ROSE-HULMAN Institute of Technology
Sophomore Engineering Curriculum

ES201 –Conservation & Accounting Principles — Winter 2015-2016

Section: □ 01 (1st period)
□ 02 (2nd period)

Name ______________________

CM ______________________

Exam 3

Feb 11, 2016

Problem 1	______/ 20
Problem 2	______/ 40
Problem 3	______/ 40
Total	______/ 100

Rules:
- Closed book/notes exam. (Unit conversion page provided)
- Help sheet allowed. (8-1/2 x 11" sheet of paper, one side, handwritten)
- Laptops may be used for computational purposes only; no pre-prepared worksheets or files may be used.

Instructions:
- Show all work for complete credit.
- Start all problems at the **analysis** stage, but clearly label any information you use for your solution.

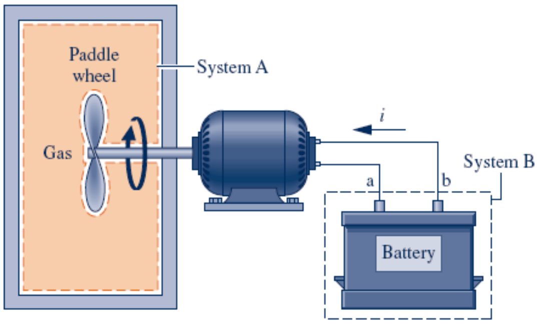
Fail bomb!

Problems involving conservation principles **must clearly identify the system in a separate drawing and show a clear, logical progression from the basic principle; otherwise no credit will be given.**

- Don't expect us to read your mind as to how or why you did something in the solution. Clearly indicate how you arrived at your answer.
- **Always crunch numbers last on an exam**. The final numerical answer is worth the least amount of points. (Especially if all I would have to do is plug in the numbers into a well-documented solution.)

Problem 1 [20 pts]

(a) [8 pts] Consider System A in the figure below, comprising only the gas. The chamber containing the gas is heavily insulated. Indicate whether the following quantities are positive, negative or zero for system A undergoing a process:,



i. [2 pts] Heat transfer to system A:

$Q_{in} < 0$ | $Q_{in} = 0$ | $Q_{in} > 0$

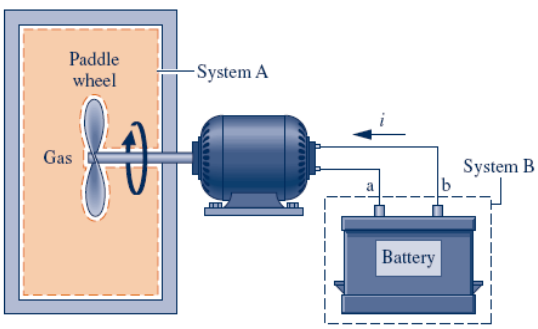
ii. [3 pts] Work transfer to system A:

$W_{in} < 0$ | $W_{in} = 0$ | $W_{in} > 0$

iii. [3 pts] $U_f - U_i$ for system A undergoing a process from state i to state f:

$U_f - U_i < 0$ | $U_f - U_i = 0$ | $U_f - U_i > 0$

(b) [5 pts] System B, the battery, does not exchange heat with the surroundings. Indicate whether the following quantities are positive, negative or zero for System B undergoing a process::,



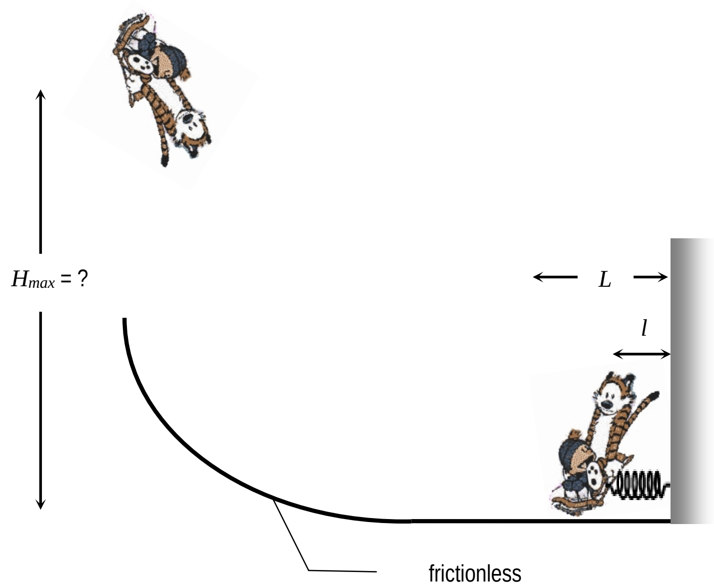
i. [2 pts] Work transfer to system B:

$W_{in} < 0$ | $W_{in} = 0$ | $W_{in} > 0$

ii. [3 pts] $U_f - U_i$ for system B undergoing a process from state i to state f.

$U_f - U_i < 0$ | $U_f - U_i = 0$ | $U_f - U_i > 0$

(c) [7 pts] Calvin and Hobbes use a massless spring with spring constant k to propel themselves up a ramp. The spring has an upstretched length L and is initially compressed to length l. The ramp is frictionless and Calvin and Hobbes have a combined mass of m.



i. [3 pts] What is the maximum height H_{max} that Calvin and Hobbes can be propelled to?

- o $H_{max} = \frac{k}{2mg}(L-l)^2$
- o $H_{max} = \frac{k}{2mg}(L^2-l^2)$
- o $H_{max} = \frac{k}{2mg}l^2$
- o None of the above

ii. [4 pts] What is the maximum speed Calvin and Hobbes attain?

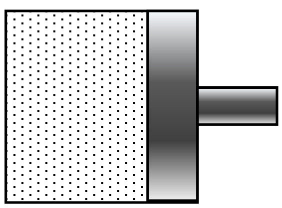
- o $V_{max} = \sqrt{\frac{k}{m}} \cdot (L-l)$
- o $V_{max} = \sqrt{2gH_{max}}$
- o Both of the above
- o None of the above

Problem 2 [40 pts]

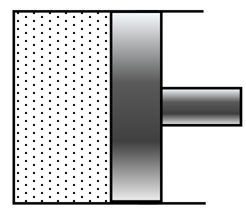
A piston-cylinder contains a mass m of air initially at T_1 and P_1. The air is then heated and expands to a volume of $\forall_2$ in a process for which $P/\forall$ = constant. Changes in kinetic and potential energy are negligible. Air can be modeled as an ideal gas with constant specific heats and ideal gas constant of c_v, c_p, and R, respectively.

(a) Find the <u>initial volume of the air</u>, $\forall_1$.
(b) Sketch the process on a P-$\forall$ diagram and calculate the <u>work into or out of the air</u>, $W_{1\to2}$.
(c) Find the <u>final pressure and temperature</u>, P_2 and T_2.
(d) Find the <u>heat transfer into or out of the air</u>, $Q_{1\to2}$.

(1) From (1) to (2) P/V = constant **(2)**



m = ✓
P_1 = ✓
T_1 = ✓
$\forall_1$ = ?



m = ✓
P_2 = ?
T_2 = ?
$\forall_2$ = ✓

Problem 3 [40 pts]

Consider a water pump that receives a steady stream of liquid water at 25°C, 100 kPa and delivers it to a same-diameter short pipe. The pressure at the exit of the pump (section 2) is 600 kPa. The water then enters a nozzle with negligible velocity. The water exits the nozzle to an atmosphere of 100 kPa. Neglect the kinetic energy in the pipes and assume that the water temperature remains constant throughout. For water ρ = 1000 kg/m³ and c = 4.13 kJ/kg·K.

(a) Find the mass flow rate if the pump draws 1 kW of power.
(b) Find the exit velocity of the nozzle, V_3.
(c) Find the exit diameter of the nozzle, D_3.