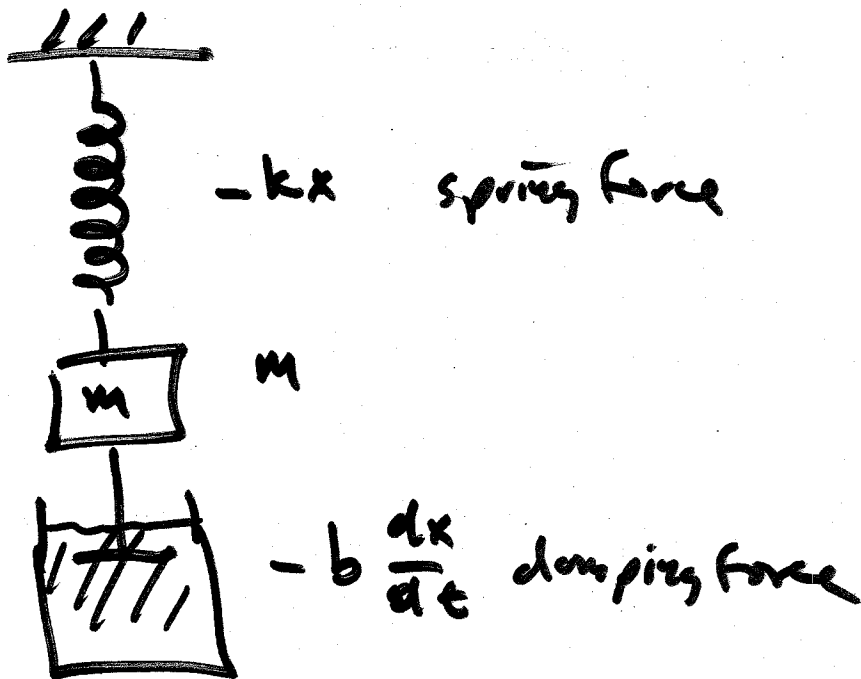


# Damped Harmonic Oscillator

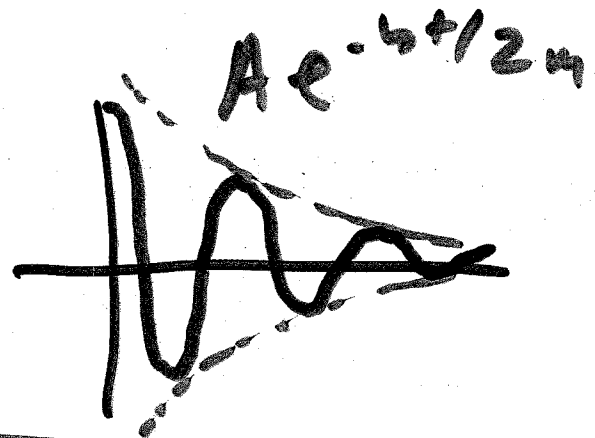
- 2nd-order system
- very basic approx. to all systems.



$$F = m a$$

$$-kx - b \frac{dx}{dt} = m \frac{d^2x}{dt^2}$$

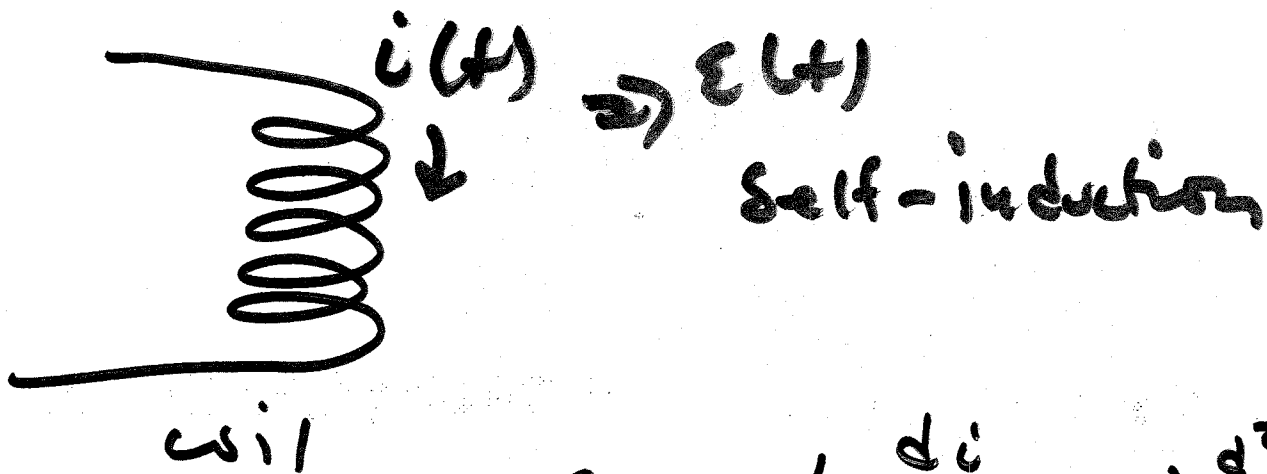
$$m \frac{d^2x}{dt^2} + b \frac{dx}{dt} + kx = 0$$



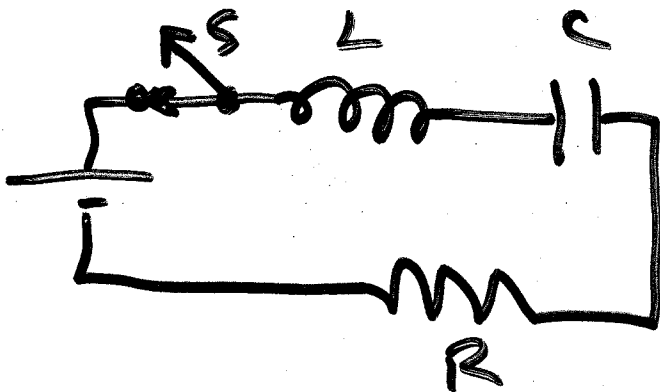
$$x = A e^{-bt/2m} \cos(\omega' t + \delta)$$

$$\omega' = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}$$

# INDUCTANCE



$$\epsilon = -L \frac{di}{dt} = -L \frac{d^2q}{dt^2}$$



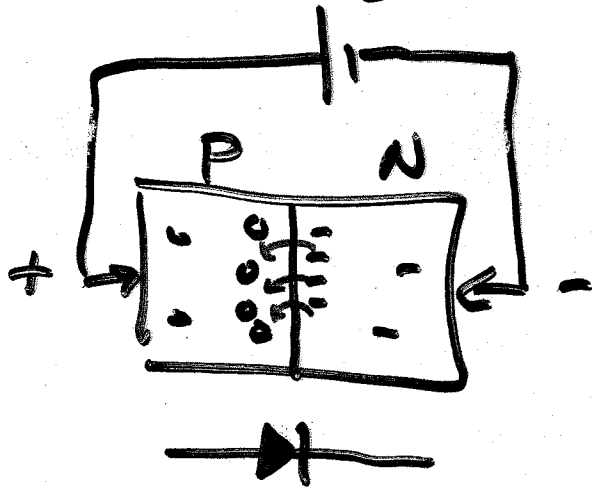
$$L \frac{d^2q}{dt^2} + R \frac{dq}{dt} + \frac{1}{C} q = 0$$

$$m \frac{d^2x}{dt^2} + b \frac{dx}{dt} + kx = 0$$

} !

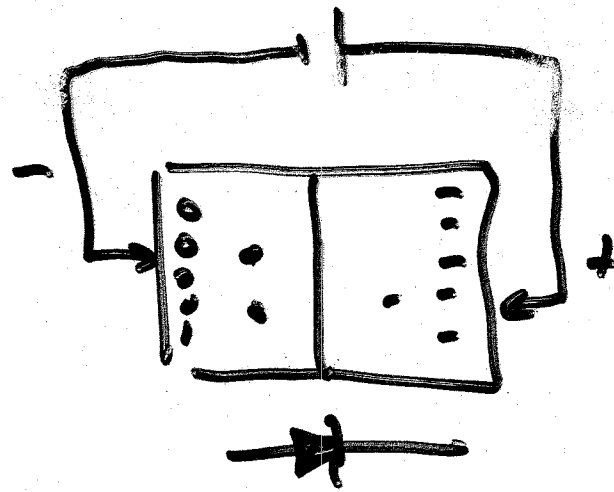
$\Rightarrow$  Analog Computers, controllers, ...

# How DIODES WORK (MIMMS)



if  $V > 0.6$  volts,  
electrons jump the  
gap!

Forward Bias



Voltage (charge)  
attracts holes and  
electrons away from  
junction. No  
jumping.

Reverse Bias

# TRANSISTOR:

• many types - bipolar  
field effect

o component of ICs; essential  
ingredient. Must know about  
it build own interfaces, want  
to connect ICs, design circuits.

o MINAS or the Art of Electronics  
Horowitz & Hill (Cambridge).

o Basic Property:

3-terminal  
active  
non linear

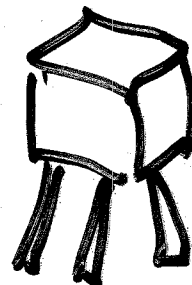
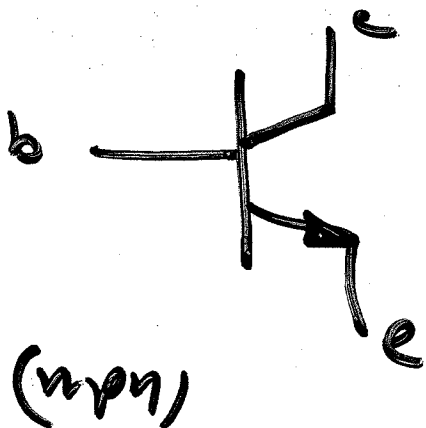
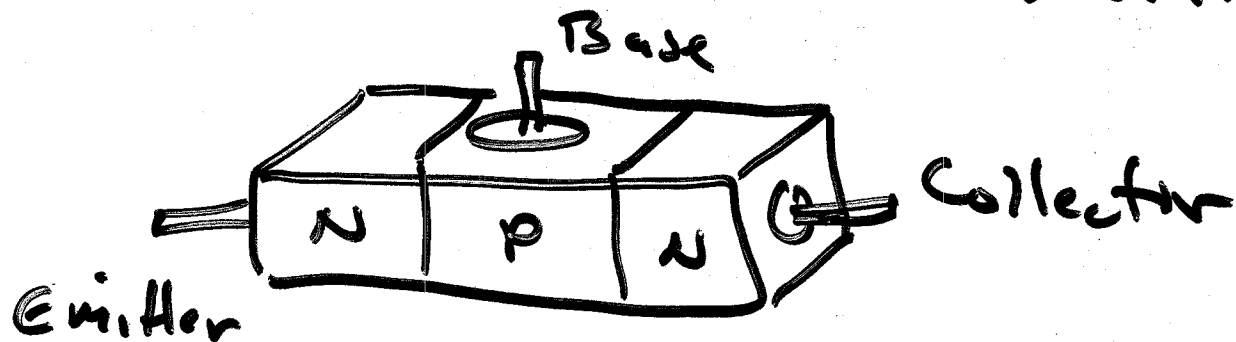
active: can amplify signals

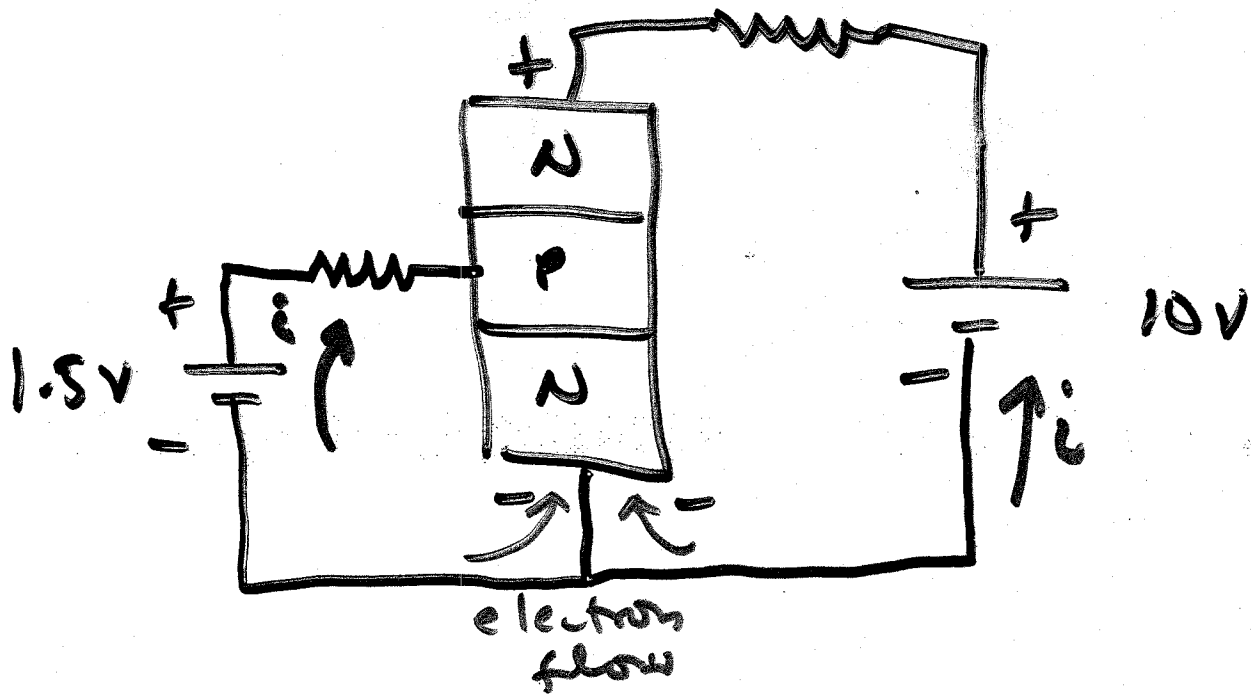
→ can build oscillators, where  
some output is fed back to  
input.

→ can control big signals with  
small ones.

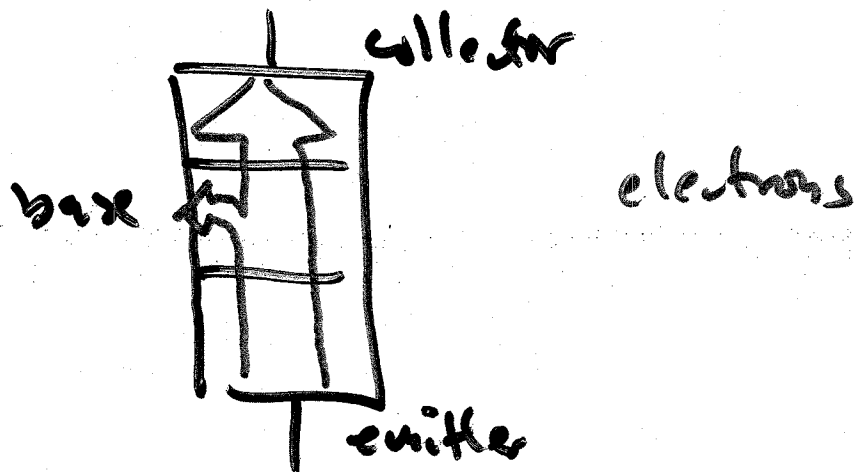
# BI POLAR :

- Add a 2nd junction to pn diode, get npn or pnp transistor.
- Middle layer acts like a faucet controlling current across all 3 layers: Its small size means it takes less current to control it.



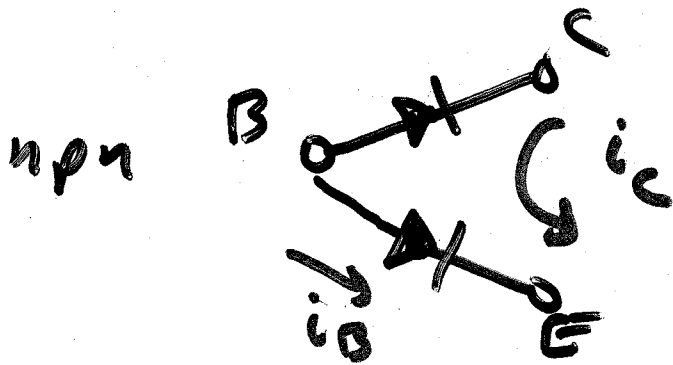


 Limit current thru transistor.



For npn!

1. Collector must be more positive than emitter.
2. Individually, base-emitter and base-collector circuits act like diodes. Normally b-e diode conducts and b-c is reverse biased.



3. Any transistor has maximum  $I_C, I_B, V_{CE}$ . Else  $\Rightarrow$  power. Also other limits.

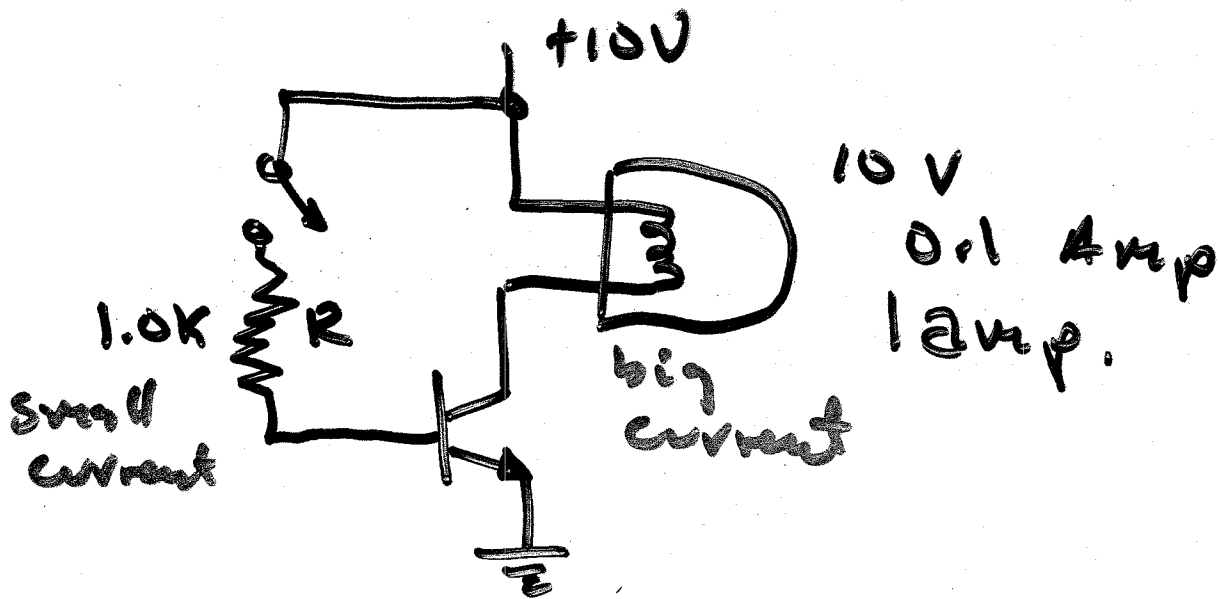
4. If ok so far, expect

$$I_C = \beta I_B, \quad \beta \approx 100$$

How? NOT FWD CONDUCTION OF BC: that's reverse-biased: it's "Transistor Action" 5

E.g.

## TRANSISTOR SWITCH



- o Close switch: base rises to .6 V.  
(b-e diode is in forward conduction)
- o Drop across R is thus 9.4 V, so base current is 9.4 mA ( $\frac{9.4}{1000}$ ).
- o Lamp lights. at 10 volts, lamp has  $I = 100$  mA current.
- o Transistor does not go to 940 mA; it saturates with collector as close to ground as it can get ( $\approx .1$  V). [6]

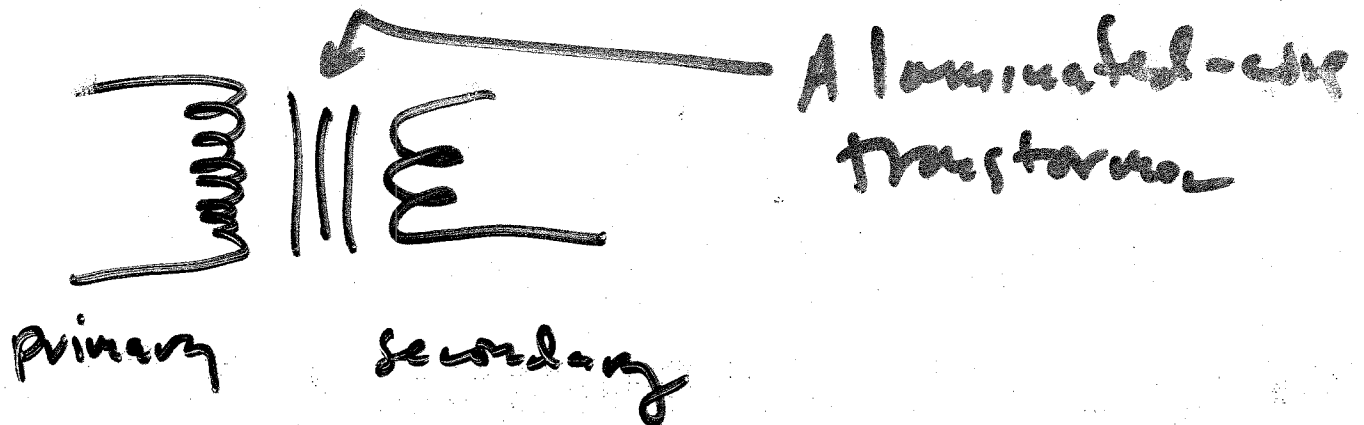


See MINUS pp 48-57

for more EGs, all about

Field-Effect Transistors, etc.

# TRANSFORMERS



AC voltage applied to primary appears at secondary with voltage multiplication proportional to the turns ratio of the transformer and current inversely proportional to the ratio.

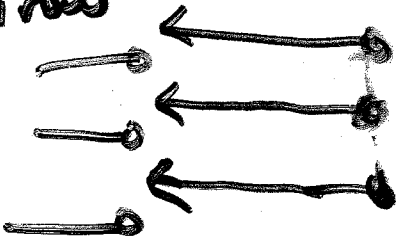
Line Voltage  $\rightarrow$  1V  
 $\rightarrow$  1,000, ... 10, 100 V.

"Power Transformers"

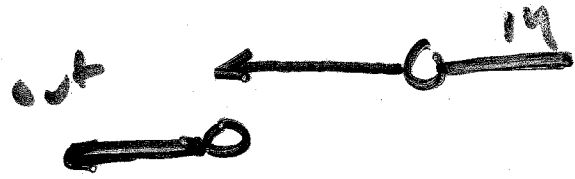
audio =  
radio =  
frequency =

# RELAYS

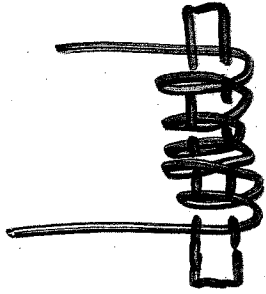
throw



poles



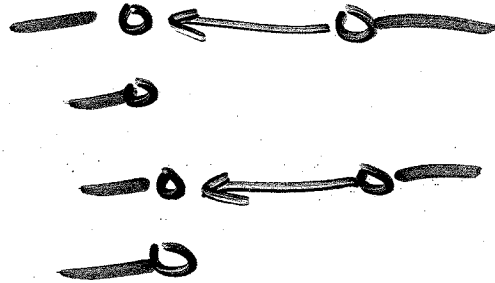
SPST



electro-  
magnet



SPDT



DPDT

# SENSORS

- TOUCH
  - SIGHT
  - TASTE
  - SMELL
  - HEARING
  - PROPRIOCEPTION
  - PROXIMITY
  - RANGE
  - DIRECTION
- } ROBOTS

## EVERETT'S BOOK ON RESERVE

MIMMS: 65-77.

J+F: Ch. 5

INTERFACING SENSORS .. J+F

(like all I/O)

(WE'LL DO LATER)

ROBOTS ARE SENSOR-DEPRIVED! <sup>↑</sup> 10

## TOUCH

- SWITCHES ( $\mu$  SWITCHES)
- FORCE (ARTIFICIAL SKIN, STRAINGAGES)

## DIRECTION

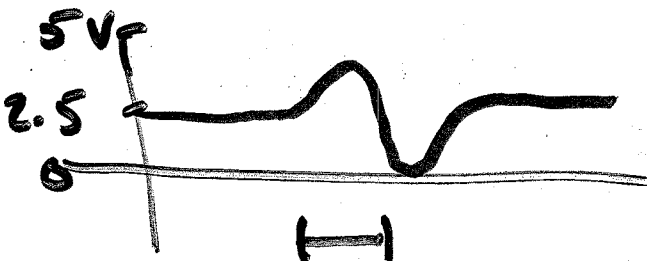
- COMPASS (SERIAL OUTPUT)
- GPS (DIFFERENCES)

## LOCATION

- GPS
- SHAFT ENCODERS (ODOMETRY)

## HEAT -

- PYROELECTRIC SENSOR  
(JFF p. 135)



Heat source goes by

## UV

- HOME FIREFIGHTING CONTEST

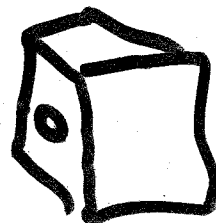
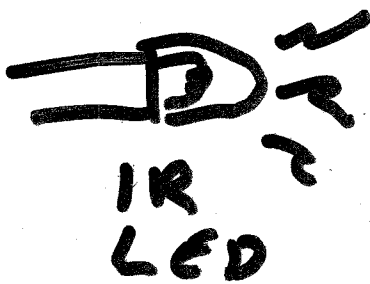
TASTE, SMELL: CURRENT RESEARCH.

HEARING:

- MICROPHONE (CLAP SENSOR; NOISE!).
- PIEZOELECTRIC FILM
  - VIBRATION
  - FORCE
  - TEMPERATURE
  - IR RADIATION
- SONAR
  - POLAROID ICIT
  - RANGE
  - PROXIMITY

PROXIMITY

- IR
- SONAR



IR Detector  
(Sharp)  
or photo X

LIGHT:

- VISION: cf Ballard & Brown  
Sunka et al

CSC 249/449

3 small cameras,  
e.g. Quickcam.

Hobby-scale devices

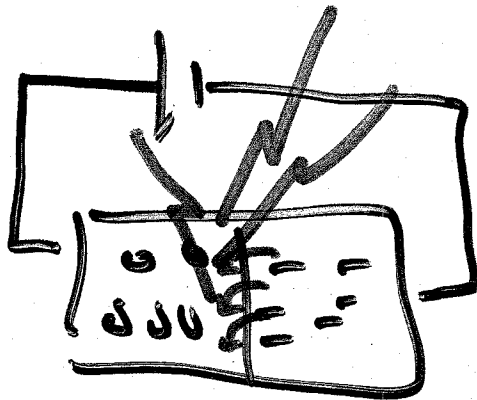
Light-Emitting Diodes (LEDs)

Photo diodes

Photo transistors

# LEDs

- Simply pn junction diodes.
- Very efficient
- Various colors, wavelengths.

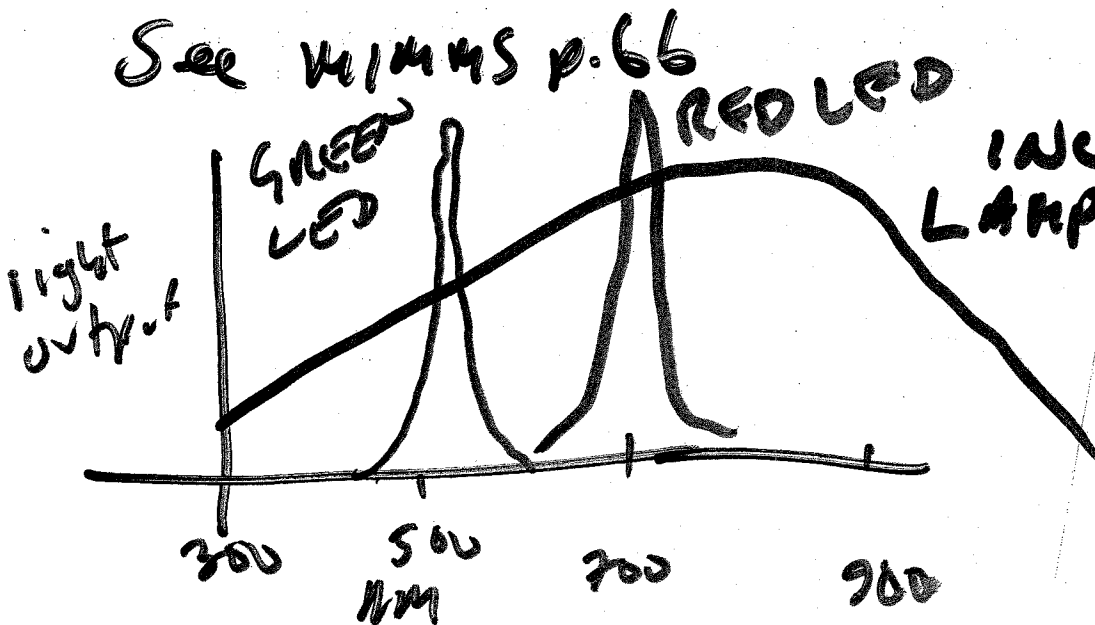


→ current  
← electrons

.6 V (silicon)  
1.3 V (Gallium Arsenide)

$R = \frac{V}{I}$

See WIKI p. 66



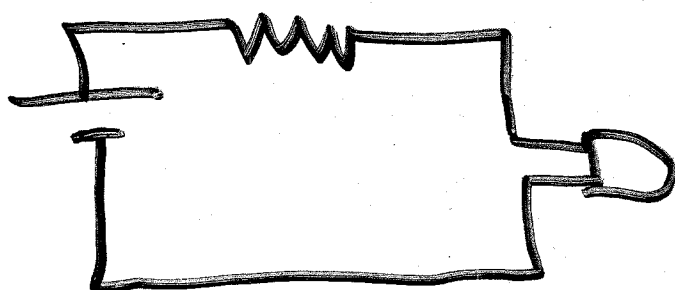
INCANDESCENT LAMP

from a 5  
if  $V_{LED} =$   
 $= 190.$

14



- voltage - current relationship limits!
- light  $\propto$  current
- voltage related to wavelength.
- pulsed operation at enormous currents.



Current-limiting resistor.

$$R = \frac{E}{I} = \frac{V - V_{LED}}{I_{LED}}$$

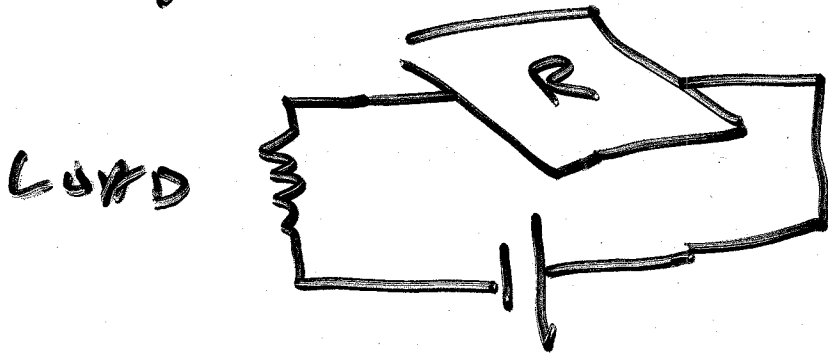
To operate LED at 20 mAmp from a 5-volt power supply, if  $V_{LED} = 1.2 \text{ V}$  (from its specs)  $= 190 \Omega$

# SEMICONDUCTOR LIGHT DETECTORS

- photons excites electrons to higher levels & create holes...
- if electrons & holes separate, can get a current.

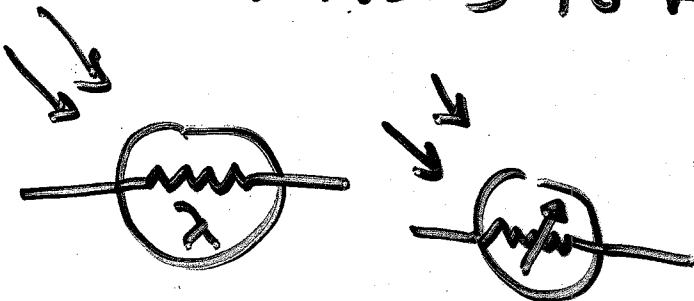
PHOTORESISTIVE (CDS) (PDS)  
(Light Meters)

green IR

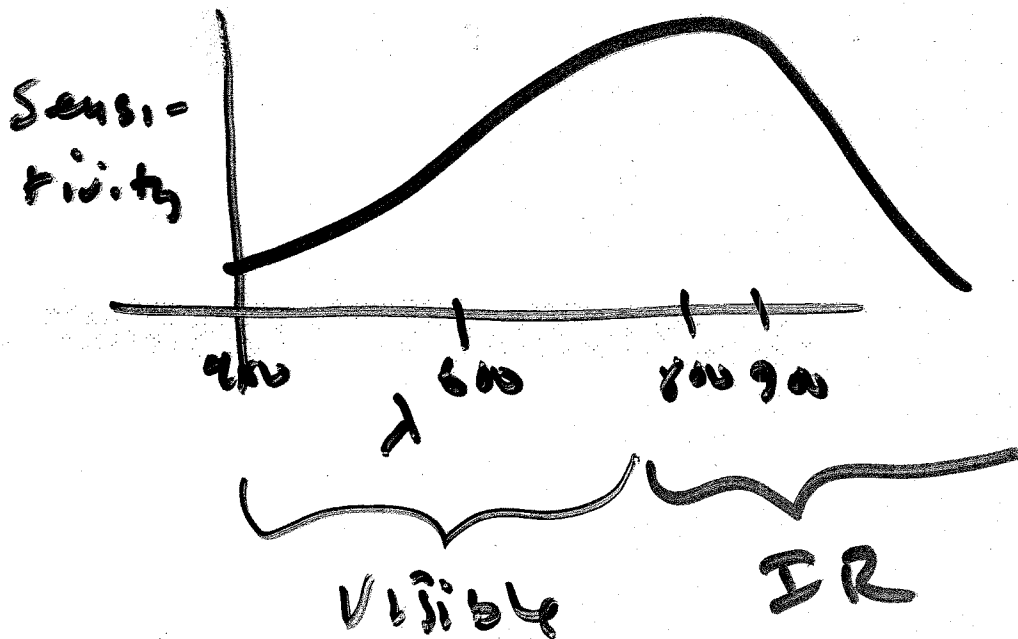


$R \approx 10^6 \Omega$  no light  
 $R \approx 10^2 \Omega$  light.

- TAKE a few  $\mu s$  to respond, minutes to return to normal.



# PHOTO DIODES (PN Junctions).



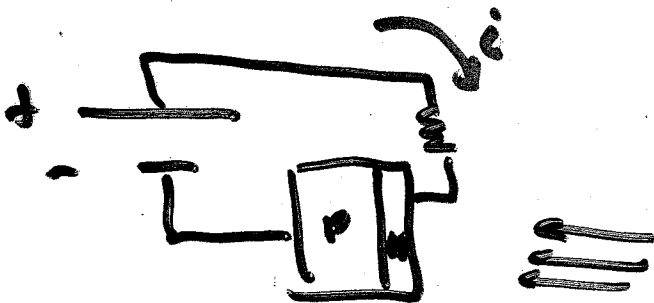
- PHOTOVOLTAIC

Illumination  $\rightarrow$  current source

- PHOTO CONDUCTIVE

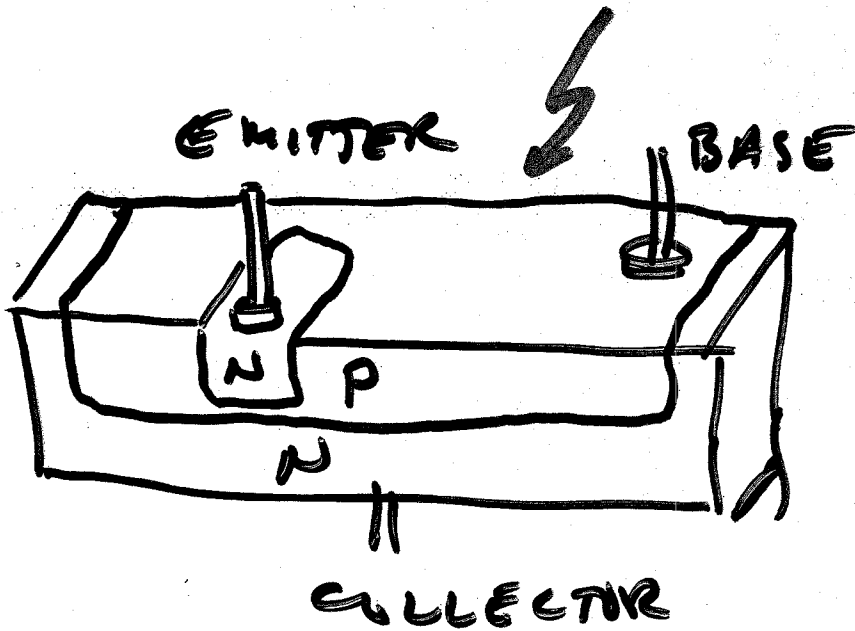
Illumination ~~is~~ overcomes reverse-bias, current flows.

Dark  $\rightarrow$  "Dark Current"

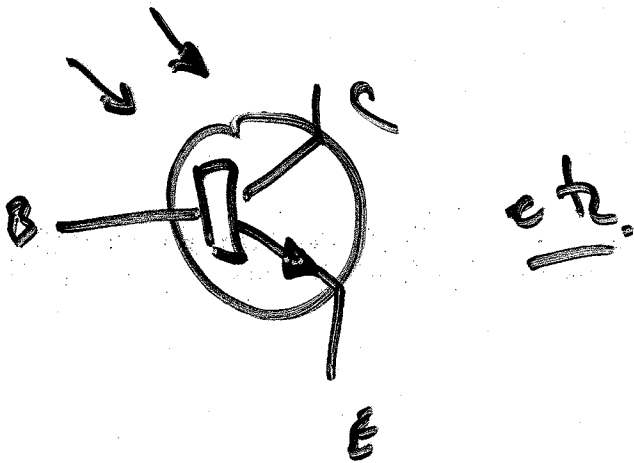


# PHOTO TRANSISTORS

All Transistors are light-sensitive.



LIGHT PHOTONS  
REPLACE THE  
BASE-EMITTER  
CURRENT, SO  
TRANSISTOR IS  
AMPLIFYING  
LIGHT VARIATION



## • PHOTO DARLINGTONS

2nd TRANSISTOR FOR  
MORE AMPLIFICATION