ES201 - Examination II　　　　Fall 2009-2010　　　　$8^{th}/9^{th}$ hours

NAME____　　　SECTION______________

BOX NUMBER__________

Problem 1　　(25)　　________________

Problem 2　　(37)　　________________

Problem 3　　(38)　　________________

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Total　　(100)　　________________

INSTRUCTIONS

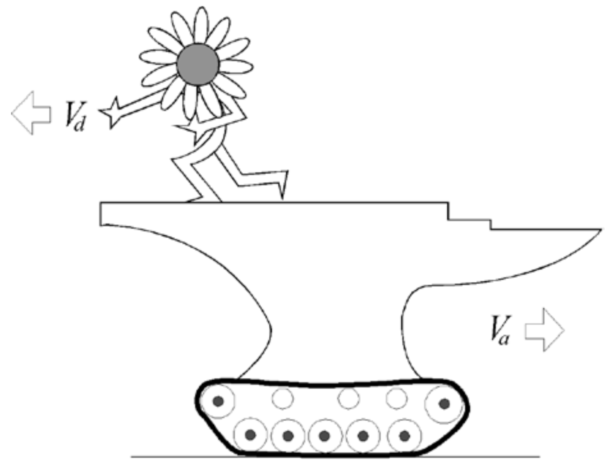
- **Closed book/notes exam. (Unit conversion page provided)**
- **Help sheet allowed. (8-1/2 x 11" sheet of paper, one side)**
- **Laptops may be used; however, no pre-prepared worksheets or files may be used.**
- **Ceci n'est pas un examen. Ceci n’est pas un test.**

1) Show all work for complete credit.
    - Start all problems at the ANALYSIS stage, but clearly label any information you use for your solution.
    - **Problems involving conservation principles MUST CLEARLY IDENTIFY THE SYSTEM IN A SEPARATE DRAWING and show a clear, logical progression from the basic principle.**
    - Don't expect us to read your mind as to how or why you did something in the solution. Clearly indicate how your 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.)
2) Useful Rule of Thumb (Heuristic): (100 point exam)/(50 min) = 2 points/minute. That means a 10 point problem is not worth more than 5 minutes of your time (at least the first time around).
3) Please remain seated until the end of class or everyone finishes. (Raise your hand and I’ll pick up your exam if you have other work you need or want to do.)

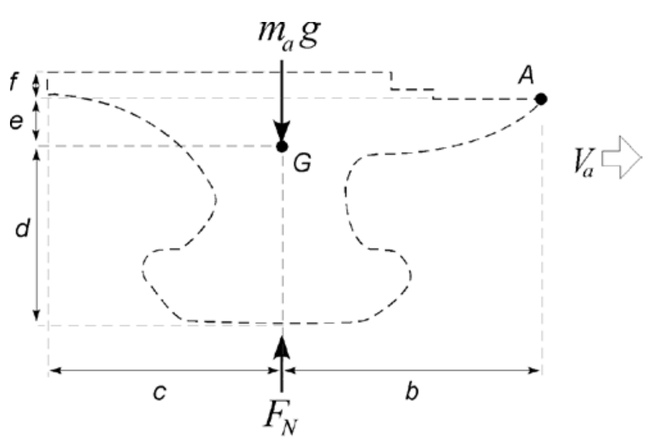
USEFUL INFORMATION	SI	USCS	Molar Mass	
Ideal Gas Constant: R_u	= 8.314 kJ/(kmol-K)	= 1545 (ft-lbf)/(lbmol-°R)	Air	28.97
		= 1.986 Btu/(lbmol-°R)	O_2	32.00
Standard Acceleration of Gravity: g	= 9.810 m/s^2	= 32.174 ft/s^2	N_2	28.01
Density of liquid water	= 1000 kg/m^3	= 62.4 lbm/ft^3	H_2	2.016
		= 1.94 slug/ft^3	CO_2	44.01

Problem 1 (25 pts)

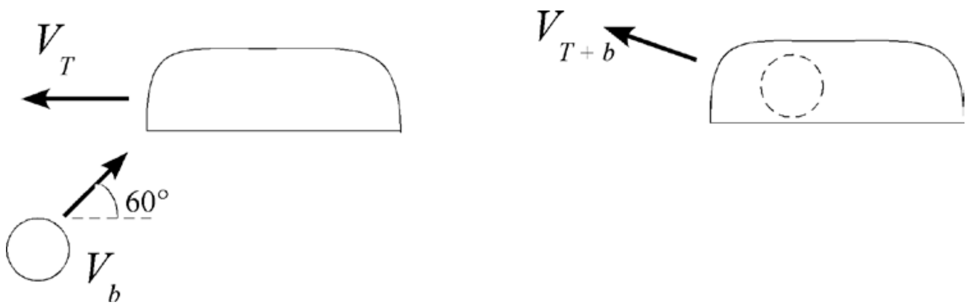
a) A daisy with mass m_d leaps off on an initially stationary anvil of mass m_a (with remarkable, frictionless tank treads) with a relative velocity, V_d. What is the resulting velocity, V_a, of the anvil to the right after the daisy jumps off?



b) After the daisy jumps off, the anvil continues moving to the right with velocity V_a. For the anvil system shown below, what is the angular momentum of the anvil about point A?



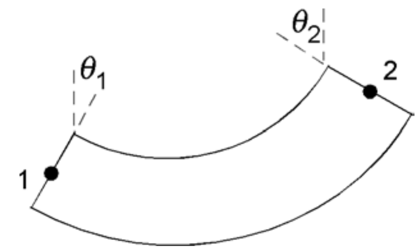
c) A Twinkie of mass $m_T = 55g$ launched by a rock candy ballista with a horizontal velocity $V_T = 3\ m/s$ is the first shot in the junk food assault on the vegetable kingdom. In defense, a leading unit of cruciferous vegetables launches a brussels sprout of mass $m_b = 25g$ to impact (and therefore intercept) the Twinkie. The brussels sprout travels upward at a velocity of $V_b = 2\ m/s$ and at an angle of 60 degrees relative to the horizontal. After the impact, the brussels sprout is embedded in the Twinkie and the combined mass has a horizontal velocity $V_{T+b,x} = 1.75\ m/s$ and a vertical velocity of $V_{T+b,y} = 0.541\ m/s$, with the directions indicated in the figure below.



What is the impulse in the y-direction delivered to the Twinkie by the impact with the brussels sprout?

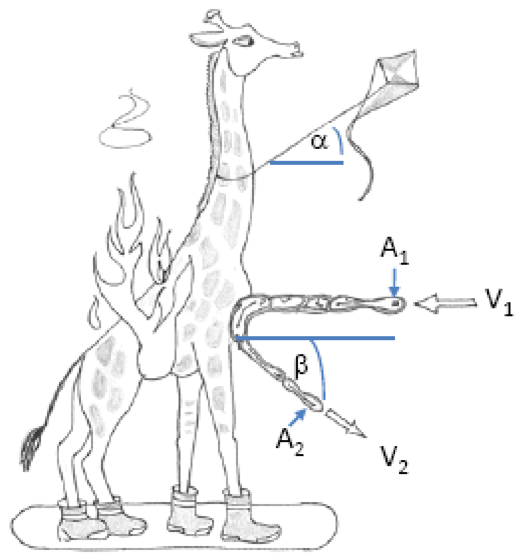
d) A pixie blows fairy dust (at location 1, pixie not shown, since invisible) through a piece of elbow macaroni to sprinkle the forest floor. The density of the fairy dust is ρ_d, moving at a velocity at the inlet of V_1, and the elbow is surrounded by atmospheric pressure. While the pixie is blowing, the pressure at 1 is P_1 and the pressure at P_2 is open to atmosphere. The macaroni areas are A_1 and A_2, respectively, and the relative angles of the macaroni openings are indicated on the figure below.

What is the net effect of pressure acting on the piece of elbow macaroni in the horizontal direction?



Problem 2 (37 pts)

A flaming giraffe (of mass m_g), is riding a snowboard (mass m_s) and flying a kite (exerting a force F_k at an angle α) whilst being impacted by a stream of liquid clocks (entering horizontally and exiting at an angle β). Assume that the density of the clocks is ρ_c, the liquid clock inlet area is A_1, the inlet velocity is V_1, the exit area is A_2, the exit velocity is V_2.



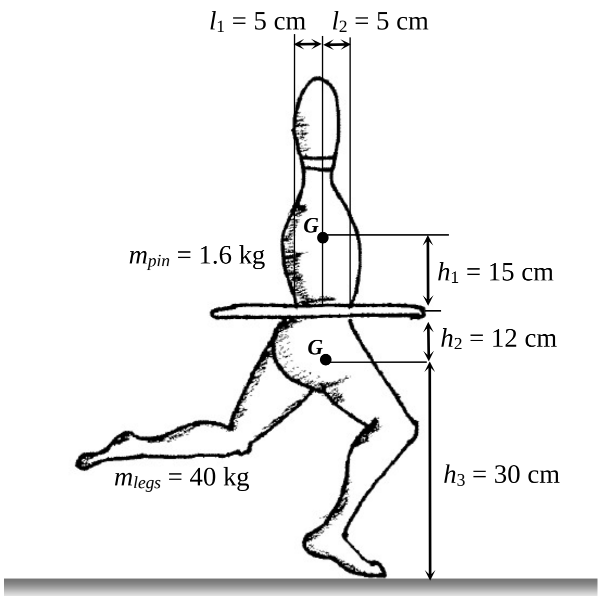
a) Find the minimum coefficient of friction between the snowboard and the ground necessary to keep the giraffe (and snowboard) stationary.

b) What is the net rate of linear momentum transfer due only to the liquid clock mass flow?

Problem 3 (38 pts)

In a Salvador Dali painting, a silver dinner tray has grown legs and starts running with a bowling pin on top of the tray. The coefficients of static and kinetic friction between the pin and the tray/legs are $\mu_s = 0.30$ and $\mu_k = 0.22$, respectively. The dimensions and masses of the tray/legs and bowling pin are shown in the figure.

a) Find the maximum acceleration of the legs so that the bowling pin does not slip on the tray.
b) Find the maximum acceleration of the legs so that the bowling pin does not tip over.
c) Assume that the pin tips before it slips, and that the value of the acceleration at which tipping occurs is 2.1 m/s^2 *(It isn't)*. For this acceleration,
   i. find the value of the force the ground exerts on the foot, and
   ii. find the value of the frictional force between the tray and the bowling pin.



Length

1 ft = 12 in = 0.3048 m = 1/3 yd

1 m = 100 cm = 1000 mm = 39.37 in = 3.2808 ft

1 mile = 5280 ft = 1609.3 m

Mass

1 kg = 1000 g = 2.2046 lbm

1 lbm = 16 oz = 0.45359 kg

1 slug = 32.174 lbm

Temperature Values

(T/K) = (T/ ºR) / 1.8

(T/K) = (T/ ºC) + 273.15

(T/ºC) = [(T/ ºF) – 32]/1.8

(T/ºR) = 1.8(T/K)

(T/ºR) = (T/ ºF) + 459.67

(T/ ºF) = 1.8(T/ ºC) + 32

Temperature Differences

$(\Delta T/{}^{o}R) = 1.8(\Delta T / K)$

$(\Delta T/{}^{o}R) = (\Delta T/{}^{o}F)$

$(\Delta T / K) = (\Delta T/{}^{o}C)$

Volume

1 m^3 = 1000 L = 10^6 cm^3 = 10^6 mL = 35.315 ft^3 = 264.17 gal

1 ft^3 = 1728 in^3 = 7.4805 gal = 0.028317 m^3

1 gal = 0.13368 ft^3 = 0.0037854 m^3

Volumetric Flow Rate

1 m^3/s = 35.315 ft^3/s = 264.17 gal/s

1 ft^3/s = 1.6990 m^3/min = 7.4805 gal/s = 448.83 gal/min

Force

1 N = 1 kg·m/s^2 = 0.22481 lbf

1 lbf = 1 slug·ft/s^2 = 32.174 lbm·ft/s^2 = 4.4482 N

Pressure

1 atm = 101.325 kPa = 1.01325 bar = 14.696 lbf/in^2

1 bar = 100 kPa = 10^5 Pa

1 Pa = 1 N/m^2 = 10^{-3} kPa

1 lbf/in^2 = 6.8947 kPa = 6894.7 N/m^2

[lbf/in^2 often abbreviated as “psi”]

Energy

1 J = 1 N·m

1 kJ = 1000 J = 737.56 ft·lbf = 0.94782 Btu

1 Btu = 1.0551 kJ = 778.17 ft·lbf

1 ft·lbf = 1.3558 J

Energy Transfer Rate

1 kW = 1 kJ/s = 737.56 ft·lbf/s = 1.3410 hp = 0.94782 Btu/s

1 Btu/s = 1.0551 kW = 1.4149 hp = 778.17 ft·lbf/s

1 hp = 550 ft·lbf/s = 0.74571 kW = 0.70679 Btu/s

Specific Energy

1 kJ/kg = 1000 m^2/s^2

1 Btu/lbm = 25037 ft^2/s^2

1 ft·lbf /lbm = 32.174 ft^2/s^2