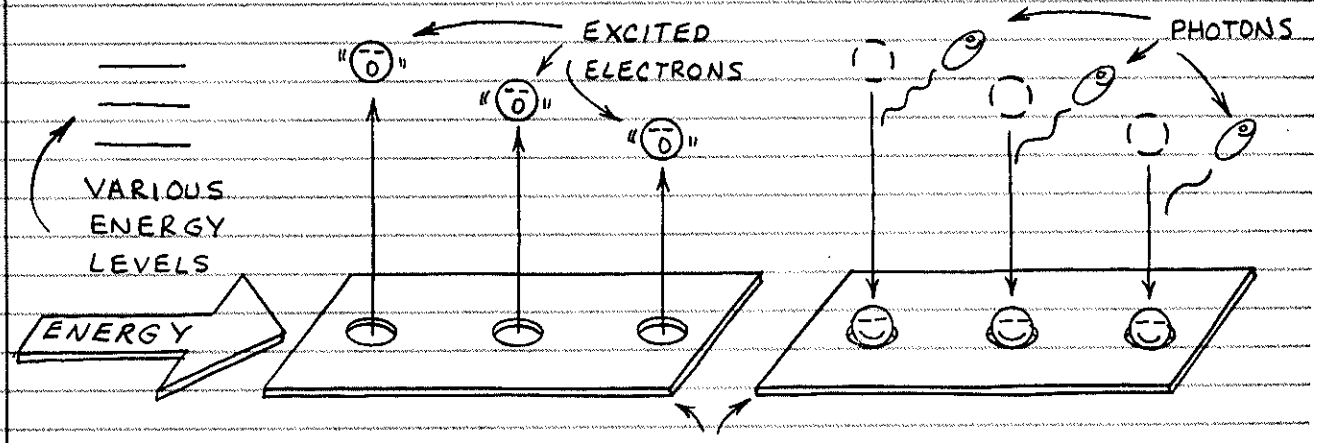
4. PHOTONIC SEMICONDUCTORS

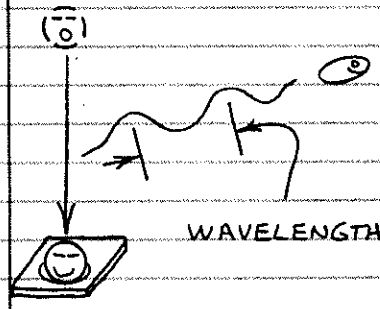
PHOTONICS IS THE FAST GROWING FIELD OF ELECTRONICS INVOLVING SEMICONDUCTOR DEVICES THAT EMIT AND DETECT LIGHT. BEFORE LOOKING AT SOME PHOTONIC COMPONENTS, LET'S TAKE A QUICK LOOK AT SOME FACTS ABOUT LIGHT.

LIGHT

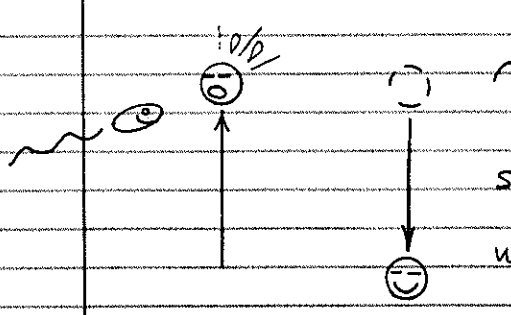
"LET THERE BE LIGHT..."

LIGHT IS COMPOSED OF PARTICLES CALLED PHOTONS THAT BEHAVE LIKE WAVES OF ENERGY. PHOTONS ARE NOT NECESSARILY VISIBLE AND ONLY THOSE YOU CAN SEE ARE COLLECTIVELY CALLED LIGHT. PHOTONS ARE PRODUCED WHEN AN ELECTRON THAT'S BEEN EXCITED TO A HIGHER THAN NORMAL ENERGY LEVEL FALLS BACK TO ITS NORMAL LEVEL.



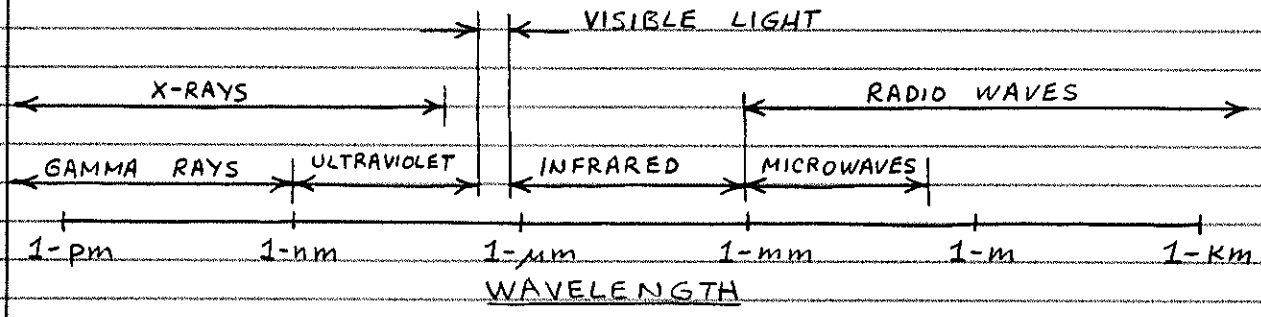


REMEMBER, PHOTONS ACT LIKE WAVES. THE DISTANCE BETWEEN CRESTS IS THE WAVELENGTH. ELECTRONS EXCITED TO HIGHER ENERGY LEVELS EMIT PHOTONS WITH SHORTER WAVELENGTHS THAN ELECTRONS EXCITED TO LOWER LEVELS.



EXCITED ELECTRONS CAN RESUME THEIR NORMAL LEVEL SPONTANEOUSLY. OR A PHOTON WITH THE PROPER WAVELENGTH CAN STIMULATE AN EXCITED ELECTRON TO RETURN TO ITS NORMAL LEVEL.

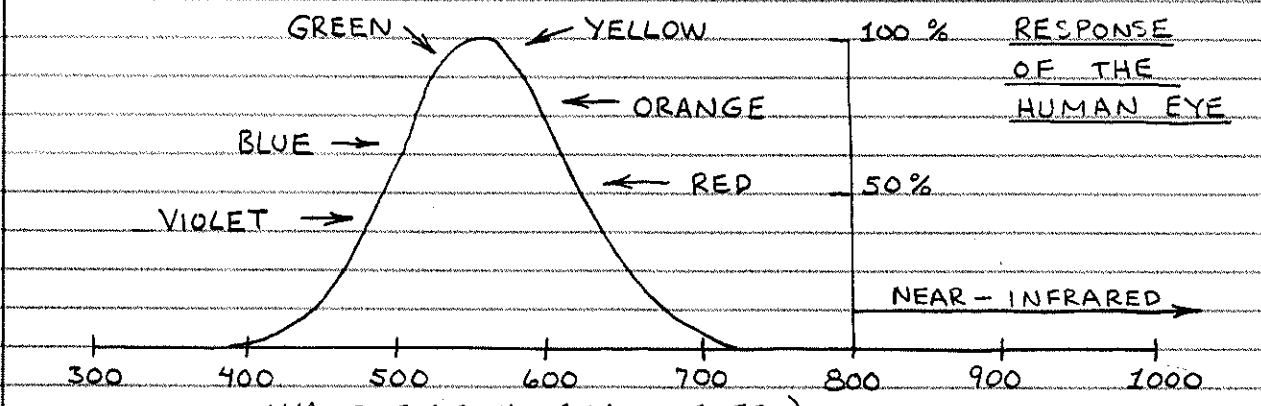
☐ THE ELECTROMAGNETIC SPECTRUM — VISIBLE LIGHT IS A FORM OF ELECTROMAGNETIC RADIATION. THE WAVELENGTH OF LIGHT IS SPECIFIED IN NANOMETERS (1-NANOMETER IS A BILLIONTH OF A METER). THE DIAGRAM BELOW SHOWS THE RELATIONSHIP OF LIGHT TO OTHER FORMS OF ELECTROMAGNETIC RADIATION.



1-pm = 1 PICOMETER (0.000 000 000 001 METER)
1-nm = 1 NANOMETER (0.000 000 001 METER)
1-μm = 1 MICROMETER (0.000 001 METER)
1-mm = 1 MILLIMETER (0.001 METER)
1-m = 1 METER (39.37 INCHES)
1-km = 1 KILOMETER (1000 METERS)

THESE LINES ARE ONE MILLIMETER (1-mm) APART. →||

☐ THE OPTICAL SPECTRUM — ULTRAVIOLET, VISIBLE AND INFRARED RADIATION ARE TOGETHER CALLED THE OPTICAL SPECTRUM. HERE'S AN EXPANDED DIAGRAM OF THE OPTICAL SPECTRUM:



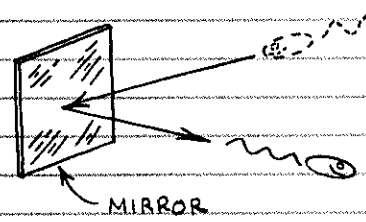
MANY PHOTONIC SEMICONDUCTORS EMIT OR DETECT NEAR-INFRARED RADIATION. SILICON, FOR EXAMPLE, CAN DETECT VISIBLE LIGHT. BUT IT IS MOST SENSITIVE TO NEAR-INFRARED AT ABOUT 880 nm. BECAUSE SO MANY PHOTONIC COMPONENTS CAN OPERATE IN BOTH THE VISIBLE AND NEAR-INFRARED, IT'S COMMON TO REFER TO NEAR-INFRARED AS LIGHT.

OPTICAL COMPONENTS

OPTICAL COMPONENTS CONDUCT, BEND OR CHANGE THE CHARACTERISTICS OF LIGHT. SEVERAL ARE VERY IMPORTANT IN MANY APPLICATIONS OF PHOTONIC SEMICONDUCTORS:

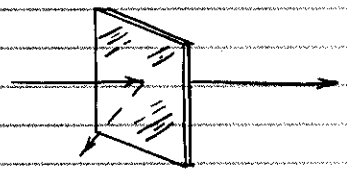
1. FILTERS TRANSMIT ONLY A NARROW BAND OF OPTICAL WAVELENGTHS.

2. REFLECTORS REFLECT SOME OR MOST OF AN ONCOMING LIGHT BEAM. SOME LIGHT MAY OR MAY NOT BE TRANSMITTED.



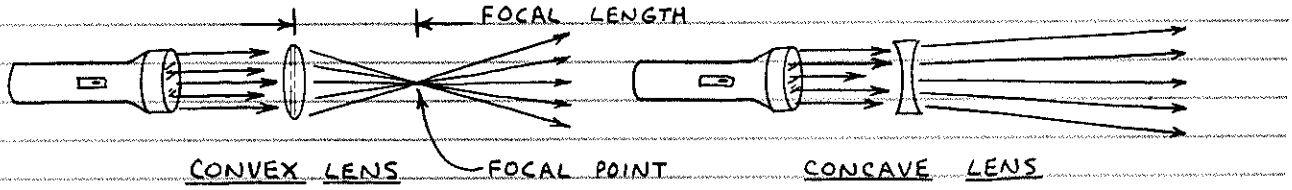
THOSE WITH A VERY SMOOTH SURFACE (LIKE MIRRORS) ARE CALLED SPECULAR REFLECTORS.

3. BEAMSPLITTERS REFLECT PART OF AN ONCOMING LIGHT BEAM AND TRANSMIT THE REMAINDER.



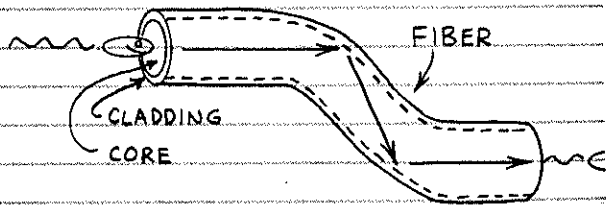
A GLASS MICROSCOPE SLIDE MAKES A GOOD BEAM SPLITTER. (EACH SURFACE REFLECTS 4%.)

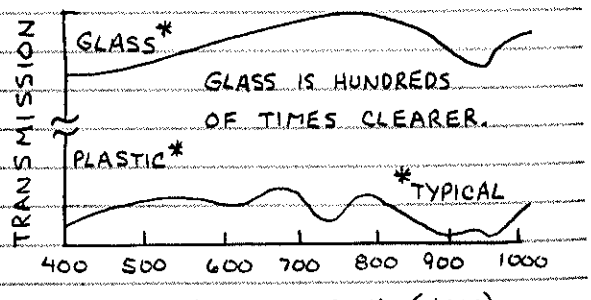
4. LENSES BEND LIGHT. THE MOST IMPORTANT ARE:



CONVEX LENSES ARE OFTEN USED IN CONJUNCTION WITH SEMICONDUCTOR LIGHT SOURCES AND DETECTORS. FOR EXAMPLE, THEY CAN COLLECT AND FOCUS LIGHT ONTO A MINIATURE DETECTOR.

5. OPTICAL FIBERS ARE THIN, FLEXIBLE STRANDS OF HIGHLY TRANSPARENT GLASS OR PLASTIC THAT CONDUCT LIGHT. THE LIGHT TRAVELS THROUGH A CORE SURROUNDED BY A THIN CLADDING. PLASTIC FIBERS ARE INEXPENSIVE. GLASS FIBERS ARE MUCH MORE TRANSPARENT. BOTH KINDS TRANSMIT SOME WAVELENGTHS MUCH BETTER THAN OTHERS. HIGH QUALITY FIBERS ARE USED TO SEND TELEPHONE CALLS AND COMPUTER DATA VIA PULSES OF LIGHT.



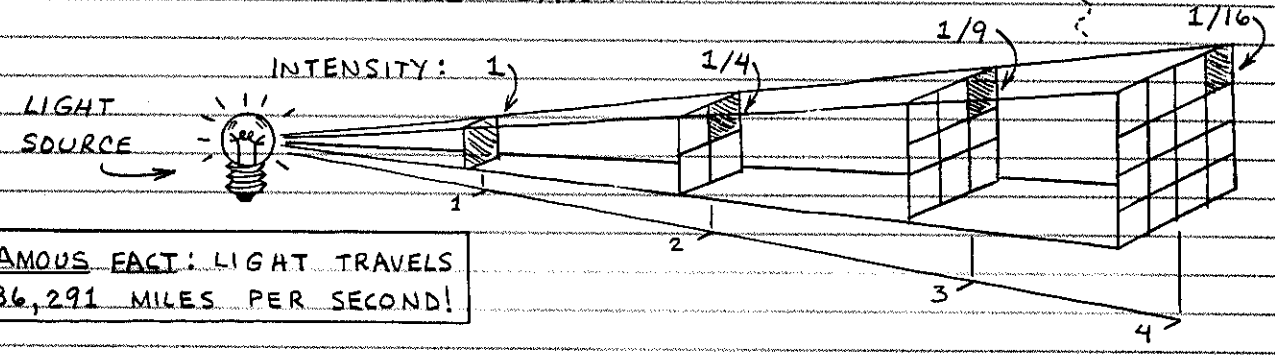


GLASS IS HUNDREDS OF TIMES CLEARER.

HOW CONVEX LENSES ARE USED

MANY SEMICONDUCTOR LIGHT SOURCES AND DETECTORS ARE EQUIPPED WITH A BUILT-IN CONVEX LENS. THIS PAGE EXPLAINS WHY AND SHOWS HOW EXTERNAL LENS ARE USED WITH SOURCES AND DETECTORS.

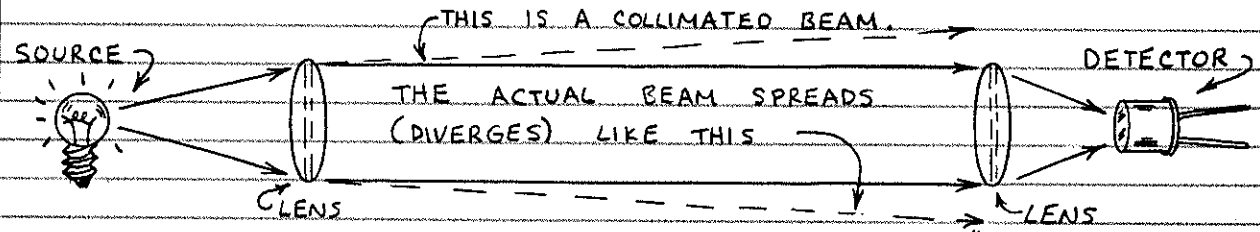
☐ THE INVERSE SQUARE LAW.



FAMOUS FACT: LIGHT TRAVELS 186,291 MILES PER SECOND!

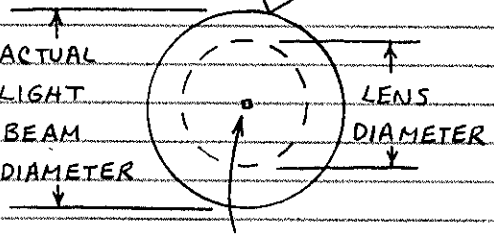
AS LIGHT FROM A VERY SMALL SOURCE SPREADS OUTWARD, ITS INTENSITY IS INVERSELY PROPORTIONAL TO THE SQUARE OF THE DISTANCE. IN OTHER WORDS, IF THE DISTANCE IS 3, THEN THE INTENSITY IS 1/9 THE INTENSITY WHEN THE DISTANCE IS 1. A CONVEX LENS CAN CANCEL THIS INTENSITY REDUCTION.

☐ THE CONVEX LENS.



THE BEAM SPREAD ANGLE (THE DIVERGENCE) IN RADIANS* IS THE DIAMETER OF THE SOURCE DIVIDED BY THE FOCAL LENGTH OF THE LENS. THIS MEANS LENSES WITH LONGER FOCAL LENGTHS GIVE NARROWER BEAMS. (BUT LENSES WITH LONG FOCAL LENGTHS COLLECT LESS LIGHT THAN THOSE WITH SHORT FOCAL LENGTHS...)

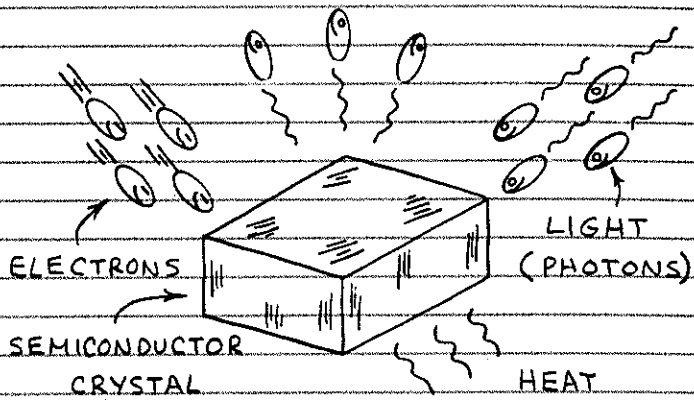
*ONE RADIAN IS 57.3 DEGREES. (THERE ARE 360° IN A CIRCLE.)



WITH CAREFUL LENS PLACEMENT ALL THE LIGHT WITHIN THE DASHED CIRCLE CAN BE FOCUSED ONTO THE LIGHT SENSITIVE PORTION OF THE DETECTOR. (SURE BEATS THE INVERSE SQUARE LAW!)

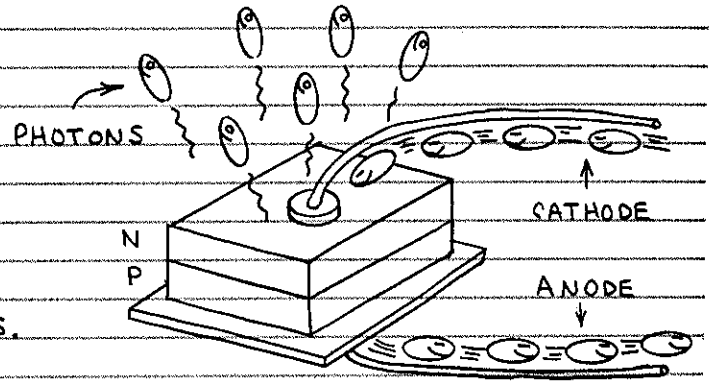
SEMICONDUCTOR LIGHT SOURCES

WHEN BOMBARDED BY LIGHT, HEAT, ELECTRONS AND OTHER FORMS OF ENERGY, MOST SEMICONDUCTOR CRYSTALS WILL EMIT VISIBLE OR INFRARED LIGHT. THE BEST SEMICONDUCTOR LIGHT SOURCES, HOWEVER, ARE PN JUNCTION DIODES.



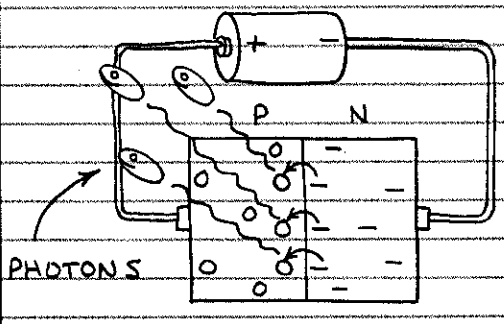
LIGHT EMITTING DIODES

THE LIGHT EMITTING DIODE CONVERTS AN ELECTRICAL CURRENT DIRECTLY INTO LIGHT. THEREFORE THE LIGHT EMITTING DIODE (LED) IS MORE EFFICIENT THAN MANY OTHER LIGHT SOURCES.

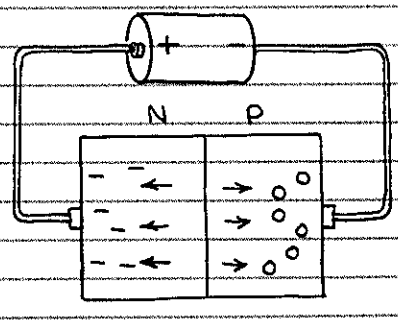


☐ LED OPERATION— THE FORWARD VOLTAGE ACROSS A DIODE MUST EXCEED A THRESHOLD LEVEL BEFORE A CURRENT CAN CROSS THE JUNCTION. FOR SILICON, WHICH EMITS A TINY AMOUNT OF NEAR-INFRARED, THE THRESHOLD IS 0.6-VOLT. FOR GALLIUM ARSENIDE, WHICH EMITS CONSIDERABLE NEAR-INFRARED, THE THRESHOLD IS 1.3-VOLTS. THIS VOLTAGE EXCITES THE ELECTRONS. WHEN THE ELECTRONS CROSS THE JUNCTION AND COMBINE WITH HOLES, THEY EMIT PHOTONS.

FORWARD BIAS

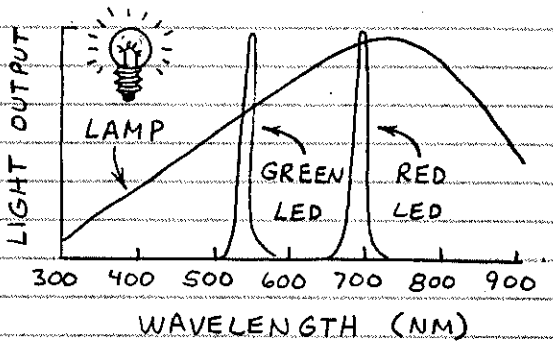


REVERSE BIAS

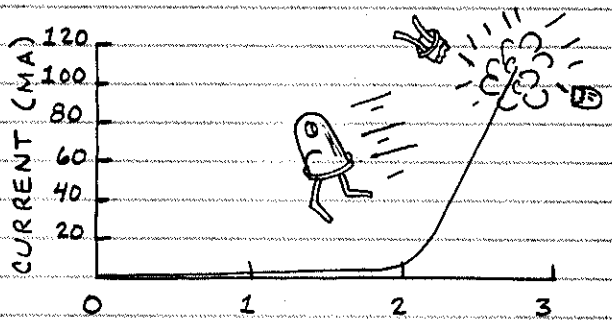


☐ MORE ABOUT LED OPERATION — HERE ARE SOME KEY ASPECTS OF LED OPERATION YOU SHOULD KNOW ABOUT:

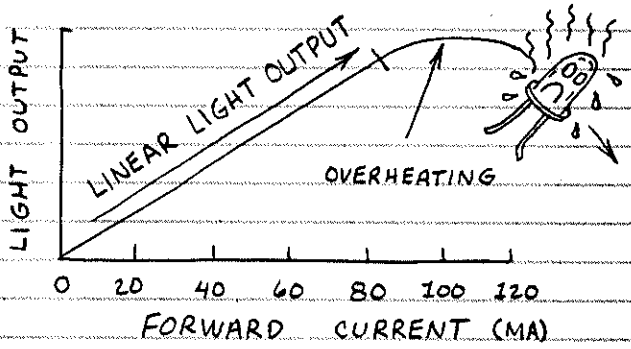
1. THE LIGHT EMITTED BY AN INCANDESCENT LAMP CONTAINS MANY WAVELENGTHS. THE LIGHT EMITTED BY AN LED HAS A NARROW WAVELENGTH RANGE. (THIS IS BECAUSE THE ELECTRONS IN THE LED ARE ALL EXCITED TO THE SAME LEVEL.)



2. WHEN AN LED BEGINS TO CONDUCT, THE VOLTAGE INCREASES GRADUALLY WHILE THE CURRENT INCREASES RAPIDLY. TOO MUCH CURRENT WILL OVERHEAT THE LED AND POSSIBLY SEPARATE THE LEADS OR MELT THE SEMICONDUCTOR CHIP.



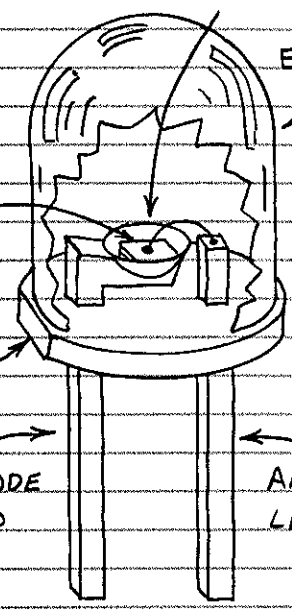
3. THE LIGHT EMITTED BY AN LED IS DIRECTLY PROPORTIONAL TO CURRENT THROUGH THE LED. THIS MEANS LEDS ARE IDEAL FOR TRANSMITTING INFORMATION. THE LIGHT OUTPUT FROM AN OVERHEATED LED WILL SOON DECREASE. THE LED MAY EVEN BE DAMAGED.



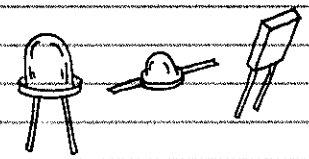
4. THE FORWARD VOLTAGE AND WAVELENGTH OF AN LED ARE DIRECTLY RELATED. THEREFORE IT'S NOT ALWAYS POSSIBLE TO SUBSTITUTE DIFFERENT LEDS WITHOUT CHANGING THE VOLTAGE AND CURRENT. MANY DIFFERENT SEMICONDUCTORS ARE USED TO MAKE VARIOUS LEDS. VISIBLE LIGHT EMITTING LEDs EMIT UP TO A MILLIWATT OR SO OF POWER. SOME INFRARED LEDs (LIKE 880 NM UNITS) EMIT 15 OR MORE MILLIWATTS! (A FLASHLIGHT EMITS 10 OR MORE MILLIWATTS.)

WAVELENGTH (NM)	VOLTAGE
565 (GREEN)	2.2 — 3.0
590 (YELLOW)	2.2 - 3.0
615 (ORANGE)	1.8 - 2.7
640 (RED)	1.6 - 2.0
690 (RED)	2.2 - 3.0
880 (INFRARED)	2.0 - 2.5
900 (INFRARED)	1.2 - 1.6
940 (INFRARED)	1.3 - 1.7

☐ KINDS OF LEDs — SINCE THE LED IS A LIGHT SOURCE, IT'S HELPFUL TO KNOW WHAT'S INSIDE THE PLASTIC OR METAL LED CASE. SHOWN HERE IS A TYPICAL LED. THE HEAVY LEADS HELP CONDUCT HEAT AWAY FROM THE CHIP. THE REFLECTOR COLLECTS LIGHT EMITTED FROM THE EDGES OF THE CHIP. THE EPOXY IS USUALLY COLORED WHEN THE LED IS A VISIBLE LIGHT EMITTER. LIGHT SCATTERING PARTICLES ARE OFTEN ADDED TO THE EPOXY. THIS DIFFUSES THE LIGHT AND CAUSES THE END OF THE LED TO APPEAR BRIGHTER.

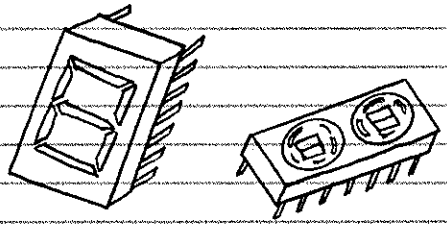


VISIBLE LIGHT LEDs.



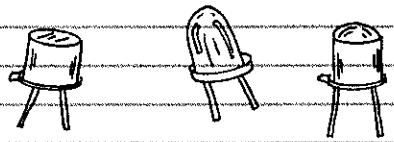
THESE INEXPENSIVE LEDs ARE USED AS INDICATOR LIGHTS. CERTAIN RED LEDs ARE USED TO TRANSMIT INFORMATION. MOST ARE ENCAPSULATED IN EPOXY.

LED DISPLAYS.



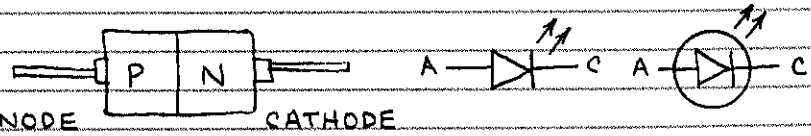
MANY KINDS OF LED READOUTS CAPABLE OF DISPLAYING DIGITS AND CHARACTERS ARE AVAILABLE. THEY ARE MORE RUGGED THAN LIQUID CRYSTAL DISPLAYS, BUT THEY USE MUCH MORE CURRENT.

INFRARED LEDs.



INFRARED LEDs SHOULD BE CALLED INFRARED EMITTING DIODES. THEY ARE USED TO TRANSMIT INFORMATION. THEY ARE ALSO USED IN INTRUSION ALARMS, REMOTE CONTROL DEVICES, ETC. A SPECIAL KIND OF INFRARED LED IS THE DIODE LASER. SOME EMIT SEVERAL WATTS!

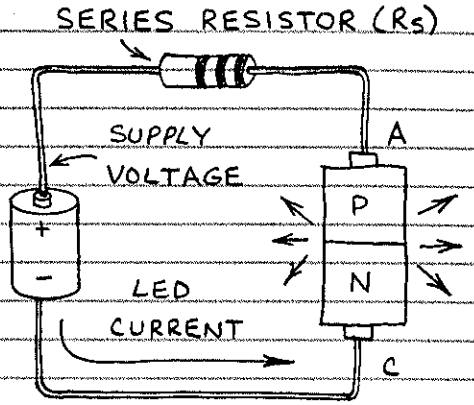
☐ LED SYMBOL. BOTH SYMBOLS SHOWN HERE ARE USED.



HOW LEDs ARE USED

LEDs CAN BE POWERED BY CONTINUOUS CURRENT OR BY BRIEF PULSES OF CURRENT. WHEN OPERATED CONTINUOUSLY, THE CURRENT CAN BE VARIED TO CHANGE THE LIGHT OUTPUT.

☐ LED DRIVE CIRCUIT — BECAUSE LEDs ARE CURRENT DEPENDENT, IT'S USUALLY NECESSARY TO PROTECT THEM FROM EXCESSIVE CURRENT WITH A SERIES RESISTOR. SOME LEDs INCLUDE A BUILT-IN SERIES RESISTOR. MOST DO NOT. IT'S IMPORTANT TO KNOW HOW TO DETERMINE THE REQUIRED SERIES RESISTANCE (R_S). THE FORMULA IS:

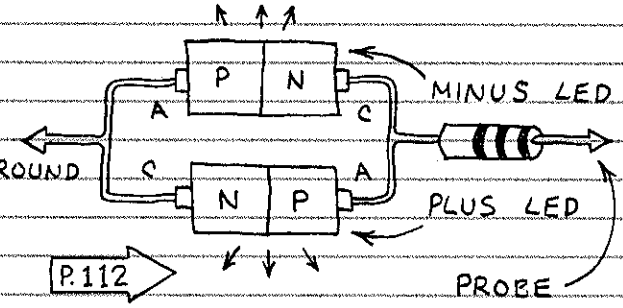


$$R_S = \frac{\text{SUPPLY VOLTAGE} - \text{LED VOLTAGE}}{\text{LED CURRENT}} \quad \text{OR} \quad R_S = \frac{V - V_{LED}}{I_{LED}}$$

P. 112

EXAMPLE: SUPPOSE YOU WANT TO OPERATE A RED LED AT A FORWARD CURRENT (I_{LED}) OF 10-MILLIAMPERES FROM A 5-VOLT SUPPLY (V). V_{LED} IS 1.7-VOLTS (FROM DATA SHEET). THEREFORE R_S IS (5 - 1.7) / 0.01 OR 330-OHMS.

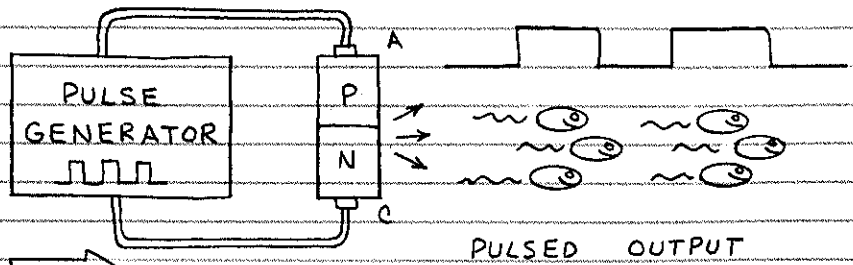
☐ LED POLARITY INDICATOR — TWO REVERSE-PARALLEL LEDs FORM A POLARITY INDICATOR. BOTH LEDs GLOW IF THE TESTED VOLTAGE IS AC. THE SERIES RESISTOR MUST BE USED!



P. 112

☐ PULSED LED — WHEN OPERATED CONTINUOUSLY, AN INFRARED LED MIGHT HAVE A MAXIMUM CURRENT OF 100-MILLIAMPERES. WHEN DRIVEN BY BRIEF PULSES OF CURRENT, THE SAME LED MAY SAFELY ACCEPT HUGE 10-AMPERE PULSES!

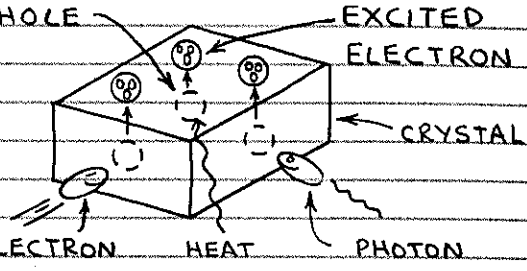
NOTE: A SERIES RESISTOR MAY NOT BE REQUIRED IF THE PULSES DO NOT EXCEED THE MAXIMUM LEVELS SPECIFIED FOR THE LED.



P. 126

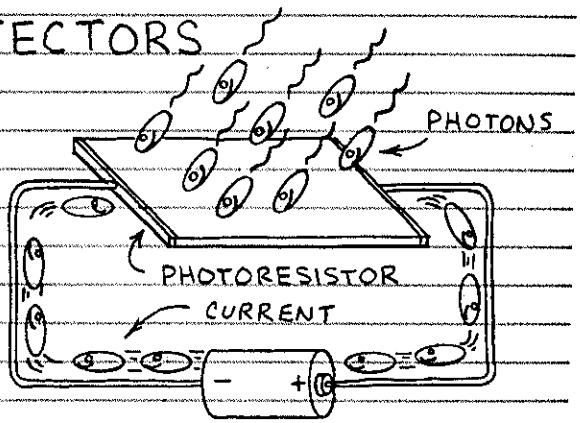
SEMICONDUCTOR LIGHT DETECTORS

ENERGY ENTERING A SEMICONDUCTOR CRYSTAL EXCITES ELECTRONS TO HIGHER LEVELS, LEAVING BEHIND HOLES. THESE ELECTRONS AND HOLES CAN RECOMBINE AND EMIT PHOTONS, OR THEY CAN MOVE AWAY FROM ONE ANOTHER AND FORM A CURRENT. THIS IS THE BASIS OF SEMICONDUCTOR LIGHT DETECTORS. THERE ARE TWO MAJOR CLASSES OF SEMICONDUCTOR LIGHT DETECTORS, THOSE WITH AND THOSE WITHOUT PN JUNCTIONS.

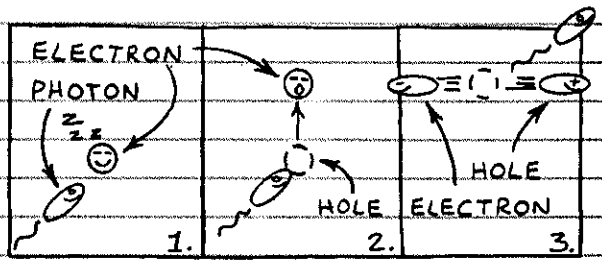


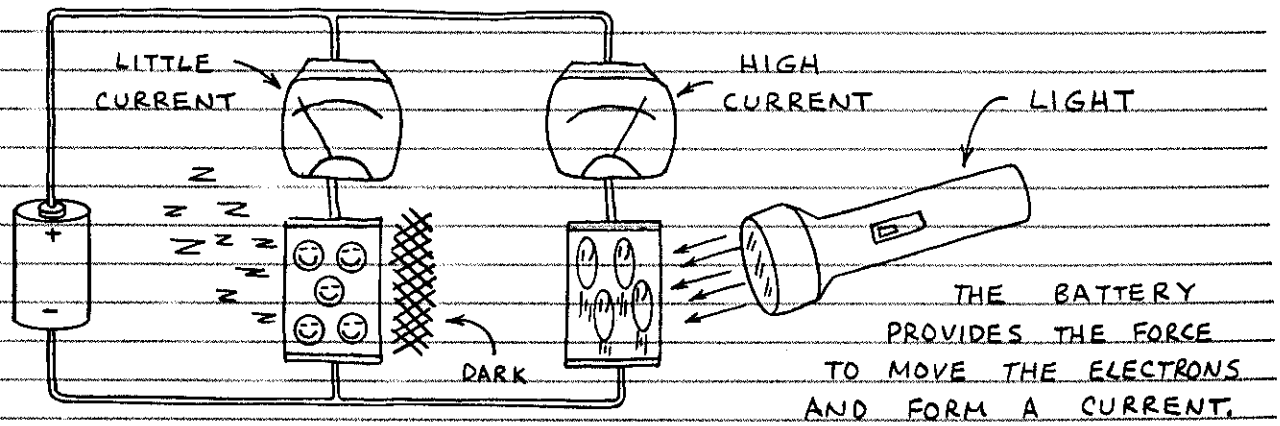
PHOTORESISTIVE LIGHT DETECTORS

PHOTORESISTORS ARE SEMICONDUCTOR LIGHT DETECTORS WITHOUT A PN JUNCTION. THEIR RESISTANCE IS VERY HIGH (UP TO MILLIONS OF OHMS) WHEN NO LIGHT IS PRESENT. WHEN ILLUMINATED, THEIR RESISTANCE IS VERY LOW (HUNDREDS OF OHMS).



☐ PHOTORESISTOR OPERATION. THIS PANEL SHOWS HOW A PHOTON CREATES A HOLE-ELECTRON PAIR. AN EXTERNAL VOLTAGE WILL FORCE THE HOLE AND ELECTRON TO MOVE.



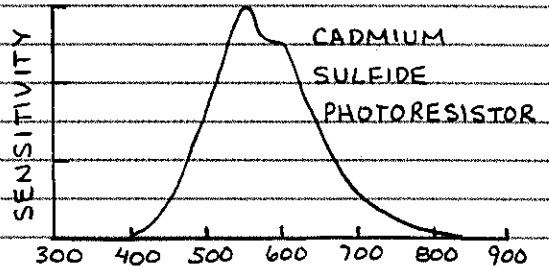


THE BATTERY PROVIDES THE FORCE TO MOVE THE ELECTRONS AND FORM A CURRENT.

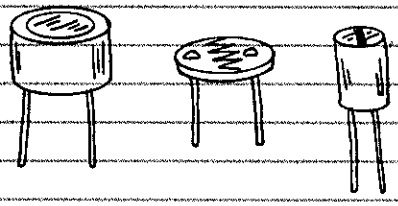
☐ MORE ABOUT PHOTORESISTOR OPERATION — HERE ARE SOME IMPORTANT ASPECTS OF PHOTORESISTOR OPERATION:

1. PHOTORESISTORS MAY REQUIRE A FEW MILLISECONDS OR MORE TO FULLY RESPOND TO A CHANGE IN LIGHT INTENSITY (THAT'S PRETTY SLOW). THEY MAY REQUIRE MANY MINUTES TO RETURN TO THEIR NORMAL DARK RESISTANCE WHEN LIGHT IS REMOVED (THE MEMORY EFFECT).

2. THE SEMICONDUCTOR MOST OFTEN USED IN PHOTORESISTORS IS CADMIUM SULFIDE. ITS SENSITIVITY TO LIGHT IS VERY SIMILAR TO THAT OF THE HUMAN EYE! LEAD SULFIDE IS USED TO DETECT INFRA-RED (OUT TO 3-MICROMETERS).



☐ KINDS OF PHOTORESISTORS — MANY DIFFERENT KINDS ARE AVAILABLE. IN MOST THE LIGHT SENSITIVE SEMICONDUCTOR IS COATED BETWEEN INTERLEAVED ELECTRODES TO INCREASE THE EXPOSED SURFACE. A PLASTIC OR GLASS WINDOW MAY OR MAY NOT BE USED.



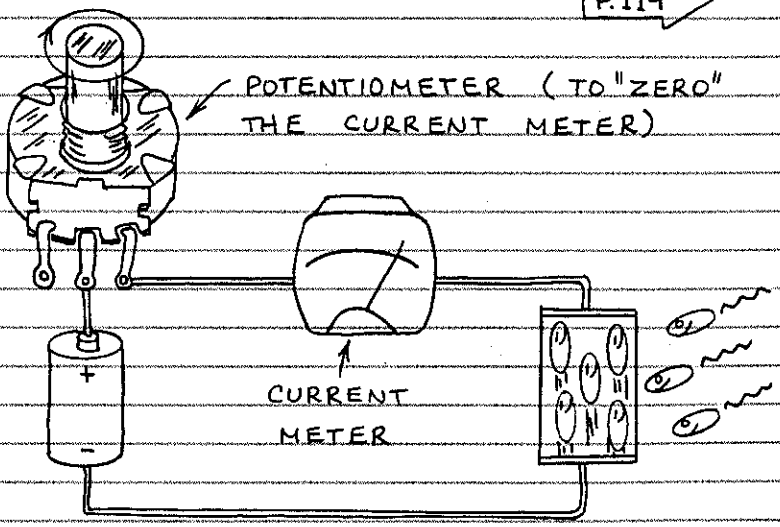
☐ PHOTORESISTOR SYMBOL. BOTH SYMBOLS SHOWN HERE ARE USED.

HOW PHOTORESISTORS ARE USED

P. 114

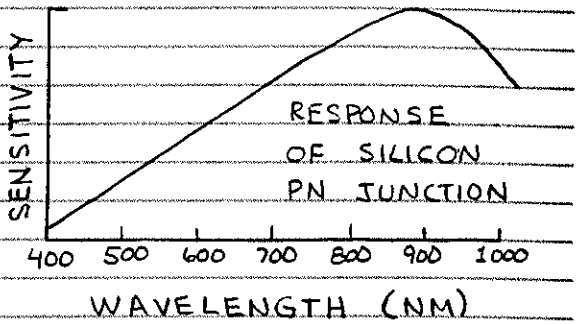
PHOTORESISTORS ARE USED IN LIGHT CONTROLLED RELAYS AND LIGHT METERS.

☐ LIGHT METER. THE ARRANGEMENT SHOWN HERE INDICATES ON A CURRENT METER THE INTENSITY OF LIGHT ILLUMINATING A CADMIUM SULFIDE PHOTORESISTOR.



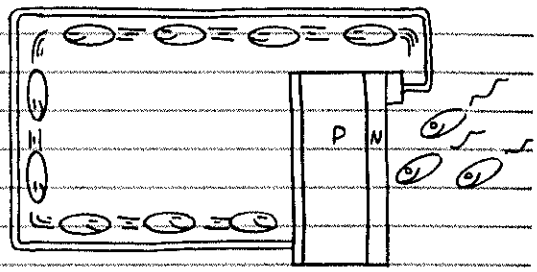
PN JUNCTION LIGHT DETECTORS

PN JUNCTION LIGHT DETECTORS FORM THE LARGEST FAMILY OF PHOTONIC SEMICONDUCTORS. MOST ARE MADE FROM SILICON AND CAN DETECT BOTH VISIBLE LIGHT AND NEAR-INFRARED.

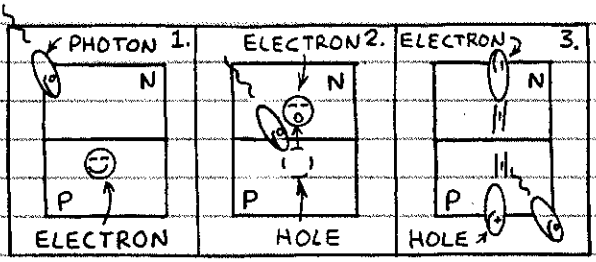


PHOTODIODES

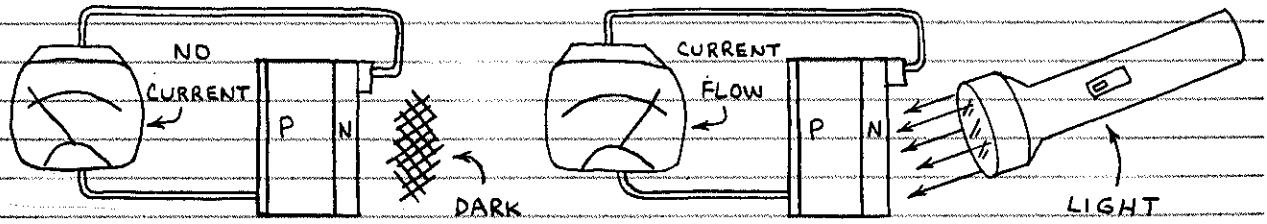
ALL PN JUNCTIONS ARE LIGHT SENSITIVE. PHOTODIODES ARE PN JUNCTIONS SPECIFICALLY DESIGNED FOR LIGHT DETECTION. THEY ARE USED IN CAMERAS, INTRUSION ALARMS, LIGHTWAVE COMMUNICATORS, ETC.

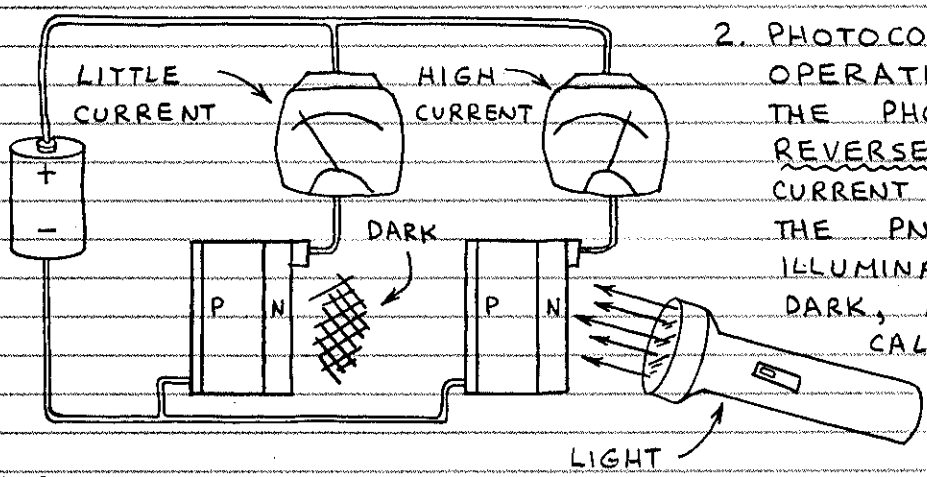


☐ PHOTODIODE OPERATION. A PHOTON WILL CREATE A HOLE-ELECTRON PAIR AT A PN JUNCTION. A CURRENT WILL FLOW IF THE TWO SIDES OF THE JUNCTION ARE CONNECTED. TWO OPERATING MODES ARE POSSIBLE:



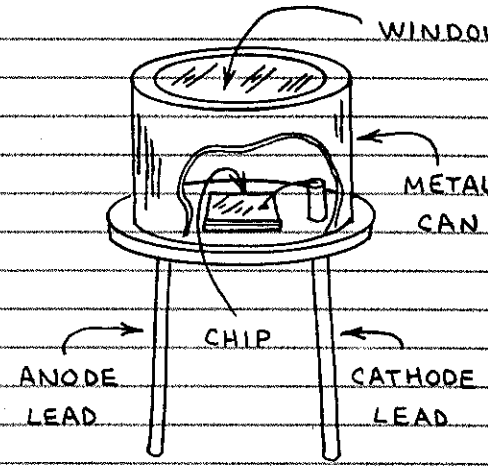
1. PHOTOVOLTAIC OPERATION — HERE THE PHOTODIODE BECOMES A CURRENT SOURCE WHEN IT IS ILLUMINATED.





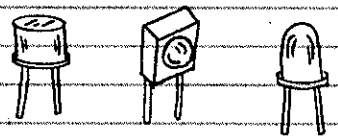
2. PHOTOCONDUCTIVE OPERATION — HERE THE PHOTODIODE IS REVERSE-BIASED. A CURRENT FLOWS WHEN THE PN JUNCTION IS ILLUMINATED. (WHEN DARK, A TINY CURRENT CALLED THE DARK CURRENT WILL FLOW.)

☐ KINDS OF PHOTODIODES.
SHOWN HERE IS A TYPICAL PHOTODIODE. MANY OTHER CASE STYLES ARE ALSO USED (PLASTIC HOUSING, BUILT-IN LENSES AND FILTERS, ETC.). THE MOST IMPORTANT DISTINCTION IS THE SIZE OF THE SEMICONDUCTOR CHIP. SPECIALIZED CHIP DESIGNS MAY BE USED TO GIVE BETTER RESPONSE TO CERTAIN WAVELENGTHS OF LIGHT.



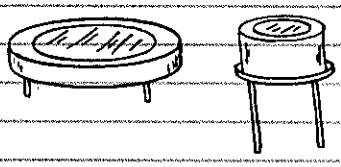
FAMOUS FACT: LEDs CAN BOTH EMIT AND DETECT LIGHT!

SMALL AREA PHOTODIODES.



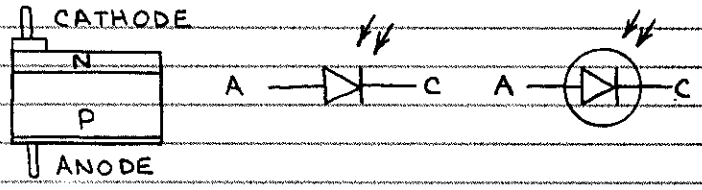
THESE PHOTODIODES HAVE VERY FAST RESPONSE TIMES WHEN USED IN THE REVERSE-BIASED PHOTOCONDUCTIVE MODE.

LARGE AREA PHOTODIODES.



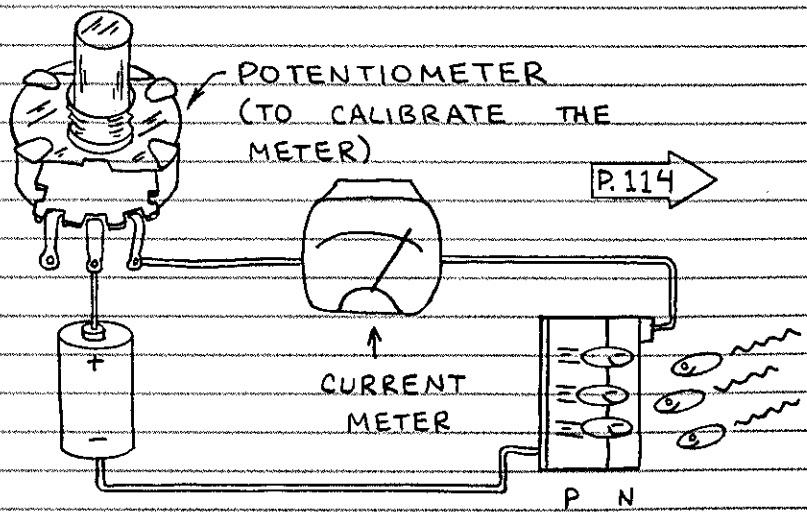
THOUGH SLOWER RESPONDING THAN SMALL AREA PHOTODIODES, THEIR LARGE AREA PROVIDES HIGH SENSITIVITY.

☐ PHOTODIODE SYMBOL.
BOTH SYMBOLS SHOWN HERE ARE USED.



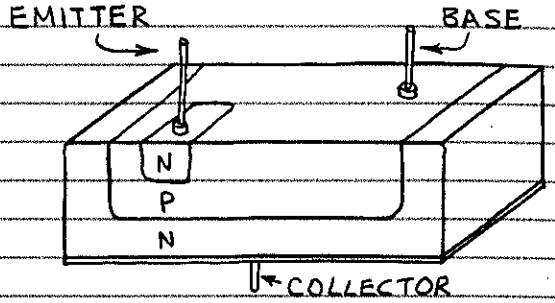
HOW PHOTODIODES ARE USED

PHOTODIODES ARE COMMONLY USED TO DETECT FAST PULSES OF NEAR INFRARED (AS IN LIGHTWAVE COMMUNICATIONS).

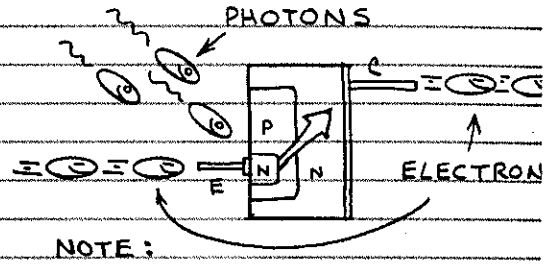


☐ LIGHT METER.
THIS ARRANGEMENT PROVIDES A BASIC PHOTOCONDUCTIVE MODE LIGHT METER. ITS RESPONSE IS VERY LINEAR.

PHOTOTRANSISTORS



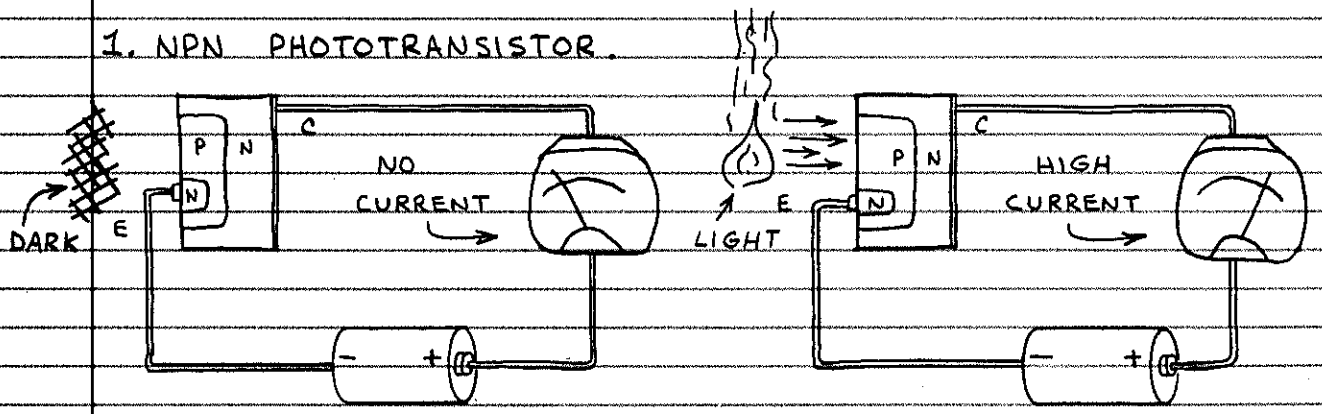
ALL TRANSISTORS ARE LIGHT SENSITIVE. PHOTOTRANSISTORS ARE SPECIFICALLY DESIGNED TO TAKE ADVANTAGE OF THIS IMPORTANT PROPERTY. LIGHT SENSITIVE FETs ARE AVAILABLE, BUT THE MOST COMMON PHOTO-TRANSISTOR IS AN NPN JUNCTION TRANSISTOR WITH A LARGE, EXPOSED BASE REGION. PHOTONS ENTERING THE BASE REPLACE THE BASE-EMITTER CURRENT OF ORDINARY NPN TRANSISTORS. THEREFORE A PHOTOTRANSISTOR DIRECTLY AMPLIFIES VARIATIONS IN THE NUMBER OF PHOTONS.



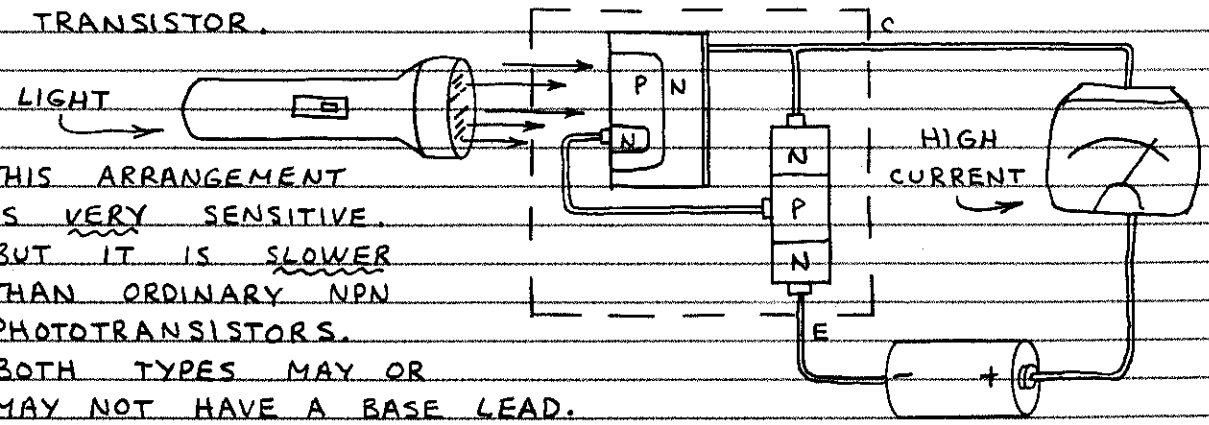
NOTE: BASE LEAD IS OPTIONAL.

☐ NPN PHOTOTRANSISTOR OPERATION — TWO TYPES OF NPN PHOTOTRANSISTORS ARE AVAILABLE. ONE IS AN NPN TRANSISTOR AS SHOWN ABOVE. THE OTHER INCLUDES A SECOND NPN TRANSISTOR TO PROVIDE MORE AMPLIFICATION.

1. NPN PHOTOTRANSISTOR.

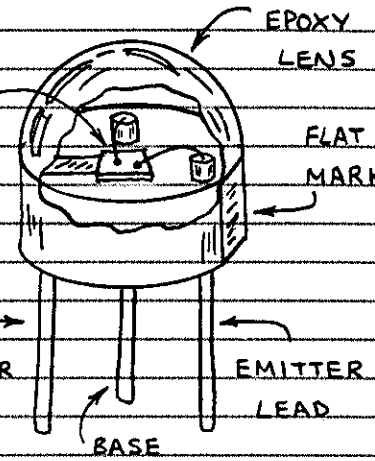


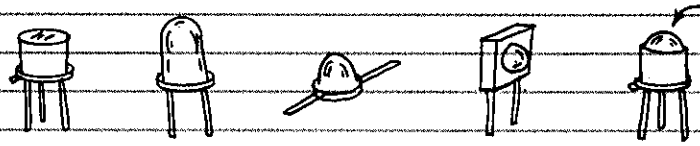
2. PHOTODARLINGTON TRANSISTOR.



THIS ARRANGEMENT IS VERY SENSITIVE. BUT IT IS SLOWER THAN ORDINARY NPN PHOTOTRANSISTORS. BOTH TYPES MAY OR MAY NOT HAVE A BASE LEAD.

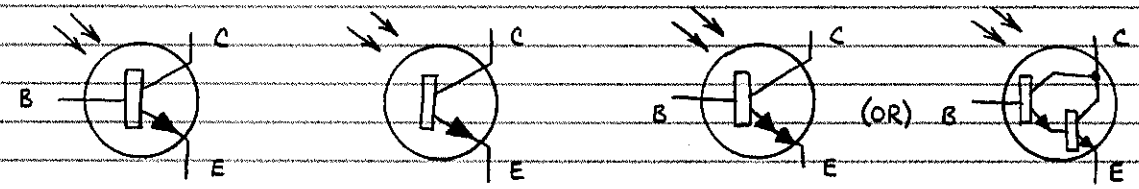
☐ KINDS OF PHOTOTRANSISTORS.
SHOWN HERE IS A TYPICAL LOW COST NPN PHOTOTRANSISTOR. MANY OTHER CASE STYLES ARE ALSO USED (METAL CANS, GLASS LENSES, FLAT WINDOWS, ETC.). IMPORTANT: THE BASE LEAD MAY OR MAY NOT BE PRESENT. MANY PHOTOTRANSISTOR CIRCUITS DO NOT USE THE BASE CONNECTION.





THESE ARE TYPICAL PHOTOTRANSISTORS.

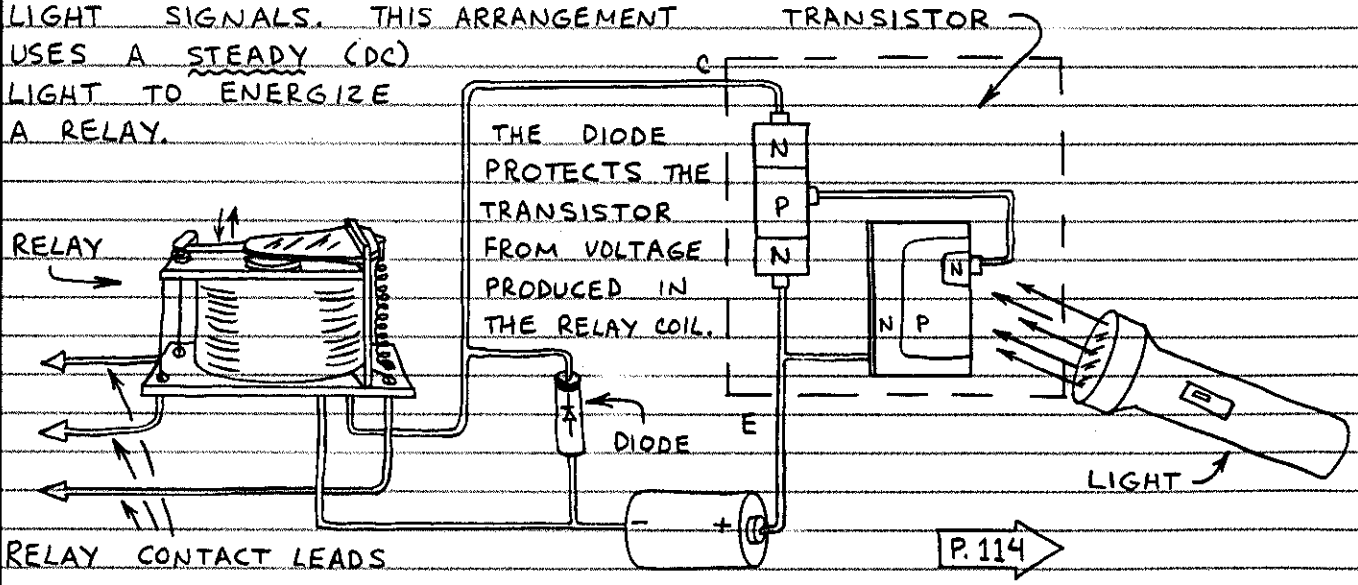
☐ PHOTOTRANSISTOR SYMBOLS.



NPN NPN (NO BASE LEAD) PHOTODARLINGTONS

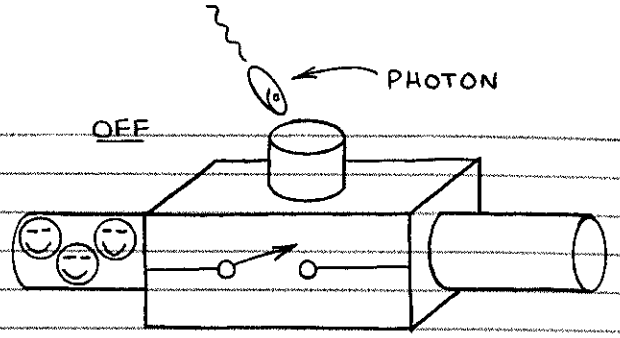
HOW PHOTOTRANSISTORS ARE USED

PHOTOTRANSISTORS ARE OFTEN USED TO DETECT FLUCTUATING (AC) LIGHT SIGNALS. THIS ARRANGEMENT USES A STEADY (DC) LIGHT TO ENERGIZE A RELAY.

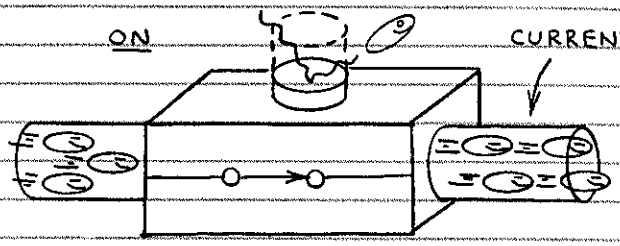


P. 114

PHOTOTHYRISTORS

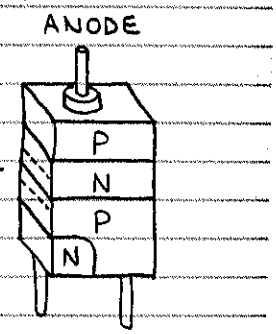


PHOTOTHYRISTORS ARE VARIOUS KINDS OF LIGHT-ACTIVATED THYRISTORS. YOU CAN THINK OF THEM AS LIGHT-ACTIVATED SWITCHES. THE MOST IMPORTANT MEMBER OF THE FAMILY IS THE LIGHT-ACTIVATED SILICON CONTROLLED RECTIFIER (LASCR). LIGHT ACTIVATED TRIACS ARE ALSO MADE. NEITHER CAN SWITCH AS MUCH CURRENT AS CONVENTIONAL THYRISTORS.

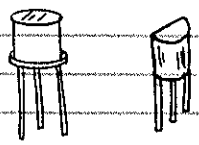


LIGHT ACTIVATED SCRs (LASCRs)

TO IMPROVE THEIR SENSITIVITY TO LIGHT, THE LASCR IS MADE THINNER THAN STANDARD SCRs. THIS LIMITS THE AMOUNT OF CURRENT THEY CAN SWITCH. FOR HIGH CURRENT APPLICATIONS A LASCR CAN BE USED TO TRIGGER A CONVENTIONAL SCR.

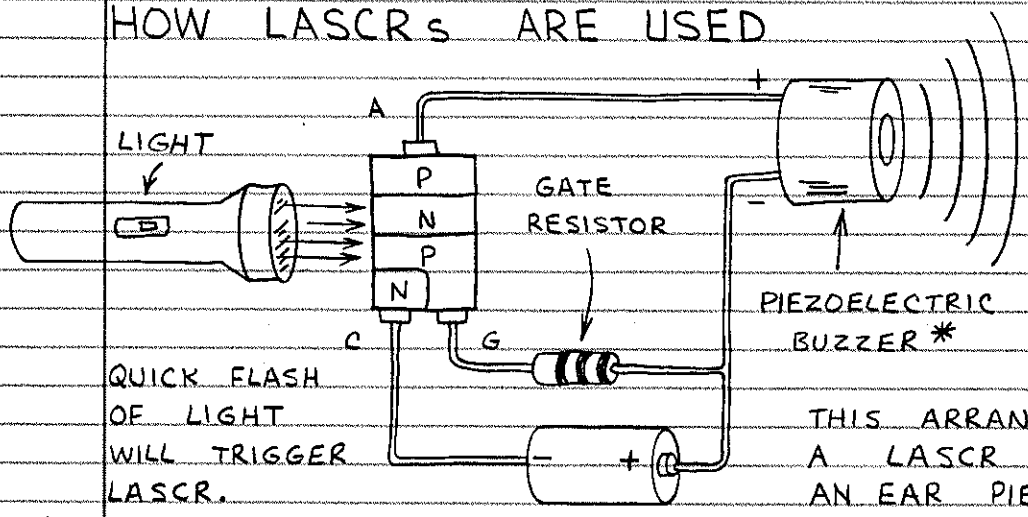


☐ KINDS OF LASCRs.



MOST LASCRs CAN SWITCH UP TO A FEW HUNDRED VOLTS. MAXIMUM CURRENT IS ONLY A FEW TENTHS OF AN AMPERE.

HOW LASCRs ARE USED



QUICK FLASH OF LIGHT WILL TRIGGER LASCR.

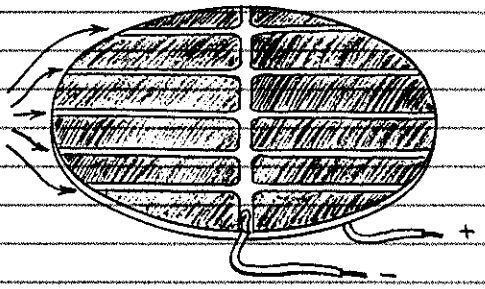
*ONCE TRIGGERED, BUZZER REMAINS ON UNTIL POWER IS INTERRUPTED.

P. 115

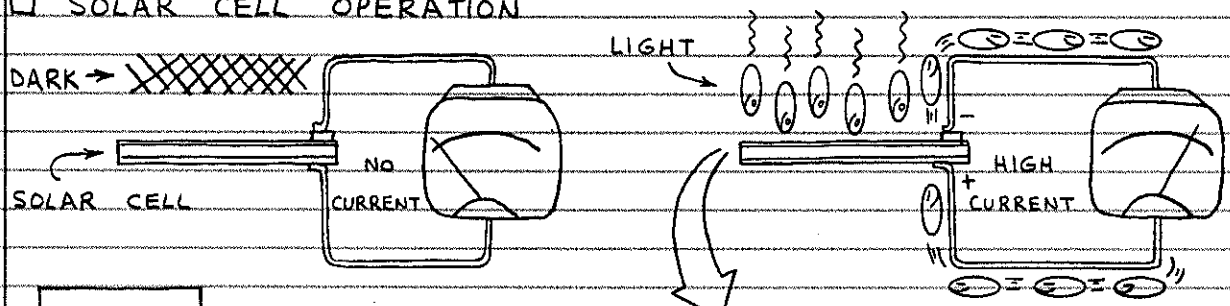
THIS ARRANGEMENT ALLOWS A LASCR TO TURN ON AN EAR PIERCING BUZZER.

SOLAR CELLS

SOLAR CELLS ARE PN JUNCTION PHOTODIODES WITH AN EXCEPTIONALLY LARGE LIGHT SENSITIVE AREA. A SINGLE SILICON SOLAR CELL GENERATES 0.5 VOLT IN BRIGHT SUNLIGHT.

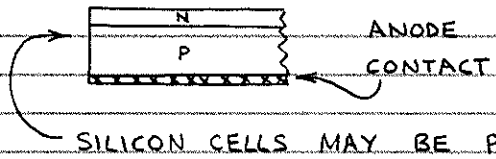


☐ SOLAR CELL OPERATION



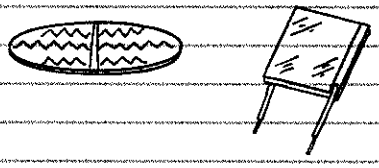
A CELL THIS SIZE GENERATES 0.1 AMPERE*

* IN BRIGHT SUNLIGHT.



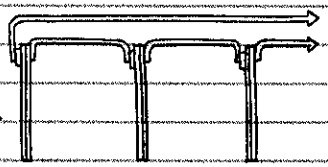
SILICON CELLS MAY BE P ON N.

☐ KINDS OF SOLAR CELLS.

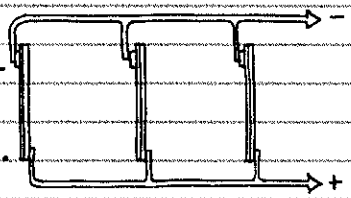


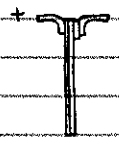
MANY DIFFERENT KINDS OF SILICON SOLAR CELLS ARE MADE. OFTEN INDIVIDUAL CELLS ARE CONNECTED IN SERIES OR PARALLEL.

SERIES: OUTPUT VOLTAGE IS SUM OF CELL VOLTAGES.



PARALLEL: OUTPUT CURRENT IS SUM OF CELL CURRENTS.





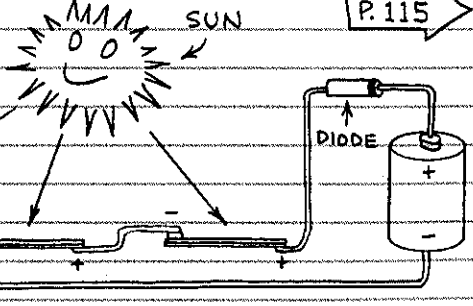
☐ SOLAR CELL SYMBOL.

REMEMBER, CELLS MAY BE P ON N.

HOW SOLAR CELLS ARE USED

ARRAYS OF SOLAR CELLS CAN CHARGE RECHARGEABLE CELLS AND BATTERIES.

P. 115



SERIES CONNECTED SOLAR CELL ARRAY