BCT 2205 - Lecture 3

✓ **Inductors and Semiconductors**

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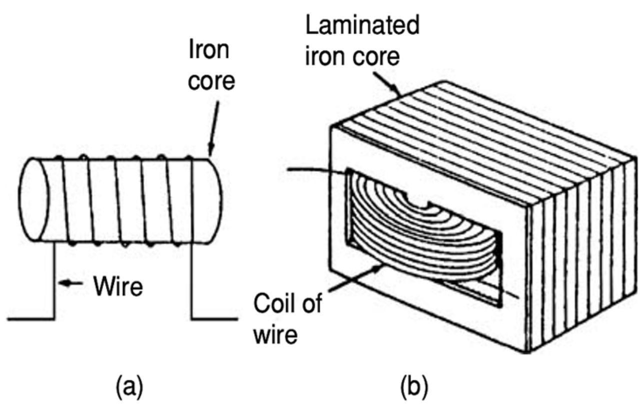
Inductors



- ***Faraday's law of electromagnetic induction***: a **varying** electric current flowing in a conductor produces a **magnetic field** around that conductor.
- The time-varying magnetic field induces a **voltage** in the conductor.
- ***Lenz law:*** the direction of induced EMF opposes change in current that created it.
- Hence, induced EMF is opposite to the voltage applied across the coil.

Inductance

- The **property of a coil to get voltage induced in it by change of current flow** is inductance.
- Inductance is obtained using

$$L = \frac{voltage}{rate\ of\ change\ of\ current}$$

- The unit of inductance is Henry (H).

- Induced EMF in a coil of N turns is,

$$\mathrm{V} = -\mathrm{N}\frac{\mathrm{d}\phi}{\mathrm{dt}}$$

$\frac{\mathrm{d}\phi}{\mathrm{dt}}$ is the rate of change of flux.

- Induced e.m.f. in a coil of inductance L is,

$$\mathbf{V} = -\mathbf{L}\frac{\boldsymbol{dI}}{\boldsymbol{dt}}$$

$\frac{dI}{dt}$ is the rate of change of current.

Examples

- Determine the e.m.f. induced in a coil of 200 turns when there is a change of flux of 25mWb linking with it in 50ms.

$$\mathrm{V} = \mathrm{N}\frac{\mathrm{d}\phi}{\mathrm{dt}} = 200\left(\frac{25\mathrm{m}}{50\mathrm{m}}\right) = 100\mathrm{V}$$

- What is the value of inductance of a coil that induces 20V when current through the coil changes from 12A to 20A in 2s?

$$\mathrm{V} = \mathrm{L}\frac{\mathrm{dI}}{\mathrm{dt}} \quad ; \quad 20 = \mathrm{L}\frac{8}{2} \quad ; \quad \mathrm{L} = \frac{20\mathrm{x}2}{8} = 5\mathrm{H}$$

- What is the rate of change of flux linking a 200-turn coil when 50V is across the coil?

$$\frac{d\phi}{dt} = \frac{V}{N} = \frac{50}{200} = 0.25\,Wb.s$$

Mutual inductance

- A **current carrying coil** produces magnetic field around it.
- If another coil is brought near this coil, such that it is in the magnetic flux region of the primary, the varying magnetic flux induces an EMF in the second coil.
- Mutual inductance - **EMF induced in the secondary coil due to varying magnetic field of the primary coil**.

- Calculate the mutual inductance between two coils when current changing at
200 A/s in one coil induces 1.5V in the other.

$$\mathrm{L} = \frac{V}{dI/dt} = \frac{1.5}{200} = 7.5\mathrm{mH}$$

- The mutual inductance between two coils is 18mH. Calculate rate of change of current in one coil to induce 0.72 V in the other.

$$V = L\frac{\mathrm{dI_1}}{\mathrm{dt}} \quad ; \; 0.72 = 18m\frac{\mathrm{dI_1}}{\mathrm{dt}}$$

$$\frac{\mathrm{dI_1}}{\mathrm{dt}} = \frac{0.72}{18\mathrm{m}} = 40\mathrm{A/s}$$

Inductors in series

- In a **series** connection,

i. total voltage is the addition of voltage drops at each individual inductance

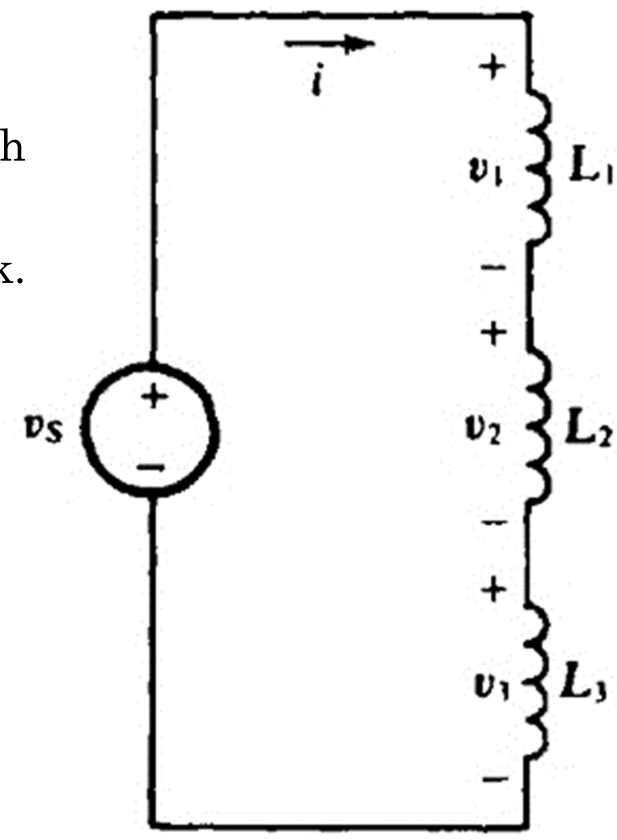
ii. current is same at all points throughout the network.

$$v_s = v_1 + v_2 + v_3$$

$$v = L\frac{di}{dt}$$

$$L_T\frac{di}{dt} = L_1\frac{di}{dt} + L_2\frac{di}{dt} + L_3\frac{di}{dt}$$

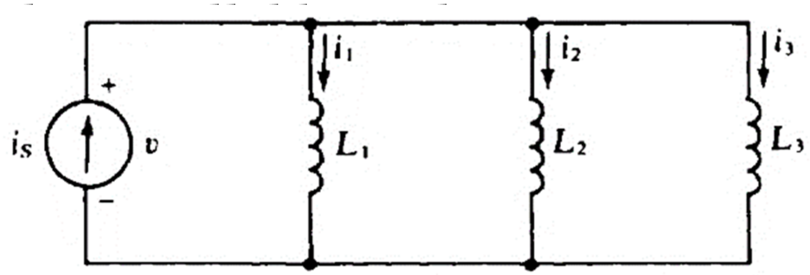
$$\boldsymbol{L_T = L_1 + L_2 + L_3}$$



Inductors in parallel

i. Applied voltage is same as voltage drop at each individual inductance

ii. Total current is the sum of individual currents flowing in



$$v = L_T \frac{di_s}{dt}$$

$$i_s = i_1 + i_2 + i_3$$

$$v = L_T \frac{d}{dt}(i_1 + i_2 + i_3)$$

$$v = L_T \left(\frac{di_1}{dt} + \frac{di_2}{dt} + \frac{di_3}{dt} \right)$$

- Using

$$\frac{di}{dt} = \frac{v}{L} \quad ; \quad \frac{v}{L_T} = \left(\frac{v}{L_1} + \frac{v}{L_2} + \frac{v}{L_3} \right)$$

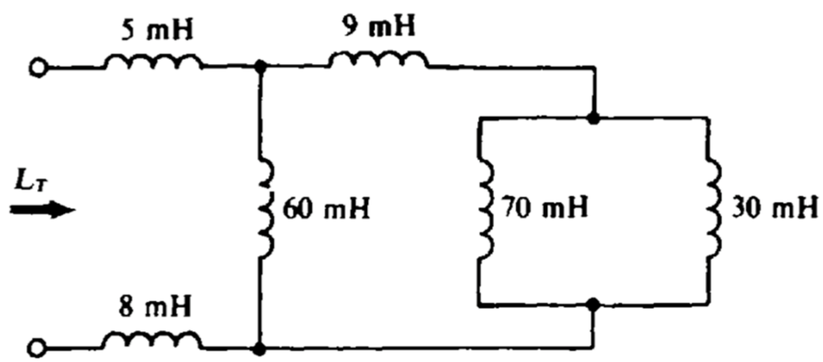
$$\mathbf{\frac{1}{L_T} = \left(\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \right)}$$

Examples

- Find total inductance of three parallel inductors: 45mH, 60mH, and 75mH.

$$L_T = \frac{1}{\frac{1}{45} + \frac{1}{60} + \frac{1}{75}} = 19.1mH$$

- Find total inductance of



- Parallel connection of 70mH and 30mH

$$\frac{70(30)}{70+30} = 21\, mH$$

- Add to 9-mH series inductor

$$21 + 9 = 30\, mH$$

- Parallel combination of 60mH and 30mH

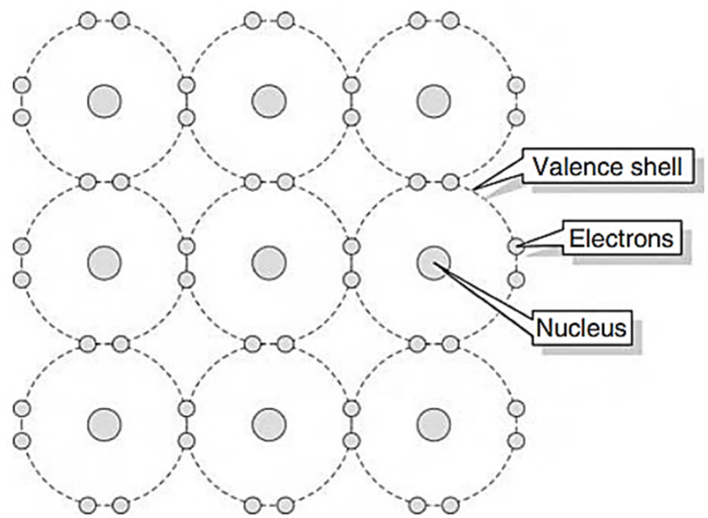
$$\frac{60(30)}{60 + 30} = 20\, mH$$

- Total inductance

$$L = 20 + 5 + 8 = 33\, mH$$

Semiconductor materials

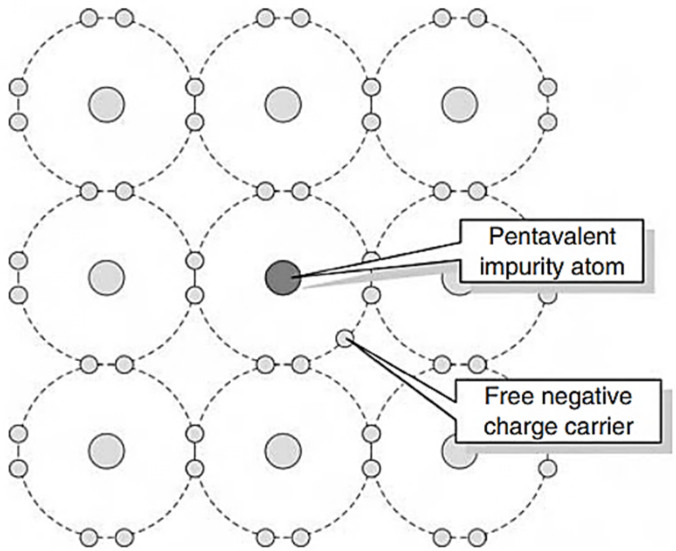
- An **atom contains** both **electrons** and **protons**. Electrons are negatively charged while protons are positively charged.
- Electron orbits are **organized into shells**.
- If the valence shell contains the **maximum number of electrons possible**, the electrons are **rigidly** bonded together, and the material is an insulator.

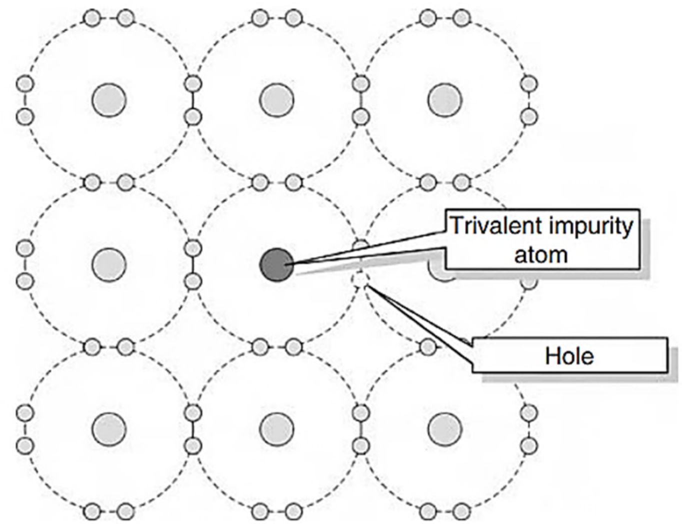


Semiconductor materials

- In its pure state, **silicon** is an insulator because the covalent bonding **rigidly** holds all electrons.
- If an impurity is introduced that has **five electrons** in its valence shell, a surplus **electron** is available for use as **charge carrier**.
- Similarly, if the impurity element introduced has **three electrons** in its valence shell, the absence of the fourth electron creates **holes**.
- The process of introducing an impurity into the lattice of a pure material is called **doping**.

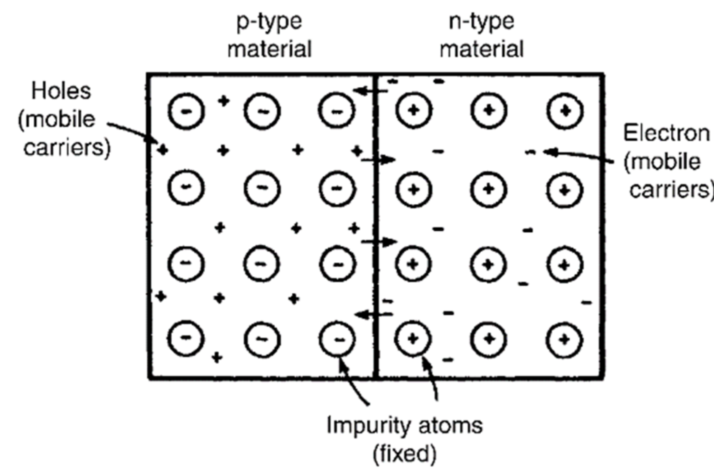
- When the pure material is doped with a **pentavalent** impurity such as phosphorus it will become an n-type (negative type) semiconductor.
- If the pure material is doped with a **trivalent** impurity such as aluminium, it will become a p-type (positive type) semiconductor.

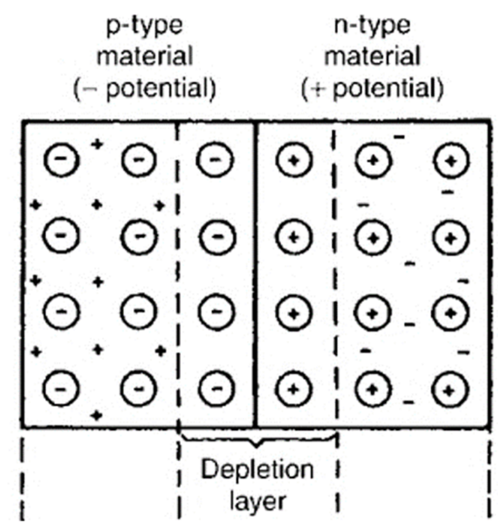




p-n junction

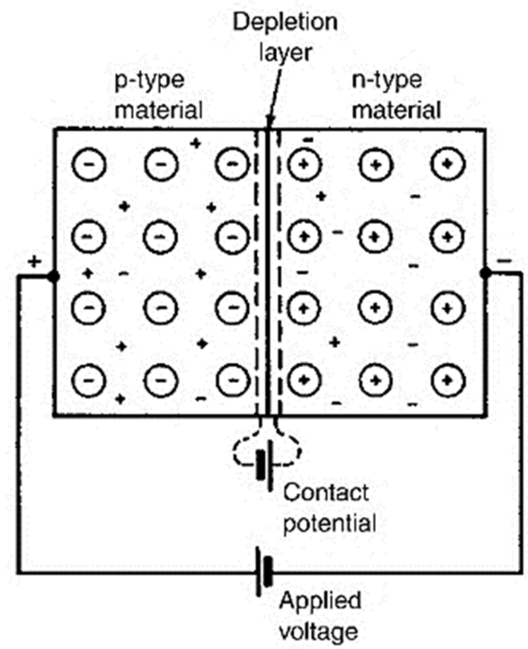
- If p-type and n-type materials are pushed together, **electrons in the n-type** material, **diffuse into the p-type** material and holes in the p-type material diffuse into the n-type material.
- **n-type** material has **lost** electrons, it acquires a **positive** potential.
- **p-type** material has **gained** electrons, it becomes **negatively** charged.
- After a short while, movement of electrons and holes stops due to the potential difference across the junction.





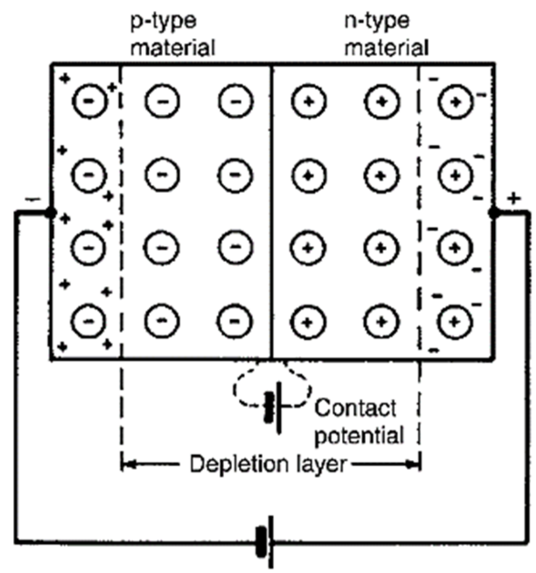
Forward bias

- When the **positive** terminal of a battery is connected to the **p-type** material and **negative** terminal to the **n-type** material, the pn junction is **forward biased**.
- Holes in the p-type material drift towards the junction. Electrons in the n-type material drift towards the junction.
- The width of the depletion layer is reduced.
- At about 0.6V, majority carriers begin to cross the junction and current starts to flow.

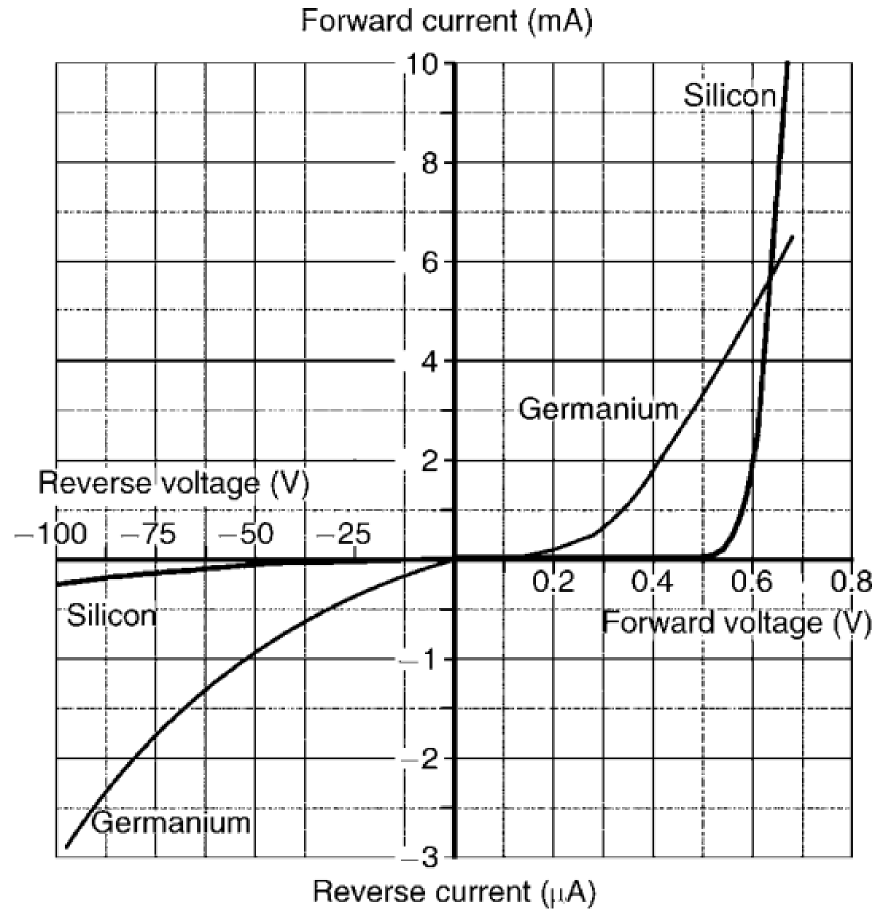


Reverse bias

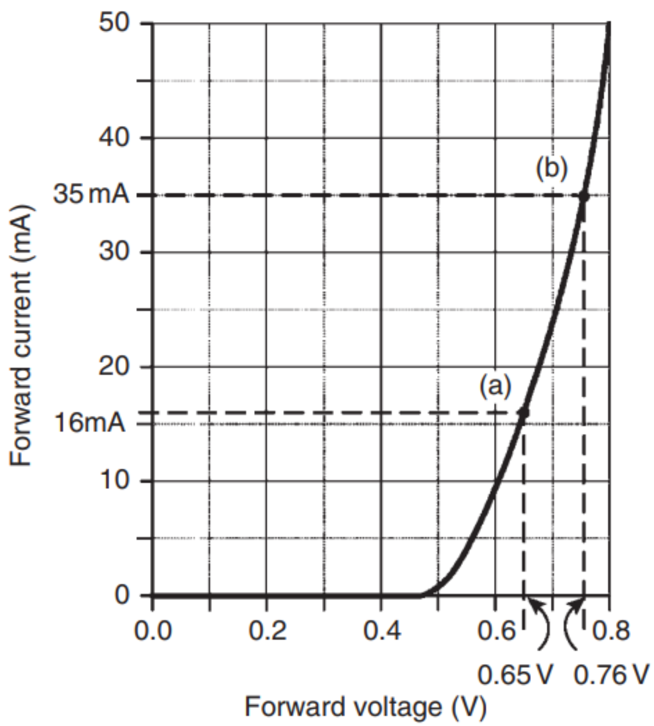
- When negative terminal of the battery is connected to the p-type material and positive terminal to the n-type material the diode is **reverse biased**.
- Holes in p-type material are attracted towards the negative terminal and electrons in n-type material are attracted towards the positive terminal.
- This drift **increases the thickness** of the depletion layer.
- Only very few majority carriers have sufficient energy to surmount the junction.



- In reverse bias, **thermally excited minority carriers** can cross the junction, resulting in a small current flowing.
- As reverse voltage is increased, a point will be reached where a large current suddenly starts to flow, called the **breakdown voltage**.



- For the characteristic shown, determine the **semiconductor** material, forward **current** when voltage is 0.65V and **voltage** when forward current is 35mA.



i. Device begins to conduct when 0.6V is applied to it. We can infer that the semiconductor material is **silicon**.

ii. When the forward voltage is 0.65V, the forward current = 16 mA

iii. When the forward current is 35 mA, the forward voltage = 0.76V.

End of session

Questions....?