Physics 111  Solution to Exam 1

Dr. Gary Morris

Chapters 1 – 4

Thursday, September 16, 2004

Do not open this exam until you are instructed to do so. Carefully read all the instructions listed below.

- Look at the seat to your left. Look at the seat to your right. If they are not BOTH unoccupied, you must change seats until the seats on either side of you contain no persons.
- Clear your desktop of all items except a pencil/pen, a (scientific) calculator, and a single 3”×5” note card (hand-written). You may not use your book or any additional notes during this exam. You must staple your note card to this exam before turning in the exam.
- You will have 75 minutes to complete the exam. When you are instructed to stop working on the exam, you must put down your pencil/pen immediately. I will notify you when there are 30 minutes, 15 minutes, and 5 minutes remaining in the exam period.
- Read through the entire exam before you start. The last page contains useful constants and mathematical formulas.
- Generous partial credit is awarded. However, you must show your work to receive credit. Do not simply write down the answers. No partial credit will be given on the multiple-choice section.
- The Multiple Choice and Essay sections are mandatory.
- You need only work 2 out of the 3 “Sections” on this exam. NOTE: you must circle on this page the numbers corresponding to the two sections you would like us to grade. We will only grade the problems that you circle. If you do not indicate which problems you would like us to grade, we will grade the first two sections you attempt.

Please sign the following statement:

I have not given, received, or tolerated the use of any unauthorized aid during this examination.

Section 1 – Interpreting Graphs
(complete 2 of Sections 1 – 3)

The following velocity versus clock reading histories describe the rectilinear motion (i.e., one-dimensional, straight-line motion) of six particles (A, B, C, D, E, and F) that started out from position $s_0$ at clock reading $t = 0$ s. On the next page is a list of questions about these graphs. For each question, circle the correct answer(s) (NOTE: There may be more than one correct answer). [25 points]

“The difficult lies not in the new ideas, but in escaping the old ones, which ramify, for those of us brought up as most of us have been, into every corner of our minds.” – John Maynard Keynes
(a) Which particle(s) are at position $s_0$ at the clock reading $t = 2.0$ s?

- A  B  C  D  E  F  NONE

(b) Which particle(s) spend at least some time moving in the negative direction?

- A  B  C  D  E  F  NONE

(c) Which particle(s) display uniform, nonzero acceleration for the entire interval $t = [0,2]$ s?

- A  B  C  D  E  F  NONE

(d) Which particle(s) started moving in the negative $s$ direction and then reversed the direction of motion, traveling back in the positive $s$ direction?

- A  B  C  D  E  F  NONE

(e) Which particle is farthest from position $s_0$ at clock reading $t = 2.0$ s?

- A  B  C  D  E  F  NONE

(f) Which particle(s) exhibited nonzero average acceleration during interval $t = [0,2]$ s?

- A  B  C  D  E  F  NONE

(g) Which particle(s) had zero velocity at some time at some point in the history plotted?

- A  B  C  D  E  F  NONE

“Always acknowledge a fault. This will throw those in authority off their guard and give you an opportunity to commit more.”

– Mark Twain
**Section 2 – 1D Kinematics**  
(complete 2 of Sections 1 – 3)

A man is running with speed “u” to catch a bus that is initially stopped. At time \( t = 0 \), the man is a distance \( s \) from the door to the bus, but the bus begins to accelerate with acceleration “\( q \)” in the direction away from the man.

**a)** [5 points] Draw a motion diagram that includes both the position of the bus and the position of the man from \( t = 0 \) until the time at which the man first catches the bus, assuming he does.

**b)** [7 points] Draw a pictorial representation. Make sure to include a well-defined coordinate system. Use a coordinate system in which the door of the bus is at position \( x = 0 \) at time \( t = 0 \). Identify the time at which the man catches the bus as \( t_{\text{catch}} \). Label the picture with symbols for the known and unknown quantities. Make a table to summarize the known and unknown quantities.

**c)** [7 points] Write down and solve the equation(s) necessary to answer the following question: At what time(s) will the man catch the bus? (Hint: You will need an equation for both the man and the bus. Then think about the condition required for the man to catch the bus.)

**d)** [6 points] Provide a physical interpretation for the meaning of your answer(s) to part (c). Drawing a sketch of the graph of position vs. time for the man and the bus might be helpful.

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**Table:**

<table>
<thead>
<tr>
<th>Known</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v_{0,\text{man}} = u )</td>
<td>( x_{f,\text{man}} )</td>
</tr>
<tr>
<td>( v_{f,\text{man}} = u )</td>
<td>( v_{f,\text{bus}} )</td>
</tr>
<tr>
<td>( a_{\text{man}} = 0 )</td>
<td>( t_{\text{catch}} )</td>
</tr>
<tr>
<td>( x_{0,\text{man}} = -s )</td>
<td>( v_{0,\text{bus}} = 0 )</td>
</tr>
<tr>
<td>( x_{0,\text{bus}} = 0 )</td>
<td>( a_{\text{bus}} = q )</td>
</tr>
<tr>
<td>( x_{f,\text{man}} = x_{f,\text{bus}} )</td>
<td></td>
</tr>
</tbody>
</table>

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**Equations:**

\[
x_f,\text{man} = x_{0,\text{man}} + v_{0,\text{man}} (\Delta t) + \frac{1}{2} a_{\text{man}} (\Delta t)^2 = -s + u(t_{\text{catch}})
\]

\[
x_f,\text{bus} = \frac{1}{2} a_{\text{bus}} (\Delta t)^2 = \frac{1}{2} q(t_{\text{catch}})^2
\]

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When the man catches the bus, $x_{f, \text{man}} = x_{f, \text{bus}}$. Setting these two equal to one another, we have a quadratic equation

$$\frac{1}{2} a (t_{\text{catch}})^2 - u t_{\text{catch}} + s = 0$$

which has a solution

$$t_{\text{catch}} = \frac{u \pm \sqrt{u^2 - 4(\frac{1}{2} a)(s)}}{2(\frac{1}{2} a)} = \frac{u \pm \sqrt{u^2 - 2qs}}{q}.$$ 

d) This equation only has a solution if $u^2 \geq 2qs$. So the minimum speed with which the man must run to catch the bus is $u = \sqrt{2qs}$. For speeds greater than this minimum, the man will catch-up to the bus then pass the bus before the bus then catches up with the man and passes the man again. So, the two solutions are these two times: the “–” man catching the bus and the “+” sign for the next coincidence of the two when the bus catches the man.

Graphically, the two solutions correspond to the intersection points of the two position versus time graphs seen below. Note that if the man’s velocity is too small, he’ll never catch the bus (imaginary solutions to the quadratic).

“*There is no such thing as a problem without a gift for you in its hands…*”

– Richard Bach, *Illusions*
Section 3 – 2D Kinematics
(complete 2 of Sections 1 – 3)

On a hot day in Houston, a girl swings on a rope suspended from an overhanging tree branch in order to launch herself into the cool bayou below. When she lets go of the rope, her initial velocity is 2.25 m/s at an angle of 35.0° above the horizontal. She flies through the air for 1.60 s after letting go of the rope before hitting the water.

a)  [5 points ] Draw a motion diagram for the girl from the time she lets go of the rope until the time she hits the water.
b)  [7 points ] Draw a pictorial representation. Make sure to include a well-defined coordinate system. Label the picture with symbols for the known and unknown quantities. Make a table to summarize the known and unknown quantities.
c)  [7 points ] Write down and solve the equation(s) necessary to answer the following question: How high above the water was the girl when she let go of the rope?
d)  [6 points ] Write down and solve the equation(s) necessary to answer the following question: With what speed does the girl hit the water?

<table>
<thead>
<tr>
<th>Known</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \theta = 35^\circ )</td>
<td>( y_0 )</td>
</tr>
<tr>
<td>( x_0 = 0 )</td>
<td>( v_y )</td>
</tr>
<tr>
<td>( y_f = 0 )</td>
<td>( v_{0,f} )</td>
</tr>
<tr>
<td>(</td>
<td>v_0</td>
</tr>
<tr>
<td>( v_{0,x} = v_0 \cos 35^\circ = 1.843 \text{ m/s} )</td>
<td></td>
</tr>
<tr>
<td>( v_{0,y} = v_0 \sin 35^\circ = 1.291 \text{ m/s} )</td>
<td></td>
</tr>
<tr>
<td>( v_{0,y} = v_0 \sin 35^\circ = 1.291 \text{ m/s} )</td>
<td></td>
</tr>
<tr>
<td>( v_{0,\text{top}} = 0 )</td>
<td></td>
</tr>
<tr>
<td>( a = -g )</td>
<td></td>
</tr>
<tr>
<td>( t_f = 1.60 \text{ s} )</td>
<td></td>
</tr>
</tbody>
</table>

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c) We’ll need the kinematic equation $y = y_0 + v_{0,y} (\Delta t) + \frac{1}{2} a_y (\Delta t)^2$. Plugging in the values we know from the table, we find

$$0 = y_0 + (1.291 \text{ m/s})(1.60 \text{ s}) + \frac{1}{2} (-9.81 \text{ m/s}^2)(1.60 \text{ s})^2$$

$$y_0 = 10.5 \text{ m}$$

d) To get the speed, we’ll need the kinematic equation $v_y = v_{0,y} + a_y (\Delta t)$ for motion in the $y$-direction. We find

$$v_y = 1.291 \text{ m/s} + (-9.81 \text{ m/s}^2)(1.60 \text{ s}) = -14.405 \text{ m/s}$$

We know that the $x$-velocity will remain constant in this case since there is not $x$-acceleration, so life’s simpler in the $x$-direction. So, the speed is

$$|\vec{v}_f| = \sqrt{v_{x,f}^2 + v_{y,f}^2} = \sqrt{(1.843 \text{ m/s})^2 + (14.405 \text{ m/s})^2} = 14.52 \text{ m/s}$$

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– Richard Bach, Illusions
Consider the figure of a ball on the track to the right. The ball is given a small initial velocity to the right and then rolls down the track. Assume the ball never leaves the track, bounces, skitters, etc.

**[25 points]**

a) Describe the motion in words.

b) Draw three graphs on the axes provided below: \( s \) vs. \( t \), \( v_s \) vs. \( t \), and \( a_s \) vs. \( t \), where \( s \) is the position measured along the track. Use the same time scale on all three graphs, so that the same instant in time on all three graphs is vertically lined up.

The \( s \)-position of the ball increases with time. Before it gets to the edge of the incline, the rate is slow and constant. As it goes down the incline, the ball experiences an acceleration in the +\( s \)-direction, leading to an increase in the \( s \)-velocity (at a constant rate) and a parabolic shape in the \( s \)-vs.-\( t \) graph. Finally, when the ball reaches the bottom of the incline, the change in \( s \)-position with time should be constant again as the velocity becomes constant and the acceleration returns to 0. The final velocity should match the velocity at the end of the incline and should be greater than the initial velocity. The slope of the \( s \)-vs.-\( t \) graph will be steeper in this last section than in the first section (before the incline).

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Multiple Choice (Required Section)

Each answer is worth 5 points for a total of **25 points**. Fill in your answers here:


1. You throw a ball straight up in the air. At the highest point, the ball’s
   
   A. velocity and acceleration are zero.  
   B. velocity is nonzero but its acceleration is zero.  
   C. acceleration is nonzero, but its velocity is zero.  
   D. velocity and acceleration are both nonzero.

2. The four figures below show arrows that have been shot into the air. All of the
   arrows were shot straight up and are the same size and shape. The arrows are made
   of different materials so they have different masses, and they have different speeds as
   they leave the bows. The values for each are given in the figures. Assume for this
   situation that the effect of air resistance can be neglected. All are shot from the same
   height.

   Rank these arrows, from greatest to least, on the basis of the maximum heights the
   arrows reach.

   Arrow I
   12 m/s
   75 g

   Arrow II
   14 m/s
   180 g

   Arrow III
   16 m/s
   100 g

   Arrow IV
   14 m/s
   75 g

   A. I = IV > II > III  
   B. II > III > I = IV  
   C. III > II = IV > I  
   D. IV > III > I > II  
   E. III > II > I = IV

3. An object is dropped from rest and falls for 10 s with uniform acceleration. What
   percentage of the total distance that it falls does it fall in the last second?

   A. More than 20 %  
   B. Close to 20 %  
   C. Close to 15%  
   D. Close to 10 %  
   E. Less than 10%

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4. Which of this pictures is an accurate graphical representation of the vector equation $\vec{A} - \vec{B} = \vec{C}$?

A. I
B. II
C. III
D. I and II
E. I, II and IV

5. Rank the $y$-components of these vectors from largest to smallest. Remember, negative numbers are less than zero.

A. V > II > I = IV > III
B. III > I > V > II > IV
C. III > V > II = IV > I
D. II > I > IV > V > III
E. II > I > III > IV > V

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