Physics 2311 – Physics I, Week 2

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Outline for W2, Day "2"

Finish measurements and errors (Ch. 1)

Motion in 1-dimension

- Position, distance, path length, displacement
- Average speed & velocity

Homework:

Ch. 1 Read sections 3-5,7 (skim 1 & 2)

Ch. 1 MisConcQs: 2-8,10; Probs:1-8,14,15,17,18, 23,24,54-56 (due today by 2:30 pm)

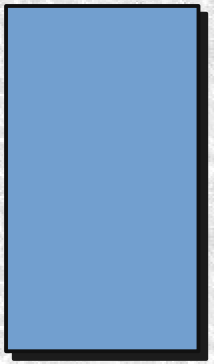
Ch. 2 Read sections 1-7,(8); Probs. 2,3,5-7,14, 23-27,35-38,53-56 (Due next Wed)

Notes: Lab is "Measurements in Physics"

- Quiz 1 next Monday on Ch 1 and some Ch 2.
- Try practice quiz online.
- I tried to fix Canvas for Sec 2.
- Tutoring confirmed Wed and Thur 7-9 pm, Het 201.

Error propagation example

1) Find the Area of a rectangular plate with $L=21.3\pm0.2$ cm, $W=9.8\pm0.1$ cm, using the "adding the fractional errors" method to determine the errors.



Final answer: $A = 209 \pm 4\ \text{cm}^2$

2) Find the same area using the correct "add fractional errors in quadrature" approach to determine the errors.

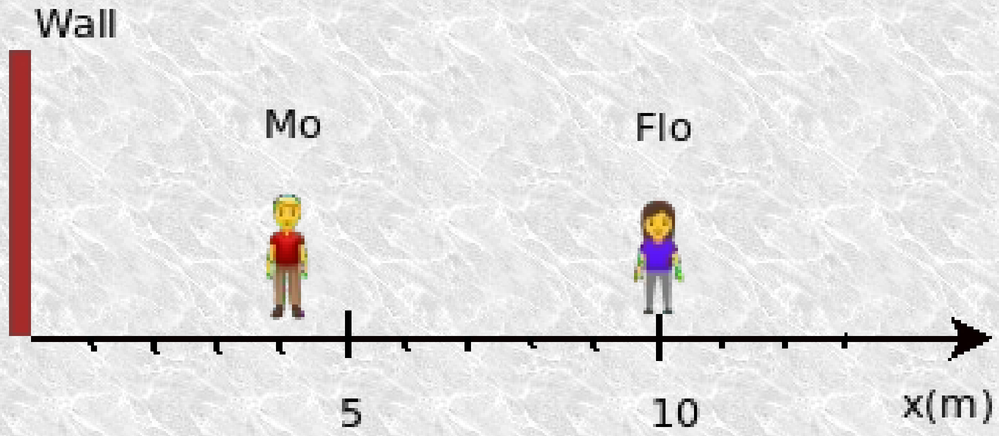
Final answer: $A = 209 \pm 3\ \text{cm}^2$

3) Find the same area supposing you were NOT given the errors, only $L=21.3$ cm, $W=9.8$ cm.

Final answer: $A = 210\ \text{cm}^2$

Motion in 1-Dimension

Mo and Flo are standing conveniently on a number line, which has its origin, x=0, where the floor meets a wall.

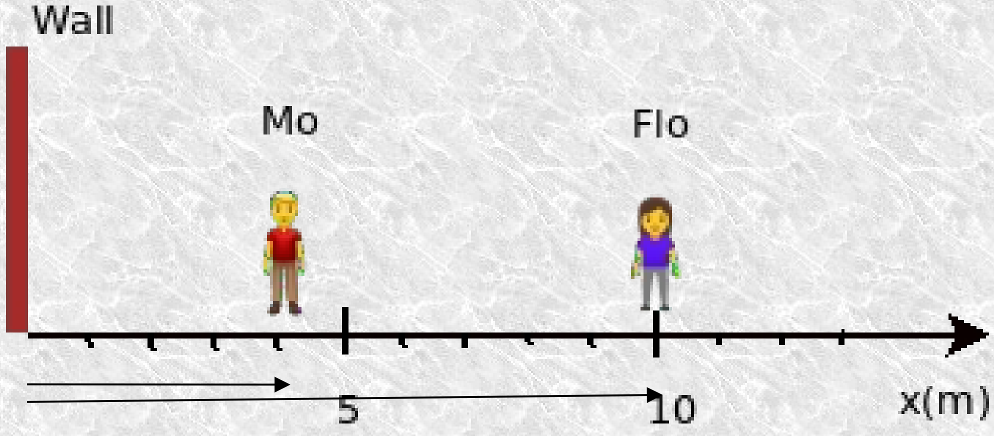


Relative to this origin, we can quantify Mo and Flo's …

Position: the distance away from a reference point.

- Symbols for position: x, y, z
- Positions for Mo and Flo: x_{mo} = 4 m and x_{flo} = 10 m.

Motion in 1-Dimension (cont.)



Position vector: a vector pointing from a reference point to an object of interest.

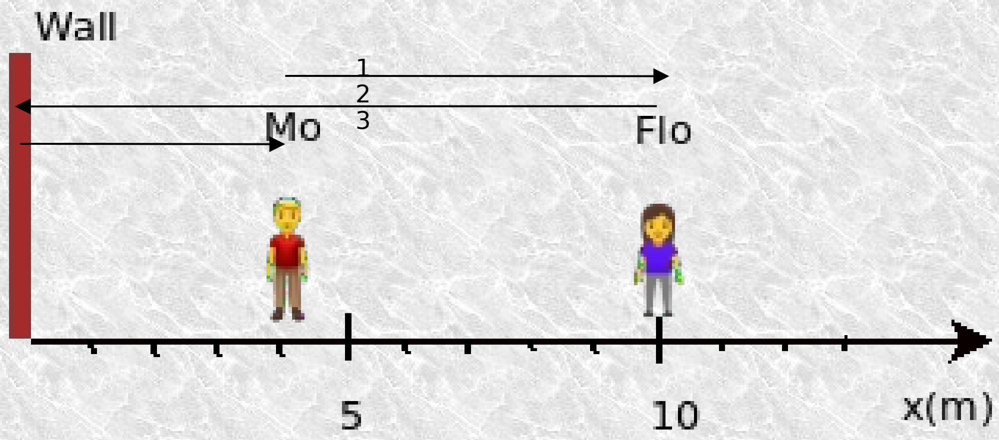
- Symbols for position vector: **x**, **r**, $\vec{x}$
- For Mo and Flo we have $\mathbf{x}_{mo}$ = 4 î m and $\mathbf{x}_{flo}$ = 10 î m.
- The position vectors for Mo and Flo are shown under the numberline.

The **distance** between two objects can be defined as the magnitude of the difference between their positions.

Ex) $d_{flo\ to\ mo} = |x_{mo} - x_{flo}| = |4 - 10| = 6$ m.

Motion in 1-Dimension

Ex) Mo walks to Flo, gets rejected, walks to the wall (x=0), and then returns to x=4.



Path length (d, l): the sum of all distances making up a path.

Ex) Mo's path length (above) is $l = d_1+d_2+d_3 = 6+10+4=20$m

Note: path length is like a cars odometer reading, only increasing.

Displacement ($\Delta\mathbf{x}$, $\Delta\vec{x}$, $\Delta\mathbf{r}$): The difference between the final position vector and the initial position vector of a journey.

$\Delta\mathbf{x} \equiv \mathbf{x}_f - \mathbf{x}_i$

Ex) Mo's displacement is $\Delta\mathbf{x} = \mathbf{x}_f - \mathbf{x}_i = 4\,\hat{\imath} - 4\,\hat{\imath} = 0\,\hat{\imath}$ m.

Week 2 (cont.)

Motion in 1-Dimension (cont.)

Average speed (s, s_{avg}, v, "average speed") = distance or path length per time.

- $s_{avg} \equiv d / \Delta t = l/\Delta t$
- s_{avg} is only positive. s_{avg} is a scalar, not a vector.
- Dimensions are L/T. MKS units are m/s.

Average velocity (**v**, $\mathbf{v}_{avg}$, $\vec{v}_{avg}$) = displacement per time.

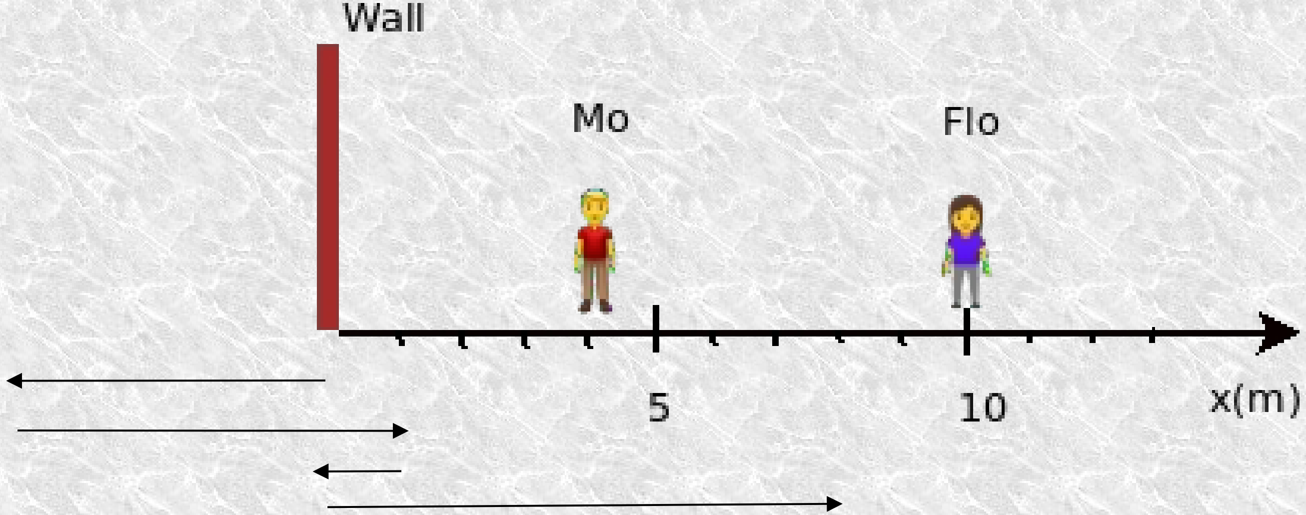
$\mathbf{v} \equiv \Delta\mathbf{x}/\Delta t$

v is a vector – it has magnitude and direction.

v can be positive (in the +x direction) or negative (in the -x direction).

Week 2 (cont.)

Motion in 1-Dimension (cont.)



Example) Doing chores, Mo starts at x=0, walks 5’ left, 6’ right, 1’ left, and 8’ right in 40 seconds. What was Mo’s average speed?

Ans: d = 5 + 6 + 1 + 8 = 20’, so s = 20’/40sec = 0.5 ft/sec.

Example) What was Mo’s average velocity for this journey?

Ans: $\mathbf{v} \equiv \Delta\mathbf{x}/\Delta t = (8\hat{\imath} - 0\hat{\imath})/\ (40\text{ sec}) = 8\hat{\imath}/40 = 0.2\ \hat{\imath}$ ft/s

Note: we don’t have enough info to say how fast Mo was moving at any point in time during this journey!

Week 2 (cont.)

Motion in 1-Dimension (cont.)

Instantaneous speed, (s, s_{inst}): the speed at an instant in time.

- Definition: $\frac{d}{\Delta t}$
- s is a scalar and so is always positive
- Dimensions: L/T

Instantaneous velocity, (**v**, $\mathbf{v}_{inst}$, $\vec{v}$): the velocity at an instant in time.

- Definition: $\frac{\Delta \vec{x}}{\Delta t} = \frac{d\vec{x}}{dt}$
- **v** is a vector, and so can be positive or negative
- Dimensions: L/T

Ex) A racecar moves obeying $\mathbf{x}(t) = 3 - 6t^2$ m î. What is it's instantaneous velocity at t=3 seconds?
Ans: $\mathbf{v}(t) = dx/dt = -12t$ î, so $\mathbf{v}(t=3) = -36$ m/s î .

Week 2 (cont.)

Motion in 1-Dimension (cont.)

Inequalities involving speed and velocity

Possible inequalities: = , $\leq$, $\geq$, $\neq$, $<$, $>$

1) The instantaneous speed is the magnitude of the instantaneous velocity.

$$s = |\vec{v}|$$

Q: Is *average* speed equal to the magnitude of average velocity?

Ans: not necessarily!

2) The average speed is greater than or equal to the magnitude of $\mathbf{v}_{avg}$.

$$s_{avg} \geq |\vec{v}_{avg}|$$

Q: When is the magnitude of average velocity less than average speed?

(Hint: see previous problem with Mo's 4-leg journey.)

Ans: when there are reversals, or "switchbacks" in the journey.

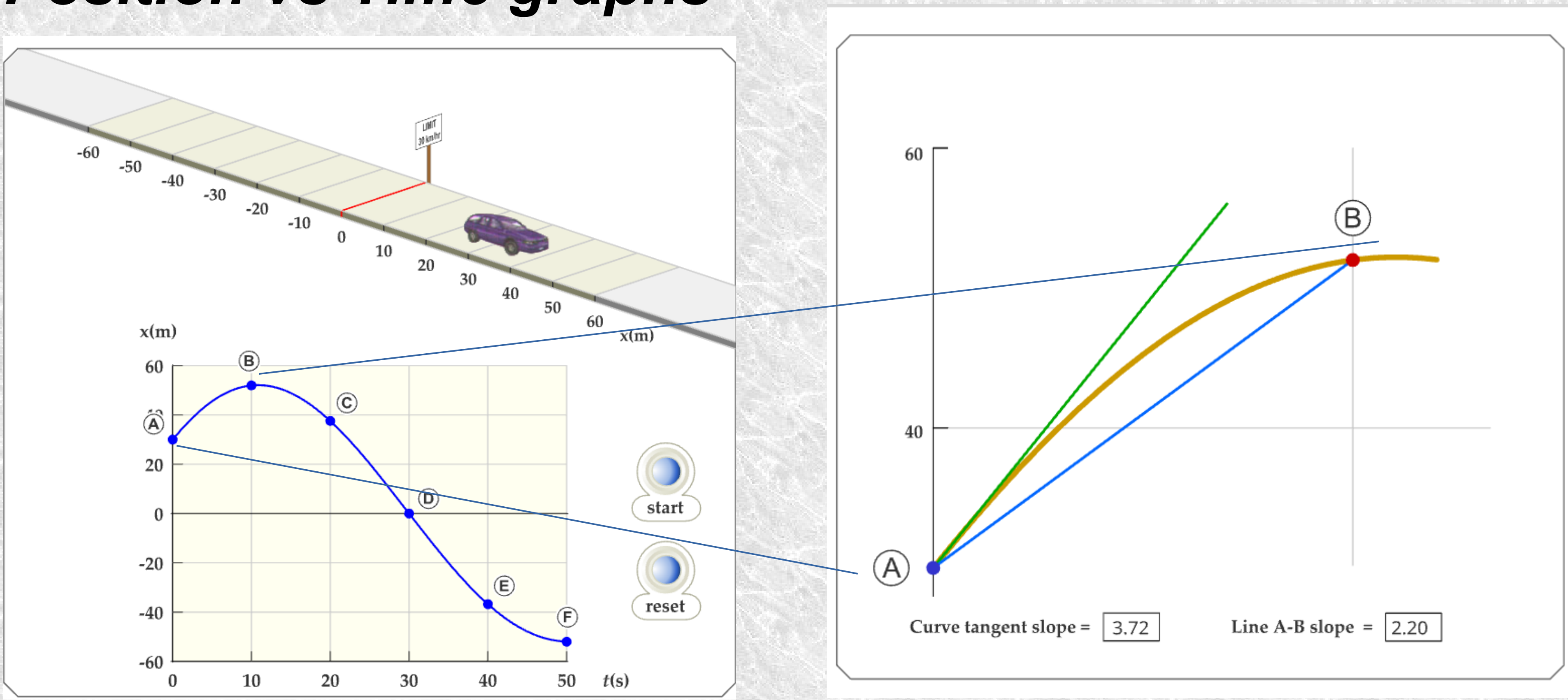
Q: What is the inequality between path length and magnitude of displacement?

$$d \geq |\Delta \vec{x}_{avg}|$$

Week 2 (cont.)

Motion in 1-Dimension (cont.)

Position vs Time graphs



The instantaneous velocity (at A) is the slope of the green line tangent to the *x* vs. *t* curve.

$$\frac{\Delta \vec{x}}{\Delta t} = \frac{d\vec{x}}{dt}$$

Week 2 (cont.)

Motion in 1-Dimension (cont.)

Average acceleration (a, $\mathbf{a}_{avg}$): a change of velocity per time.

$\mathbf{a}_{avg} \equiv \Delta\mathbf{v}/\Delta t = (v_f - v_i)/(t_f - t_i)$

$\mathbf{a}_{avg}$ (and a) are vectors

Negative $\mathbf{a}_{avg}$ means “to the left” (NOT decelerating!)

Slope of a line connecting 2 points on a v vs t graph

Instantaneous acceleration ($\mathbf{a}$,$\mathbf{a}_{inst}$): rate of change of velocity with time at an instant.

$\mathbf{a} \equiv \lim(\Delta t \to 0)\ \Delta\mathbf{v}/\Delta t = d\mathbf{v}/dt$

a is a vector. We will NOT have a scalar version of acceleration which is always positive.

Negative **a** means “to the left” (NOT decelerating)

Slope of a tangent to a v vs t graph.

Week 2 (cont.)

Example problems involving acceleration definitions

Average acceleration (a, $\mathbf{a}_{avg}$): $\mathbf{a}_{avg} \equiv \Delta\mathbf{v}/\Delta t = (v_f - v_i)/(t_f - t_i)$

Instantaneous acceleration ($\mathbf{a}$, $\mathbf{a}_{inst}$): $\mathbf{a} \equiv \lim(\Delta t \to 0)\ \Delta\mathbf{v}/\Delta t = d\mathbf{v}/dt$

Ex (P. 2.24): A car accelerates at $a=1.8\ m/s^2$. How long does it take to accelerate from 65 km/hr to 120 km/hr?

Soln: $\mathbf{a}_{avg} = \Delta\mathbf{v}/\Delta t = 1.8\ m/s^2$ so solve for $\Delta t = \Delta\mathbf{v} / \mathbf{a}_{avg}$

Need to convert units of $\Delta\mathbf{v}$ = (120 – 65 km/hr)

= 55 km/hr * (1hr/3600s)*(1000m/km)= 15.28 m/s

So $\Delta t = 15.28/1.8 = 8.49$ sec $\to$ $\boxed{8.5 \text{ sec.}}$

Ex (P. 2.26): If $x(t)=4.8t + 7.3\ t^2$, what is the acceleration as a function of time?

Soln: $a = dv/dt = d^2x/dt^2$ so find $dx/dt = 4.8 + 14.6\ t$

And then $d^2x/dt^2 = \boxed{14.6\ m/s^2}$

Week 2 (cont.)

Motion in 1-Dimension (cont.)

More on graphing

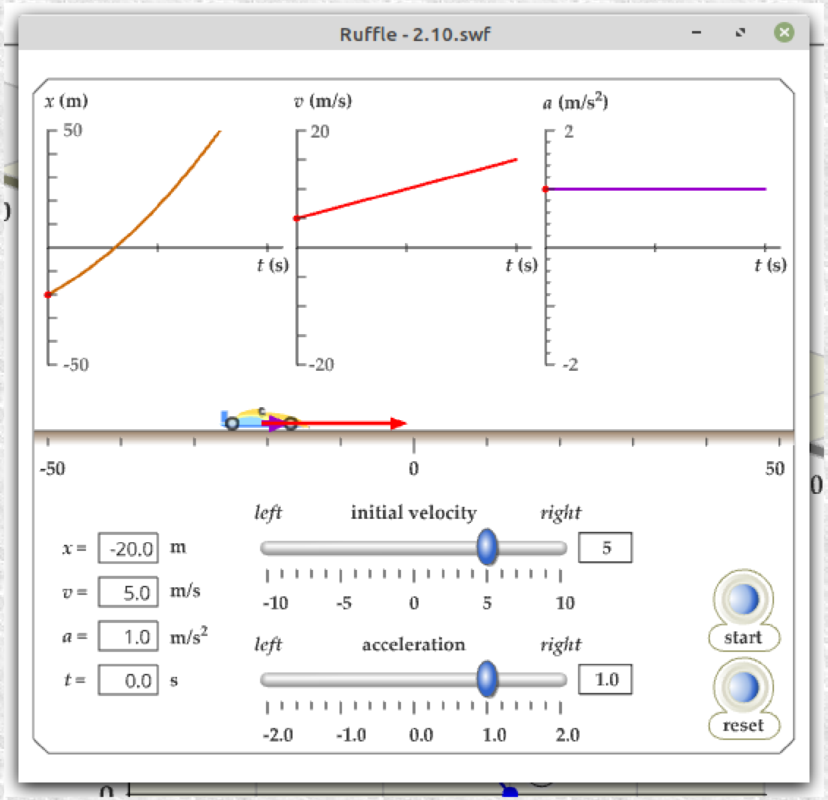
x vs t: $\mathbf{v}_{inst}$ is slope of x vs t (but area under x vs t is nothing!)

v vs t: $\mathbf{a}_{inst}$ is slope of v vs t

v vs t: $\Delta\mathbf{x}$ is area under v vs t

a vs t: $\Delta\mathbf{v}$ is area under a vs t

See 2.10.swf:



Week 2 (cont.)

Motion in 1-Dimension (cont.)

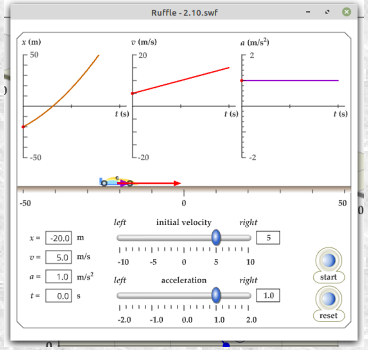
Equations of motion: equations which show x as a function of time.

$x=x_0$ Object is stationary!

$x=x_0+v_0t$ Object moves with a constant speed/velocity.
x_0 is position at t=0, v_0 is velocity at t=0.

$x=x_0+v_0t+\frac{1}{2}at^2$ Object has uniform acceleration.

Show graphs on board and with swf:



Week 2 (cont.)

Motion in 1-Dimension (cont.)

Next: Equations of uniform acceleration.