Course: Physics IV (6444)
Semester: Autumn, 2021

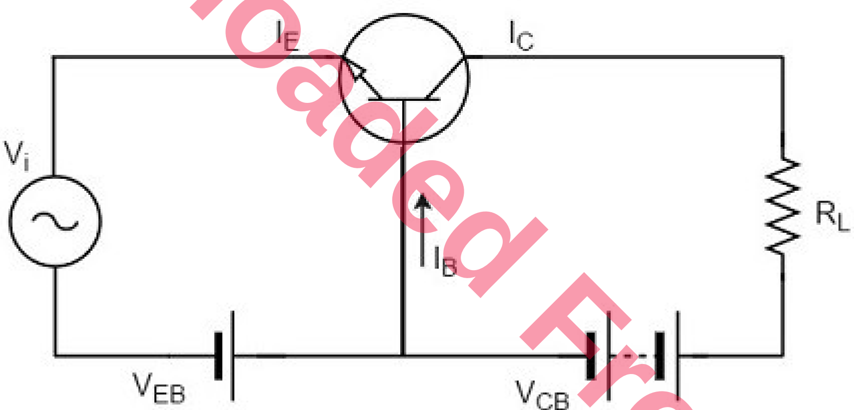
ASSIGNMENT No. 1

Q.1 Explain the process of amplification using transistor, also derive its mathematical form.

For a transistor to act as an amplifier, it should be properly biased. We will discuss the need for proper biasing in the next chapter. Here, let us focus how a transistor works as an amplifier.

Transistor Amplifier

A transistor acts as an amplifier by raising the strength of a weak signal. The DC bias voltage applied to the emitter base junction, makes it remain in forward biased condition. This forward bias is maintained regardless of the polarity of the signal. The below figure shows how a transistor looks like when connected as an amplifier.



The low resistance in input circuit, lets any small change in input signal to result in an appreciable change in the output. The emitter current caused by the input signal contributes the collector current, which when flows through the load resistor R_L, results in a large voltage drop across it. Thus a small input voltage results in a large output voltage, which shows that the transistor works as an amplifier.

Example

Let there be a change of 0.1v in the input voltage being applied, which further produces a change of 1mA in the emitter current. This emitter current will obviously produce a change in collector current, which would also be 1mA.

A load resistance of 5kΩ placed in the collector would produce a voltage of

5 kΩ × 1 mA = 5V

Hence it is observed that a change of 0.1v in the input gives a change of 5v in the output, which means the voltage level of the signal is amplified.

Performance of Amplifier

As the common emitter mode of connection is mostly adopted, let us first understand a few important terms with reference to this mode of connection.

Input Resistance

As the input circuit is forward biased, the input resistance will be low. The input resistance is the opposition offered by the base-emitter junction to the signal flow.

By definition, it is the ratio of small change in base-emitter voltage (ΔV_{BE}) to the resulting change in base current (ΔI_B) at constant collector-emitter voltage.

Input resistance, Ri=ΔVBEΔIB

Where R_i = input resistance, V_{BE} = base-emitter voltage, and I_B = base current.

Output Resistance

The output resistance of a transistor amplifier is very high. The collector current changes very slightly with the change in collector-emitter voltage.

By definition, it is the ratio of change in collector-emitter voltage (ΔV_{CE}) to the resulting change in collector current (ΔI_C) at constant base current.

Output resistance = Ro=ΔVCEΔIC

Where R_o = Output resistance, V_{CE} = Collector-emitter voltage, and I_C = Collector-emitter voltage.

Effective Collector Load

The load is connected at the collector of a transistor and for a single-stage amplifier, the output voltage is taken from the collector of the transistor and for a multi-stage amplifier, the same is collected from a cascaded stages of transistor circuit.

By definition, it is the total load as seen by the a.c. collector current. In case of single stage amplifiers, the effective collector load is a parallel combination of R_C and R_o.

Effective Collector Load, RAC=RC/Ro

=RC×Ro / RC+Ro=RAC

Hence for a single stage amplifier, effective load is equal to collector load R_C.

In a multi-stage amplifier (i.e. having more than one amplification stage), the input resistance R_i of the next stage also comes into picture.

Effective collector load becomes parallel combination of R_C, R_o and R_i i.e,

Effective Collector Load, RAC=RC/Ro/R

RC/Ri=RCRi / RC+Ri

As input resistance R_i is quite small, therefore effective load is reduced.

Current Gain

The gain in terms of current when the changes in input and output currents are observed, is called as **Current gain**. By definition, it is the ratio of change in collector current (ΔI_C) to the change in base current (ΔI_B).

Current gain, β=ΔICΔIB

The value of β ranges from 20 to 500. The current gain indicates that input current becomes β times in the collector current.

Voltage Gain

The gain in terms of voltage when the changes in input and output currents are observed, is called as **Voltage gain**. By definition, it is the ratio of change in output voltage (ΔV_{CE}) to the change in input voltage (ΔV_{BE}).

Voltage gain, AV=ΔVCEΔVBE

=Change in output current×effective load / Change in input current×input resistance=

=ΔIC×RAC / ΔIB×Ri=ΔIC / ΔIB×RAC / Ri=β×RAC / Ri

For a single stage, $R_{AC} = R_C$.

However, for Multistage,

RAC=RC×Ri / RC+Ri

Where R_i is the input resistance of the next stage.

Power Gain

The gain in terms of power when the changes in input and output currents are observed, is called as **Power gain**.

By definition, it is the ratio of output signal power to the input signal power.

Power gain, AP=(ΔIC)2×RAC / (ΔIB)2×Ri

=(ΔIC / ΔIB)×ΔIC×RAC / ΔIB×Ri

= Current gain × Voltage gain

Hence these are all the important terms which refer the performance of amplifiers.

Q.2 Explain positive and negative feedback of amplifier. Also describe working of monostable multi vibrator.

There are two types of feedback in amplifier.

• Positive feedback

• Negative feedback

If original input signal and feedback signal are in phase, the feedback type is known as positive feedback. It tends to increase the output.

If original input signal and feedback signal are out of phase, the feedback type is known as negative feedback. It tends to reduce the output.

Depending upon sampling type and mixing networks, feedback amplifiers are categorized as follows.

• Voltage series feedback

• Current series feedback

• Current shunt feedback

• Voltage shunt feedback

Parameter	Positive Feedback	Negative Feedback

Overall phase shift	0 or 360 degrees	180 degrees
Input and output voltage, noise	increases due to feedback	Decreases due to feedback
Feedback signal and input signal	In phase	Out of phase
Gain	increases	decreases
Stability	poor	better
applications or use	oscillators	amplifiers

Multivibrator is an electronic circuit which will work as two stage amplifier operating in both stable and astable mode.In the multivibrator the output of first stage is given to the second stage and the second stage output is again feed back to the first stage by this the cutoff state will become saturate and saturate state will become to cutoff. Because of the transition of states the multivibrator can be used as oscillators, timers and flip-flops.

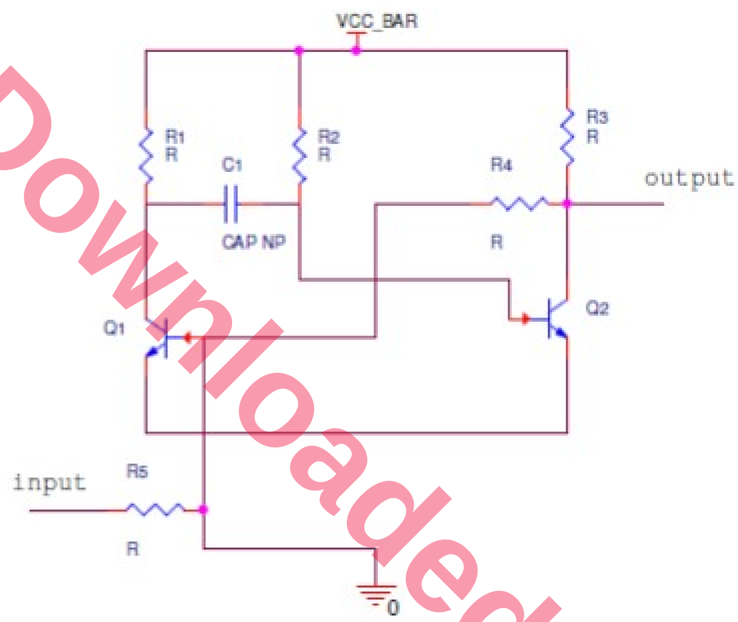
Monostable Multivibrator:

Monostable multivibrator has one stable state and one quasi stable state (astable state). When an external trigger applied to the circuit, the multivibrator will jump to quasi stable state from stable state.

After the period of time it will automatically set back to the stable state, for returning to the stable state multivibrator does not require any external trigger. The time period to returning to stable state circuit is always depends on the passive elements in the circuit (resistor and capacitor values

Monostable Multivibrator Circuit Operation:

Circuit Diagram:



Monostable Multivibrator Circuit Diagram

Circuit Operation:

- When there is no external trigger to the circuit the one transistor will be in saturation state and other will be in cutoff state. Q1 is in cutoff mode and put at negative potential until the external trigger to operate, Q2 is in saturation mode.
- Once the external trigger is given to the input Q1 will get turn on and when the Q1 reaches the saturation the capacitor which is connected to the collector of Q1 and base of Q2 will make transistor Q2 to turn off. This is state of turn off Q2 transistor is called astable stable or quasi state.
- When capacitor charges to VCC the Q2 will turn on again and automatically Q1 is turn off. So the time period for charging of capacitor through the resistor is directly proportional to the quasi or astable state of multivibrator when a external trigger occurred (t=0.69RC).

Q.3 Explain angular momentum of electron and quantum numbers.

There are four quantum numbers that make up the address for an electron. Of the four quantum numbers, our focus for this lesson is the **angular momentum quantum number**, which is also known as the **secondary quantum number** or **azimuthal quantum number**.

The angular momentum quantum number is a quantum number that describes the 'shape' of an orbital and tells us which subshells are present in the principal shell. We can think about it this way: each of our homes has its own architecture. In the subatomic level, the 'home' of electrons is an orbital, and each orbital has its own shape. The symbol that is used when we refer to the angular momentum quantum number looks like this:

Symbol

$$\ell$$

Electrons occupy a region called 'shells' in an atom. The angular momentum quantum number, l, divides the shells into subshells, which are further divided into orbitals. Each value of l corresponds to a particular subshell. The lowest possible value for l is 0. This following table shows which subshells correspond to the angular momentum quantum number:

Angular Momentum Quantum Number, ℓ	Name of Subshell
0	s
1	p
2	d
3	f

The angular momentum quantum number can also tell us how many nodes there are in an orbital. A **node** is an area in an orbital where there is 0 probability of finding electrons. The value of l is equal to the number of nodes. For example, for an orbital with an angular momentum of l = 3, there are 3 nodes.

Relationship with Principal Quantum Number

It is important to point out that there is a relationship between the principal quantum number and the angular momentum quantum number. To recap, the **principal quantum number** tells us what principal shells the electrons occupy. It determines the energy level and size of the shell and uses the symbol n and is any positive integer.

The angular momentum quantum number values range from 0 to n - 1, and cannot be greater than n. This table shows the relationship between the two quantum numbers:

Principal Quantum Number, *n*	Angular Momentum Quantum Number, ℓ ℓ = 0, 1, 2... n-1	Subshells
1	$\ell=0$	s (1 subshell)
2	$\ell=0$ $\ell=1$	s p (2 subshells)
3	$\ell=0$ $\ell=1$ $\ell=2$	s p d (3 subshells)
4	$\ell=0$ $\ell=1$ $\ell=2$ $\ell=3$	s p d f (4 subshells)

We can think about the relationship between these two quantum numbers as this: the principal quantum number is the number of the floors, and the angular momentum quantum numbers are the rooms in each floor. The floor contains the rooms, and each room has its own unique appearance.

It's important to note that the value of l never exceeds n, and its greatest value is equal to n - 1. Let's go over a few examples to further understand this relationship.

Q.4 Explain Bohr's Magneton by providing examples and its uses.

Bohr Magneton is magnetic dipole moment associated with an atom due to orbital motion and spin of an electron. The Bohr magneton (symbol μB) is a physical constant and the natural unit for expressing the magnetic moment of an electron caused by either its orbital or spin angular momentum and is given by:

$\mu B = e\hbar / 2me$

where, e is the elementary charge, $\hbar$ is the reduced Planck constant, me is the electron rest mass, The value of Bohr magneton in SI units is 9.27400968(20)×10−24JT−1.

- Walther Ritz (1907) and Pierre Weiss are responsible for the concept of elementary magnets. Several researchers suggested that the magneton should have Planck's constant h even before the Rutherford model of atomic structure.
- By postulating that the ratio of electron kinetic energy to orbital frequency should be equal to h, Richard Gans computed a value that was twice as large as the Bohr magneton in September 1911.
- In 1911, Romanian physicist Stefan Procopiu discovered the expression for the electron's magnetic moment. In Romanian scientific literature, the importance is often referred to as the "Bohr–Procopiu magneton."

- In 1911, the Weiss magneton was discovered to be a unit of magnetic moment equal to 1.531024 joules per tesla, or around 20% of the Bohr magneton.
- As a result of his atom model, the Danish physicist Niels Bohr obtained the values for the natural units of atomic angular momentum and magnetic moment in the summer of 1913.
- Wolfgang Pauli named the it in a 1920 article in which he compared it with the experimentalists' magneton, which he called the Weiss magneton.

The magnitude of the dipole moment is

$|\mu|=I.area$

$|\mu|=(qv/2\pi r)2\pi r$

$|\mu|=qrp/2m$, where p is the linear momentum.

Since the radial vector r is perpendicular to p,

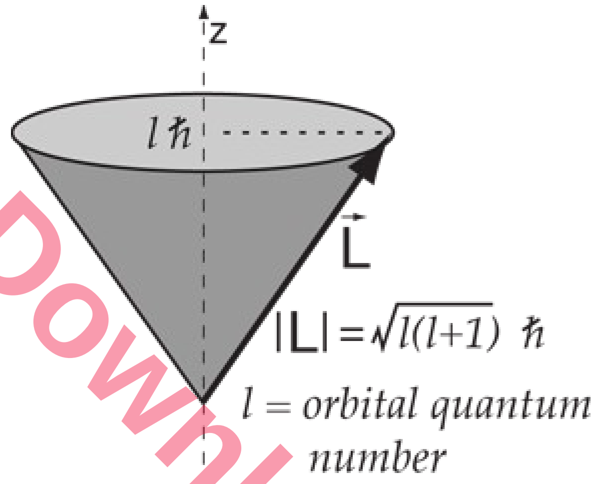
we have $\mu=(qr\times p)/2m=qL/2m$,

where L is the angular momentum. The magnitude of the orbital magnetic momentum of an electron with orbital-angular momentum quantum l is$\mu=e\hbar/2me[l(l+1)]1/2=\mu B[l(l+1)]1/2$Here, μB is a constant called Bohr magneton, and is equal to $\mu B=e\hbar/2me$ $\mu B = (1.6 \times 10\text{-}19C) \times (6.626 \times 10\text{-}34J \cdot s/2\pi) /2 \times 9.11 \times 10\text{-}31kg$ $\mu B = 9.274 \times 10{-}24J/T$where T is the magnetic field, Tesla.For the electron, it is the simplest model possible to the smallest possible current to the smallest possible area closed by the current loop.

Q.5 Explain Vector Atomic model also provide its pictorial explanation for deep understanding of concept.

The orbital angular momentum for an atomic electron can be visualized in terms of a vector model where the angular momentum vector is seen as precessing about a direction in space. While the angular momentum vector has the magnitude shown, only a maximum of l units can be measured along a given direction, where l is the orbital quantum number.

Since there is a magnetic moment associated with the orbital angular momentum, the precession can be compared to the precession of a classical magnetic moment caused by the torque exerted by a magnetic field. This precession is called Larmor precession and has a characteristic frequency called the Larmor frequency.

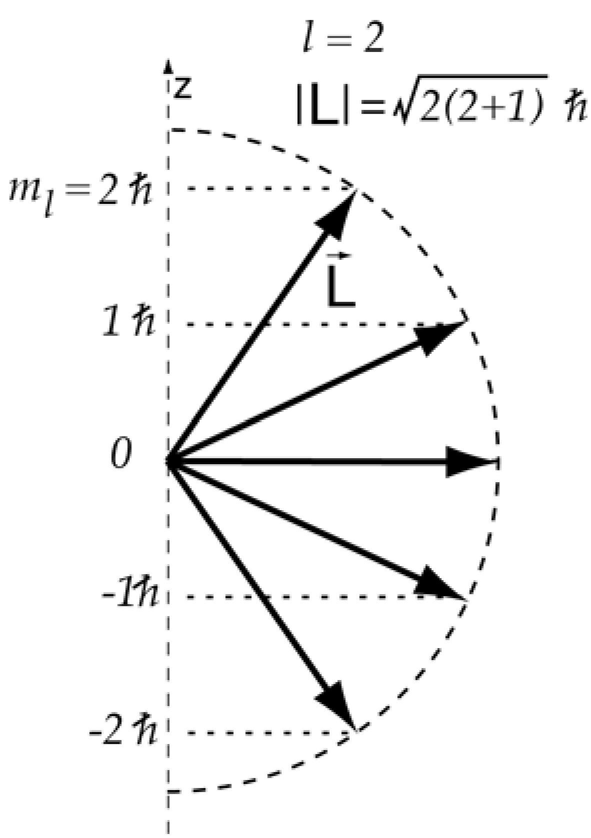


While called a "vector", it is a special kind of vector because its projection along a direction in space is quantized to values one unit of angular momentum apart. The diagram shows that the possible values for the "magnetic quantum number m_l for l=2 can take the values

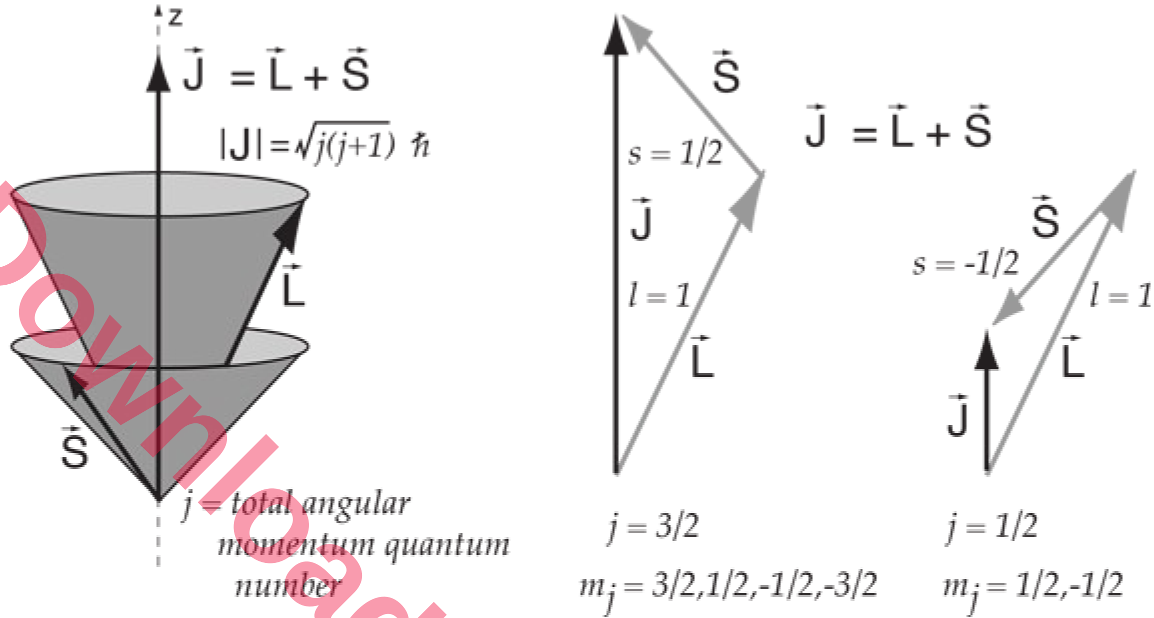
$$m_\ell = -2, -1, 0, 1, 2$$

or, in general

$$m_\ell = -l, -l+1, ..., l-1, l.$$



Vector Model for Total Angular Momentum



When orbital angular momentum **L** and electron spin angular momentum **S** are combined to produce the total angular momentum of an atomic electron, the combination process can be visualized in terms of a vector model. Both the orbital and spin angular momentua are seen as precessing about the direction of the total angular momentum **J**. This diagram can be seen as describing a single electron, or multiple electrons for which the spin and orbital angular momenta have been combined to produce composite angular momenta S and L respectively. In so doing, one has made assumptions about the coupling of the angular momenta which are described by the L-S coupling scheme which is appropriate for light atoms with relatively small external magnetic fields.

The combination is a special kind of vector addition as is illustrated for the single electron case l=1 and s=1/2. As in the case of the orbital angular momentum alone, the projection of the total angular momentum along a direction in space is quantized to values differeing by one unit of angular momentum.