COURSE TITLE: PHYSICALELECTRONICS
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MODULE 1.0

1.1 Atomic Theory

Matter is composed of elements, and elements are made up atoms. The atom is regarded as the smallest part of an element which retains the physical and chemical identity of that element. Up to the present time, 105 elements have been identified and the atoms of all these elements are made of various numbers of the fundamental particles known as the proton, neutron and electron.

1.2 Bohr Theory

Bohr in 1913 proposed the following postulates:

- The atom has certain energy state for which electrons revolve in stable orbits and do not radiate. The angular momentum of the electron in a stable orbit is an integral multiple of $h/_{2\pi}$, where h is planck's constant.
- An electron can move from a low energy state W_1 to a higher energy state W_2 by the absorption of electromagnetic energy, or it can move a high energy state W_2 to a lower energy W_1 by radiating electromagnetic energy at a frequency f given by $f = (W_2 - W_1)/_{h}$.

1.3 Wave Mechanics

Electromagnetic radiation was known to behave both as a wave and as a particle. This wave-particle duality was extended in 1924 by de Broglie to other particles such as the electron, atoms and matter in general. He showed that a particle, such as an electron, with mass m and moving with velocity v can be associated with a wavelength λ given by the de Broglie equation

$$\lambda = h/mv$$

or

$$\lambda = \ h/p$$

Where p is the momentum of the electron and h is Planck's constant.
This result, when applied to atomic electrons, verified Bohr's theory of stable orbits and confirmed that they were given by an integral number of λ such that

$$n\lambda = 2\pi r$$

with

$$\lambda = h/p$$

or

$$nh/p \ = 2\pi r$$

and

$$pr = nh/2\pi = nh$$

which shows that the angular momentum of the electron is quantized, as postulated by Bohr.

MODULE 2.0

2.1 Semiconductor Theory

Solid materials like copper, silver or gold conduct electricity easily and are called good conductors. They have a conductivity at room temperature around $10^7 Sm^{-1}$. In contrast, solid materials such as glass, mica or porcelain are extremely poor conductors of electricity and are called insulators. Their conductivity is very low and around $10^{-16} Sm^{-1}$. However, there also some materials such as germanium and silicon and are called semiconductors.

2.2 Conductor And Insulator

At 0K the electrons are in the lowest energy levels which are all filled. This is valence band. For conduction to take place, electrons must be raised into unfilled energy levels which exist in the conduction band. It requires an applied electric field which can raise the electrons above the forbidden energy gap, into the conduction band. Such valence electrons are then free to move about from atom to atom and give rise to a current flow.

In an insulator, the conduction band and valence bands are separated by a large forbidden energy gap. The gap 7eV for an insulator like diamond and a few eV for other insulators. At normal temperatures and applied fields, the probability of valence electrons acquiring sufficient energy to overcome the energy gap is negligible. Hence, a current cannot flow readily because virtually no electrons are present in the conduction band.

2.3 Semiconductors

In some materials like germanium and silicon, their small energy gap of about 1eV at room temperature makes them partial conductors. Hence, they are called semiconductors and there are two types known respectively as intrinsic semiconductors and extrinsic semiconductors.

2.4 p-n Junction

A p-n junction is formed when a p-type semiconductor is in contact with an n-type semiconductor. The junction is either of the grown, alloyed or diffused type, whereby the crystal structure is maintained throughout the junction region.

When a p-n junction is formed, holes in the p-type material diffuse across the junction into the n-type material. Likewise, electrons in the n-type material diffuse into the p-type material. Due to the fixed charged ions on either side of the junction, the p-type material acquires a negative potential and the n-type material acquires a positive potential, thus creating a region of space-charge at the junction.

MODULE 3.0

3.1 Solid-State Devices

3.1.1 Semiconductor Diodes

Various diodes now in use are the junction diode, zener diode, varactor diode and tunnel diode.

3.1.1.1 Junction diode

An ordinary p-n junction diode can be used for rectifying purposes because it conducts mainly in one direction only.

3.1.1.2 Zener diode
When a p-n junction is reverse biased there is a large increase in current at a particular value of voltage. This is known as a breakdown phenomenon and there are two mechanisms causing this breakdown. The first is called the zener effect and the second is called the avalanche effect.

3.1.1.4 Varactor diode
A p-n junction diode with reverse bias can function as a variable capacitance. The region on either side of the junction is therefore depleted of charge and is called the depletion layer. The varactor diode finds applications in FM modulators for producing an FM signal or in parametric amplifier for low-noise amplification.

3.1.1.5 Tunnel diode
If a p-n diode is doped heavily in both the p-region and n-region, the diode has a negative resistance over part of its characteristics when forward bias is applied. The negative resistance effect can be explained readily using quantum mechanical principles.

Other special diodes include:
- Gunn diodes
- Impatt diodes
- Trapatt diodes

Other solid state devices include:
- Junction transistors
- Field effect transistors
- Masers
- Lasers

MODULE 4.0
4.1 Electron Dynamics
4.1.1 Electron focusing
A beam of electrons which is diverging from a point source may be re-focused to a point using an electrostatic or magnetic lens. Electrostatic focusing can be achieved by allowing the diverging beam to enter a non uniform electric field

4.1.2 Electron emission
The emission of electrons from a metallic surface is basic to many electronic devices. Four methods may be employed and are known as:

- Thermionic emission
- Photoelectric emission
- Secondary emission
- Field emission