

Index

a

absorbed photons 69–72, 76, 143, 144
 accelerator vacuum chambers 175, 265
 amount of ideal gas 217
 effective pumping speed 227
 gas close volume 216–218
 gas density and pressure 216–217
 gas density evolution, equations for 422–425
 gas dynamics modelling 265
 gas flow rate 217, 218, 220
 materials for
 aluminium alloys 83–84
 ceramics 85–86
 copper and copper alloys 84–85
 elastomer 87
 glass 82, 85–87
 stainless steel 82–83
 titanium and titanium alloys 85
 molar and molecular mass, of common gases 219
 NEG coating to 188
 operating requirements 81–82
 pumping characteristics 221–222
 purpose of 81
 surface treatments
 air bake 106
 bakeout method 105–106
 cleaning procedure 102–105
 surface coatings 108–109
 vacuum firing 106–107
 thermal outgassing 87–101
 total and partial pressure 218
 vacuum conductance
 of long tubes 224–225

 in molecular flow regime 223
 orifice 224
 series and parallel connection of tubes 226
 of short tubes 225–226
 vacuum system with pump 223
 velocity of gas molecules 218–219
 accelerator vacuum system design 25, 62, 142, 215, 246, 265
 activated charcoal 281, 324, 333–336, 338, 340–343
 adsorption equilibrium 88–90
 adsorption isotherm 89–91, 270, 272, 273, 275, 276, 279, 282–284, 286, 324, 331, 332, 334, 335, 337
 alumina 83, 85, 86, 96, 375
 aluminium based absorbers 338–340
 amorphous carbon coating 337–338, 369
 angular flux 32, 34, 50
 antechambers 18–20, 69, 153–155, 175, 176, 181, 186, 187, 208, 227, 230, 232, 233, 240, 251, 252, 357, 359, 361, 363, 365, 408, 445

b

beam chamber size lower limit 17
 beam chamber size upper limit 17
 beam conditioning 131, 149, 205, 208, 371, 380, 384, 403
 beam–gas interaction
 background noise in detectors 8
 beam particle loss 8
 Bremsstrahlung radiation 10
 lifetime 8

- beam–gas interaction (*contd.*)
 - particle accelerators associated with 8
 - radiation damage of instruments 10–11
 - residual gas ionisation 9
 - risk to personnel safety 11
 - sensitive surface, contamination of 9–10
 - beam-induced electron multipacting (BIEM)
 - effects on vacuum 376
 - electron cloud build-up, in LHC beam pipe 350
 - electron sources 356
 - negative impacts 350
 - observation in CERN Large Hadron Collider (LHC) 380, 381
 - observation tools 386
 - synchrotrons 408, 409
 - vacuum chamber wall properties 382–386
 - vacuum pressure 381–382
 - vacuum stability 405–408
 - beam-induced pressure instability 471
 - beam lattice 14–15, 19, 25
 - beam scrubbing 131, 140, 151, 481, 489, 496, 497
 - beam vacuum system design
 - beam lattice 14–15
 - check list for 14
 - data extrapolations 23
 - distributed pumping layout 19–20
 - experimental data interpretation 23
 - experimental errors 23
 - gas dynamics model 24
 - limiting factors 17–18
 - lumped pumping layout 19
 - magnet design 17
 - mechanical engineering 17
 - number and size of pumps 20
 - required mechanical aperture 15–16
 - sources of residual gas 20
 - thermal outgassing 20
 - total outgassing rate 20, 21
 - vacuum chamber cross sections 18–19
 - vacuum modelling and design considerations 21, 22
 - Boyle–Mariotte law 217
 - Bremsstrahlung radiation 8, 10, 11, 208, 279, 357
 - Brunauer, Emmett, Teller (BET)
 - equation 275, 276
 - isotherm 90, 275, 276
 - bunched-beam heavy ion accelerators 472, 473
 - dynamic vacuum processes of 473
- C**
- carbon based adsorbers 333–337
 - carbon fibre material 334, 335
 - charged particle accelerators 1, 2, 7, 29, 269
 - chemisorption 273, 274
 - Clausius–Clapeyron law 93, 286, 288
 - COLDEX
 - beam screen calorimetric system 396
 - BS with saw-tooth, PSD of 326–328
 - Cu beam screen, PSD for 324
 - experimental facility 321–324
 - secondary PSD yields 325–326
 - temperature oscillations 329–331
 - vacuum transient effect 328
 - conductance-limited pumping 228, 242, 475, 478
 - copper based absorbers 340–341
 - critical current 421, 433
 - beam–gas ionisation cross sections 465
 - for cryogenic vacuum chamber 426–427
 - for infinity long vacuum chamber 427–428
 - ion impact energy 465
 - ion-stimulated desorption yields 465–466
 - pumping speed 466
 - for short vacuum chamber 431–434
 - total error in 466

- cryogenic vacuum chambers
 adsorption isotherms 273–279
 cryosorbers 331–341
 cryotrapping 279–281
 desorbed gas, temperature of
 318–321
 equilibrium pressure 273
 hydrogen gas 276
 operating temperature, selection of
 286–289
 photon induced molecular cracking,
 of cryosorbed gas 312–318
 photon-stimulated desorption
 process
 discovery of secondary 301–306
 experimental facility for 301
 initial considerations 300
 primary PSD yields 308–310
 PSD yields calculation 306–308
 secondary PSD yields 310–312
 physisorption 281–282
 pressure and gas density 269–272
 synchrotron radiation 289
 infinitely long vacuum chamber
 291–294
 short vacuum chamber 294–300
 types 290
 cryosorbers for beam screen
 aluminium based 338–340
 amorphous carbon coating 337–338
 carbon
 activated charcoal 333–334
 carbon fibre material 334, 335
 considerations 341
 copper 340–341
 criteria for 333
 distributed 342
 laser ablation surface engineering
 341
 cryosorption 273, 298, 331, 338, 341,
 343
 cryotrapping 279–281
- d**
- Dalton law 218
 desorption yield measurements
 481–482
- Diamond Light Source (DLS) 11, 24,
 232, 258–259
 differential pumping, vacuum system
 with 265, 266
 DR equation 276
 DRK equation 276, 278, 284
 dynamic pressure and beam lifetime
 calculations 476–479
 dynamic vacuum instabilities,
 mitigation of 504–505
- e**
- effective pumping speed 88, 98,
 109–111, 156, 226–228, 251,
 258–260, 296, 301, 328, 407, 425,
 426, 476, 482, 486, 487
 elastic recoil detection analysis (ERDA)
 195, 483
 electron cloud (E-cloud)
 build-up in LHC beam pipe 350
 electron sources 356
 models 351–356
 observation in CERN Large Hadron
 Collider 379
 observation tools 386–390
 problem 349
 synchrotrons 408, 409
 vacuum chamber wall properties
 382–386
 vacuum effects 376
 vacuum pressure 381–382
 electron energy estimation 376
 electron stimulated desorption (ESD)
 bakeout effect 122–123
 copper surface preparation 125
 definition 109, 110
 for different materials as function of
 dose 112–113
 estimation 378
 as function of amount of desorbed gas
 113–114
 as function of electron energy
 119–122
 measurements 109–111
 vs photon stimulated desorption
 144
 pumping duration effect 114–119

- electron stimulated desorption (ESD) (*contd.*)
- surface polishing 123–125
 - surface treatment 125
 - vacuum chamber temperature 125–128, 142
 - vacuum firing 125
- electronic stopping 495, 499, 500
- equivalent free path, of gas molecules 220
- f**
- fast ion instability 9, 14
- forward scattering photon reflectivity 64, 66, 71
- Freundlich equation 274, 276–278
- g**
- Ga–As photocathode lifetime 9
- gas close volume 216–218
- gas dynamics model
- cryogenic vacuum chambers under SR 289–300
 - infinitely long vacuum chamber 291–294
 - short vacuum chamber 294–300
 - of vacuum system 24–25
- gas flow rate 215, 217, 218, 220–223, 231–233, 241, 246, 248, 249, 252, 255
- gas injection, into tubular vacuum chamber 241
- getters 108, 109, 176, 177, 179, 188, 193, 195, 230, 466, 472, 475, 492, 493, 505
- Glidcop® 85, 112
- grazing incidence 63, 64, 66, 142, 143, 308, 472, 474, 478, 487, 489–491, 493–496, 504
- h**
- He and H₂ isotherms on Cu plated stainless steel 278
- heavy ion-induced desorption 480
- angle dependence 495–496
 - CERN set-up 486, 487
 - cleaning methods 493–494
 - conditioning methods 496–497
 - copper 491–492
 - cryogenic targets 488–489, 497–499
 - desorption yield measurements 481–482
 - energy loss scaling 494–495
 - experimental results 489–499
 - GSI set-up 486–488
 - high-melting materials 492
 - IMP set-up 489
 - inelastic thermal spike model 500–504
 - ions interaction with matter 499–500
 - materials analysis 483–485
 - noble getter surface coatings 493
 - noble metal surface coatings 492–493
 - stainless steel materials 490
 - TiZrV-coated sample tubes 491
 - TSL set-up 488
- Henry's law 273, 274
- He pressure wave measurements 280
- H₂ isotherms on bare surface 283
- H₂ isotherms on Cu plated stainless steel 276–278, 283, 285, 286
- H₂ isotherms on electro-polished stainless steel 286
- H₂ isotherms on stainless steel 285
- H₂ isotherms, temperature dependence of 283
- hydrogen adsorption isotherms 270, 272, 286, 331, 332
- i**
- ideal volumetric pumping speed 222
- impingement rates 221, 248, 260–263
- incident electron flux estimation 376–377
- inelastic thermal spike model 500–504
- infinitely long vacuum chambers 425
- critical current 444–445
 - gas density
 - critical current 426, 427
 - cryogenic vacuum chamber 426–427
 - quasi-static case 427

- room temperature vacuum chamber 425–426
 - stability criteria 428
 - vacuum chamber with beam screen 426
 - vacuum chamber with pumping slots 425
 - vacuum chamber without beam screen 426
 - vacuum chamber without pumping slots 425
 - ion stimulated desorption on gas density 441–443
 - synchrotron radiation 291
 - with holes in beam screen 292–294
 - without beam screen 292
 - two-gas system 443
 - insulating materials 364, 374–376
 - intersecting storage ring (ISR) vacuum system, 471
 - ion desorption stability 421, 465
 - ion energy in vacuum chamber
 - dipole magnetic field 461
 - quadrupole magnetic field 461–462
 - solenoid magnetic field 462–464
 - without magnetic field
 - circular beams 455–458
 - flat beams 458–460
 - ion-induced desorption 421, 423–426, 428, 441, 449, 453–455, 472–474, 480–504
 - ion induced pressure instability
 - infinitely long vacuum chamber 425–428
 - multi-gas system 437–438
 - short vacuum chamber 428–437
 - two-gas system 438–440
 - VASCO code 447–455
 - ion stimulated desorption (ISD) 155
 - bakeout effect and argon discharge cleaning 161
 - for condensed gases 163
 - for different materials 160
 - vs. electron stimulated desorption 161
 - function of ion dose 156–158
 - function of ion energy 158
 - function of ion mass 159–160
 - function of temperature 161–163
 - on gas density
 - infinitely long vacuum chambers 441
 - single gas estimation 446
 - two gases system 443, 446
 - vacuum chambers with given pumping speed 441–442
 - ion trapping instability 9, 14
- k**
- Knudsen number 220
 - Kovar[®] 86
- l**
- Langmuir isotherm 89, 90, 274, 276
 - Large Hadron Collider (LHC)
 - BIEM and E-cloud observations 379–405
 - cryogenic vacuum system 401–405
 - laser ablation surface engineering (LASE) 341, 360
 - Lorentz equation 32
- m**
- M-branch 488
 - metallisation brazing 85
 - molecular beaming effect
 - GaAs photocathode electron gun 262–264
 - heavy ion stimulated induced desorption 264
 - Molflow+ 58, 59, 245, 246
 - Monte Carlo methods 2, 154, 190, 245
- n**
- non-evaporable getter (NEG) coated vacuum chambers 20, 176
 - ASTeC activation procedure 185
 - beam path 187
 - CERN–BINP activation procedure 183–184
 - manufacturing cost 176
 - nature of getter materials 176
 - NEG coatings 177–179

- non-evaporable getter (NEG) coated vacuum chambers (*contd.*)
 - operation conditions 176
 - synchrotron radiation 196–199
 - ultimate pressures in 195–196
 - use of 208–209
 - non-evaporable getter (NEG) coatings
 - activation temperature 178
 - activation procedure 182–188
 - benefits 207–208
 - classification of sorption pumps 177
 - cylindrical magnetron deposition
 - configuration 180
 - electron stimulated desorption yield 204
 - film characterisation 181–182
 - gas diffusion barrier 178
 - high pumping speed 178
 - lifetime 193–195
 - at low temperature 207
 - magnetron sputtering 179
 - planar magnetron deposition 179, 180
 - primary and secondary electron yields 204–206
 - pumping optimisation at ASTeC 190
 - pumping optimisation at CERN 188
 - pure metal alloy 178
 - reducing particle/electron stimulated desorption from 200
 - sticking probabilities 200
 - surface resistance 206–207
 - Ti–Zr–V films 189, 190
 - vacuum chamber cross sections 186, 187
 - non-evaporable getter (NEG) pumps 177
- O**
- one-dimensional gas diffusion model 228
 - accelerator vacuum chamber section 231–232
 - advantage 231
 - closed loop boundary conditions 233, 235, 237
 - continuous flow fluid dynamics 229
 - gas balance 229
 - gas injection, into tubular vacuum chamber 241
 - global and local coordinates 238–240
 - molecular beaming effect 259–264
 - open end boundary conditions 233, 237
 - and TPMC model 257, 258
 - uncertainties 240
 - vacuum chambers
 - with known pressures 244–245
 - with known pumping speeds at the ends 241–244
 - OrAnge SYNchrotron Suite (OASYS) 56
 - OSCARS 59
 - oxide dispersion strengthened (ODS) copper 85
 - oxygen-free high conductivity copper 84, 491, 492
- P**
- particle accelerators
 - associated with beam gas-interaction
 - background noise detectors 8
 - beam particle loss 8
 - Bremsstrahlung radiation 10
 - radiation damage of instruments 10–11
 - residual gas ionisation 9
 - risk to personnel safety 11
 - sensitive surface, contamination of 9–10
 - synchrotron radiation 29
 - vacuum design objectives 12
 - vacuum specifications 6–13
 - photoelectron energy distribution curves
 - of Cu co-laminated on stainless steel 74
 - of gold 72, 73
 - modification 75
 - photoelectron production
 - incidence angle effect 76

- photon energy effect 72–75
 - total photoelectron yield 69–72
 - photon induced molecular cracking, of
 - cryosorbed gas 312–318
 - photon reflectivity 61, 64
 - copper mirror 62, 63
 - diffuse and forward scattered reflectivity 64
 - experimental set-up 64, 65
 - flat and sawtooth copper surface 67, 68
 - flat LHC copper surface 69
 - photon stimulated desorption (PSD) 128
 - bakeout effect 137–140
 - critical photon energy 136–137
 - for different materials 131–134
 - vs. electron stimulated desorption 144
 - as function of amount of desorbed gas 135
 - as function of photon dose 131
 - gauge method 129
 - incident angle effect 142–144
 - in-depth studies of 321
 - measurements 129, 130
 - vacuum chamber temperature 141
 - yield data use
 - distributed and lump SR absorbers 153–155
 - lump SR absorber 151–153
 - scaling the photon dose 145
 - SR photon flux 148–151
 - synchrotron radiation from dipole magnets 145–148
 - physisorption 273
 - vs. condensation 273
 - cryotrapping 279–281
 - on gas condensates 281–282
 - pressure instabilities, in heavy ion accelerators 472, 480
 - angle dependence 495–496
 - CERN set-up 486, 487
 - cleaning methods 493–494
 - closed system (vessel) 476–478
 - conditioning methods 496–497
 - copper 491–492
 - cryogenic targets 488, 497
 - desorption yield measurements 481–482
 - dynamic pressure and beam lifetime calculations 476–479
 - energy loss-scaling 494–495
 - experimental results 489–499
 - getter surface coatings 492–493
 - GSI set-up 486–488
 - heavy ion-induced desorption 480
 - high-melting materials 492
 - IMP set-up 489
 - inelastic thermal spike model 500–504
 - ion-optical simulation 478
 - ions interaction with matter 499–500
 - longitudinal vacuum profile 478–479
 - materials analysis 483–485
 - noble metal surface coatings 492–493
 - stainless steel materials 490–491
 - TiZrV-coated sample tubes 491
 - TSL set-up 488
 - pressure rise method 481
- r**
- radiated energy and power density 31–32
 - Redhead's equation 101
 - residual gas, in vacuum chambers 79–81
 - ring accelerator, stable operation of 479
 - Rutherford back scattering (RBS) spectrometry 483
- s**
- secondary electron emission
 - incidence angle 374
 - insulating materials 374–376
 - re-diffused electrons 371–374
 - reflected electrons 371–374
 - surface material effect 368–369
 - surface roughness effect 369–371
 - surface treatment effect 367

- secondary electron emission (*contd.*)
 - true secondary electrons 371–374
 - secondary electron yield (SEY)
 - as function of incident electron energy 367
 - incidence angle 374
 - insulating materials 374
 - measurement method 365–367
 - re-diffused electrons 371–374
 - reflected electrons 371–374
 - surface material effect 368–369
 - surface roughness effect 369–371
 - surface treatment effect 367
 - true secondary electrons 371–374
 - short vacuum chambers 428
 - with gas density at the ends 428–431
 - with pumping speed at the ends 431–434
 - synchrotron radiation 294
 - given pressure at the ends 296–298
 - given pumping speed at ends 298–300
 - two-gas system 439, 440
 - without beam screens 434–437
 - spectra 56–59, 73, 74, 100, 101, 388, 389, 437, 492
 - sputter ion pump (SIP) 18, 20, 175, 177, 230, 466
 - sputtering 74, 179, 481, 492, 497, 500
 - sticking coefficient 222, 475
 - sticking probability of sorbing surface 221, 273, 325, 399
 - storage rings, good vacuum in 8
 - StrahlSim code 478, 479
 - superconducting magnets 11, 17, 269, 279, 282, 300, 320, 321, 331, 390, 472
 - synchrotron radiation (SR) 128
 - angular flux 32
 - charged particle emission, in magnetic field 29–32
 - from dipoles
 - emission duration and critical energy 33–34
 - photon flux 34–37
 - photon power 39–41
 - from insertion devices 43–55
 - angular aperture 51–52
 - K*-factor 47
 - method for estimation absorbed power 54–55
 - motion of charged particles 43–45
 - power collected by simple geometry aperture 54
 - power distribution in wiggler 52–54
 - resonant wavelength 45–46
 - undulator mode 46–51
 - wiggler mode 46–51
 - from quadrupoles 42–43
 - radiated energy and power density 31–32
 - synchrotron radiation-vacuum chamber wall interaction 61
 - photoelectron production 69–76
 - photon reflectivity 61–69
 - Synchrotron Radiation Workshop (SRW) 56
 - SYNRAD+ 58–59, 246
- t**
- test particle Monte-Carlo (TPMC)
 - method 245
 - code input 246–248
 - code output
 - gas density and pressure 250
 - gas flow rate 248–249
 - mass of molecules 251
 - pump effective capture coefficient 251
 - temperature effect 251
 - transmission probability 250–251
 - vacuum conductance 250–251
 - input parameters, defined set of 252–253
 - molecular beaming effect 259–264
 - one-dimensional gas diffusion model 257–264
 - result accuracy 256–257
 - vacuum chamber in 246

- with variable parameters 253–256
 - virtual pumping surfaces 252
 - thermal desorption 22, 87, 93, 94, 100, 101, 112, 130, 156, 175, 185, 230, 252, 253, 289, 308, 337–339, 376, 407, 423, 424, 447, 449, 473–475, 480, 502
 - thermal outgassing 87
 - equilibrium pressure 89–91
 - measurement methods
 - conductance modulation method 98
 - gas accumulation method 99–100
 - thermal desorption spectroscopy 100–101
 - throughput method 97–98
 - two-path method 98–99
 - during pumping 88
 - rate of materials 93–97
 - vapour pressure 91–93
 - thermal transpiration effect 270–272
 - titanium sublimation pump (TSP) 20, 177, 466
 - total beam lifetime 8
 - transmitted photons 144
 - turbo-molecular pumps (TMP) 20, 83, 186, 265–267, 270, 323, 466
- U**
- ultra-high vacuum/extreme high vacuum (UHV/XHV) vacuum system design 175
- V**
- vacuum
 - definition 5
 - ranges/degrees of 5
 - vacuum chamber design
 - active methods 363–365
 - active *vs.* passive mitigation methods 365
 - chamber wall properties 382
 - DAΦNE dipole 364
 - with given pumping speed 441, 442
 - insulating materials 374–376
 - KEK 359
 - observations with beams 394–401
 - passive mitigation methods 357
 - pressure variation 381
 - surface properties at cryogenic temperature 391–394
 - wiggler 359
 - vacuum conductance
 - of long tubes 224, 225
 - in molecular flow regime 223
 - orifice 224
 - series and parallel connection of tubes 226
 - of short tubes 225, 226
 - Vacuum Plumber's Formulas 223
 - vacuum specifications 11–12
 - for particle accelerators 6–13
 - vacuum system designer 6, 13, 95
 - VASCO code
 - basic equation 447–448
 - cylindrical geometry 447
 - finite elements 447–448
 - multi-gas model
 - in matrix form 448–451
 - vs.* single gas model 452–455
 - second order linear differential equation, transformation of 450–451
 - set of equations 451–452
 - time invariant parameters 447
- X**
- Xe adsorption isotherms 331
 - xenon adsorption isotherm 332
 - X-ray Oriented Programs (XOP) 56

