Study Guide for Final Exam

Approximate Relative importance: Homeworks>Slides>Book
Final exam covers lectures #1-39; topics below:

Topics	Book	Lecture# with advice on most important slides/concepts[1]	Date	Home-work
I. Introduction • Environmental Engineering Overview	Chapter 1			
• Environmental Legislation & Regulation		2 Slides 6, 52, 54 58-62	6 Sept	
II. Environmental Chemistry • Basics: Bonding & definitions	Chapter 2&3	3 Slides 36,43,44	11 Sept	
• Units of concentration • Solids analysis		4 Slides: 9-11,23-28	13 Sept	#1
• Reactions & stoichiometry • Equilibrium • Oxygen demand		5 Slides: 7, 13-52; no need to memorize constants or concentrations	16 Sept	#2
• Kinetics • Water, soil & air chemistry • Ionic strength		6 Slides 2-5, 6-10, 14-29	18 Sept	
• Thermodynamics • Acids & Bases • Equilibria, calculations		7 Slides 2-21, 25-29, 32 Chemical names in slides 25, 26, but don't memorize the constants	20 Sept	#3
• Equilibria • Organic Nomenclature		8 Slides 3-5, 10-15, 20-36	23 Sept	
III. Physical Processes • Mass balances; reactors	Chapter 4	9 Slides: 9-33, 37-47	25 Sept	#4
• Energy and Energy balances		10 Slides 6-10, 17-18	27 Sept	
• Reactor Models		11 Slides 4-24	30 Sept	

[1] I've listed slides by number within each lecture as they are currently (Oct 21) posted on the CEE 370 website (http://www.ecs.umass.edu/cee/reckhow/courses/370/sched.htm). Specifics of example problems are not too important, but the problems are useful in learning to apply the important concepts. This is my best general assessment, but it isn't perfect. There may be a few questions on topics not listed among the most important slides.

IV. Biological Principles • Basic principles	Chapter 5	12 Slides 2-11 (no need to know exact structures of these organic molecules)	2 Oct	
• Biochemical pathways • Energy transfer and yields • Enzymes		13 Slides: 2-9, 11-14, 20, 23-27, 29 (but no need to know details of biochemical pathways or half-reactions and related constants)	4 Oct	
• Genetics • Transcription		14 Slides 2-4, 6, 9-17, 30-32, 47	9 Oct	
• Microorganisms, organelles		15 Slides: all (minus details of algal types; and species names)	7 Oct	
• Water quantities • Nutrient cycles		16 Slides 2-9 don't memorize fluxes or quantities, 11-21, 26-29, 35-36, 44-53	7 Oct	
• Growth models		17 Slides: 3-31	9 Oct	
V. Risk • Perception, assessment, toxicology	Chapter 6	18 Slides: #9-11, 26-27	11 Oct	
VI. Water Quantity & Quality • Basic principles, mass balance	Chapter 7	19 Slides: 4-6, 9-15, 17	15 Oct	
• Stream flow • Water balances		20 Slides: #8-12, 14-16, 22-25, 27-31, 36-42, 46-50	16 Oct	
• Groundwater flow • Hydraulic conductivity		21 Slides: #2-10	18 Oct	#6
• Darcy's Law • Retardation		22 Slides: #2-16, 18-24	21 Oct	
• Water quality constituents • DO, BOD, organics		23 Slides: #4-7, 9-15, 19-23, 25-26	23 Oct	#7
• River management & modeling • DO sag; Streeter-Phelps		24 Slides: #3-8, 11, 13-20, 22-35, 38-50	25 Oct	
• Lake Stratification • Lake Models • Photolysis, biodegradation		25 Slides: #3-4, 8-39	28 Oct	
• CSOs, Marine anoxia		26 Slides: #2, 5-6, 8	30 Oct	

VII. Water Treatment • Basic principles, mass balance	Chapter 8	27 Slides: #2-4, 6, 8, 10-12, 14-20, 23, 25-35	1 Nov	#8
• Flocculation, coagulation		28 Slides: #2, 4-10, 16-25, 32-33, 35-41, 43-49	4 Nov	
• Softening • Coagulation, filtration • Disinfection, Basic principles, mass balance		29 Slides: #5-15, 20-25, 27-28, 33-34	6 Nov	
VIII. Wastewater Treatment • Basic characteristics	Chapter 9	30 Slides: #2, 5-7, 9-10, 12-18	8 Nov	
• Preliminary treatment Settling • Biological treatment		31 Slides: all	13 Nov	
• Activated sludge models • Sludge Treatment		32 Slides: all	15 Nov	
IX. Solid Waste Engineering • Basic principles, mass balance	Chapter 10	33 Slides: #2-3, 10, 13-18, 21-26	18 Nov	#9
• Landfilling • Leachate treatment		34 Slides: #2, 5-13, 16	20 Nov	
• Hazardous waste basics • Hazardous waste treatment		35 Slides: #2-6, 11-18, 22-25	22 Nov	
X. Air Quality & Pollution Control • Health, Laws & control	Chapter 11	36 Slides: #2, 8-10, 14-15, 17-19, 23-25, 27	2 Dec	
• NOX, SOX • Air transport		37 Slides: #2-4, 9-15, 17, 24, 26-30, 33	4 Dec	
• Air pollution control		38 Slides: all	6 Dec	
Hazardous Site Remediation		39 Slides: all	11 Dec	

Instructions provided with Exam

Closed Book, two sheets of notes allowed

Answer 6 of 11 questions.

Special information provided with Exam

Conversions

7.48 gallon = 1.0 ft^3 1 gal = 3.7854×10^{-3} m^3

1 MGD = 694 gal/min = 1.547 ft^3/s = 43.8 L/s

1 ft^3/s = 449 gal/min

g = 32 ft/s^2

$W=\gamma$ = 62.4 lb/ft^3 = 9.8 N/L

1 hp = 550 ft-lbs/s = 0.75 kW

1 mile = 5280 feet 1 ft = 0.3048 m

1 watt = 1 N-m/s

1 psi pressure = 2.3 vertical feet of water (head)

At 60 ºF, $\nu = 1.217 \times 10^{-5}$ ft^2/s

Selected Chemical Constants

Element	Symbol	Atomic #	Atomic Wt.	Valence	Electronegativity
Aluminum	Al	13	26.98	3	1.47
Boron	B	5	10.81	3	2.01
Calcium	Ca	20	40.08	2	1.04
Carbon	C	6	12.01	2,4	2.50
Chlorine	Cl	17	35.453	1,3,5,7	2.83
Chromium	Cr	24	52.00	many	1.56
Helium	He	2	4.00	0	
Holmiuum	Ho	67	164.93	3	1.10
Hydrogen	H	1	1.01	1	2.20
Magnesium	Mg	12	24.31	2	1.23
Manganese	Mn	25	54.94	2,3,4,6,7	1.60
Nitrogen	N	7	14.01	many	3.07
Oxygen	O	8	16.00	2	3.50
Potassium	K	19	39.10	1	0.91
Sodium	Na	11	22.99	1	1.01
Sulfur	S	16	32.06	2,4,6	2.44

Selected Acidity Constants (Aqueous Solution, 25°C, I = 0)

NAME	FORMULA	pK_a
Hydrochloric acid	$HCl = H^+ + Cl^-$	-3
Sulfuric acid	$H_2SO_4 = H^+ + HSO_4^-$	-3

Nitric acid	$HNO_3 = H^+ + NO_3^-$	-0
Bisulfate ion	$HSO_4^- = H^+ + SO_4^{-2}$	2
Phosphoric acid	$H_3PO_4 = H^+ + H_2PO_4^-$	2.15
Hydrofluoric acid	$HF = H^+ + F^-$	3.2
Nitrous acid	$HNO_2 = H^+ + NO_2^-$	4.5
Acetic acid	$CH_3COOH = H^+ + CH_3COO^-$	4.75
Propionic acid	$C_2H_5COOH = H^+ + C_2H_5COO^-$	4.87
Carbonic acid	$H_2CO_3 = H^+ + HCO_3^-$	6.35
Hydrogen sulfide	$H_2S = H^+ + HS^-$	7.02
Dihydrogen phosphate	$H_2PO_4^- = H^+ + HPO_4^{-2}$	7.2
Hypochlorous acid	$HOCl = H^+ + OCl^-$	7.5
Ammonium ion	$NH_4^+ = H^+ + NH_3$	9.24
Hydrocyanic acid	$HCN = H^+ + CN^-$	9.3
Phenol	$C_6H_5OH = H^+ + C_6H_5O^-$	9.9
Bicarbonate ion	$HCO_3^- = H^+ + CO_3^{-2}$	10.33
Monohydrogen phosphate	$HPO_4^{-2} = H^+ + PO_4^{-3}$	12.3
Bisulfide ion	$HS^- = H^+ + S^{-2}$	13.9

PHYSICAL AND CHEMICAL CONSTANTS

Avogadro's number	$N = 6.022 \times 10^{23}\ \text{mol}^{-1}$
Elementary charge	$e = 1.602 \times 10^{-19}\ \text{C}$
Gas constant	$R = 8.314\ \text{J mol}^{-1}\ \text{K}^{-1}$
	$= 1.987\ \text{cal mol}^{-1}\ \text{K}^{-1}$
	$= 0.08205\ \text{L atm mol}^{-1}\ \text{K}^{-1}$
Planck's constant	$h = 6.626 \times 10^{-34}\ \text{J s}$
Boltzmann's constant	$\mathbf{k} = 1.381 \times 10^{-23}\ \text{J K}^{-1}$
Faraday's constant	$F = 9.649 \times 10^{4}\ \text{C mol}^{-1}$
Speed of light	$c = 2.998 \times 10^{8}\ \text{m s}^{-1}$
Vacuum permittivity	$\varepsilon_0 = 8.854 \times 10^{-12}\ \text{J}^{-1}\ \text{C}^2\ \text{m}^{-1}$
Earth's gravitation	$g = 9.806\ \text{m s}^{-2}$

CONVERSION FACTORS

1 cal	= 4.184 joules (J)
1 eV/molecule	= 96.485 kJ mol^{-1}
	= 23.061 kcal mol^{-1}
1 wave number (cm^{-1})	= 1.1970×10^{-2} kJ mol^{-1}
1 erg	= 10^{-10} kJ
1 atm	= 1.01325×10^{5} Pa
1 Å	= 10^{-10} m
1 L	= $10^{-3}\ \text{m}^3$

PROPERTIES OF WATER

T(°C)	ρ, Density ($\text{kg} \cdot \text{m}^{-3}$)	μ Viscosity ($\text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-1}$)	σ, Surface Tension against Air ($\text{J} \cdot \text{m}^{-2}$)	ε Dielectric Constant ($\text{C} \cdot \text{V}^{-1} \cdot \text{m}^{-1}$)	pK_w, Ionization Constant ($\text{mol}^2 \cdot \text{L}^{-2}$)
0	999.868	0.001787	0.0756	88.28	14.9435
5	999.992	0.001519	0.0749	86.3	14.7338
10	999.726	0.001307	0.07422	84.4	14.5346
15	999.125	0.001139	0.07349	82.5	14.3463
20	998.228	0.001002	0.07275	80.7	14.1669
25	997.069	0.0008904	0.07197	78.85	13.9965
30	995.671	0.0007975	0.07118	77.1	13.8330

SI PREFIXES

Multiplication Factor	Prefix	Symbol	Multiplication Factor	Prefix	Symbol
10^{12}	tera	T	10^{-2}	centi	c
10^{9}	giga	G	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	μ
10^{3}	kilo	k	10^{-9}	nano	n
10^{2}	hecto	h	10^{-12}	pico	p
10^{1}	deka	da	10^{-15}	femto	f
10^{-1}	deci	d	10^{-18}	atto	a