

# Subject Index

## A

Abbreviations for periodicals, 839-840;  
*see also* Symbols  
Accelerator, cyclic particle, 37  
Acceptor, 780  
Activation, cathode, 90, 92  
Active circuit elements, 800-801  
Admittance, input, 419-428  
Alkali metals, characteristics of, 113-115  
Alpha particle, 58  
Ammeter, rectifier-type, 314  
Amplification, *see also* Amplifier; Gain by gas tube, 259  
by grid control, 176  
by pentodes and tetrodes, 416, 428  
cathode-follower, 432  
complex, 413-416  
definition of, 412  
differs from amplification factor, 415  
frequency dependency of, 413-415  
gas, 147, 151  
limited by interelectrode capacitance, 202, 425  
modulation includes, 689  
noise limits, 494  
nonlinear, 438-439; *see also* Harmonic generation  
of modulated wave, 626  
power, 176  
in cathode follower, 432  
short-circuit current, 809  
transistor, 785-787, 799-804, 809  
voltage, with cathode impedance, 416-419

Amplification factor, definition of, 193  
differs from amplification, 415  
gas, 151-152  
pentode, 210  
triode, constancy of, 189, 195  
relation of, to tube capacitances, 189, 193  
sign of, 193  
variable-mu-tube, 211-212

Amplifier, audio-frequency, 488-489; *see also* Amplifier, Class A<sub>1</sub>; Amplifier, Class AB; Amplifier, Class B balanced, 503-504  
balanced-to-ground, 530-531  
bandwidth, limitations of, 498  
broad-band, 490, 563-570, 765  
cascade, 487-608  
voltage amplification of, 493-494  
cathode-bias in, 397-399, 416-419, 463, 510, 555, 588-589  
cathode-follower, 428-435, 587-588  
characteristics of, representation of, 491-494  
Class A<sub>1</sub>, definition of, 403  
Class AB, 609-613  
definition of, 403-404  
Class B, 619-629  
analysis tabulation for, 634  
applicability of, 609, 619-620  
as modulator, 707-712  
definition of, 404  
incremental equivalent circuit of, 625  
linear, 626  
load resistance for, 628  
optimum conditions in, 626-628  
phase relations in, 622-624  
semi-graphical analysis for, 631-638  
Class C, 629-652  
analogy of, with pendulum clock, 638-640  
analysis tabulation for, 634  
applicability of, 609, 630  
approximate analysis for, 630  
cathode-modulated, 714  
conditions in, for high efficiency, 640-641  
definition of, 404  
design considerations for, 638-642  
grid-bias modulated, 713-714  
grid-bias voltage for, 629-630, 641-643  
load resistance for, 637  
over-all efficiency for, 641

- Amplifier, Class C, plate dissipation in, 638  
 plate efficiency in, 638, 640-641  
 plate modulation of, 630, 705-713  
 $Q$  of load for, 638-640, 648-652  
 semi-graphical analysis for, 631-638  
 vector diagram for, 643-644  
 classes of, 403-404  
 compensated, 563-570  
 complex voltage amplification in, 413-416  
 computer, 592  
 definitions of, 390, 403-404  
 degenerative, 570, 577  
 difference, 503-509  
 differentiating, 592  
 direct-coupled, 499-509  
   stair-step coupling in, 502  
   voltage-divider coupling in, 501-502  
   zero drift in, 503-504  
 distortion in, 437-438; *see also* Distortion; Harmonic generation  
 driver stage of, 619  
 dynamic transfer characteristic of, 439-444, 737  
 feedback, 570-600  
   analysis of, by superposition, 574-576  
   complex locus for, 577-580  
   distortion reduced in, 584-585  
   driving point impedance in, 585-589  
   gain stability in, 580-581  
   input impedance of, 585-589  
   noise reduction in, 581-584  
   output impedance of, 585-589  
   resistance-capacitance-coupled, 592-600  
   stability in, 576-580  
 for modulated wave, 626  
 frequency characteristic of, 491-494  
 frequency-range classification of, 487-491  
 frequency response of, 491-494, 563-570  
 gain-bandwidth product in, 525, 557  
 gain-of-minus-one, 592  
 grid-bias voltage in, 395; *see also* Cathode bias  
 grid-current effect in, 393, 404-405, 523  
 grid-signal voltage in, 399-400  
 grounded-base transistor, 789, 793-796, 807-808, 812  
 grounded-collector transistor, 810-811, 813  
 Amplifier, grounded-emitter transistor, 796-798, 808-810, 812-813  
 grounded-grid, 428-429, 435-437  
 grounded-plate, 428-435  
 in feedback oscillator, 658-661, 682-685  
 incremental equivalent circuit for, 405-412, 625; *see also* Equivalent circuit, incremental  
 inductance-capacitance-coupled, 529-530  
 input admittance of, 419-428  
 input impedance of, 585-589  
 integrating, 592  
 intermediate-frequency, 563, 757-758, 813-814  
 inverse feedback, 570-600  
 linear, Class B, 626  
   conditions for, 195, 198-200, 391, 399-405, 737  
 load line for, 395-397, 452-460, 471; *see also* Path of operation in amplifier  
 load resistance for maximum power output from, 452-455  
 loads for, 394  
 maximum power output from, 448-456  
 maximum power sensitivity in, 448-451  
 multistage transistor, 811-814  
 narrow-band, 491, 547  
 noise in, 494-499, 581-584, 761, 772-773  
 oscillations in, 596, 598-600, 681-682  
 output impedance of, 585-589  
 output transformer in, 456-458, 533-534  
   for plate modulation, 712-713  
 overexcited, 404-405  
 path of operation in, *see* Path of operation in amplifier  
 pentode in, 425-428  
 phase characteristic of, 491, 525-527, 543-544, 565-568  
 phase-inverter, 530-533, 592  
 phase relations in, 403, 409-411, 414-415, 622-624  
 plate dissipation in, 445-447, 638; *see also* Plate dissipation  
 plate efficiency of, 448, 455-456, 638, 640-641; *see also* Plate efficiency  
 plate-modulated, 630, 705-713  
 power output from, 444-457  
 power supply in, common, 554-555  
 pulse, 217  
 push-pull, *see* Push-pull amplifier  
 $Q$  of, 557, 560, 638-640, 648-652

- Amplifier, quiescent operating point for, 397  
 quiescent operation of, 394-399  
 radio-frequency, 491, 554-563; *see also*  
     Amplifier, tuned  
     rate of rise in, 568-569  
     regenerative, 570, 577, 598  
     regenerative pulse, 821, 823  
     resistance-capacitance-coupled, 509-529  
         complex locus for, 527-529  
         feedback around, 592-600  
         frequency characteristic of, 511-525  
         gain-bandwidth product in, 525  
         half-power frequencies in, 515-516  
         logarithmic frequency characteristic  
             of, 519-520  
         middle range of frequencies of, 512-  
             514, 521  
         nondimensional frequency character-  
             istic for, 518-521  
         phase angle in, 517-518, 525-529  
         phase characteristic of, 525-527  
         stray capacitance in, 511-512  
         vector diagrams for, 516-518  
         voltage gain of, 511-525  
     selectivity of, 557-558, 560, 563, 570,  
         580, 645, 651  
     shift of dynamic load line in, 458-460  
     shunt feed in, 530  
     single-stage, 390-486, 803-811  
     stage of, 487  
     stagger-tuned, 563  
     time delay in, 567-568  
     transformer-coupled, feedback in, 578-  
         579, 595-598  
         tuned, 558-563  
         untuned, 533-547  
 transistor, 803-814  
     cascade, 811-814  
     intermediate-frequency, 813-814  
 tube symbols for, 391-392  
 tuned, 491, 554-563  
     capacitance-coupled, 554-558  
     Class B, 619-629  
     Class C, 629-652  
     effective *Q* in, 557, 560, 648-652  
     gain-bandwidth product in, 557  
     transformer-coupled, 558-563  
     vector diagrams for, 643-644  
 tuned circuits for, 547-553  
 unilateral, 571  
 vector diagrams for, 409-411, 643-644
- Amplifier, video, 490; *see also* Amplifier,  
     broad-band  
     voltage, 487  
     voltage amplification in, 412-419; *see*  
         *also* Amplification; Gain  
     wide-band, 217  
     with reactive load, 409-411, 414-415  
 Amplitude, instantaneous, 770  
 Amplitude modulation, *see* Modulation,  
     amplitude  
 Angstrom unit, 111  
 Angular frequency, instantaneous, 693,  
     695, 770  
     resonant, 548  
 Angular modulation, *see* Modulation, an-  
     gular  
 Anode, 6, 173; *see also* Plate  
     control, 273  
     excitation, 248-251  
     ignition, 248-251  
     starter, 273  
 Anode glow, 155-156  
 Anode sheath, 245-246  
 Anode voltage, *see also* Maximum peak  
     inverse voltage; Plate voltage  
     critical, 236-237  
     forward, maximum, 270  
 Anode voltage drop in mercury arc, 246  
 Answers to representative problems, 837-  
     838  
 Antennas, size of, 490, 690, 702-703  
 Aperture lens, 28  
 Approximations, for diodes, linear, 282-  
     284  
     for pentode, linear, 210-211  
     for triodes, linear, 198-200, 406  
         nonlinear, 187, 734-738  
         successive, 733-734, 736-737, 743  
 Arc, 159, 160-162; *see also* Cathode spot;  
     Mercury-arc rectifiers; Plasma  
     role of excited and metastable atoms  
         in, 148  
 Arc-back, *see* Backfires  
 Argon, 139, 143, 232, 237, 829  
     Tungar contains, 241  
     use of, in gas tubes, 243, 270  
 Arrester, lightning, 159-160  
 Astable switching operation, 823-825  
 Atom, chemical behavior of, 62  
     constituents of, 2-4, 62  
     excited, 136  
         role of, in gas discharge, 148

Atom, ionization of, 137-139, 145-148  
 metastable, 137-139  
 causes ionization below ionizing voltage, 230  
 role of, in gas discharge, 148  
 normal state of, 136  
 penetration of, 145  
 physical properties of, 135-139  
 radiation from, 136  
 structure of, 62  
 Atomic lattice, 62, 65, 96, 780  
 Atomic number, 63  
 Atomic theory of matter, 61-62  
 Atomic weight, of various gases, 829  
 Audibility, frequency limits of, 488-489  
 Auto-electronic emission, 101-102; *see also* Field emission  
 Automatic volume control, 212, 219  
 Autosyn, 378  
 Available power, 450, 806  
 Available power gain, 806-807  
 Avalanche, electron, 152  
 Avogadro number, 829

## B

Backfires, 248  
 shields to prevent, 248-251, 253  
 Balanced-to-ground amplifier, 509, 530-531  
 Band, allowed, 66  
 energy level, 66, 101-102, 778-780  
 Fermi, 73, 101-102  
 filled, 66  
 frequency, 462, 488, 510  
 in transformer-coupled amplifiers, 535  
 side, *see* Side bands  
 Band-pass coupling, 563  
 Bandwidth; *see also* Gain-bandwidth product  
 of resonance curve, 552  
 of system, 495  
 Barkhausen criterion for oscillators, 662-664, 680-681  
 Barrier, potential-energy, 65, 71, 96-99, 101, 103, 111  
 Barrier-layer rectifier, 277, 782  
 Base of transistor, 784-788  
 Battery-charging rectifier circuit, 302  
 Beam-power tubes, 212-215  
 incremental equivalent circuit for, 427

Beats, modulation differs from, 757  
 Beginning voltage, 152  
 Bessel functions, 763, 767  
 Betatron, 36, 39  
 Bevatron, 40  
 Bias, cathode, *see* Cathode bias  
 grid, 395  
 grid-leak-and-capacitor, 642-643, 670-672, 676-678  
 self, *see* Cathode bias  
 Bibliography, 839-844  
 Bidirectional transmission, 811  
 Bisection theorem, 505  
 Bistable switching operation, 819-821, 823-825  
 Black body, radiation from, 115  
 Breakdown, electrical, of gas, 152-155  
 forward, in gas tube, 233, 257, 267  
 inverse, in gas diode, 241-243  
 Breakdown voltage, 152-154  
 Brush discharge, 155  
 Bulb, glass, limitations on use of, 173  
 outgassing of, 172  
 Bunches, electron, 222

## C

Capacitance, direct, 184  
 input, for pentodes, 428  
 of cathode follower, 434-435  
 interelectrode, *see* Interelectrode capacitance  
 output, of pentodes, 428  
 Capacitance operator, mutual, 184  
 Capacitor, by-pass, 419  
 of no avail in direct-coupled amplifier, 502  
 cathode-bias, *see* Cathode bias  
 coupling, 509  
 decoupling, 555  
 Capacitor-input filter, 316-329, 348-354  
 Capacitron, 251-252  
 Carburization of thoriated tungsten, 89-90  
 Cardioid locus, 597-600  
 Carrier, pulse, 698  
 Carrier-current telephony, 691, 744-746, 753  
 Carrier frequencies, 489  
 Carrier wave, 554, 689, 699  
 disappearance of, in frequency modulation, 767, 768

- Carrier wave, suppression of, 753  
 Cathode, 6; *see also* Oxide-coated cathode; Thoriated-tungsten cathode; Tungsten cathode  
   cold, 273-274  
   cooling of, by electron evaporation, 171  
   disintegration of, 236-238  
   evaporation of, in gas tube, 239  
   heat-shielded, 239  
   indirectly heated, 94-95, 391-392  
   mercury-pool, 101, 244-252  
     maintenance of, 333  
     starting of, 247-252  
   Strobotron, 276  
   symbols for, 391-392  
 Cathode bias, in Class A<sub>1</sub> amplifier, 397-399, 416-419, 463, 510, 555, 588-589  
   in Class AB amplifier, 613  
   in Class B amplifier, 618  
   in push-pull Class A<sub>1</sub> amplifier, 463  
   is current feedback, 588-589  
   voltage amplification with, 416-419  
 Cathode current, 182  
 Cathode-follower amplifier, 428-435, 587-588  
   unsymmetrical behavior of, 433  
 Cathode glow, 155-156  
 Cathode-ray oscilloscope, 19-25, 35-36, 508  
 Cathode sheath, 235, 245  
 Cathode spot, mercury-pool, 101, 244, 247-252, 333  
 Cathode voltage drop, in glow discharge, 157  
   in mercury arc, 245-247  
   in thermionic gas tubes, 235  
 Cavity resonator, 223-224  
 Cesium, 104-105, 113-117, 276  
 Channel, frequency, 702  
 Characteristic, frequency, *see* Frequency characteristic  
 Characteristic, phase, 438, 491, 525-527, 543-544, 565-568  
 Characteristic curves, arc, 159  
   beam-power-tube, 213, 215  
   capacitor-input-filter, 322, 324, 325, 350, 351  
   cathode-bias, 398-399  
   cathode-follower, 430  
   cold-cathode tube, 272, 274  
   compensated amplifier, 566, 567, 569  
   composite, 467-475, 611, 614  
   Characteristic curves, constant-current, 189, 631-633  
   critical-grid-voltage, 366-367  
   crystal diode, 781  
   gas-diode, 233  
   gas-phototube, 150-151  
   gaseous-discharge, 159  
   gated-beam tube, 216-217  
   germanium power rectifiers, 783  
   glow-discharge, 156-159  
   inductor-input-filter, 343, 348  
   Kino lamp, 159-160  
   magnetron, 52  
   mercury-arc-rectifier, 246  
   modulation, 705  
   neon lamp, 159-160  
   pentode, 207-209, 835, 836  
   phase-shift thyratron-control, 372-374  
   phototube, 118-119, 121, 150-151  
   rectification, type 6H6 diode, 722  
   tetrode, 202-203, 205  
   thyratron, 260, 261, 265  
   Townsend-discharge, 149, 159  
   transfer, 189, 209  
   transistors, 788-792  
   transition, 274  
   triode, 188, 190-191, 472, 633, 833, 834, 835  
   type 2A3 triode, 835  
   type 5T4 diode, 350  
   type 5U4-G diode, 832  
   type 5Y3-G diode, 832  
   type 6A3 triode, 835  
   type 6AL5 diode, 833  
   type 6AU6 pentode, 208-209  
   type 6B4-G triode, 835  
   type 6C4 triode, 834  
   type 6CB6 pentode, 836  
   type 6H6 diode, 722  
   type 6J5 triode, 833  
   type 6K6-GT pentode, 836  
   type 6L6 beam power tube, 215  
   type 6SJ7 pentode, 835  
   type 12AU7 triode, 196, 834  
   type 12AX7 triode, 834  
   type 929 phototube, 118-119  
   type 931-A multiplier phototube, 121  
   type 5559/FG-57 thyratron, 262  
   type 5720/FG-33 thyratron, 262  
   type 5728/FG-67 thyratron, 262  
   type 5851 phototube, 151  
   vacuum-diode, 166-168, 722, 832, 833

- Characteristic curves, vacuum-phototube, 116-119  
 vacuum-triode, 187-192, 472, 633, 833-835  
 vacuum tube, shape of, for linear operation, 195, 198-200, 391, 399-405, 737
- Characteristics, vacuum-tube, average, 175
- Charge, alpha particle, 58  
 electron, 3, 829  
 image, 96  
 positive-ion, 137  
 space, *see* Space charge
- Charge-to-mass ratio for electrons, 3, 34, 48, 829
- Charged particles, liberation of, 61, 70-75; *see also* Emission  
 measurement of velocity of, 43-44  
 motion of, in concurrent fields, 42-54  
   in electrostatic fields, 8-17  
   in magnetostatic fields, 29-42  
 path of, *see* Path of charged particles
- Charges on glass walls, effect of, in thyatron, 267
- Child's law, 132; *see also* Limitation of current by space charge
- Choke, 338; *see also* Inductor  
 first, in rectifier filters, 344, 346, 374  
 radio-frequency, 678-679  
 swinging, 346
- Choke-input filter, *see* Inductor-input filter
- Circuit breaker, 161
- Circular path of charged particles, 33-34
- Clamper, 390
- Clean-up of gases, 243, 270-271
- Clipping, 217, 390, 433
- Clock, analogy of, with Class C amplifier, 638-640  
 with oscillator, 657, 678  
 with resonator, 223
- Coating of oxide-coated cathode, 92
- Code, binary, for pulse modulation, 698
- Coefficient, coupling, 558  
 electrostatic-induction, 184  
 temperature, of thermionic emission, 81
- Coefficients, pentode, 210  
 power-series, measurement of, 737  
 vacuum-tube, 192-198
- Coefficients, vacuum-tube, dependence of, on plate current, 195-196  
 measurement of, 198  
 reflex, 196  
 relation of, to characteristic curves, 195-198  
 relationship among, 195  
 variable-mu-tube, 211-212
- Coil, *see also* Choke; Inductor  
 $Q$  of, 340, 553, 650
- Coincidence detection, 217
- Cold-cathode effect, 101-102
- Collector of transistor, 784-787
- Collision processes in a gas, 139-148
- Collisions between particles, consequences of, 145-148  
 elastic, 141, 145  
 inelastic, 141, 145  
 prevention of, 145  
 probability of, 143-145
- Color sensitivity of phototube, 113-115
- Common-mode component, in d-c amplifier, 505
- Communication, frequency ranges of, 488-491  
 radio, *see* Radio communication
- Commutation in rectifier circuit, 304
- Complex locus for amplifier, 527-529, 577-580
- Complex numbers, symbols for, 47
- Composite characteristics, 467-475, 610-618
- Composite surfaces, *see* Oxide-coated cathode; Thoriated-tungsten cathode; Photoelectric emission; Secondary emission
- Concentration, *see also* Density  
 of electrons in a metal, 69, 73  
 of molecules in a gas, 142
- Condenser-input filter, *see* Capacitor-input filter
- Conditional stability, 579-580
- Conductance, mutual, *see* Mutual conductance
- Conduction, electrical, by electrons, 779-780  
 by holes, 779-780  
 in metals, 62, 66-68  
 through vacuum, gases, and vapors, 1, 124-163
- Conduction angle of rectifier circuit, 298-299

- Conductivity, unidirectional, in a diode, 165  
 Conformal transformations, 183  
 Conservation of energy, 11, 15  
 Constant, atomic weight, 829  
     Avogadro, 829  
     Boltzmann, 69, 829  
     gas, 829  
     Planck, 5, 69, 111, 136, 829  
     Stefan-Boltzmann, 82, 173, 829  
 Constant-current characteristic curves, 189, 631, 633  
 Constants, electronic, 3, 829  
     emission, 77-80, 89, 93; *see also* Oxide-coated cathode; Thoriated-tungsten cathode; Tungsten cathode  
     physical, 829, 831  
     tube, *see* Coefficients  
 Constituents of atom, 2-4, 62  
 Contact difference of potential, 74-75, 168, 186, 255  
     effect of, in triodes, 186  
     on grid-current curve, 255  
 Continuous control of thyratrons, by phase-shift of grid voltage, 372-382  
 Control, feedback in, 600  
     grid, *see* Grid control  
     of thyratrons, *see* Thyratron circuits  
 Control characteristic of thyratron, 261-262  
     effect of changes in, 370, 375  
 Control ratio, grid, of thyratron, 262  
 Control voltage, 621, 667  
 Controlled gas tubes, *see* Ignitron; Permatron; Relay tube; Strobotron; Thyratron  
 Controlled-rectifier circuits, 365-389  
 Conversion factors, 17-19, 830-831  
 Conversion transconductance, 760-761  
 Converter, frequency, vacuum-tube, 210, 218-219, 759-761  
     pentagrid, 219, 761  
 Cooling, anode, 173  
     grid, 174  
     mercury-arc-rectifier, 247-248, 251  
     of cathode by electron evaporation, 171  
     plate, 173, 447  
 Co-ordinate system, rectangular, 31  
 Copper-oxide rectifier, 277, 314, 783  
 Copper-sulphide rectifier, 783  
 Core materials for oxide-coated cathode, 92  
     Corona discharge, 155, 273  
     Cosmic rays, ionization by, 150  
     Coulomb's law, 63, 96  
     Coupling coefficient, 558  
     Coupling networks, oscillator, design of, 674-678  
     tube-to-load, design considerations for, 644-652  
 Crater lamp, 276  
 Critical anode voltage, 236-237  
 Critical-grid-voltage curve, 366-367  
 Crystal, piezoelectric, 659, 680  
     solid, 62, 65, 96  
 Crystal diode, 758, 781-782  
 Crystal lattice, 62, 65, 96  
     imperfections in, 780  
 Current, cathode, 176-178  
     displacement, 129, 166, 186, 202, 220, 401, 420  
     emission, *see* Emission current  
     grid, *see* Grid current  
     minimum, in mercury-arc rectifiers, 247  
     in voltage-regulator tube, 355  
 plate, *see* Plate current  
 random positive-ion, 263-264  
 ratio of electron to positive-ion, 231-232  
 reference direction for, 391-393  
 saturation, *see* Saturation current  
 space, 77, 126  
 space-charge limitation of, *see* Limitation of current by space charge  
 thermionic-emission, 77, 78; *see also* Emission current  
 Current amplification, transistor, 785, 787, 799-804, 809  
 Current-carrying capacity of a tube, effect of gas on, 230  
 Current density, at cathode spot, 244  
     field-emission, 101  
     in germanium power rectifiers, 783  
     in glow discharge, normal value of, 157-158  
     random, in a metal, 66, 102  
     space-charge limited, 130-132  
 Current feedback, 571, 573; *see also* Feedback  
 Curve, tube, *see* Characteristic curves  
 Cut-off, in diode, 170  
 Cut-off frequency, transistor, 818  
 Cut-off grid voltage, 180  
     indefiniteness of, 180, 186

- Cut-off grid voltage, remote, 211-212  
 Cycloidal path of charged particles, 44-48  
 Cyclotron, 36-37, 58
- D**
- D-c power output of rectifier, 290, 295  
 Dark spaces in glow discharge, 155-156  
 Davission chart, 82-83  
 Decibel, 492-494, 519-520  
 Decibels per octave, 520  
 Decoupling circuit, 555  
 Deflection, electron-beam, electrostatic, 19-25  
     magnetic, 35-36  
 DeForest triode, 185  
 De-ionization time in thyratrons, 266-267  
 Delay time in amplifier, 567-568  
 Demodulation, 491, 691-777; *see also*  
     Detection; Modulation  
     definition of, 690-691  
     square-law, 740  
 Demodulator, 390; *see also* Demodulation; Detection; Detector; Modulation  
 Density, *see also* Concentration  
     current, *see* Current density  
     space-charge, 129, 132  
     tungsten, 88  
 Detection, 491, 690-777  
     anode-bend, 749  
     conversion, 758  
     definition of, 690-691  
     grid-current, 749-750  
     linear, 715-725  
         reverts to square-law, 750  
     plate, 749  
     power, 750  
     square-law, 716, 740  
         distortion in, 748-750  
         with diode, 750  
         with triode, 746-750  
 Detector, 390; *see also* Demodulation; Detection; Modulation  
     diode, 715-725, 740, 750  
     first, 757  
     linear, 715-725  
     square-law, 740, 746-750  
 Determinant, circuit, 804-805  
 Deviation, amplitude, 692  
     frequency, 693-696, 765, 766-768  
     phase angle, 694-696
- Diameter, electron, 5, 141  
     molecule, 5, 141  
 Dielectric constant, 129, 130  
     of free space, 63, 829  
 Difference component, in d-c amplifier, 505  
 Differences, method of finite, 726-730  
 Differentiating amplifier, 592  
 Diode, 7, 164  
     crystal, 277, 781-782  
         as mixer, 758  
         noise in, 498  
     equivalent, 181  
     gas, 229-243  
         cathode disintegration in, 236-238  
         cold-cathode, 271-276  
         critical anode voltage of, 237  
         effect of gas in, 229-232, 239-243  
         effect of spacing in, 236  
         filament voltage rating of, 238  
         firing of, 233  
         forward breakdown in, 233  
         inverse-peak-voltage rating of, 241-243  
         peak-current rating of, 238  
         permissible pressure range in, 241-243  
         plasma in, 235-236  
         potential distribution in, 234-236  
         potential maximum in, 235  
         volt-ampere curve of, 233  
         voltage drop in, independent of current, 234  
         voltage-drop magnitude in, 234  
 ideal, 283-284  
 vacuum, characteristics of, 165-172  
     current-voltage characteristic of, 166-168  
     displacement current in, 129, 166, 720  
     linear approximations for, 282-284  
     linear detector, 715-725  
     logarithmic characteristic of, 170  
     oxide-coated cathode, 167-168  
     potential distribution in, 125-132  
     potential minimum in, 126  
     power series for, 725-730  
     rating of, 172-176  
     rectification characteristics for, 721-724  
     space-charge distribution in, 132  
     Taylor series for, 730-734

- Diode, vacuum, tungsten-filament, 167, 229  
  ultra-high frequency, 220
- Direct transmission, 575
- Directions of currents and voltages, reference, meaning of, 391-393, 395, 476
- Discharge, gas, *see* Gaseous discharges
- Discriminator circuit, 317, 390, 765-766, 771
- Disintegration of cathode, 236-238
- Disintegration voltage for a gas, 236-238
- Dispersion, in transit time, 818  
  of electrons around grid wires, 207, 212
- Displacement, electric, 128-129
- Dissipation, plate, *see* Plate dissipation
- Distortion, *see also* Harmonic generation  
  amplitude, 437  
  attenuation, 438  
  delay, 438  
  frequency, 438, 492, 568  
  in amplifiers, 437-444  
    for push-pull operation, 465-467, 474-475  
    permissible maximum, 441, 451  
  in linear detectors, 723-725  
  in modulation, 746  
  in square-law detection, 748-750  
  intercept, 438  
  intermodulation, 438, 744  
  nonlinear, 437; *see also* Harmonic generation  
    feedback reduces, 570, 584-585
- Distribution, Fermi-Dirac, 68-72  
  kinetic energy, of electrons in a metal, 68-71  
    of secondary electrons, 106  
  of free paths among particles, 143-145  
  of radiant power from incandescent lamp, 115 [156]  
  of various quantities in glow discharge, potential, along filament, 170  
    between infinite parallel planes, 12  
    in beam power tubes, 212-213  
    in gas diodes, 234-236  
    in mercury arc, 244-247  
    in pentodes, 206-207  
    in tetrodes, 203-204  
    in triodes, 178, 183-184  
    in vacuum diode, 125-132  
  relation of space-charge distribution to, 234-235
- Distribution, potential-energy, of electrons in a metal, 64-65, 70-71  
  space-charge, in vacuum diode, 132  
  temperature, along filament, 170-171  
  velocity, among emitted electrons, 255-256  
    in plasma, 236
- Distribution function, 68, 69; *see also* Distribution
- Donor, 780
- Doubler, frequency, 622  
  voltage, 334-336
- Drift, zero, 502
- Driver stage, 619
- Driving-point impedance, effect of feedback on, 585-589
- Duality in transistor circuits, 802
- Dynamic transfer characteristic, 439-444, 737
- Dynatron, 103, 206, 659
- Dynode, 120
- E**
- Ear, characteristics of, 489-491
- Edison effect, 171
- Efficiency, emission, *see* Emission efficiency  
  plate, *see* Plate efficiency  
  power conversion, in transistor, 819
- Elastic collisions, 141, 145
- Electrode voltages, conventional reference point for, 393
- Electrolysis of glass, 174
- Electrometer tube, 191-192
- Electron, *see* Electrons
- Electron ballistics, 1-60
- Electron beam, density-modulated, 221-222  
  velocity-modulated, 221-225
- Electron device, definition of, 1
- Electron emission, 61-123; *see also* Field emission; Photoelectric emission; Secondary emission; Thermionic emission  
  four modes of, 76
- Electron escape from a metal, 61, 70-75
- Electron gas, in a metal, 62-71  
  in a plasma, 236
- Electron gun, 21; *see also* Focusing;  
  Lens, electron,
- Electron lens, *see* Lens, electron
- Electron loading of the grid, 220

- Electron optics, 25-29; *see also* Lens, electron
- Electron tubes, *see also* Diode; Gas tubes; Pentode; Tetrode; Thyatron; Triode; Tubes; Vacuum tubes  
classification of, 6-7, 164  
vacuum, applications of, 390
- Electron volt, 17-19, 829
- Electronic-computer tube, 217
- Electronic conduction, 1, 2, 62, 66-68
- Electronics, definition of, 1
- Electrons, 3-5  
average kinetic energy of thermionically emitted, 256  
bound, 66  
concentration of, 69, 73  
conduction by, 779-780  
dispersion of, around grid wires, 207  
drift velocity of, in metal, 62, 66  
in plasma, 236  
energy levels of, 65  
free, 62, 66, 71  
heat of evaporation of, 171  
initial velocities of, 134  
mean energy of, in a gas discharge, 147  
mean free path of, 141-145  
path of, *see* Path of charged particles  
photoelectric emission of, 110-121  
potential energy of, 63, 65, 70-71  
primary, 103-104  
probability of escape of, 77, 111  
properties of, 3-5, 101  
random current density of, 66  
recombination of, with ions, 137  
secondary, 45, 103-110; *see also* Secondary emission  
in pentodes, 206-207  
in tetrodes, 203  
suppression of, in beam-power tubes, 212-213  
space charge of, *see* Limitation of current by space charge; Space charge  
temperature of, 147  
total ionizing power of, 146  
valence, 62, 65-66, 70  
velocity distribution of, in plasma, 236  
wave nature of, 5, 77, 101-102  
 $\alpha$ -associated kinetic energy of, 71-72
- Element, chemical, 62
- Emission, auto-electronic, *see* Field emission
- electron, 61-123; *see also* Field emission; Photoelectric emission; Secondary emission; Thermionic emission
- field, *see* Field emission
- four modes of, 76
- photoelectric, *see* Photoelectric emission
- secondary, *see* Secondary emission
- thermionic, *see* Thermionic emission
- Emission constants, *see* Thermionic emission, constants of; Oxide-coated cathode; Thoriated-tungsten cathode; Tungsten cathode
- Emission current, 77, 80, 126  
field effect on, 99  
grid, 174-175, 254  
plate, 173  
pulsed, 95  
space current differs from, 77, 126  
temperature coefficient of, 81
- Emission efficiency, 84, 88, 91, 94; *see also* Oxide-coated cathode; Thoriated-tungsten cathode; Tungsten cathode
- gas-pressure effect on, 239-241  
gas-tube, 238-239  
photoelectric, 105  
secondary-emitter, 104
- Emissivity, spectral-radiation, 82, 93  
total-radiation, 82, 84, 91, 93
- Emitter of transistor, 784-787
- Energy, excitation, 136, 139  
internal, 135  
ion, 137-139
- Energy level, Fermi, 69  
zero, 72
- Energy levels, 65-69, 102, 136-139  
band of, 66, 101-102, 778-780  
of mercury atom, 138-139  
transitions between, 136-139
- Energy storage in tuned circuit, 638-640, 677
- Energy transfer at a collision, 145-147
- Envelope of modulated wave, 699, 717-720
- Equivalent circuit, incremental, cathode follower, 430-432
- Class B amplifier, 625
- current-source, 407

Equivalent circuit, incremental, grounded-grid amplifier, 435-437  
 linear Class A<sub>1</sub> amplifier, 405-412  
 pentode, 407, 426-428  
 push-pull amplifier, 463-465  
 tetrode, 407, 427  
 transistor, 798-803, 808, 810  
 ultra-high-frequency applicability of, 219  
 vector diagrams for, 409-411  
 voltage-source, 407-408  
 with interelectrode capacitances included, 420, 426-427

Escapement, analogy of Class C amplifier with, 638-640, 678

Evaporation, rate of, 84

Even function, 442

Excitation energy, 136, 139

Excitation probability, 146

Excited state of atom, 136, 148

Excitron, 250-251

Exclusion principle, Pauli, 68

Extinction angle of rectifier circuit, 319

Extinction current in mercury arc, 247

Extrinsic semiconductor, 780

Eye, relative luminosity of, 113-115

**F**

Feedback, amount of, 577  
 applied to modulation, 715  
 bridge, 589-592  
 current, 571, 573  
 effect of, on half-power frequencies, 594-595, 597  
 in nonelectrical systems, 600  
 in transistor amplifier, 794-795, 811  
 negative, definition of, 577  
 shunt, 589-592  
 types of, 570  
 voltage, 571-573

Feedback amplifiers, 570-600; *see also* Amplifier, feedback

Feedback factor, 572

Feedback ratio, complex, 526

Feedback transfer impedance, 573

Feedback transfer voltage ratio, 571

Feedback transistor characteristics, 789-792

Field emission, mercury-pool-cathode, 101, 245

Figure of merit, for triodes, 450

Figure of merit, for tuned circuit, 549  
 for vacuum tube, 192, 525

Filament, *see* Cathode; Oxide-coated cathode; Tungsten cathode

Filament voltage, maximum, in gas tubes, 238

Filter circuit, rectifier, capacitor, 316-328  
 capacitor-input, *see* Capacitor-input filter  
 choke-input, *see* Inductor-input filter  
 condenser-input, *see* Capacitor-input filter  
 inductor, 329-334  
 inductor-input, *see* Inductor-input filter  
 necessity for, 316

Firing, of gas diode, 233  
 of thyratron, 257-258, 266, 270

Fischer-Hinnen method of harmonic analysis, 442-444

Five-halves-power equation, 170

Flicker noise, 498

Flip-flop switching operation, *see* Bi-stable switching operation

Fluorescent screen, 21, 107-110

Flywheel effect of tuned circuits, 638-640, 677

Focusing, electrostatic, 25-29  
 magnetic, 41-42, 59

Focusing electrodes, in beam-power tube, 212

Force, between electrons, 6  
 image, 96-97  
 on a charged particle, 8, 12, 30, 33, 42

Forming process, transistor, 787

Forward transistor characteristics, 789-792

Fourier integral, 488

Fourier series, for full-wave rectifier, 294  
 for half-wave rectifier, 289, 327  
 for plate current, 440-444

Free electrons, 62, 66, 71

Free path, 141

Free paths, distribution of, 143-145

Free-running switching operation, 823-825

Frequency, angular, instantaneous, 693, 695, 770  
 resonant, 548  
 audio, 488  
 carrier, 554, 699  
 geometric-mean, 519

Frequency, half-power, 515-516, 552  
 mid-band, 519  
 middle range of, 512-514, 521, 542  
 modulation, 699  
 of atomic radiation, 136  
 radio, 489-491, 554  
 side, *see* Side frequencies  
 threshold, 111  
 video, 489-490  
 wave, 691-692

Frequency characteristic, 491-494  
 logarithmic, 519-520  
 with negative feedback, 594-598

Frequency-converter tubes, 218-219, 757-761

Frequency limits of thyratron, 266

Frequency modulation, *see* Modulation, frequency

Frequency-modulation tube, 217

Frequency ranges, communication, 488-491  
 of amplifiers, 487-491

Frequency response, 491-494  
 extension of, 563-570

Full-wave rectifier, *see* Single-phase rectifier circuits, full-wave

Functional notation, 280, 468

## G

Gage, ionization, 256-257

Gain, 400; *see also*, Amplification  
 available power, 806-807  
 loop, 572  
 maximum available power, 807  
 operating power, 806  
 stabilization of, by feedback, 580-581  
 voltage, *see also* Amplification, voltage  
 cascade-amplifier, 493-494  
 decibels of, 493-494

Gain-bandwidth product, in resistance-capacitance-coupled amplifier, 525  
 in tuned amplifier, 557

Gain stability, feedback amplifier, 570

Gas, breakdown voltage of, 152-154  
 clean-up of, 243, 270, 271  
 collision processes in, 139-148  
 effect of, in a diode, 229-232, 239-243  
 in a triode, 252-258  
 on cathode evaporation, 239-241  
 electron, 62-71  
 in electronic devices, 124, 134-135

Gas, inert, 135; *see also* Argon; Helium; Krypton; Neon; Xenon  
 kinetic theory of, 140-145  
 mean free path in, 141-145  
 monatomic; *see also* Argon; Helium; Krypton; Mercury vapor; Neon; Xenon  
 excitation energies of, 139  
 ionization energy of, 139

Gaseous discharges, 148-149, 154-155, 162; *see also* Arc; Breakdown; Glow discharge; Townsend discharge  
 classification of, 148-149  
 low-pressure, spectrum of, 137

Gas noise, 498

Gas pressure, effect of, in gas tubes, 229-232, 239-243  
 in thyratron, 269-271  
 on grid current, 252-258  
 on sparking voltage, 152-154  
 in vacuum tubes, 124, 134, 145, 232, 252-258  
 of mercury vapor, effect of temperature on, 242

Gas tubes, 6, 164, 229-276; *see also* Diode; Phototube; Rectifier; Thyratron; Triode  
 amplifier, 259  
 behave as short circuits, 234  
 clean-up of gas in, 243, 270-271  
 critical anode voltage of, 236-237  
 glow-discharge, 354  
 life of, 237-238  
 maximum filament-voltage rating of, 238  
 pressure range permissible in, 241-243  
 smoothing capacitor not used with, 326, 334  
 spacing effect in, 236  
 use of inert gases in, 243, 270-271  
 voltage-reference, 359  
 voltage-regulator, 354-359

Gas-type rectifier, 283-284, 297-392; *see also* Single-phase rectifier circuits

Gated-beam tube, 214-217

Gating, 216, 390

Gauss' law, 128

Geometric-mean frequency, 519

Germanium rectifier, 783

Glass, electrolysis of, 174

- Glass, for electron tubes, 172  
 puncture of, 107
- Glow, anode, 155-156  
 negative, 155-156
- Glow discharge, 155-160  
 abnormal form of, 158-159, 160  
 cathode voltage drop in, 157  
 in thyratrons, 270  
 normal form of, 157-159  
 positive column of, 155-157; *see also*  
 Plasma  
 transition to arc from, 160-161
- Glow modulator lamp, 276
- Gradient, 8  
 potential, in mercury-arc plasma, 245-  
 246
- Graphical analysis, of nonlinear circuits,  
 280-282, 395-397  
 of transistor circuits, 789-798
- Grid, 7  
 accelerator, 214  
 blocking, 268  
 control, 201  
 in polyphase rectifiers, 267  
 in thyratron, 267-269  
 trigger action of, 258-259  
 in vacuum tubes, control of current  
 by, 176-187  
 electron loading of, 220  
 emission current from, 174-175, 254  
 heating of, 174-175  
 nonuniform, 211-212  
 limiter, 214  
 quadrature, 214  
 screen, 202, 206, 425-428  
 shield, 268  
 space-charge, 201  
 suppressor, 206-207, 212-213, 714-715  
 trigger, 268
- Grid-bias voltage, 395; *see also* Cathode  
 bias
- Grid control, in polyphase rectifier cir-  
 cuit, 267  
 in vacuum tubes, 176-187  
 of thyratron rectifiers, 365-382
- Grid control ratio of thyratrons, 262
- Grid current, 195-196; *see also* Screen-  
 grid current  
 causes of, 252-255  
 gated-beam tube, 217  
 thyratron, 259-260, 263-265
- Grid current, thyratron, effect of, in  
 phase-shift circuit, 381-382  
 effect of, on grid-voltage waveform,  
 371, 373  
 limiting resistor necessary for, 367
- vacuum-tube, 174-175, 190-192  
 displacement, 420  
 effect of, in amplifiers, 393, 404-405,  
 523  
 effect of, in oscillators, 665, 670-672,  
 675-678
- electron, 178, 254-258
- limits grid resistor, 523
- magnitude of, 191-192
- positive-ion, 254-258
- reduction of, 192
- subscript indication of, 403-405
- Grid-driving power, 619  
 in Class C amplifiers, 637, 641-642  
 in oscillators, 674-678
- Grid emission, in thyratron, 268; *see also*  
 Grid current  
 in vacuum tubes, 174-175, 254
- Grid-leak-and-capacitor bias voltage, 642-  
 643  
 build-up of, 670-672  
 effect on oscillator stability of, 676-678
- Grid-signal voltage, 399-400
- Grid voltage, bias, 395; *see also* Cathode  
 bias  
 customary reference point for, 393  
 cut-off, 180, 186  
 remote, 211-212
- Grounded-base transistor amplifier, 789,  
 793-796, 807-808, 812
- Grounded-base transistor pulse circuit,  
 819-823
- Grounded-collector transistor amplifier,  
 810-811, 813
- Grounded-emitter transistor amplifier,  
 796-798, 808-810, 812-813
- Grounded-emitter transistor pulse circuit,  
 824-825
- Gun, electron, 21; *see also* Focusing;  
 Lens, electron

## H

- Half-power frequencies, effect of feed-  
 back on, 594-595, 597
- Half-power frequency, transistor, 818

- Half-wave rectifier, *see* Single-phase rectifier circuits, half-wave
- Hall effect, 68, 780
- Harmonic analysis, Fischer-Hinnen method of, 442-444
- Harmonic generation, *see also* Distortion effect of feedback on, 584-585 in Class A amplifier, 438-444 per cent, 441, 443 permissible maximum, 441, 451 push-pull, 465-467, 474-475
- Harmonics, *see also* Distortion; Harmonic generation in polyphase rectifiers, 307-308 in single-phase rectifiers, 289, 294
- Heating, anode, 172-173, 446-447 grid, 174-175 induction, 658 plate, 172-173, 446-447
- Heating time of heat-shielded cathodes, 239
- Helical path of charged particles, 40-41
- Helium, 110, 139, 143, 232, 829 use of, in gas tubes, 243, 270
- Heptode, 164
- Hexode, 164
- Holes, 67 conduction by, 779-780
- Hook-collector transistor, 788
- Hot spots on oxide-coated cathode, 94
- Hum, 495, 584
- Humps, potential-energy, 64, 70, 73
- Hydrogen, atomic weight of, 829 mean free paths in, 143
- I**
- Iconoscope, 488
- Igniter, band, 252; *see also* Ignitor
- Ignition angle of rectifier circuit, 299
- Ignition voltage, 152
- Ignitor, 251 reverse current detrimental in, 382
- Ignitron, 251-252, 365
- Ignitron circuits, 382-384
- Image charge, 96
- Impedance, effect of feedback on, 585-589
- Impedance angle, 331
- Imperfections in crystal lattice, 780
- Imprisonment of radiation, 148
- Impurities in semiconductors, 780
- Incremental resistances, of transistor, 799, 801-803
- of vacuum tube, *see* Coefficients; Plate resistance
- Induced-grid noise, 497
- Inductance, cathode lead, 220-221 critical, 344, 346, 374 incremental magnetizing, 536
- Inductor; *see also* Choke Q of, 340, 553, 650
- Inductor-input filter, 338-348 critical inductance in, with thyratrons, 374
- inductors for, 346 internal impedance of, 340-341 multi-section, 345
- Inelastic collisions, 141, 145
- Inert gas, *see also* Argon; Helium; Krypton; Neon; Xenon use of, in gas tubes, 243, 270-271
- Initial velocities of emission, 255-256
- Initial voltage, 152
- Injection, electron and hole, 785-787
- Input impedance, *see also* Driving-point impedance of two-loop network, 562, 586-587
- Input-resistance curves, 793-796
- Input resistance of two-terminal-pair networks, 805
- Input signal voltage, 430-431
- Instability in transistor circuits, 794, 796, 804
- Insulator, 67, 779 secondary emission from, 107-110
- Integrating amplifier, 592
- Interelectrode capacitance, 181 effect of, on input admittance, 419-428
- grid-to-plate, 201-202
- incremental equivalent circuit including, 420, 426, 427
- limits amplification, 202, 425
- measurement of, 419
- pentode, 425-427
- reduction of, by screen grid, 202-203, 425
- tetrode, 201-203, 425-427
- Interference, radio, minimization of, 492, 554, 767-773
- Intermodulation distortion, 744
- Intrinsic semiconductor, 780
- Inverse feedback, *see* Feedback

- Inverse-peak voltage, in rectifier circuits, 291-292, 297, 313-314, 316, 318, 329, 334
- Inverse-peak-voltage rating, of gas tube, 241-243  
of vacuum tube, 174
- Inverter, d-c to a-c, similarity of, to oscillator, 657  
phase, 530-533, 592
- Ion, 4  
energy of, 137-139  
multiple-charged, 4, 146  
negative, *see* Negative ions  
positive, *see* Positive ions
- Ionization, 137-139, 145-148  
by collision, 147  
by photons, 148  
by positive-ions, 147  
increase of space-charge-limited current by, 229-232  
multistage, 148  
probability of, 146  
residual, 150
- Ionization gage, 256-257
- Ionization time in thyratrons, 266
- Ionizing energy, 139
- Ionizing potential, drop in gas tube differs from, 230
- Ionizing power of electrons, 146
- Isotopes, 34
- J
- Jones and Langmuir tables, 85-88
- Junction transistor, 784-788
- K
- Kenotron, 165; *see also* Diode, vacuum
- Kinescope tube, 19-25, 35-36, 488
- Kinetic energy of electron, *x*-associated, 71-72
- Kinetic theory of gases, 140-145
- Klystron, 221-225
- Konel metal, 92
- Krypton, 139, 232, 829  
use of, in gas tubes, 243, 270
- L
- L/C* ratio, 558, 648
- Lamp, fluorescent, 359
- Lamp, gaseous-discharge, 137  
cathodes for, 239-241  
glow modulator, 276  
incandescent, radiation from, 115  
mercury-arc, problem on, 361  
neon, characteristic curve of, 159  
oscillator-stabilizing, 684
- Langmuir's equation, 132
- Lattice, atomic, 62, 65, 96, 780
- Leakage current, grid, 255
- Lens, electron, 28-29, 41-42
- Level, energy, *see* Energy levels
- Life, cathode, 84, 85, 88, 94  
excited state, 136  
metastable atom, 137
- thermionic gas tubes, 237-238  
vacuum tube, 176
- Light, speed of, 4, 829, 831
- Limitation of current by space charge, 125-134; *see also* Three-halves-power equation  
effect of ionization on, 229-232  
in positive-ion sheath, 235-236, 262-264
- Limiter, amplitude, 217, 390, 765-766, 771
- Linear amplifier, Class B, 626
- Linear approximations, for diodes, 282-284  
for triodes, 198-200, 406
- Linear operation of vacuum tube, conditions for, 195, 198-200, 391, 399-405, 737
- Lines of electric force, 127
- Load line, 395-397, 452-460, 471; *see also* Path of operation in amplifier  
a-c, 459  
d-c, 458-459  
dynamic, shift of, 458-460
- Load resistance, Class A<sub>1</sub> amplifier, 192-193, 394  
for maximum power output, 452-455  
for push-pull connection, 475  
for resistance-capacitance coupling, 521-523
- Class B amplifier, 628
- Class C amplifier, 637
- plate-to-plate, 463, 475
- Loading, electron, of the grid, 220
- Logarithmic diode characteristic, 170
- Logarithmic frequency characteristic, 519-520
- Loop transmission, 572, 575
- Loud speaker, winding of, 450

- Lumen, 115, 119  
 Luminosity curve, relative, for eye, 113-115
- M**
- Magnetron, 48-54, 60, 103  
 cavity, 225-226
- Majority carrier, 785-786
- Mass, alpha-particle, 58  
 dependence of, on speed, 4  
 electron, 3, 829  
 positive-ion, 137  
 rest, 4, 829
- Matched transistor load resistance, 807
- Matched transistor source resistance, 807
- Matching, impedance, 451-458, 806-808
- Matrix representation, of electronic circuits, 574, 811
- Maximum available power gain, 807
- Maximum peak inverse voltage, double-way rectifier, 313-314  
 full-wave rectifier, 297  
 half-wave rectifier, 291-292  
 polyphase double-way rectifier, 316  
 with capacitor filter, 318, 329  
 with inductor filter, 334
- Maximum power output, *see* Power output, maximum
- Mean free path, 141-145
- Measurement, of charge-to-mass ratio, 34, 48  
 of charged-particle velocity, 43-44  
 of Class C amplifier grid-driving power, 642  
 of constants for Richardson's equation, 80-84  
 of  $h$ ,  $n$ , and  $k$ , 69  
 of interelectrode capacitance, 419  
 of phototube spectral sensitivity, 114-115  
 of potential distribution in triodes, 183  
 of power-series coefficients, 737  
 of thermionic-emission constants, 80-84  
 of tube coefficients, 198  
 of vacuum, 256-257
- Mechanical model of rectifying device, 277
- Melting points, of metals, 79, 113
- Mercury-arc rectifiers, 101, 161, 247-252  
 circuits for, *see* Polyphase rectifier circuits
- Mercury-arc rectifiers, conditions for high efficiency in, 301-302  
 extinction in, 247  
 glass bulb, 247-248  
 grid control of, 267
- Mercury vapor, atomic weight of, 829  
 cathode-disintegration voltage for, 237  
 condensation of, in rectifiers, 247-248  
 energy levels of, 138-139  
 excitation and ionization energies of, 139  
 ion speeds in, 232  
 mean free paths in, 143  
 pressure of, 241-243  
 secondary emission by ions of, 110
- Meson, 3
- Metal, atomic structure of, 62, 67  
 boundary of, 64  
 conduction in, 62, 66-68, 779-780  
 electron gas in, 62-71
- Metallic rectifier, 782
- Metastable atom, 137-139, 148, 230
- Meter-kilogram-second units, 830-831
- Microphonic noise, 495
- Microscope, electron, 25-26
- Microwave frequency, 489
- Microwave tubes, 221
- Mid-band frequency, 519
- Middle range of frequencies, 512-514, 521, 542
- Miller effect, 422, 593
- Minority carrier, 785-787
- Mixer, 210, 390, 757-761  
 pentagrid, 219, 758
- Modulated wave, amplifier for, 626  
 components of, 700-704, 763-767  
 differs from beat wave, 757  
 envelope of, 699, 717-720  
 sinusoid differs from, 699-700
- Modulation, 490, 689-777  
 alternating-current, 689-691  
 amplitude, 692-693, 698-705  
 definition of, 692  
 linear, 705-706  
 modulation characteristic for, 705-706  
 square-law, 704  
 vector representation of, 693, 700-701
- wave zeros during, 697, 701  
 angular, 692-697, 761-773  
 wave zeros during, 697, 701

- Modulation, balanced, 750-753  
 cathode, 714  
 definition of, 689  
 density, 221-222  
 distortion in, 746  
 for d-c amplification, 503  
 frequency, 692-697, 761-773  
   alternator example of, 694  
   comparison of, with phase modulation, 695-697  
   definition of, 693  
   interference with, 767-773  
   modulation index for, 763  
   narrow-band, 762-763  
   wide-band, 764-766  
 frequency deviation in, 765, 766-768  
 frequency translation by, 690-691, 702-703  
 grid-bias, 713-714  
 Heising, 707  
 in radio, 690, 702-703  
 pentode, 714-715  
 per cent, 699, 704  
   maximum for detector, 724  
 phase, 692-697, 765  
   alternator example of, 695  
   comparison of, with frequency modulation, 695-697  
   definition of, 694  
 plate, 630, 705-713  
 pulse, 692, 697-698  
 single-side-band, 704, 753, 771  
 square-law, 737  
   with diodes, 738-742, 750  
   with triodes, 742-746, 750, 753  
 suppressor grid, 210, 714-715  
 tetrode, 714  
 time-varying-parameter, 689, 741-742, 759  
 types of, 691-698  
 Van der Bijl, 713, 744-746  
 velocity, 221-225  
 Modulation characteristics, 705-706  
 Modulation factor, 698-699  
   for square-law modulation, 740  
   Van der Bijl, 746  
 Modulation frequency, 699  
 Modulation index for frequency modulation, 763  
 Modulator, 390; *see also* Modulation amplifier as, 707  
 balanced, 750-753
- Modulator, semiconductor, 725  
 Molecules, average kinetic energy of, 141  
   concentration of, 142  
   mean free path of, 142-145  
   radius of, 5  
 Monatomic gases, 139; *see also* Argon; Helium; Krypton; Mercury vapor; Neon; Xenon  
 Monostable switching operation, 821-825  
 Motion of charged particles, *see* Charged particles, motion of  
 Multiplication with vacuum tubes, 218, 592  
 Multiplier, frequency, 622, 765  
 Multiplier phototube, 44-48, 103, 119-121  
 Multivibrator, 390  
 Music, frequency range of, 488-489  
 Mutual conductance, 194  
   average, 668  
   constancy of, 195  
   in pentodes, 210  
 Mutual impedance, 562, 586
- N
- n-p-n* transistors, 785-788  
 Negative conductance, at input of triode, 423-425  
 Negative feedback, *see* Feedback  
 Negative glow, 155-156  
 Negative ions, 4, 137-138  
   effect of oxygen on formation of, 138  
   properties of, 137-138  
 Negative resistance, in diode, 220  
   in secondary-emission tube, 218  
   in tetrode, 205-206  
 Negative transconductance, 216  
 Negative-transconductance oscillator, 685, 688  
 Neon, 139, 143, 232, 237, 829  
   in Strobotron, 276  
   use of, in gas tubes, 243, 270  
 Neon lamp, *see* Lamp, neon  
 Neon sign, 155, 160  
 Neutralization, electron-space-charge, 147, 229-232  
   in amplifiers, 425, 558, 562, 707  
   positive-ion, at walls, 147  
 Neutrino, 3  
 Neutron, 3  
 Nitrogen, mean free paths in, 143  
 Noise, amplifier, 494-499

- Noise, electrical contact, 814  
 low-frequency, 502  
 reduction of, by feedback, 570  
 thermal, 495-496  
 transistor, 498, 814-817
- Noise figure, 498-499  
 transistor, 816-817
- Nonlinear circuit element, as modulator, 689, 740-742, 757  
 as rectifier, 277-280
- Nonlinear function, power series for, 725-730  
 Taylor series for, 730-734
- Nonself-maintaining gaseous discharge, 149-152, 154-155; *see also* Townsend discharge
- Normal current density, 157-158
- Nucleus, atomic, 62
- Nyquist criterion, 578-580
- O
- Octode, 164
- Offset of tungsten filament, 89
- On-or-off control of thyratrons, 365, 370-371, 374
- One-shot switching operation, 821-825
- Operating power gain, 806
- Oscillation, in amplifiers, 596, 598-600, 681-682  
 in transistor circuits, 794, 796, 798, 804, 823-825
- Oscillators, 390, 657-688  
 amplitude stability of, 668-670, 672, 675-678, 684-685  
 analogy of, with clock, 616  
 analysis of, 659-664, 672-678, 680-681  
 Barkhausen criterion for, 662-664, 680-681  
 Barkhausen-Kurtz, 56, 659  
 beat-frequency, 754-757, 771  
 blocking, 390, 678  
 classification of, 658-661  
 Colpitts, 679  
 dynatron, 206, 659  
 feedback, 596, 658-685  
   self-excitation in, 660-664, 666, 668, 680-681  
 frequency stability of, 660, 680, 754  
 Gill-Morrell, 659  
 Hartley, 678-679, 681-682  
 heterodyne, 754-757
- Oscillators, local, 757-761  
 magnetostriction, 659  
 magnetron, 53, 659  
 master, 754  
 modulated, 697, 707  
 negative-resistance, 658, 822-826  
 negative-transconductance, 685, 688  
 nonelectrical, 657  
 nonlinearity stabilizes, 669, 684  
 piezoelectric, 659, 680  
 $Q$  of tuned circuit for, 674-675, 677-678  
 relaxation, 388, 659, 822-825  
 resistance-capacitance, 682-685  
 self-starting of, 670-672  
 shunt feed in, 678-679  
 sinusoidal, 659, 682-685  
 transistor, 825-826  
 tuned-grid, 679  
 tuned-grid tuned-plate, 679-680  
 tuned-plate, 664-670, 672-678, 680-681  
   design of, 672-678  
   frequency of oscillation in, 666-667, 674, 680-681  
   self-excitation in, 664-670, 680-681  
   starting of, 668-671  
   vector diagram for, 673-675  
 types of, 658-660  
 ultra-high-frequency, 225  
 Wien-bridge, 682-685
- Oscilloscope, electron, 19-25, 35-36, 58, 508
- Outgassing, temperature for, 172
- Output impedance, *see also* Driving-point impedance
- Output-resistance curves, 793-794
- Output resistance of two-terminal-pair networks, 805
- Overexcited operation of vacuum tube, 404-405
- Overshoot, transient, in amplifiers, 568
- Oxide-coated cathode, 91-95  
 diode with, 167-168  
 disintegration of, by positive ions, 236-238
- effect of field on emission from, 93  
 gaseous-lamp, 241
- heat-shielded, 239  
   emission efficiency of, 239  
   heating-time requirement of, 239
- hot spots on, 94
- indirectly heated, 94-95, 238-239
- Oxygen, 138, 143

**P**

*p-n-p* transistors, 785-786  
 Parabolic path of charged particles, 16, 23  
 Parallel-T network, 682  
 Particles, elementary, 2-6  
 Partition noise, 497  
 Paschen's law, 154, 241  
 Passive circuit elements, 801  
 Path, free, 143  
     mean free, 141-145  
 Path of charged particles, circular, 33-34  
     cycloidal, 44-48  
     helical, 40-41  
     in beam-power tube, 214  
     in electron lens, 28-29  
     parabolic, 16, 23  
 Path of operation in amplifier, 395-397  
     curved for push-pull operation, 473  
     elliptical, 412  
     for composite tube, 471  
     for maximum power output, 452-455  
     on constant-current curves, 631  
     with transformer, 457-458  
 Pauli exclusion principle, 68  
 Peak-current rating, of mercury-arc rectifier, 247  
     of thermionic gas tube, 238  
     with smoothing capacitor, 326, 334  
 Peaked waves for grid control, 375-376  
 Peaker, 390  
 Pentagrid converter, 219, 761  
 Pentagrid mixer, 219, 758  
 Pentode, 164, 206-212  
     as cathode follower, 435  
     as mixer, 758  
     cathode-bias for, 399  
     characteristic curves of, 207-209  
     coefficients of, 210  
     impedance matching in, 450  
     in Class A<sub>1</sub> amplifier, 425-428  
     in Class B audio-frequency amplifier, 618  
     in tuned amplifier, 555, 558, 560, 562-563  
     incremental equivalent circuit for, 407, 426-428  
     input admittance of, 428  
     input capacitance of, 428  
     interelectrode capacitances in, 425-427  
     interstage transformers with, 547  
     maximum power output from, 456

Pentode, modulation with, 714-715  
     output capacitance of, 428  
     potential distribution in, 206-207  
     remote-cut-off, 211-212  
     shielding required for, 428  
     voltage amplification with, 416, 428  
 Permatron, 271  
 Permeability of free space, 829  
 Permittivity, *see* Dielectric constant  
 Perveance of vacuum tube, 134, 181  
 Phase characteristic, 438, 491, 525-527, 543-544, 565-568  
 Phase inverter, 530-533, 592  
     difference amplifier as, 508-509  
 Phase modulation, *see* Modulation, phase  
 Phase-shift control of thyratrons, *see* Thyratron circuits  
 Phase-shifting device, 372, 378  
 Phase-shifting methods for thyratron control, 378-382  
 Phasor, 379-380  
 Phosphor, 21, 107-110  
 Photoelectric emission, 75, 110-121; *see also* Phototube  
     grid current from, 254  
     laws of, 112-113  
     linearity of, with light intensity, 112  
     spectral-sensitivity characteristic of, 114-116  
     threshold wavelength of, 111, 114  
 Photon, 111, 136; *see also* Radiation  
     in gas discharge, 148  
     release of electrons at cathode by, 148  
 Phototransistor, 788  
 Phototube, *see also* Photoelectric emission  
     cesium, 115-117  
     control of thyratron by, 367, 370, 380  
     gas, 117-121, 150-152  
         characteristic curves of, 150-151  
     manufacture of, 117  
     response of, to incandescent lamp, 115  
     spectral sensitivity of, 114-116  
     vacuum, 117-119  
 Plasma, 235-236, 245-246  
     formation of, 235, 270  
 Plasmatron, 259  
 Plate, 6; *see also* Anode  
     carbonized-nickel, 173  
     emission current from, 173  
     forced-air-cooled, 173  
     graphite, 173

- Plate, heating of, 172-173, 446-447  
 permissible power dissipation of, 173  
 water-cooled, 173
- Plate characteristic curves, *see* Characteristic curves
- Plate current, a function of two variables, 187, 189  
 average value of, 441  
 Fourier series for, 440-444  
 rectified component of, 441  
 space-charge limited, 132, 133  
 total differential of, 195, 405
- Plate dissipation, 445-447  
 during modulation, 710-712  
 in Class C amplifier, 638  
 in push-pull amplifier, Class AB, 612  
     Class B, 615-617  
 in tuned Class B amplifier, 626-628  
 permissible, 173  
 quiescent, 445
- Plate efficiency, Class A amplifier, 448, 455-456  
 Class AB amplifier, 613  
 Class C amplifier, 638, 640-641  
 during modulation, 710, 711-712, 714, 715  
 in push-pull amplifier, Class AB, 613  
     Class B, 615-617
- Plate modulation, *see* Modulation, plate
- Plate power supply, to be understood in diagrams, 503-504
- Plate resistance, composite-tube, 470  
 constancy of, 195  
 diode, 732  
     negative, 220  
     dynamic, 194  
     incremental, 194  
     negative, 205-206  
     pentode, 210  
     variational, 194
- Plate-to-plate load resistance, 463, 475
- Plate voltage, 12, 129, 133  
 customary reference point for, 393  
 limitations on, 174  
 maximum-inverse-peak, 174; *see also*  
     Maximum peak inverse voltage  
     reference direction for, 392-393
- Plutonium, 62
- Point-contact transistor, 784, 787-788
- Point discharge, 155
- Poisson's equation, 128-130, 234
- Polarity, 395; *see also* Directions of currents and voltages, reference
- Polyphase rectifier circuits, 302-312, 314-316  
 advantages of, 302-303  
 bridge, 314-316  
 commutation in, 304  
 delta, six-phase, double-wye, 310-312  
 delta-wye-connected, 303-304  
 direct output voltage in, 304  
 double-way, 314-316  
 effect of leakage reactance in, 312  
 harmonics in, 307-308  
 interphase transformer in, 310-312  
 load current in, assumed constant, 309  
 losses in, 312  
 p-phase, 306-310  
     transformer rating for, 309-310  
 reactor in, 309  
 rectified voltage in, 304, 306-307  
 transformer effect in, 304
- Polyphase rectifiers, 248, 302-312; 314-316; *see also* Mercury-arc rectifiers; Polyphase rectifier circuits
- Positive column in glow discharge, 155-157; *see also* Plasma
- Positive ions, 4, 137  
 cathode disintegration by, 236-238  
 current augmentation by, 147, 151  
 deactivation by, 91, 93  
 diffusion of, in thyratrons, 266-267  
 disintegration voltage for, 236-238  
 grid-current contribution of, 254-258  
 ionization by, 147  
 motion of, in plasma, 235-236  
 neutralization of, at walls, 147  
 neutralization of electron space charge by, 147, 229-232  
 random current density, 263-264  
 recombination of, with electrons, 137  
 secondary emission by, 110  
 speed of, relative to electrons, 232  
 sputtering by, 148, 161, 236-237, 241  
 transfer of energy at collisions by, 147
- Positron, 3
- Potential difference, contact, 74-75, 168, 186, 255
- Potential distribution, *see* Distribution, potential
- Potential-energy barrier, 65, 71, 96-99, 101, 103, 111

- Potential-energy distribution, *see* Distribution, potential-energy  
 Potential minimum, in diode, 169  
     in triode, 180  
 Power, a-c output, 446-448  
     cools plate, 447  
     available, 450, 806  
     d-c load, 445  
     direct-current, 440-445  
 Power-emission chart, 82-83  
 Power output, maximum, Class A<sub>1</sub> amplifier, for large amplitudes, 451-456  
     Class A amplifier, for push-pull connection, 474-475  
     Class A amplifier, for small amplitudes, 448-451  
     from square-law modulator, 740, 742  
     from transistor, 818-819  
     maximum undistorted, 452  
 Power sensitivity, 449  
     maximum, Class A amplifier, 448-451  
 Power series, 725-730; *see also* Taylor series  
     effect of square term in, 739-740  
     for dynamic transfer characteristic, 440, 444, 737  
     utility of, 725, 730, 738  
 Pre-emphasis circuit, 772-773  
 Pressure, gas, *see* Gas pressure  
 Probability, collision, 143-145  
     electron-escape, 77, 111  
     excitation, 146  
     ionization, 146  
 Propagation, radiation, 490  
 Proton, 3, 62  
 Proximity effect limits *Q*, 553  
 Pulse carrier, 698  
 Pulse modulation, 692, 697-698  
 Pulse operation of transistors, 819-825  
 Pulse train, 698  
 Puncture of glass, 107  
 Push-pull amplifier, Class A<sub>1</sub>, 460-476  
     autotransformer effect in, 462-466, 468  
     cathode-bias in, 463 [475]  
     harmonic generation in, 465-467, 474-475  
     incremental equivalent circuits for linear operation of, 463-465  
     load resistance for, 475  
     maximum power output from, 474-475  
 Push-pull amplifier, nonlinear operation in, 465-476  
     plate-to-plate load resistance in, 463, 475  
     quiescent operation in, 461-462  
 Class AB, 609-613  
 Class B, 614-619  
     composite characteristics for, 467-475, 610-618  
     composite tube for, 467-474  
     even harmonics eliminated in, 466, 472  
     plate-to-plate load resistance in, 463, 475  
     transformers in, 462-466  
 Pyrometer, optical, 80, 82
- Q
- Q*, coil, 449-450, 553, 650  
     effective, in tuned amplifiers, 557, 560, 648-652  
     filter-inductor, 340  
     interstage-transformer, 543  
     piezoelectric-crystal, 680  
     tuned-circuit, 549  
         in oscillators, 674-675, 677-678  
         loaded, 648-652, 674-678  
         relation of, to energy storage, 639, 677  
 Quantized values for pulse modulation, 698  
 Quantum of energy, 111, 136  
 Quiescent operating point, 397  
 Quiescent operation of amplifiers, 394-399
- R
- Radar frequencies, 489  
 Radar, microwave, 48  
 Radiation, black-body, 115  
     excited-atom, 136  
     of a-c power, 690, 702-703  
     imprisonment of, 148  
     photon of, 111, 136  
     propagation of, 490  
     recombination seldom a cause of, 137  
 Radio communication, amplitude-modulation, 754-755  
     frequency-modulation, 761-773  
     frequency range of, 489-491  
     modulation essential for, 690, 702-703  
     single-side-band, 704, 753, 771  
     system for, 754-755

- Radio frequency, 489-491, 554  
 Radio receiver, 754, 757-761, 777  
 Radius, electron, 5  
     molecule, 5, 141  
     of curvature of electron path, 33  
 Ramsauer effect, 143  
 Random current density of electrons, 66  
 Rating, absolute maximum, 175  
     design-center maximum, 175  
 gas-tube, inverse-peak-voltage, 241-243  
     maximum-filament-voltage, 238  
     maximum-forward-anode-voltage,  
         270-271  
     peak-current, 238  
 mercury-arc-tube, peak-current, 247  
 vacuum-tube, 172-176  
     maximum-inverse-peak-voltage, 174  
     maximum-plate-voltage, 174  
     plate-heating, 173  
 Rationalized units, 17, 830-831  
 Reactance, leakage, effect of in rectifier  
     circuits, 312  
 Reactor; *see also* Choke; Inductor  
     load, polyphase rectifier, 309  
 Reciprocity theorem, 800  
 Recombination of electrons and ions, 137  
 Recontrol time in thyratrons, 266-267  
 Rectification, 278; *see also* Polyphase  
     rectifier circuits; Rectifier; Single-  
     phase rectifier circuits  
     sufficient condition for, 737  
 Rectification characteristics, 721-724  
 Rectified component of plate current,  
     441, 737  
 Rectified voltage, 304; *see also* Poly-  
     phase rectifier circuits  
 Rectifier, 165; *see also* Detector; Diode;  
     Mercury-arc rectifiers  
     barrier-layer, 277, 782  
     battery-charging tube, 241  
     cold-cathode, 271-272  
     copper-oxide, 277, 314, 783  
     copper-sulphide, 783  
     definition of, 277  
     elementary theory of, 278-280  
     gas-type, 283-284  
         approximate representation of, 283-  
             284  
         power loss in, 301  
     high-voltage, 174  
     ideal, 283-284  
     mechanical analogy of, 277  
 Rectifier, mercury-arc, *see* Mercury-arc  
     rectifiers  
 mercury-pool, 244-252  
 nonlinear, 277-280  
 polyphase, 248, 302-312, 314-316; *see*  
     *also* Mercury-arc rectifiers; Poly-  
     phase rectifier circuits  
 selenium, 277  
 semiconductor, as modulator, 725  
 synchronous-switch, 278-280  
 time-varying, 278-280  
 vacuum-type, 283-284                         [284]  
     approximate representation of 283-  
     power loss in, 290, 295  
 Rectifier circuits, *see* Polyphase rectifier  
     circuits; Single-phase rectifier cir-  
     cuits; Thyratron circuits  
 Rectifier filter circuit, *see* Filter circuit,  
     rectifier  
 Rectifier-type instrument, 313-314  
 Rectifying device, *see* Rectifier  
 Rectigon, 241  
 Regeneration, 570, 571, 598  
 Regulation, in single-phase rectifier, with  
     inductor-input filter, 343  
     with smoothing capacitor, 325-326,  
         352  
 Relativity, 4  
 Resistance, bleeder, 338, 339, 344  
 Resistance, grid, for thyratrons, 367  
     for vacuum tubes, 523  
 grid leak, 642-643, 670-671, 677  
 load, *see* Load resistance  
 plate, *see* Plate resistance  
 plate-to-plate load, 463, 475  
 reflected, 560, 647  
 Resistors, carbon, noise in, 498  
 Resonance, 547-553; *see also* Tuned cir-  
     cuits  
 Resonance curve, universal, 551  
 Resonator, cavity, 223-224  
 Rest mass of electron, 4, 829  
 Return ratio, feedback, 572  
 Richardson's equation, 77-81, 102  
 Ripple, suppression of, by feedback, 584  
 Ripple factor, 291, 297  
     with capacitor-input filter, 328, 329  
     with inductor-input filter, 342, 345

## S

Samples for pulse modulation, 698

- Saturation current, 80, 93, 96, 100; *see also* Emission current; Space current  
 effect of gas on, 231  
 from oxide-coated cathode, 93  
 from thoriated-tungsten cathode, 90  
 in gas discharge, 150  
 in phototubes, 118  
 true value of, 100
- Saturating-reactor ignitor excitation, 384
- Schottky effect, 96-101, 167-168  
 with oxide-coated cathode, 93  
 with thoriated-tungsten cathode, 90
- Screen, fluorescent, 21, 107-110
- Screen-grid current, 204, 208-209
- Screen-grid tube, *see* Beam power tubes; Pentode; Tetrode
- Secondary emission, 22, 45, 75, 103-110  
 by positive ions, 110  
 elimination of, in beam power tubes, 212-213  
 in pentodes, 206-207  
 grid current from, 254  
 in tetrode, 203  
 in vacuum tubes, 175  
 limits tetrode power output, 205
- Secondary-emission electron multiplier, 44-48, 103, 119-121
- Secondary-emission noise, 498
- Secondary-emission ratio, 104, 107
- Secondary-emission tubes, 217-218
- See-saw, electrical, 593
- Selected-ordinate method of harmonic analysis, 442-444
- Selectivity, 557-558, 560, 563, 645, 651  
 feedback improves, 570  
 of coupling network, 645-646, 651  
 of detector, 724
- Selenium rectifier, 782
- Self-impedance, 562, 586
- Self-maintained gaseous discharges, 149, 154-155, 163; *see also* Breakdown
- Selsyn, 378
- Semiconductor, 67, 92  
 classes of, 780  
 definition of, 778
- Semiconductor rectifiers, 778-784
- Semi-graphical analysis, Class B and Class C amplifier, 631-638
- Series, Fourier, *see* Fourier series  
 power, *see* Power series
- Taylor, *see* Taylor series
- Servomechanisms, 600
- Shannon sampling theorem, 698
- Shearing in graphical analysis, 282
- Sheath, anode, 245-246  
 cathode, 235, 245  
 positive-ion, 235  
 around thyratron grid, 262-265  
 at mercury-pool cathode, 245  
 overlapping of, 264, 266
- Shell, atomic, 65
- Shielding, pentodes and tetrodes require, 428  
 to prevent hum, 495
- Shields to prevent backfires, 248-250, 251, 253
- Shift of dynamic load line, 458-460
- Short-circuit current amplification, transistor, 809
- Short-circuit unstable transistor, 808
- Shot noise, 496
- Shunt feed, 530, 678
- Side bands, amplitude-modulation, 702-704  
 separation of, from carrier, 704, 753  
 frequency-modulation, 763, 766-768
- Side frequencies, 700-702  
 for frequency modulation, 763, 766-768  
 power in, 703  
 separation of carrier from, 704, 753
- Signal-source line, transistor, 793-794
- Signal-to-noise ratio, 498, 582-584
- Silicon rectifier, 783
- Single-ended tubes, advantages of, 428
- Single-phase rectifier circuits, 277-364  
 battery-charging, 302  
 biphasic, *see* full-wave (*below*)  
 bleeder resistor in, 338, 339, 344  
 bridge, 312-314  
 conduction angle of, 298-299  
 controlled, *see* Ignitron circuits; Thyatron circuits  
 d-c power output of, 290, 295  
 diametric, *see* full-wave (*below*)  
 double-way, 312-314  
 efficiency of, 290-291, 296  
 extinction angle of, 319  
 full-wave-circuit advantages, 295-297  
 full-wave gas-type with *R* load, 302  
 full-wave vacuum-type with *R* load, 292-297  
 efficiency of, 296  
 Fourier series for, 294

- Single-phase rectifier circuits, full-wave vacuum-type with  $R$  load, similarity of, to Class B amplifier, 615  
 full-wave with capacitor-input filter, 285-286, 348-354  
 full-wave with inductor-input filter, 337-348  
 full-wave with smoothing capacitor, 321, 328-329  
 gas-type with  $R$  load, 297-302  
 graphical analysis of, 280-282  
 grid controlled, *see* Thyratron circuits  
 half-wave gas-type with battery load, 302  
 half-wave gas-type with  $R$  load, 297-302  
 half-wave vacuum-type with  $R$  load, 286-292  
 efficiency of, 290-291  
 Fourier series for, 289  
 similarity of, to Class B amplifier, 616  
 half-wave with  $C$  load, 317-318  
 half-wave with smoothing capacitor, 316-328  
 as linear detector, 715-725  
 half-wave with smoothing inductor, 329-334  
 ignition angle of, 299  
 peak currents with smoothing capacitor in, 326, 334  
 regulation of, with smoothing capacitor, 325-326, 352  
 ripple factor of, 291, 297  
 simplifying assumptions for analysis of, 282-286  
 transformer effect neglected in, 284-285  
 vacuum-type with  $R$  load, 286-297  
 voltage-multiplying connections of, 334-337  
 Skin effect, limits  $Q$ , 553  
 Smoothing-filter circuit, *see* Filter-circuit, rectifier  
 Solid state, 778  
 Solids, atomic structure of, 61-63  
 Space, dark, *see* Dark space  
 Space charge, 7  
   around thyratron grid, 262-265  
   density of, related to potential distribution, 234-235  
   effect of, on potential distribution in diode, 125-132  
 Space charge, effect of, on potential distribution in triode, 183-184  
 limitation of current by, 125-134; *see also* Limitation of current by space charge; Three-halves-power equation  
 necessary for grid control, 177-178  
 neutralization of, by positive-ions, 147, 229-232  
 unimportant in phototube, 118  
 utilization of, in beam power tubes, 212  
 Space-charge distribution, glow-discharge, 156  
   vacuum-diode, 132  
 Space current, in tetrode, 204  
 Spacing, effect of, in gas tubes, 236  
   on sparking voltage, 153-154  
 Spark, 154  
 Sparking voltage, 152  
 Spectral sensitivity of phototubes, 114-116  
 Spectrometer, mass, 34  
 Spectrum, characteristic line, 136  
   forbidden lines in, 139  
 frequency, 488  
   for amplitude modulation, 701-704  
   for frequency modulation, 763, 766-768  
 line, 136  
   of low-pressure gaseous discharges, 137  
 mercury-vapor, 138-139  
   visible, 112  
 Speech, frequency range of, 488-489  
 Speed; *see also* Velocity  
   effect of, on mass, 4  
   of light, 4, 829, 831  
   positive-ion, relative to electron, 232  
 Spot, cathode, *see* Cathode spot  
 Sputtering, by positive ions, 148, 161, 236-237, 241  
   effect of gas pressure on, 241  
   of electrodes in arc, 161  
   of oxide-coated cathode, 241  
   of thoriated-tungsten cathode, 236-237  
 Square-law modulation, *see* Modulation, square-law  
 Square term in power series, effect of, 739-740  
 Squegging, 678  
 Stability, gain, in amplifiers, 570, 580-581

- Stability, in feedback amplifiers, 576-581  
 of oscillators, amplitude, 668-670, 672,  
 675-678, 684-685  
 frequency, 660, 680, 754
- Stability criterion, transistor, 804-805,  
 808, 810
- Stabilization of direct voltage, electronic,  
 357-359  
 by gas tube, 354-357
- Stage, driver, 619
- Stage of amplification, 487
- Stagger-tuning, 563
- Starter anode, 273
- State, of atom, excited, 136, 148  
 metastable, 137-139  
 normal, 136
- Static, 764, 767
- Static characteristics of vacuum triode,  
 187-192; *see also* Characteristic  
 curves
- Statistical methods, 68-71
- Stefan-Boltzmann law, 82, 173
- Sticking potential, 110
- Storage tubes, 103
- Stroboscope, 388
- Stroboscopic photography, 275-276
- Subcarrier, 698
- Successive approximations, method of,  
 733-734, 736-737, 743
- Sum component, in d-c amplifier, 505
- Superheterodyne, 757-761, 777
- Superposition method of feedback analy-  
 sis, 574-576
- Suppression of carrier wave, 753
- Suppressor grid, 206-207, 212-213, 714-  
 715
- Surges, in thyratron grid circuit, 265
- Sweep generator, 390
- Switching operation, transistor, 819-825
- Symbols, for electron tubes, 391-392  
 for grid current, 403-405  
 for grids, 201  
 for transistor, 788  
 for vacuum-tube circuit analysis, 391-  
 393, 441, 476-477  
 problem on, 485-486  
 for vectors, 8, 32  
 functional notation, 280, 468
- Symmetrical components in d-c ampli-  
 fier, 505
- Synchro, 378
- Synchrocyclotron, 38
- Synchronous commutator as rectifier,  
 278-280
- Synchrotron, 36, 39
- T
- Tantalum, 84, 173
- Taylor series, 198, 406; *see also* Power  
 series  
 for diode, 730-734  
 for diode and load, 732-734  
 for nonlinear functions, 198, 730-735  
 for triode, 198, 734-738  
 for triode and load, 736-738  
 utility of, 730, 734, 738
- Telegraphy, frequency range of, 488-489
- Telephone transmitter, 689
- Telephony, carrier-current, 691, 744-746,  
 753  
 frequency range of, 488-489
- Television, frequency range of, 489-490
- Temperature, brightness, 82  
 condensed-mercury, 242  
 distribution of, along filament, 170-171  
 for outgassing of glass, 172  
 of electron gas, 147  
 practical-operating, oxide-coated-  
 cathode, 94  
 thermionic-emitter, 84, 88, 90, 94  
 thoriated-tungsten, 91
- Tetrode, 7, 164, 200-206; *see also* Beam  
 power tubes  
 as mixer, 758
- gas, *see* Strobotron; Thyratron, shield  
 grid
- incremental equivalent circuit for, 407,  
 427
- in tuned amplifier, 558, 560, 562-563
- input admittance of, 428
- interelectrode capacitances in, 201-203,  
 425-427
- modulation with, 714
- negative resistance in, 205-206
- plate characteristic curves of, 202-203,  
 205
- potential distribution in, 203-204
- screen-grid, 202-206
- secondary emission in, 203
- shielding required for, 428
- space-charge-grid, 201
- transistor, 787-788
- voltage amplification with, 416, 428

- Thermal noise, 495-496  
 Thermionic emission, 75-95; *see also*  
     Oxide-coated cathode; Thoriated-tungsten cathode; Tungsten cathode  
     constants of, 77-80, 89, 93  
     current density of, 77, 78  
 Thevenin's theorem, use of, 514, 539, 589  
 Thoriated-tungsten cathode, 89-91  
     carburization of, 89-90  
     disintegration of, by positive ions, 236-237  
     limitations of, 91  
 Three-halves-power equation, derivation of, 127-132  
     for positive-ion sheath, 236, 263  
     in triodes, 187  
 Thyatron, 254, 258-271; *see also* Thyatron circuits  
     control characteristic of, 261-262, 370, 375  
     current-limiting impedances necessary with, 259, 265  
     definition of, 258  
     de-ionization time in, 266-267  
     effect of negative grid voltage in, 258, 262-265  
     grid action after firing in, 262-265  
     grid action before firing in, 260  
     grid in, 257-259, 267-269  
     grid sheath in, 262-265  
     hydrogen, 266-267  
     negative-control, 262, 268  
     phototube control of, 367, 370, 380  
     positive-control, 262, 266, 268, 270  
     shield-grid, 268-269  
     starting characteristics of, 260-262, 370, 375  
     trigger action of grid in, 258-259  
 Thyatron circuits, average current in, 368-369  
     classification of control methods in, 365  
     continuous control of, by amplitude of a.c., 377-378  
         by d.c., 367-371  
         by d.c. and a.c., 376-377  
         by phase-shift of grid voltage, 372-382  
     critical-grid-voltage curve for, 366-367  
     effect of grid current in, 371, 373, 381-382  
 Thyatron circuits, grid control in, 365-382  
     grid resistor for, 367  
     on-or-off control of, by a.c., 374  
         by d.c., 370-371  
         by phase shift of grid voltage, 374  
         phase-shift control in, 372-382  
 Time-varying circuit element, as modulator, 689, 741-742, 759  
     as rectifier, 278-280  
 Tolerance in vacuum-tube ratings, 176  
 Total differential of plate current, 195, 405  
 Townsend discharge, 149-152, 159  
 Trajectory, *see* Path of charged particle  
 Transconductance, conversion, 760-761  
     grid-plate, 194; *see also* Mutual conductance  
     negative, 216, 685, 688  
 Transfer characteristic curves, 189; *see also* Characteristic curves  
 Transformation, conformal, 183  
 Transformer, air-core, 558-563  
     effect of, in polyphase rectifiers, 304  
         in push-pull amplifier, 462-466, 468  
         in single-phase rectifiers, 284-285  
     input, 533  
     interphase, 310-312  
     interstage, 533-547  
     output, 456-458, 533-534  
         for plate modulation, 712-713  
         push-pull, 462-466  
     peaking, 375-376  
     rectifier, *see* Polyphase rectifier circuits  
     shielded, 530  
 Transformer coupling, in amplifiers, 533-547, 558-563, 578-579, 595-598  
 Transient response of compensated amplifier, 568-569  
 Transistor, *see* Transistors  
 Transistor amplifier, 803-814  
 Transistor coefficients, 798-803  
 Transistor cut-off frequency, 818  
 Transistor incremental equivalent circuits, 798-803, 808, 810  
 Transistor oscillator, 825-826 [819]  
 Transistor performance limitations, 814-  
 Transistor pulse operation, 819-825  
 Transistor switching operation, 819-825  
 Transistors, 778, 784-826  
     advantages and disadvantages of, 778  
     feedback with, 570, 576

- Transistors, frequency limitations of, 817-818  
maximum power output from, 818-819  
noise in, 498, 814-817  
power efficiency of, 818-819  
types of, 784-788
- Transit time, 14, 15, 25, 54, 56, 166, 219-220, 222, 437  
in oscillators, 667  
transistor, dispersion in, 818
- Transition, between energy levels, 136-139
- from glow to arc, 160-161  
from vacuum to gas diode, 229-232  
from vacuum triode to thyratron, 257
- Translation, frequency, by modulation, 490, 690-691, 702-703
- Trigger action of thyratron grid, 258-259
- Trigger generator, 390
- Triode, as mixer, 758  
cathode-bias for, 399  
definition of, 7, 164  
gas, 252-258; *see also* Thyratron  
vacuum, amplification factor of, 189, 193  
at ultra-high frequencies, 220, 223  
capacitance ratio in, 185, 193  
characteristic curves of, 187-192; *see also* Characteristic curves  
coefficients of, 192-198  
cut-off grid voltage in, 180  
disadvantage of, 201-202  
effect of contact potential difference in, 186  
electric field in, 178-180  
figure of merit for, 450  
grid current in, *see* Grid current  
linear approximations for, 198-200, 406  
maximum power output from, 456  
mutual conductance of, 194  
plate resistance of, 194  
potential distribution in, 178, 183  
potential minimum in, 180  
ratings of, 174-176  
reflex coefficients for, 196  
space charge in, 176-178  
Taylor series for, 734-738
- Tripler, frequency, 622
- Tubes, band-igniter, 252  
battery-charging, 241  
beam power, 212-215  
Tubes, capacitron, 251-252  
cathode-ray, 19-25, 35-36  
characteristic curves of, *see* Characteristic curves  
cold-cathode, 164, 271-276  
composite, 467-474  
corona discharge, 273, 354  
counting, 275  
critical-distance, 212  
diode, *see* Diode  
disc-seal, 221  
electrometer, 191-192  
electron-beam, classification of, 20  
electron-multiplier, 44-48, 103, 119-121  
electronic-computer, 217, 275  
exciton, 250-251  
frequency-converter, 218-219, 759-761  
frequency-modulation, 217  
gas, *see also* Gas tubes  
amplifier, 259  
gated-beam, 214-217  
glow-discharge, 354  
high-vacuum, *see* Vacuum tubes  
ignitron, 251-252, 365  
inductive-output, 224  
Kenotron, 165  
Klystron, 221-225  
lighthouse, 221  
mercury-arc, *see* Mercury-arc rectifiers  
microwave, 221  
pentode, *see* Pentode  
Permatron, 271  
plasmatron, 259  
radar, 210  
reactance, 764-765  
Rectigon, 241  
remote-cut-off, 212  
secondary-emission, 217-218  
sharp-cut-off, 212  
stepping-relay, 275  
storage, 103  
Strobotron, 275-276  
supercontrol, 212  
telephone ringing, 275  
television, 19, 25, 210  
tetrode, *see* Tetrode  
thyratron, *see* Thyratron  
traveling-wave, 225-226  
trigger, 217-218  
triode, *see* Triode  
Tungar, 241  
ultra-high-frequency, 219-226

- Tubes, vacuum, *see* Vacuum tubes  
 variable- $\mu$ , 212  
 velocity modulated, 221-225  
 voltage-reference, 359  
 voltage-regulator, 272-273, 354-359  
 Tuned circuits, 547-553  
 Class B and C amplifiers require, 619-620  
 coupled, 644-652  
 flywheel effect of, 638-640, 677  
 half-power frequencies in, 552  
 in oscillators,  $Q$  of, 674-675, 677-678  
 $L/C$  ratio in, 558, 648  
 losses in, 547-550  
 representation of, 547-550, 556  
 sluggishness of, 677-678  
 stored energy in, 638-640, 677  
 Tungar, 241  
 Tungsten cathode, 79, 84-89  
 emission constants for, 79, 85-88  
 life of, 84, 85, 88
- U
- Unipolar field-effect transistor, 788  
 Units, numerical computations with, 17-19  
 rationalization of, 17, 830  
 tables of, 830-831  
 Uranium, 62  
 Utilization factor, 310, 316
- V
- Vacuum, test for, in vacuum tubes, 254  
 Vacuum measurement, ionization gage for, 256-257  
 Vacuum tubes, 6, 164-228; *see also* Diode; Pentode; Tetrode; Triode  
 applications of, classified, 390  
 at very high frequencies, 219-226  
 coefficients for, 192-198  
 effect of gas pressure on grid current in, 252-258  
 figure of merit for, 192, 450, 525  
 gas pressure in, 135, 145, 232, 252-258  
 grid control in, 176-187  
 mean free path in, 145  
 multi-electrode, 218-219  
 multiplication of voltage in, 218  
 mutual conductance of, 194
- W
- Vacuum tubes, permeance of, 134, 181  
 plate resistance of, 194  
 rating of, 172-176  
 Vacuum-type rectifier, 283-284; *see also* Single-phase rectifier circuits  
 Valence electrons, 779  
 Valve, 277, 640; *see also* Gas tubes; Tubes; Vacuum tubes  
 Vector cross products, 32  
 Vectors, representation of, 8, 32; *see also* Complex numbers  
 Velocity, angular, of electron, 37  
 charged particle, measurement of, 43-44  
 drift, in a metal, 62, 66  
 in plasma, 235-236  
 initial emission, 14, 169, 180, 186, 255-256  
 random, of electrons in a metal, 66  
 Velocity distribution, in plasma, 236  
 of emitted electrons, 255-256  
 Velocity-modulated electron beam, 221-225  
 Video frequencies, 489-490  
 Visible spectrum, 112  
 Visibility curve, 113  
 Volt, electron, 17-19, 829  
 Volt-ampere characteristic, *see* Characteristic curves  
 Voltage, anode, *see* Anode voltage  
 control, 621, 667  
 grid, *see* Grid voltage  
 inverse, *see* Inverse-peak voltage  
 plate, *see* Plate voltage  
 reference direction for, 391-393, 395, 476  
 Voltage equivalent of work function, 73, 79  
 Voltage feedback, 571-573; *see also* Feedback  
 Voltage-multiplying connections of single-phase rectifiers, 334-337  
 Voltmeter, peak-indicating, 329  
 peak-to-peak indicating, 336  
 rectifier-type, 314  
 Volume expander, 219
- W
- Wave, definition of, 689  
 modulating, 689

Wave nature of electron, 5, 77, 101-102	X
Wavelength, threshold, 111, 114	
White noise, 497	x-associated kinetic energy of an elec-
Wien bridge, 682	tron. 71-72
Work function, 73-75	X-rays, contribution of, to grid current,
definition of, 73	254
effect of field on, 96-99	Xenon, 139, 232, 829
of oxide-coated cathodes, 93	use of, in gas tubes, 243, 270
photoelectric, 113-114	
variation of, 80	Z
voltage equivalent of, 73, 79	Zero-drift, 502

