Unit -2
Display Devices and Light Sources

Luminescence

- Emission of radiation from a solid when it is supplied with some form of energy.
- **Photoluminescence**- excitation arises from the absorption of photons
- **Cathodoluminescence**- excitation is by bombardment with a beam of electrons
- **Electroluminescence**- by applying electric field (DC or AC)

Whatever the form of energy input to the luminescing material, the final stage in the process is an electronic transition between two energy levels, E_1 and E_2 ($E_2 > E_1$), with the emission of radiation of wavelength λ_0 where

$$\frac{hc}{\lambda_0} = E_2 - E_1$$

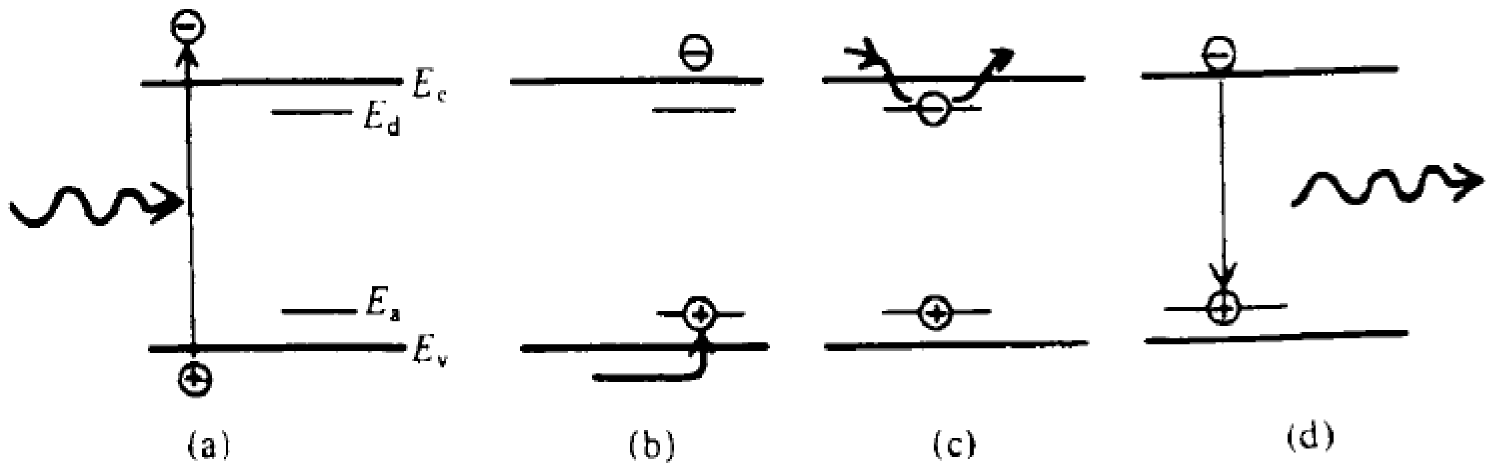
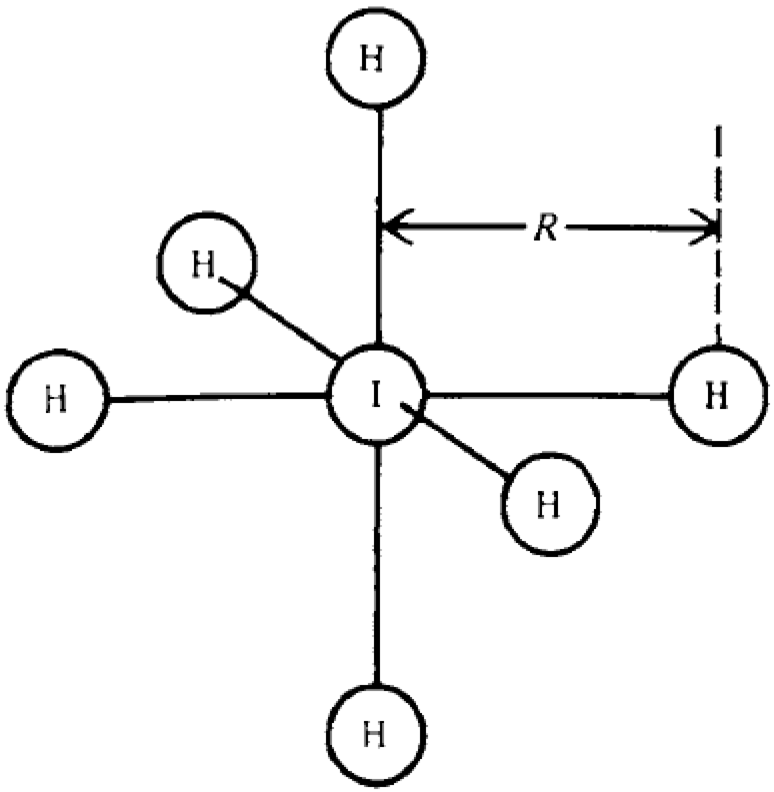


FIG. Electron–hole generation and recombination processes in non-characteristic luminescent materials. Electron–hole pairs are generated by photon absorption (a), and the holes are quickly trapped at acceptor sites (b). Electrons may then recombine with these trapped holes, thereby giving rise to luminescent emission (d). However, before such a recombination can take place, the electron itself may spend some time trapped at a donor site (c).

Photoluminescence

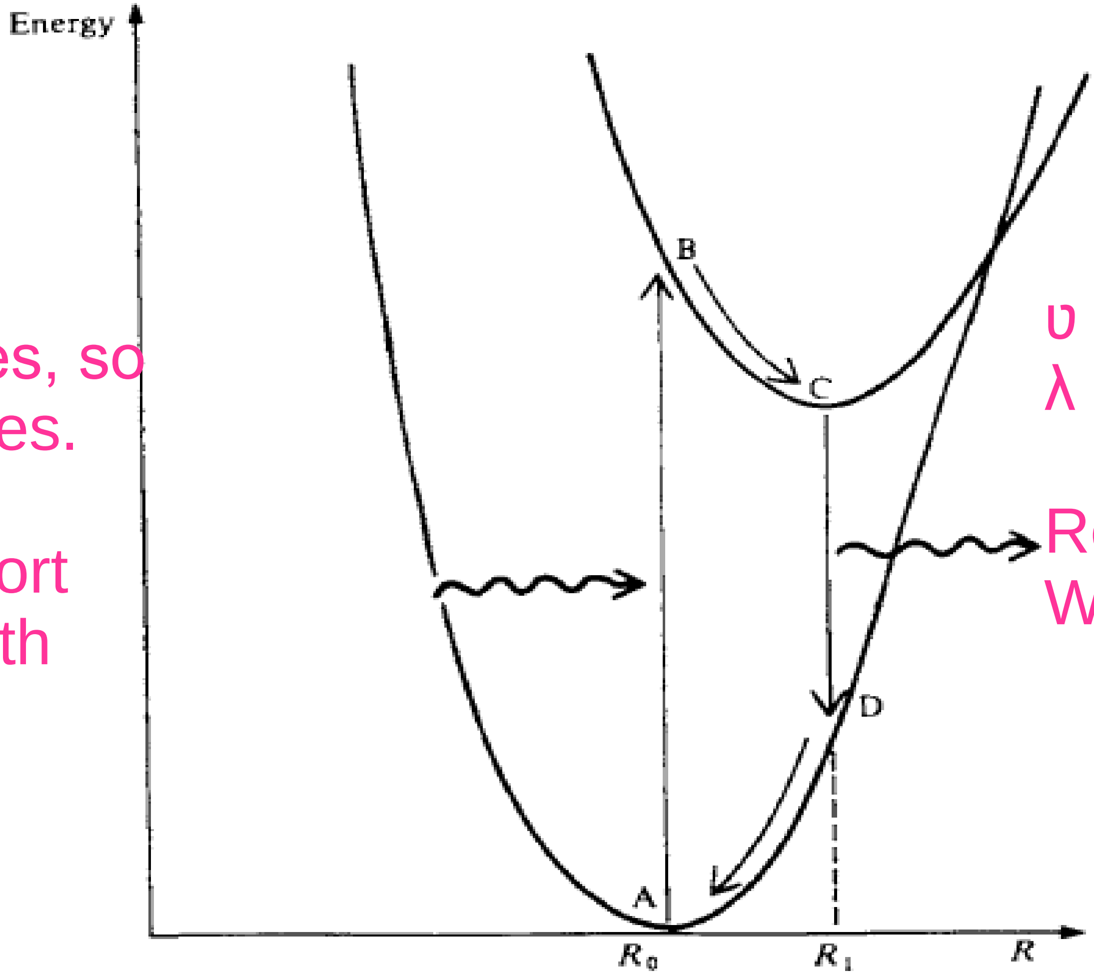
The impurity ion I is surrounded by six host ions H at a distance R from it.



Variation in the energy of two electron energy levels of an impurity ion in a characteristic luminescent material as a function of the nearest neighbour ion separation R.

Stokes Shift

E=hυ



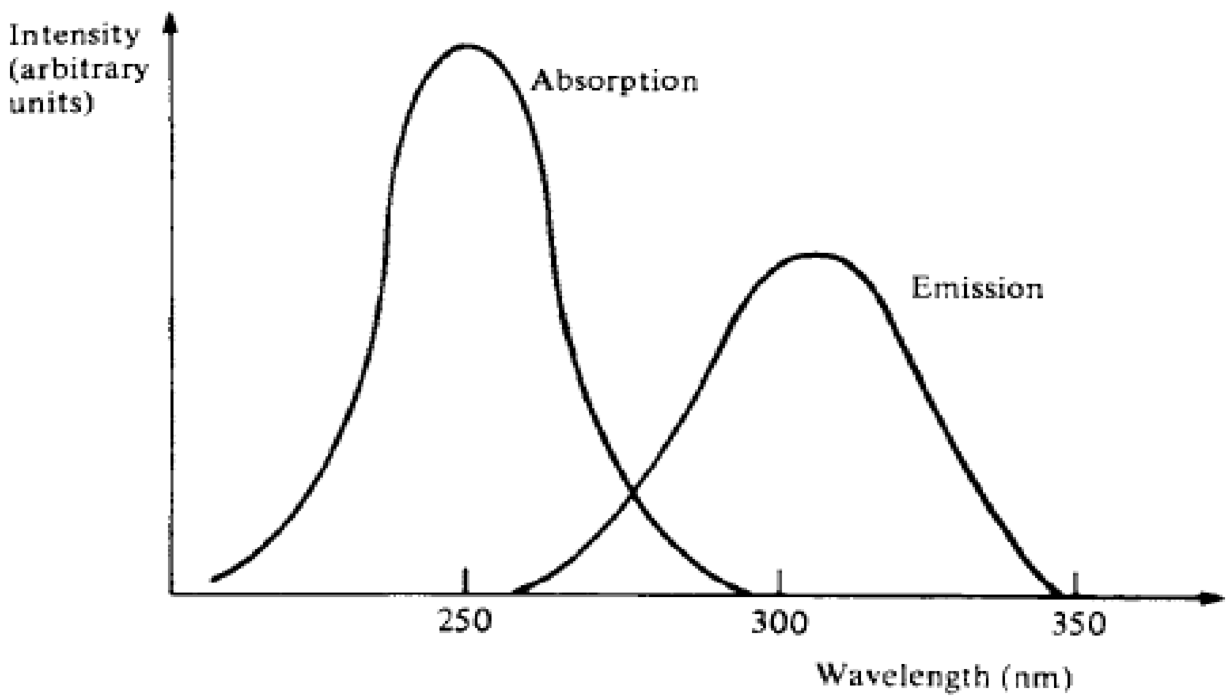
υ increases, so
λ decreases.

Blue – Short Wavelength

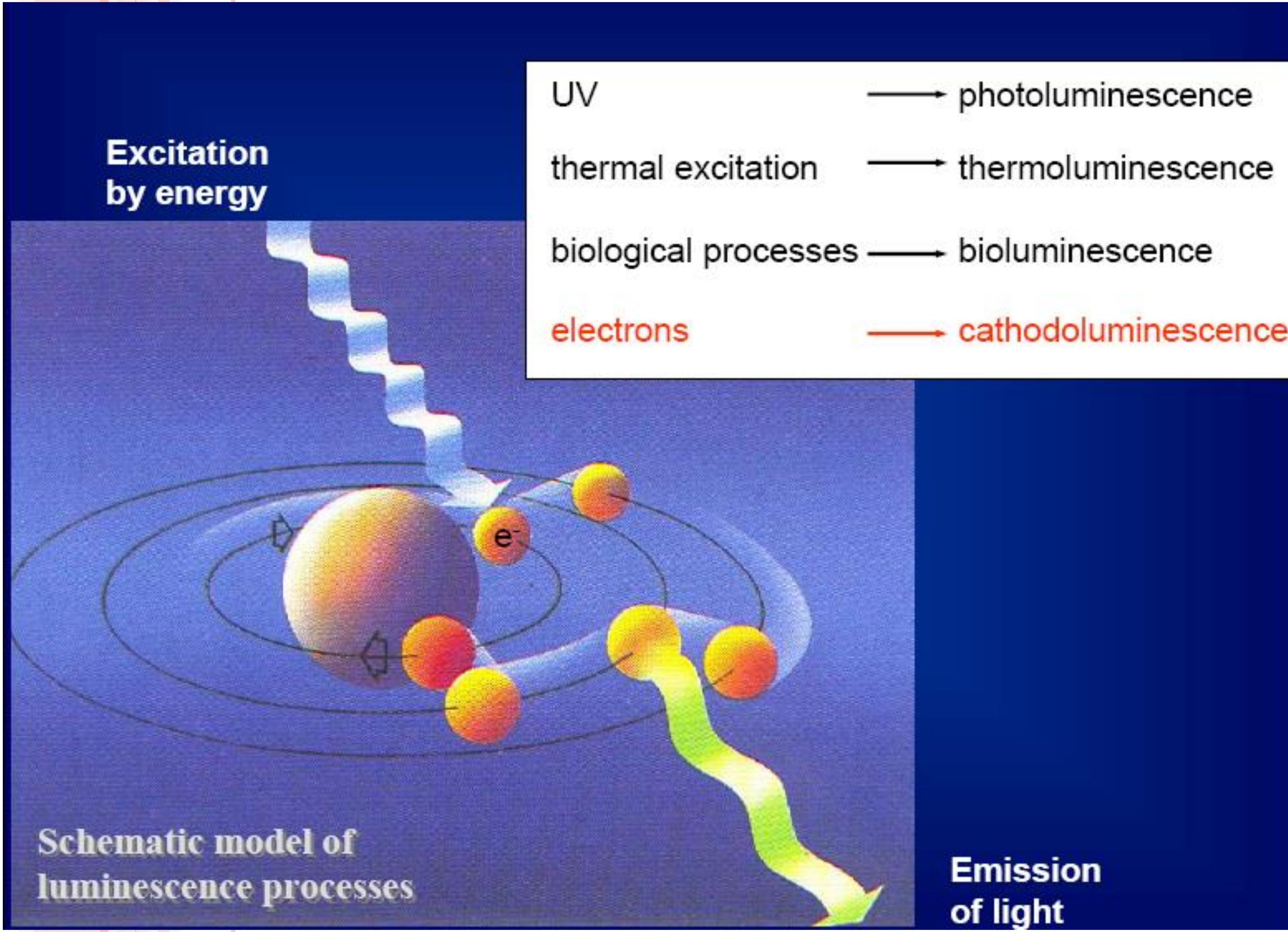
υ decreases, so
λ incresaes.

Red – Long Wavelength

- Absorption and emission spectra for thallium activated potassium chloride at room temperature
- Emission peaks occurs at a higher wavelength than that of the absorption curve
- **Stokes Shift**



Cathodoluminescence


Excitation
by energy
UV → photoluminescence
thermal excitation → thermoluminescence
biological processes → bioluminescence
electrons → cathodoluminescence
e⁻
Schematic model of
luminescence processes
Emission
of light

Based on

Some materials, when excited by **electrons**, produce certain ‘secondary’ electron excitation which then releases small quanta of energy in the range of a few eV…which translated into wavelengths, is the visual light spectrum.

CL images can yield valuable information not <u>easily</u> seen by other means.

- This is an optical (visible/nearly visible light) phenomenon. CL occurs in semiconductors/insulators.

- Electrons in the **<u>valence band</u>** of these materials are excited into the **<u>conduction band</u>** for a brief time; <u>subsequently these electrons recombine with the holes left in the valence band</u>.

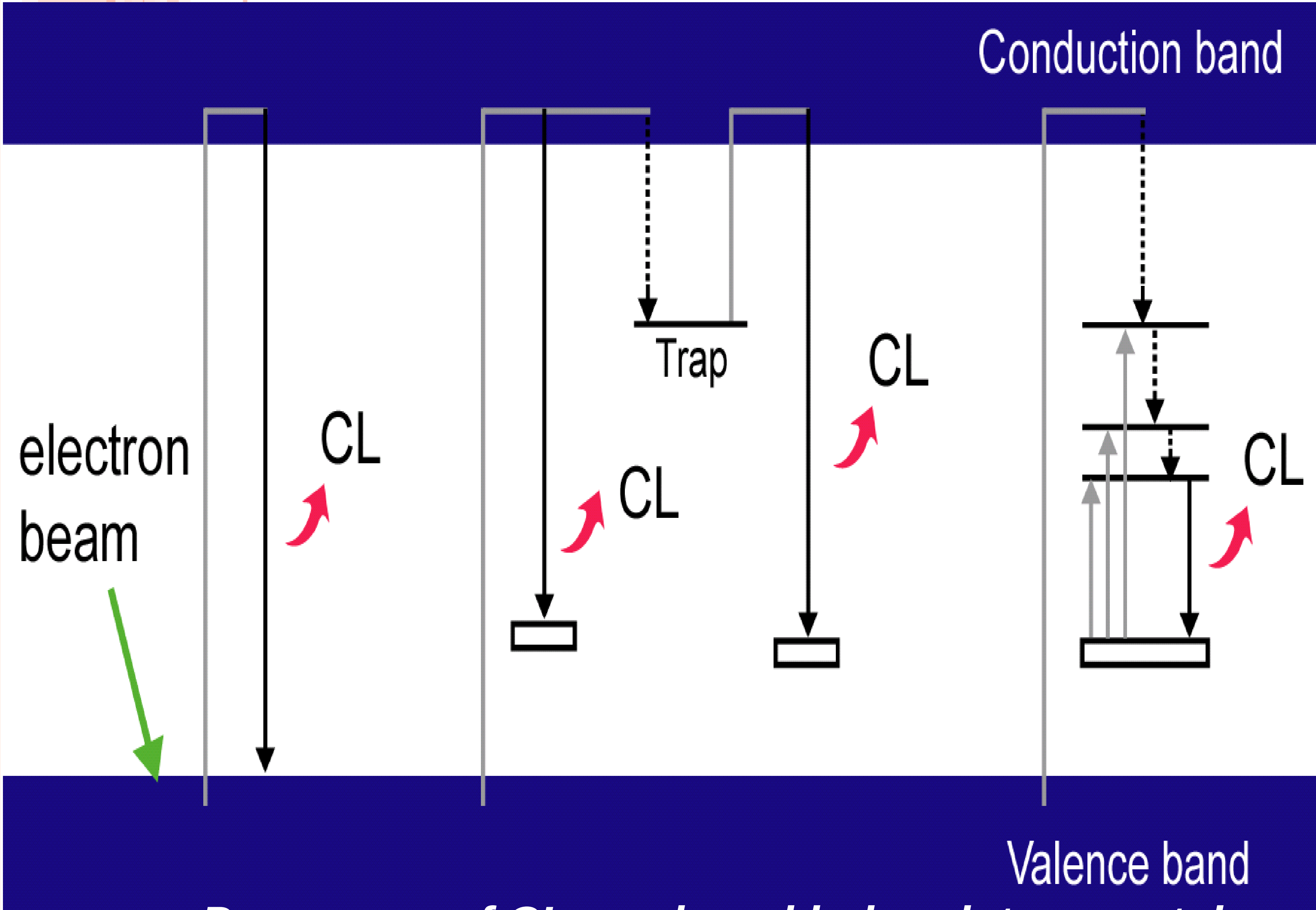
- The energy difference is released as a photon of wavelength of light.

Two commonly used applications are

(1) Locating strain (lattice mismatch) in semiconductors, and

(2) Evaluating minerals for heterogeneous growth (complex history, overgrowths, dissolution, crack infilling).

Mechanism of CathodoLuminance



Processes of CL produced in insulator crystals

- When a beam of energetic electrons hits a solid, a fraction is backscattered.

- The remainder penetrate into the solid where they rapidly lose energy (ejection of bound electrons from parent ions)

- These secondary electrons in-turn generates further secondary electrons (if they have sufficient energy)

- Excitation of electrons from the states at the top of valence band Ev to those at the bottom of the conduction band Ec.

- Primary electrons rapidly loose energy , So they penetrate only a little way into the solid.
- Penetration depth or Range (Rc) of an electron beam of energy E_B is
- $Rc = K(E_B)$^b where K and b are constants.
- Find Rc? Given k=1.2 * (10)^-4 ; b=1.75 for a 10 keV electron beam?

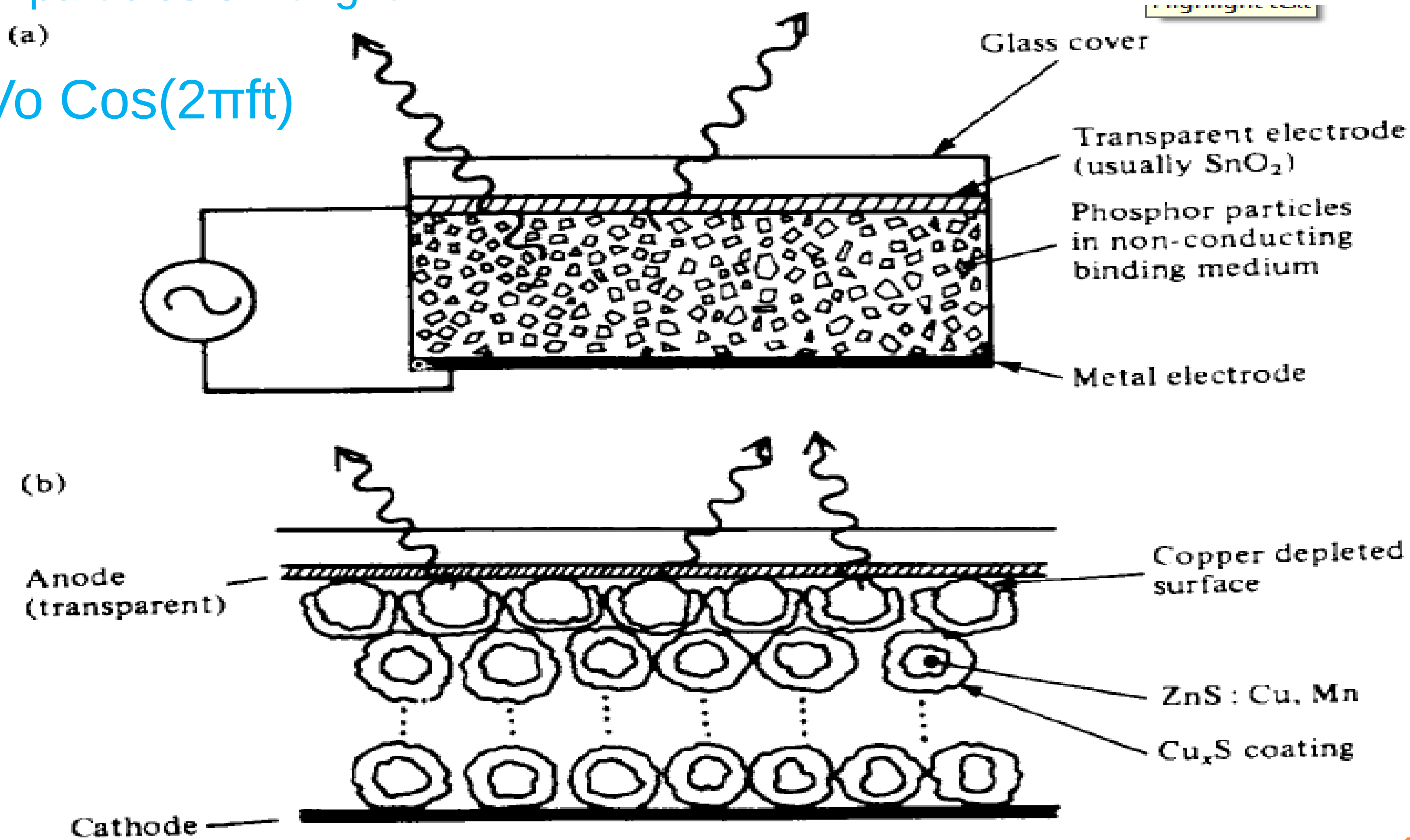
$R_c = 0.7\ \mu m$

Electroluminescence

Construction of an AC electroluminescent device

When an alternating voltage is applied to the electrodes the phosphor particles emit light.

Vo Cos(2πft)



Under normal conditions, light is emitted only from the CUxS depleted particles.

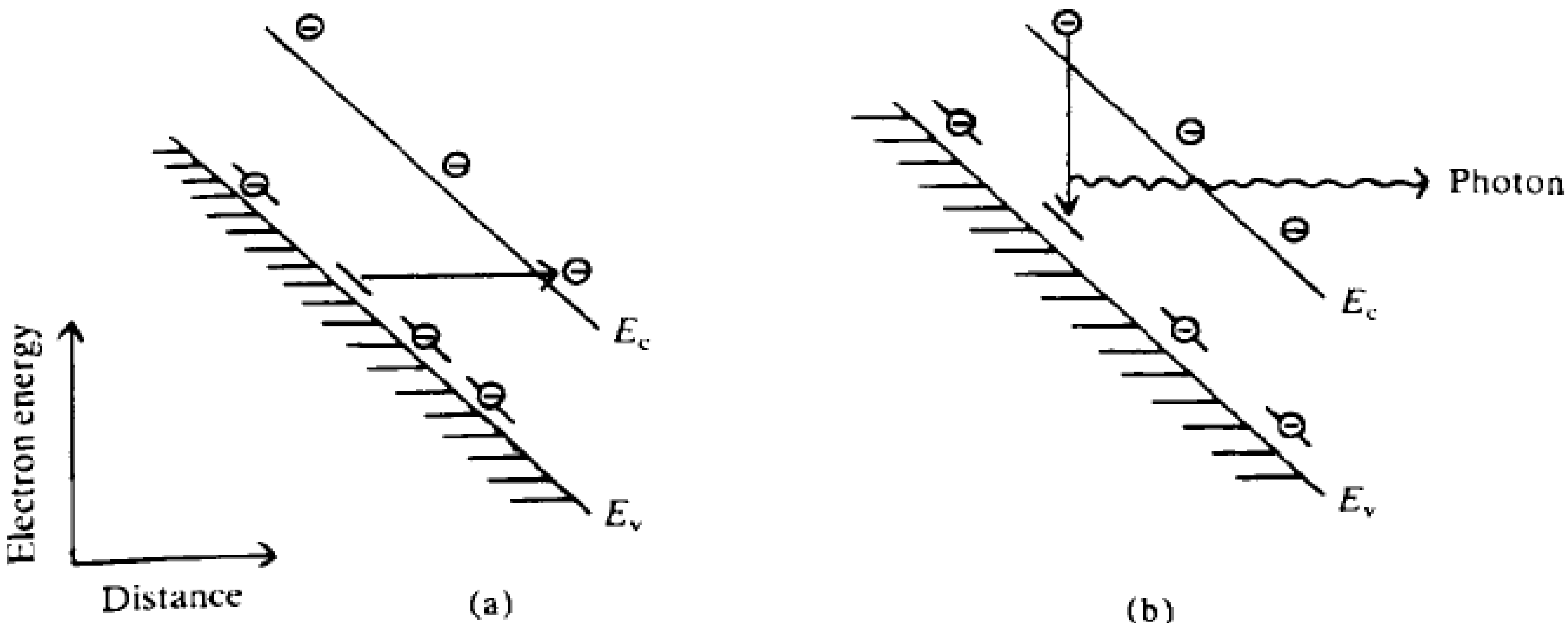
- **(A)** Phosphor particles are suspended within a transparent insulating medium and sandwiched between two electrodes, one of which is transparent.
- **(B)** The constuction of a d.c. electroluminescent device.
- The phospor particles have a coating of CUxS.
- This coating is removed from the anode side of the particles in contact with the anode by the application of an initial high current pulse.
- Under normal conditions, light is emitted only from the CUxS depleted particles.
- The integrated light output power P is

$$P = P_0(f)\exp\left[-\left(\frac{V_1}{V_0}\right)^{1/2}\right]$$

Where V1 is constant
Po(f) is a function of frequency

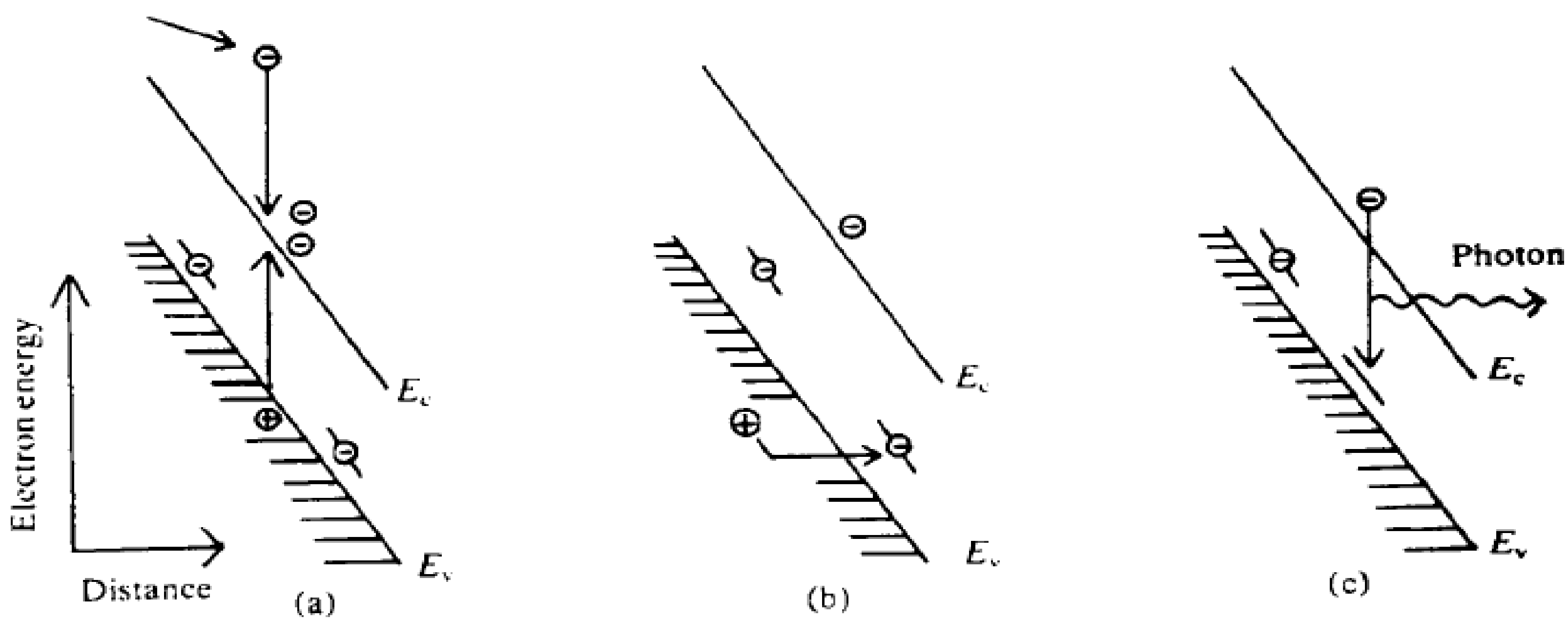
Emission involving Quantum mechanical tunnelling

- (A) An electron in an acceptor state "tunnels" through the forbidden gap region into states of the same energy.
- It is only able to do this if there is a considerable electric field present, thus cause the energy bands to be tilted.
- (B) An electron in the conduction band may now fall into the vacated level resulting in radiative emission.

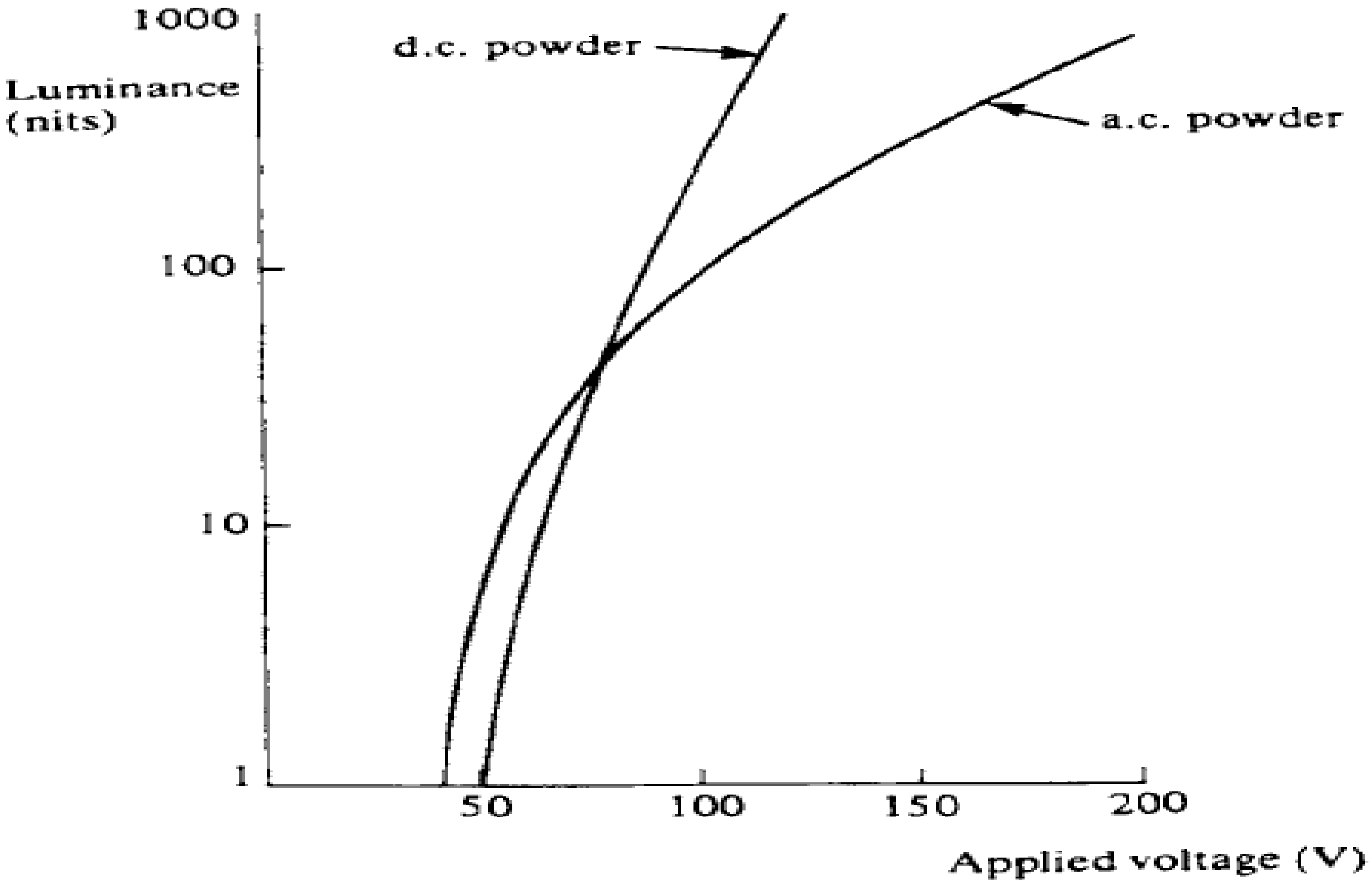


EMISSION INVOLVING AN AVALANCHE PROCESS

- (A) An electron moving in the high electric fields present may acquire sufficient energy to excite an electron from the valence band into the conduction band.
- The hole left behind then moves up into an acceptor state effectively emptying it of an electron.
- (B) An electron in the conduction band may then make a radiative transfer into the empty acceptor level.

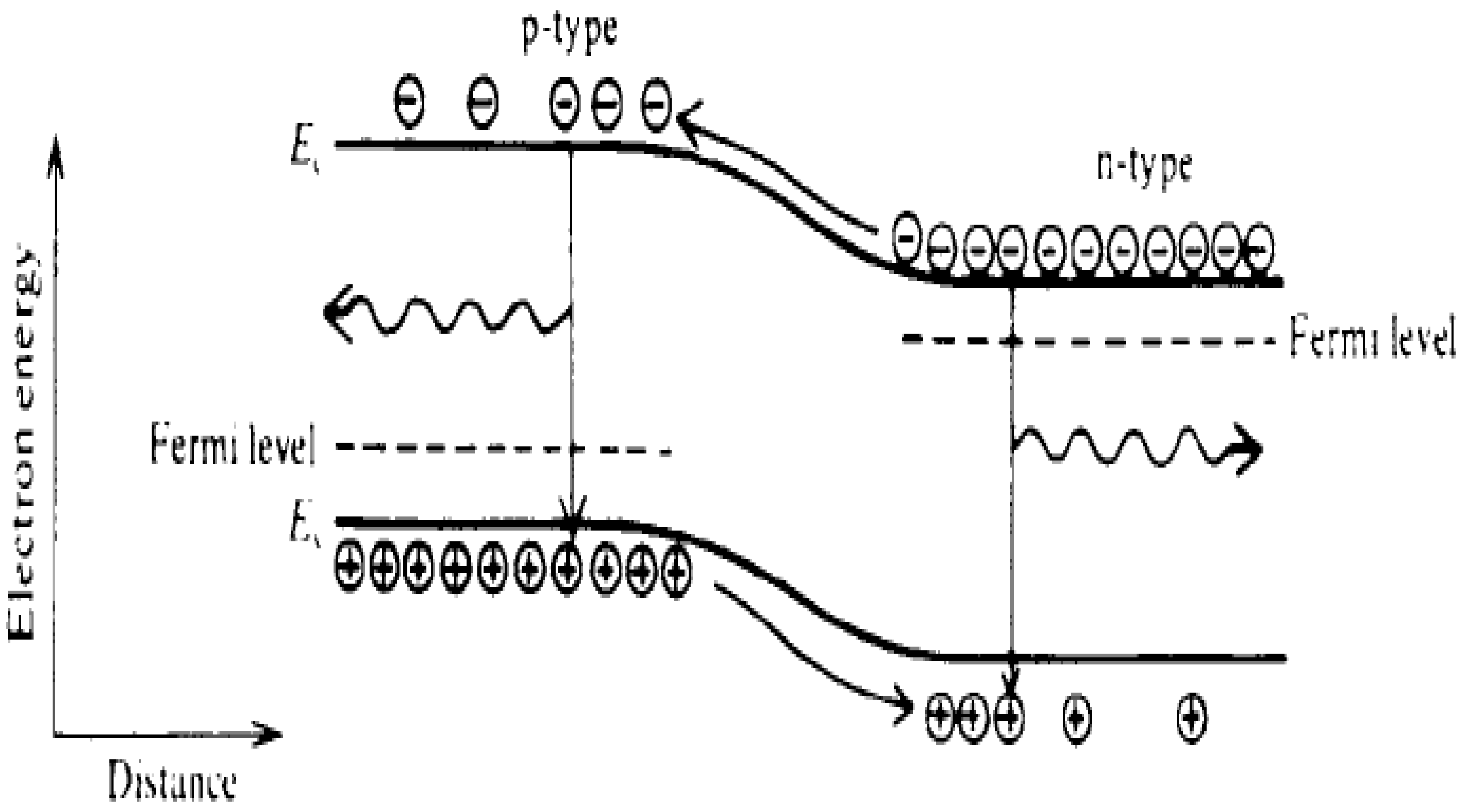


Typical luminances for AC & DC EL power devices



INJECTION LUMINESCENCE

Injection of minority carriers and subsequent radiative recombination with the majority carriers in a FB p-n junction



- Under FB, majority carriers from both sides of the junction cross the internal potential barrier and enter the material at the other side.
- Now they causes the local minority carrier population to be larger than normal—Minority Carrier Injection.
- Recombines with majority carriers- Radiative recombination