

# PHYS 201 STUDY GUIDE FOR PART ONE: VECTORS AND BASIC MOTION

## INTRODUCTION:

In this first part of the course, we consider: 1. what physics is; 2. the concept of vectors, and 3. the basic description of motion. We first of all consider what physics is. A first attempt at a definition might be this: *Physics is the science that considers the basic structure of matter, the basic properties of matter, the basic interactions between pieces of matter, and the basic descriptions of motion. Physics attempts to describe as many natural phenomena (happenings) as it can in terms of as few basic principles (laws) as it can.*

Note: Natural phenomena are usually very complex things and, to start with, we will be making many idealizations and simplifying assumptions. Once the basic principles are known, you can begin to consider removing some of these simplifying assumptions and try to obtain more and more accurate descriptions of real phenomena.

## INTRODUCTION

### OUTLINE:

- 1) Introduction A
  - a) definition of physics
  - b) review of math [algebra, simultaneous equations]
  - c) measurements, dimensions and units
  - d) the metric system [meters, kilograms, seconds]
  - e) dimensional analysis
  - f) order of magnitude estimates
  
- 2) Positions B,C,D
  - a) lengths
  - b) angles  $\theta$ (in radians) =  $s/r$  [where s is arclength]
  - c) 2-D coordinate systems
    - (1) rectangular (x,y) [most basic - due to addition properties]
    - (2) polar (r, $\theta$ ) [most common - magnitude, direction]
    - (3) latitude and longitude [on curved surface of earth]
  - d) transformations from one form to the other:
    - (1) polar to rectangular:  $x = r \cos(\theta)$ ;  $y = r \sin(\theta)$
    - (2) rectangular to polar:  $r = \sqrt{x^2 + y^2}$ ;  $\theta = \tan^{-1}(y/x)$
  
- 3) Vectors E
  - a) idea of a vector: magnitude and direction (position is example)
  - b) components of a vector (MOST IMPORTANT!)
    - (1) rectangular (x and y components)
    - (2) polar (magnitude and direction)
    - (3) three (or more) dimensions
  - c) addition and subtraction of vectors: add/subtract rectangular components!
  
- 4) Force
  - a) the idea of force: a push or pull
  - b) force is a vector: it has magnitude and direction
  - c) forces can be added as vectors to get resultant force

LETTER PROBLEMS:

A. Given the following three equations, solve them for x, y, and z:

$$ax + by - cz = 5 \quad \text{where } a,b,c \text{ are the last three digits of your phone number}$$

(e.g., 321-3448 means  $a=4$ ,  $b=4$ ,  $c=8$ )

$$-dx + ey + fz = 8 \quad \text{where } d,e,f \text{ are the last three digits of your (or your parent's) street address or box number}$$

$$gx - hy - kz = 0 \quad \text{where } g,h,k \text{ are the last three digits of your (or your parent's) zip code}$$

HINT: in the look back stage (step 7), check your answers by substituting in your answers into the equations to show that they indeed work.

B. If the arc length is 3.0 meters and the radius is 12 meters, what is the angle: a) in radians? b) in degrees? c) in revolutions?

C. The moon has a diameter of 3,500 km and is 384,000 km away. a) When viewed from the earth, what angle does the moon make with a person's eye? b) Given that the earth has a diameter of 12,750 km and is 384,000 km away from the moon, when viewed from the moon, what angle does the earth make with an astronaut's eye?

D. What is the displacement of the point of a wheel initially in contact with the ground when the wheel rolls forward  $3/4$  of a revolution? (The radius of the wheel is 'R' and the 'X-axis' is the forward direction.) (HINT: break the motion into two part: the translation of the wheel and the rotation of the wheel. Only look at initial and final points, not the actual trajectory.)

E. A car drives five blocks East, turns North for two blocks, then turns back West for 2 blocks. What is the final position of the car relative to the initial position. Express in both rectangular and polar form.

ANSWERS TO LETTER PROBLEMS:

A. you are on your own - you should be able to check this yourself.

B. a) 0.25 radians, b) 14.32°, c) 0.0398 revolutions.

C. a)  $9.11 \times 10^{-3}$  radians = 0.52°; b) .033 radians = 1.9°.

D.  $(5.71 \cdot R, 1.00 \cdot R)$  or  $(5.80 \cdot R, 9.9^\circ)$

E. (3 blocks East, 2 blocks North) or (3.61 blocks, 33.7° North of East)

**MOTION IN ONE DIMENSION**OUTLINE:

1) Introduction: Motion is change in position with time

2) Velocity: change in position with time

a) average velocity:  $v_{x\text{-avg}} = \Delta x / \Delta t$ ,

use with DISCRETE DATA POINTS & NUMERICAL METHODS (computers!)

b) velocity is a vector: magnitude (speed) and direction, but work in rectangular!

c) instantaneous velocity  $v_{x\text{-inst}} = dx(t)/dt$  [calculus derivative], use with FUNCTIONS

3) Acceleration: change in velocity with time

F

a) average acceleration:  $a_{x\text{-avg}} = \Delta v_x / \Delta t$

use with DISCRETE DATA POINTS & NUMERICAL METHODS (computers!)

b) acceleration is a vector: magnitude and direction, but work in rectangular!

c) instantaneous acceleration  $a_{x\text{-inst}} = dv_x(t)/dt$  (another derivative) use with FUNCTIONS

- 4) Going backward: finding  $v_x$  from  $a_x$ ,  $x$  from  $v_x$  G  
 a)  $\Delta v_x = a_{x\text{-avg}} \Delta t$ , or  $v_{x\text{-final}} = v_{x\text{-init}} + a_{x\text{-avg}} t$   
 b)  $\Delta x = v_{x\text{-avg}} \Delta t$ , or  $x_{\text{final}} = x_{\text{init}} + v_{x\text{-avg}} t$   
 c) for functions, can use calculus (inverse of derivative is integral)
- 5) A useful special case: constant acceleration H,I  
 a) formulas from calculus:  $x(t) = x_0 + v_0 t + \frac{1}{2} a t^2$ ;  $v(t) = v_0 + a t$   
 b) freely falling bodies:  $a_y = -9.8 \text{ m/s}^2$  (+ means up, - means down; freely means with negligible air resistance)
- 6) Motion graphs J,K,L  
 a) getting velocity from position [slope of  $x(t) \leftrightarrow$  value of  $v(t)$ ]  
 b) getting acceleration from velocity [slope of  $v(t) \leftrightarrow$  value of  $a(t)$ ]  
 c) getting position from velocity [value of  $v(t) \leftrightarrow$  slope of  $x(t)$ ]  
 d) getting velocity from acceleration [value of  $a(t) \leftrightarrow$  slope of  $v(t)$ ]

**LETTER PROBLEMS:**

F. Below are the numerical values of position at specific times. a) Calculate the average velocity between each two times. b) Assuming the average velocities calculated in the previous part are equal to the velocities at the mid-point in the time interval, calculate the average accelerations between the mid-points in time (which are approximately the accelerations at the actual time points).

points.	<u>x (in m)</u>	<u>t (in sec)</u>	<u>x (in m)</u>	<u>t (in sec)</u>
	5.00	0	-2.50	4
	4.33	1	-4.33	5
	2.50	2	-5.00	6
	0.00	3	-4.33	7

G. Below are the numerical values of velocity at specific times as well as the functional expression for velocity. a) Using the numerical method calculate the average acceleration during the time between  $t=5$  seconds and  $t=6$  seconds. b) To check yourself, use the functional form for  $a(t)$  given below to find the acceleration,  $a$ , at  $t = 5.5$  seconds. c) Using the numerical method calculate the position,  $x$ , at  $t=6$  seconds assuming that  $x = -3 \text{ m}$  when  $t=0$  seconds [i.e.,  $x_0 = -3 \text{ m}$ ]. d) To check yourself, use the functional form for  $x(t)$  given below (this was derived using calculus assuming  $x_0 = -3 \text{ m}$ ) to find the position,  $x$ , at  $t=6$  seconds.

*HINT: remember for the numerical method you use:*

$$v_{\text{avg}} = \Delta x / \Delta t, \text{ and } a_{\text{avg}} = \Delta v / \Delta t \text{ where } \Delta x = x_{i+1} - x_i, \Delta t = t_{i+1} - t_i.$$

**NUMERICAL DATA:**

$v(0 \text{ sec}) = 8.0 \text{ m/s}$	$v(4 \text{ sec}) = -1.6 \text{ m/s}$
$v(1 \text{ sec}) = 7.4 \text{ m/s}$	$v(5 \text{ sec}) = -7.0 \text{ m/s}$
$v(2 \text{ sec}) = 5.6 \text{ m/s}$	$v(6 \text{ sec}) = -13.6 \text{ m/s}$
$v(3 \text{ sec}) = 2.6 \text{ m/s}$	

**FUNCTIONAL FORMS:**

$$v(t) = 8.0 \text{ m/s} + (-0.6 \text{ m/s}^3)t^2$$

$$a(t) = (-1.2 \text{ m/s}^3)t$$

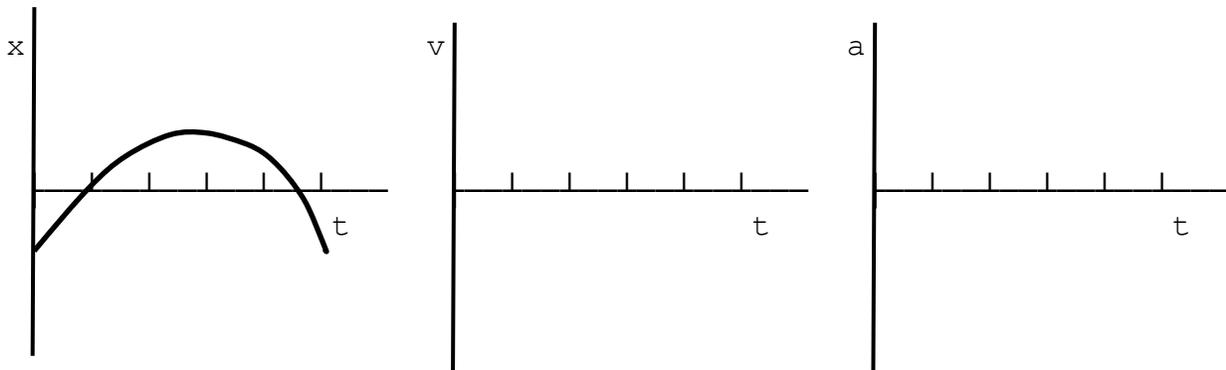
$$x(t) = -3 \text{ m} + (8.0 \text{ m/s})t - (0.2 \text{ m/s}^3)t^3$$

H. A car accelerates (assume uniformly) from rest with an acceleration of  $1.8 \text{ m/s}^2$ . a) How long a time will it take for the car to reach a speed of  $25 \text{ m/s}$ ? b) How far will the car have gone in this time? c) How fast will the car be going after 10 seconds? d) How far will the car have gone after 10 seconds?

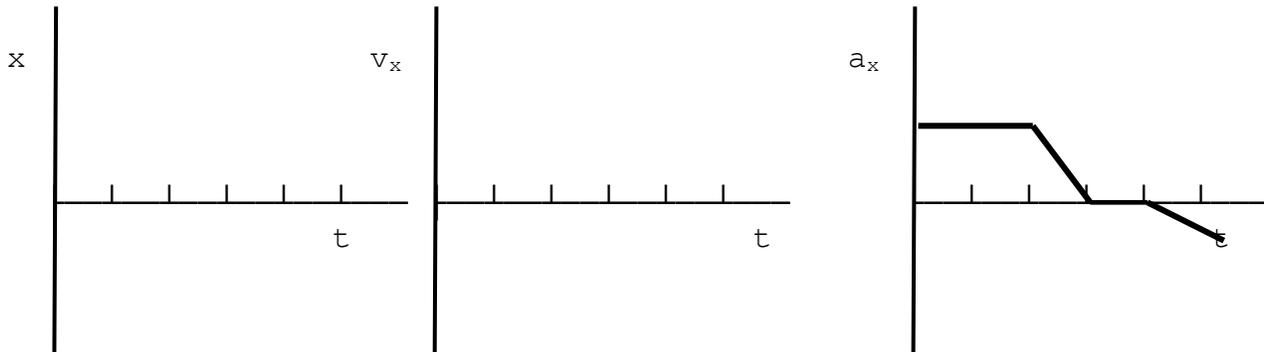
I. A ball is thrown upwards from the top of a building 14 meters high with an initial speed of  $25 \text{ m/s}$ . a) How long will it take the ball to reach it's highest point? b) How high will this highest point be? c) How long will it take the ball to hit the ground (at the bottom of the building)? d) How fast will the ball be going when it hits the ground?

J. For the situation in problem G above, graph  $v(t)$  versus  $t$ . From this graph, be able to qualitatively graph  $x(t)$  versus  $t$ , and  $a(t)$  versus  $t$ .

K. Below is a graph of  $x(t)$ . On the graphs beside it, sketch  $v(t)$  and  $a(t)$ .



L. Below is a graph of  $a_x(t)$ . On the graphs beside it, sketch  $x(t)$  and  $v_x(t)$  assuming that  $x_0 > 0$  and  $v_{x0} < 0$ .



**ANSWERS TO LETTER PROBLEMS:**

F. a) $v$ (in m/s)		$t$ in sec		b) $a$ (in $\text{m/s}^2$ )		$t$ in sec	
-0.67	0.5	-1.83	4.5	-1.16	1	+0.67	4
-1.83	1.5	-0.67	5.5	-0.67	2	+1.16	5
-2.50	2.5	+0.67	6.5	0.00	3	+1.34	6
-2.50	3.5						

G. a)  $a_{\text{num}} = -6.60 \text{ m/s}^2$ ; b)  $a_{\text{cal}} = -6.60 \text{ m/s}^2$ ; c)  $x_{\text{num}} = 1.20 \text{ m}$ ; d)  $x_{\text{cal}} = 1.80 \text{ m}$

H. a) 13.89 sec; b) 173.61 m; c) 18 m/s; d) 90 m.

I. a) 2.55 sec; b) 45.89 m; c) 5.61 sec; d) -29.99 m/s.