Q21. Distinguish between unpolarized and plane polarized light. An unpolarized light is incident on the boundary between two transparent media. State the condition when the reflected wave is totally plane polarized. Find out the expression for the angle of incidence in this case.

Answer

For unpolarized light , light waves vibrate in more than one plane. Therefore independent light waves whose planes of vibrations are randomly oriented about the direction of propagation are said to be **unpolarized.**

For Polarized light , vibrations of light waves occur in a single plane. When the light waves transmit only one component parallel to a special axis, then the resulting light is called **plane polarized** or **linearly polarized** light.

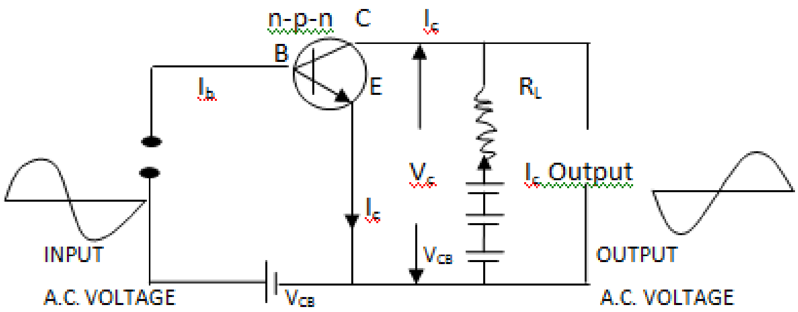
When reflected wave is perpendicular to the refracted wave, the reflected wave is totally polarized wave. The angle of incidence in this case is called **Brewster's angle** and is denoted by i_B.

The relation with incident angle i_B is given by $\mu = \tan i_B$

Q22. Draw the labeled circuit diagram of a common-emitter transistor amplifier. Explain clearly how the input and output signals are in opposite phase.

Answer

The circuit details for using an npn transistor as common emitter amplifier are shown in the figure.



The input (base-emitter) circuit is forward biased and the output (collector-emitter) circuit is reversed biased. When no a.c. signal is applied, the potential difference V_C between the collector and emitter, is given by

$$V_C = V_{ce} - I_C \times R_L \quad \dots\dots(1)$$

Where V_{ce} is the voltage of battery V_{CE}

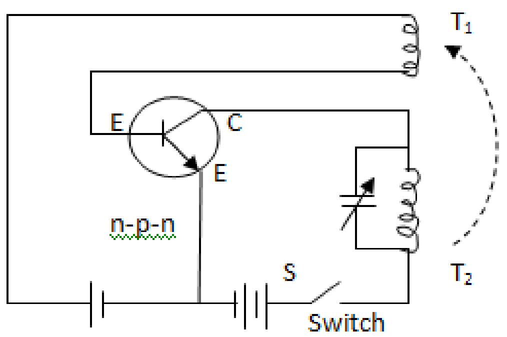
When an a.c. signal is fed to the input circuit, the forward bias increases during the positive half cycle of the input. This results in an increase in I_C and a consequent decrease in V_C, as is clear from (1). Thus during positive half cycle of the input, the collector becomes less positive.

During the negative half cycle of the input, the forward bias is decreased resulting in a decrease in I_E and hence I_C. Therefore, from (1) V_C would increase, making the collector more positive. *Hence in a common-emitter amplifier, the output voltage is 180 ^{0} out of phase with the input voltage.*

Q22(II) State briefly the underlying principle of a transistor-oscillator. Draw a circuit diagram showing how the feedback is accomplished by inductive coupling. Explain the oscillator action.

Answer

Transistor as an oscillator: In an oscillator, the output at a desired frequency is obtained without applying any external input voltage. The common emitter npn transistor as an oscillator is shown in the figure. A variable capacitor C of suitable range is connected in parallel to coil L to give the variation in frequency.



Oscillator action: As in an amplifier, the base-emitter junction is forward biased while the base collector junction is reversed biased. When the switch S is put on, a surge of collector current flows in the coil T_2. The inductive coupling between coil T_2 and T_1 cause a current to flow in the emitter circuit i.e., feedback from input to output. As a result of positive feedback, the collector current reaches at maximum. When there will be no further feedback from T_2 to T_1, the emitter current begins to fall and collector current decreases. Therefore, the transistor has reverted back to its original state. The whole process now repeats itself.

The resonance frequency (f) of the oscillator is given by

$$f = \frac{1}{2\pi\sqrt{LC}}$$

The tank of tuned circuit is connected in the oscillator side. Hence it is known as *tuned collector oscillator*.

Q23. The ground state energy of hydrogen atom is -13.6 eV.

(I) What is the kinetic energy of an electron in the 2nd excited state?

(II) If the electron jumps to the ground state from the 2nd excited state, calculate the wavelength of the spectral line emitted.

Answer

The energy of an electron in nth orbit is given by

$$E_n = \frac{-13.6}{n^2} \text{ eV}$$

(I) For 2nd excited state, n = 3

$$\therefore\ E_3 = \frac{-13.6}{3^2} = \frac{-13.6}{9} = -1.51 \text{ eV}$$

(II) Required energy to jump electron to the ground state from the 2nd excited state

$E = E_3 - E_1$

$$= \frac{-13.6}{(3)^2} - \left(\frac{-13.6}{(1)^2}\right) = -1.51 + 13.6 = 12.09 \text{ eV}$$

$\therefore$ Wavelength of the spectral line emitted is

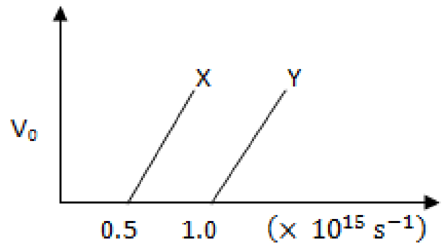
$$\lambda = \frac{hc}{E} \qquad \left[\because E = \frac{hc}{\lambda}\right]$$

$$\lambda = \frac{6.626\times10^{-34}\times3\times10^{8}}{12.09\times1.6\times10^{-19}}$$

$$= \frac{19.878\times10^{-7}}{19.344}$$

$$= 1.027 \times 10^{-7} \text{ m} = 1027 \text{ Å}$$

Q24. The following graph shows the variation of stopping potential V_0 with the frequency ν of the incident radiation for two photosensitive metals X and Y:



Which of the metal has larger threshold wavelength? Give reason.

(i) Explain, giving reason, which metal gives out electrons, having larger kinetic energy, for the same wavelength of the incident radiation.
(ii) If the distance between the light source and metal X is halved, how will the kinetic energy of electrons emitted from it change? Give reason.

Ans.

(i) Let ν_0 and ν'_0 be the Frequencies of incident radiations of metal Y and X respectively.

$\therefore\ \nu_0 > \nu'_0$

$\because\ \nu_0 = \frac{c}{\lambda_0}\ \therefore \frac{c}{\lambda_0} > \frac{c}{\lambda'_0}\ \Rightarrow \lambda_0 < \lambda'_0$

Therefore, metal X has larger threshold wavelength.

(ii) Since $E = h\,\nu_0\ \Rightarrow E \propto \nu_0$

Therefore, metal Y has larger kinetic energy.

(iii) $E = e\,V_0$

Therefore, kinetic energy of the emitted photoelectron is independent of the intensity of the incident light, hence K.E. of the emitted photoelectrons remains unchanged if the intensity of the incident radiation is halved.

Q25. A circular coil of 200 turns and radius 10 cm is placed in a uniform magnetic field of 0.5 T, normal to the plane of the coil. If the current in the coil is 3.0 A, calculate the

(i) Total torque on the coil.
(ii) Total force on the coil.
(iii) Average force on each electron in the coil, due to the magnetic field.

Assume the area of cross-section of the wire to be 10^{-5} m^2 and the free electron density is $10^{29}/m^3$.

Answer

Given $n = 200, r = 10\text{ cm} = 0.1\text{ m}, B = 0.5\text{ T}, \alpha = 0^\circ$ and $I = 3.0\text{ A}$

Area of the coil $A = \pi r^2 = 3.14 \times (0.1)^2$

$\therefore A = 3.14 \times 0.01 = 0.0314\text{ m}^2$

(i) $\tau = nIBA \sin\alpha = nIBA \sin 0^\circ = 0$

(ii) Total force on a planar current loop in a magnetic field

is always zero.

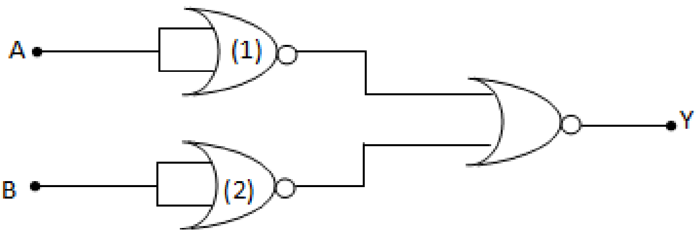
(iii) Given $N = 10^{29}/m^3, A = 10^{-5} m^2$

Average force on an electron of charge (e), moving with drift velocity (v_d) in the magnetic field (B) is given by

$$F = Be\,v_d = Be\,\frac{I}{neA} \quad [\because I = ne\,Av_d]$$

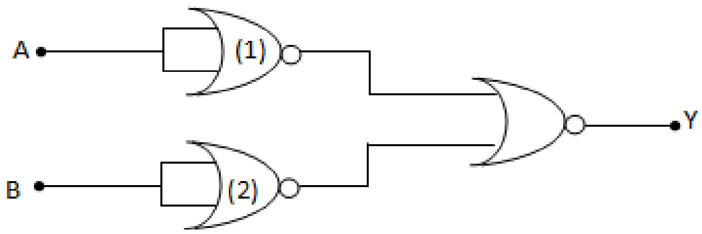
$$F = \frac{BI}{nA} = \frac{0.5 \times 3.0}{10^{29} \times 10^{-5}} = 1.5 \times 10^{-24}\text{ N.}$$

Q26. The inputs A and B are inverted by using two NOT gates and their outputs are fed to the NOR gate as shown below.



Analyze the action of the gates (1) and (2) and identify the logic gate of the complete circuit so obtained. Give its symbol and the truth table.

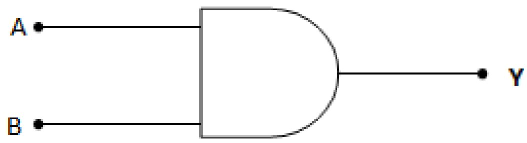
Answer



The output Y = $\overline{\overline{A} + \overline{B}} = \overline{\overline{A}} . \overline{\overline{B}} = A . B$

(i) The gates (1) and (2) act as NOT gate.

(ii) The logic gate of the complete circuit is AND gate.

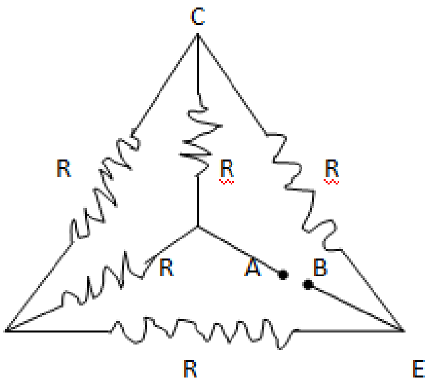


Truth Table

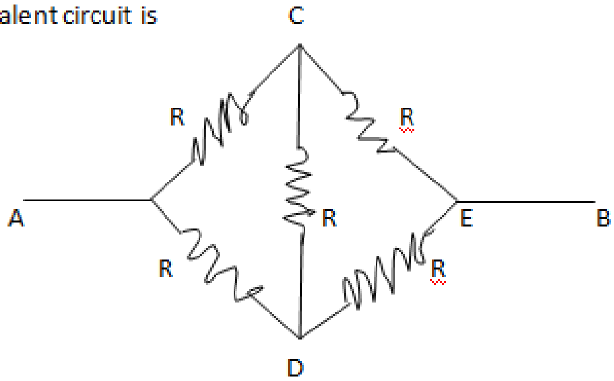
Input		Output Y = A + B
A	**B**	
0	0	0
0	1	0
1	0	0
1	1	1

Q27. (i) Calculate the equivalent resistance of the given electrical network between points A and B.

(ii) Also calculate the current through CD and ACB, if a 10 V d.c. source is connected between A and B, and the value of R is assumed as 2 Ω .



Ans. (i) Equivalent circuit is



Which is a balanced *Wheatstone bridge* . Therefore, the resistance of arm CD is ineffective.

Thus resistance of arm ACB, R1 = R + R = 2R and resistance of arm ADB, R2 = R + R = 2R

∴ Effective resistance between A and B is

$$\frac{1}{R_P} = \frac{1}{2R} + \frac{1}{2R} \Rightarrow \frac{1}{R_P} = \frac{2}{2R}$$

∴ $R_P = R$

(ii) ∴ resistance of arm CD is ineffective

∴ No current flows in arm CD

Resistance of arm ACB $= 2R = 2 \times 2 = 4\ \Omega$

∴ Current through ACB, $I = \frac{V}{R} = \frac{10}{4} = 2.5\ A$

Q28. Derive an expression for the energy stored in a parallel plate capacitor.

On charging a parallel plate capacitor to a potential V, the spacing between the plates is halved, and a dielectric medium of $\epsilon_r = 10$ is introduced between the plates, without disconnecting the d.c. source. Explain, using suitable expressions, how the (i) capacitance, (ii) electric field and (iii) energy density of the capacitor change.

Ans. **Energy stored in a parallel plate capacitor:** Work is done in charging a capacitor. This work done is stored as its electrical potential energy. Suppose a capacitor is charged with charge q show that potential difference between its plates is

$$V = \frac{q}{C}$$

Work done to increase the charge by an around dq is

$$dW = V\,dq = \frac{q}{C}\,dq$$

Total work done to charge the capacitor from 0 to Q is

$$W = \int_0^Q \frac{q}{C}\,dq = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{Q^2}{2C}$$

$$\therefore \text{Energy of the capacitor, } U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV \quad \left[\because C = \frac{Q}{V}\right]$$

i. Here $K = \epsilon_r = 10 \quad \because C = \frac{\epsilon_0 A}{d}$

$$\therefore\ C_1 = K\frac{\epsilon_0 A}{d/2} = 10 \times 2 \times \frac{\epsilon_0 A}{d} = 20\ C$$

$\therefore$ Capacitance becomes 20 times.

(ii) Electric field between the plates remains unchanged (E1 = E) because the p.d. across the plates remains unchanged.

iii. $U = \frac{1}{2}CV^2$

$$\therefore\ U_1 = \frac{1}{2}C_1V^2 = \frac{1}{2} \times 20C \times V^2$$

$$= 20\left(\frac{1}{2}C\,V^2\right) = 20\ U$$

$\therefore$ Energy stored increases 20 times.