University of Maryland, College Park
Dept. of Physics

PHYSICS 161
Spring 2003

Exam I

Lubna Rana
Monday, March 3, 2003

Solutions.

Special Notes:

1). This is a CLOSED BOOK examination. No Calculators, Notes or Electronic Devices are allowed.

2). There are FOUR (4) Problems on this test.

Problem 1 (pg 2); parts a-f: 30 points

Problem 2 (pg 3); parts a-d: 25 Points

Problem 3 (pg 4); parts a-c: 20 Points

Problem 4 (pg 5); parts a-f: 25 Points

3). There are SIX (6) PAGES on this test.

4). The FORMULA SHEET is on the last page. You may tear it off for easy reference.

5). DO NOT UNSTAPLE OR SEPARATE ANY PAGES OTHER THAN THE FORMULA SHEET.

6).Show COMPLETE WORK and/or REASONING for CREDIT. When asked to make plots or draw vectors, draw carefully. DO NOT SCRIBBLE. If things are not drawn clearly they will be MARKED WRONG.

7). If a question is unclear, please ASK IMMEDIATELY.

Lots of Luck!

NAME: ______________________________

SECTION: ______________________________

Problem 1: (30 Points)

The following questions refer to the situation in Fig 1 where a rock is thrown upwards with initial speed v_0 at an angle θ above the horizontal at time $t = 0$. On its way down, the rock lands on the roof of a hotel building a height H above the ground and a horizontal distance L away from its original position. Let t_C denote the instant *right before* the ball hits the roof.

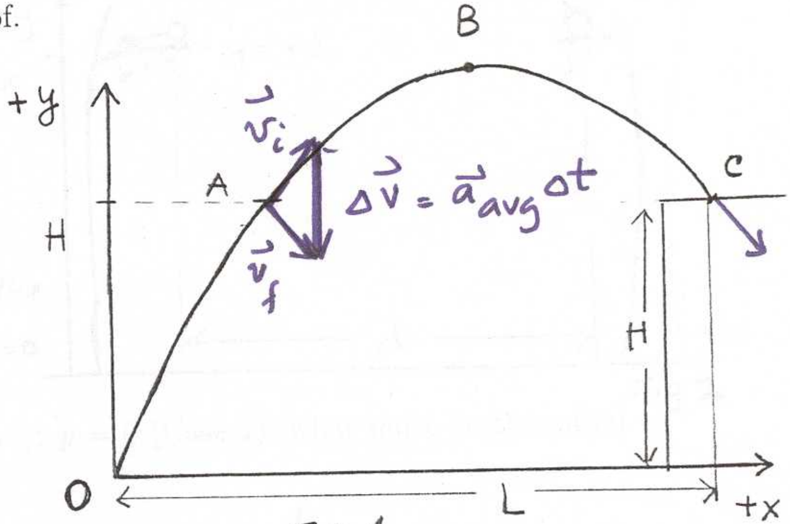


Fig 1.

a). Write down the final position vector of the ball $\vec{r}_f$ at $t = t_C$.

$\vec{r}_f = L\hat{i} + H\hat{j}$

b). What does the length of the curve OC represent if anything?

The total distance covered by the ball.

c). Draw the velocity vectors of the ball at points A and C. Use them to graphically find the *direction* of the average acceleration vector of the ball between times t_A and t_C.

see figure –

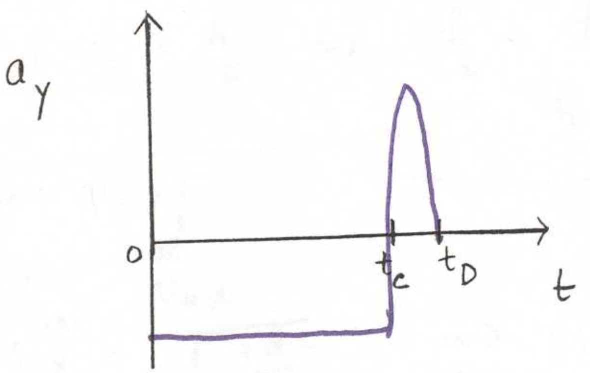
d). Do you expect the average acceleration vector over t_A to t_B to be the same or different than your result in part c? Why or why not?

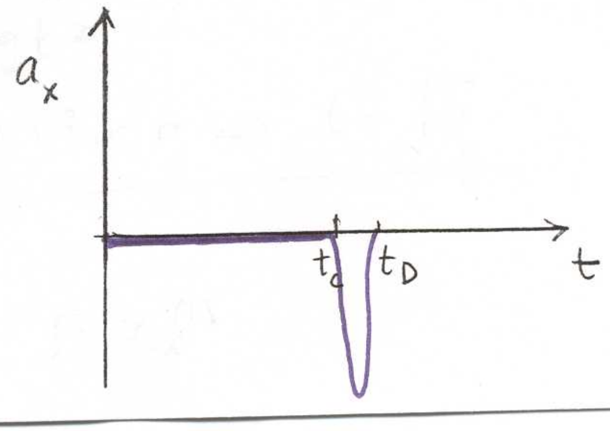
The same since $\vec{a} = -g\hat{j}$ = constant.

e). Find the magnitude and the direction of the average velocity vector $\vec{v}_{avg}$ over times t_A and t_C in terms of v_0, angle θ and acceleration due to gravity g.

$v_{avg,y} = 0$; $v_{avg} = v_0\hat{i}$ [use $v_{avg,x} = \frac{v_{ix} + v_{fx}}{2}$ & $v_{avg,y} = \frac{v_{iy} + v_{fy}}{2}$].

f). The ball hits the roof of the building at time t_C and comes to rest shortly thereafter at time t_D. During this time interval does it have an acceleration in the (i) y direction? (ii) x-direction? If yes then what are their respective directions? Draw a plot of a_y vs t and a_x vs t for $t = 0$ to $t = t_D$.





Problem 2: (25 Points)

Fig. 2 illustrates a monkey and a hunter with a blow pipe intent on hitting a falling monkey with his dart. The hunter and the monkey are located at the same vertical level h high above the ground and a horizontal distance d apart. The hunter fires his gun at the precise instant the monkey begins to fall from rest. (Assume that effects of air friction are negligible).

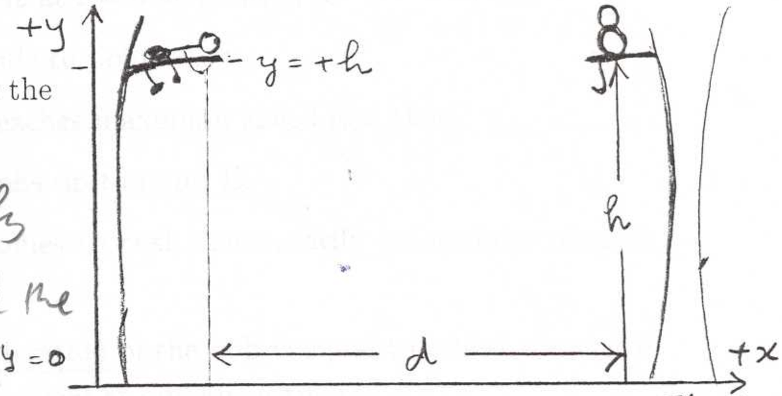


Fig 2

a). At what angle with respect to the horizontal should the hunter aim his gun? Explain briefly.

The hunter must aim directly at the monkey. In that case the vertical motion of the bullet & the monkey are identical.

b). If the dart is to hit the monkey at $y = 0$ (Case 1), what must be the initial speed of the dart? Let's call it v_{01}.

$v_{0y} = 0$; $d = v_{0x} t_{flight} \Rightarrow v_{0x} = \frac{d}{t_{flight}}$

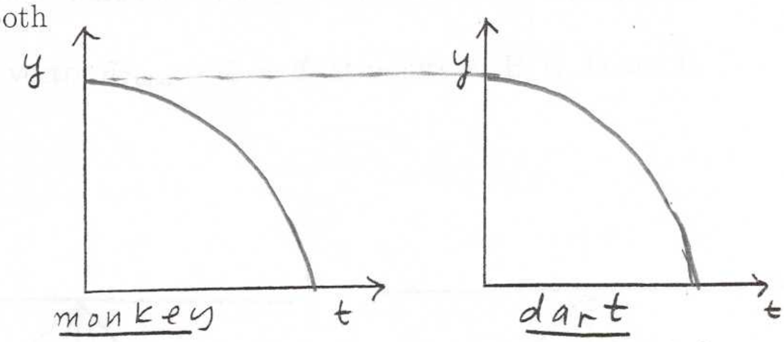
$y_f = y_i + v_{iy} t - \frac{1}{2} g t^2$

$0 = h + 0 - \frac{1}{2} g t^2$

$t = \sqrt{\frac{2h}{g}}$

$= \frac{d\sqrt{g}}{\sqrt{2h}} = \sqrt{\frac{d^2 g}{2h}}$.

c). Draw a plot of y vs t for both the monkey and the dart.



d). If the dart is to hit the monkey at $y = h/2$ (Case 2), should the initial speed of the dart v_{02} be such that $v_{02} = 2v_{01}$; ~~$v_{02} > v_{01}$~~ or $v_{02} < 2v_{01}$? Explain. $2v_{01} > v_{02} > v_{01}$

if $y_f = \frac{h}{2} \Rightarrow \frac{h}{2} = h - \frac{1}{2} g t^2$

$\Rightarrow \frac{h}{2} - \frac{1}{2} g t^2 = 0 \Rightarrow t = \sqrt{\frac{h}{g}}$.

$d = v_{0x} T$

$v_{0x} = \frac{d}{v_{0x}}$

$v_{0x}^{(2)} = \sqrt{\frac{g d^2}{h}} \Rightarrow v_{0x}^{(2)} = \sqrt{2}\, v_{0x}^{(1)}$.

Problem 3 (20 Points)

Fig 3 shows a swinging pendulum consisting of a bob attached to a string of length L. The bob is released at rest from an initial angle θ_0. Its motion along the circular arc AE is such that:

i). **At Point A:** it starts from **rest** at $t = 0$ at point A &

ii). **A to C:** speeds up as it decends to point C.

iii). **At Point C:** At point C it reaches maximum speed and then

iv). **C to E:** slows down as it climbs up to point E.

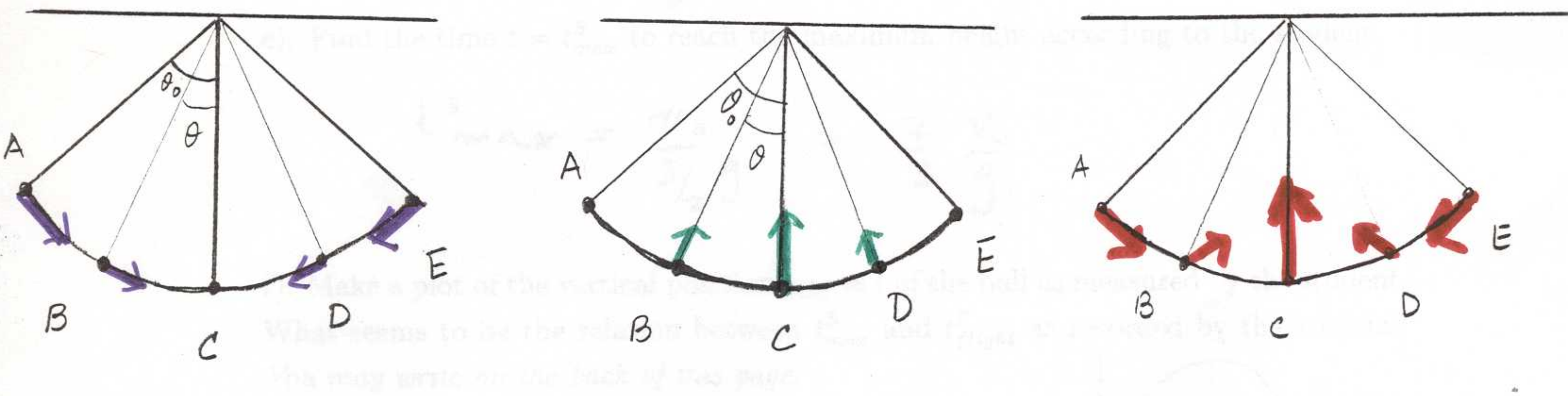
v). **At Point E:** it once again comes to **rest** momentarily before beginning its journey back to point A and so on.

The magnitude of the tangential acceleration of the bob is equal to $g\, sin\theta$ where θ is the angle the string makes with the vertical at any given time.

a). Draw vectors at points A, B , C , D and E indicating the tangential acceleration $\vec{a}_t$ of the bob at those points on its way from A to E. If the magnitude of $\vec{a}_t$ at two different points is different, make sure that you draw vectors with clearly different lengths. If the acceleration at a given point is zero, indicate that by writing $a_t = 0$ at that point.

b). Draw the radial acceleration vector $\vec{a}_r$ at points A, B, C, D and E. Again, if the magnitude of a_r is different at two different points, draw vectors with clearly different lengths. If a_r is zero at a given point, indicate that by writing $a_r = o$ at that point.

c). Draw the **total acceleration** vector $\vec{a}_{Total} = \vec{a}_r + \vec{a}_t$ at points A, B, C, D and E.



(a) Tangential Accel.

(b) Radial Accel

(c) $\vec{a}_T$ = Total Accel

Problem 4: (25 Points)

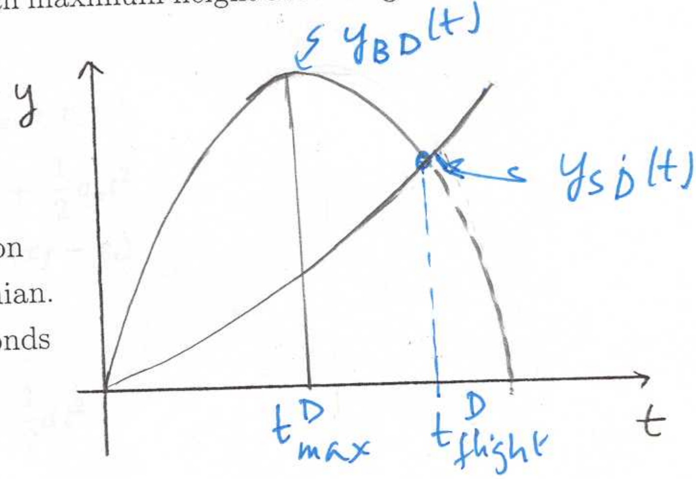
Physics experiments are being carried out by a Physics 161 student in a lab equipped with rockets that give the lab a constant acceleration upwards as measured by the TA Damian stationed on the ground i.e., $\vec{a}_{SD} = 0.5g\hat{j}$. At the instant the student throws a ball up with speed v_0 as measured by her i.e., $\vec{v}_{iBS} = v_0\hat{j}$. At that precise instant, Damian records the velocity of the accelerating student to be $\vec{V}_{SD} = +V_1\hat{j}$.

a). Find the time t^D_{max} it takes the ball to reach maximum height according to Damian.

$\vec{v}_{BDi} = (V_1 + v_0)\hat{j} \Rightarrow t^D_{max} = \frac{V_1 + v_0}{g}$

$\vec{a}_{BD} = -g\hat{j}$

b). Draw a plot of vertical position y_{BD} vs t of the ball as recorded by Damian. On the same graph, plot the vertical position y_{SD} vs t of the student as recorded by Damian. On the plots, indicate which curve corresponds to $y_{BD}(t)$ and which one to $y_{SD}(t)$.



c). On the above graph, **mark and label** the instant which Damian would record as t^D_{max} **as well as** the instant he would record as t^D_{flight} ≡ the total time of flight of the ball.

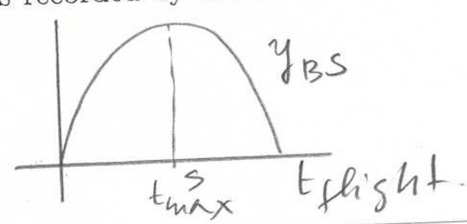
d). Write down an equation for $y_{BD}(t)$ and $y_{SD}(t)$. According to your answer for part (c) above, how should one proceed to solve for the total time of flight as measured by Damian? (You do not have to solve it).

$$\left.\begin{array}{l} y_{BD}(t) = v_{oy}t - \frac{1}{2}gt^2 \\ y_{SD}(t) = v_1 t + \frac{1}{4}gt^2 \end{array}\right\} \text{ then set } \boxed{y_{BD}(t) = y_{SD}(t)}$$

e). Find the time $t = t^S_{max}$ to reach the maximum height according to the student.

$$t^S_{max} = \frac{v_0}{3/2\, g} = \frac{2}{3}\frac{v_0}{g}.$$

f). Make a plot of the vertical position y_{BS} vs t of the ball as measured by the student. What seems to be the relation between t^S_{max} and t^S_{flight} as recorded by the student? *You may write on the back of this page.*



$t^S_{flight} = 2t^S_{max}$