DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS

IB PHYSICS

LSN 2-1B, MOTION
- UNIFORMLY ACCELERATED MOTION
- ACCELERATION OF FREE FALL

Questions From Reading Activity?

- Anyone still not know how to do Cornell notes?

Essential Idea:

- Motion may be described and analyzed by the use of graphs and equations.

Nature Of Science:

- Observations.
- The ideas of motion are fundamental to many areas of physics, providing a link to the consideration of forces and their implication.
- The kinematic equations for uniform acceleration were developed through careful observations of the natural world.

International-Mindedness:

- International cooperation is needed for tracking shipping, land-based transport, aircraft and objects in space.

Understandings:

- Acceleration
- Graphs describing motion
- Equations of motion for uniform acceleration

Applications And Skills:

- Determining instantaneous and average values for acceleration
- Solving problems using equations of motion for uniform acceleration
- Sketching and interpreting motion graphs
- Determining the acceleration of free-fall experimentally

Guidance:

- Calculations will be restricted to those neglecting air resistance.

Data Booklet Reference:

$$v = u + at$$

$$s = ut + 1/2\,at^2$$

$$v^2 = u^2 + 2as$$

$$s = \frac{(v + u)t}{2}$$

Utilization:

- Biomechanics (see Sports, exercise and health science SL sub-topic 4.3)
- Quadratic functions (see Mathematics HL sub-topic 2.6; Mathematics SL sub-topic 2.4; Mathematical studies SL sub-topic 6.3)
- The kinematic equations are treated in calculus form in Mathematics HL sub-topic 6.6 and Mathematics SL sub-topic 6.6

Aims:

- Aim 2: much of the development of classical physics has been built on the advances in kinematics

Aims:

- Aim 6: experiments, including use of data logging, could include (but are not limited to): determination of g, estimating speed using travel timetables, analyzing projectile motion, and investigating motion through a fluid

Aims:

- Aim 7: technology has allowed for more accurate and precise measurements of motion, including video analysis of real-life projectiles and modeling/ simulations of terminal velocity

Introductory Video

Average acceleration

- the change in velocity divided by the time required to make this change

$$\overline{a} = \frac{\Delta v}{\Delta t} = \frac{v - u}{t - t_0}$$

- the bar over the *a* indicates average
- Δ means "change in"

Average acceleration

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v-u}{t-t_0}$$

- acceleration can be either positive or negative
  - positive acceleration means velocity is increasing
  - negative acceleration means velocity is decreasing
  - negative acceleration is often called deceleration

Units

- typical units for acceleration are *m/s²*

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{m/s}{s} x \frac{s}{s} = \frac{m}{s^2}$$

- but can be any unit of length over, or per, unit of time squared

Instantaneous Acceleration

- **the change in velocity over an infinitesimally short period of time**

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$$

SAMPLE PROBLEM 1

- *I am driving at 15 m/s behind a big truck. I punch the accelerator to pass the truck and 18 seconds later I am at 25 m/s. What was my average acceleration?*

SAMPLE PROBLEM 1

- *I am driving at 15 m/s behind a big truck. I punch the accelerator to pass the truck and 18 seconds later I am at 25 m/s. What was my average acceleration?*

$$\bar{a} = \frac{v - u}{t - t_0}$$

$$\bar{a} = \frac{25 - 15}{18}$$

$$\bar{a} = 0.56\, m/s^2$$

SAMPLE PROBLEM 2

- *While travelling at 30m/s, I decide to stop using an average acceleration (deceleration) of -2.13m/s^2. How long will it take me to stop?*

SAMPLE PROBLEM 2

- ***While travelling at 30m/s, I decide to stop using an average acceleration (deceleration) of -2.13m/s². How long will it take me to stop?***

$$v_0 = 30\, m/s$$

$$\bar{a} = -2.13\, m/s^2$$

$$v = 0$$

$$t_0 = 0, v = 0$$

$$\bar{a} = \frac{v - u}{t - t_0}$$

$$\bar{a} = \frac{-u}{t}$$

$$t = \frac{-u}{\bar{a}} = \frac{-30}{-2.13} = 14.1s$$

Uniformly Accelerated Motion

- occurs when acceleration is constant and in a straight line
  - Assume that we are starting at a time of zero, the equation for constant acceleration becomes

$$a = \frac{v - u}{t}$$

  - (no bar over a because it is now constant instead of an average)

How fast?

- A common problem is to find the velocity after an object has accelerated for a given period of time.
- To do this, we solve the constant acceleration equation for velocity:

How fast?

- **A common problem is to find the velocity after an object has accelerated for a given period of time.**
- **To do this, we solve the constant acceleration equation for velocity:**

$$a = \frac{v - u}{t}$$

$$at = v - u$$

$$u + at = v$$

$$v = u + at$$

Where we be?

- **Next, we will find position after traveling at a certain average velocity for a given period of time:**

- **To do this, we solve the average velocity equation for final position:**

Where we be?

- **Next, we will find position after traveling at a certain average velocity for a given period of time:**

- **To do this, we solve the average velocity equation for final position:**

$$\bar{v} = \frac{x - x_0}{t}$$

$$\bar{v}t = x - x_0$$

$$x_0 + \bar{v}t = x$$

$$x = x_0 + \bar{v}t$$

Where we be?

- **Next, we will find position after traveling at a certain average velocity for a given period of time:**
- **Next, we clean it up and IBalize it**

$$x = x_0 + \bar{v}t$$

$$x - x_0 = \bar{v}t$$

$$s = \bar{v}t$$

$$\bar{v} = \frac{(v+u)}{2}$$

$$s = \frac{(v+u)t}{2}$$

Where we be?

- **Now we will find the position of an object after undergoing constant acceleration for a given time, t**

Where we be?

- **Now we will find the position of an object after undergoing constant acceleration for a given time, t**

- **Average velocity is the velocity midway between initial and final velocities:**

$$\bar{v} = \frac{v + u}{2}$$

Where we be?

- **Now we will find the position of an object after undergoing constant acceleration for a given time, t**
- **This can be substituted into our equation for displacement:**

$$\bar{v} = \frac{v+u}{2}$$

$$x = x_0 + \bar{v}t$$

$$x = x_0 + \frac{v+u}{2}t$$

Where we be?

- **Now we will find the position of an object after undergoing constant acceleration for a given time, t**
- **We can then substitute our equation for v into the above equation:**

$$x = x_0 + \frac{v+u}{2}t$$

$$v = u + at$$

$$x = x_0 + \frac{u+at+u}{2}t$$

$$x = x_0 + \frac{2u}{2}t + \frac{at}{2}t$$

$$x = x_0 + ut + 1/2\,at^2$$

Where we be?

- **Now we will find the position of an object after undergoing constant acceleration for a given time, t**
- **The IB Data Guide equation is given in terms of displacement, s**

$$s = x - x_0$$

$$x = x_0 + ut + 1/2\,at^2$$

$$x - x_0 = ut + 1/2\,at^2$$

$$s = ut + 1/2\,at^2$$

Where we be?

- **We now derive a fourth equation that is useful when elapsed time is not known. We start at a point near the beginning of the last derivation:**

Where we be?

- **We now derive a fourth equation that is useful when elapsed time is not known. We start at a point near the beginning of the last derivation:**
- ***What happens next, Batman?***

$$x = x_0 + \frac{v+u}{2}t$$

$$v = u + at$$

$$\frac{v-u}{a} = t$$

$$x = x_0 + \left[\frac{v+u}{2}\right]\left[\frac{v-u}{a}\right]$$

Where we be?

- We now derive a fourth equation that is useful when elapsed time is not known. We start at a point near the beginning of the last derivation:

- ***Curses Batman, FOILed again!***

$$x = x_0 + \left[\frac{v+u}{2}\right]\left[\frac{v-u}{a}\right]$$

$$x = x_0 + \left[\frac{v^2 - u^2}{2a}\right]$$

$$2a(x - x_0) = v^2 - u^2$$

$$v^2 = u^2 + 2as$$

Summary of 1-dimensional motion at constant acceleration:

- **The following four equations apply for *linear* motion *when a is constant*:**

$$v = u + at$$

$$s = ut + 1/2\,at^2$$

$$v^2 = u^2 + 2as$$

$$s = \frac{(v + u)t}{2}$$

Let’s Go Vertical!

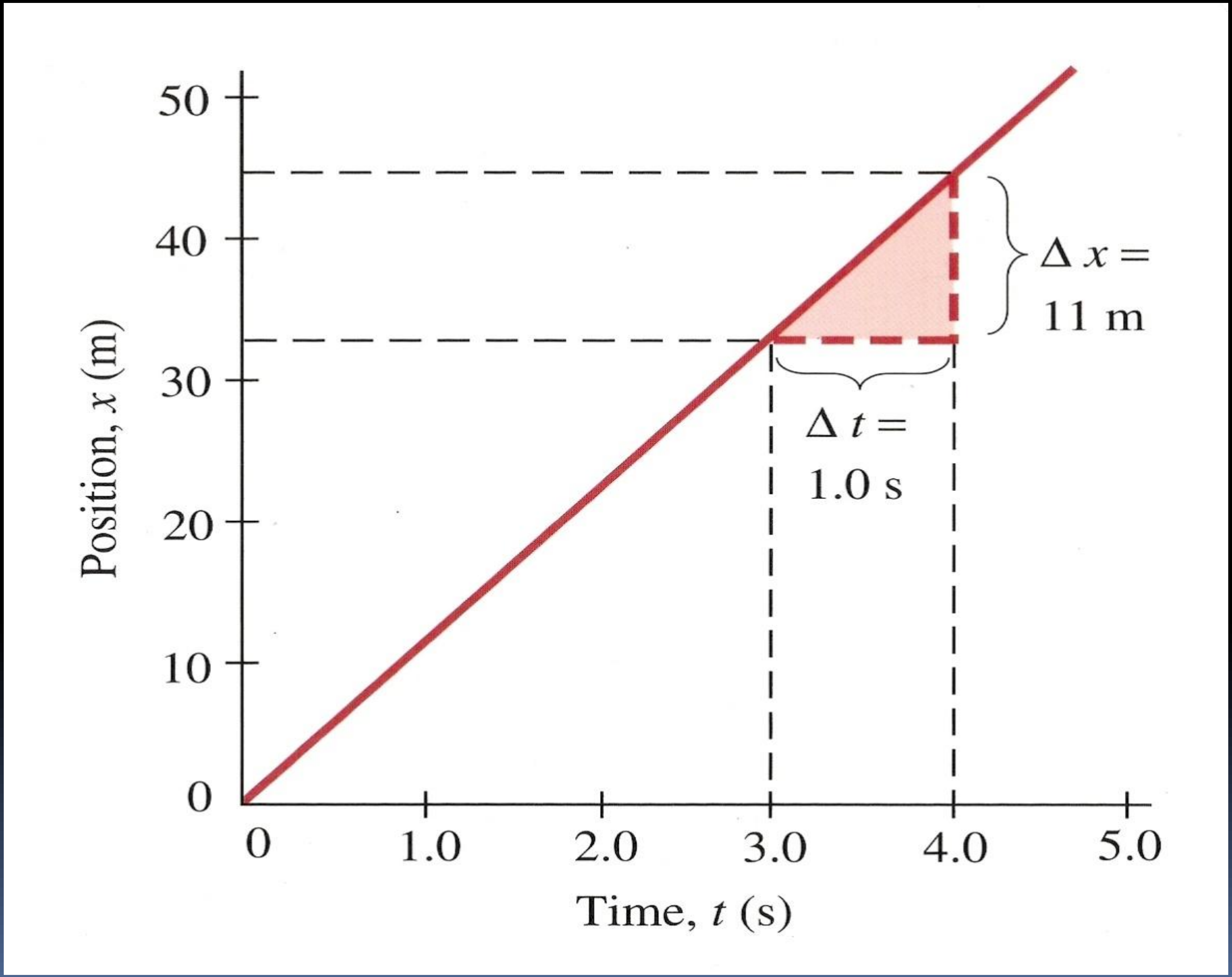
- For vertical freefall motion, the acceleration of the object is due to the acceleration due to gravity, g, and on average, the value of g at the surface of the earth is 9.81 m/s^2
- To properly orient to the vertical direction, we would change all of our x’s to y’s, but since IB uses displacement s, this point is moot
- Our four equations then become:

Let’s Go Vertical!

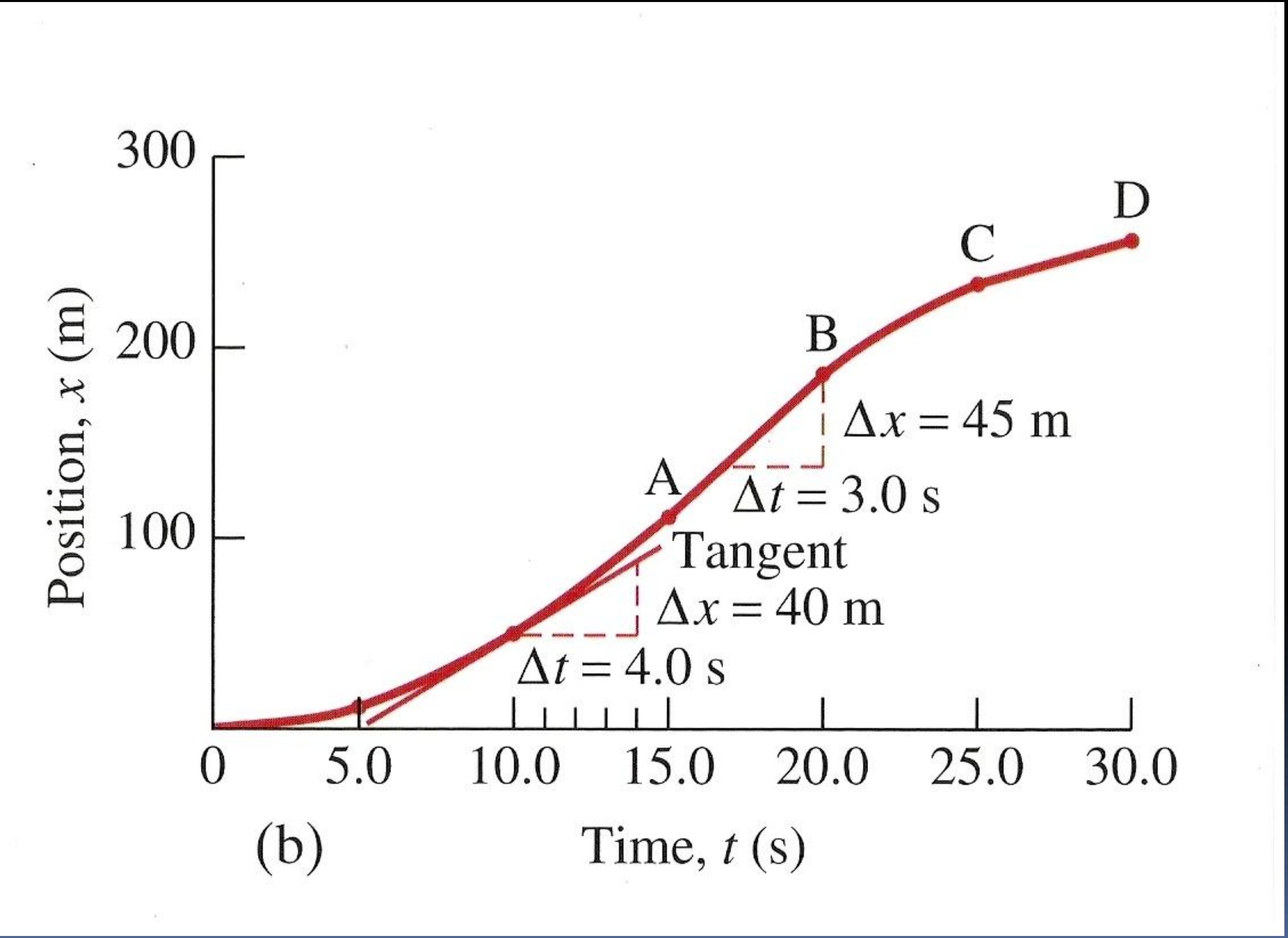
Horizontal	**Vertical**
$v = u + at$	$v = u + gt$
$s = ut + 1/2\,at^2$	$s = ut + 1/2\,gt^2$
$s = \frac{(v + u)}{2}t$	$s = \frac{(v + u)}{2}t$
$v^2 = u^2 + 2as$	$v^2 = u^2 + 2gs$

Note: IB Data Guide does not differentiate between vertical and horizontal!

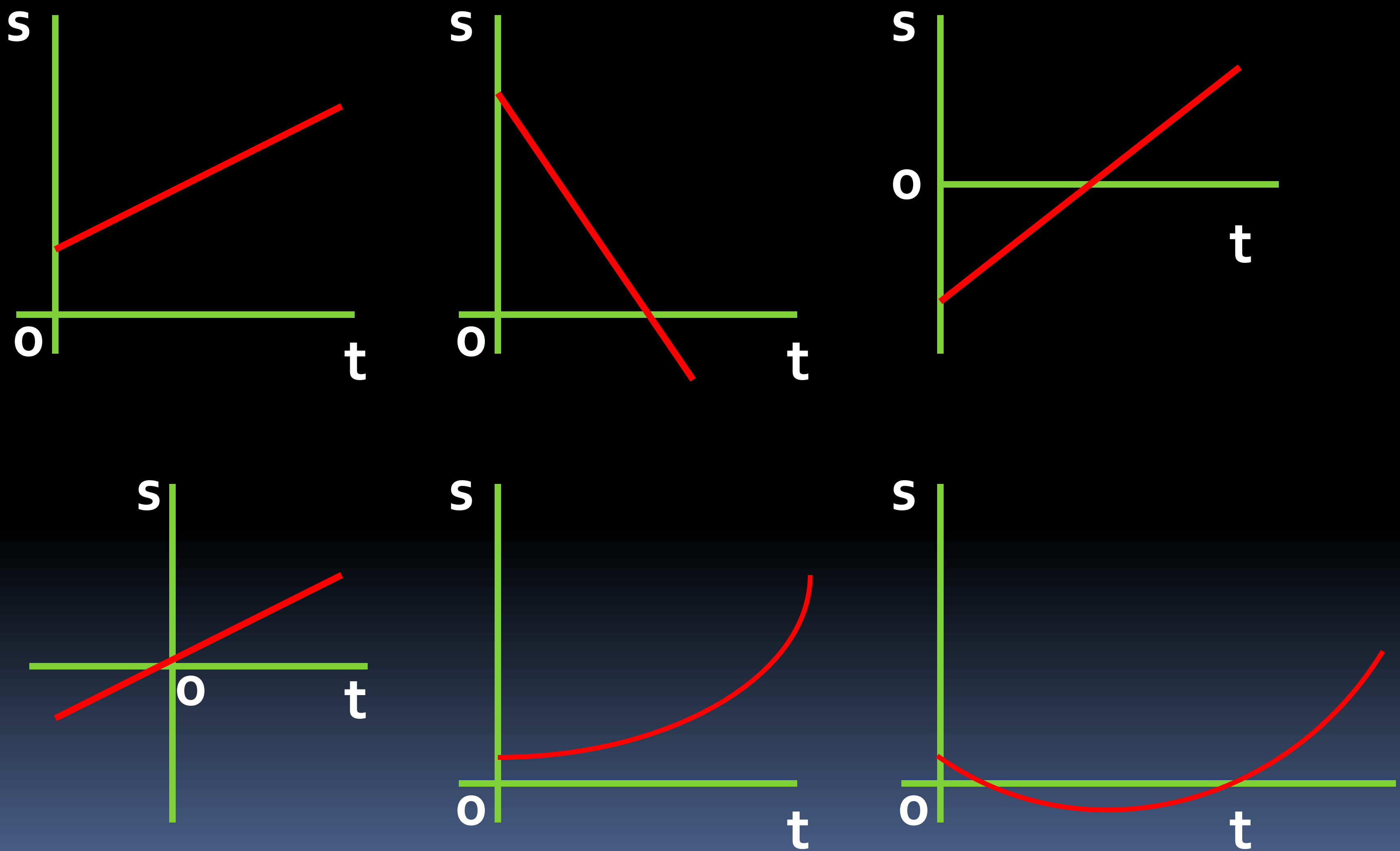
Graphical Analysis



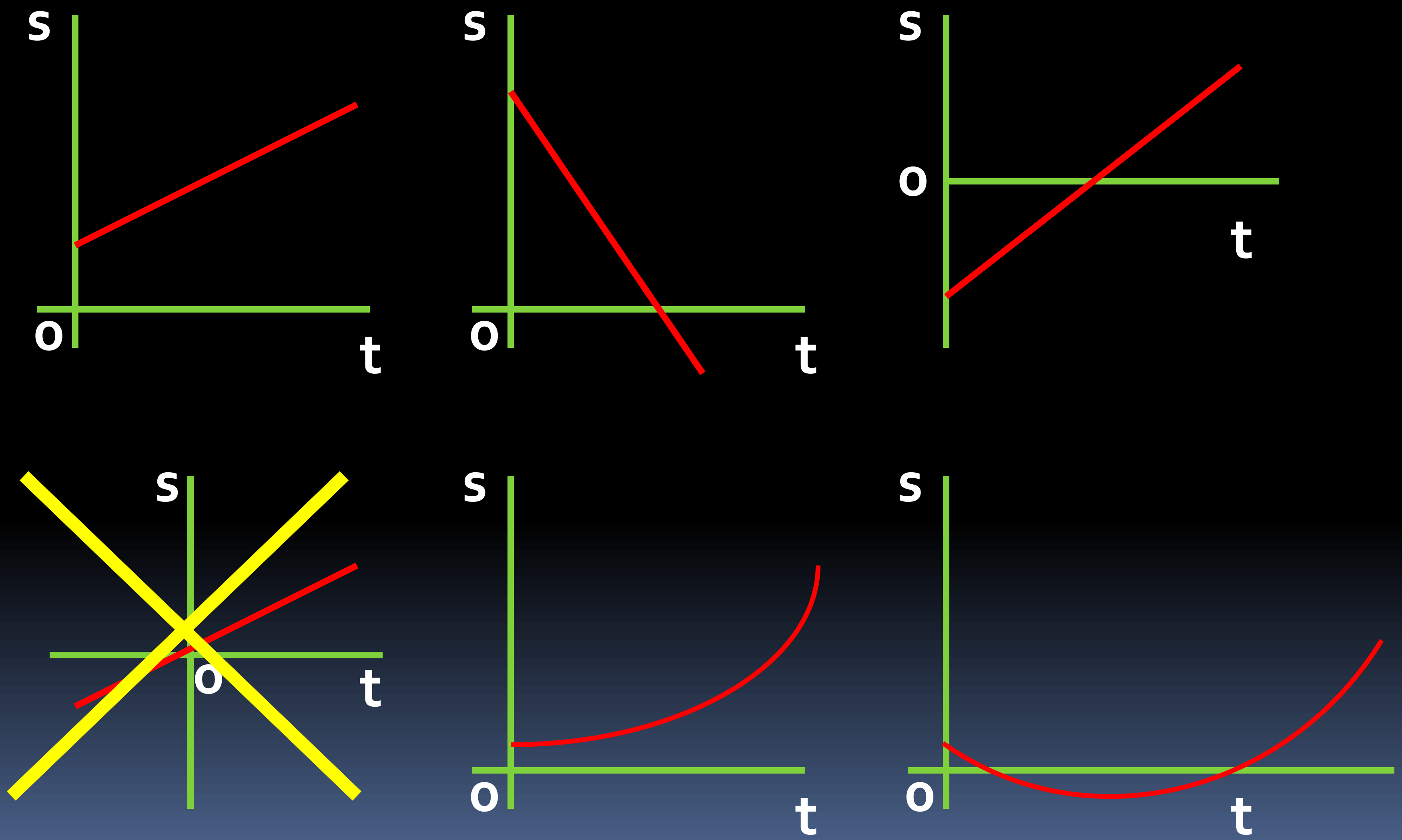
Graphical Analysis



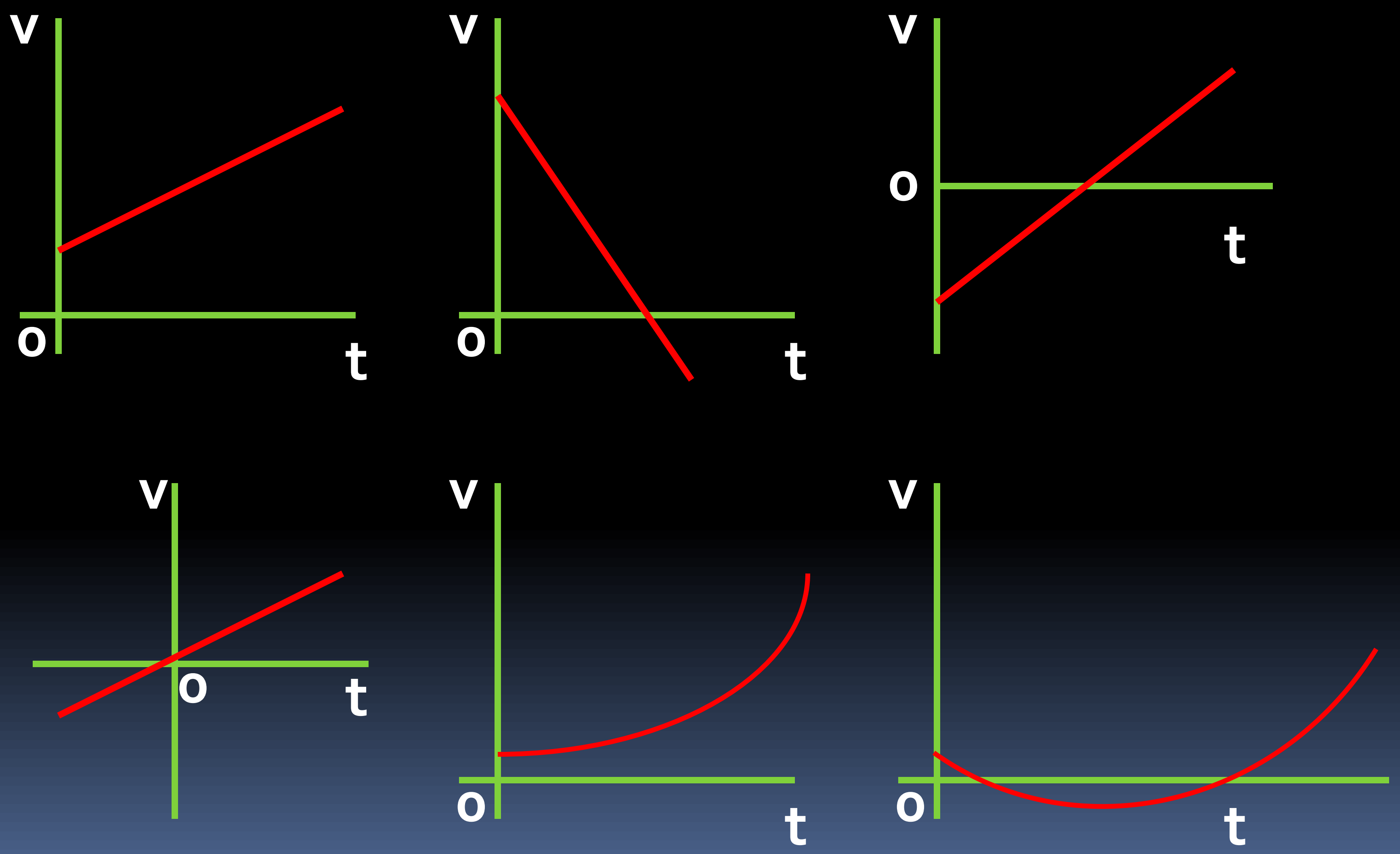
Analysis of Graphs: s vs t



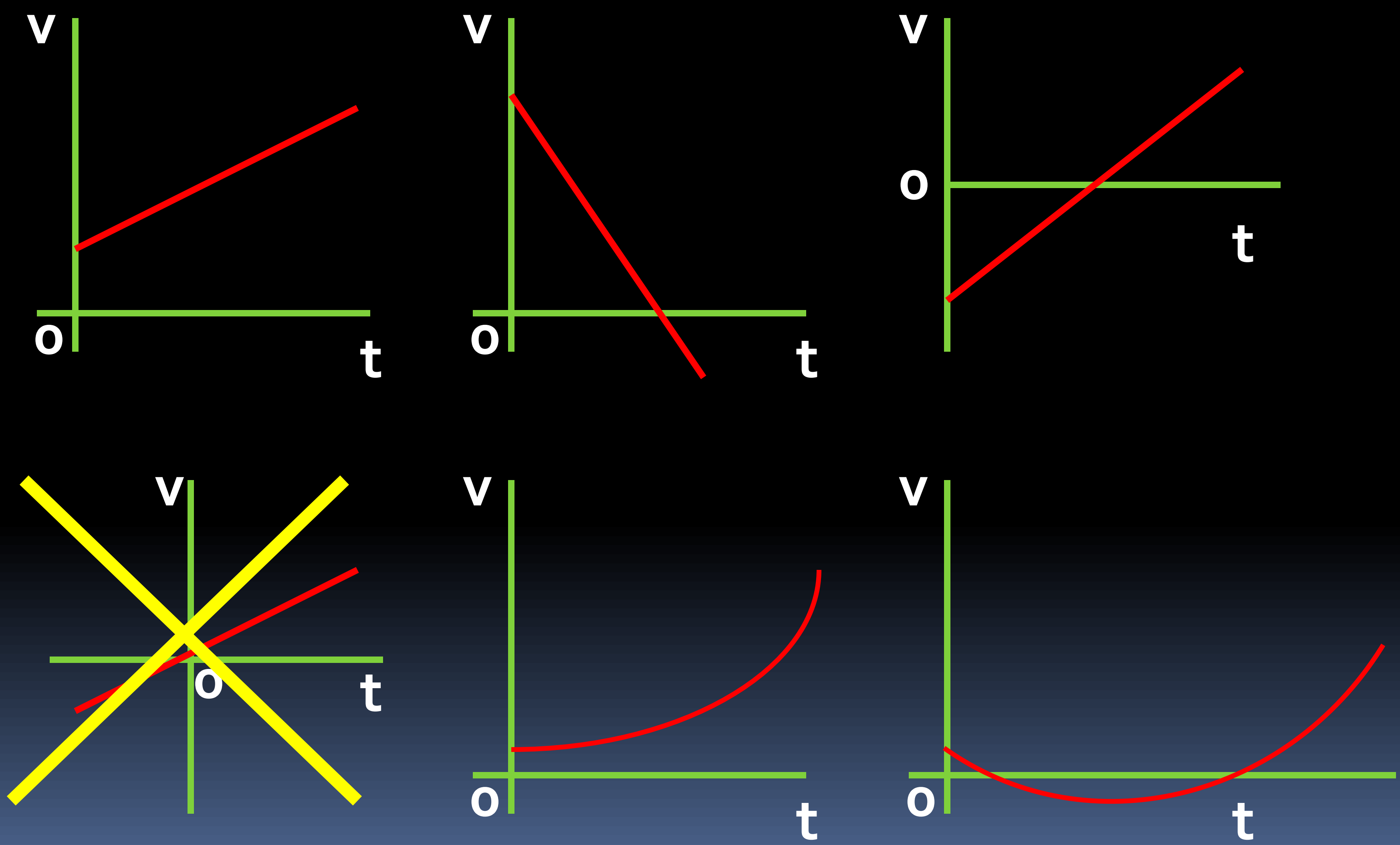
Analysis of Graphs: s vs t



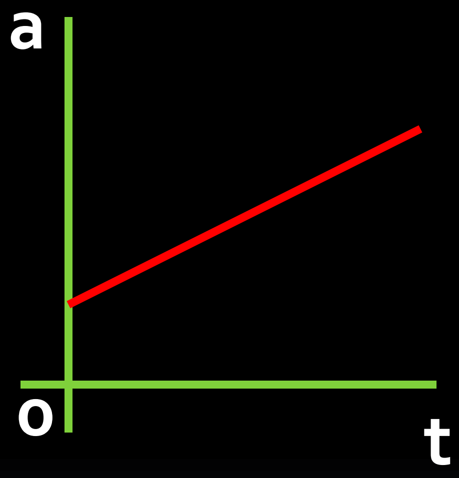
Analysis of Graphs: v vs t

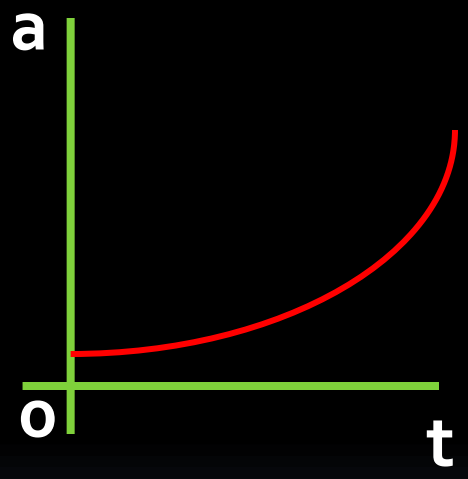


Analysis of Graphs: v vs t

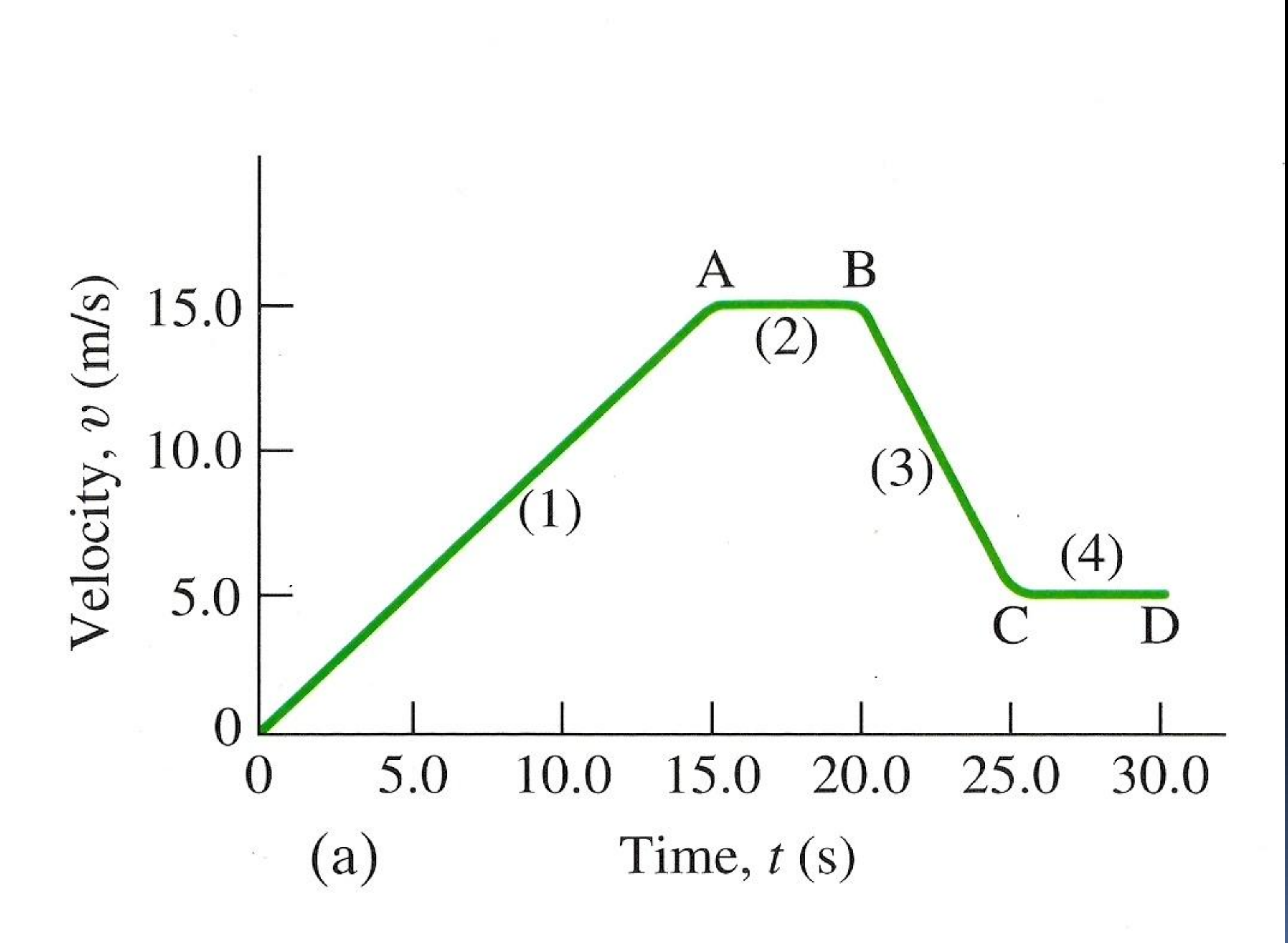


Analysis of Graphs: a vs t





Graphical Analysis



Acceleration Due To Gravity

- *Since the earth is rotating, why don't we all fly off into space like a kid falling off a merry-go-round?*

Acceleration Due To Gravity

- Law of gravitational attraction:

$$F = G\frac{Mm}{r^2}$$

- *What order of magnitude is the force?*

Acceleration Due To Gravity

- Law of gravitational attraction:

$$F = G\frac{Mm}{r^2}$$

Surprised?

- ***What order of magnitude is the force?***

$$F = \left(6.67x10^{-11}\right)\frac{\left(5.98x10^{24}\right)\left(90\right)}{\left(6.38x10^{6}\right)^2} = 881N$$

Acceleration Due To Gravity

- **Law of gravitational attraction:**

$$F = G\frac{Mm}{r^2}$$

Surprised?

- ***What order of magnitude is the force?***

$$F = \left(6.67x10^{-11}\right)\frac{\left(5.98x10^{24}\right)\left(90\right)}{\left(6.38x10^{6}\right)^2} = 881N$$

$$F = ma = 90x9.81 = 883N$$

Acceleration Due To Gravity

- Law of gravitational attraction:

$$F = G\frac{Mm}{r^2}$$

- ***Is acceleration due to gravity 9.81 m/s² everywhere on earth? If not** (and I wouldn't be asking if it was)**, why not?***

Understandings:

- Acceleration
- Graphs describing motion
- Equations of motion for uniform acceleration

Data Booklet Reference:

$$v = u + at$$

$$s = ut + 1/2\,at^2$$

$$v^2 = u^2 + 2as$$

$$s = \frac{(v + u)t}{2}$$

Applications And Skills:

- Determining instantaneous and average values for acceleration
- Solving problems using equations of motion for uniform acceleration
- Sketching and interpreting motion graphs
- Determining the acceleration of free-fall experimentally

Essential Idea:

- Motion may be described and analyzed by the use of graphs and equations.

QUESTIONS?

Homework

Pg 53-57 #5-24

<u>Do you want to skip any?</u>