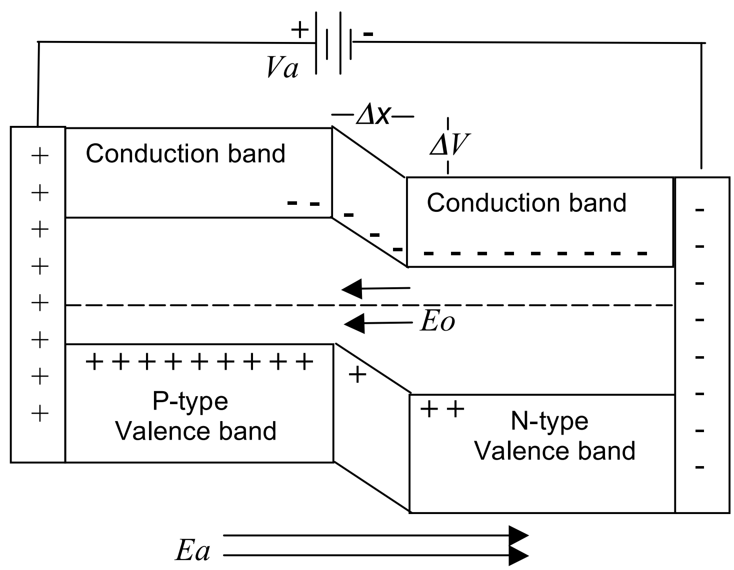
Light Emitting Diodes

Object: We study the characteristics of light emitting diodes and use them to demonstrate the quantum nature of light *E=hf.* Planck's constant h = 4.13 x 10^{-15} eV/s is determined by measuring the diffusion voltage vs. light emission.

P-n Junction: P-material contains excess +holes and n-material contain excess -electrons. Upo joining p-side holes diffuse across the junction to the right and n-side electrons diffuse across the junction to the left until electrostatic equilibrium is reached. A contact potential difference Uo (diffusion voltage) is developed across the junction correstonding to an internal electric field $Eo = -dU/dx$.

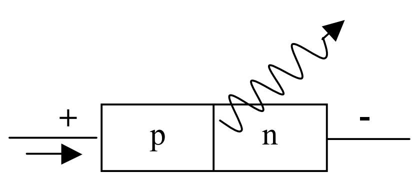
By forward biasing the diode with an applied electric field $Ea \geq Eo$ *current begins flowing through the diode junction, electrons to the left and holes to the right.*



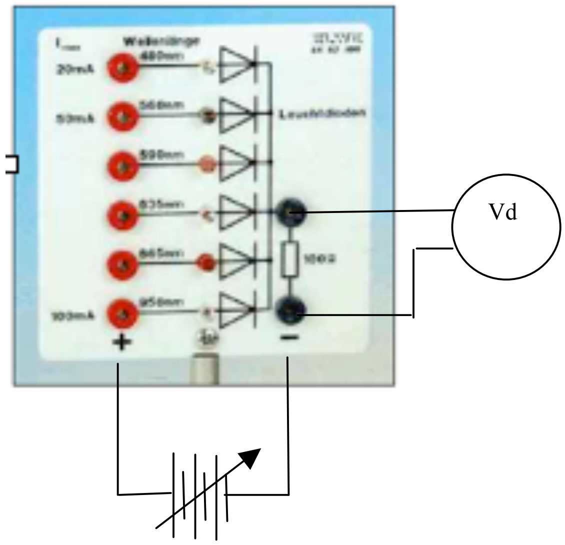
As the current flows electrons are continually meeting holes in the p-n interface. When an electron drops in to a hole level a photon is released with energy *E=hf*. The frequency or wavelength of light (color) will depend on the semiconductor material and diffusion voltage *Uo*. The diode will turn on exactly when *Va = Uo. T*he energy lost in the electron-hole collision is converted to a photon of energy

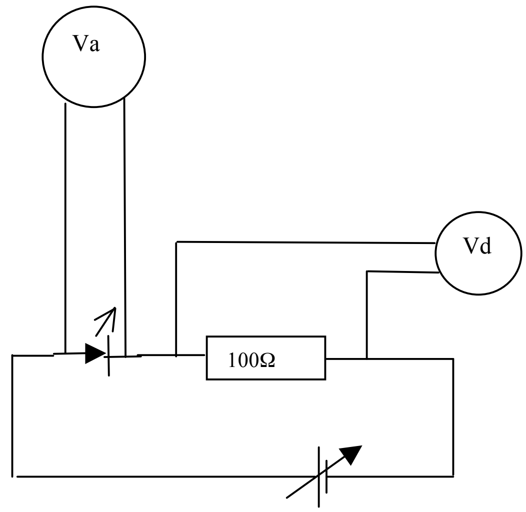
$$hf = e\,Uo = eVa.$$

The LED junction must be thin and/or transparent so the light emission can escape.



Apparatus: A variable voltage supply is placed in series with the diode and 100Ω ***current limiting*** resistor. A voltmeter *Va* measures applied diode voltage and a 2nd voltmeter measures the voltage drop *Vd* across the 100Ω resistor.





Part 1: LED I-V curve Attach the positive voltage terminal to the red LED. In small steps increase the the supply voltage 0 < Va < 2V and measure the current flowing in the circuit *I = Vd/100.* Graph the *I-V* characteristic curve for the red LED. Determine the diffusion voltage *Uo* or when the red LED just turns on *(I >0)* from the graph. Determine an associated error.

Va	0.	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
I=Vd/100	0.										

Part 2: Measurement of Planck's constant *h*. Attach the voltage supply to each LED in question and measure the diffusion voltage *Uo*. Increase the voltage *Va* until the LED just turns on or forward current *Vd/100~0*. Record the value of *Va = Uo* for each diode.

LED	465nm	560nm	585nm	635nm	660nm	950nm
Uo						

We must have that *eUo = hf* to satisfy the resonance condition. Plot the data *Uo* vs *f*. Fit the data to a straight line y=a + bx or *Uo* =(h/e) x. The slope=b=*h/e* should give Planck's constant h =eb! The fit and error can be determined by using the **LED_Calculator** given on the PHYS471 web page.