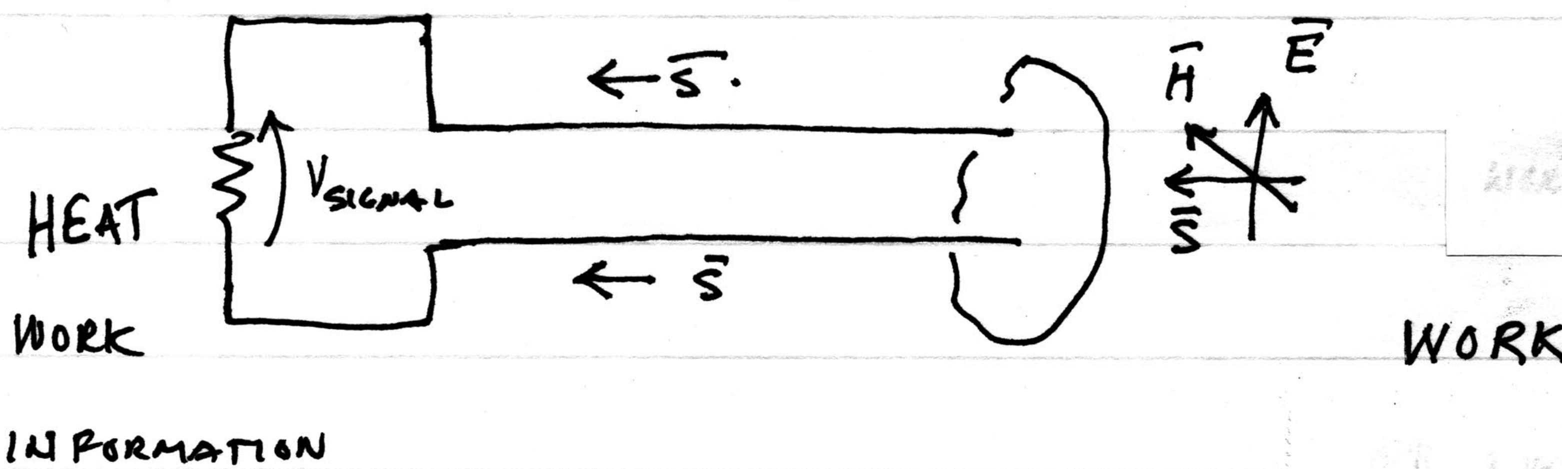
CIRCUIT FROM EM VIEWPOINT

TEM MODES



EXTENDED CIRCUITS :





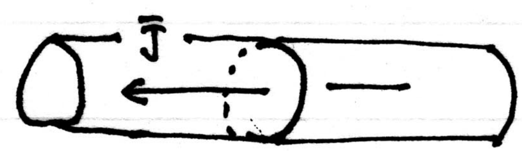
FUNDAMENTAL EM RELATIONS – REVIEW

Sources: $\rho(x, y, z, t)$ coulombs / m^3

charge density

current density

$\bar{J} = \bar{J}(x, y, z, t)$ amperes / m^2



current — I = amperes = coulombs / sec

/...

Maxwell's Equations, Differential form

$$\nabla \times \bar{E} = -\frac{\partial \bar{B}}{\partial t} \qquad \nabla \cdot \bar{E} = \rho/\epsilon$$

$$\nabla \times \bar{H} = \frac{\partial \bar{D}}{\partial t} + \bar{J} \qquad \nabla \cdot \bar{B} = 0$$

E volts/m = newtons/coulomb

H ampere-turns/m

D = $\epsilon \cdot E$ coulombs/m^2

B newtons/ampere-m

/...

$\bar{E}$ electric vector or electric field

$\bar{B}$ magnetic induction or magnetic flux vector

$\bar{E}, \bar{B}$ form electromagnetic field ($\bar{E}, \bar{H}$?)

$\bar{D}$ electric displacement

$\bar{H}$ magnetic field

$$\int_a^b \bar{H} \cdot \overline{dl}$$ magnetostatic potential

etc.

/...

$\nabla \cdot \bar{J} = -\frac{\partial \rho}{\partial t}$ conservation of charge

$\bar{B} = \mu \bar{H}$ permeability μ

$\bar{D} = \epsilon \bar{E} = \epsilon_0 \bar{E} + \bar{P}$; $\bar{J}_D = \dot{\bar{P}} + \epsilon_0 \dot{\bar{E}}$

permittivity ϵ

$q\, \bar{v} \times \bar{B} = \bar{F}_B$ $\epsilon_0 \doteq \frac{1}{36\pi} \times 10^{-9}$ (farads/m)

$q\, \bar{E} = \bar{F}_E$

$\mu_0 = 4\pi \times 10^{-7}$ henrys/m

$\epsilon \neq \epsilon_0$, $\mu \neq \mu_0$ in presence of charge, current

/...

Sinusoidal Steady State $\quad e^{+j\omega t}$ time variation

$$\left(\bar{H} = Re\left[\bar{H}(x,y,z) e^{j\omega t} \right] \right)$$

$$\nabla \times \bar{E} = -j\omega \bar{B} = -j\omega\mu \bar{H}$$

$$\nabla \times \bar{H} = j\omega \bar{D} + \bar{J} = j\omega\epsilon \bar{E} + \bar{J}$$

$$\nabla \cdot \bar{E} = \rho/\epsilon \quad , \quad \nabla \cdot \bar{H} = 0$$

μ constant
$\neq \mu(x,y,z)$

/...