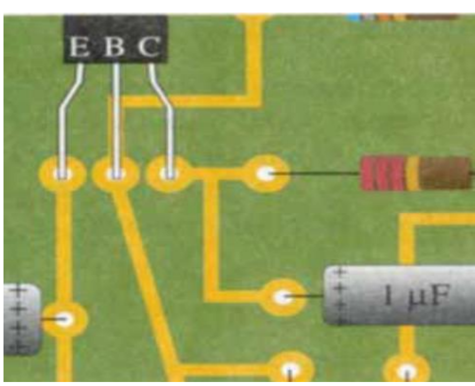
S.Y.B.Sc. SEM – III

Subject: Physics

Paper- 301

Unit -5

SINGLE STAGE TRANSISTOR AMPLIFIER



- Introduction
- How transistor amplifies?
- Graphical demo of amplifier
- Practical circuit of transistor amplifier
- Phase reversal
- Load line analyses
- Voltage gain
- Classification of amplifier
- Frequency response

❖ INTRODUCTION :

❖ "SINGLE STAGE TRANSISTOR AMPLIFIER" :

"When only one transistor with associated circuitry is used for amplifying a weak signal, the circuit is known as **single stage transistor amplifier."**

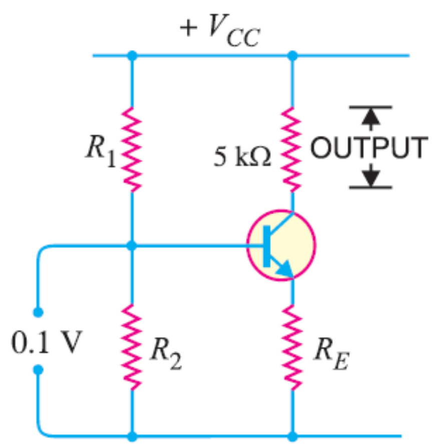


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FIG 1 :

- A single stage transistor amplifier has one transistor, bias circuit and other auxiliary components.
- Yet such a complex circuit can be conveniently split up into separate single stages.
- By analyzing carefully only a single stage and using this single stage analysis repeatedly, we can effectively analyses the complex circuit.
- That single stage amplifier analysis is of great value in understanding the practical amplifier circuits.

❖ How Transistor Amplifies?:

- Fig. 1 shows a single stage transistor amplifier.
- When a weak a.c. signal is given to the base of transistor, a small base current (which is a.c.) starts flowing.

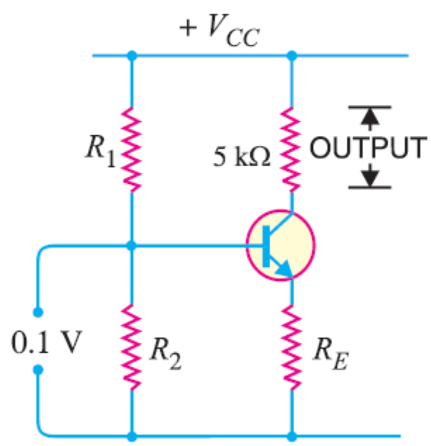


FIG 1:

- Due to transistor action, a much larger (times the base current) a.c. current flows through the collector load *RC*.
- As the value of *RC* is quite high (usually 4-10 kΩ), therefore, a large voltage appears across *RC*.
- Thus, a weak signal applied in the base circuit appears in amplified form in the collector circuit.
- It is in this way that a transistor acts as an amplifier.

SRNO	QUESTION	ANSWER
1	A single stage transistor amplifier contains........... and associated circuitry.	**One transistor**
2	We can analyze the complex circuit by using ________ repeatedly.	**Single stage**
3	Weak a.c. signal is given to the________ terminal of transistor.	**Base**
4	A weak signal applied in the base circuit appears in amplified form in the ___________ circuit.	**collector**

- **Graphical Demonstration of Transistor Amplifier :**

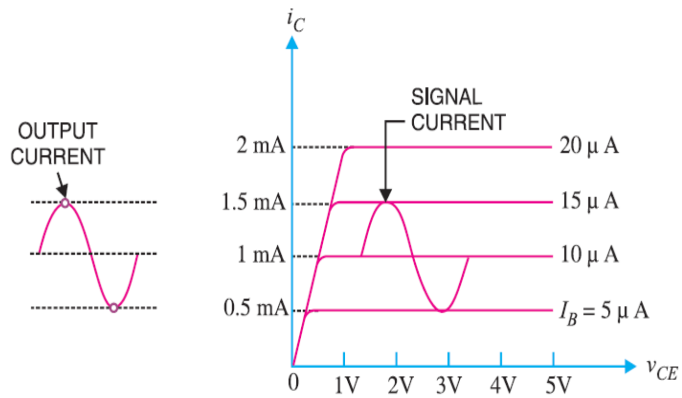


FIG : 2

- The function of transistor as an amplifier can also be explained graphically. Fig. 2 shows the output characteristics of a transistor in *CE* configuration.
- When an a.c. signal is applied to the base, it makes the base, say positive in the first half-cycle and negative in the second half cycle. Therefore, the base and collector currents will increase in the first half-cycle when base-emitter junction is more forward-biased.
- They will decrease in the second half-cycle when the base-emitter junction is less forward biased.
- It is clear from Fig.2 that 10 μA base current variation results in 1mA (1,000 μA) collector current variation *i.e*. by a factor of 100. This large change in collector current flows through collector resistance *RC*. The result is that output signal is much larger than the input signal.
- Thus, the transistor has done amplification.

SRNO	QUESTION	ANSWER
1	When a.c. signal is applied to the base_______ in first half cycle,________ in second half cycle.	**Positive, Negative**
2	From graph characteristic output signal is much _______ than input signal.	**Larger**

❖ Practical Circuit of Transistor Amplifier :

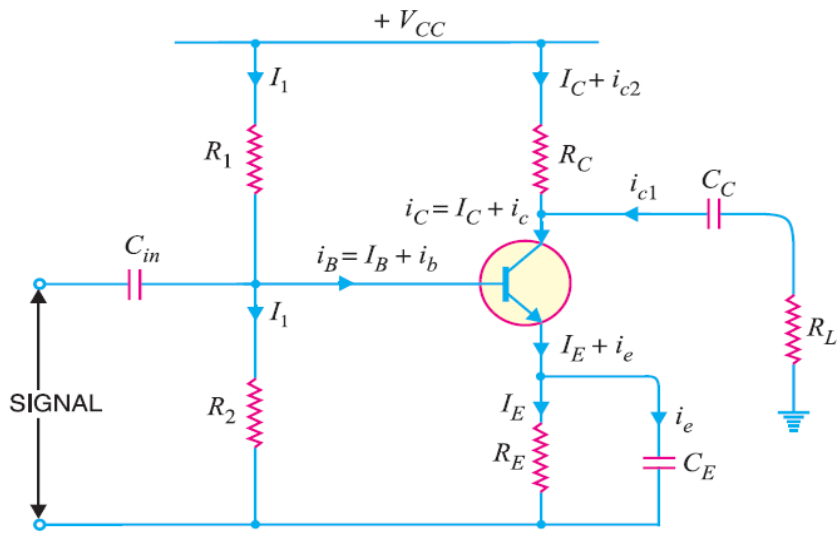


FIG : 3

❖ Fig. 3 shows a practical single stage transistor amplifier. The various circuit elements and their functions are described below :

(i) **Biasing circuit.** The resistances R_1, R_2 and R_E form the biasing and stabilization circuit. The biasing circuit must establish a proper operating point otherwise a part of the negative half-cycle of the signal may be cut off in the output.

(ii) **Input capacitor C_{in} ;** An electrolytic capacitor C_{in} is used to couple the signal to the base of the transistor. If it is not used, the signal source resistance will come across R_2 and thus change the bias. The capacitor C_{in} allows only a.c. signal to flow but isolates the signal source from R_2.*

(iii) **Emitter bypasse capacitor C_E.** An emitter bypass capacitor C_E is used in parallel with R_E to provide a low reactance path to the amplified a.c. signal. If it is not used, then amplified a.c. signal flowing through *RE* will cause a voltage drop across it, thereby reducing the output voltage.

(iv) **Coupling capacitor C_C.** The coupling capacitor C_C couples one stage of amplification to the next stage. If it is not used, the bias conditions of the next stage will be drastically changed due to the shunting effect of R_C.

❖ **Various circuit currents:**

It is useful to mention the various currents in the complete amplifier circuit.

(*i*) Base current: When no signal is applied in the base circuit, d.c. base current I_B flows due to biasing circuit. When a.c. signal is applied, a.c. base current i_b also flows. Therefore, with the application of signal, total base current i_B is given by:

$$i_B = I_B + i_b$$

(*ii*) Collector current. When no signal is applied, a d.c. collector current *IC* flows due to biasing circuit. When a.c. signal is applied, a.c. collector current i_c also flows. Therefore, the total collector current i_C is given by:

$$i_C = I_C + i_c$$

(*iii*) Emitter current. When no signal is applied, a D.C. emitter current I_E flows. With the application of signal, total emitter current i_E is given by:

$$i_E = I_E + i_e$$

SR NO	QUESTION	ANSWER
1	_______is used to couple the signal to the base of the transistor.	Input capacitor
2	__________couples one stage of amplification to the next stage.	Coupling capacitor
3	Zero signal collector current *IC* = _________.	βI_B

❖ Phase Reversal :

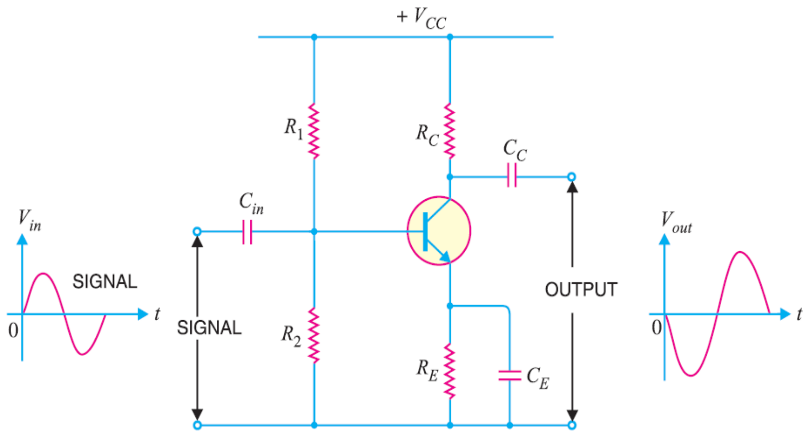


FIG : 4

"The phase difference of 180° between the signal voltage and output voltage in a common emitter amplifier is known as ***phase reversal."***

- Consider a common emitter amplifier circuit shown in Fig 4. The signal is fed at the input terminals (*i.e.* between base and emitter) and output is taken from collector and emitter end of supply. The total instantaneous output voltage v_{CE} is given by :

$$v_{CE} = V_{CC} - i_C R_C$$

- In other words, as the signal voltage is increasing in the positive half cycle, the output voltage is increasing in the negative sense *i.e.* output is 180° out of phase with the input.
- In a common emitter amplifier, the positive half-cycle of the signal appears as amplified negative half-cycle in the output and *vice-versa*.
- It may be noted that amplification is not affected by this phase reversal.The negative sign shows that output voltage is 180° out of phase with the input signal voltage.
- ***For every amplifier type (CE, CB and CC), the input and output currents are in phase. Common emitter (CE) circuit is the only configuration that has input and output voltages 180° out of phase.***

SR NO	QUESTION	ANSWER
1	The phase difference between the output and input voltages of a *CE* amplifier is..........	180º
2	What is Phase reversal?	Phase difference of 180 º In applied signal

❖ Load Line Analysis :

- The output characteristics of transistor represent the relation between V_{CE} and I_C. It is also represent by mathematical relation between I_C and V_{CE} graphically.
- "The relationship between V_{CE} and I_C is linear so that it can be represented by a straight line on the output characteristics. This is known as a *load line*."
- As in a transistor circuit both d.c. and a.c. conditions exist, therefore, there are two types of load lines, namely; d.c. load line and a.c. load line.

❖ D.C. load line:

- *It is the line on the output characteristics of a transistor circuit which gives the values of IC and VCE corresponding to zero signal or D.C. conditions.* Consider the transistor amplifier shown in Fig.5. In the absence of signal, D.C. conditions prevail in the circuit as shown in Fig.5. Referring to this circuit and applying Kirchhoff's voltage law,

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E$$
$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

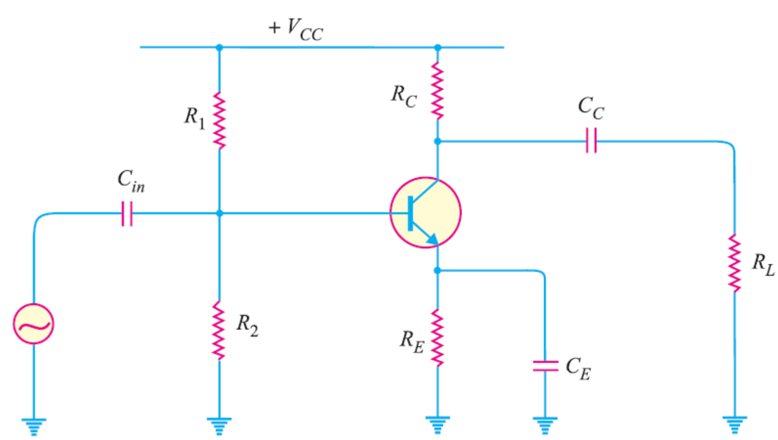


Fig : 5

- As for a given circuit, *VCC* and (*RC* + *RE*) are constant, therefore, it is a first degree *equation and can be represented by a straight line on the output characteristics. This is known as *d.c. load line* and determines the loci of *VCE* and *IC* points in the zero signal conditions. The d.c. load line can be readily plotted by locating two *end points* of the straight line.

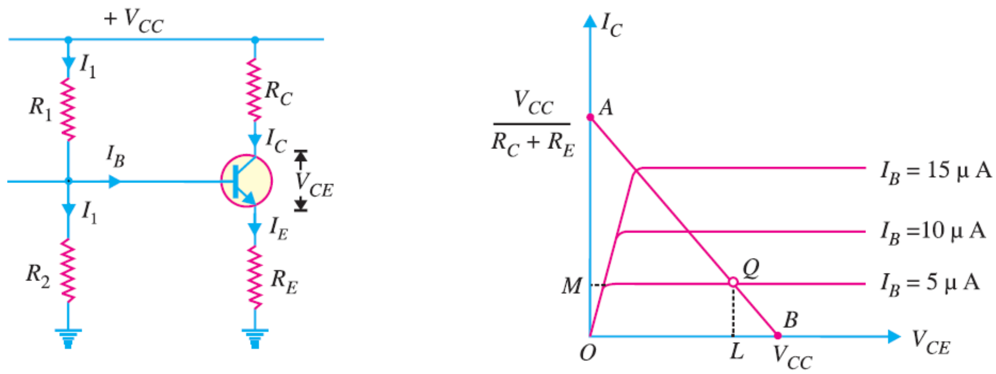


Fig 5.1

- The value of V_{CE} will be maximum when $I_C = 0$. Therefore, by putting $I_C = 0$ in equation we get, Max. $V_{CE} = V_{CC}$. This locates the first point *B* ($OB = V_{CC}$) of the d.c. load line. The value of I_C will be maximum when $V_{CE} = 0$.

$$\text{Max. } I_C = \frac{V_{CC}}{R_C + R_E}$$

- This locates the second point *A* ($OA = V_{CC}/R_C + R_E$) of the d.c. load line. By joining points *A* and *B*, d.c. load line *AB* is constructed as shown in fig 5.1.

❖ A.C. load line:

- This is the line on the output characteristics of a transistor circuit which gives the values of i_C and v_{CE} when signal is applied.

- To add a.c. load line to the output characteristics, we again require two end points–one maximum collector-emitter voltage point and the other maximum collector current point.

- Max. Collector-emitter voltage = $V_{CE} + I_C R_{AC}$. This locates the point *C* of the a.c. load line on the collector-emitter voltage axis.

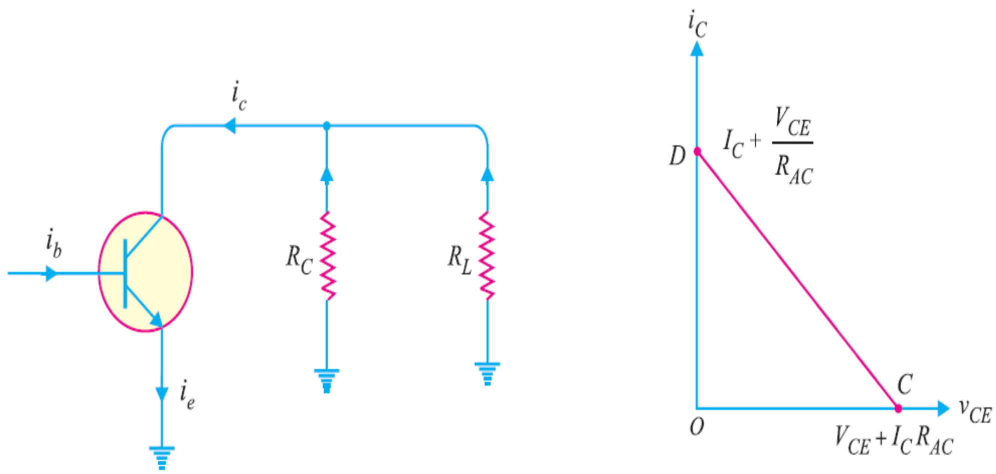


Fig 6

$$\text{Maximum collector current} = I_C + \frac{V_{CE}}{R_{AC}}$$

where $$R_{AC} = R_C \parallel R_L = \frac{R_C R_L}{R_C + R_L}$$

- This locates the point *D* of a.c. load line on the collector-current axis. By joining points *C* and *D*, the a.c. Load line *CD* is constructed as shown in fig 6.

SR NO	QUESTION	ANSWER
1	When an a.c. signal is applied to an amplifier, the operating point moves along........	a.c. load line
2	In the zero signal conditions, a transistor sees .... load.	d.c
3	The point of intersection of d.c. and a.c. load lines is called.......	operating point
4	The slope of a.c. load line is .... that of d.c. load line.	more than

❖ Voltage Gain:

- The basic function of an amplifier is to raise the strength of an a.c. input signal. The voltage gain of the amplifier is the ratio of a.c. output voltage to the a.c. input signal voltage.
- For this purpose, we should look at the a.c. equivalent circuit of transistor amplifier.

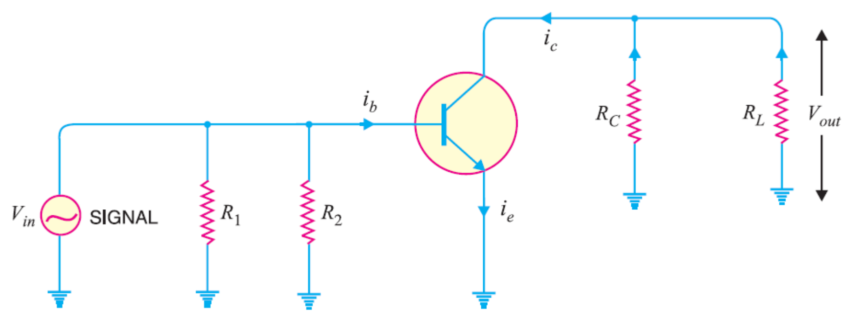


Fig -7

It is clear that as far as a.c. signal is concerned, load R_C appears in parallel with R_L. Therefore, effective load for a.c. is given by :

$$\text{a.c. load, } R_{AC} = R_C \,||\, R_L = \frac{R_C \times R_L}{R_C + R_L}$$

$$\text{Output voltage, } V_{out} = i_c R_{AC}$$

$$\text{Input voltage, } V_{in} = i_b R_{in}$$

$$\therefore \quad \text{Voltage gain, } A_v = V_{out}/V_{in}$$

$$= \frac{i_c R_{AC}}{i_b R_{in}} = \beta \times \frac{R_{AC}}{R_{in}} \qquad \left(\because \frac{i_c}{i_b} = \beta\right)$$

Incidentally, power gain is given by;

$$A_p = \frac{i_c^2 R_{AC}}{i_b^2 R_{in}} = \beta^2 \times \frac{R_{AC}}{R_{in}}$$

SR NO	QUESTION	ANSWER
1	In a *CE* amplifier, voltage gain =..... $\times \frac{R_{AC}}{R_{in}}$	β
2	In practice, the voltage gain of an amplifier is expressed........	in *db*

❖ CLASSIFICATION OF AMPLIFIER:

The transistor amplifiers may be classified as to their *usage, frequency capabilities, coupling methods* and *mode of operation.*

- **According to use :**

  The classifications of amplifiers as to usage are basically *voltage amplifiers* and *power amplifiers*. The former primarily increases the voltage level of the signal whereas the latter mainly increases the power level of the signal.

- **According to frequency capabilities:**

  According to frequency capabilities, amplifiers are classified as *audio amplifiers, radio frequency amplifiers* etc. The former are used to amplify the signals lying in the audio range.

- **According to coupling methods :**

  The output of one stage is coupled to the next stage. Depending upon the coupling device used, the amplifiers are classified as *R-C coupled amplifiers, transformer coupled amplifiers* etc.

- **According to mode of operation :**

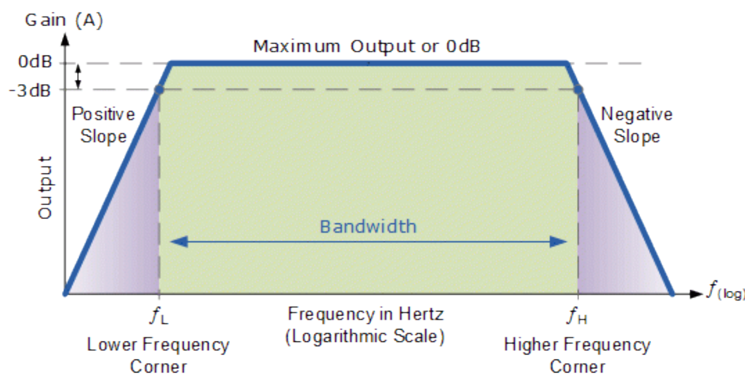
  The amplifiers are frequently classified according to their mode of operation as *class A, class B* and *class C* amplifiers. This classification depends on the portion of the input signal cycle during which collector current is expected to flow.

SR NO	QUESTION	ANSWER
1.	How many types of amplifier?	4
2.	Which are the types of according to mode of operation?	Class A, Class B, Class C.
3.	Which are the types of according to coupling method?	RC coupled amplifier Transformer coupled amplifier

❖ Frequency response of CE Amplifier:

Frequency response is a very important characteristic of an amplifier. The voltage gain of an amplifier varies with signal frequency. The degree to which this is done is usually indicate by a frequency response curve.

- The curve between voltage gain and signal frequency of an amplifier is known as frequency response.



- The performance of an amplifier depends to a great extent upon its frequency response. while designing an amplifier, necessary step must be taken to ensure that gain is essentially uniform over the frequency range it is to be used.
- It is necessary that all audio frequencies should be amplified uniformly otherwise results in a distorted output.

SR NO	QUESTION	ANSWER
1	In frequency response f_l is known as ________.	Lower frequency
2	In frequency response f_H is known as ________.	Higher frequency
3	________ is a layer between lower frequency & higher frequency.	Bandwidth

❖ Chapter Review Topics:

1. What do you understand by single stage transistor amplifiers?
2. Draw the circuit of a practical single stage transistor amplifier. Explain the function of each component.
3. Show the various currents and voltages in a single stage transistor amplifier.
4. Show that the output voltage of a single stage common emitter transistor amplifier is 180º out of phase with the input voltage.
5. What do you understand by D.C. and a.c. load lines? How will you construct them on the output characteristics?
6. Write short notes on the following :

   (*i*) phase reversal (*ii*) d.c. and a.c. load lines

   (*iii*) Operating point (*IV*) classification of amplifiers.

❖ Problems :

1. In transistor amplifier, the collector current swings from 2 mA to 5 mA as the base current are changed from 5 μA to 15 μA. Find the current gain. **[Ans : 300]**
2. A transistor amplifier employs a 4 kΩ as collector load. If the input resistance is 1 kΩ, determine the voltage gain. Given β = 100, gm =10 mA/volt and signal voltage = 50 mV. **[Ans : 1.04]**
3. A *CE* amplifier has a voltage gain Av = 59.1 and β = 200. Determine the power gain and output power of the amplifier when input power is 80 μW.. **[Ans : 11820 ; 945.6 mW]**
4. A standard *CE* amplifier has the following values : VCC = 30V, $R1$ = 51 k, $R2$ = 5.1 k, RC = 5.1 k, RE = 910 and β = 250. Determine the voltage gain of the amplifier. **[Ans : 455.4]**