Physics 207 – Lecture 2

Physics 207 Labs……start this week (MC1a & 1c)

Physics 207, Lecture 2, Sept. 10

Agenda for Today

- Finish Chapter 1, Chapter 2.1, 2.2
  - ❖ Units and scales, order of magnitude calculations, significant digits (on your own for the most part)
  - ❖ Position, Displacement
  - ❖ Velocity (Average and Instantaneous), Speed
  - ❖ Acceleration
  - ❖ Dimensional Analysis

Assignments:

- For next class: Finish reading Ch. 2, read Chapter 3 (Vectors)
- Mastering Physics: HW1 Set due this Wednesday, 9/10
- Mastering Physics: HW2 available soon, due Wednesday, 9/17 (Each assignment will contain, 10 to 11 problems

Length

Distance___	Length (m)
Radius of Visible Universe	1×10^{26}
To Andromeda Galaxy	2×10^{22}
To nearest star	4×10^{16}
Earth to Sun	1.5×10^{11}
Radius of Earth	6.4×10^{6}
Sears Tower	4.5×10^{2}
Football Field	1×10^{2}
Tall person	2×10^{0}
Thickness of paper	1×10^{-4}
Wavelength of blue light	4×10^{-7}
Diameter of hydrogen atom	1×10^{-10}
Diameter of proton	1×10^{-15}

Time

Interval__	Time (s)
Age of Universe	5×10^{17}
Age of Grand Canyon	3×10^{14}
Avg age of college student	6.3×10^{8}
One year	3.2×10^{7}
One hour	3.6×10^{3}
Light travel from Earth to Moon	1.3×10^{0}
One cycle of guitar A string	2×10^{-3}
One cycle of FM radio wave	6×10^{-8}
One cycle of visible light	1×10^{-15}
Time for light to cross a proton	1×10^{-24}

Mass

Object___	Mass (kg)
Visible universe	$\sim 10^{52}$
Milky Way galaxy	7×10^{41}
Sun	2×10^{30}
Earth	6×10^{24}
Boeing 747	4×10^{5}
Car	1×10^{3}
Student	7×10^{1}
Dust particle	1×10^{-9}
Bacterium	1×10^{-15}
Proton	2×10^{-27}
Electron	9×10^{-31}
Neutrino	$<1 \times 10^{-36}$

Some Prefixes for Power of Ten

Power	Prefix	Abbreviation
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	*nano*	n
10^{-6}	micro	µ
10^{-3}	milli	m
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E

Order of Magnitude Calculations / Estimates

Question: How many french fries, placed end to end, would it take to reach the moon?

- Need to know something from your experience:
  - ❖ Average length of french fry: 3 inches or 8 cm, 0.08 m
  - ❖ Earth to moon distance: 250,000 miles
  - ❖ In meters: 1.6 x 2.5 X 10^5 km = 4 X 10^8 m

$$ff \approx \frac{4\times10^{8}\text{ m}}{8\times10^{-2}\text{ m}} \approx 0.5\times10^{10}$$

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Dimensional Analysis

- This is a very important tool to check your work
  - ❖ Provides a reality check (if dimensional analysis fails then no sense in putting in the numbers; this leads to the GIGO paradigm)
- Example

  When working a problem you get the answer for distance $d = v\,t^2$ (velocity x time^2)

  Quantity on left side = L

  Quantity on right side = L / T x T^2 = L x T
- Left units and right units don't match, so answer is nonsense

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Lecture 2, *Exercise 1*
Dimensional Analysis

- **The force (F) to keep an object moving in a circle can be described in terms of:**
  - ❖ **velocity (v, dimension L / T) of the object**
  - ❖ **mass (m, dimension M)**
  - ❖ **radius of the circle (R, dimension L)**

Which of the following formulas for *F could* be correct ?

(a) $F = mvR$ **(b)** $F = m\left(\frac{v}{R}\right)^2$ **(c)** $F = \frac{mv^2}{R}$

Note: *Force* has dimensions of ML/T^2

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Lecture 2, *Exercise 1*
Dimensional Analysis

Which of the following formulas for *F could* be correct ?

Note: *Force* has dimensions of ML/T^2

Velocity (v, dimension L / T)
Mass (m, dimension M)
Radius of the circle (R, dimension L)

✘ A. → $F = mvR$

✘ B. → $F = m\left(\frac{v}{R}\right)^2$

✘ C. → $F = \frac{mv^2}{R}$

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Converting between different systems of units

- Useful Conversion factors:
  - ❖ 1 inch = 2.54 cm
  - ❖ 1 m = 3.28 ft
  - ❖ 1 mile = 5280 ft
  - ❖ 1 mile = 1.61 km
- Example: Convert miles per hour to meters per second:

$$1\frac{\text{mi}}{\text{hr}} = \frac{1\,\cancel{\text{mi}}}{\cancel{\text{hr}}}\times\frac{5280\,\cancel{\text{ft}}}{\cancel{\text{mi}}}\times\frac{1\,\text{m}}{3.28\,\cancel{\text{ft}}}\times\frac{1\,\cancel{\text{hr}}}{3600\,\text{s}} = 0.447\,\frac{\text{m}}{\text{s}} \approx \frac{1}{2}\,\frac{\text{m}}{\text{s}}$$

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Lecture 2, Home *Exercise 1*
Converting between different systems of units

- When on travel in Europe you rent a small car which consumes 6 liters of gasoline per 100 km. What is the MPG of the car ?

  (There are 3.8 liters per gallon.)

$$\frac{100}{6}\,\frac{\text{km}}{l} = \frac{100\,\text{km}}{6\;\;l}\times\frac{\text{mi}}{1.6\,\text{km}}\times\frac{3.8\,l}{\text{gal}} = 39.6\,\frac{\text{mi}}{\text{gal}} = 40\,\frac{\text{mi}}{\text{gal}}$$

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Significant Figures

- The number of digits that have merit in a measurement or calculation.
- When writing a number, all non-zero digits are significant.
- Zeros may or may not be significant.
  - ❖ those used to position the decimal point are **not** significant (unless followed by a decimal point)
  - ❖ those used to position powers of ten ordinals may or may not be significant.
- In scientific notation all digits are significant
- Examples:

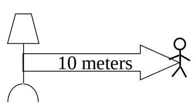
2	1 sig fig
40	ambiguous, could be 1 or 2 sig figs (use scientific notations)
4.0×10^1	2 significant figures
0.0031	2 significant figures
3.03	3 significant figures

Significant Figures

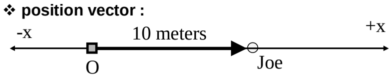
- When multiplying or dividing, the answer should have the same number of significant figures as the <u>least</u> accurate of the quantities in the calculation.
- When adding or subtracting, the number of digits to the right of the decimal point should equal that of the term in the sum or difference that has the smallest number of digits to the right of the decimal point.
- Examples:
  - ❖ $2 \times 3.1 = 6$
  - ❖ $4.0 \times 10^1 / 2.04 \times 10^2 = 1.6 \times 10^{-1}$
  - ❖ $2.4 - 0.0023 = 2.4$

Motion in One-Dimension (Kinematics)
Position / Displacement

- Position is usually measured and referenced to an origin:

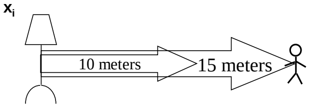


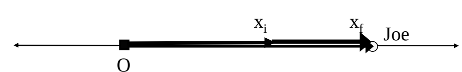
- ❖ **At time= 0 seconds Joe is 10 meters to the right of the lamp**
- ❖ **origin = lamp**
- ❖ **positive direction = to the right of the lamp**
- ❖ **position vector :**



Position / Displacement

- **One second later Joe is 15 meters to the right of the lamp**
- **Displacement is just change in position.**
  - ❖ $\Delta x = x_f - x_i$





$x_f = x_i + \Delta x$

$\Delta x = x_f - x_i = 5$ meters

$\Delta t = t_f - t_i = 1$ second

Average speed and velocity
Changes in position *vs* Changes in time

- Average velocity = total distance covered per total time,

$$\bar{v}(\text{average velocity}) = \frac{\Delta x(\text{net displacement})}{\Delta t(\text{total time})}$$

- Speed is just the magnitude of velocity.
  - ❖ The "how fast" without the direction.

$$\bar{s}(\text{average speed}) = \frac{\text{distance taken along path}}{\Delta t(\text{total time})}$$

<u>Active Figure 1</u> http://www.phy.ntnu.edu.tw/ntnujava/main.php?t=282

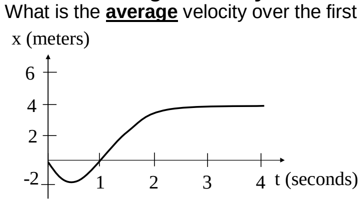
- Instantaneous velocity, velocity at a given instant

$$v(\text{velocity}) = \lim_{\Delta t \to 0} \frac{\Delta x(\text{displacement})}{\Delta t(\text{time})} = \frac{dx}{dt}$$

<u>Active Figure 2</u> http://www.phy.ntnu.edu.tw/ntnujava/main.php?t=230

Average Velocity Exercise *2*

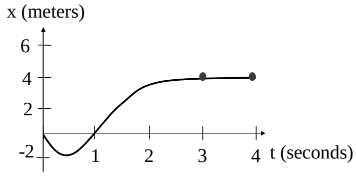
What is the **<u>average</u>** velocity over the first 4 seconds ?



A. 2 m/s
B. 4 m/s
C. 1 m/s
D. 0 m/s

Average Velocity *Exercise 3*

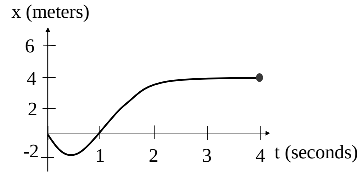
What is the **average** velocity in the last second (t = 3 to 4) ?



- A. 2 m/s
- B. 4 m/s
- C. 1 m/s
- D. 0 m/s

Instantaneous velocity *Exercise 4*

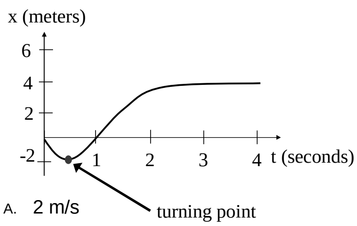
What is the **instantaneous** velocity in the last second?



- A. -2 m/s
- B. 4 m/s
- C. 1 m/s
- D. 0 m/s

Average Speed Exercise *5*

What is the **average** speed over the first 4 seconds ?

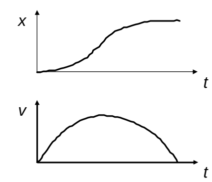


- A. 2 m/s
- B. 4 m/s
- C. 1 m/s
- D. 0 m/s

Key point:

- If the position x is known as a function of time, then we can find both velocity v

$$x = x(t)$$
$$v = \frac{dx}{dt}$$
$$x = \int_{t_0}^{t_1} dt\ v(t)$$



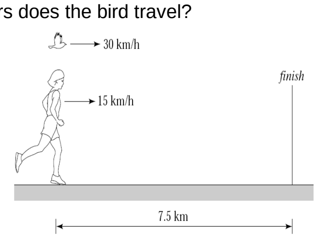
- Area under the v(t) curve yields the change in position
- Algebraically, a special case, if the velocity is a constant then $x(t) = v\,t + x_0$

***Exercise 6*, (and some things are easier than they appear)**

A marathon runner runs at a steady 15 km/hr. When the runner is 7.5 km from the finish, a bird begins flying from the runner to the finish at 30 km/hr. When the bird reaches the finish line, it turns around and flies back to the runner, and then turns around again, repeating the back-and-forth trips until the runner reaches the finish line.

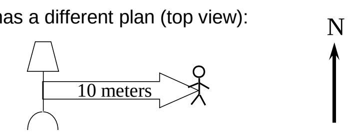
How many kilometers does the bird travel?

- A. 10 km
- B. 15 km
- C. 20 km
- D. 30 km

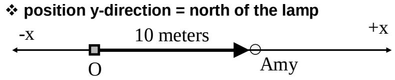


Motion in Two-Dimensions (Kinematics) Position / Displacement

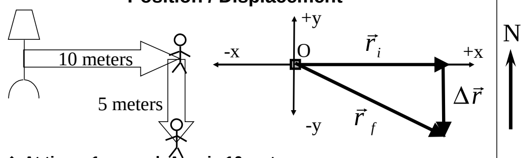
- Amy has a different plan (top view):



- **At time= 0 seconds Amy is 10 meters to the right of the lamp (East)**
- **origin = lamp**
- **positive x-direction = east of the lamp**
- **position y-direction = north of the lamp**



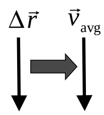
Motion in Two-Dimensions (Kinematics) Position / Displacement



❖ **At time= 1 second Amy is 10 meters to the right of the lamp and 5 meters to the south of the lamp**

❖ $\Delta\vec{r} \equiv \text{Displacement vector} = \vec{r}_f - \vec{r}_i$

❖ $\vec{v}_{avg} \equiv \Delta\vec{r}/\Delta t = \text{Average velocity}$



Position, velocity & acceleration

- All are vectors!
- Cannot be used interchangeably (different units!)

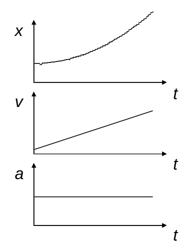
(e.g., position vectors cannot be added directly to velocity vectors)

- But the directions <u>can</u> be determined
  - ❖ "Change in the position" vector gives the direction of the velocity vector $\vec{v}$
  - ❖ "Change in the velocity" vector gives the direction of the acceleration vector $\vec{a}$
- Given x(t) → v(t) → a(t)
- Given a(t) → v(t) → x(t)

And given a <u>constant acceleration</u> we can integrate to get explicit *v* and *a*

$$x = x(t)$$
$$v = \frac{dx}{dt}$$
$$a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$$

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$
$$v = v_0 + at$$
$$a = const$$



Assignment Recap

- Reading for Wednesday's class on 9/12
  - » Finish Chapter 2 (gravity & the inclined plane)
  - » Chapter 3 (vectors)
  - » And first assignment is due this Wednesday