PHYSICS I

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A Note About Slopes

The slope of a graph of physical data represents the ratio of change in the quantity represented on the vertical axis to the change in the quantity represented by the horizontal axis.

The slope has units

- Unless both axes have the same units

Instantaneous Velocity, equations

The general equation for instantaneous velocity is:

$$v_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

The instantaneous velocity can be positive, negative, or zero.

Instantaneous Speed

The instantaneous speed is the magnitude of the instantaneous velocity.

The instantaneous speed has no direction associated with it.

Analysis Models

Analysis models are an important technique in the solution to problems.

An analysis model is a description of:

- The behavior of some physical entity, or
- The interaction between the entity and the environment.

Try to identify the fundamental details of the problem and attempt to recognize which of the types of problems you have already solved could be used as a model for the new problem.

Analysis Models, cont

Based on four *simplification models*

- Particle model
- System model
- Rigid object
- Wave

Problem approach

- Identify the analysis model that is appropriate for the problem.
- The model tells you which equation to use for the mathematical representation.

Model: A Particle Under Constant Velocity

Constant velocity indicates the instantaneous velocity at any instant during a time interval is the same as the average velocity during that time interval.

- $v_x = v_{x,\,avg}$
- The mathematical representation of this situation is the equation.

$$v_x = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t} \quad or \quad x_f = x_i + v_x \Delta t$$

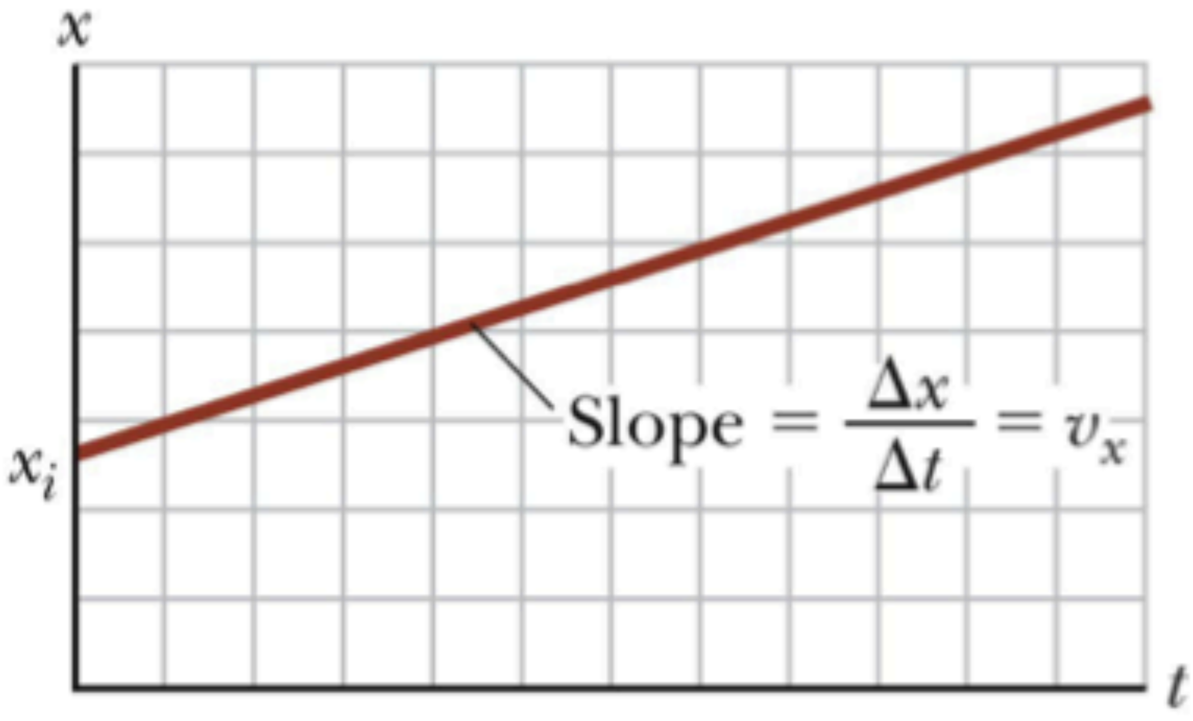
- Common practice is to let $t_i = 0$ and the equation becomes: $x_f = x_i + v_x\, t$ (for constant v_x)

Particle Under Constant Velocity, Graph

The graph represents the motion of a particle under constant velocity.

The slope of the graph is the value of the constant velocity.

The y-intercept is x_i.



Model: A Particle Under Constant Speed

A particle under constant velocity moves with a constant speed along a straight line.

A particle can also move with a constant speed along a curved path.

This can be represented with a model of a **particle under constant speed.**

The primary equation is the same as for average speed, with the average speed replaced by the constant speed.

$$v = \frac{d}{\Delta t}$$

Average Acceleration

Acceleration is the rate of change of the velocity.

$$a_{x,avg} \equiv \frac{\Delta v_x}{\Delta t} = \frac{v_{xf} - v_{xi}}{t_f - t_i}$$

Dimensions are L/T^2

SI units are m/s^2

In one dimension, positive and negative can be used to indicate direction.

Instantaneous Acceleration

The instantaneous acceleration is the limit of the average acceleration as Δt approaches 0.

$$a_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt} = \frac{d^2 x}{dt^2}$$

The term acceleration will mean instantaneous acceleration.

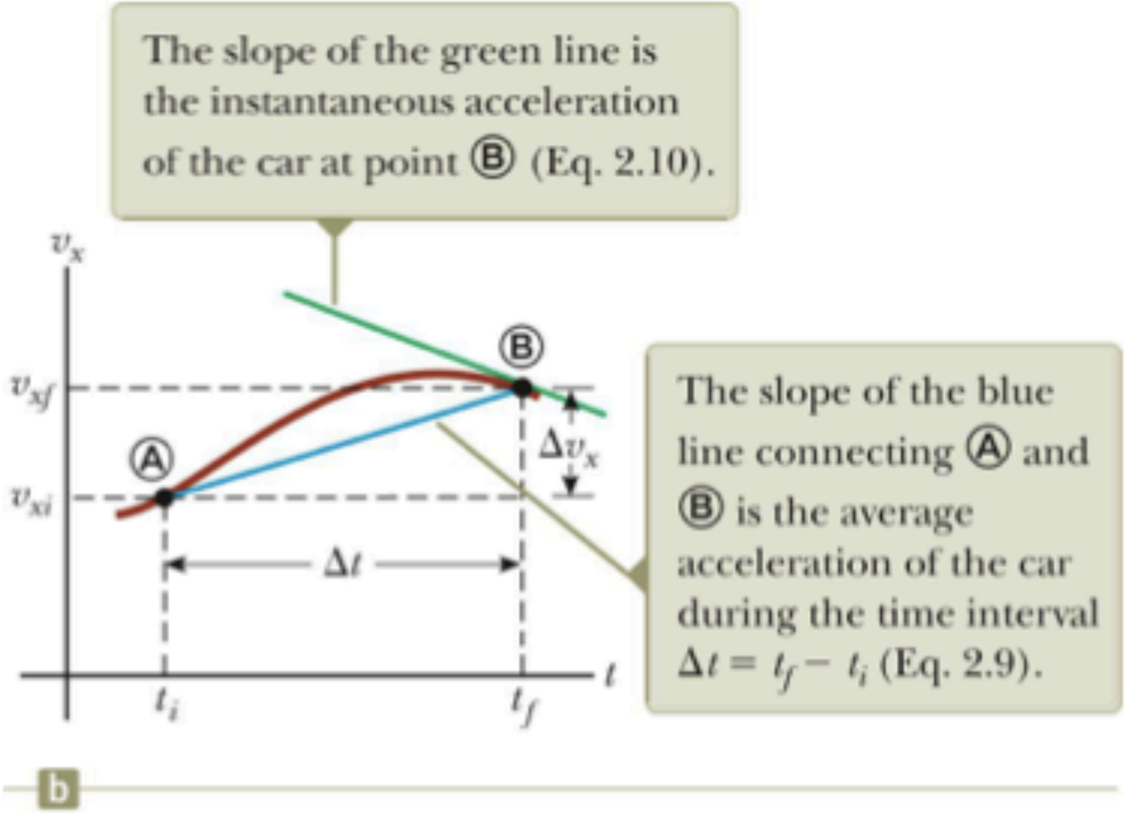
- If average acceleration is wanted, the word average will be included.

Instantaneous Acceleration – graph

The slope of the velocity-time graph is the acceleration.

The green line represents the instantaneous acceleration.

The blue line is the average acceleration.

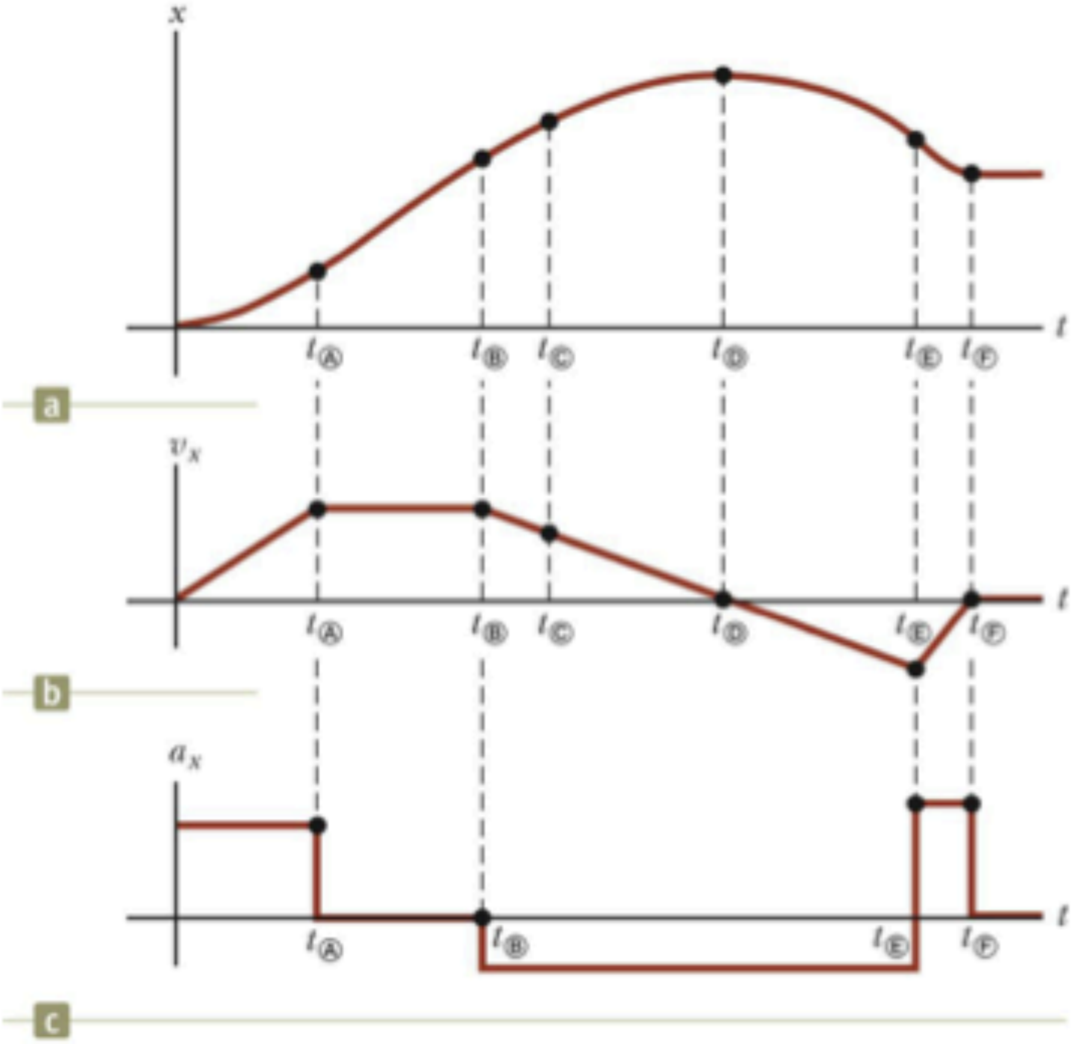


Graphical Comparison

Given the displacement-time graph (a)

The velocity-time graph is found by measuring the slope of the position-time graph at every instant.

The acceleration-time graph is found by measuring the slope of the velocity-time graph at every instant.



Acceleration and Velocity, Directions

When an object's velocity and acceleration are in the same direction, the object is speeding up.

When an object's velocity and acceleration are in the opposite direction, the object is slowing down.

Acceleration and Force

The acceleration of an object is related to the total force exerted on the object.

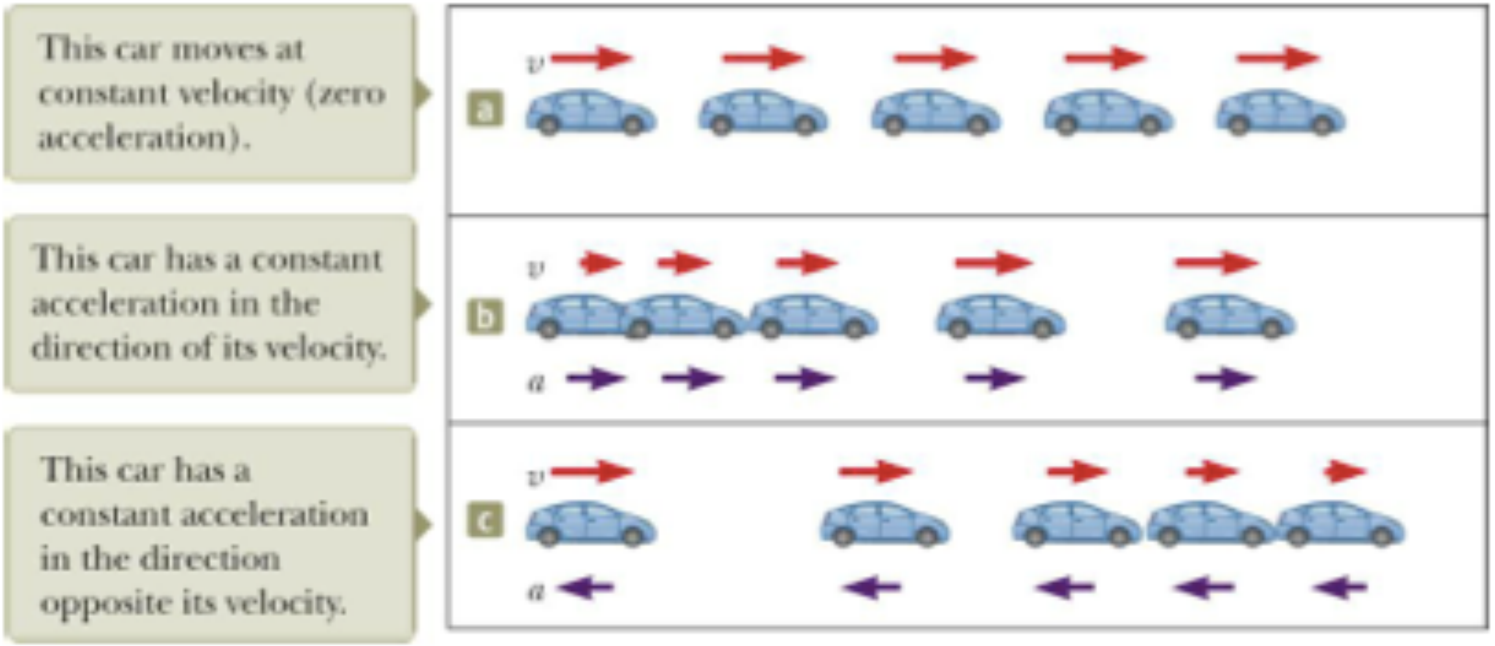
- The force is proportional to the acceleration, $F_x \propto a_x$.
- Assume the velocity and acceleration are in the same direction.
  - The force is in the same direction as the velocity and the object speeds up.
- Assume the velocity and acceleration are in opposite directions.
  - The force is in the opposite direction as the velocity and the object slows down.

Motion Diagrams

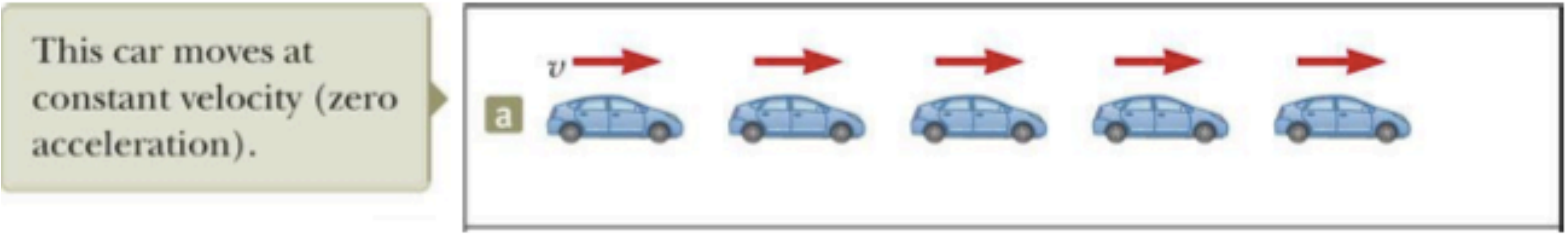
A motion diagram can be formed by imagining the stroboscope photograph of a moving object.

Red arrows represent velocity.

Purple arrows represent acceleration.



Constant Velocity

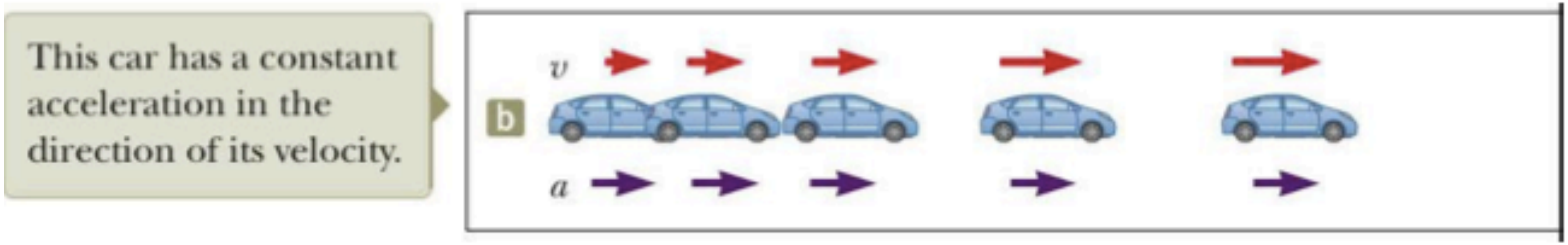


Images are equally spaced.

The car is moving with constant positive velocity (shown by red arrows maintaining the same size).

Acceleration equals zero.

Acceleration and Velocity, 3



Images become farther apart as time increases.

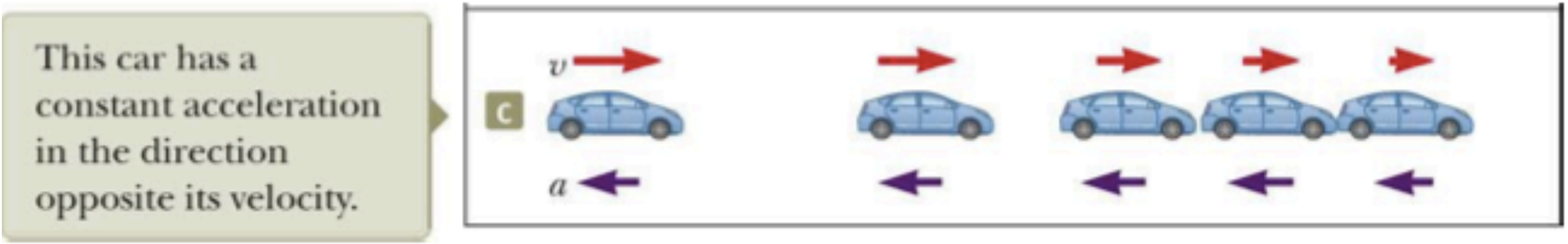
Velocity and acceleration are in the same direction.

Acceleration is uniform (violet arrows maintain the same length).

Velocity is increasing (red arrows are getting longer).

This shows positive acceleration and positive velocity.

Acceleration and Velocity, 4



Images become closer together as time increases.

Acceleration and velocity are in opposite directions.

Acceleration is uniform (violet arrows maintain the same length).

Velocity is decreasing (red arrows are getting shorter).

Positive velocity and negative acceleration.

Acceleration and Velocity, final

In all the previous cases, the acceleration was constant.

- Shown by the violet arrows all maintaining the same length

The diagrams represent motion of a particle under constant acceleration.

A particle under constant acceleration is another useful analysis model.

Kinematic Equations, 1

For constant a_x,

$$v_{xf} = v_{xi} + a_x t$$

Can determine an object's velocity at any time t when we know its initial velocity and its acceleration

- Assumes $t_i = 0$ and $t_f = t$

Does not give any information about displacement

Kinematic Equations, 2

For constant acceleration,

$$v_{x,avg} = \frac{v_{xi} + v_{xf}}{2}$$

The average velocity can be expressed as the arithmetic mean of the initial and final velocities.

- This applies only in situations where the acceleration is constant.

Kinematic Equations, 3

For constant acceleration,

$$x_f = x_i + v_{x,avg}\, t = x_i + \frac{1}{2}\left(v_{xi} + v_{fx}\right)t$$

This gives you the position of the particle in terms of time and velocities.

Doesn't give you the acceleration

Kinematic Equations, 4

For constant acceleration,

$$x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$$

Gives final position in terms of velocity and acceleration

Doesn't tell you about final velocity

Kinematic Equations, 5

For constant *a*,

$$v_{xf}^2 = v_{xi}^2 + 2a_x\left(x_f - x_i\right)$$

Gives final velocity in terms of acceleration and displacement

Does not give any information about the time

When a = 0

When the acceleration is zero,

- $v_{xf} = v_{xi} = v_x$
- $x_f = x_i + v_x\, t$

The constant acceleration model reduces to the constant velocity model.

Problem Solving – Conceptualize

Think about and understand the situation.

Make a quick drawing of the situation.

Gather the numerical information.

- Include algebraic meanings of phrases.

Focus on the expected result.

- Think about units.

Think about what a reasonable answer should be.

Problem Solving – Categorize

Simplify the problem.

- Can you ignore air resistance?
- Model objects as particles

Classify the type of problem.

- Substitution
- Analysis

Try to identify similar problems you have already solved.

- What analysis model would be useful?

Problem Solving – Analyze

Select the relevant equation(s) to apply.

Solve for the unknown variable.

Substitute appropriate numbers.

Calculate the results.

- Include units

Round the result to the appropriate number of significant figures.

Problem Solving – Finalize

Check your result.

- Does it have the correct units?
- Does it agree with your conceptualized ideas?

Look at limiting situations to be sure the results are reasonable.

Compare the result with those of similar problems.

Problem Solving – Some Final Ideas

When solving complex problems, you may need to identify sub-problems and apply the problem-solving strategy to each sub-part.

These steps can be a guide for solving problems in this course.