

NAME _____ BOX NUMBER _____

Problem 1 (30) _____

Problem 2 (35) _____

Problem 3 (35) _____

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 principles MUST clearly identify the system 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 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.)

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.)

<u>USEFUL INFORMATION</u>	SI	USCS	Molar Mass	
Ideal Gas Constant: $R_u = 8.314 \text{ kJ}/(\text{kmol}\cdot\text{K})$		$= 1545 \text{ (ft}\cdot\text{lbf)}/(\text{lbmol}\cdot^\circ\text{R})$	Air	28.97
		$= 1.986 \text{ Btu}/(\text{lbmol}\cdot^\circ\text{R})$	O ₂	32.00
Standard Acceleration of Gravity: $g = 9.810 \text{ m/s}^2$		$= 32.174 \text{ ft/s}^2$	N ₂	28.01
Density of liquid water $= 1000 \text{ kg/m}^3$		$= 62.4 \text{ lbm/ft}^3$	H ₂	2.016
		$= 1.94 \text{ slug/ft}^3$	CO ₂	44.01

Length

$$1 \text{ ft} = 12 \text{ in} = 0.3048 \text{ m} = 1/3 \text{ yd}$$

$$1 \text{ m} = 100 \text{ cm} = 1000 \text{ mm} = 39.37 \text{ in} = 3.2808 \text{ ft}$$

$$1 \text{ mile} = 5280 \text{ ft} = 1609.3 \text{ m}$$

Mass

$$1 \text{ kg} = 1000 \text{ g} = 2.2046 \text{ lbm}$$

$$1 \text{ lbm} = 16 \text{ oz} = 0.45359 \text{ kg}$$

$$1 \text{ slug} = 32.174 \text{ lbm}$$

Temperature Values

$$(T/K) = (T/^{\circ}\text{R}) / 1.8$$

$$(T/K) = (T/^{\circ}\text{C}) + 273.15$$

$$(T/^{\circ}\text{C}) = [(T/^{\circ}\text{F}) - 32] / 1.8$$

$$(T/^{\circ}\text{R}) = 1.8(T/K)$$

$$(T/^{\circ}\text{R}) = (T/^{\circ}\text{F}) + 459.67$$

$$(T/^{\circ}\text{F}) = 1.8(T/^{\circ}\text{C}) + 32$$

Temperature Differences

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

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

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

Volume

$$1 \text{ m}^3 = 1000 \text{ L} = 10^6 \text{ cm}^3 = 10^6 \text{ mL} = 35.315 \text{ ft}^3 = 264.17 \text{ gal}$$

$$1 \text{ ft}^3 = 1728 \text{ in}^3 = 7.4805 \text{ gal} = 0.028317 \text{ m}^3$$

$$1 \text{ gal} = 0.13368 \text{ ft}^3 = 0.0037854 \text{ m}^3$$

Volumetric Flow Rate

$$1 \text{ m}^3/\text{s} = 35.315 \text{ ft}^3/\text{s} = 264.17 \text{ gal/s}$$

$$1 \text{ ft}^3/\text{s} = 1.6990 \text{ m}^3/\text{min} = 7.4805 \text{ gal/s} = 448.83 \text{ gal/min}$$

Force

$$1 \text{ N} = 1 \text{ kg}\cdot\text{m}/\text{s}^2 = 0.22481 \text{ lbf}$$

$$1 \text{ lbf} = 1 \text{ slug}\cdot\text{ft}/\text{s}^2 = 32.174 \text{ lbm}\cdot\text{ft}/\text{s}^2 = 4.4482 \text{ N}$$

Pressure

$$1 \text{ atm} = 101.325 \text{ kPa} = 1.01325 \text{ bar} = 14.696 \text{ lbf}/\text{in}^2$$

$$1 \text{ bar} = 100 \text{ kPa} = 10^5 \text{ Pa}$$

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

$$1 \text{ lbf}/\text{in}^2 = 6.8947 \text{ kPa} = 6894.7 \text{ N}/\text{m}^2$$

[lbf/in² often abbreviated as “psi”]

Energy

$$1 \text{ J} = 1 \text{ N}\cdot\text{m}$$

$$1 \text{ kJ} = 1000 \text{ J} = 737.56 \text{ ft}\cdot\text{lbf} = 0.94782 \text{ Btu}$$

$$1 \text{ Btu} = 1.0551 \text{ kJ} = 778.17 \text{ ft}\cdot\text{lbf}$$

$$1 \text{ ft}\cdot\text{lbf} = 1.3558 \text{ J}$$

Energy Transfer Rate

$$1 \text{ kW} = 1 \text{ kJ}/\text{s} = 737.56 \text{ ft}\cdot\text{lbf}/\text{s} = 1.3410 \text{ hp} = 0.94782 \text{ Btu}/\text{s}$$

$$1 \text{ Btu}/\text{s} = 1.0551 \text{ kW} = 1.4149 \text{ hp} = 778.17 \text{ ft}\cdot\text{lbf}/\text{s}$$

$$1 \text{ hp} = 550 \text{ ft}\cdot\text{lbf}/\text{s} = 0.74571 \text{ kW} = 0.70679 \text{ Btu}/\text{s}$$

Specific Energy

$$1 \text{ kJ}/\text{kg} = 1000 \text{ m}^2/\text{s}^2$$

$$1 \text{ Btu}/\text{lbm} = 25037 \text{ ft}^2/\text{s}^2$$

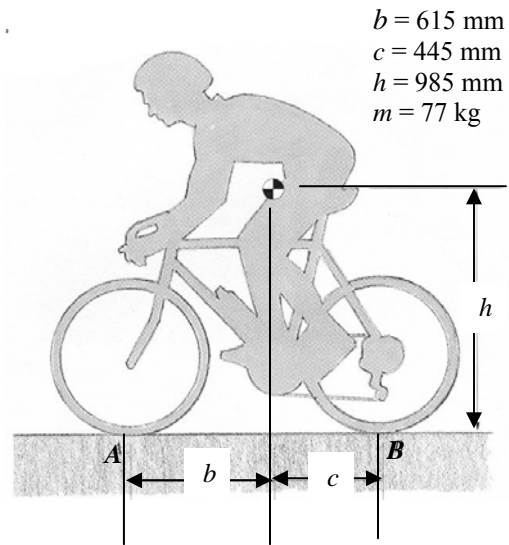
$$1 \text{ ft}\cdot\text{lbf}/\text{lbm} = 32.174 \text{ ft}^2/\text{s}^2$$

Problem 1 (30 points)

A cyclist is traveling on a level road at a speed $V = 15$ m/s. The combined mass of the person and bicycle shown in the figure is $m = 77$ kg. The location of the combined center of mass relative to the wheels is also shown.

Suddenly the cyclist uses the handlebar brakes to stop the bike. If she only applies the front brakes, determine

- (a) the maximum horizontal force of the ground (the braking force) on the bike at Point A that can be applied without the bike flipping (neglect any horizontal force exerted by the ground on the rear wheel), and
- (b) the corresponding deceleration of the cyclist and bike measured in g's, e.g. 8.3 g, and
- (c) the maximum allowable value of the *kinetic friction coefficient* between the front wheel and the ground if the front wheel locks under these conditions and slides on the ground.



Problem 2 (35 points)

A crate with mass $m = 500$ lbm is attached to a motorized winch and positioned on a sloping dock with inclination angle $\theta = 30^\circ$ as shown in the figure. The winch exerts a tension force T on the crate through the winch cable. The friction coefficients between the crate and the dock surface are $\mu_s = 0.30$ for static friction and $\mu_k = 0.25$ for kinetic friction.

Initially, the crate is stationary and the winch brake is on to prevent any motion. Suddenly at $t = 0$, the brake is released and the winch exerts a constant tension force $T = 100$ lbf on the crate. At $t > 2$ seconds, the tension force exerted by the winch on the crate suddenly increases to a constant value $T = 400$ lbf

- (a) Consider the forces on the *stationary* crate when the winch brake is on.
—Find the value or range of values for the tension force T under these conditions?
- (b) Consider the crate's motion for $0 \leq t \leq 2$ s when the tension force is $T = 100$ lbf.
—Find the crate's *acceleration*, *velocity* and *position* at $t = 2$ seconds.
- (c) Consider the crate's motion for the period $t > 2$ s when the tension force is $T = 400$ lbf.
—*Qualitatively* describe how the crate moves during this period (Be concise; use words not numbers!)
- (d) Calculate the *impulse* for the tension force T over the time interval $t = 0$ to 4 seconds. Be sure to indicate *both* the direction and magnitude.

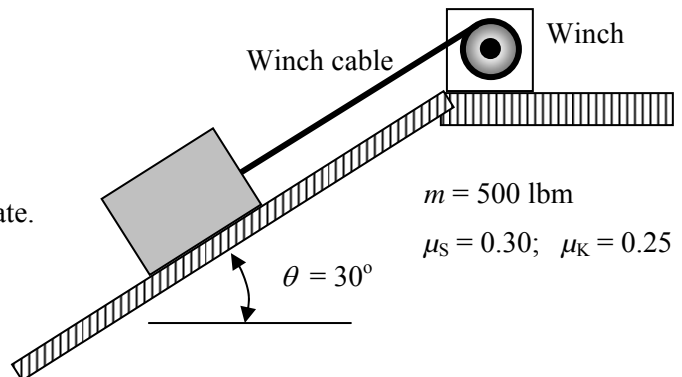
Winch Operating Conditions

$t < 0$: Winch locked and crate stationary

$0 \leq t \leq 2$ s : Winch operating; $T = 100$ lbf.

$t > 2$ s : Winch operating; $T = 400$ lbf

where T is the tension force of the winch on the crate.



Problem 3 (35 points)

Water flows steadily through the elbow-nozzle assembly shown in the figure. The assembly is in the vertical plane (the plane of the paper) and gravity acts as indicated. The assembly is supported entirely by the flange bolts which must resist forces in the x- and y-directions as well as a moment. For purposes of analysis, *you may assume that all flange reactions are concentrated at the dark “dot” at the centerline of the flange*. The available information about the geometry and operating conditions of the assembly are shown in the figure.

Determine the forces and moment (the reactions) that must be applied to the flange to support the elbow-nozzle assembly.

