**AP Physics C – Summer Work – Print and bring this sheet signed by you and your parent on the first day of school.**

You will have an equation, units, and constants quiz on the first day of school. The AP Physics C Table of Information and Equations sheets are the only resources you need to study. If you are motivated, please go to: AP® Physics C: Mechanics Equations Sheet and AP® Physics C: Electricity and Magnetism

You should be prepared and able to reproduce any of the equations listed in the Mechanics section if given a suitable prompt. A list of variables is provided so you can understand what each equation involves. You should also have the Universal Gravitational Constant (G), the acceleration due to Earth's gravity at the surface (g), and the speed of light (c) memorized. You should know all of the SI Prefixes listed.

**First semester (Mechanics)** will be a review of topics studied in AP-1 but with the addition of calculus and more complex problems.

**Second semester (Emag)** will be entirely new for you and will require substantially more calculus than first semester. It will be the hardest work that you do with the most complicated calculus (integrals). Your lack of exposure to these topics in AP1 will provide an additional hurdle so please have the proper mindset as you prepare yourself for this course.

All of our tests will require the memorization of equations. You will not be allowed to use graphing calculators on our tests, only scientific calculators with a memory clear.

Students are required to use non-graphing calculators on our tests to prevent the storage of information and to require them to solve calculus problems by hand. Please ensure that you have such a calculator.

Attendance in AP Physics C is a critical factor in the success of students. Our daily lessons, discussions and practice are not replicated through "Participating Remotely" days or other absences. While I understand that some absences are unavoidable, and can be important experiences for students, students should make every effort to attend class. Low attendance rates often create significant challenges for students.

Please sign below acknowledging that you have read the above information. Please feel free to contact me via school email at arsovan@fultonschools.org if you have any questions.

**Student Name Printed ___________________________** **Student Signature ______________________**

**Parent Name Printed _____________________________** **Parent Signature _______________________**

**Date:____________________**

# ADVANCED PLACEMENT PHYSICS C TABLE OF INFORMATION

| CONSTANTS AND CONVERSION FACTORS | |
|---|---|
| Proton mass, $m_p = 1.67 \times 10^{-27}$ kg | Electron charge magnitude, $e = 1.60 \times 10^{-19}$ C |
| Neutron mass, $m_n = 1.67 \times 10^{-27}$ kg | 1 electron volt, $1 \text{ eV} = 1.60 \times 10^{-19}$ J |
| Electron mass, $m_e = 9.11 \times 10^{-31}$ kg | Speed of light, $c = 3.00 \times 10^8$ m/s |
| Avogadro's number, $N_0 = 6.02 \times 10^{23}\ \text{mol}^{-1}$ | Universal gravitational constant, $G = 6.67 \times 10^{-11}\ (\text{N}\cdot\text{m}^2)/\text{kg}^2$ |
| Universal gas constant, $R = 8.31$ J/(mol·K) | Acceleration due to gravity at Earth's surface, $g = 9.8\ \text{m/s}^2$ |
| Boltzmann's constant, $k_B = 1.38 \times 10^{-23}$ J/K | |

| | |
|---|---|
| 1 unified atomic mass unit, | $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg} = 931 \text{ MeV}/c^2$ |
| Planck's constant, | $h = 6.63 \times 10^{-34}\ \text{J}\cdot\text{s} = 4.14 \times 10^{-15}\ \text{eV}\cdot\text{s}$ |
| | $hc = 1.99 \times 10^{-25}\ \text{J}\cdot\text{m} = 1.24 \times 10^{3}\ \text{eV}\cdot\text{nm}$ |
| Vacuum permittivity, | $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$ |
| Coulomb's law constant, | $k = 1/(4\pi\varepsilon_0) = 9.0 \times 10^9\ (\text{N}\cdot\text{m}^2)/\text{C}^2$ |
| Vacuum permeability, | $\mu_0 = 4\pi \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$ |
| Magnetic constant, | $k' = \mu_0/(4\pi) = 1 \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$ |
| 1 atmosphere pressure, | $1 \text{ atm} = 1.0 \times 10^5\ \text{N/m}^2 = 1.0 \times 10^5$ Pa |

| UNIT SYMBOLS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | meter, | m | mole, | mol | watt, | W | farad, | F |
| | kilogram, | kg | hertz, | Hz | coulomb, | C | tesla, | T |
| | second, | s | newton, | N | volt, | V | degree Celsius, | °C |
| | ampere, | A | pascal, | Pa | ohm, | Ω | electron volt, | eV |
| | kelvin, | K | joule, | J | henry, | H | | |

| PREFIXES | | |
|---|---|---|
| Factor | Prefix | Symbol |
| $10^9$ | giga | G |
| $10^6$ | mega | M |
| $10^3$ | kilo | k |
| $10^{-2}$ | centi | c |
| $10^{-3}$ | milli | m |
| $10^{-6}$ | micro | μ |
| $10^{-9}$ | nano | n |
| $10^{-12}$ | pico | p |

| VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\theta$ | 0° | 30° | 37° | 45° | 53° | 60° | 90° |
| $\sin\theta$ | 0 | $1/2$ | $3/5$ | $\sqrt{2}/2$ | $4/5$ | $\sqrt{3}/2$ | 1 |
| $\cos\theta$ | 1 | $\sqrt{3}/2$ | $4/5$ | $\sqrt{2}/2$ | $3/5$ | $1/2$ | 0 |
| $\tan\theta$ | 0 | $\sqrt{3}/3$ | $3/4$ | 1 | $4/3$ | $\sqrt{3}$ | $\infty$ |

The following assumptions are used in this exam.

I. The frame of reference of any problem is inertial unless otherwise stated.
II. The direction of current is the direction in which positive charges would drift.
III. The electric potential is zero at an infinite distance from an isolated point charge.
IV. All batteries and meters are ideal unless otherwise stated.
V. Edge effects for the electric field of a parallel plate capacitor are negligible unless otherwise stated.

# ADVANCED PLACEMENT PHYSICS C EQUATIONS

## MECHANICS

$v_x = v_{x0} + a_x t$

$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$

$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$

$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$

$\vec{F} = \frac{d\vec{p}}{dt}$

$\vec{J} = \int \vec{F}\,dt = \Delta\vec{p}$

$\vec{p} = m\vec{v}$

$\left|\vec{F}_f\right| \le \mu\left|\vec{F}_N\right|$

$\Delta E = W = \int \vec{F} \cdot d\vec{r}$

$K = \frac{1}{2}mv^2$

$P = \frac{dE}{dt}$

$P = \vec{F} \cdot \vec{v}$

$\Delta U_g = mg\Delta h$

$a_c = \frac{v^2}{r} = \omega^2 r$

$\vec{\tau} = \vec{r} \times \vec{F}$

$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$

$I = \int r^2 dm = \sum mr^2$

$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$

$v = r\omega$

$\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega}$

$K = \frac{1}{2}I\omega^2$

$\omega = \omega_0 + \alpha t$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$a$ = acceleration
$E$ = energy
$F$ = force
$f$ = frequency
$h$ = height
$I$ = rotational inertia
$J$ = impulse
$K$ = kinetic energy
$k$ = spring constant
$\ell$ = length
$L$ = angular momentum
$m$ = mass
$P$ = power
$p$ = momentum
$r$ = radius or distance
$T$ = period
$t$ = time
$U$ = potential energy
$v$ = velocity or speed
$W$ = work done on a system
$x$ = position
$\mu$ = coefficient of friction
$\theta$ = angle
$\tau$ = torque
$\omega$ = angular speed
$\alpha$ = angular acceleration
$\phi$ = phase angle

$\vec{F}_s = -k\Delta\vec{x}$

$U_s = \frac{1}{2}k(\Delta x)^2$

$x = x_{\max}\cos(\omega t + \phi)$

$T = \frac{2\pi}{\omega} = \frac{1}{f}$

$T_s = 2\pi\sqrt{\frac{m}{k}}$

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$\left|\vec{F}_G\right| = \frac{Gm_1m_2}{r^2}$

$U_G = -\frac{Gm_1m_2}{r}$

## ELECTRICITY AND MAGNETISM

$\left|\vec{F}_E\right| = \frac{1}{4\pi\varepsilon_0}\left|\frac{q_1q_2}{r^2}\right|$

$\vec{E} = \frac{\vec{F}_E}{q}$

$\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\varepsilon_0}$

$E_x = -\frac{dV}{dx}$

$\Delta V = -\int \vec{E} \cdot d\vec{r}$

$V = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i}$

$U_E = qV = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$

$\Delta V = \frac{Q}{C}$

$C = \frac{\kappa\varepsilon_0 A}{d}$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$I = \frac{dQ}{dt}$

$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2$

$R = \frac{\rho\ell}{A}$

$\vec{E} = \rho\vec{J}$

$I = Nev_d A$

$I = \frac{\Delta V}{R}$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$P = I\Delta V$

$A$ = area
$B$ = magnetic field
$C$ = capacitance
$d$ = distance
$E$ = electric field
$\mathcal{E}$ = emf
$F$ = force
$I$ = current
$J$ = current density
$L$ = inductance
$\ell$ = length
$n$ = number of loops of wire per unit length
$N$ = number of charge carriers per unit volume
$P$ = power
$Q$ = charge
$q$ = point charge
$R$ = resistance
$r$ = radius or distance
$t$ = time
$U$ = potential or stored energy
$V$ = electric potential
$v$ = velocity or speed
$\rho$ = resistivity
$\Phi$ = flux
$\kappa$ = dielectric constant

$\vec{F}_M = q\vec{v} \times \vec{B}$

$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I$

$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{\ell} \times \hat{r}}{r^2}$

$\vec{F} = \int I\,d\vec{\ell} \times \vec{B}$

$B_s = \mu_0 nI$

$\Phi_B = \int \vec{B} \cdot d\vec{A}$

$\mathcal{E} = \oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$

$\mathcal{E} = -L\frac{dI}{dt}$

$U_L = \frac{1}{2}LI^2$

**Optional Summer Work**

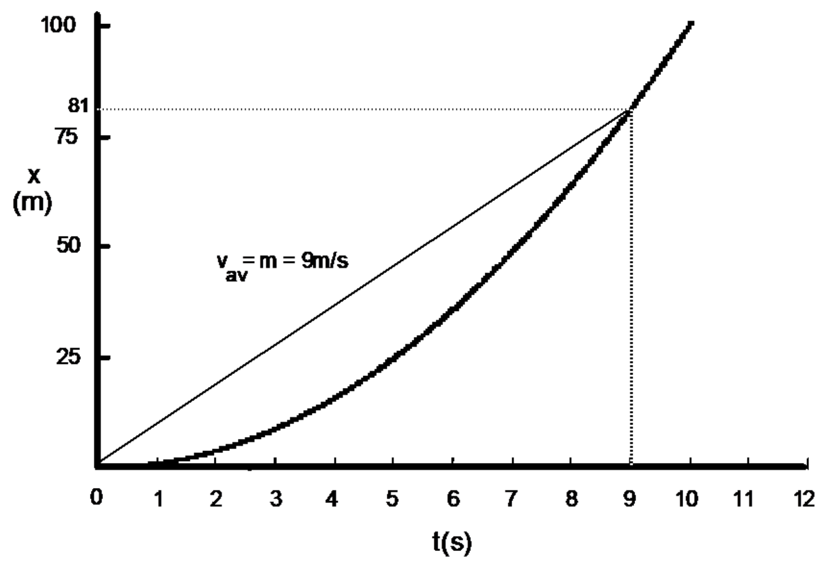
*The MOST important part of your summer work will be to remember what you have done in your first-year physics course. AP Physics C will be taught as a 2nd-year course which means we will build upon and enhance ideas that you have already been exposed to but we will not re-teach those ideas. In addition, we will introduce new ideas that will require your full attention. It will be a fast-paced course covering both mechanics and emag (electricity and magnetism). In addition, I need for those students who will be taking calculus concurrently with AP Physics C to have a solid understanding of the derivative and the anti-derivative (integral) before you come into class. I have included information on both of those that should look familiar to ideas we applied last year, but that now includes a more general approach. Study the documents below. Some parts might be challenging at first—that's completely normal. If something doesn't make sense right away, consider looking up explanations online, talking to someone who's taken calculus, or revisiting the material later. The goal isn't to get everything perfect on the first try, but to make a genuine effort to understand. Every bit of time you spend with the material will help you feel more confident when the school year begins.*

*Remember that the area under a force vs. displacement function is work. We did this last year but the force had to vary linearly with respect to position so we could find the value using geometry. Well, now it doesn't b/c through the wonders of calculus, we can handle a varying force without having regular geometric areas.*

**AP Physics** **The Derivative** **Stieve '89**

The following discussion is meant to provide an introduction and elementary working knowledge of the derivative. It will give a sufficient background for the initial work done at the start of this course. The derivations and background provided in your calculus course will enable you to gain a better comprehension of how the derivative works and how it is extended to functions other than polynomials.

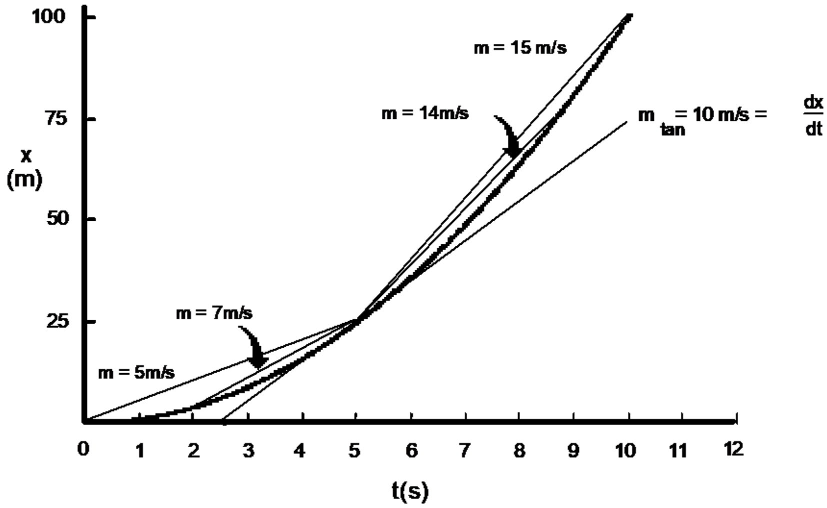
In physics, a concept that is of constant interest is how a physical quantity such as position, velocity or momentum changes with time. As an example, let us examine the position *vs.* time graph shown here.




You will notice that the average rate of change in position for the first 9 seconds can be found by taking the over all change for some interval and dividing it by the elapsed time. This quantity is called the average velocity and is given by $v_{av} = \Delta x/\Delta t$. You should notice that this is the same as the slope of a straight line drawn from the beginning of the interval to the end of the interval. In a like manner the slope of a straight line connecting any two points on the graph represents the average velocity over that time interval. If the quantity had been something other than position, the slope of such lines would clearly represent the average rate of change of that quantity with respect to time.

Now, the role of the differential calculus is to find the instantaneous rate of change of a function. We will leave the derivations for your calculus class and simply state that the method of achieving this involves inspection of the limit of the average rate of change over smaller and smaller intervals. Shown on the next page is the same position *vs.* time graph however the lines representing the average velocity for intervals to either side of the time t = 5.0s have been shown.

Notice that as the intervals become shorter to either side of this point the slope gets closer to 10. The slope of the graph at t = 5.0s, and therefore the velocity at the instant t = 5.0s, is said to be 10.m/s. A line drawn through this point and having this slope is *defined* as a tangent drawn to the curve at this point. The instantaneous rate of change is represented by the symbol $^d/_d$ associated with the appropriate variables. Here we have v = $^{dx}/_{dt}$. Because, in general, $^{dx}/_{dt}$ will be a function which is derived from the original function, we refer to it as the *derivative.*




The question remains how do we find the exact value for this instantaneous rate of change of the function? Fortunately, even though the proofs are rather involved, the answer is relatively easy for most functions. For our immediate purposes we will consider only monomials and polynomials. Three rules will serve:

i. For a constant x = C, $\frac{dx}{dt} = 0$.

ii. For a monomial $x = Cx^n$ , $\frac{dx}{dt} = nCx^{n-1}$

iii. For a polynomial simply take the sum of the derivatives of the individual monomial parts. That is: *the derivative of a sum is the sum of the derivatives.*

For the graph shown above the function is $x = t^2$, and the derivative is $^{dx}/_{dt} = 2t$. At the point we considered t = 5 therefore the velocity was 2 X 5 or 10.

The units were left out of the above for simplicity. Actually, the original equation should be written as $x = (1m/s^2)t^2$ and the derivative will follow automatically as v = $^{dx}/_{dt} = 2X(1m/s^2)t$. Putting t = 5.0s in the last expression gives us that v = 10.0 m/s.

What if the original equation had expressed the velocity as a function of time? The slope of a straight line drawn between any two points on the graph would express the average rate of change of the velocity with respect to time. This quantity is referred to as the average acceleration. It follows then that the slope of a tangent drawn to a point on such a graph has a slope which describes the instantaneous rate of change of velocity with respect to time; that is the instantaneous acceleration. In terms of the function then,

a = $^{dv}/_{dt}$.

In summary then, we start with x =f(t), v = $^{dx}/_{dt}$ and a = $^{dv}/_{dt}$ and we can think of a as the "derivative of the derivative" or the "second derivative" of position with respect to time. This is written as $a = d^2x/dt^2$.

One final word about notation. The following shows some of the various notations that are used for the first and second derivative of a function. The final ones, referred to as "x dot" and "x double dot", are Newton's notation and are used in physics for the derivative with respect to time and are not used if the independent variable is some other expression.

$$\frac{dx}{dt} = f'(x) = D_t x = \dot{x} \qquad \frac{d^2x}{dt^2} = f''(x) = D_t^2 x = \ddot{x}$$

As a first example, suppose we wish to find the area bounded by the line f(x) = 3x, the x axis, x = 0 and x = 2. This area is shown in figure 1. We recognize this as a triangle and can compute its area by the simple formula:

$A = \frac{1}{2}$ bh. The answer is, of course, 6.

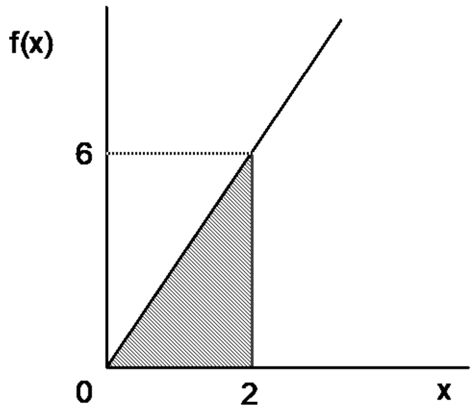



figure 1

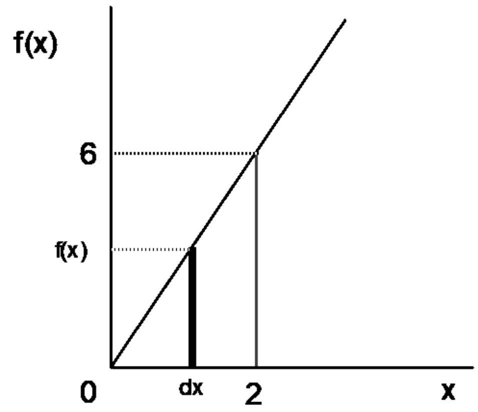



figure 2

Now let us find the area using calculus. The same graph is shown in figure 2, but this time an extremely narrow rectangle is also shown. The height of the rectangle is simply the value of the function at that point, f(x). The width we will represent by the symbol dx which stands for the minute difference in the x values on the left and right sides of the rectangle. The area of this small rectangle we will symbolize by dA, therefore dA = f(x)dx. Now to get the area of the entire triangle we must take the sum of all such rectangles which can be drawn to cover the given area. To indicate this process we use the distorted S, for *Sum*, known as the integral sign, $\int$. We take this sum for values of x from O to 2. An expression for this is:

$$\int_0^2 dA = \int_0^2 f(x)dx$$

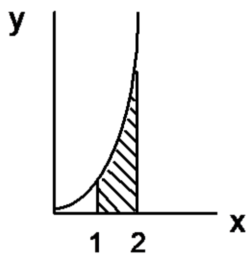
To evaluate this expression we resort to the following theorem (*The Fundamental Theorem of Integral Calculus)* : If the function f is continuous on the closed interval [a,b] and if F is any antiderivative of f on [a,b], then

$$\int_a^b f(x)dx = F(x)_a^b = F(b) - F(a)$$

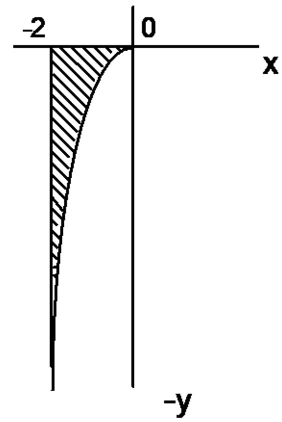
For the above example we have:

$$A_0^2 = \int_0^2 dA = \int_0^2 f(x)dx = \int_0^2 3x dx = \frac{3}{2}x^2\Big|_0^2 = \frac{3}{2}(2^2) - \frac{3}{2}(0^2) = 6$$

The answer is of course the same as that achieved using the area of a triangle, however this method works for all functions that meet the criterion of continuity expressed above. Clearly this is not a rigorous mathematical treatment of the definite integral. That is left to your mathematics course. The following examples should help you apply this powerful tool to physics problems.




Example 1




Example 2

EXAMPLE 1: Find the area bounded by the graph of f(x) = $x^2$, the x axis, x = 1 and x = 2.

$$A_1^2 = \int_1^2 f(x)dx = \int_1^2 x^2 dx = \frac{1}{3}x^3\Big|_1^2 = \frac{1}{3}(2^3) - \frac{1}{3}(1^3) = \frac{8}{3} - \frac{1}{3} = \frac{7}{3}$$

Note that if we take the limits of integration in the reverse order we get the negative of the area.

$$A_2^1 = \int_2^1 f(x)dx = \int_2^1 x^2 dx = \frac{1}{3}x^3\Big|_2^1 = \frac{1}{3}(1^3) - \frac{1}{3}(2^3) = \frac{1}{3} - \frac{8}{3} = -\frac{7}{3}$$

This may be interpreted as the result of taking the area of the minute rectangle as f(x)dx, because dx, the difference in x, if you insist on moving from right to left, i.e. from 2 to 1, is negative making the entire product f(x)dx negative. Then in turn the sum of these will come out negative.

EXAMPLE 2: Find the area bounded by the curve f(x) = $x^3$, the x axis, x = -2 and x = 0.

$$A_{-2}^0 = \int_{-2}^0 f(x)dx = \int_{-2}^0 x^3 dx = \frac{x^4}{4}\Big|_{-2}^0 = \frac{0^4}{4} - \frac{(-2)^4}{4} = -4$$

Note that here the area comes out negative in spite of the fact that we move from left to right, i.e. from x = -2 to x = 0. The dx is positive here (b/c you are moving in the +x direction; from -2 to 0), but the height of the minute rectangle, f(x), is negative (b/c it is in the –y direction) producing a negative product for f(x)dx. Signed areas have meaning in physics. For example, the area under a velocity *vs.* time graph represents displacement. A negative area represents a negative displacement.

Try this simulation on the PhET site. It allows you to view several basic functions, make basic changes and see how those changes affect the integral and derivative functions. Think about these with regards to position, velocity and acceleration.

http://phet.colorado.edu/simulations/sims.php?sim=Calculus_Grapher

**LAB: WALKING MAN (Visit the PhET site @ http://phet.colorado.edu/simulations/index.php?cat=Motion.**

You actually don't need to go to the website to complete this but you can have some fun if you do.

**Purpose**: In this activity you will validate the fundamental theorem of calculus that says that accumulation of the area under the graph is equal to change of value of the antiderivative.

The scenarios show a man walking along a straight line. The initial position, velocity, and time interval for the motion are given on the simulation. Use *x (t)* to denote the position function, *v (t)* to denote velocity function, and *a (t)* to denote the acceleration function.

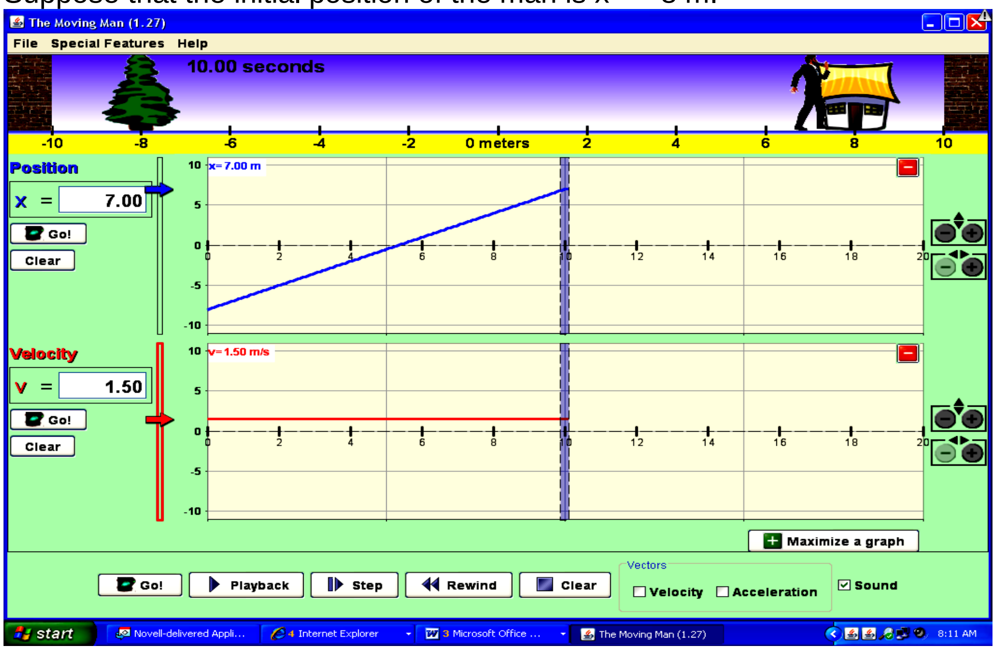
**PART 1**

**Problem**: Will the displacement of the man calculated from the velocity – time graph and from the position-time graph over the same time interval be same in value?

**Hypothesis:** ____________________________________________________________

Scenario A

Suppose that the initial position of the man is x = - 8 m.




**1**. By referring to the quantities given in the situation shown above (you do not need to reproduce this with the simulation), find the displacement of the man using

a. Position – time graph; $\Delta x =$ ______________________________

b. Velocity – time graph; $\Delta x =$ ______________________________

**2**. Do the results support your hypothesis? ____________

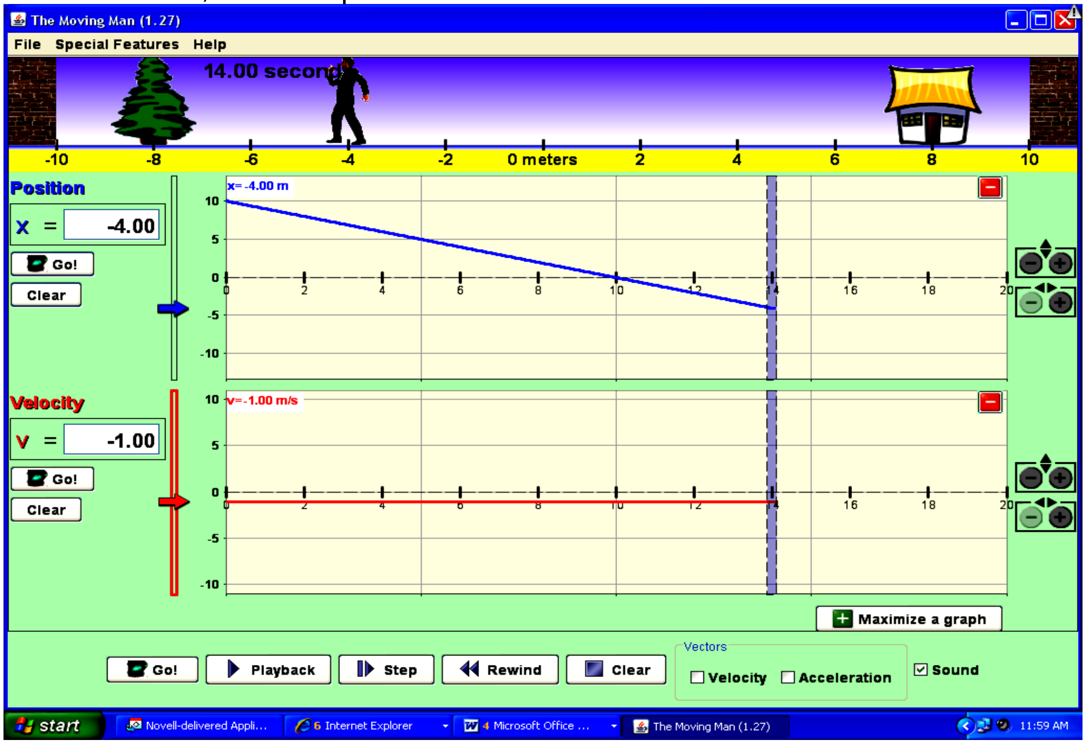
**3**. In the calculations above, two different processes were applied $\Delta x = F(x_2) - F(x_1)$ and $\Delta x = \int_{x_1}^{x_2} f(x)dx$ .

Identify the processes in 1a,b and express them using the functions; x(t), v(t), and

1a; _______ _________1b;__________________

Scenario B

In this scenario, the initial position of the man is 10m.




**1**. Find the displacement of the man using

a. Position – time graph ______________________________

b. Velocity – time graph ______________________________

**2**. Do the results of your calculations support your hypothesis? ____________

**3**. Concluding the results from the scenario A and B, is your hypothesis correct? ______________________

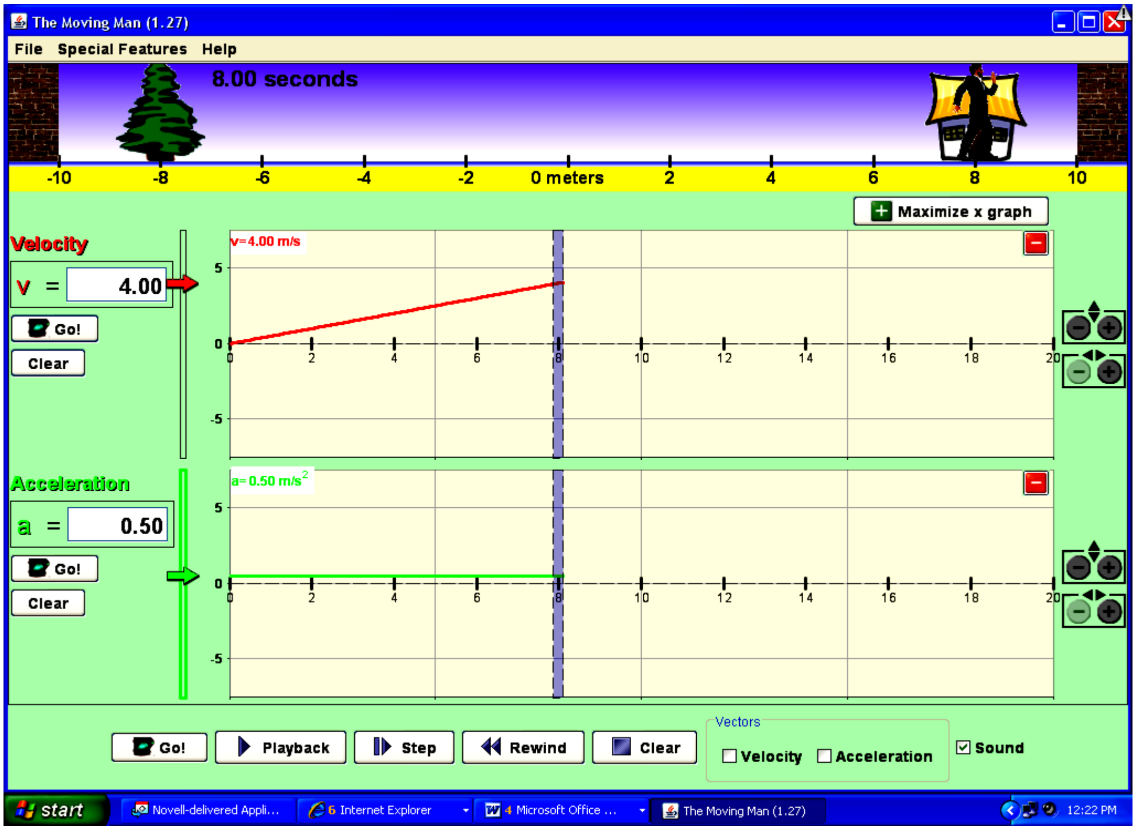
**4**. Is it correct to say that the change of antiderivative of f(x) can be calculated by finding the accumulation of its derivative F(x)? ____________________________

**5**. The general form of the first fundamental theorem of calculus is $\int_{x_1}^{x_2} f(x)dx = F(x_2) - F(x_1)$

Express it using x(t) and v(t).

## PART 2

In this part you will further validate the conclusion from part 1 by applying it to velocity and acceleration graphs.




**1**. Find the change of velocity of the man using

a. Velocity – time graph ______________________________

b. Acceleration – time graph ______________________________

**2.** Are results from 1a and 1b identical?

**3.** The initial position of the man was -8m. Using either of the graphs above (or both) and the fundamental theorem calculate the displacement of the man.

**4.** Suppose that his initial position were -16m. Suppose also that the velocity and acceleration were the same as in the example above.

a. Will either of the quantities change? Use yes or no for each.

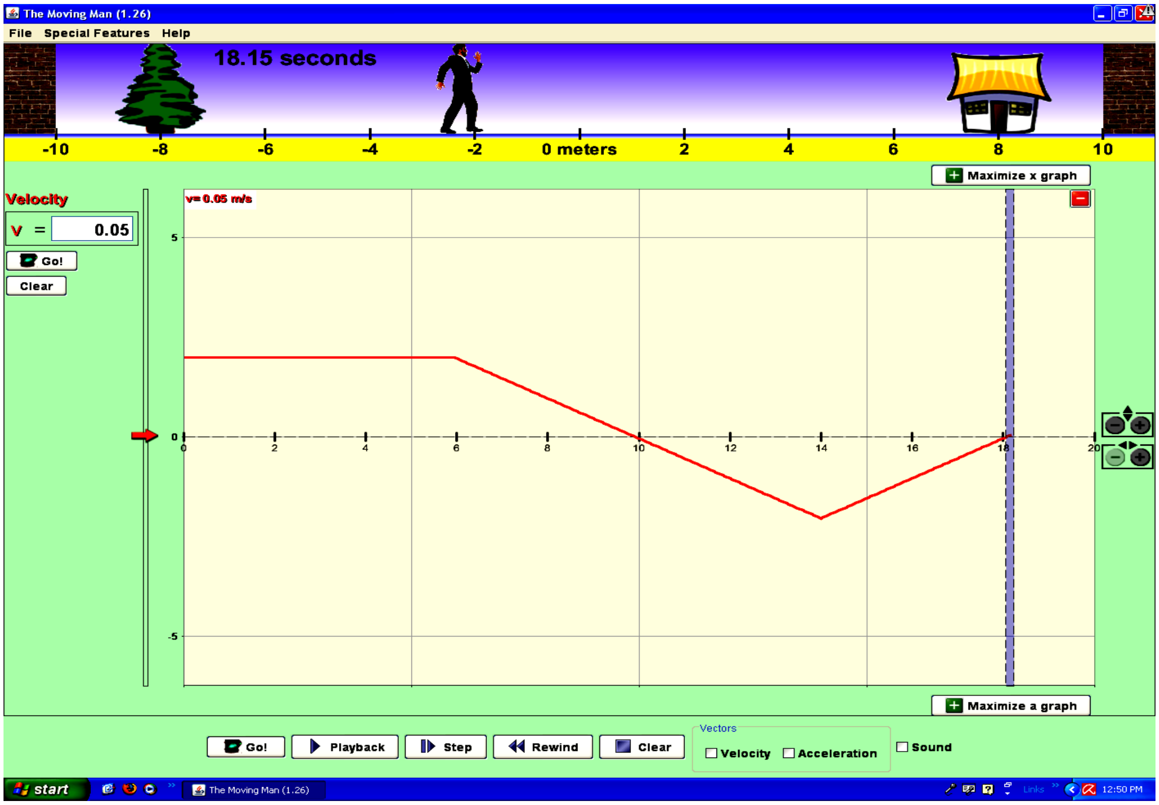
Displacement ___________ Final position _____________

b. Determine his final displacement and position under the new circumstances.

**5**. Express $\int_{x_1}^{x_2} f(x)dx = F(x_2) - F(x_1)$ v(t) and a(t).

## PART 3. Applications of the fundamental theorem of calculus

Given graph represents velocity function of a man walking along a straight line. The man's position can be described by $x(t) = \int_0^t v(t)dt$ . At t = 0, the position of the man is -10 m. The man's initial velocity is 2m/s.




**A.** Using the above graph, calculate the following quantities and describe verbally what each quantity represents and state the unit of each quantity *m, m/s* or *m/s²*.

**a.** $x(6) =$ ____________________________, the quantity represents ______________________________

**b.** $\int_6^{14} v(t)dt =$ _________________________, the quantity represents ______________________________

**c.** $\frac{1}{18}\int_0^{18} v(t)dt =$ _____________________, the quantity represents ______________________________

**d.** $\left.\frac{dv(t)}{dt}\right|_{t=5} =$ _________________________, the quantity represents______________________________

**e.** $\frac{v(12)-v(8)}{12-8} =$ ______________________, the quantity represents______________________________

**B**. Referring to the v-t graph, answer additional questions.

**a**. What is the maximum position of the man in the right direction? ______________________________

**b**. What is the absolute maximum of the position function? ____________________________________

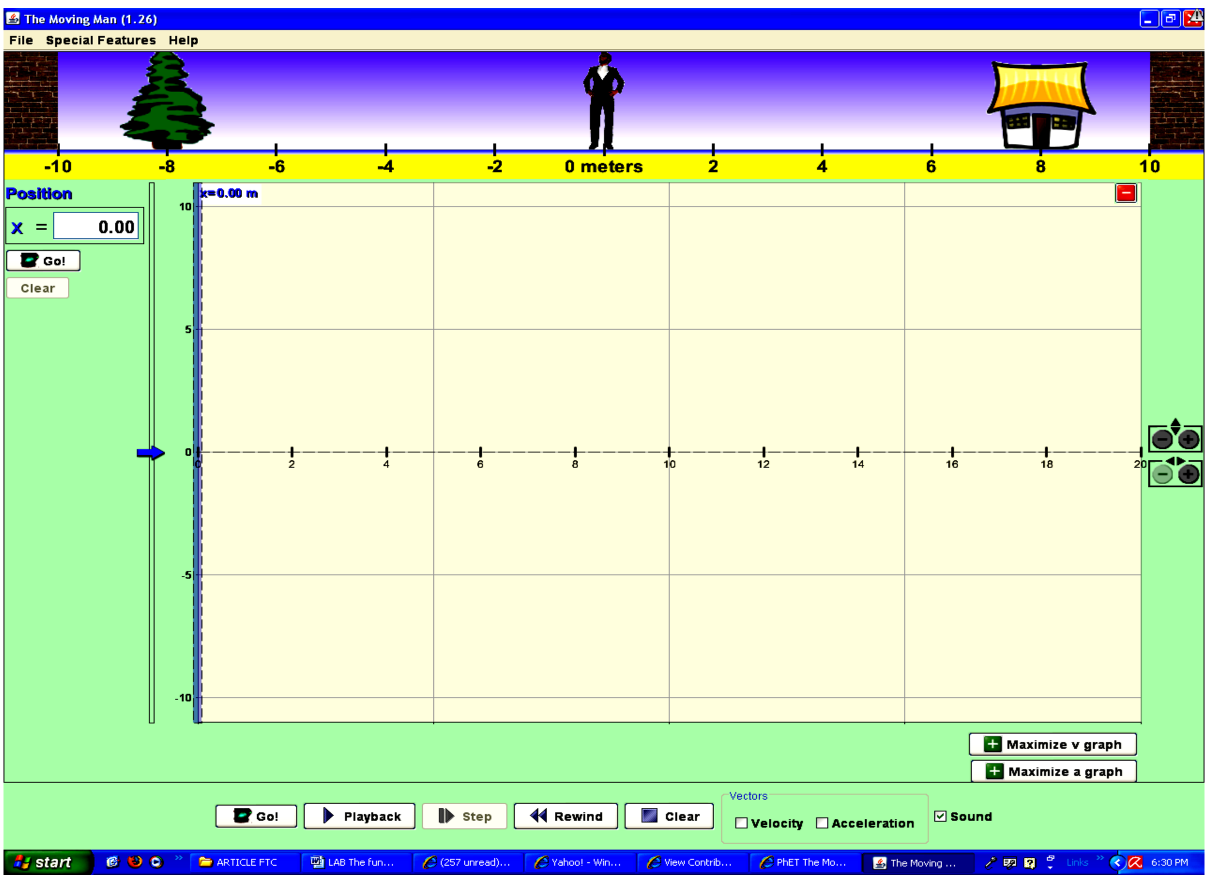
**c**. Should the answers from *a* and *b* be the same? _______________________________________

**d**. Is *v(t)* differentiable (can you take its derivative) h at t = 6s?

- What is the value of acceleration at this instant of time? ____________________________
- Is there any other time instant when the acceleration cannot be determined? __________

**e**. When did the man change the direction of motion? ________________________________________

**f**. Sketch the position function of the man of the grid below.

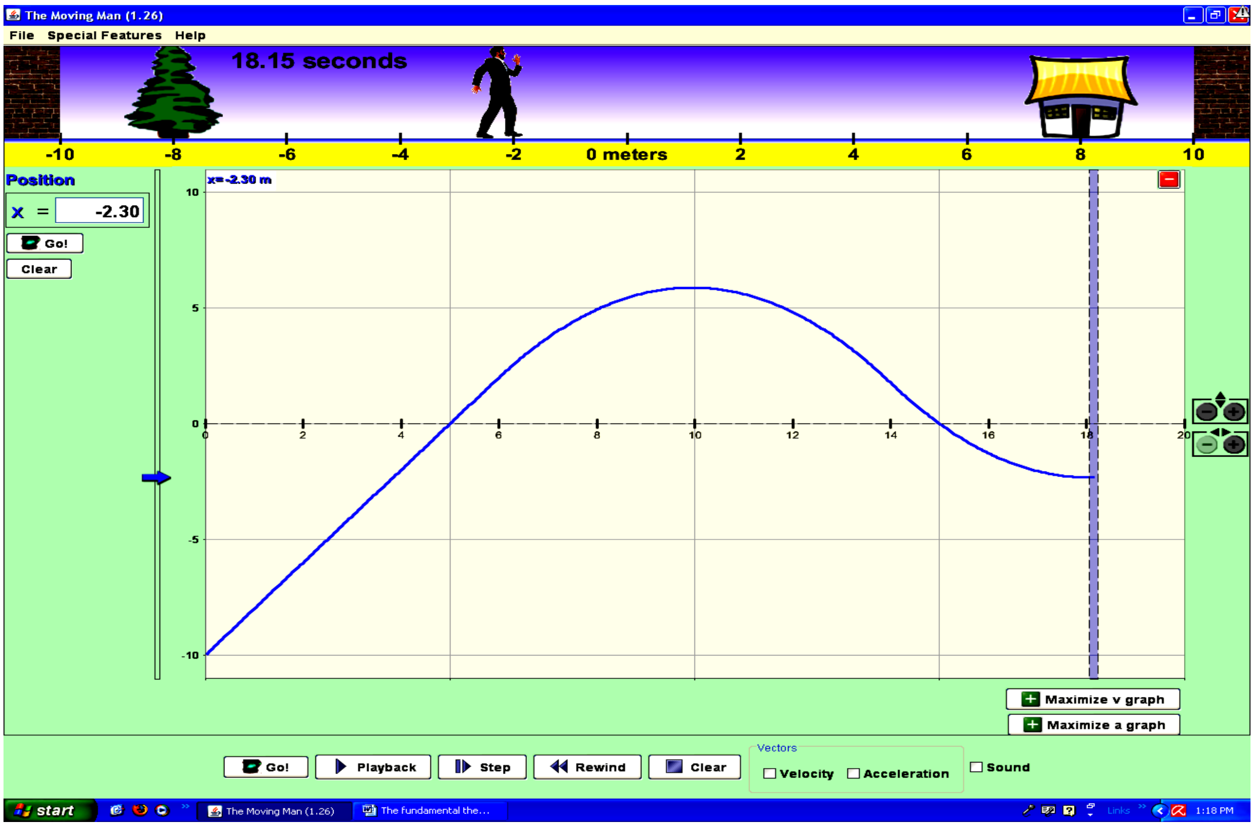


**PART 4: Analysis of the position-time graph**

**Problem:** Is the average rate of change calculated from the position function equivalent to an average value of the velocity?

**Your hypothesis**:____________________________________________________________

Note the given below graph represents the position of the man that corresponds to position graph in **PART 3**. The value of his final position is shown on the top of the diagram. Verify if your graph from # 3 B is similar to the one presented below. Make respective corrections where needed.




**1**. Using the graph above calculate the average velocity of the man.

**2**. What is the average velocity of the man calculated from the velocity – time graph (refer the Part 1 and the answer to the equation # Part 3Ac _______________

**3**. Are these answers the same? ______________________Is your hypothesis correct?____________________

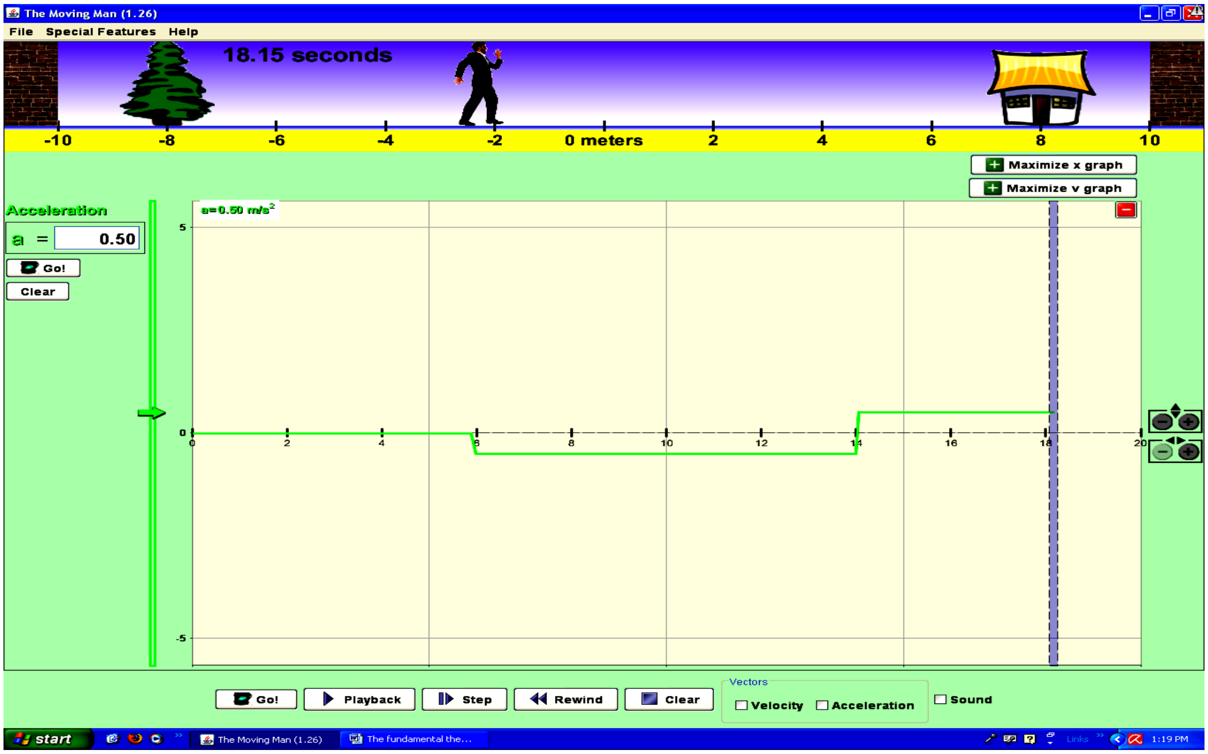
**4**. Referring to the conclusion from # 3, can you say that the value of the slope of a secant line of *f(x)* on a given interval is equivalent the average value of $\frac{df(x)}{dx}$ on the same interval?

_________________________________

**5.** Referring to the graph verify if the man's maximum position in the positive direction corresponds to the one that you calculated in Part 1 #Ac?

**PART 5**: **Analysis of acceleration – time graph**

This graph shows the acceleration of the man that corresponds to the position and velocity-time graphs shown above.




**1**. Determine the man's acceleration at t = 10 and t = 16 s?

**2**. Calculate $\int_{5}^{14} a(t)\,dt$ . Note the final acceleration is shown on the top of the simulation.

What does the calculated value represent?

**3**. Is $\int_{0}^{18} a(t)dt = v(18) - v(0)$ ? ______________________________

Prove this statement using respective graphs.

**4**. Referring to the *a (t)* graph, for what value of *t*, does x(t) have a point of inflection? _______________
Verify your answer with the x (t) graph.

**5**. What is the rate of change of acceleration at t = 6 s and t = 14s? ____________________________

**6**. Is the velocity function differentiable at these instants of time? _________________________

What is the concept that the simulation helped you comprehend? _____________________