Physics 211 Exam 1

Problem 1	Problem 2	Problem 3	Problem 4	Total
/25	/25+5	/25	/25	/100

Name: ______________________________

Recitation section number: ___________

(see back page)

- There are four questions worth a total of 100 points, with a potential for 5 points of extra credit.
- **You must show your reasoning to receive credit**. A numerical answer with no logic shown will be treated as no answer.
- You are highly encouraged to use both pictures and words to show your reasoning, not just algebra.
- If you run out of room, continue your work on the scratch paper on the back.
- Remember, show your reasoning as thoroughly as possible for partial credit.
- You may use $g = 10\,\mathrm{m/s^2}$ throughout, except where indicated, to minimize arithmetic.

Recitation Schedule

M005	10:35-11:30A	Physics B129E	Bradley Cole
M013	10:35-11:30A	Physics 106	Emily Syracuse
M021	10:35-11:30A	Heroy 013	Xuan Zheng
M006	11:40A-12:35P	Physics B129E	Bradley Cole
M014	11:40A-12:35P	Physics 106	Kesavan Manivannan
M022	11:40A-12:35P	Heroy 013	Alexander Hartwell
M007	12:45-1:40P	Physics B129E	Merrill Asp
M015	12:45-1:40P	Physics 106	Emily Syracuse
M008	2:15-3:10P	Physics B129E	Bradley Cole
M016	2:15-3:10P	Physics 106	Kesavan Manivannan
M009	3:45-4:40P	Physics B129E	Ohana B. Rodrigues
M017	3:45-4:40P	Physics 104N	Kesavan Manivannan
M010	5:15-6:10P	Physics B129E	Julia Giannini
M018	5:15-6:10P	Physics 106	Emily Syracuse
M003	8:25-9:20A	Physics B129E	Merrill Asp
M011	8:25-9:20A	Physics 106	Julia Giannini
M004	9:30-10:25A	Physics B129E	Merrill Asp
M012	9:30-10:25A	Physics 106	Julia Giannini
M020	9:30-10:25A	Heroy 013	Xuan Zheng
M024	9:30-10:25A	Hall/Lang 205	Alexander Hartwell

Reference

If an object moves with constant acceleration a, its velocity and position as a function of time will be

$$v(t) = at + v_0$$
$$x(t) = \frac{1}{2}at^2 + v_0 t + x_0$$

Combining these two gives the "third kinematics equation" $v_f^2 - v_0^2 = 2a(x_f - x_0)$.

The quadratic equation $At^2 + Bt + C$ has solutions $t = \dfrac{-B \pm \sqrt{B^2 - 4AC}}{2A}$.

$$\sin = \frac{\text{opposite}}{\text{hypotenuse}}$$
$$\cos = \frac{\text{adjacent}}{\text{hypotenuse}}$$
$$\tan = \frac{\text{opposite}}{\text{adjacent}}$$

If a right triangle has sides A and B and a hypotenuse C, then their lengths are related by the Pythagorean theorem $A^2 + B^2 = C^2$.

Question 1

A hollow ball falls into a pond from a height of 1m. While it is in the air, it is in freefall. When it is underwater, it has an acceleration of 5 m/s^2 upward, because it is light enough to float.

You may assume that its velocity does not change as it passes through the surface of the water.

a) With what velocity does it strike the surface? (5 points)

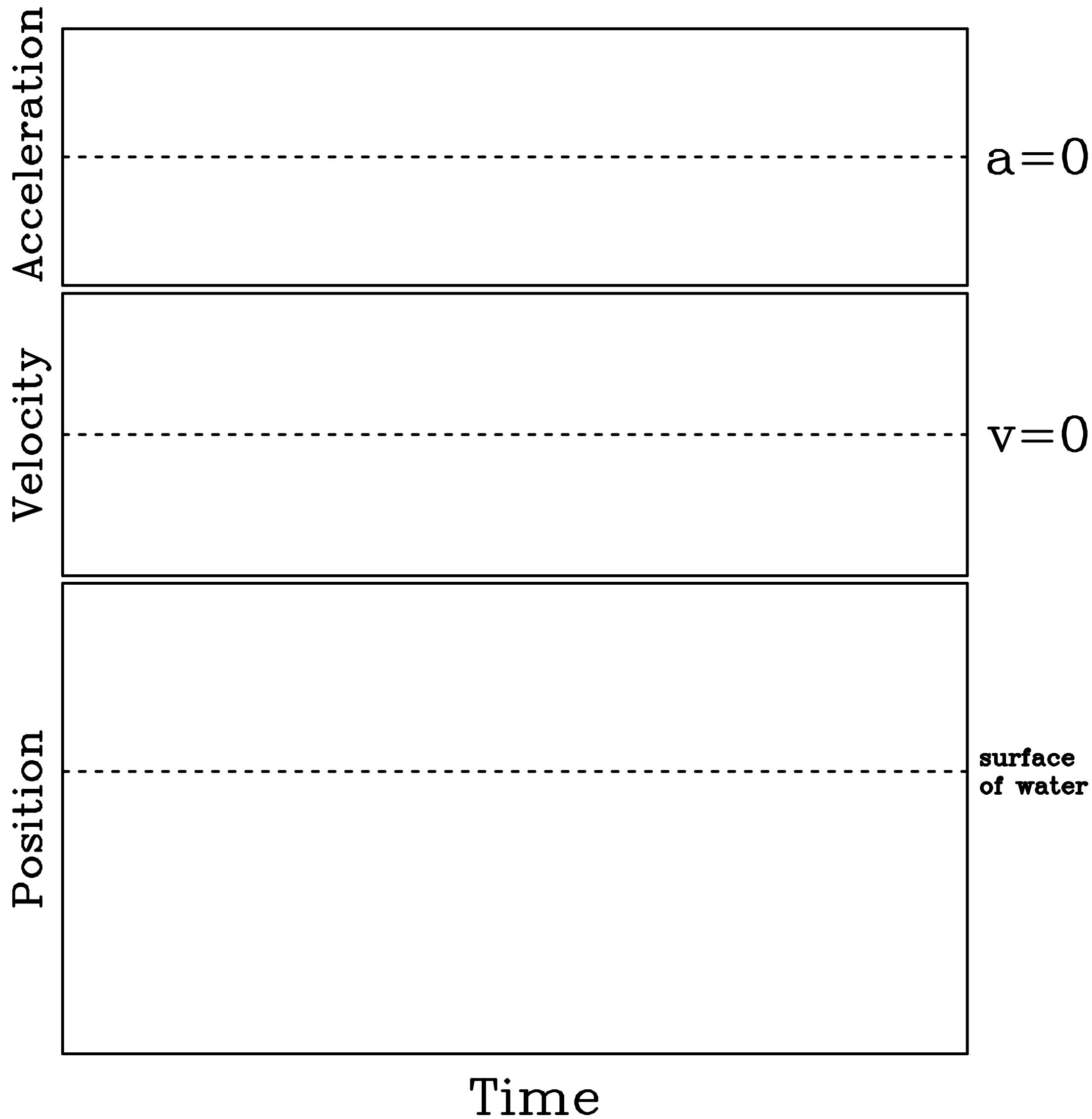
b) What is the deepest point that the ball reaches? (5 points)

c) How long after it is dropped does it take for the ball to reach the surface again? (5 points)

(This question continues on the next page.)

Question 1, continued

d) Sketch graphs of acceleration vs. time, velocity vs. time, and position vs. time on the axes provided, starting from when the ball is dropped and ending when it reaches the surface again. We are not looking for exact numbers, but we want zero crossings, maxima and minima, slopes, concavity, etc. to be correct. (10 points)



Question 2

A Syracuse University student has built a catapult that launches snowballs. This machine can propel a snowball at a speed v_0 at an angle θ above the horizontal. Suppose that they set their machine up on a large flat area. Ignore air resistance for this problem.

(The below space is for you to draw a diagram and label a coordinate system.)

a) Write expressions for $x(t)$, $y(t)$, $v_x(t)$, and $v_y(t)$ in terms of v_0, θ, and g. (5 points)

b) Determine how long the snowballs will be in the air before they land again, in terms of v_0, θ, and g. (5 points)

(This question continues on the next page.)

c) Show that the distance between the catapult and the point where the snowballs strike the ground is

$$d = \frac{2v_0^2 \sin\theta \cos\theta}{g} \text{ (10 points).}$$

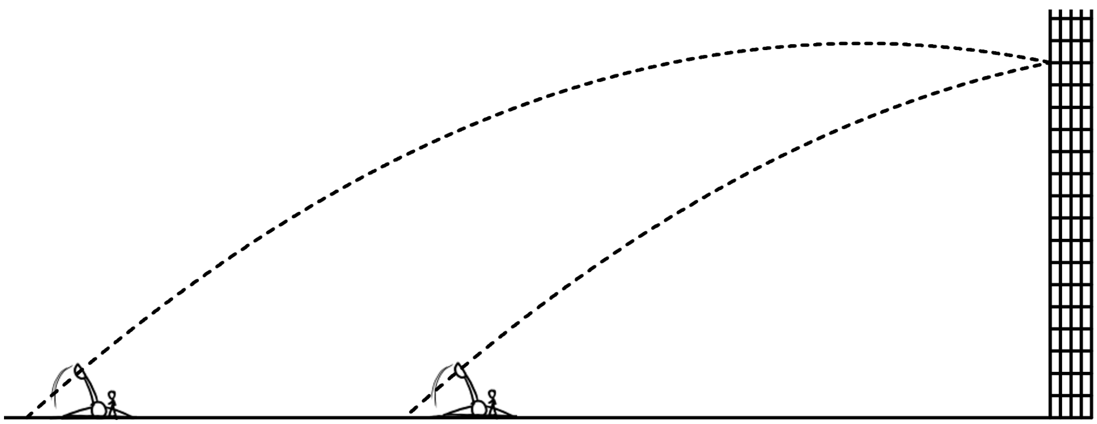
d) Determine the maximum height reached by the snowballs in terms of v_0, θ, and g. (5 points)

e) For a given launch speed v_0, prove that launching the snowballs at an angle $\theta = 45°$ maximizes the distance that they travel. (5 points extra credit)

Question 3

The student from the previous problem wants to use the catapult to throw snowballs from the Quad through the center of Walter's open window in the Physics Building. Suppose that the catapult fires snowballs at an angle $\theta = 40°$ above the horizontal at a speed of $v_0 = 20$ m/s, and the center of the window is a height $h = 8$ m above the ground.[1]

There are two places on the Quad where they could put their catapult. From one position the snowballs will go through Walter's window on the way up; from the other position, they will hit his window on the way down. In this problem, you will figure out where those two locations are.



a) Indicate your choice of coordinate system on the diagram above, and label any other distances/points you want to assign variables to. (3 points)

b) Discuss in words your approach to figuring out where to place the catapult. In particular, what mathematical condition means "the snowball goes in the window"? What variable are you going to solve for?

You may answer this part by simply writing question in terms of your algebraic variables, as we have practiced. (5 points)

(This question continues on the next page.)

[1] Catapult image from Randall Munroe/xkcd, used under CC-BY-NC. See, we cite our sources too!

c) Determine the two points on the Quad where the snowballs will go into the window. Which one is which? (10 points)

d) If you repeat this problem with $v_0 = 15$ m/s, you will find that you get a negative under the square root sign in the quadratic formula. What is the physical interpretation of this?[2] (7 points)

[2] If you did not use the quadratic formula for part (c), then describe instead what will happen with $v_0 = 15$ m/s, and how you would know based on your method.

Question 4

Otto is a red-tailed hawk who raises chicks every year in his nest on Lyman Hall along with his partner Sue. Otto decides to go get breakfast for them. He flies 20 degrees north of east for 150 meters to his favorite tree. From his perch in the tree, he sees a tasty squirrel 250 meters straight north, and flies off to catch it.

After he catches the squirrel, he brings it back to Sue. She has flown from their nest to the Hall of Languages, 300 meters west of their nest; he flies in a straight line to her.

*a) Sketch a diagram of the flight paths of the birds, and label each vector with a name (*e. g. $\vec{A}$*). Then write a vector equation that relates them (*e. g. $\vec{A} + \vec{B} = \vec{C}$*). (5 points)*

(This question continues on the next page.)

b) When Otto flies back to Sue, how far does he have to fly? (10 points)

c) When Otto flies back to Sue, in what direction should he fly? (10 points)

(This is the end of the exam.)

Scratch Paper

Scratch Paper

Scratch Paper