Guide to Free Falling Up

PHYSICS 203, PROFS. BEAN & MARTENS YAVERBAUM
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A. A rocket takes off from earth's surface and flies upwards with a constant acceleration of 24 m/s/s. How far will it travel in the first second?

Be CAREFUL with your variables:
Acceleration is NOT the same as average velocity.
Average velocity is NOT the same as final velocity.
It's not THAT simple.

FIRST, draw a picture of the situation (as always). Your picture should show:

- a rocket (could be just a dot);
- earth's surface (a horizontal line or a curve or a circle, it doesn't matter);
- an arrow to show the rocket's acceleration, with "a = 24 m/s/s" written next to the arrow;
- a bracket or I-bar showing the distance the rocket travels and a variable (d?) for that dist.

SECOND, write down all the kinematics equations you know. Not sure which kinematics equations you know? Look on the course website, in the RIGHT-HAND COLUMN, right next to the links for this week's HW.

ASK YOURSELF: what values do I know? What value am I looking for?

LOOK FOR an equation which contains ONE and only one value that you do NOT know.

(NOTE: there might be a couple equations that will help.)

Plug into this equation and solve for the variable you don't know. Now look for another equation that can help you. Keep going until you KNOW EVERYTHING!

How far will it travel in the first 1/3 of a second?

Solve this in EXACTLY the same way you solved the other part. The only difference is the ***time***.

You do NOT need to draw a new picture—just add a new dot to the old picture to show the rocket's location after 1/3 of a second.

Should this dot be above or below the dot for its location after 1 second of flight?

A. **Version 1:** A cheese sandwich is sitting on a cafeteria table, at rest. Suddenly and mysteriously, it begins to move across the cafeteria, maintaining a constant acceleration throughout its motion. Amidst gasps and shrieks, one self-possessed young woman thinks to time the sandwich.

She discovers that it takes exactly 1 second to traverse the room and splatter against the cafeteria wall.

Later, she measures the room and discovers that it was exactly 48 feet from the sandwich's starting location to the wall where it spattered.

i. What was the sandwich's ***acceleration***, in ft/s/s?
ii. What was the sandwich's velocity at the instant that it slammed into the wall?

As always, start with a PICTURE of the situation. It should include:
- the cheese sandwich (could be just a dot);
- an arrow to show its acceleration, labeled with an *a*;
- the wall (could be just a vertical line);
- a bracket or I-bar to show the displacement of the sandwich over the course of its trip;
- "V_0" at the sandwich's starting point and "V_f" at its ending position.

NEXT, write down the kinematics equations you know.

ASK YOURSELF: what values do I know? What values am I looking for?

HINT: in the first sentence of the problem, it says "the cheese sandwich is sitting on a cafeteria table, at rest." What does this tell you? (It gives you a value for one of the kinematics variables.)

LOOK FOR an equation which contains ONE and only one value that you do NOT know.

(NOTE: there are actually a couple options.)

Solve this equation, and you will have another variable you know. Now look for another equation that can help you. Keep going until you KNOW EVERYTHING!

Version 2: Now imagine that the cheese sandwich took exactly 4 seconds to slam into the wall. All other factors, including the distance it traveled, remain the same.

i. What was its acceleration?
ii. What was its velocity at the instant it slammed into the wall?

Same method, just different values. You do NOT have to draw a new diagram.

II. Catch-22

Assume that near the surface of the Earth, an object free-falls at a ***constant acceleration*** of 22 miles/hr/sec.

A gigantic object is dropped from rest.

How far does the object descend in the first MINUTE of free-fall?!

Notice that you have a UNITS PROBLEM.

BEFORE doing any kinematics, convert everything to the same units.

But NOTICE that ***THREE*** different units of time appear in this problem. They must ALL be converted into the same unit.

For t, this conversion might not be too hard.
For a, this conversion might be kind of tricky.

If you're stuck, try this:

1. Write out your unit conversions as equations (as in, 1 foot = 12 inches).
2. Substitute for the units in your acceleration, using your conversion equations.
3. Use algebra to simplify the resulting fraction.

If you're feeling clever:
Try solving this problem by converting everything to MINUTES.
It's not the easiest way to do it, but if you get how to do it, it's the FASTEST & the COOLEST.

Once you have converted the units, write down your kinematics equations & carry out the same types of steps you used in Warm Ups A & C.

III. DERIVATION OF EQUATION #5:

This problem is just algebra. It's similar to Warm-Up problem B in this homework, but more complicated. You're just combining equations, using algebraic methods. No need for a picture.

Start by writing out your kinematics equations. (Remember: we are assuming that a is constant.)

Consider the following algebraic techniques: substituting, distributing, simplifying.

IV. Chopper.

Assume that a free-falling object accelerates ***down*** at a constant rate. Assume, further, that this rate, ***a***, is approximately 10 yards/second^2.

A helicopter carries a package of pumpkins high above a renown pumpkin patch.
The package dangles from a 10 yard rope dangling from the bottom of the helicopter.
The helicopter accelerates ***up*** at a perpetually constant rate of 15 yard/second^2.

Suddenly, at the moment the helicopter has achieved an ***upward instantaneous velocity*** of 20 yards/second, the rope breaks.

By how many yards are the helicopter and package separated precisely 4 seconds after the rope breaks?

Draw a picture of the situation.

ASK YOURSELF:

1. Immediately before the rope is cut, what is the acceleration of the package?
2. Immediately before the rope is cut, what is the velocity of the package?
3. Immediately after the rope is cut, what is the acceleration of the package?
4. Immediately after the rope is cut, what is the velocity of the package?

Of the four questions above, the last one is the surprising one. As an experiment, try pulling an object quickly upwards and then suddenly letting go. What happens to the object? Does it keep going up for a while or does it start going down right away?

Write out all your knowns & unknowns in an organized way. As you do, keep in mind that:

- There are TWO objects in this problem. You need to find out how far APART they are. That means you need to know the location of EACH object. So you have to analyze each object SEPARATELY.
- You are interested in what happens during the 4 seconds AFTER the rope is cut. This experiment "begins" when the rope is cut and ends 4 seconds later.

Once you have all your knowns written down, look for a ***kinematics equation*** that can help you, and solve. Keep in mind that the rope is 10 feet long at the beginning.

Now look at your list of kinematics equation & find one that contains ONE and only one variable that you do NOT know the value of.

But note: you just (hopefully) PROVED equation #5 in the preceding problem. So that is now FAIR GAME (and it might prove useful for this problem, and for many others)!

V. Windows 9.8.

Assume that a free-falling object accelerates ***down*** at a constant rate.

Assume, further, that this rate, ***a***, is approximately 4 ***geshes***/second^2. It TRULY does not matter if you have never heard of a ***gesh***.

a) One day, a cat sits near a window and watches the world outside. The length of the window is 3 ***geshes*** from top to bottom.

There is a ledge above the window. The distance between the ledge and the top of the window is unknown.

At some moment, all of a sudden, a flower pot falls off the ledge and plummets past the window.

The cat notices that the flower pot takes 1/4 second to traverse the entire vertical length of the window.

In ***geshes***, how high above the top of the window is the ledge?

This one is trickier… but START out the way you always do, with a PICTURE.

Your picture should show all relevant values, including the STARTING LOCATION of the flower pot. There is one thing mentioned in the problem that does NOT need to be in your picture, because it does not move and has no values associated with it… but it can still be there, if you like to draw those animals.

Then, as always, write out your kinematics equations.

NOW, the tricky thing about this problem is that there are two different SECTIONS of the flower pot's journey that have to be considered separately. The two sections are:

1. The trip from the ledge to the top of the window.
2. The trip from the top of the window to the bottom of the window.

Somehow mark these two sections on your diagram.

The value you are looking for is in the first of these sections.

Most of the values that you actually have are in the second section.

Analyze the section you know more about first.

Try to find the INITIAL VELOCITY for this second section of the trip. This is NOT the initial velocity at the <u>beginning</u> of the fall; it's the initial velocity of the SECTION of the fall when the pot is in front of the window. So it's the velocity at the TOP of the window.

Once you find this, you will need to find the TIME that the flower pot takes to get from the ledge to the top of the window. There is an equation that can help you do this.

Next, you will find the DISPLACEMENT of the flower as it fell from the ledge to the window.

b) Later, the cat observes the flower pot zoom up and then down past the window. The landlord, standing somewhere below the window, has attempted to throw the pot back onto the ledge. Evidently he missed. The flower pot, therefore, has gone up, reached some peak height and fallen down. In this scenario, therefore, a cat has observed the flower pot free-fall a full ‘round-trip’: up and then down. The pot has spent a *total* of **1/2** second in front of the window (up+down). In ***geshes***, how high above the top of the window was the peak height attained by the pot for this round trip?

This one is quite similar. But there’s one thing you need to know:
ROUND TRIPS UNDER CONSTANT ACCELERATION ARE SYMMETRICAL.
In other words, if something is thrown upwards near the surface of a planet, the trip up is EXACTLY LIKE the trip down in reverse.

A hint: you can look at EITHER the trip up OR the trip down to find the initial height of the ledge.

A final hint: if the answer looks oddly familiar, don’t be alarmed. That might not be a bad thing.