

Study Guide for Final Exam

Approximate Relative importance: Homeworks>Slides>Book
 Final exam covers all lectures and topics below:

Topics	Book	Lecture# with advice on most important slides/concepts ¹	Date	Home- work
I. Introduction	Chapter 1	<u>1</u> Know terms, mass balances Slides 10-17	9 Sept	
- Environmental Engineering Overview, legislation - Mass Balances				
Environmental Legislation & Regulation		<u>2</u> Slides 6, 37, 39, 47-50, 53-55	11 Sept	
II. Environmental Chemistry	Chapter 2&3	<u>3</u> Slides 2-12	14 Sept	
Basics: Bonding & definitions				
- Units of concentration - Reactions & stoichiometry - Equilibrium		<u>4</u> Slides: all	16 Sept	<u>#1</u>
- Kinetics - Water, soil & air chemistry - Ionic strength		<u>5</u> Slides: all; no need to memorize equations on slide 17	18 Sept	<u>#2</u>
- Thermodynamics - Acids & Bases		<u>6</u> Slides 2-5, 6-10, 14-29	21 Sept	
Equilibria, calculations		<u>7</u> Chemical names in slides 3, 22, 25, 26, but don't memorize the constants, slides 4-21, 27-32.	23 Sept	<u>#3</u>
Organic Nomenclature		<u>8</u> Slides 2-11, 16-33	25 Sept	
III. Physical Processes	Chapter 4	<u>9</u> Slides: all	28 Sept	<u>#4</u>
Mass balances; reactors				
Energy and Energy balances		<u>10</u> Slides 4, 11-15	30 Sept	
Microbiology & Biochemical pathways		<u>11</u> Slides 2-24 (minus details in #15)	2 Oct	

¹ I've listed slides by number within each lecture as they are currently (Dec 12) posted on the CEE 370 website (<http://www.ecs.umass.edu/cee/reckhow/courses/370/sched.htm>). I generally don't list example problems, because the specifics of these aren't too important. They are useful, however, 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	Chapter 5	12 Slides 2-12 (no need to know exact structures of these organic molecules)	5 Oct	
• Basic principles				
• Biochemical pathways		13 Slides: all (but no need to know details of biochemical pathways or half-reactions and related constants)	7 Oct	
• Energy transfer and yields				
• Enzymes				
• Genetics		14 Slides 2-4, 6, 9-17, 30-32, 47	9 Oct	
• Transcription		15 Slides: all (minus details of algal types; and species names)	13 Oct	
• Microorganisms, organelles		16 Slides 2-9 don't memorize fluxes or quantities, 11-25, 27, 29-49 (don't memorize values in slide 34)	13 Oct	
• Water quantities		17 Slides: all	14 Oct	#5
• Nutrient cycles		18 Slides: #4, 6-9, 11-13, 15, 18-22	16 Oct	
V. Risk	Chapter 6			
• Perception, assessment, toxicology				
VI. Water Quantity & Quality	Chapter 7	19 Slides: 2-7, 9-13, 15, 22-24	19 Oct	
• Basic principles, mass balance				
• Stream flow		20 Slides: #6, 8-13, 15-16, 22-25, 27-37, 40, 42, 47-53, 55-56	21 Oct	
• Water balances		21 Slides: #3-10	23 Oct	#6
• Groundwater flow		22 Slides: #2-16, 18-24	26 Oct	
• Hydraulic conductivity		23 Slides: #4-5, 7-8, 13-44, 47-50, 52-57	28 Oct	#7
• Darcy's Law		24 Slides: #3-8, 11, 13-20, 22-35, 38-50	30 Oct	
• Retardation		25 Slides: #3-4, 8-39	2 Nov	
• Water quality constituents		26 Slides: #3, 5-6, 8	4 Nov	
• DO, BOD, organics		27 Slides: #2-4, 6, 8, 10-11	6 Nov	#8
• River management & modeling		28 Slides: #2-7, 10, 12-24	9 Nov	
• DO sag; Streeter-Phelps		29 Slides: #2, 4-10, 16-33, 35-41 43-49	13 Nov	
• Lake Stratification		30 Slides: #3-9, 12-16, 19-23, 25-36	16 Nov	
• Lake Models				
• Photolysis, biodegradation				
• CSOs, Marine anoxia				
VII. Water Treatment	Chapter 8			
• Basic principles, mass balance				
• Flocculation, coagulation				
• Softening				
• Coagulation, filtration				
• Disinfection, Basic principles, mass balance				

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

Instructions provided with Exam

Closed Book, three sheets of notes allowed

Special information provided with Exam

Conversions

$$7.48 \text{ gallon} = 1.0 \text{ ft}^3 \quad 1 \text{ gal} = 3.7854 \times 10^{-3} \text{ m}^3$$

$$1 \text{ MGD} = 694 \text{ gal/min} = 1.547 \text{ ft}^3/\text{s} = 43.8 \text{ L/s}$$

$$1 \text{ ft}^3/\text{s} = 449 \text{ gal/min}$$

$$g = 32 \text{ ft/s}^2$$

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

$$1 \text{ hp} = 550 \text{ ft-lbs/s} = 0.75 \text{ kW}$$

$$1 \text{ mile} = 5280 \text{ feet} \quad 1 \text{ ft} = 0.3048 \text{ m}$$

$$1 \text{ watt} = 1 \text{ N-m/s}$$

$$1 \text{ psi pressure} = 2.3 \text{ vertical feet of water (head)}$$

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

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	
Holmium	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	$\text{HCl} = \text{H}^+ + \text{Cl}^-$	-3
Sulfuric acid	$\text{H}_2\text{SO}_4 = \text{H}^+ + \text{HSO}_4^-$	-3

Nitric acid	$\text{HNO}_3 = \text{H}^+ + \text{NO}_3^-$	-0
Bisulfate ion	$\text{HSO}_4^- = \text{H}^+ + \text{SO}_4^{2-}$	2
Phosphoric acid	$\text{H}_3\text{PO}_4 = \text{H}^+ + \text{H}_2\text{PO}_4^-$	2.15
Hydrofluoric acid	$\text{HF} = \text{H}^+ + \text{F}^-$	3.2
Nitrous acid	$\text{HNO}_2 = \text{H}^+ + \text{NO}_2^-$	4.5
Acetic acid	$\text{CH}_3\text{COOH} = \text{H}^+ + \text{CH}_3\text{COO}^-$	4.75
Propionic acid	$\text{C}_2\text{H}_5\text{COOH} = \text{H}^+ + \text{C}_2\text{H}_5\text{COO}^-$	4.87
Carbonic acid	$\text{H}_2\text{CO}_3 = \text{H}^+ + \text{HCO}_3^-$	6.35
Hydrogen sulfide	$\text{H}_2\text{S} = \text{H}^+ + \text{HS}^-$	7.02
Dihydrogen phosphate	$\text{H}_2\text{PO}_4^- = \text{H}^+ + \text{HPO}_4^{2-}$	7.2
Hypochlorous acid	$\text{HOCl} = \text{H}^+ + \text{OCl}^-$	7.5
Ammonium ion	$\text{NH}_4^+ = \text{H}^+ + \text{NH}_3$	9.24
Hydrocyanic acid	$\text{HCN} = \text{H}^+ + \text{CN}^-$	9.3
Phenol	$\text{C}_6\text{H}_5\text{OH} = \text{H}^+ + \text{C}_6\text{H}_5\text{O}^-$	9.9
Bicarbonate ion	$\text{HCO}_3^- = \text{H}^+ + \text{CO}_3^{2-}$	10.33
Monohydrogen phosphate	$\text{HPO}_4^{2-} = \text{H}^+ + \text{PO}_4^{3-}$	12.3
Bisulfide ion	$\text{HS}^- = \text{H}^+ + \text{S}^{2-}$	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	$k = 1.381 \times 10^{-23} \text{ J K}^{-1}$
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	$\epsilon_0 = 8.854 \times 10^{-12} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$
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 m ³

PROPERTIES OF WATER

T(°C)	ρ , Density (kg · m ⁻³)	μ , Viscosity (kg · m ⁻¹ · s ⁻¹)	σ , Surface Tension against Air (J · m ⁻²)	ϵ , Dielectric Constant (C · V ⁻¹ · m ⁻¹)	pK_w , Ionization Constant (mol ² · 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