Physics 2101, Final Exam, Spring 2008

May 8, 2008

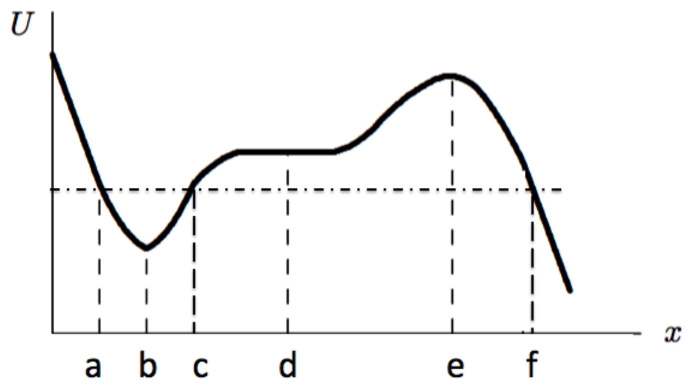
Name: ____

Section: (Circle one)

1 (Rupnik, MWF 8:40am)	2 (Giammanco, MWF 10:40am)
3 (González, MWF 12:40pm)	4 (Rupnik, MWF 2:40pm)
5 (Rupnik, TTh 9:10am)	6 (Sheehy, TTh 12:10pm)

- Please be sure to write your name and circle your section above.
- For the questions, no work needs to be shown (there is no partial credit).
- Please carry units through your calculations when needed, lack of units will result in a loss of points.
- You may use scientific or graphing calculators, but you must derive your answer and explain your work.
- Feel free to detach, use and keep the formula sheet. No other reference material is allowed during the exam.
- For the problems, explain your reasoning as much as possible. Partial credit will be awarded, and correct answers with no work shown will not receive full credit.
- **GOOD LUCK!**

Question 1 (7 pts): The figure shows a plot of potential energy versus position $U(x)$ of a conservative force $F(x)$. A particle is at point $x = b$ at $t = 0$, moving towards the left. It temporarily stops when it reaches $x = a$, and then it begins moving towards the right.



(a) (3pts) What is the maximum **kinetic energy** that the particle will have ?

0 $\quad$ $U(a)$ $\quad$ $U(b)$ $\quad$ $U(a) - U(b)$ $\quad$ $U(c)$ $\quad$ $U(d)$

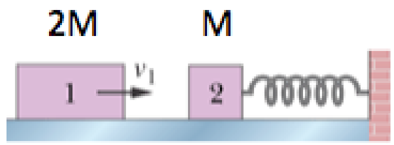
(b) (2pts) Will the particle ever reach point d?

Yes $\quad$ No $\quad$ We need more information to decide.

(c) (2pts) What are the turning points for this particle's motion?

a, b, c $\quad$ a, c $\quad$ a, c, f $\quad$ b, d, e

Question 2 (6pts): In the figure shown, block 2, with mass M, is at rest on a frictionless surface and touching the end of a relaxed spring of constant k. The other end of the spring is fixed to a wall. Block 1, of mass $2M$, traveling at speed v_1, collides with block 2, and the two blocks stick together, beginning an oscillation with frequency ω. The collision happens in a very short time.



(a) (2pts) What is the velocity of the two blocks together just after the collision?

v_1 $\qquad$ $2v_1$ $\qquad$ $2v_1/3$ $\qquad$ $v_1/3$ $\qquad$ $v_1/2$

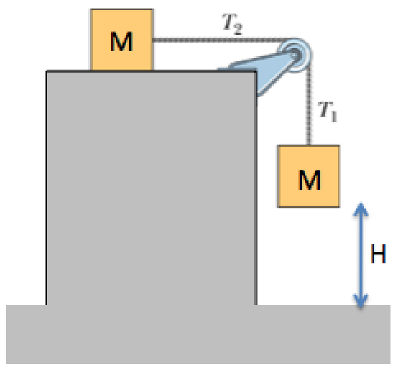
(b) (2pts) If the collision happens at $t = 0$, and the origin of the x axis is at the position of block 2 before the collision, with the positive direction to the right, which of these expressions describe the oscillation after the collision?

(i) $x(t) = x_m \cos(\omega t)$
(ii) $x(t) = x_m \cos(\omega t + \pi/2)$
(iii) $x(t) = x_m \cos(\omega t - \pi/2)$
(iv) $x(t) = x_m \cos(\omega t + \pi)$

(c) (2pts) Now imagine block 1 **bounces off** of block 2 instead of sticking. Which equation correctly describes the frequency ω_b of the resulting motion?

$\omega_b > \omega$ $\qquad$ $\omega_b < \omega$ $\qquad$ $\omega_b = \omega$ $\qquad$ It depends on the final velocity of block 1

Question 3 (6pts) The figure shows two blocks, with the same mass M, connected by a massless string over a pulley with rotational inertia I. The string does not slip over the pulley, there is no friction force between the table and the sliding block; the pulley's axis is frictionless. The system is released from rest, and the sliding block moves to the right, while the hanging block moves down.



(a) (2pt) Which tension has larger magnitude?

T_1 $\qquad$ T_2 $\qquad$ The tensions are equal

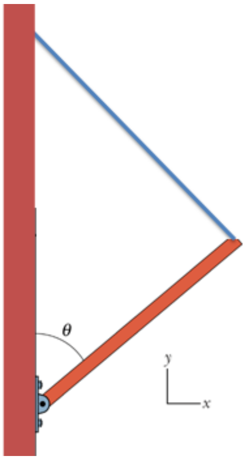
(b) (2pts) The net work done by the tension forces on the pulley is ...

zero $\qquad$ positive $\qquad$ negative

(c) (2pts) Assume that v is the velocity of the sliding block just before the other block strikes the floor, after traveling a distance H from rest. Assume that ω is the angular velocity of the pulley at the same time. What is the kinetic energy of the system consisting of **both blocks and the pulley** at that time?

$\frac{1}{2}Mv^2$ $\qquad$ Mv^2 $\qquad$ $\frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$ $\qquad$ $Mv^2 + \frac{1}{2}I\omega^2$ $\qquad$ $Mv^2 + I\omega^2$

Problem 1(13pts): A uniform beam of length L is supported by a cable perpendicular to the beam and a hinge at angle θ. The tension in the cable is T. Express your answers to the following questions in terms of T, g, L, θ and numerical constants as needed.



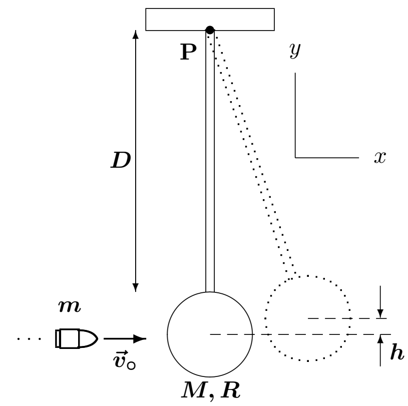
(a) (3pts) Next to the figure, draw a free body diagram for the beam.

(b) (3pts) What is the mass of the beam?

(c) (4pts) What is the force of the hinge on the beam?Write an expressions for the magnitude of the horizontal and vertical components of the hinge force.

(d) (3pts) The cable snaps. Just after the cable snaps, what is the magnitude of the angular acceleration of the beam about the hinge?

Problem 2 (12pts): A solid disk of mass $M = 1.5\,\text{kg}$ and radius $R = 0.10\,\text{m}$ is hanging from a massless thin rod of length $D = 1.2\,\text{m}$.



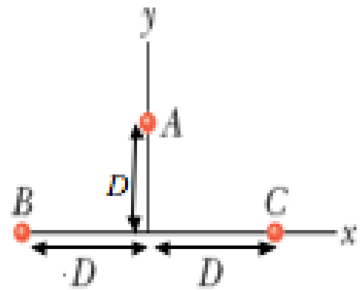
(a) (2 pts) What is the rotational inertia of the disk-rod system with respect to the attachment point **P**?

(b) (3 pts) A bullet with mass $m = 20.0\,\text{g}$ is fired horizontally towards the center of mass of the disk with a speed of $v_0 = 500\,\text{m/s}$. In unit vector notation, what is the angular momentum $\vec{L}$ of the bullet with respect to point P just before it collides with the disk? Use the coordinate system with axes as shown in the figure, with the z-axis out of the page.

(c) (4 pts) After the very short collision, the bullet gets embedded in the disk. In unit vector notation, what is the angular velocity $\vec{\omega}$ of the thin rod-bullet-disk system just after the collision?

(d) (3 pts) Find the distance h to which the center of mass of the disk-bullet system swings after the collision.

Problem 3 (12 pts): Three spheres with the same mass M are placed in the positions shown in the figure, with spheres B and C on the x-axis, and sphere A on the y axis, at a distance D from the origin. Express your answer to the following questions in terms of M, D, Newton's constant G and numerical constants as needed.

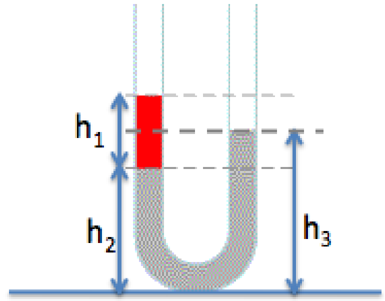


(a) (5 pts) In unit-vector notation, what is the gravitational force on A due to B and C?

(b) (5 pts) What is the total gravitational potential energy stored in the system? Assume $U = 0$ at infinity.

(c) (2 pts) Initially, all spheres were at rest at an infinite distance; you brought them one by one and set them at the positions shown in the figure, again at rest. What is the total work done <u>**by you**</u> to assemble the system?

Question 4 (6 pts) The figure shows a dark liquid and a light liquid in static equilibrium in a U-tube.



(a) (2pts) Which liquid has a higher density?

- (i) dark liquid
- (ii) light liquid
- (iii) They have the same density
- (iv) We cannot tell from information given

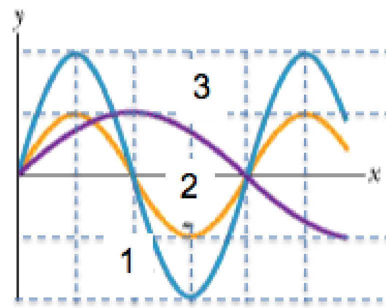
(b) (2pts) Consider the horizontal level indicated by the lowest dashed line, at the deep end of the dark liquid. At that level, is the pressure in the left tube larger, smaller, or equal to the pressure on the right tube?

larger smaller equal

(c) (2pts) Assume the density of the dark liquid is ρ_d, the density of the light liquid is ρ_l, and p_0 is atmospheric pressure. What is a way to express the pressure at the lowest point inside the tube?

- (i) $p_0 + g(\rho_l h_2 + \rho_d h_1)$
- (ii) $p_0 + \rho_l g(h_1 + h_2)$
- (iii) $p_0 + g(\rho_d h_1 + \rho_l h_3)$
- (iv) $p_0 + \rho_l(h_3 - h_2)$

Question 5 (7pts): The figure shows three waves, #1, #2 and #3, that are separately sent along **the same string** that is stretched under the same tension τ, along the x axis. The grid shows equal divisions in the vertical and horizontal scales.



(a) (2pts) Which wave has has the largest speed?

(1) (2) (3) (1) and (2) are equal (2) and (3) are equal All are equal

(b) (2pts) Which wave has the shortest period?

(1) (2) (3) (1) and (2) are equal (2) and (3) are equal All are equal

(c) (3pts) In which wave is the maximum vertical velocity of the string particles the largest?

(1) (2) (3) (1) and (2) are equal (2) and (3) are equal All are equal

Problem 4 (12pts) : A 40g piece of ice is taken from the freezer at $-15.0°C$, and dropped in to 200g of water in a thermally insulated container, initially at $25.0°C$. After a while, the system reaches an equilibrium temperature $T_f > 0°$.

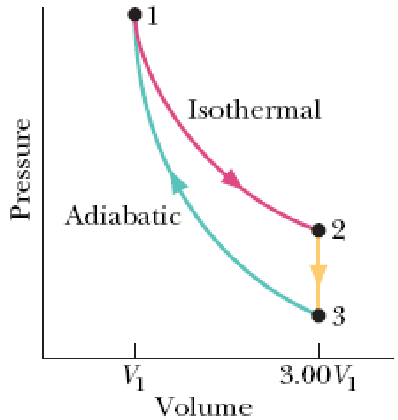
(a) (3pts) What is the heat absorbed by the ice after it warmed up to $0°C$?

(b) (3pts) What is the heat absorbed by the ice to completely melt at $T = 0°C$?

(c) (3pts) What would be the heat released by the water if it had cooled down to freezing temperature, $0°C$?

(d) (3pts) What is the actual final equilibrium temperature T_f?

Question 6 (7pts) : In the p-V diagram shown in the figure, an ideal gas undergoes an isothermal expansion, then a pressure reduction at constant volume, and finally an adiabatic compression to the initial volume.



(a) (2pts) In which of the three processes is the gas absorbing heat?

$1 \rightarrow 2$ $\quad$ $2 \rightarrow 3$ $\quad$ $3 \rightarrow 1$ $\quad$ All of them $\quad$ None of them

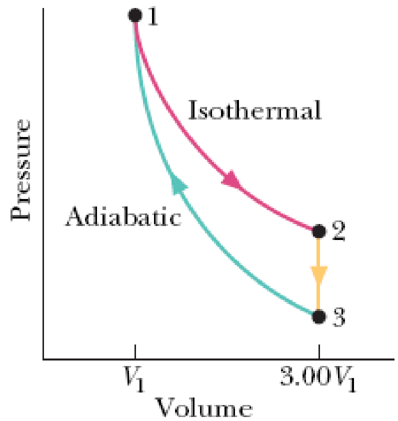
(b) (3pts) In which of the three processes is the gas decreasing entropy?

$1 \rightarrow 2$ $\quad$ $2 \rightarrow 3$ $\quad$ $3 \rightarrow 1$ $\quad$ All of them $\quad$ None of them

(c) (2pts) The cycle $1 \rightarrow 2 \rightarrow 3 \rightarrow 1$ is a ...

a heat engine $\quad$ a refrigerator $\quad$ neither a heat engine nor a refrigerator

Problem 5 (12 pts): In the p-V diagram shown in the figure, two moles of an ideal diatomic gas undergo the processes shown in the figure. The initial pressure and temperature at point 1 are $p_1 = 1\text{atm}$ and $T_1 = 300\text{K}$.



(a) (4pts) What is the initial volume, at point 1?

(b) (4 pts) What are the pressure and temperature at point 3?

(c) (4 pts) What are the work done by the gas and the change in internal energy of the gas in the process $3 \rightarrow 1$?