

## Index

### **a**

acceptance angle 63, 85, 127, 358, 373, 375  
 additive color mixing 183, 188, 394  
 advanced driving beam 377  
 albedo 171, 221, 254  
 angular dependent magnification 53  
 angular extent 34, 49, 93, 94, 96, 103, 161, 224, 233  
 angular luminance meter 120  
 ANSI lumen 199, 291, 292  
 aperture 42, 62, 65, 74, 95, 105, 107, 335, 347, 352, 353, 375, 384  
 aperture stop 61  
 AR coating 133, 173  
 architectural lighting 179, 267  
 asphere 44, 56, 78, 302  
 astigmatism 370  
 asymptote 49  
 asymptotes 79  
 atmosphere 165, 166, 171  
 automotive 27, 140, 319, 324, 372, 375, 377

### **b**

backlight 156, 182  
 backward ray tracing 261  
 backward raytracing 284  
 ball lenses 44  
 basic radiance 126  
 beam parameter product 99, 311  
 bike light 318  
 bilirubin 181  
 black body 160  
 blackbody 160, 172–174, 192, 204  
 blue LED 178  
 branches 78  
 brightness 369  
 brilliant-mix 207  
 butterfly diagram 73

### **c**

camera 158, 286, 289, 291  
 camera sensor 286, 291  
 candle power 365  
 CEC *see* compound elliptical concentrator  
 center beam candle power 128  
 center equation 67, 79  
 CHC *see* compound hyperbolic concentrator 84  
 chief ray 103  
 chlorophyll 169, 273  
 CIE standard illuminant 196  
 cinema lamp 365, 376  
 cladding 32, 354  
 coating 45, 133, 225  
 CoB LED 65, 116, 117, 248, 334  
 coefficient of thermal expansion 8  
 coherence 8, 45, 123, 369  
 coherent scattering 8  
 collimation 40, 42, 51, 58, 63, 80, 112 117–119, 136, 338, 384  
 collimation strength 136  
 color coordinates 186  
 color distance 189  
 color matching functions 185  
 color mixing 202  
 color space 183  
 color weight 187, 203, 208  
 colorimetry 183  
 coma 68  
 coma ray 103  
 compound elliptical concentrator 74  
 compound hyperbolic concentrator 80  
 compound parabolic concentrator 62, 259  
 concentration ratio 258  
 concentrator 62, 74, 164, 172, 173  
*concentrator* 53, 80  
 condenser 62, 282, 293, 334, 335, 384

configuration factor 109–313  
 conic section 52, 53, 57, 66  
 conic term 56  
 conservation law 33, 63, 98, 125, 132, 134, 164, 321  
 conversion efficacy 177  
 conversion efficiency 201  
 correlated color temperature 191  
 $\cos^4$  law 158–238  
 $\cos^n$  beam 137–325  
 cosine correction 284  
 cover glass 36, 112, 115  
 CPC *see* compound parabolic concentrator  
 critical angle 6  
 CTE *see* coefficient of thermal expansion

## **d**

daylight 259, 263  
 deflection 37  
 defocus 45, 153, 335  
 density 6  
 desk lighting 243, 259  
 diagonal ray 103  
 diaphragm 384  
 differential projected solid angle element 21  
 differential solid angle 20  
 diffraction 49, 147, 256  
 diffuser 48, 135, 171, 190, 243, 259, 280  
 digital micromirror device 199  
 dilution 322, 323, 353, 362, 364  
 directrix 53, 66, 69  
 dispersion 8  
 displacement 35  
 display 156, 189, 199, 292, 314, 377  
 distortion 5, 345–347  
 DMD *see* digital micromirror device 377  
 dome 125, 230, 264, 323  
 dominant wavelength 179, 202  
 double slit 122  
 downlight 136, 247  
 dynamic range 288

## **e**

eccentricity 53, 57, 67, 68, 70, 72, 79, 81, 339  
 effective luminance 125  
 efficacy 175, 196, 200, 207, 219, 225, 233, 268, 270, 365, 381  
 efficiency 24, 77, 98, 106, 115, 174, 177, 182, 201, 225, 233, 247, 269, 281, 287, 292, 299, 313, 320, 336, 347, 357, 366, 372, 377, 384  
 electrodeless lamp 280  
 electromagnetic disturbance 8  
 ellipse 27, 53, 54, 66, 70, 76, 191  
 ellipsoid 69, 70, 76  
 ellipsoidal 299  
 elliptical mirror chamber 74  
 elliptical reflector 72  
 emission 125, 134, 149, 172, 223  
 emissivity 172  
 endoscope 33, 113, 349  
 energy of a photon 268  
 entrance pupil 45, 97, 101

entropy 126  
 etendue 94, 254, 302, 318  
 etendue measurement 115  
 etendue quantum 99  
 evanescent 30  
 evil boss 258, 294, 298, 313, 315, 317, 359  
 exit pupil 74, 116, 281, 292  
 exitance 124, 137, 150, 154, 161, 171, 219, 227, 241, 252, 275, 283, 358, 360, 368, 379  
 extraction efficiency 135  
 eye 157, 158, 170, 175, 180, 183, 221  
 eye box 377, 380  
 eye pupil 157

## **f**

number 41, 97, 221, 254, 287, 314, 372  
 facet 65, 224, 301  
 Fermat's principle 113  
 fiber 354, 358  
 fiber coupling 354  
 filament 224, 280, 301, 338, 339, 363, 376  
 filament temperature 225, 338, 376  
 first law 126  
 flying spot 311  
 focal ratio 67  
 Fresnel fixture 305, 307, 308  
 Fresnel lens 304, 314, 343, 345  
 Fresnel light *see* Fresnel fixture  
 Fresnel reflection 30, 37, 133, 228

## **g**

gamut 189, 199, 200  
 Gaussian beam 48  
 Gaussian distribution 46–351  
 gel filter 363  
 glare 247, 250, 251, 260, 372  
 gobo projector 298  
 goniometer 143  
 gradient index 9  
 GRIN 9, *see* gradient index  
 growlight 181, 269, 272

## **h**

halogen lamp 225, 303, 338  
 HBO lamp 72  
 HCR *see* high concentration region  
 head up display 377  
 headlamp 45, 318, 319, 324, 372, 377  
 high concentration region 80  
 high-pressure sodium 268  
 horticulture 269  
 Hottel's formula 103  
 HPS *see* high pressure sodium  
 HUD *see* head up display  
 hyperbola 49, 53, 78–80

## **i**

illuminance 125  
 immersion 115, 230, 323  
 incandescent lamp 160, 200, 219, 225, 364, 372, 376

infrared 194, 225, 271, 273, 376  
 integrating sphere 276  
 integrator 62, 65, 96, 275, 341  
 intensity 47  
 inverse square law 140, 306, 319  
 IODC problem 104  
 irradiance 125

**j**

just noticeable color difference 191

**k**

köhler design 346

**l**

Lagrange invariant 97, 103  
 Lambertian emitter 115, 129, 132, 136  
 Lambertian source 130  
 LARP 342, 357, 377  
 laser 45, 48, 99, 127, 280, 311, 368  
 laser beam scanning 311  
 latitude 92  
 law of Malus and Dupin 132  
 LCR *see* low concentration region  
 LDC 73  
 LED collimation 40  
 LED growlight 273  
 lens maker equation 39  
 LES *see* light emitting surface  
 light distribution curve 73, 136, 308  
 light emitting surface 226  
 light guide 30, 32, 109, 112  
     115–354  
 light pipe 297  
 light recipes 268  
 light tube 66, 74, 78, 81, 101, 108,  
     113, 149, 151, 163, 221, 237, 253, 316,  
     352, 379  
 liquid crystal display 199  
 longitude 93  
 Lorenz-Lorentz equation 8  
 low concentration region 80  
 luminance 106, 120, 124, 127, 129,  
     130, 137, 149, 151, 155, 157, 209, 220, 226,  
     237, 248, 250, 256, 261, 264, 274, 279, 287,  
     292, 293, 299, 318, 321, 322, 353, 378  
 luminance diagram 293, 321  
 luminance meter 130  
 luminance of a ray 127  
 luminescent concentrators 164  
 luminosity 255  
 luminous efficacy 177, 221  
 luminous efficacy of a source 176  
 luminous efficacy of radiation 162,  
     165, 273  
 luminous exitance 227  
 Luminous flux 175

**m**

mad inventor 45, 123, 163, 278, 294  
 magnification 60, 68  
 marginal ray 103, 113

McCree curve 269  
 melanopic 180  
 melanopic sensitivity 180  
 melanopsin 180  
 melatonin 180  
 mercury lamp 72  
 microlens array 380  
 microscope 36  
 mirage 5  
 mobile phone 283  
 moon 220, 221, 253, 314, 319  
 moonlight 170  
 MR16 224, 340

**n**

neonatal jaundice 181  
*Newton's imaging equation* 40  
 numerical eccentricity 53, 67, 68, 79

**o**

obliquity factor 20  
 off axis parabola 59  
 office lighting 243  
 OLED 314  
 opposition surge 171  
 optical design 1  
 optical efficiency 281  
 optimization 43, 193, 197, 293  
 output gain conversion 287  
 overcast sky 170  
 overfill 106, 310, 377

**p**

PAR *see* photosynthetically active radiation  
 PAR efficacy 273  
 parabola 52, 57, 62, 221, 336, 339,  
     363, 365  
 parabolic reflector 221–222  
*paraxial approximation* 17  
*paraxial ray tracing equation* 38  
 PFAS 33  
 phase delay 8  
 phase space diagram 103  
 phase space transformation 98  
 phosphor 45, 117, 177, 193, 201, 207, 223,  
     232, 322, 342, 357, 371  
 Photobiologic effects 181  
 photometer 274  
 photon energy 287  
 photopic 180  
 photosynthesis 269  
 photosynthetic photon flux 269  
 photosynthetically active radiation 269  
 phototherapy 180  
 pinhole 232  
 pixelated headlight 377  
 Planck 123  
 plane parallel plate 34  
 polar form 61, 85  
 polarization 295  
 PPF *see* photosynthetic photon flux  
 prescribed illuminance 354  
 primaries 184, 189, 199

projected solid angle 131  
 projection lens 104  
 projection microdisplays 373  
 projector 104, 189, 291, 292, 294, 299, 310, 311, 313, 315  
 pupil 103, 110, 141, 158, 221, 299, 310, 334, 346

**r**

radiance 124, 126, 160, 163, 167, 178, 258, 270, 280, 371  
 radiance enhancer 164  
 radiant exitance 163  
 radiation temperature 174  
 radiator 162  
 ray 91  
 raydata 45, 193, 246, 357, 361, 371  
 Rayleigh length 49, 51  
 receptors 183  
 rectangular beam 311  
 recycling 229, 294, 323  
 reflectance measurement 280  
 reflector size 224  
 refractive index 6, 8  
 relative illuminance 158  
 remote phosphor 201  
 retina 157  
 reverse ray tracing 261  
 ring light 241

**s**

saturation equivalent exposure 288  
 saturation level 288  
 scattering 8, 106, 127, 135, 219, 228, 259, 276, 284, 323, 379  
 scotopic 180  
 screen 91, 98, 124, 129, 226, 228, 231  
 screen gain 379  
 second law of thermodynamics 164  
 semilatus rectum 67, 79  
 sensitivity 287  
 Sirius 257  
 sky luminance 170  
 slope error 36  
 software 1  
 solar cell tester 337  
 solar collection 252  
 Solar simulator 336  
 solar spectrum 166  
 solid angle 19  
 Source Four 299, 304  
 source imaging 117  
 spatial coherence 123

special rays 101  
 spectral luminance 166, 167  
 spectral radiance 160, 166, 167  
 spectral radiant flux 175  
 spectral weight 179  
 spherical aberration 35, 45  
 spherical excess 25  
 spotlight 334, 381  
 stage lighting 20, 297, 299, 308  
 Stefan-Boltzmann law 161  
 steradian 19  
 stigmatic 67  
 stray light 42, 262, 282  
 sulfur lamp 280  
 sun 164, 252, 271, 340  
 suns 342  
 supergauss 352  
 surface slope deviation 36

**t**

tapered cone 120  
 telecentric 96, 119  
 telescope 252  
 temperature 6, 8, 160, 164, 165, 172, 192, 225  
 thermal expansion 8  
 thin film LEDs 228  
 thin lens 40  
 TIR *see* total internal reflection  
 total included angle 139  
 total internal reflection 6, 31, 229  
 transformation parameter 51  
 Trolands 157  
 trougher 339  
 trumpet 80, 83  
 tunable white 204

**u**

UGR *see* unified glare rating  
 unified glare rating 250  
 upper limit of collection 127

**v**

V number 99  
 $V(\lambda)$  175  
 vertex equation 54

**w**

waist 48, 49  
 wall plug efficiency 176  
 warm white 206  
 well capacity 288  
 Wien's displacement law 169  
 WPE *see* wall plug efficiency