Disclaimer: This practice exam is intended to give further practice for the Physics 8A final. Its structure is modeled in the form of Professor Kolomensky’s exam, but keep in mind not all material you are responsible for is covered on this practice exam. Your final, as well as this practice test, are both designed to be about \( \frac{1}{3} \) old material (before the 2\(^{nd}\) midterm) and \( \frac{2}{3} \) new material.

Reminder: On the actual 180-minute exam, you are allowed 3 pages of notes and a calculator.

1. Blitz Problems

B1. \( c_p \) (the molar specific heat at constant pressure) is larger than \( c_v \) (the molar specific heat at constant volume). Why is this?
   
   a) An extra amount of heat \( nRT \) goes into mechanical work when the gas expands.
   
   b) Internal energy is always lost when heating a gas under constant pressure.
   
   c) Heating under constant pressure process is an adiabatic process, which requires extra energy.
   
   d) None of the above.

B2. A small cube of ice is thrown into a large 20°C lake and allowed to come into equilibrium. This process is best described as:

   a) Isothermal.
   
   b) Adiabatic.
   
   c) Irreversible.
   
   d) Both b) and c).

B3. If the absolute temperature of a gas is doubled, the rms-velocity of the gas particles

   a) Is unchanged.
   
   b) Increases by a factor of \( \sqrt{2} \)
   
   c) Increases by a factor of 2.
   
   d) Increases by a factor of 4.
B4. The potential energy associated with an ideal spring is a _________ function of displacement from equilibrium.

a) Constant (and equal to zero)

b) Constant (and nonzero)

c) Linear

d) Quadratic

B5. A baseball pitcher throws a ball towards home plate while standing still. What best describes the force of the ball on the pitcher and the frictional force of the ground on the pitcher?

a) \( F_{\text{ball on pitcher}} \) points toward home plate, while \( F_{\text{ground on pitcher}} \) points away from home plate.

b) \( F_{\text{ball on pitcher}} \) points away from home plate, while \( F_{\text{ground on pitcher}} \) points toward home plate.

c) Both \( F_{\text{ball on pitcher}} \) and \( F_{\text{ground on pitcher}} \) point toward home plate.

d) Both \( F_{\text{ball on pitcher}} \) and \( F_{\text{ground on pitcher}} \) point away from home plate.

B6. Rotational Kinetic Energy:

a) Is always less than translational kinetic energy.

b) Is proportional to angular acceleration.

c) Is unitless and positive, by convention.

d) None of the above.

B7. Which of the following is the closest to the magnitude of the buoyancy force on you due to air (assuming you’re about 70 kilograms \( \approx 155 \) pounds, that your average density is that of water, and that the density of air is \( 1.2 \text{ kg/m}^3 \))?

a) 0.008 Newtons.

b) 0.08 Newtons.

c) 0.8 Newtons.

d) 8 Newtons.
B8. Suppose a mass $M$ is hung by a light rope that is attached to the ceiling. The speed of a transverse wave in the rope is measured to be $100 \text{ m/s}$. If instead we used a new rope with the same material but twice the diameter, and hung a mass $2M$ from the ceiling, what would be the speed of transverse waves in the new rope?

B9. A violinist playing middle C (261.63 Hz) needs to play a C♯ note (277.18 Hz). Instead of moving her finger, the violinist runs toward the (stationary) audience. With what speed must she run for the audience to hear a C♯?

B10. A block of mass $M$ is at rest. It shoots forward 1% of its mass, and as a result recoils. What is the ratio of kinetic energy of the ejected 1% mass to the kinetic energy of the leftover (0.99$M$) piece?
2. Hanging by Magic!

A mass $M_1 = 10$ kg rests on a frictionless table and is connected by a string to a mass $M_2 = 60$ kg. The string passes through a hole in the table so that $M_2$ dangles. The surface is frictionless.

a) Assume $M_1$ and $M_2$ are initially at rest. What is the acceleration of the system?

b) For the situation described in part a), how long does it take for $M_1$ to reach the hole if it starts at a distance $R = 1$ m?

c) Now assume that $M_1$ has a velocity $v$ on the surface, perpendicular to the line connecting the hole to $M_1$. $M_2$ remains at rest as $M_1$ swings around in a circle of radius $R = 1$ meter. What is this velocity $v$?

d) Suppose we have the situation described in part c), with mass $M_1$ rotating. We forcibly move $M_2$ down a distance $R/2$ and hold it there. How fast is mass $M_1$ moving after the move?

e) For the situation in part d), what is the tension in the rope?
3. Walking down a rod, then shiii…

Sally (mass $M_p$) walks down a rod (mass $M_r$, length $L$) that is pivoted at a wall and held up by a rope with maximum tension $T$ (see figure 1). The rope makes an angle $\theta$ with respect to the rod. She reaches a distance $x$ from the pivot when the rope breaks, and Sally starts to fall. A trampoline, which acts as an ideal spring with spring constant $k$, waits for her a vertical distance $H$ below, but halfway down sally sees a bird (mass $M_b$) hovering in place. Wanting to slow herself down, sally grabs the bird as she passes by (sucks for the bird). Sally and the bird (safely?) fall to the trampoline together.

When Sally and the bird reach the trampoline, it compresses a distance $d$.

a) What is $x$, the distance at which the rope breaks?

b) What is Sally’s velocity $v_0$ just before she grabs the bird?

c) What is Sally’s velocity $v$ just after she grabs the bird?

d) Set up, but do not solve, an equation for $d$.

Take the following values for parts a-d:

- $H = 10$ meters.
- $L = 1$ meter.
- $\theta = 30$ degrees.
- $M_p = 60$ kg.
- $M_r = 100$ kg.
- $M_b = 5$ kg (fat bird).
- $T = 2000$ Newtons.
- $k = 30,000 \text{ N/m}$. 
4. Diatomic Molecule as a Spring

The Morse Potential is used to approximate the graph of potential energy $V$ vs. internuclear distance $r$ for two atoms. Two atoms are attractive above a certain equilibrium length $r_e$, but repulsive when the distance becomes less than $r_e$. The Morse potential can be approximated as $V(r) = a^2 \cdot D_e \cdot (r - r_e)^2$, where $D_e$ is the disassociation energy of the bond, $a$ is a parameter controlling the range of the force, and $r$ is the distance between nuclei. We wish to model the $\text{N}_2$ bond using the Morse potential.

a) The energy of the $\text{N}_2$ bond is $945 \text{ kJ/mol}$, the equilibrium bond length is 110 picometers, and $a$ is $1.1 \cdot 10^{10} \text{ m}^{-1}$ (the reciprocal of $a$ gives the length scale of these atomic forces). What is the spring constant $k$ of this system? (hint: note the similarity of $V(r)$ to the equation we’re used to).

b) The 2-mass system is equivalent to a 1-mass harmonic oscillator with a mass equal to half of one Nitrogen atom (and the same spring constant). With this knowledge, what is the frequency, angular frequency, and period of oscillations of the diatomic molecule?

c) Assuming a temperature of 300K, what is the average kinetic energy of a molecule?

d) The average kinetic energy is half of the total energy of the oscillator. What is the minimum distance separating the two Nitrogen molecules during the oscillations?
5. Guitar Hero*

Suppose we have a guitar string of length L fixed at both ends. A driving force creates a standing wave
in the string, exciting the 1st and 3rd fundamental modes in the guitar string (but not the 2nd mode).

a) On separate graphs of amplitude vs. position along the guitar string, draw the 1st fundamental
mode and the 3rd fundamental mode (at a time when the waves have nonzero amplitude). On
each graph indicate any nodes that are present (not including the endpoints of the string).

b) What is the ratio of the frequency of the 3rd fundamental mode to the frequency of the 1st
fundamental mode?

c) For the third fundamental mode, write an equation for the displacement y of the string as a
function of y_m, L, \( \omega \), t, and x (where y_m is the maximum displacement of the 3rd mode and x is
the position along the string). Any phase factor is acceptable.

*I realize this problem has nothing to do with guitar hero, but you’re a hero in my book if you solve it.
6. Older Pennies vs. Newer Pennies

In 1983 the United States began coining the cent piece out of copper-clad zinc rather than pure copper. The mass of the old copper penny is 3.083g, while that of the new cent is 2.517g. The density of copper is 8.960 g/cm$^3$ and that of zinc is 7.133 g/cm$^3$, and the old and new coins have the same volume. We heat both an old penny and a new penny from 300K to 1000K. While copper stays a solid in this temperature range, zinc melts at 693K.

a) Calculate the percentage of zinc (by volume) in the new (post-1983) cent.

b) Calculate the energy required to heat an old (pre-1983) penny from 300K to 1000K.

c) Calculate the energy required to heat a new penny from 300K to 1000K.

d) Now, suppose you want to lift a new penny by blowing over it (parallel to the surface on which the penny lies). With what velocity must you blow in order to lift the penny (note: the density of air is about 1.2 kg/m$^3$, and the area of the face of a penny is 2.85 x 10$^{-4}$ m$^2$)?

Useful Info: $c_{\text{copper}} \approx c_{\text{zinc}} = 0.4 \ J/\text{g} \cdot \text{K}$, $L_{f, \text{zinc}} = 0.11 \ \text{kJ/g}$, and assume $c_{\text{zinc \ (liquid)}} \approx c_{\text{zinc \ (solid)}}$. The fact that $c_{\text{copper}} \approx c_{\text{zinc}}$ is due to the fact that they have approximately the same molar mass and transition metals (at high enough temperatures, like 300K – 1000K) all have the same molar heat capacity.
7. Little Johnny plays with Helium

Suppose we have 1 m$^3$ of Helium in a sealed, container (fixed volume) at 1 atm and 300K. Little Johnny, an excited young toddler, shakes the container until the temperature of the container reaches 350K. Johnny then opens the container and the gas escapes quickly (adiabatically) to atmospheric pressure. Johnny’s dad, a physicist, is able to collect the gas and magically cool it back down to 300K in an isobaric process, afterward scolding Johnny for the hassle.

a) Draw a (qualitative) PV diagram for this cycle. Include in your drawing a dotted curve giving the isotherm going through the point which represents the state of the gas just before Johnny opens the container.

b) Calculate $\Delta E_{\text{int}}$, $Q_{\text{to}}$ (the heat added to the gas), and $W_{\text{by}}$ (the work done by the gas) for each of the three stages of the cycle.

c) What is the maximum volume occupied by the gas over the course of the cycle? Also, find the maximum pressure of the gas as well as the maximum temperature of the gas.

d) Explain qualitatively what happens to the entropy of the gas along each of the 3 paths (does entropy increase, decrease, or remain constant?). What is larger in magnitude, $\Delta S$ during the first leg of the cycle, or $\Delta S$ during the third leg of the cycle? Why?

(Possibly) useful information for Helium:

Molar Mass: 4 g/mol
$\gamma \equiv \frac{c_p}{c_v} = \frac{5}{3}$
$c_v = \frac{\gamma}{2-\gamma} R$
$c_p = \frac{\gamma}{2-\gamma} R$