NAME____BOX NUMBER_________________

Problem 1 (20) ___________

Problem 2 (40) ___________

Problem 3 (40) ___________

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.**

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 or accounting principles MUST clearly identify the system and show a clear, logical progression from the basic principle(s).**
   - **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 and how you used the given information in the process.
   - **Always crunch numbers last on an exam**. The final numerical answer is worth the least amount of points. (Especially if all we 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 point/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 [kg/kmol; lbm/lbmol]	
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

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/ ^{o}R) / 1.8

(T/K) = (T/ ^{o}C) + 273.15

(T/^{o}C) = [(T/ ^{o}F) – 32]/1.8

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

(T/^{o}R) = (T/ ^{o}F) + 459.67

(T/ ^{o}F) = 1.8(T/ ^{o}C) + 32

Temperature Differences

(ΔT/^{o}R) = 1.8(ΔT / K)

(ΔT/^{o}R) = (ΔT/^{o}F)

(ΔT / K) = (ΔT/^{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

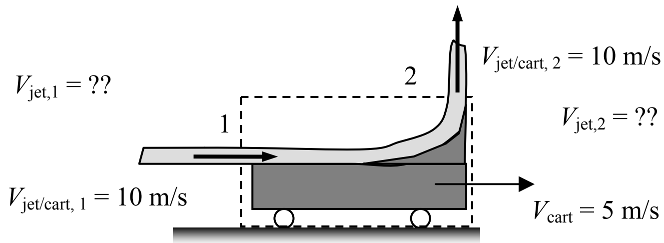
1 Btu/lbm = 25037 ft^2/s^2

1 ft·lbf /lbm = 32.174 ft^2/s^2

Problem 1

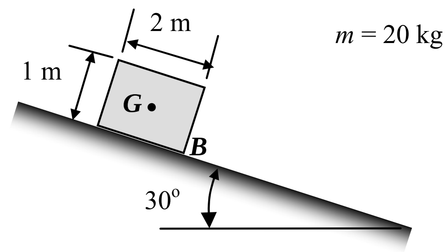
(a) (6 points) A cart moves to the right at a constant velocity of V_{cart} = 5 m/s and is driven by a water jet as shown in the figure. The velocity of the water jet measured with respect to the cart is $V_{jet/cart}$ = 10 m/s at the inlet 1 and the outlet 2.

Determine the absolute velocity, *magnitude* and *direction*, of the jet at the inlet 1 and at the outlet 2.

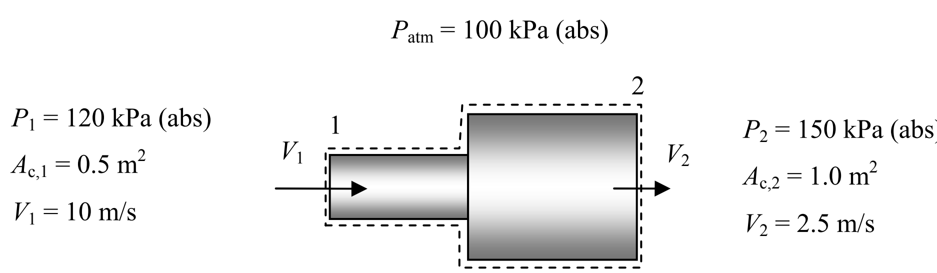


Problem 1 (continued)

(b) (6 points) A 20-kg block slides down a frictionless plane under the influence of gravity. At the instant when its velocity is 5 m/s, determine the ***angular momentum*** of the block, *magnitude* and *direction*, about point ***B,*** the lower right-hand corner of the block.



(c) (8 points) Water flows steadily through the pipe expansion fitting shown in the figure below. Use the information given in the figure, determine the **net pressure force** acting *on* the open system in the figure. Be sure and indicate both *magnitude* and *direction*.



Problem 2 (40 points)

Professor Chambers has instrumented his giant truck and bumper to collect crash test data. His truck weighs 1400 N and will be traveling at 14 m/s when he hits a stationary Toyota Prius which weighs 700 N.

The crash can be modeled as two stages:

> Primary Impact Stage — The truck hits the Prius and the two vehicles stick together. Approximate time is 0.05 seconds.
>
> Travel Stage — The mangled truck and Prius slide over the ground and eventually stop moving. Approximate time is 1.0 second.

Determine the following:

(a) the velocity of the vehicles immediately after the primary impact,

(b) the average impulsive force exerted *by* the truck *on* the Prius during the primary impact, and

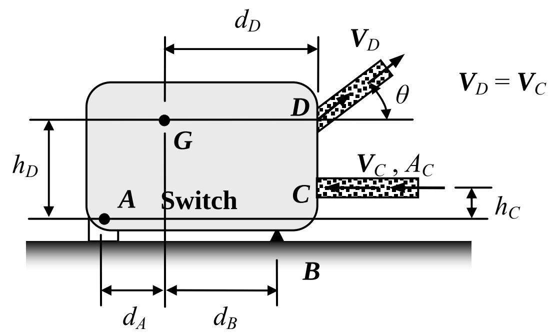
(c) the average value of the coefficient of kinetic friction during the travel stage.

Problem 3 (40 points)

A mechanical safety "switch" opens and safely stops a stream of water when the inlet velocity exceeds a predetermined value.

When the switch is closed (see figure) a stream of water enters the switch at point C with velocity $\boldsymbol{V_C}$ and inlet area A_C. The water exits the switch at point D as shown in the figure. The speed of the water at the inlet and exit are the same, $V_C = V_D$.

When the velocity $\boldsymbol{V_C}$ exceeds a specified value, the switch mass m_G rotates about the frictionless pin at point A and lifts off from the frictionless support at point B.



(a) Develop an equation to predict velocity $\boldsymbol{V_C}$ when the switch is just ready to open, i.e. the switch mass is on the verge rotating.

(b) Develop equations for the reactions on the switch at point A when the switch is just ready to open, i.e. the switch mass is on the verge rotating.n