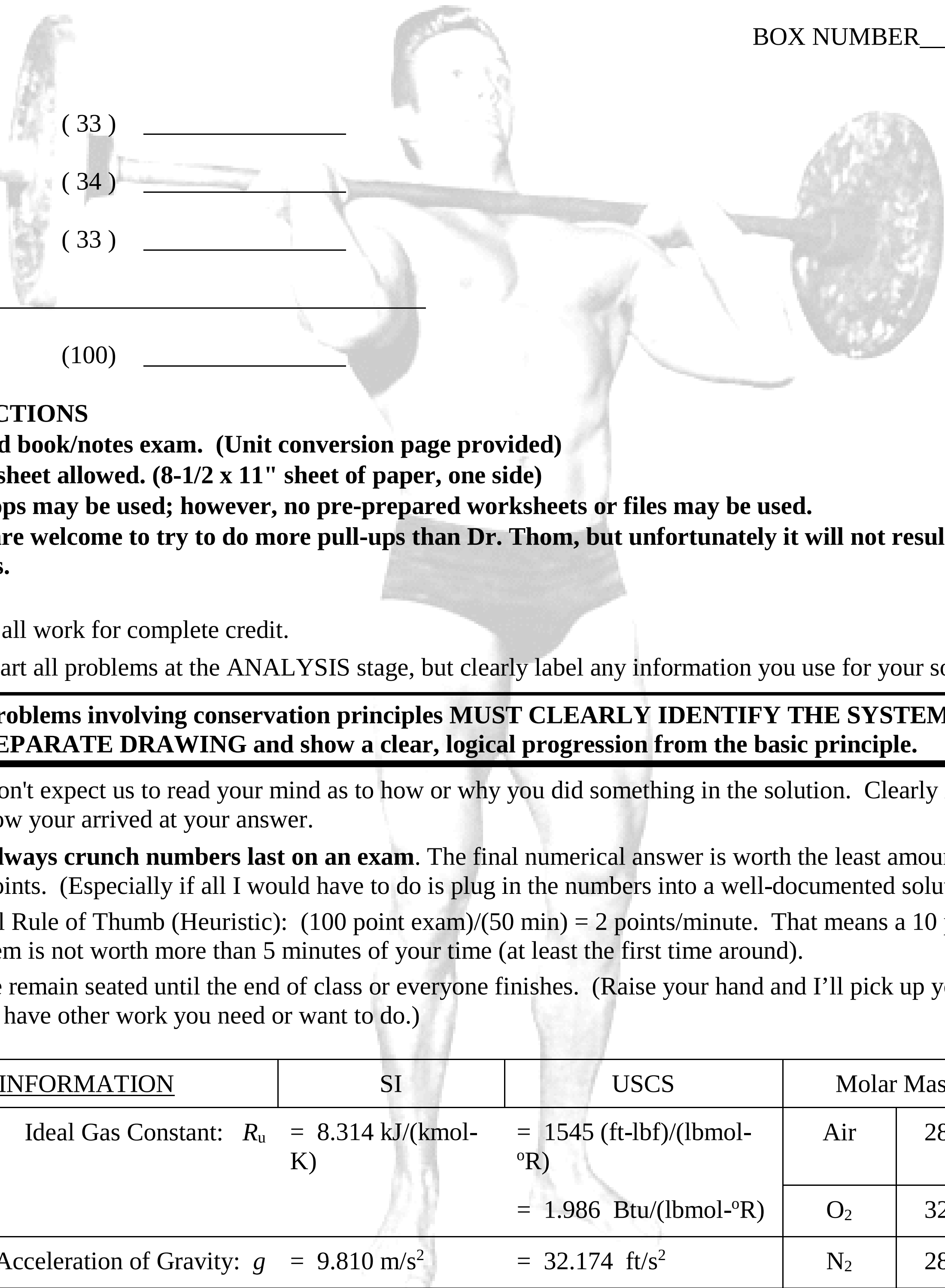
NAME____ SECTION_______________

BOX NUMBER__________



Problem 1 (33) ________________

Problem 2 (34) ________________

Problem 3 (33) ________________

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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.**
- **You are welcome to try to do more pull-ups than Dr. Thom, but unfortunately it will not result in extra points.**

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

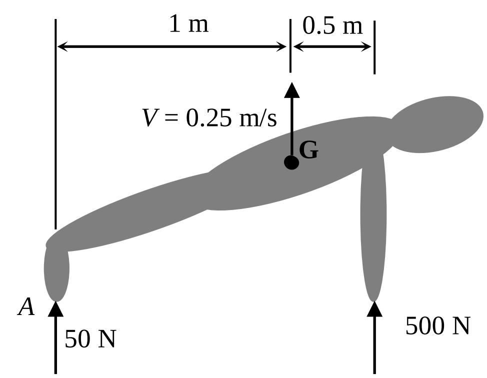
Problem 1 (33 pts)

a) (5 pts) If your speed relative to a moving tread-mill is 5 m/s forward and the tread-mill is moving backward at 7 m/s, what is your running speed relative to an observer standing in the gym? Circle the correct answer.

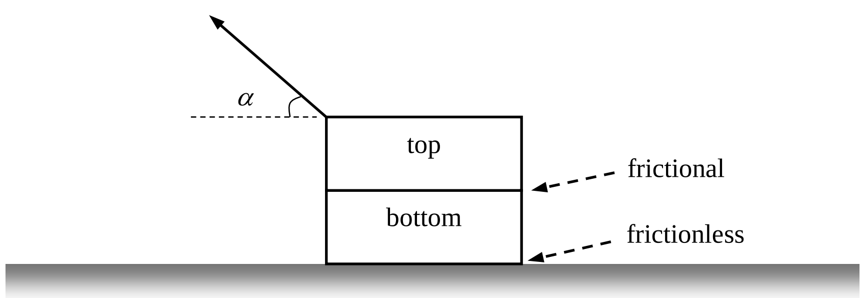
- 12 m/s forward
- 2 m/s forward
- 12 m/s backward
- 2 m/s backward
- None of the above

b) (5 pts) While doing a push-up, Arnold moves vertically at a speed of 0.25 m/s. The floor exerts normal forces on his hands and feet of 500 N and 50 N, respectively. If Arnold's mass is 110 kg, what is the angular momentum about point *A* in the figure?

- 750 N-m counterclockwise
- 75 N-m clockwise
- 27.5 N-m counterclockwise
- 27.5 kg-m²/s counterclockwise
- None of the above

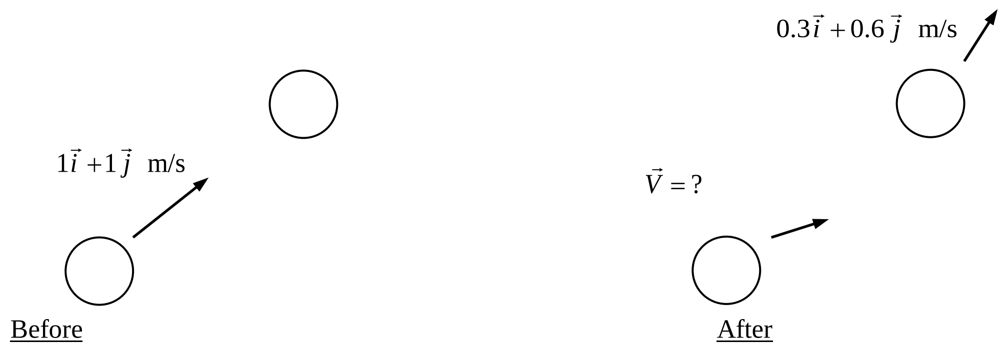


c) (10 pts) Consider two vertically-stacked weight blocks in the following figure. The top block is pulled by a metallic cable at an inclined angle α.



You are asked to choose two separate systems: the top block and the bottom block in this problem. Clearly indicate all the forces on the two systems in the following diagram. No equations are necessary.

d) (13 pts) A moving medicine ball collides with a stationary one as shown in the following figure.



Assume both medicine balls have a mass of 150 g. Determine the following quantities:

i. the impulse exerted by the moving ball on the stationary one during the impact

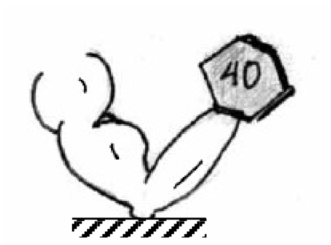
ii. the average impulsive force exerted by the stationary ball on the moving one during the impact if the time of contact if 0.1 second.

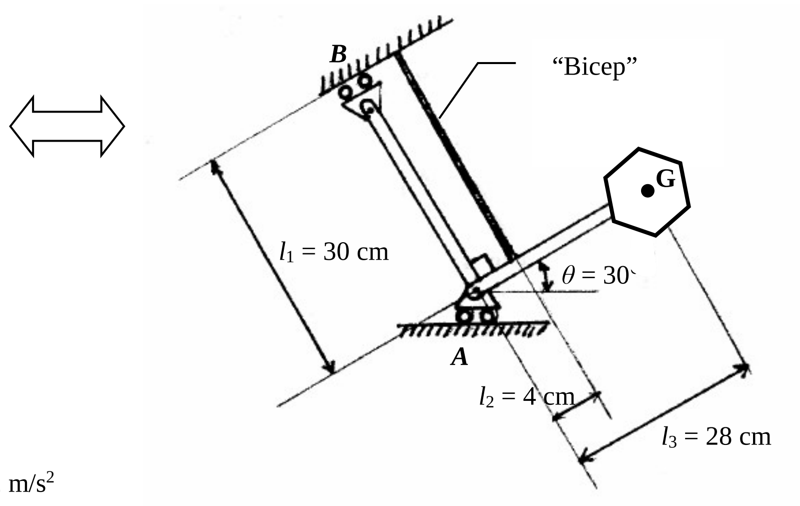
Problem 2 (34 pts)

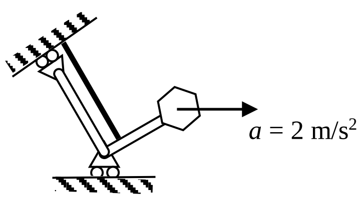
Arnold is doing bicep curls with a 40-kg dumbbell while resting his elbow on a table. The bones of his arm can be modeled as two massless, rigid rods connected to two frictionless rollers, which approximate his shoulder and elbow. His bicep muscle is modeled as a rope in tension.

a) For the dimensions in the figure, find the tension in Arnold's "bicep", the force exerted by the table on his elbow (roller reaction at *A*), and the force acting on his shoulder (roller reaction at B). Assume Arnold holds the dumbbell stationary and that his arm is bent at a right angle.

b) Arnold's gym buddy Lou secretly sneaks up behind him and pushes him to the right, imparting a constant acceleration of $a = 2$ m/s^2 to Arnold's entire arm. Find the new tension in Arnold's bicep.







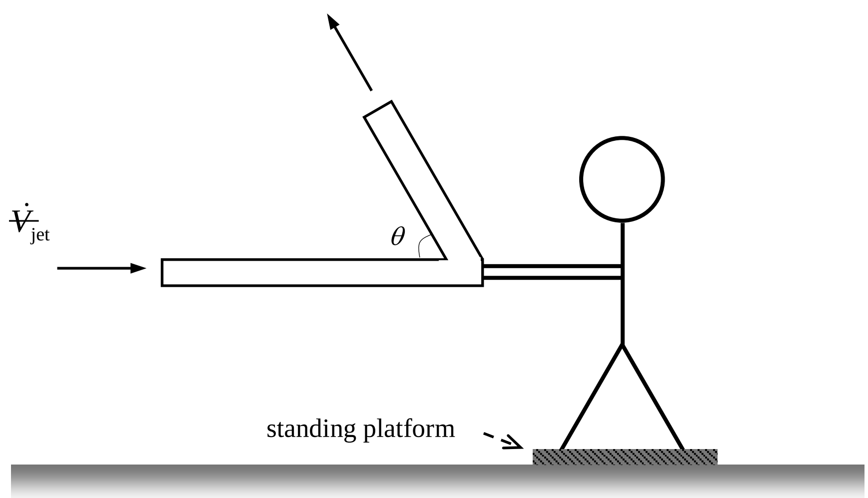
Part b)

Problem 3 (33 pts)

In the Rosie Gym, a water jet has become popular lately as a wrist training device. It strengthens one's wrist muscles by deflecting a horizontal jet of water to an angle θ through a tube with constant diameter, D_{tube}. It has two distinct modes of operation – endurance and strength.

a) In the endurance mode, the athlete sets the desired volumetric flow rate to $\dot{V}_{jet}$ and passively holds the tube turning angle at a constant $\theta = 90^o$ for an extended period of time. Determine the force the athlete must exert on the water tube, in terms of the density of water ρ_{water}, the tube diameter D_{tube}, and the volumetric flow rate $\dot{V}_{jet}$. Be careful to include ALL relevant components of the force.

b) In the strength mode, the athlete sets the desirable volumetric flow rate $\dot{V}_{jet}$ and actively reduces the tube turning angle to $\theta < 90^o$. As a safety precaution, the standing platform is free to slide on the ground. The roughness at the interface can be quantified by the static and the kinetic coefficient of friction μ_s and μ_k, respectively. Derive an equation which governs the minimum tube turning angle θ such that the standing platform is kept stationary, in terms of the density of water ρ_{water}, the tube diameter D_{tube}, the volumetric flow rate $\dot{V}_{jet}$, the coefficients of friction μ_s and/or μ_k, and the body weight of the athlete, W. You do NOT need to solve the equation.



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

(ΔT/ºR) = 1.8(ΔT / K)

(ΔT/ºR) = (ΔT/ºF)

(ΔT / K) = (ΔT/ºC)

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