

## Summer Work – AP Physics C - 2009

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 definitely be taught as a 2<sup>nd</sup>-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. It will be a fast-paced course covering both mechanics and emag (electricity and magnetism). Enjoy your summer and come in ready for a calculus-based physics experience.

Since physics is the study of relationships in nature, and these relationships are often expressed in the form of mathematical equations, we need to make sure that you remember some basic equations from your first-year physics course. Expect a quiz in the first couple of days, and 5 or 6 more times in the semester! We will be adding significantly to this list as the course goes on. If you are motivated, please go to:

[http://apcentral.collegeboard.com/apc/public/repository/physics\\_equation\\_tables\\_2008\\_09.pdf](http://apcentral.collegeboard.com/apc/public/repository/physics_equation_tables_2008_09.pdf)

Make sure that you look at the AP Physics C equation sheet and not the AP Physics B sheet. Remember that you will need to know all of the Mechanics and Emag equations by May, 2010.

I have also included a handout on the derivative. This is a calculus topic that will be introduced in physics before you get to it in your calculus class. I need for you to have a basic understanding b/c we will get to this the first week of school.

Units:

Variable	Symbol	SI unit	“Dead Scientists Society”
Mass	m	kg	
Length/displacement	L or x	m	
Time	t	sec	
Velocity	v	m/s	
Acceleration	a	m/s/s	
Force	F	kg·m/s <sup>2</sup>	Newton (N)
Kinetic energy	K	kg·m <sup>2</sup> /s <sup>2</sup>	Joule (J)
Potential energy	U	kg·m <sup>2</sup> /s <sup>2</sup>	Joule (J)
Torque	τ	N·m	
Work	W	N·m	Joule
Momentum	p	kg·m/s	
Power	P	J/s	Watt (W)
Spring constant	k	N/m	

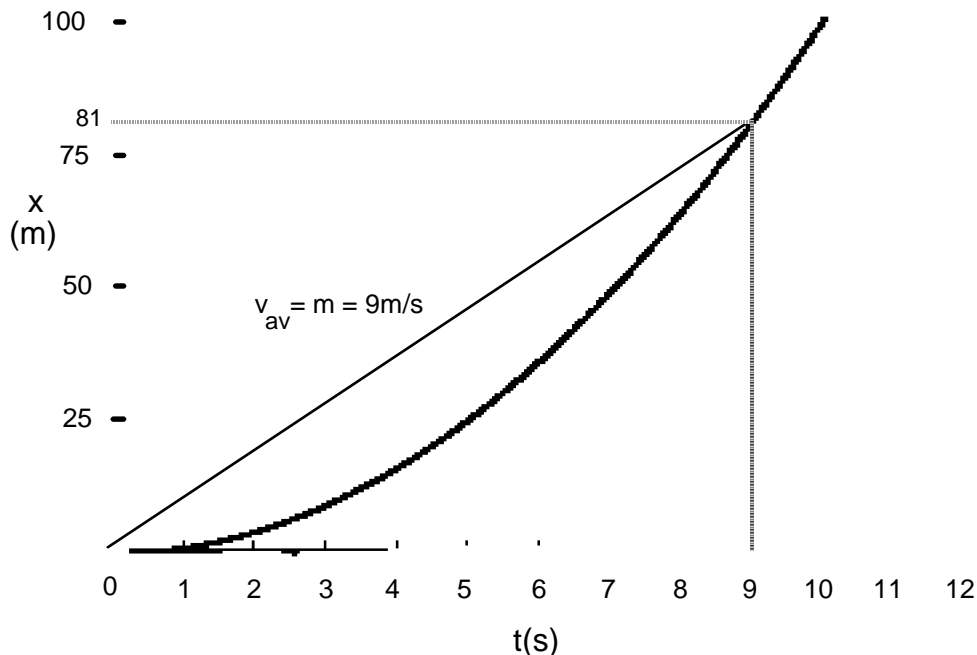
Equations (Mechanics)

Prompt	Equation
Average velocity	$v = \frac{x_f - x_i}{\Delta t}$
Average acceleration	$a = \frac{v_t - v_0}{t}$
Kinematics equation (no x)	$v_f = v_i + at$
Kinematics equation (no a)	$\Delta x = \frac{1}{2}(v_i + v_0)t$

Kinematics equation (no t)	$2a\Delta x = v_i^2 - v_0^2$
Kinematics equation (no $v_f$ )	$\Delta x = v_o t + \frac{1}{2} a t^2$
Newton's second law	$\sum F = ma$
Frictional force in terms of the normal force	$F_f = \mu F_N$
Torque	$\tau = F \cdot d$
Linear momentum	$p = mv$
Impulse (2 definitions)	$I = \Delta p = F \cdot \Delta t$
Kinetic energy	$K = \frac{1}{2} mv^2$
Potential energy due to gravity near Earth's surface	$U_g = mgh$
Work (2)	$W = Fd \cos \theta$ and $W_{net} = KE_f - KE_i$
Mechanical Power (2)	$P = \frac{W}{\Delta t}$ ; $P = F \cdot v$
Potential energy due to a spring	$U_s = \frac{1}{2} k(\Delta x)^2$
Law of gravity	$F_g = \frac{GM_1 M_2}{r^2}$
Centripetal acceleration	$a_c = \frac{v^2}{r}$
Weight (near Earth's surface)	$F_g = mg$

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.

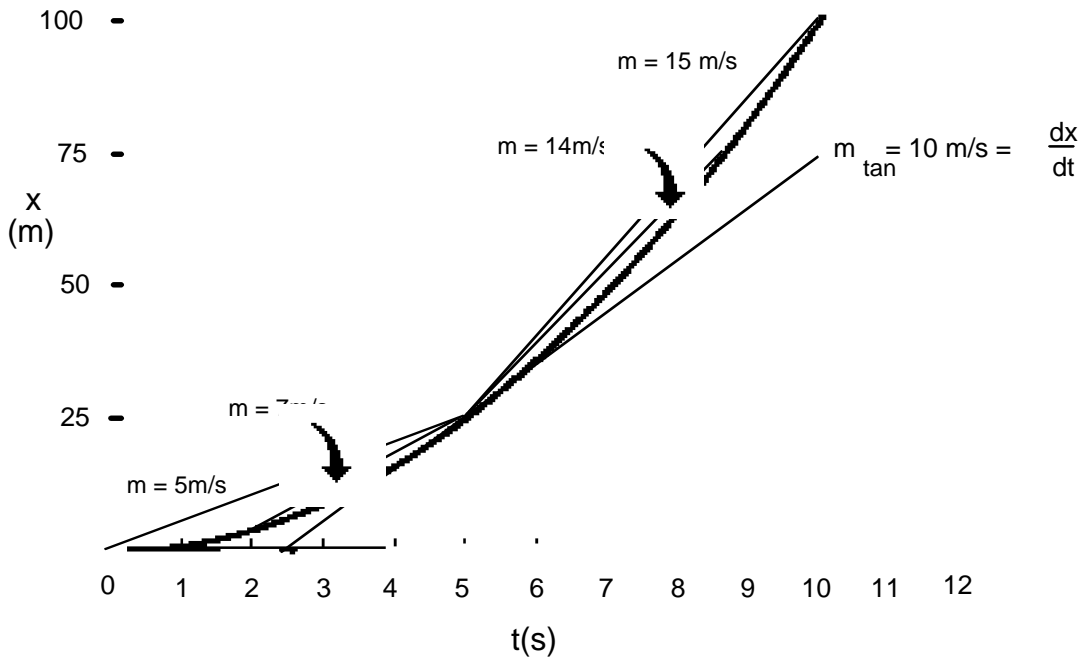
In physics, a concept that is of constant interest is how a physical quantity such as position, velocity or momentum changes with time. As an example, let us examine the position vs. time graph shown here.



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  $\frac{dx}{dt} = 2t$ . At the point we considered  $t = 5$  therefore the velocity was  $2 \times 5$  or 10.

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

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,

$$a = \frac{dv}{dt}.$$

In summary then, we start with  $x = f(t)$ ,  $v = \frac{dx}{dt}$  and  $a = \frac{dv}{dt}$  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  $a = \frac{d^2x}{dt^2}$ .

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.

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