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Chapter 1

Introduction to Hi-Fi

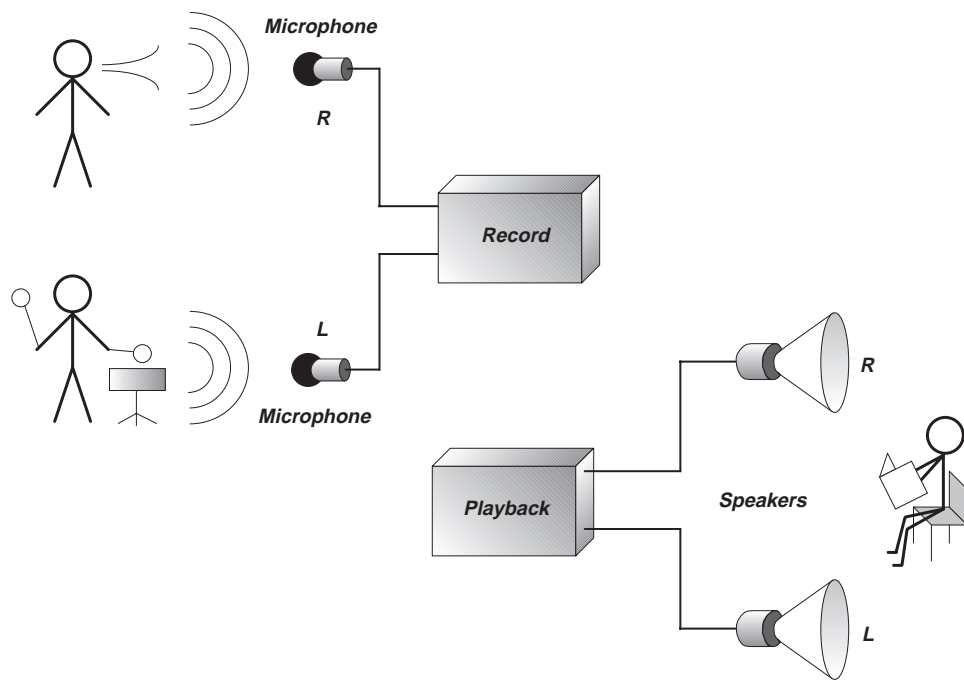


Figure 1.1: Stereo process in recording and playback.

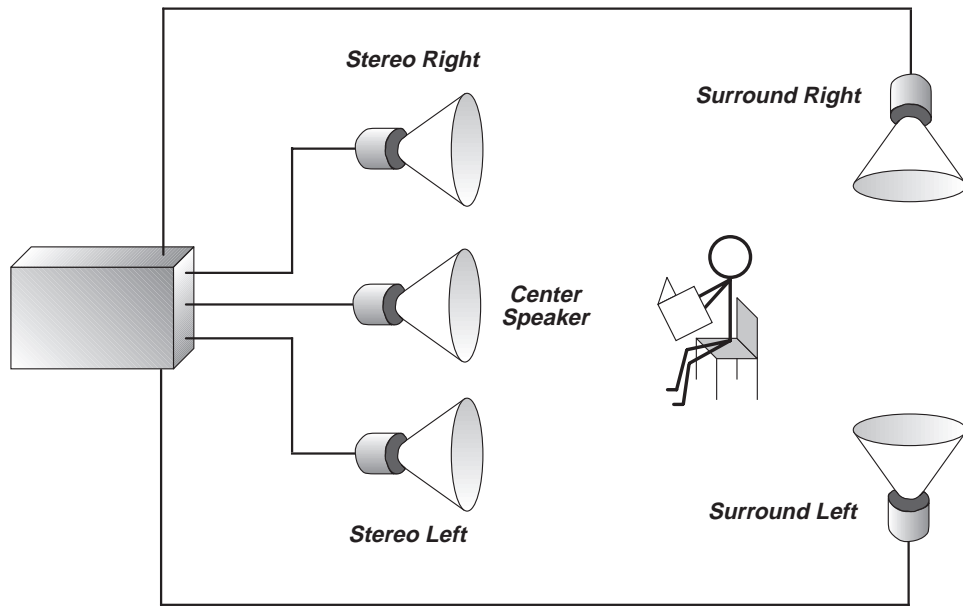


Figure 1.2: Surround sound reproduction of audio information.

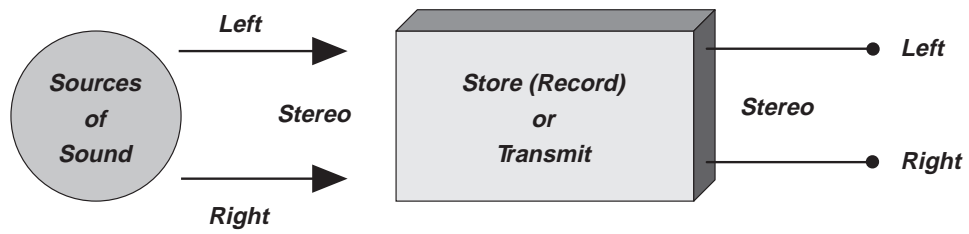


Figure 1.3: Storage or transmission of sound in stereo.

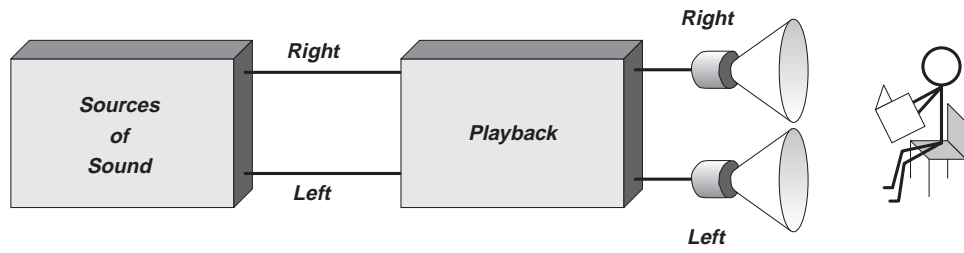


Figure 1.4: Playback process in stereo.

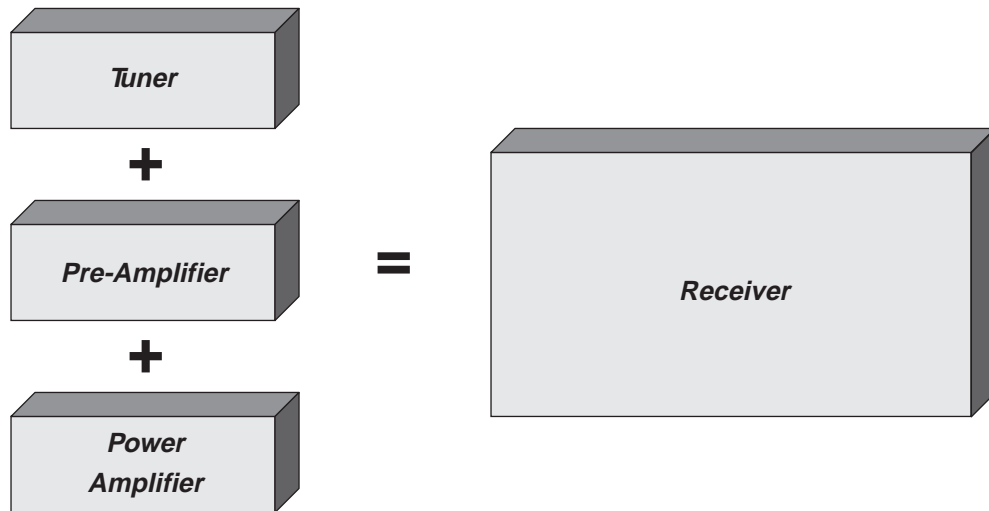


Figure 1.5: Elements of a receiver.

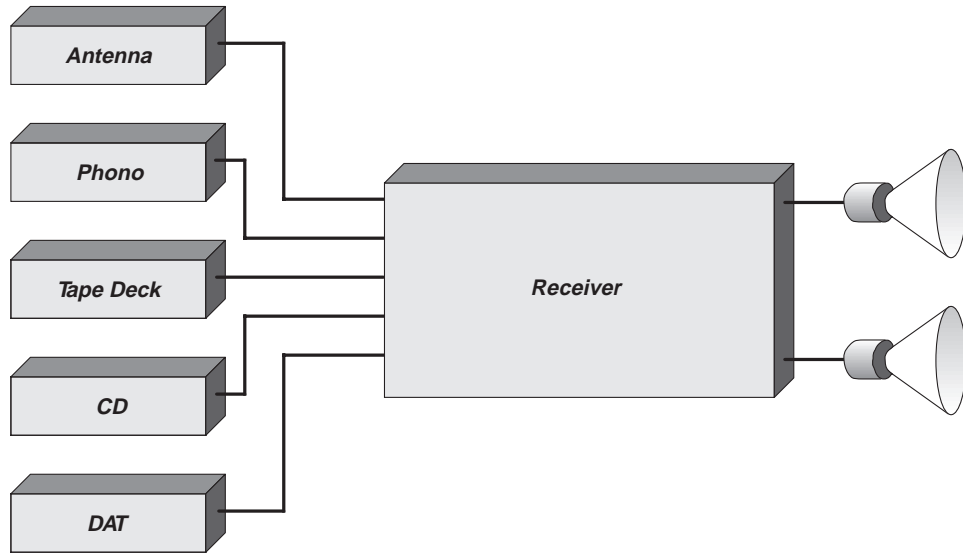


Figure 1.6: Example of basic connections to a receiver.

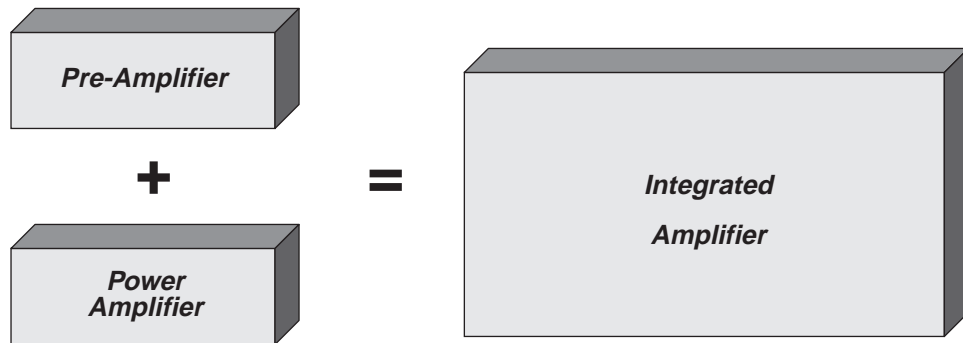


Figure 1.7: Elements of an integrated amplifier.



Figure 1.8: Connections to an integrated amplifier.

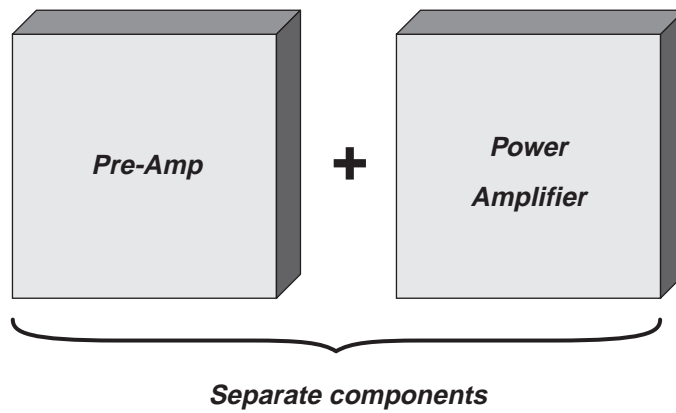


Figure 1.9: All separate approach.

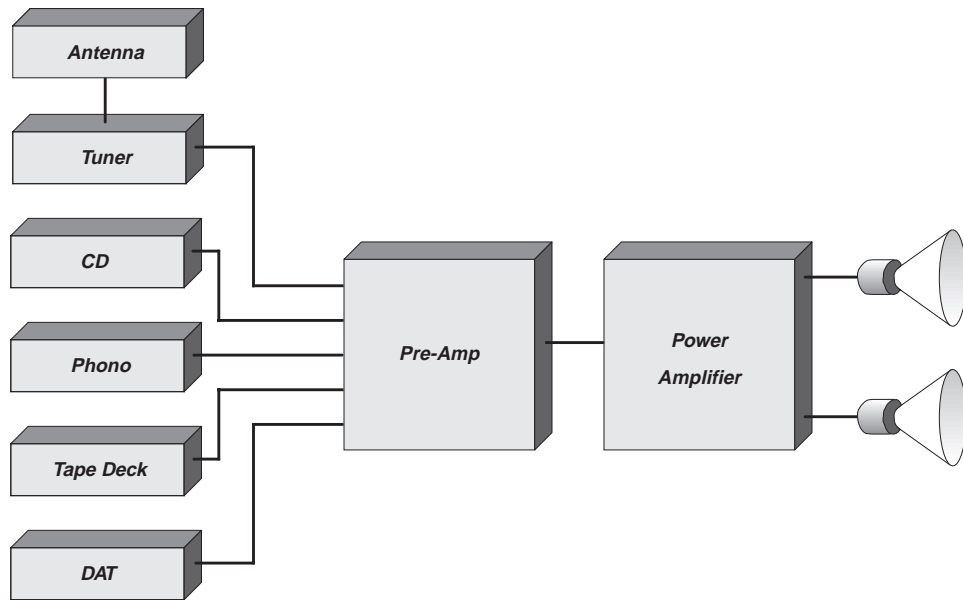


Figure 1.10: Connections in all-separate approach.

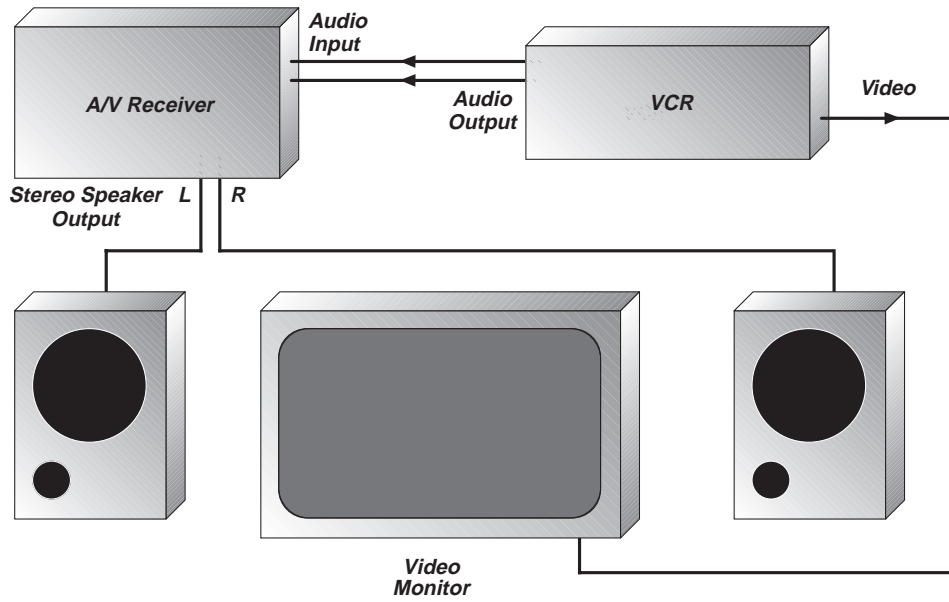


Figure 1.11: Basic A/V System.

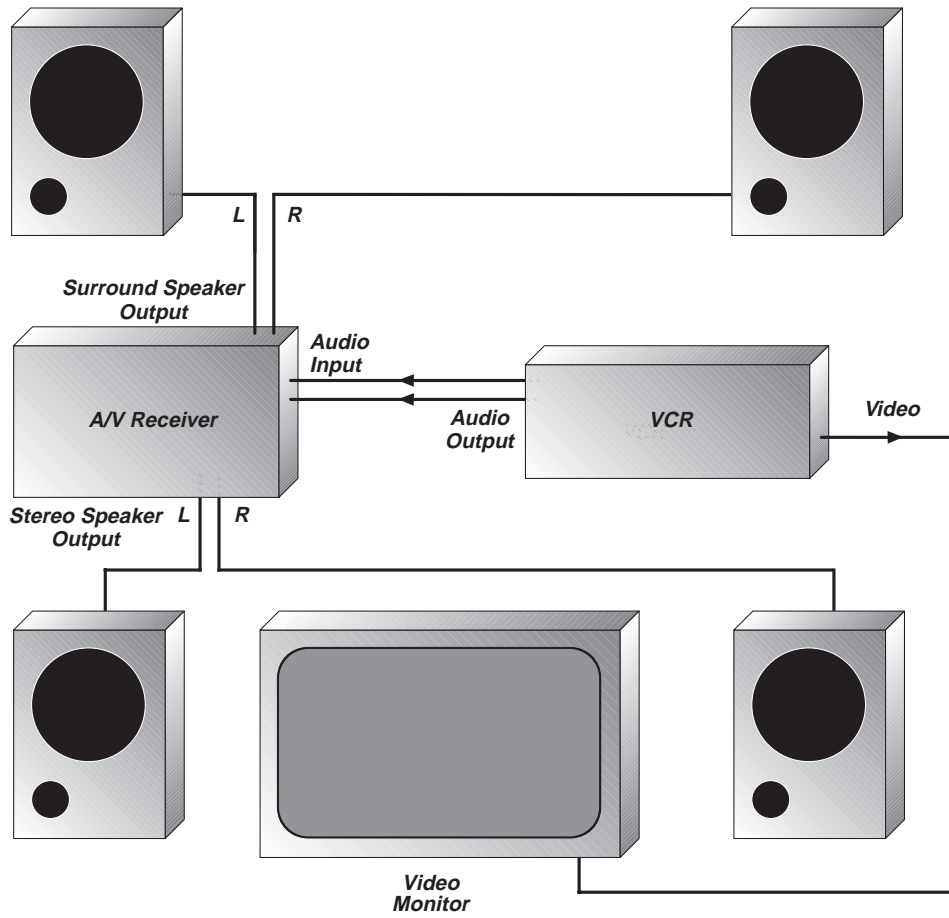


Figure 1.12: A/V receiver driving a surround-sound system.

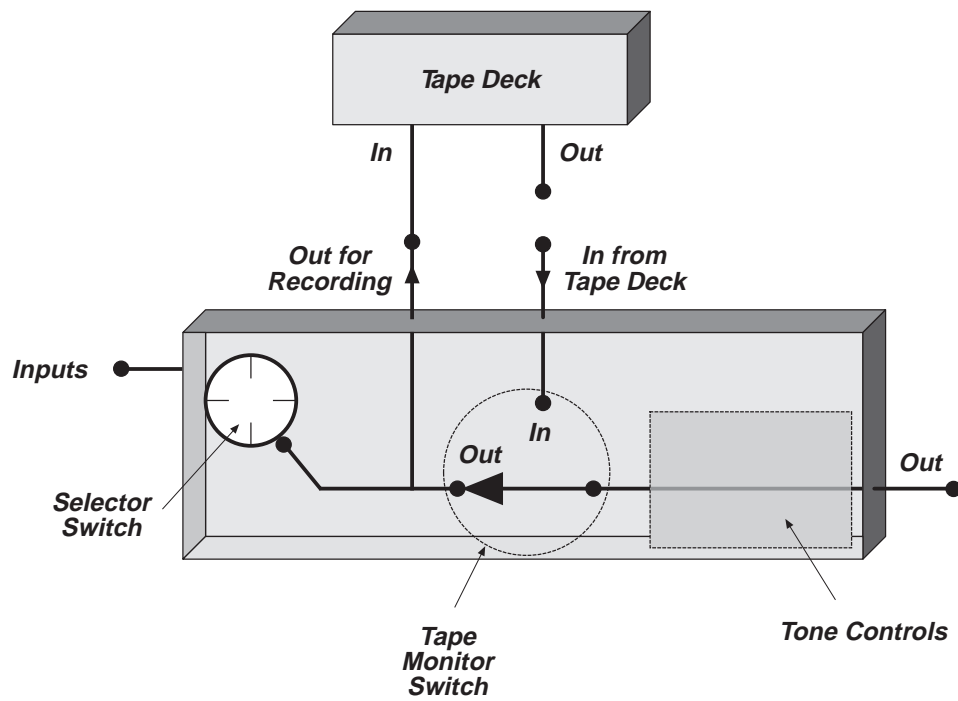


Figure 1.13: Details of the tape monitor switch when listening to a sound source with available tape recording.

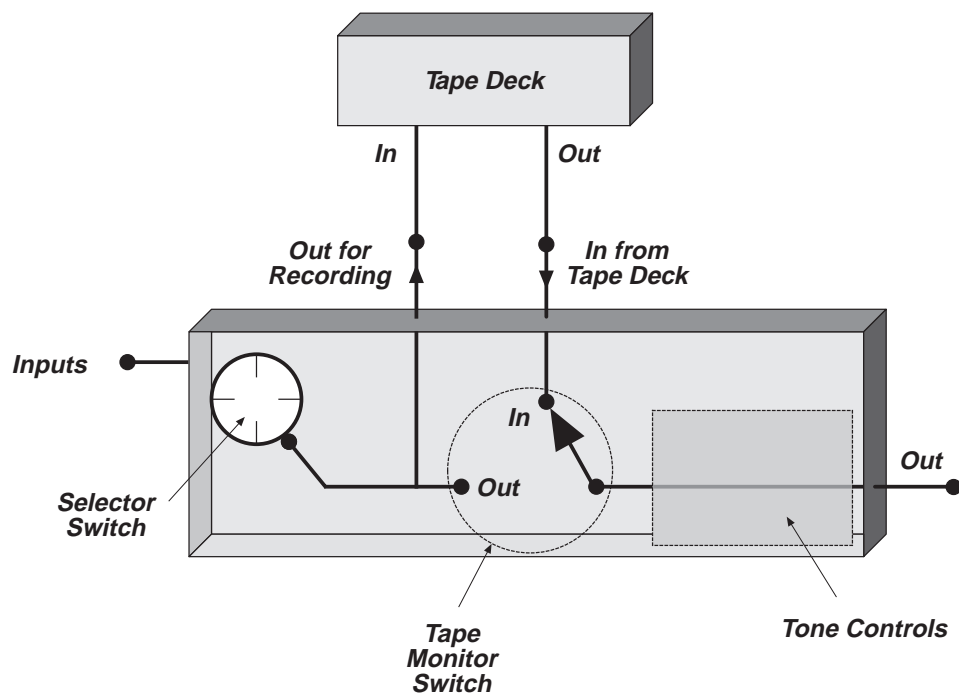


Figure 1.14: Listening to a tape; tape switch in.

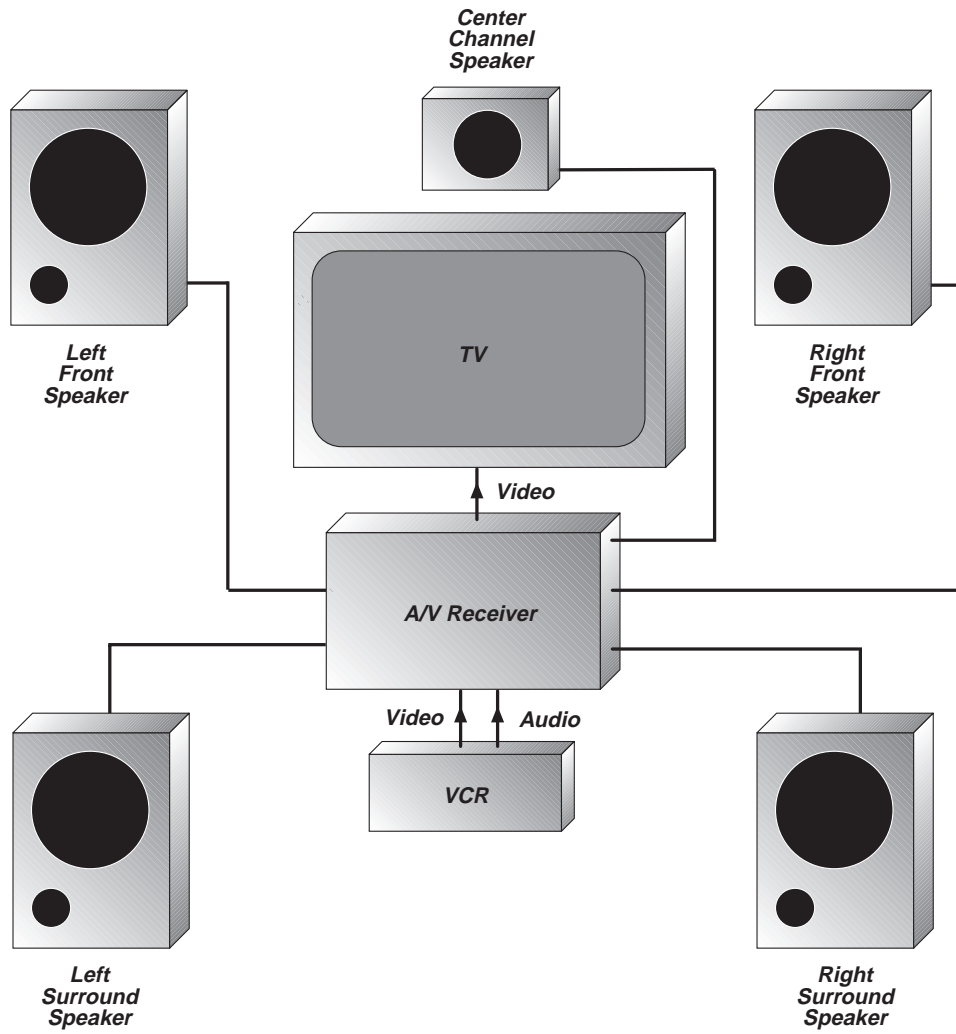


Figure 1.15: A/V receiver with Dolby Pro Logic processor.

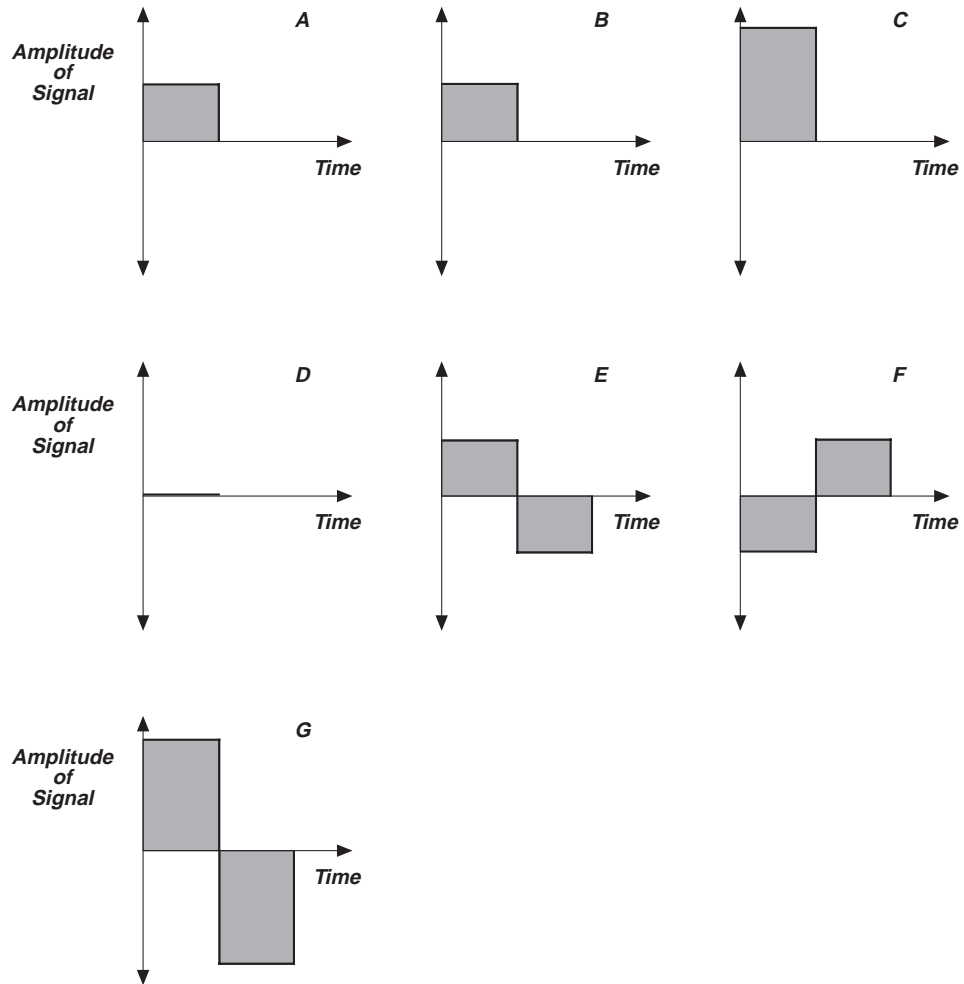


Figure 1.16: Various wave forms.

Chapter 2

Waves

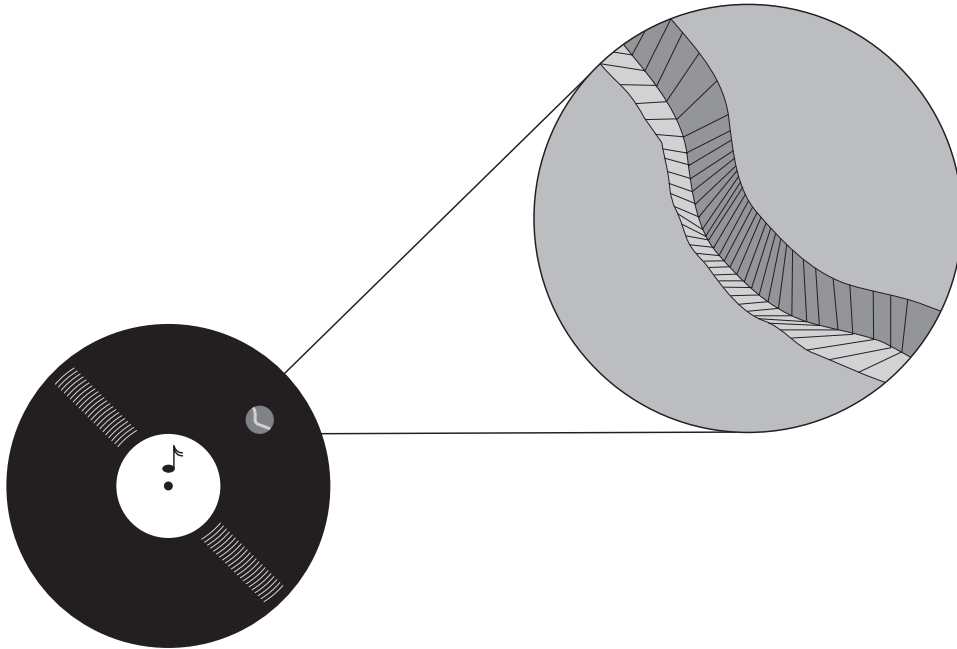


Figure 2.1: Phono record and an enlarged groove showing engraved wave representing sound.

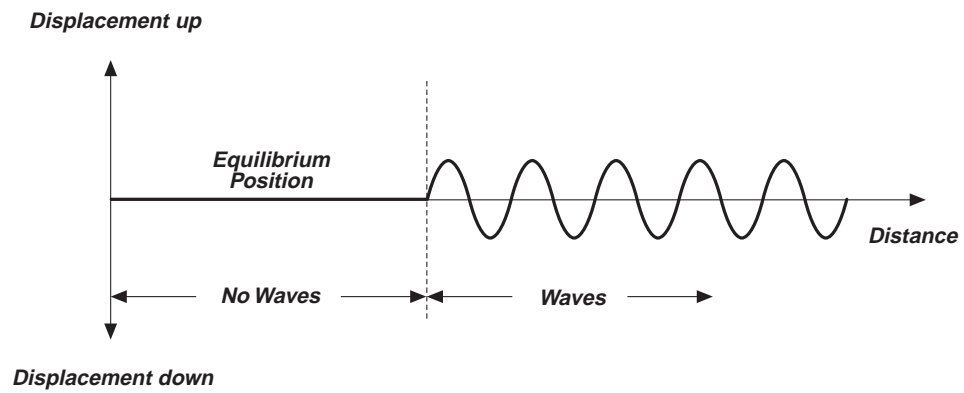


Figure 2.2: Simplified picture of a water wave; displaced water as a function of position.

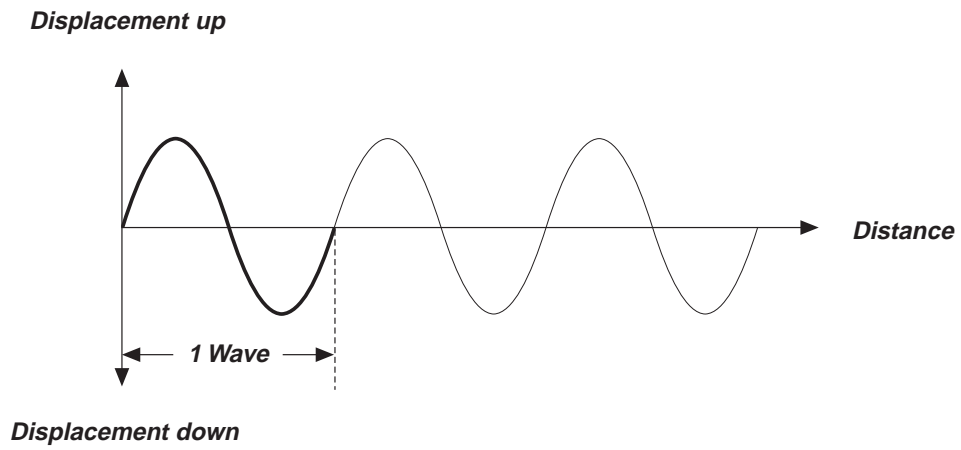


Figure 2.3: Details of one wave as a function of position.

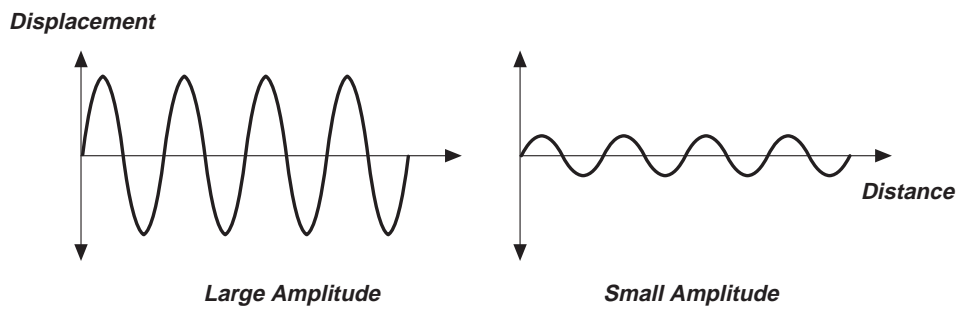


Figure 2.4: Large and small amplitude waves.

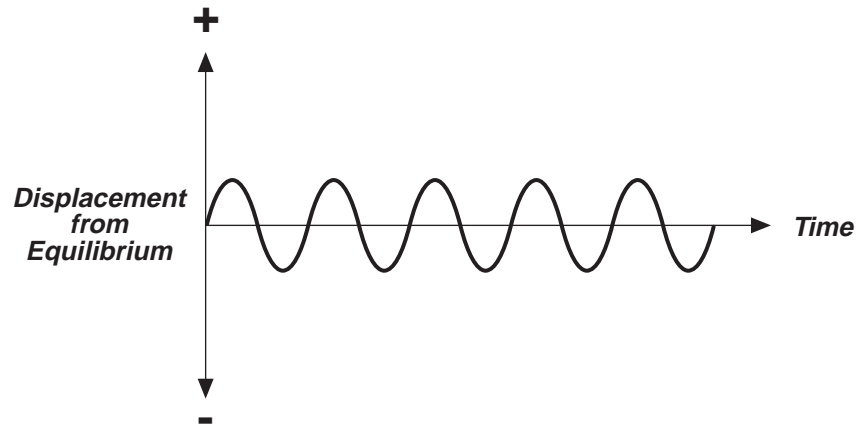


Figure 2.5: Time dependence of displacement of a point on a water wave.

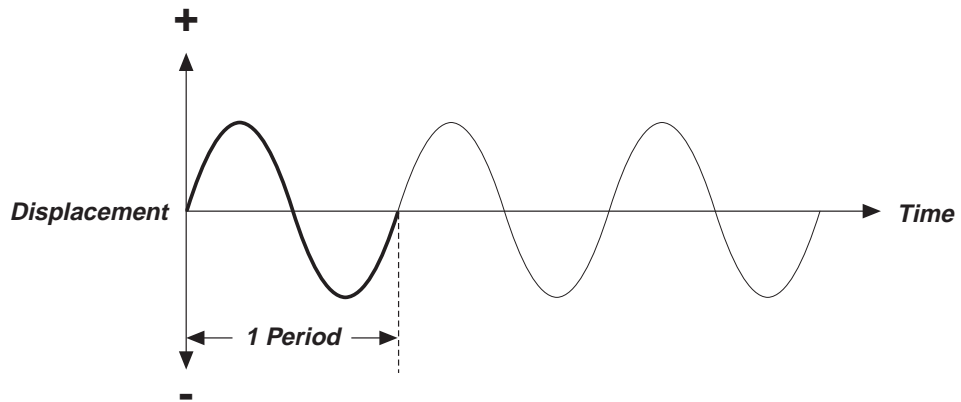


Figure 2.6: Displacement as a function of time; time required to complete one wave.

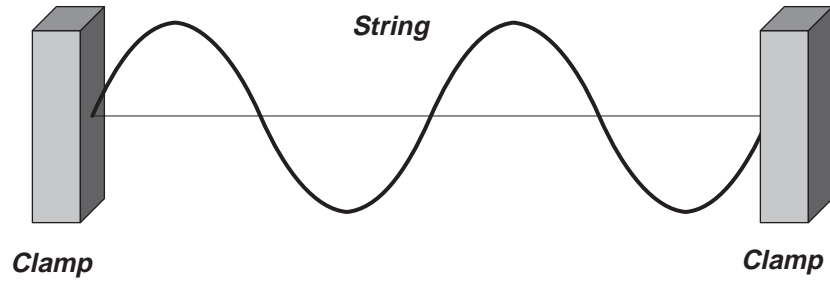


Figure 2.7: Transverse wave on a string.

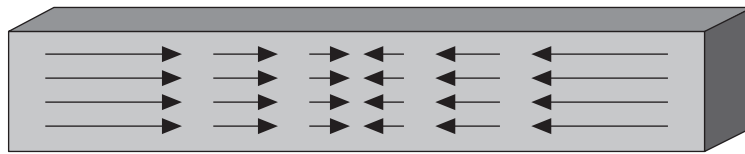


Figure 2.8: Longitudinal waves along a solid bar.

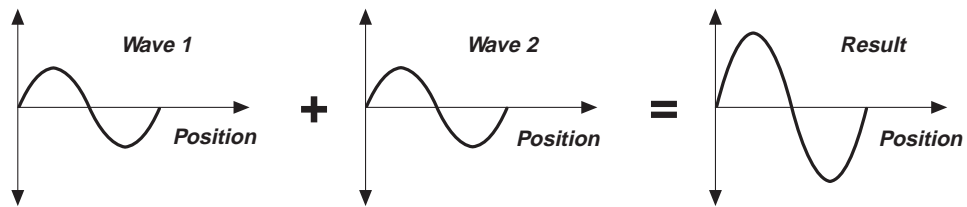


Figure 2.9: Addition of two waves.

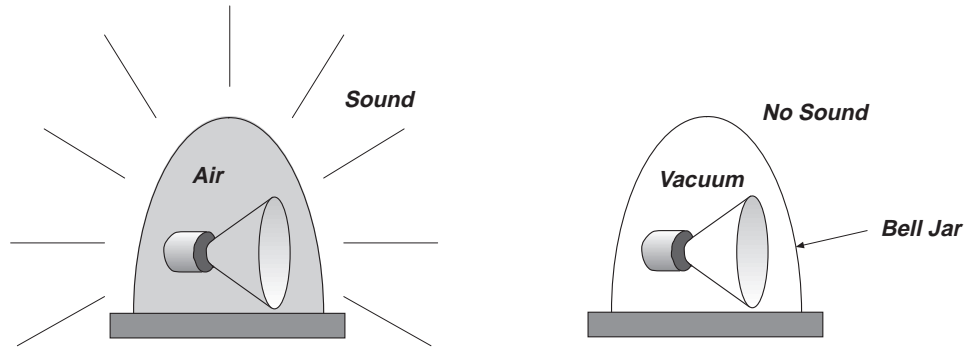


Figure 2.10: Sound requires a medium in which to propagate; in a vacuum there is no sound propagation.

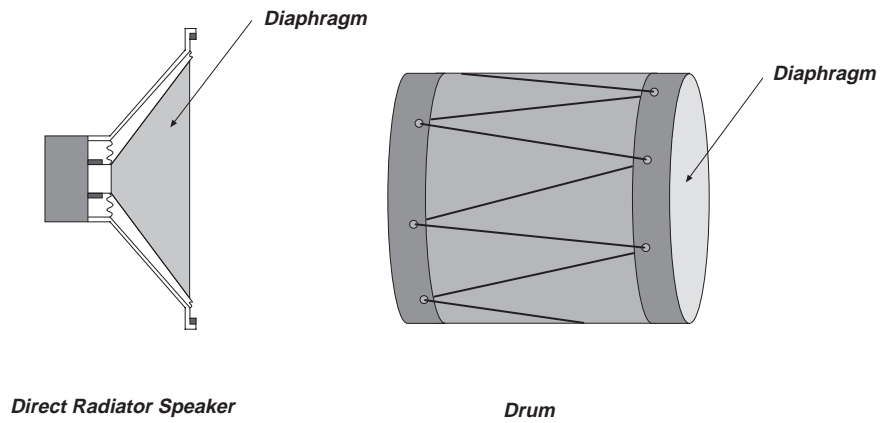


Figure 2.11: Direct radiator speaker can move air like a drumhead.

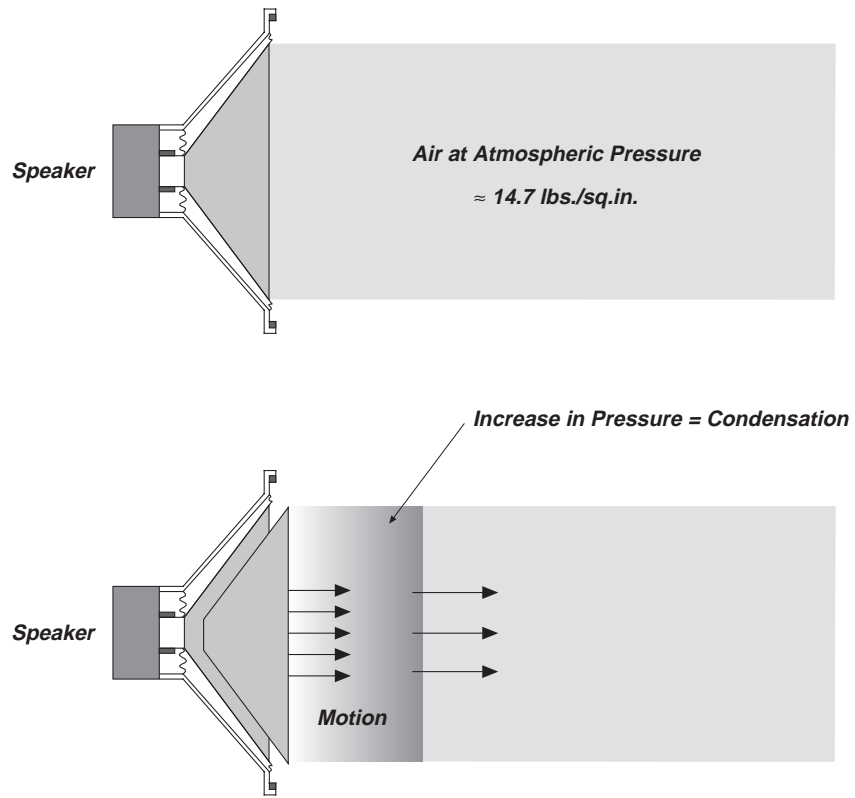


Figure 2.12: Generation of sound by loudspeaker.

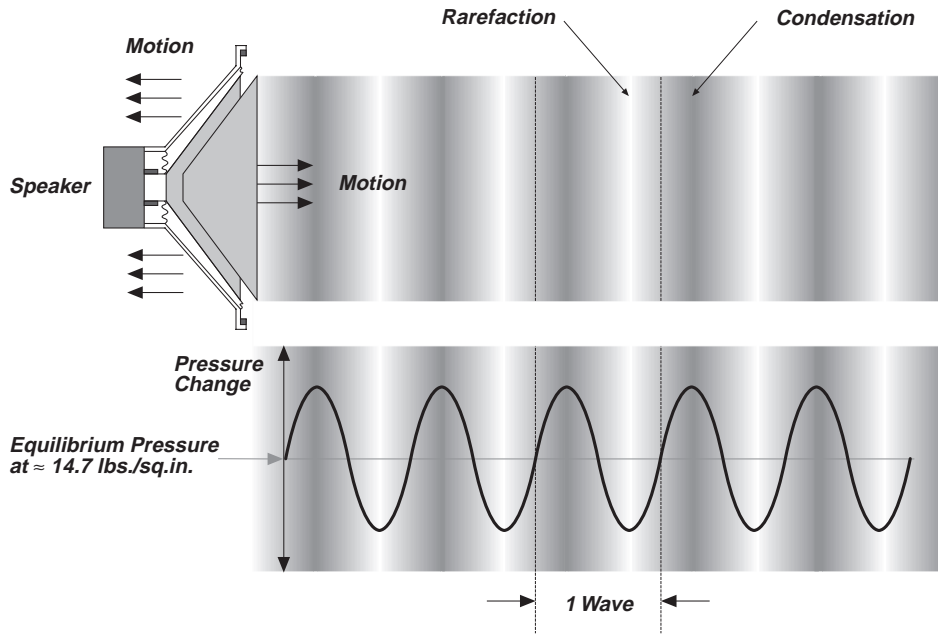


Figure 2.13: Disturbances created by loudspeaker; pressure changes cause sound.

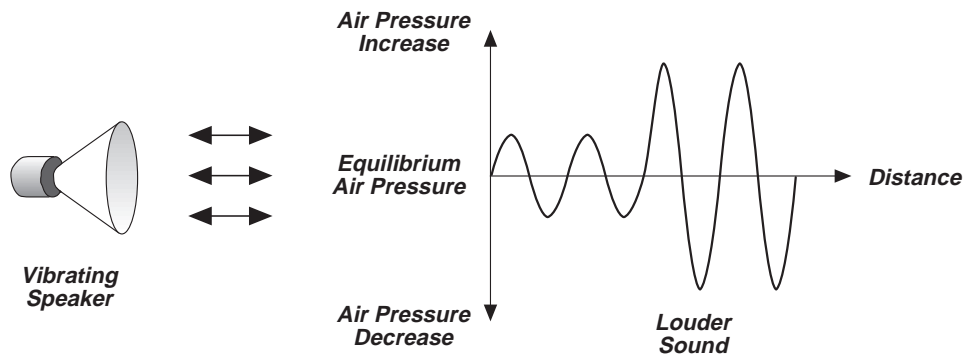


Figure 2.14: Representation of sound created by a loudspeaker.

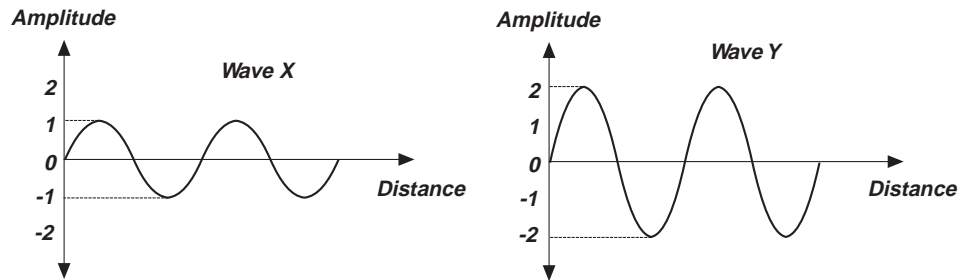


Figure 2.15: Wave **Y** has 4 times the power of wave **X**, but their amplitudes differ only by a factor of 2.

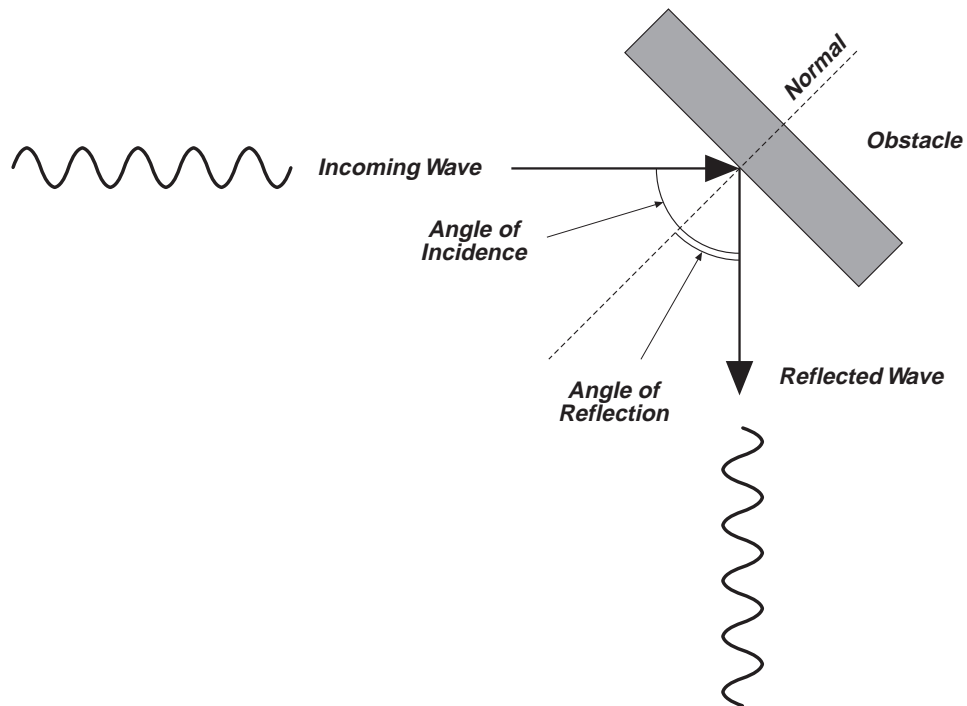


Figure 2.16: Reflection of a wave by an obstacle or a different medium.

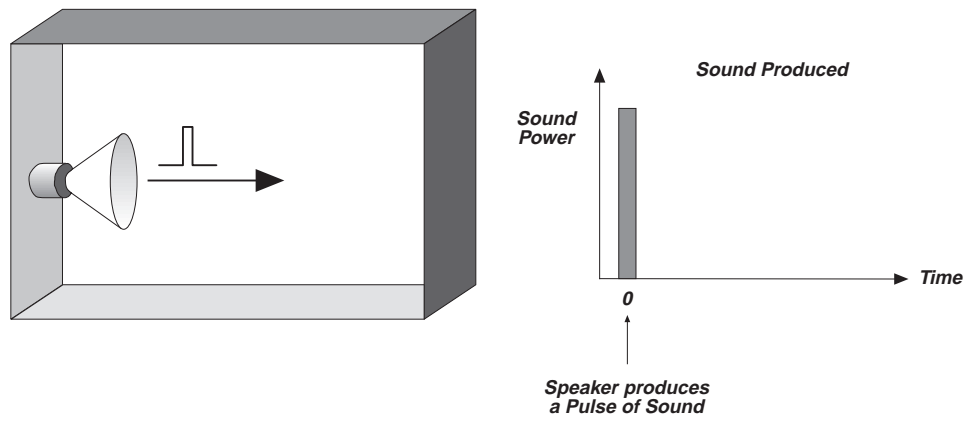


Figure 2.17: Speaker producing a pulse of sound in a hall.

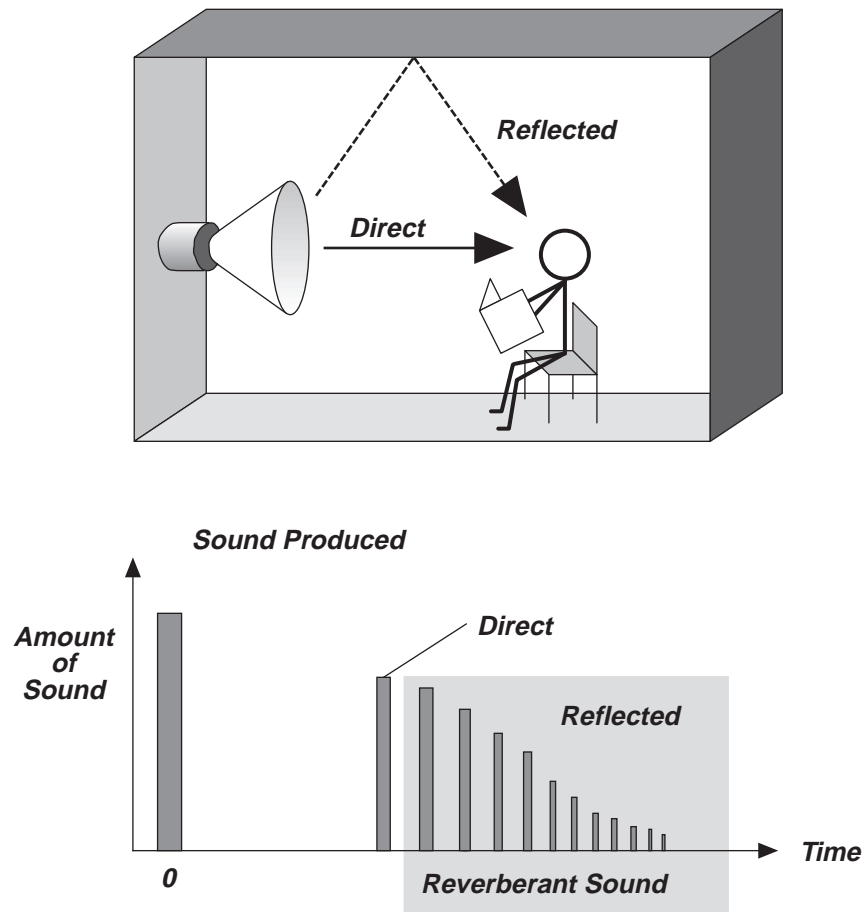


Figure 2.18: Paths of direct and reflected sound in a hall.

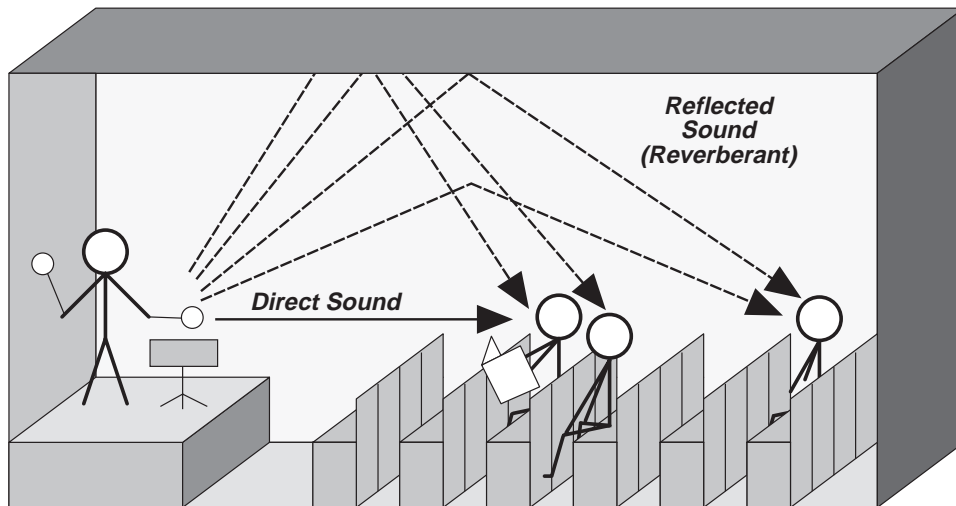


Figure 2.19: Direct and reverberant sound in a hall.

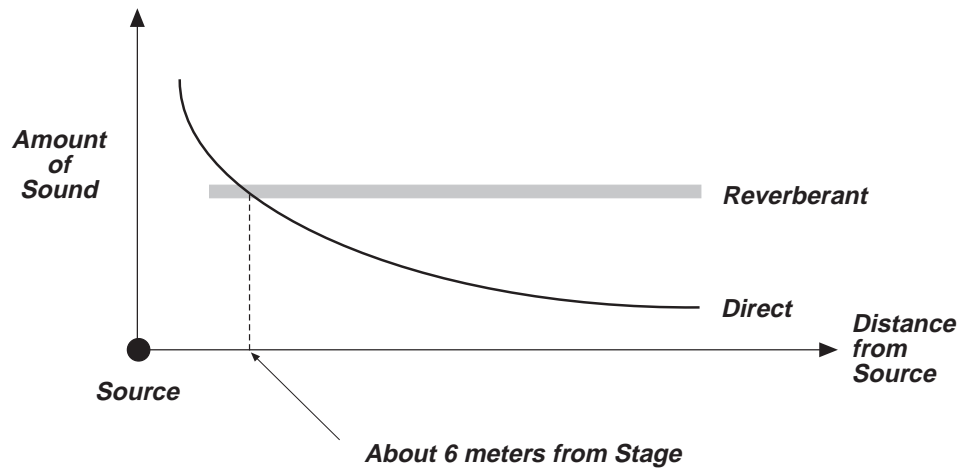


Figure 2.20: Direct and reverberant sound contributions to sound in a hall.

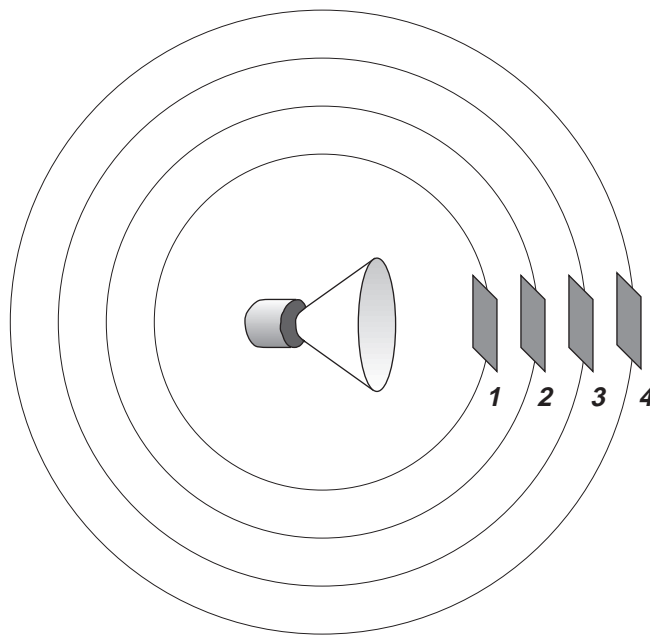


Figure 2.21: Sound radiated by a speaker; as one moves away the intensity decreases.

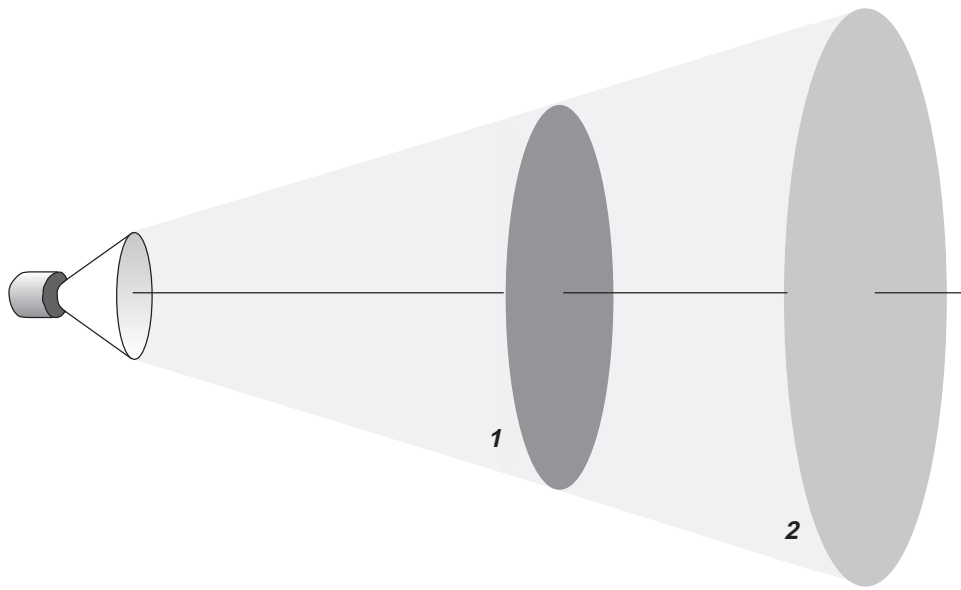


Figure 2.22: Sound intensity through surface 2 is different from that of 1.

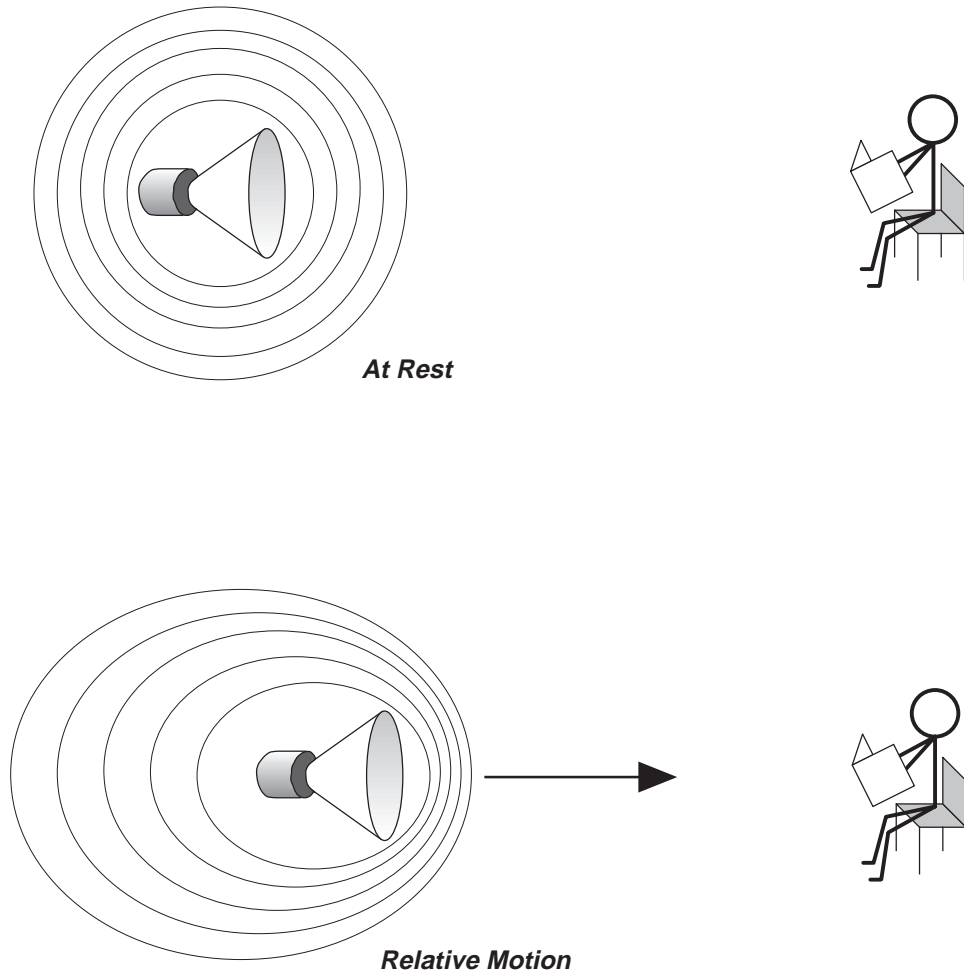


Figure 2.23: Observer and source at rest and in relative motion.

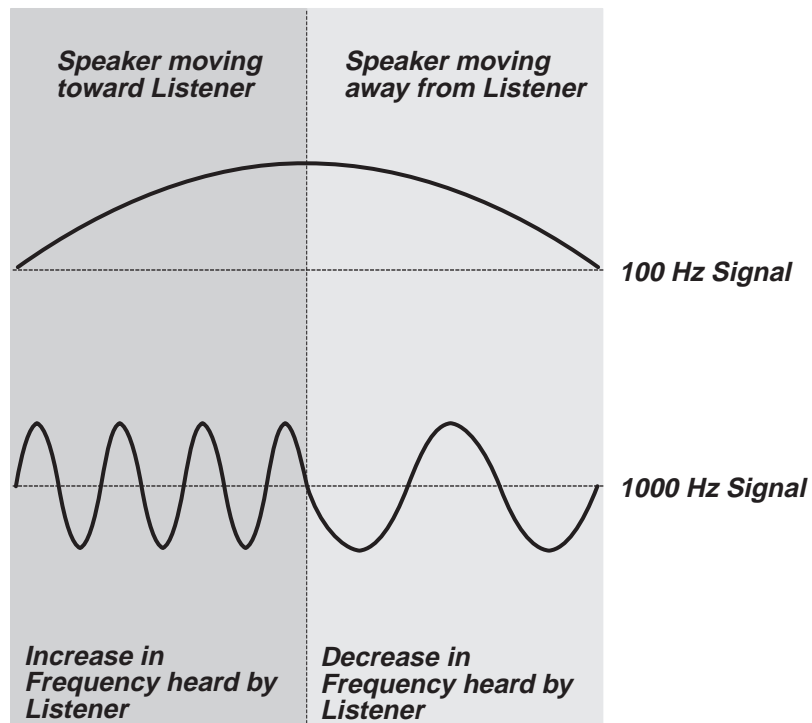


Figure 2.24: Doppler Effect produced by speaker producing simultaneously 100 Hz and 1,000 Hz sound waves.

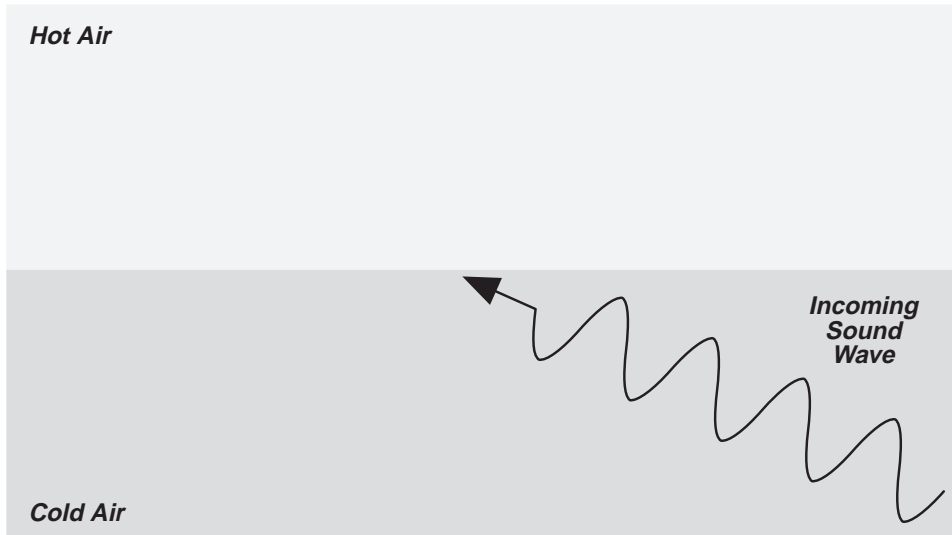


Figure 2.25: Sound wave in cold air entering hot air.

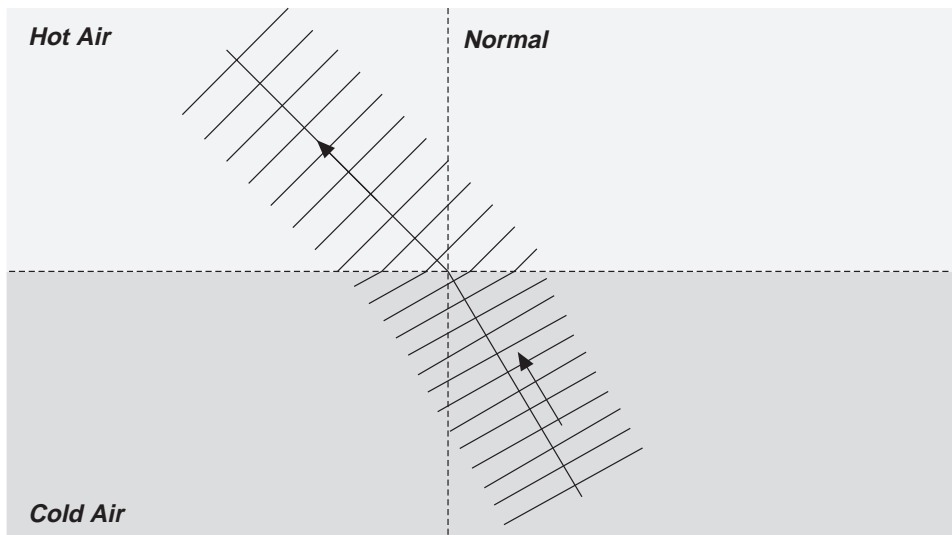


Figure 2.26: Refraction of a sound wave.

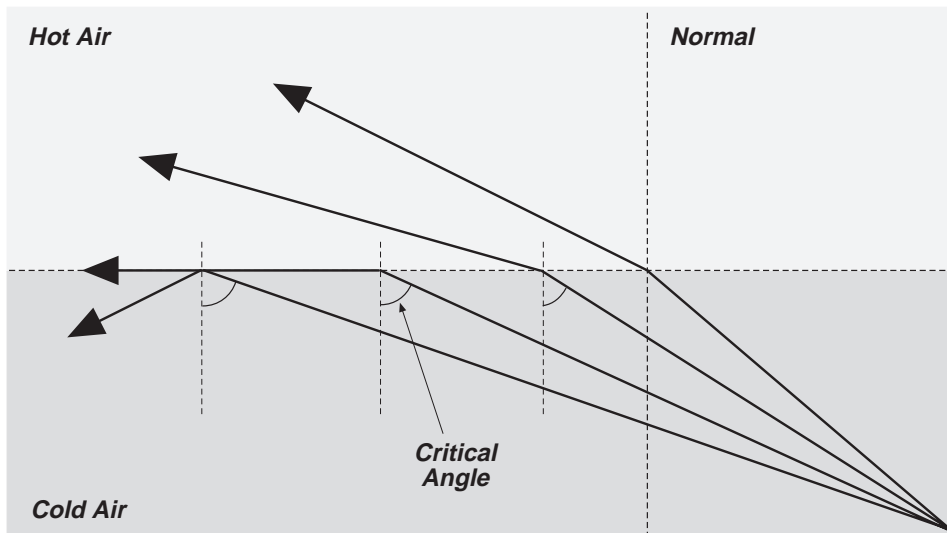


Figure 2.27: Above a critical angle of incidence there is only reflection.

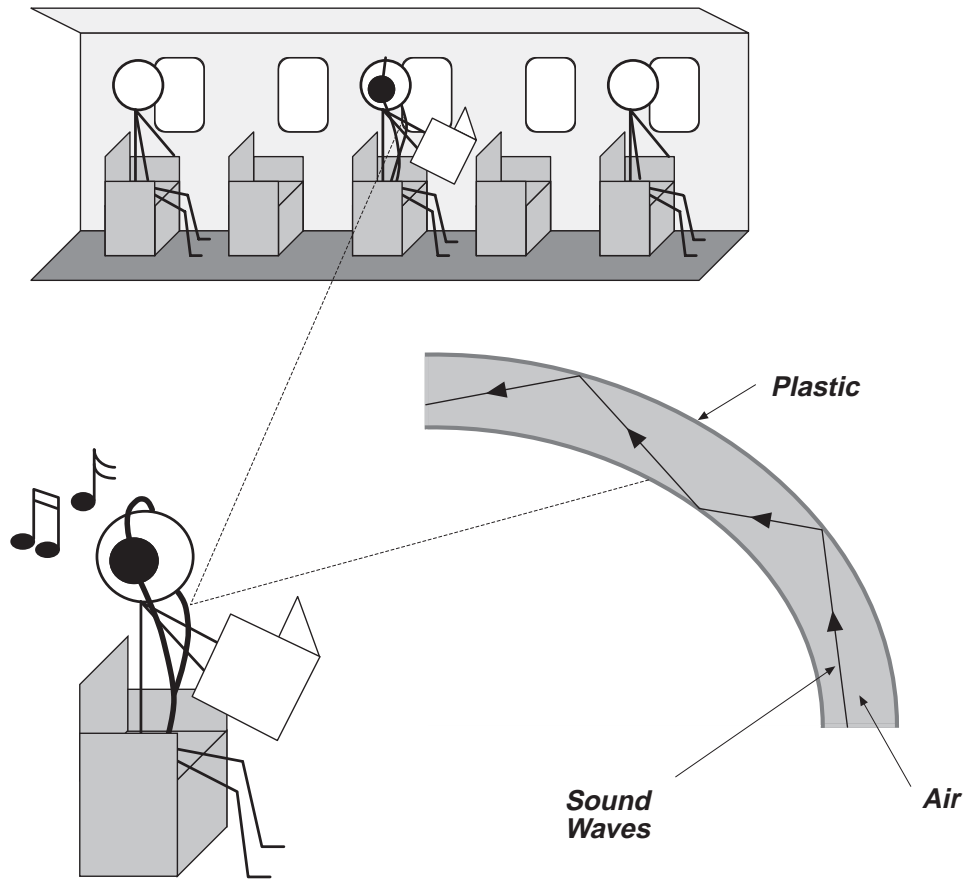


Figure 2.28: Sound travels in a curved hollow plastic tube by multiple reflections.

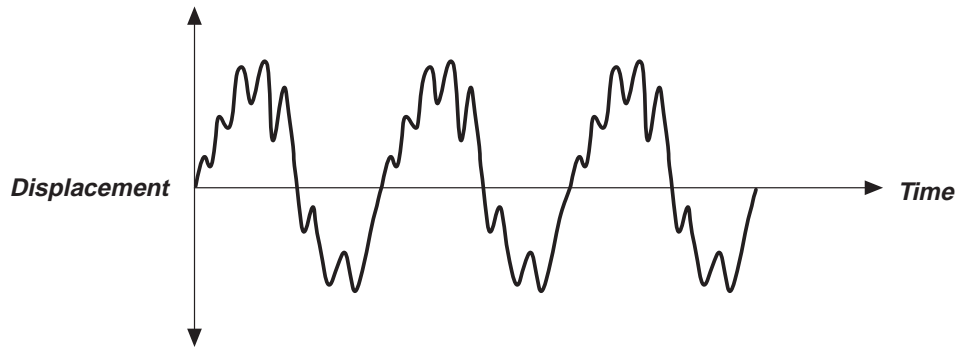


Figure 2.29: Sound wave produced by a musical group; a complex wave.

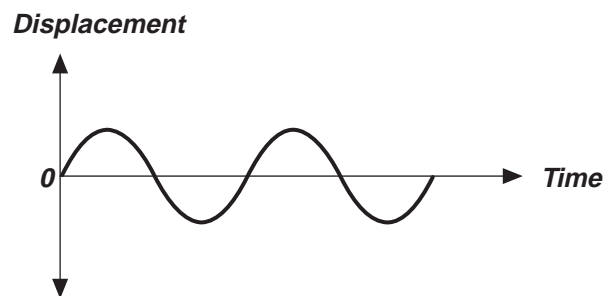


Figure 2.30: Simple sine waveform.

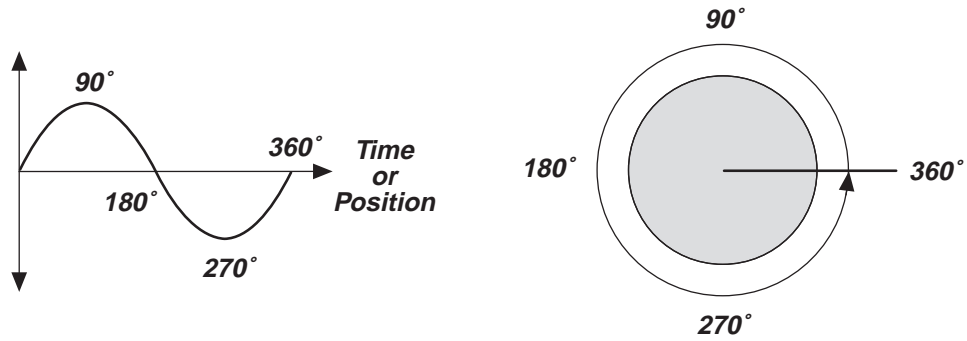


Figure 2.31: Comparison between one full wave and one rotation of a circle.

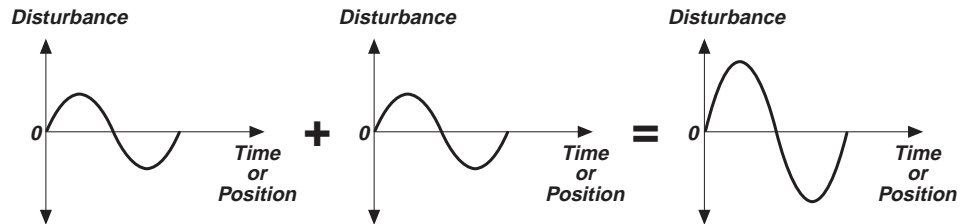


Figure 2.32: Addition of two waves.

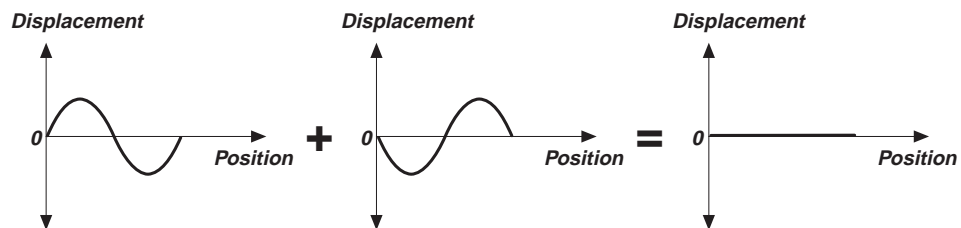


Figure 2.33: Addition of two waves out of phase by 180 degrees.

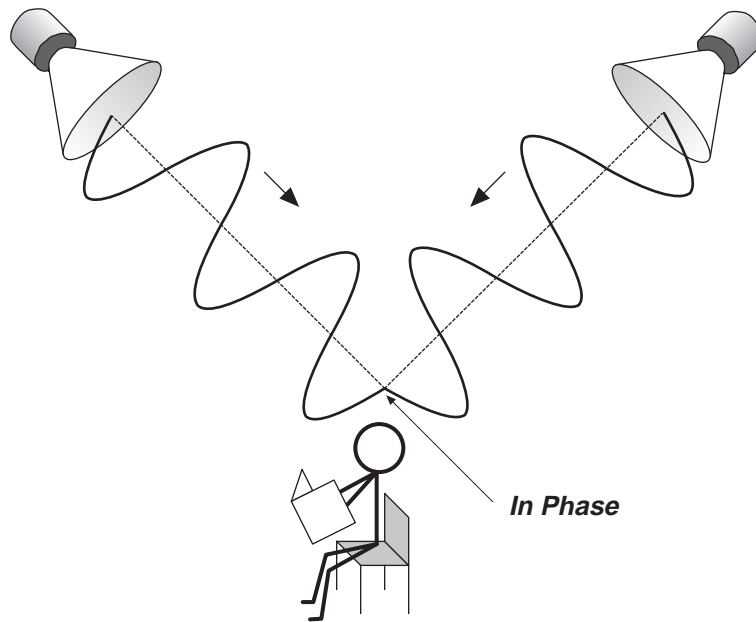


Figure 2.34: Constructive interference.

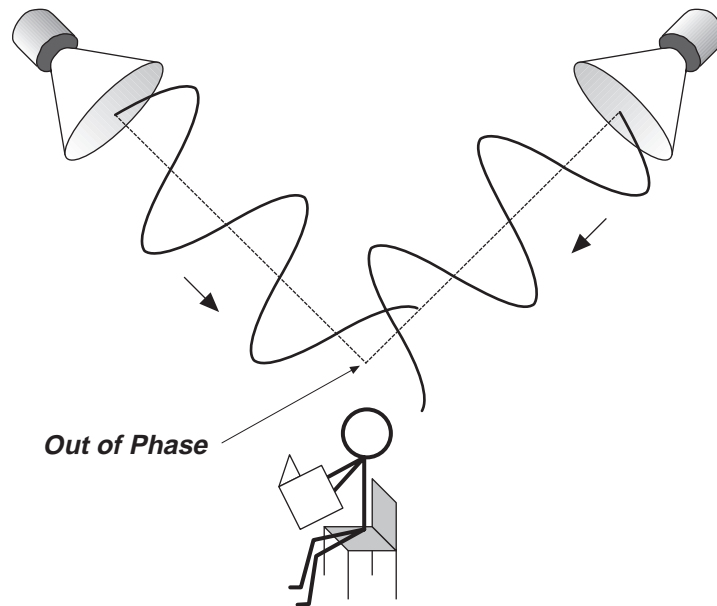


Figure 2.35: Destructive interference.

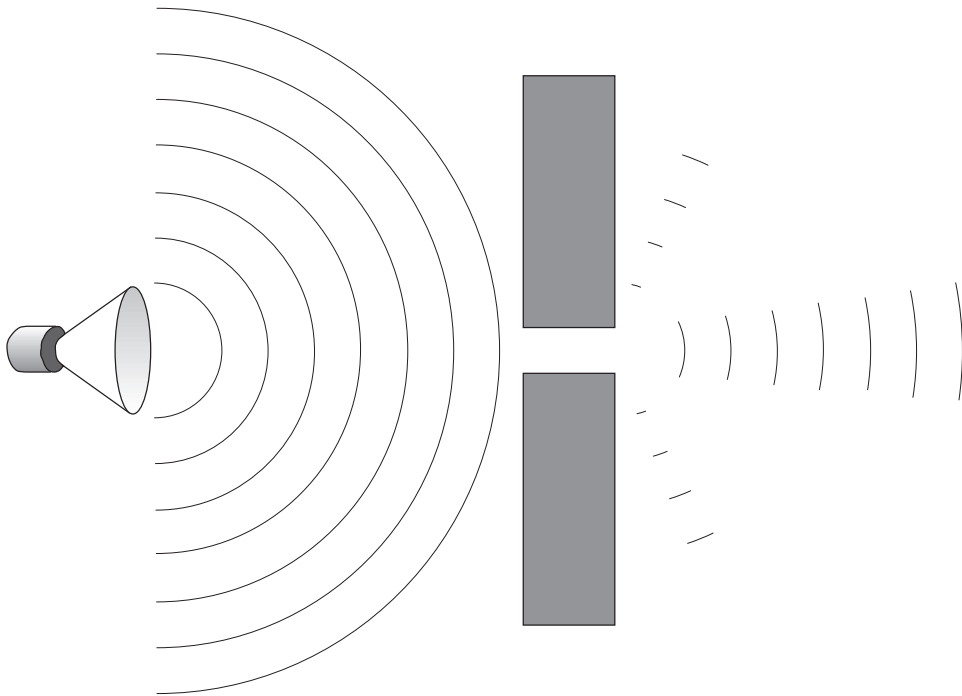


Figure 2.36: Obstacle with aperture receiving high frequency waves.

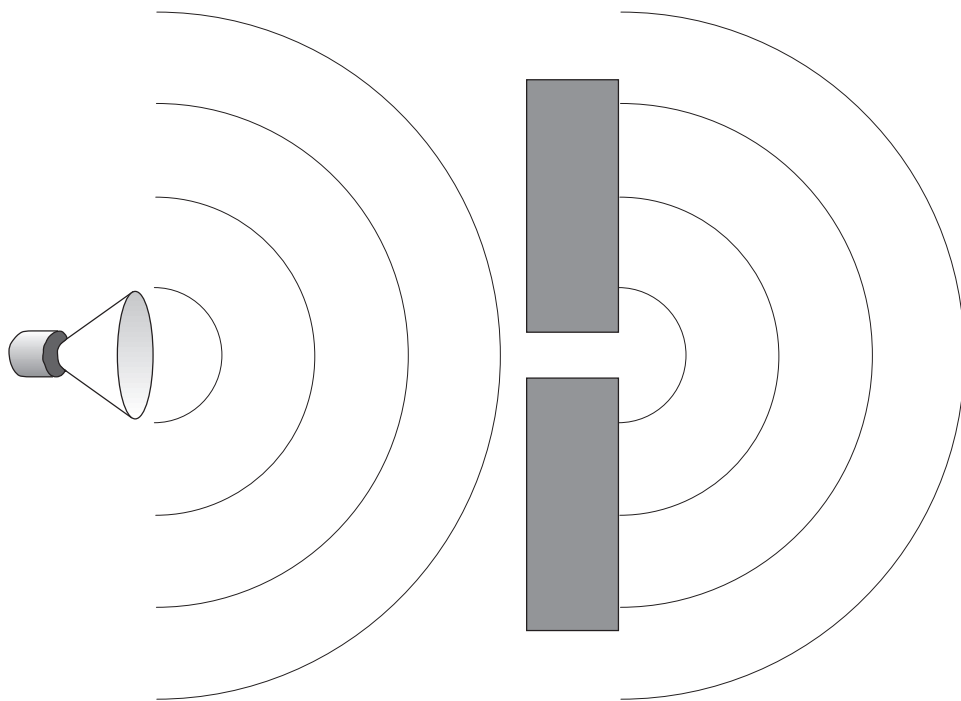


Figure 2.37: Low frequency behavior of obstacle and aperture.

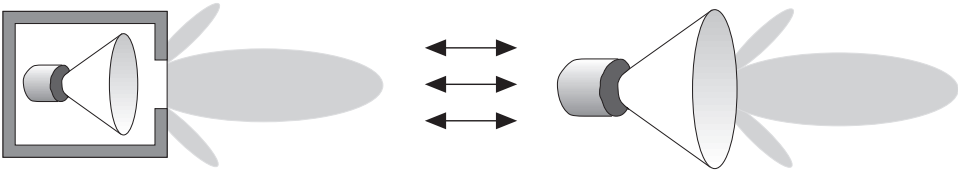


Figure 2.38: Comparison of diffraction behavior of a room with opening and a loudspeaker.

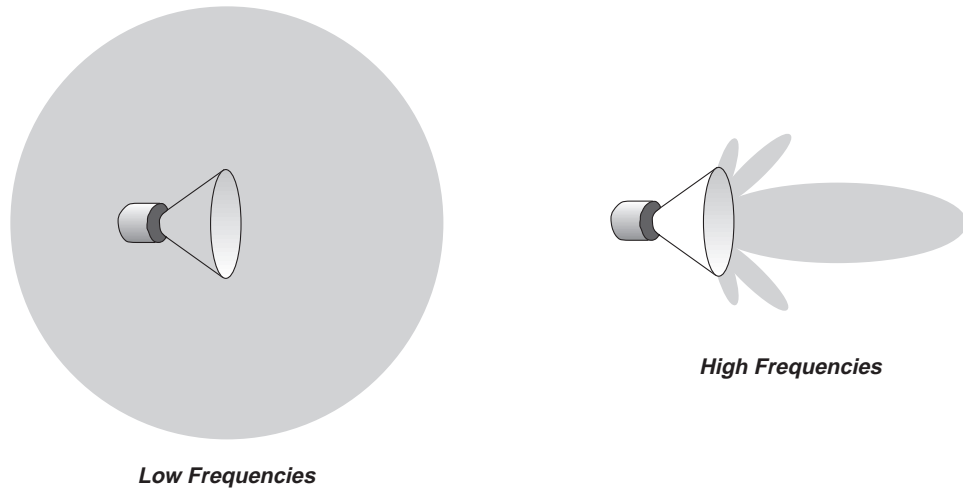


Figure 2.39: Dispersion characteristics of a speaker.

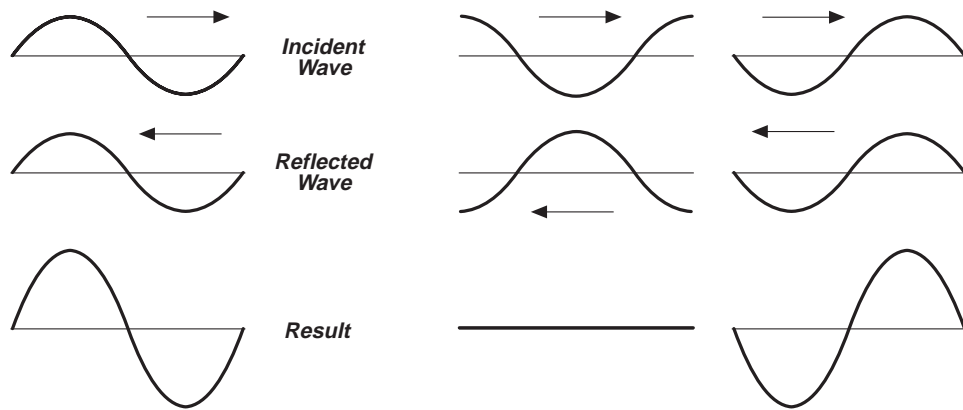


Figure 2.40: Standing wave produced by incident and reflected waves.

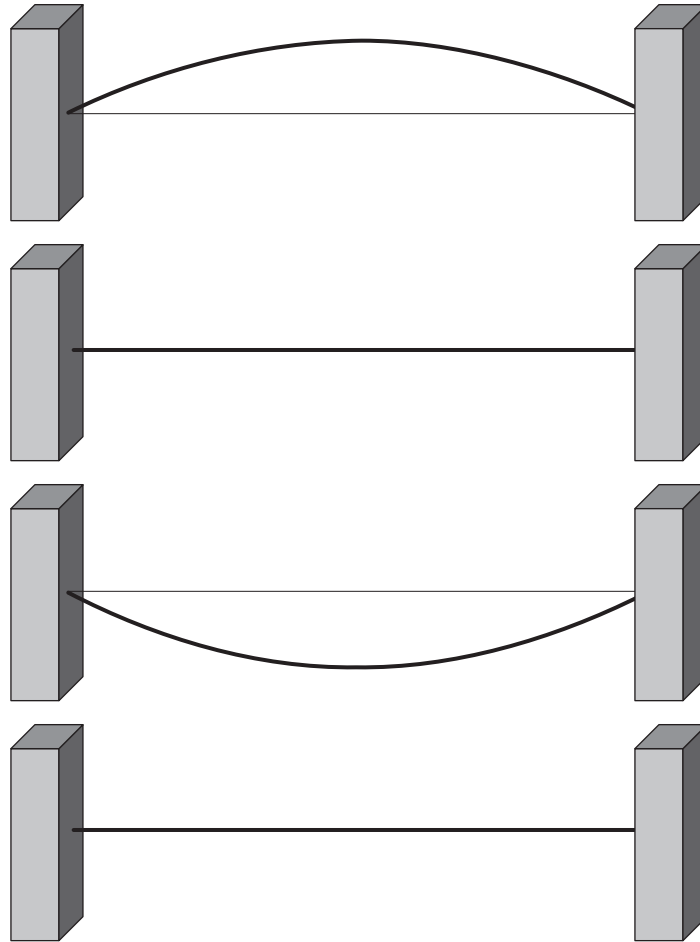


Figure 2.41: Simplest possible standing wave on a string.

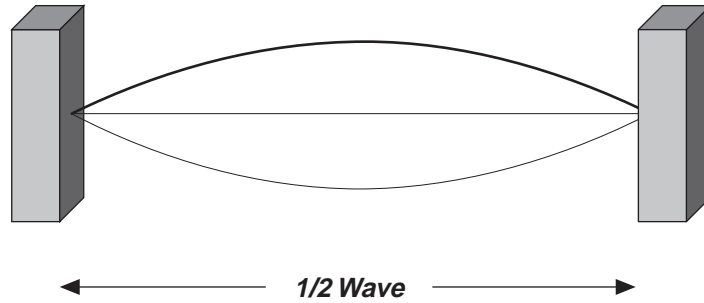


Figure 2.42: Simplest standing wave on a string during one cycle.

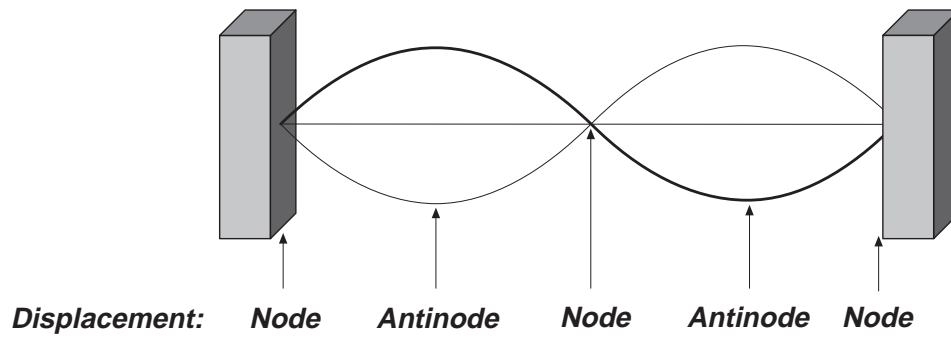


Figure 2.43: Second harmonic on a string showing position of nodes and antinodes.

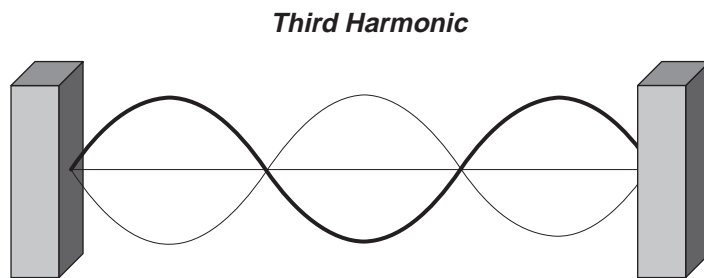
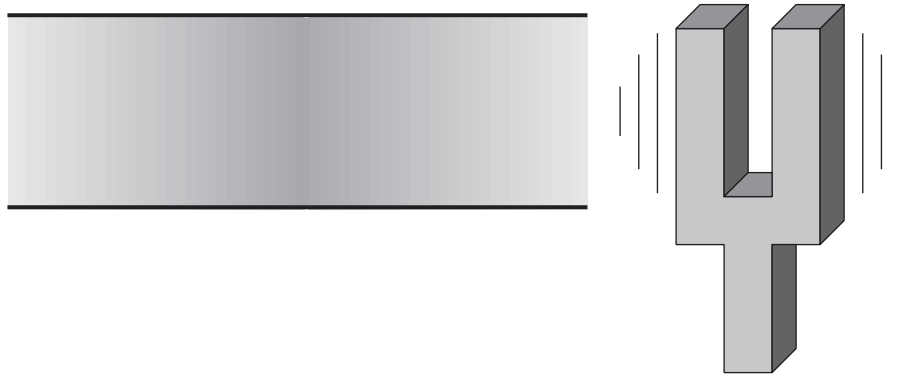


Figure 2.44: Third harmonic on a string clamped at both ends.



Or

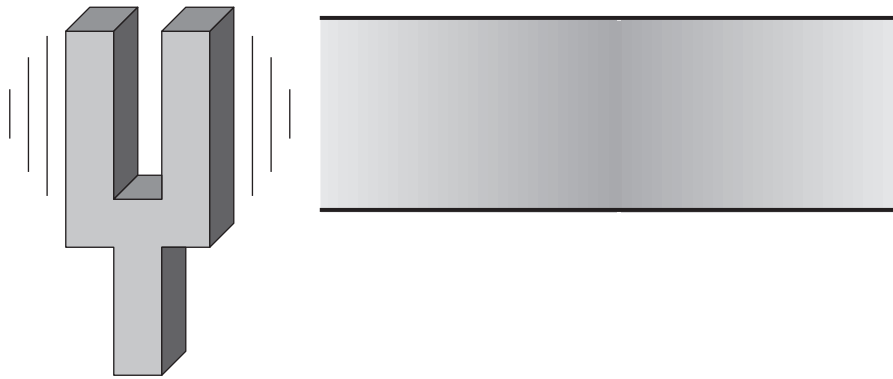


Figure 2.45: Setting up a standing wave in a tube.

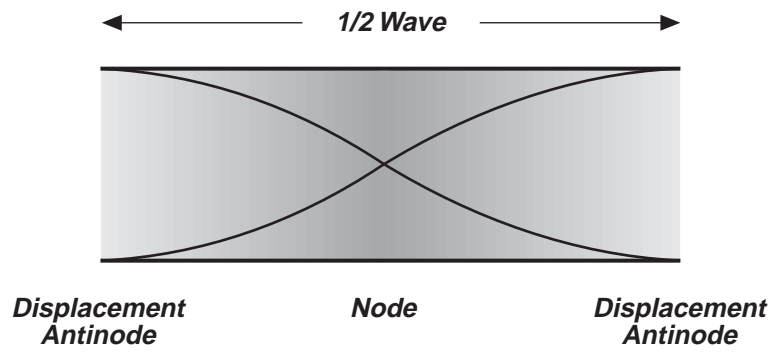


Figure 2.46: Simplest standing wave in a tube open at both ends.

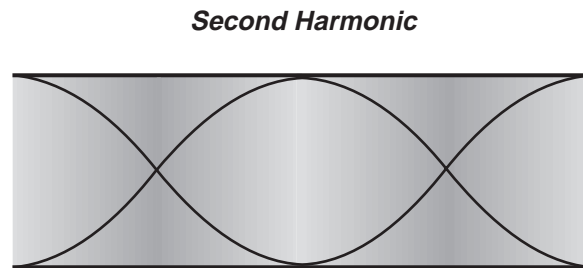


Figure 2.47: Second harmonic in tube open at both ends.

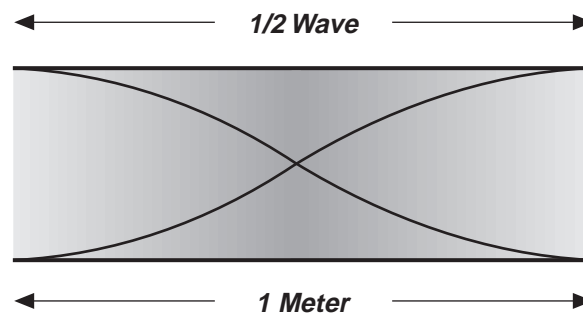


Figure 2.48: Fundamental in a tube.

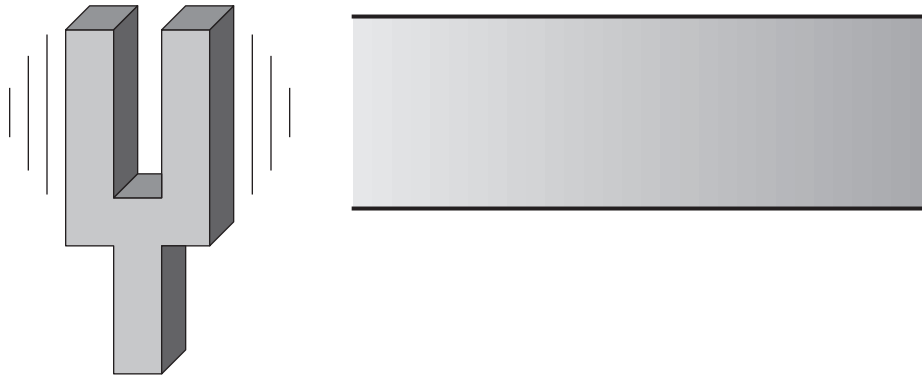


Figure 2.49: Tube open at one end excited by a tuning fork.

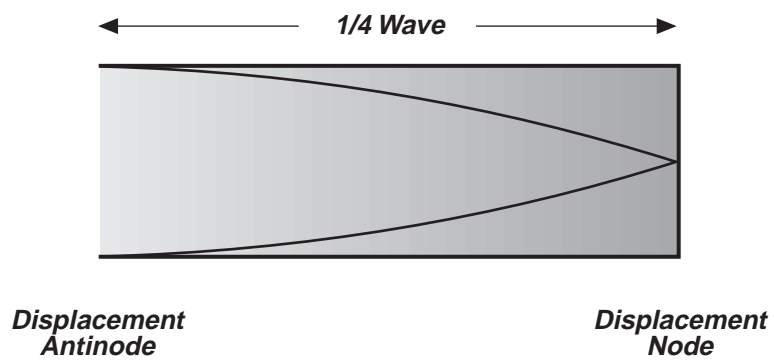


Figure 2.50: Fundamental in tube open at one end.

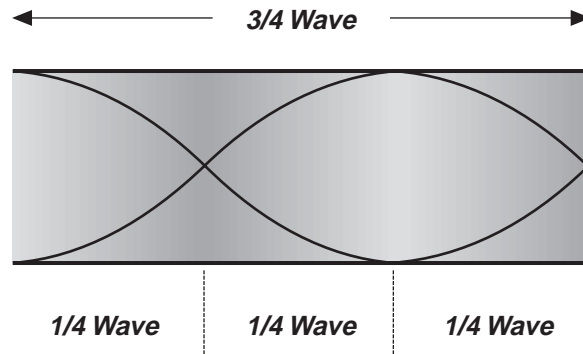


Figure 2.51: Next more complicated standing wave; the third harmonic.

Fifth Harmonic

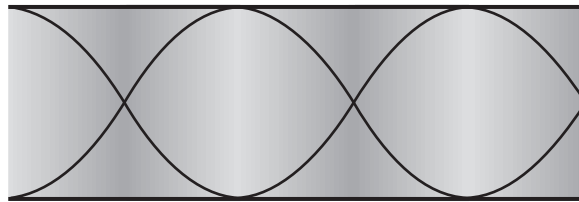


Figure 2.52: Fifth harmonic.

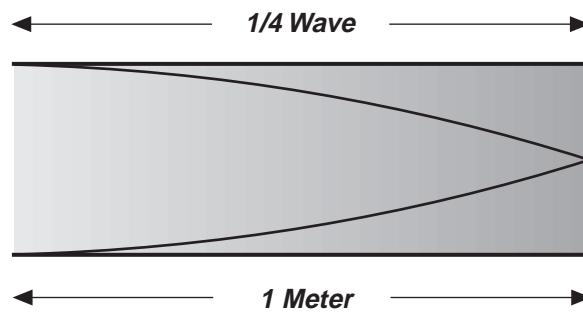


Figure 2.53: Standing wave in a tube 1 meter long; fundamental.

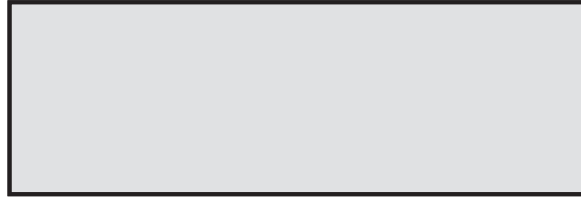


Figure 2.54: Tube closed at both ends.

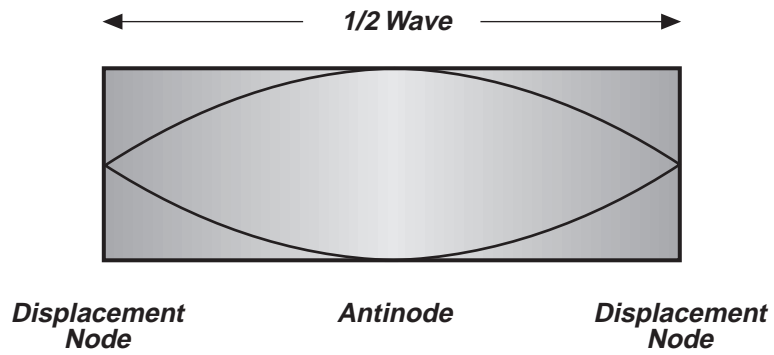


Figure 2.55: Fundamental of a tube closed at both ends.

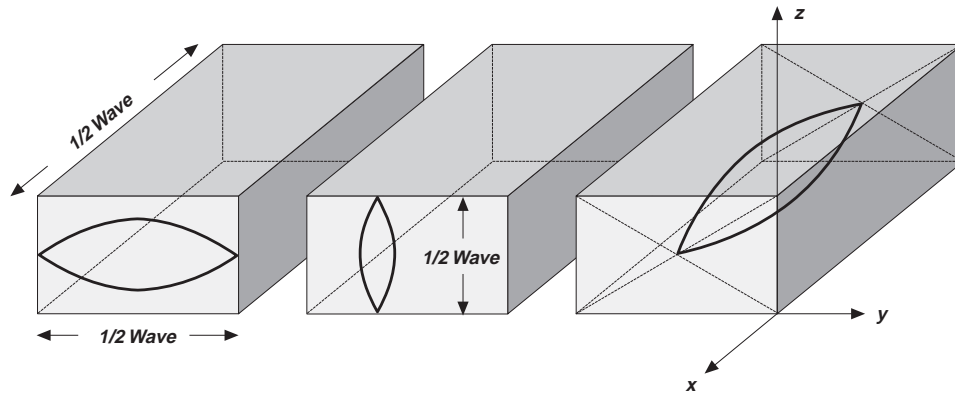


Figure 2.56: Room where independent standing waves can be set up in the x, y, and z directions.

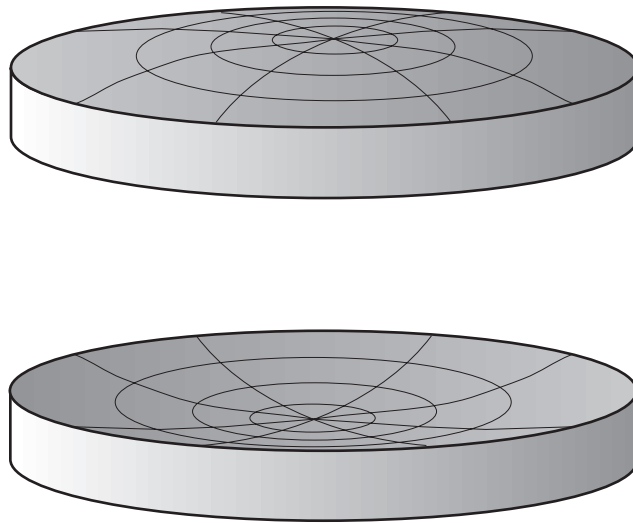


Figure 2.57: A drumhead fixed at its edges and its fundamental mode of vibration.

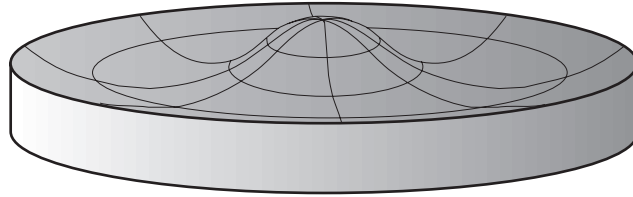


Figure 2.58: Overtone on a drumhead.

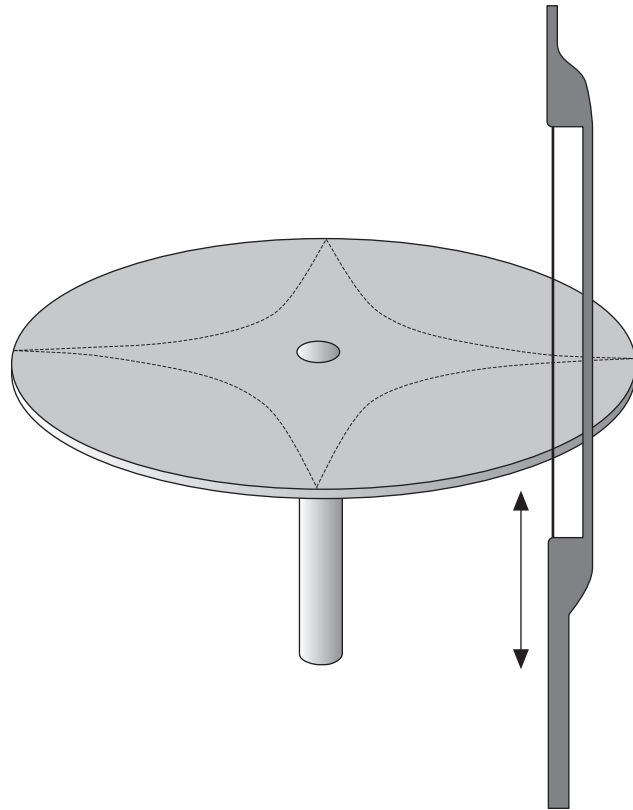


Figure 2.59: Standing wave pattern on a Chladni plate.

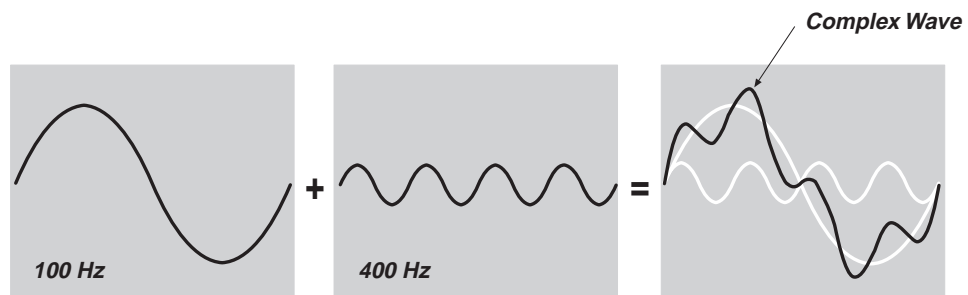


Figure 2.60: Complex wave created by the superposition of a 100 Hz fundamental and its fourth harmonic.

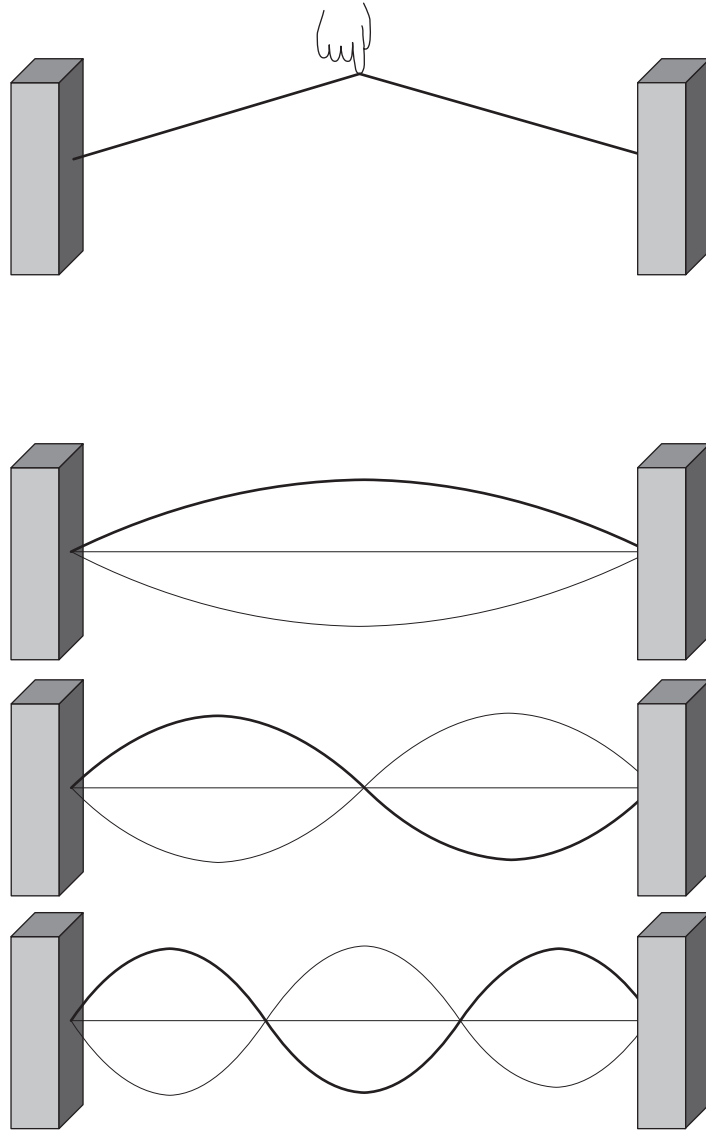


Figure 2.61: Violin string plucked by a finger and producing all sorts of harmonics.

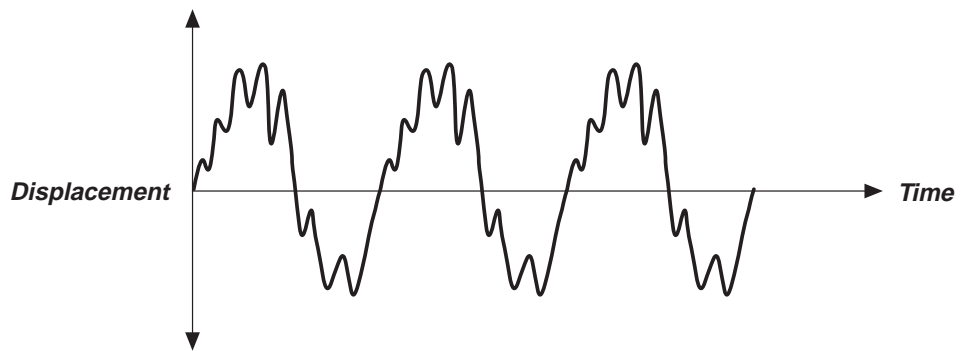
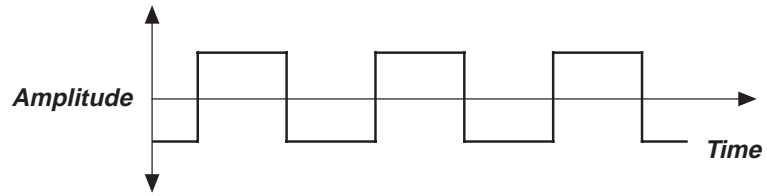


Figure 2.62: Complex wave generated by plucking string.



| | <i>Frequency</i> | <i>Relative Amplitude</i> |
|----------|------------------|---------------------------|
| | f | 1 |
| | | |
| | $3f$ | $1/3$ |
| | | |
| | $5f$ | $1/5$ |
| \vdots | \vdots | \vdots |
| | nf | $1/n$ |

$n = \text{odd integer}$

Figure 2.63: Square wave; it is made up of many harmonics.

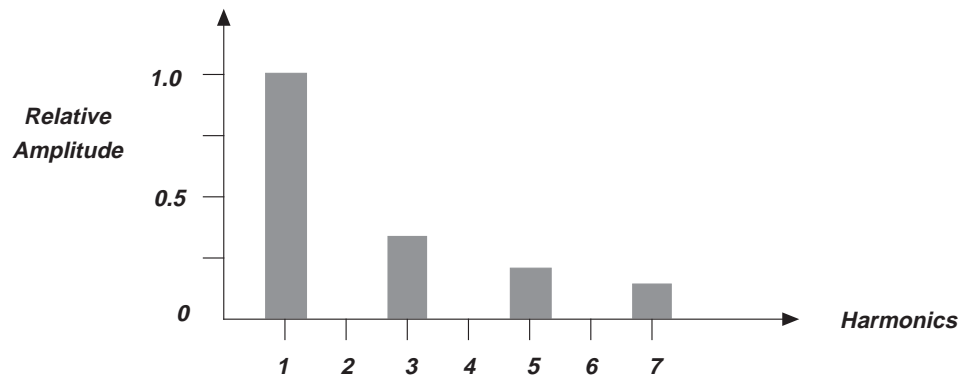
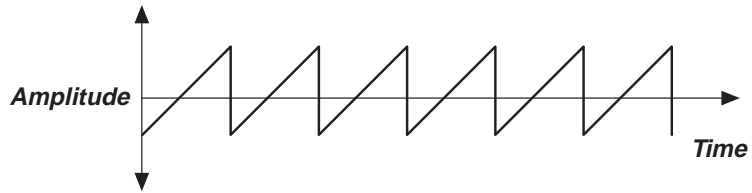


Figure 2.64: Spectrum of a square wave.



| | <i>Frequency</i> | <i>Relative Amplitude</i> |
|---|------------------|---------------------------|
| | f | 1 |
| | $2f$ | $1/2$ |
| | $3f$ | $1/3$ |
| | $4f$ | $1/4$ |
| | $5f$ | $1/5$ |
| ⋮ | ⋮ | ⋮ |
| | nf | $1/n$ |

$n = \text{integer}$

Figure 2.65: Sawtooth wave and its harmonic content.

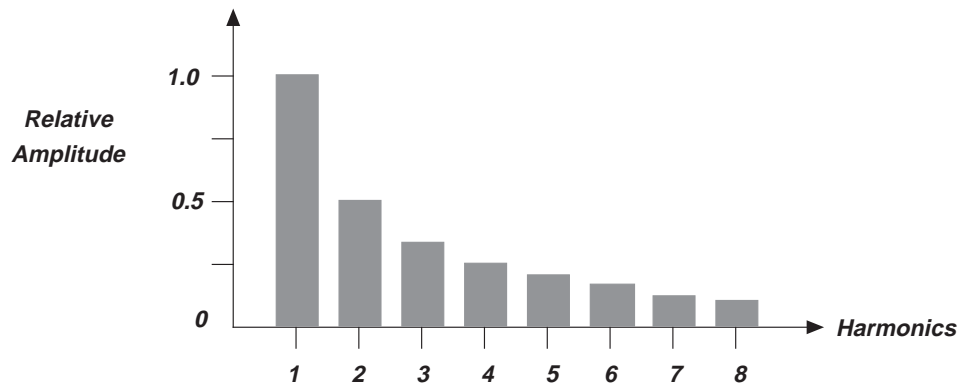


Figure 2.66: Spectrum of a sawtooth wave.

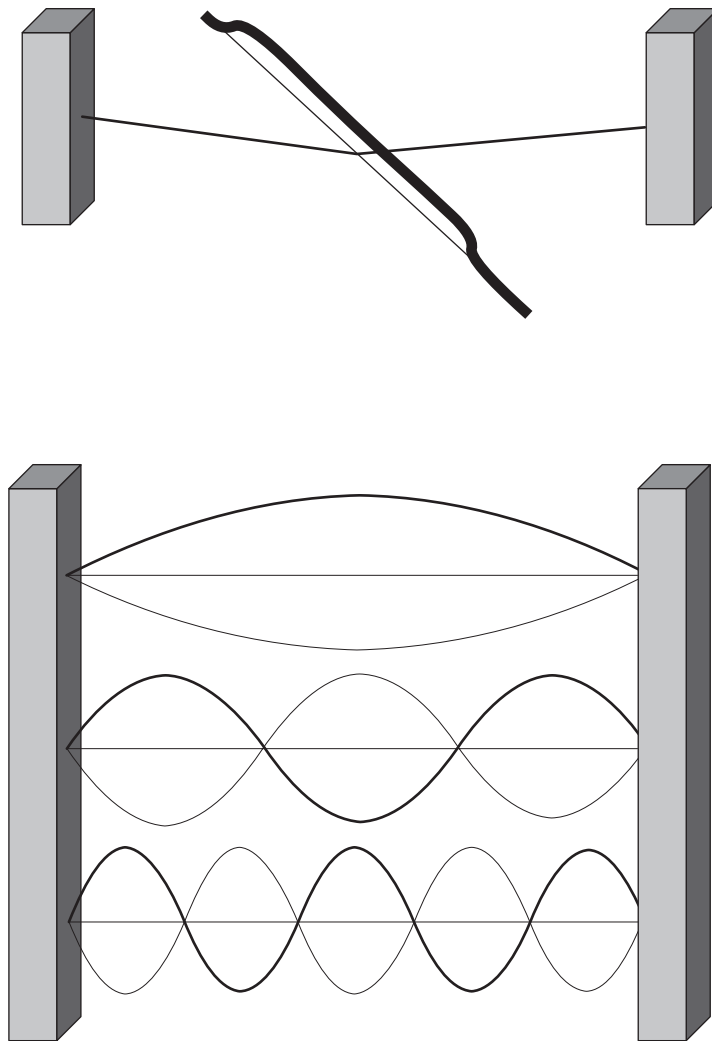


Figure 2.67: A string bowed at its middle and harmonics which are excited.

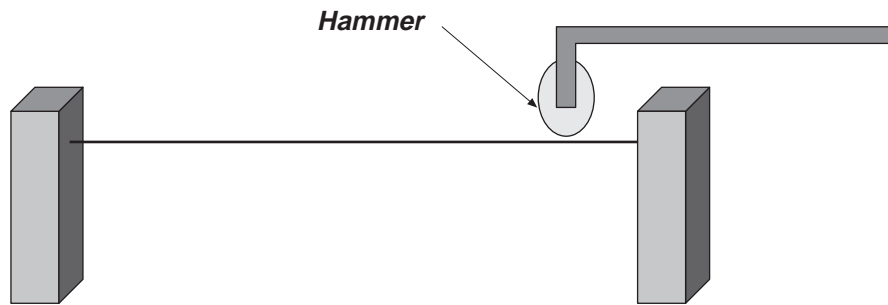


Figure 2.68: String on a piano struck by hammer at a distance $1/10$ the string length from one end.

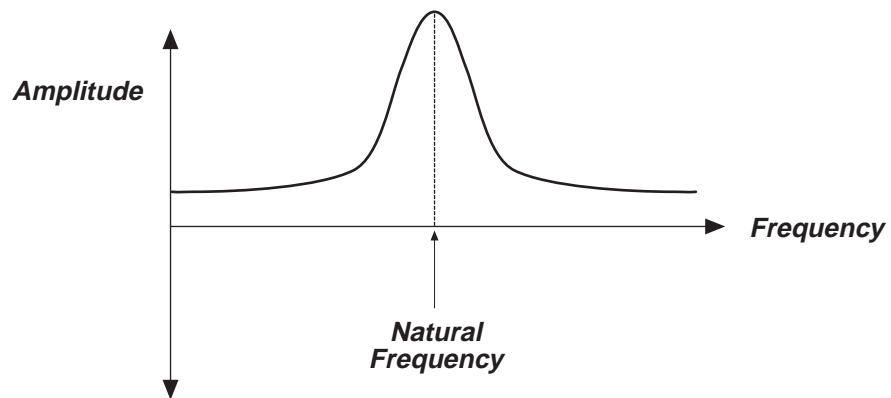


Figure 2.69: Vibrations of an object at different excitation frequencies.

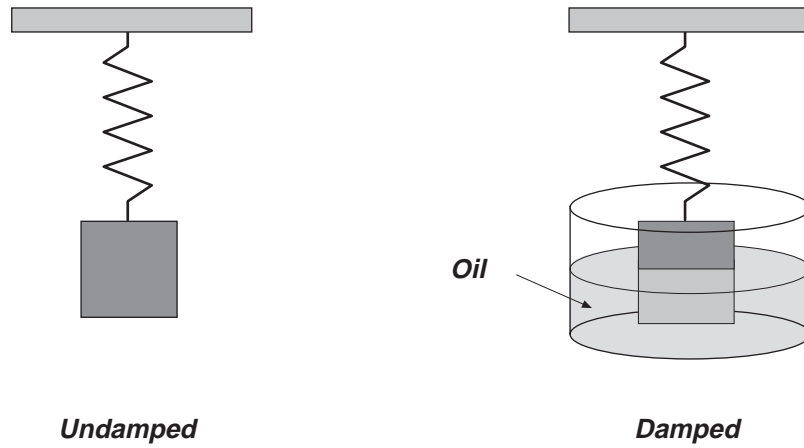


Figure 2.70: Oscillations of a mass on a spring, undamped and damped when submersed in oil.

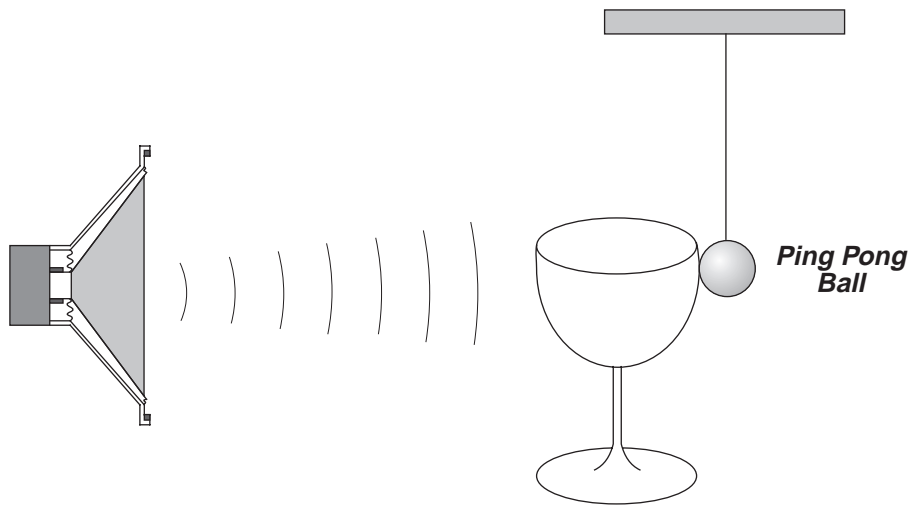


Figure 2.71: Resonance of wine glass excited by sound.

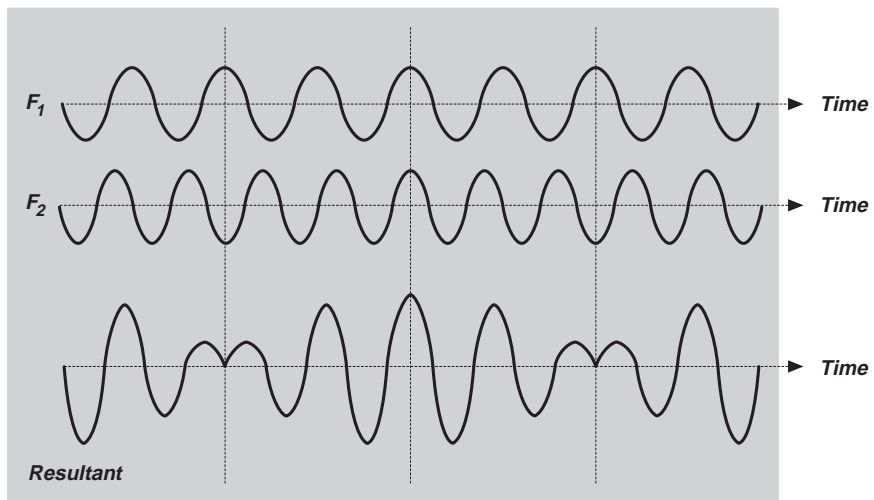


Figure 2.72: Beats caused by the combination of two waves with slightly different frequencies.

Chapter 3

Decibels



Figure 3.1: Decibel meter.

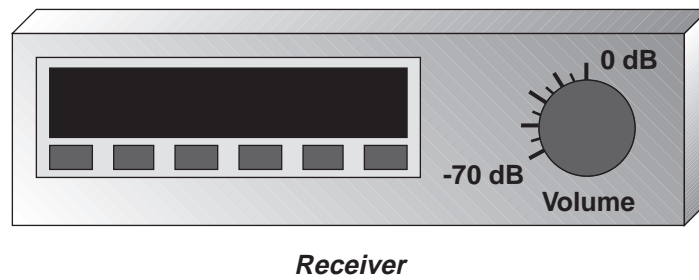


Figure 3.2: Receiver with volume control marked in dB.

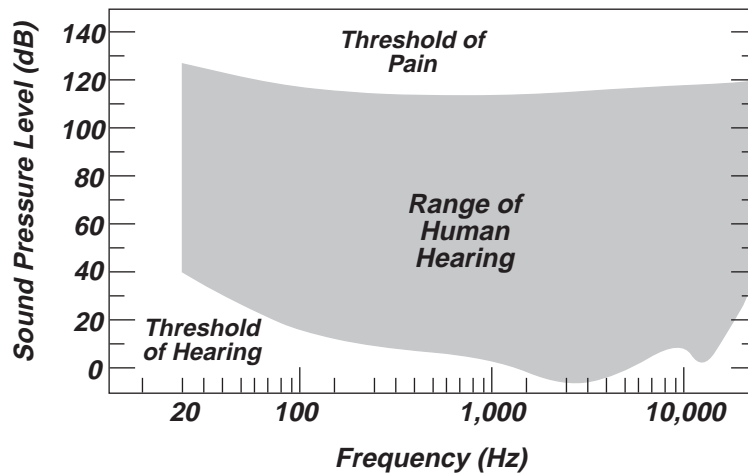


Figure 3.3: Response of human ears at the threshold of hearing.

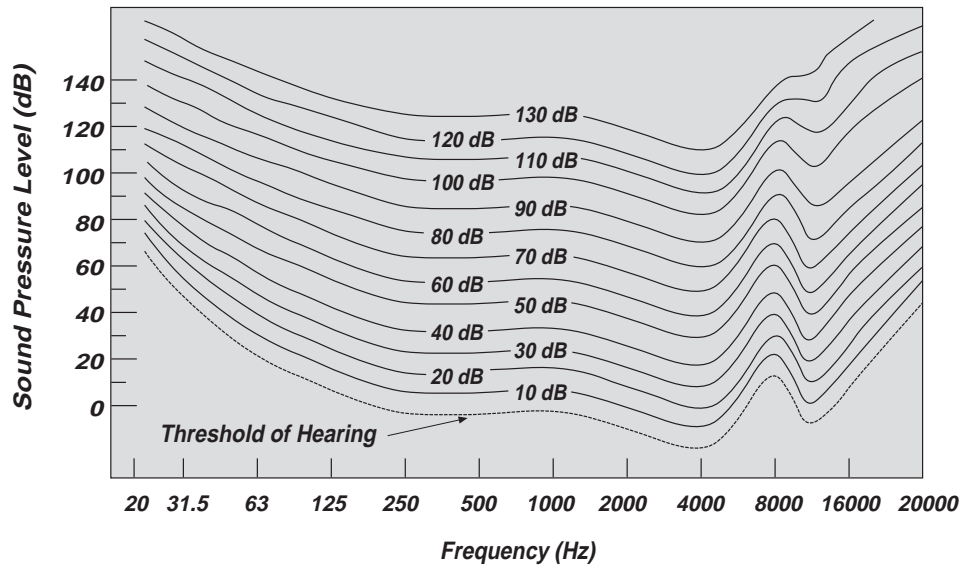


Figure 3.4: Response of human ears for various sound levels: Fletcher-Munson curves.

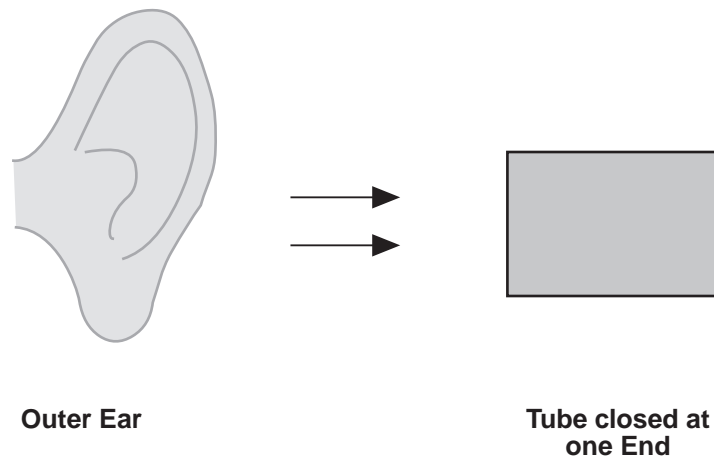


Figure 3.5: Outer ear approximated by a tube closed at one end.

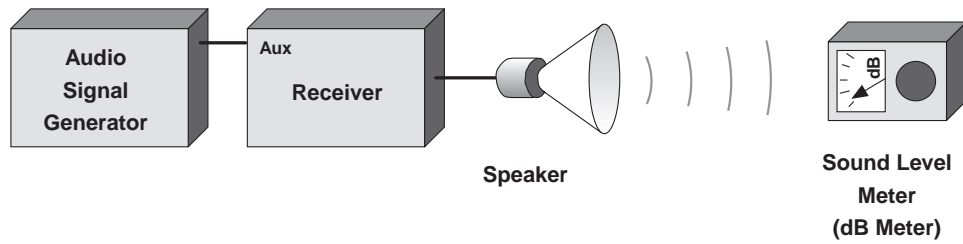


Figure 3.6: Measuring the frequency response of a speaker.

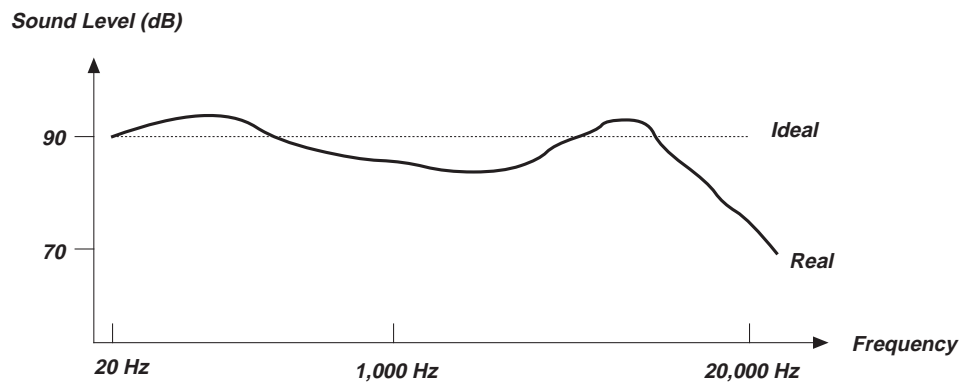


Figure 3.7: Frequency response of a speaker.

Chapter 4

Loudspeakers

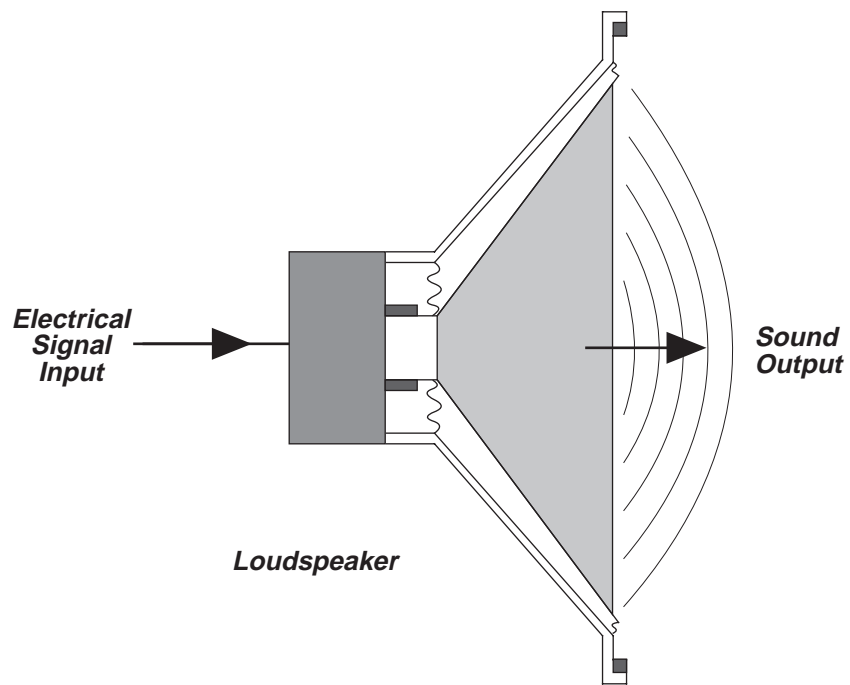


Figure 4.1: Role of loudspeaker.

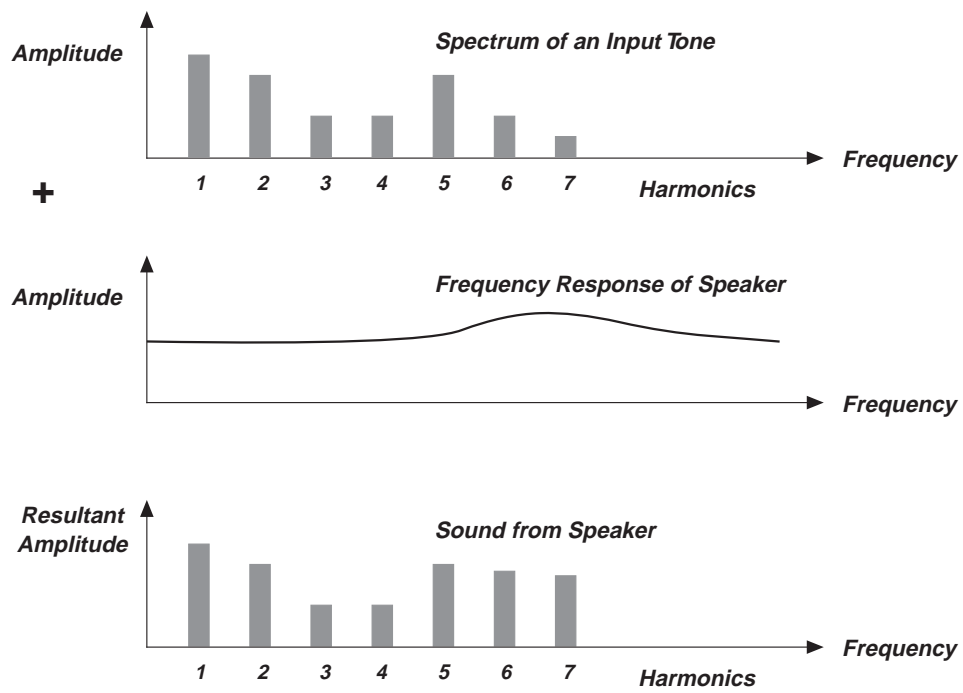


Figure 4.2: Distortion of spectrum of original waveform by non-flat frequency response of speaker.

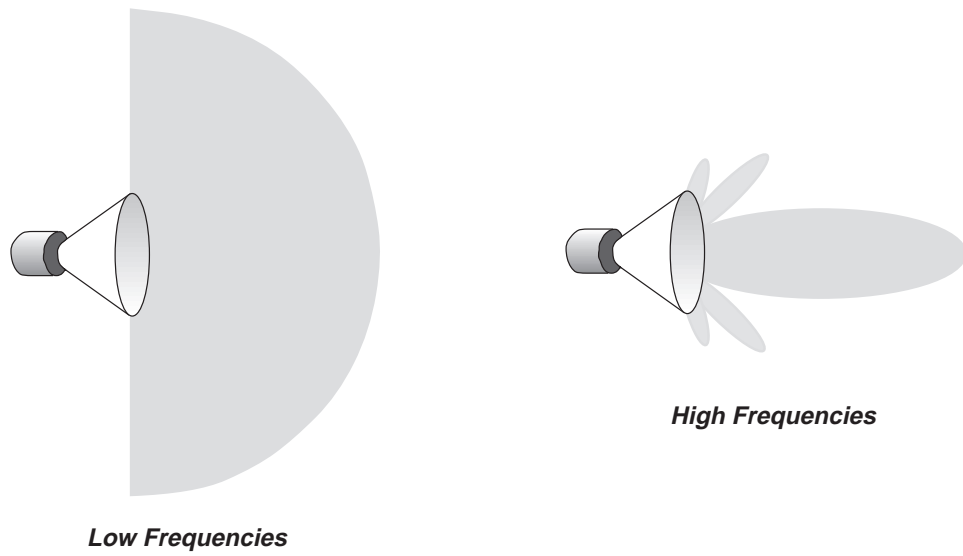


Figure 4.3: Dispersion properties of speakers.

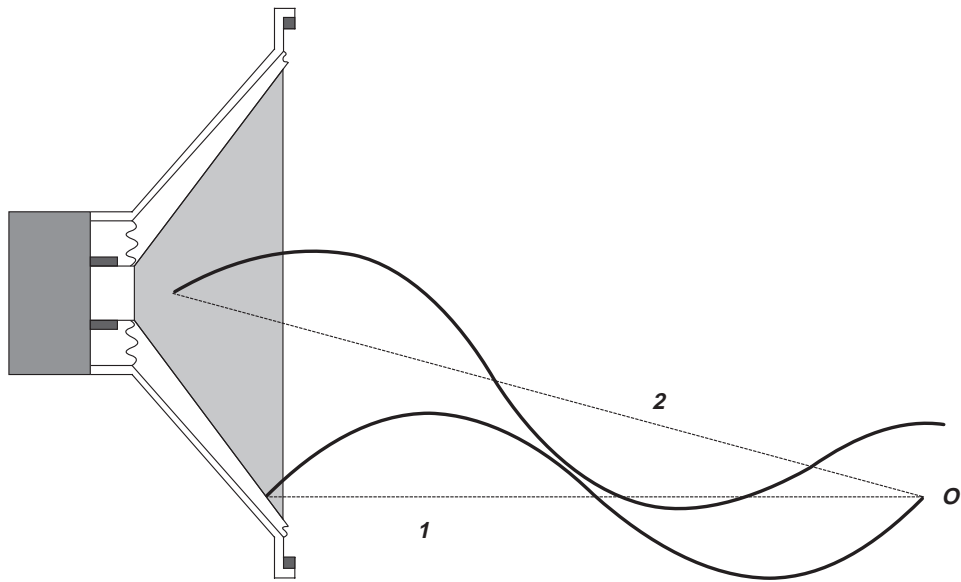


Figure 4.4: Two low frequency waves from speaker arriving at O.

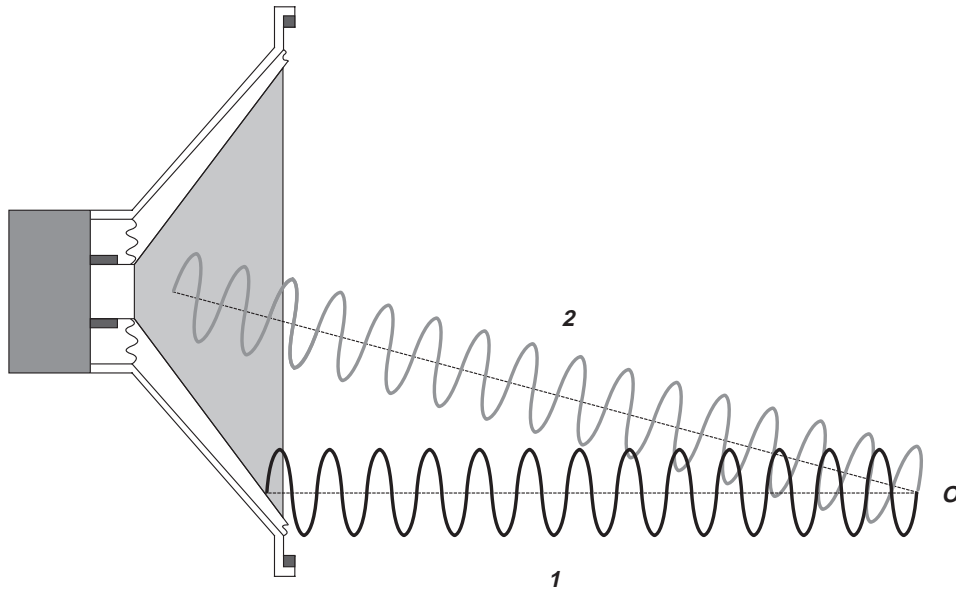


Figure 4.5: Two high frequency waves from speaker arriving at O.

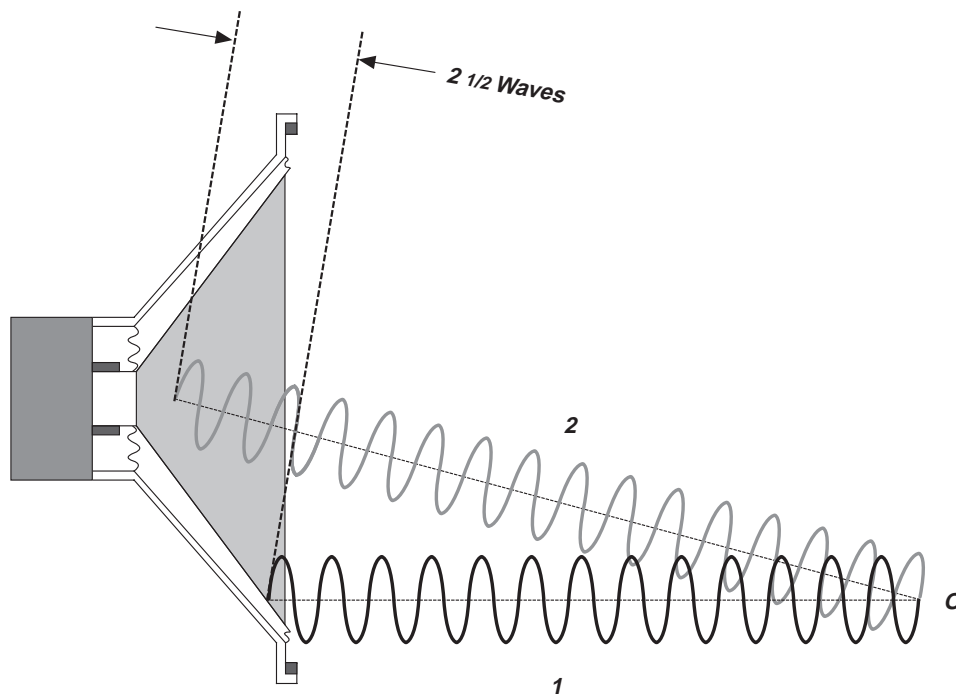


Figure 4.6: Details of waves 2 and 1 at high frequencies.

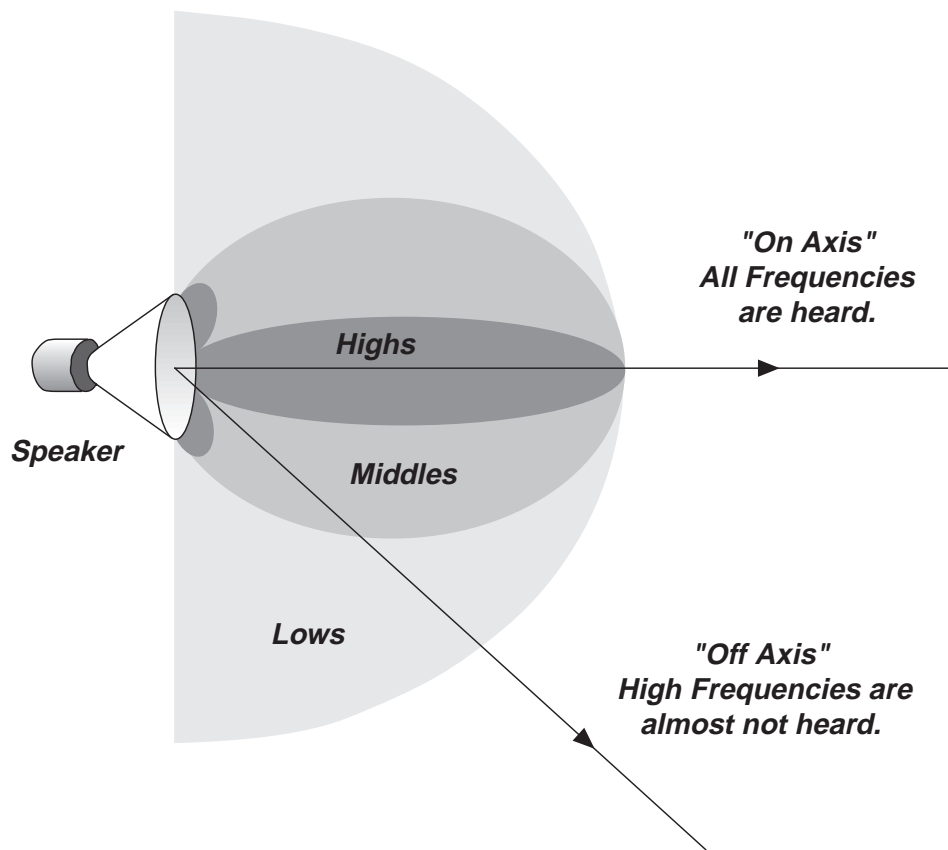


Figure 4.7: Sound dispersion of a driver as the frequency is increased.

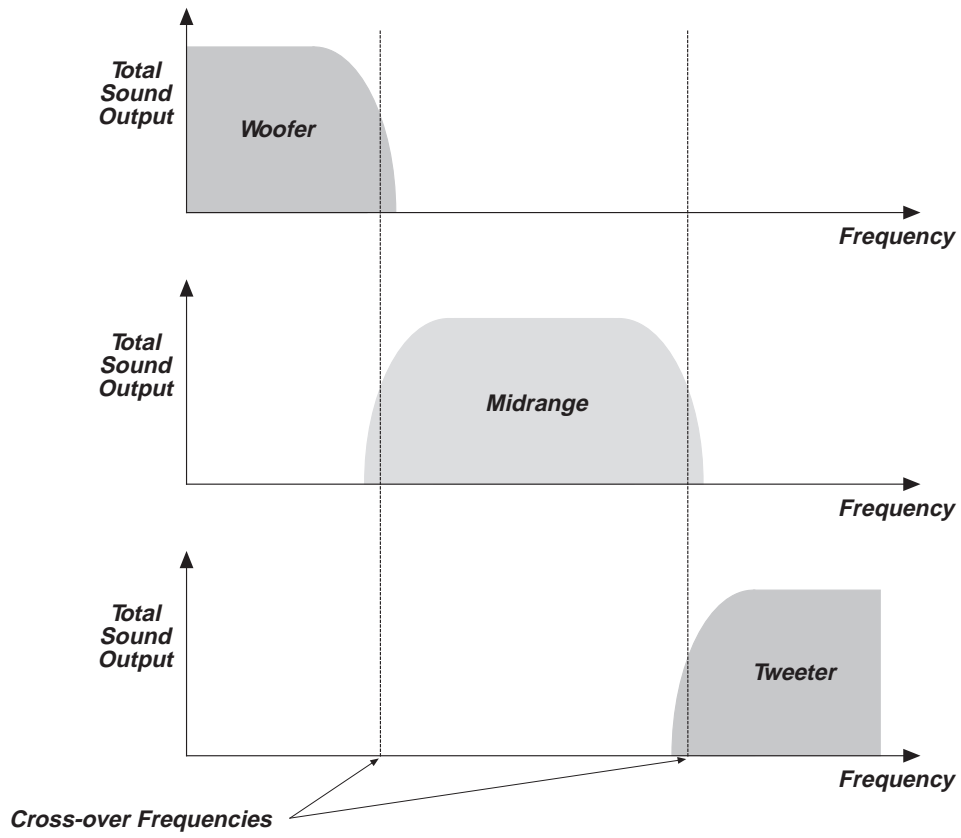


Figure 4.8: Division of audio spectrum for a three-way loudspeaker.

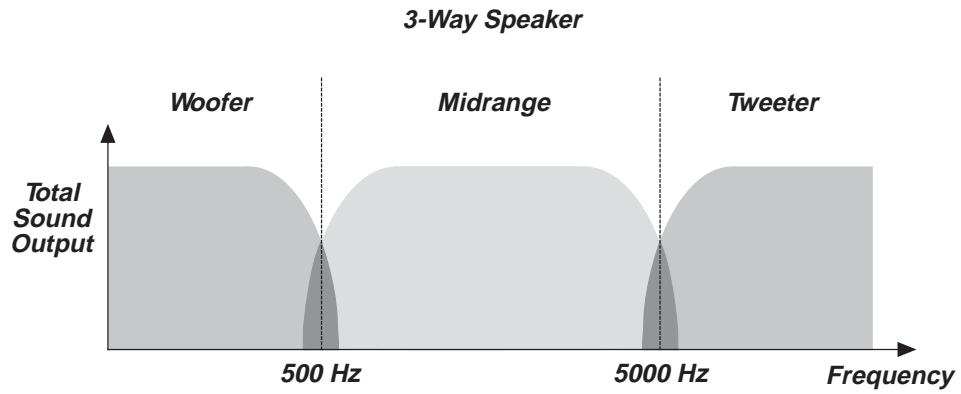


Figure 4.9: Net effect of subdividing the whole audio range into three sections.

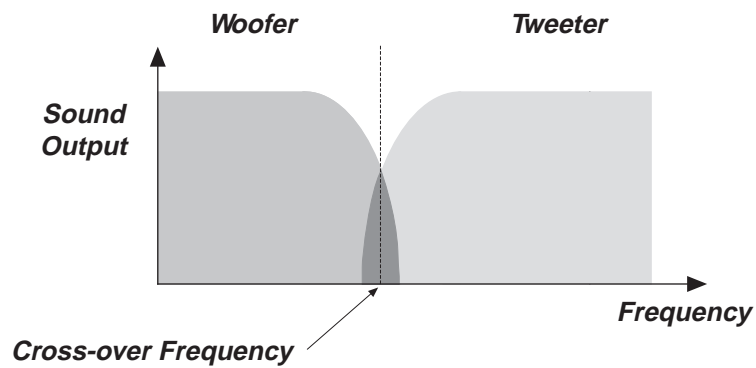


Figure 4.10: Subdivision of audio spectrum in a two-way system.

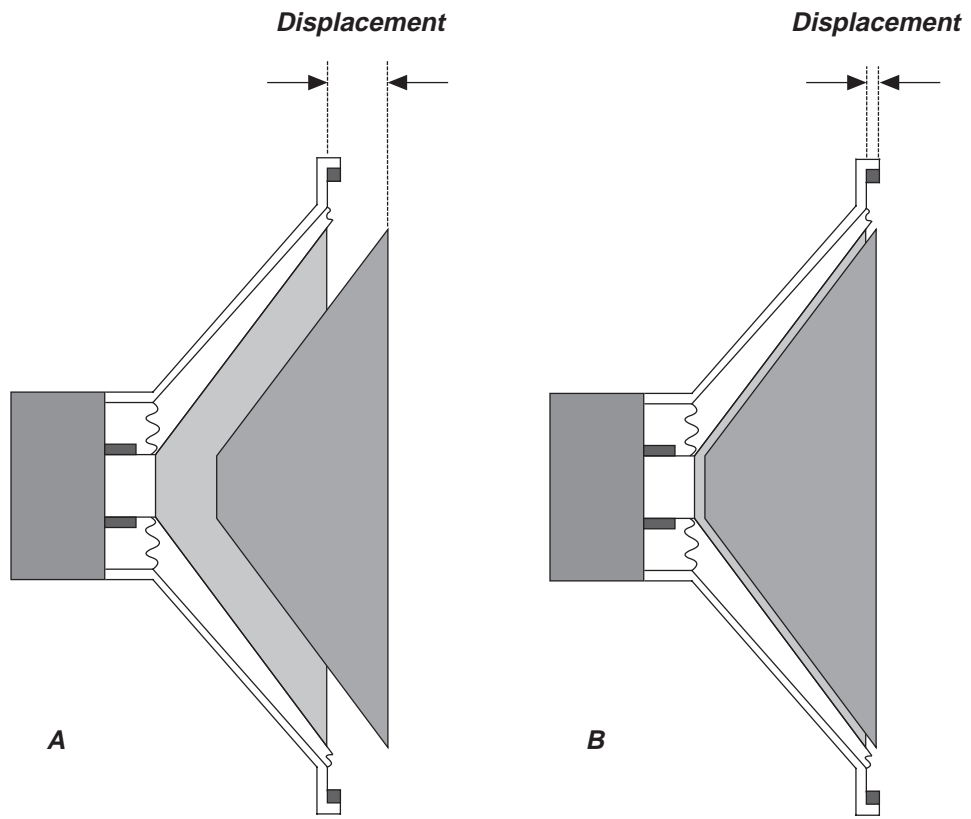


Figure 4.11: Amount of sound produced depends on volume displacement. A is louder than B.

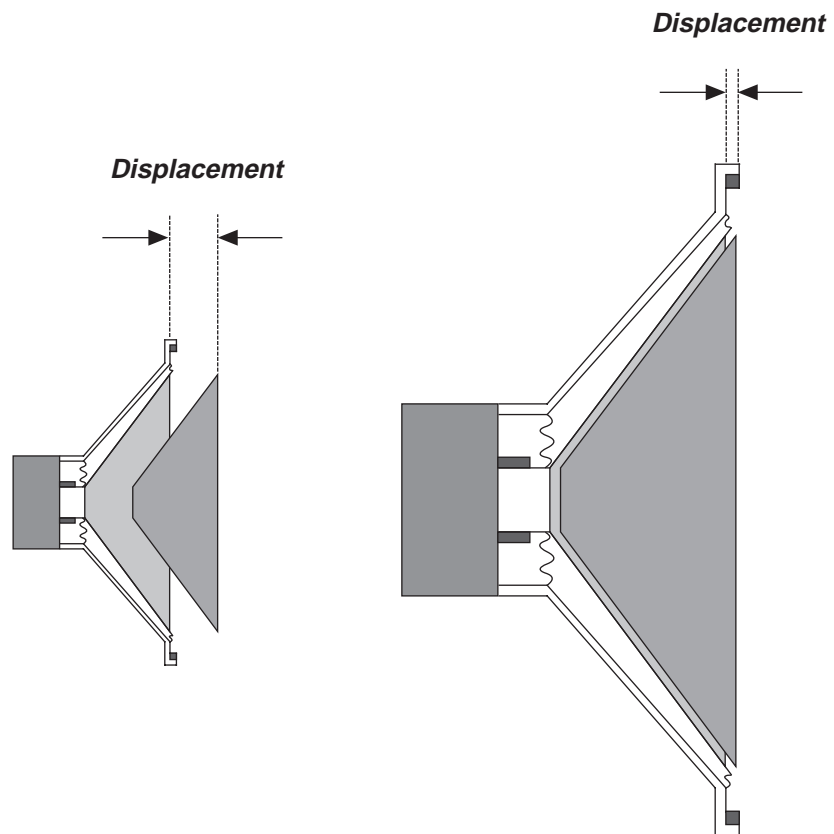


Figure 4.12: To produce same amount of sound by both drivers at the same frequency, the small one has to move through a larger distance than the big one.

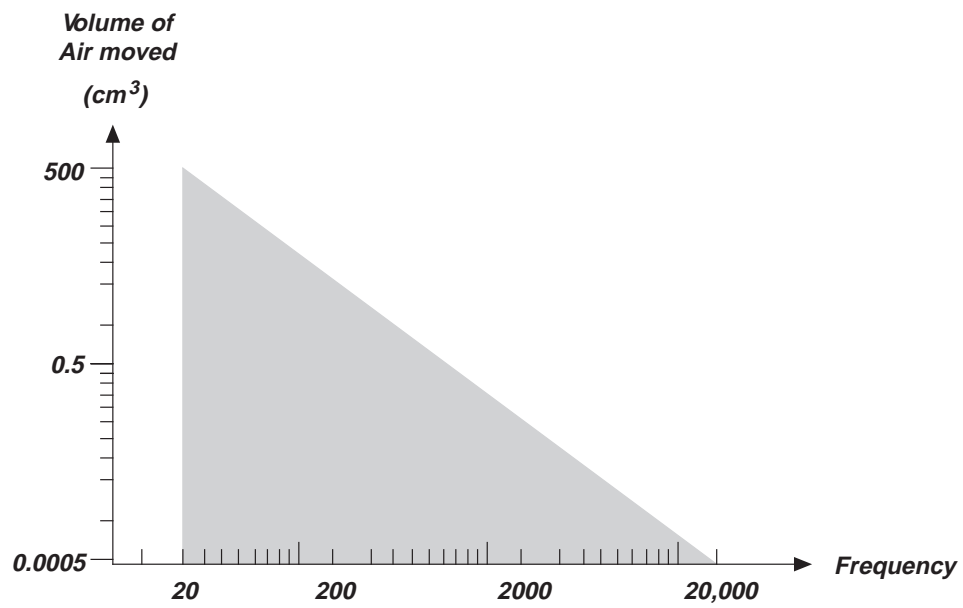


Figure 4.13: Volume of air moved by loudspeaker as a function of frequency to produce same loudness of sound.

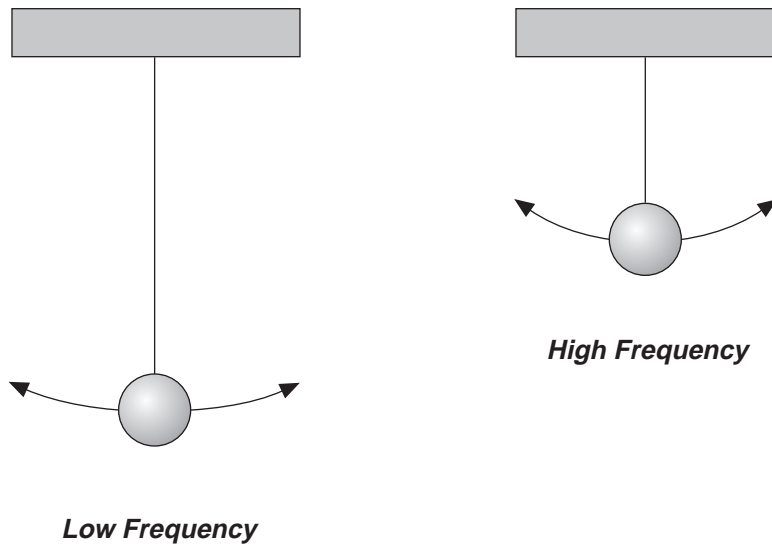


Figure 4.14: Low frequency and high frequency simple pendulums doing different amounts of work per second for same amplitude of displacement.

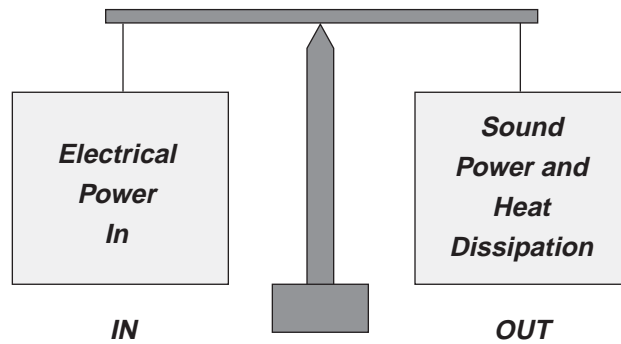


Figure 4.15: Balance between electrical power going to driver and the production of sound power and heat dissipation by driver.

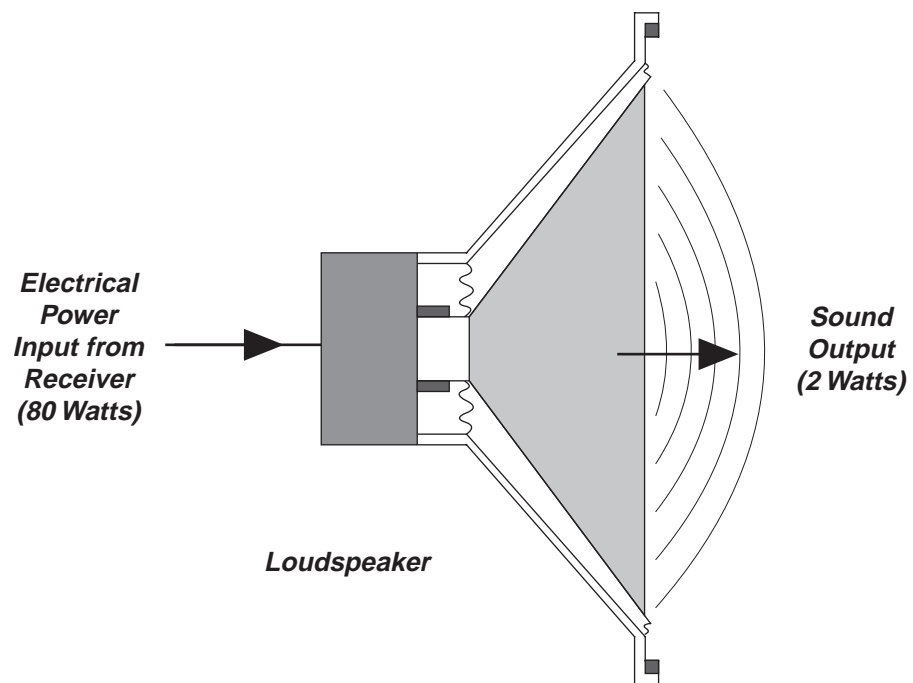


Figure 4.16: Example of a loudspeaker whose efficiency is less than 100%.

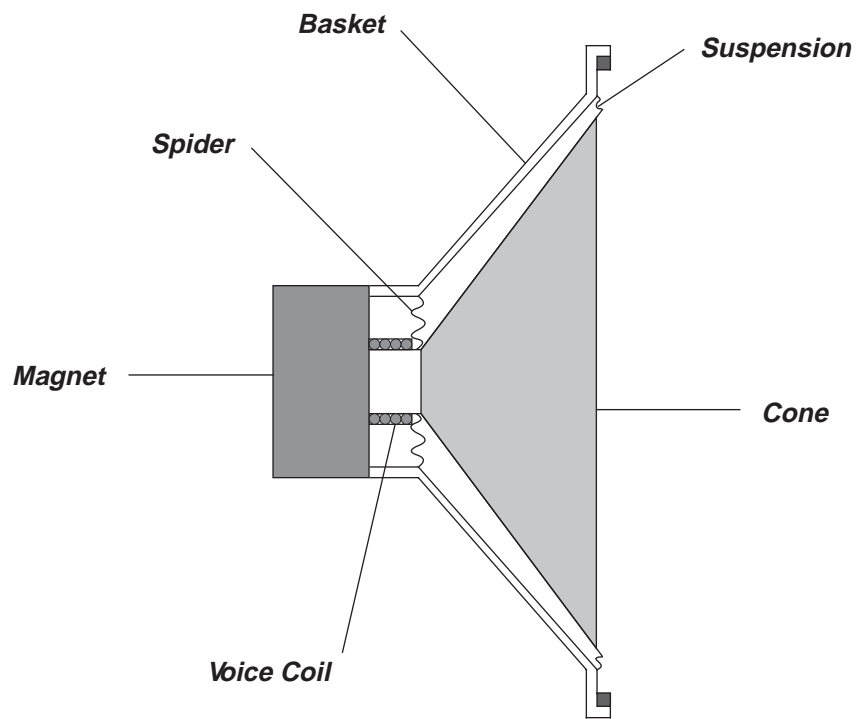
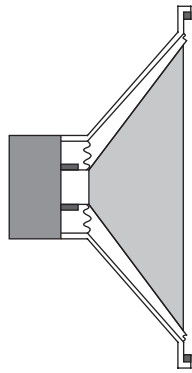
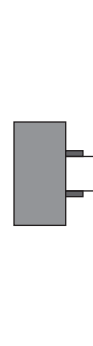


Figure 4.17: Basic cone speaker.



Cone-shaped Diaphragm



Flat Diaphragm

Figure 4.18: Comparison of cone-shape over flat shape for mechanical strength when thin material is used.

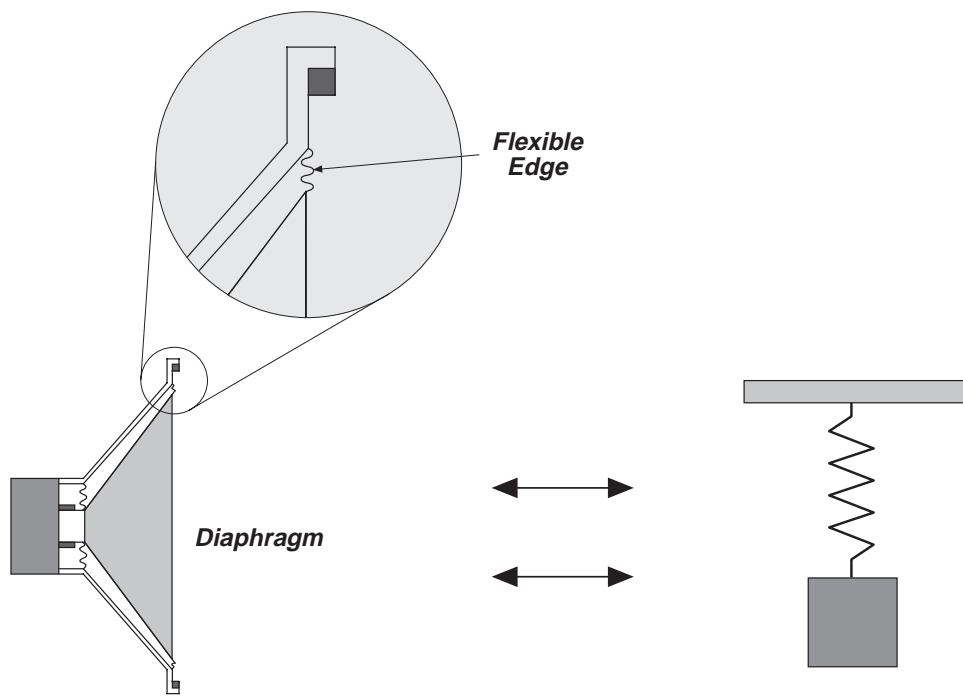


Figure 4.19: Modeling of diaphragm action by mass-spring oscillating system.

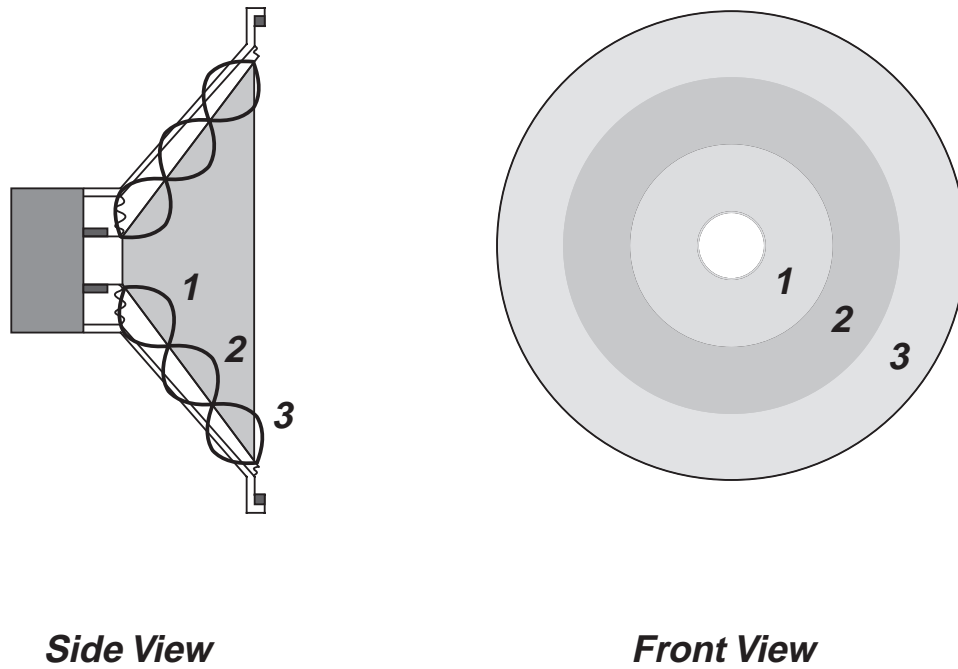


Figure 4.20: Standing wave on diaphragm of driver.

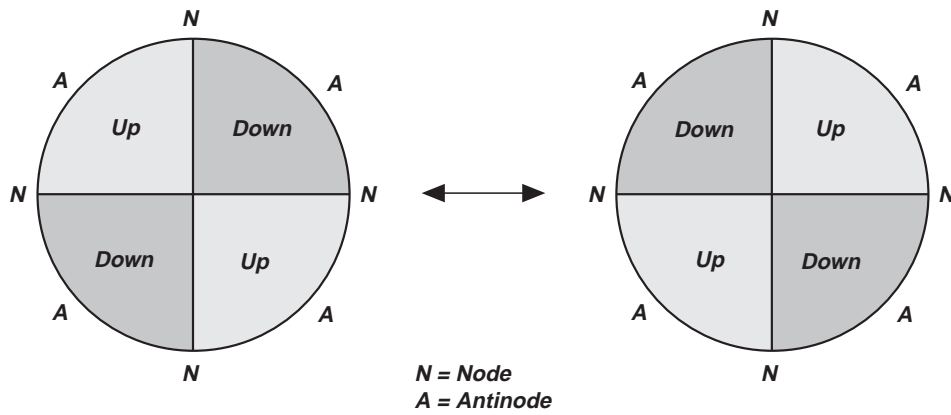


Figure 4.21: Standing wave around rim of diaphragm.

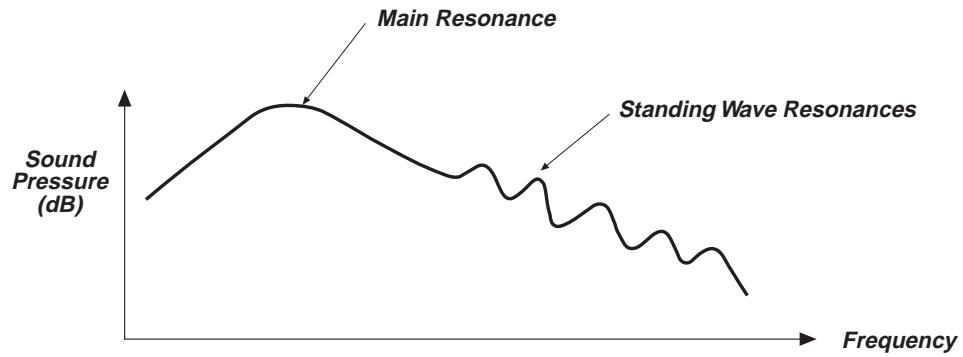


Figure 4.22: Typical frequency response of a cone speaker.



Figure 4.23: Baffle problem in cone driver.

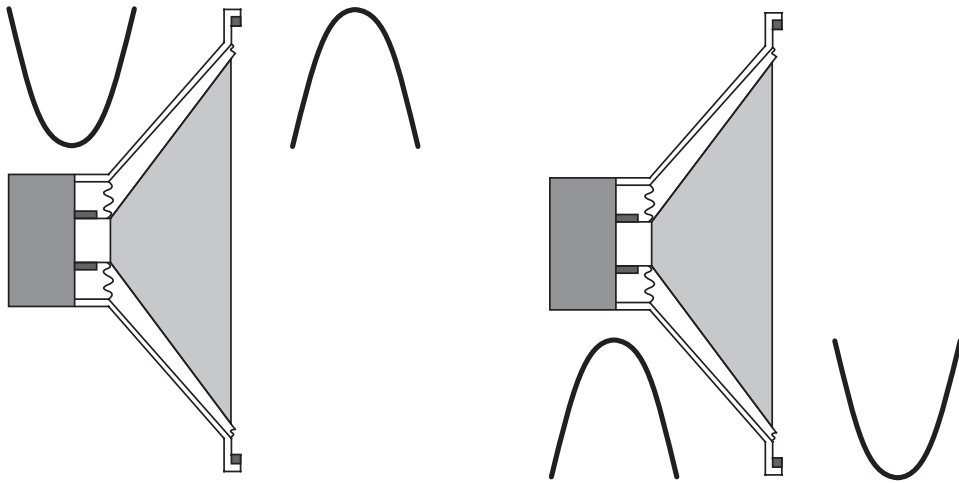


Figure 4.24: Front and rear of cone speakers are 180° out of phase.

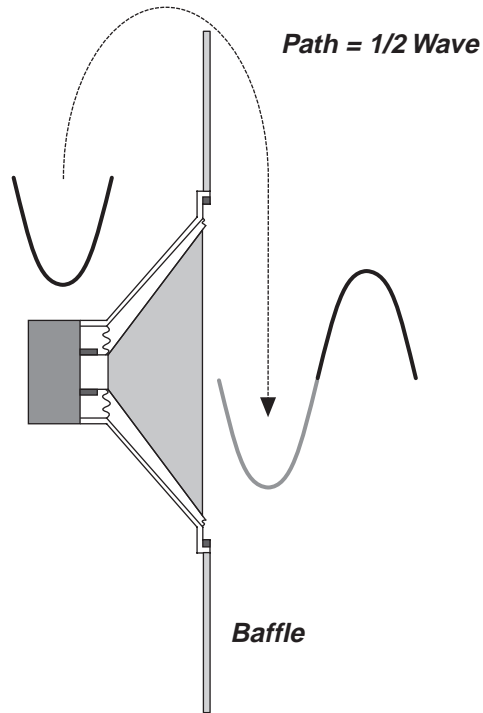


Figure 4.25: Baffle action.

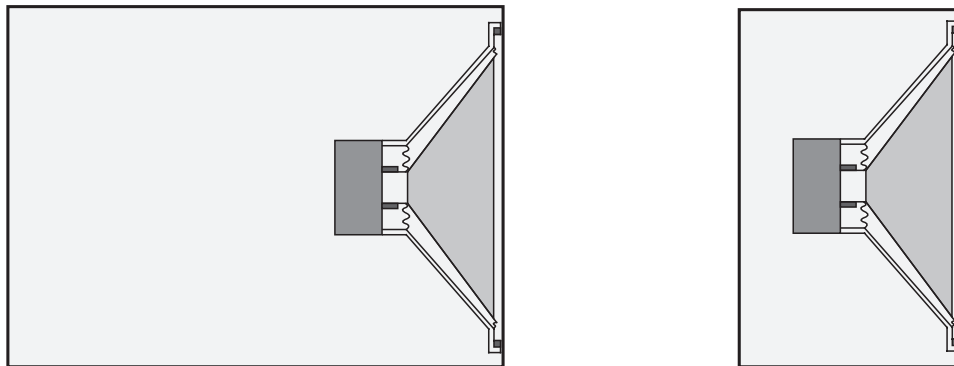


Figure 4.26: Two possible approaches for trapping rear sound in a speaker by means of an enclosure.

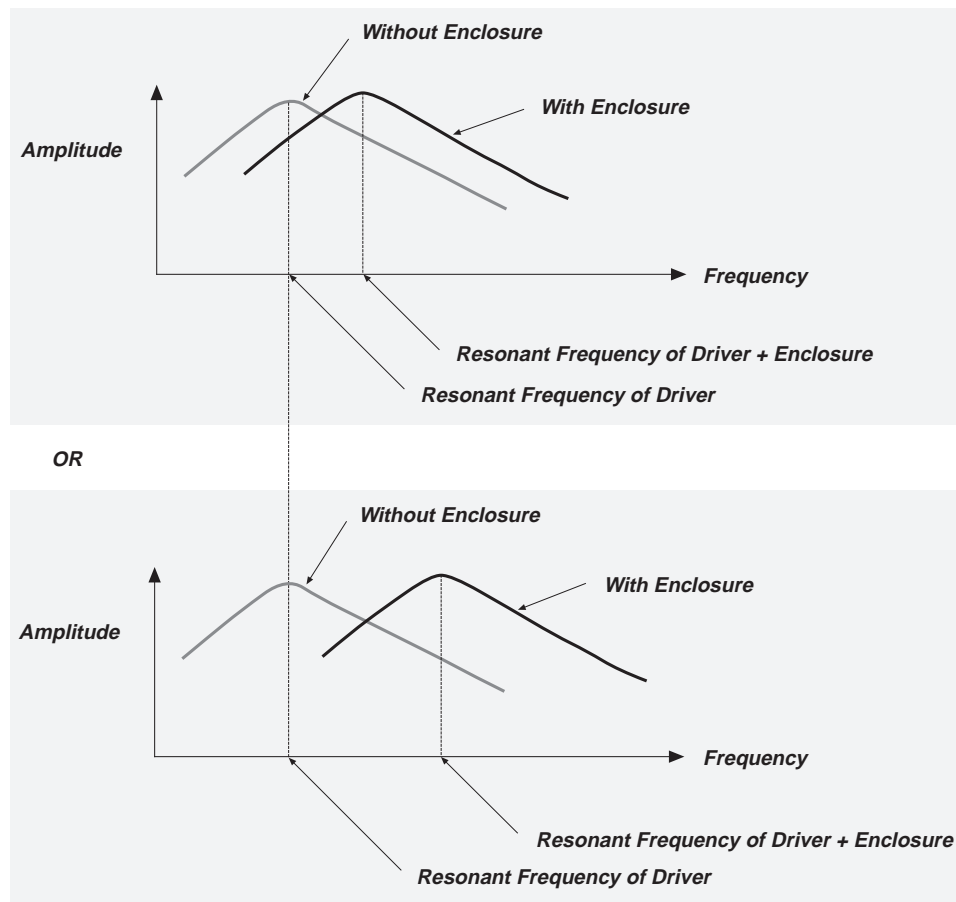


Figure 4.27: Effect of enclosure on frequency response of speaker.

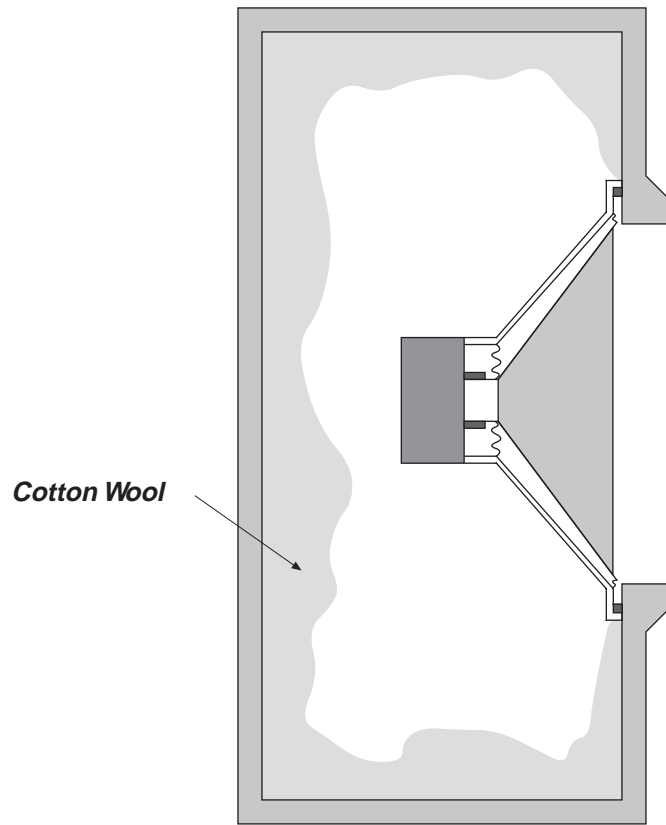


Figure 4.28: Reducing standing waves inside speaker enclosure.

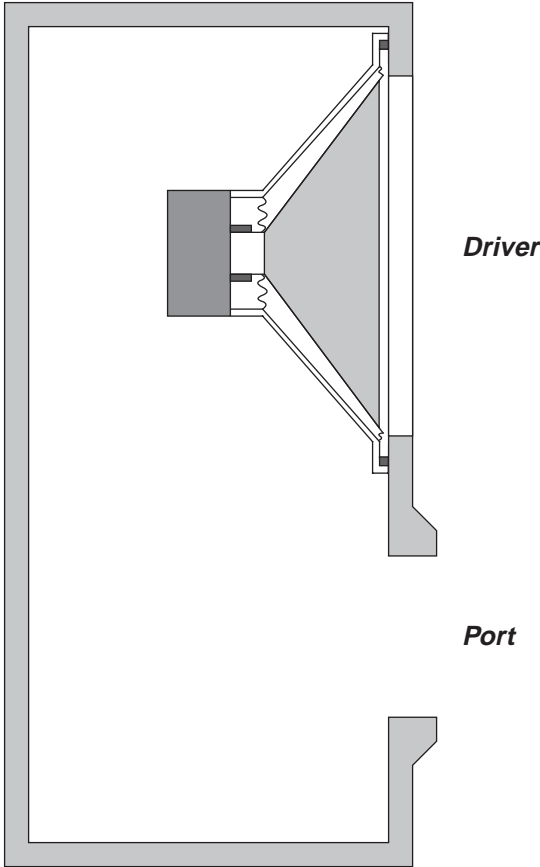


Figure 4.29: Basic bass-reflex enclosure.

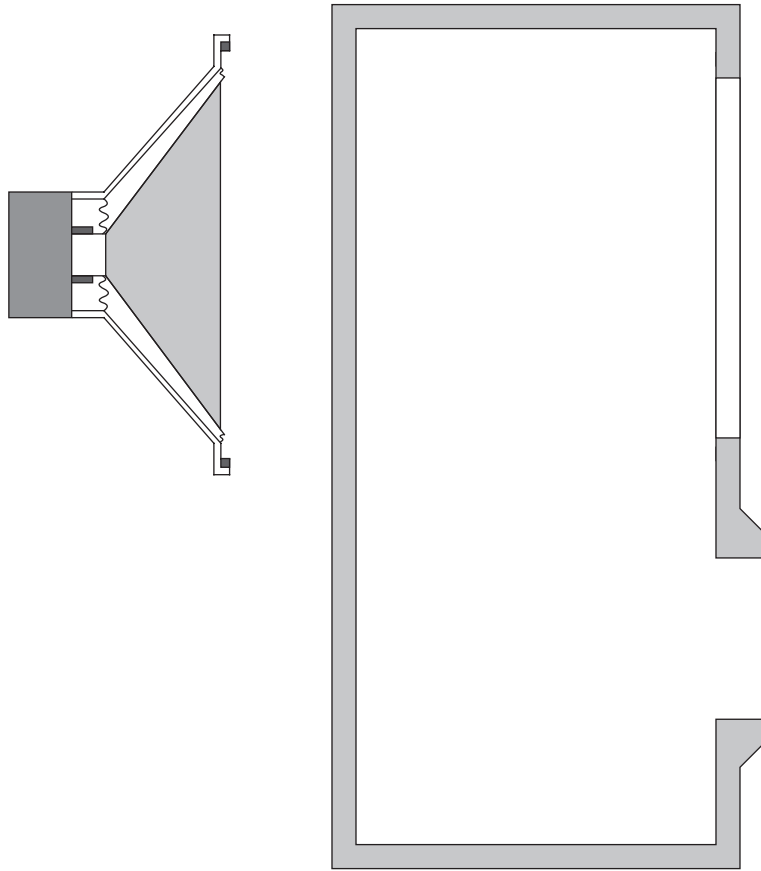


Figure 4.30: Oscillating components of bass-reflex speaker.

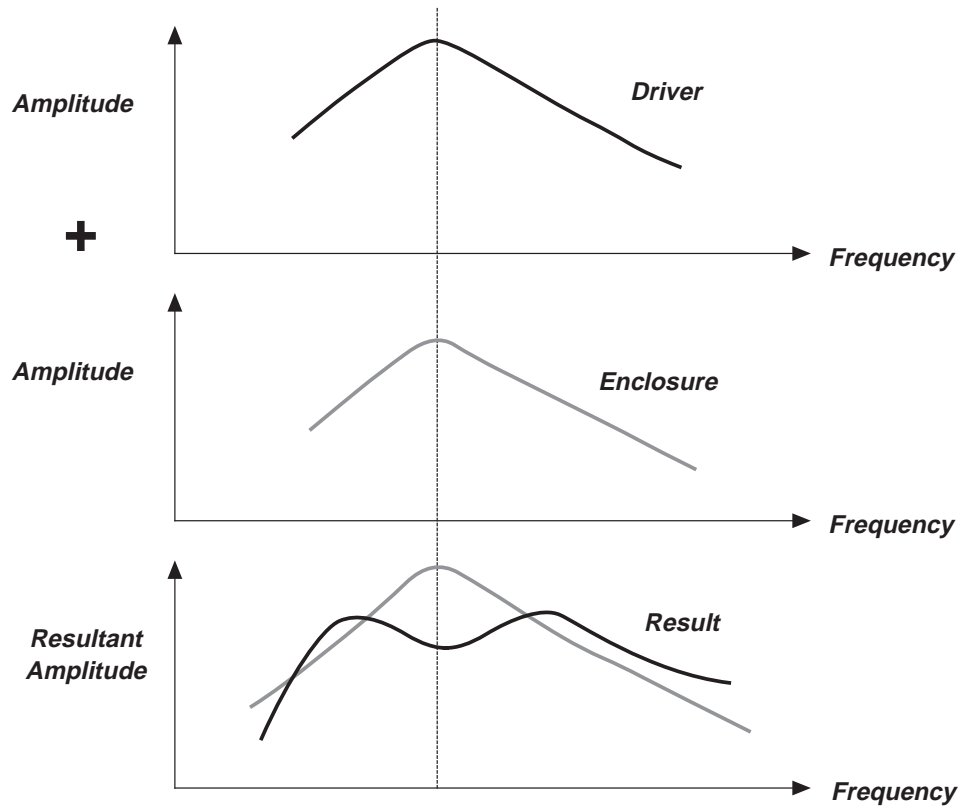


Figure 4.31: Splitting of original resonance into two new resonances in bass-reflex system.

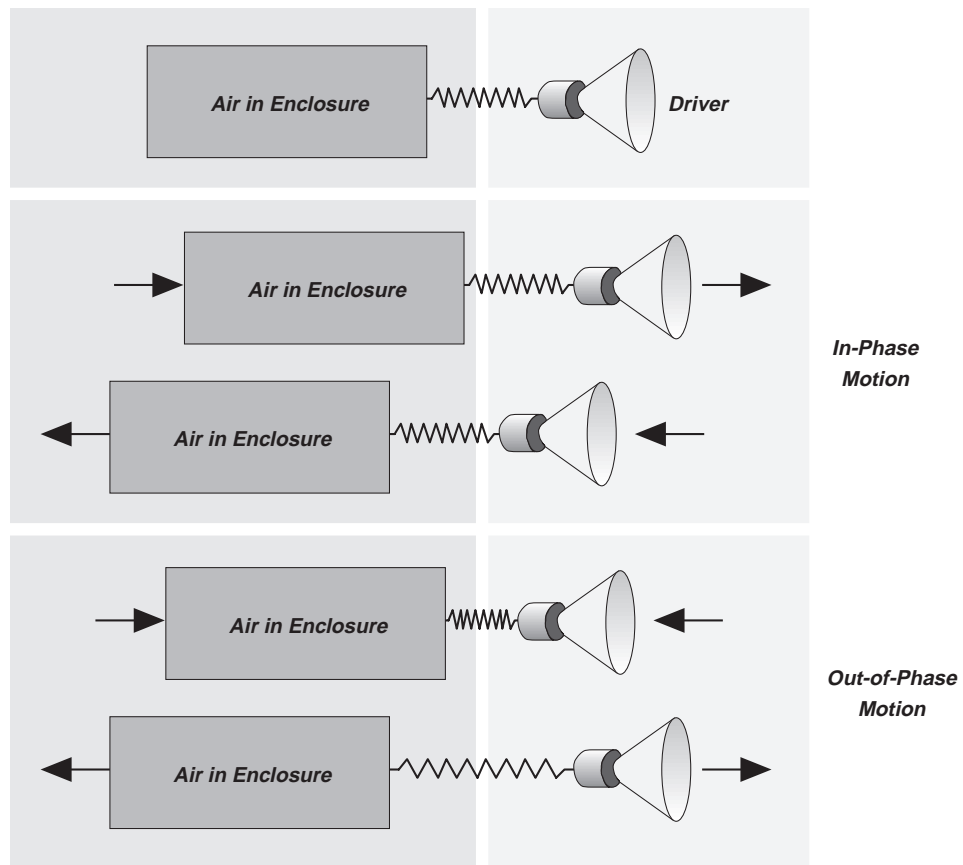


Figure 4.32: Resonant behavior, in-phase and out-of-phase, motion of strongly coupled components of bass-reflex system.

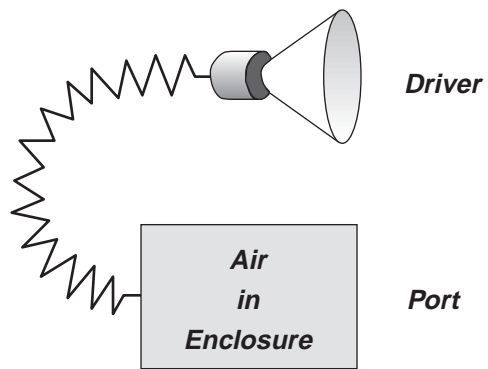


Figure 4.33: Coupled components of a bass-reflex speaker.

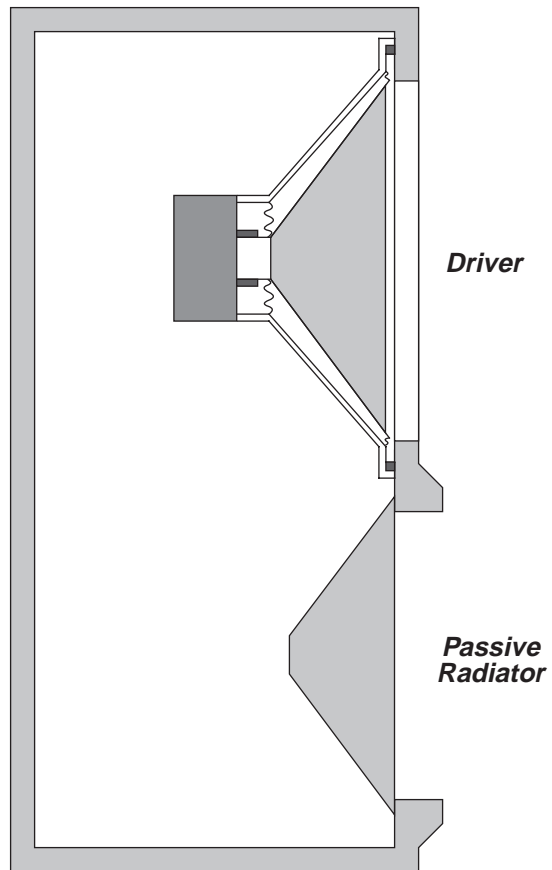


Figure 4.34: Bass-reflex speaker using a passive radiator over the port.

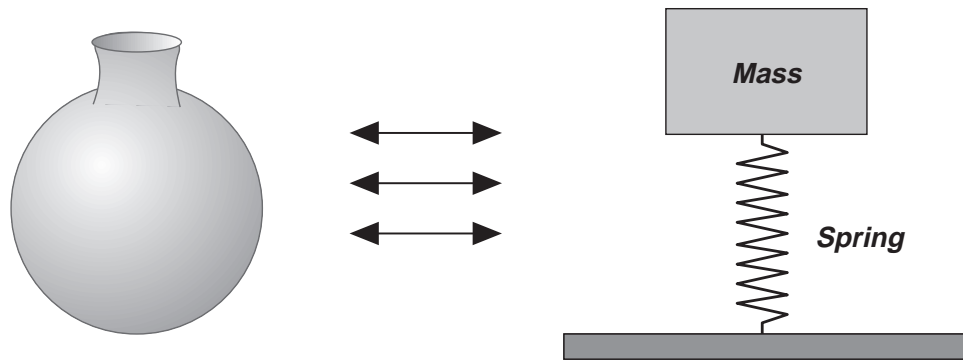


Figure 4.35: Helmholtz resonator behaves like mass-spring system.

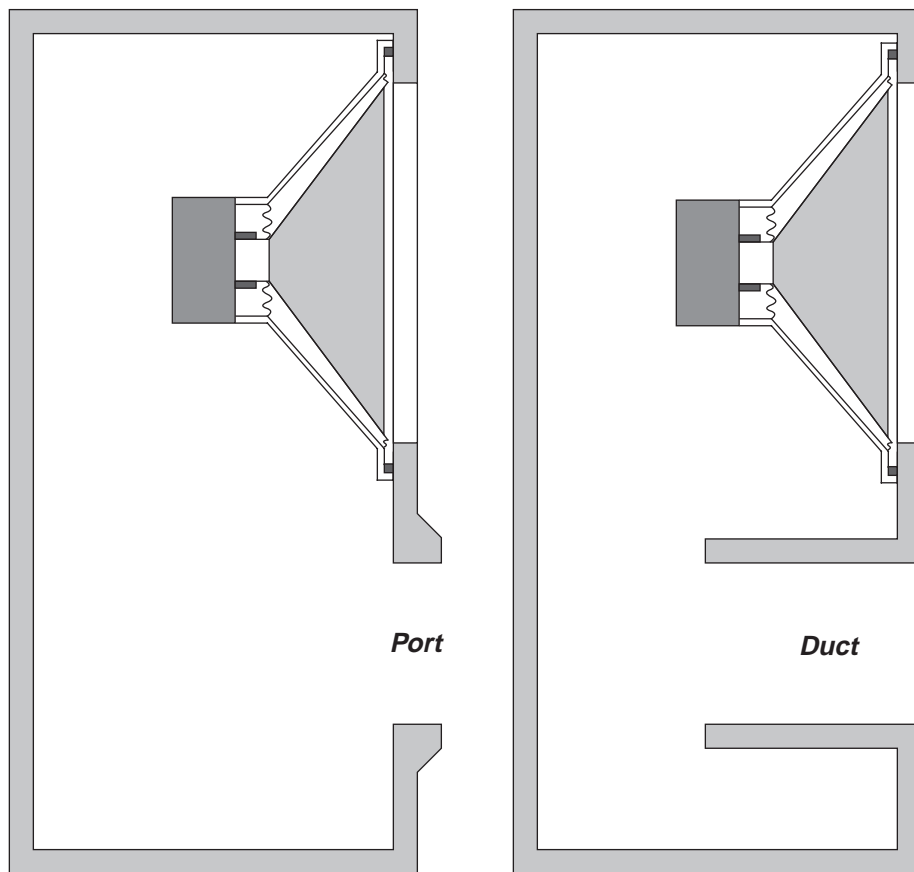


Figure 4.36: Bass-reflex speaker using a port or a duct.

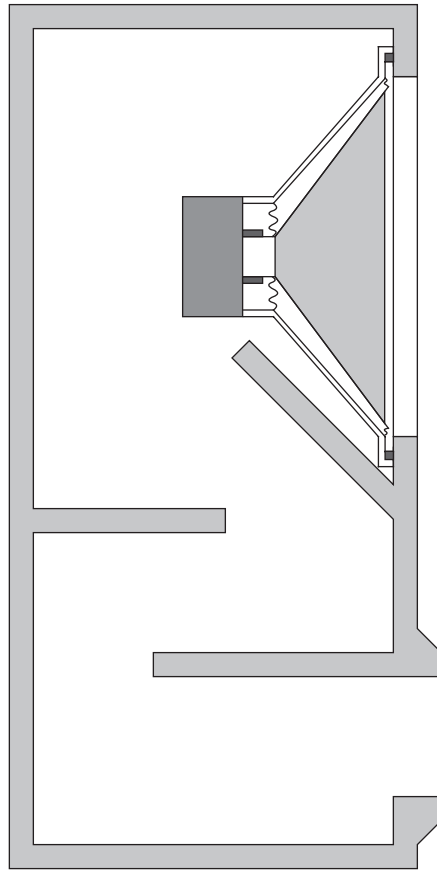


Figure 4.37: Acoustic labyrinth enclosure.

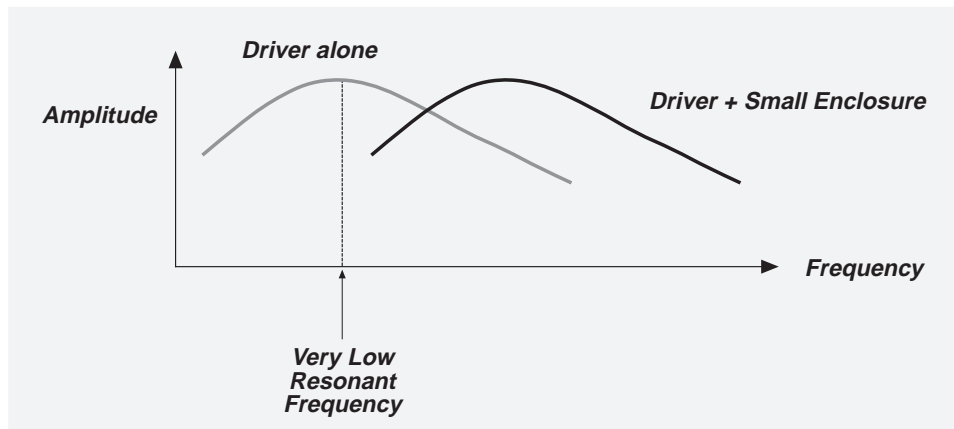


Figure 4.38: Change of frequency response of speaker when a small enclosure is used.

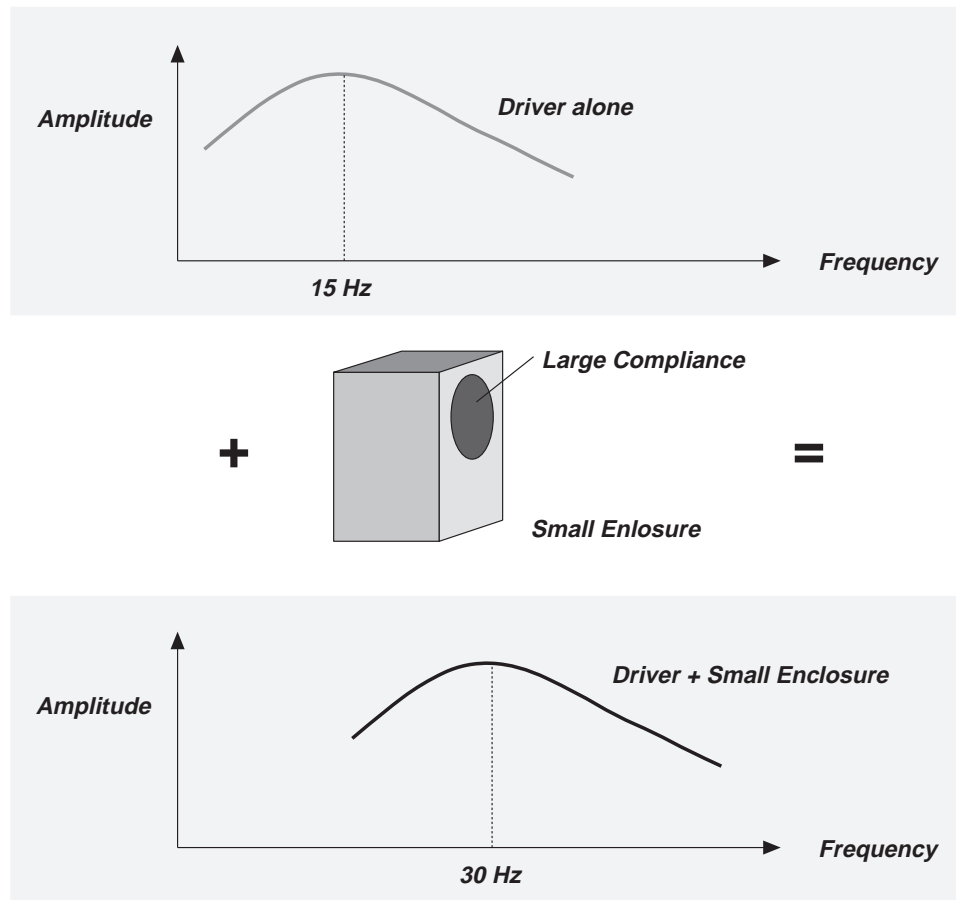


Figure 4.39: Effect of small enclosure on frequency response of driver.

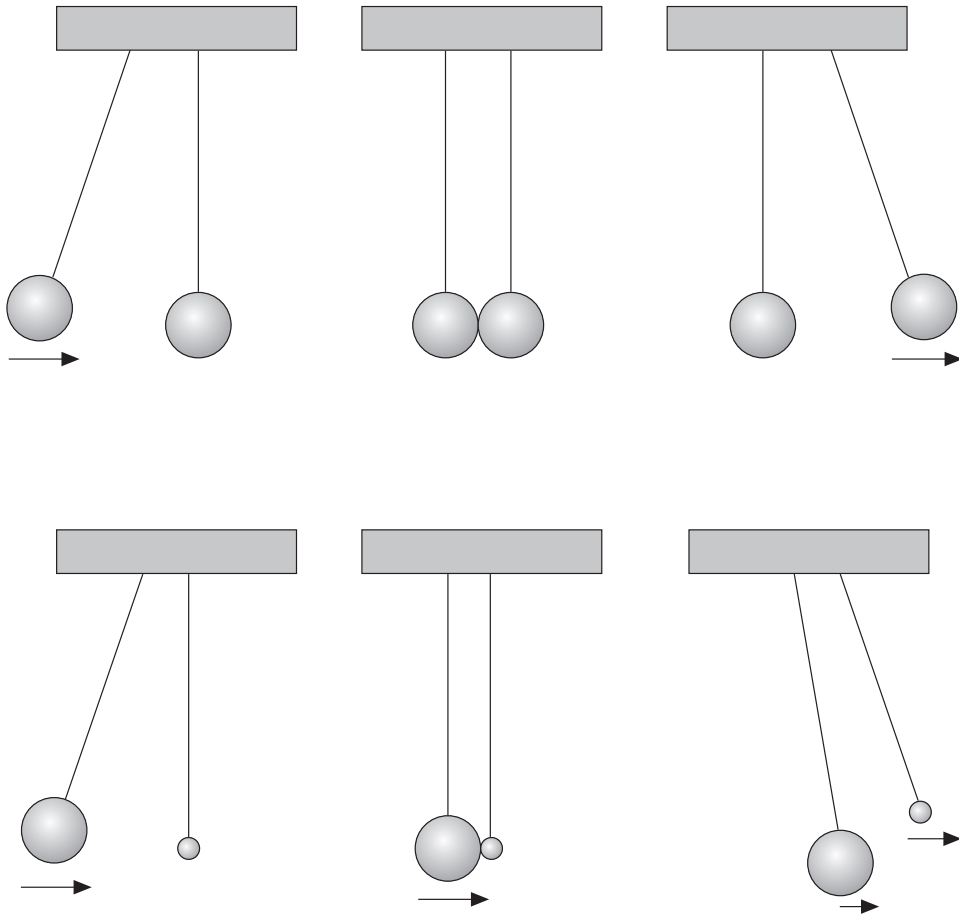


Figure 4.40: Transfer of energy from a bob to one of equal mass, and to one of different mass.

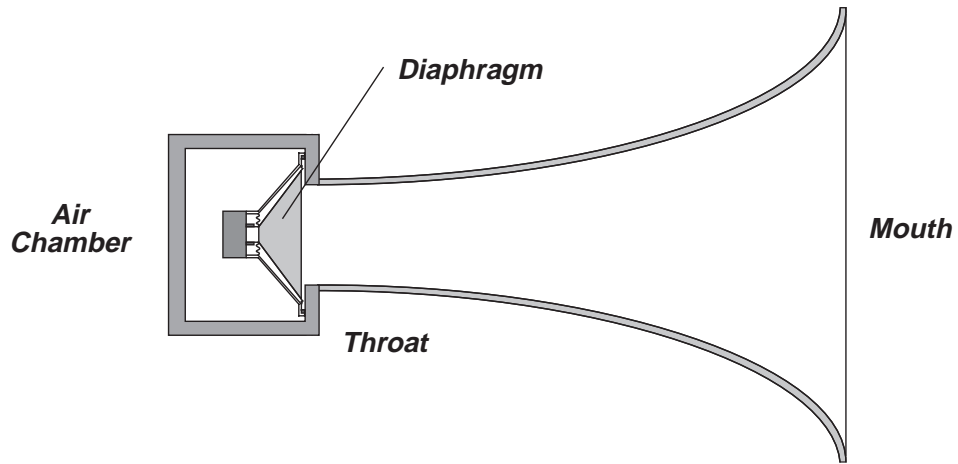


Figure 4.41: A horn for matching vibrations of a light diaphragm to a large volume of air.

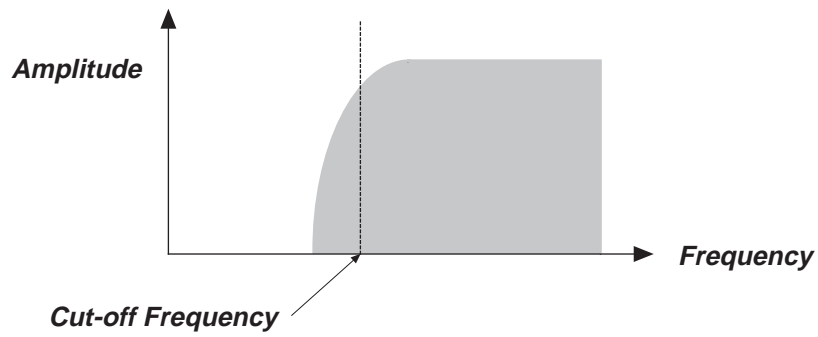


Figure 4.42: Low frequency response of a horn.

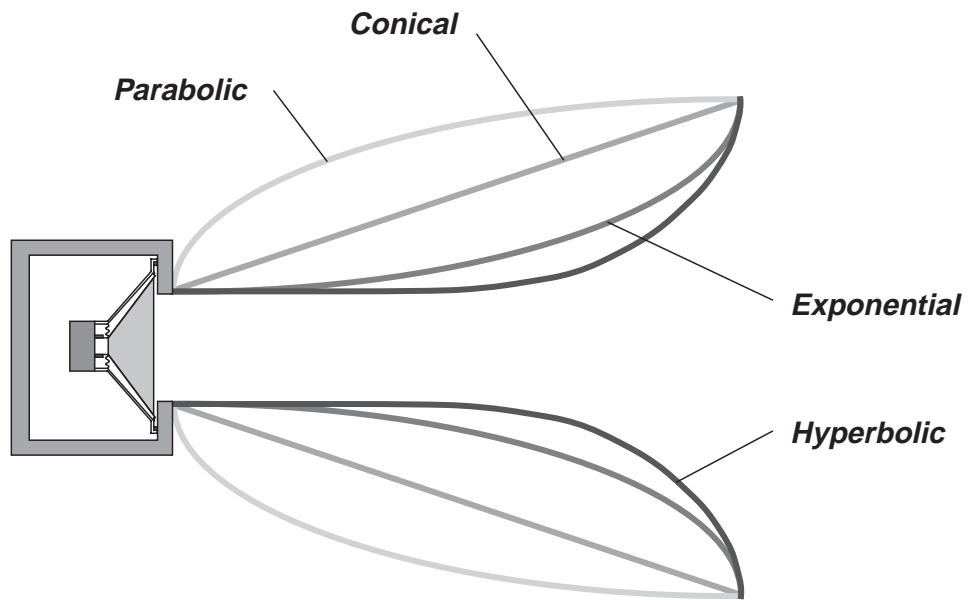


Figure 4.43: Some common horn shapes.

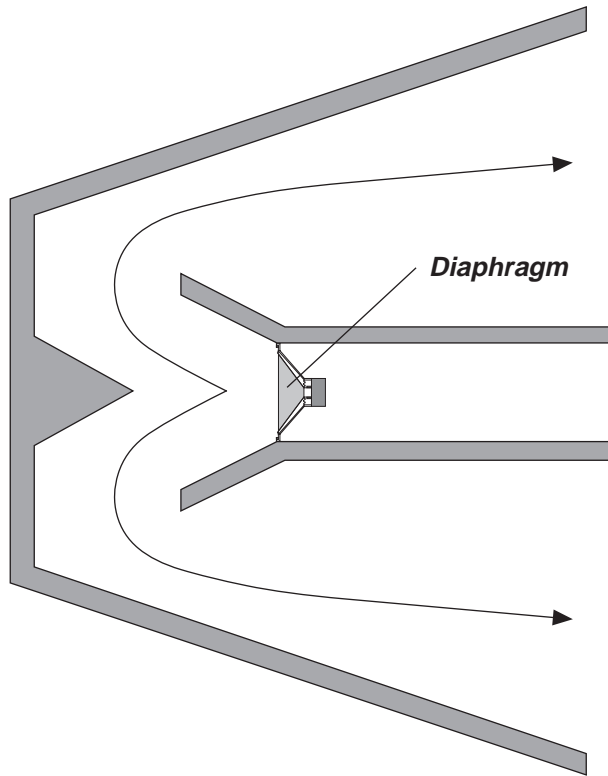


Figure 4.44: Folded horn.

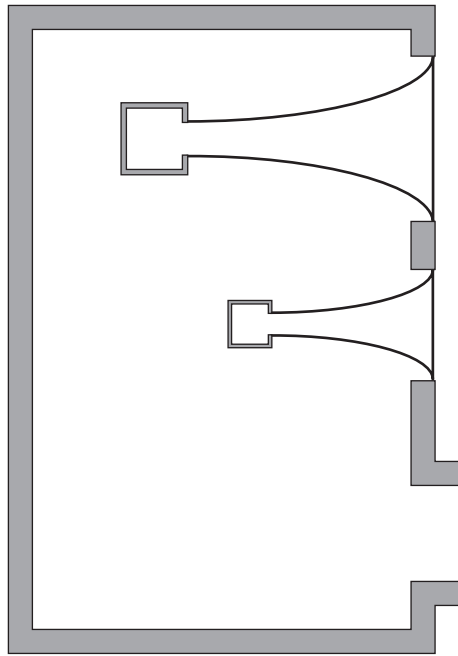


Figure 4.45: Two-way horn loudspeaker with bass-reflex enclosure.

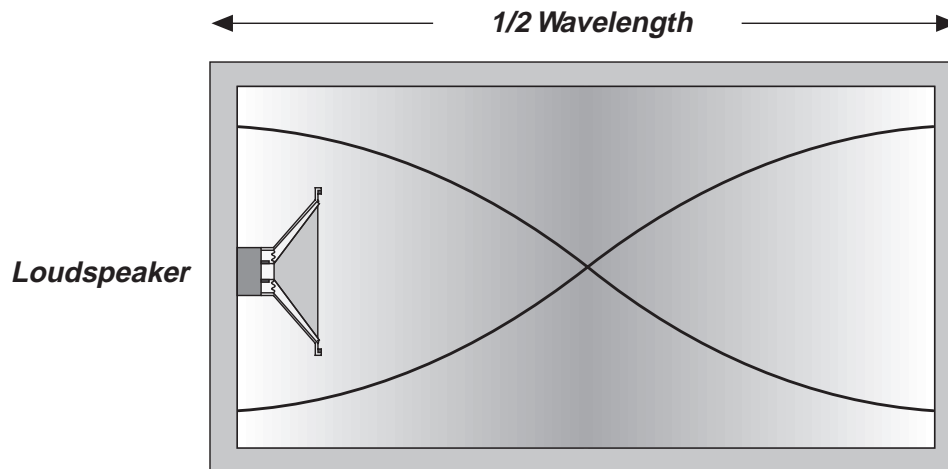


Figure 4.46: Standing wave set up in a room with maxima and minima in sound pressure.

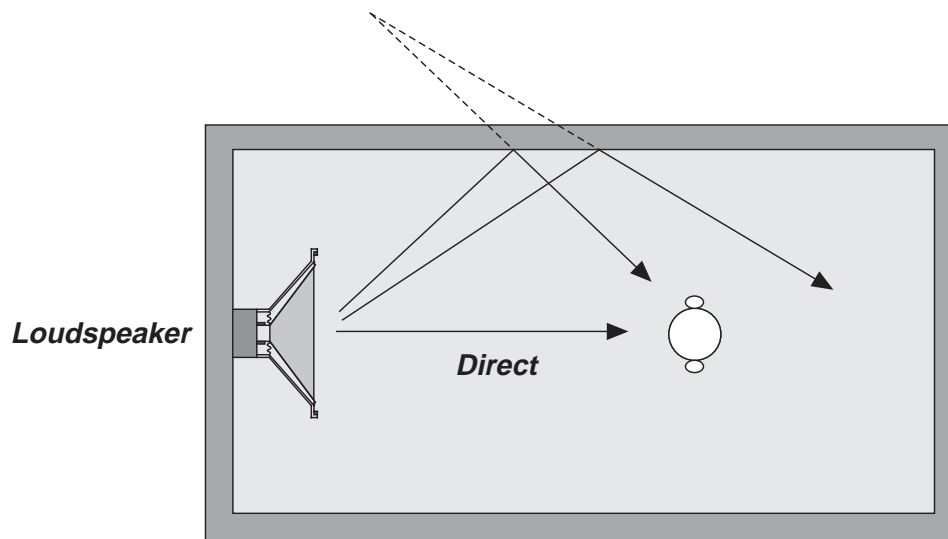


Figure 4.47: Reflected waves by a wall appear to come from behind the wall since it acts like a mirror.

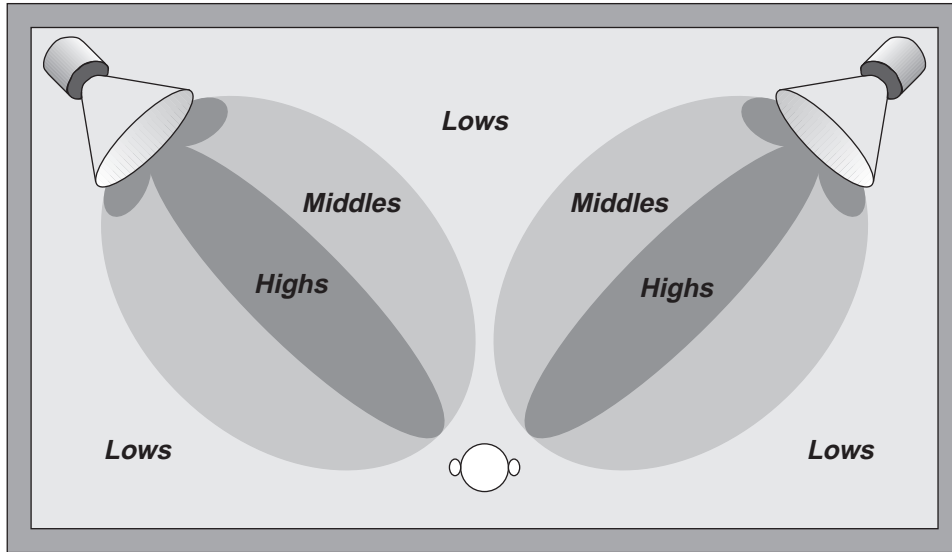


Figure 4.48: Stereo coverage in a room.

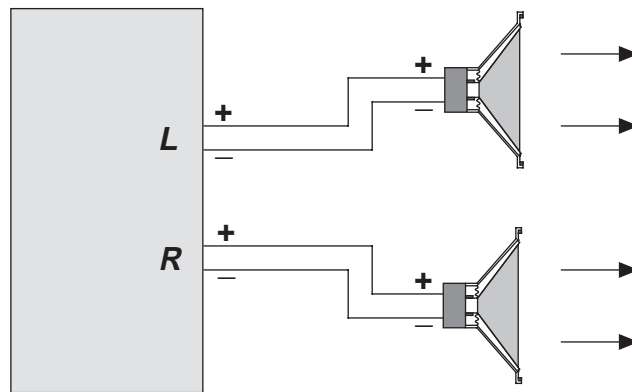


Figure 4.49: Speaker phasing: speakers are in phase.

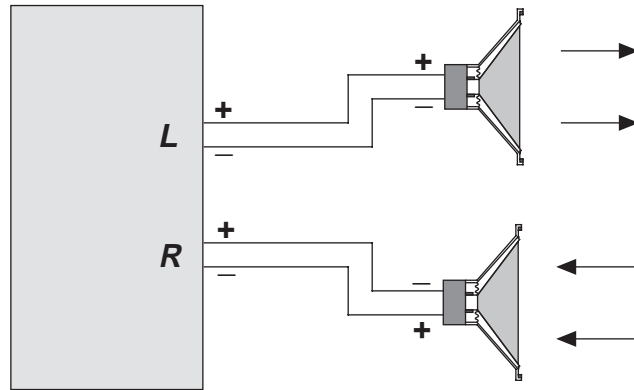


Figure 4.50: Speaker phasing: speakers are out of phase.

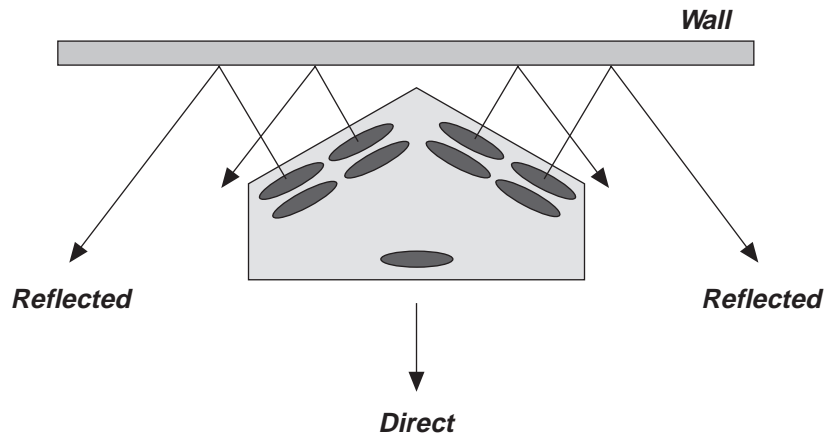


Figure 4.51: Geometry of a Bose 901 speaker.

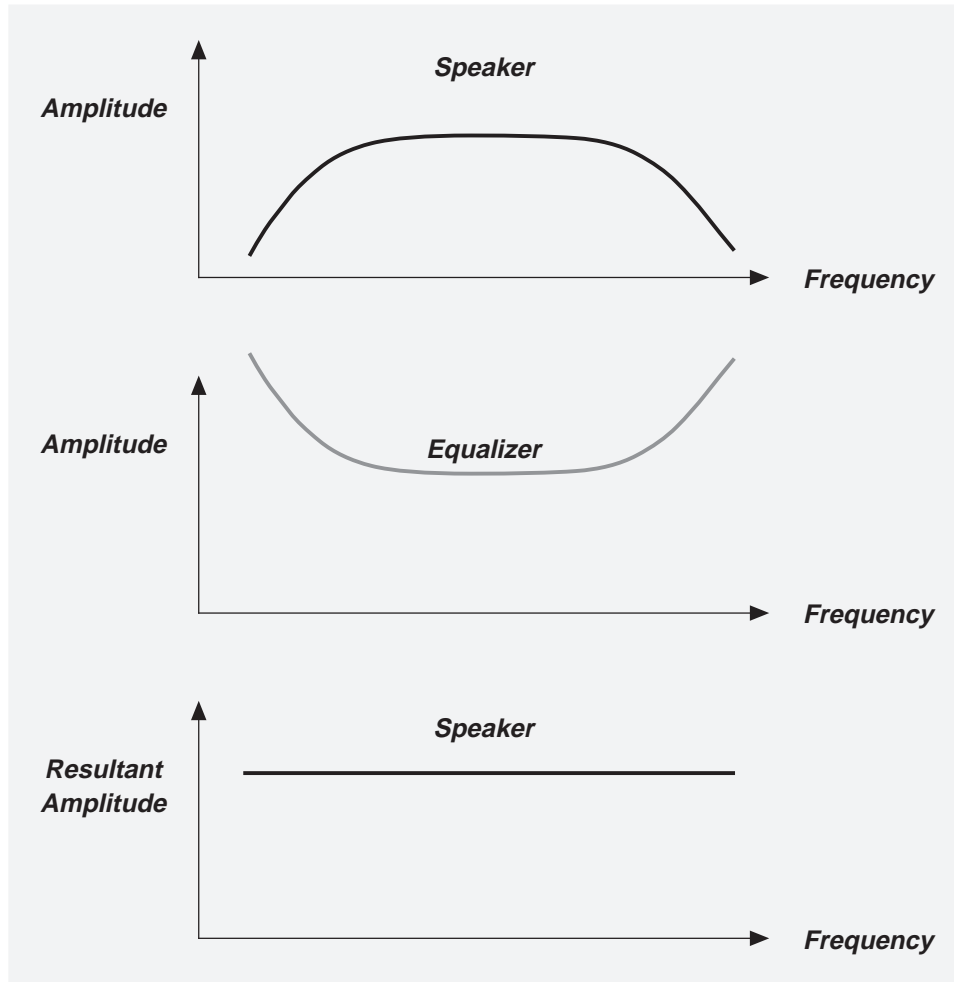


Figure 4.52: Effect of equalizer on frequency response of Bose speakers.

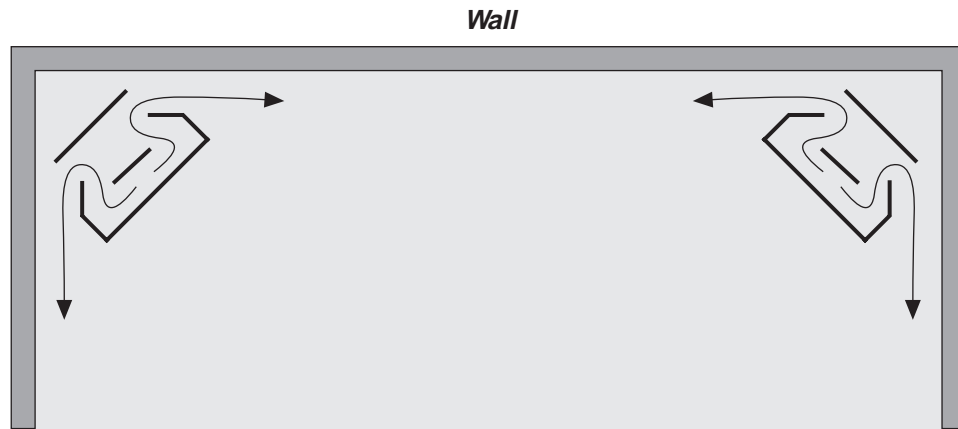


Figure 4.53: Bass horn in Klipsch horn speaker.

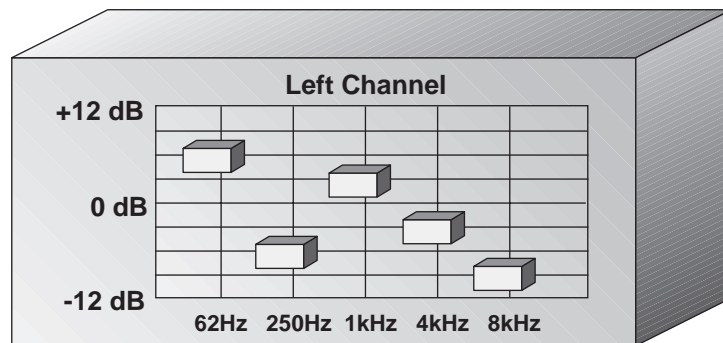


Figure 4.54: Graphic equalizer.

Chapter 5

Electricity

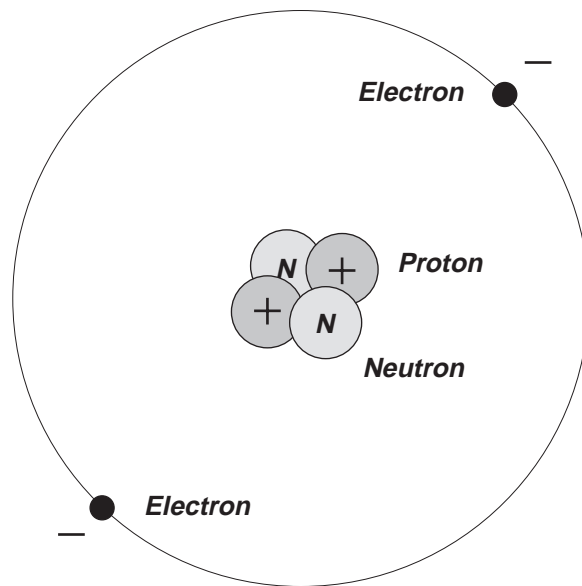


Figure 5.1: Example of an atom: a Helium atom.

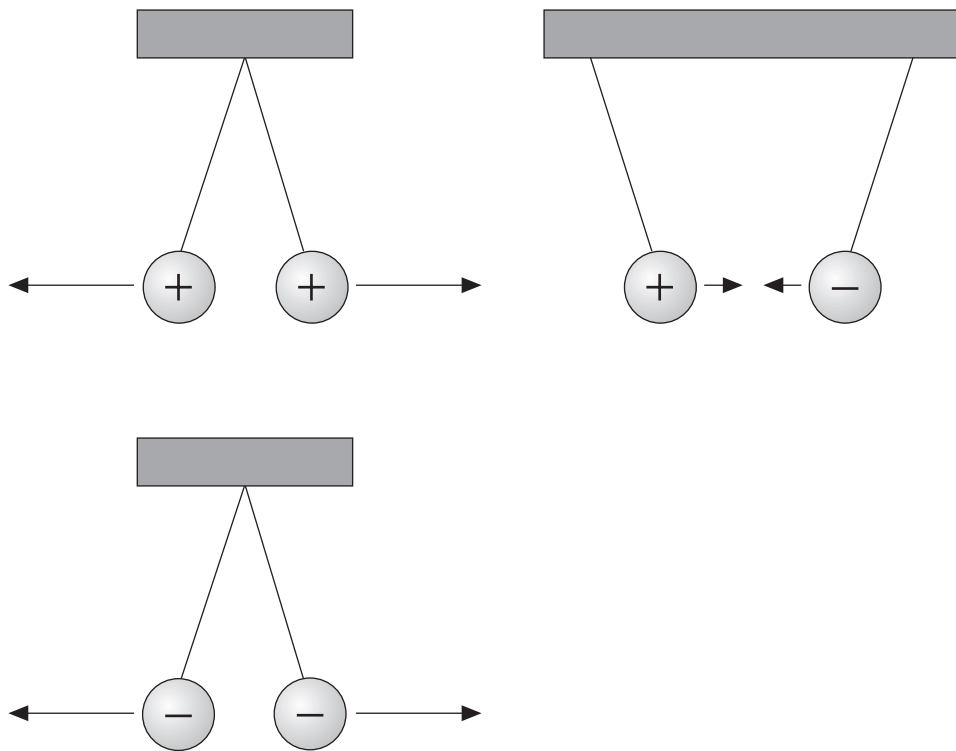


Figure 5.2: Forces between charged objects; like charges repel and unlike charges attract.

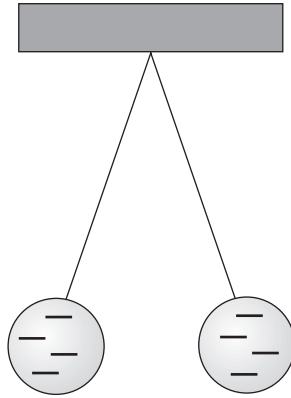


Figure 5.3: Charged ping-pong balls repelling each other.

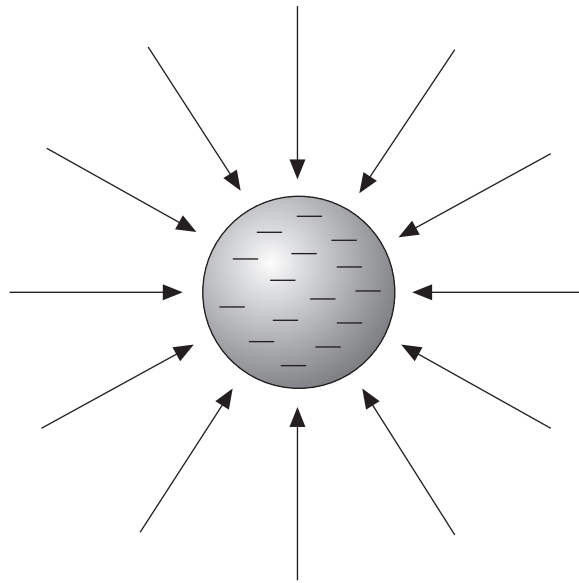


Figure 5.4: Electric field produced by a charged object.

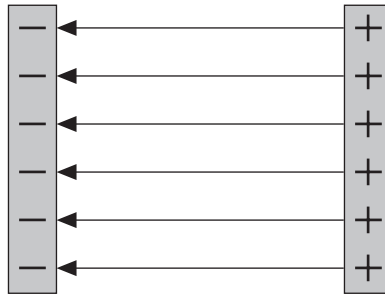


Figure 5.5: Electric field between two charged plates.

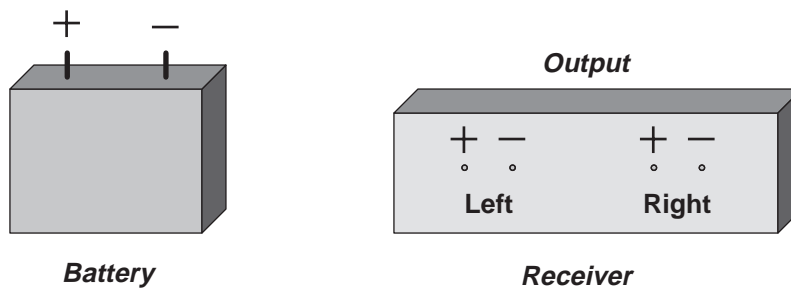


Figure 5.6: Examples of voltage sources: a battery, the output of a receiver.

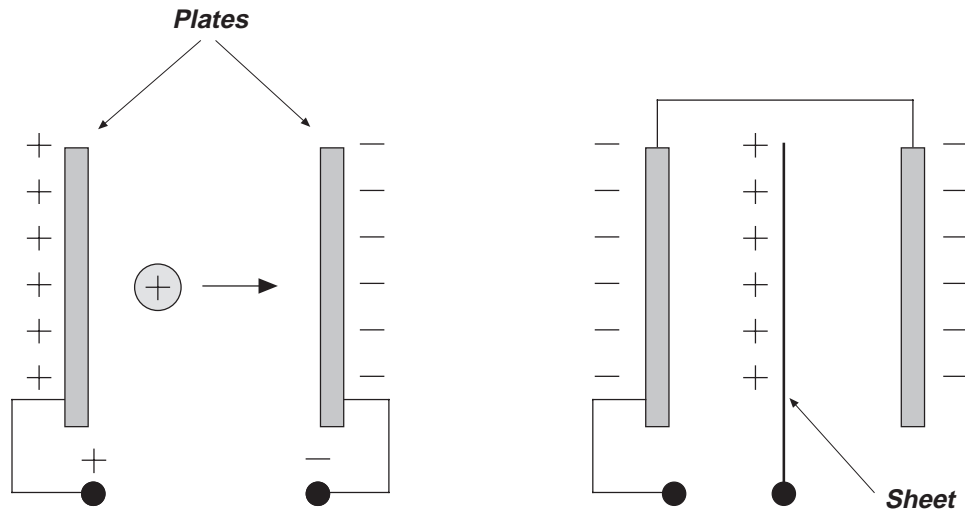


Figure 5.7: Electrostatic speaker: basic principle and actual speaker.

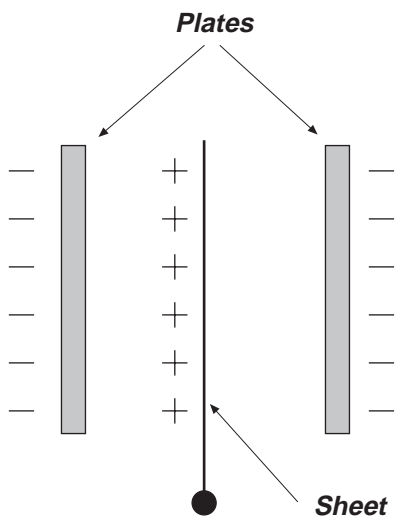


Figure 5.8: Simplified version of an electrostatic speaker at equilibrium.

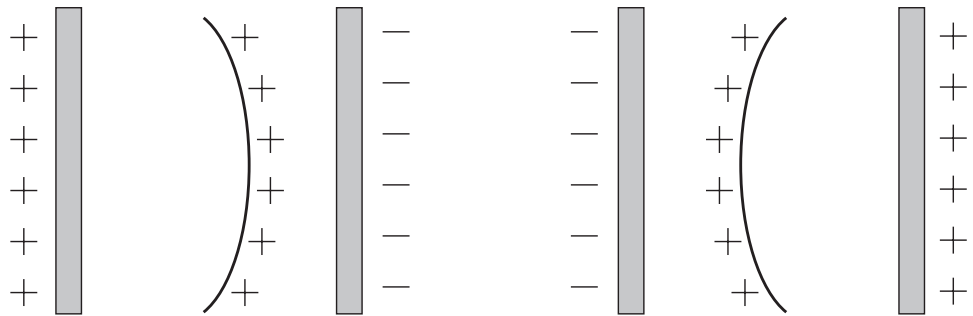


Figure 5.9: Push-pull action by two plates on charged sheet.

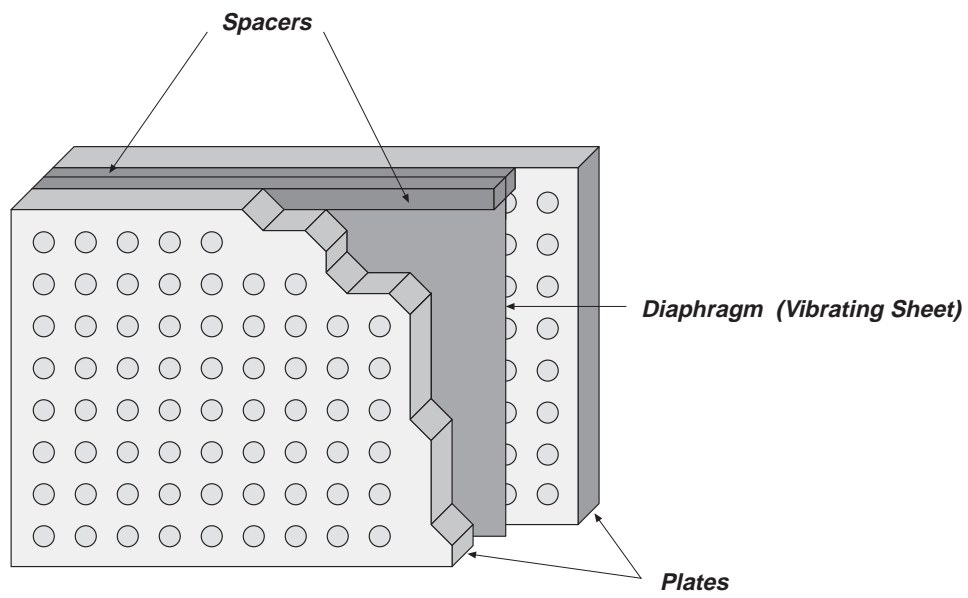


Figure 5.10: An electrostatic speaker.

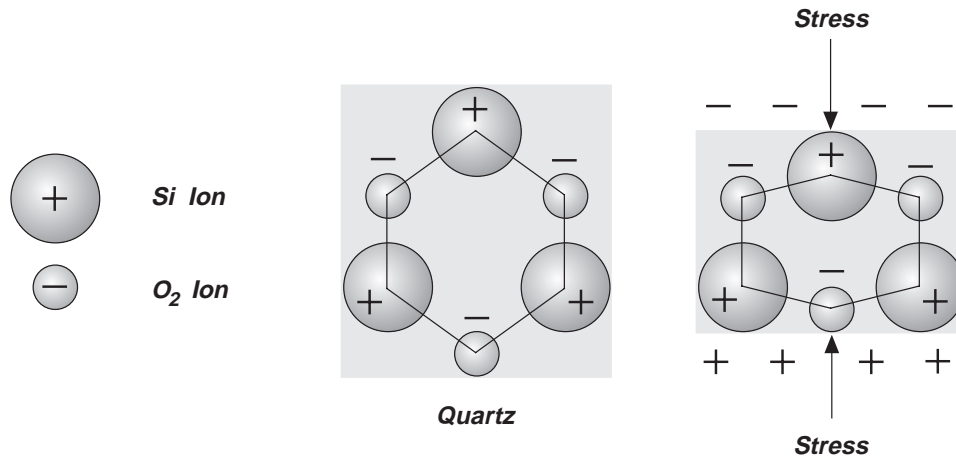


Figure 5.11: Some crystals under pressure produce positive and negative charges on surface.

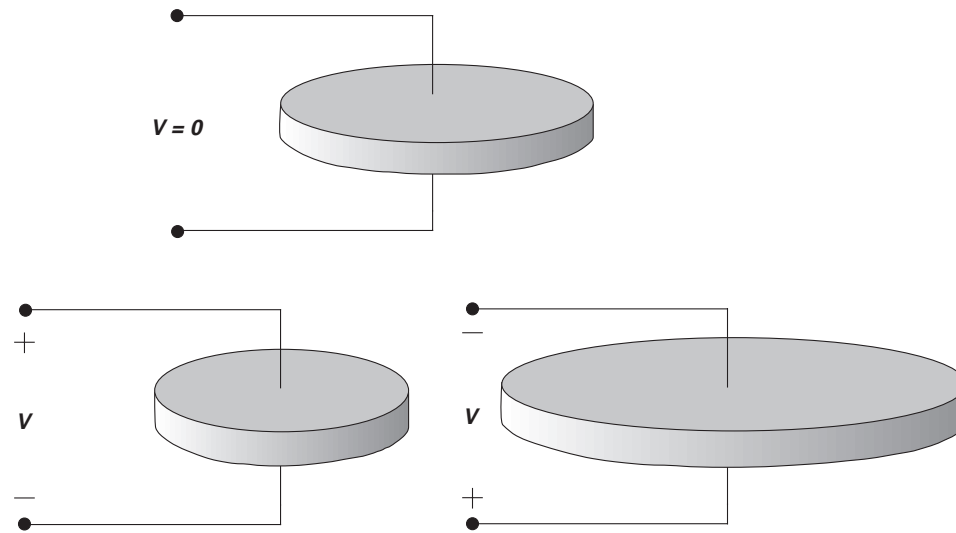


Figure 5.12: Dimensional changes of a piezoelectric ceramic when a voltage is applied.

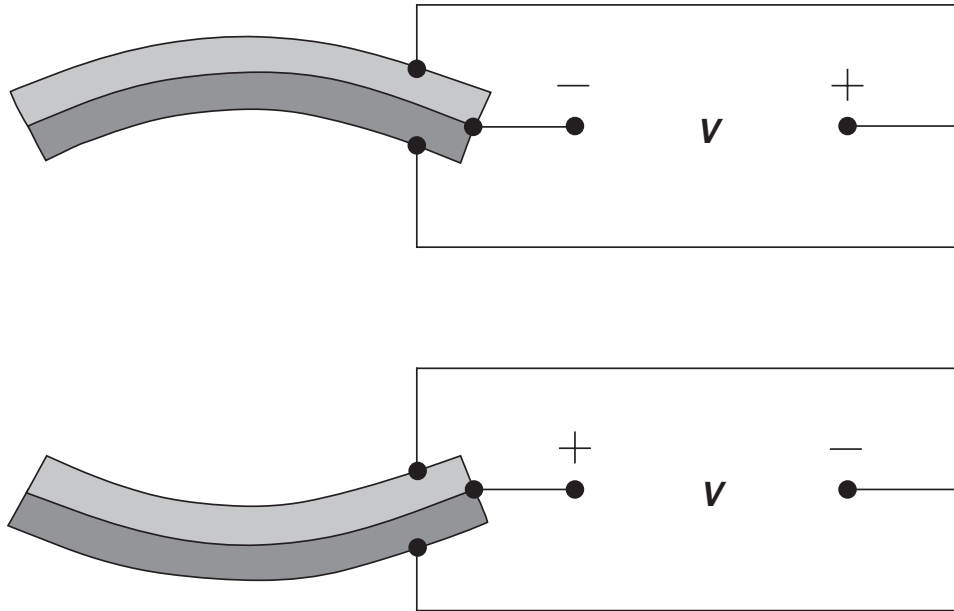


Figure 5.13: Bending action of a double piezoelectric driver.

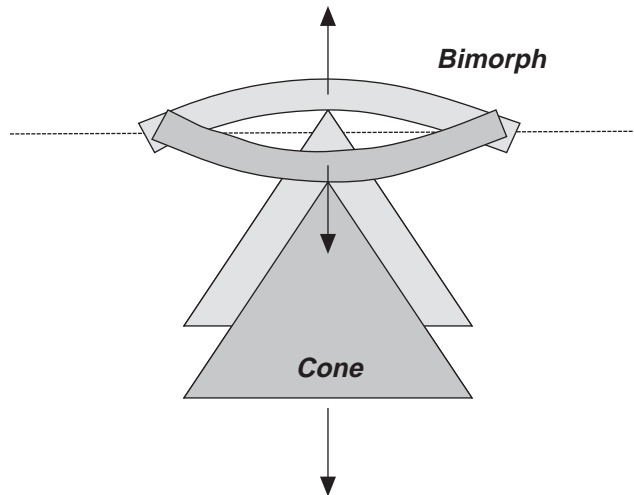


Figure 5.14: Pumping action of cone caused by bending of bimorph.

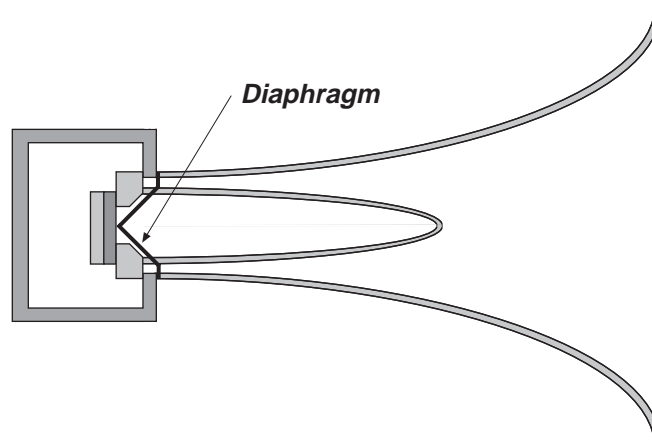


Figure 5.15: Typical piezo horn.

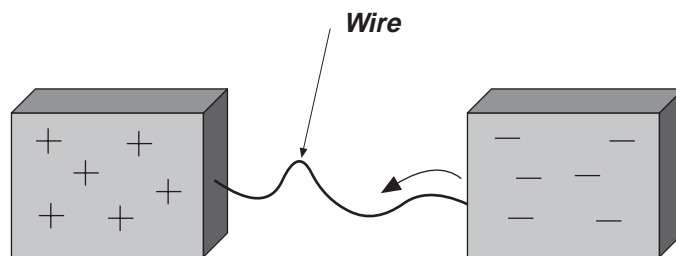


Figure 5.16: Wire connected between two charged objects allows charges to be transferred.

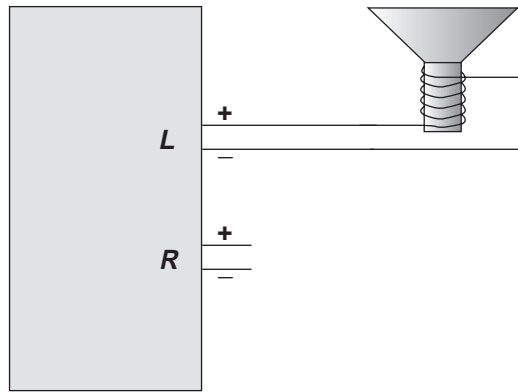


Figure 5.17: Flow of electric current from amplifier to speaker.

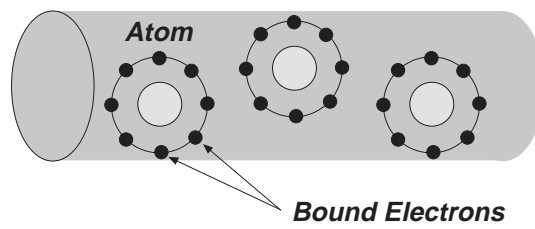


Figure 5.18: Solid with atoms where electrons are tightly bound and which does not conduct electricity under normal circumstances.

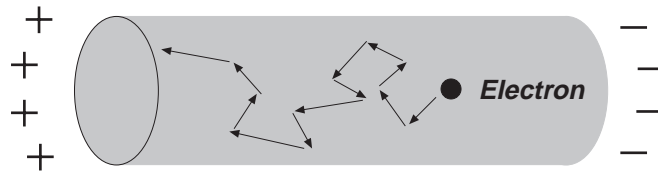


Figure 5.19: Motion of one electron in a conductor in the presence of an electric field. Changes of direction are due to scattering.

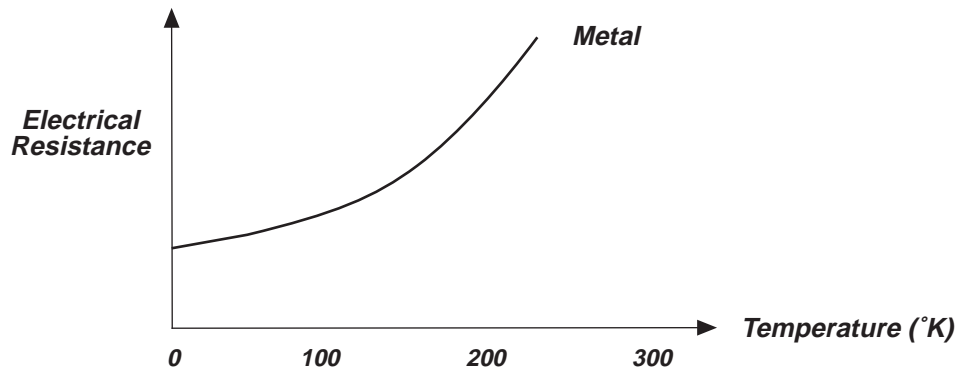


Figure 5.20: Temperature dependence of the electrical resistance in a conductor.

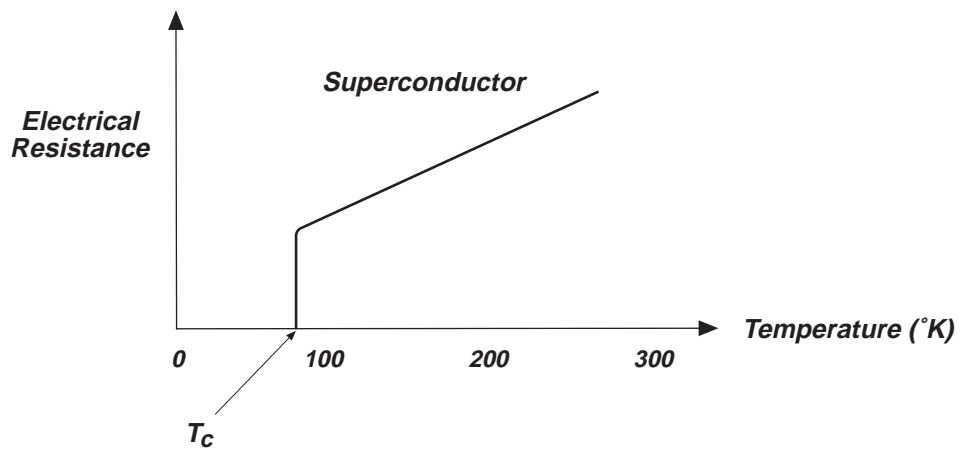


Figure 5.21: Superconductivity at T_c below which the resistance is zero.

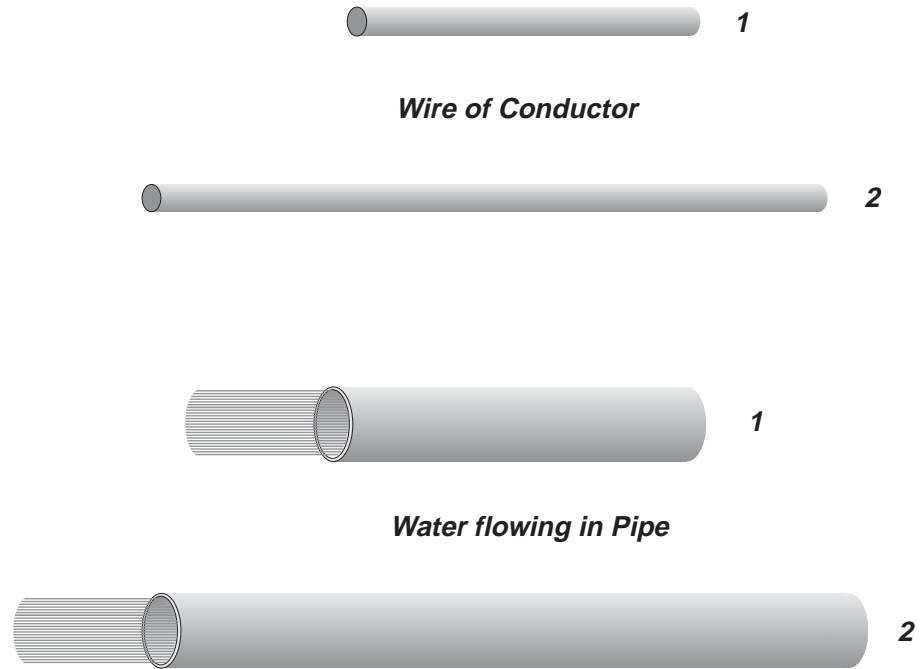


Figure 5.22: The resistance to current or to water flow increases as the length of a conductor or pipe increases. Resistance of 2 is double that of 1.

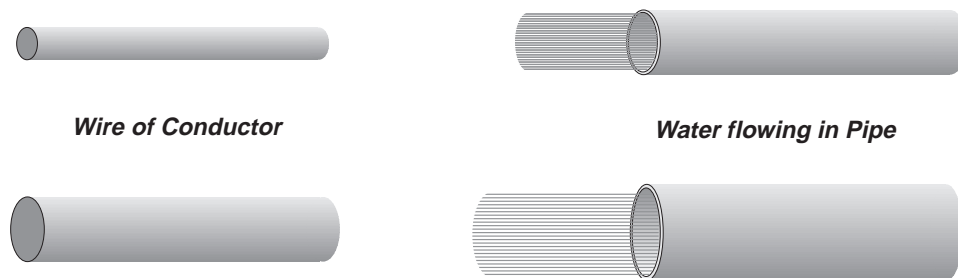


Figure 5.23: By increasing the cross-sectional area of a conductor, resistance to current or water flow decreases.

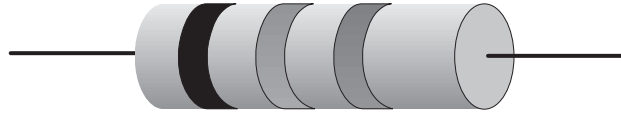


Figure 5.24: Resistor with colored bands to specify its resistance value.

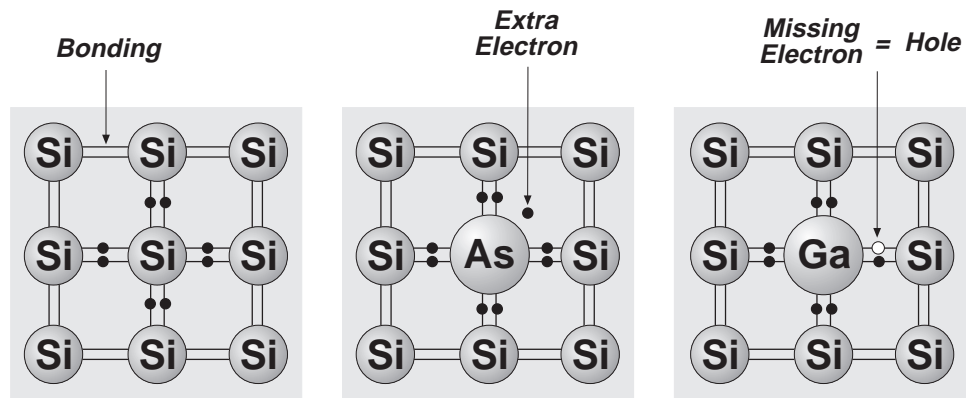


Figure 5.25: Pure silicon, silicon doped with arsenic, and silicon doped with gallium.

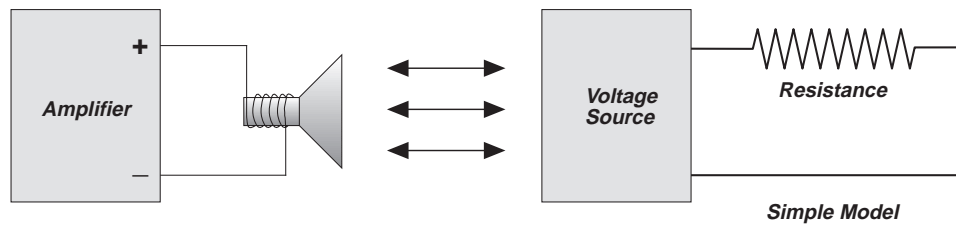


Figure 5.26: Example of simple circuit.

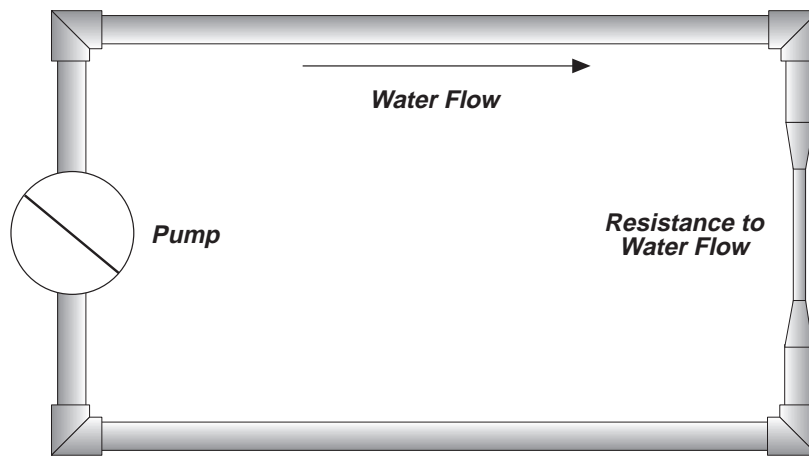


Figure 5.27: Model using water for electric circuit.

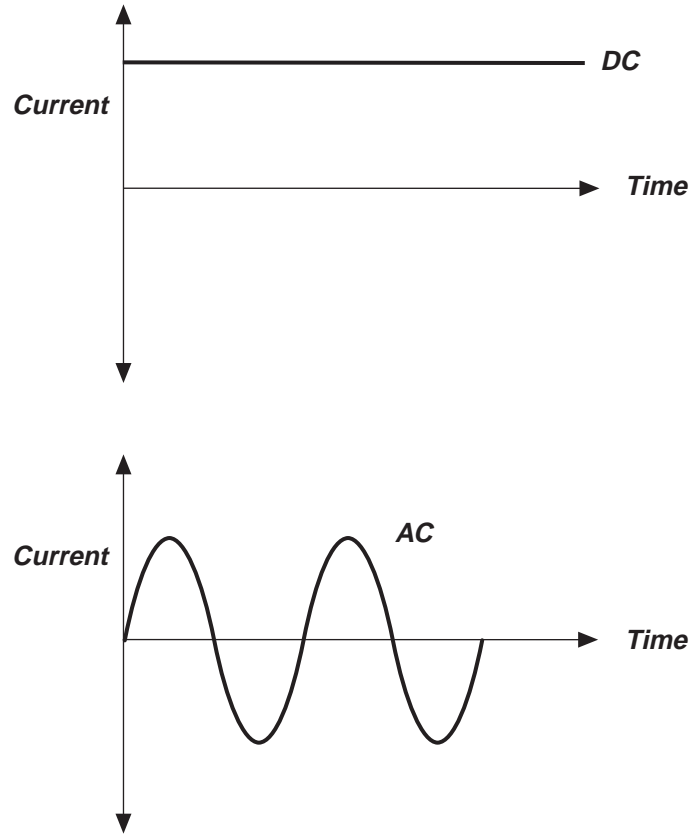


Figure 5.28: Comparison between DC and AC current.

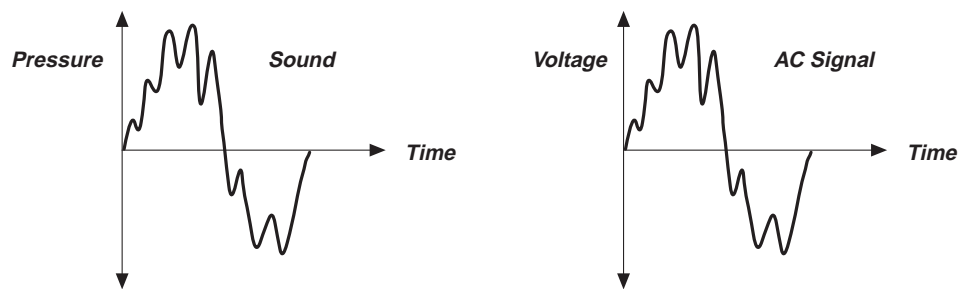


Figure 5.29: Representation of a sound wave by an AC electrical signal.

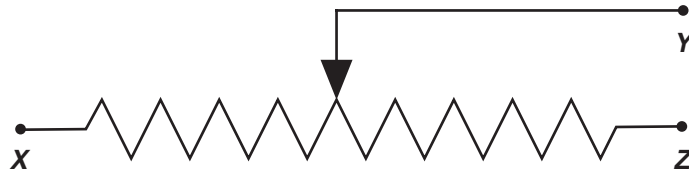


Figure 5.30: Variable resistance between X and Y.

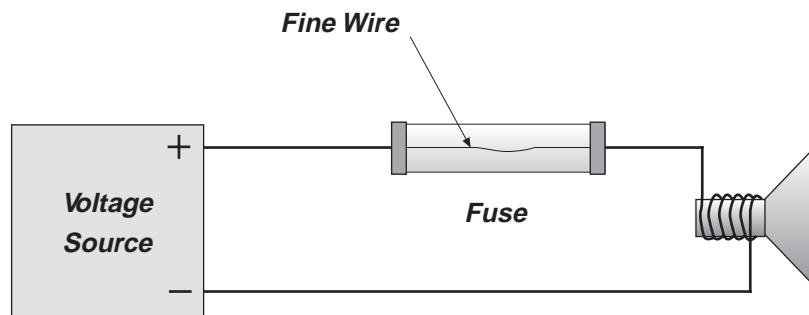


Figure 5.31: Fuse to protect speaker.

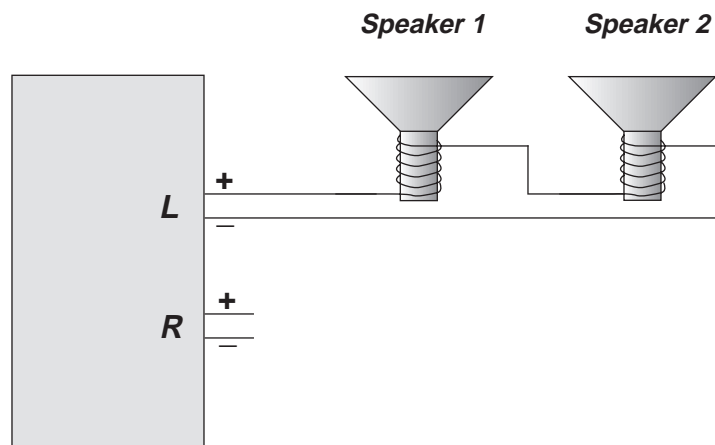


Figure 5.32: Two speakers connected in series to one channel of amplifier.

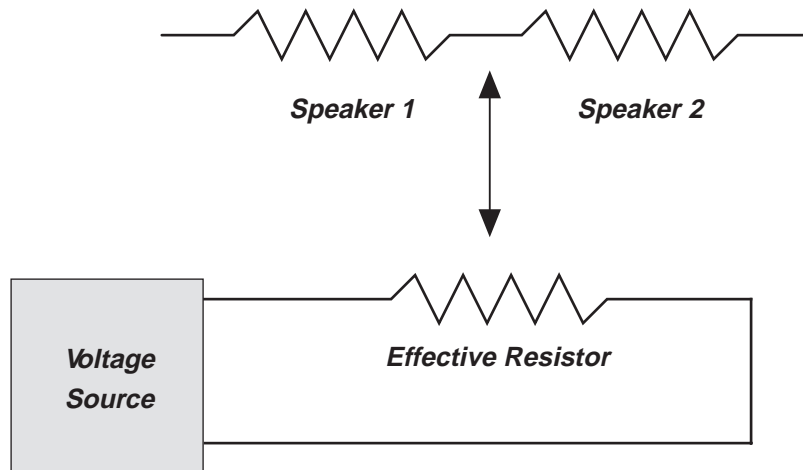


Figure 5.33: Model of series circuit.

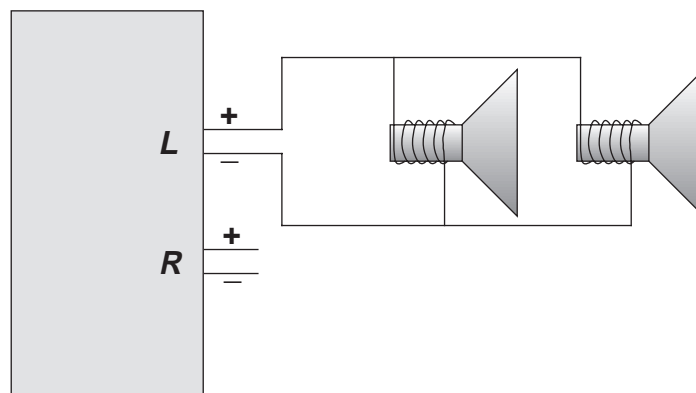


Figure 5.34: Parallel connection of two speakers to an amplifier.

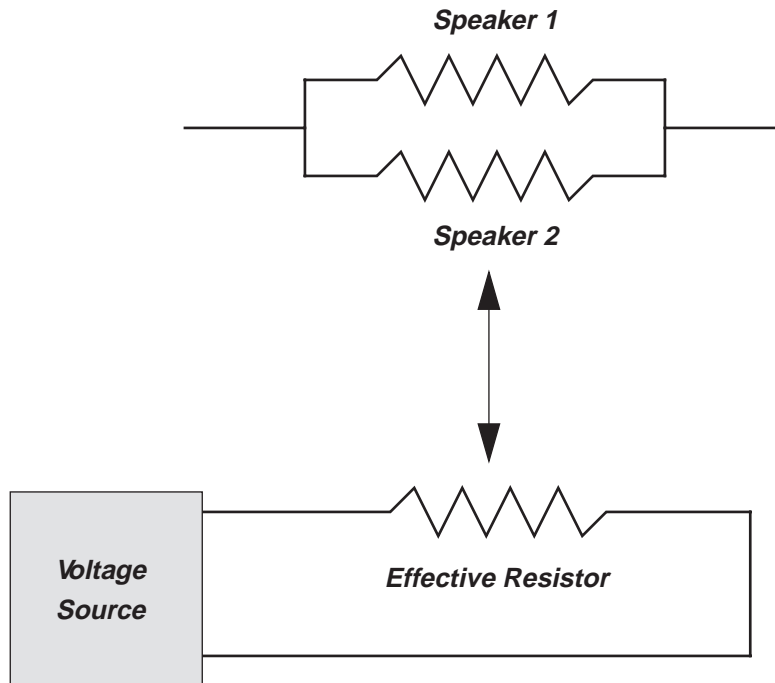


Figure 5.35: Model of parallel connections.

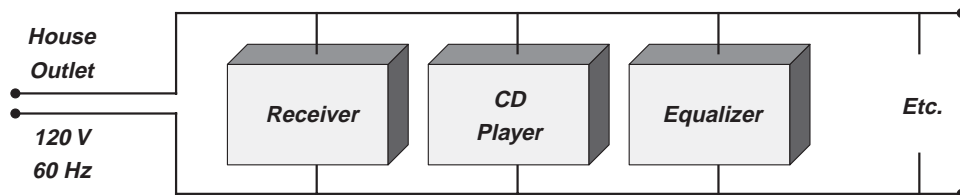


Figure 5.36: Parallel connections of hi-fi components to house electrical outlet.

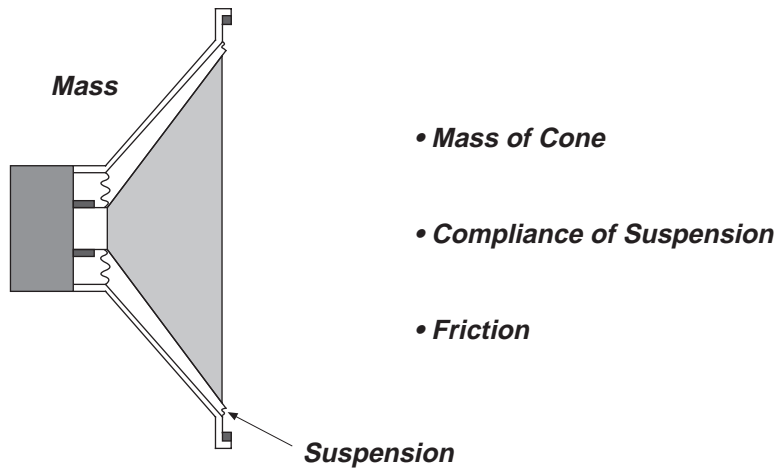


Figure 5.37: Response of cone speaker to a force.

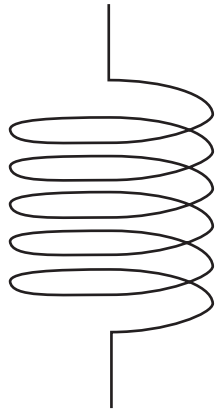


Figure 5.38: Coil used to produce a magnetic field when a current flows through it. It has inductance.

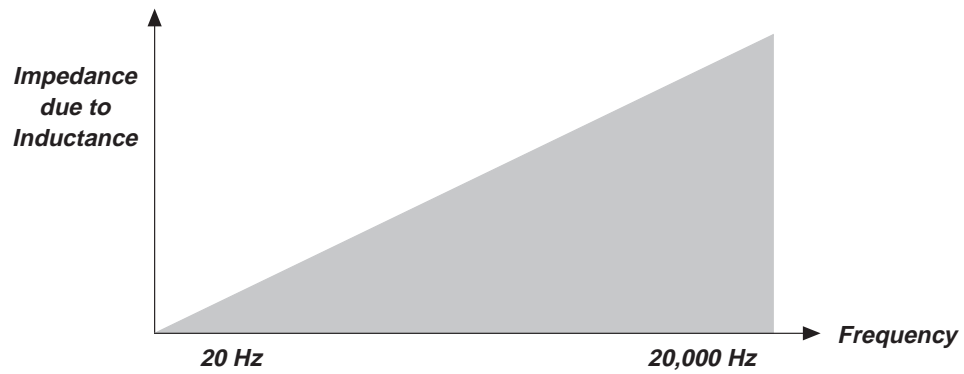


Figure 5.39: Frequency dependence of impedance associated with inductance.

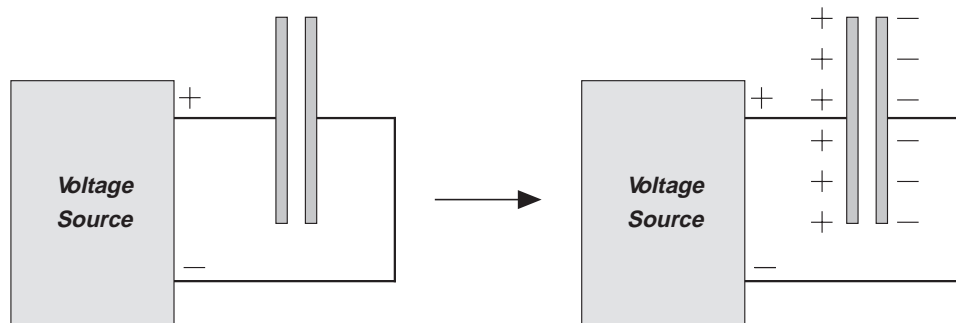


Figure 5.40: Charging of a capacitor.

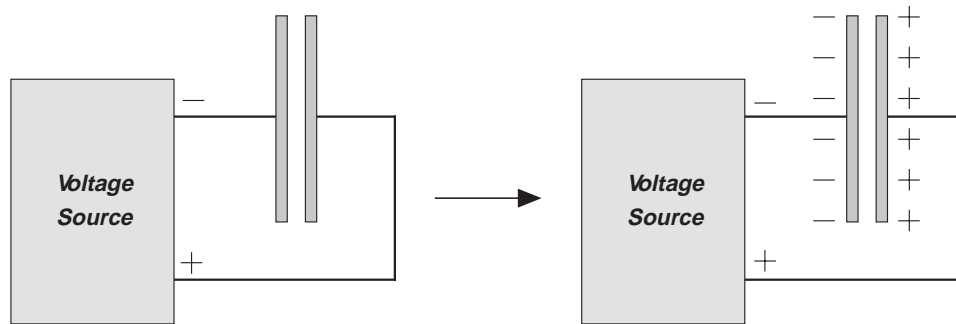


Figure 5.41: Charging of a capacitor when polarity of voltage source is reversed.

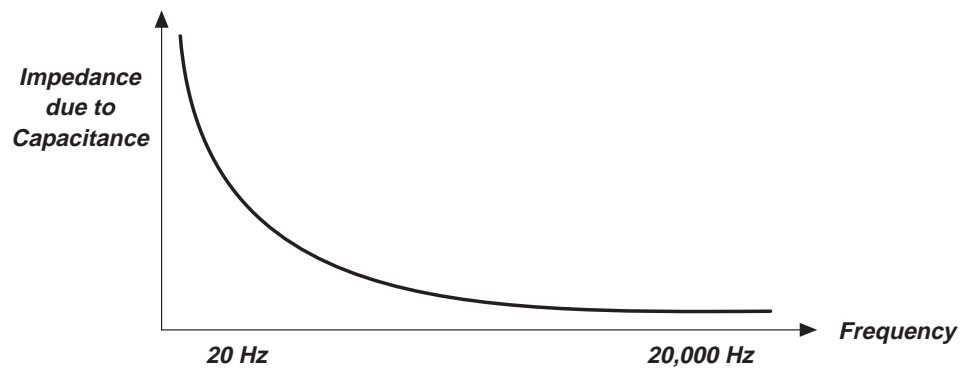


Figure 5.42: Frequency dependence of impedance due to capacitance.

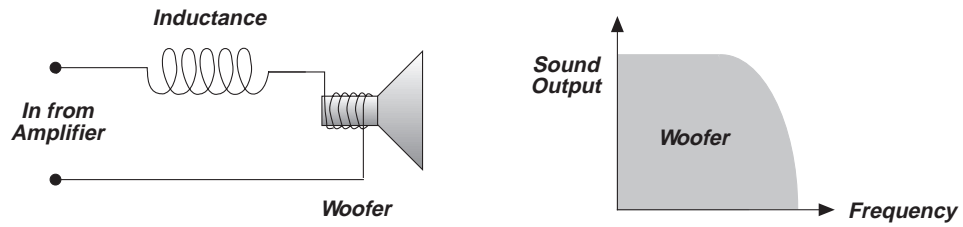


Figure 5.43: Inductance in series with woofer prevents high frequencies from reaching it.

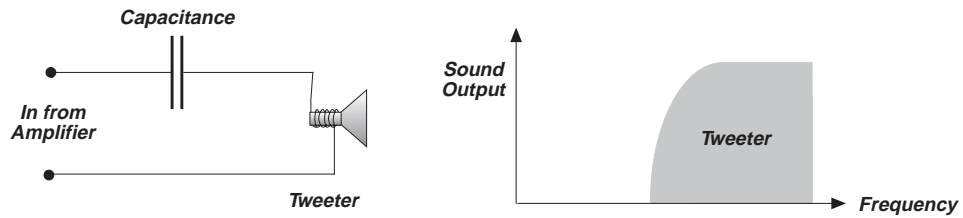


Figure 5.44: Capacitance in series with tweeter. It prevents low frequencies from reaching it.

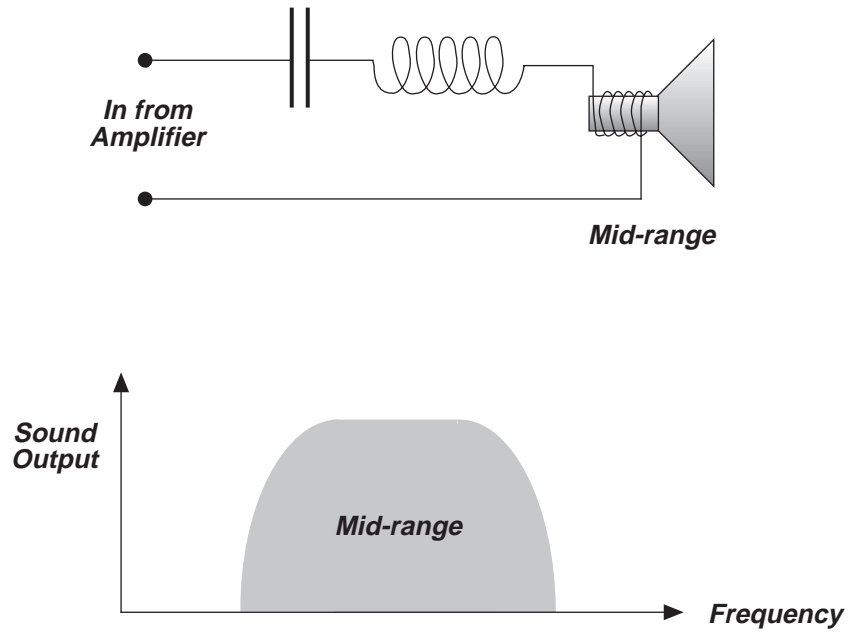


Figure 5.45: Capacitance and inductance in series with mid-range speaker to prevent the high and low frequencies from reaching it.

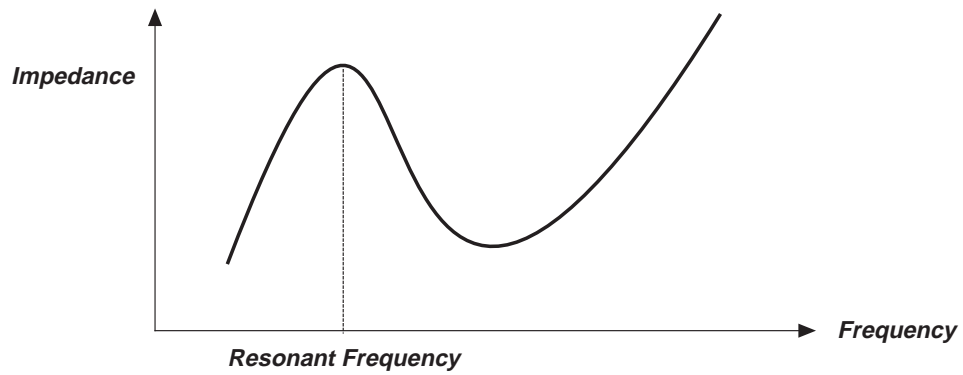


Figure 5.46: Impedance curve of driver.

Chapter 6

Amplifiers

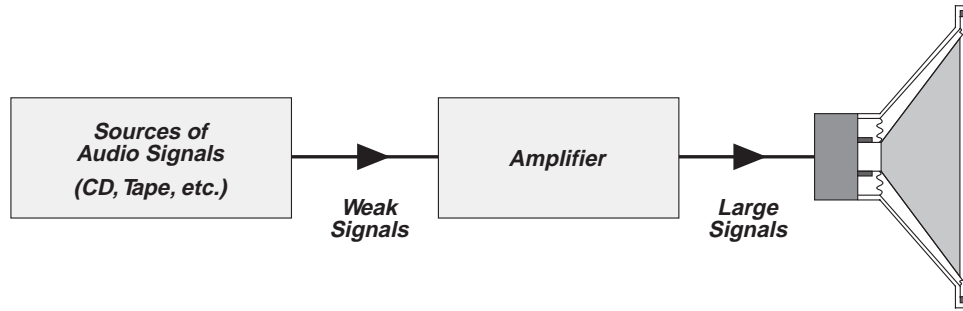


Figure 6.1: Importance of amplifier in hi-fi system.

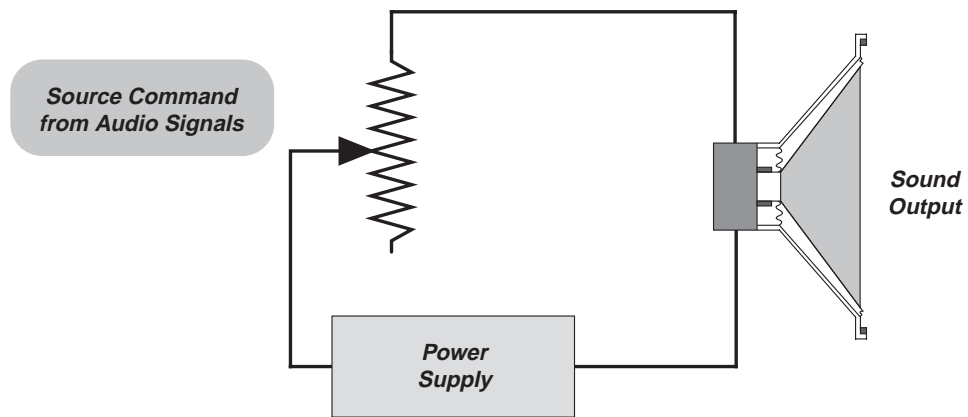


Figure 6.2: Basic amplifier.

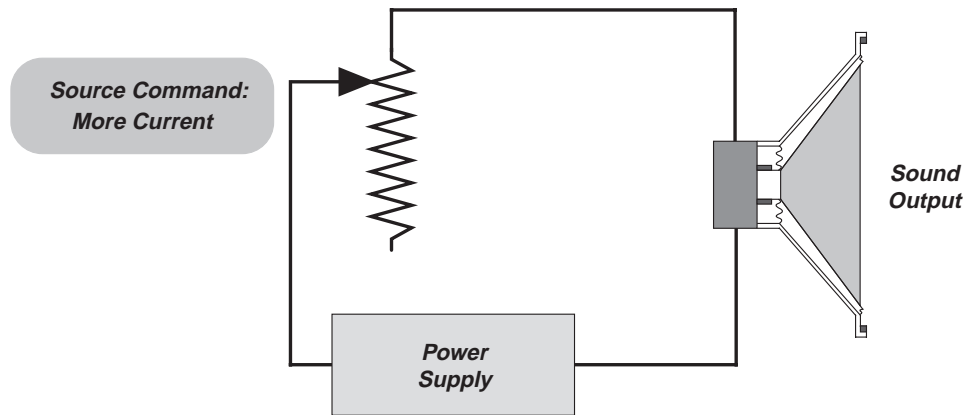


Figure 6.3: Amplifier command for more current.

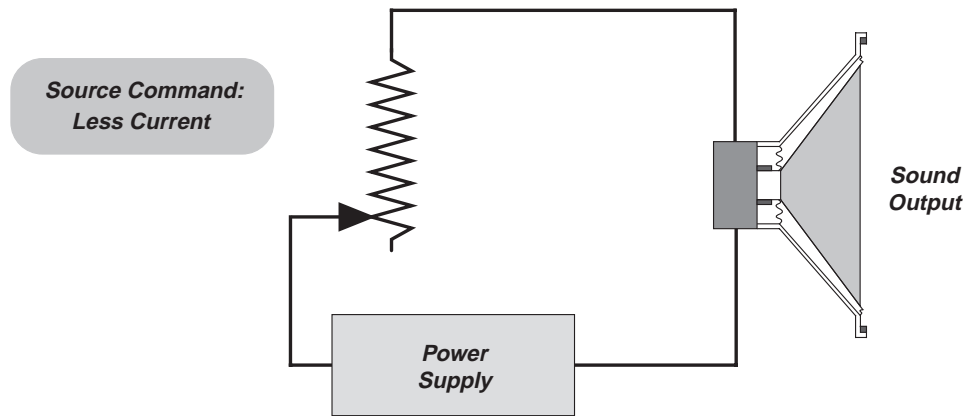


Figure 6.4: Amplifier command for less current.

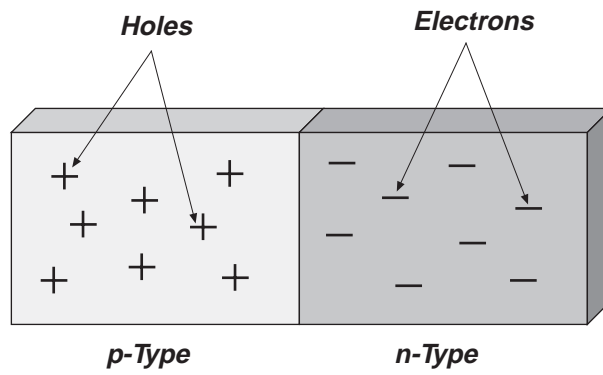


Figure 6.5: Semiconductor junction.

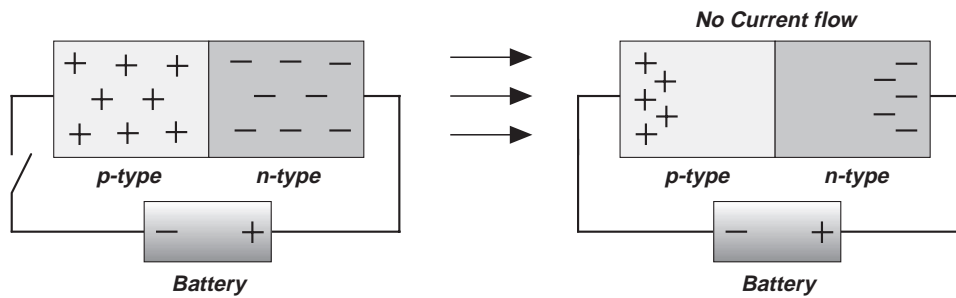


Figure 6.6: Reverse-biased semiconductor junction.

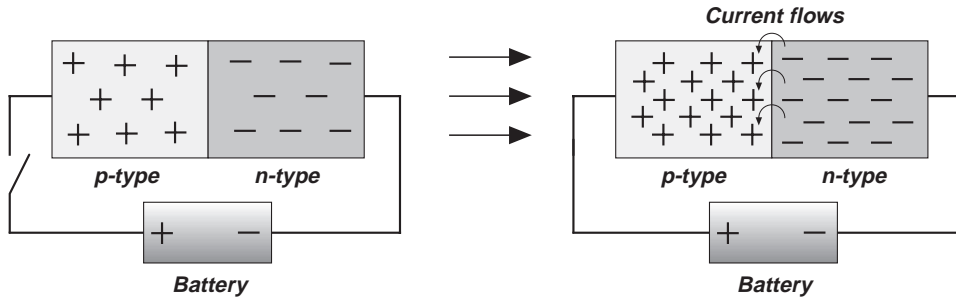


Figure 6.7: Forward-biased semiconductor junction.

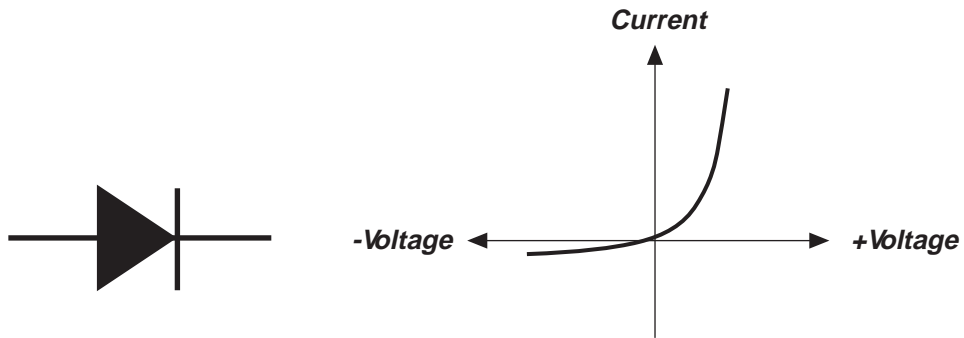


Figure 6.8: Symbol for diodes and its characteristics.

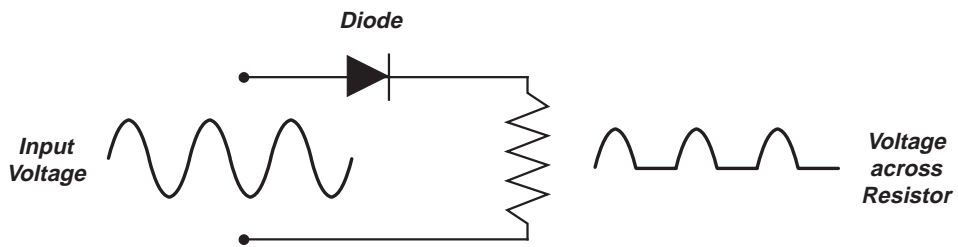


Figure 6.9: Rectifier action of a diode when an AC voltage is applied.

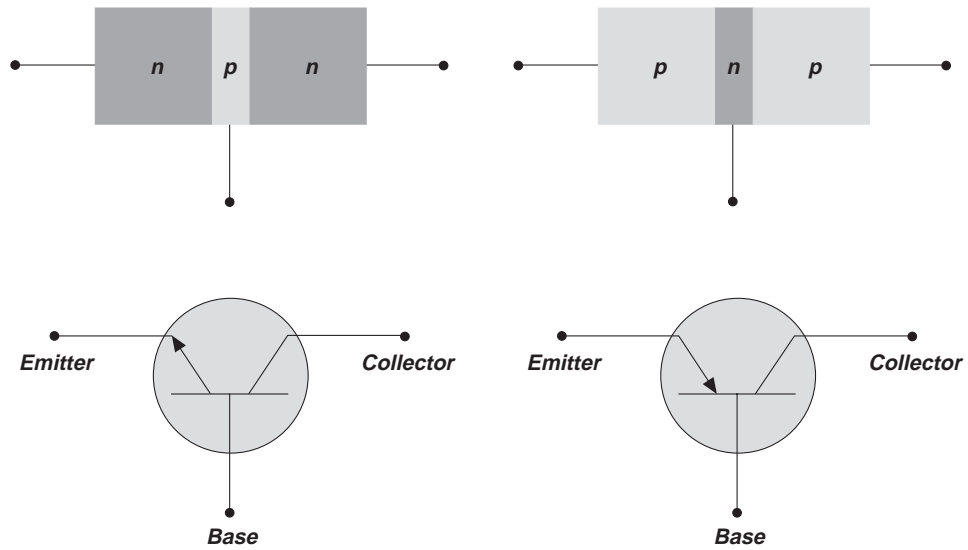


Figure 6.10: Diagram of transistor and its circuit symbol for two possibilities.

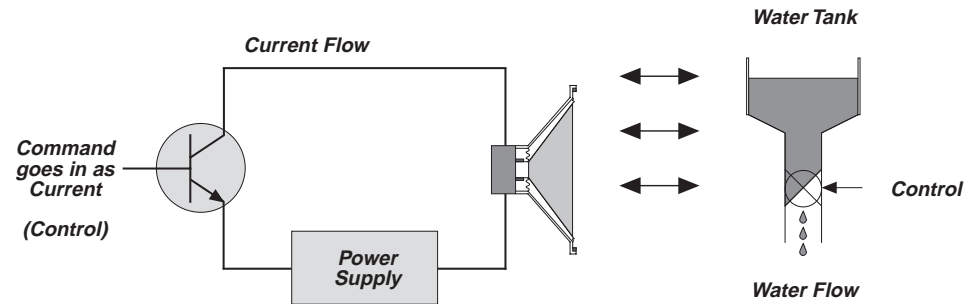


Figure 6.11: Amplifier action of transistor in a circuit compared to control of water flow.

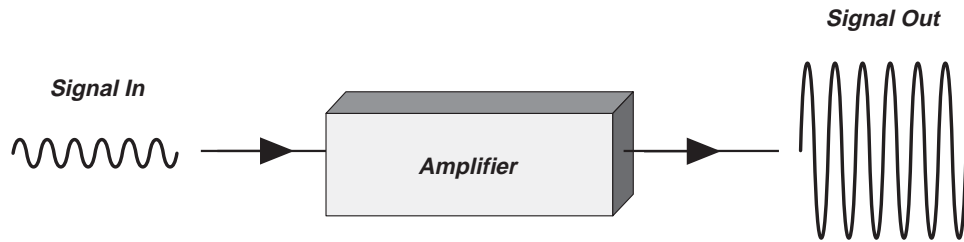


Figure 6.12: Function of an amplifier.

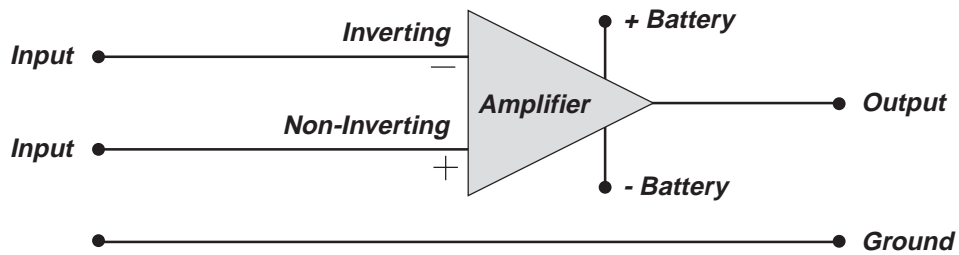


Figure 6.13: Amplifier integrated on a chip.

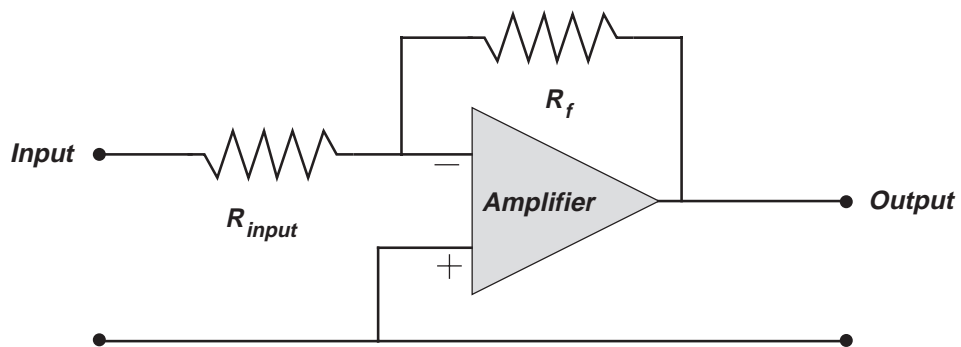


Figure 6.14: Operational amplifier with negative feedback.

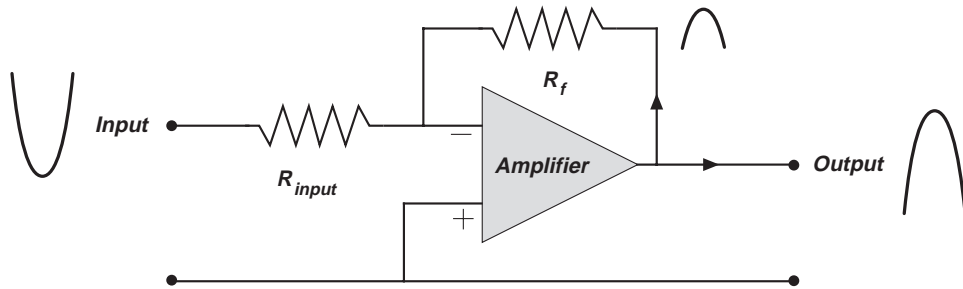


Figure 6.15: Negative feedback corrects fluctuations in gain.

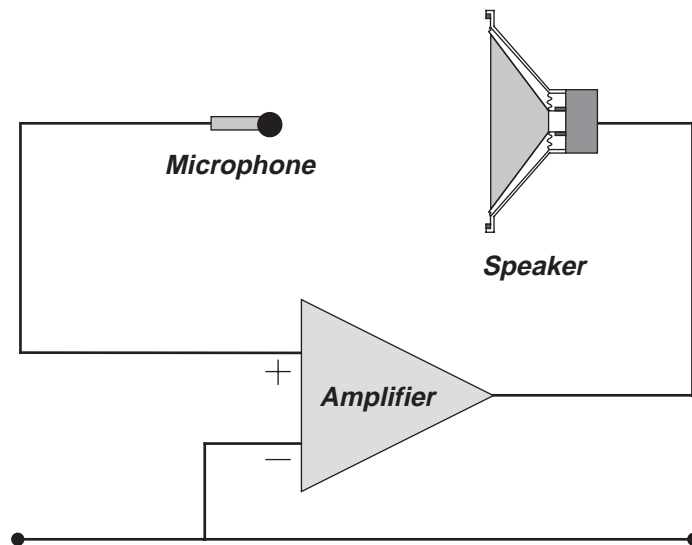


Figure 6.16: Positive feedback in large hall with a mike and a loudspeaker system driven by mike.

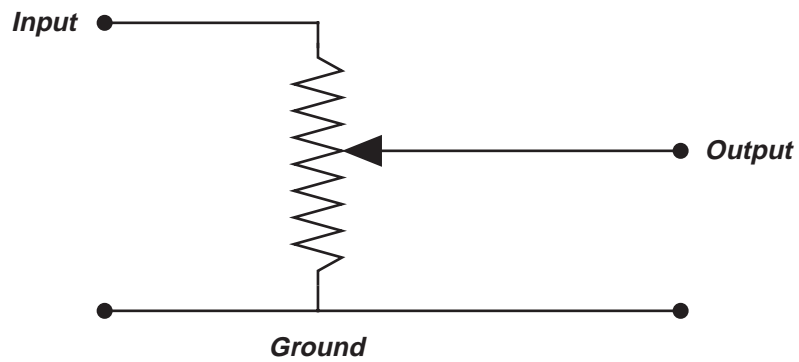


Figure 6.17: Volume control.

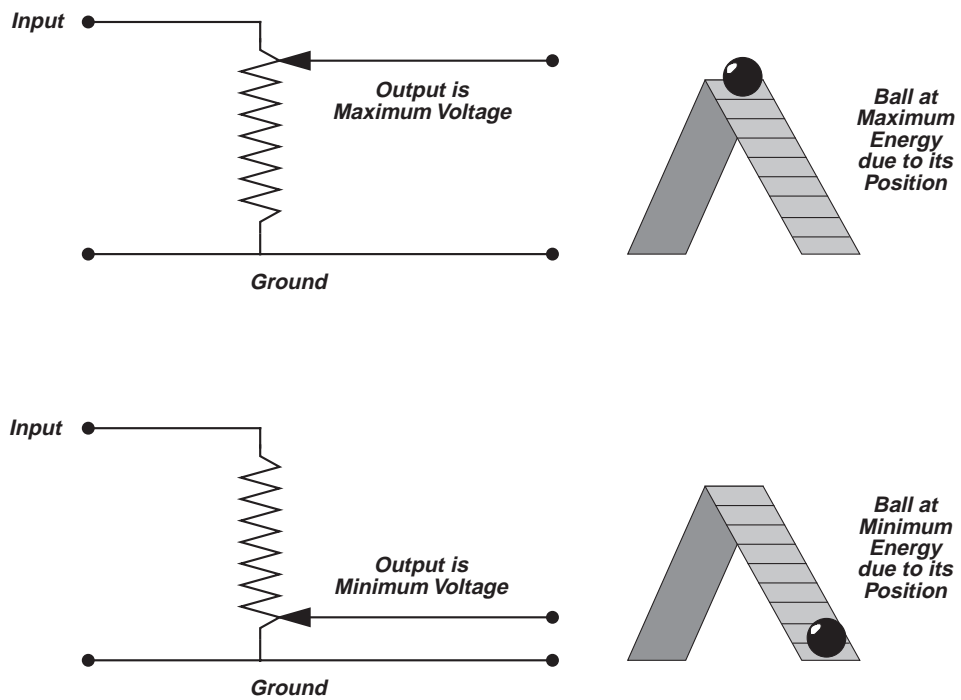


Figure 6.18: Comparison of potentiometer action with energy of a ball on a ladder.



Figure 6.19: Bass and Treble controls.

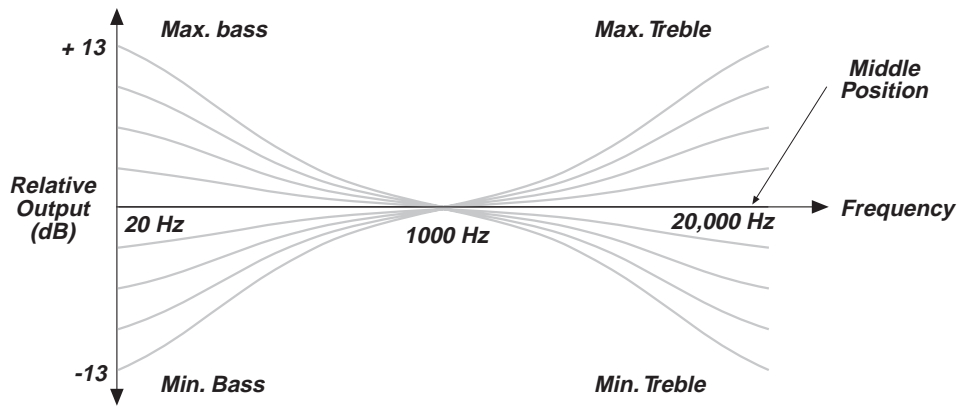


Figure 6.20: Effect on signal spectrum of Bass and Treble controls.

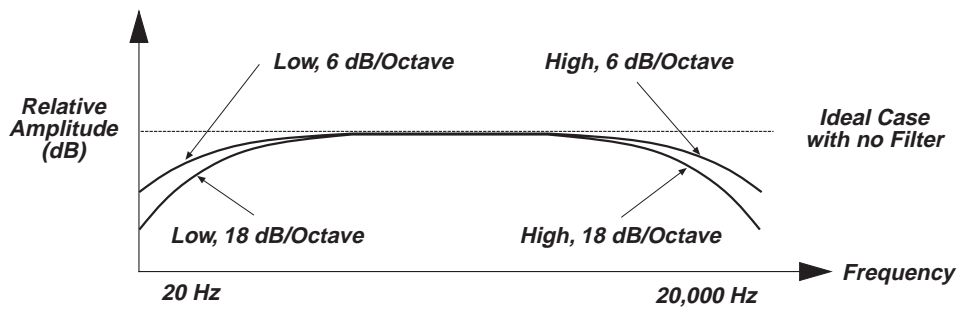


Figure 6.21: Action of LOW and HIGH filters with 6 dB/octave attenuation, and also with 18 db/octave attenuation.

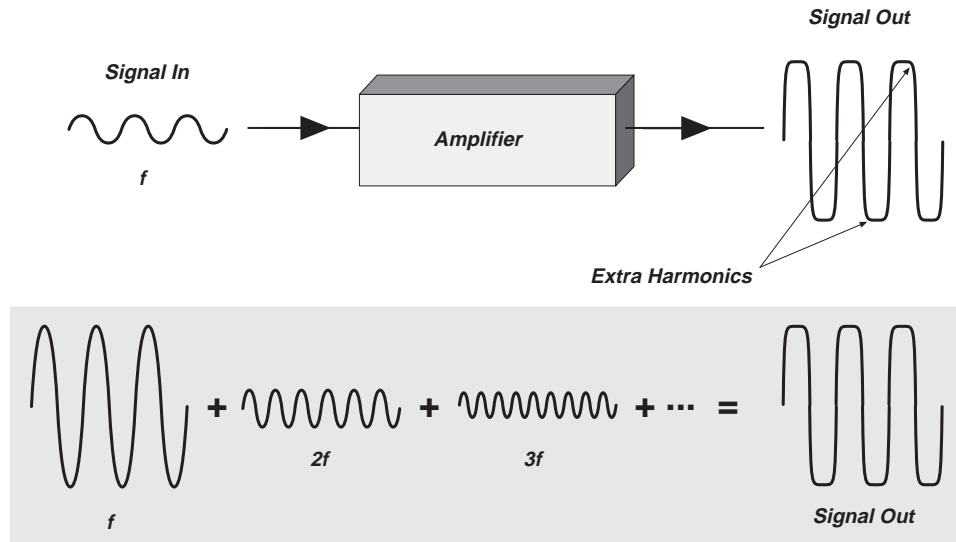


Figure 6.22: Harmonic distortion by amplifier.

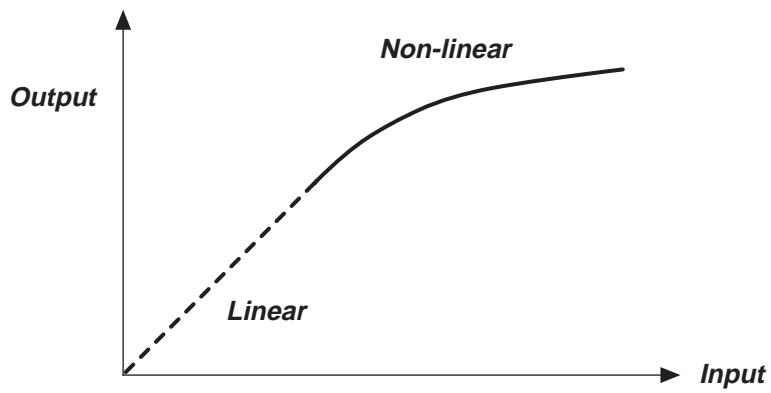


Figure 6.23: Non-linear gain of amplifier.

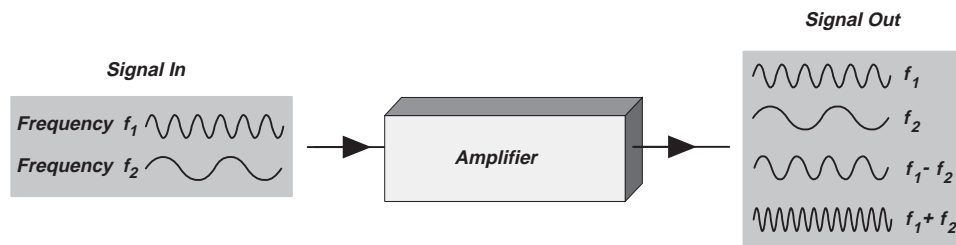


Figure 6.24: IM distortion in amplifier.

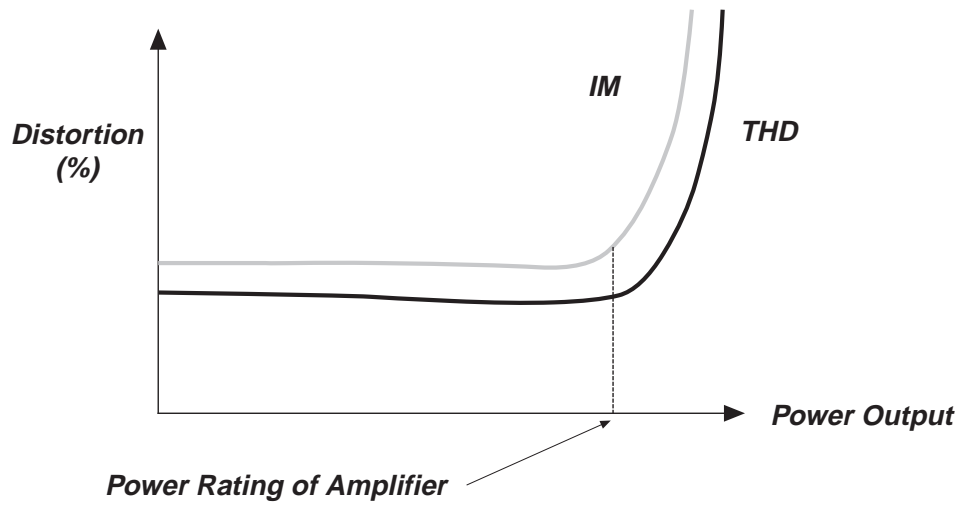


Figure 6.25: Distortion increases sharply about power rating of amplifier.

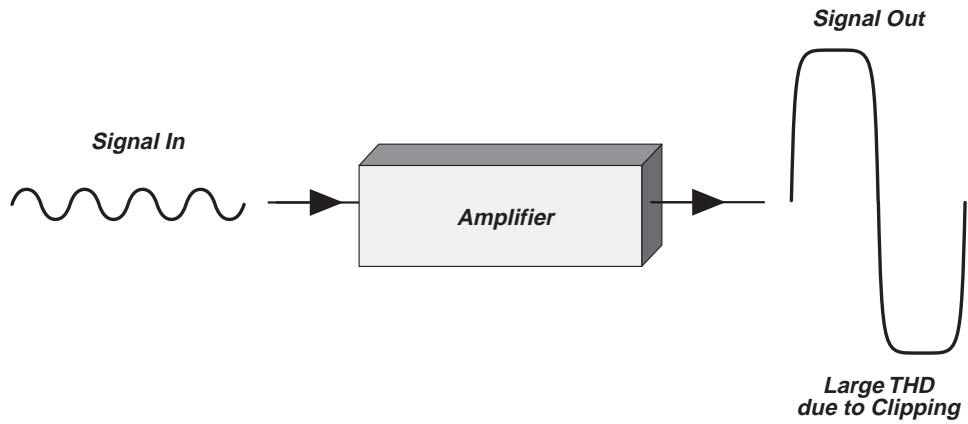


Figure 6.26: Clipping of waveform by amplifier at high output levels beyond the rated value.

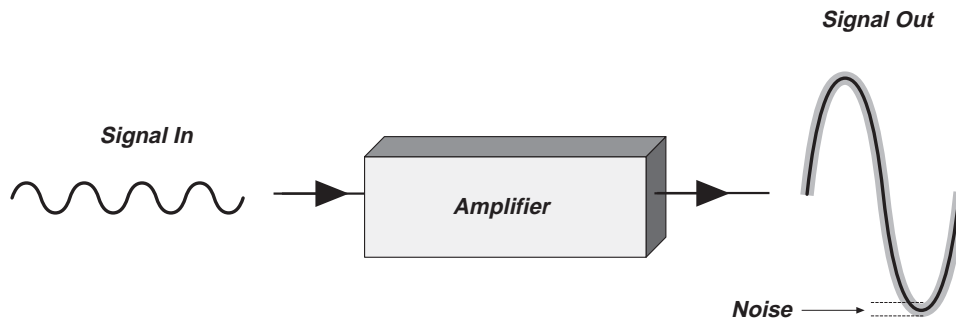


Figure 6.27: Effect of noise from amplifier.

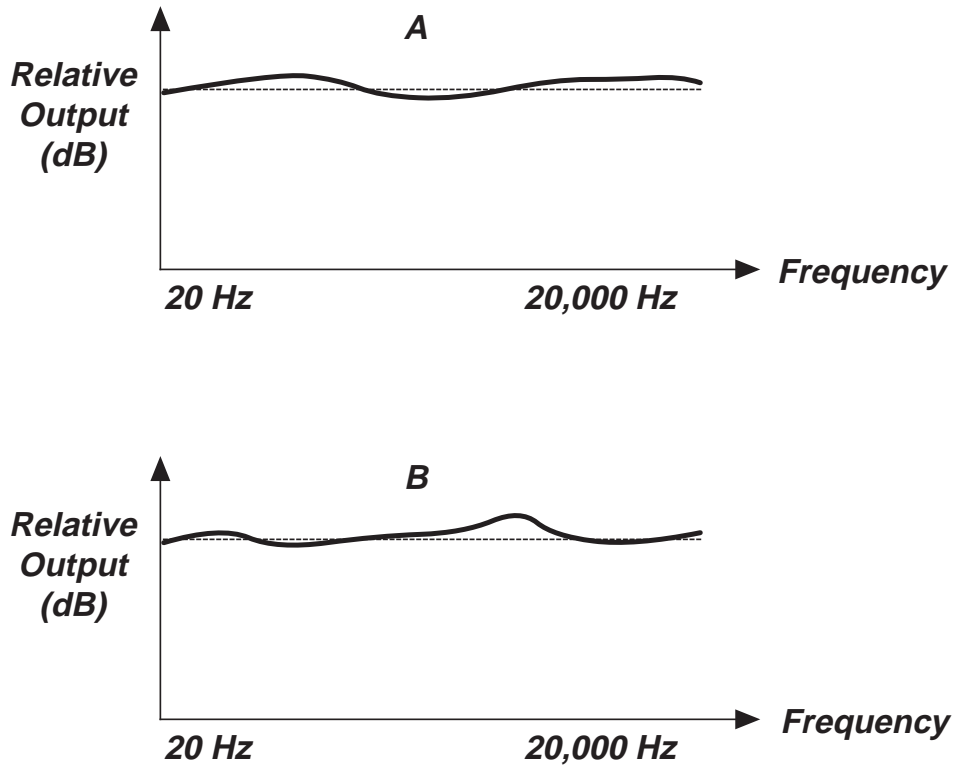


Figure 6.28: Comparing 2 amplifiers with the same specs. Even though their specs are the same, the amplifiers will sound different.

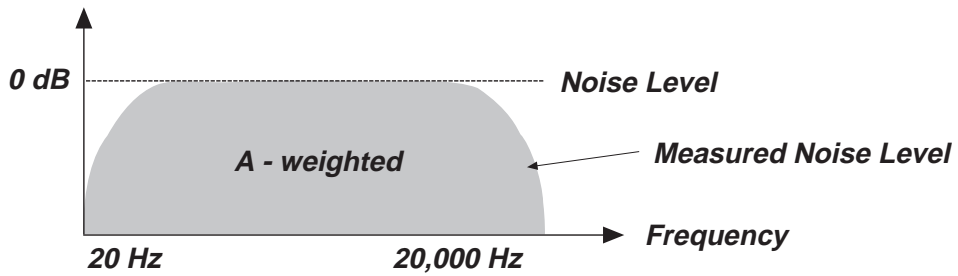


Figure 6.29: A-weighted method of measuring noise.

Chapter 7

Electromagnetism

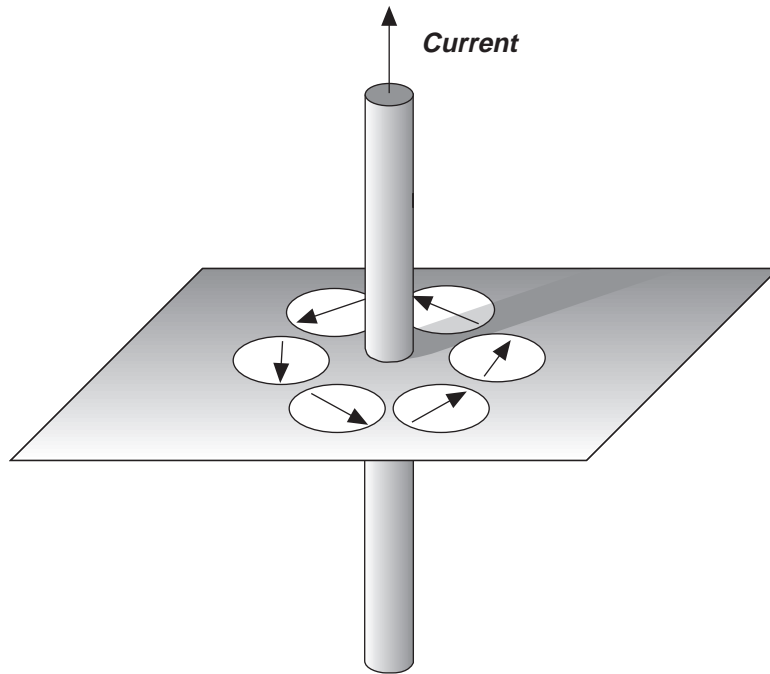


Figure 7.1: Effect of current in a wire on compasses around it.

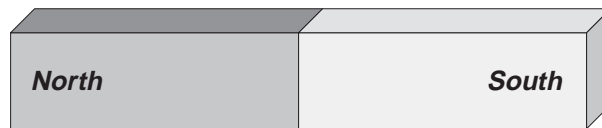


Figure 7.2: Bar magnet has a north pole and a south pole.

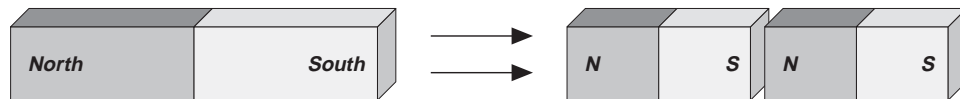


Figure 7.3: Cutting a bar magnet produces shorter magnets each with its own respective north and south poles.

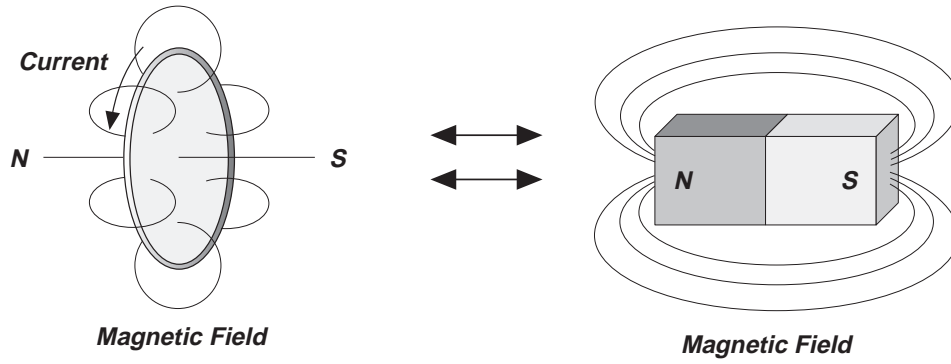


Figure 7.4: Magnetic dipole is the basic unit of magnetism.

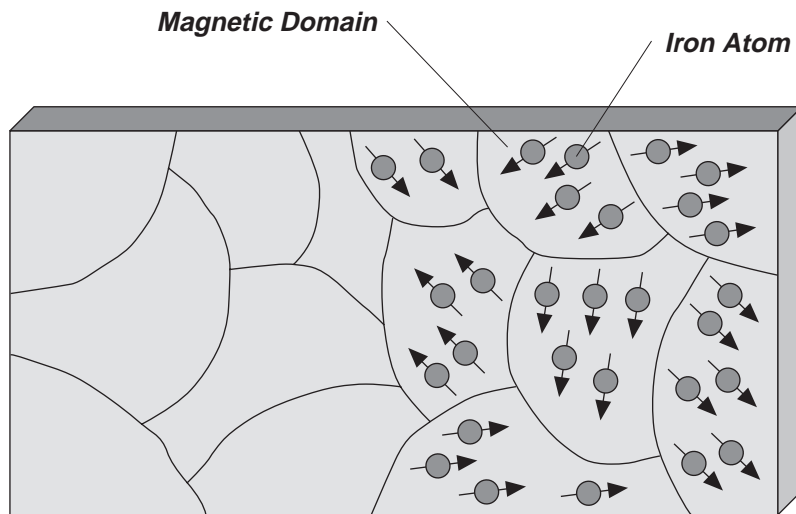


Figure 7.5: Unmagnetized piece of iron.

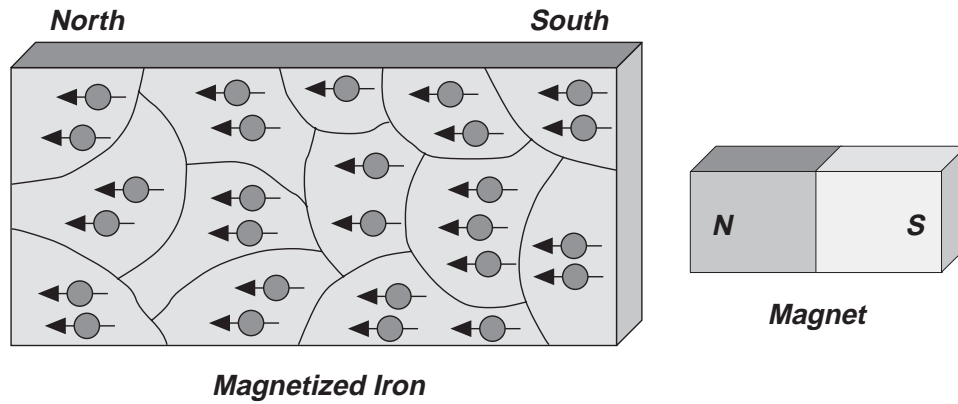


Figure 7.6: Alignment of domains in a piece of iron by a bar magnet. Iron becomes magnetized.

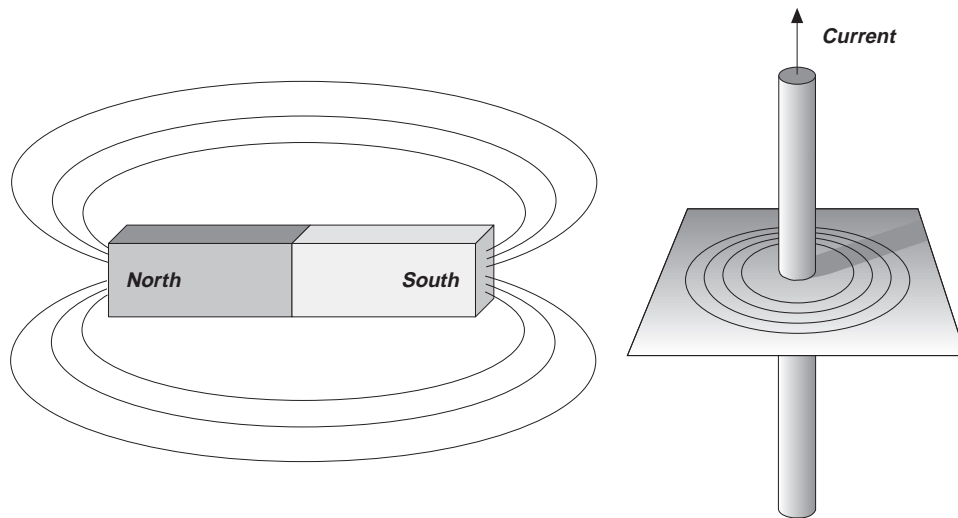


Figure 7.7: Magnetic field around a bar magnet and a wire carrying a current.

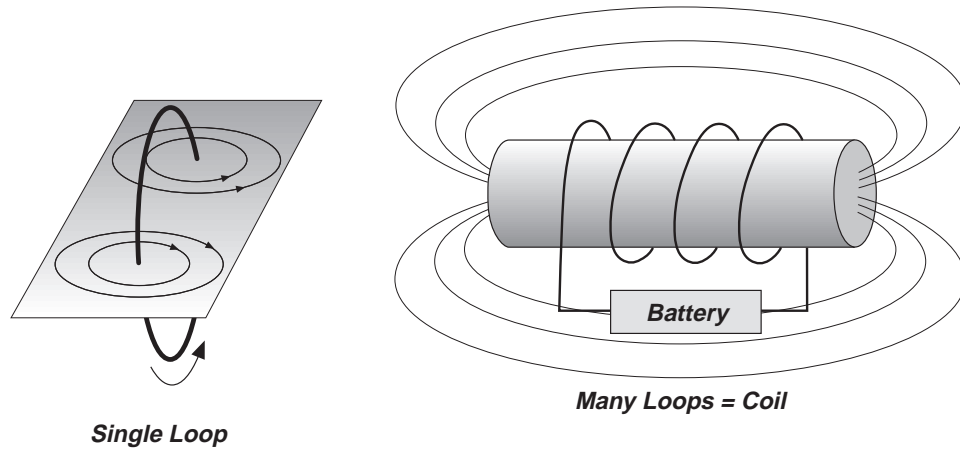


Figure 7.8: Increasing the magnetic field produced by a current in a wire: by forming a loop, and by using many loops.

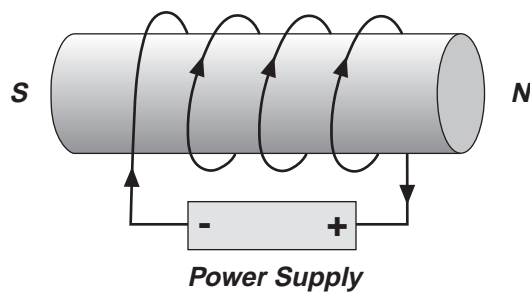


Figure 7.9: An electromagnet.

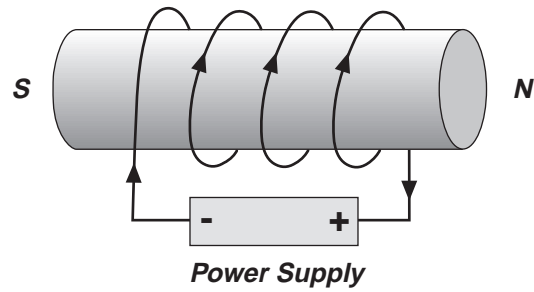


Figure 7.10: Determination of direction of magnetic field using first left-hand rule.

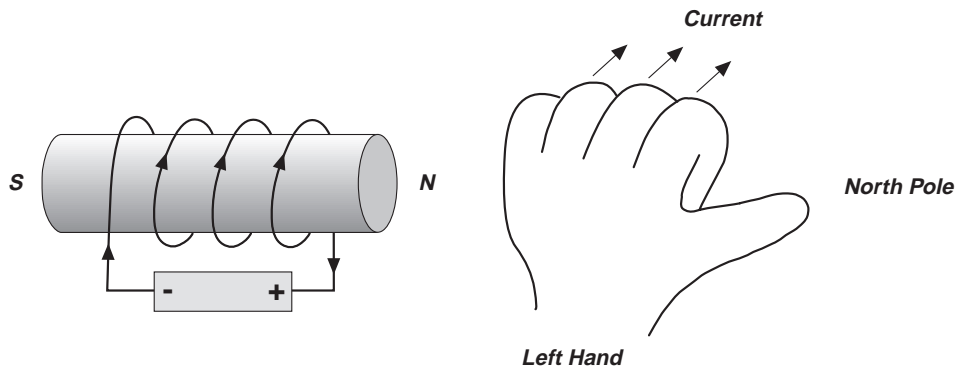


Figure 7.11: Rule for determining direction of magnetic field in an electromagnet.

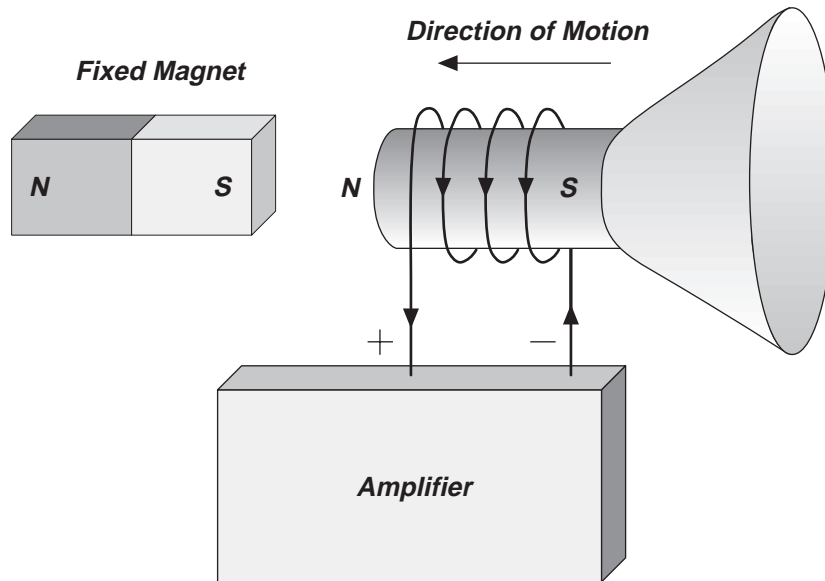


Figure 7.12: First left-hand rule and how a cone speaker works.

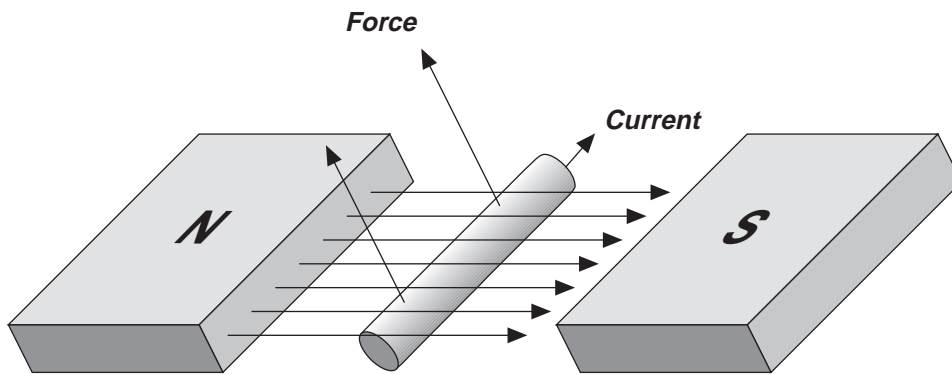


Figure 7.13: Force on wire carrying a current in a magnetic field.

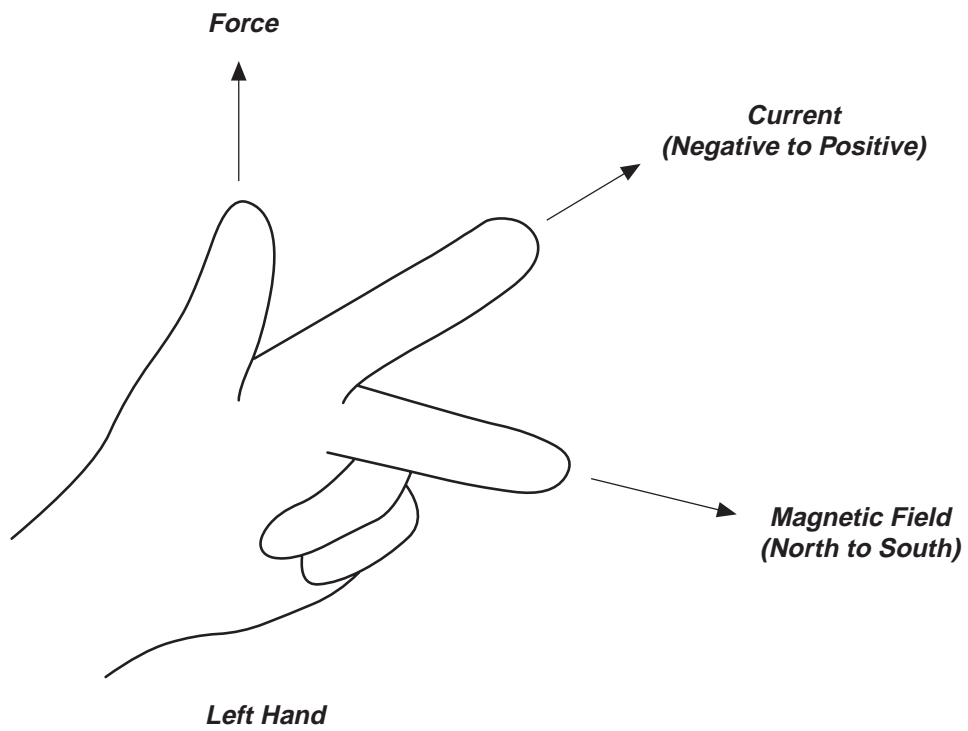


Figure 7.14: The second left-hand rule showing direction of force on wire carrying a current in a magnetic field.

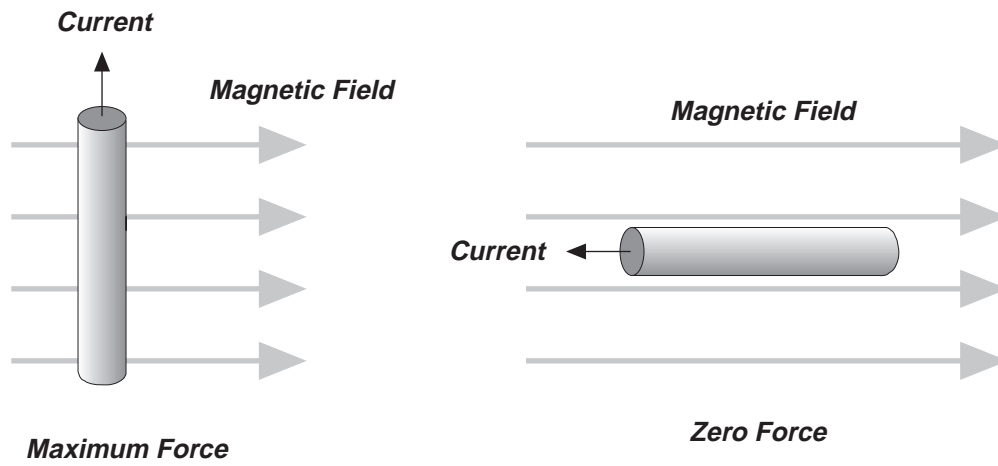


Figure 7.15: Direction of force depends on orientation of current with respect to magnetic field.

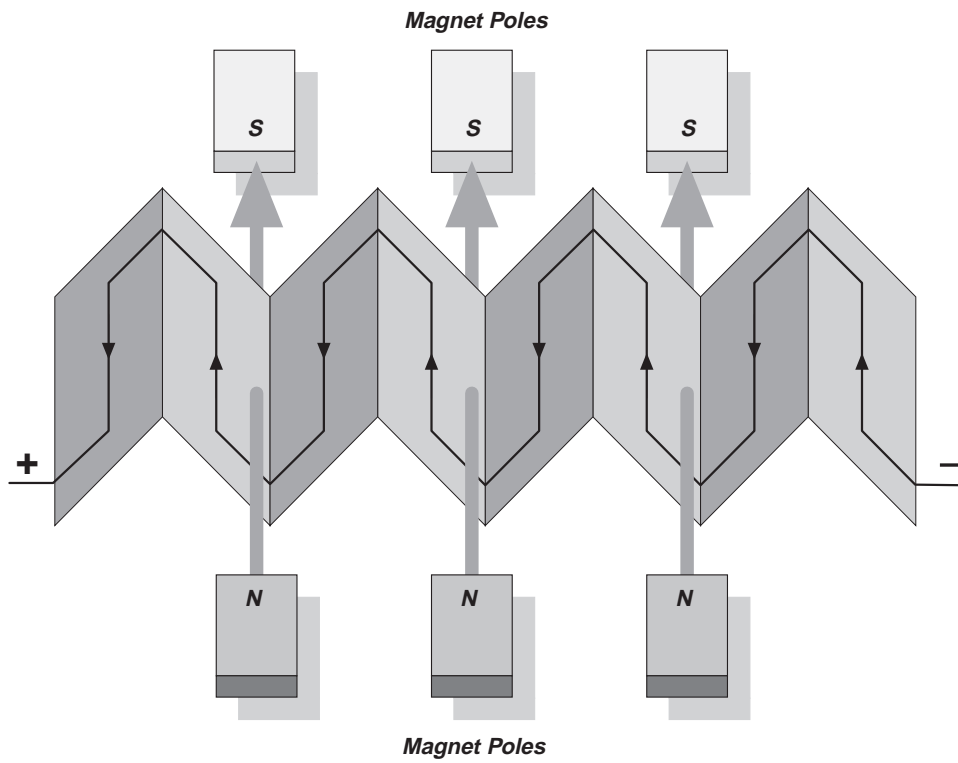


Figure 7.16: A Heil Speaker.

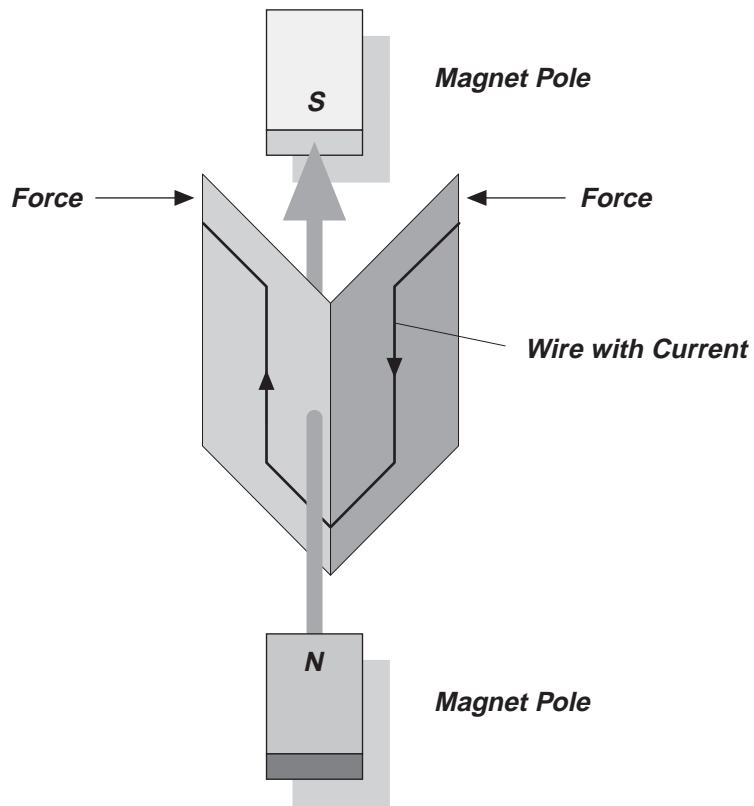


Figure 7.17: One set of folds in Heil speaker.

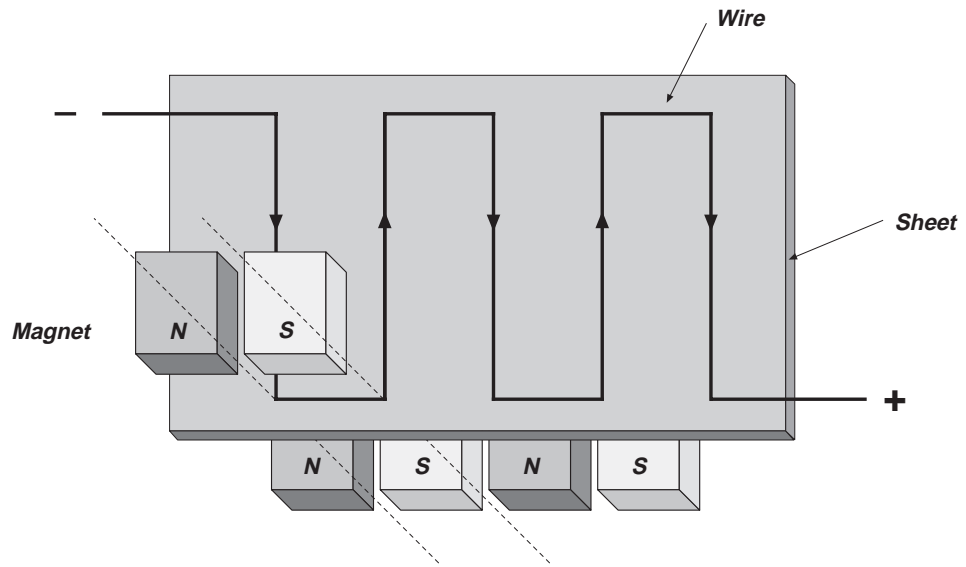


Figure 7.18: Magnetic Planar Speaker.

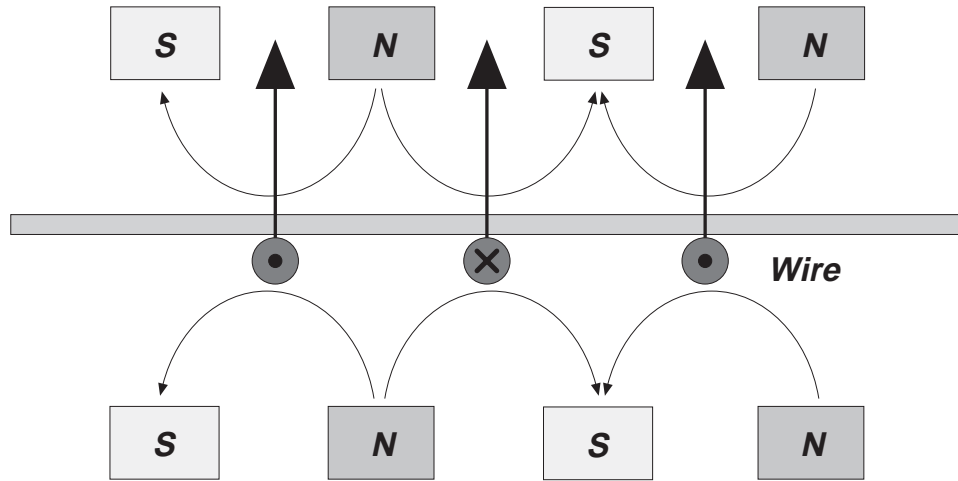


Figure 7.19: Forces on diaphragm when current direction is as indicated.

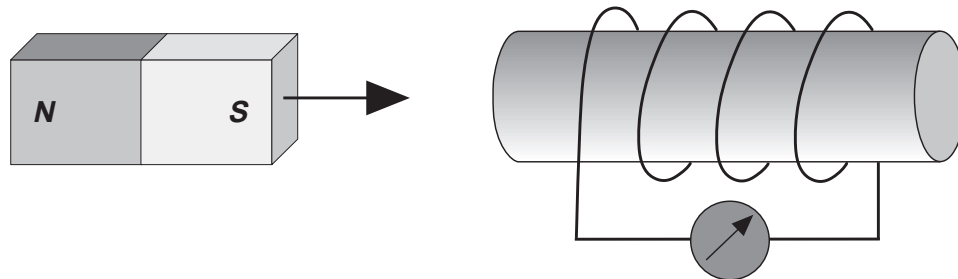


Figure 7.20: A bar magnet moving into a coil induces an electric current in that coil.

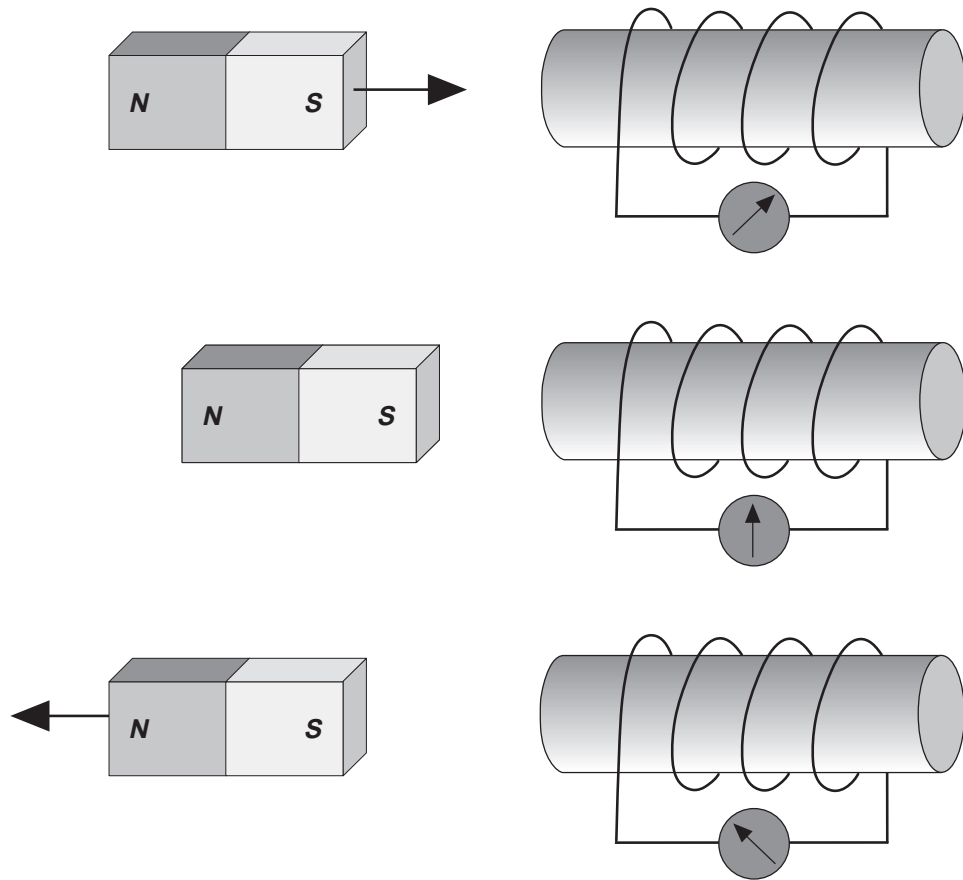


Figure 7.21: Induced current in coil by moving magnet.

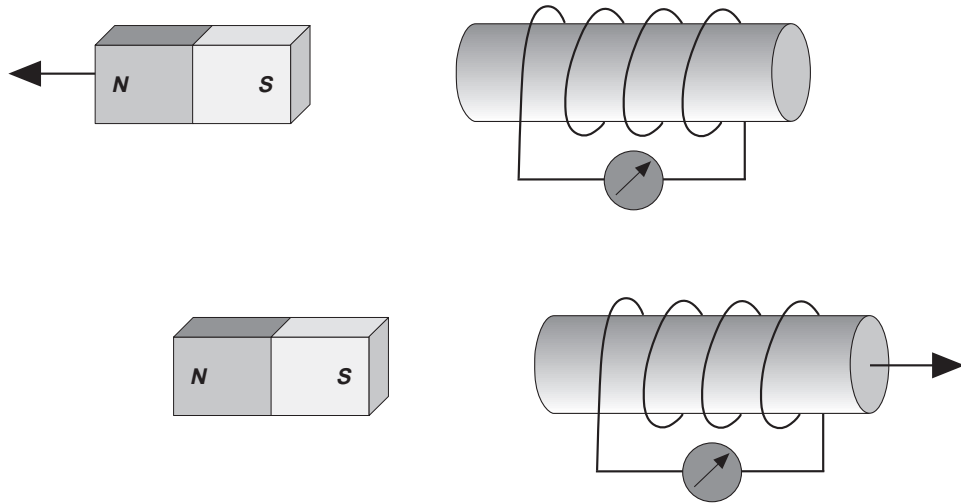


Figure 7.22: Significance of relative motion between magnet and coil.

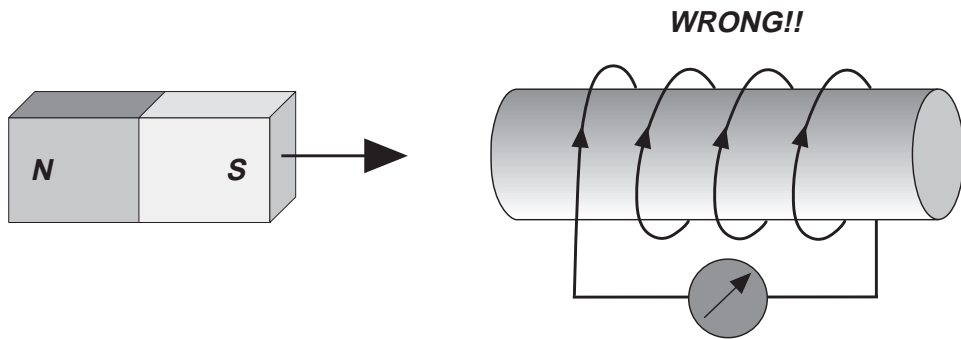


Figure 7.23: Direction of induced current (wrong).

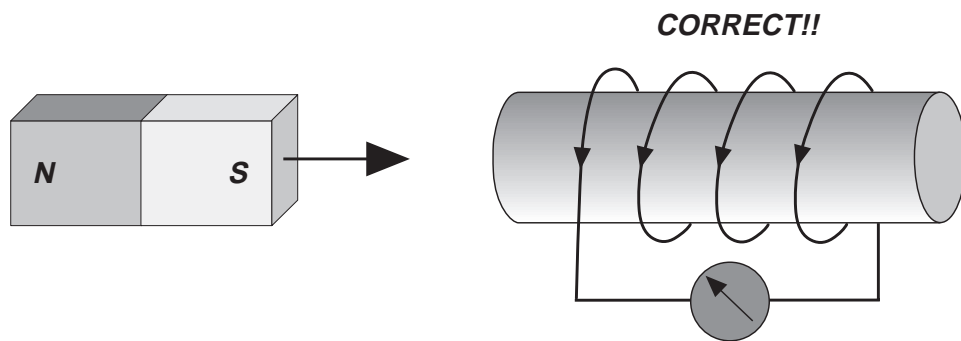


Figure 7.24: Direction of induced current (correct).

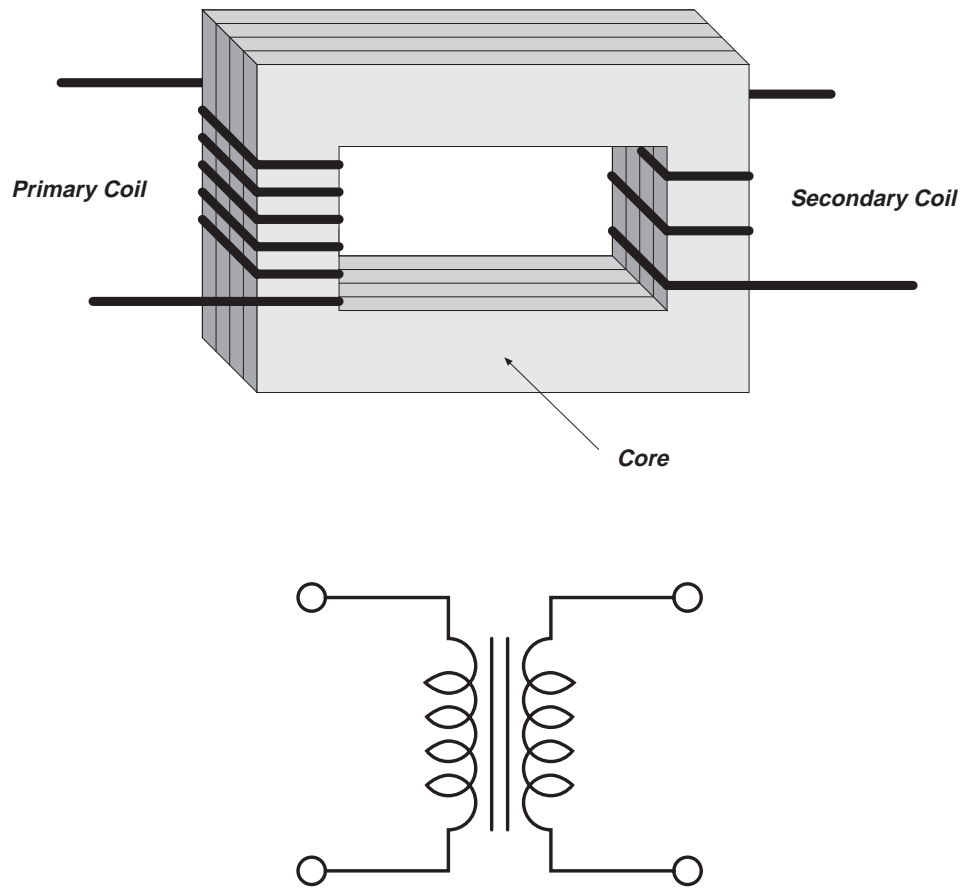


Figure 7.25: Schematic of a transformer and its circuit symbol.

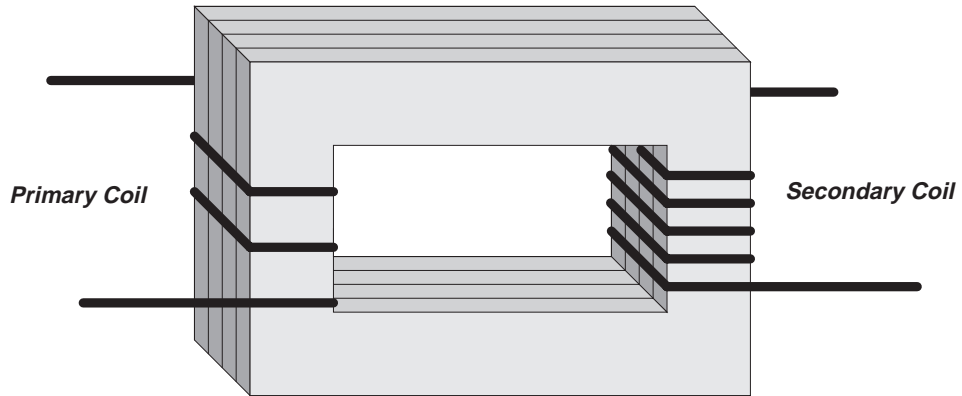


Figure 7.26: Step-up transformer.

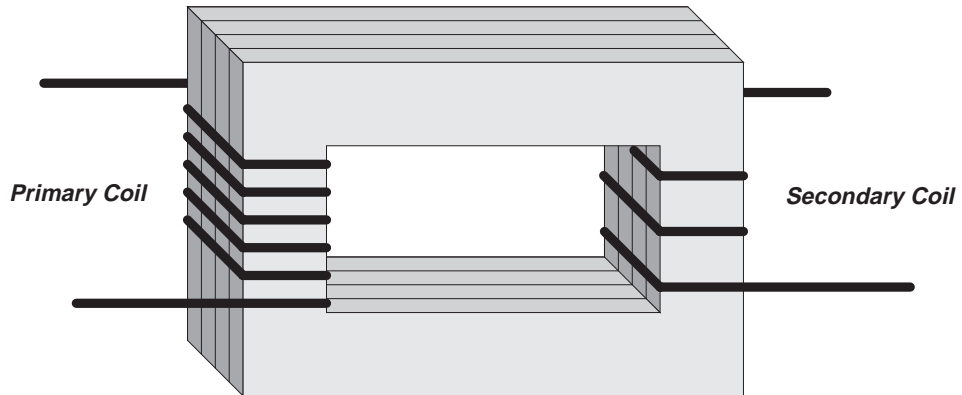


Figure 7.27: Step-down transformer.

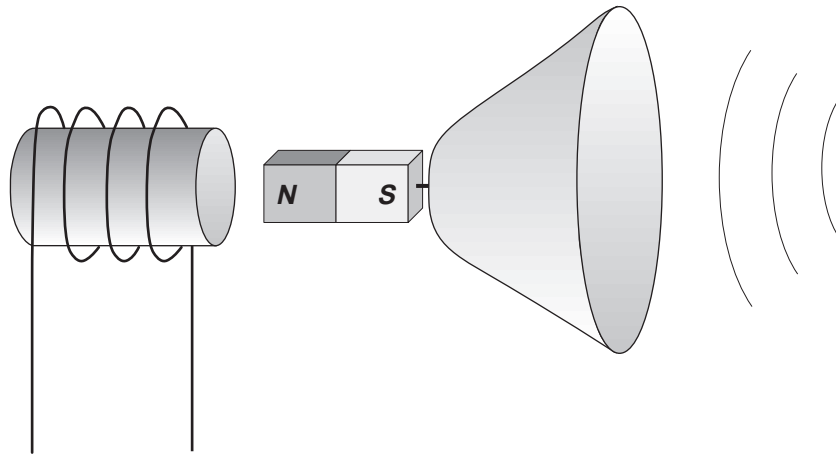


Figure 7.28: Schematic of microphone based on Faraday's law of induction.

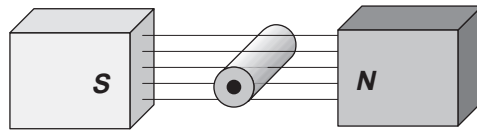


Figure 7.29: Exercise 7.14.

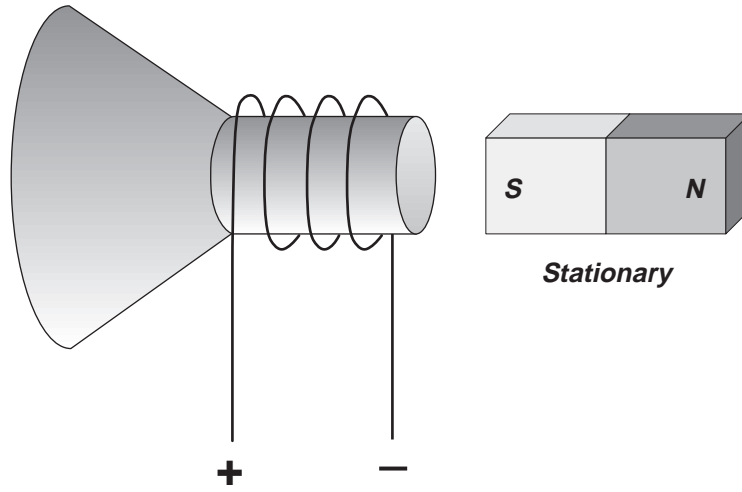


Figure 7.30: Exercise 7.15.

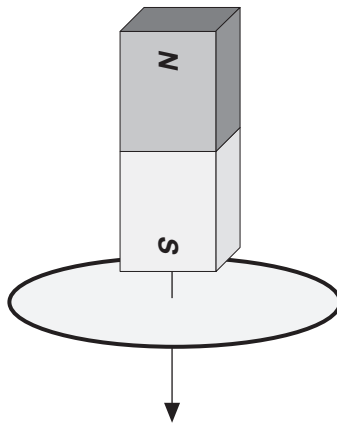


Figure 7.31: Exercise 7.18.

Chapter 8

Electromagnetic Waves and Tuners

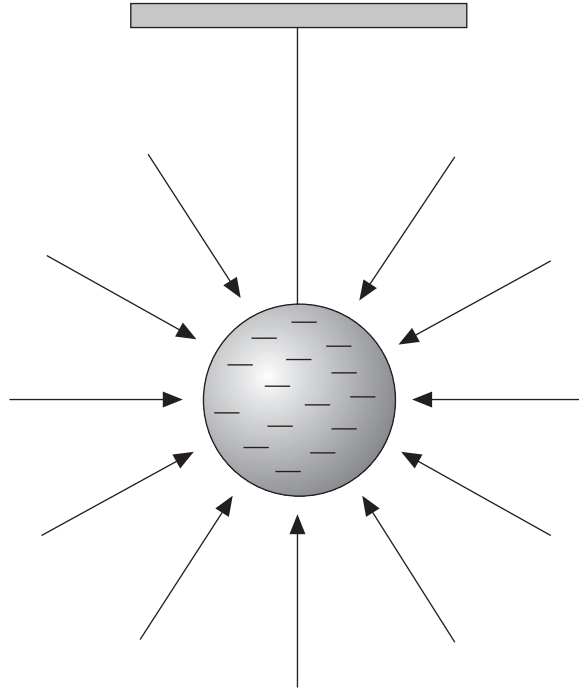


Figure 8.1: Electric Field around charged ping-pong ball.

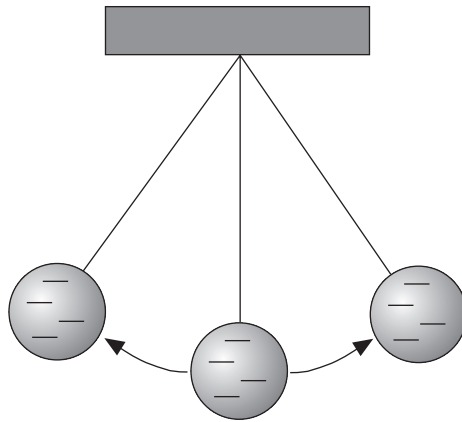


Figure 8.2: Oscillating charged ball.

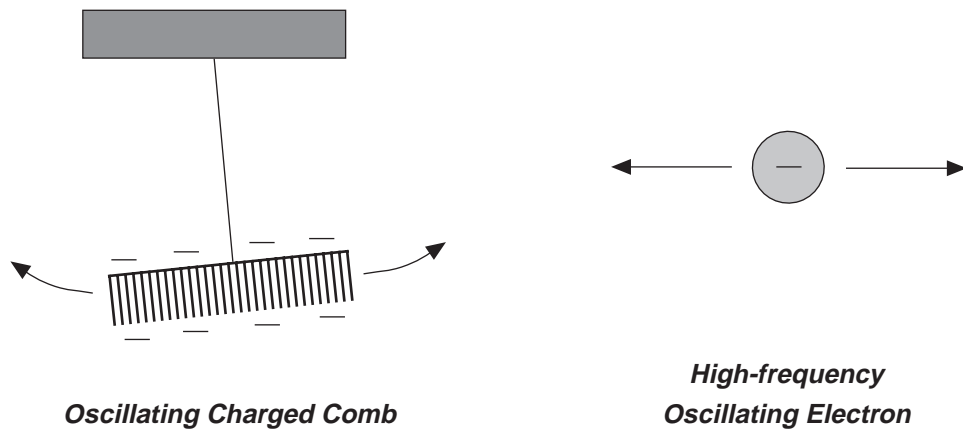


Figure 8.3: Generation of electromagnetic waves at two different frequencies.

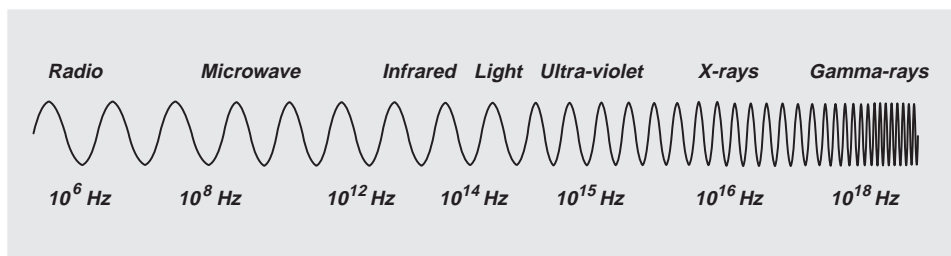


Figure 8.4: Spectrum of electromagnetic waves.

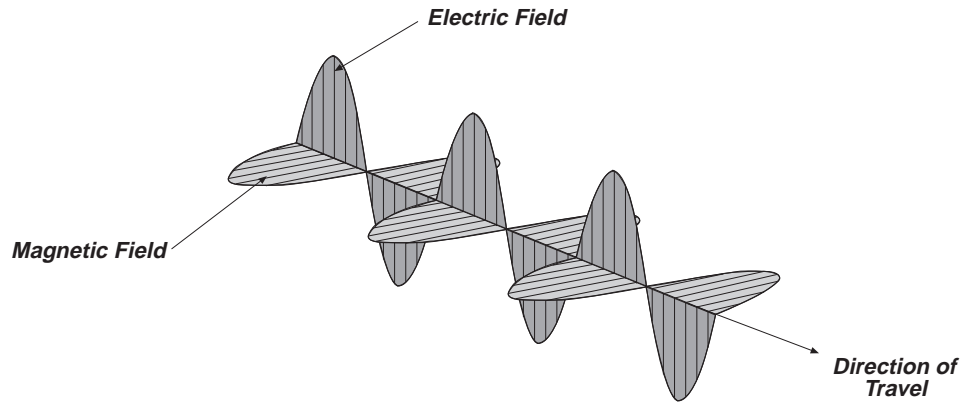


Figure 8.5: Electromagnetic waves are transverse waves with oscillating electric and magnetic fields.

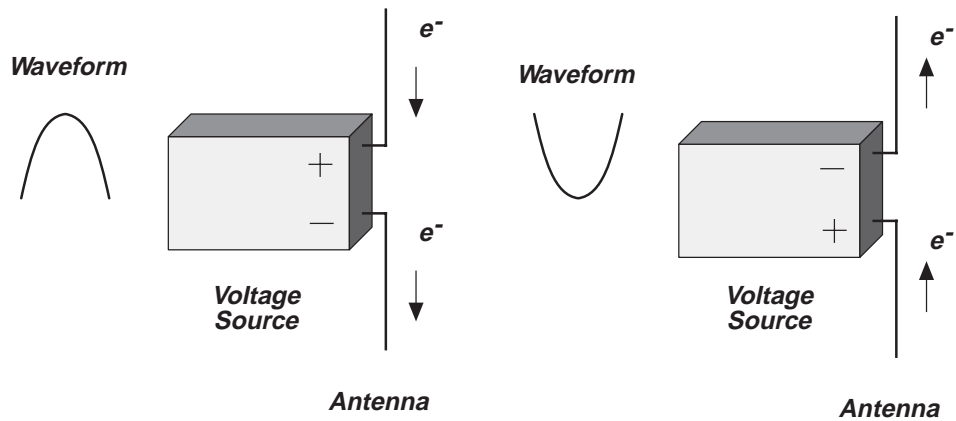


Figure 8.6: Production of electromagnetic waves by oscillating electrons in antenna.

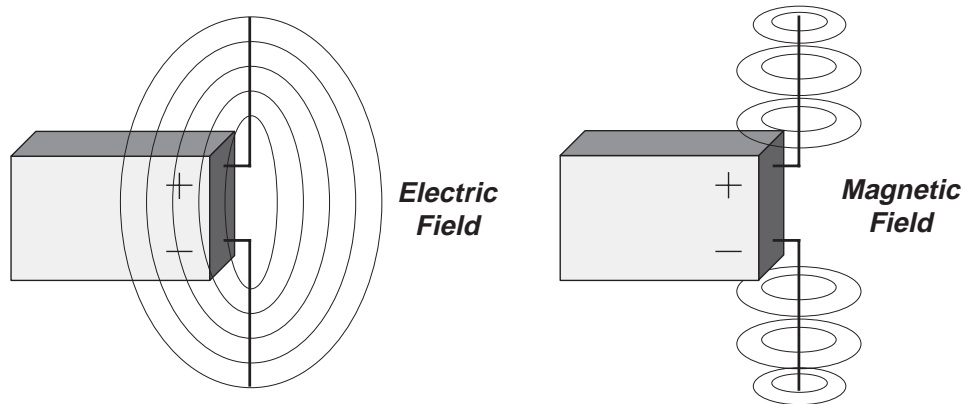


Figure 8.7: Generation of electric and magnetic fields by antenna.

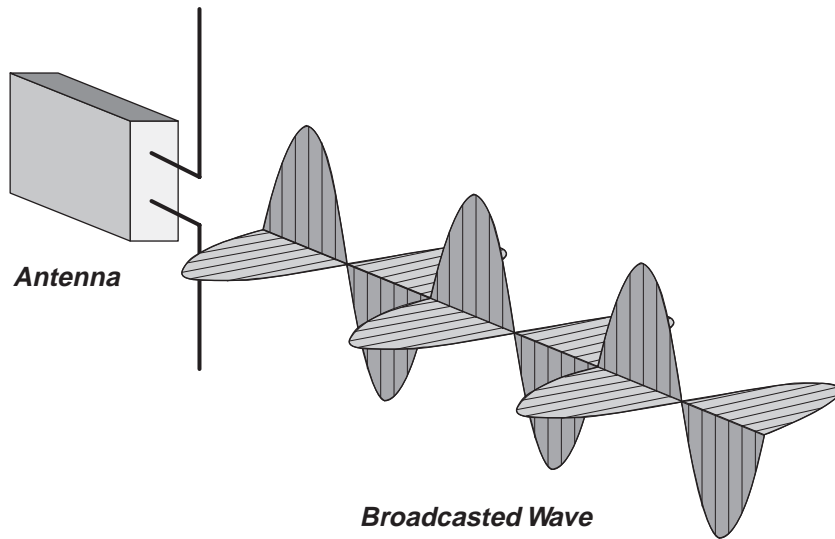


Figure 8.8: Production of electromagnetic waves by antenna.

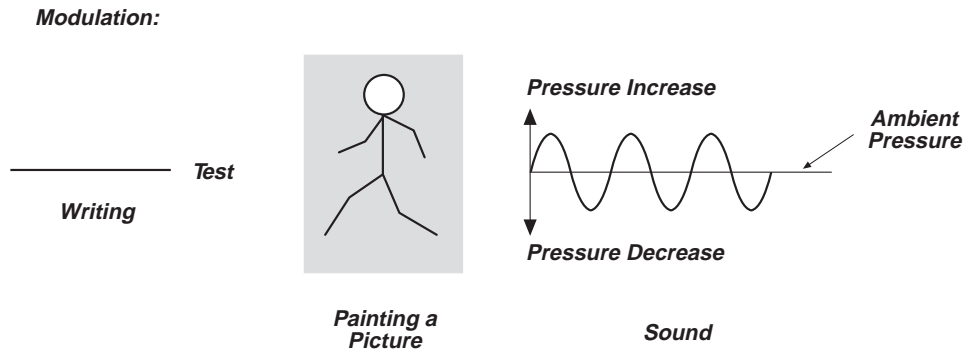


Figure 8.9: Some examples of modulation.

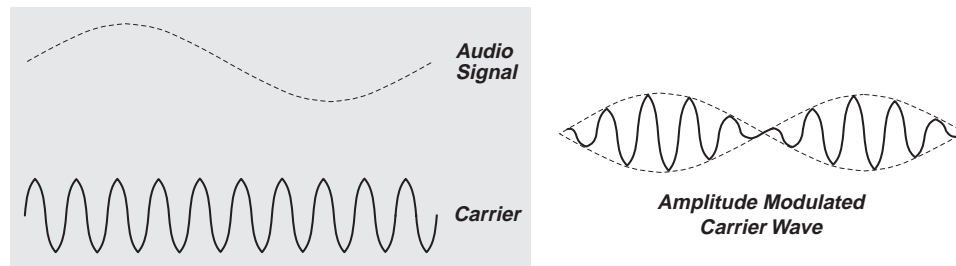


Figure 8.10: Amplitude modulation.

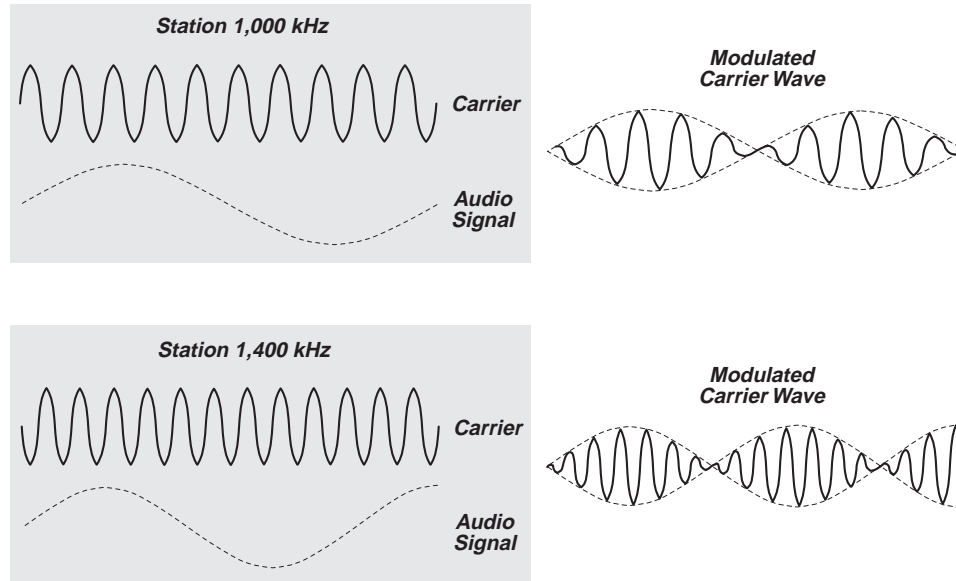


Figure 8.11: Carrier and audio signals broadcast by two stations.

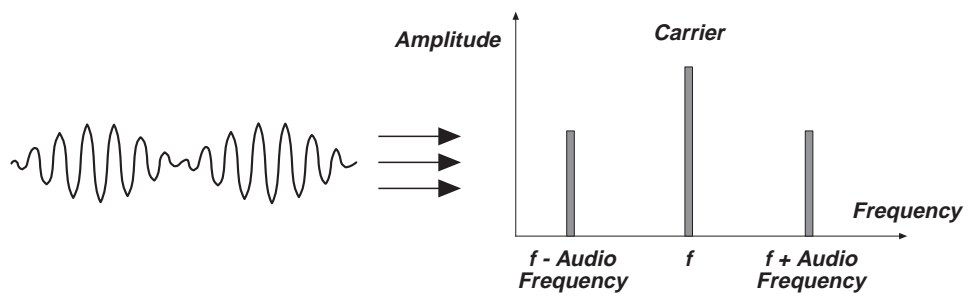


Figure 8.12: Spectrum of an AM carrier at frequency f when modulated by audio signal.

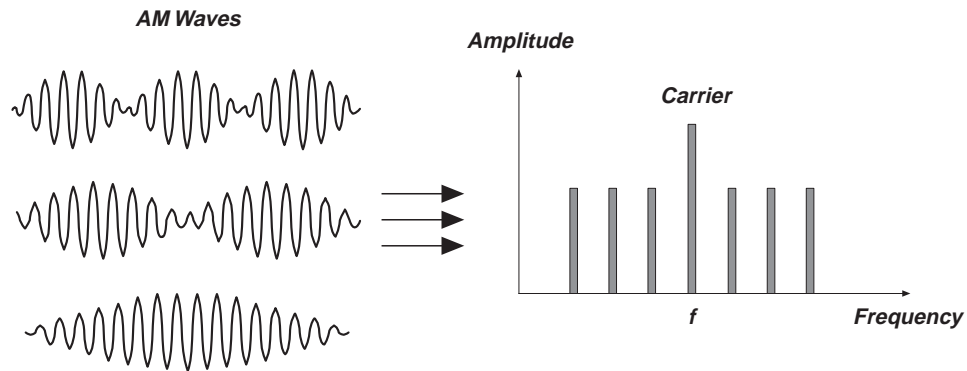


Figure 8.13: Audio frequencies modulating carrier.

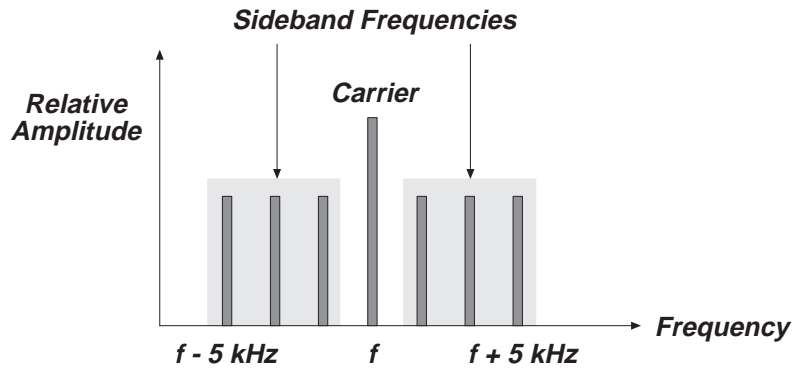


Figure 8.14: Spectrum of frequencies on carrier for audio frequencies up to 5 kHz.

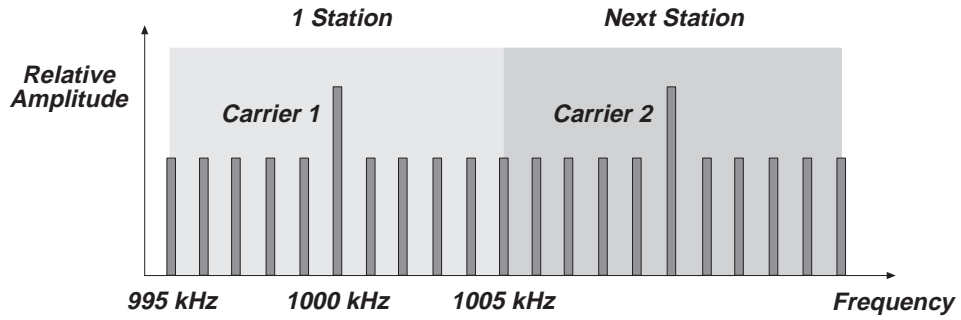


Figure 8.15: Spectrum of frequencies due to modulation of carrier.

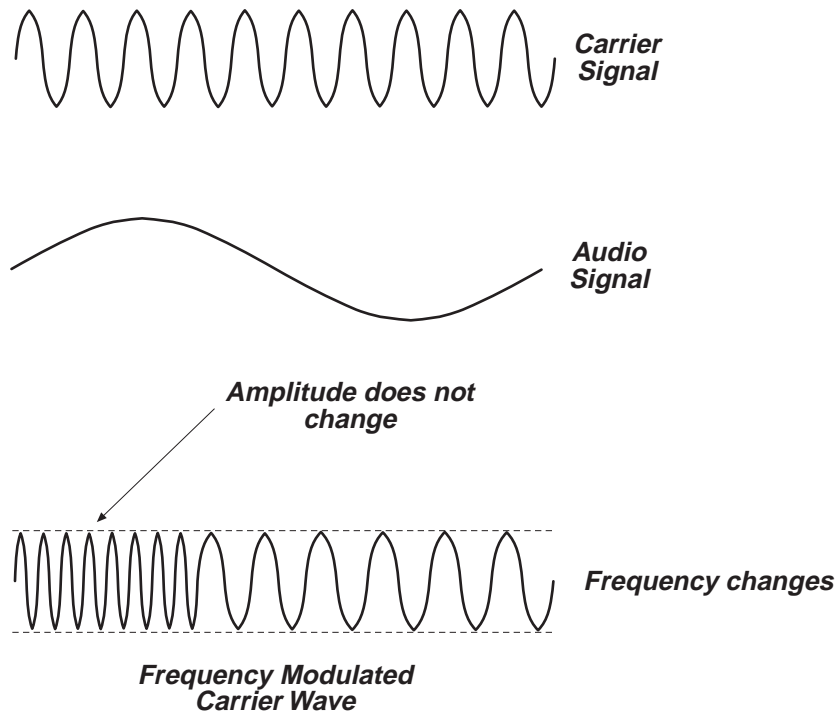


Figure 8.16: Frequency modulation (FM).

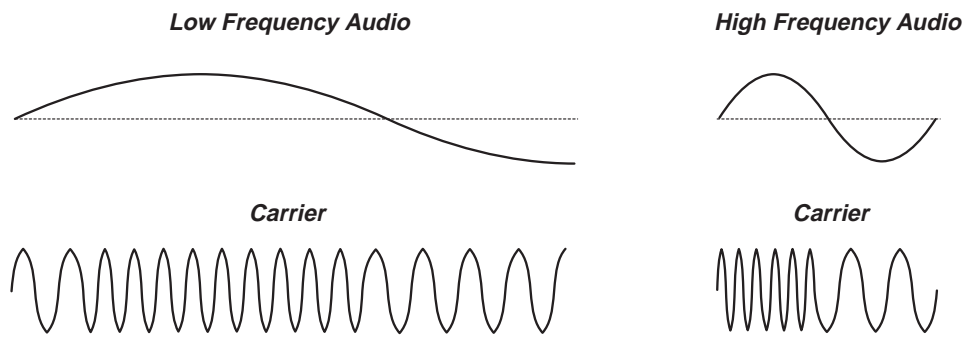


Figure 8.17: A low frequency and a high frequency audio signal frequency modulating a carrier.

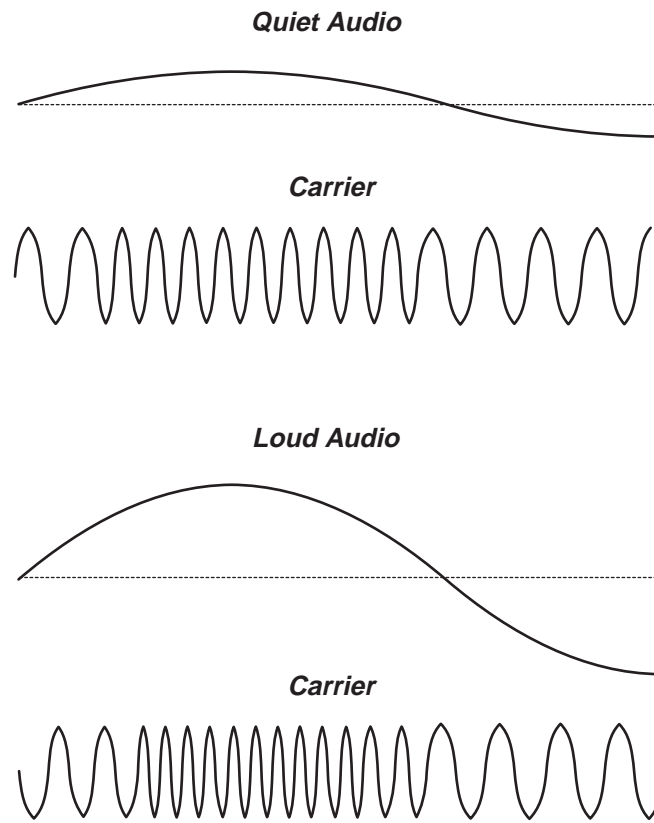


Figure 8.18: A loud and a quiet audio signal frequency modulating a carrier.

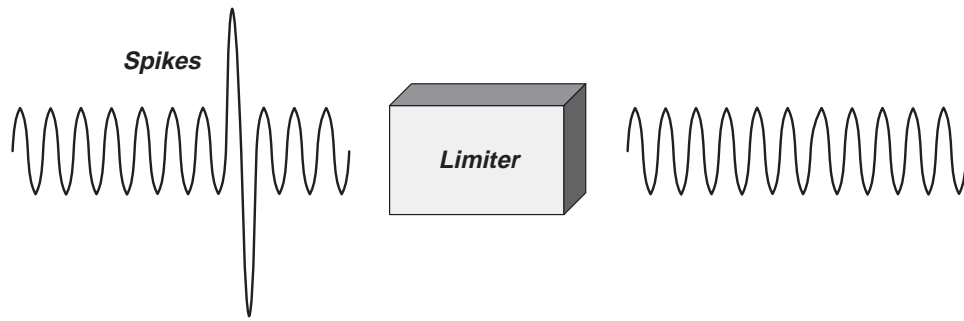


Figure 8.19: Action of limiter in FM.

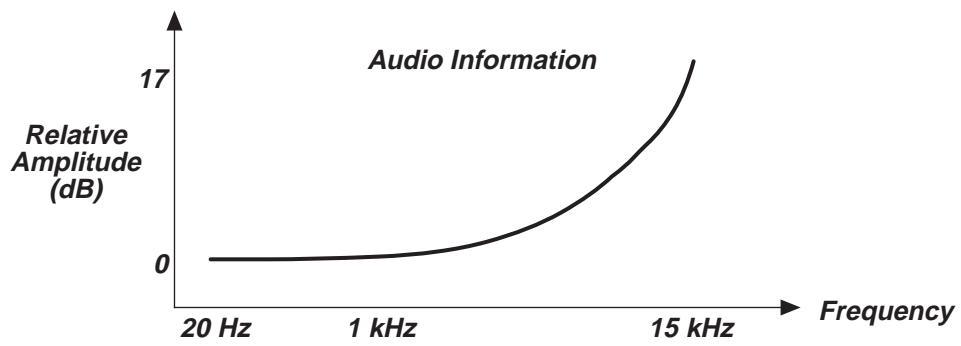


Figure 8.20: Pre-emphasis in FM broadcasting.

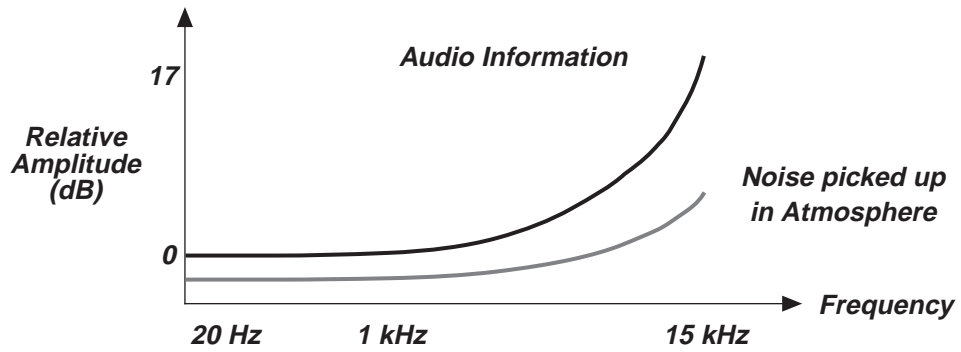


Figure 8.21: Information brought to tuner on carrier.

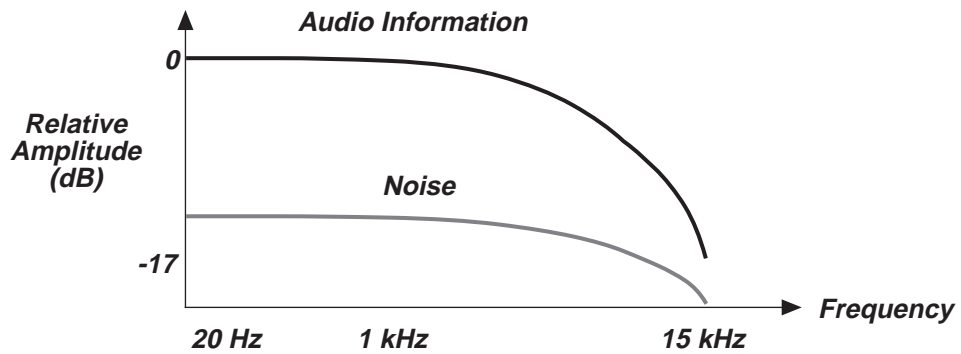


Figure 8.22: De-emphasis of audio information to reduce high frequency noise.

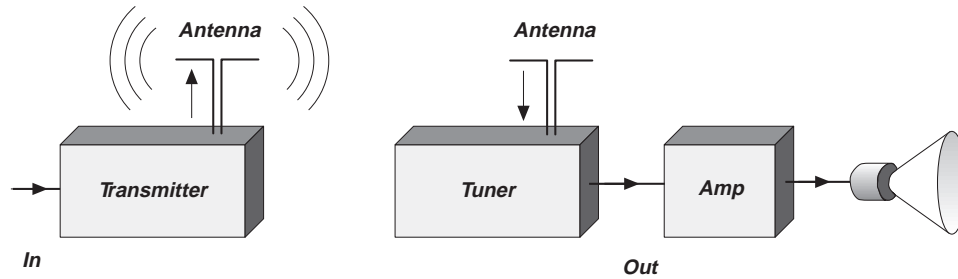


Figure 8.23: Elements of radio communications.

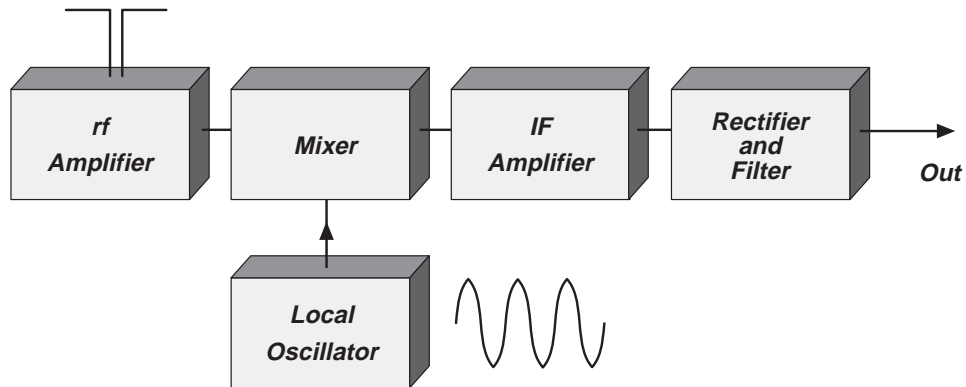


Figure 8.24: Superheterodyne receiver.

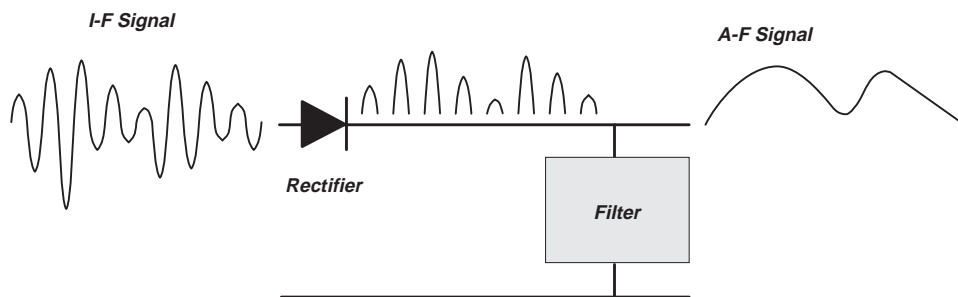


Figure 8.25: Processing part of AM signal with a simple diode and filters.

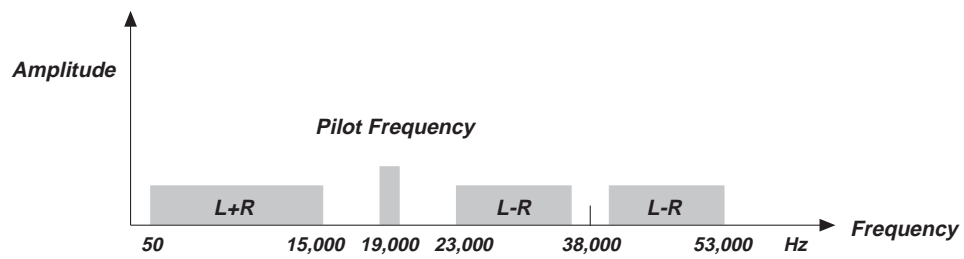


Figure 8.26: Audio information which will modulate carrier in stereo broadcasting.

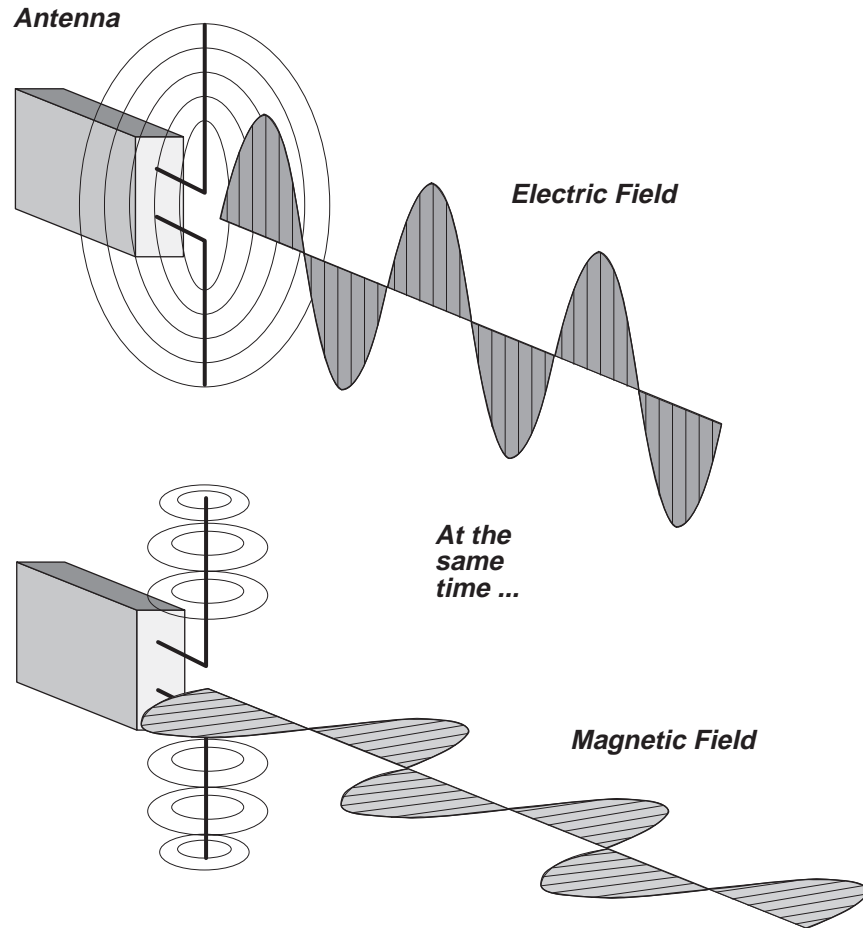


Figure 8.27: Alternating current in antenna produces electromagnetic wave.

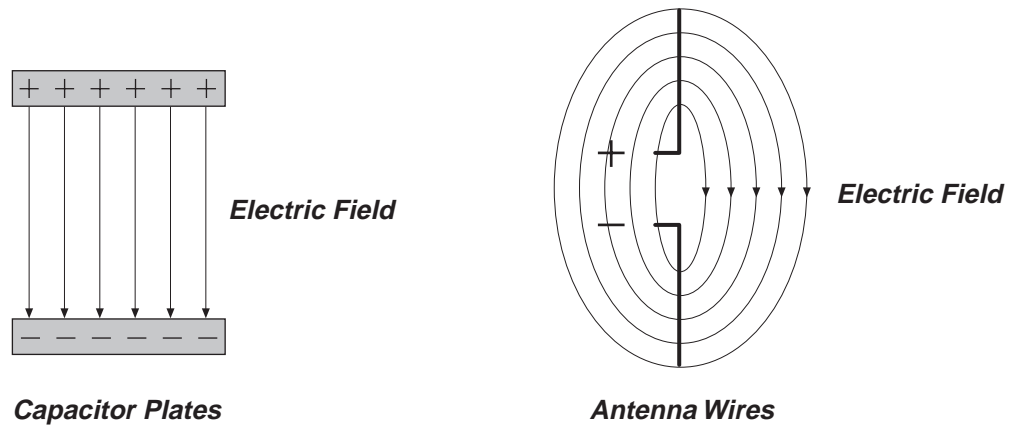


Figure 8.28: Electric field around charged antenna wires is similar to that between charged capacitor plates.

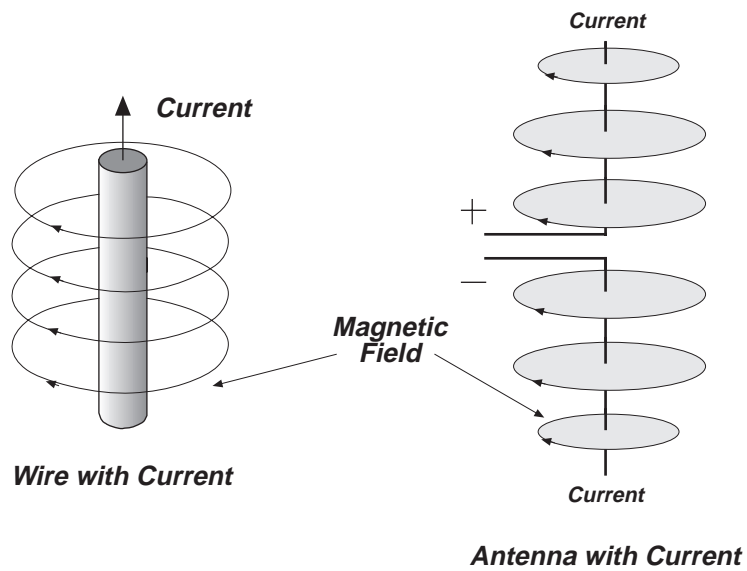


Figure 8.29: Magnetic fields around a wire and antenna with current.

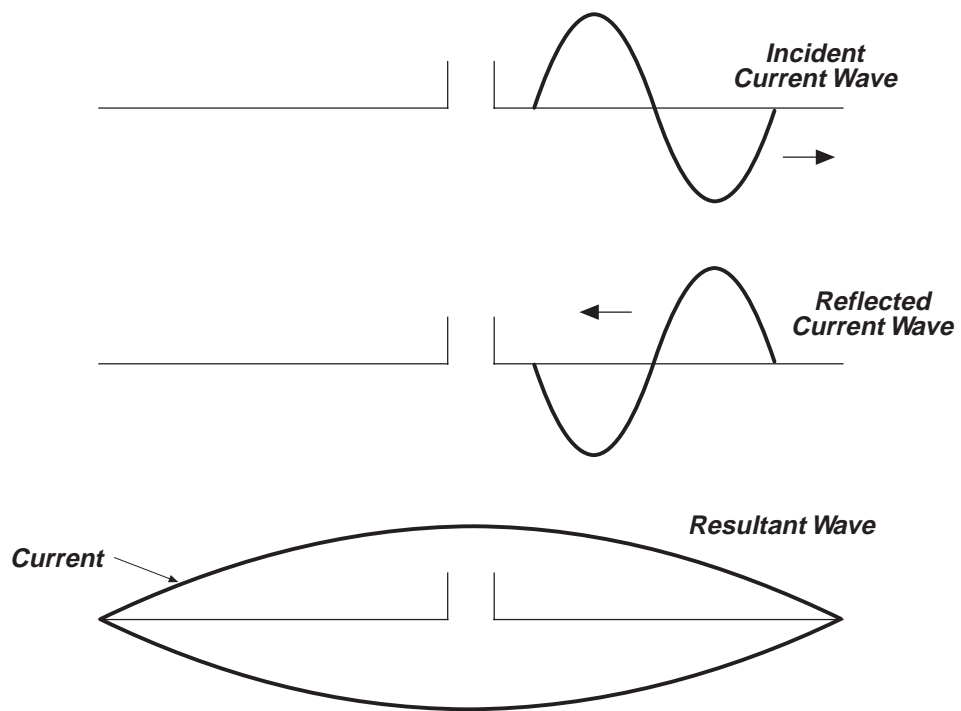


Figure 8.30: Development of a standing wave on antenna.

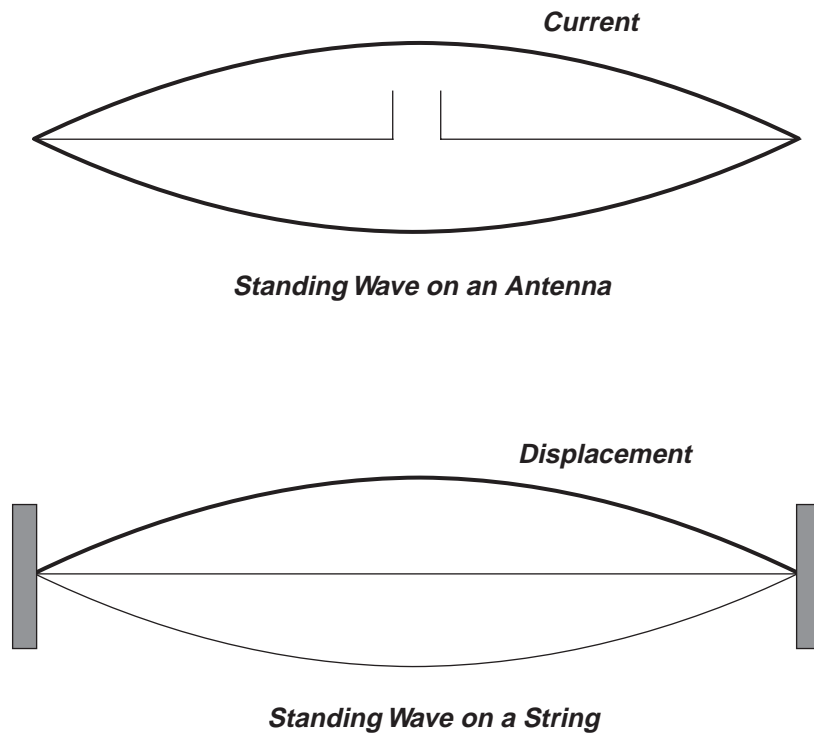


Figure 8.31: Comparison of standing wave on antenna to that of a string.

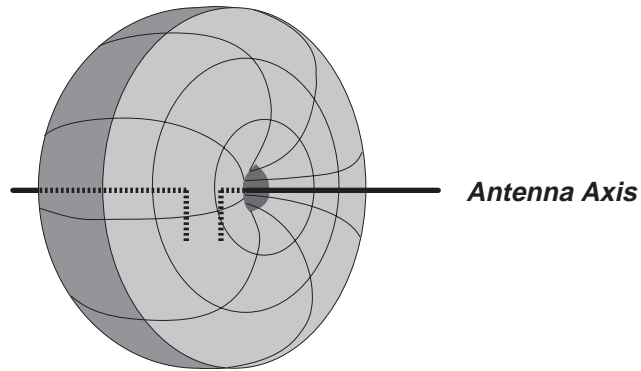


Figure 8.32: Radiation pattern of electric field around half-wave dipole antenna.

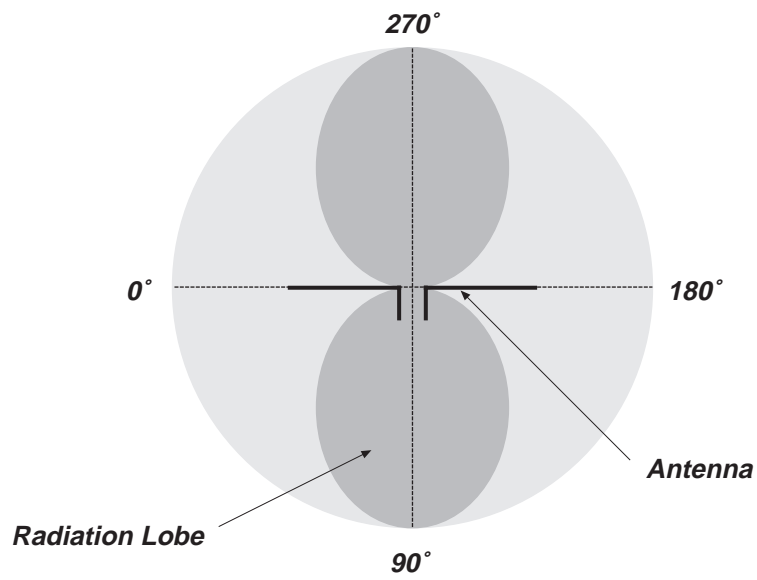


Figure 8.33: Polar graph representation of radiation pattern around half-wave dipolar antenna.

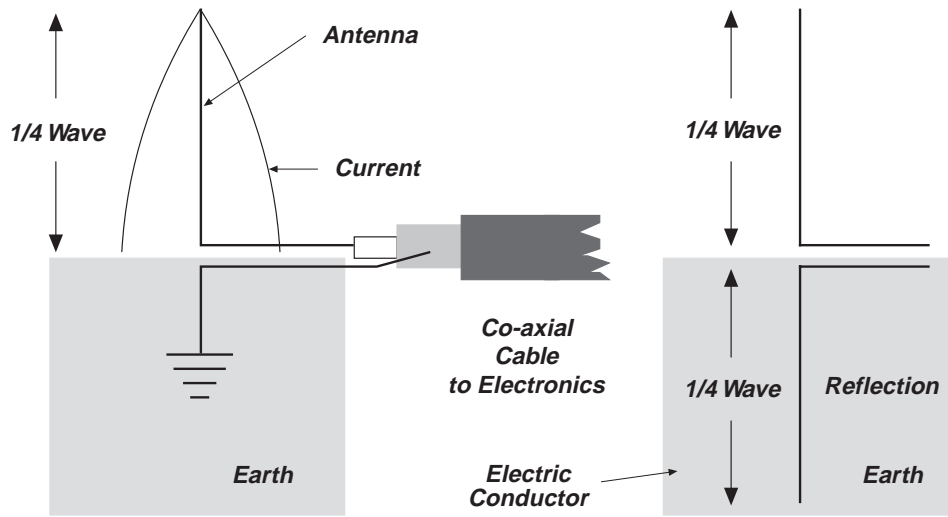


Figure 8.34: Basic elements of a grounded vertical antenna.

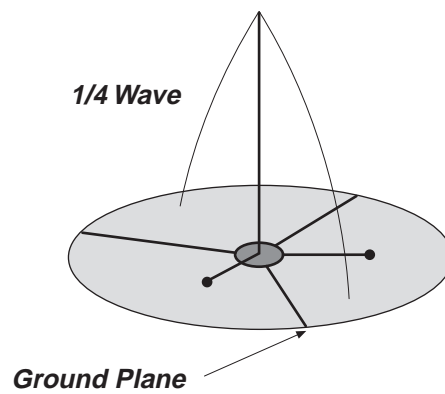


Figure 8.35: Quarter-wave antenna.

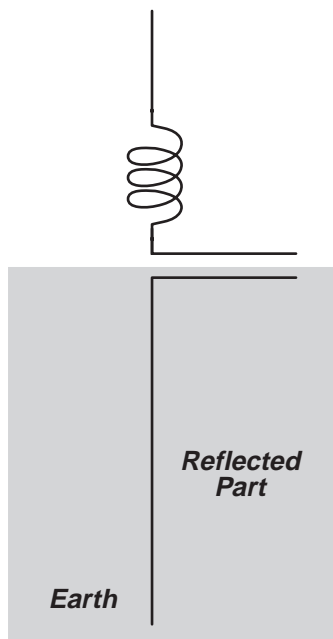


Figure 8.36: Total antenna length is made shorter by inserting a coil in series.

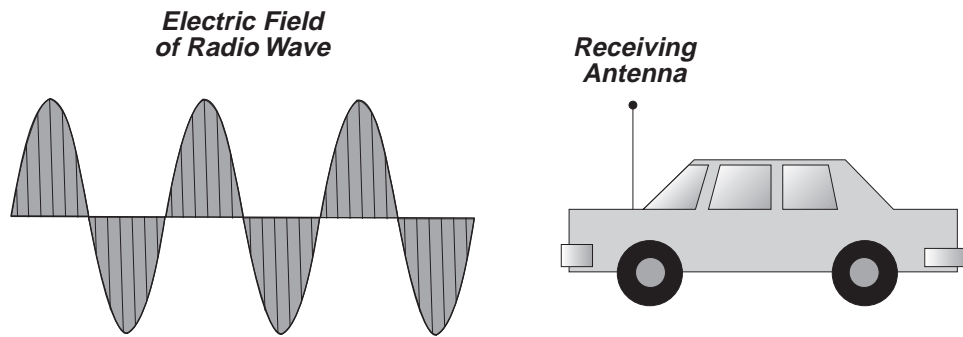


Figure 8.37: When the electric field of radio wave is vertical, the receiving antenna should also be vertical.

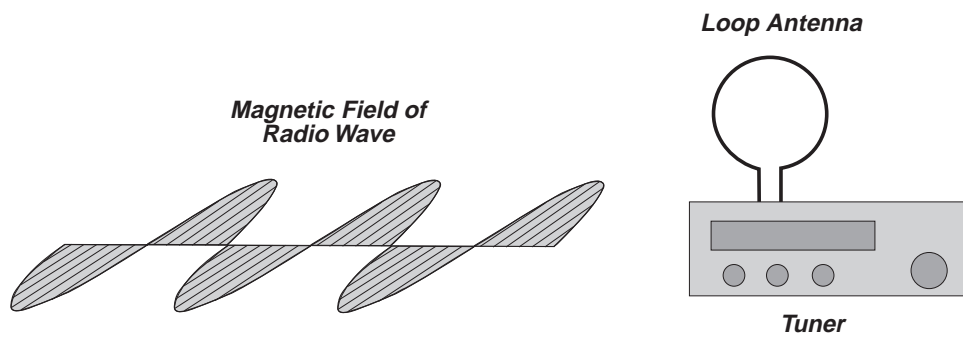


Figure 8.38: Loop antenna detects the magnetic field part of radio wave.

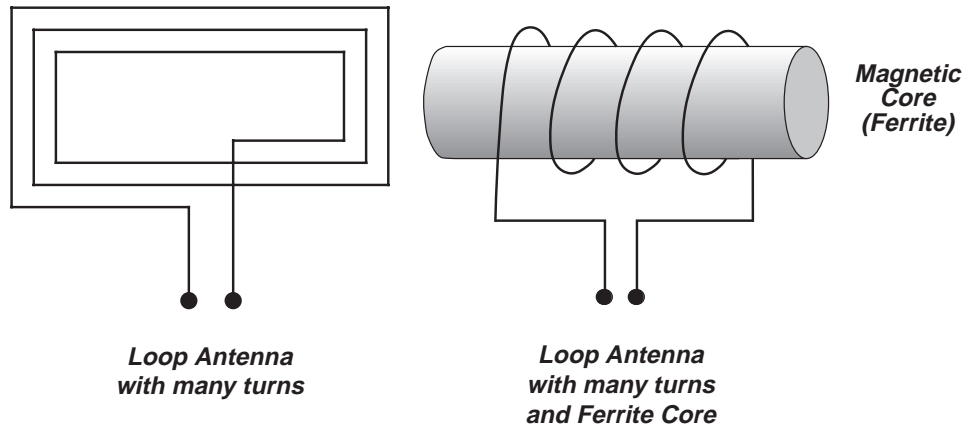


Figure 8.39: Two common loop antennas.

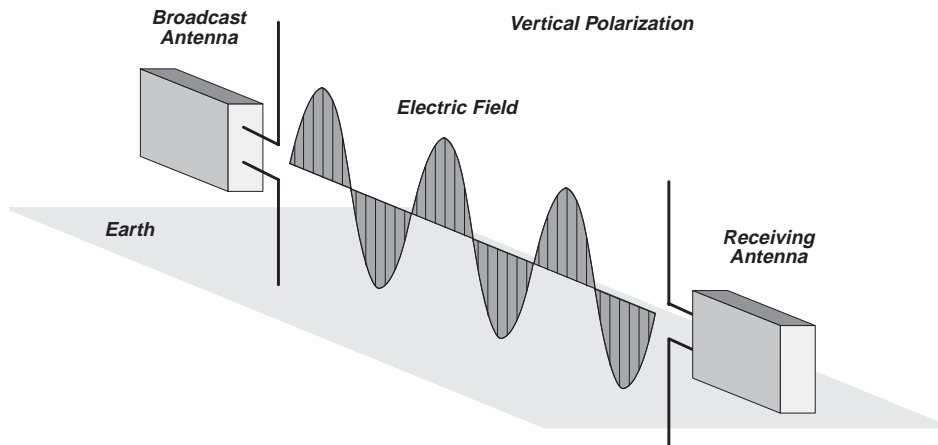


Figure 8.40: Vertically polarized radio wave.

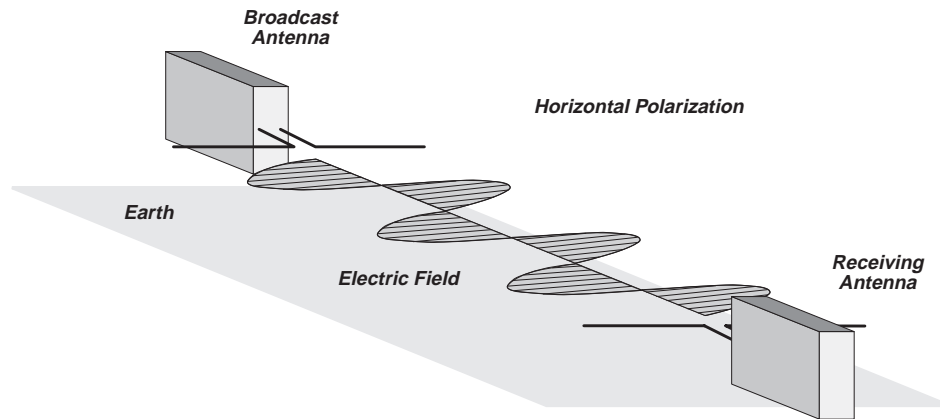


Figure 8.41: Horizontally polarized radio wave.

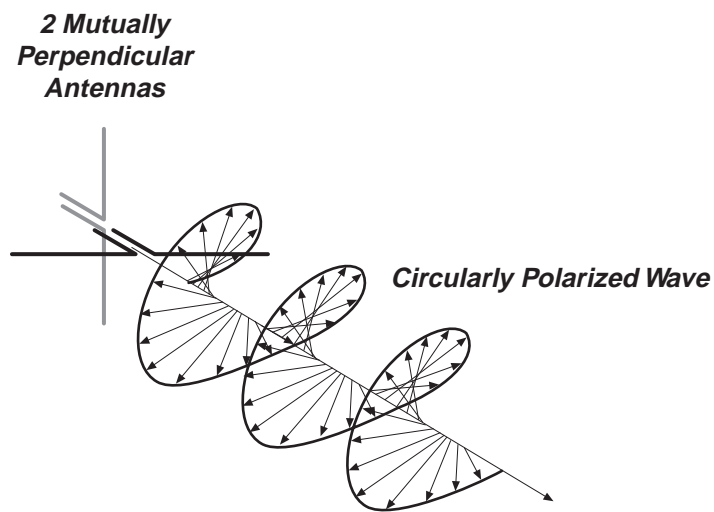


Figure 8.42: Broadcasting with circular polarization.

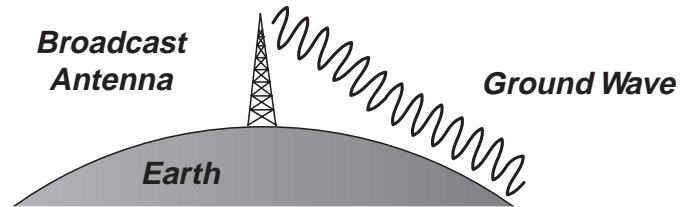


Figure 8.43: Low frequency ground wave follows curvature of earth.

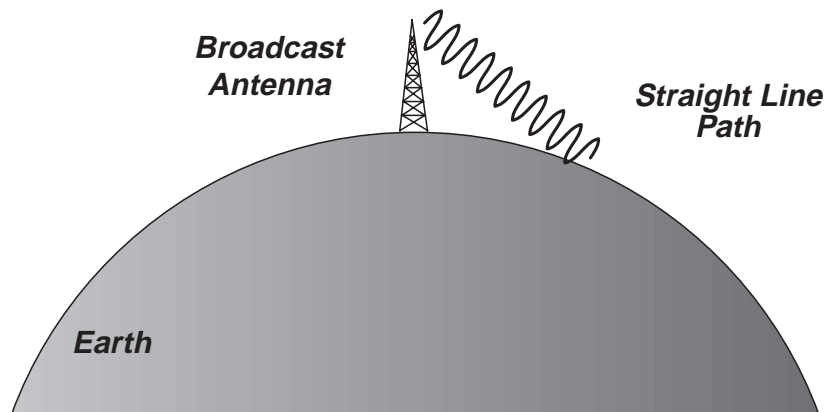


Figure 8.44: Direct (line-of-sight) mode of propagation.

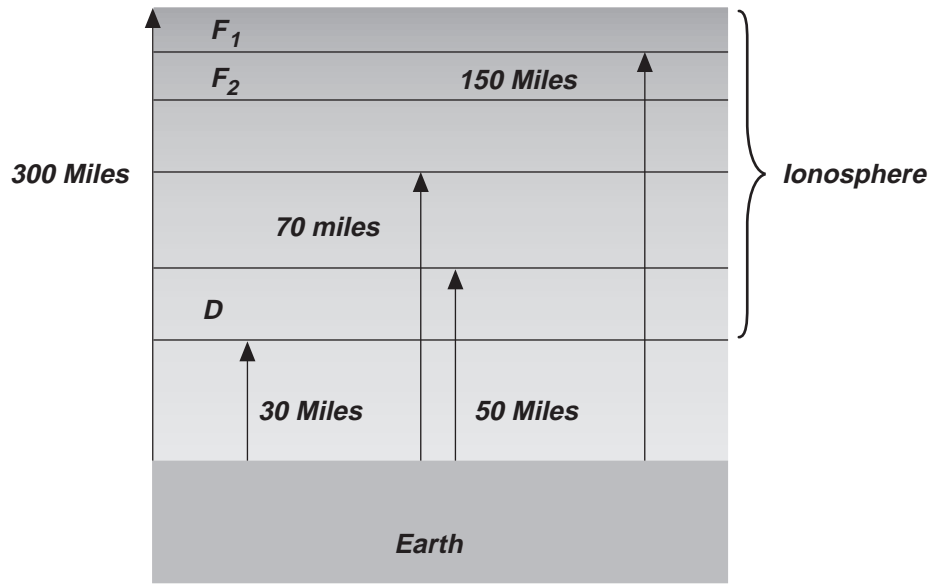


Figure 8.45: Earth's ionosphere layers.

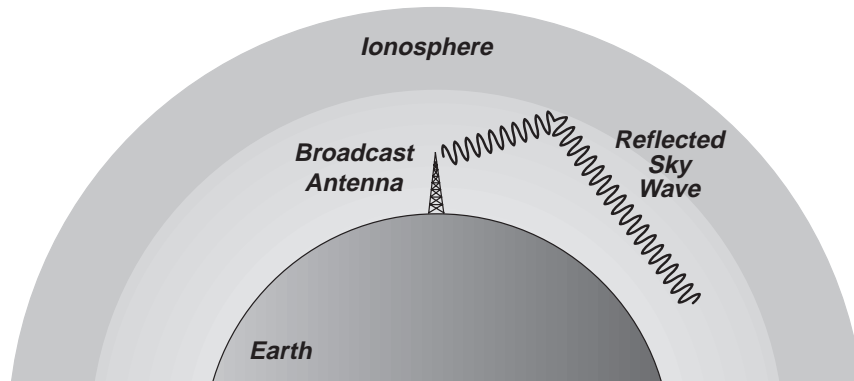


Figure 8.46: Sky wave world communications.

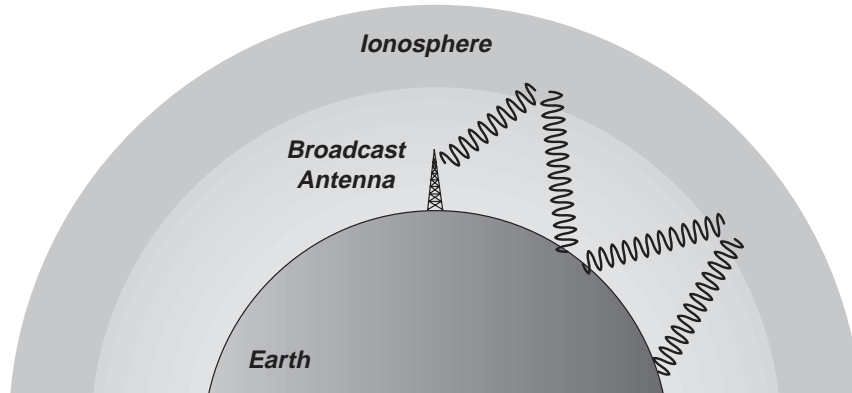


Figure 8.47: Two-hop transmission of radio wave using ionosphere.

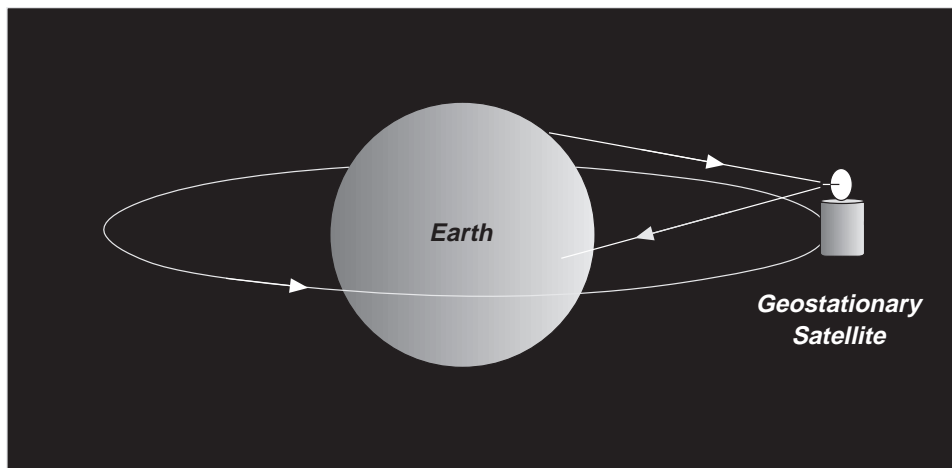


Figure 8.48: Communication using a satellite.

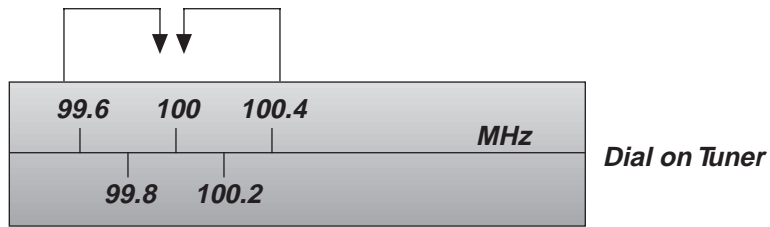


Figure 8.49: Selectivity relates to how well alternate channels are rejected.

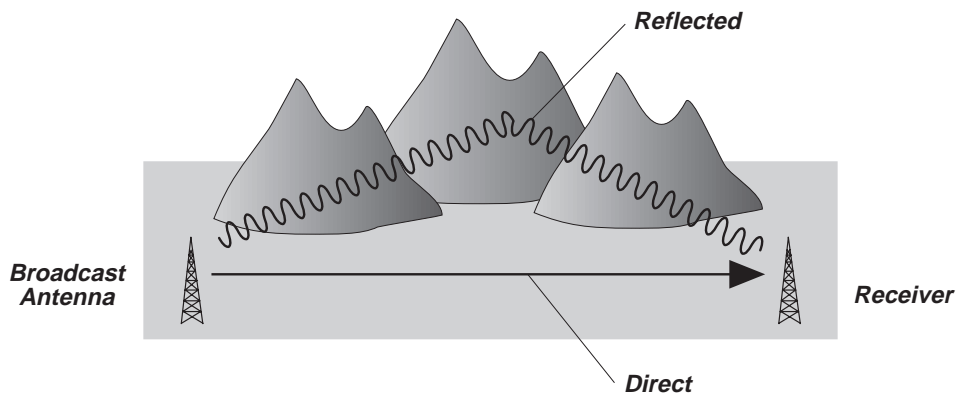


Figure 8.50: Direct and reflected waves from a broadcasting station.

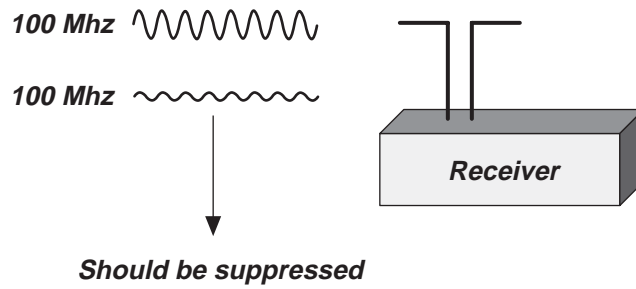


Figure 8.51: Capture ratio in tuner.

Chapter 9

Analog Recording and Playback

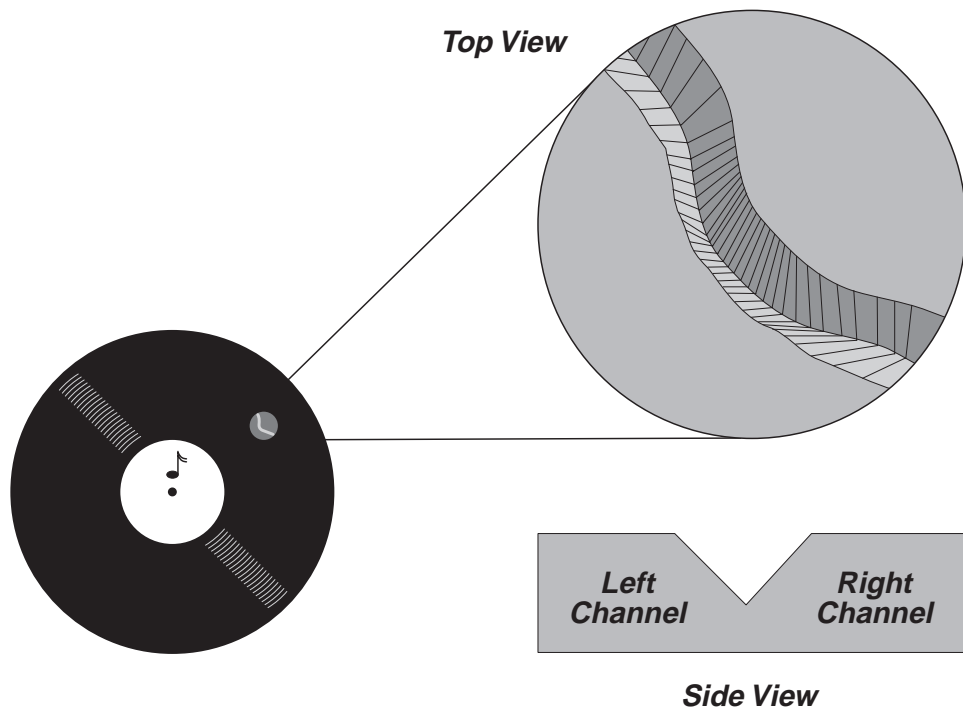


Figure 9.1: Record with grooves representing mechanically engraved waves.

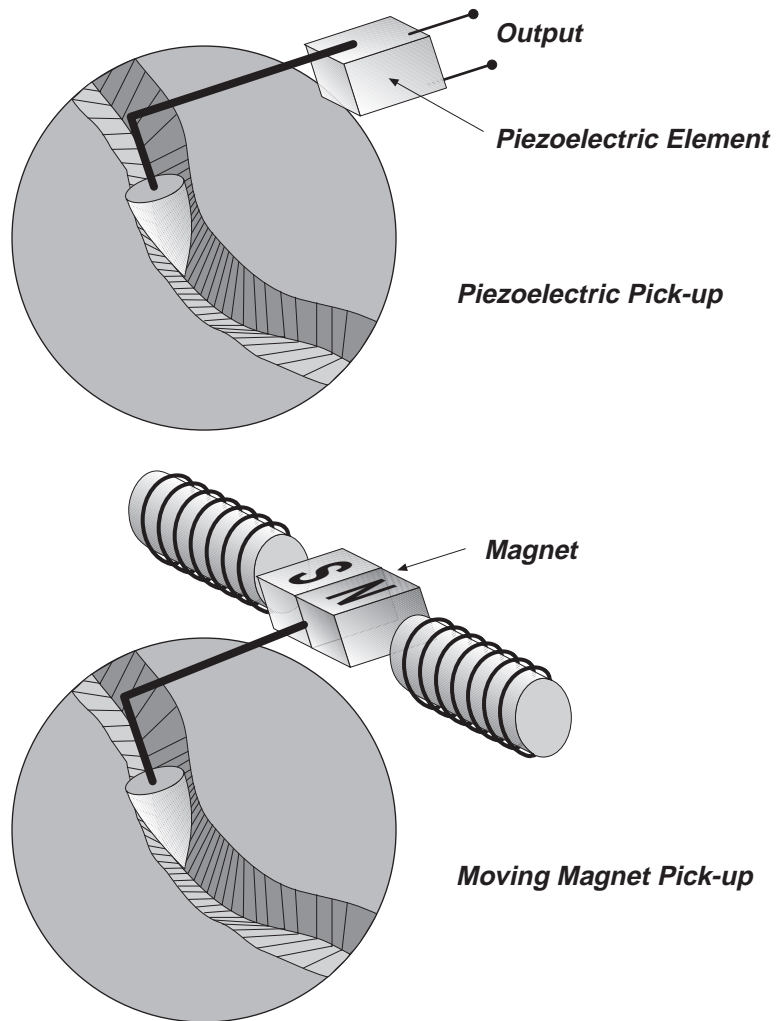


Figure 9.2: Phono playback systems.

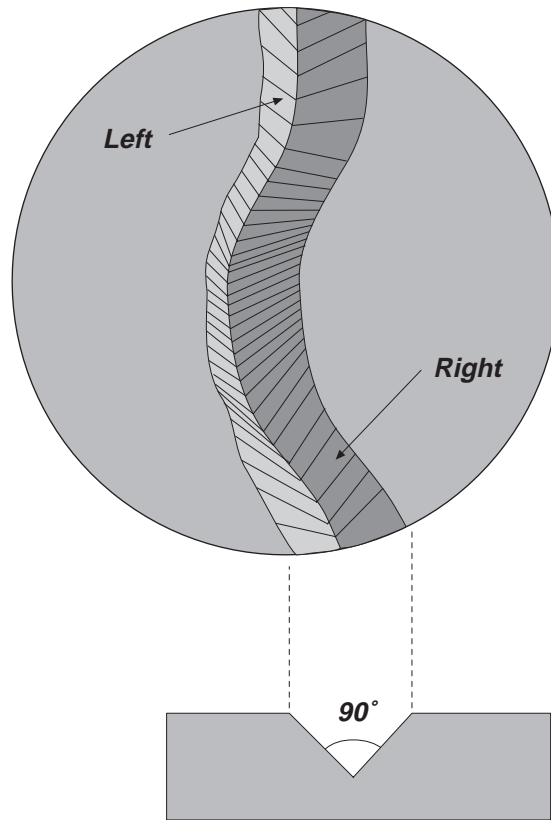


Figure 9.3: Stereo with only one stylus.

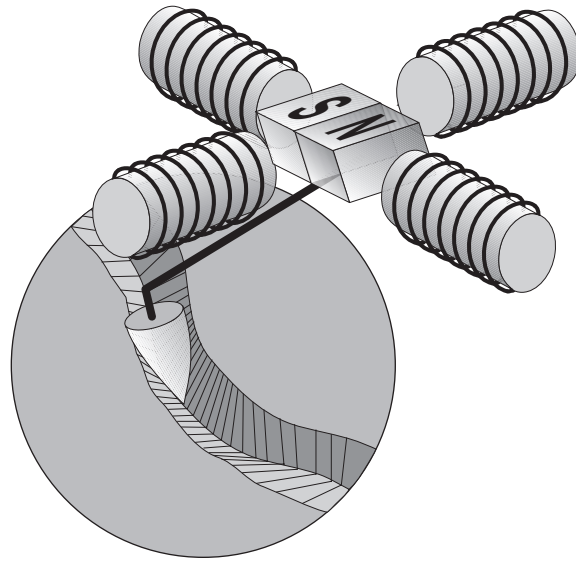


Figure 9.4: A stereo moving magnet phono cartridge.

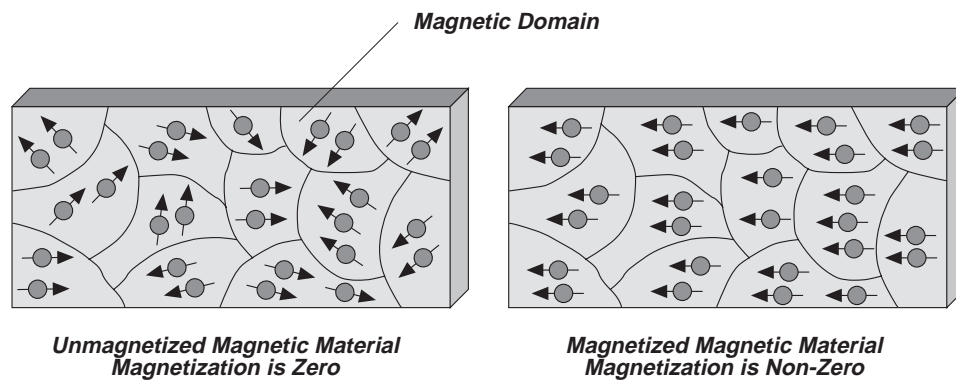


Figure 9.5: Unmagnetized and magnetized magnetic material.

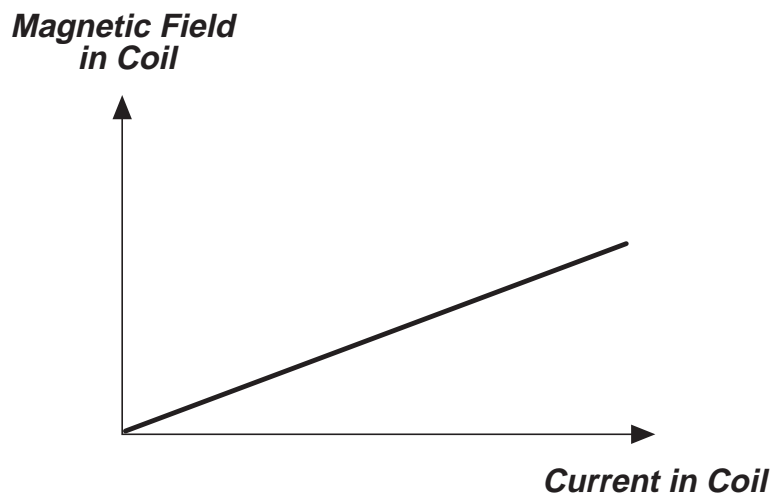
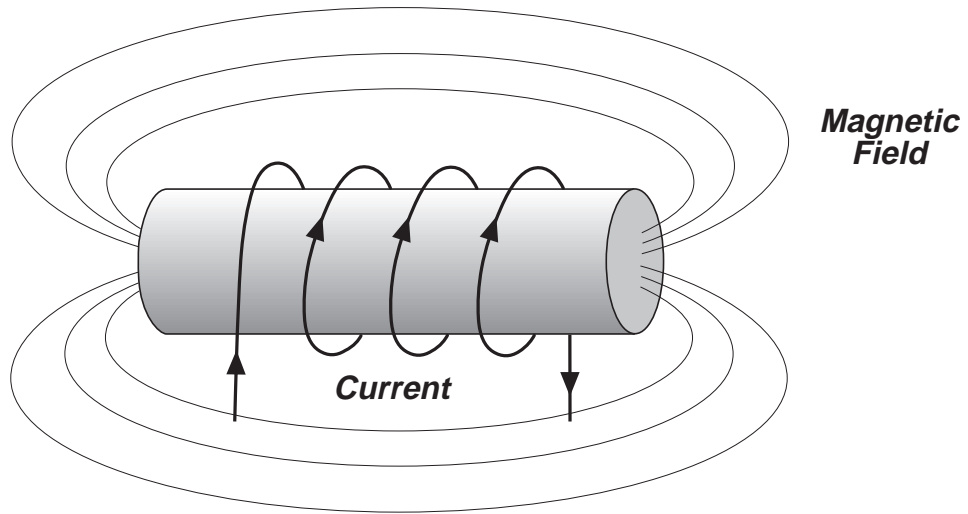


Figure 9.6: Magnetic field produced by a coil when current flows through it.

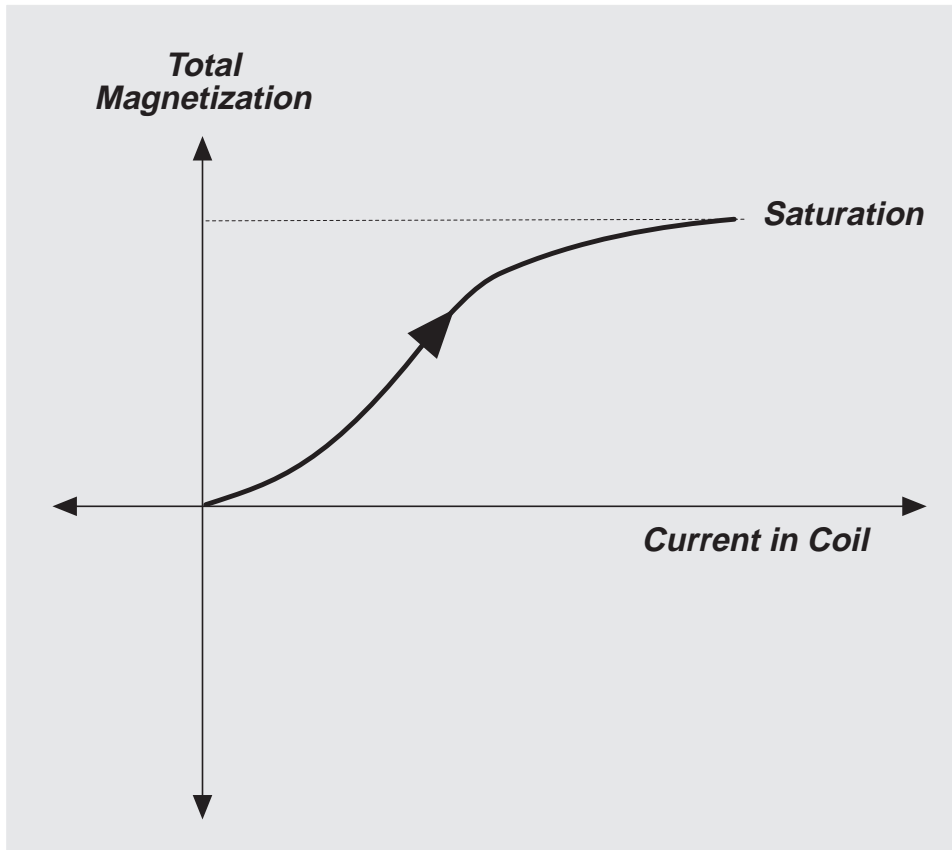


Figure 9.7: Alignment of domains in a magnetic material.

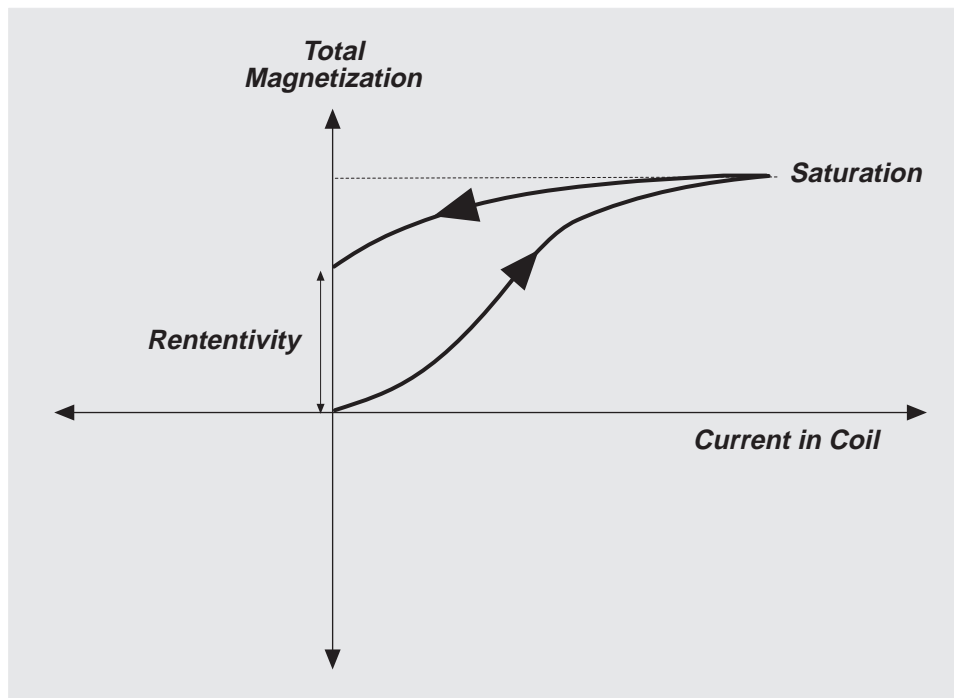


Figure 9.8: Behavior of magnetic material in a coil whose current is increased and decreased to zero.

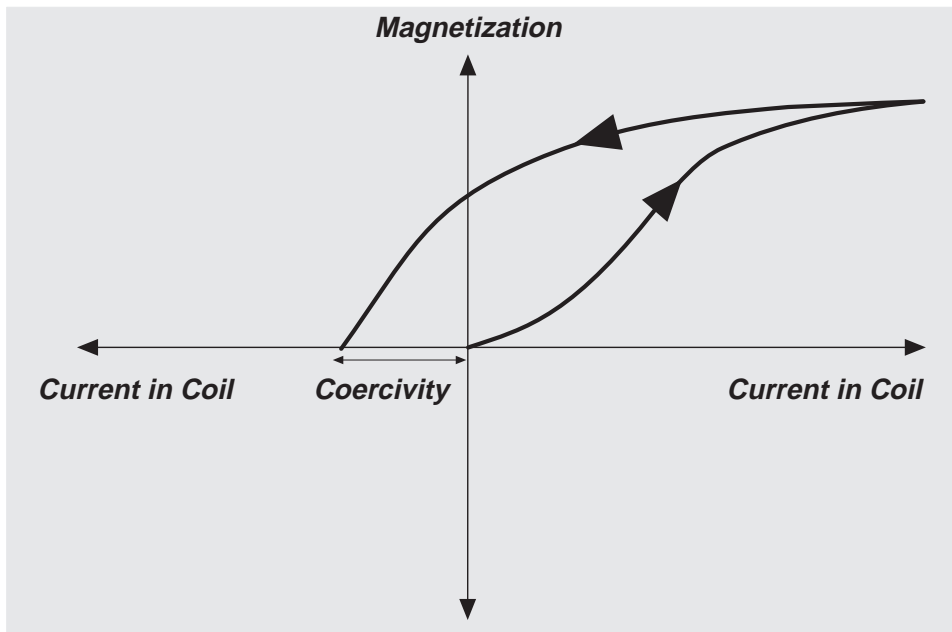


Figure 9.9: Memory is destroyed by reversed current in coil.

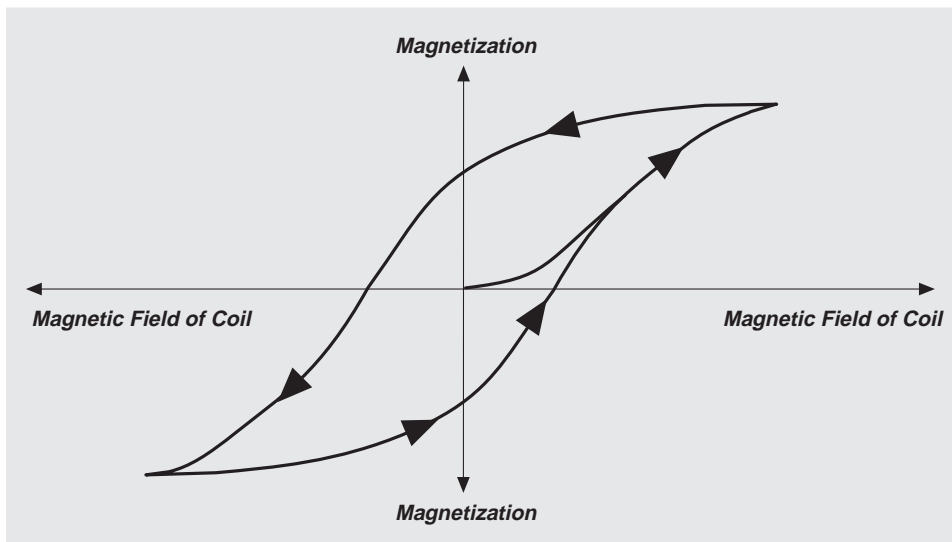


Figure 9.10: Hysteresis curve of magnetic material.

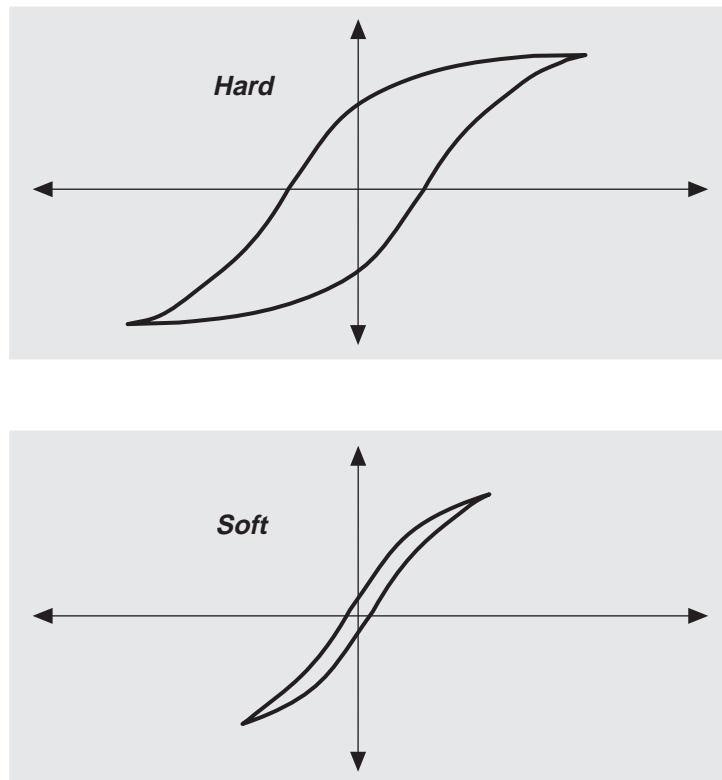


Figure 9.11: Groups of magnetic materials.

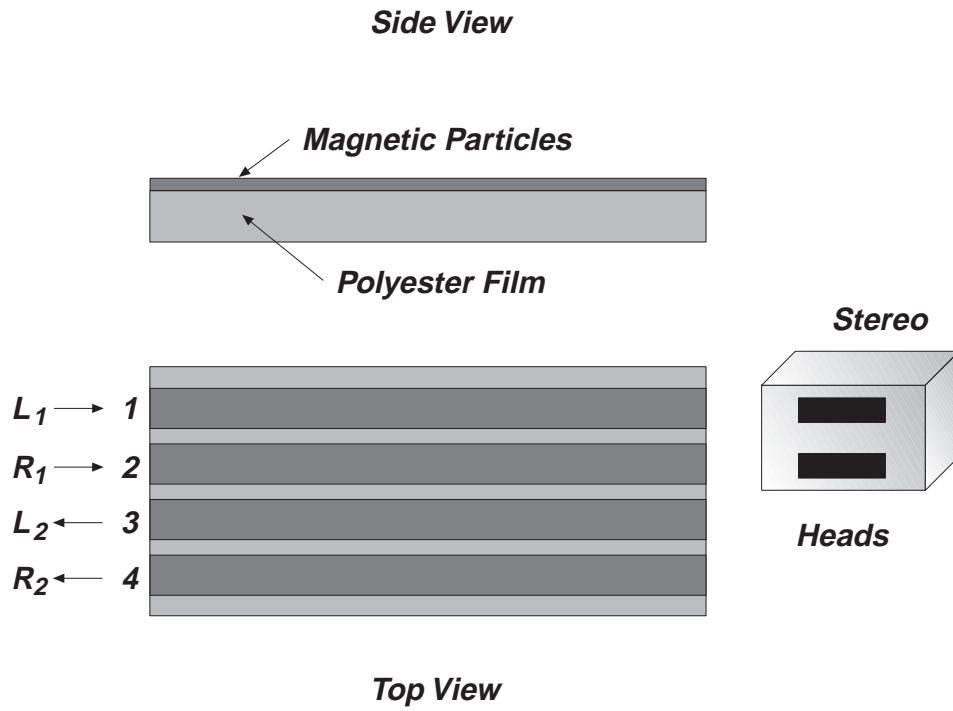


Figure 9.12: Side and top views of magnetic tape.

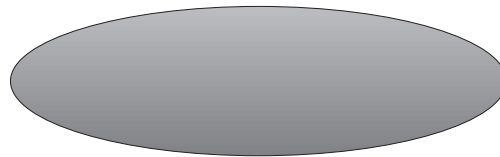


Figure 9.13: Magnetic particle of gamma – Iron (III) Oxide as used on tapes.

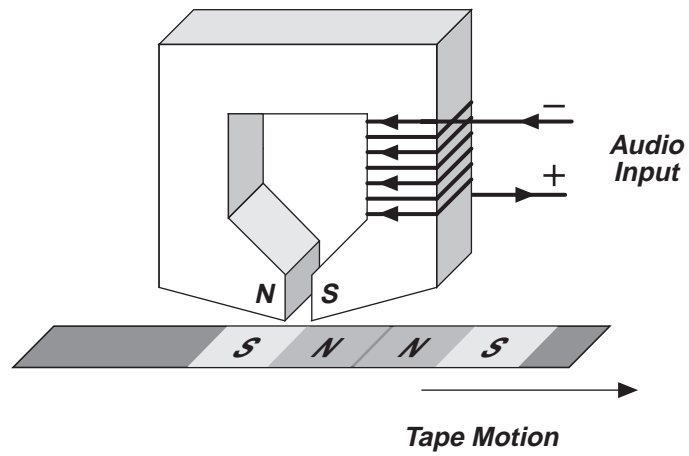


Figure 9.14: Recording head aligning magnetic domains on tape.

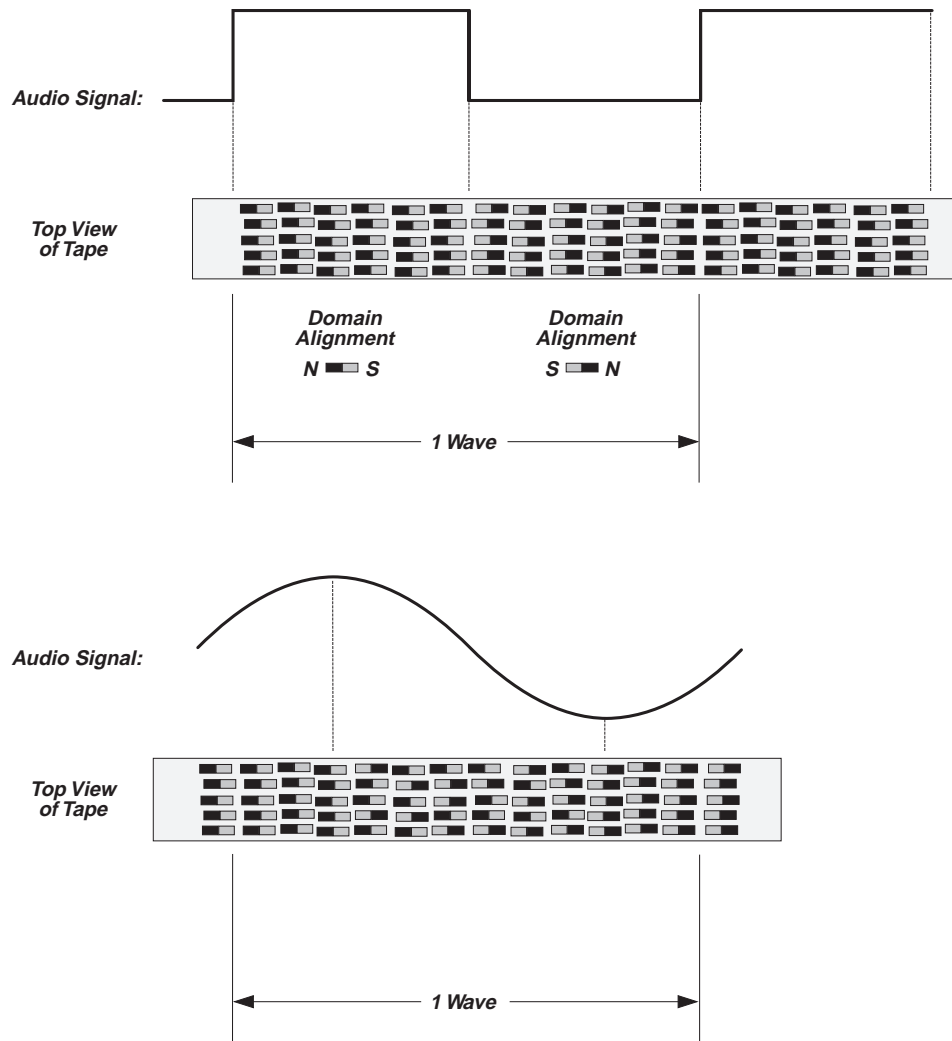


Figure 9.15: Analog recording on a magnetic tape.



Figure 9.16: Recorded information on magnetic tape.

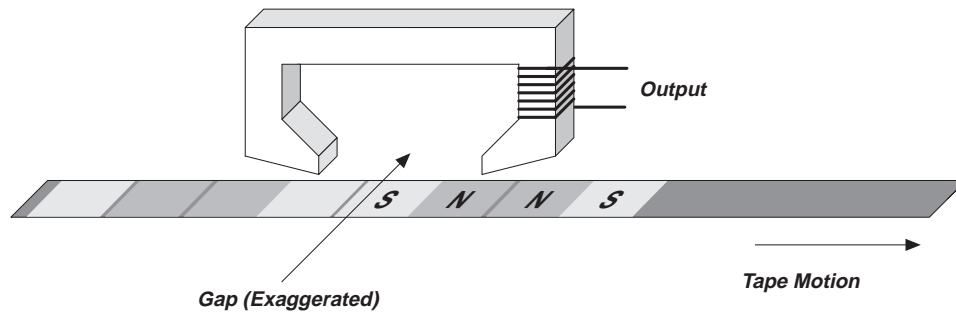


Figure 9.17: Playback head for reading information on a tape.

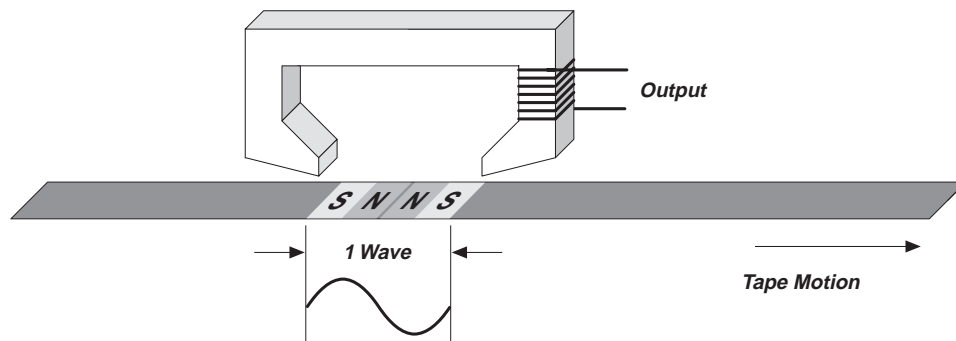


Figure 9.18: Playback head reading signals.

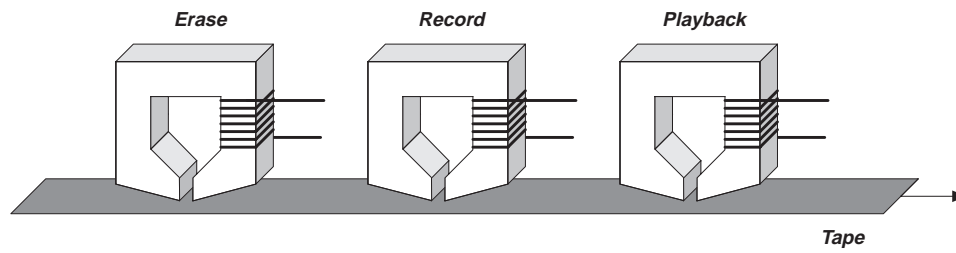


Figure 9.19: Order of heads on a tape deck.

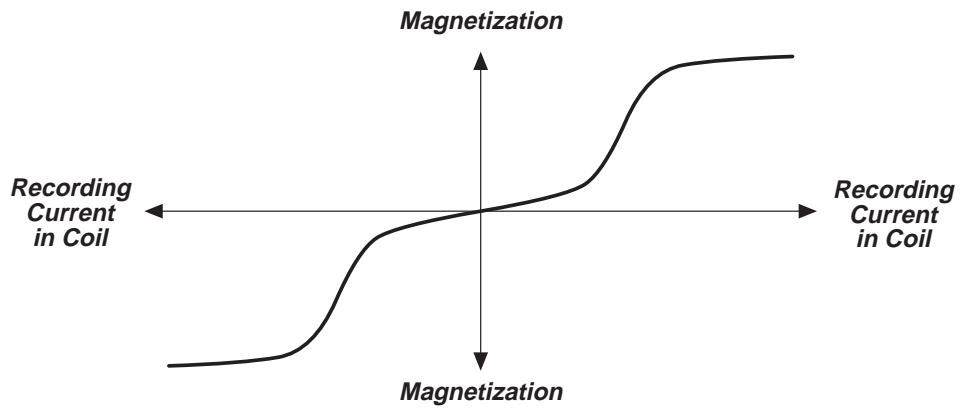


Figure 9.20: Recording on material with magnetic hysteresis.

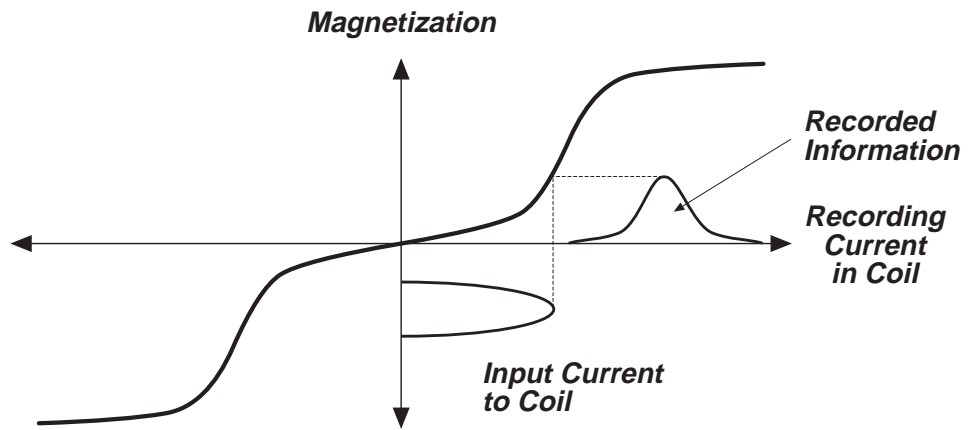


Figure 9.21: Recording a signal on a tape.

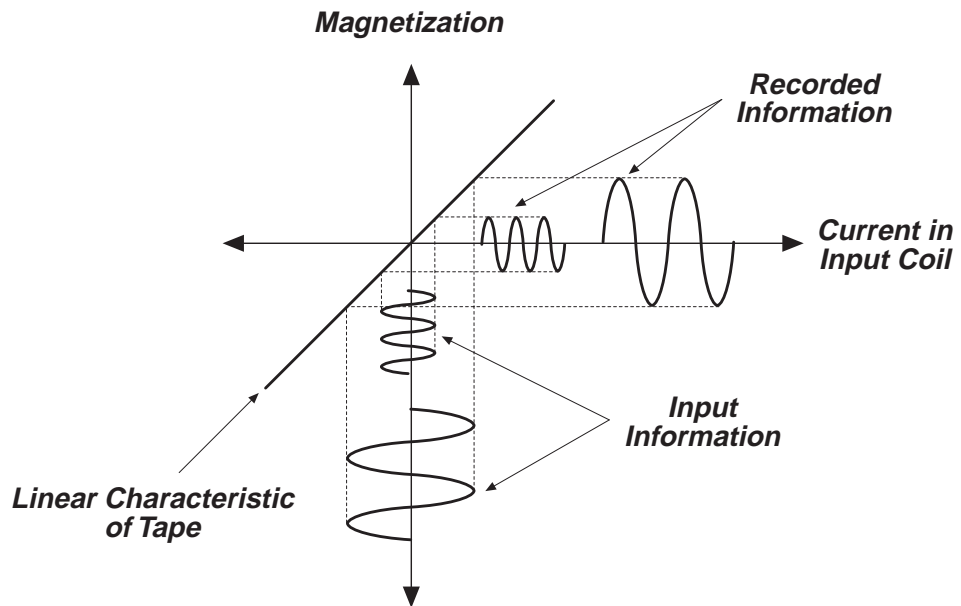


Figure 9.22: Ideal magnetic characteristics for tape — linear behavior.

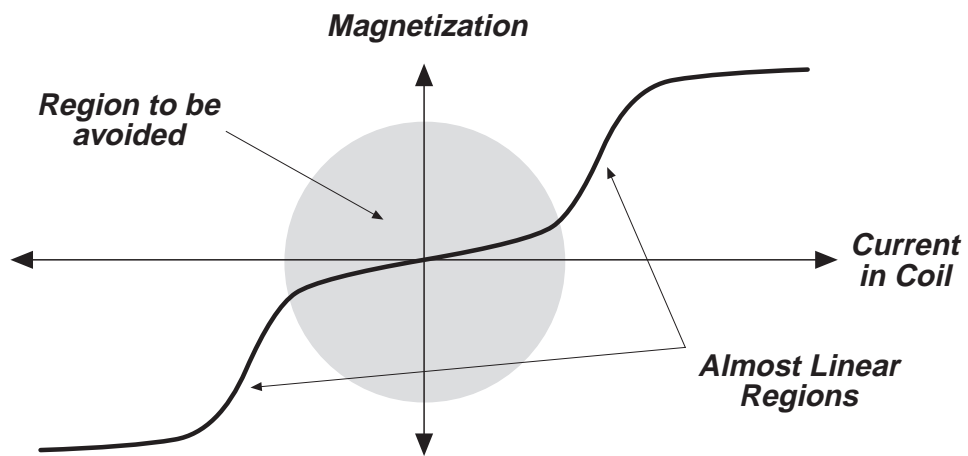


Figure 9.23: Useful region on hysteresis curve for magnetic recording.

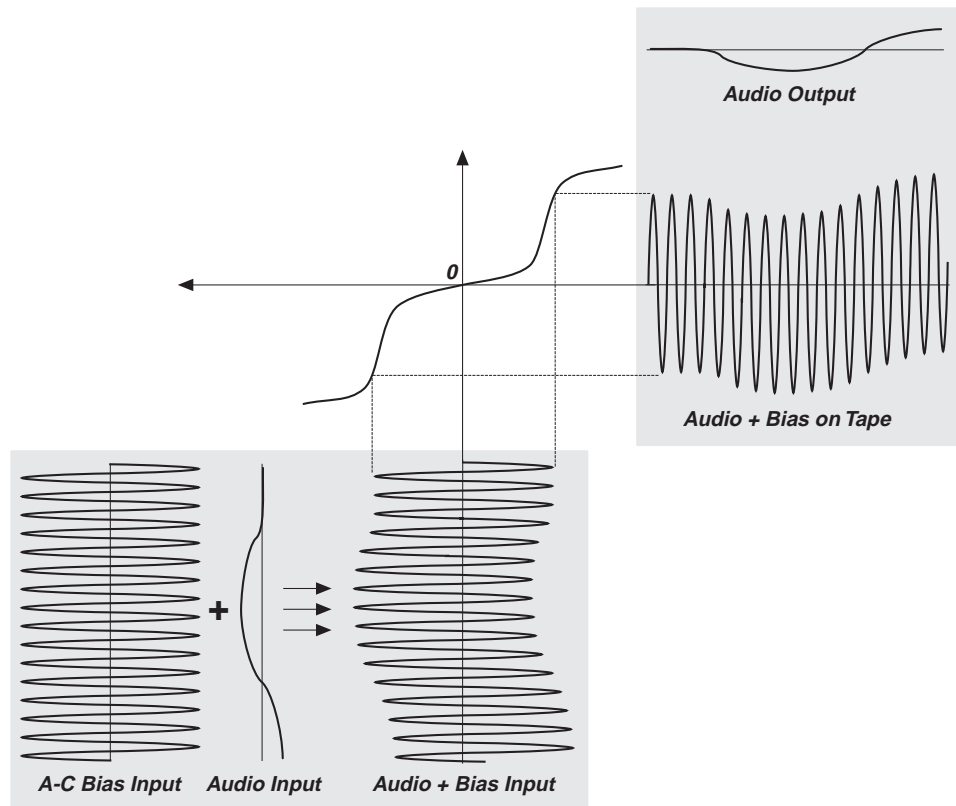


Figure 9.24: Recording on magnetic tape with bias.

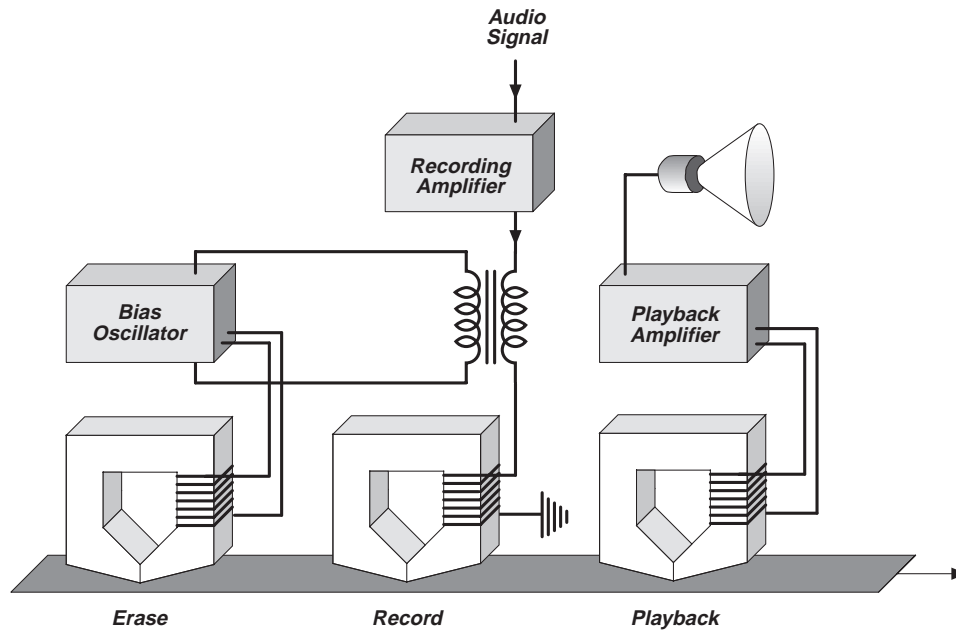


Figure 9.25: Details of heads for magnetic recording.

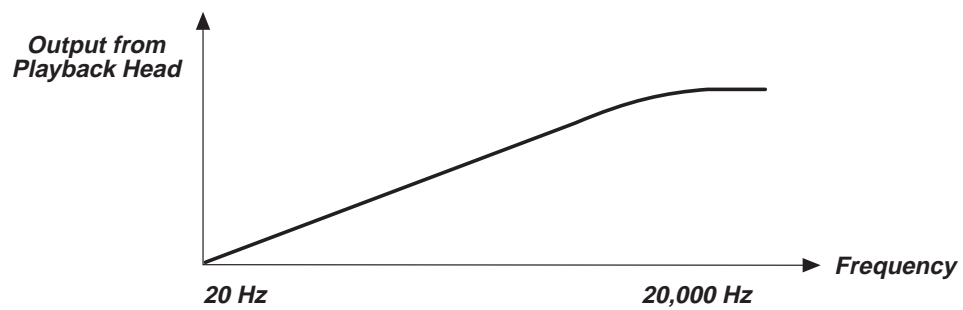


Figure 9.26: Frequency dependence of output from playback head.

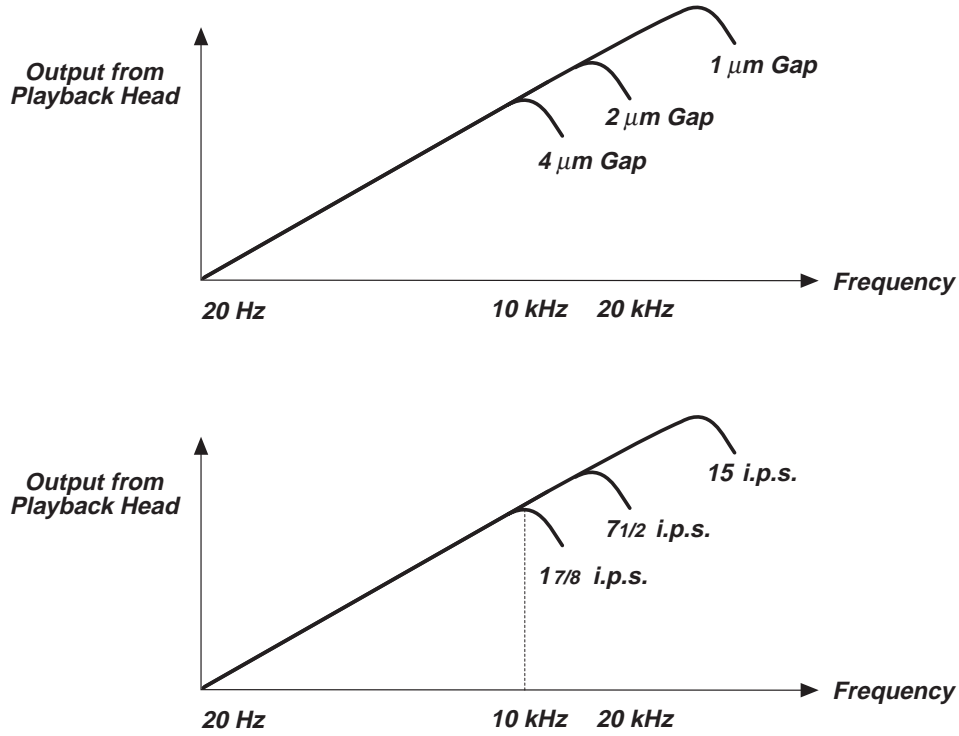


Figure 9.27: Output from playback head as a function of frequency for various gap sizes and tape speeds.

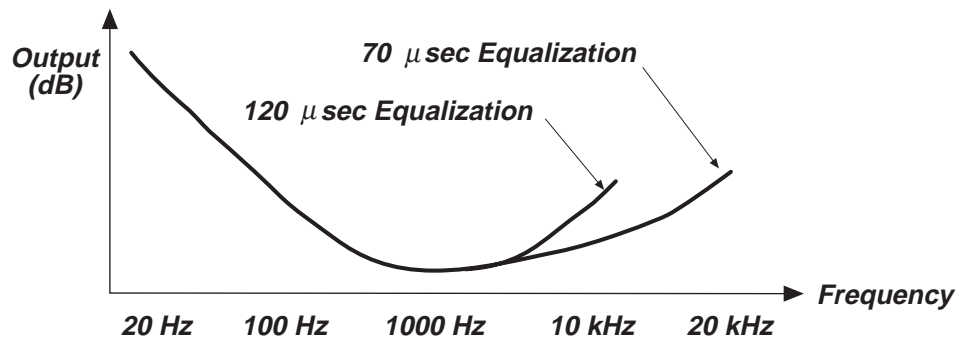


Figure 9.28: Equalization in playback.

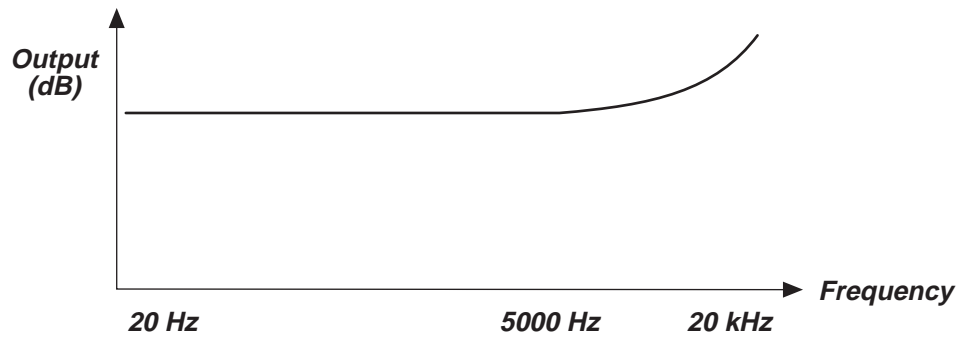


Figure 9.29: Equalization in recording.

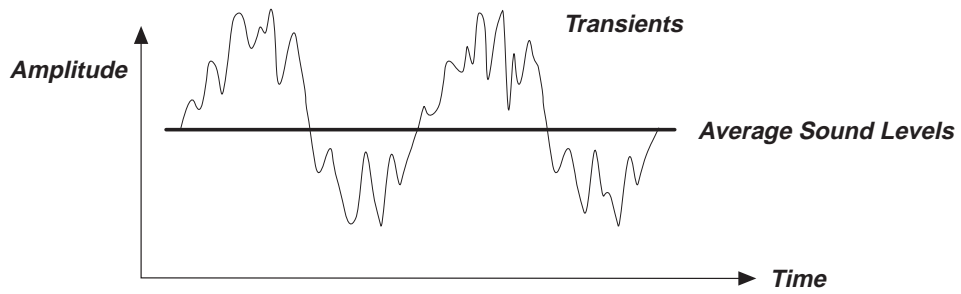


Figure 9.30: Typical musical spectrum.

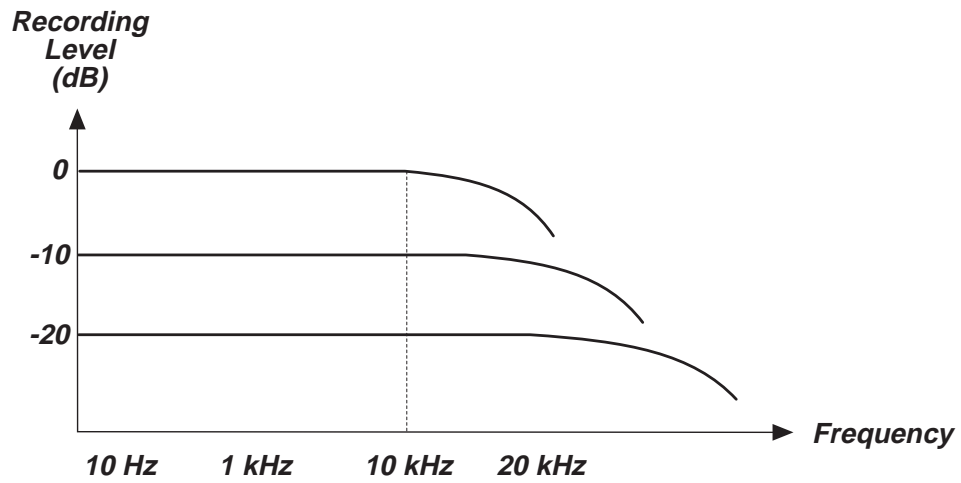


Figure 9.31: Frequency response at different recording levels.

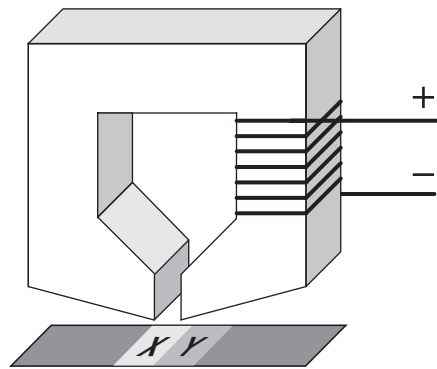


Figure 9.32: Exercise 9.4.

Chapter 10

Digital Optical Recording & Playback

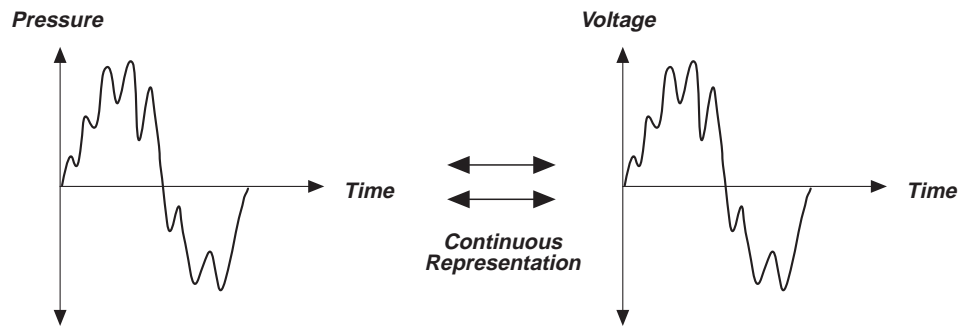


Figure 10.1: Sound wave and its analog representation as a voltage.

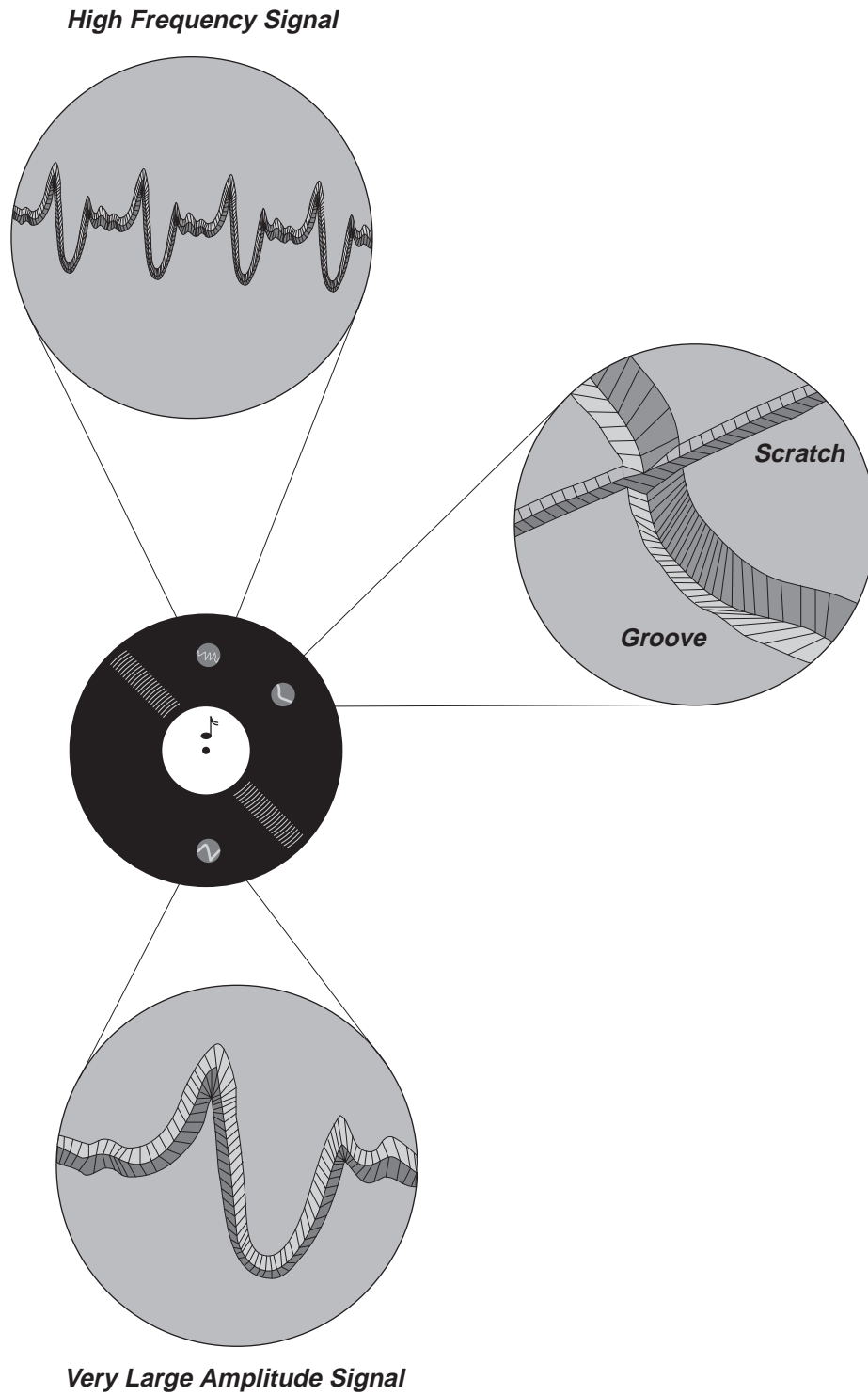


Figure 10.2: Grooves on a record representing analog signals.

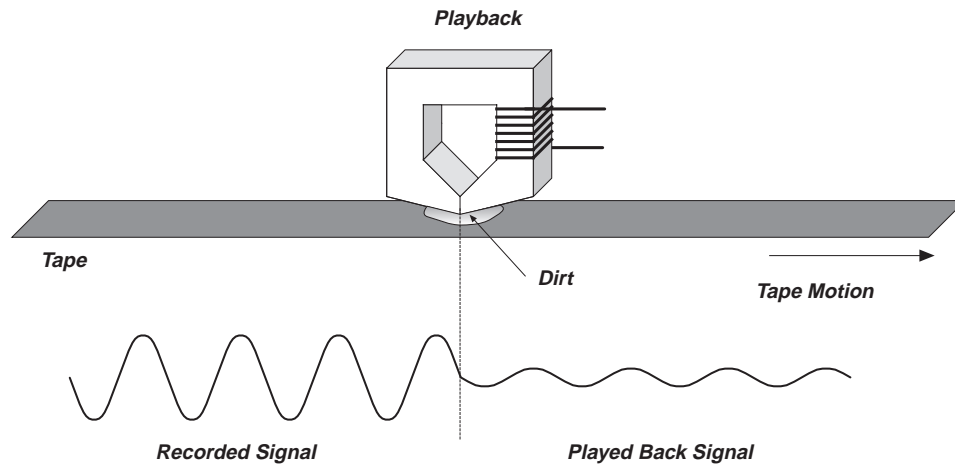


Figure 10.3: Distortion of analog signal by dirt stuck between playback head and tape.

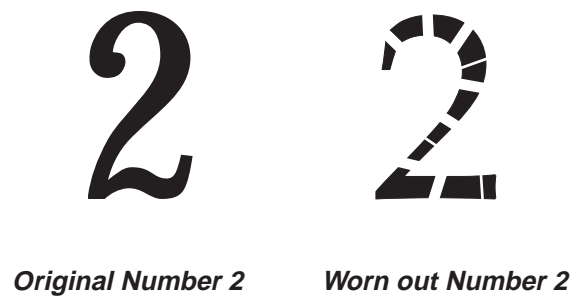


Figure 10.4: Original number 2 and worn out number 2; basic information is not lost when number is worn out.

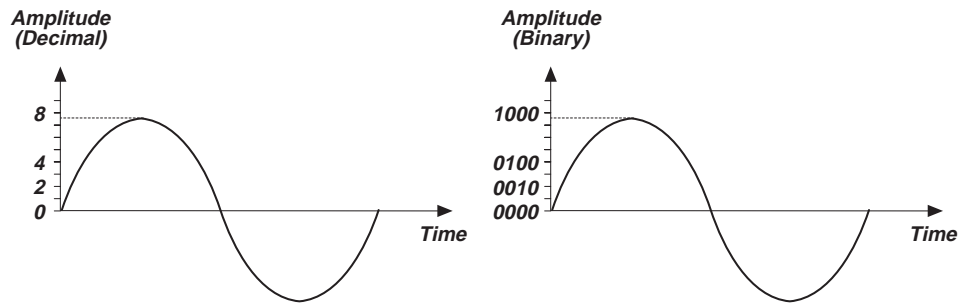


Figure 10.5: (a) Analog signal, decimal scale (b) Analog signal, binary scale.

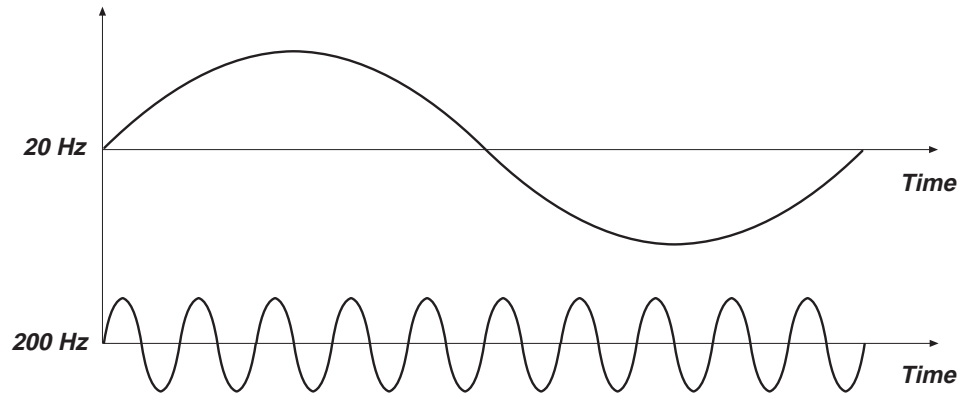


Figure 10.6: 20 Hz wave will get more samples per wave than a 200 Hz wave.

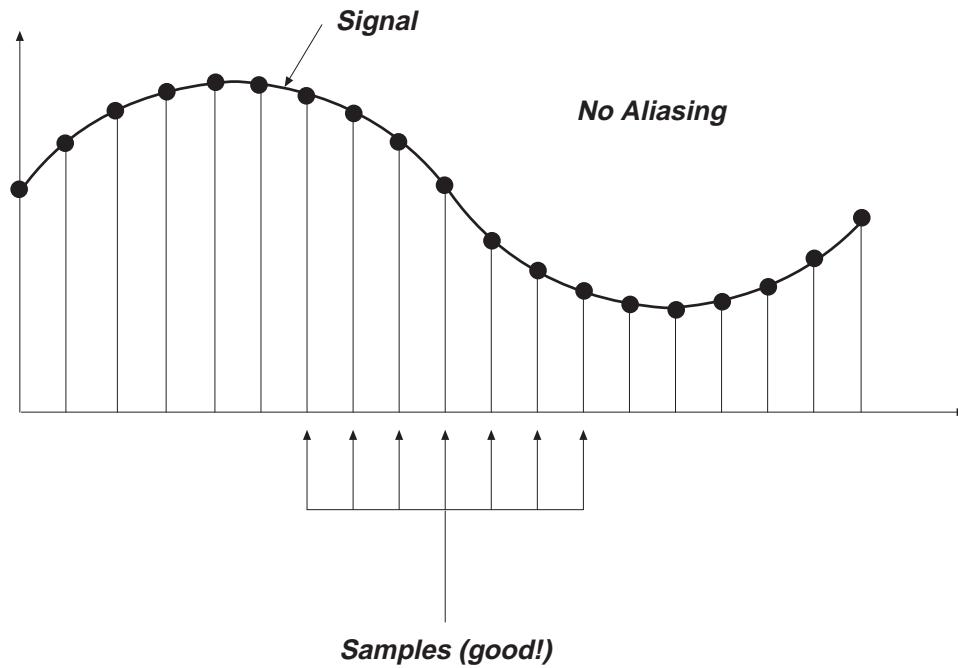
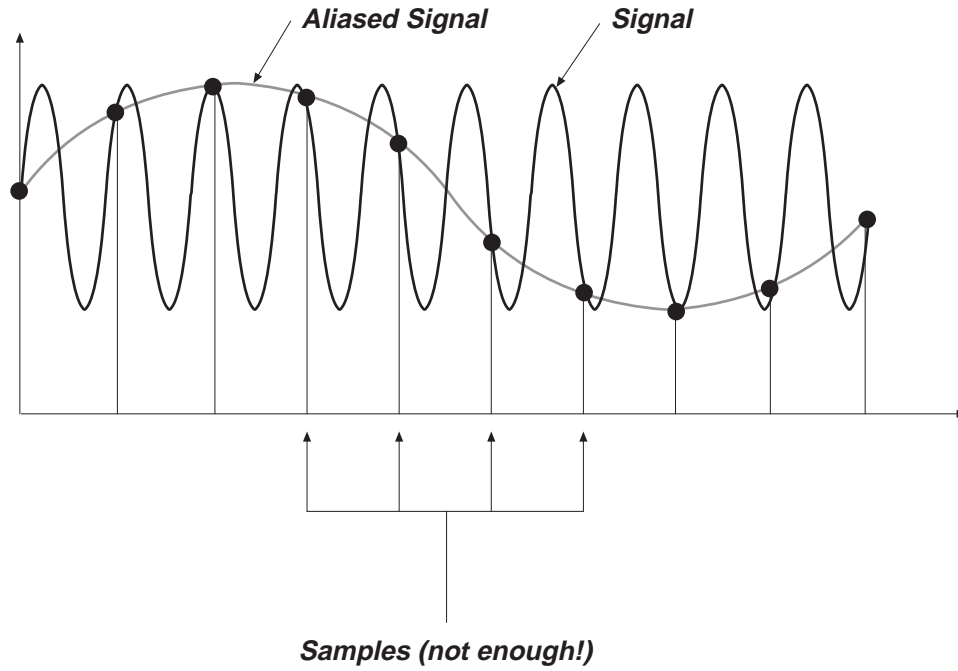


Figure 10.7: Aliasing due to inadequate sampling rate.

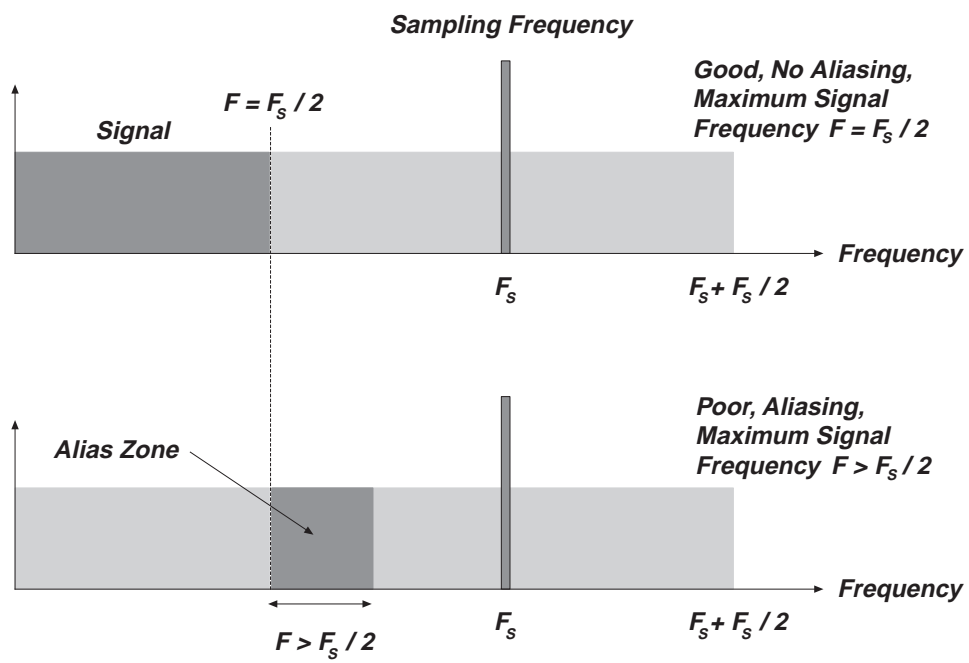


Figure 10.8: Audio spectrum and sideband frequencies due to sampling.

Sample and Hold of Analog Signal

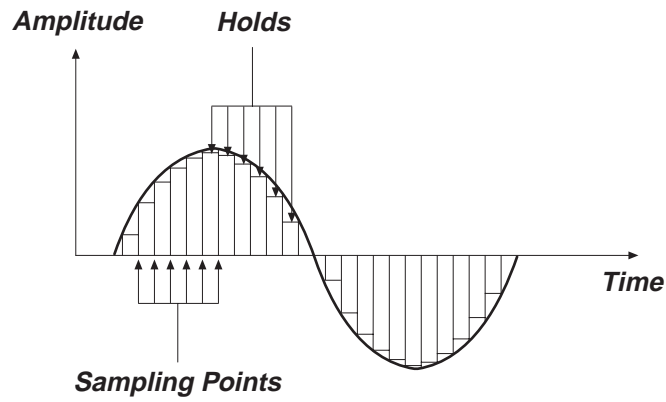


Figure 10.9: Sample and hold of a signal for digitizing.

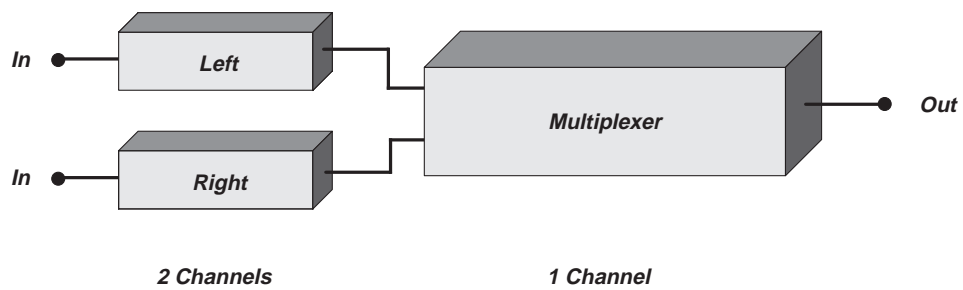


Figure 10.10: Multiplexing of left and right channels.

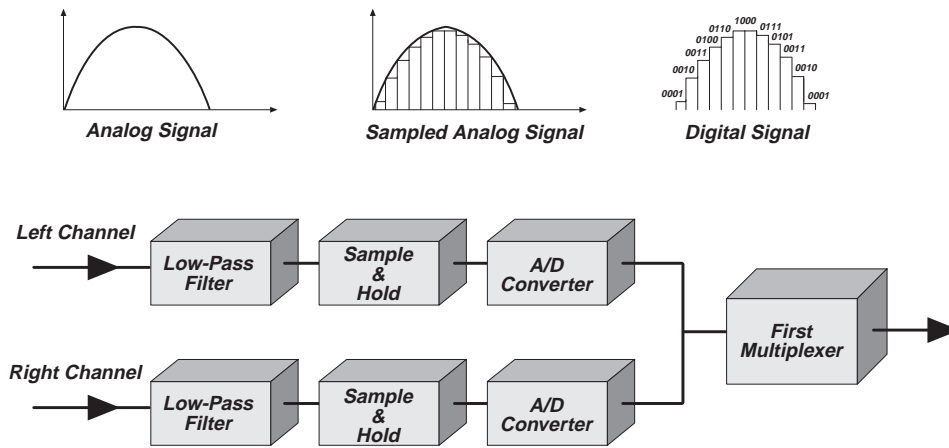


Figure 10.11: Digitizing a signal.

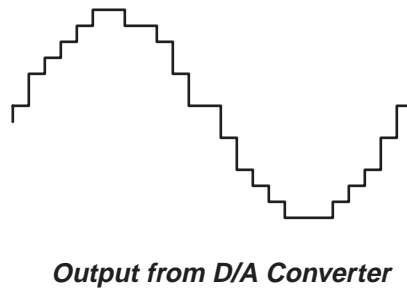


Figure 10.12: Output of D-A converter.

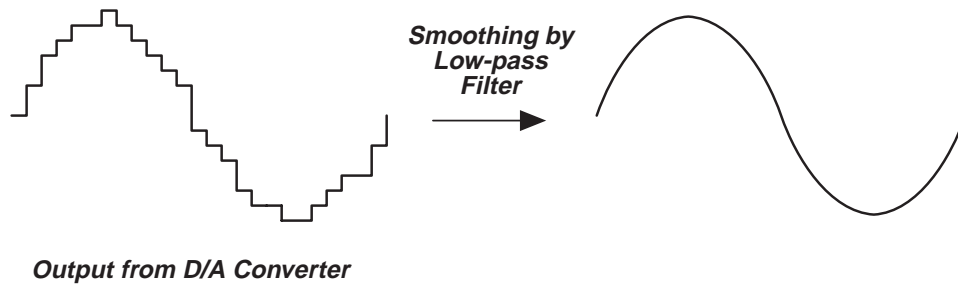


Figure 10.13: Output of low-pass filter.

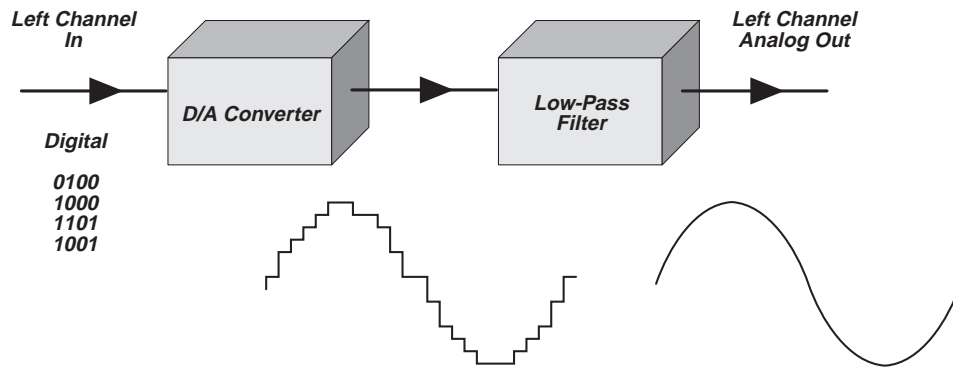


Figure 10.14: Main features of playback of digital signal.

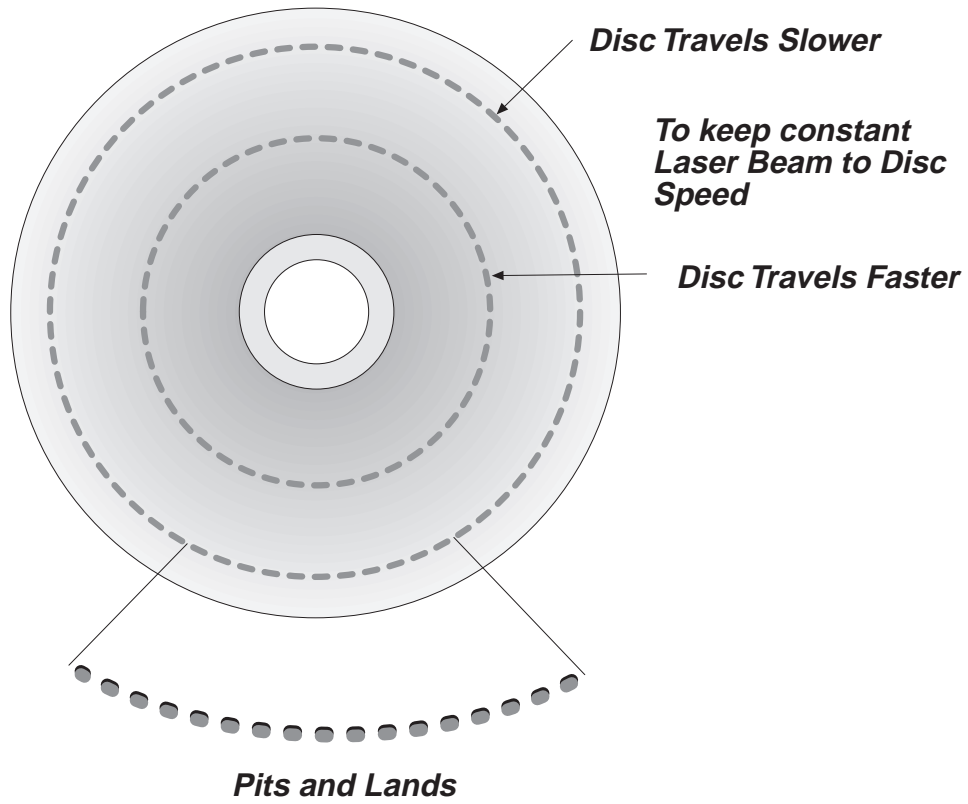


Figure 10.15: Details of information on a CD.

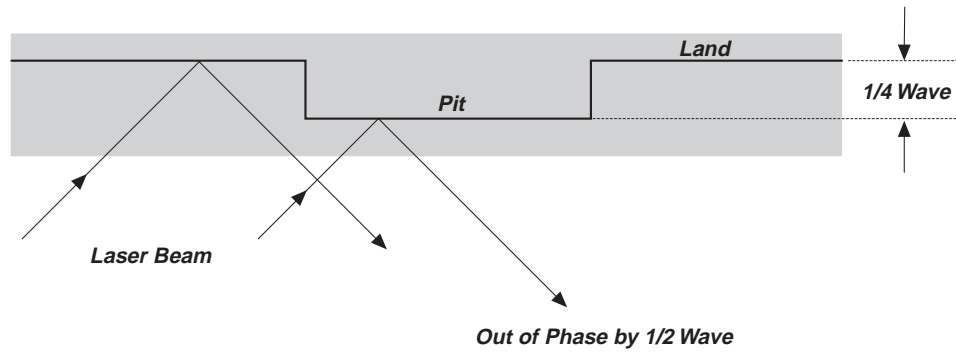


Figure 10.16: Interference between light beam reflected from pit and from flat.

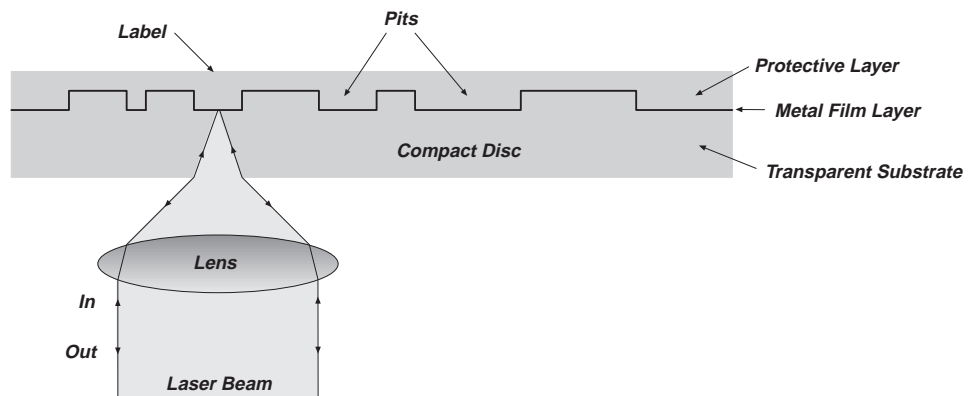


Figure 10.17: Focusing action of a laser beam by lens.

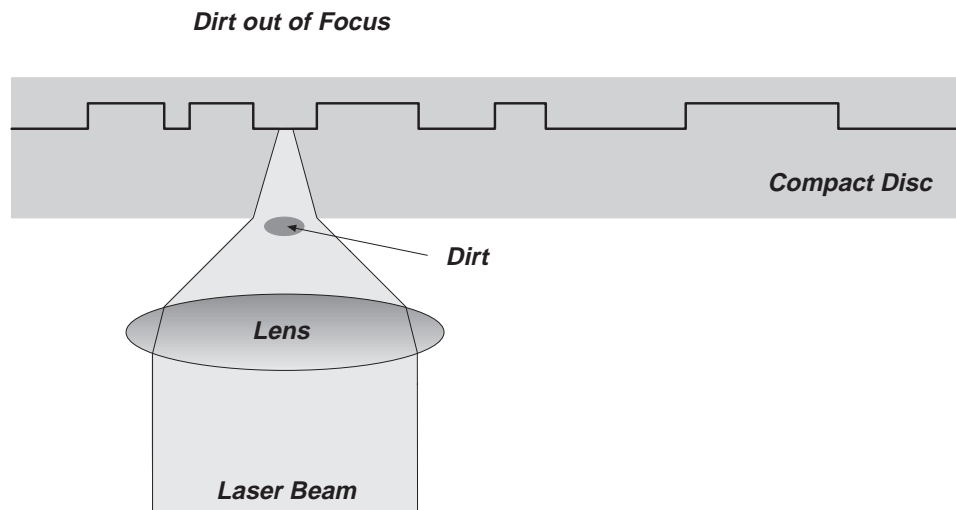


Figure 10.18: Reduced effect of surface defect on CD.

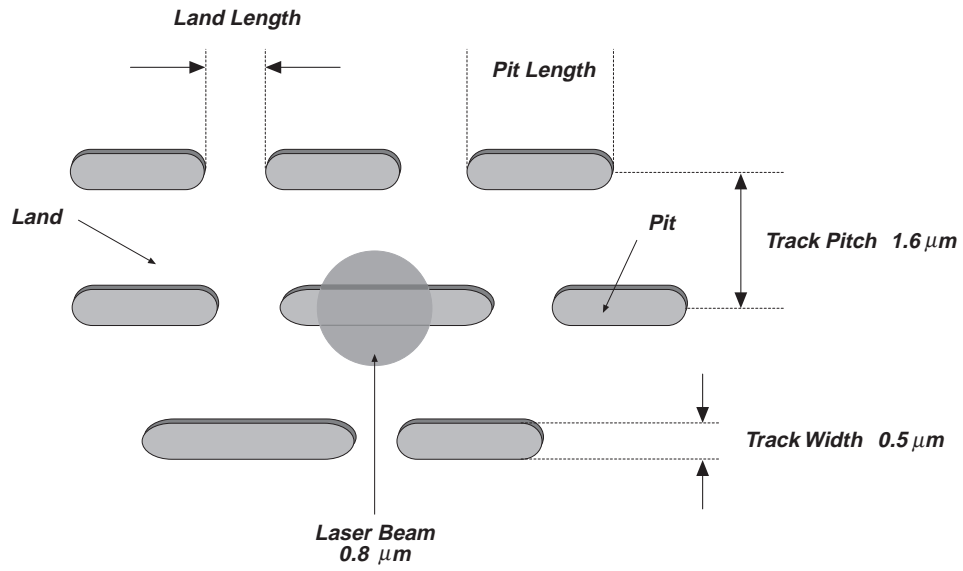


Figure 10.19: Laser spot focused on disc data.

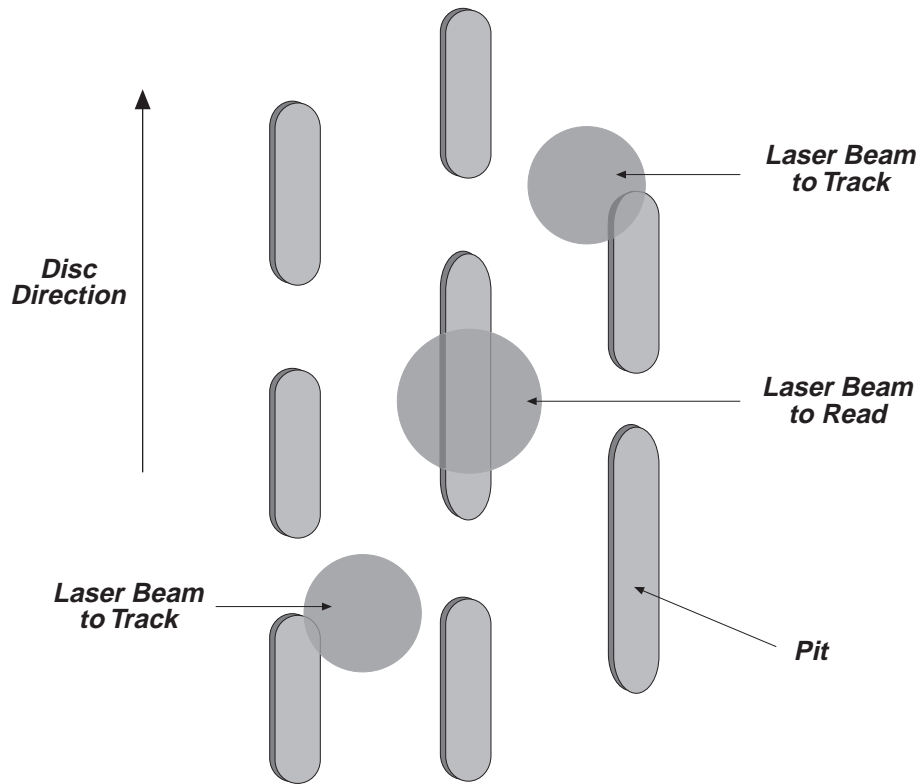


Figure 10.20: Three-beam detection; one for read-out and two beams for tracking.

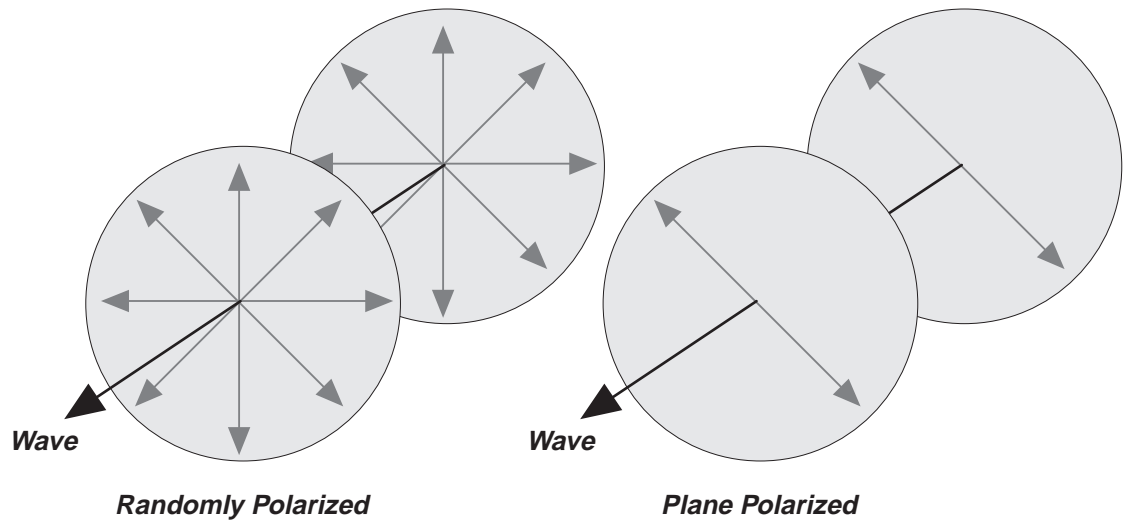


Figure 10.21: Randomly polarized beam and plane-polarized beam.

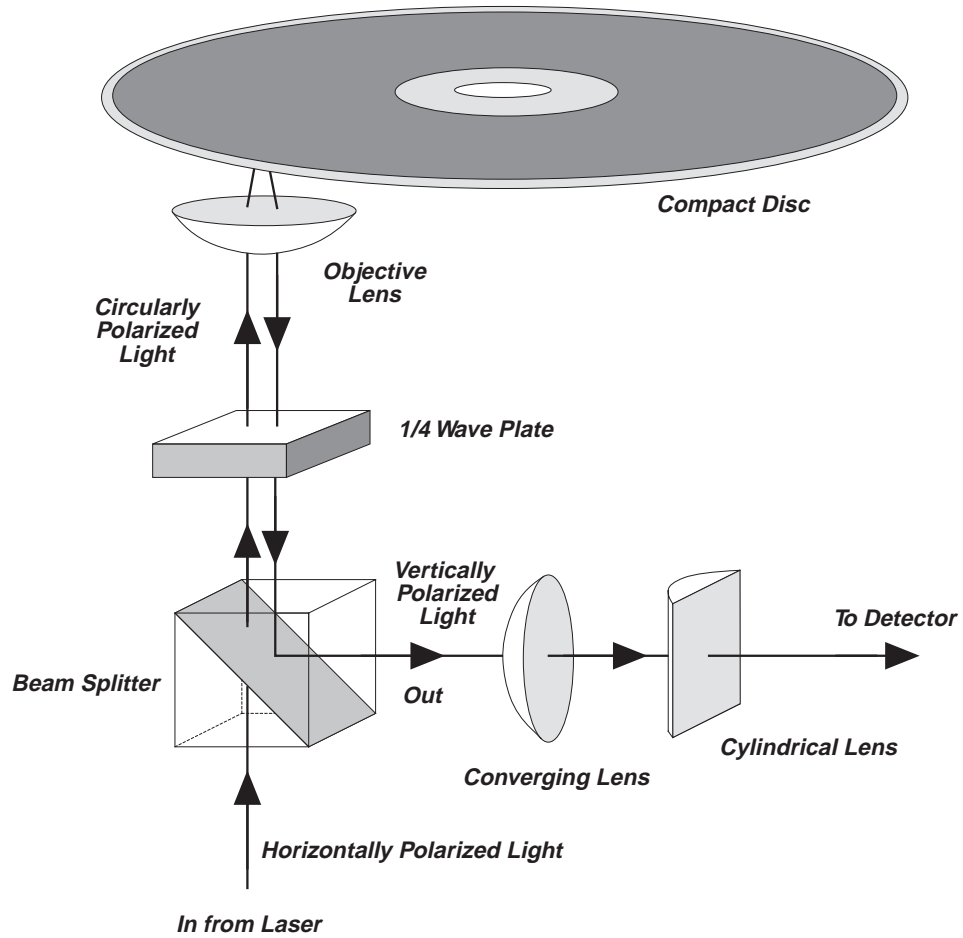
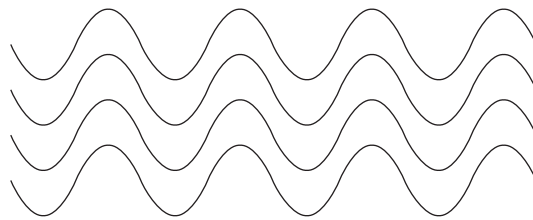
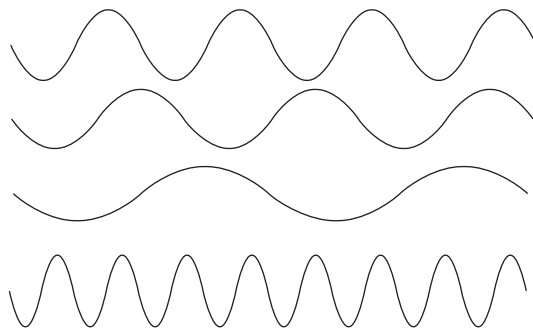


Figure 10.22: Path of laser beam and role of its polarization.



Coherent Beam of Light



Incoherent Beam of Light

Figure 10.23: Coherent and incoherent beams of light.

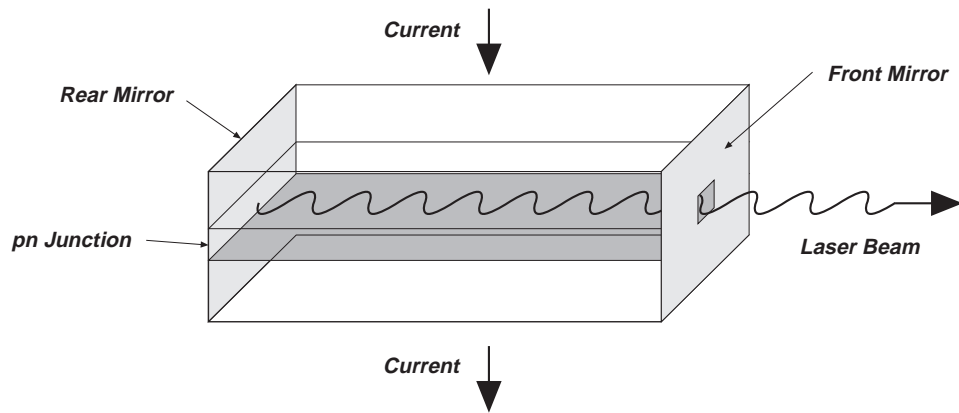


Figure 10.24: Semiconductor laser.

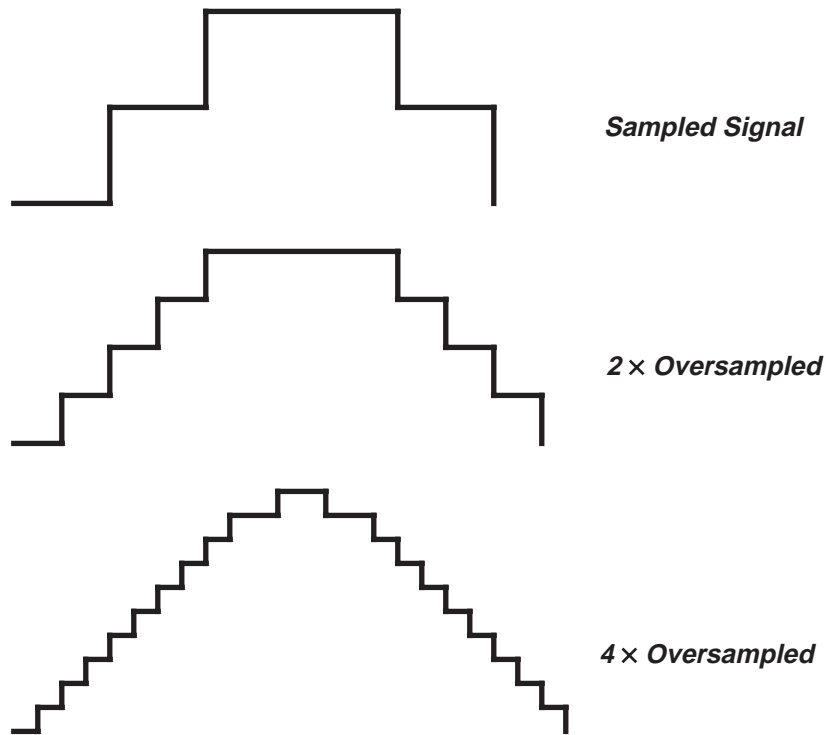


Figure 10.25: Effect of 2-times and 4-times oversampling.

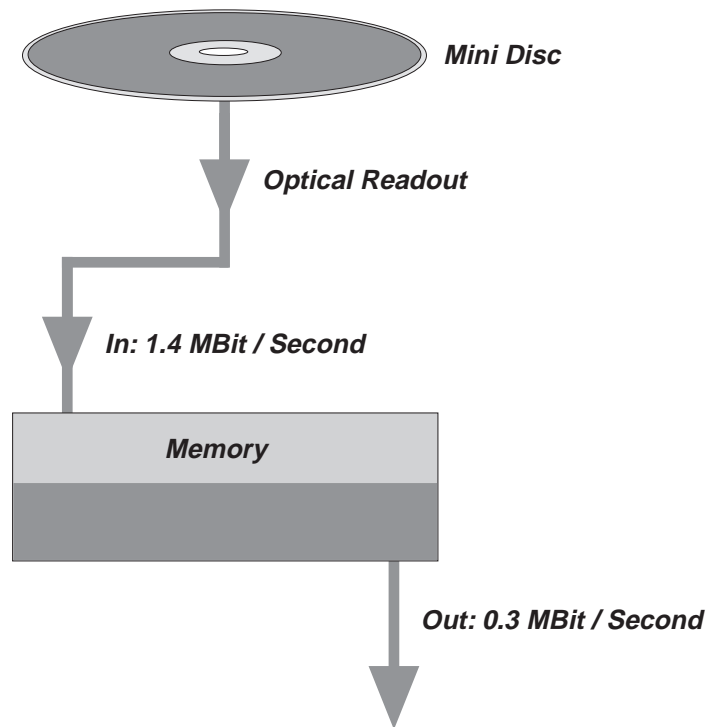


Figure 10.26: Shock-proof memory in mini-disc.

Chapter 11

Digital Magnetic Recording & Playback

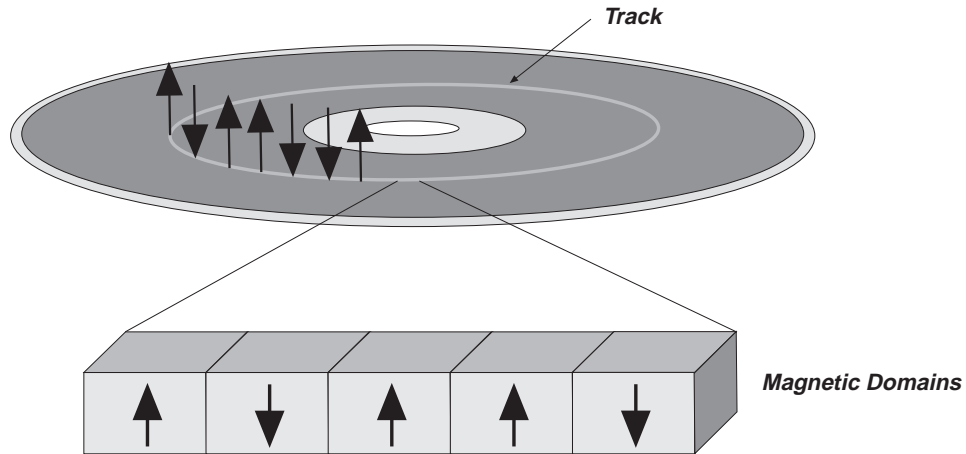


Figure 11.1: Magnetic digital signals recorded vertically on a mini disc.

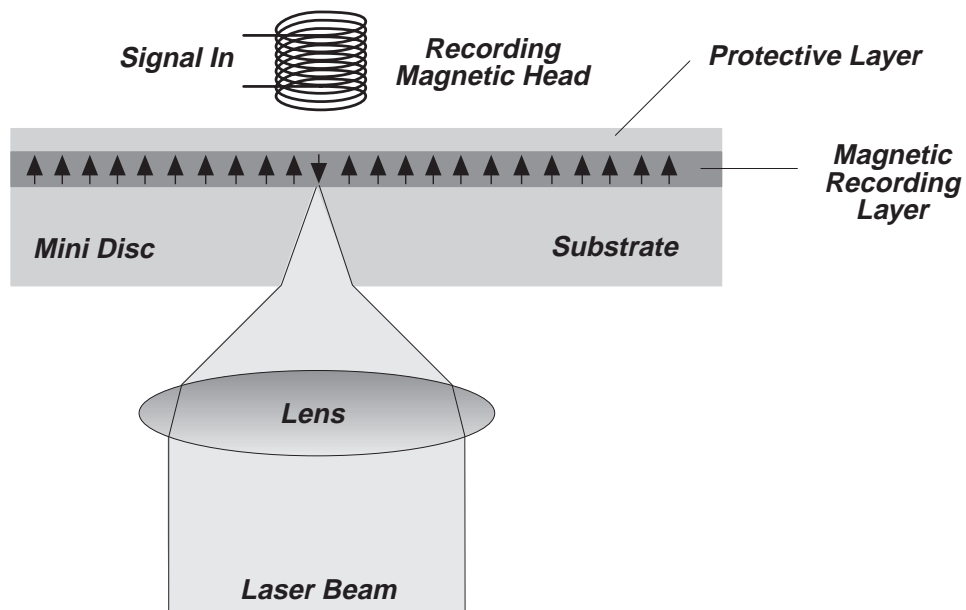


Figure 11.2: Recording digital signals on a mini disc.

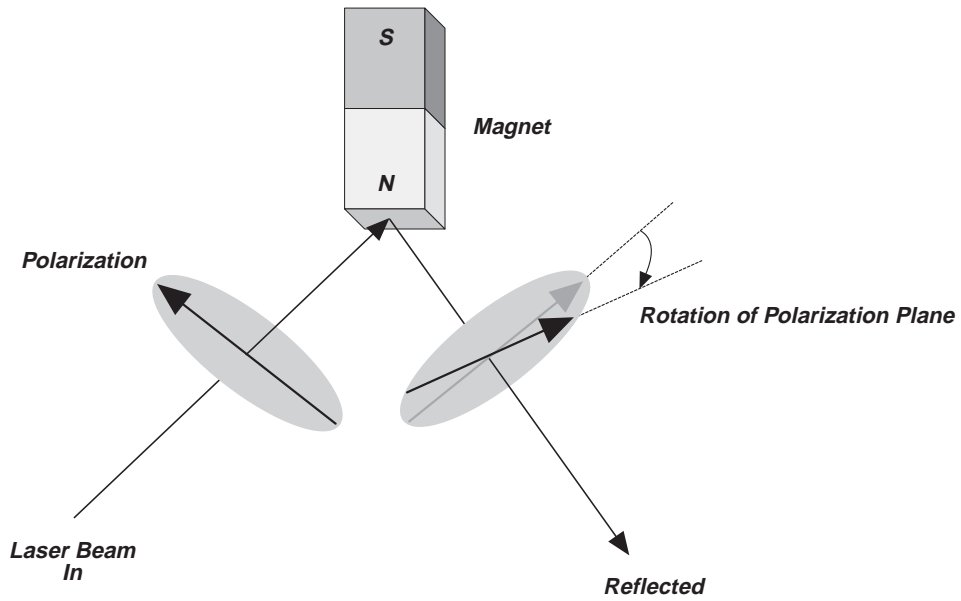


Figure 11.3: Kerr effect: plane of polarization of light beam rotates upon reflection from a magnetized surface.

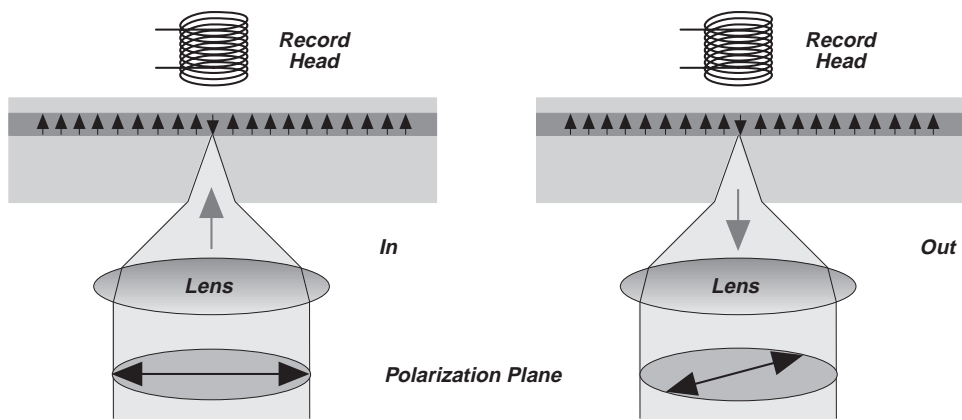


Figure 11.4: Read-out of digital information using Kerr effect. Magnetic field direction affects plane of polarization of reflected laser beam.

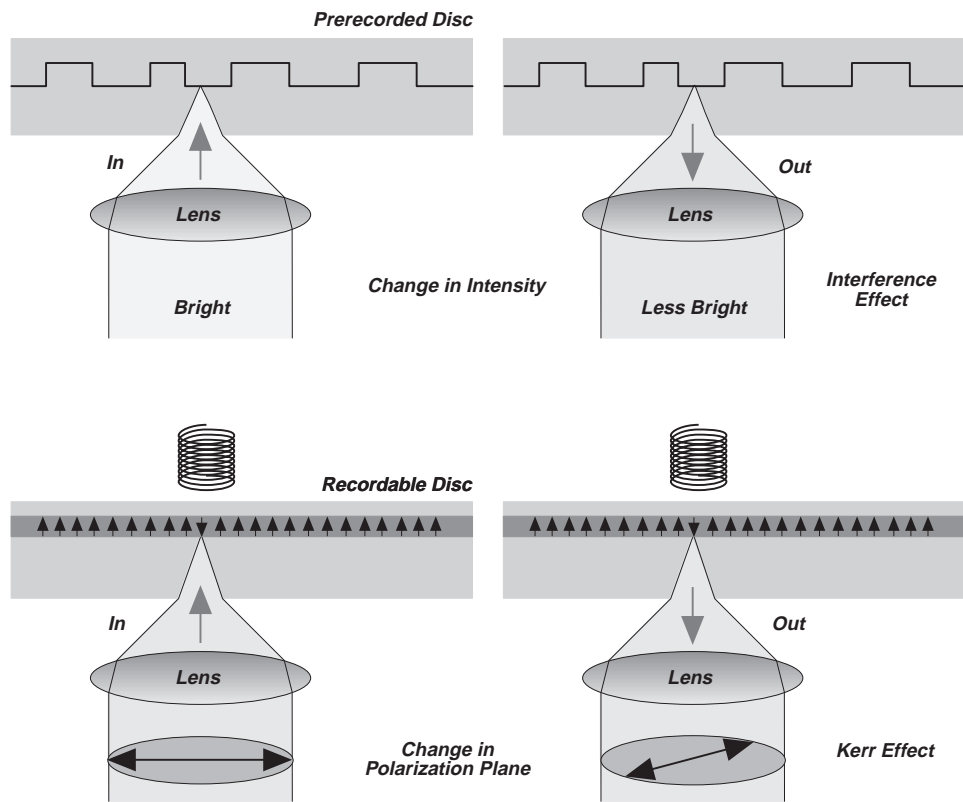


Figure 11.5: Difference in read-out between pre-recorded and recordable mini-discs.

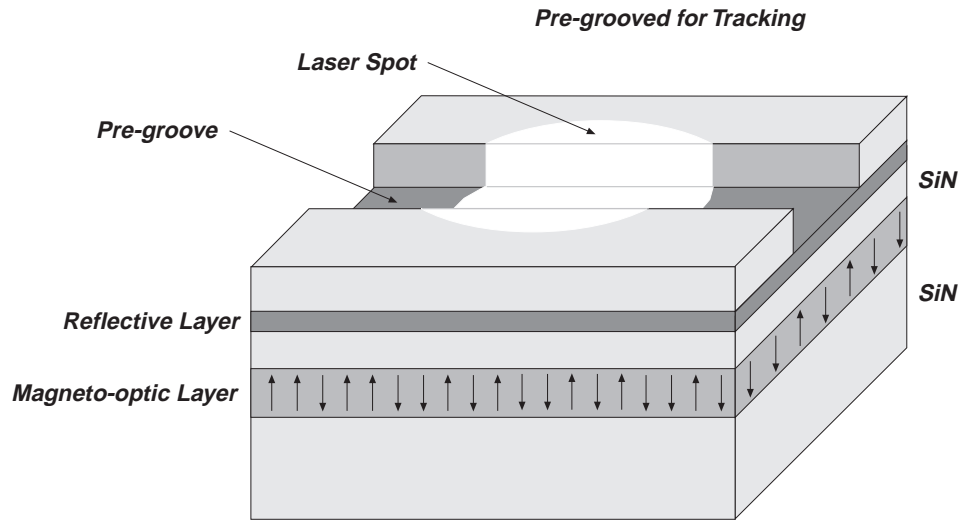


Figure 11.6: Section of a recordable mini disc.

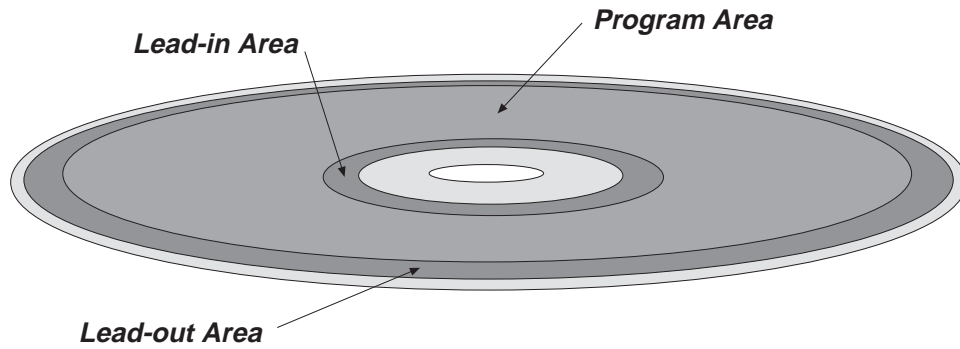


Figure 11.7: Layered structure of recordable mini disc.



Figure 11.8: Track pattern in DCC tape.

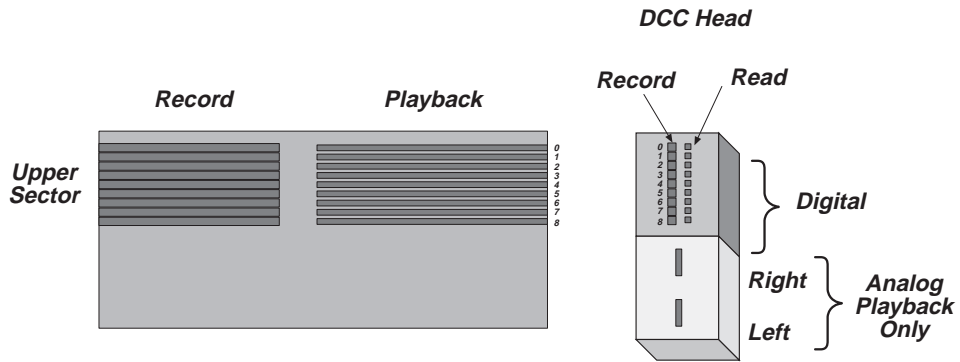


Figure 11.9: The playback head reads only a portion of the recorded track.

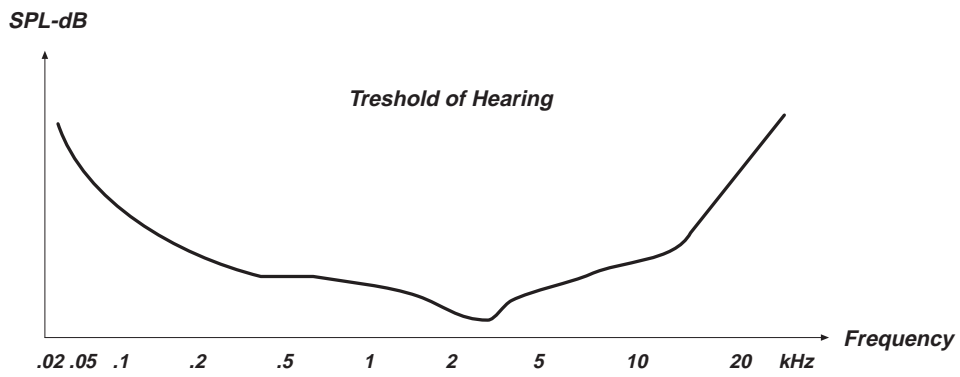


Figure 11.10: Threshold of hearing curve.

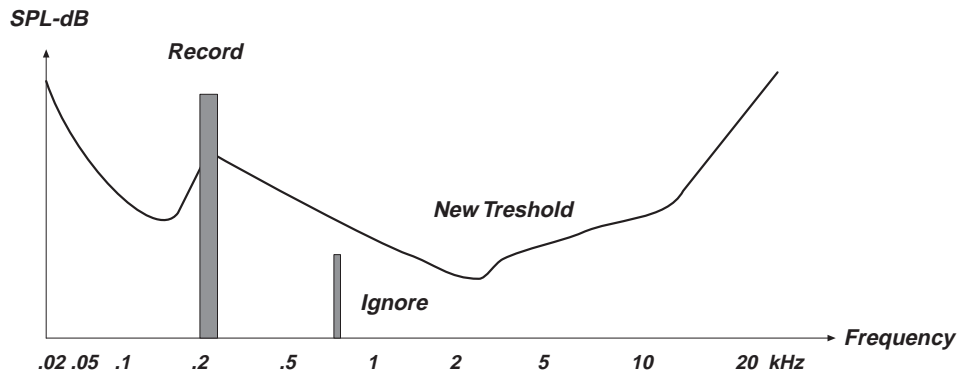


Figure 11.11: Sounds which will be recorded by PASC and masking of quiet passages.

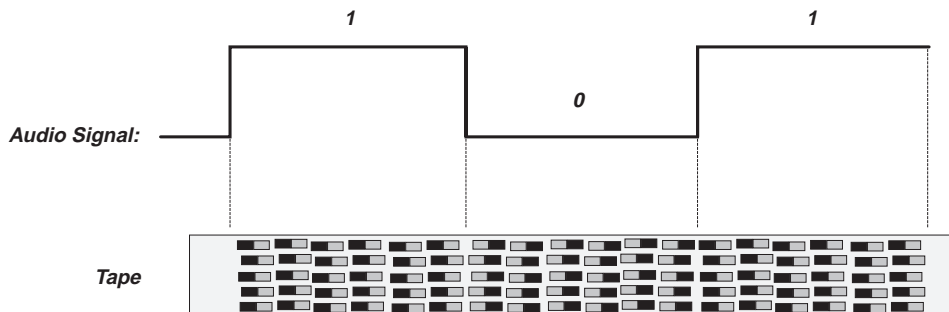


Figure 11.12: Representation of digital signal on magnetic tape.

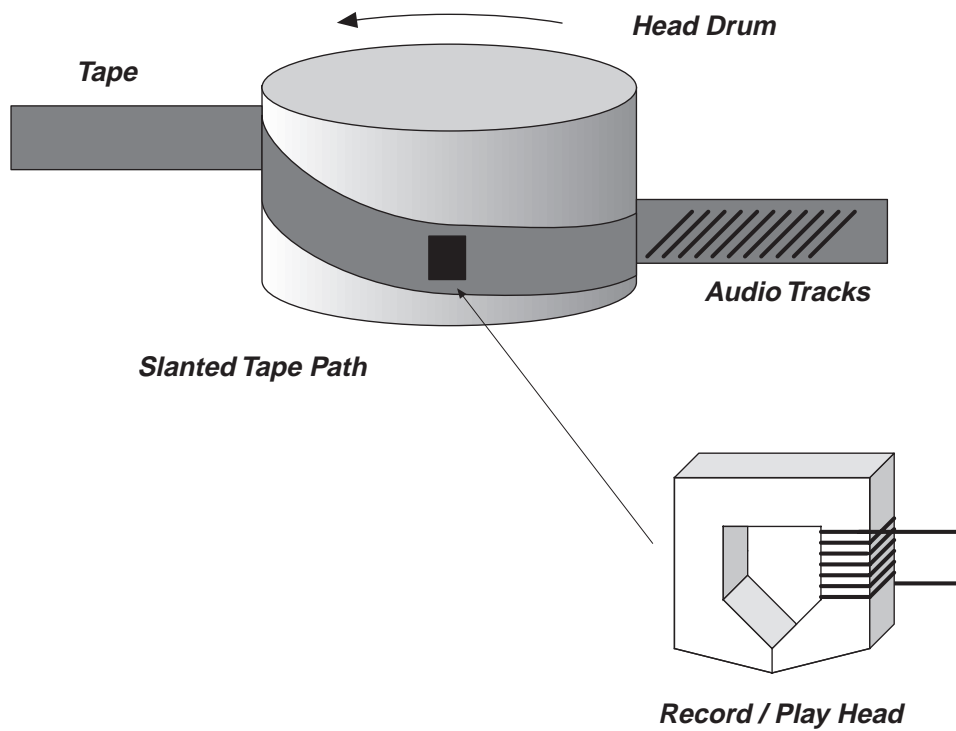


Figure 11.13: Helical recording with rotating heads.

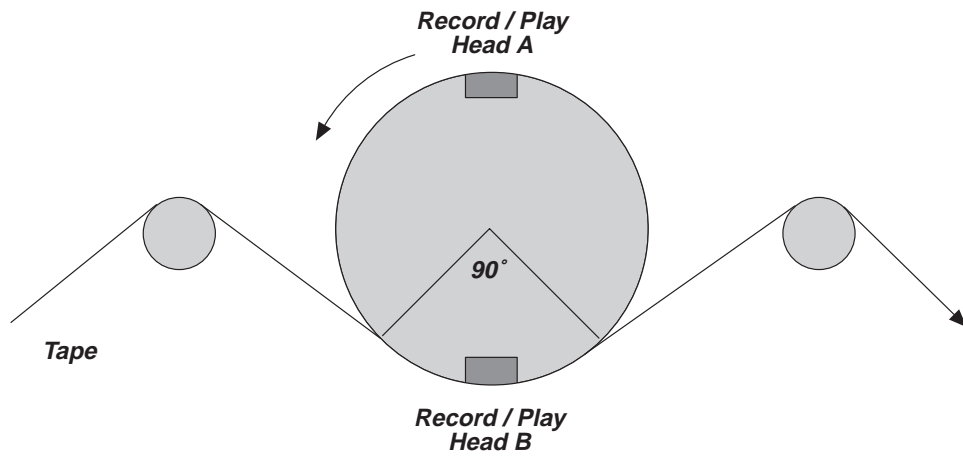


Figure 11.14: Tape contact to rotating head.

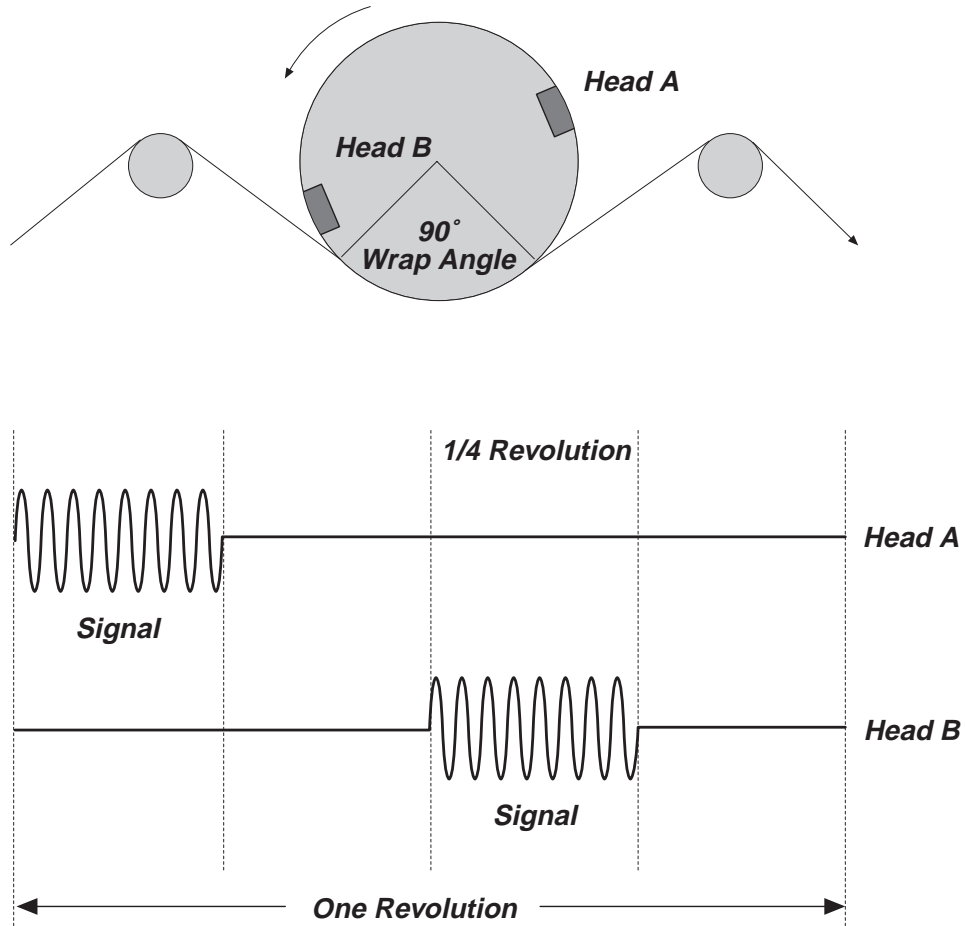


Figure 11.15: Time compression to reduce wrap angle.

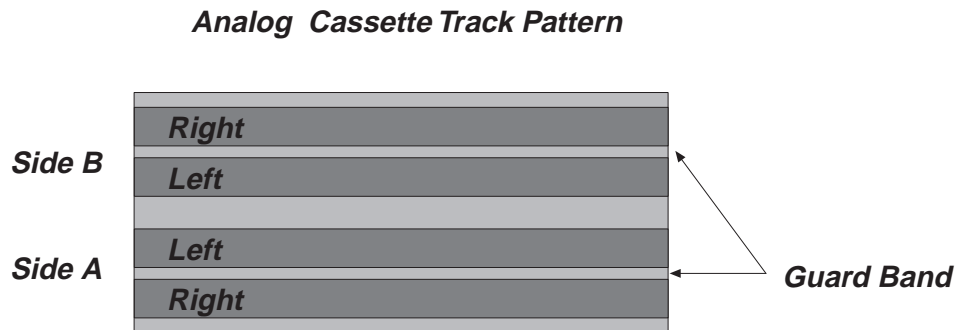


Figure 11.16: Guard band between tracks on analog tape reduces cross-talk.

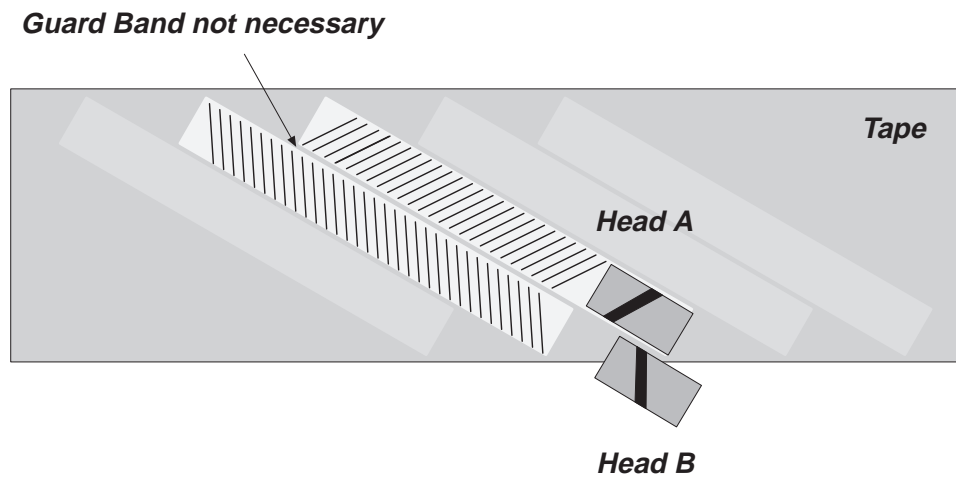


Figure 11.17: Azimuthal recording.

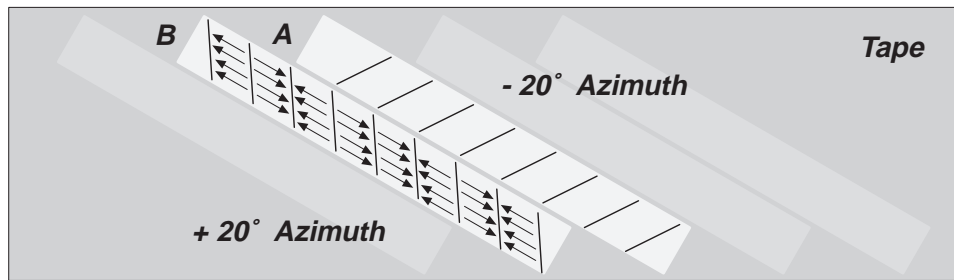


Figure 11.18: Digital information on magnetic tape recorded longitudinally.

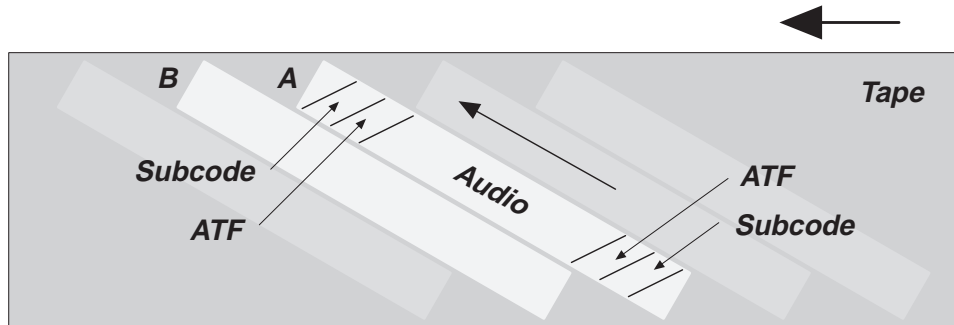


Figure 11.19: Arrangement of signals on a tape.

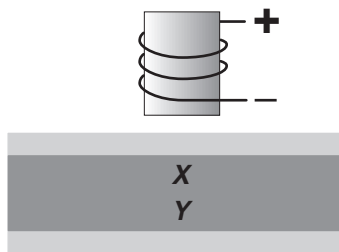


Figure 11.20: Exercise 11.7.

Chapter 12

Heat

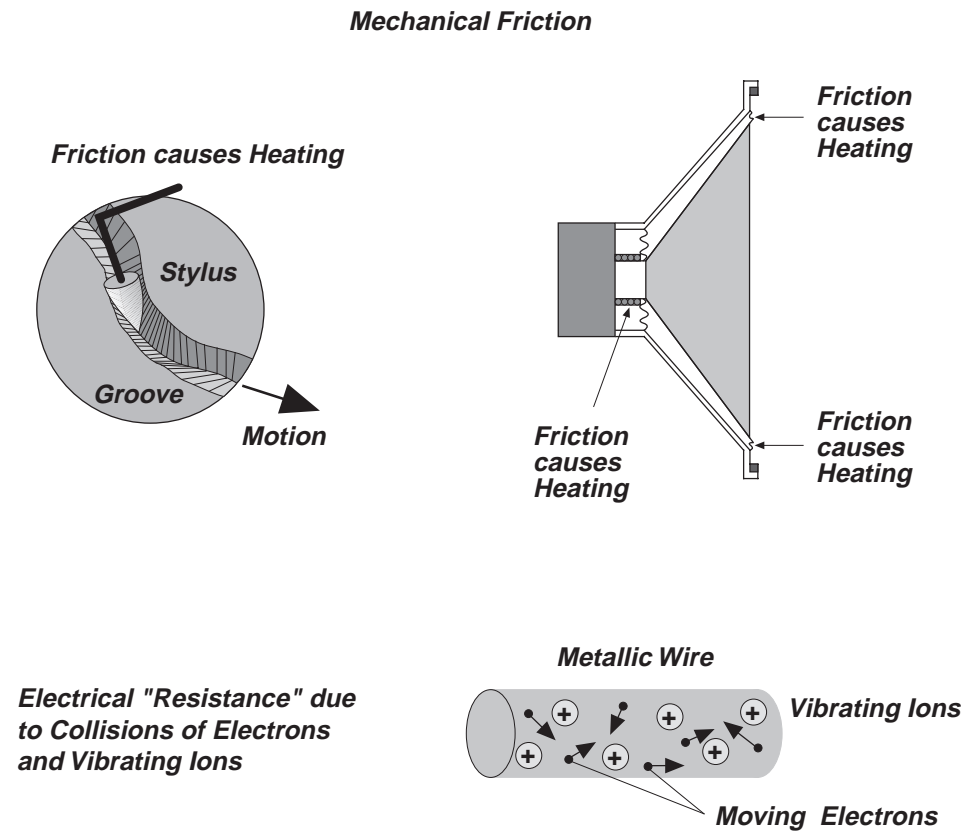


Figure 12.1: Sources of heating in hi-fi due to mechanical friction and electrical "friction".

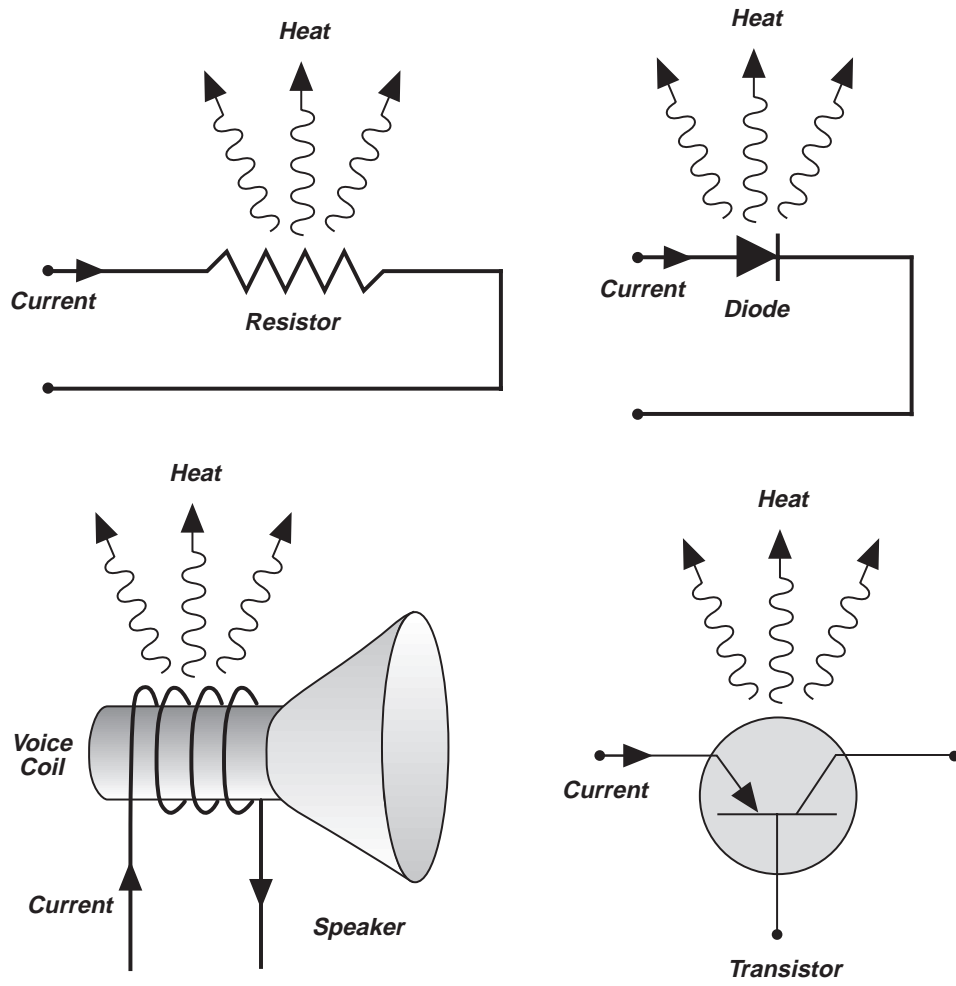


Figure 12.2: Electrical “friction” causes heating in amplifier components and voice coil.

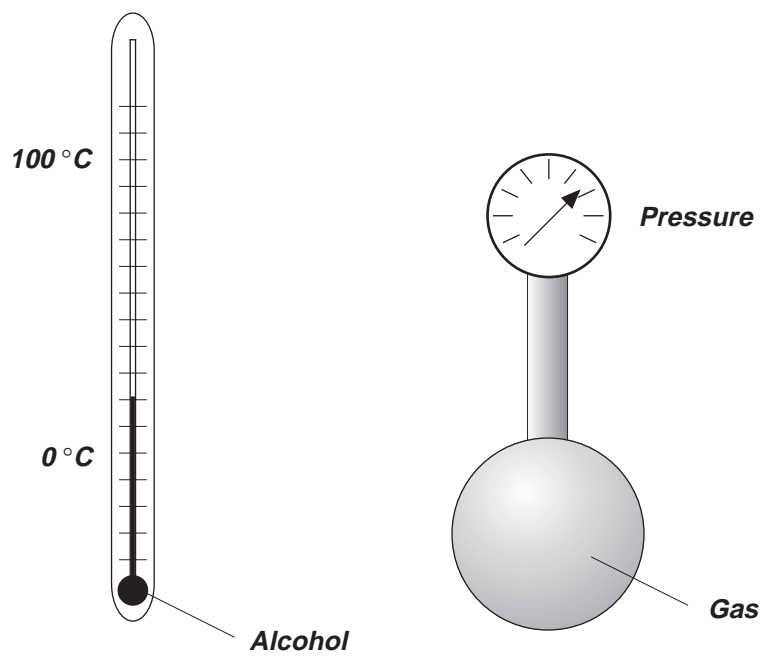


Figure 12.3: Two types of thermometers: alcohol expansion thermometer and gas thermometer.

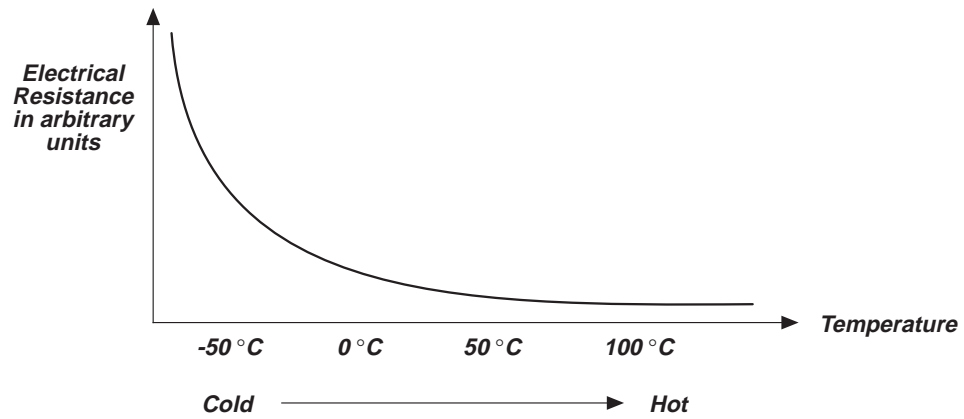


Figure 12.4: Temperature dependence of electric resistance of a semiconductor.

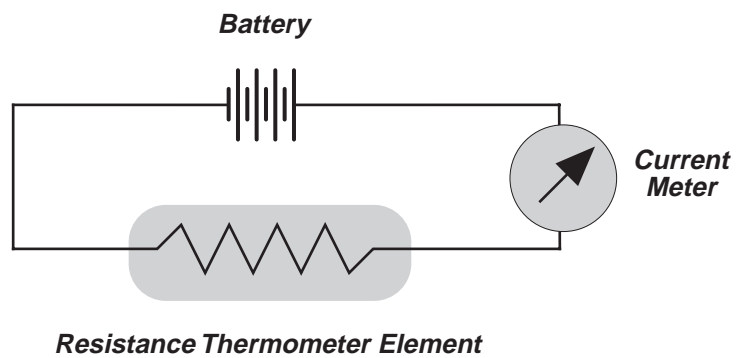


Figure 12.5: Basic circuit for resistance thermometer.

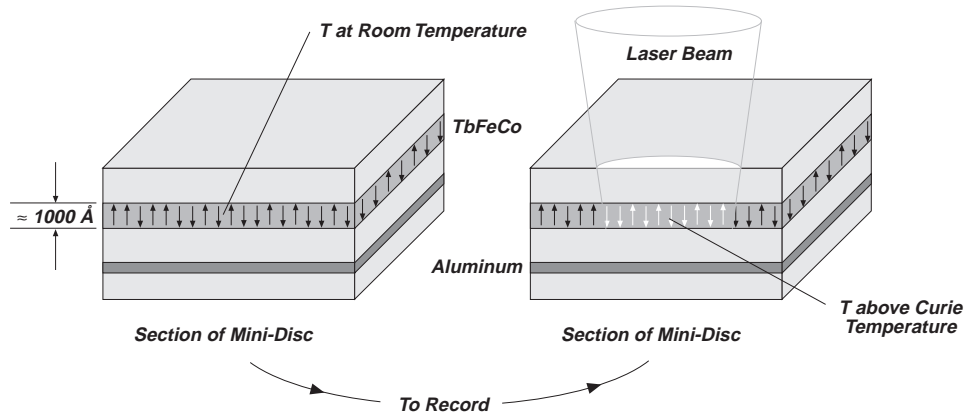


Figure 12.6: Heating of spot on mini-disc for recording.

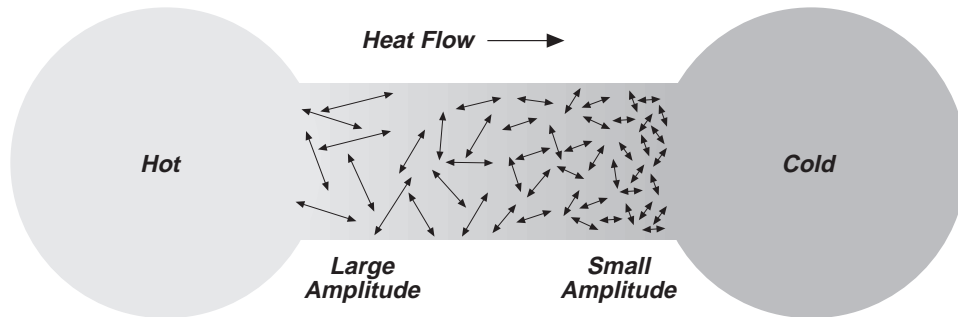


Figure 12.7: Heat conduction along a bar between a hot body and a cold one.

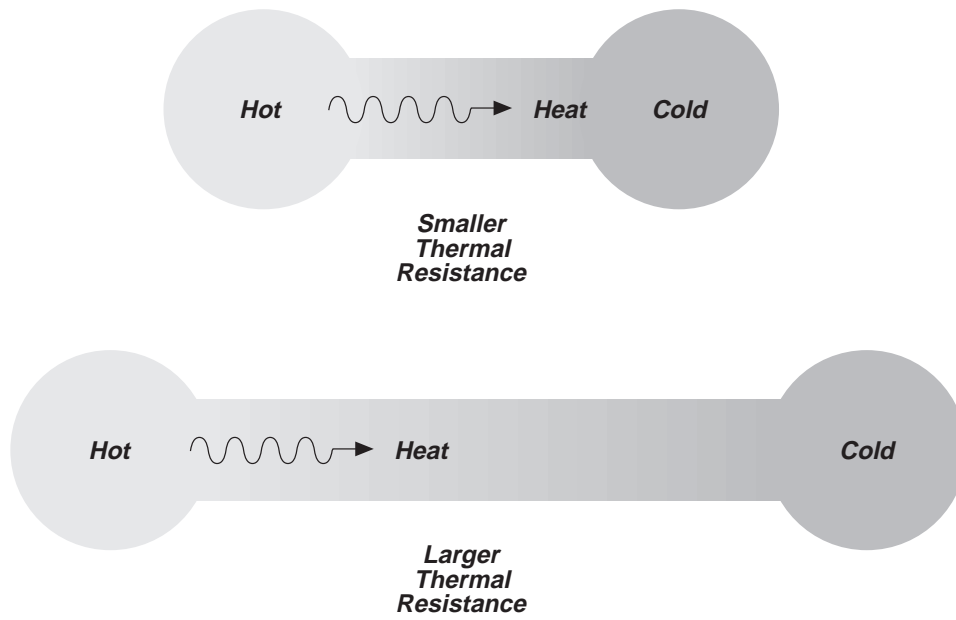


Figure 12.8: Thermal resistance depends on length of heat conductor.

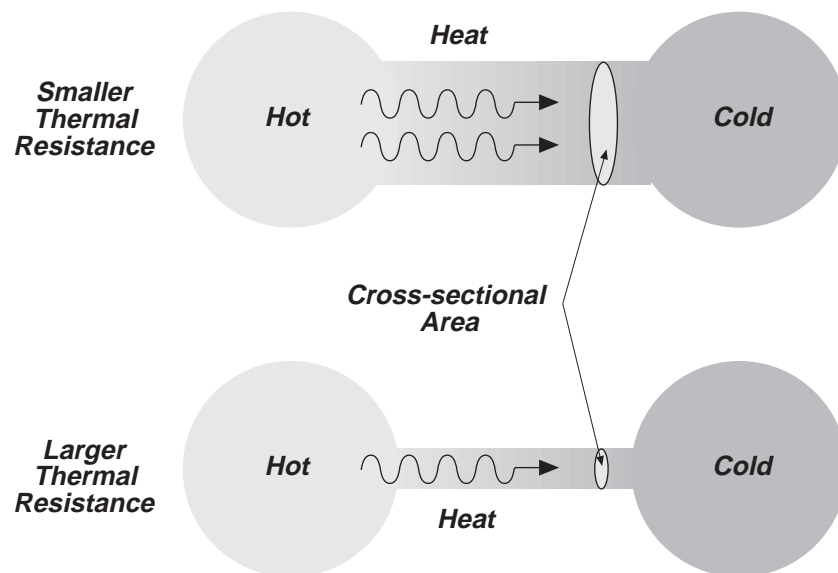


Figure 12.9: Thermal resistance depends inversely on cross-sectional area of heat conductor.

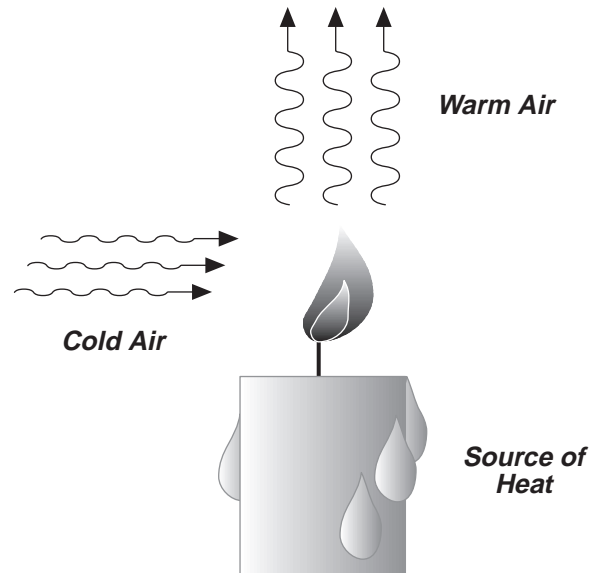


Figure 12.10: Transfer of heat in air by convection.

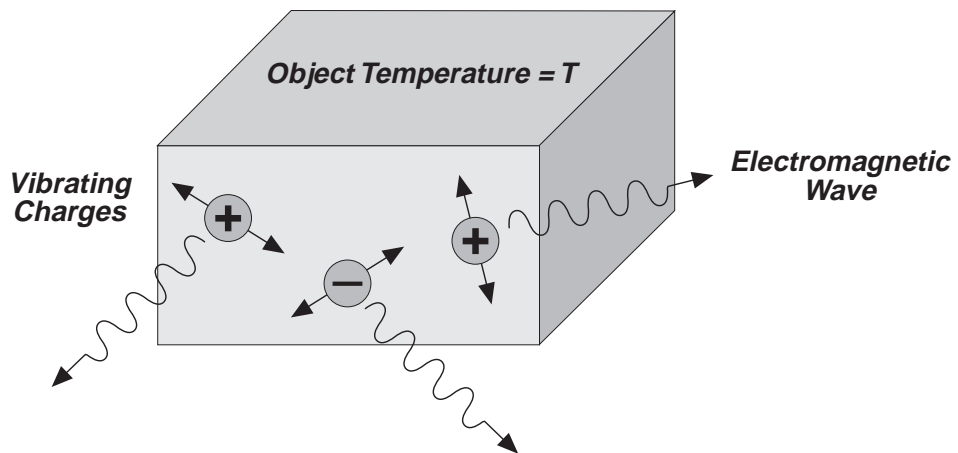


Figure 12.11: Object at temperature T emits electromagnetic waves.

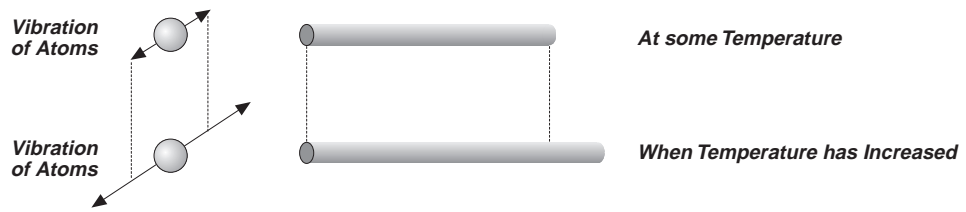


Figure 12.12: Thermal expansion of an object when heated.

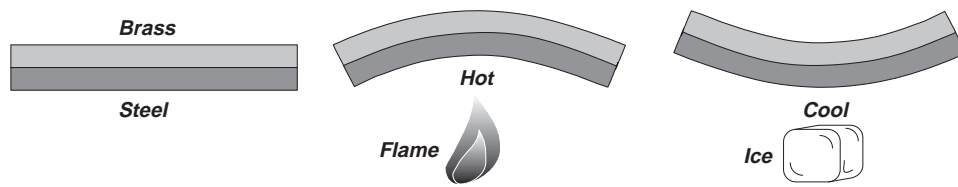


Figure 12.13: Bimetallic strip and its behavior when heated or cooled.

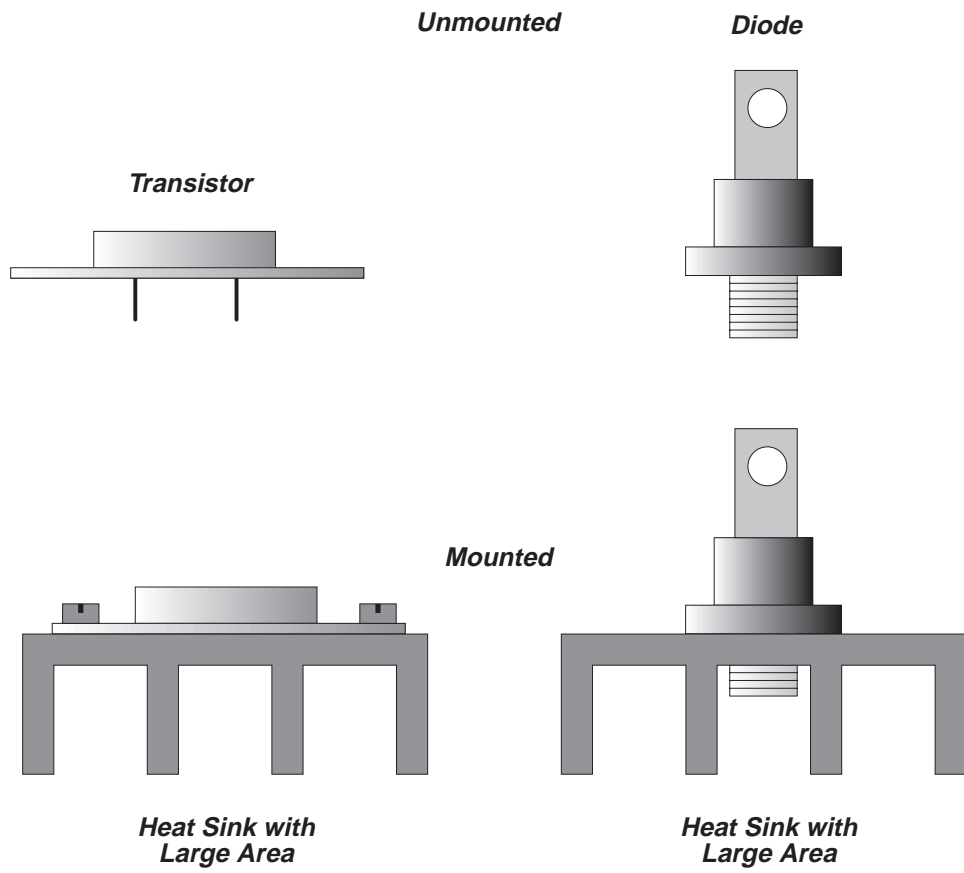


Figure 12.14: Mounting of transistor and diode on heat sink to transfer heat away from devices by heat conduction.

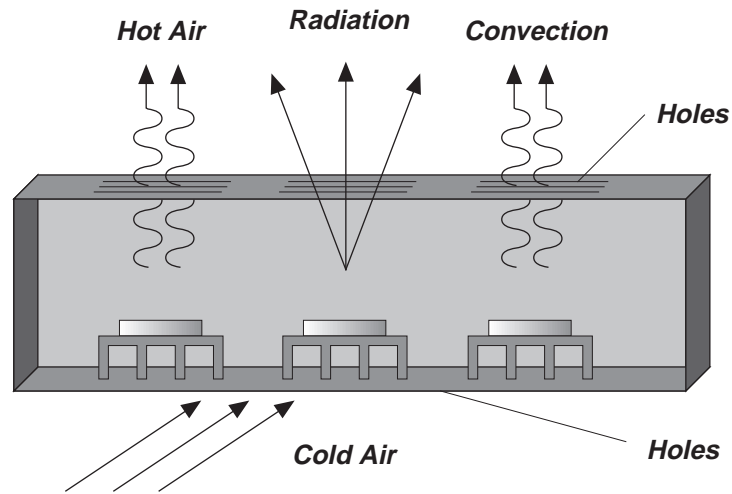


Figure 12.15: Heat removal by convection and radiation.

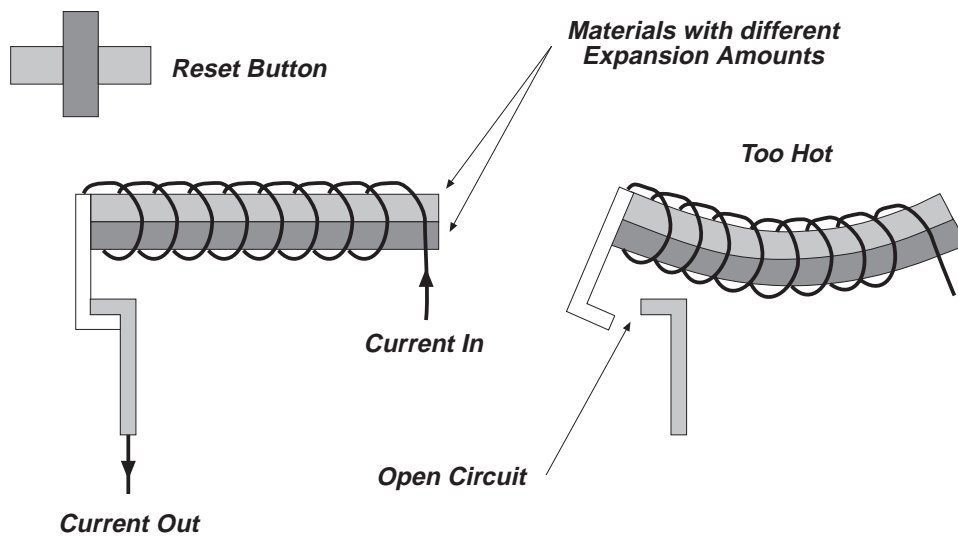


Figure 12.16: Action of circuit-breaker when too hot.

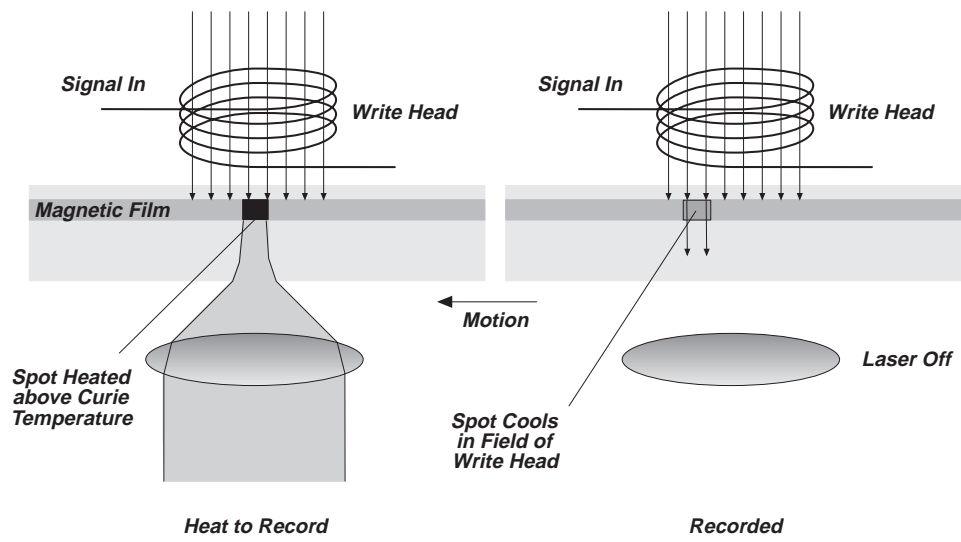


Figure 12.17: Thermo-magnetic recording on mini-Disc.

Chapter 13

Mechanics

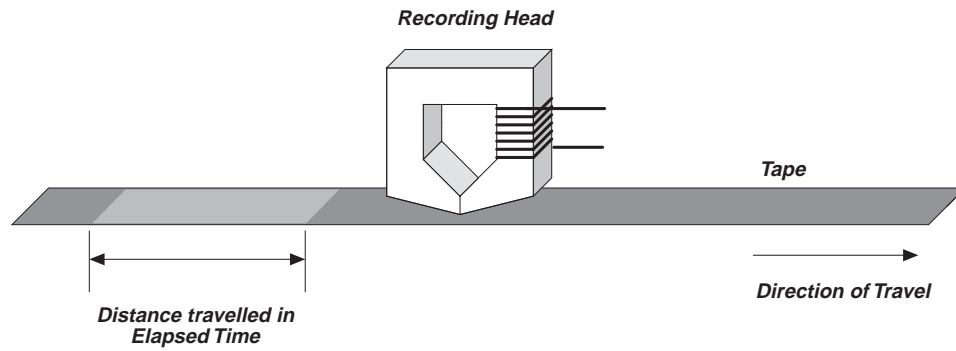


Figure 13.1: Speed of tape past recording head.

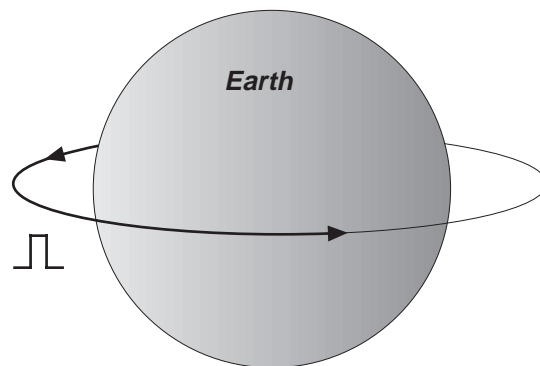


Figure 13.2: Time for a radio wave to go around the Earth at the equator.

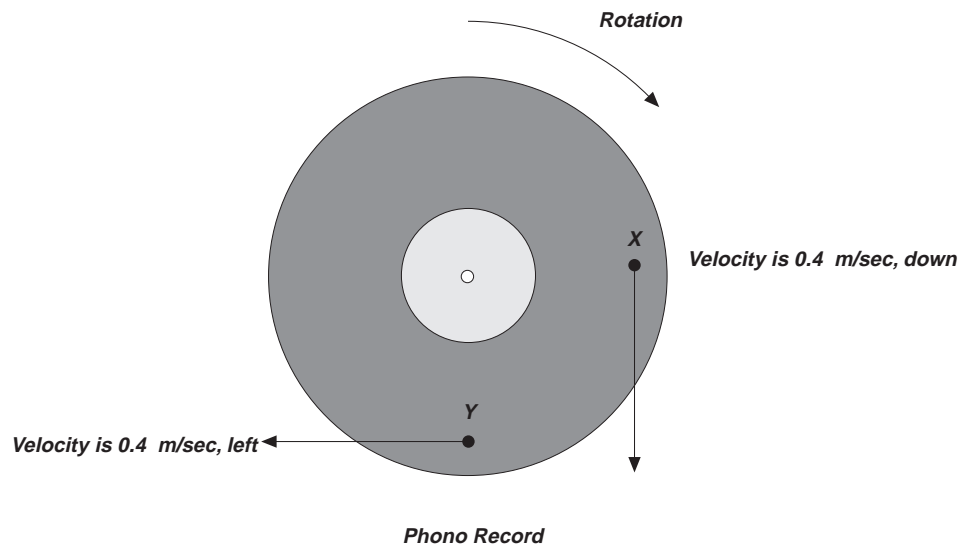


Figure 13.3: Speed of a recorded signal is the same at **X** and at **Y**; their velocities are different.

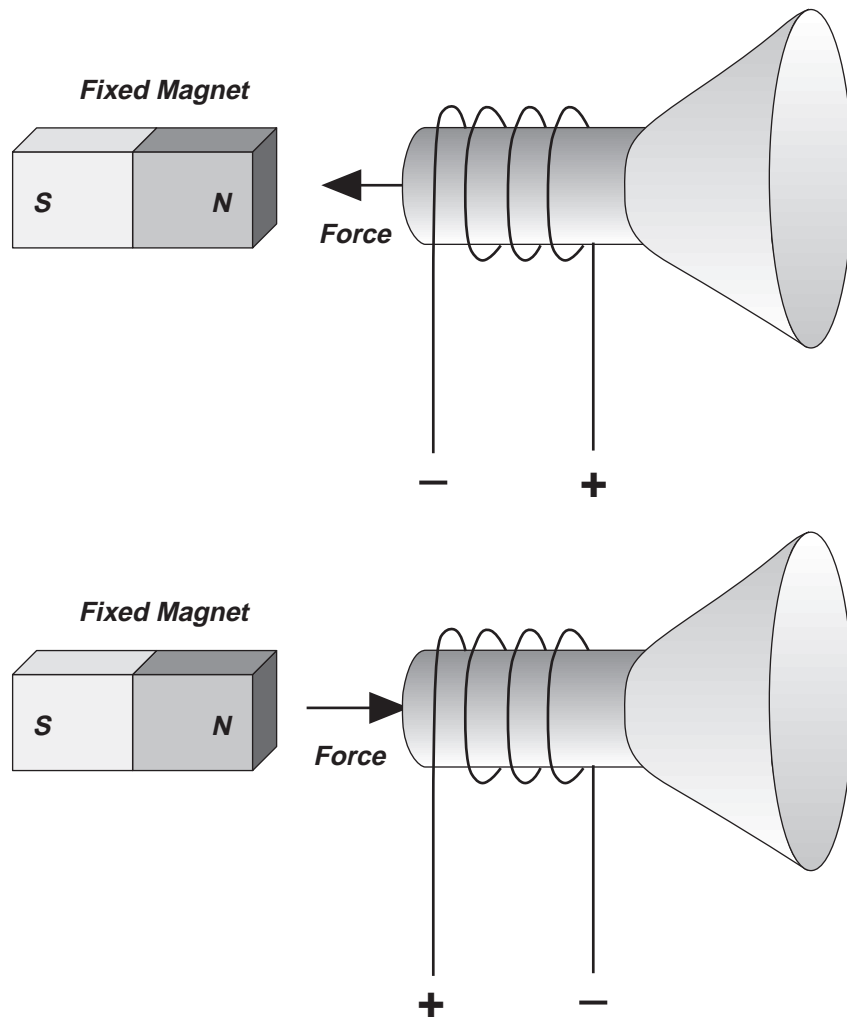


Figure 13.4: Force on voice coil giving it a push or a pull depending on direction of current in voice coil.

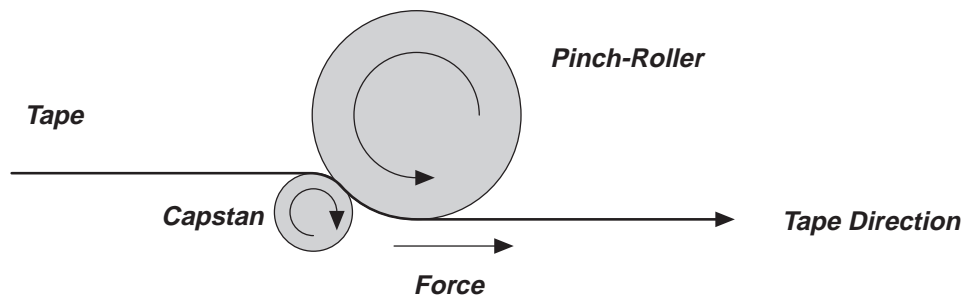


Figure 13.5: Force on tape by capstan-pinch roller.

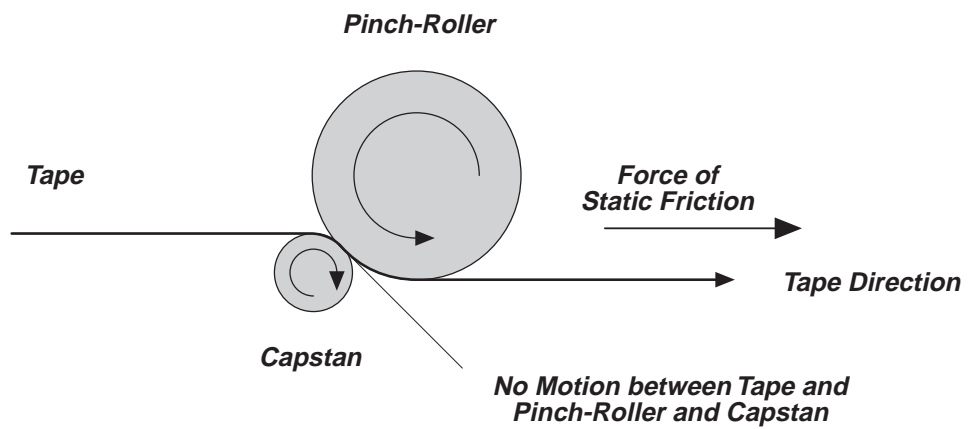


Figure 13.6: Static friction-force pulling on tape.

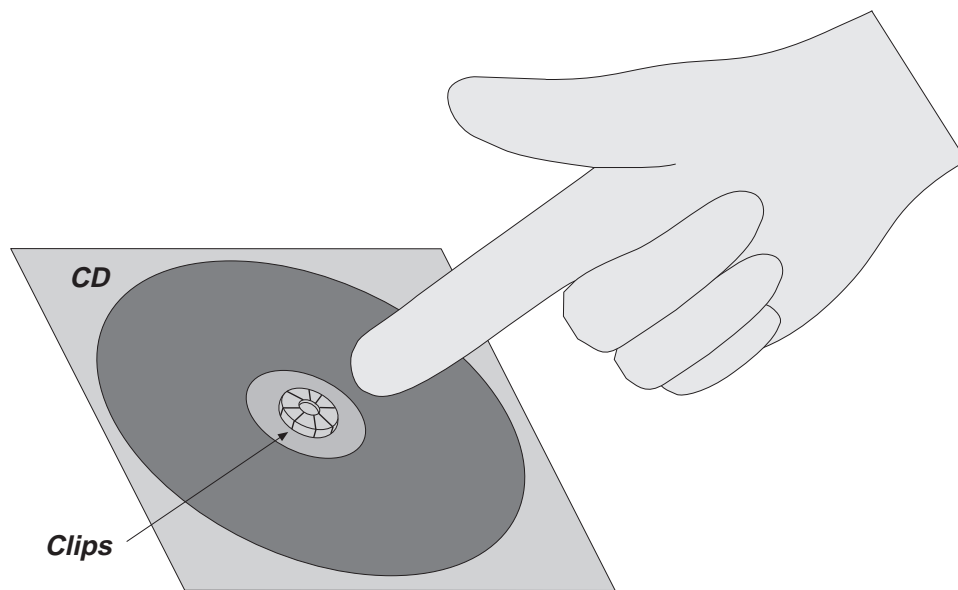
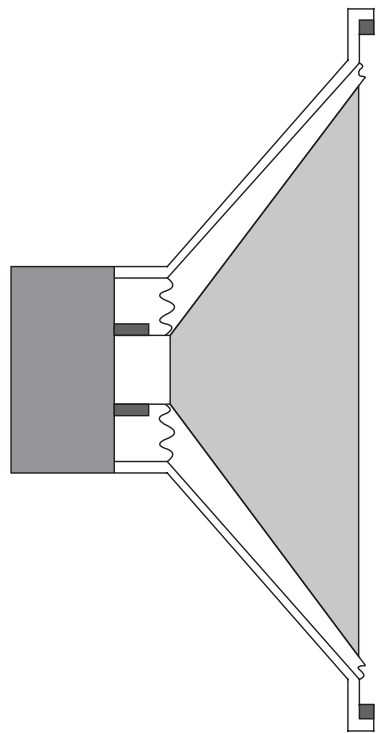
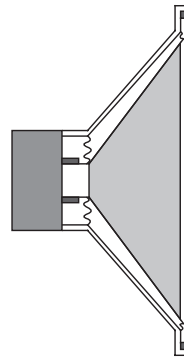


Figure 13.7: Releasing a CD from its case by applying a pressure on the clips with a finger.



Woofer has Large Inertia



Tweeter has Small Inertia

Figure 13.8: Inertia of a tweeter is less than that of a woofer.

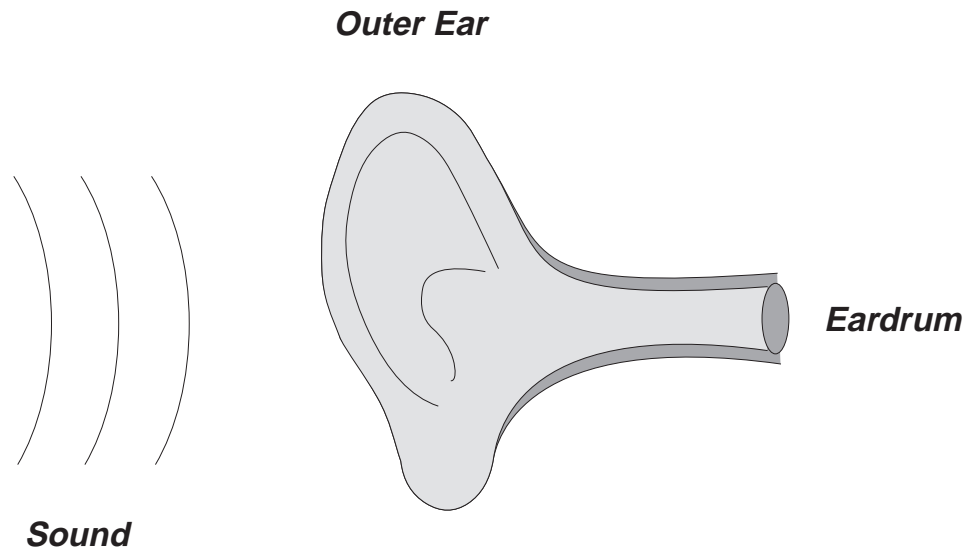


Figure 13.9: Outer ear; ear drum's inertia limits response at frequencies above 20 kHz.

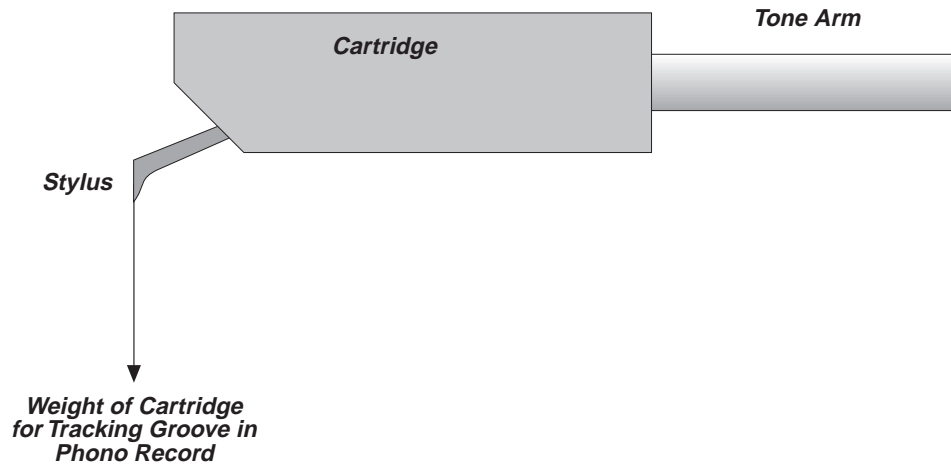


Figure 13.10: Adjusted weight in cartridge for helping the stylus to track the groove in phono record.

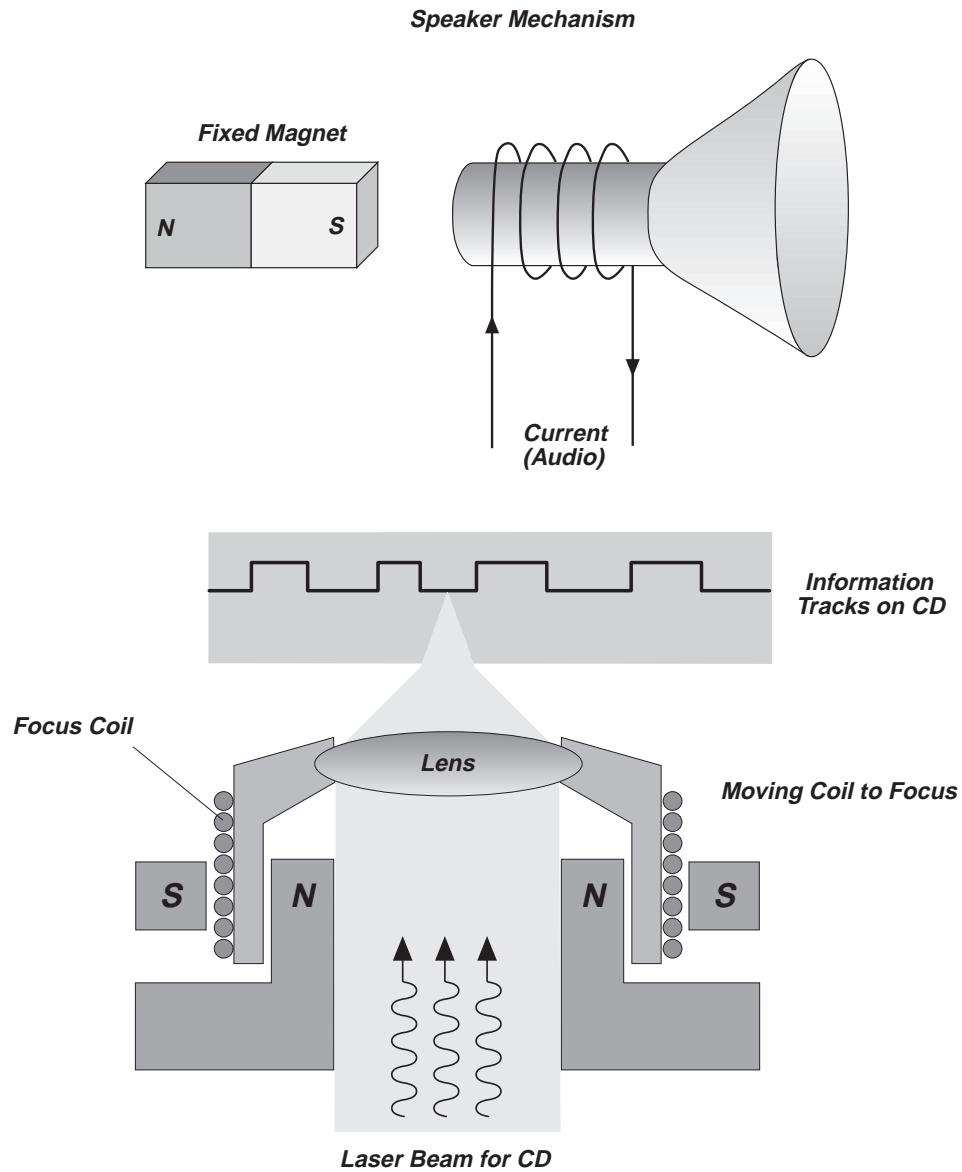


Figure 13.11: Force of clamped magnet on a voice coil accelerates diaphragm in loudspeaker. Force of clamped magnet on focus coil accelerates focus lens in CD player.

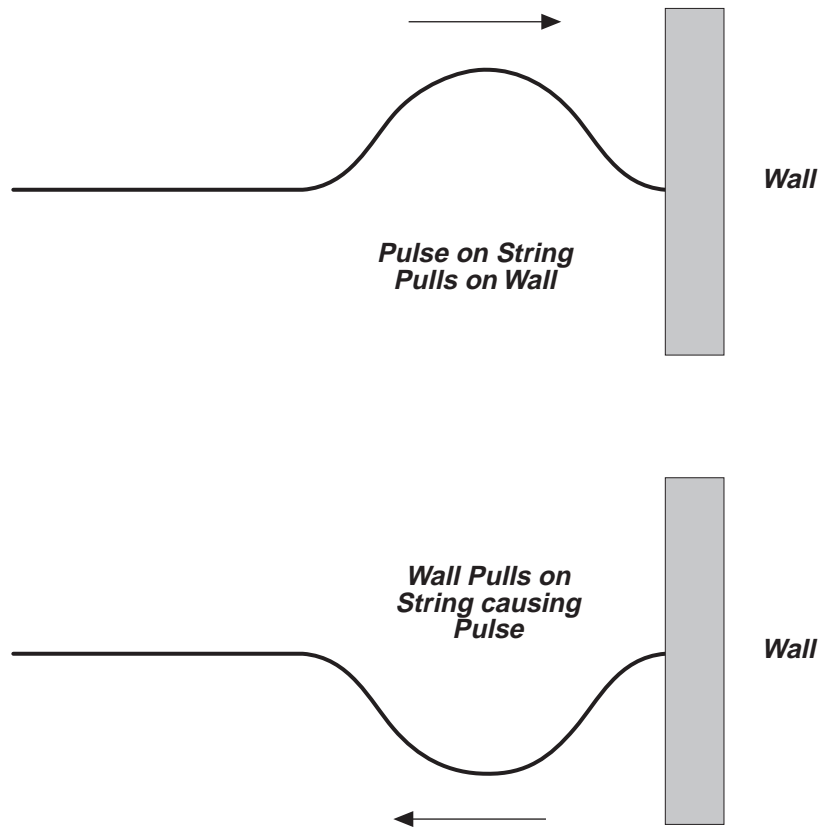


Figure 13.12: Reflection of a pulse on a string clamped at wall and its inversion.

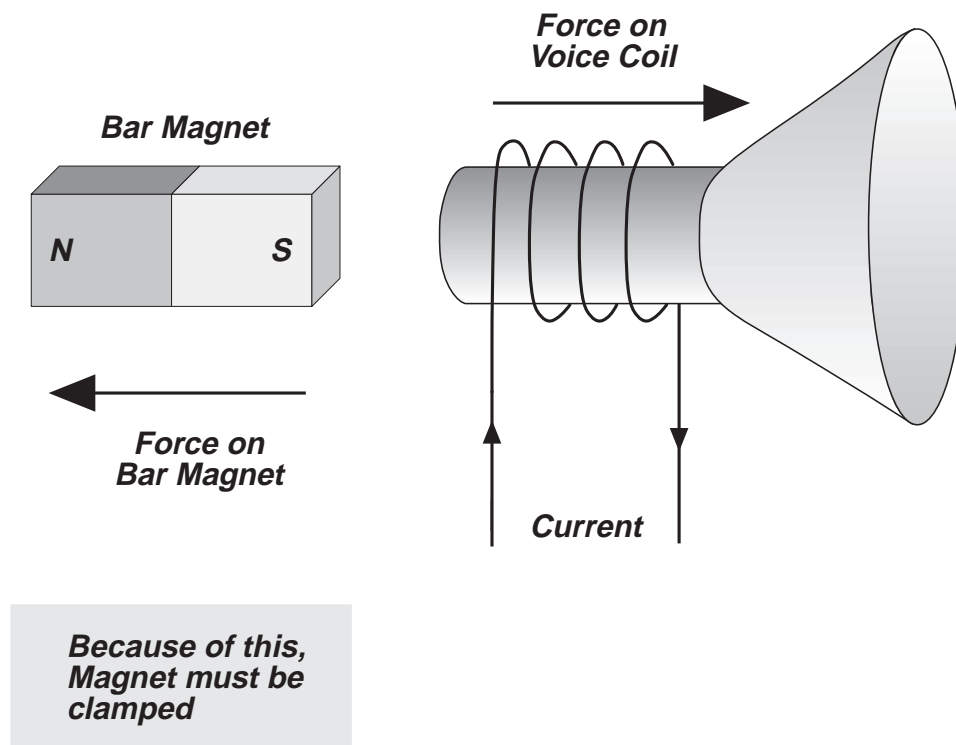


Figure 13.13: Force on voice coil and force on magnet.

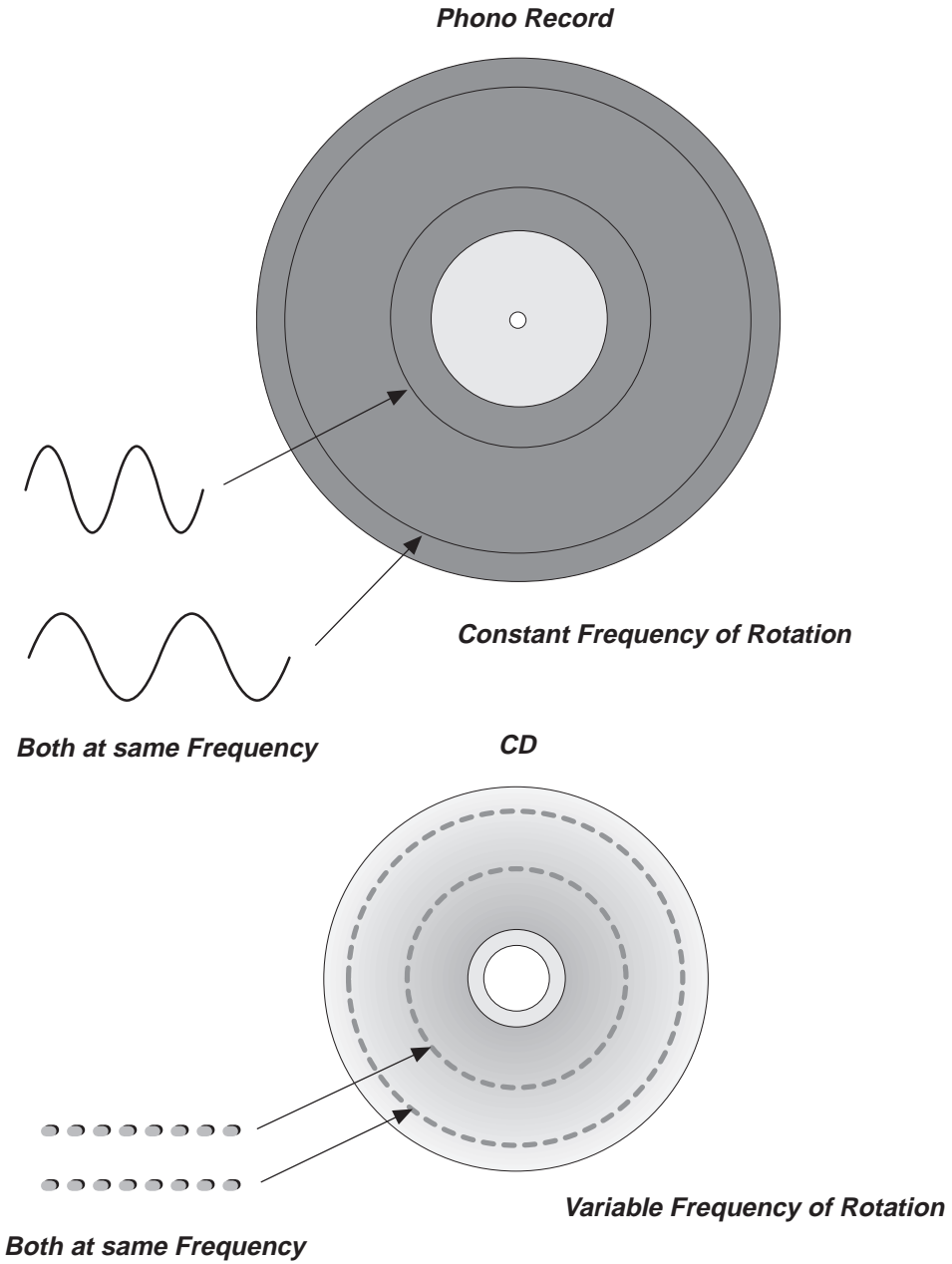


Figure 13.14: Waves recorded on a phono record and a CD.

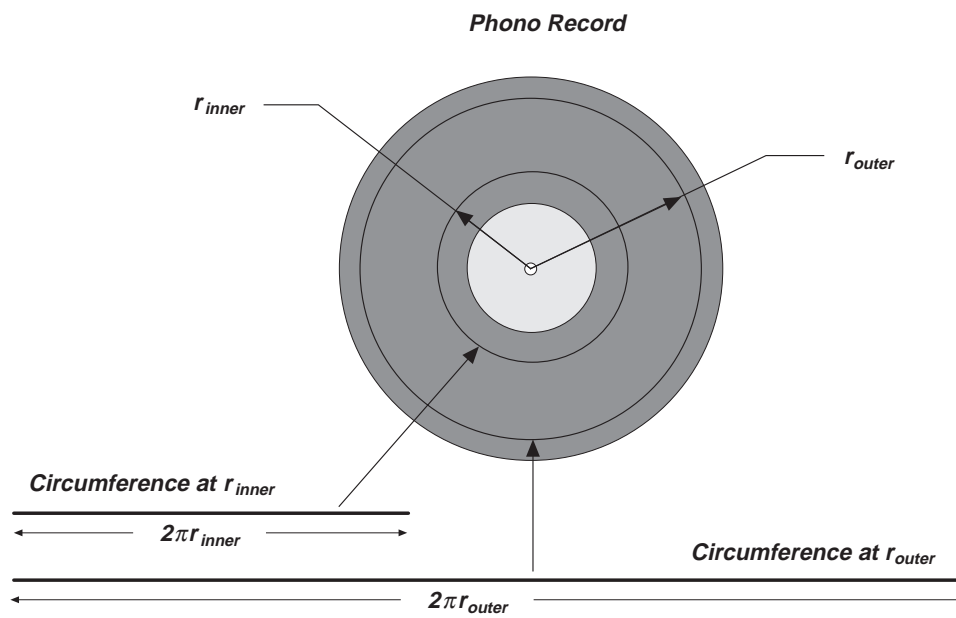


Figure 13.15: Distances covered along outer track and inner track on a phono record.

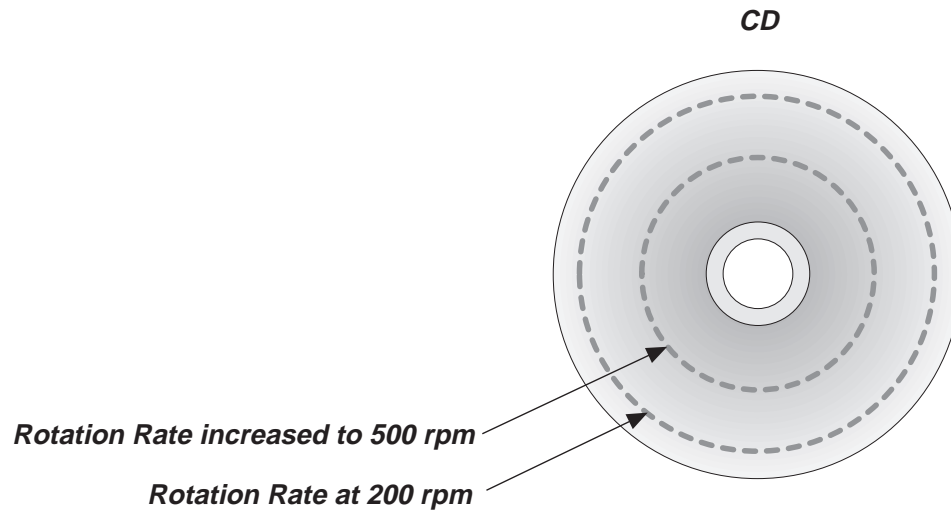


Figure 13.16: Frequency of rotation of a CD is made higher near the inner edge and lower near the outer edge to maintain constant linear speed on a tracks.

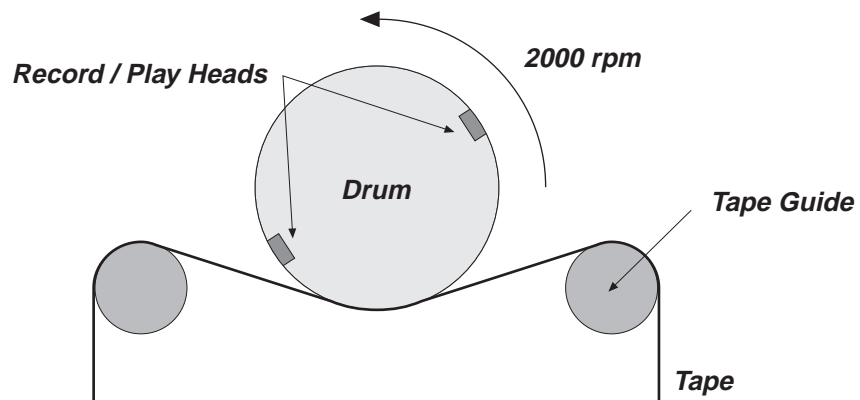
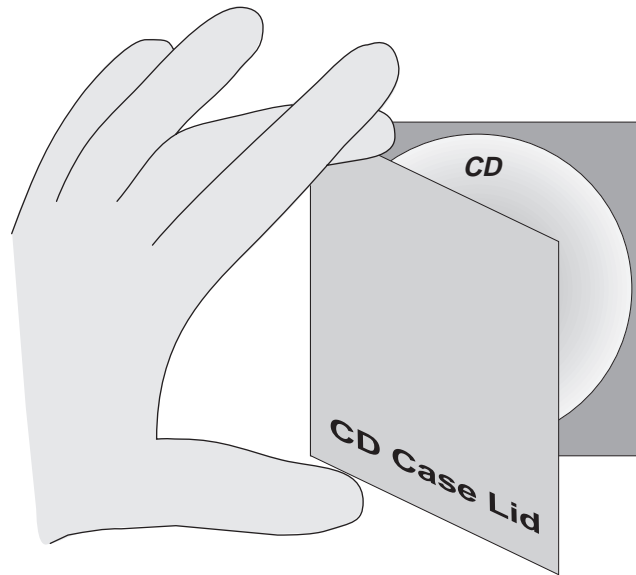
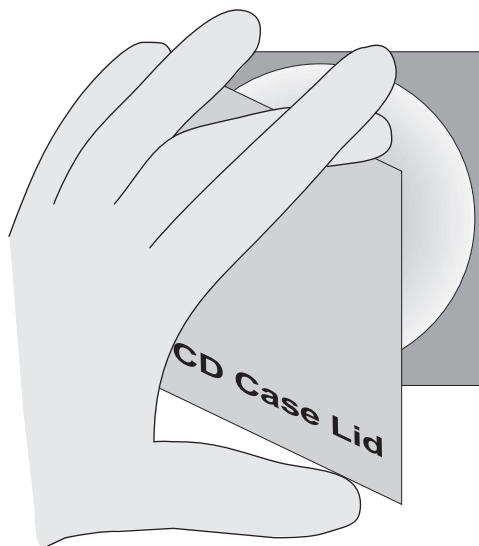


Figure 13.17: Rotation of drum head relative to magnetic tape in DAT.



A. Harder to Open



B. Easier to Open

Figure 13.18: When same force is applied to the CD case lid, it is easier to open the lid near the edge because torque is larger there.

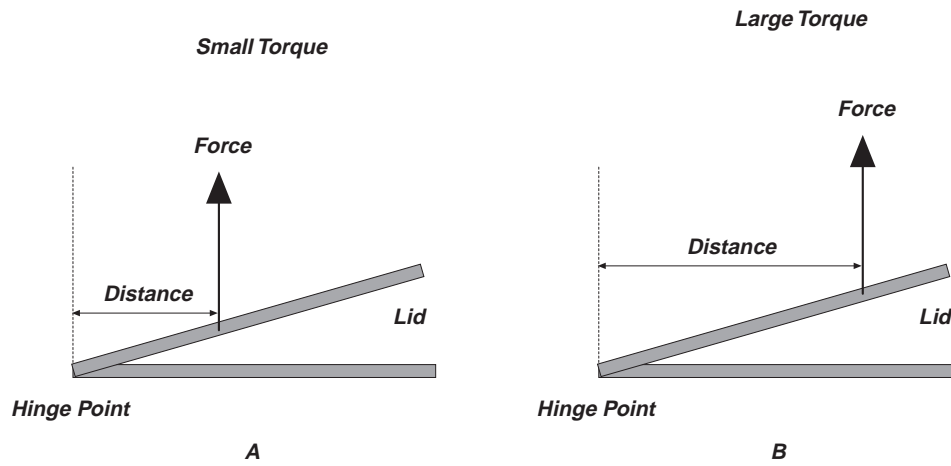


Figure 13.19: For the same force exerted on lid, the torque is larger in B than in A.

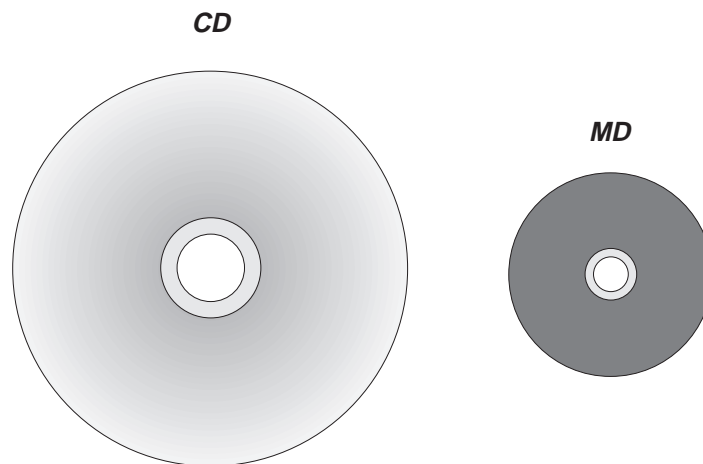


Figure 13.20: Moment of inertia of a CD is larger than that of a mini-Disc.