

Index

acoustic, analogy, 143 sphere, 14, 30 turbulent eddy, 149 energy density, 32 compact Green's function, preliminary far field, 37 intensity, 31, 34, 107 definition, 63, 66 particle velocity, 6, 9 circular aperture, 90, 129 circular cylinder, 72, 85 power, 34 wavenumber, 12 circular disc, 90 added mass, piston, 115 cylindrical bodies, 70 definition for Helmholtz equation, 75 sphere, 81 tensor, 80, 177, 193 definition for wave equation, 76 advanced potential, 48 deletion of trailing edge singularity, 180, compact Green's function, 129 184, 189 derivation of Kirchhoff's formula, 57 disc at air-water interface, 266 airfoil, 180 et seq. duct open end, 88 duct with neck, 87 general form, 84 baffle, 105 half-plane, 87 baffle-plate aperture, 218 incompressible limit, 102 bias flow, 131 rigid strip, 72, 85 energy equation, 135 sphere, 68, 85 perforated screen, 136 surface irregularity, 84 Biot-Savart formula, 160 symmetric, 74 blade-vortex interaction, 181, 188 synthetic jet device, 239 bursting balloon, 21, 35 two dimensional, 91 Babinet's principle, 119 compressive stress, 150 Batchelor, 65, 79, 80, 131, 147, 157, complex potential, definition, 94 circular cylinder, 94 Bernoulli's equation, 102, 194 for strip, 73 uniform flow, 94 Cauchy's problem, 21 vortex, 95 Cauchy-Riemann equations, 94 complex velocity, 94 causality, 14 conductivity, defined, 126 clover leaf quadrupole pattern, 40 annular aperture in a duct, 220 combustion, 27 annular aperture, 211, 284 compact, acoustically, 13 aperture in a duct, 214 aperture, 124



292 Index

circular aperture, 127, 205 complex, 135 duct of variable diameter, 232 duct with flanged exit, 228 duct with small axisymmetric opening, 225 duct with small flanged exit, 228, 246 Rayleigh's approximation, 205 conformal transformation, 96 half-plane, 96 of sources and vortices, 96 continuity equation, 2 linearised, 7 contraction ratio, 131, 135 control surface, 49	energy, compressional, 32 density, 32 equation for aperture flow, 128 equation, 3 flux, 32, 34, 169 for aperture flow in a duct, 233 for synthetic jet device, 241 internal, 5 kinetic, 32 power, 34 enthalpy, definition, 5 perfect gas, 6 entropy, 4 equation of state, 4
Crighton, 173	•
Crocco's equation, 5, 138, 158, 164 Cummings, 135 Cummings-Fant equation, 134 synthetic jet, 241 with mean flow, 234 Curle, 150 Curle's equation, 152 differential form, 151	far field, 31, 37 Fraunhofer, 38, 119, 254 Fresnel transition region, 42, 119, 120 hydrodynamic, 160 Ffowcs Williams, 147 Ffowcs Williams-Hawkings equation, 154 flame holder, 220
differential form, 131	fluid particle, 2
D141 1 0	Fock, 214
D'Alembert, 9 damping by vorticity production, 135, 139 at circular and annular duct apertures, 235 linearised approximation, 135, 140, 234 perforated screen, 136, 140	Fock's problem, 214 solved by Rayleigh's method, 216 force, for body in translational motion, 193 in potential flow, 194 in terms of added mass, 80 in terms of vorticity, 178, 192
decibel, 6	Fourier transform, 58
descent, Hadamard's method, 20 diffraction, Kirchhoff theory, 116 aperture, 119 disc, 120 edge, 121 diffraction radiation, 256 disc, vibrating, 104 drag coefficient, 196	Fraunhofer far field, 38, 119, 254 dipole source, 38 quadrupole source, 40 Fresnel zone, 42, 109, 119 aperture, 119 baffled piston, 110 disc, 120
	generalised function, 17
efficiency, pulsating sphere, 269 surface dipole, 153 synthetic jet, 244 turbulence sound source, 149 vibrating sphere, 35, 269 eighth power law, 149	Green's function, see also compact Green's function definition, 19 for hard wall, 54 for pressure-release surface, 54, 265 free space, 19
end correction, 223	in one dimension, 20
circular duct exit, 224, 247 duct with flanged exit, 228 duct with small axisymmetric opening, 225 duct with small flanged exit, 228, 246, 281	in two dimensions, 21 time-domain, 19, 59 time-harmonic, 59 gust, 179, 187
	0,,



Index 293

Hadamard, 20	material derivative, 2
harmonic echoes, 83	momentum equation, 3
Heaviside function, definition, 20	Crocco's form, 5
in surface/volume integrals, 48	linearised, 7
Helmholtz, equation, 59	Reynolds form, 144
resonator, 142, 242	momentum, density, 150, 212
homentropic motion, 5	flux tensor, 144
approximation, 7	monopole, 25
Howe, 190	multipole expansion, 41
Huygens' principle, 116, 117	
	Navier-Stokes equation, 3
ideal fluid, definition, 7	near field, 31
in two dimensions, 93	hydrodynamic, 31
impedance, 61	no-slip condition, 157, 180
impulse, vortex, 161	Noble, 124
impulsive pressure, 212	
incompressible fluid, 14	Ohm's law, 126
intensity, 31, 34, 107	orifice plate, 232
•	outgoing wave, 16, 18
Kelvin, circulation theorem, 155, 197	
definition of vorticity, 155	piston, baffled, 105
minimum energy theorem, 157, 205	in uniform tube, 10
theorem for impulsive motion, 213	surface force, 113
kinetic energy, acoustic, 32	time-harmonic vibrations, 106
incompressible and irrotational, 126, 156	plane wave, 9
Kelvin's theorem, 157, 205, 213	point source, 16
Kirchhoff, vector, 66	impulsive, 18
spinning vortex 198, 272	Poisson, 22, 121
Kirchhoff diffraction theory, 116	potential flow interaction, 184,
aperture, 119	191
disc, 120	Powell, 167
edge, 121	power, acoustic, 34
Kirchhoff formula, 50	pressure, impulsive, 212
applied to vibrating body, 51	in terms of potential, 8
for velocity potential, 55	thermodynamic, 5
generalised, 52, 58	•
in frequency domain, 60	quadrupole, 28
Kutta condition, 185	Lighthill's, 146
see also singularities	
2	radiation condition, 14
Laplace equation, 13	rate of strain tensor, 4, 139, 144
axisymmetric, 67	Rayleigh, 61, 81, 83, 115, 205, 228,
cylindrically symmetric, 71	282
two dimensions, 93	Rayleigh's integral, 106
Lighthill, 17	reciprocal theorem, 62, 64, 74
Lighthill's, acoustic analogy, 145	reduced frequency, 182
equation, 146	reflection, from closed end, 10
v^{8} -law, 146	open end, 10
stress tensor, 145	resonance frequency, open ended tube,
theory reformulated in terms of vorticity,	11
165	retarded, potential, 20
loudspeaker, 104	time, 15



294 Index

D 11 2 144	1 . 4 . 1 . 1 . 6 . 2
Reynolds, equation, 144	total enthalpy, definition, 6
number, 153	as acoustic variable, 164
stress, 146, 147	homentropic flow, 164
Runge-Kutta integration, 100, 243	relation to pressure, 165, 167 relation to velocity potential, 165
scattering, Rayleigh, 81	turbulence, source of sound, 143, 145
sphere, 83	eddy, 148
Sears, 180, 185	near compact body, 152
Sears function, 185	gust, 179
self potential, vortex, 97	
singularities, deleting from Green's function,	uniqueness, outgoing wave solution, 56
180, 182, 184, 189	uniqueness, outgoing wave solution, 50
slug length, 126	vibrating compact body, 51, 77, 81, 154
annular aperture, 211, 284	disc, 104
annular aperture in a duct, 220	sphere, 30, 78, 81
aperture in a duct, 214, 281	viscosity, bulk, 3
circular aperture, 127, 205	kinematic, 3
relation to kinetic energy, 205	shear, 3
source, dipole, 27	values for air and water, 4
impulsive, 18	velocity potential, 8
monopole, 25	volume, flux, 15
quadrupole, 28	point source, 16
volume, 7	source, 7
speed of sound, 6, 8	velocity, 15
nonlinear, 10	vortex, complex potential, 95
perfect gas, 9	equation of motion, 97
values in air and water, 9	impulse, 161
sphere, compact, 14, 68	*
modelled by point source, 17	motion near half-plane, 98, 173
near dipole source, 68	pair motion towards a plane, 261 ring, 199, 201
pulsating, 13	sheet, 131
radiated power, 34	
vibrating, 30, 78	spinning pair, 167
stationary phase, method, 112,	surface interaction noise, 170, 181, 186, 188
169, 275	tube, 157
Stokesian fluid, 3	
stream function, 94, 175	vortex shedding, 179, 181
equation, 226	influence on sound generation, 179
stress, compressive, 150	vortex line, 157 interaction with blade, 181, 188
Lighthill's, 145	
Reynolds, 146–148	molecular diffusion, 159
viscous, 144	stretching and rotation, 159
Strouhal number, 133, 136	vortex sound, at high Reynolds
synthetic jet, 237	number, 173
characteristic equation, 242	equation, 166
1	from compact body, 176
toot function 17, 272, 276	general solution, 172
test function, 17, 272, 276	linearised, 187
thermodynamic pressure, 5	produced by blade-vortex interaction,
time-harmonic, Green's function, 59	181, 188
wave equation, 59	produced by vortex near an edge, 173 two-dimensions 178
uannie cuec, sineulant, 100	two-unicusions, 1/8



Index 295

vorticity, definition, 3
damping of sound, 139
equation, 158
frozen, 179, 187
generated by sound, 131
measure of angular velocity, 157
molecular diffusion, 159
quasi-static approximation, 133
sound source, 164
stretching and rotation, 159

wave equation, ideal fluid, 7 inhomogeneous, 8 initial value problem, 21 of classical acoustics, 8 of linear acoustics, 144 one dimensional, 9, 14 solution in free space, 29 vortex-sound, 166 wavenumber, acoustic, 12