Damped Harmonic Oscillator
- 2nd order system
- Very basic approach to all systems.

\[
\begin{align*}
\text{m} & \quad \text{mass} \\
-kx & \quad \text{spring force} \\
-b \frac{dx}{dt} & \quad \text{damping force}
\end{align*}
\]

\[ F = ma \]

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

\[ m \frac{d^2\chi}{dt^2} + b \frac{d\chi}{dt} + k\chi = 0 \]

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

\[
\omega' = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}
\]
**Inductance**

\[ i(t) \rightarrow L \rightarrow e(t) \]

**Self-induction**

\[ L \frac{di}{dt} = -L \frac{d^2q}{dt^2} = 3 \]

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

\[ m \frac{d^2x}{dt^2} + b \frac{dx}{dt} + k x = 0 \]

\[ \exists \text{ Analog Computers, controllers, } \ldots \]
How Diodes Work (Maths)

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: bipolar
  - many types: field effect
  - component of ICs: essential ingredient. Must know about it build own interfaces, want to connect ICs, design circuits.
  - Mimas or the Art of Electronics
    Horowitz's Skill (Cambridge)

- 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.
BIPOLAR:

1. Add a 2nd junction to pn diode, get npn or pnp transistor.

2. 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 through transistor.
For n-p-n:

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.

\[ \text{npn} \quad B \quad C \quad i_c \]
\[ i_e \quad \hat{o} \quad E \]

3. Any transistor has maximum \( I_c, I_B, V_{CE} \). Else \( \beta \) small. Also other limits.

4. It's ok so far, expect

\[ I_c = \beta I_B, \quad \beta \approx 100 \]

E.G.

**TRANSISTOR SWITCH**

![Diagram of a transistor switch with labels: 10V, 0.1 Amp, big current, small current, 1.0K resistor.]

- Close switch: base rises to 0.6 V. (b-b0ode is in forward conduction)
- Drop across R is thus 9.4 V, so base current is 9.4 mA (\(\frac{9.4}{1000}\)).
- Lamp lights. at 10 volts, lamp has \(1 = 100\) mA current.

If
- Transistor does not go to 940 mA, it saturates with collector as close to ground as it can get (\(\approx 0.1V\)).
See Minns pp 48-57 for more Eqs, all about Field-Effect Transistors etc.
TRANSFORMERS

 primary  secondary

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 110 → 1V
Voltage ↓ to 1,000, ... 10, 100 V.

"Power Transformers"

coupled
radio =
frequency...
RELAYS

Thermal

Electro-magnet

Poles

SPST

SPDT

DPDT
SENSORS

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

EVERTT'S BOOK ON RESERVE

MINMs: 65°F.

J+F: Ch. 5

INTERFACING SENSORS ... J+F
(like all I/O)
(we'll do later)

ROBOTS ARE SENSOR-DEPRIVED!
**TOUCH**
- Switches (µ switches)
- Force (Artificial skin, strain gauges)

**DIRECTION**
- Compass (Serial output)
- GPS (Differences)

**LOCATION**
- GPS
- Shaft encoders (Odometry)

**HEAT**
- Pyroelectric sensor

5Vp
2.5
0

Heat source goes by

UV

- Home Firefighting Contest
TASTE, SMELL: CURRENT RESEARCH.

HEARING:
- MICROPHONE (CLAP SENSOR, NOISE!)
- PIEZO ELECTRIC FILM
  - VIBRATION
  - FORCE
  - TEMPERATURE
  - IR RADIATION

- SONAR
  - POLAROID IC
  - RANGE
  - PROXIMITY

PROXIMITY
- IR
- SONAR = D
  IR
  LED
  IR DETECTOR (SHARP)
  OR PHOTON X
Light

- Vision: of Ballard & Brown
  Sonka 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

![Diagram of LEDs]

- 0.6 V (silium)
- 1.3 V (gallium arsenide)

R = \frac{1}{I}

See Wimms p. 66

Green LED

RED LED

include factors from a 5

if \( V_{LED} = 190 \)
- voltage - current relationship limits
- light & current
- voltage related to wavelength
- pulsed operation at enormous currents.

\[ R = \frac{E}{I} = \frac{V - V_{\text{LED}}}{I_{\text{LED}}} \]

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

- Photons excite electrons to higher levels & create holes...
- If electrons & holes separate, can get a current.

PHOTO RESISTORS (Cds) (PbS)

- Green IR
- $R \approx 10^6 \, \Omega$ in light
- $R \approx 10^2 \, \Omega$ in dark
- Take a few ms to respond, minutes to return to normal.
PHOTO DIODES (PN Junctions).

- **Photoelectric**
  - Illumination → Current Source

- **Photovoltaic**
  - Illumination, overcomes reverse-bias, current flows
  - Dark → "Dark Current"
Photo Transistors

All Transistors are light-sensitive.

Light photons replace the base-emitter current, so the transistor is amplifying light variation.

- Photo Varlinsions

2nd Transistor for more amplification