Display and Printing Devices

Overview of the Talk

- Basics of printing documents
- Basics of display mechanisms
- Daisy wheel printer
- Bit mapped devices
- Filament lamps
- Light Emitting Diodes
- CRTs
- Liquid Crystal Displays
- Different types of printers
- Page description languages

Basics of Printing

• Printers were initially based on typewriter technology

A character shaped piece of metal was moved into contact with an inked ribbon in contact with the paper so that ink is transferred.

• Development of this technology culminated in the daisy wheel printer, a relatively low cost yet high quality device.

• Each character is placed on the end of a flexible arm and a complete set arranged around a central hub.

• This collection spins around and a hammer behind the wheel is triggered at the correct time to force the required character into contact with the ribbon.

• The flexible arm allows the character to stop momentarily to prevent smearing.

• The wheel mechanism is placed on a carriage which moves along a line of text, as shown in Fig.

Daisy wheel printer

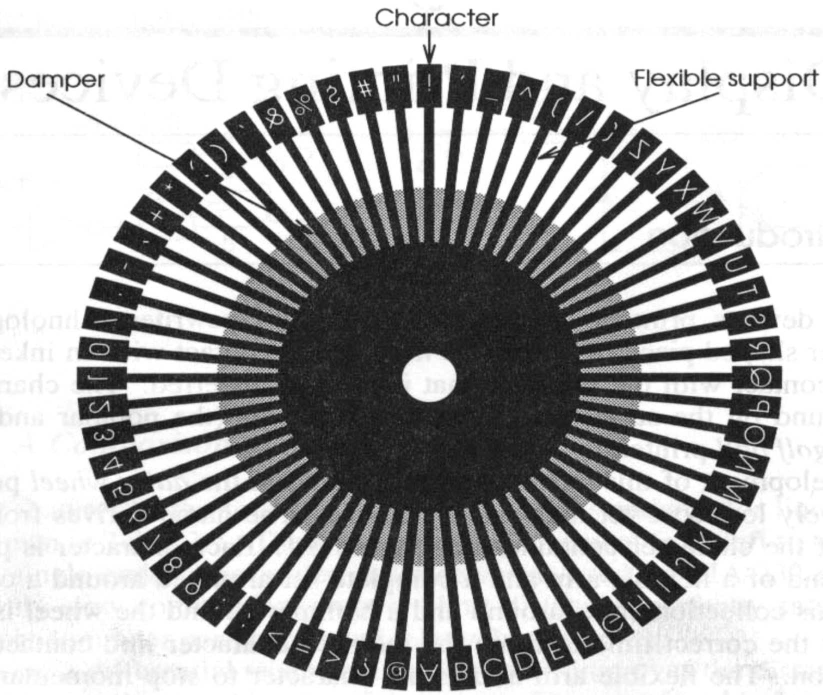


Figure 3.1 *A 'daisy wheel' (full size)*

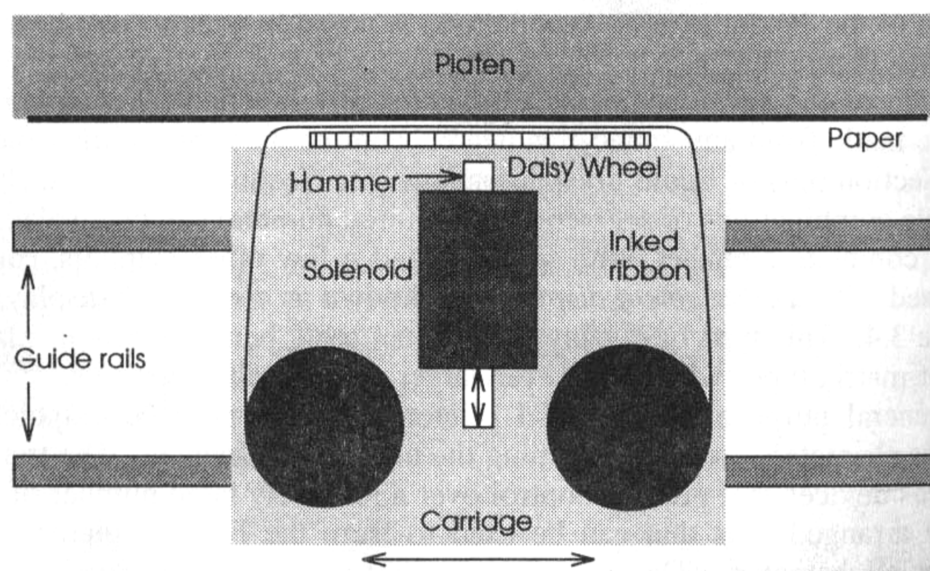


Figure 3.2 *'Daisy wheel' printer mechanism (viewed from above)*

Display Basics

- Stylized character sets were utilized for display purposes.
- Applications requiring only a limited set of characters are able to use simple combinations of indicator
- Applications – Displaying numerals in test and measuring equipment, cash registers etc.
- A 7-segment display can be used to display 10 digits and some letters as shown in Fig. 3.3
- Each of the seven segments, labelled from ‘a’ to ‘g’, can be made from any suitable indicator; commonly LEDs or LCDs.
- A complete alphabet, with numbers and a few other symbols, can be obtained with a 16-segment display as shown in Fig. 3.4

7-Segment Display

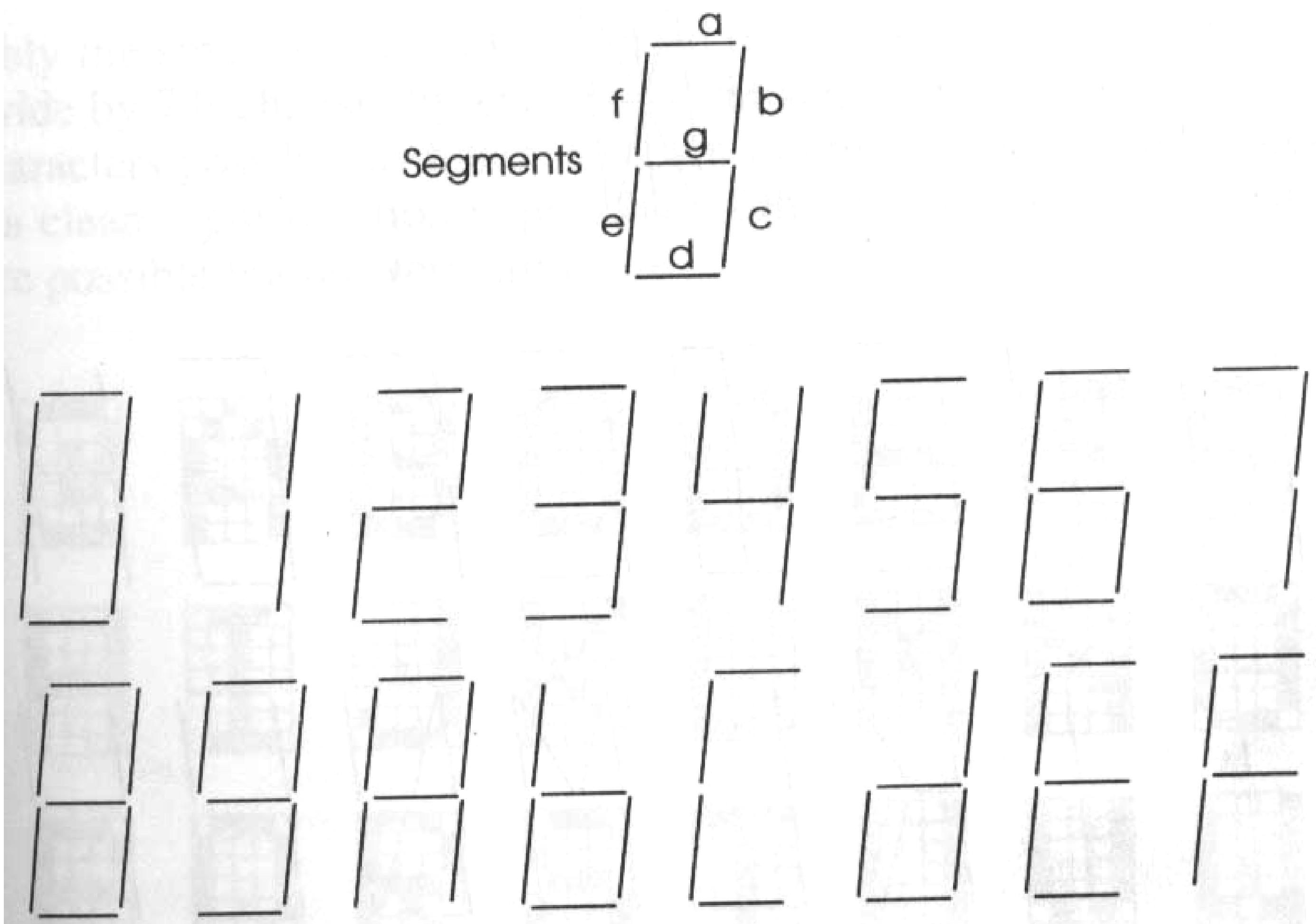


Figure 3.3 *7-segment characters.*

16-Segment Display

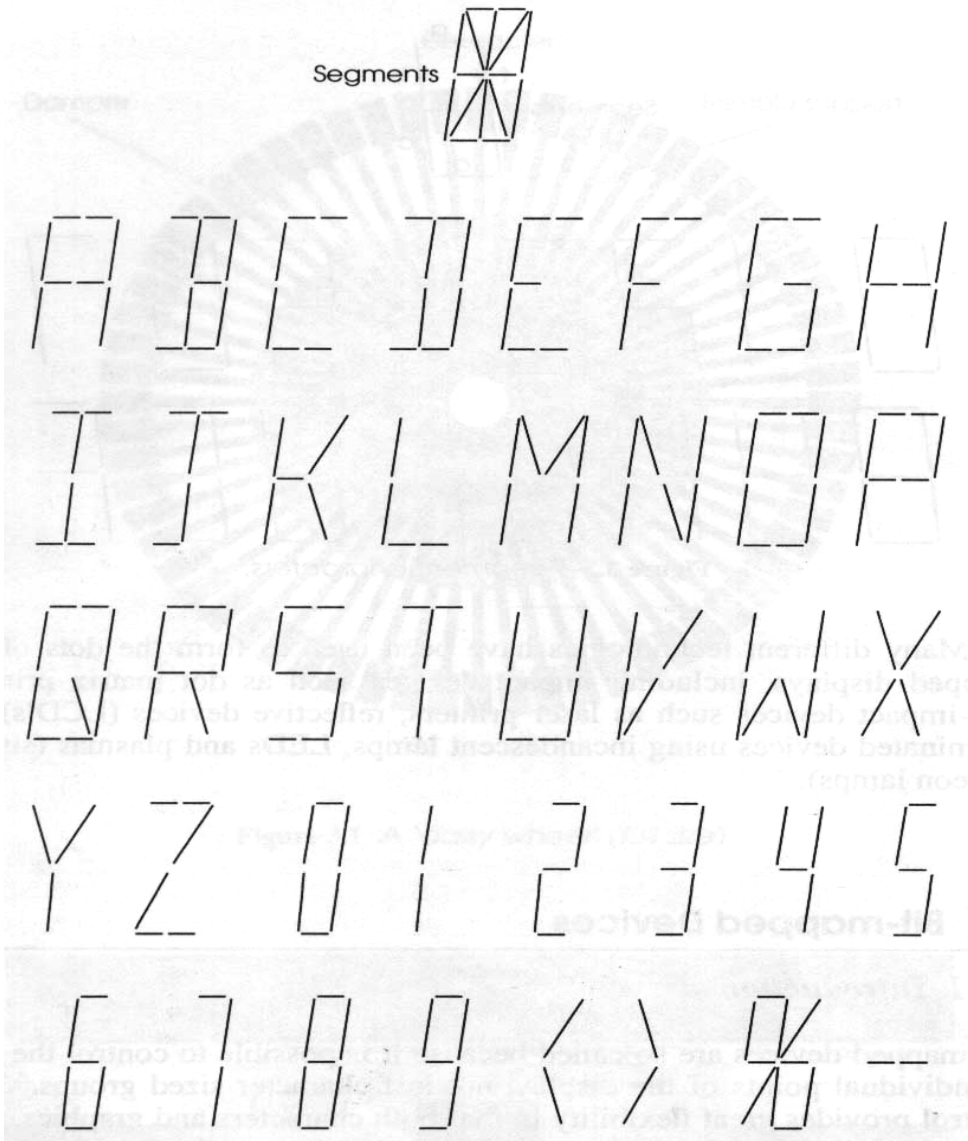


Figure 3.4 *16-segment characters*

High Quality Printing and Display

- General Purpose displays and printers that can produce graphics as well as characters are now becoming the normal requirement.
- The trend is towards devices that provide control over a relatively large number of regularly arranged dots that can be used to form the lines of pictures and shapes of characters.
- These devices are known as *bit-mapped devices.*

Bit-mapped Devices

- Bit mapped devices can control the state of individual points of the display, not just character sized groups.
- Characters, graphics, lines and other arbitrary shapes may be drawn with greater flexibility.
- Fonts can be created by a number of points.
- Dedicated hardware is used to form a bit-pattern that describes the information on a complete page and to allow control of the state of individual points or pixels.
- For a single line display, it requires a trivial amount of memory
- But for a 600 dpi printer it is in the region of 4MB for a page
- And a high quality colour device needs near about 100MB

Character Fonts

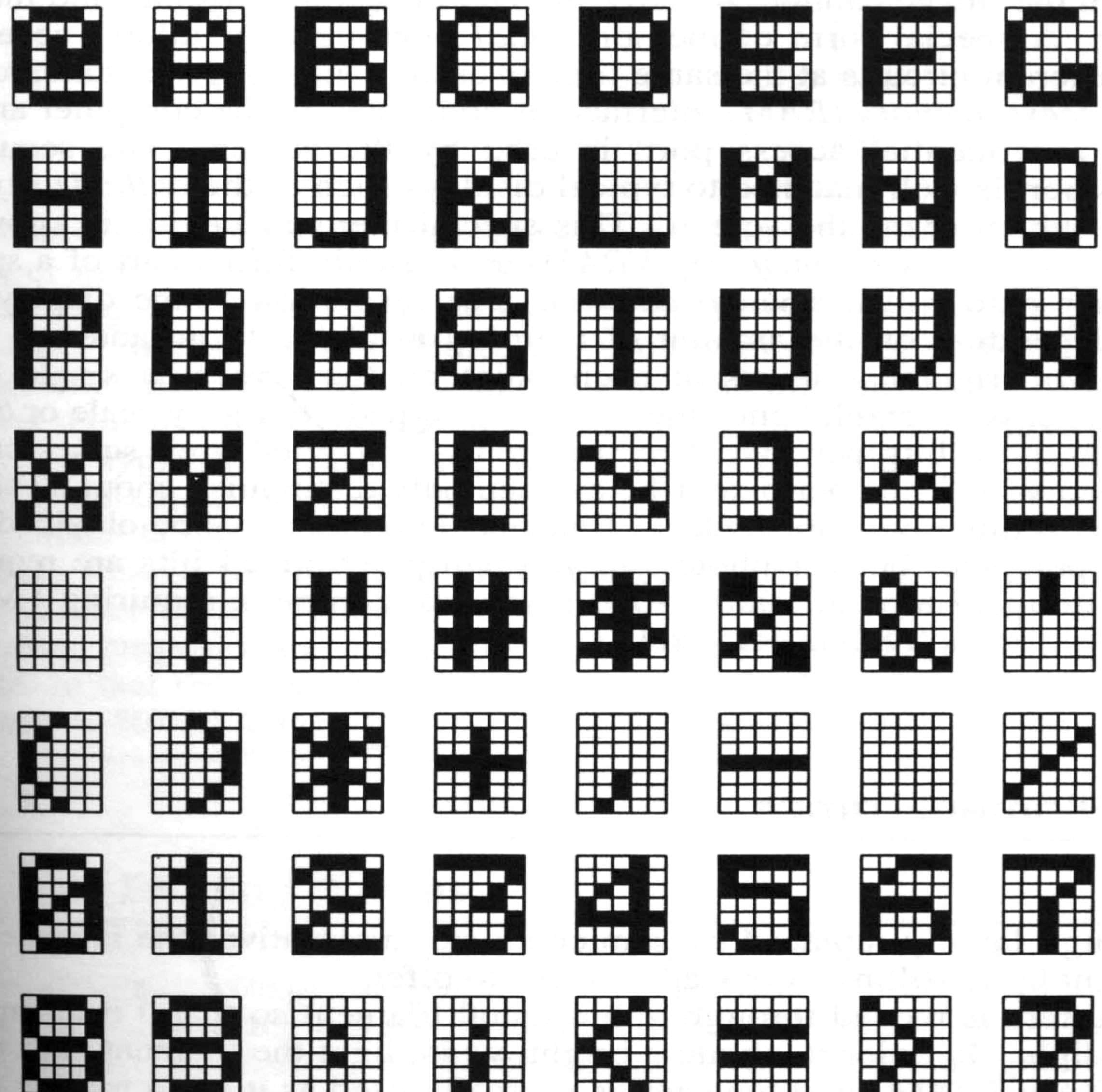


Figure 3.5 *5× 7 dot characters*

Display Implementation

- Dynamic display devices (computer screen) must be given data continuously, even at the same time as it is being created.

- The data rate for a video display is such that the memory used to form the image can not be easily shared between the display and the processor.

- An special form of memory, dual port memory, allows access by two different circuits at the same time is used.

- One port, the standard *Random Access Memory (RAM)* interface, is connected to the computer and the other, a sequential access port, is used by the screen.

- The sequential access port is well matched to typical displays such as the *cathode Ray Tube (CRT)* which scans the screen.

- This special memory device is known as Video Random Access Memory (VRAM) and usually forms part of a special interface card called a *video adaptor.*

Filament Lamps

- Incandescent filament lamps have already been largely replaced by semiconductor devices. Still has some advantages.

- Current is passed through a thin metal filament so that it heats up and emits light.

- The tungsten filament is normally used, having melting point of 3387^0C.

- The filament must reach at 2800^0C to 3000^0C to emit bright and white light.

- The filament is formed into a spiral shape to minimize the heat loss.

- Oxidation (burning) of the filament is prevented by placing it into an evacuated glass bulb.

Filament Lamps

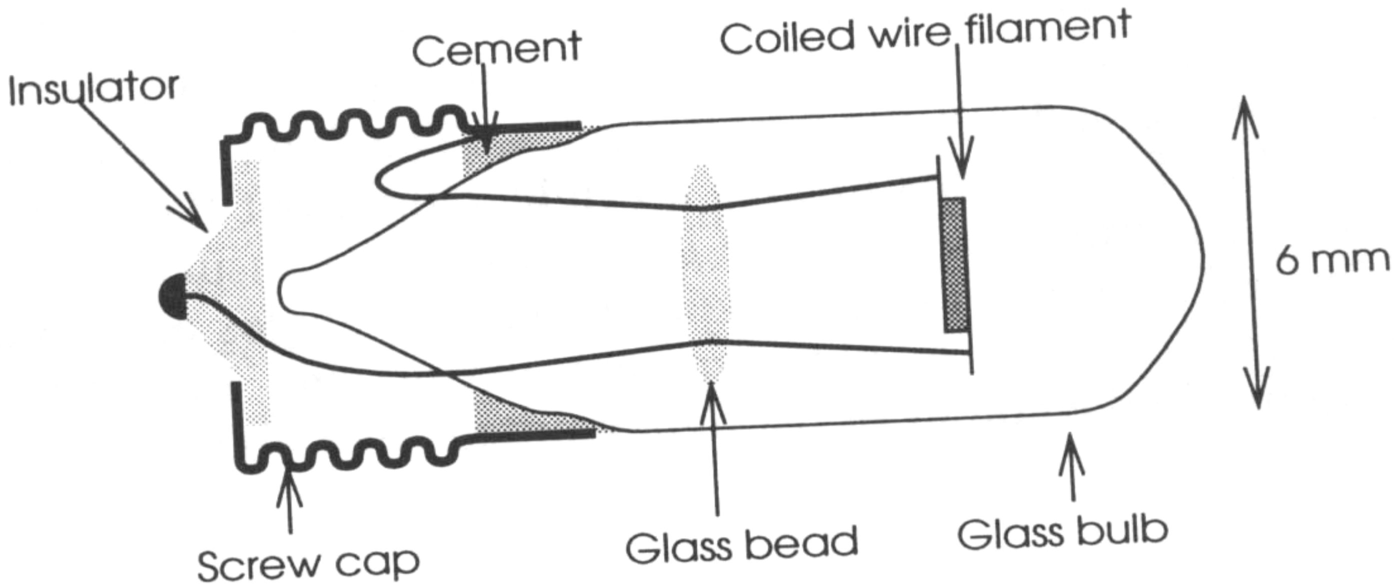


Figure 3.6 *Filament lamp construction*

Lifetime – Typically 5000 hours to 50000 hours.

Light Emitting diodes

- **Light emitting diodes**, commonly called LEDs, are found in different kinds of devices.
- Among other things, they form the numbers on digital clocks,l ight up watches and tell you when your appliances are turned on. Collected together, they can form images on a jumbo television screen or illuminate a traffic light.
- Basically, LEDs are just tiny light bulbs that fit easily into an electrical circuit. But unlike ordinary incandescent bulbs, they don't have a filament that will burn out, and they don't get especially hot. They are illuminated solely by the movement of electrons in a semiconductor material, and they last just as long as a standard transistor.

Light Emitting Diodes

•A range of colours from infra-red, through red, orange, yellow and green, to blue is now available.

• *Gallium phosphide* (*GaP*), formed into a p-n diode, was found to emit red light when forward biased.

• A pure *GaP* diode emits green light but impurities change the colour of light emitted, current red light diodes use *Gallium arsenide phosphide* (*GaAsP*).

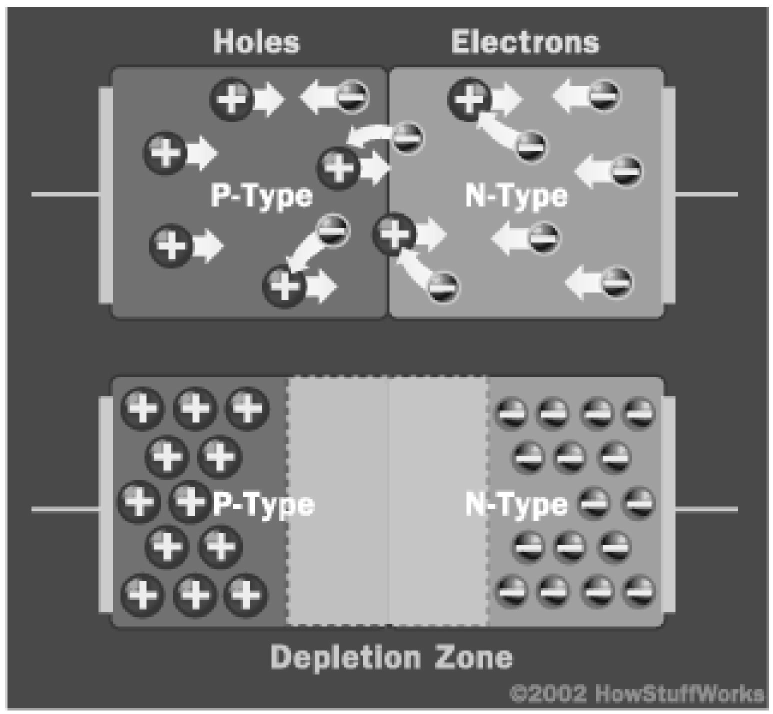
• *Gallium arsenide* (*GaAs*) is used to produce infra-red light and *Silicon carbide* (*SiC*) for blue light.

- **What is Diode?**
- A **diode** is the simplest sort of semiconductor device.
- A semiconductor is a material with a varying ability to conduct electrical current. Most semiconductors are made of a poor conductor that has had **impurities** (atoms of another material) added to it. The process of adding impurities is called **doping**.
- In the case of LEDs, the conductor material is typically **aluminum-gallium-arsenide** (AlGaAs). In pure aluminum-gallium-arsenide, all of the atoms bond perfectly to their neighbors, leaving no free **electrons** (negatively-charged particles) to conduct electric current. In doped material, additional atoms change the balance, either adding free electrons or creating **holes** where electrons can go. Either of these additions make the material more conductive.

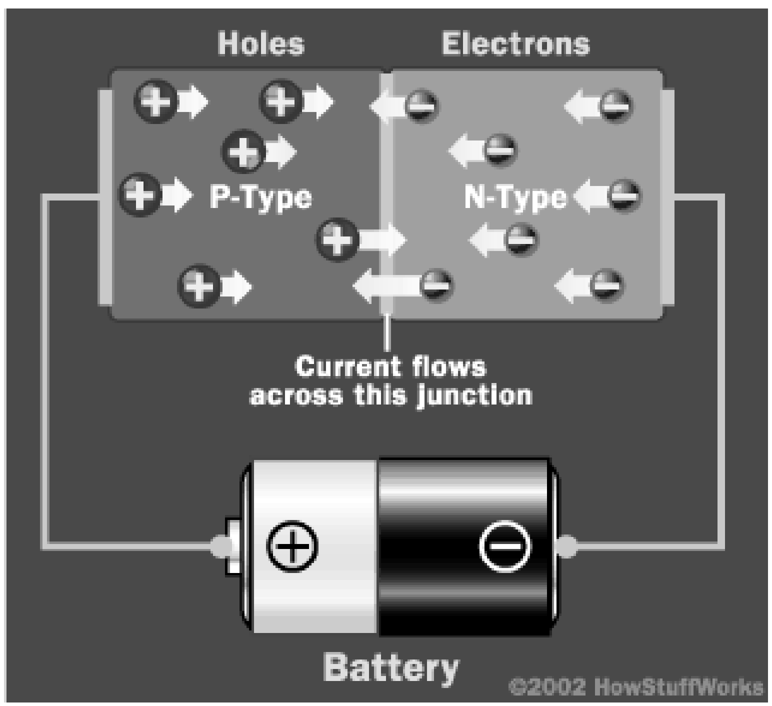
  A semiconductor with extra electrons is called **N-type material**, since it has extra **n**egatively-charged particles. In N-type material, free electrons move from a negatively-charged area to a positively charged area**.**

  A semiconductor with extra holes is called **P-type material**, since it effectively has extra **p**ositively-charged particles. Electrons can jump from hole to hole, moving from a negatively-charged area to a positively-charged area. As a result, the holes themselves appear to move from a positively-charged area to a negatively-charged area.

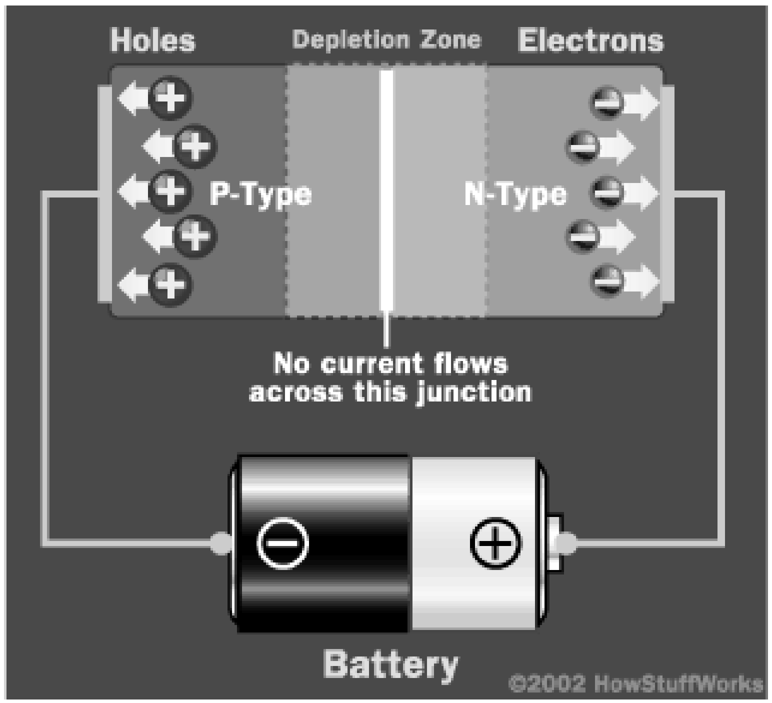
A diode comprises a section of N-type material bonded to a section of P-type material, with electrodes on each end. This arrangement conducts electricity in only one direction. When no voltage is applied to the diode, electrons from the N-type material fill holes from the P-type material along the junction between the layers, forming a depletion zone. In a depletion zone, the semiconductor material is returned to its original insulating state -- all of the holes are filled, so there are no free electrons or empty spaces for electrons, and charge can't flow.



To get rid of the depletion zone, you have to get electrons moving from the N-type area to the P-type area and holes moving in the reverse direction. To do this, you connect the N-type side of the diode to the negative end of a circuit and the P-type side to the positive end. The free electrons in the N-type material are repelled by the negative electrode and drawn to the positive electrode. The holes in the P-type material move the other way. When the voltage difference between the electrodes is high enough, the electrons in the depletion zone are boosted out of their holes and begin moving freely again. The depletion zone disappears, and charge moves across the diode.



If we try to run current the other way, with the P-type side connected to the negative end of the circuit and the N-type side connected to the positive end, current will not flow. The negative electrons in the N-type material are attracted to the positive electrode. The positive holes in the P-type material are attracted to the negative electrode. No current flows across the junction because the holes and the electrons are each moving in the wrong direction. The depletion zone increases.



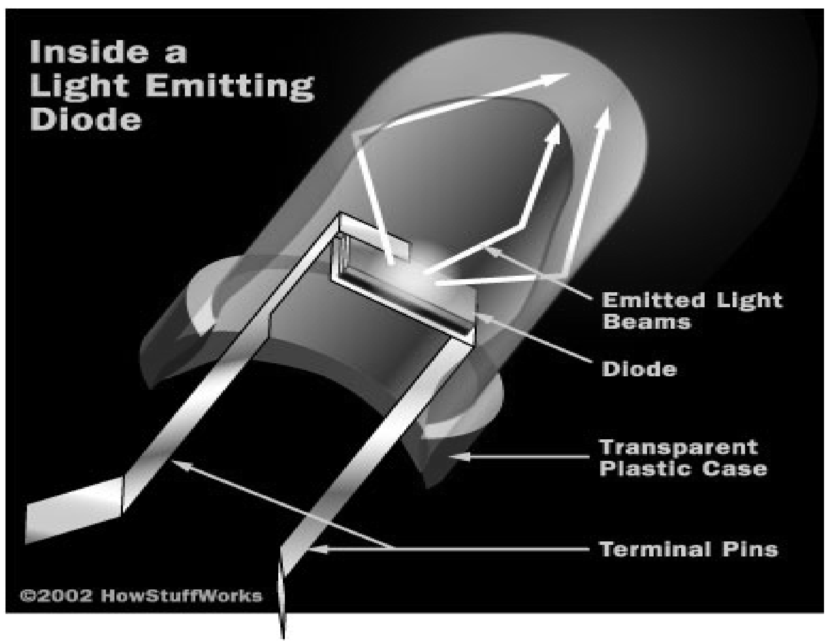
The interaction between electrons and holes in this setup has an interesting side effect -- it generates light!

How Can a Diode Produce Light?

- Light is a form of energy that can be released by an atom. It is made up of many small particle-like packets that have energy .These particles, called **photons**, are the most basic units of light. Photons are released as a result of moving electrons.
- In an atom, electrons move in orbital around the nucleus. Electrons in different orbital have different amounts of energy. Electrons with greater energy move in orbitals farther away from the nucleus.
- For an electron to jump from a lower orbital to a higher orbital, something has to boost its energy level. Conversely, an electron releases energy when it drops from a higher orbital to a lower one. This energy is released in the form of a **photon**. A greater energy drop releases a higher-energy photon, which is characterized by a higher frequency.
- Free electrons moving across a diode can fall into empty holes from the P-type layer. This involves a drop from the *conduction band* to a lower orbital, so the electrons release energy in the form of photons. This happens in any diode, but you can only see the photons when the diode is composed of certain material. The atoms in a standard silicon diode, for example, are arranged in such a way that the electron drops a relatively short distance. As a result, the photon's frequency is so low that it is invisible to the human eye -- it is in the infrared portion of the light spectrum. This isn't necessarily a bad thing, of course: Infrared LEDs are ideal for remote controls, among other things.

Visible light-emitting diodes (VLEDs), such as the ones that light up numbers in a digital clock, are made of materials characterized by a *wider gap* between the conduction band and the lower orbitals. The size of the gap determines the frequency of the photon -- in other words, it determines the color of the light.

While all diodes release light, most don't do it very effectively. In an ordinary diode, the semiconductor material itself ends up absorbing a lot of the light energy. LEDs are specially constructed to release a large number of photons outward. Additionally, they are housed in a plastic bulb that concentrates the light in a particular direction. As we can see in the diagram, most of the light from the diode bounces off the sides of the bulb, traveling on through the rounded end.



Advantages & Disadvantages of LED

LEDs have several advantages over conventional incandescent lamps.

- They don't have a filament that will burn out, so they last much longer.
- They also fit more easily into modern electronic circuits.
- The main advantage is efficiency. In conventional incandescent bulbs, the light-production process involves generating a lot of heat (the filament must be warmed). This is completely wasted energy, unless the lamp is used as a heater. Because a huge portion of the available electricity isn't going toward producing visible light. LEDs generate relatively very little heat . A much higher percentage of the electrical power is going directly to generating light, which cuts down on the electricity demands considerably.

It has a disadvantage also.

- Up until recently, LEDs were too expensive to use for most lighting applications because they're built around advanced semiconductor material.

Cathode Ray Tubes (CRTs)

The **cathode ray tube (CRT)**, invented in 1897, is an evacuated glass envelope containing an electron gun (a source of electrons) and a screen, usually with means to accelerate and deflect the electrons. When electrons strike the screen, light is emitted.

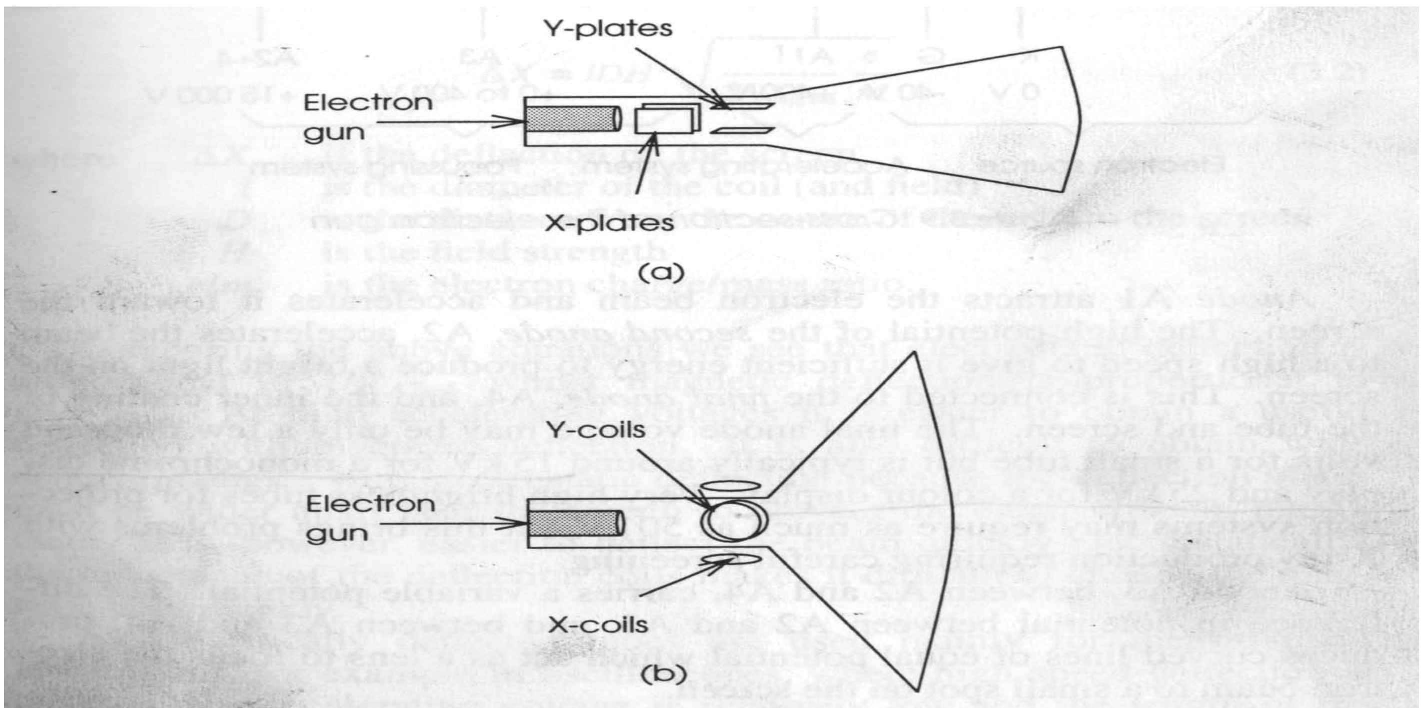
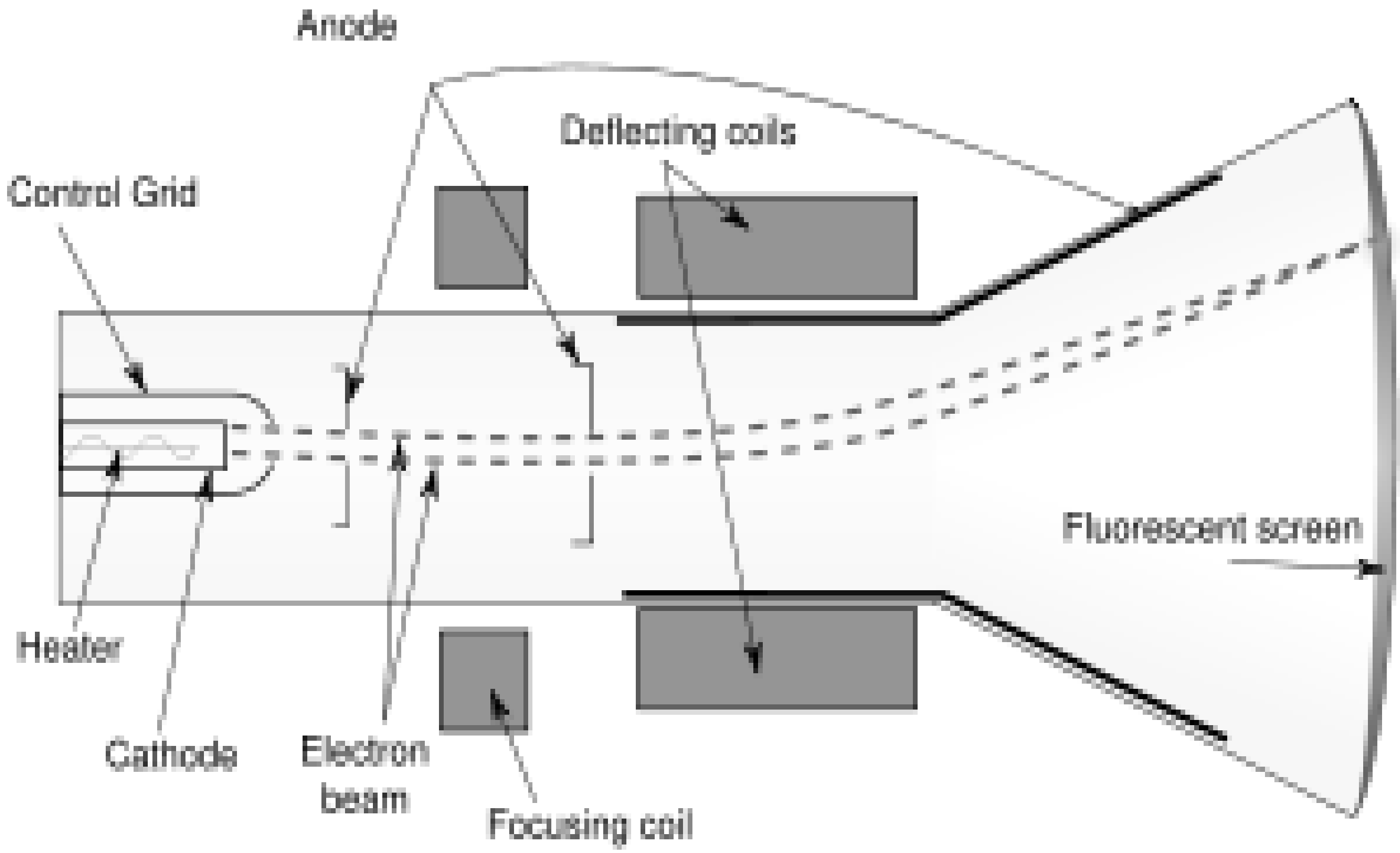


Figure 3.8 *Cathode-ray tube construction: (a) with electrostatic deflection; (b) with magnetic deflection*

Cathode Ray Tubes (CRTs)



Cathode Ray Tubes (CRTs)

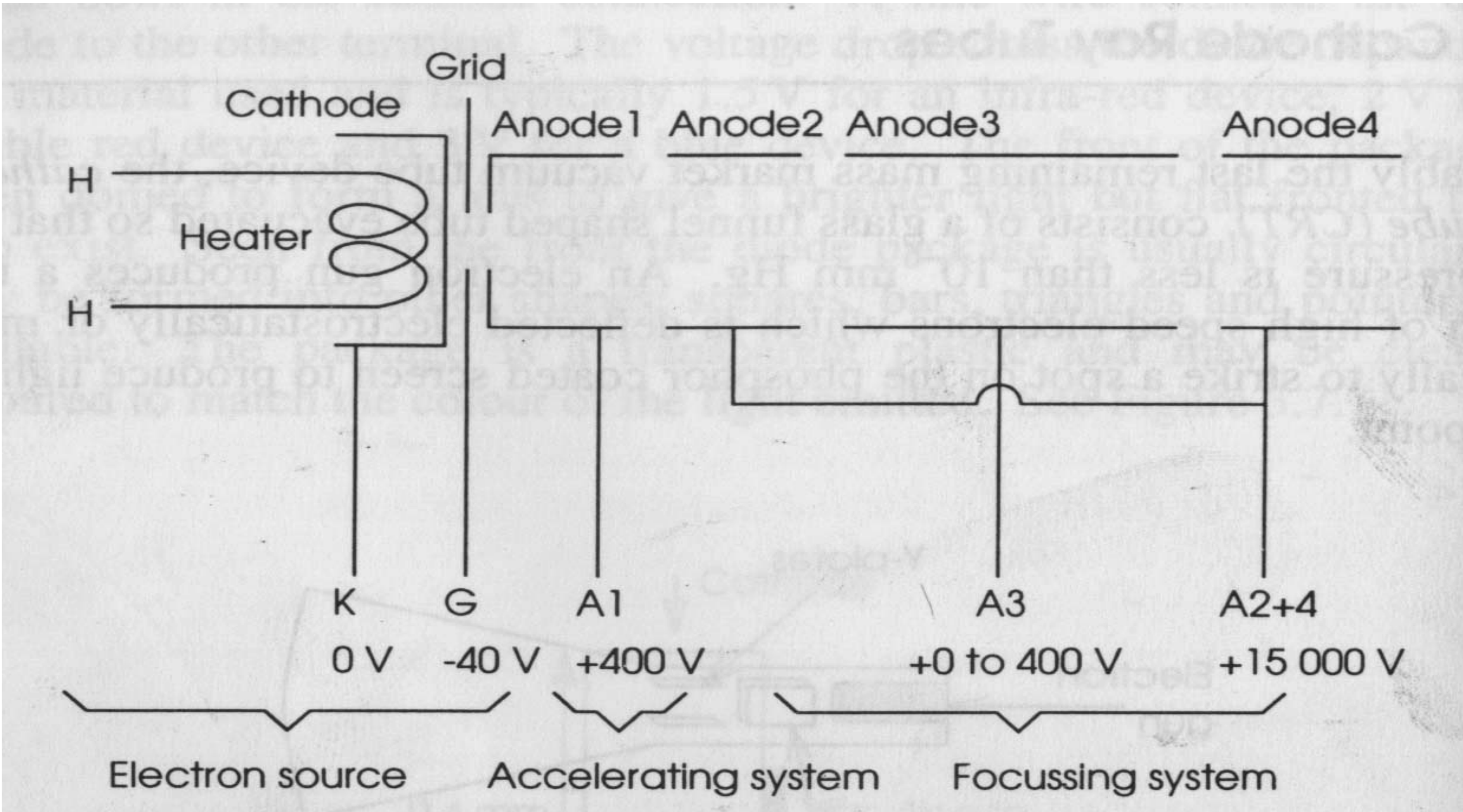


Figure 3.9 *Cross-section of the electron gun*

- **Several electrodes form the *electron gun*.**
- **A *cathode*, made from nickel coated with an oxide mixture,**

  is heated directly by a filament heater and raised to a temperature that causes electrons to be emitted from its surface.
- **The grid electrode is situated immediately in front of the cathode and controls the intensity of the beam and thus the brightness of the spot**.(A negative potential on the grid with respect to the cathode repels the negatively charged electrons and reduces the intensity. A sufficient potential---around –20V to –100 V stops the beam entirely and known as cutoff potential).
- ***Anode* A1 attracts the electron beam and accelerates it toward the screen. Second anode A2 accelerates the beam to a high speed to give it sufficient energy to produce a bright light on the screen. This is connected to final anode A4 and inner coating of the tube and the screen.**

- Anode A3 (between A2 & A4) acts as a lens to focus the electron beam to a small spot on the screen.
- Deflection of the electron beam to the required part of the screen may be by either electrostatic or magnetic means.
- Electrostatic deflection requires plates within the CRT.
- Magnetic deflection is obtained by generating a magnetic field from coils.
- Electrostatically deflected tubes are used for measurement applications such as in oscilloscopes.
- Magnetically deflected tubes are suitable for data display applications.

Cathode Ray Tubes (CRTs)

For electrostatic deflection

$$\Delta X = VLD/2V_{A2+4}d$$

where ΔX is the deflection on the screen
V is the voltage between the deflection plates
L is the length of the deflection plates
D is the distance from the deflection plates to the screen (measured from the centre of the plates)
V_{A2+4} is the accelerating voltage (on A2+4)
d is the distance between the deflection plates.

Magnetic deflection is obtained by generating a magnetic field from coils external to the tube. Whilst within the magnetic field the electrons move in the arc of a circle giving a deflection

$$\Delta X = lDH\sqrt{\frac{1}{2V_{A2+4}}\frac{e}{m}} \qquad (3.2)$$

where ΔX is the deflection on the screen
l is the diameter of the coil (and field)
D is the distance from the centre of the field to the screen
H is the field strength
e/m is the electron charge/mass ratio.

Electrostatic & Magnetic Deflection

- The beam can be moved much more rapidly, and it is easier to make the beam deflection accurately proportional to the applied signal, by using electrostatic deflection .But it is difficult to obtain wide deflection angles.

- Magnetic deflection is achieved by passing currents through coils external to the tube; it allows the construction of much shorter tubes for a given screen size.

- In principle either type of deflection can be used for any purpose; but electrostatic deflection is best for *oscilloscopes* with relatively small screens and high performance requirements, while a *television* receiver with a large screen and electrostatic deflection would be many meters deep.

Phosphor Screen

- **When the beam of electrons hits the phosphor coating on the inside of the screen it gives up its energy which is converted into light.**
- **The phosphor is a mixture of chemicals such as oxides and sulphides of cadmium, zinc and manganese, together with metals such as silver.**
- **Particular combinations give particular characteristics such as color and phosphorescence.**

Phosphor Screen

- The phosphors used in the screens of oscilloscope tubes are different from those used in the screens of other display tubes.
- Phosphors used for displaying moving pictures should produce an image which fades very rapidly to avoid smearing of new information by the remains of the previous picture. They should have short persistence. An oscilloscope will often display a trace which repeats unchanged, so longer persistence is not a problem; but it is a definite advantage when viewing a single-shot event, so longer-persistence phosphors are used.

Gamma Correction

Screen brightness is not a linear function of electron beam strength and this, in turn, is non-linearly dependent on drive voltage.

To a large extent these two cancel each other out but there still remains a less than perfect relationship between drive and brightness.

This relationship can be fairly well described by the equation

$$\textit{Brightness} \;\alpha\; \textit{Voltage}^{\gamma}$$

With a typical value γ of is 1.2

Gamma Correction

Values for the look-up table can be derived from the formula

***Table value* = *R* (x/n)$^{1/\gamma}$**

R = Max. value in the look-up table=255

x = Brightness level to be encoded=0 to 7

γ =1.2

n= Maximum brightness level to be encoded=7

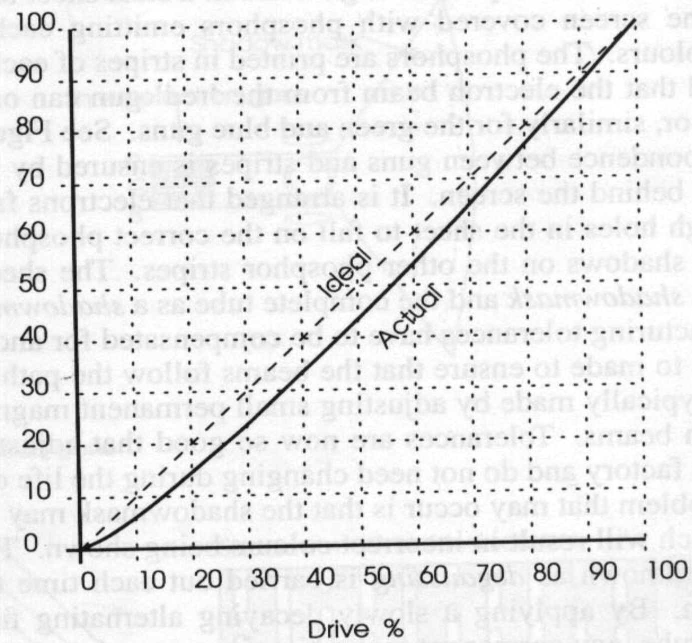


Figure 3.10 *Brightness v. drive*

Table 3.1 *Linear and gamma corrected values for a look-up table*

Brightness step	Linear value	γ corrected value
0	0	0
1	36	50
2	73	90
3	109	126
4	146	160
5	182	193
6	219	224
7	255	255

Gamma Correction

- **Marked problem is at low drive and brightness levels.**
- **The difference is small, but need to be corrected for high quality applications.**
- **In broadcast television the correction, known as *gamma correction,* is applied once at the studio rather than on each television set.**

Colour Tubes

- **Colour cathode ray tubes are a clever combination of three tubes in one – one red, one blue and one green colour**
- **Three separate electron guns are used to produce three individually controlled beams which pass through holes in a steel sheet to land on three areas of the screen covered with phosphors emitting each of the three required colours.**
- **Correspondence between guns and phosphor stripes is ensured by the steel sheet placed just behind the screen.**
- **The sheet is therefore known as *shadow mask* and the complete tube as a *shadow mask CRT.***

Shadow-mask

**A shadow mask is a thin metal screen filled with very small holes. Three electron beams pass through the holes to focus on a single point on a CRT displays' phosphor surface. The shadow mask helps to control the electron
beams so that the beams strike the correct phosphor at just the right intensity to create the desired colors and image on the display. The unwanted beams are blocked or "shadowed.“**

Colour Tubes

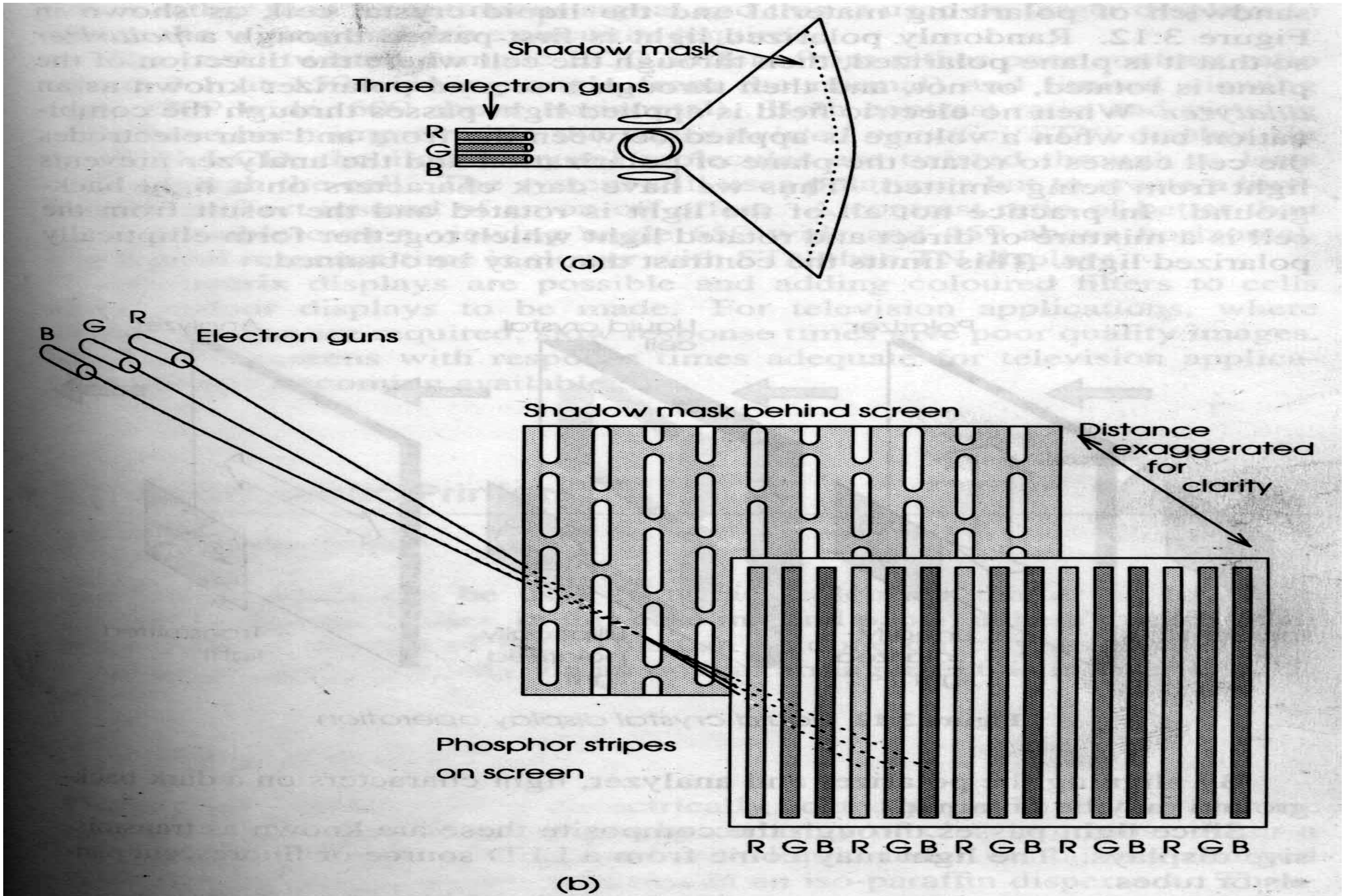


Figure 3.11 *Shadow mask colour CRT: (a) cross-section (from above), (b) electron beam path*

Colour Tubes

Degaussing

- One problem that may occur is that the shadowmask may become magnetized which will result in incorrect colours being shown.
- To prevent this a procedure known as *degaussing* is carried out each time the display is switched on.
- By applying a slowly decaying alternating field, via coils around the tube, any permanent magnetism is removed.

Other Techniques

Aperture-grill: Monitors based on the Trinitron technology, which was pioneered by Sony, use an **aperture-grill** instead of a shadow-mask type of tube. The aperture grill consists of tiny vertical wires. Electron beams pass through the aperture grill to illuminate the phosphor on the faceplate.

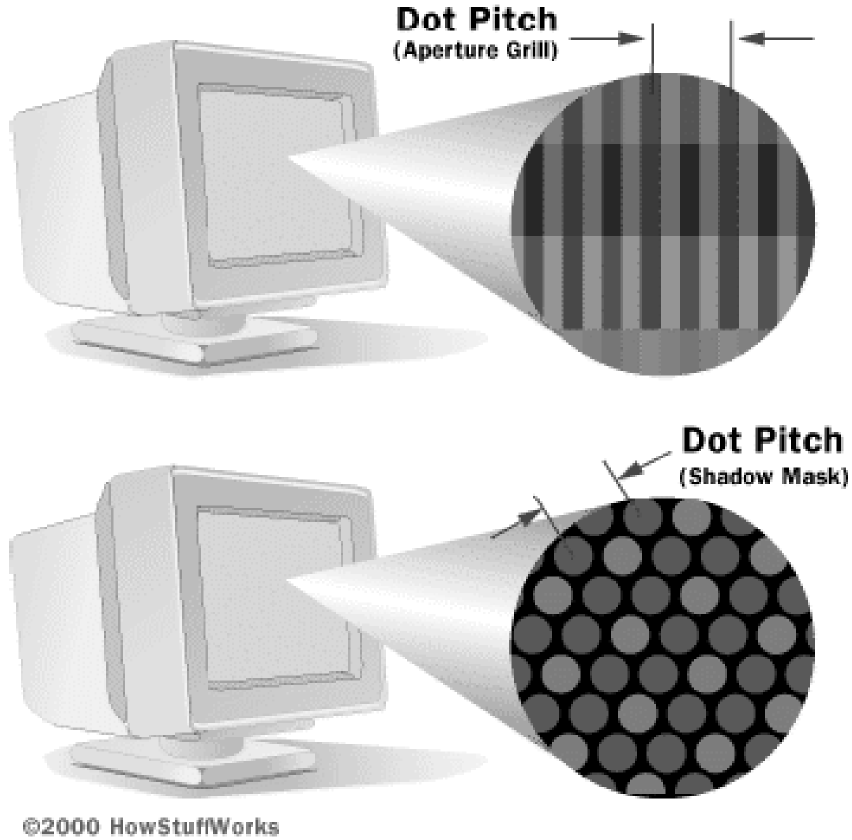
However, aperture-grill displays are normally more expensive. Slot-mask

Slot-mask: A less-common type of CRT display, a **slot-mask tube** uses a combination of the shadow-mask and aperture-grill technologies. Rather than the round perforations found in shadow-mask CRT displays, a slot-mask display uses vertically aligned slots. The design creates more brightness through increased electron transmissions combined with the arrangement of the phosphor dots.

Dot pitch

•Dot pitch is an indicator of the sharpness of the displayed image.
•It is measured in millimeters (mm), and a smaller number means a sharper image.
•How you measure the dot pitch depends on the technology used:
In a shadow-mask CRT monitor, you measure dot pitch as the *diagonal distance* between two like-colored phosphors.
•The dot pitch of an aperture-grill monitor is measured by the *horizontal distance* between two like-colored
phosphors. It is also sometimes are called stripe pitch.
The smaller and closer the dots are to one another, the more realistic and detailed the picture appears. When the

Dot Pitch (Cont..)



Electrostatic Printers

- Electrostatic fields attract coloring matter on to paper.
- Oppositely charged bodies,(in this case) ink and paper, adhere to each other, causing transfer of ink.

Two types of Electrostatic Printers:

→Direct Transfer

→ Indirect Transfer (Laser Printers)

Electrostatic Printer

- **Electrostatic printers employ electric charge on the paper by an array of charging nibs.**
- **After a line has been charged it is sprayed with liquid toner containing charged particles.**
- (Certain areas of paper are negatively charged by the nibs & toner is positively charged).
- **These particles stick to the charged areas of the paper and form an image.**
- **Surplus toner is removed and the paper is dried before handling.**

Electrostatic Printer

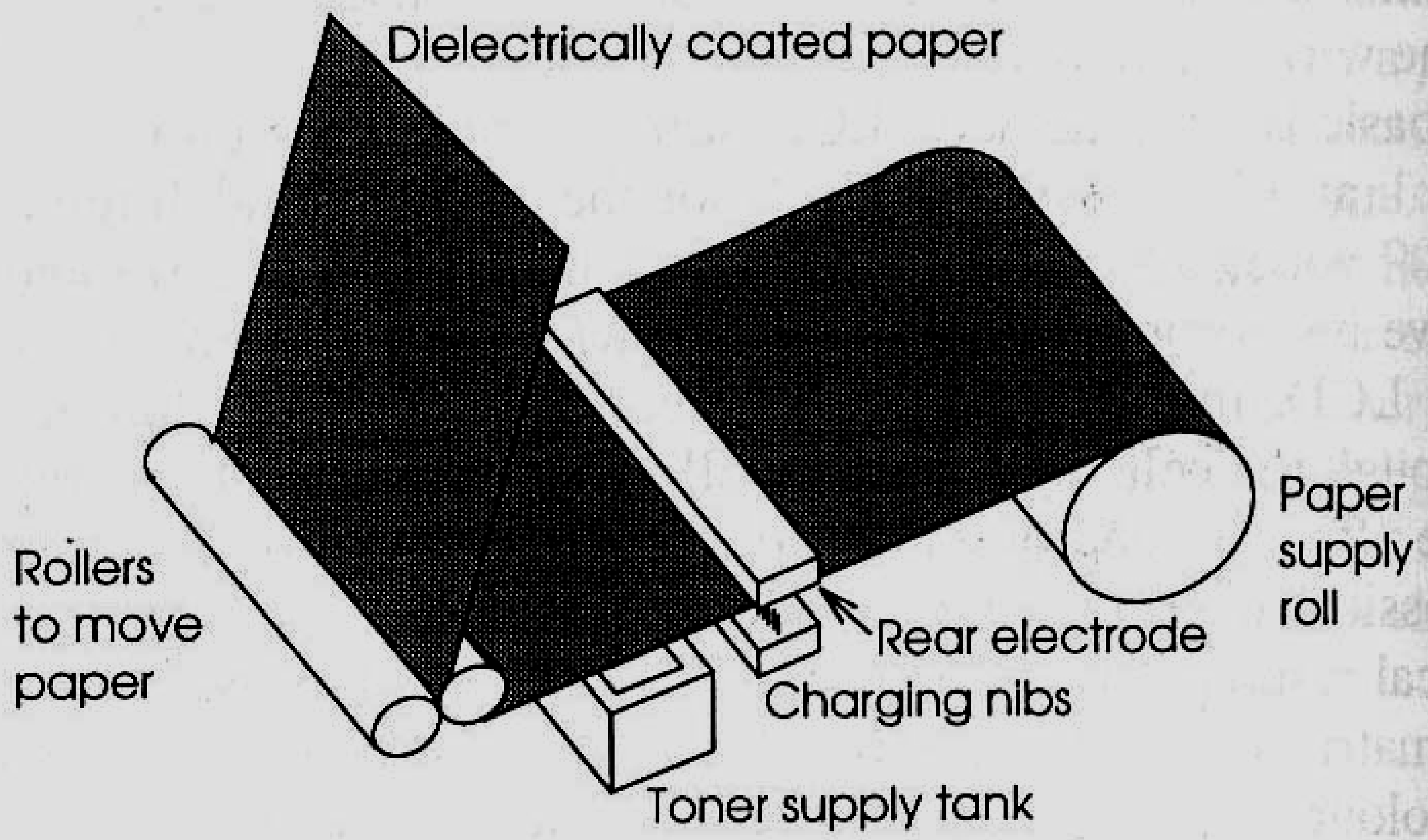


Figure 3.13 *Electrostatic printer*

Electrostatic Printers

- Air gap between the nibs and the paper – 0.6mm (0.025 inch)
- There is a continuous electrode touching the other side.
- Spacing between nibs – 0.25mm, giving a resolution of 100 dpi.
- Two rows of nibs staggered slightly can be used to double the resolution.
- Color printing can be achieved by running the paper through several times with a different colored toner each time.

Laser Printers

- Made for high speed and high volume production.
- **Photosensitive** drum is coated with selenium based material.
- In the dark it acts as a capacitor which is charged to a high voltage as it passes under the charging wire.
- A laser beam is reflected off a rotating polygonal mirror which causes the beam to scan along a line on the drum.
- The beam passes over the complete surface of the rotating drum.
- Light falling on the drum causes the capacitor to discharge and thus removing the high voltage.

Laser Printers

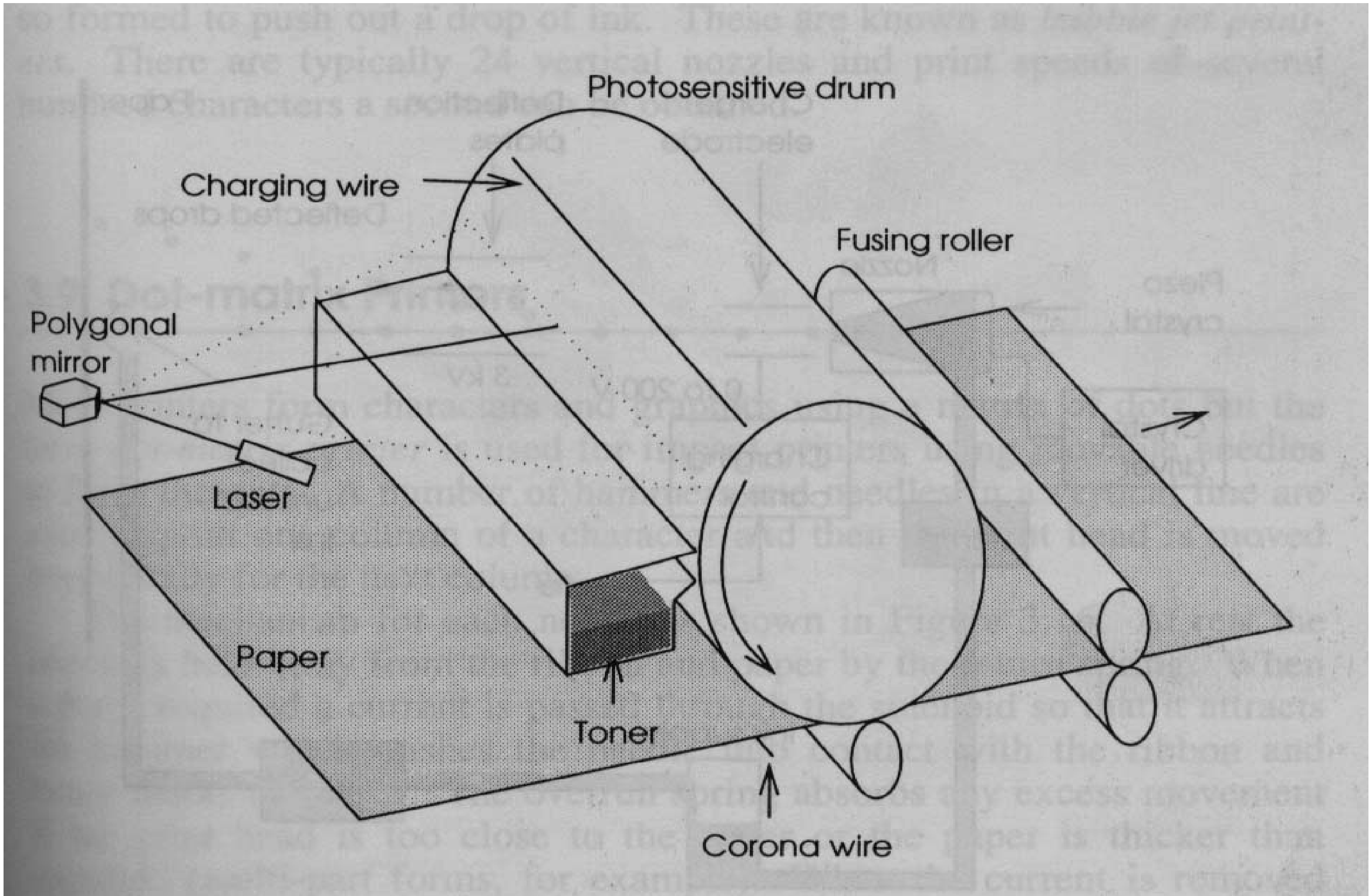


Figure 3.14 *Laser printer*

Laser Printers

- **By modulating the brightness of the laser, points on the drum can be selectively discharged or left with a high voltage.**

- **As the drum passes the toner reservoir, the charged areas attracts particles of the dry powder which stick to its surface;**
- **the discharged areas attract no toner.**
- **The paper is given a charge as it passes the corona wire so that as it passes the drum the toner is transferred to the paper.**
- **A hot fusing roller at about 260^{0}C melts the toner particles so that, in combination with the pressure of the rollers, they are permanently stuck to the paper.**

Ink jet Printer

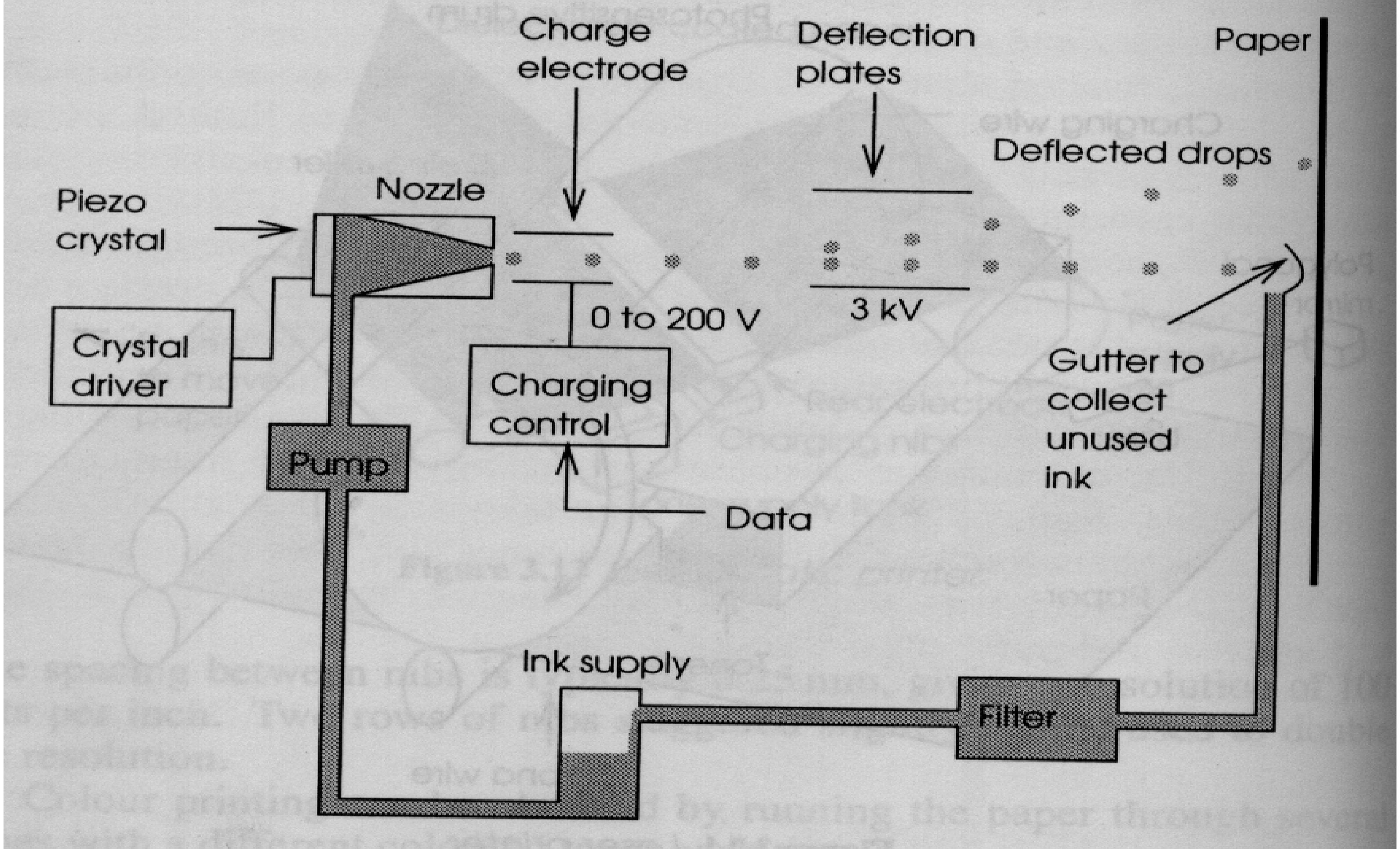


Figure 3.15 *Ink jet printer*

What is Piezoelectric effect ?

- **Crystals, which acquire a charge when compressed, twisted or distorted, are said to be piezoelectric.**
- Piezoelectricity **is the ability of some materials (notably crystals and certain ceramics) to generate an electric charge in response to applied mechanical stress.**
- **The piezoelectric effect is reversible in that materials exhibiting the *direct piezoelectric effect* (the production of electricity when stress is applied) also exhibit the *converse piezoelectric effect* (the production of stress and/or strain when an electric field is applied). Some crystals will exhibit a maximum shape change of about 0.1% of the original dimension.**

Piezoelectric Ink Jet

All Epson printers and most commercial and industrial ink jet printers use a piezoelectric material in an ink-filled chamber behind each nozzle instead of a heating element. When a voltage is applied, the crystal changes shape or size, which generates a pressure pulse in the fluid forcing a droplet of ink from the nozzle. This is essentially the same mechanism as the thermal inkjet but generates the pressure pulse using a different physical principle. Piezoelectric ink jet allows a wider variety of inks than thermal or continuous ink jet but is more expensive

Ink jet Printers

- Conductive ink is forced through a very small nozzle to produce a high speed stream or jet of drops of ink.
- The size and spacing of these drops are made constant by vibrating the nozzle compartment at an ultrasonic frequency with a crystal.

  Vibrating frequency of crystal: 100KHz.

  Drop diameter – 0.06mm (0.0025 inch)

  Drop spacing – 0.15mm (0.006 inch)
- Each drop of ink, after leaving the cavity, is given a specific charge as it passes through a charging electrode located next to the nozzle.
- The drops are deflected vertically by a second electrode structure and strike the paper.
- The horizontal position is normally controlled by moving the ink jet system.

Ink jet Printers

- The amount of deflection is determined by the charge on the drop.
- With no charge there is no deflection and these drops are collected in a gutter placed close to the paper.
- Increasing charge increases deflection so that drops can be placed as desired.
- For high quality printing approx. 1000 drops are required per character. With 10^5 drops per second release from the nozzle (100KHz vib. rate), 100 characters can be printed per second.

Dot Matrix Printer

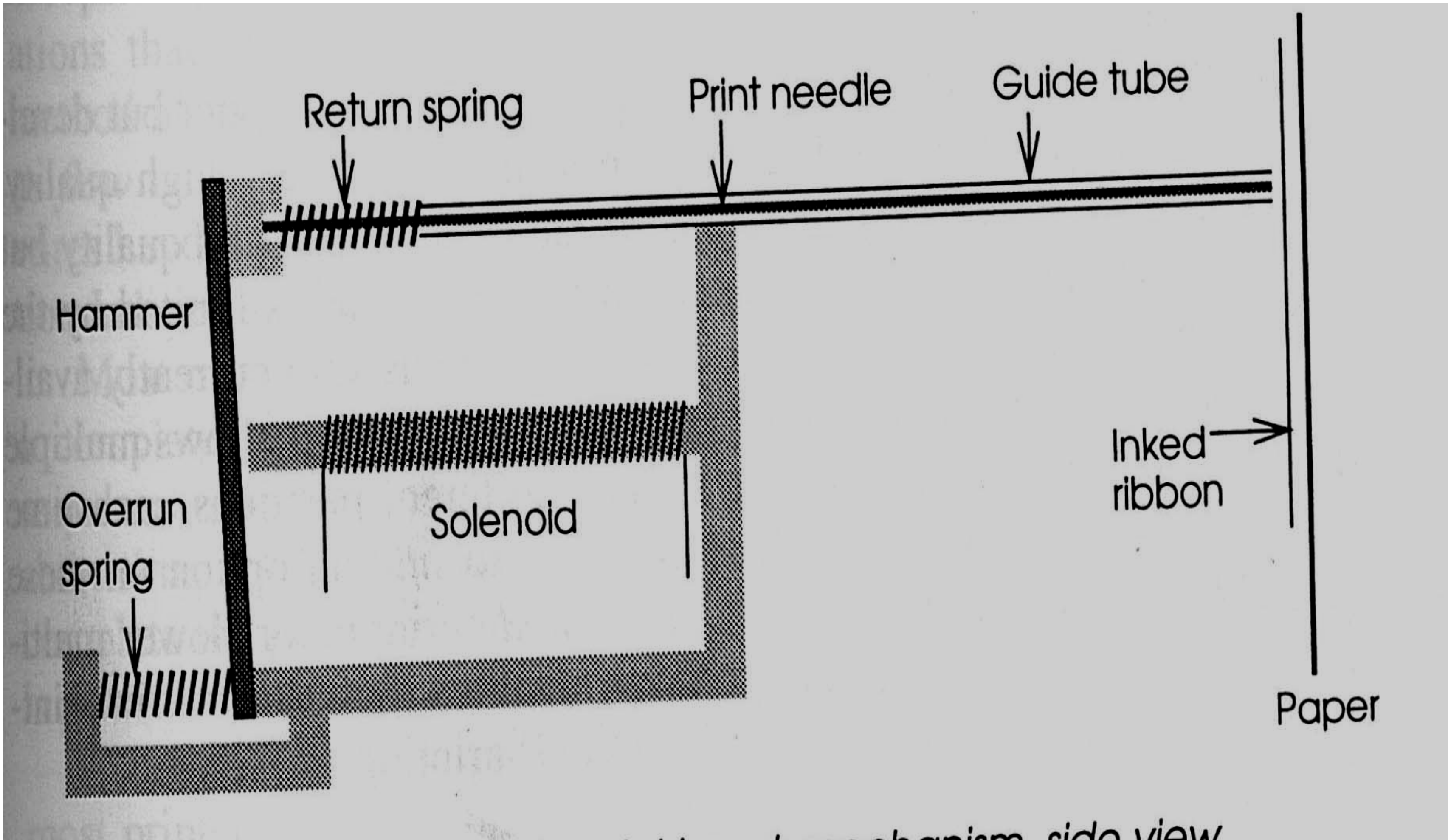


Figure 3.16 *Needle print head: mechanism, side view*

Dot Matrix Printers

- Dot matrix printers are impact printers, use movable needles to form the dots.
- A number of hammers and needles in a vertical line are used to print one column of a character and then the print head is moved horizontally for the next column.
- At rest the needle is held away from the ribbon and paper by the return spring.
- When a dot is required, a current is passed through the solenoid so that it attracts the hammer which pushes the needle into contact with the ribbon and hence marks the paper.

Dot Matrix Printers

- The overrun spring absorbs any excess movement if the print head is too close to the paper or the paper is thicker than expected.
- When the current is removed the needle return to its rest position.
- Printing can be done in unidirectional or bidirectional.
- Print quality of early Dot-matrix printer is poor.
- The number of dots used to make up a character determines its quality.

Page Description Language

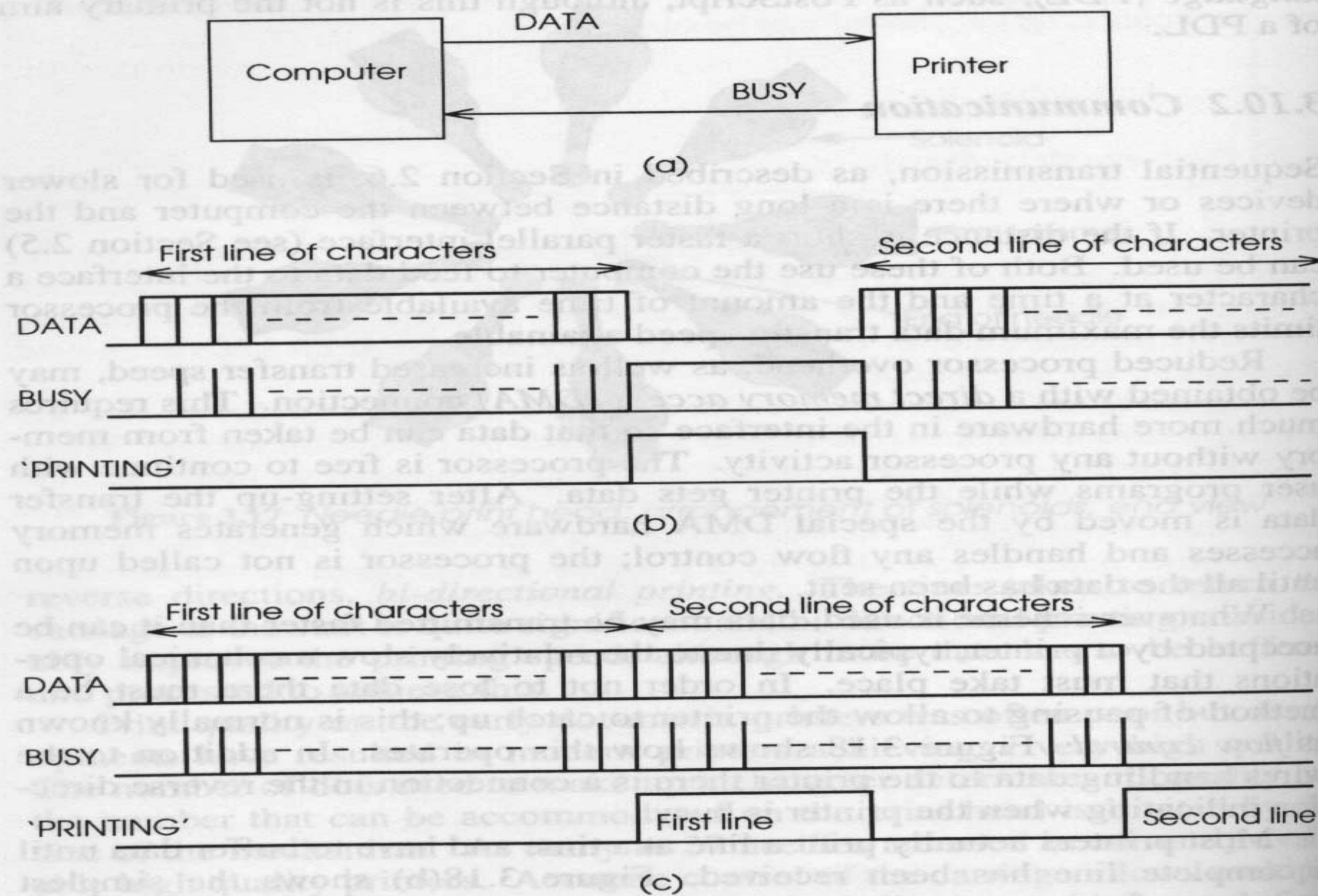
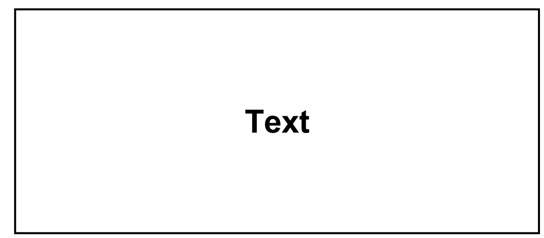


Figure 3.18 *Data transmission with flow control: (a) interconnection; (b) signals with single line buffer; (c) signals with double line buffer*

Page Description Language (PDL)

```
 0    0        move to
0  40          line to
90  40         line to
90    0        line to
close path
stroke
/ Times-Roman    find font
  12 scale font
   set font
  10  15 move to
  (Text)  show
  show page
```



Thank You