

Table of Contents

ALGEBRA OF VECTORS AND TENSORS	1
VECTOR MULTIPLICATION	1
<i>Definition of Dyadic Product</i>	2
DECOMPOSITION INTO SCALAR COMPONENTS	3
SCALAR FIELDS.....	3
GRADIENT OF A SCALAR.....	4
<i>Geometric Meaning of the Gradient</i>	6
<i>Applications of Gradient</i>	7
CURVILINEAR COORDINATES	7
<i>Cylindrical Coordinates</i>	7
DIFFERENTIATION OF VECTORS W.R.T. SCALARS	9
VECTOR FIELDS.....	11
<i>Fluid Velocity as a Vector Field</i>	11
PARTIAL & MATERIAL DERIVATIVES	12
CALCULUS OF VECTOR FIELDS	14
GRADIENT OF A SCALAR (EXPLICIT).....	14
DIVERGENCE, CURL, AND GRADIENT	16
<i>Physical Interpretation of Divergence</i>	16
<i>Calculation of $\nabla \cdot \mathbf{v}$ in R.C.C.S.</i>	16
<i>Evaluation of $\nabla \times \mathbf{v}$ and $\nabla \mathbf{v}$ in R.C.C.S.</i>	18
<i>Evaluation of $\nabla \cdot \mathbf{v}$, $\nabla \times \mathbf{v}$ and $\nabla \mathbf{v}$ in Curvilinear Coordinates</i>	19
<i>Physical Interpretation of Curl</i>	20
VECTOR FIELD THEORY.....	22
DIVERGENCE THEOREM.....	23
<i>Corollaries of the Divergence Theorem</i>	24
<i>The Continuity Equation</i>	24
<i>Reynolds Transport Theorem</i>	26
STOKES THEOREM	27
<i>Velocity Circulation: Physical Meaning</i>	28
DERIVABLE FROM A SCALAR POTENTIAL.....	29
THEOREM III	31
TRANSPOSE OF A TENSOR, IDENTITY TENSOR	31
DIVERGENCE OF A TENSOR.....	32
INTRODUCTION TO CONTINUUM MECHANICS*	34
CONTINUUM HYPOTHESIS.....	34
CLASSIFICATION OF FORCES	36
HYDROSTATIC EQUILIBRIUM.....	37
FLOW OF IDEAL FLUIDS	37
EULER'S EQUATION.....	38
KELVIN'S THEOREM	41
IRROTATIONAL FLOW OF AN INCOMPRESSIBLE FLUID.....	42
<i>Potential Flow Around a Sphere</i>	44
<i>d'Alembert's Paradox</i>	50

STREAM FUNCTION.....	52
TWO-D FLOWS.....	53
AXISYMMETRIC FLOW (CYLINDRICAL)	55
AXISYMMETRIC FLOW (SPHERICAL)	55
ORTHOGONALITY OF ψ =CONST AND ϕ =CONST	56
STREAMLINES, PATHLINES AND STREAKLINES.....	56
PHYSICAL MEANING OF STREAMFUNCTION	57
INCOMPRESSIBLE FLUIDS.....	59
VISCOUS FLUIDS.....	61
TENSORIAL NATURE OF SURFACE FORCES.....	61
GENERALIZATION OF EULER'S EQUATION	65
MOMENTUM FLUX.....	67
RESPONSE OF ELASTIC SOLIDS TO UNIAXIAL STRESS.....	69
RESPONSE OF ELASTIC SOLIDS TO PURE SHEAR	71
GENERALIZED HOOKE'S LAW	72
RESPONSE OF A VISCOUS FLUID TO PURE SHEAR.....	74
GENERALIZED NEWTON'S LAW OF VISCOSITY	75
NAVIER-STOKES EQUATION	76
BOUNDARY CONDITIONS	77
EXACT SOLUTIONS OF N-S EQUATIONS	79
PROBLEMS WITH ZERO INERTIA	79
<i>Flow in Long Straight Conduit of Uniform Cross Section.....</i>	<i>80</i>
<i>Flow of Thin Film Down Inclined Plane</i>	<i>83</i>
PROBLEMS WITH NON-ZERO INERTIA	88
<i>Rotating Disk*.....</i>	<i>88</i>
CREEPING FLOW APPROXIMATION	90
CONE-AND-PLATE VISCOMETER.....	90
CREEPING FLOW AROUND A SPHERE ($Re \rightarrow 0$)	95
<i>Scaling.....</i>	<i>95</i>
<i>Velocity Profile.....</i>	<i>98</i>
<i>Displacement of Distant Streamlines.....</i>	<i>100</i>
<i>Pressure Profile</i>	<i>101</i>
CORRECTING FOR INERTIAL TERMS.....	104
FLOW AROUND CYLINDER AS $Re \rightarrow 0$	107
BOUNDARY-LAYER APPROXIMATION.....	108
FLOW AROUND CYLINDER AS $Re \rightarrow \infty$	108
MATHEMATICAL NATURE OF BOUNDARY LAYERS.....	109
MATCHED-ASYMPTOTIC EXPANSIONS.....	113
MAE'S APPLIED TO 2-D FLOW AROUND CYLINDER.....	118
<i>Outer Expansion.....</i>	<i>119</i>
<i>Inner Expansion.....</i>	<i>120</i>
<i>Boundary Layer Thickness</i>	<i>123</i>
PRANDTL'S B.L. EQUATIONS FOR 2-D FLOWS	125
ALTERNATE METHOD: PRANDTL'S SCALING THEORY.....	126
SOLUTION FOR A FLAT PLATE.....	132
<i>Time Out: Flow Next to Suddenly Accelerated Plate.....</i>	<i>134</i>
<i>Time In: Boundary Layer on Flat Plate.....</i>	<i>135</i>
<i>Boundary-Layer Thickness.....</i>	<i>136</i>
<i>Drag on Plate.....</i>	<i>139</i>

SOLUTION FOR A SYMMETRIC CYLINDER.....	140
<i>Boundary-Layer Separation</i>	143
<i>Drag Coefficient and Behavior in the Wake of the Cylinder</i>	144
THE LUBRICATION APPROXIMATION	146
TRANSLATION OF A CYLINDER ALONG A PLATE.....	153
CAVITATION.....	155
SQUEEZING FLOW	156
REYNOLDS EQUATION.....	160
TURBULENCE	164
GENERAL NATURE OF TURBULENCE.....	164
TURBULENT FLOW IN PIPES	165
TIME-SMOOTHING	167
TIME-SMOOTHING OF CONTINUITY EQUATION	167
TIME-SMOOTHING OF THE NAVIER-STOKES EQUATION	168
ANALYSIS OF TURBULENT FLOW IN PIPES.....	169
PRANDTL'S MIXING LENGTH THEORY.....	171
PRANDTL'S "UNIVERSAL" VELOCITY PROFILE.....	175
PRANDTL'S UNIVERSAL LAW OF FRICTION.....	178
ELECTROHYDRODYNAMICS.....	180
ORIGIN OF CHARGE	180
GOUY-CHAPMAN MODEL OF DOUBLE LAYER.....	181
ELECTROSTATIC BODY FORCES	184
ELECTROKINETIC PHENOMENA	185
SMOLUCHOWSKI'S ANALYSIS (CA. 1918).....	186
ELECTRO-OSMOSIS IN CYLINDRICAL PORES	190
ELECTROPHORESIS	190
STREAMING POTENTIAL.....	191
SURFACE TENSION	193
MOLECULAR ORIGIN.....	193
BOUNDARY CONDITIONS FOR FLUID FLOW	195
INDEX.....	198