

## Problems Listed by Subject Areas

**Table I-1** Problems in Basic Principles and Calculations

NO.	PROBLEMS IN BASIC PRINCIPLES AND CALCULATIONS	PAGE
2.1	MOLAR VOLUME AND COMPRESSIBILITY FACTOR FROM VAN DER WAALS EQUATION	15
2.2	MOLAR VOLUME AND COMPRESSIBILITY FACTOR FROM REDLICH-KWONG EQUATION	19
2.3	STOICHIOMETRIC CALCULATIONS FOR BIOLOGICAL REACTIONS	20
2.4	STEADY-STATE MATERIAL BALANCES ON A SEPARATION TRAIN	23
2.5	FITTING POLYNOMIALS AND CORRELATION EQUATIONS TO VAPOR PRESSURE DATA	25
2.6	VAPOR PRESSURE CORRELATIONS FOR SULFUR COMPOUNDS IN PETROLEUM	33
2.7	MEAN HEAT CAPACITY OF n-PROPANE	34
2.8	VAPOR PRESSURE CORRELATION BY CLAPEYRON AND ANTOINE EQUATIONS	36
2.9	GAS VOLUME CALCULATIONS USING VARIOUS EQUATIONS OF STATE	38
2.10	BUBBLE POINT CALCULATION FOR AN IDEAL BINARY MIXTURE	41
2.11	DEW POINT CALCULATION FOR AN IDEAL BINARY MIXTURE	44
2.12	BUBBLE POINT AND DEW POINT FOR AN IDEAL MULTICOMPONENT MIXTURE	45
2.13	ADIABATIC FLAME TEMPERATURE IN COMBUSTION	46
2.14	UNSTEADY-STATE MIXING IN A TANK	49
2.15	UNSTEADY-STATE MIXING IN A SERIES OF TANKS	52
2.16	HEAT EXCHANGE IN A SERIES OF TANKS	53
4.1	EXCEL—MOLAR VOLUME AND COMPRESSIBILITY FROM REDLICH-KWONG EQUATION	101
5.1	MATLAB—MOLAR VOLUME AND COMPRESSIBILITY FROM REDLICH-KWONG EQUATION	153

**Table I-2** Problems in Thermodynamics

NO.	PROBLEMS IN THERMODYNAMICS	PAGE
2.1	MOLAR VOLUME AND COMPRESSIBILITY FACTOR FROM VAN DER WAALS EQUATION	15
2.2	MOLAR VOLUME AND COMPRESSIBILITY FACTOR FROM REDLICH-KWONG EQUATION	19
2.5	FITTING POLYNOMIALS AND CORRELATION EQUATIONS TO VAPOR PRESSURE DATA	25
2.6	VAPOR PRESSURE CORRELATIONS FOR SULFUR COMPOUNDS IN PETROLEUM	33
2.7	MEAN HEAT CAPACITY OF n-PROPANE	34
2.8	VAPOR PRESSURE CORRELATION BY CLAPEYRON AND ANTOINE EQUATIONS	36
2.9	GAS VOLUME CALCULATIONS USING VARIOUS EQUATIONS OF STATE	38
2.10	BUBBLE POINT CALCULATION FOR AN IDEAL BINARY MIXTURE	41
2.11	DEW POINT CALCULATION FOR AN IDEAL BINARY MIXTURE	44
2.12	BUBBLE POINT AND DEW POINT FOR AN IDEAL MULTICOMPONENT MIXTURE	45
2.13	ADIABATIC FLAME TEMPERATURE IN COMBUSTION	46
3.1	ESTIMATION OF ANTOINE EQUATION PARAMETERS USING NONLINEAR REGRESSION	57
3.2	ANTOINE EQUATION PARAMETERS FOR VARIOUS HYDROCARBONS	61
3.3	CORRELATION OF THERMODYNAMIC AND PHYSICAL PROPERTIES OF n-PROPANE	62
3.4	TEMPERATURE DEPENDENCY OF SELECTED PROPERTIES	72
3.8	CORRELATION OF BINARY ACTIVITY COEFFICIENTS USING MARGULES EQUATIONS	81
3.9	MARGULES EQUATIONS FOR BINARY SYSTEMS CONTAINING TRICHLOROETHANE	86
3.14	CALCULATION OF ANTOINE EQUATION PARAMETERS USING LINEAR REGRESSION	95
4.1	EXCEL—MOLAR VOLUME AND COMPRESSIBILITY FROM REDLICH-KWONG EQUATION	101
4.4	EXCEL—CORRELATION OF THE PHYSICAL PROPERTIES OF ETHANE	128
4.5	EXCEL—COMPLEX CHEMICAL EQUILIBRIUM BY GIBBS ENERGY MINIMIZATION	144

NO.	PROBLEMS IN THERMODYNAMICS	PAGE
5.1	MATLAB—MOLAR VOLUME AND COMPRESSIBILITY FROM REDLICH-KWONG EQUATION	153
5.4	MATLAB—CORRELATION OF THE PHYSICAL PROPERTIES OF ETHANE	182
5.5	MATLAB—COMPLEX CHEMICAL EQUILIBRIUM BY GIBBS ENERGY MINIMIZATION	195
6.6	EXPEDITING THE SOLUTION OF SYSTEMS OF NONLINEAR ALGEBRAIC EQUATIONS	223
7.1	COMPRESSIBILITY FACTOR VARIATION FROM VAN DER WAALS EQUATION	243
7.2	COMPRESSIBILITY FACTOR VARIATION FROM VARIOUS EQUATIONS OF STATE	248
7.3	ISOTHERMAL COMPRESSION OF GAS USING REDLICH-KWONG EQUATION OF STATE	251
7.4	THERMODYNAMIC PROPERTIES OF STEAM FROM REDLICH-KWONG EQUATION	255
7.5	ENTHALPY AND ENTROPY DEPARTURE USING THE REDLICH-KWONG EQUATION	258
7.6	FUGACITY COEFFICIENTS OF PURE FLUIDS FROM VARIOUS EQUATIONS OF STATE	263
7.7	FUGACITY COEFFICIENTS FOR AMMONIA—EXPERIMENTAL AND PREDICTED	265
7.8	FLASH EVAPORATION OF AN IDEAL MULTICOMPONENT MIXTURE	267
7.9	FLASH EVAPORATION OF VARIOUS HYDROCARBON MIXTURES	271
7.10	CORRELATION OF ACTIVITY COEFFICIENTS WITH THE VAN LAAR EQUATIONS	272
7.11	VAPOR LIQUID EQUILIBRIUM DATA FROM TOTAL PRESSURE MEASUREMENTS I	274
7.12	VAPOR LIQUID EQUILIBRIUM DATA FROM TOTAL PRESSURE MEASUREMENTS II	279
7.13	COMPLEX CHEMICAL EQUILIBRIUM	280
7.14	REACTION EQUILIBRIUM AT CONSTANT PRESSURE OR CONSTANT VOLUME	281

Table I-3 Problems in Fluid Mechanics

NO.	PROBLEMS IN FLUID MECHANICS	PAGE
4.2	EXCEL—CALCULATION OF THE FLOW RATE IN A PIPELINE	110
5.2	MATLAB—CALCULATION OF THE FLOW RATE IN A PIPELINE	165
8.1	LAMINAR FLOW OF A NEWTONIAN FLUID IN A HORIZONTAL PIPE	283
8.2	LAMINAR FLOW OF NON-NEWTONIAN FLUIDS IN A HORIZONTAL PIPE	289
8.3	VERTICAL LAMINAR FLOW OF A LIQUID FILM	291
8.4	LAMINAR FLOW OF NON-NEWTONIAN FLUIDS IN A HORIZONTAL ANNULUS	294
8.5	TEMPERATURE DEPENDENCY OF DENSITY AND VISCOSITY OF VARIOUS LIQUIDS	297
8.6	TERMINAL VELOCITY OF FALLING PARTICLES	299
8.7	COMPARISON OF FRICTION FACTOR CORRELATIONS FOR TURBULENT PIPE FLOW	301
8.8	CALCULATIONS INVOLVING FRICTION FACTORS FOR FLOW IN PIPES	303
8.9	AVERAGE VELOCITY IN TURBULENT SMOOTH PIPE FLOW FROM MAXIMUM VELOCITY	306
8.10	CALCULATION OF THE FLOW RATE IN A PIPELINE	307
8.11	FLOW DISTRIBUTION IN A PIPELINE NETWORK	309
8.12	WATER DISTRIBUTION NETWORK	313
8.13	PIPE AND PUMP NETWORK	315
8.14	OPTIMAL PIPE LENGTH FOR DRAINING A CYLINDRICAL TANK IN TURBULENT FLOW	317
8.15	OPTIMAL PIPE LENGTH FOR DRAINING A CYLINDRICAL TANK IN LAMINAR FLOW	320
8.16	BASEBALL TRAJECTORIES AS A FUNCTION OF ELEVATION	322
8.17	VELOCITY PROFILES FOR A WALL SUDDENLY SET IN MOTION—LAMINAR FLOW	325
8.18	BOUNDARY LAYER FLOW OF A NEWTONIAN FLUID ON A FLAT PLATE	328
10.15	DIFFUSION AND REACTION IN A FALLING LAMINAR LIQUID FILM	438

**Table I-4** Problems in Heat Transfer

NO.	PROBLEMS IN HEAT TRANSFER	PAGE
2.16	HEAT EXCHANGE IN A SERIES OF TANKS	53
3.5	HEAT TRANSFER CORRELATIONS FROM DIMENSIONAL ANALYSIS	73
3.6	HEAT TRANSFER CORRELATION OF LIQUIDS IN TUBES	79
3.7	HEAT TRANSFER IN FLUIDIZED BED REACTOR	80
6.8	METHOD OF LINES FOR PARTIAL DIFFERENTIAL EQUATIONS	229
9.1	ONE-DIMENSIONAL HEAT TRANSFER THROUGH A MULTILAYERED WALL	333
9.2	HEAT CONDUCTION IN A WIRE WITH ELECTRICAL HEAT SOURCE AND INSULATION	338
9.3	RADIAL HEAT TRANSFER BY CONDUCTION WITH CONVECTION AT BOUNDARIES	344
9.4	ENERGY LOSS FROM AN INSULATED PIPE	346
9.5	HEAT LOSS THROUGH PIPE FLANGES	347
9.6	HEAT TRANSFER FROM A HORIZONTAL CYLINDER ATTACHED TO A HEATED WALL	352
9.7	HEAT TRANSFER FROM A TRIANGULAR FIN	355
9.8	SINGLE-PASS HEAT EXCHANGER WITH CONVECTIVE HEAT TRANSFER ON TUBE SIDE	357
9.9	DOUBLE-PIPE HEAT EXCHANGER	361
9.10	HEAT LOSSES FROM AN UNINSULATED TANK DUE TO CONVECTION	365
9.11	UNSTEADY-STATE RADIATION TO A THIN PLATE	368
9.12	UNSTEADY-STATE CONDUCTION WITHIN A SEMI-INFINITE SLAB	370
9.13	COOLING OF A SOLID SPHERE IN A FINITE WATER BATH	373
9.14	UNSTEADY-STATE CONDUCTION IN TWO DIMENSIONS	378
10.12	SIMULTANEOUS HEAT AND MASS TRANSFER IN CATALYST PARTICLES	423
11.22	MATERIAL AND ENERGY BALANCES ON A BATCH REACTOR	502
11.23	OPERATION OF A COOLED EXOTHERMIC CSTR	504
11.24	EXOTHERMIC REVERSIBLE GAS PHASE REACTION IN A PACKED BED REACTOR	509
11.25	TEMPERATURE EFFECTS WITH EXOTHERMIC REACTIONS	512
13.6	DYNAMICS AND CONTROL OF A STIRRED TANK HEATER	586
13.7	CONTROLLER TUNING USING INTERNAL MODEL CONTROL (IMC) CORRELATIONS	593
13.8	FIRST ORDER PLUS DEAD TIME MODELS FOR STIRRED TANK HEATER	596
13.9	CLOSED-LOOP CONTROLLER TUNING—THE ZIEGLER-NICHOLS METHOD	597
13.10	PI CONTROLLER TUNING USING THE AUTO TUNE VARIATION "ATV" METHOD	600
13.11	RESET WINDUP IN A STIRRED TANK HEATER	603
13.12	TEMPERATURE CONTROL AND START-UP OF A NONISOTHERMAL CSTR	604
13.14	PI CONTROL OF FERMENTER TEMPERATURE	609

**Table I-5** Problems in Mass Transfer

NO.	PROBLEMS IN MASS TRANSFER	PAGE
6.5	SHOOTING METHOD FOR SOLVING TWO-POINT BOUNDARY VALUE PROBLEMS	218
10.1	ONE-DIMENSIONAL BINARY MASS TRANSFER IN A STEFAN TUBE	383
10.2	MASS TRANSFER IN A PACKED BED WITH KNOWN MASS TRANSFER COEFFICIENT	389
10.3	SLOW SUBLIMATION OF A SOLID SPHERE	391
10.4	CONTROLLED DRUG DELIVERY BY DISSOLUTION OF PILL COATING	396
10.5	DIFFUSION WITH SIMULTANEOUS REACTION IN ISOTHERMAL CATALYST PARTICLES	400
10.6	GENERAL EFFECTIVENESS FACTOR CALCULATIONS FOR FIRST-ORDER REACTIONS	404
10.7	SIMULTANEOUS DIFFUSION AND REVERSIBLE REACTION IN A CATALYTIC LAYER	406
10.8	SIMULTANEOUS MULTICOMPONENT DIFFUSION OF GASES	413

NO.	PROBLEMS IN MASS TRANSFER	PAGE
10.9	MULTICOMPONENT DIFFUSION OF ACETONE AND METHANOL IN AIR	418
10.10	MULTICOMPONENT DIFFUSION IN A POROUS LAYER COVERING A CATALYST	419
10.11	SECOND-ORDER REACTION WITH DIFFUSION IN LIQUID FILM	421
10.12	SIMULTANEOUS HEAT AND MASS TRANSFER IN CATALYST PARTICLES	423
10.13	UNSTEADY-STATE MASS TRANSFER IN A SLAB	428
10.14	UNSTEADY-STATE DIFFUSION AND REACTION IN A SEMI-INFINITE SLAB	434
10.15	DIFFUSION AND REACTION IN A FALLING LAMINAR LIQUID FILM	438
11.4	CATALYTIC REACTOR WITH MEMBRANE SEPARATION	455
11.26	DIFFUSION WITH MULTIPLE REACTIONS IN POROUS CATALYST PARTICLES	514
14.5	DIFFUSION WITH REACTION IN SPHERICAL IMMOBILIZED ENZYME PARTICLES	630
14.16	DYNAMIC MODELING OF AN ANAEROBIC DIGESTER	663
14.17	START-UP AND CONTROL OF AN ANAEROBIC DIGESTER	668

Table I-6 Problems in Chemical Reaction Engineering

NO.	PROBLEMS IN CHEMICAL REACTION ENGINEERING	PAGE
3.10	RATE DATA ANALYSIS FOR A CATALYTIC REFORMING REACTION	87
3.11	REGRESSION OF RATE DATA—CHECKING DEPENDENCY AMONG VARIABLES	89
3.12	REGRESSION OF HETEROGENEOUS CATALYTIC RATE DATA	93
3.13	VARIATION OF REACTION RATE CONSTANT WITH TEMPERATURE	94
4.3	EXCEL—ADIABATIC OPERATION OF A TUBULAR REACTOR FOR CRACKING OF ACETONE	119
4.5	EXCEL—COMPLEX CHEMICAL EQUILIBRIUM BY GIBBS ENERGY MINIMIZATION	144
5.3	MATLAB—ADIABATIC OPERATION OF A TUBULAR REACTOR FOR CRACKING OF ACETONE	173
5.5	MATLAB—COMPLEX CHEMICAL EQUILIBRIUM BY GIBBS ENERGY MINIMIZATION	195
6.1	SOLUTION OF STIFF ORDINARY DIFFERENTIAL EQUATIONS	203
6.2	STIFF ORDINARY DIFFERENTIAL EQUATIONS IN CHEMICAL KINETICS	206
6.3	MULTIPLE STEADY STATES IN A SYSTEM OF ORDINARY DIFFERENTIAL EQUATIONS	207
6.5	SHOOTING METHOD FOR SOLVING TWO-POINT BOUNDARY VALUE PROBLEMS	218
6.6	EXPEDITING THE SOLUTION OF SYSTEMS OF NONLINEAR ALGEBRAIC EQUATIONS	223
10.5	DIFFUSION WITH SIMULTANEOUS REACTION IN ISOTHERMAL CATALYST PARTICLES	400
10.6	GENERAL EFFECTIVENESS FACTOR CALCULATIONS FOR FIRST-ORDER REACTIONS	404
10.7	SIMULTANEOUS DIFFUSION AND REVERSIBLE REACTION IN A CATALYTIC LAYER	406
10.11	SECOND-ORDER REACTION WITH DIFFUSION IN LIQUID FILM	421
10.14	UNSTEADY-STATE DIFFUSION AND REACTION IN A SEMI-INFINITE SLAB	434
10.15	DIFFUSION AND REACTION IN A FALLING LAMINAR LIQUID FILM	438
11.1	PLUG-FLOW REACTOR WITH VOLUME CHANGE DURING REACTION	445
11.2	VARIATION OF CONVERSION WITH REACTION ORDER IN A PLUG-FLOW REACTOR	450
11.3	GAS PHASE REACTION IN A PACKED BED REACTOR WITH PRESSURE DROP	453
11.4	CATALYTIC REACTOR WITH MEMBRANE SEPARATION	455
11.5	SEMBATCH REACTOR WITH REVERSIBLE LIQUID PHASE REACTION	458
11.6	OPERATION OF THREE CONTINUOUS STIRRED TANK REACTORS IN SERIES	462
11.7	DIFFERENTIAL METHOD OF RATE DATA ANALYSIS IN A BATCH REACTOR	465
11.8	INTEGRAL METHOD OF RATE DATA ANALYSIS IN A BATCH REACTOR	467
11.9	INTEGRAL METHOD OF RATE DATA ANALYSIS—BIMOLECULAR REACTION	468
11.10	INITIAL RATE METHOD OF DATA ANALYSIS	470
11.11	HALF-LIFE METHOD FOR RATE DATA ANALYSIS	471

**Table I-6 (Continued) Problems in Chemical Reaction Engineering**

<b>NO.</b>	<b>PROBLEMS IN CHEMICAL REACTION ENGINEERING</b>	<b>PAGE</b>
11.12	METHOD OF EXCESS FOR RATE DATA ANALYSIS IN A BATCH REACTOR	474
11.13	RATE DATA ANALYSIS FOR A CSTR	476
11.14	DIFFERENTIAL RATE DATA ANALYSIS FOR A PLUG-FLOW REACTOR	477
11.15	INTEGRAL RATE DATA ANALYSIS FOR A PLUG-FLOW REACTOR	479
11.16	DETERMINATION OF RATE EXPRESSIONS FOR A CATALYTIC REACTION	481
11.17	PACKED BED REACTOR DESIGN FOR A GAS PHASE CATALYTIC REACTION	485
11.18	CATALYST DECAY IN A PACKED BED REACTOR MODELED BY A SERIES OF CSTRs	488
11.19	DESIGN FOR CATALYST DEACTIVATION IN A STRAIGHT-THROUGH REACTOR	491
11.20	ENZYMIC REACTIONS IN A BATCH REACTOR	496
11.21	ISOTHERMAL BATCH REACTOR DESIGN FOR MULTIPLE REACTIONS	498
11.22	MATERIAL AND ENERGY BALANCES ON A BATCH REACTOR	502
11.23	OPERATION OF A COOLED EXOTHERMIC CSTR	504
11.24	EXOTHERMIC REVERSIBLE GAS PHASE REACTION IN A PACKED BED REACTOR	509
11.25	TEMPERATURE EFFECTS WITH EXOTHERMIC REACTIONS	512
11.26	DIFFUSION WITH MULTIPLE REACTIONS IN POROUS CATALYST PARTICLES	514
11.27	NITRIFICATION OF BIOMASS IN A FLUIDIZED BED REACTOR	516
11.28	STERILIZATION KINETICS AND EXTINCTION PROBABILITIES IN BATCH FERMENTERS	519
13.3	DYNAMICS AND STABILITY OF AN EXOTHERMIC CSTR	574
13.12	TEMPERATURE CONTROL AND START-UP OF A NONISOTHERMAL CSTR	604
13.14	PI CONTROL OF FERMENTER TEMPERATURE	609
13.15	INSULIN DELIVERY TO DIABETICS USING PI CONTROL	612
14.1	ELEMENTARY STEP AND APPROXIMATE MODELS FOR ENZYME KINETICS	617
14.2	DETERMINATION AND MODELING INHIBITION FOR ENZYME-CATALYZED REACTIONS	622
14.3	BIOREACTOR DESIGN WITH ENZYME CATALYSTS—TEMPERATURE EFFECTS	626
14.4	OPTIMIZATION OF TEMPERATURE IN BATCH AND CSTR ENZYMIC REACTORS	628
14.5	DIFFUSION WITH REACTION IN SPHERICAL IMMOBILIZED ENZYME PARTICLES	630
14.6	MULTIPLE STEADY STATES IN A CHEMOSTAT WITH INHIBITED MICROBIAL GROWTH	635
14.7	FITTING PARAMETERS IN THE MONOD EQUATION FOR A BATCH CULTURE	638
14.8	MODELING AND ANALYSIS OF KINETICS IN A CHEMOSTAT	640
14.9	DYNAMIC MODELING OF A CHEMOSTAT	643
14.10	PREDATOR-PREY DYNAMICS OF MIXED CULTURES IN A CHEMOSTAT	647
14.11	BIOKINETIC MODELING INCORPORATING IMPERFECT MIXING IN A CHEMOSTAT	650
14.12	DYNAMIC MODELING OF A CHEMOSTAT SYSTEM WITH TWO STAGES	652
14.13	SEMICONTINUOUS FED-BATCH AND CYCLIC-FED BATCH OPERATION	655
14.14	OPTIMIZATION OF ETHANOL PRODUCTION IN A BATCH FERMENTER	658
14.15	ETHANOL PRODUCTION IN A WELL-MIXED FERMENTER WITH CELL RECYCLE	660
14.16	DYNAMIC MODELING OF AN ANAEROBIC DIGESTER	663
14.17	START-UP AND CONTROL OF AN ANAEROBIC DIGESTER	668

**Table I-7** Problems in Phase Equilibria and Distillation

NO.	Problems in Phase Equilibria and Distillation	Page
2.10	BUBBLE POINT CALCULATION FOR AN IDEAL BINARY MIXTURE	41
2.11	DEW POINT CALCULATION FOR AN IDEAL BINARY MIXTURE	44
2.12	BUBBLE POINT AND DEW POINT FOR AN IDEAL MULTICOMPONENT MIXTURE	45
3.8	CORRELATION OF BINARY ACTIVITY COEFFICIENTS USING MARGULES EQUATIONS	81
3.9	MARGULES EQUATIONS FOR BINARY SYSTEMS CONTAINING TRICHLOROETHANE	86
3.14	CALCULATION OF ANTOINE EQUATION PARAMETERS USING LINEAR REGRESSION	95
7.8	FLASH EVAPORATION OF AN IDEAL MULTICOMPONENT MIXTURE	267
7.9	FLASH EVAPORATION OF VARIOUS HYDROCARBON MIXTURES	271
7.10	CORRELATION OF ACTIVITY COEFFICIENTS WITH THE VAN LAAR EQUATIONS	272
7.11	VAPOR LIQUID EQUILIBRIUM DATA FROM TOTAL PRESSURE MEASUREMENTS I	274
7.12	VAPOR LIQUID EQUILIBRIUM DATA FROM TOTAL PRESSURE MEASUREMENTS II	279
12.1	THREE STAGE FLASH EVAPORATOR FOR RECOVERING HEXANE FROM OCTANE	523
12.2	NON-IDEAL VAPOR-LIQUID AND LIQUID-LIQUID EQUILIBRIUM	527
12.3	CALCULATION OF WILSON EQUATION COEFFICIENTS FROM AZEOTROPIC DATA	535
12.4	VAN LAAR EQUATION COEFFICIENTS FROM AZEOTROPIC DATA	541
12.5	NON-IDEAL VLE FROM AZEOTROPIC DATA USING THE VAN LAAR EQUATION	542
12.6	FENSKE-UNDERWOOD-GILLILAND CORRELATIONS FOR SEPARATION TOWERS	544
12.7	FENSKE-UNDERWOOD-GILLILAND CORRELATIONS IN DEPROPANIZER DESIGN	550
12.8	RIGOROUS DISTILLATION CALCULATIONS FOR A SIMPLE SEPARATION TOWER	551
12.9	RIGOROUS DISTILLATION CALCULATIONS FOR HEXANE-OCTANE SEPARATION TOWER	558
12.10	BATCH DISTILLATION OF A WATER-ETHANOL MIXTURE	559
12.11	DYNAMICS OF BATCH DISTILLATION OF FERMENTER BROTH	563

**Table I-8** Problems in Process Dynamics and Control

NO.	Problems in Process Dynamics and Control	PAGE
2.14	UNSTEADY-STATE MIXING IN A TANK	49
2.15	UNSTEADY-STATE MIXING IN A SERIES OF TANKS	52
2.16	HEAT EXCHANGE IN A SERIES OF TANKS	53
6.1	SOLUTION OF STIFF ORDINARY DIFFERENTIAL EQUATIONS	203
6.2	STIFF ORDINARY DIFFERENTIAL EQUATIONS IN CHEMICAL KINETICS	206
6.3	MULTIPLE STEADY STATES IN A SYSTEM OF ORDINARY DIFFERENTIAL EQUATIONS	207
6.8	METHOD OF LINES FOR PARTIAL DIFFERENTIAL EQUATIONS	229
6.9	ESTIMATING MODEL PARAMETERS INVOLVING ODES USING FERMENTATION DATA	235
8.14	OPTIMAL PIPE LENGTH FOR DRAINING A CYLINDRICAL TANK IN TURBULENT FLOW	317
8.15	OPTIMAL PIPE LENGTH FOR DRAINING A CYLINDRICAL TANK IN LAMINAR FLOW	320
8.16	BASEBALL TRAJECTORIES AS A FUNCTION OF ELEVATION	322
8.17	VELOCITY PROFILES FOR A WALL SUDDENLY SET IN MOTION—LAMINAR FLOW	325
9.11	UNSTEADY-STATE RADIATION TO A THIN PLATE	368
9.12	UNSTEADY-STATE CONDUCTION WITHIN A SEMI-INFINITE SLAB	370
9.13	COOLING OF A SOLID SPHERE IN A FINITE WATER BATH	373
9.14	UNSTEADY-STATE CONDUCTION IN TWO DIMENSIONS	378
10.3	SLOW SUBLIMATION OF A SOLID SPHERE	391
10.4	CONTROLLED DRUG DELIVERY BY DISSOLUTION OF PILL COATING	396
10.13	UNSTEADY-STATE MASS TRANSFER IN A SLAB	428

**Table I-8 (Continued) Problems in Process Dynamics and Control**

<b>NO.</b>	<b>Problems in Process Dynamics and Control</b>	<b>PAGE</b>
10.14	UNSTEADY-STATE DIFFUSION AND REACTION IN A SEMI-INFINITE SLAB	434
11.5	SEMIBATCH REACTOR WITH REVERSIBLE LIQUID PHASE REACTION	458
11.6	OPERATION OF THREE CONTINUOUS STIRRED TANK REACTORS IN SERIES	462
11.11	HALF-LIFE METHOD FOR RATE DATA ANALYSIS	471
11.18	CATALYST DECAY IN A PACKED BED REACTOR MODELED BY A SERIES OF CSTRs	488
11.20	ENZYMATIC REACTIONS IN A BATCH REACTOR	496
11.21	ISOTHERMAL BATCH REACTOR DESIGN FOR MULTIPLE REACTIONS	498
11.22	MATERIAL AND ENERGY BALANCES ON A BATCH REACTOR	502
11.28	STERILIZATION KINETICS AND EXTINCTION PROBABILITIES IN BATCH FERMENTERS	519
12.10	BATCH DISTILLATION OF A WATER-ETHANOL MIXTURE	559
12.11	DYNAMICS OF BATCH DISTILLATION OF FERMENTER BROTH	563
13.1	MODELING THE DYNAMICS OF FIRST- AND SECOND-ORDER SYSTEMS	565
13.2	DYNAMICS OF A U-TUBE MANOMETER	572
13.3	DYNAMICS AND STABILITY OF AN EXOTHERMIC CSTR	574
13.4	FITTING A FIRST-ORDER PLUS DEAD-TIME MODEL TO PROCESS DATA	576
13.5	DYNAMICS AND CONTROL OF A FLOW-THROUGH STORAGE TANK	580
13.6	DYNAMICS AND CONTROL OF A STIRRED TANK HEATER	586
13.7	CONTROLLER TUNING USING INTERNAL MODEL CONTROL (IMC) CORRELATIONS	593
13.8	FIRST ORDER PLUS DEAD TIME MODELS FOR STIRRED TANK HEATER	596
13.9	CLOSED-LOOP CONTROLLER TUNING—THE ZIEGLER-NICHOLS METHOD	597
13.10	PI CONTROLLER TUNING USING THE AUTO TUNE VARIATION “ATV” METHOD	600
13.11	RESET WINDUP IN A STIRRED TANK HEATER	603
13.12	TEMPERATURE CONTROL AND START-UP OF A NONISOTHERMAL CSTR	604
13.13	LEVEL CONTROL OF TWO INTERACTIVE TANKS	605
13.14	PI CONTROL OF FERMENTER TEMPERATURE	609
13.15	INSULIN DELIVERY TO DIABETICS USING PI CONTROL	612
14.1	ELEMENTARY STEP AND APPROXIMATE MODELS FOR ENZYME KINETICS	617
14.4	OPTIMIZATION OF TEMPERATURE IN BATCH AND CSTR ENZYMATIC REACTORS	628
14.6	MULTIPLE STEADY STATES IN A CHEMOSTAT WITH INHIBITED MICROBIAL GROWTH	635
14.7	FITTING PARAMETERS IN THE MONOD EQUATION FOR A BATCH CULTURE	638
14.8	MODELING AND ANALYSIS OF KINETICS IN A CHEMOSTAT	640
14.9	DYNAMIC MODELING OF A CHEMOSTAT	643
14.10	PREDATOR-PREY DYNAMICS OF MIXED CULTURES IN A CHEMOSTAT	647
14.12	DYNAMIC MODELING OF A CHEMOSTAT SYSTEM WITH TWO STAGES	652
14.13	SEMICONTINUOUS FED-BATCH AND CYCLIC-FED BATCH OPERATION	655
14.16	DYNAMIC MODELING OF AN ANAEROBIC DIGESTER	663
14.17	START-UP AND CONTROL OF AN ANAEROBIC DIGESTER	668

**Table I-9** Problems in Biochemical Engineering

NO.	Problems in Biochemical Engineering	PAGE
2.3	STOICHIOMETRIC CALCULATIONS FOR BIOLOGICAL REACTIONS	20
6.1	SOLUTION OF STIFF ORDINARY DIFFERENTIAL EQUATIONS	203
6.9	ESTIMATING MODEL PARAMETERS INVOLVING ODEs USING FERMENTATION DATA	235
11.20	ENZYMIC REACTIONS IN A BATCH REACTOR	496
11.27	NITRIFICATION OF BIOMASS IN A FLUIDIZED BED REACTOR	516
11.28	STERILIZATION KINETICS AND EXTINCTION PROBABILITIES IN BATCH FERMENTERS	519
12.11	DYNAMICS OF BATCH DISTILLATION OF FERMENTER BROTH	563
13.14	PI CONTROL OF FERMENTER TEMPERATURE	609
13.15	INSULIN DELIVERY TO DIABETICS USING PI CONTROL	612
14.1	ELEMENTARY STEP AND APPROXIMATE MODELS FOR ENZYME KINETICS	617
14.2	DETERMINATION AND MODELING INHIBITION FOR ENZYME-CATALYZED REACTIONS	622
14.3	BIOREACTOR DESIGN WITH ENZYME CATALYSTS—TEMPERATURE EFFECTS	626
14.4	OPTIMIZATION OF TEMPERATURE IN BATCH AND CSTR ENZYMIC REACTORS	628
14.5	DIFFUSION WITH REACTION IN SPHERICAL IMMOBILIZED ENZYME PARTICLES	630
14.6	MULTIPLE STEADY STATES IN A CHEMOSTAT WITH INHIBITED MICROBIAL GROWTH	635
14.7	FITTING PARAMETERS IN THE MONOD EQUATION FOR A BATCH CULTURE	638
14.8	MODELING AND ANALYSIS OF KINETICS IN A CHEMOSTAT	640
14.9	DYNAMIC MODELING OF A CHEMOSTAT	643
14.10	PREDATOR-PREY DYNAMICS OF MIXED CULTURES IN A CHEMOSTAT	647
14.11	BIOKINETIC MODELING INCORPORATING IMPERFECT MIXING IN A CHEMOSTAT	650
14.12	DYNAMIC MODELING OF A CHEMOSTAT SYSTEM WITH TWO STAGES	652
14.13	SEMICONTINUOUS FED-BATCH AND CYCLIC-FED BATCH OPERATION	655
14.14	OPTIMIZATION OF ETHANOL PRODUCTION IN A BATCH FERMENTER	658
14.15	ETHANOL PRODUCTION IN A WELL-MIXED FERMENTER WITH CELL RECYCLE	660
14.16	DYNAMIC MODELING OF AN ANAEROBIC DIGESTER	663
14.17	START-UP AND CONTROL OF AN ANAEROBIC DIGESTER	668