Physics 111

Lecture 06

Thursday, September 9, 2004

- Ch 3: Kinematic Equations
  Structured Approach to Problem Solving
- Ch 4: Projectile Motion

EXAMPLES!

Announcements

Help sessions meet
Sunday, 6:30 - 8 pm in CCLIR 468
Wednesday, 8 - 9 pm in NSC 118/119

You must bring both your Lab Manual and Lab Notebook to Lab or you will not be allowed to begin this week. There will be another short quiz at the beginning of lab.

Announcements

Ch 2: One Dimensional Motion

Kinematic Equations

(uniform acceleration ONLY)

\[
\vec{v}_f = \vec{v}_i + \vec{a} (\Delta t)
\]

\[
\vec{x}_f = \vec{x}_i + \vec{v}_i (\Delta t) + \frac{1}{2} \vec{a} (\Delta t)^2
\]

where \( \Delta t \equiv t_f - t_i \)

These equations are easy to derive using calculus.

How do we interpret these relationships graphically?

The area under the curve is the distance traveled by the object over the time interval.

Area of rectangle = \( v_i t \)
\[
\Delta v = v_f - v_i = at
\]

Area of triangle = \( \frac{1}{2} at^2 \)
What if the acceleration is NOT constant?

The “area” under the curve is still the distance traveled by the object over the time interval. Split up the interval of interest into a bunch of little time intervals in which the velocity is approximately constant.

\[ \Delta x = v(t) \Delta t \]

Problem Solving: A Structured Approach

Let’s set up a procedure for problem solving that is thoughtful and organized. Our procedure needs to be versatile enough to help us work through a wide range of problems of varied difficulty.

1) Physical Representation
   - Motion Diagrams
   - We’ll learn other Physical Representations in the near future

This approach involves 3 steps, two of which we already have covered:

1) Physical Representation
2) Pictorial Representation (new!)
3) Mathematical Representation

3) Mathematical Representation
   - Definitions of position, displacement, velocity, and acceleration
   - Kinematic equations
   - More to come!
Problem Solving: A Structured Approach

1) Physical Representation - Motion Diagram
   - Draw pictures of the physical situation at all the key times in the problem
   - Define the coordinate system
   - Define the variables
   - List knowns and unknowns

2) Pictorial Representation (New!)
   - Draw pictures of the physical situation at all the key times in the problem

3) Mathematical Representation
   - Kinematic equation for George:
     \[ x_{G,f} = x_{G,i} + v_{G,i}(\Delta t) + \frac{1}{2}a_{G}(\Delta t)^2 \]
     \[ = 0 + (60 \text{ mph})(t_f - t_i) + 0 = (60 \text{ mph})t_f \]
   - Kinematic equation for Annabel:
     \[ x_{A,f} = x_{A,i} + v_{A,i}(\Delta t) + \frac{1}{2}a_{A}(\Delta t)^2 \]
     \[ = 400 \text{ miles} + (-40 \text{ mph})(t_f - t_i) + 0 = 400 \text{ miles} - (40 \text{ mph})t_f \]

Problem Solving: A Structured Approach

The approach is best demonstrated with a problem. Let’s try this one together:

George lives in Chicago and wants to meet up with his friend Annabel for lunch, but Annabel lives in Pittsburg, 400 miles East of Chicago. If George leaves home at 9 am traveling 60 mph East and Annabel leaves at the same time traveling 40 mph West, where will they meet?

Known:
- \( t_f = 0 \), \( x_{G,i} = x_{A,f} = x_f \)
- \( v_{G,i} = 0 \), \( v_{A,i} = 400 \text{ miles} \)
- \( v_{G} = +60 \text{ mph} \), \( v_{A} = -40 \text{ mph} \)
- \( x_{G,i} = 0 \), \( x_{A,i} = 0 \)

Unknown:
- \( t_f \), \( x_f \)

The condition for meeting at time \( t_f \) is that \( x_{G,f} = x_{A,f} \), so we need to set the two kinematic equations from the last slide equal to one another.

\[ x_{G,f} = 400 \text{ miles} - (40 \text{ mph})t_f = (60 \text{ mph})t_f = x_{A,f} \]

(100 mph)\( t_f = 400 \text{ miles} \)

\( t_f = 4 \text{ hours} \)
Ch 2: One Dimensional Motion

George lives in Chicago and want to meet up with his friend Annabel for lunch, but Annabel lives in Pittsburg, 400 miles East of Chicago. If George leaves home at 9 am traveling 60 mph East and Annabel leaves at the same time traveling 40 mph West, where will they meet?

3) Mathematical Representation

So, they’ll meet up at 1 pm, but the question wants to know where. To find out, we can use either of the kinematic equations, plugging in our answer for t.

\[ x_{f} = 400\text{ miles} - (40\text{ mph})(4\text{ hours}) = 240\text{ miles} \]

4) Sanity Check

It’s useful to ask yourself if the answer makes sense. We know that George was traveling with a higher speed. We also know that they both left at the same time. That means that when they meet up, they’ll both have been traveling for the same amount of time. So, George must have gone further than Annabel. Indeed, our answer of 240 miles East of Chicago is farther from Chicago than Pittsburg. Good deal!

Becky & Tom are skiing on a dangerous, double black diamond slope in Vail. Today, the slope is completely ice, so there’s no friction. The angle of the slope is 10° above horizontal. Tom starts from rest. If Becky starts down the slope 5 s after Tom, what’s the minimum initial speed Becky must have in order to catch Tom before they reach the bottom of the slope, 500 m away?

Problem Solving Worksheet

Chapter 4

Two-Dimensional Motion

This chapter looks at motion in two dimensions. These problems are simply 2, one-dimensional problems. We’ll look at a special case of 2-D motion: projectile motion.

Motion Diagrams

Both blocks are falling under the influence of Earth’s gravity, so they both have the same acceleration.

Note that the x-components of velocity do not change while the y-components match in this case.

In this demo, which object should strike the floor first? (Assume no air resistance.)
1) Falling block
2) Flying block
3) Neither. They’ll hit at the same time.
The block demo is an example of an object undergoing:

Class of problems in which an acceleration is present in only one direction of motion.

The acceleration is often due to the Earth’s gravity in experiments conducted at or near the surface of the Earth.

An artillery shell is fired with an initial velocity of 300 m/s at 55.0° above the horizontal. It explodes on a mountainside 42.0 s after firing. What are the x and y coordinates of the shell when it explodes?

(0,0) = location of the launching point of the shell.

Problem Solving Worksheet