SYNERGY THROUGH SHARING: OPEN RESOURCES AND TECHNOLOGICAL INNOVATION IN CHEMICAL ENGINEERING EDUCATION

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INTRODUCTION

“Improvement in post-secondary education will require converting **teaching from a solo sport** to a community-**based** research **activity**”

- Herbert Simon, 1986

Image: Richard Rappaport [3] [4] [CC BY 3.0] via Wikimedia Commons

INTRODUCTION

Open educational resources are educational materials (e.g., course textbooks, research articles, videos, assessments, simulations, etc.) that are either (a) **licensed under an open copyright license (e.g., Creative Commons)** or (b) in the **public domain**.

Wiley & Green, 2012

Image: Public domain via Wikimedia Commons

INTRODUCTION

Redistribute

Reuse

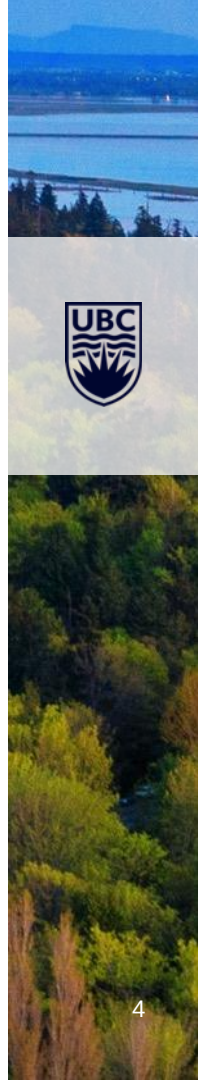
Revise

Remix

Retain

David Wiley 5 “R’s”
- 2007, 2014

http://www.opencontent.org/definition/



OPEN EDUCATION INITIATIVES

1. WeBWorK Online Homework

2. Jupyter Notebooks

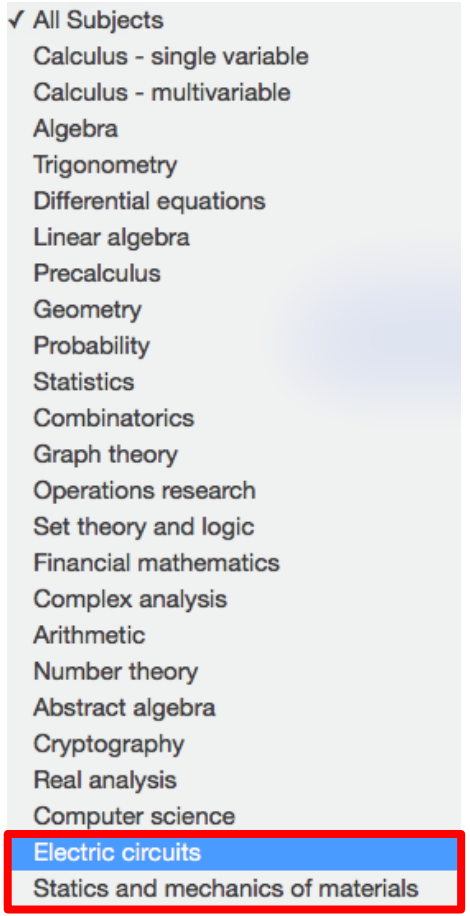
Images: WeBWorK Logo by Mathematical Association of America GNU Free Documentation License 1.2 , Cameron Oelsen [BSD (http://opensource.org/licenses/bsd-license.php)] via Wikimedia commons

WEBWORK BACKGROUND

- WeBWorK is an open-source online homework system
- Typical usage: each student assigned a unique set of numerical values, allowed multiple (up to unlimited) attempts, and given instant feedback (correct/incorrect)
- ~35,000 problems in Open Problem Library (OPL), mostly math (prior to this project, only ~260 engineering problems in three topics[1,2])
- UBC engineering students exposed to WeBWorK through math course homework in first year

- **Goal: develop WeBWorK problems in common subjects at second-year level in engineering**

Prior subject areas in WeBWorK[1]



1. WeBWorK OPL, 2. Evans 2017

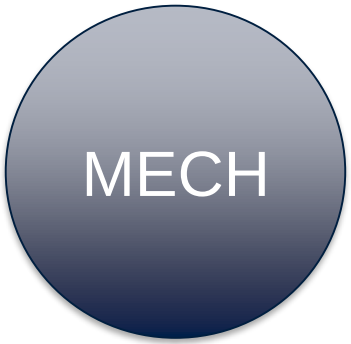
WEBWORK IN UBC ENGINEERING BEFORE THIS PROJECT

Departments working in isolation.

No (or very few) questions available openly.

No sharing of questions in courses that may have content overlap.

Electrical and Computer Engineering (EECE)



Mechanical Engineering (MECH)

Chemical and Biological Engineering (CHBE)

WEBWORK IMPACTS ON STUDENTS/INSTRUCTORS BEFORE THIS PROJECT

EECE student survey*:

88% rated their experience with WeBWorK as satisfactory

86% liked immediate feedback

78% liked the lack of cost

MECH student survey**:

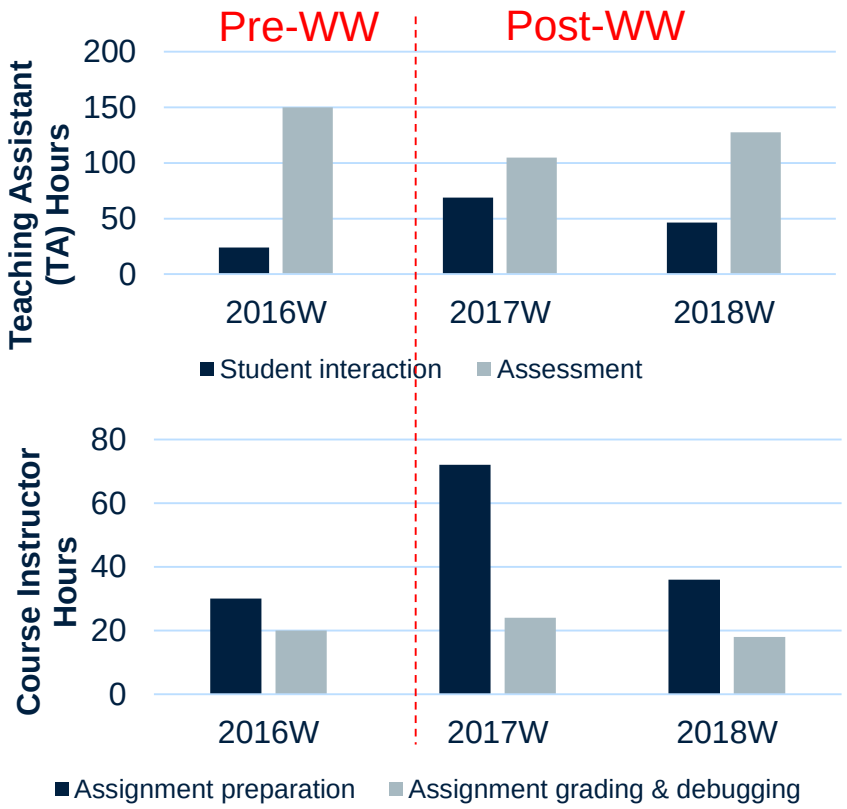
92% preferred WeBWorK to other systems

1 = Strongly disagree, 3 = Neutral, 5 = Strongly agree

Selected statements	Blackboard [mean (SD)]	WeBWorK [mean (SD)]
The **feedback** was EASY TO ACCESS	1.7 (1.0)	**4.4 (0.9)**
The **feedback** was CLEAR	1.9 (1.0)	**4.2 (1.1)**
The tool **enhanced my learning**	1.9 (1.0)	**4.5 (0.7)**
I would **like to use** the tool in the future	1.3 (0.6)	**4.7 (0.6)**

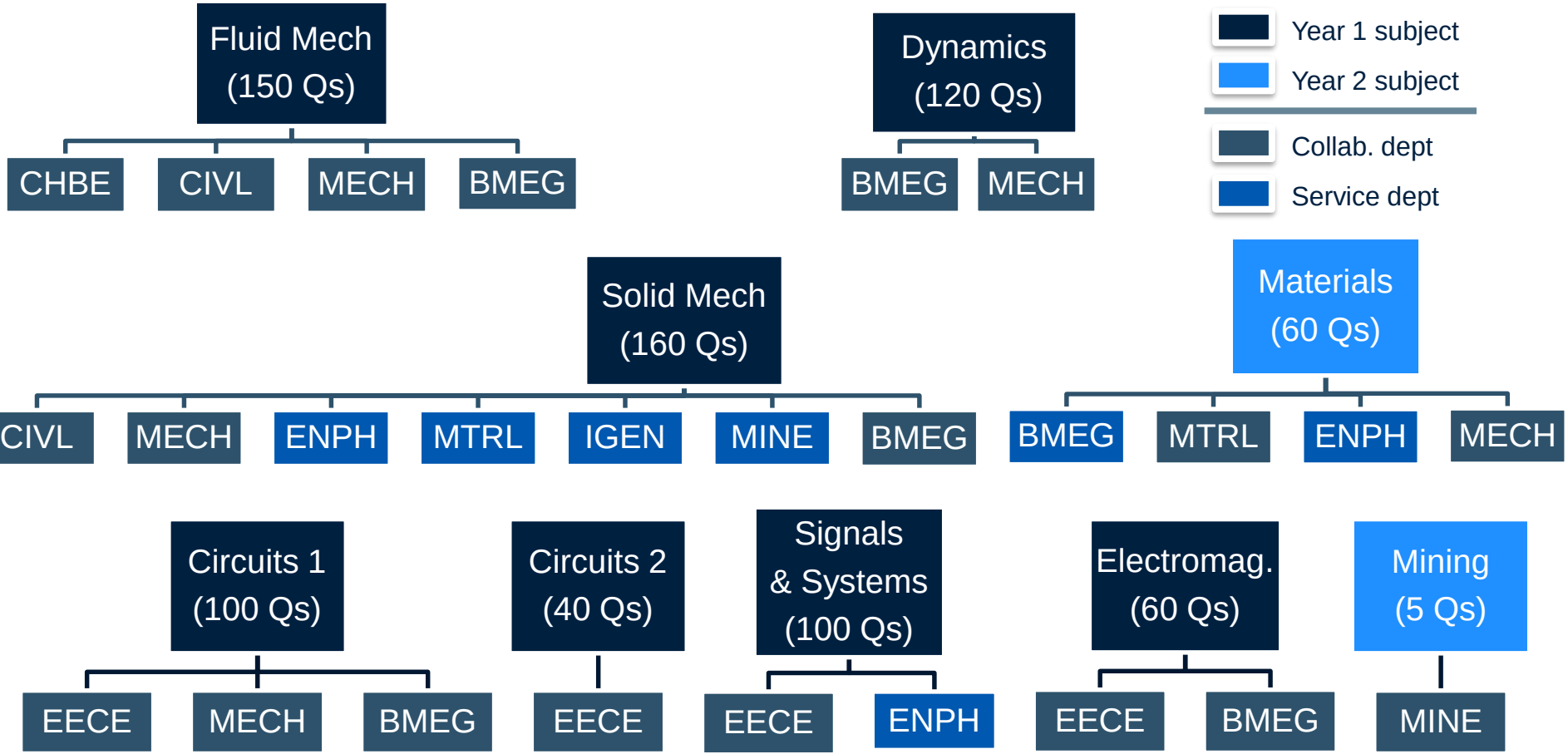
*d'Entremont, Verrett, M. Harandi, CEEA 2019; **d'Entremont et al., CEEA 2017

CHBE TA/Instructor working hours:



ENGINEERING WEBWORK PROJECT OVERVIEW

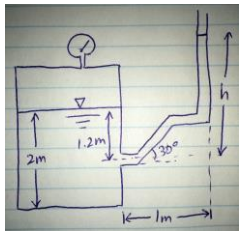
UBC TLEF $50,000
BCcampus OER $7,500



PROBLEM DEVELOPMENT PROCESS – STUDENT DEVELOPERS

Guidance from instructors → Develop problem → Create image and code problem → Check problem → Deploy to students → Support problem corrections → Upload to OPL

Subject: Fluids
Focus: General
Chapter: Pressure distribution in fluids
Section: Hydrostatic pressure distribution
Keywords: Hydrostatic pressure



Variables:
$FluidSpGrav = (0.8,2,0.06) [-]
$PressureReadingTmp = (5,10,0.25) [psig]

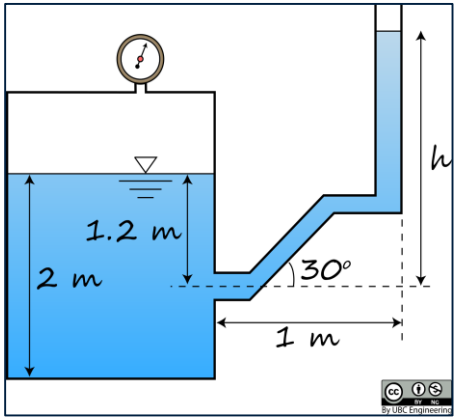
Solution formula(e):
PressureReading = $PressureReadingTmp*6894.75729
FluidDensity = 1000*$FluidSpGrav
Ans_a = (PressureReading + FluidDensity*9.81*2)/1000 [kPa]
Ans_b = (PressureReading + FluidDensity*9.81*1.2)/(FluidDensity *9.81) [m]

Problem text:
The tank shown in the figure contains a fluid with a specific gravity of $FluidSpGrav. The region above the fluid is filled with vapor. The pressure gauge located at the top of the tank indicates a reading of $PressureReadingTmp psig. (a) Determine the gauge pressure at the bottom of the tank. (b) Determine the height of the liquid column in the vertical tube?

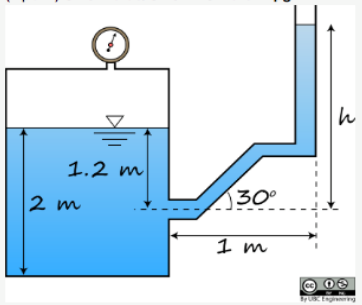
Answer text:
Answer tolerance: +/- 0.1 [m]

Does the image need to be created/recreated? Yes

Numerical check:
$FluidSpGrav = 2 [-]
$PressureReadingTmp = 10 [psig]
Ans_a = 108.188 [kPa]
Ans_b = 4.714 [m]



(1 point) **UBC Fluids/UBC-FLU-18-012.pg**

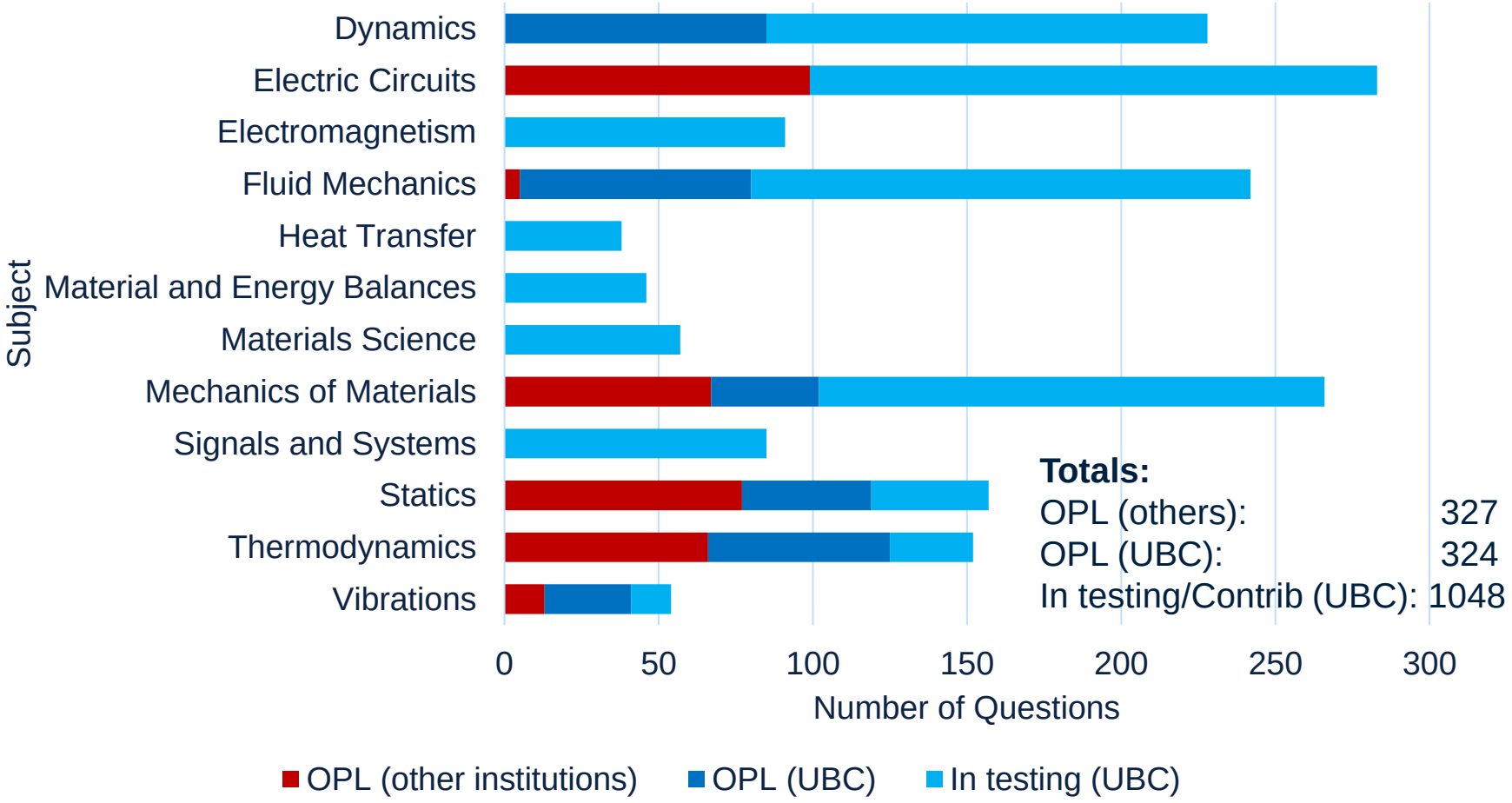


The tank shown in the figure contains a fluid with a specific gravity of 1.46. The region above the fluid is filled with vapor. The pressure gauge located at the top of the tank indicates a reading of 7.75 *psig*.

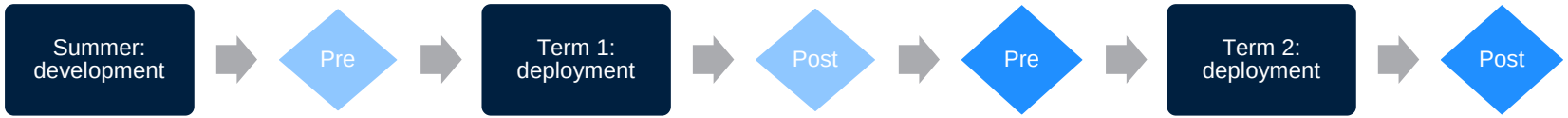
1. Determine the gauge pressure at the bottom of the tank.
2. Determine the height of the liquid column in the vertical tube.

$P_{gauge} =$ ____ *kPa*
$h =$ ____ *m*

ENGINEERING QUESTIONS IN THE OPEN PROBLEM LIBRARY (OPL)



EVALUATION



- 13 partner course sections adopted questions from this project (over both terms)
- Student pre-survey:
  - **Past experience with online homework systems (WeBWorK and others)**
  - Important aspects/features of online homework
- Student post-survey:
  - **Quality of problems, staff/instructor/TA support**
  - **Motivation and learning**
  - Interactions during course around WeBWorK questions
- Instructor feedback

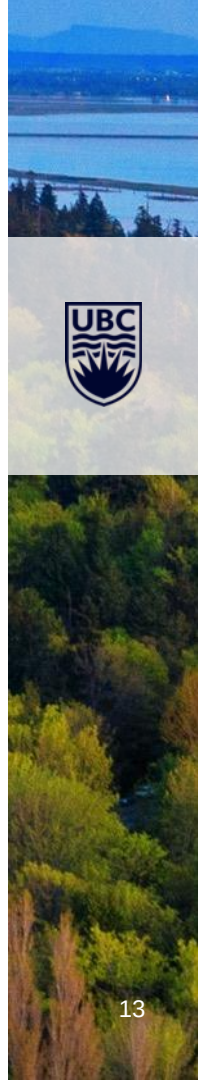
*d'Entremont, Verrett, M. Harandi, CEEA 2019

PRE-SURVEY RESULTS – WEBWORK AND OTHER OHW SYSTEMS

1 = Strongly disagree, 3 = Neutral, 5 = Strongly agree

Rate your experience with online homework systems in the past, considering the most recent time.	WeBWorK (n = 320)	Other Systems (n = 295)
The system was easy to use	**4.3***	3.7
The site was easy to navigate	**4.2***	3.7
The question presentation was clear	4.0	3.9
The required answer formats were straightforward	3.5	3.7
The feedback was clear and easy to access	3.3	**3.8***
The system enhanced my learning	**4.0***	3.7
The system motivated me to persist in finding the correct answer	**3.8***	3.6
I would like to use the system in the future	**4.0***	3.2

*Statistically significant difference (Mann-Whitney rank sum test)

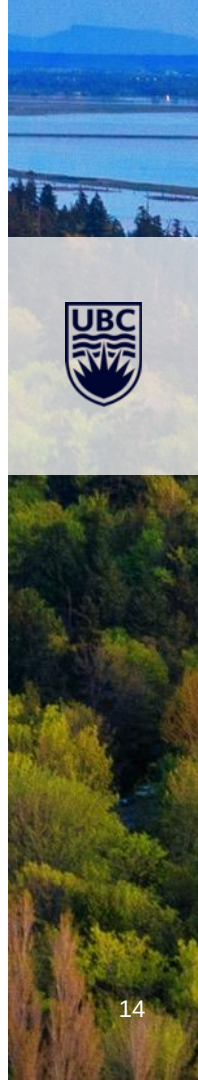


*d'Entremont, Verrett, M. Harandi, CEEA 2019

POST-SURVEY RESULTS – ABOUT NEW WW PROBLEMS

1 = Strongly disagree, 3 = Neutral, 5 = Strongly agree

Please rate how you agree or disagree with the following statements about issues with the problems you used this term.	n = 239
The problems had few errors (missing values, incorrect answers, etc.)	2.8
The problems had few issues with answer tolerances	3.1
Problem text was almost always clear and understandable	3.6
Errors or other issues with the problems were corrected quickly	3.2
The problems were at the same level of difficulty as tests/exams	2.9
The problems were more challenging than tests/exams	3.2
Images were almost always clear and understandable	4.1
The instructor(s) and/or TA(s) knew how to use the system	3.6

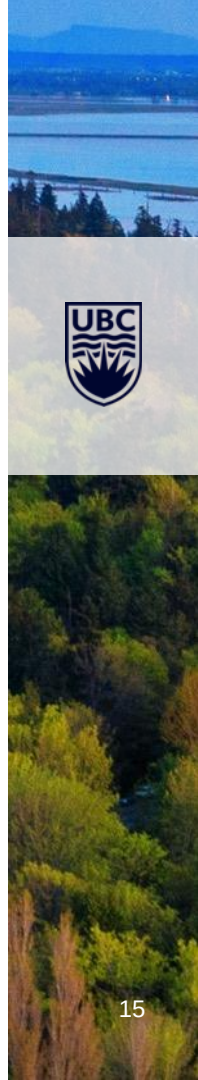


*d'Entremont, Verrett, M. Harandi, CEEA 2019

POST-SURVEY RESULTS – MOTIVATION AND LEARNING

1 = Strongly disagree, 3 = Neutral, 5 = Strongly agree

How did WeBWorK impact your studies this term in your engineering courses?	n = 237
I was motivated to attempt to solve all problems that counted for marks	4.3
I was motivated to attempt to solve all problems that did not count for marks	2.9
I was motivated to successfully complete all problems that counted for marks	4.2
I was motivated to successfully complete all problems that did not count for marks	2.7
I was motivated to correct my errors in understanding	3.8
I expect using WeBWorK will help me to be well prepared for the final exam in this course	3.8
I enjoyed using WeBWorK	3.4
I believe WeBWorK enhanced my learning	4.0

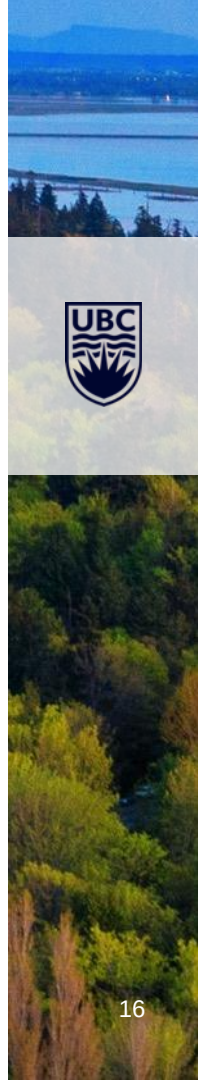


BENEFITS/STRENGTHS

- **Positive instructor response** to system/problems overall
- **Reduced marking** time, **more formative feedback** for students
- **Shared problems**, with the ability to adapt them
- **On-call support** for new problems helpful (quick corrections)
- Scripts for **automated conversion** from other problem systems

CHALLENGES/SUPPORT THAT WOULD HAVE HELPED

- Time to create/implement/test 1 problem: ~1.5-2 hours
- Making shareable graphics (copyright and licensing)
- **Errors** in code, correct **tolerances** for final answer
- **More funds** (testing, error identification for students)
- **Support for instructor time** to create
- Co-creation opportunities with students
- Better documentation for WeBWorK /expertise on coding within UBC



JUPYTER NOTEBOOKS

- Develop interactive learning materials for computationally heavy course topics
- Reactor design and process control in year 3 term 2
- Notebooks integrate text, code, images into an easy to copy and manipulatable format for students to use in tutorials, assignments, projects, etc.

$$x_1 + x_2 + x_3 = 10 \; 2x_1 + x_2 + x_3 = 5 \; -x_1 + 2x_2 + 4x_3 = 4$$

In Math 152 (or any equivalent introductary linear algebra course) you may have learned to solve this using Gaussian elimination and back-substitution. However, all these steps can be easily bypassed by using Python's built-in functions:

$$A = \begin{bmatrix} 1 & 1 & 1 \\ 2 & 1 & 1 \\ -1 & 2 & 4 \end{bmatrix}, b = \begin{bmatrix} 10 \\ 5 \\ 4 \end{bmatrix}$$

The solution is $A^{-1}b$ which we now compute.

In [56]:
```
# Import relevant packages
%matplotlib inline
import matplotlib.pyplot as plt # for plots
import numpy as np # for most computations
```

Implementation:

- Server: syzygy.ca
- Local: Anaconda

Introductory materials:

- 6 tutorial notebooks to introduce students to Python and relevant functions for solving a variety of mathematical systems.

Available at: github.com/OpenChemE/Tutorials-2018W2

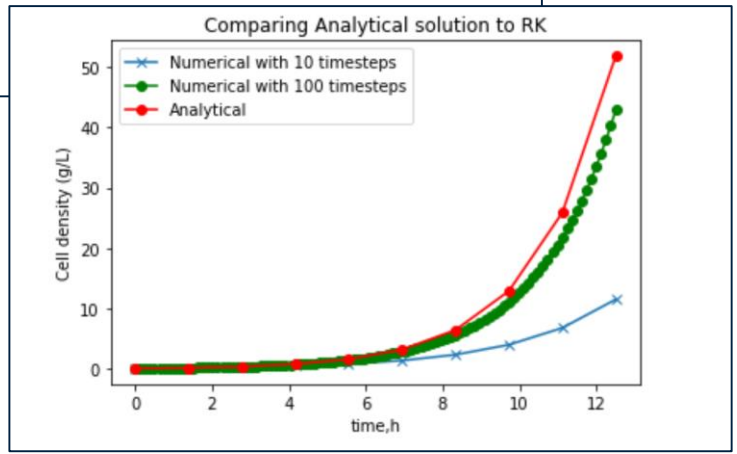
Comparing Analytical solutions with Numerical Solver

Using the Cellular biomass equation as a test, we observe the efficacy of the simplest Runge kutta method.

$$X_{i+1} = X_i + \mu_g X_i \Delta t$$

and compare it with the known analytical solution.

$$X = X_0 e^{\mu_g (t - t_0)}$$



PROCESS CONTROL

Notebooks for:

- 6 tutorials
- 1 take home assignment
- 1 final project

Available at:

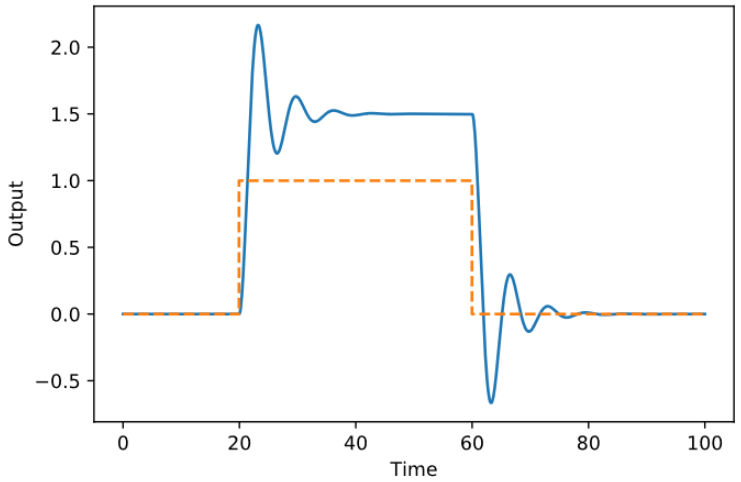
github.com/OpenChemE/CHBE356

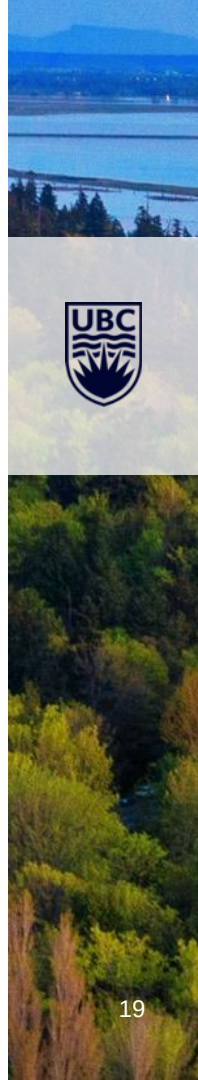
In [82]:

```
# Generate a step response
T = np.linspace(0,100,1000)

# Our input is one between t=20 and t=60
U = np.zeros(len(T))
U[200:600] = 1

t, yout, _ = control.forced_response(G_s, T, U)

# Plot
plt.figure()
plt.xlabel('Time')
plt.ylabel('Output')
plt.plot(t,yout)
plt.step(t,U, linestyle='--')
```

Out[82]:

```
[<matplotlib.lines.Line2D at 0x11e2085c0>]
```





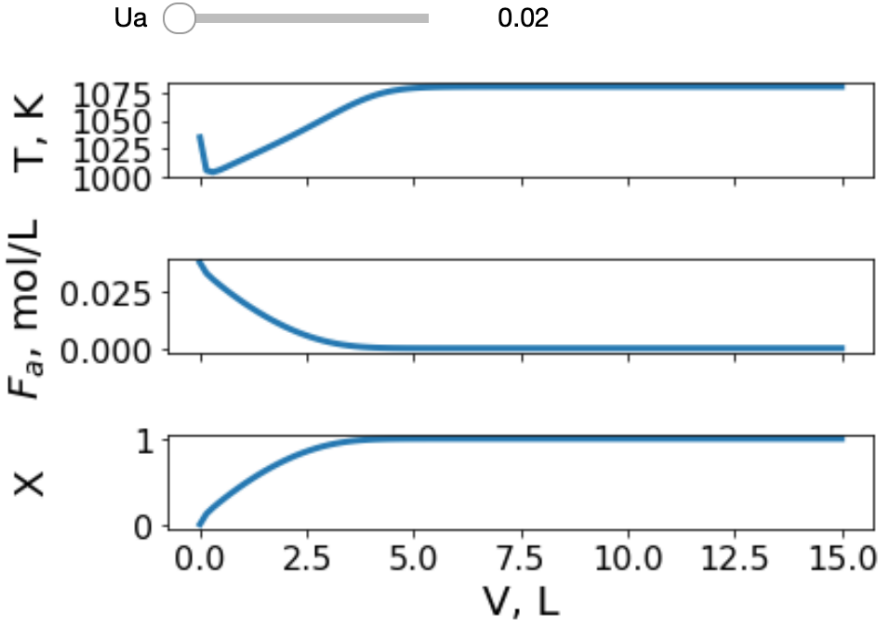
REACTION ENGINEERING

Notebooks for:

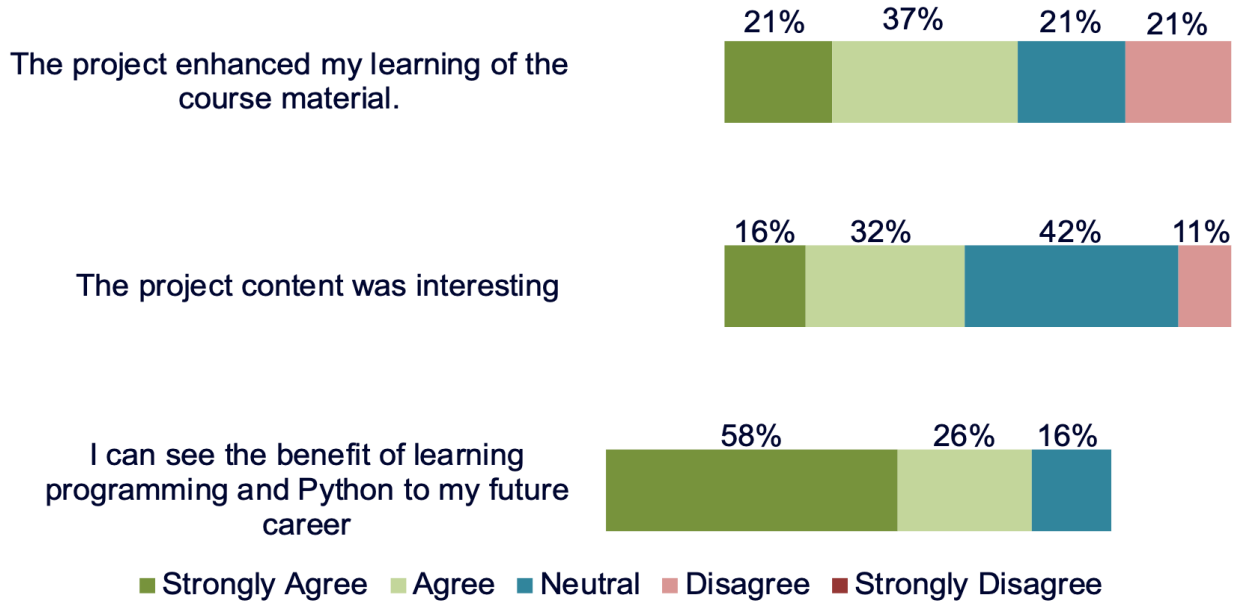
- 6 tutorials
- 2 take home assignments
- 1 final project

Available at:

github.com/OpenChemE/CHBE355



STUDENT FEEDBACK



ACKNOWLEDGEMENTS

WEBWORK

Project co-leads: Dr. Agnes d'Entremont (MECH), Dr. Negar M. Harandi (ELEC), Dr. Jonathan Verrett (CHBE). This work was completed on the traditional, ancestral, and unceded territory of the Musqueam people.

Funding

- UBC Vancouver students via the Teaching and Learning Enhancement Fund
- BCcampus
- UBC Applied Science Dean's Office

Thanks

- UBC APSC Centre for Instructional Support
- Instructors, academic assistants, and staff involved
- Gianni Co, coder and graphics-maker
- The UBC engineering students who used our new problems (2018-2019)

All posted UBC WeBWorK problems:
tinyurl.com/UBCWW

JUPYTER NOTEBOOKS

Project lead: Dr. Jonathan Verrett

Process Control: Dr. Yankai Cao, Dr. Bhushan Gopaluni, Student developers: Y. Tsai (lead), S. Lim, S., N.T. Lo, E.Q. Shen.

Reactions: Dr. Vikramaditya Yadav. Student developers: V. Triandafilidi (lead), T. Kritharis, N. Ioannidis.

This work was completed on the traditional, ancestral, and unceded territory of the Musqueam people.

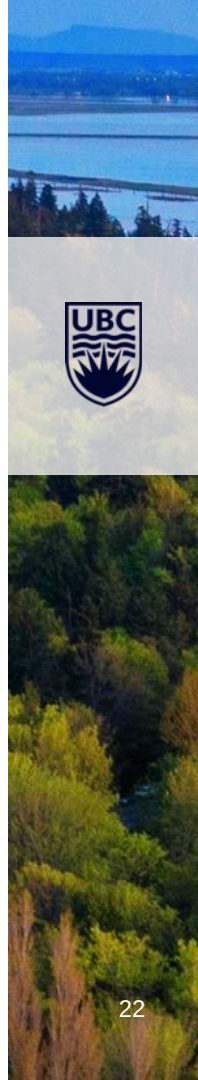
Funding

- UBC Vancouver students via the Teaching and Learning Enhancement Fund

Thanks

- UBC Department of Chemical and Biological Engineering
- The UBC CHBE students (2018-2019)

Repository for these notebooks, and other UBC CHBE open projects:
github.com/OpenChemE



RESOURCE LINKS

WeBWorK

All posted UBC problems:
tinyurl.com/UBCWW

Statics problems converted:
tinyurl.com/WhatcomStatics

Fluid mechanics problem converted:
tinyurl.com/QueensFluids

OpenStax Physics (Brock):
tinyurl.com/BrockOpenStaxPhysics

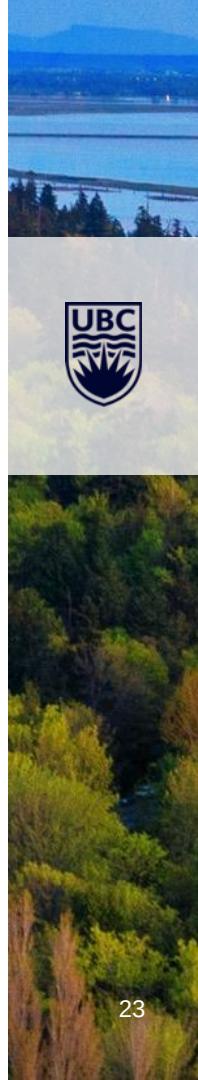
Jupyter

Main repository:
github.com/OpenChemE/

Introductory notebooks:
github.com/OpenChemE/Tutorials-2018W2

Process Control:
github.com/OpenChemE/CHBE356

Reactions Engineering:
github.com/OpenChemE/CHBE355




a place of mind
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