Name: _____

Partner(s): _____

PHYS 1101 Section: _____

Desk # _____

Date: _____

Surviving a High-Rise Fall

Figure 1: http://www.physlink.com/education/askexperts/Images/ae411a.jpg

Introduction

The equation describing the motion of an object falling in the air is

$$mg - bv^2 = ma \text{, or } a = g - \frac{b}{m}v^2$$

where bv^2 is the drag force. In the optimum positions, b/m is roughly 0.003 m^{-1} for a human skydiver, and 0.02 m^{-1} for a cat. We will use these numbers in this lab.

Procedure

Open the spreadsheet you made during the prelab. Talk with one or two classmates to compare what you have created and confirm your understanding. Then return to your own spreadsheet and begin the following:

Graphing the motion of the skydiver

To plot a *v* vs. *t* graph, select the relevant data in columns A and C, (hold the "Ctrl" key to select column C), then click menu item "Insert – Chart", choose "XY (Scatter)" option, and click "Finish". Create an *a* vs. *t* graph similarly.

We also want to know how the position changes with time. You need to add a new column "distance" after the "acceleration" column:

$$y_1 = 0$$
$$y_2 = y_1 + v_1 \Delta t$$
$$y_3 = y_2 + v_2 \Delta t$$
………

and graph *y* vs. *t*. The three curves, *y* vs. *t*, *v* vs. *t* and *a* vs. *t* give us a good understanding of the motion of the skydiver with air resistance.

Graphing the motion of the cat

Copy your worksheet to a new sheet and find the motion of a cat falling with air resistance by changing the *b/m* value.
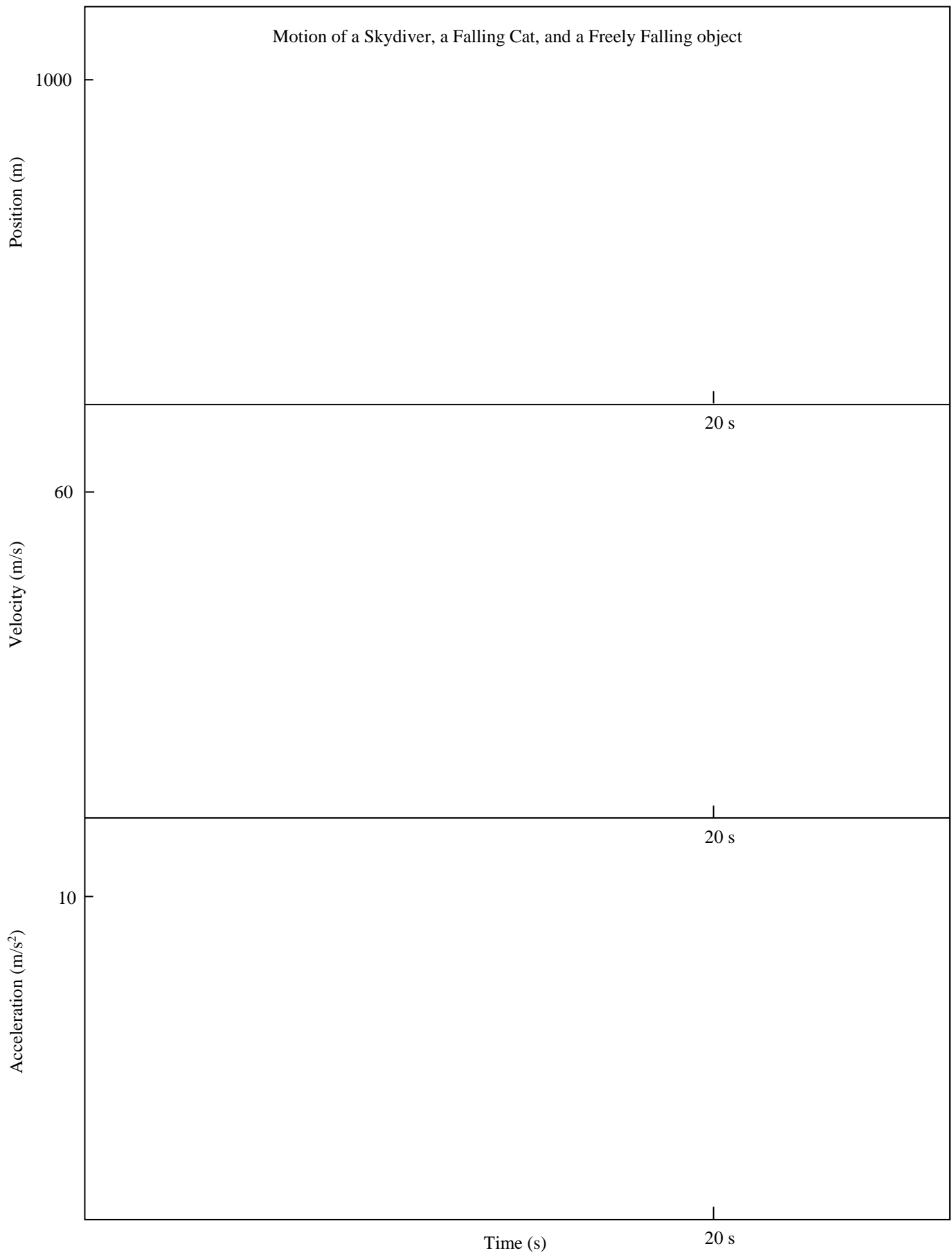
Graphing free fall

Copy your worksheet to another sheet and modify it to model a free falling object (no air resistance).

Comparing the motions all together

Now you should have 3 worksheets with names like "skydiver", "cat" and "free fall". On the next page, sketch the curves for the position, the velocity and the acceleration of each. There will be nine lines. *Do not spend more than 10 minutes on the sketches*.

- Label each axis with the proper name and unit. (This is done for you.)
- Use different types or colours of lines for each object and state them in a legend.
- What is important to show is the relationship between the curves, not the exact values.

Motion of a Skydiver, a Falling Cat, and a Freely Falling object

Position (m)

1000 —

| | 20 s |

Velocity (m/s)

60 —

| | 20 s |

Acceleration (m/s²)

10 —

Time (s) | 20 s |

1101 Air Resistance Spreadsheet (Handout) - 3

Understanding the motion

1. Describe the motion (acceleration and velocity) of an object in free fall.

2. Draw a FBD when a skydiver just starts falling (zero speed), when a skydiver has been falling for a short while, and when he/she has been falling for a long time. Besides each FBD, draw the velocity vector and the acceleration vector with proper relative sizes. Then explain in words how and why the velocity and the acceleration changed. (*Hint: use the net force to explain acceleration, and use the acceleration to explain velocity.*)

3. Given enough height, an object falling in air will eventually reach a constant velocity, called the "terminal velocity". Redraw the last FBD in the previous question below, and derive an equation between the terminal velocity v_T and b/m.

4. Calculate the terminal velocity for the skydiver using the relation you just derived and the numbers on the bottom of Page 1.

5. Calculate the terminal velocity of the cat similarly.

6. Do the terminal velocities on your spreadsheets agree with your results of Question 4 and 5?

7. Who reaches the terminal velocity earlier, the cat or the skydiver?

8. Fill in blanks based on your sketches or worksheets, to 2 or 3 significant digits. You may want to change to a smaller time interval (Δt) for this question and later questions.

8a.   If there were no air, a skydiver jumping from 25 stories high (about 100 m) will land on the

ground with a speed of _____ m/s. A cat jumping from 25 stories will land with a speed of

_____ m/s. The two speeds are _____ (same / different) because

_____ _____.

8b.   With the presence of air, a skydiver jumping from 25 stories high will land on the ground with a speed of _____ m/s. A cat jumped from 25 stories will land with _____ m/s. The two speeds are _____ (same / different). This shows the _____ (skydiver / cat) will have a much better chance of survival.

8c.   In Question 8b, the landing speed of the skydiver is equivalent to free falling from _____ stories. The landing speed of the cat is equivalent to free falling from _____ stories.

9.   Landing of the skydiver: Obviously, the skydiver cannot land with the terminal velocity as given in your sketch or worksheet. He has to open his parachute before landing. Let's examine the effects of opening the parachute:

9a.   Effects on the acceleration: Before opening the parachute (after falling a long time), the skydiver's acceleration is _____ ____. Right after opening the parachute, the direction of the skydiver's acceleration is pointing _____. This is because the magnitude of the upward drag force on the skydiver is _____ (bigger than / smaller than / equal to) the force of gravity.

9b.   Effects on the velocity: Before opening the parachute (after falling a long time), the skydiver's velocity is pointing _____ and its magnitude is _____ (increasing / decreasing / constant). Right after opening the parachute, the skydiver's velocity is pointing _____ and its magnitude is _____ (increasing / decreasing / constant).

9c.   Effects on the *b/m* value of the skydiver and on his terminal velocity: Opening the parachute will make the *b/m* value of the skydiver _____ (bigger / smaller) and his terminal velocity _____ (bigger / smaller).

10. Landing of the cat: During the fall, the best gesture of the cat to keep is facing down with legs stretched out (picture 3 in Figure 1). However, the cat has to pull in her legs right before landing (picture 4 in Figure 1). It is painful to imagine what would happen if she did that too late. But, what would happen if she did it too early? (This illustrates how tough it is to survive the high-rise fall, even for the cat.) Use the concepts you learned in this lab.

If you did not complete your prelab, do the following now

Start Microsoft Excel or Google Docs. Create a spreadsheet like the one below:

	A	B	C	D	E	F
1	Skydiver					
2	Parameters					
3	g	9.81	m/s^2			
4	b/m	0.003	m^(-1)			
5	delta t	0.5	s			
6	Initial data					
7	t initial	0	s			
8	v initial	0	m/s			
9	y initial	0	m			
10						
11	start time	end time	velocity	acceleration		
12	s	s	m/s	m/s^2		
13	0	0.5	0	9.81		
14	0.5	1	4.905	9.7378229		

Formulae are used when the content of a cell is calculated from other cells. A formula is composed of cell addresses, numbers, and operators and starts with an "=" sign. For example:

In cell A13   type   =B7

> *This sets the "start time" in row 13 equal to "t initial" or cell B7.*

In cell B13   type   =A13+$B$5

> *This sets the "end time" of the first time interval to be the "start time" (cell A13) plus Δt (cell B5). A13 is called a relative address and $B$5 with the dollar signs is called an absolute address. If you copy this cell to other cells, the relative address changes accordingly and the absolute address remains the same. So, if you copy cell B13 to B14, the formula will become A14+$B$5.*

In cell C13   type   =B8

> *This sets the "velocity" in row 13 equal to "v initial" or cell B8.*

In cell D13   type   =$B$3-$B$4*C13^2

> *This calculates the "acceleration" in row 13 based on $a_1 = g - \dfrac{b}{m} v_1^2$*

Now, work out what you should enter on row 14, fill in the blanks below, and type them in Excel. This is the most important row in this spreadsheet, and every cell must start with an "=" sign.

In cell A14   type   _____

> *Set the "start time" of the second interval to the "end time" of the first interval. Should this formula contain "$" sign?*

For cell B14   copy B13 to B14.

> *Similar to B13, B14 sets the "end time" to the "start time" plus Δt. That is why you can copy from B13. Two ways to copy are: 1. "Copy" then "Paste". 2. Click the little black square and drag down.*

In cell C14   type   _____

> *Type in the formula based on $v_2 = v_1 + a_1 \Delta t$, paying attention to relative or absolute addresses. Tip: the "$" sign can be turned on/off with the "F4" key on your keyboard.*

For cell D14   copy D13 to D14.

$$\text{This is the quickest way to get the right formular } a_2 = g - \left(\frac{b}{m}\right) v_2^2$$

You have spent some time to work out the motion for the first of the motion. The rest is easy now: copy Row 14 to rows below to calculate the velocity and acceleration to 20 seconds.

Name: _____

Surviving a High-Rise Fall - Prelab

Introduction

The equation describing the motion of an object falling in the air is

$$mg - bv^2 = ma \text{ , or } a = g - \frac{b}{m}v^2$$

where bv^2 is the drag force. In the optimum positions, b/m is roughly 0.003 m^{-1} for a human skydiver, and 0.02 m^{-1} for a cat. We will use these numbers in this lab.

Prelab

For this lab, you may use either Microsoft Excel or Google Docs. You will have to make your prelab available to yourself for use in lab. For Excel, this is most easily done by saving the file to a thumb drive that you bring with you. For Google Docs, you can log into your Google account on the workstation in T346. Create a spreadsheet like the one below:

	A	B	C	D	E	F
1	Skydiver					
2	Parameters					
3	g	9.81	m/s^2			
4	b/m	0.003	m^(-1)			
5	delta t	0.5	s			
6	Initial data					
7	t initial	0	s			
8	v initial	0	m/s			
9	y initial	0	m			
10						
11	start time	end time	velocity	acceleration		
12	s	s	m/s	m/s^2		
13	0	0.5	0	9.81		
14	0.5	1	4.905	9.7378229		

In lab, you will use this spreadsheet to compare the motion of a person in free fall, a person with a parachute, and a cat (because they do that cool, twisty, landing-on-their feet thing when falling). The exercises on this page will prepare your spreadsheet for use and make sure that you understand spreadsheets enough before lab.

Formulas are used to calculate things using values listed in other cells. A formula can be composed of cell addresses, numbers, and operators. Formulas must start with an "=" sign. For example:

In cell A13, type   =B7
       This sets the "start time" in row 13 equal to "t initial" or cell B7.

In cell B13, type   =A13+$B$5
       This sets the "end time" of the first time interval to be the "start time" (cell A13) plus Δt (cell B5). A13 is called a relative address and $B$5 with the dollar signs is called an absolute address. If you copy this cell to other cells, the relative address changes accordingly and the absolute address remains the same. So, if you copy cell B13 to B14, the formula will become A14+$B$5.

In cell C13, type   =B8
       This sets the "velocity" in row 13 equal to "v initial" or cell B8.

In cell D13, type   =$B$3-$B$4*C13^2

       This calculates the "acceleration" in row 13 based on $a_1 = g - \dfrac{b}{m} v_1^2$

Now, work out what you should enter on row 14. Fill in the blanks below, and type them in Excel.

1. Set the "start time" of the second interval to the "end time" of the first interval.

   In cell A14 type _____

   Should this formula contain "$" sign?

2. Similar to B13, B14 sets the "end time" to the "start time" plus Δt. That is why you can copy from B13. Two ways to copy are: 1. "Copy" then "Paste". **OR** 2. Click the little black square and drag down. For cell B14 copy B13 to B14.

3. Enter the formula based on $v_2 = v_1 + a_1 \Delta t$ into cell C14, paying attention to relative or absolute addresses.

Make sure that your spreadsheet is saved and will be accessible to you in lab. For your Brightspace prelab submission, you only have to include a picture of the next page ("Understanding the motion").

Understanding the motion - these questions appear near the end of the worksheet you will complete in lab next week. Your answers here should be well thought out, but it is okay if, after completing the lab in class, you write a different answer.

11. Describe the motion (acceleration and velocity) of an object in free fall.

12. Draw a FBD when a skydiver just starts falling (zero speed), when a skydiver has been falling for a short while, and when he/she has been falling for a long time. Besides each FBD, draw the velocity vector and the acceleration vector with proper relative sizes. Then explain in words how and why the velocity and the acceleration changed. (*Hint: use the net force to explain acceleration, and use the acceleration to explain velocity.*)

13. Given enough height, an object falling in air will eventually reach a constant velocity, called the "terminal velocity". Redraw the last FBD in the previous question below, and derive an equation between the terminal velocity v_T and *b/m*.