
SAMPLE FINAL EXAM - PHYSICS C1401X

PROFESSOR SCIULLI

FALL 2003

ATTENTION:

1. Do NOT open either this exam book or the blue book until you have been given permission by the proctor.
2. When you are told to stop the exam, you MUST immediately put down your pen(cil) and close BOTH the exam and your blue book. Then return your exam to one of the proctors. Include your signed handwritten supplementary page.
3. When you turn in your exam, you must show your Columbia ID to the proctor.

Please write on blue book your name, first name followed by last.

Further Instructions: There are six problems to be answered in the blue book. Give numerical answers with units when appropriate. In order to obtain partial credit, be sure to make clear your reasoning. It is **strongly** suggested that you read through the exam and answer **first** the questions you consider easier. Indicate by roman numeral in the blue book which question you are answering and by arabic numeral which part. Start each new problem (of the six) on a new page in your blue book. You may use additional blue books, as required, available from a proctor. You may use a calculator for calculations only. You may also have formulae or other information on a supplementary page, written by you, on **both** sides of an 8 1/2" × 11" paper. No other notes or books are allowed. Note that the last two problems are worth slightly more than the others.

Some constants and formulae:

$$g = 9.80 \text{ m/s}^2$$

$$P_{\text{atmosphere}} = 1.0 \times 10^5 \text{ Pa}$$

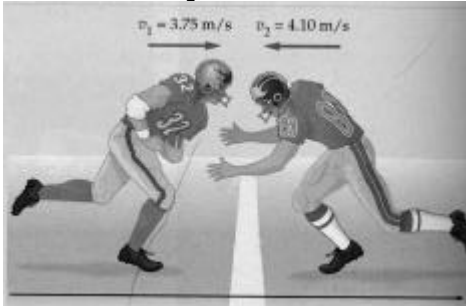
$$\text{Cylinder } I = \frac{1}{2} MR^2$$

Moments of Inertia about center of mass: Sphere $I = \frac{2}{5} MR^2$

$$\text{Rod } I = \frac{1}{12} ML^2$$

	<i>Water</i>	<i>Ice</i>
Specific Heat (J/kg· K)	4190	2220
Heat of Fusion (J/kg)	334×10^3 @ 0°C	
Density (kg/m³)	1.0×10^3	$.92 \times 10^3$

Problem I – 30 points



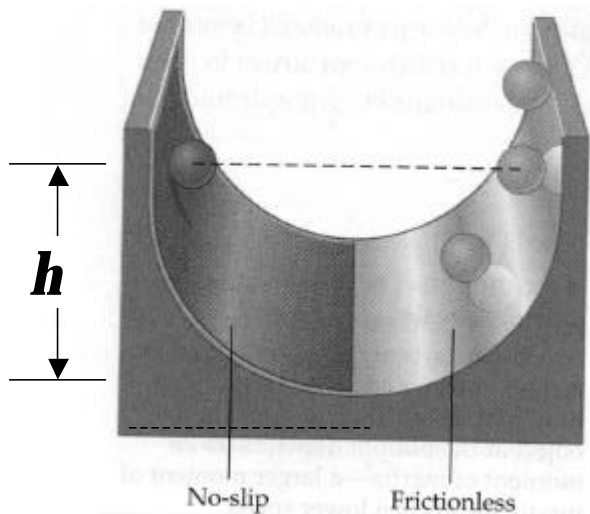
$$V_1 = 3.75 \text{ m/s}$$

$$V_2 = 4.10 \text{ m/s}$$

The football player on the left in the figure is trying to carry the football across the goal line (shown in white), with the speed v_1 shown. Each player has a mass of 75 kg. The football player on the right, with the speed v_2 , is trying to prevent him from crossing the goal. Assume they collide in midair, with the ball at their combined center of mass at the goal line, but vertically above ground 1.2 meters. The players and ball then fall freely while stuck together.

1. (10 pts) Where (distance to the right or left of the goal line) does the ball end up?
2. (10 pts) What fraction of the initial kinetic energy is still kinetic energy immediately after the midair collision?
3. (10 pts) After the play is completely over, how much total energy has been used up? Where did it come from and where did it go?

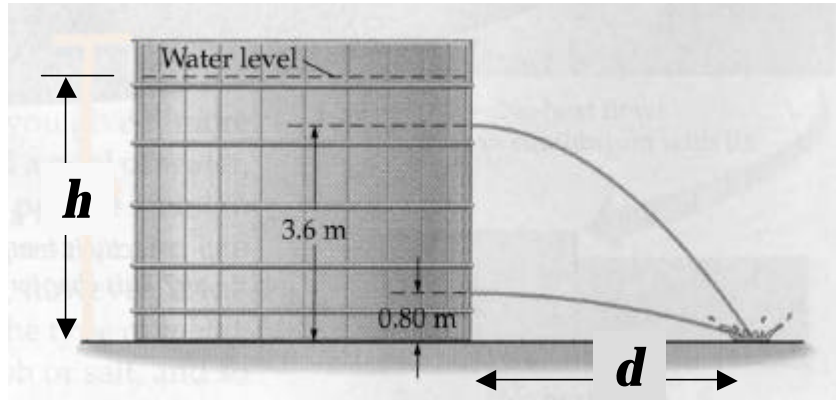
Problem II – 30 points



The apparatus shown consists of a semicircular ramp, with the surface on the left side a non slip surface, and the surface on the right completely frictionless. A ball is released from rest on the left surface, with the center of the ball at a height $h = 1.0$ meters above its lowest point at the bottom of the ramp, and rolls down without slipping.

1. (15 pts) Find the speed and angular velocity when the ball reaches the bottom.
2. (15 pts) Find how high the ball reaches as it subsequently rises on the frictionless surface to the right. Explain if the height is different from where the ball started.

Problem III – 30 points



A water barrel has holes at two heights above the ground, as given numerically in the figure. The water streams hit the ground at the same point as shown.

1. (15 pts) Find the unique height h of the water in the barrel for which this can happen.
2. (5 pts) Find the horizontal distance d from the barrel wall where the water streams hit the ground.
3. (10 pts) If the water level drops 0.5 m from the above situation, how far apart are the water streams on the ground?

Problem IV – 30 points

Mass of the Earth $M_E = 6.0 \times 10^{24}$ kg

Radius of the Earth $R_E = 6.4 \times 10^6$ m

Far out in space a spherical asteroid has radius 12 km and mass 3.45×10^{15} kg. From this information, the gravitational acceleration at the Earth's surface, and the above given values for the mass and radius of the Earth, provide formula and numerical value for

1. (8 pt) the acceleration of gravity on the surface of the asteroid?

Suppose the asteroid spins about an axis through the center, like the Earth, with an angular speed ω .

2. (11 pts) At what values for ω will loose rocks begin to fly off the surface at the asteroid's equator?
3. (11 pts) At what values for ω will a loose rock (that flies off at the equator) not return to the surface?

Problem V – 35 points [Hint in last part: take care about units!]

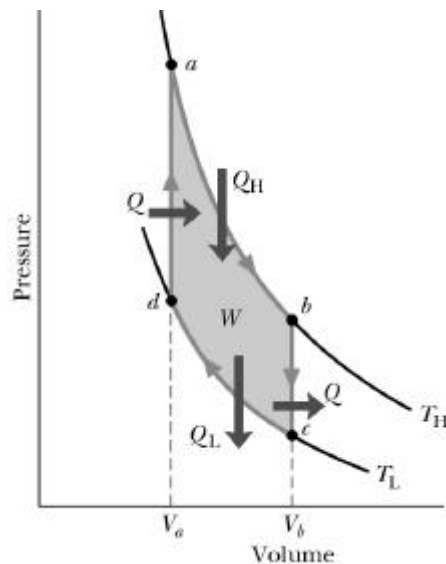
You wish to have iced tea for your afternoon party. You have an insulated container with 3.0 kg of tea (essentially water) at 20°C , to which you add ice at -10°C .

- (20 pt) How much ice at -10°C do you need to add to the 20°C tea in order to have, once the tea and ice are in equilibrium, a resulting mixture of water (tea) with 0.2 kg of ice? What is the temperature?

Suppose the container with the iced tea is left in the state discussed in section 1, and the temperature outside the container is fixed at 20°C . Suppose further that the container has a total surface area of 2500 cm^2 , a thickness of 1.0 cm, and is made of material with a thermal conductivity $0.025\text{ W/m}\cdot^{\circ}\text{C}$. While there is still ice left,

- (8 pt) find the rate at which heat energy is entering the container.
- (7 pt) find the time it takes for all the ice inside the container to melt.

Problem VI – 35 points



The figure shows the pV diagram (from the text) of the operation of a Stirling engine. The cycle involves an isothermal expansion ($a@b$), an isochoric reduction of pressure and temperature ($b@c$), followed by an isothermal contraction ($c@d$), and a final isochoric increase of pressure and temperature ($d@a$). Suppose you are given the temperatures (T_H and T_L) of the isothermals, and the volumes V_a and V_b . You also know how many moles of gas, n , the specific heat at constant volume, C_V , and the gas constant, R . Obtain formulae for the following in terms of these givens.

- (9 pts) Find the heat, Q , added and removed during the isochoric processes.
- (10 pts) Find the heat, Q_H , added during the isothermal expansion and the heat, Q_L , removed during the isothermal contraction.
- (6 pts) Find the work done over the entire cycle.
- (10 pts) Find the change in entropy of the system during the $d@a$ part of the cycle.

End of Exam