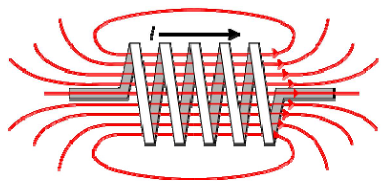
SIERRA COLLEGE

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

Class 12
Reactive Components I
Inductors



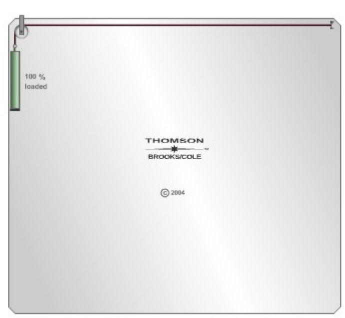
1

SIERRA COLLEGE

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Faraday's Experiment
  - Electromagnetic Induction



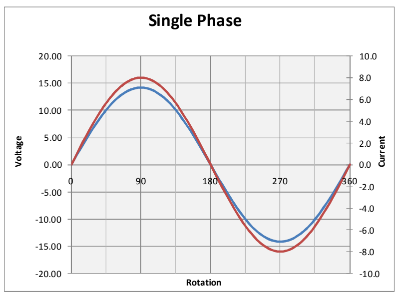
2

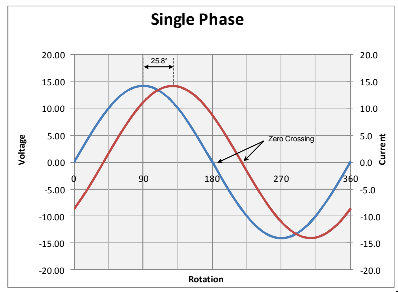
SIERRA COLLEGE

MECH 10
Fundamentals of Electronics

Mechatronics Real Skills Real Jobs

- Reactive Components
  - An electrical component that opposes changes in current or voltage
  - Causes a phase shift between current and voltage





3

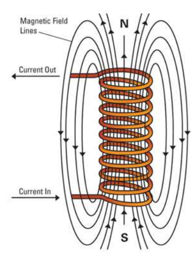
SIERRA COLLEGE

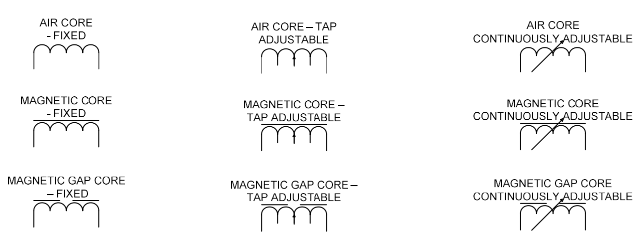
MECH 10
Fundamentals of Electronics

Mechatronics Real Skills Real Jobs

- Reactive Components
  - Inductor – a coil of wire that stores energy in it's magnetic field

$$E_{stored} = \frac{1}{2}LI^2$$





4

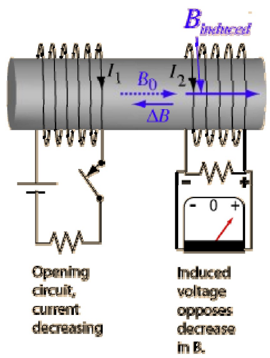
SIERRA COLLEGE

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Reactive Components
  - Inductance – the opposition to ***change*** in current

$$L = \frac{Wb}{A}$$



If the rate of change of current in a circuit is one ampere per second and the resulting electromotive force is one volt, then the inductance of the circuit is ***one henry.***

Name	Unit symbol	Quantity	Symbol
inductance	H	Henry's	L

5

SIERRA COLLEGE

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Inductance
  - Inductance is directly related to
    - Number of coil turns squared (N^2)
    - Cross-sectional area
    - Relative permeability (core)
  - Inductance is inversely related to
    - Length of coil

$$L = 12.57 \times 10^{-7} \times \frac{\mu_r N^2 A}{l}$$

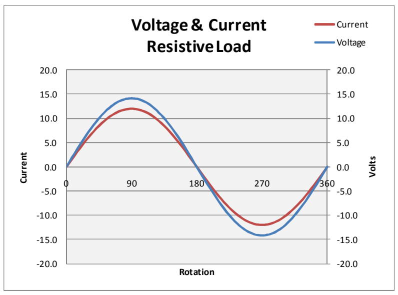
Where;
L = inductance (Henrys)
12.57E-7 = absolute permeability of air
μ_R = relative permeability
N = number of turns
A = cross sectional area (M^2)
l = length of coil

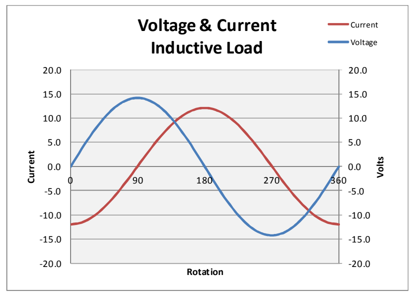
6

MECH 10
Fundamentals of Electronics

- Inductance
  - Induction phase shift
    - ELI – voltage leads current
    - 90° for a perfect inductor

Inductors react to changes in current by converting energy to/from a magnetic field

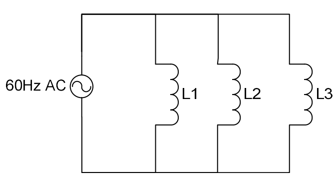




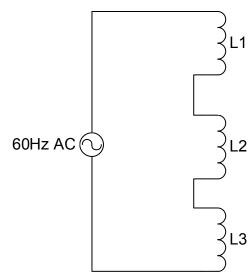
7

MECH 10
Fundamentals of Electronics

- Inductance
  - Series Inductance
    - Additive
  - Parallel Inductance
    - Double Inverse



$$L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots \frac{1}{L_n}}$$



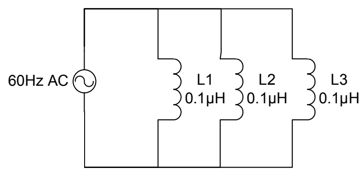
$$L_T = L_1 + L_2 + L_3 \ldots + L_n$$

8

MECH 10
Fundamentals of Electronics

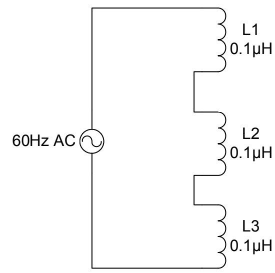
Mechatronics
Real Skills Real Jobs

- Inductance
  - Series Inductance Example
    - Find L_T (henrys, H)
  - Parallel Inductance Example
    - Find L_T (henrys, H)



$$L_T = \cfrac{1}{\cfrac{1}{L_1} + \cfrac{1}{L_2} + \cfrac{1}{L_3} + \ldots \cfrac{1}{L_n}}$$

$$L_T = ??H$$



$$L_T = L_1 + L_2 + L_3 \ldots + L_n$$

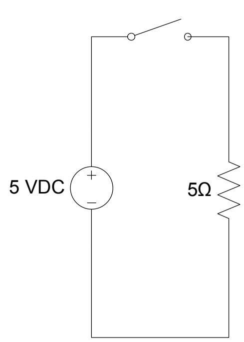
$$L_T = ??H$$

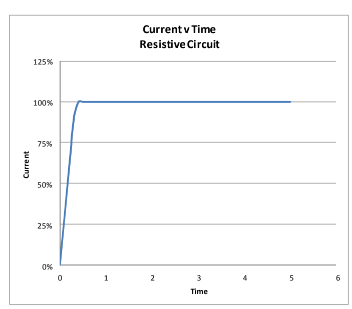
9

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Inductance
  - L/R Time Constant
    - The time required to charge an inductive circuit to full source voltage or to discharge it to no voltage



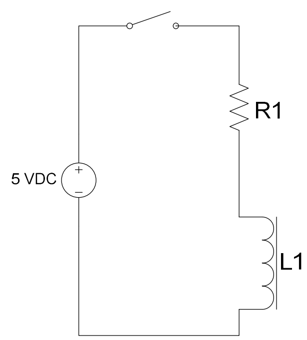


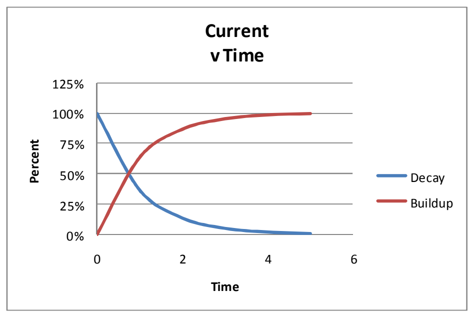
10

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Inductance
  - L/R Time Constant (tau)
    - 5 tau = the time required to charge or discharge an inductive circuit to full of source voltage or to no voltage



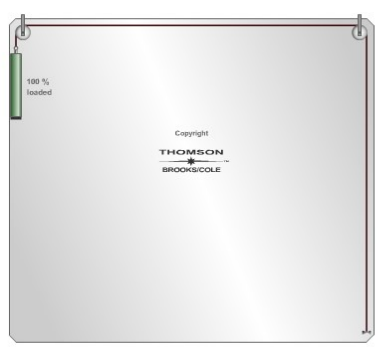


11

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Inductance
  - L/R Time Constant (τ)
    - 5 tau = the time required to charge or discharge an inductive circuit to full source voltage or to no voltage

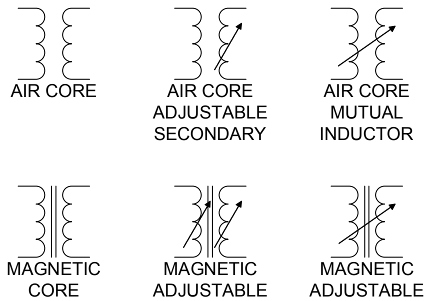


12

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Transformers
  - Transfer energy from circuit to circuit by electromagnetic induction



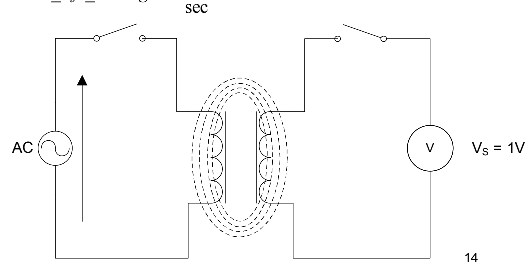
13

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Transformers
  - Mutual Inductance
    - 1 permeable core
    - 2 inductors (windings)
    - Changing current

$$Rate\_of\_Change = \frac{1Amp}{\sec}$$

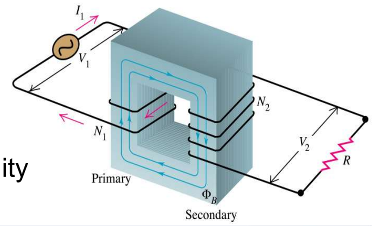


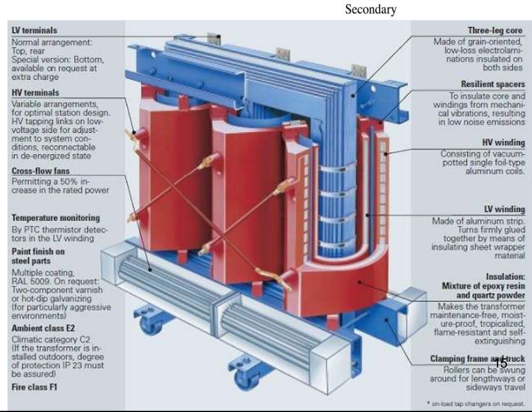
14

Mutual Inductance = 1 Henry

MECH 10
Fundamentals of Electronics

- Transformers
  - Mutual Inductance - Cores
    - Low reluctance, high permeability



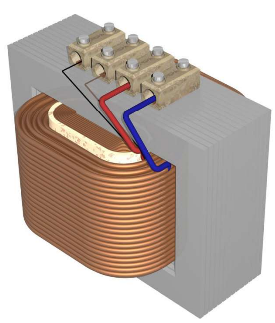


1 permeable core
2 inductors (windings)
Changing current

15

MECH 10
Fundamentals of Electronics

- Transformers
  - Mutual Inductance - Windings
    - Primary & Secondary
      - Concentric wound
      - Turns ratio
      - Multi-tap



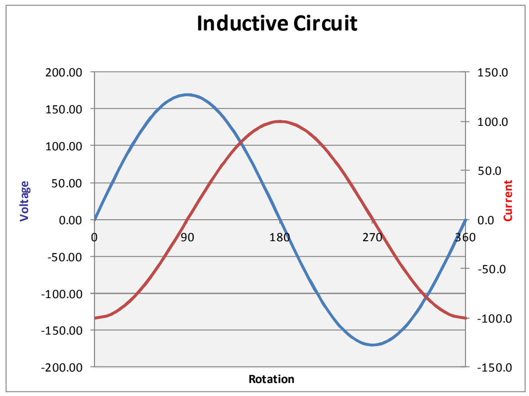
1 permeable core
2 inductors (windings)
Changing current

16

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

- Transformers
  - Mutual Inductance – Changing Current

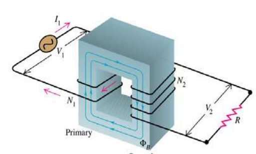


1 permeable core
2 inductors (windings)
Changing current

17

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs



- Transformers
  - Turns Ratios
    - Number of secondary windings divided by the number of primary windings
  - Voltage Ratio
    - Secondary to primary voltage ratio equals the turns ratio
  - Current Ratio
    - Secondary to primary current ratio equals the inverse turns ratio

$$\alpha = \frac{N_{Secondary}}{N_{Primary}}$$

α < 1 → step down xfmr
α > 1 → step up xfmr

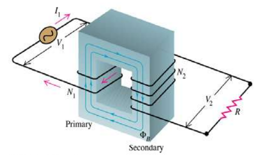
$$\frac{V_{Secondary}}{V_{Primary}} = \frac{N_{Secondary}}{N_{Primary}}$$

$$\frac{I_{Secondary}}{I_{Primary}} = \frac{N_{Primary}}{N_{Secondary}}$$

18

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs



- Transformers
  - Turns Ratio Example
    - A transformer has 100 secondary windings and 500 primary windings
    - Find the turns ratio (aka transformation ratio)

$$TR = \frac{N_{Secondary}}{N_{\Pr imary}}$$

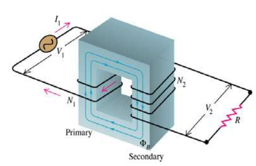
$$TR = \frac{100}{500} = ?\alpha$$

- Transformation Ratio
  - Step Up > 1
  - Step Down < 1

19

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs



- Transformers
  - Voltage Ratio Example
    - A transformer has a transformation ratio of 0.2 and a primary voltage of 120VAC
    - Find the secondary voltage

$$\frac{V_{Secondary}}{V_{\Pr imary}} = \frac{N_{Secondary}}{N_{\Pr imary}}$$

$$\frac{V_{Secondary}}{120V_P} = 0.200$$

$$V_{Secondary} = 0.200 \times 120V_P$$

$$V_{Secondary} = ??V$$

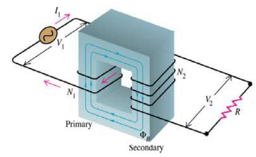
Step down transformer secondary voltage is reduced from primary

Step up transformer secondary voltage is increased from primary

20

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs



- Transformers
  - Current Ratio Example
    - A transformer has a 500 primary and 100 secondary windings. The primary draws 10 amperes.
    - Find the secondary current

$$\frac{I_{Secondary}}{I_{Primary}} = \frac{N_{Primary}}{N_{Secondary}}$$

$$\frac{I_{Secondary}}{10A_{Primary}} = \frac{500}{100}$$

$$I_{Secondary} = \frac{500 \times 10A}{100}$$

$$I_{Secondary} = ??A$$

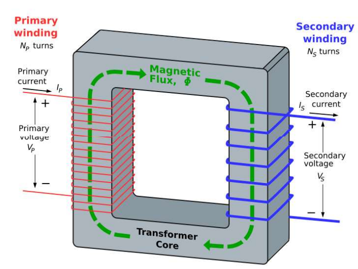
Step down transformer secondary current is increased from primary

Step up transformer secondary current is reduced from primary

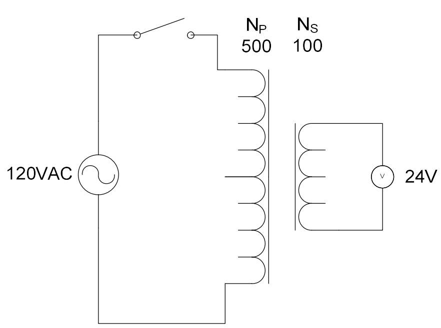
21

MECH 10
Fundamentals of Electronics

Mechatronics
Real Skills Real Jobs

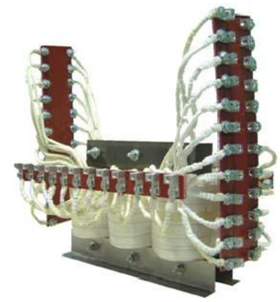


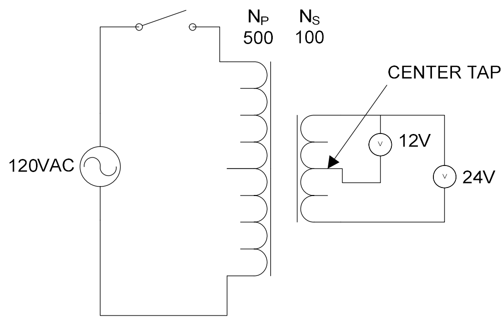
- Transformers
  - Single tap secondary – secondary wired to provide a single voltage output



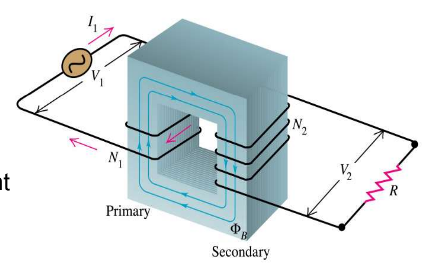
22

- Transformers
  - Multi-tap secondary – secondary wired to provide multiple voltage outputs





- Transformers
  - Losses
    - I^2R copper – from winding resistance, lost as heat
    - I^2R iron – from eddy current in core materials
    - Hysteresis – magnetic domain switching



$$Efficiency\ \% = \frac{Power_{out}}{Power_{in}} x100\ \%$$