CHEMICAL & BIOLOGICAL ENGINEERING
COLORADO SCHOOL OF MINES

CBEN409 Petroleum Refining Processes

Instructor	John Jechura
Class Semester **Class Location** **Class Hours**	Fall 2017 AH 140 Tue/Thu 11:00 am to 12:15 pm
Office Location **Office Hours**	AH 437 Mon 3:00 - 4:00, Tue & Thu 2:00 - 4:00, Wed 1:00 - 2:00, & by appointment
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Syllabus	

Page Revisions

October 5. Fixed solutions to Homeworks #2 & #3 posted. Solution for Quiz #2 posted.
October 3. Posted solutions to Homeworks #2 & #3. Posted due date for Homework #4.
September 26. Homeworks #2 & #3 delayed until Monday.
September 7. Posted tentative due date for Homeworks #2 & #3.
September 2. Posted solution to Homework #1.
August 29. Due date for Homework #1 changed.
August 2017. Content initialized for Fall Semester.

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Class notes (associated chapters in text). Visitors, please contact instructor to get printable versions of the slides.

Introduction (printable handout)

- Summary of US refinery capacities (as of January 1, 2017)
- EXTERNAL: Energy consumption diagram (Lawrence Livermore National Laboratory)
- EXTERNAL: How Stuff Works - How Oil Refining Works
- EXTERNAL: AFPM - The refinery process

Refinery Feedstocks & Products (Chapters 2 & 3) (printable handout)

- Summary of correlations in presentation
- Analysis of Assay #1
- Analysis of Assay #2 (Hibernia from Chevron site)
- Analysis of Assay #3 (Hibernia from ExxonMobil site)
- Analysis of Assay #4 (WTI from OGJ)
- Example spreadsheet for assay analysis developed in class
- Conversion of D86 temperatures to TBP
- Blend example involving D86 temperatures
- Octane blending example
- Gasoline Blend Info & Properties (SAE 902098) (Spreadsheet)
- Crude oil assays:
    - From Oil & Gas Journal: West Texas Intermediate, Brent
    - Crude oil assays from various oil companies
        - EXTERNAL: Capline crude oil assays
        - EXTERNAL: Chevron crude oil assays (assays not currently published)
        - EXTERNAL: BP crude oil assays
        - EXTERNAL: Eni crude oil assays (assays not currently published)
        - EXTERNAL: ExxonMobil crude oil assays
        - EXTERNAL: Poseidon Crude Oil
        - EXTERNAL: Statoil crude oil assays
        - EXTERNAL: Total crude oil assays
    - EXTERNAL: Strategic Petroleum Reserve Crude Oil Assays
    - EXTERNAL: Crude oil assays at the Environmental Technology Centre web page
    - EXTERNAL: Canadian crude oils summarized at crudemonitor.ca maintained by Crude Quality, Inc.
- EXTERNAL: How Stuff Works -- Gasoline & Diesel engines

Crude Oil Distillation (Chapter 4) (printable handout)

- Simulation using Aspen Plus (this is printable)
- Simulation using Aspen HYSYS (this is printable)
- EXTERNAL: Discussion of column internals at separation.com

Bottom of the Barrel Processing: Coking & Thermal Processes, Hydroprocessing, & Solvent Deasphalting (Chapters 5 & 8) (printable handout)

Delayed Coking (Chapter 5) (printable handout)

- Example using yield estimation correlations
- EXTERNAL: Foster-Wheeler paper, "Shot Coke: Design & Operations" (Local copy)
- EXTERNAL: Delayed Coker Communications Forum
- Paul Ellis & Chris Paul, Great Lakes Carbon, "Tutorial: Delayed Coking Fundamentals" (Local copy)

Catalytic Cracking (Chapter 6) (printable handout)

- Example using yield estimation charts

Hydroprocessing: Hydrocracking & Hydrotreating (Chapters 7 & 9) (printable handout)

- Example using hydrocracking yield estimation charts

Gasoline Upgrading: Reforming, Isomerization, & Alkylation (Chapters 10 & 11) (printable handout)

- Example using reformer yield estimation charts
- EXTERNAL: CDTech Alkylation publications

Supporting Processes (Chapter 13) (printable handout)

Blending & Optimization (Chapters 12 & 14) (printable handout)

- Sample spreadsheet

Future? New feedstock sources, government mandates, CCS, renewable fuels ... (printable handout)

- EXTERNAL: EPA's 2016 Renewable Fuel Standard data
- EXTERNAL: U.S. Billion-Ton Update

Summary of refinery operations

Using process simulation software

- HYSYS (printable handout)
- Aspen Plus (printable handout)

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Extra instructor notes

Useful VBA (Visual Basic for Applications) code (notes for downloading):

- Vapor pressure vs. temperature (Maxwell-Bonnell correlation)
- Estimated properties for petroleum fractions: molecular weight, critical pressure & temperature, gross & net heating values
- Linear interpolation
- Spline interpolation
- Interpolation of distillation curves internally using the probability function transformation of yield values. Code allows this to be done using linear interpolation or spline interpolation (on a temperature vs. transformed yield basis).
    - Further instructions on how to use the interpolation macros.

The use of the VBA code is potentially limited depending upon which version of Microsoft Excel one is using.

- The code was originally developed to run with Excel 2000. It has been tested & it runs properly with Excel 2007, 2010, & 2013. Here are notes to incorporate the VBA macros into an Excel 2010 spreadsheet. Below are other sites that describe what needs to be done to allow the macros to work.
    - http://support.microsoft.com/kb/919195
    - http://www.dummies.com/how-to/content/how-to-set-the-macro-security-level-in-excel-2007.html#comments

- There have been issues if one wants to use these macros on a Mac. Excel 2004 has VBA support built-in but Excel 2008 did not. The latest version are supposed to have VBA support.
- If you are using a version of Excel (or some other spreadsheet) that cannot run these macros then here is a sample spreadsheet for doing the interpolation calculations without requiring macros (the user will have to be careful to copy cells with formulas as necessary). There are separate sheets for linear interpolation (arbitrary X & Y values) and interpolation of cumulative yield data (°F vs. yield%).

Calculation of Physical Properties from Properties of Petroleum Fractions

Pure component data (spreadsheet)

Fundamental Conversion Factors

Modeling petroleum systems with HYSYS:

- Crude Tower Simulation - HYSYS v10 using Windows 10 (Previous version for HYSYS v8.6)
  - Starting HYSYS file with compositions defined but not unit models
- Crude Tower Simulation – Aspen Plus v8.6
- Spreadsheet with the crude oil assay values (Tables 1 to 3)

Modeling petroleum systems with Aspen Plus® (from the Aspen Tech support web site):

- "Getting Started Modeling Petroleum Processes"
- Summary of information for models
- Calculate & report RVP values in Aspen

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Homework Assignments

Homework assignments are to be emailed to the instructor usually in spreadsheet (Excel) format. The following rules must be followed:

- There is to be a summary page with all answers in the order & units requested. Values in the summary are not to be copied by values but rather linked to any additional pages where the calculations are actually performed.
- All spreadsheets are to be self contained, i.e., there are to be no links to other spreadsheets.

A sample spreadsheet with the preferred format is here.

	Due Date & Link to Problem Statement	**Topic & Link to Solution**
#1	~~Wednesday, Aug 30~~ Friday, Sept 1	Chemical species that make up petroleum
#2	~~Wed Sept 27~~ Mon Oct 2	Crude Oil Assay
#3	~~Wed Sept 27~~ Mon Oct 2	Crude Oil Assay (cont.)
#4	Thu Oct 12	Blending Crude Oil Assays
#5	TBD	Fuel oil blending
#6	TBD	Delayed Coking
#7	TBD	FCC

#8	TBD	Hydrotreating
#9	TBD	Hydrocracking
#10	TBD	Gasoline upgrading - reforming & alkylation
#11	TBD	Product Blending
#12	TBD	Optimized Gasoline Blending
#13	TBD	Downstream effects of slumped tower operation

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Quizzes

	Quiz Date	**Topic & Link to Solution**
#1	Sept 7	General info
#2	Oct 3	Blending calculation
#3		
#4		
#5		

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Simulation Project

Simulation project memo. Project due no later than 6:00 pm Thursday, December 15, 2016. **Questions answered through Thursday December 7, 2017.**

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Safety Topics

TUESDAY	**THURSDAY**
August 22 Safety Culture	August 24 Safety & Star Wars (Eastman)
August 29 Driving safety (Madenjian)	August 31 H2S safety (Pugliese)
September 5 PPE in midstream services (Brewer)	September 7 Career Day safety (Kimball)
September 12 NO CLASS - CAREER DAY	September 14 NO CLASS

September 19 Ice-related slip & fall injuries (Richardson)	September 21 Heat-Related Illnesses (San Nicolas)
September 26 Safety Case Study - Alderson Hall (Tommen)	September 28 Safety in Thunderstorms (Schneiderman)
October 3 Grilling safety (Walton)	October 5 Ladder safety (Miller)
October 10 TBD (Kressin) TBD (Winsor)	October 12 TBD (Law) TBD (Basic)
October 17 NO CLASS - FALL BREAK	October 19
October 24	October 26
October 31	November 2
November 7	November 9
November 14	November 16
November 21	November 23 NO CLASS - THANKSGIVING
November 22	November 30
December 5	December 7

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Useful EXTERNAL Links

Crude Oil:

- Bloomberg Energy Prices
- CNN Financial Network
- NYMEX Exchange via ino.com
- Flint Hills Resources crude pricing bulletins (primarily crude oils in the central U.S.)
- Plains All American crude purchase bulletins

Refined Products -- Gasoline, & Heating Oil:

- Bloomberg Energy Prices

Petroleum Technology Companies:

- Amec Foster Wheeler
- Axens
- CB&I (Lummus Technology, CDTECH)
- GTC Technology
- Haldor Topsøe
- KBR
- Shell Global Solutions
- UOP

Petroleum Companies:

U.S. Department of Energy:

- U.S. DOE Energy Information Agency
- Annual Energy Outlook
- Annual Energy Review
- U.S. Petroleum Prices
- History of energy consumption in the United States, 1775–2009
- U.S. Refinery Capacities

Environmental Protection Agency:

- CNN Financial Network
- NYMEX Exchange via ino.com

Retail Gasoline Prices:

- Cheapest Gasoline in Denver Area (part of gasbuddy.com)
- EIA Gasoline and Diesel Fuel Update (Regional, couple days old)

- Phillips 66
- ExxonMobil
- Chevron
- BP
  - Reports & Publications. Get *Statistical Review of World Energy* from here.
- Marathon Petroleum Company
- PBF Energy
- Shell US
- Valero

Industry Groups:

- American Petroleum Institute (API)
- American Fuel & Petrochemical Association (AFPM) — formerly NPRA

Industry News Services, Journals, & Magazines:

- OPIS
- Oil & Gas Journal
- Hydrocarbon Processing
- Digital Refining

Refining Technical Topics:

- Process Engineering Associates

Social Networks:

- RefinerLink (free account)

- Volatility (RVP) Standards
- Tier 2 Vehicle and Gasoline Sulfur Program

California Energy Commission:

- Gasoline Price Breakdown & Margin Details

Safety Related Sites:

- AIChE Center for Chemical Process Safety (CPSS)
  - Process Safety Beacon
- Chemical Safety Board
- OSHA Safety & Health Topics
- OSHA Fatal Facts
- OSHA Publications
- NIOSH Safety & Health Topics

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