

Index

- 1D magnetic field, 29, 49, 100
- 2D magnetic field, 29
- 3D magnetic field, 30
- 3D space, 30, 101, 130, 135, 138, 154, 156

- absolute positioning device, 11
- AC motor, 1
- acrylic, 16
- actuator design, 21, 30, 69, 70
- actuator torque, 31, 37, 42, 47, 50, 52, 56, 61, 62, 66, 67, 69, 70, 75, 77, 81, 107, 115, 116, 118, 119, 126, 130, 153
- air bearing, 95, 96
- air slot, 31
- air source, 95
- air space, 32
- air-core coil, 17, 18, 37, 49, 50, 58, 70, 93
- alloys, 89
- aluminum, 31, 88, 89, 93
- American Wire Gauge (AWG), 90
- Ampere's circuital law, 40
- angular acceleration, 47, 157
- angular diameter, 73
- angular displacement, 47, 157
- angular velocity, 47, 157
- armature, 10, 11
- arrangement patterns, 56
- associated Legendre function, 35
- asynchronous motor, 2
- attraction force, 30, 119
- automated apparatus, 21, 130, 154, 156

- B-H curve, 32,
 see also hysteresis loop
- backlash, 2
- barcode, 21
- bearing, 5, 8, 11, 14, 133

- boundary condition, 19, 30, 35–42, 45, 153
- boundary surface, 40, 48
- brushless motor, 48
- brushless PM machine, 29

- cable-driven spherical actuator, 5
- calibration, 106
- Cartesian coordinate, 44, 54, 59
- Cartesian vector, 56
- centering pins, 93
- ceramics, 6
- characteristic roots, 63
- charge-coupled device (CCD), 11
- clockwise, 31
- closed contour, 40
- coarse-fine-manipulation, 9
- coenergy method, 48, 49
- coercivity, 32
- coil frame(s), 83, 86, 91, 93
- coil geometry(ies), 83, 86
- commutator, 1
- compass, 31
- complex conjugate, 36, 37
- computer simulation, 47
- computing efficiency, 61
- concentricity, 93
- condition number(s), 63, 66
- conductivity, 89
- conical coil, 84, 85, 91
- conjugate transpose, 63
- control vector, 66
- cooling system, 91
- copper, 88
- corrosion resistant, 89
- cosine function, 61
- cross product, 21, 49, 52
- cross section, 86

- current density, 51, 86
- current input, 19, 21, 123
- current input vector, 66
- current-carrying conductor, 21, 49, 51, 100

- data acquisition (DAQ), 103, 106
- data processing, 22, 146
- DC motor, 1
- deflection, 115
- Delrin, 93, 95, 157
- demagnetization curve, 32
- deposit, 10, 11
- differential element, 54
- differential force, 21, 51
- differential length segment, 21, 52
- differential torque, 21, 52, 153
- differential winding segment, 52
- dihedral cone, 31
- dimensionless parameter, 110
- displacement element, 49
- displacement sensor, 106
- divergence, 34
- double 2D methodology, 30
- double-sided linear induction motor (DLIM), 48
- dynamic performance, 32, 76

- earth magnetic field, 31
- eccentricity, 106
- eddy current, 69, 93–95, 157
- eigenvalues, 63
- electric circuit, 49
- electric current(s), 1, 11, 57, 86
- electric motor, 1
- electric wire, 91
- electrical energy, 18
- electrolytic processing, 11
- electromagnetic actuator(s), 10, 11, 18, 47
- electromagnetic excitation, 18
- electromagnetic products, 48
- electromagnetic spherical actuator, 18, 100
- electromagnetism, 1, 7
- electrostatic forces, 1
- encoder, 9, 11, 133, 154
- endoscope, 17
- energy formation, 49
- equatorial plane, 58, 103
- Euler angle, 59
- excitation loss, 18
- exponential term, 38
- Extended Homotopy, 137

- far field, 38
- ferromagnetic material, 7, 32, 48, 78, 100

- field excitation, 18
- finite boundary condition, 41
- finite element (FE), 48
- finite-element analysis (FEA), 30
- fixture, 103, 106, 124
- fluid mechanics, 108
- flux density, 19, 21, 29, 30, 32, 37, 38, 41, 43, 45, 50, 73, 76, 77, 81, 100
- flux density continuity, 36
- flux density measurement, 94, 100–102
- force generating elements, 96
- force/torque sensor, 116, 154
- forward dynamics, 47
- free space, 32
- friction, 13, 133
- frictional torque, 69, 95, 96
- fringing flux, 100
- full rank, 62, 63
- fundamental term, 37

- galvanic corrosion, 89
- Gauss meter, 101–103
- geometric parameter, 19
- gimbal, 11
- global frame, 136, 137
- good condition, 63
- gradient, 19, 33, 45, 153

- Halbach array, 17
- Hall effect sensor, 21, 93, 134, 155
- Hall probe, 100–103, 106, 107, 154, 156
- harmonic term, 43, 112
- heat dissipation, 88, 94
- heat resistance grade, 91
- Helmholtz's theorem, 33
- hexahedron, 16
- horizontal direction, 115
- hydrodynamic lubrication system, 107
- hydrostatic bearing, 13
- hysteresis loop, 32, *see also* B-H curve

- ill-conditioned, 63
- induction motor, 2
- inductor(s), 10, 11
- inertia moment, 8, 21, 31, 32, 76, 78, 79, 133, 134, 149
- inertial force, 108
- inertial moment, 155, 156
- insulation layer, 91
- integration, 52–54, 56
- integration range, 54
- inverse dynamics, 47, 157
- inverse electromagnetics, 62, 65, 66, 154

- iron gallium alloy, 17
- irrotational field, 33
- isolation, 90

- laminated ferromagnetic material, 95
- laminated metal, 93, 95
- Laplace's equation, 19, 29, 30, 33–35, 45, 153, 155
- Laplacian operator, 34
- latitudinal angle, 31, 70, 73, 76, 103
- law of conservation, 38
- line integral, 40, 52
- linear motion, 1
- linear PM synchronous machine, 29
- linear step motor, 14
- linear torque model, 18
- local frame, 136, 137
- longitudinal angle, 31, 70, 73, 75, 103
- Lorentz force law, 19, 29, 42, 43, 48–51, 66, 153, 155
- low friction coating, 95

- magnet saddle, 13
- magnetic actuator, 48
- magnetic characteristics, 32
- magnetic charge, 29
- magnetic circuit, 49
- magnetic energy, 30, 48–50, 157
- magnetic energy loss, 32, 95
- magnetic field expression, 19, 22, 153, 155
- magnetic field intensity, 32, 33, 40
- magnetic flux loop, 48
- magnetic force(s), 50
- magnetic intensity, 19, 40
- magnetic thrust, 48
- magnetically levitated, 9
- magnetization direction, 31
- magnetomotive force, 17, 49
- manifold, 112
- matrix, 56, 62, 63
- matrix multiplication, 58
- Maxwell equation, 29, 34
- Maxwell stress tensor (MST), 48
- measurement coordinates, 103
- micro actuator, 17
- micro motor, 115
- miniature spherical motor, 17
- minimum right-inverse solution, 62, 65, 66, 154
- misalignment, 107
- moment arm, 21, 52, 96
- motion control, 19, 21, 61, 67, 69, 93, 123, 153, 155, 156
- motion resolution, 7, 18, 102, 139, 155

- neural network, 14
- non-linear torque model, 67
- non-singular orientation, 62
- non-square matrices, 63
- nondimensionalization, 21, 107, 108, 110, 130, 156
- nonsingularity, 62, 66
- nonzero eigenvalues, 63
- nonzero vector, 63
- normalization, 21, 107, 108, 110, 156

- octahedron, 16
- open-loop (OL), 9, 11
- operating principle, 11, 135, 149, 156
- operating temperature, 91, 102
- optical sensor, 21, 93, 133, 134, 155
- optimization, 65
- orientation dependant, 66, 155, 156
- orientation measurement, 9, 133, 134, 138, 139, 149, 153–156
- orthogonal direction, 18
- orthonormal function, 39
- output power per volume, 18
- oxide film, 89

- packing density, 88
- packing pattern, 86, 87
- pan-tilt mechanism, 11
- parallel mechanism, 6
- parametrization, 96
- pendulum, 115
- permeability, 32, 78, 157
- piezoelectric (PZT) elements, 6
- piezoelectric effect, 1
- piezoelectricity, 5
- planar motor, 29
- planer step motor, 16
- PM generator, 29
- Poisson's equation, 34, 153
- polar coordinate, 29
- polarization pattern, 30, 31
- pole arrangement, 29, 31
- polygon, 15
- position and velocity control, 29, 67
- positive definite matrix, 66
- positive weightings, 66
- potential energy, 13
- power consumption, 7, 65, 66, 81, 83, 154, 157
- power supply, 116
- precision, 3, 102, 144
- principle of superposition, 115, 123, 153, 154
- principle of triangulation, 134
- prototype, 69, 99
- prototype development, 69, 77, 88

- PZT material, 6
- quadratic function, 67
- quasi-Poissonian, 29
- rank, 62
- rare-earth magnet, 31, 32
- rare-earth material, 12, 18, 30, 32, 79
- rare-earth PMs, 13, 18
- reaction force, 51
- real-time motion control, 48, 153
- recoil permeability, 32
- regular pattern, 86
- relative permeability, 32, 48, 78
- relative recoil permeability, 32
- reliability, 89
- reluctance, 48, 49
- reluctance torque, 115
- remanence, 33
- repeatability, 12
- repulsion force, 30, 119
- research prototype, 21, 22, 69, 70
- residual magnetization, 36
- residual magnetization vector, 33–37, 45, 153
- resistance, 49, 66
- response time, 11
- resultant force, 119
- reverse piezoelectric effect, 6
- Reynolds number, 108
- robust control, 14
- rolling friction, 95
- rolling motion, 95
- rotation matrix, 58
- rotational motion, 96
- rotor core radius, 31, 70, 73, 77
- rotor equator, 30, 70, 119
- rotor frame, 52, 56–59, 61, 116, 123
- rotor orientation, 50, 52, 58, 59, 62, 63, 66, 70, 93, 115, 116, 126, 154, 155
- rotor radius, 31, 70, 73
- round wire, 88
- sampling point, 103, 106
- sawtooth current, 17
- scalar potential, 19, 30, 32–37, 45, 130, 153, 155
- self-inducing torque, 31
- self-shielding effect, 17
- separation of variables method, 35
- servo control, 47, 153
- servo motor, 101, 106, 107, 138, 139, 148
- single-axis motor(s), 5, 6, 101, 115, 145, 148
- single-sided linear induction motor (SLIM), 48
- singular matrix, 63
- singular values, 63
- singularity, 2, 62, 65, 154
- singularity points, 63
- sliding friction, 95
- slope, 32
- soft iron, 32, 34, 48, 100, 157
- solenoidal magnetic field, 34
- source-free field, 34
- speed ripple, 14
- spherical bearing, 70, 78, 95, 96
- spherical boundary, 38
- spherical coordinate, 29, 31, 33, 35, 51, 52, 54, 107
- spherical DC servo motor, 11
- spherical harmonic expansion, 35, 37, 45, 153
- spherical harmonic function, 35–37, *see also* spherical harmonics
- spherical harmonics, 35, 37, 39, *see also* spherical harmonic function
- spherical induction motor, 7, 8, 29, 48
- spherical motion, 7, 31
- spherical motion mechanism, 4, 6, 100
- spherical pointing motor (SPM), 11
- spherical step motor, 15, 16
- spherical surface, 31, 50
- spherical wheel motor (SWM), 9
- square matrix(ices), 62, 63
- square roots, 63
- square wire, 88
- stacking density, 86, 87
- stacking pattern, 21, 86
- stator equator, 93
- stator frame, 58, 70
- stator shell, 93
- step motor, 8, 13, 14
- stepped coil, 91, 93
- stiffness, 13
- straight coil, 91, 93
- supporting mechanism, 95
- surface coating, 13
- surface current, 40
- surface integral, 36
- suspension, 115
- switched reluctance motors (SRM), 49
- synchronous machine, 29, *see also* synchronous motor
- synchronous motor, 2, *see also* synchronous machine
- system control, 30
- system efficiency, 95
- theoretical analysis, 21
- theoretical models, 19, 21, 22, 96
- tilting motion, 96

- torque computation, 86
- torque generating elements, 96
- torque integral, 53
- torque matrix, 58, 59, 61–63, 66, 70
- torque ripple, 17
- transfer bearing(s), 95
- translational stage, 101–103
- trapezoid coil, 91, 93
- triangular vertex, 15
- trigonometric functions, 61, 62

- ultrasonic actuator, 6, 7, 115,
 see also ultrasonic motor
- ultrasonic motor, 7,
 see also ultrasonic actuator
- ultrasonic spherical actuator, 6
- unit vector(s), 33, 51, 52, 54, 59, 61

- variable reluctance spherical motor (VRSM),
 8, 49, 66, 67, 95, 115, 133
- vector, 56, 59
- vector potential, 29
- viscous force, 108
- voltage operation, 18

- weight, 107
- winding blocks, 7
- winding techniques, 96
- winding turns, 91
- wire turns, 91
- working efficiency, 69, 149
- working principle, 6, 18, 22, 133
- working range, 18, 155
- workspace, 10, 19, 21, 58, 62, 63, 65, 66, 100,
 115, 116, 130, 154