Arvind Borde / PHY 11, Week 2: Kinematics in 1d

(1) We'll be studying mechanics. What's that?

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(2) This week we start kinematics. What's that?

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(3) Later we'll study dynamics. What's that?

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(4) This week we're in 1d. What be dat?

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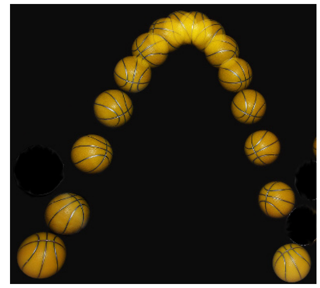
1

We'll study objects moving along lines, ignoring any internal motion: ________________



2

We treat these objects as if they were single points with no size or internal structure, and we call them

____

This is obviously ______________, but it's worked extraordinarily well.

3

We have very precise knowledge of the locations, movements, etc., of astronomical bodies – such as planets, (which are huge and have a complex internal structure) – simply by treating them as point particles.

We send spacecraft out to do precise things (land at exact locations, for example) based largely on this approximation

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Positions and motions must be described with respect to a ________________

It makes no sense to say your position is two feet, unless you say ________________.

(5) New York is ~ 200 miles from

a) Boston?

b) Beijing?

c) Buenos Aires?

5

It make no sense to say you are traveling at 60 mph unless you say with respect to what.

You're loitering on the street, as usual, and car A flashes by at 60 mph, as measured by you.

(6) Car B passes you at 30 mph. What's the speed of car A as measured by car B? ________

(7) Car C passes you at 90 mph. What's the speed of car A as measured by car C? ________

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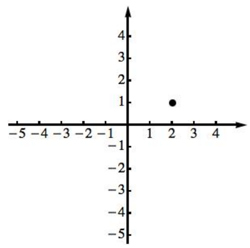
ADDITIONAL NOTES

We'll use standard coordinate systems as our reference frames. In 2-d, these are our familiar x-y plots:



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We'll distinguish between quantities that only have magnitude (size), called __________, and those with magnitude and direction, called __________.

We'll put an arrow on the top of something to indicate it's a vector; all others are scalars.

Vector: $\vec{V}$ Scalar: S.

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(8) Which of these is a vector ($\vec{V}$) and which a scalar (S)?

- Mass: ________________
- Force: ________________
- Temperature: ________________

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When describing motion we want to describe several things.

1) **How far something has gone.**

We use two quantities:

- ___________________, a vector, and
- _______________, a scalar.

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You travel 1000 m to the right, then back 200 m to the left.

(9) You've traveled a distance (d) of _______.

(10) Your net displacement ($\vec{x}$) is ______.

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We'll take displacements pointing to the right as ________, and to the left as ___________.

Notation for the difference of any two quantities, q_i and q_f:

where q_i is the initial value and q_f the final value.

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ADDITIONAL NOTES

(11) You're walking around on a piece of graph paper (an activity you find weirdly pleasurable). You start at $x = 10$, walk to $x = -13$ then return to $x = 10$. What is your displacement and the total distance you've traveled?

____

____

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2) **How fast is something is going.**

average __________ = ____________________

____________________.

average __________ = ____________________.

____________________.

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If an object is at position $\vec{\boldsymbol{x}}_i$ at an initial time t_i and at position $\vec{\boldsymbol{x}}_f$ at the final time t_f, then the average velocity $\vec{\boldsymbol{v}}$ is

$$\vec{\boldsymbol{v}} = \frac{\vec{\boldsymbol{x}}_f - \vec{\boldsymbol{x}}_i}{t_f - t_i} = \frac{\Delta \vec{\boldsymbol{x}}}{\Delta t}.$$

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(12) In Q11, if distances were measured in meters and you started your walk at $t_i = 11:20$ and finished it at $t_f = 11:30$ what was your average velocity and your average speed?

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____

____

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Runner's average velocity. The position of a runner as a function of time is plotted as moving along the x axis of a coordinate system. During a 3.00-s time interval, the runner's position changes from $x_1 = 50.0$ m to $x_2 = 30.5$ m, as shown in Fig. 2–7. What is the runner's average velocity?

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ADDITIONAL NOTES

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Distance a cyclist travels. How far can a cyclist travel in 2.5 h along a straight road if her average velocity is 18 km/h?

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Car changes speed. A car travels at a constant 50 km/h for 100 km. It then speeds up to 100 km/h and is driven another 100 km. What is the car's average speed for the 200-km trip?

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Note, average velocity is not the same as instantaneous velocity – the velocity at an instant of time:

$$\vec{\boldsymbol{v}}_{\text{inst}} = \lim_{\Delta t \to 0} \frac{\Delta \vec{\boldsymbol{x}}}{\Delta t}.$$

This is best studied with calculus.

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3) **How fast is velocity changing.**

This is the rate of change of velocity, and is called

____________________.

$$\text{average acceleration} = \frac{\text{change of velocity}}{\text{time taken}}.$$

In formulas:

$$\vec{\boldsymbol{a}} = \frac{\vec{\boldsymbol{v}}_f - \vec{\boldsymbol{v}}_i}{t_f - t_i} = \frac{\Delta \vec{\boldsymbol{v}}}{\Delta t}.$$

An instantaneous acceleration can be defined by letting $\Delta t \to 0$.

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ADDITIONAL NOTES

Average acceleration. A car accelerates on a straight road from rest to 75 km/h in 5.0 s, Fig. 2–10. What is the magnitude of its average acceleration?

APPROACH Average acceleration is the change in velocity divided by the elapsed time, 5.0 s. The car starts from rest, so $v_1 = 0$. The final velocity is $v_2 = 75\text{ km/h}$.

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Constant Acceleration

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i}$$

Let $t_i = 0$, rename v_i as v_0 and let us call t_f and v_f simply t and v. Then

$$a = \frac{v - v_0}{t}.$$

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(13) Solve for v.

______________ ______________________

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In the same way we can get

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

where $\bar{v}$ is the average velocity:

$$\bar{v} = \qquad\qquad .$$

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(14) Plug $\bar{v}$ into the formula for x and use eqn. **A** to get x without v or $\bar{v}$ in it.

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(15) From eqn. **A**, what is v^2?

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ADDITIONAL NOTES

We can rewrite the previous result as follows:

$$\begin{aligned} v^2 &= v_0^2 + 2v_0 at + a^2t^2 \\ &= v_0^2 + 2a(v_0 t + \frac{1}{2}at^2). \end{aligned}$$

(16) From eqn. **B**, what is $x - x_0$?

____

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Plugging in we get

$$v^2 = v_0^2 + 2a(x - x_0) \qquad \text{Eqn. } \mathbf{C}$$

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Equations of motion: constant acceleration

$$v = v_0 + at \qquad \mathbf{A}$$

$$x = x_0 + v_0 t + \frac{1}{2}at^2 \qquad \mathbf{B}$$

$$v^2 = v_0^2 + 2a(x - x_0) \qquad \mathbf{C}$$

$$\bar{v} = \frac{v + v_0}{2} \qquad \mathbf{D}$$

x_0, x: initial and later position;

v_0, v: initial and later velocity;

33 a: acceleration (constant); t: (later) time.

(17) Why so many equations?

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In all the questions below, assume a is known. Which eqn. would you use if you're given

(18) x_0, v_0 and t, and asked for x? ________

(19) x, x_0 and v_0, and asked for v? ________

(20) x, x_0 and v_0, and asked for t? ________

(21) v and v_0 and asked for t? ________

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The variable x is used for horizontal motion. If we talk about vertical motion, we'll use y.

Vertical motion near the surface of the earth is governed by the acceleration due to gravity. That's roughly constant, $a = -g$, where $g = 9.80\,\text{m/s}^2$.

(22) Assuming the up direction is positive, why is the acceleration due to gravity negative?

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ADDITIONAL NOTES

(23) You throw a ball upward at an initial speed of $15.0\,\mathrm{m/s}$. How high does it go?
Hint: What is its speed at the highest point?

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(24) You drop a ball from a height of $100\,\mathrm{cm}$. How fast is it going when it hits the ground?

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ADDITIONAL NOTES

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