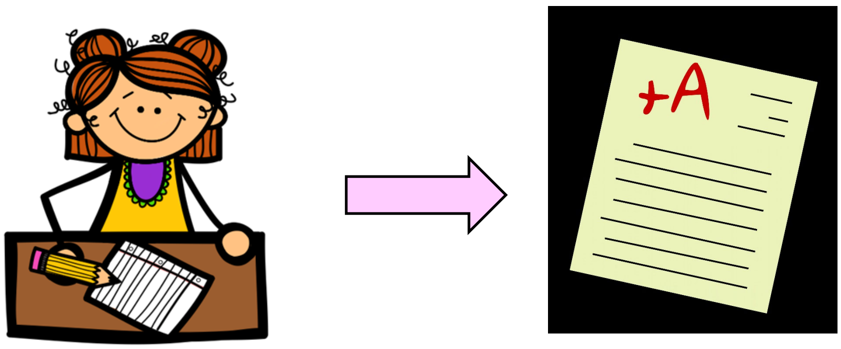
How did Exam 2 go?



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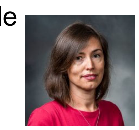
Professional Program Application

- Due **Nov. 18, 2022** to Lavdie Huff (ChE UG Advisor)
- You will receive an add code for ChEn 374 from Lavdie **after you turn in the application**
  - The sooner the better
  - https://chemicalengineering.byu.edu/undergraduate/apply-to-the-professional-program

Step 1. Sister Huff wants to see your forms and planned schedule



- Grades in pre-professional classes
  - Put grade you expect in current classes in parentheses (A+)
- Excel file to plan all classes to graduation
  - Specific elective class plans (make sure it is offered in the semester you want to take it)

Step 2. You must then see your faculty advisor

- Talk about grades and career goals

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Class 23

Introduction to Energy

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Where Are We Going?

- Today
  - Conservation of Energy
    - Kinetic
    - Potential
    - Internal
    - Work
    - Heat
  - Closed Systems
- Next time
  - Open Systems
  - Steam Tables
    - Temperature
    - Energy level

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Please bring your textbooks to class the rest of the semester!

There are lots of tables and charts to learn about!

At least print the tables and charts in Appendix B and bring them to class

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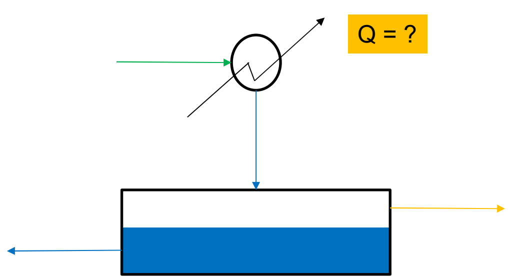
A. Perspective: Where are we going?

Consider a partial condenser



Now we have to worry about how much heat was removed!

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B. Energy Concepts

- Total Energy is conserved
  - 1^{st} Law of Thermodynamics
- Energy can transform from one form to another

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C. Forms of Energy

- Kinetic energy $E_k = \frac{1}{2}mv^2$
- Potential energy $E_p = mgh$
- Internal energy $U = f(T, etc.)$
  - More complicated
  - May also be f(P or V)
  - Measure of kinetic and potential energy of molecules

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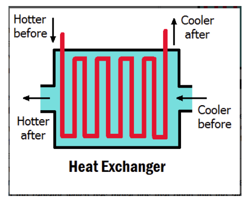
D. Closed vs Open Systems

Closed System

- No mass crosses a boundary
  - Sealed container or piston
  - Energy can cross boundary!
  - $\dot{m}_{in} = \dot{m}_{out} = 0$
- Heat and work can cross boundary

Open System

- Mass crosses a boundary
  - Like a pipe or distillation column
  - $\dot{m}_{in} = \dot{m}_{out}$ at steady state



E. Heat and Work

- **Heat**
  - Energy flow caused by ΔT
  - Q = positive when transferred <u>to</u> the system <u>from</u> the surroundings
  - Q = 0 means adiabatic
- **Work**
  - Sign is different in every book
  - Positive when work is done on the system by the surroundings (4th Ed.)
    - 3rd edition of text has positive when work done on the surroundings!
  - Types of work:
    - Shaft (pump, compressor)
    - Electrical
    - Flow
    - PV work (mechanical piston)

F. Closed System Energy Balance

- Principle: Energy cannot be created or destroyed

$$accum = in - out + \cancel{gen} - \cancel{cons}$$

- We usually deal with energy transfer, which means change in energy

change in energy = energy in – energy out

energy transferred to the system = initial energy – final energy

$$\Delta U + \Delta E_k + \Delta E_p = Q + W$$

Internal energy	Kinetic energy	Potential energy	Heat transferred to system	Work performed on system

G. Units of Energy

- cal or kcal
  - 1 kcal = energy to raise 1 kg H_2O(liq) by 1°C
  - 1 cal = 4.184 J
- SI: Joules or KJ
  - ergs in CGS
  - 1 J = 1 N·m = 1 kg m^2/s^2
- American: Btu, ft·lb_f, kW·hr
  - 1 Btu = energy to raise 1 lb_m H_2O(liq) by 1°F
    - British thermal unit
    - 1 Btu = 1054 J
  - About the energy of one lighted match

Application of Closed System Energy Balance

- Carefully read the problem statement
- Evaluate which terms in the energy balance are zero

$$\Delta U + \Delta E_k + \Delta E_p = Q + W$$

- Write simplified equation
- Plug in known values and solve for desired unknown

Note: The sign in front of the work term is positive in the 4^{th} Ed., but negative in the 3^{rd} Ed.!!!
I will use the sign convention in the 4^{th} Ed.

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Terms

- **Isothermal:** constant temperature
  - Q may not be zero
  - Example: exothermic reaction, but keep T = constant
    - Heat must be taken away in order to keep the temperature constant, so Q for the system is negative
- **Adiabatic:** Q = 0
  - No heat transferred through boundary
  - Temperature in the system may change
    - Exothermic reaction would raise the temperature

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Example 1

A gas cylinder contains N_2 at 200 atm and 80°C. As a result of cooling at night, the pressure in the cylinder drops to 190 atm and the temperature to 30°C.

$$\Delta U + \Delta E_k + \Delta E_p = Q + W$$

Which of the terms in the energy equation are zero?

(ΔE_k, ΔE_p, W)

For the non-zero terms, are their values positive or negative?

Q = negative

ΔU = Q (negative)

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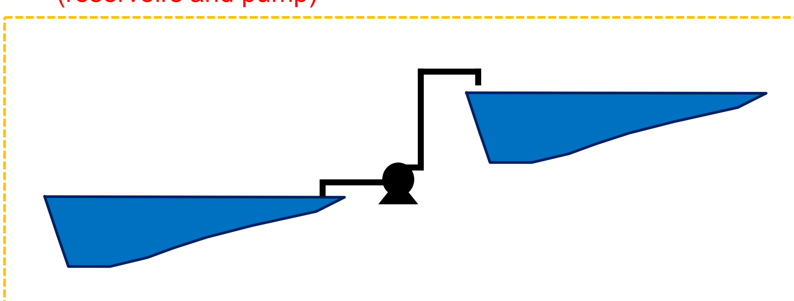
Example 2

Water is pumped from one reservoir to another 300 ft away. The water level in the second reservoir is 40 ft above the water level of the first reservoir. How much work per mass of water was performed?

What is the system?

(reservoirs and pump)



As defined here, is this an open or closed system?

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Example 2 (cont)

Water is pumped from one reservoir to another 300 ft away. The water level in the second reservoir is 40 ft above the water level of the first reservoir. How much work per mass of water was performed?

$$\Delta U + \Delta E_k + \Delta E_p = Q + W$$

Which terms are zero? Why? (ΔU, ΔE_k, Q)

What is the simplified form of the energy balance?

$\Delta E_P = W = mgh$

How was the work performed? Pump

What is the answer in Btu/lb_m? $W/m = g\Delta h$

$$\frac{W}{m} = \frac{\left(32.2\frac{ft}{s^2}\right)(40\ ft)}{\left(32.2\frac{lb_m ft}{lb_f s^2}\right)}\left(\frac{9.486\times10^{-4}\ Btu}{0.7376\ ft\cdot lb_f}\right) = 0.0514\ Btu/lb_m$$

$$= 1.51\times10^{-5}\ \frac{kW\cdot hr}{lb_m}$$

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Example 2 (cont)

How much energy is needed to raise the level in the upper reservoir by 1 ft if the surface area is 8 square miles?

$$m = \left(62.4\frac{lb_m}{ft^3}\right)(8 sq\ miles)(1\ ft)\left(\frac{5280\ ft}{mile}\right)^2 = 1.392\times10^{10}\ lb_m$$

$$W = \left(1.392\times10^{10}\ lb_m\right)\cdot\left(1.51\times10^{-5}\ \frac{kW\cdot hr}{lb_m}\right) = 2.097\times10^5\ kW\cdot hr$$

$$\$\$ = \left(2.097\times10^5\ kW\cdot hr\right)\cdot 8.5\frac{cents}{kW\cdot hr} = \$17,820$$

Assumes 100% pump efficiency!

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Example 2

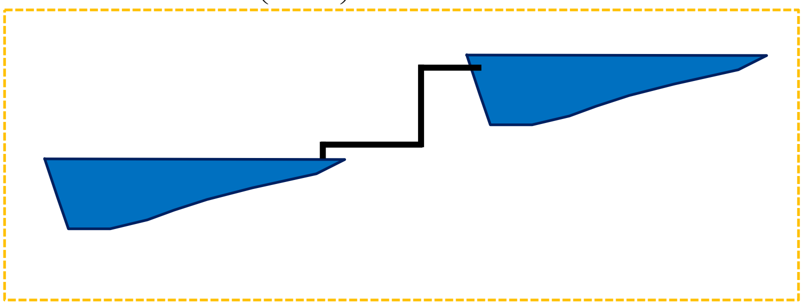
What about just letting water flow downhill?

Where does the energy go?

Friction causes slight increase in water temperature (ΔU)

$\Delta U + \Delta E_p = 0$

$$\left(0.514\ Btu/lb_m\right)\cdot\left(\frac{lb_m\ ^\circ R}{1.0\ Btu}\right) = 0.0514^\circ F$$



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Problems 7.5 & 7.6

Work on Whiteboard

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Problem 7.6 (7.5 3rd Ed.)

Air at 300°C and 130 kPa flows through a horizontal 7-cm ID pipe at a velocity of 42.0 m/s.

- Calculate $\dot{E}_k$ in Watts, assuming ideal gas behavior.
- If the air is heated to 400°C at constant pressure, what is $\Delta\dot{E}_k$ (=$\dot{E}_k$(400°C) - $\dot{E}_k$(300°C))?
- Why would it be incorrect to say that the rate of transfer of heat to the gas in part (b) must equal the rate of change of kinetic energy?

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Problem 7.7 (7.6 in 3rd Ed.)

Suppose you pour a gallon of water on a yowling cat 10 ft below your bedroom window.

- How much potential energy (in ft-lb_f) does the water have?
- How fast is the water traveling (in ft/s) just before impact?
- True or false: Energy must be conserved, therefore the kinetic energy of the water before impact must equal the kinetic energy of the cat after impact.

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