Physics 160, Section 003
Final Examination

Spring 2004

This is an open-book, open-notebook test. Any use of a resource actively associated with a person other than yourself (such as, but not limited to, another test-taker or a respondent of an electronic communication) constitutes cheating. A determination by the instructor of cheating results in automatic failure of this examination and of the course and in a report to the Honor Council.

Answer on this test sheet, but feel free to attach any other work you deem relevant. There are eight (8) questions (some with parts) each worth 5 points, for a total of 40 points.
1. Below is an acceleration versus clock reading history of a rectilinear motion showing intervals of uniform acceleration with abrupt changes of acceleration. Acceleration cannot change instantaneously, of course, but it can change in a time interval that is very short compared to the resolution of a clock and/or in comparison to the scale of the graph. Therefore, take the graph as being realistic given the tools available.

(a) [3 points] On the graph provided, plot a velocity versus clock reading history of this motion (corresponding to the acceleration history), assuming the body starts from rest at $t = 0$.

(b) [2 points] Describe what the graph would look like if the object had some non-zero initial velocity at $t = 0$. 

![Graph of acceleration versus clock reading history](image-url)
2. Standing at the edge of a building, you throw a ball $A$ vertically upward with an initial velocity $+ |v_{0y}|$ and a second ball $B$ vertically downward with an initial velocity of the same magnitude $- |v_{0y}|$. Both balls land on the ground below the edge of the building.

(a) [1 point] Assuming negligible air resistance, what is the velocity of ball $A$ as it passes on the way down the height at which it was thrown? Explain your reasoning.

(b) [1 point] Assuming negligible air resistance, how will the velocities of the two balls compare with each other when they strike the ground? Will they be equal or unequal in magnitude? If unequal, which will be greater? Explain your reasoning.

(c) [1 point] If air resistance were significant, how will the two velocities compare with each other when the balls strike the ground? Will they be equal or unequal in magnitude? If unequal, which will be greater? Explain your reasoning.

(d) [2 points] Suppose that you throw from the same location a third ball $C$ with a vertical component of the velocity $+ |v_{0y}|$ and a horizontal component of the same magnitude directed away from the building. Assuming negligible air resistance, how will the magnitude of the total velocity of $C$ on striking the ground compare with that of $A$? Draw a relevant diagram, determine the ratio in terms of the information given, and explain your reasoning.
3. A projectile is aimed at a target *not at the same horizontal level* [see figure below].

![Diagram of projectile and target](image)

The target is released from rest and the projectile is launched at the same instant. By interpreting the appropriate equations, verify that,

(a) [2 points] the objects will meet at the initial level of the projectile \(y = 0\) if the initial velocity is

\[v_{0, \text{crit}} = \sqrt{\frac{gL}{\sin 2\alpha}};\]

(b) [1 point] the two objects may meet while the projectile is still rising if \(v_0 > v_{0, \text{crit}}\);

(c) [1 point] the objects may meet below the initial level of the projectile if \(v_0 < v_{0, \text{crit}}\);

(d) [1 point] the objects would reach the ground and not meet if the ground is located at level \(y = 0\) and \(v_0 < v_{0, \text{crit}}\).
4. A ball is launched off the end of a table with horizontal velocity \( v_x \). [Assume no air resistance.]

(a) [1 point] Assuming the ball lands on the floor, sketch a trajectory (the path followed by the ball) from the edge of the table to the floor.

(b) [1 point] On the diagram you made for (a), sketch three other trajectories
   i. for a smaller value of \( v_x \);
   ii. for a larger value of \( v_x \);
   iii. and for an extremely large value of \( v_x \).
Label each trajectory with comparative sizes of \( v_x \) (that is, the smallest value should have the smallest label, etc.).

(c) [1 point] The trajectory is called parabolic in the ideal case in which air friction is negligible. What is a “parabola”? That is, how is this kind of curve defined? How do we know that the shape of the trajectory is parabolic?

(d) [1 point] Assume the table and the wall toward which the ball flies are separated by a finite distance (that is, they are not touching). What would the magnitude of \( v_x \) have to be such that you couldn’t discern with the naked eye a decrease in the ball’s height above the floor during the interval of its flight until it hits the wall? You need to choose explicitly reasonable values for the change in height and for the distance to the wall. What effect would you expect the ball to have on the wall under these circumstances? Justify your answers.

(e) [1 point] On the original sketch, draw another trajectory for a second ball with a very much larger mass number than that of the first ball but with exactly the same initial velocity \( v_x \). Explain your reasoning.
5. (a) [1 points] Consider a closed system of two objects $A$ and $B$. If, during some time interval $\Delta t$, they interact, then, as a result of the interaction, there results a momentum transfer. Prove that the change in magnitude of each particle’s velocity is inversely proportional to its mass number.

(b) [1 points] Imagine compressing a spring between two frictionless carts, one with a standard mass number $m_s$, the other with unknown mass number $m$. When released, the carts move away from each other, and you measure the velocity of each. Based on this interaction, and using momentum conservation, give a simpler definition of mass $m$ in terms of $m_s$ than the one given in lecture: $m = \frac{m_s^2 v}{v_1}$. Notice that one cannot merely compare formulas; a physical definition includes the operations required to make the measurement.

(c) [1 points] Imagine a cannon that is free to roll on wheels. Initially, both the cannon and cannon ball are at rest. Explain how it is that, when the cannon is fired, the cannon ball flies away at a large speed while the cannon recoils only a little.

(d) [2 points] In each case above, (a), (b), and (c), explain how the magnitude of the interaction (the force) depends on the respective mass numbers of the separate constituents. That is, in (a), which object, $A$ or $B$, experiences the larger force; in (b), which object, $m_s$ or $m$, experiences the larger force; in (c), which object, the cannon or the cannon ball, experiences the larger force. Explain your response and how the ensuing motions result as they do.
6. A ball rolls down an inclined plane starting from rest at the top. It is halfway down after a time interval \( \Delta t \).

   (a) [1 point] Will the time interval to get the rest of the way to the bottom be equal to, greater than, or smaller than \( \Delta t \)? Explain your reasoning.

   (b) [1 point] How will the ball’s translational kinetic energy at the bottom compare to that at the halfway point? Justify your answer.

   (c) [1 point] How will its rotational kinetic energy at the bottom compare to that at the halfway point? Justify your answer.

   (d) [1 point] How will its total kinetic energy at the bottom compare to that at the halfway point? Justify your answer.

   (e) [1 point] If the object were a cylinder rather than a ball, how would your answers to the previous questions change? Justify your answer.
7. You must design a safety net to catch a person jumping from the top of a 20-story building.

   (a) [2 points] What approximate velocity will such a person reach before hitting the net?
   (b) [3 points] How much energy will be transferred in breaking the fall?

   Explicitly state your assumptions.

8. You look down on a racetrack around which travels a car. The car maintains the magnitude of its velocity at a constant value. On the respective diagrams show for each one of the numbered positions

   (a) [1 points] the car’s velocity vector;
   (b) [2 points] the car’s acceleration vector;
   (c) [2 points] the net horizontal force component acting on the car.